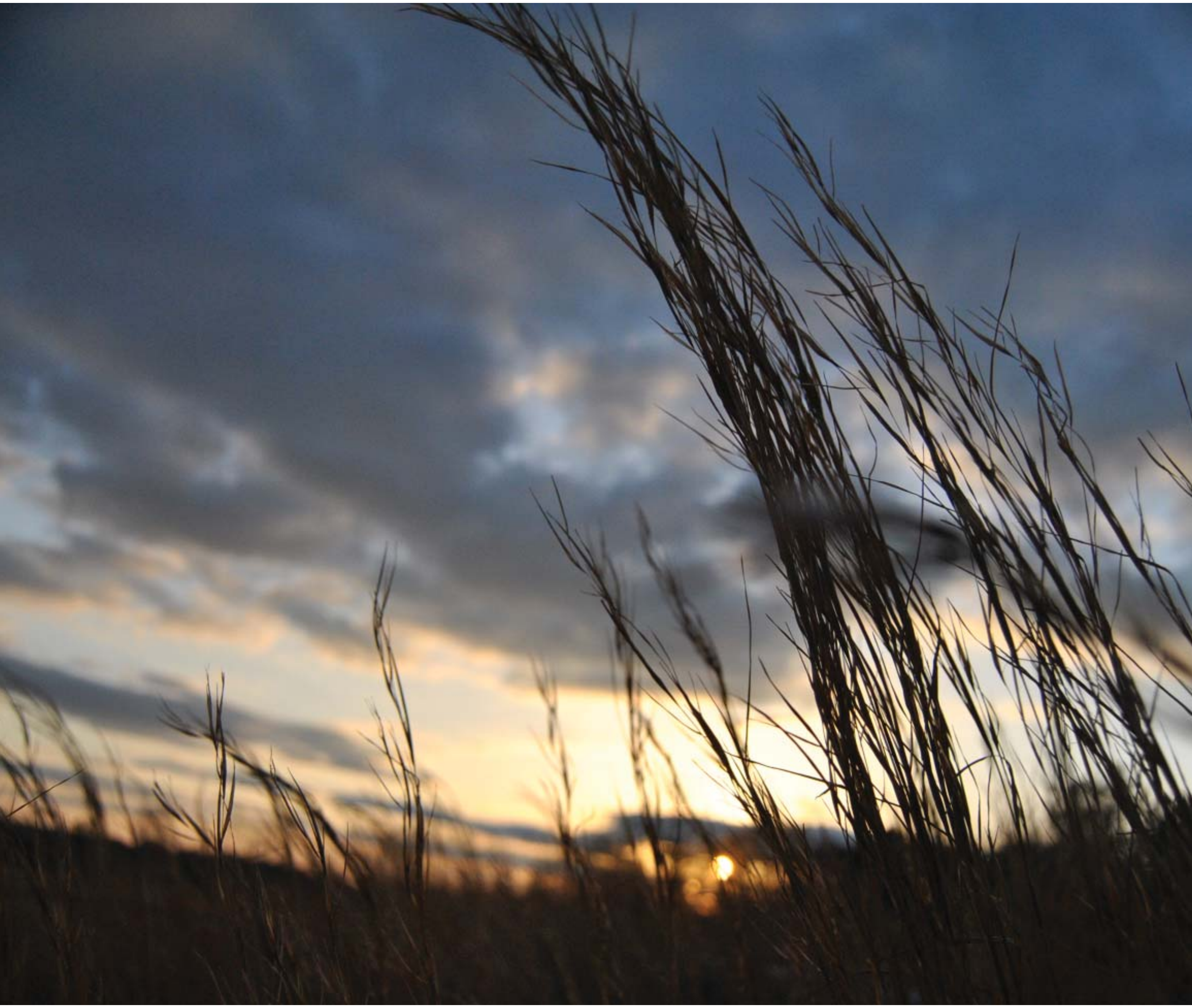
Low Impact Development Handbook for the State of Alabama



Alabama Department of Environmental Management
Alabama Cooperative Extension System
Auburn University

Low Impact Development Handbook

Alabama Department of Environmental Management in cooperation with the Alabama Cooperative Extension System and Auburn University

Contributing Authors:

Katie L. Dylewski
Jessica T. R. Brown
Charlene M. LeBleu
Dr. Eve F. Brantley

Graphic Design:

Domini V.J. Cunningham
Taylor French
Oliver Preus

Appreciation is extended to the reviewers who provided expertise and guidance: Barry Fagan, Earl Norton, Perry Oakes, Missy Middlebrooks, Patti Hurley, Norm Blakey, and Randy Shaneyfelt. Thanks also to those who provided guidance on stormwater control measures and vegetation considerations: Dr. Mark Dougherty, Ryan Winston, Dr. Amy Wright, Dr. Julie Price, Kerry Smith, Dr. Bob Pitt, Vernon 'Chip' Crockett, Jeff Kitchens, and Rhonda Britton.

This project was partially funded by the Alabama Department of Environmental Management through a Clean Water Act Section 319(h) nonpoint source grant provided by the U.S. Environmental Protection Agency - Region 4 to support the Alabama Nonpoint Source Management Program, the Alabama Coastal Nonpoint Pollution Control Program under the Coastal Zone Act Reauthorization Amendments of 1990 (CZARA), and implementation of CWA Section 319 and CWA Section 6217 Coastal NPS management actions and measures.

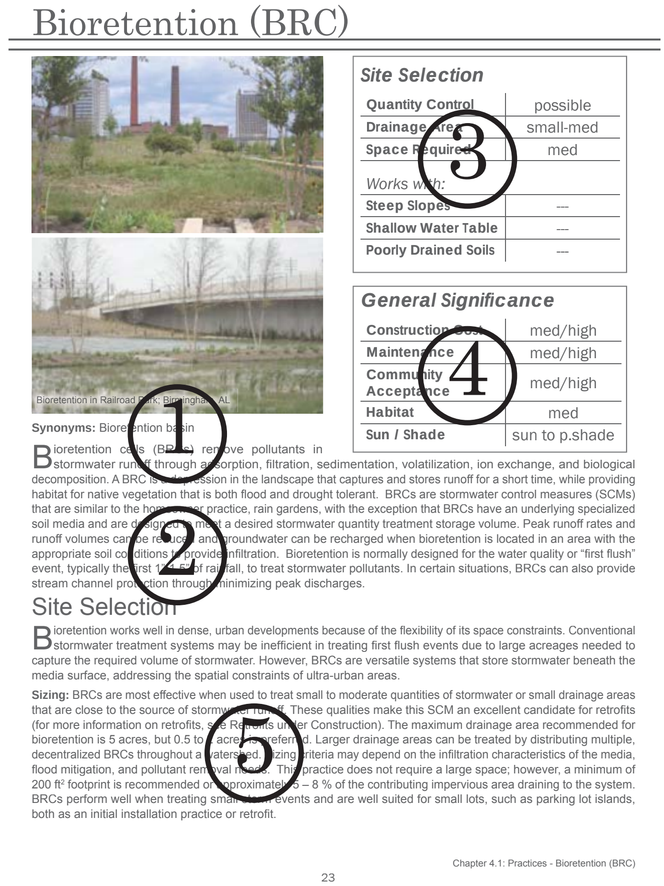
Acronyms

ADEM .... Alabama Department of Environmental Management
ADPH .... Alabama Department of Public Health
ALDOT .... Alabama Department of Transportation
ALNHP .... Alabama Natural Heritage Program
ASTM .... American Society for Testing and Materials
BRC .... Bioretention Cell
CC .... Curb Cut
CGP .... Concrete Grid Pavers
cfs .... Cubic feet per second
CN .... Curve number
CPESC .... Certified Erosion and Sediment Control Professional
CRF .... Controlled Release Fertilizer
CWA .... Clean Water Act
CSW .... Constructed Stormwater Wetland
DD .... Disconnected Downspout
DA .... Drainage area
DIY .... Do-It-Yourself
FAC .... Facultative
FACW .... Facultative wet
FEMA .... Federal Emergency Management Agency
fps .... Feet per second
GFS .... Grassed Filter Strip
GI .... Green Infrastructure
gpm .... gallons per minute
GR .... Green Roof
GS .... Grassed Swale
HOA .... Home Owner’s Association
HSG .... Hydrologic Soil Group
IA .... Impervious area
IBC .... International Building Code
IDF curve .... Intensity-Duration-Frequency curve
IS .... Infiltration Swale
IWS .... Internal water storage
LA .... Landscape Architect
LEED .... Leadership in Energy and Environmental Design
LID .... Low Impact Development
LS .... Level Spreader
MOU .... Memorandum of Understanding
MS4 .... Municipal Separate Storm Sewer Systems
NOAA .... National Oceanic and Atmospheric Administration
NPDES .... National Pollutant Discharge Elimination System
NPS .... Nonpoint Source
NRCS .... Natural Resources Conservation Service
OBL .... Obligate
PA .... Porous Asphalt
PC .... Pervious Concrete
PE .... Professional Engineer
psf .... pounds per square foot
psi .... pounds per square inch

PICP .... Permeable Interlocking Concrete Pavers
PP .... Permeable Pavement
PRG .... Plastic Reinforcement Grids
RB .... Riparian Buffers
RG .... Rain Garden
ROW .... Right of way
RW .... Rainwater Harvesting
SA .... Surface Area
SCM .... Stormwater control measure
SITES .... Sustainable Sites Initiative
TSS .... Total Suspended Solids
TRM .... Turf Reinforced Matting
UPL .... Upland
USACE .... United States Army Corps of Engineers
USDA .... United States Department of Agriculture
USEPA .... United States Environmental Protection Agency
USFWS .... United States Fish and Wildlife Service
USGBC .... United States Green Building Council
WIS .... Wetland indicator status
WS .... Wet Swale

How to Use This Handbook

Below are example sections for each stormwater control measure (SCM) subchapter. This guidance explains to the reader where they can find specific information related to each practice. These samples are intended to familiarize the reader with the layout for the practices outlined throughout the handbook.



Bioretention (BRC)

Site Selection

Quantity Control	possible
Drainage Area	small-med
Space Required	med
Works with:	
Steep Slopes	---
Shallow Water Table	---
Poorly Drained Soils	---

General Significance

Construction Cost	med/high
Maintenance	med/high
Community Acceptance	med/high
Habitat	med
Sun / Shade	sun to p.shade

Bioretention in Railroad Park; Birmingham, AL

Synonyms: Bioretention basin

Bioretention cells (BRCs) remove pollutants in stormwater runoff through adsorption, filtration, sedimentation, volatilization, ion exchange, and biological decomposition. A BRC is a depression in the landscape that captures and stores runoff for a short time, while providing habitat for native vegetation that is both flood and drought tolerant. BRCs are stormwater control measures (SCMs) that are similar to the homeowner practice, rain gardens, with the exception that BRCs have an underlying specialized soil media and are designed to meet a desired stormwater quantity treatment storage volume. Peak runoff rates and runoff volumes can be reduced and groundwater can be recharged when bioretention is located in an area with the appropriate soil conditions to provide infiltration. Bioretention is normally designed for the water quality or “first flush” event, typically the first 1”-1.5” of rainfall, to treat stormwater pollutants. In certain situations, BRCs can also provide stream channel protection through minimizing peak discharges.

Site Selection

Bioretention works well in dense, urban developments because of the flexibility of its space constraints. Conventional stormwater treatment systems may be inefficient in treating first flush events due to large acreages needed to capture the required volume of stormwater. However, BRCs are versatile systems that store stormwater beneath the media surface, addressing the spatial constraints of ultra-urban areas.

Sizing: BRCs are most effective when used to treat small to moderate quantities of stormwater or small drainage areas that are close to the source of stormwater runoff. These qualities make this SCM an excellent candidate for retrofits (for more information on retrofits, see Retrofits under Construction). The maximum drainage area recommended for bioretention is 5 acres, but 0.5 to 1 acres is preferred. Larger drainage areas can be treated by distributing multiple, decentralized BRCs throughout a watershed. Sizing criteria may depend on the infiltration characteristics of the media, flood mitigation, and pollutant removal needs. This practice does not require a large space; however, a minimum of 200 ft^2 footprint is recommended or approximately 5 – 8 % of the contributing impervious area draining to the system. BRCs perform well when treating small storm events and are well suited for small lots, such as parking lot islands, both as an initial installation practice or retrofit.

Chapter 4.1: Practices - Bioretention (BRC)

23

1. Synonyms

Other Low Impact Development (LID) manuals or information may refer to practices as different names. This section states any aims to state any interchangeable names associated with the practice.

2. Practice

A brief introduction to the practice is offered here to summarize information about the practice in a short paragraph.

3. Site Selection Table

The Site Selection Table is designed for a quick look at what site characteristics will or will not work for each practice.

Quantity Control [yes, no, or possible]: All practices in this handbook are stormwater quality practices. In other words, the practices are designed to treat stormwater runoff to reduce pollutant loads. However, all practices are not designed for stormwater quantity control because a large volume of stormwater is unable to be stored. In some practices such as bioretention, quantity control is possible, meaning that if designed properly it can help control quantity, but it is not typically considered a quantity control practice.

Drainage Area Size [small, medium (med), or large]: Drainage area size refers to the acreage that drains to the LID practice. The ratings for drainage area sizes are relative to other SCM drainage area requirements. For example, swales and bioretention drain small acreages, while constructed stormwater wetlands drain large acreages.

Space Required [small, medium (med), or large]: Similarly to drainage area size, the rating for the space or land area (footprint) required by the practice is based on the comparison made between SCMs.

Steep Slopes [check mark (yes) or --- in table (no)]: When a practice works with a steep slope, regrading of the area to a gentle slope (3 – 5:1) is not necessary. A steep slope is considered to be greater than a 3:1 slope. Some SCMs will require a relatively flat surface to function or cannot handle increased flow velocities associated with steep slopes.

Shallow Water Table [check mark (yes) or --- in table (no)]: Practices such as bioretention require a minimum of two feet between the bottom of the cell and the water table. Intercepting the water table is only appropriate when practices such as constructed stormwater wetlands need to maintain a permanent pool.

Poorly Drained Soils [check mark (yes) or --- in table (no)]: Some practices are not appropriate for poorly drained soils. Practices with standing water such as wet swales and constructed stormwater wetlands work well in poorly drained soils. Practices such as bioretention and infiltration swales that are designed to infiltrate stormwater require well-drained soils.

4. General Significance Table

The General Significance Table provides a quick reference for construction cost, maintenance, community acceptance, habitat, and sunlight requirement for the practice.

Construction Cost [low, medium (med), or high]: Construction cost compares each practice in relationship to the cost to construct them. It should be noted that in cases where equipment or labor is donated or inkind, cost would be decreased. Practices that require intense soil movement will cost more to construct.

Maintenance [low, medium (med), or high]: The purpose of maintenance is to keep the SCM functioning for its intended use. Maintenance frequency is dependent on location of practice, client or owner preferences, surrounding land use, etc. The rating for maintenance compares each practice according to maintenance burden. For example, practices that may have a tendency to clog such as bioretention and permeable pavement will have increased maintenance activities and frequency in comparison to a swale.

Community Acceptance [low, medium (med), or high]: Community acceptance rates the practice on whether it is readily accepted by community members. Practices such as swales are generally more easily accepted because they are commonplace on roadsides and they aren't a "new" idea. Lesser known practices may require education and community wide understanding.

Habitat [low, medium (med), high, or – (not applicable)]: Habitat refers to whether a practice positively contributes to or provides an environmental benefit or habitat for wildlife. For example, constructed stormwater wetlands provide more habitat for wildlife compared to permeable pavement.

Sun / Shade [sun to part shade (sun to p. shade), sun and/or shade (either), or – (not applicable)]: Some practices are better suited to sunny conditions, especially those that aim to treat or kill pathogenic bacteria.

5. Site Selection

The Site Selection Section offers a more in depth look at site selection for the practice. It may include information related to hydrologic soil group, infiltration rate, drainage area size, and seasonally high water table.

Site Selection: Constraints & Limitations Table: This table summarizes constraints that might be encountered and a recommendation for each.

6. Design

Components: The Components Section focuses on each part of the SCM, including pretreatment, wetland zones, underdrains, and any other element that may need to be designed or is a critical part of the practice.

Design Guidance: The Design Guidance Section gives design formulas and each step of the design process for the practice.

Design Example: The Design Example presents a design problem and a step by step design process.

7. Construction

The Construction Section focuses on construction activities, sequencing, plant installation and establishment, and soil testing.

8. Vegetation

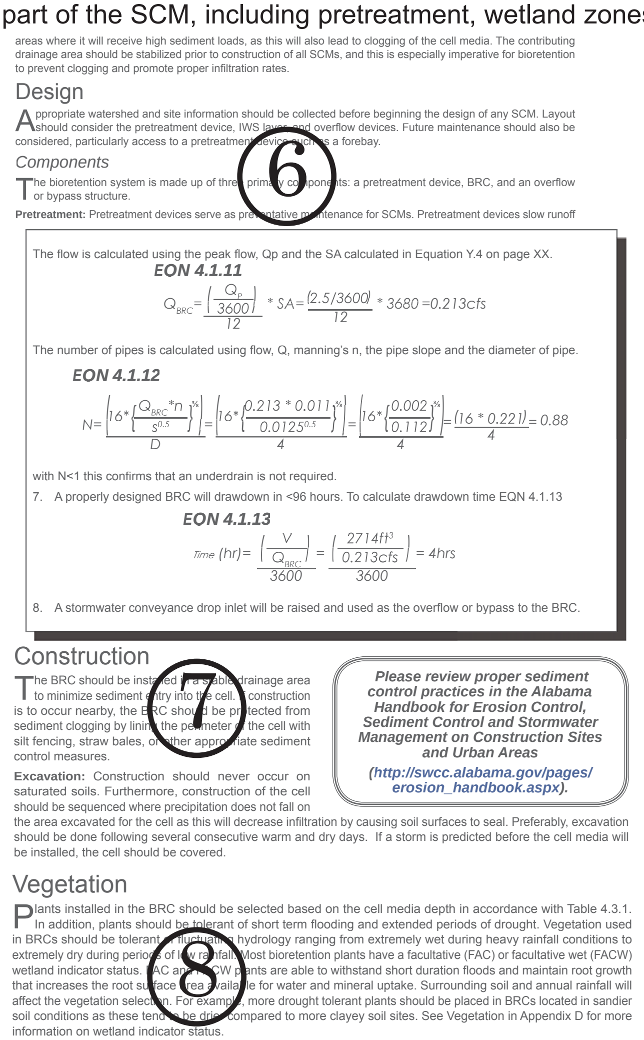
The Vegetation Section provides information on plants specific to the practice.

Vegetation Design Guidelines: This bulleted list gives suggestions pertaining to plant spacing, layout, aesthetics, plant types, etc.

Vegetation Design Example: The vegetation design example presents a design problem to show how to design the practice, shows a vegetation list, and presents a landscape drawing or graphic (to scale).

Plant List: Plant lists are offered for each practice that utilizes vegetation. Recommended plants are native to all or a portion of Alabama (except turfgrasses).

Botanical Name – The Botanical Name provides the genus and species for the plant.



areas where it will receive high sediment loads, as this will also lead to clogging of the cell media. The contributing drainage area should be stabilized prior to construction of all SCMs, and this is especially imperative for bioretention to prevent clogging and promote proper infiltration rates.

Design

Appropriate watershed and site information should be collected before beginning the design of any SCM. Layout should consider the pretreatment device, IWS layer, and overflow devices. Future maintenance should also be considered, particularly access to a pretreatment device such as a forebay.

Components

The bioretention system is made up of three primary components: a pretreatment device, BRC, and an overflow or bypass structure.

Pretreatment: Pretreatment devices serve as preventative maintenance for SCMs. Pretreatment devices slow runoff

The flow is calculated using the peak flow, Qp and the SA calculated in Equation Y.4 on page XX.

EQN 4.1.11

$$Q_{BRC}=\frac{\left(\frac{Q_P}{3600}\right)}{12} * SA=\frac{(2.5/3600)}{12} * 3680 = 0.213cfs$$

The number of pipes is calculated using flow, Q, manning's n, the pipe slope and the diameter of pipe.

EQN 4.1.12

$$N=\frac{\left|16*\left\{\frac{Q_{BRC}*n}{s^{0.5}}\right\}^{3/8}\right|}{D}=\frac{\left|16*\left\{\frac{0.213*0.011}{0.0125^{0.5}}\right\}^{3/8}\right|}{4}=\frac{\left|16*\left\{\frac{0.002}{0.112}\right\}^{3/8}\right|}{4}=\frac{(16*0.221)}{4}=0.88$$

with N<1 this confirms that an underdrain is not required.

7. A properly designed BRC will drawdown in <96 hours. To calculate drawdown time EQN 4.1.13

EQN 4.1.13

$$Time\ (hr)=\frac{\left(\frac{V}{Q_{BRC}}\right)}{3600}=\frac{\left(\frac{2714ft^3}{0.213cfs}\right)}{3600}=4hrs$$

8. A stormwater conveyance drop inlet will be raised and used as the overflow or bypass to the BRC.

Construction

The BRC should be installed in a stable drainage area to minimize sediment entry into the cell. If construction is to occur nearby, the BRC should be protected from sediment clogging by lining the perimeter of the cell with silt fencing, straw bales, or other appropriate sediment control measures.

Please review proper sediment control practices in the Alabama Handbook for Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas (http://swcc.alabama.gov/pages/erosion_handbook.aspx).

Excavation: Construction should never occur on saturated soils. Furthermore, construction of the cell should be sequenced where precipitation does not fall on the area excavated for the cell as this will decrease infiltration by causing soil surfaces to seal. Preferably, excavation should be done following several consecutive warm and dry days. If a storm is predicted before the cell media will be installed, the cell should be covered.

Vegetation

Plants installed in the BRC should be selected based on the cell media depth in accordance with Table 4.3.1. In addition, plants should be tolerant of short term flooding and extended periods of drought. Vegetation used in BRCs should be tolerant of fluctuating hydrology ranging from extremely wet during heavy rainfall conditions to extremely dry during periods of low rainfall. Most bioretention plants have a facultative (FAC) or facultative wet (FACW) wetland indicator status. FAC and FACW plants are able to withstand short duration floods and maintain root growth that increases the root surface area available for water and mineral uptake. Surrounding soil and annual rainfall will affect the vegetation selection. For example, more drought tolerant plants should be placed in BRCs located in sandier soil conditions as these tend to be drier compared to more clayey soil sites. See Vegetation in Appendix D for more information on wetland indicator status.

Common Name – Only one of the plant's common names is given, though plants may have more.

Habit – The Habit describes whether the plant is considered a herbaceous perennial, grass, tree, or shrub. For more information on these plant habits, see the Appendix D on Vegetation.

Prefers – This describes the plant's sunlight preference, which may be sun, shade, or a combination of both.

Comments – Any recommendations for cultivars or other general comments about the plant are provided here.

9. Maintenance

The Maintenance Section introduces routine maintenance tasks in order to maintain the functionality of the practice.

Maintenance Schedule: An example maintenance schedule shows how often tasks should be completed and gives helpful comments for each task.

Maintenance

Clogging: The most common failure mechanism of a BRC is clogging of the cell media. The underdrain pipe can be unclogged via the clean out pipe(s). However, if water remains ponded on the cell surface and clogging persists, it may be necessary to remove and replace the top few inches of media. Following this replacement, if the cell surface continues to remain ponded for longer than 12 hours, then the cell media is likely clogged and will need to be completely replaced. Extended surface ponding provides favorable conditions for mosquito breeding and is detrimental to plants unaccustomed to extended flooding.

Mulch: The top 1 to 2" of mulch and 4" of media have been shown to accumulate sediment and metals. Periodic replacement of these top layers can facilitate removal of sediment bound phosphorus and metals. Upon the need to dispose of any potentially contaminated mulch or media associated with BRCs, the ADEM Environmental Services Branch should be contacted for guidance associated with the requirements for waste determination and disposal procedures. For more information, please call 334-271-7700 or 1-800-533-2336.

9

Table 4.1.8
Maintenance Schedule

Task	How Often	Comments
Mulching	As needed, full replacement every 2 to 3 years	Bare areas from erosion should be replaced as necessary. Mulching can be done any time of the year, but the best time is late spring after soil has warmed. Mulch should be replaced annually if the watershed is high in heavy metals.
Re-planting	When plants die	If plants consistently suffer from mortality consider using more appropriate plant species for the area.
Weeding	Twice a year	Weeding should decrease over time as vegetation establishes.
Inspect plants	Monthly until establishment, then twice a year	Inspect for diseased or insect infested vegetation.
Inspection	After 0.5" or greater rainfall event	Visually inspect all components including any pretreatment, pipes, or IWS where applicable.
Fertilization	At planting	Most BRCs are used in nutrient sensitive watersheds. Fertilizing beyond plant establishment will increase nutrients leaving the BRC.
Unclog Underdrain Pipes	As needed	Ponded surface water should drain away within 12 hours or less (i.e. eliminate standing water conditions). If water remains ponded on the surface of the cell for longer than 12 hours this may indicate that the underdrain pipe or cell media is clogged.
Pruning	Annually	Pruning will help maintain plant shape. See Vegetation in Appendix D for pruning recommendations.
Sediment Removal	As needed	If sediment clogs the media, the top few inches may need to be removed and replaced. Removed sediment should be properly disposed of as it may contain toxic materials such as heavy metals. Contact the ADEM Environmental Services Branch for guidance at 334-271-7700 or 1-800-533-2336.
Trash Removal	As needed	In high traffic areas, frequent trash removal will be necessary.
Mulch removal from outlets	As needed	Mulch may collect in the outlet or overflow during heavy rains.

Pollutant Removal

Table 4.1.9
Pollutant Removal Table

Sediment	Nutrients		Metals	Pathogens	Temperature
	N	P			
a.85%	40%	45%	No Data	No Data	No Data
b.80%	50%	60%	MOD	No Data	No Data
c.80%	50%	60%	MOD	No Data	No Data

a. NCDENR, 2007*
b. City of Auburn, 2011
c. Georgia Manual, 2001

* Research has demonstrated pollutant removal efficiencies of 60% for both N and P in the Coastal Plains.

10

Bioretention pollutant removal is dependent on the presence of plants, microorganisms, specialized cell media, and mulch; the absence of one of these components decreases the pollutant removal efficiency associated with the BRC. Bioretention shows greater than 35% reduction in nutrients and a minimum of 80% reduction in total suspended solids (TSS). Nutrient removal is more variable compared to TSS, which is likely due to the complexities of chemical breakdown processes and the behavior of nutrients.

References

Alabama Soil and Water Conservation Committee. 2009. Alabama Handbook for Erosion Control, Sediment Control, and Stormwater Management on Construction Sites and Urban Areas. Montgomery, AL.

Brown, R.A., W.F. Hunt, and S.G. Kennedy. 2009. Designing Bioretention with an Internal Water Storage (IWS) Layer: Design guidance for an innovative bioretention feature. North Carolina Cooperative Extension. AG-588-19W.

Brown, R.A. and W.F. Hunt. 2009. Improving Exfiltration from BMPs: Research and Recommendations. North Carolina Cooperative Extension.

Christian, K. J., A. N. Wright, J. L. Sibley, E. F. Brnatley, J. A. Howe. and C. LeBleu. 2012. Effect of Phosphorus Concentration on Growth of Muhlenbergia capillaris in Flooded and Non-Flooded Conditions. Journal of Environmental Horticulture 30(4): 219-222.

11

City of Auburn Manual. 2011.

Davis, Allen P., William F. Hunt, Robert G. Traver, and Michael Clar. 2009. Bioretention Technology: An Overview of Current Practice and Future Needs. Journal of Environmental Engineering. March.

Davis, Allen P. 2007. Field Performance of Bioretention: Water Quality. Environmental Engineering Science, 24(8) 1048-1063.

Davis, A. P., M. Shokouhian, H. Sharma, and C. Minami, C. 2006. Water Quality Improvement Through Bioretention Media: Nitrogen and Phosphorus Removal. Water Environment Research 78 (3), 284–293.

Davis, A. P., M. Shokouhian, H. Sharma, and C. Minami. 2001. Laboratory Study of Biological Retention for Urban Storm Water Management, Water Environment Research 73(1), 5-14.

Dylewski, K. L., A. N. Wright, K. M. Tilt, and C. LeBleu. 2012. Effect of Previous Flood Exposure on Flood Tolerance

10. Pollutant Removal

The Pollutant Removal Section contains detailed information on pollutant load reductions specific to the practice.

Pollutant Removal Table: The Pollutant Removal Table shows pollutant removal efficiency data noted in other LID manuals or municipalities. Pollutant removal efficiency is expressed as a percent and represents the reduction in pollutant concentration measured in outflow from the SCM compared with inflow to the SCM. Pollutant removal efficiencies listed in the Pollutant Removal Table are based on sampling data, modeling, and best professional judgment. For more information on pollutant removal, please see Pollutant Removal in Appendix A on Stormwater Hydrology.

Sediment – Shows a reduction in total suspended solids (TSS).

Nutrients – Shows a reduction in N (total nitrogen) and P (total phosphorus).

Metals – Shows a reduction in metals such as zinc.

Pathogens – Shows a reduction in pathogenic bacteria such as *E. coli*.

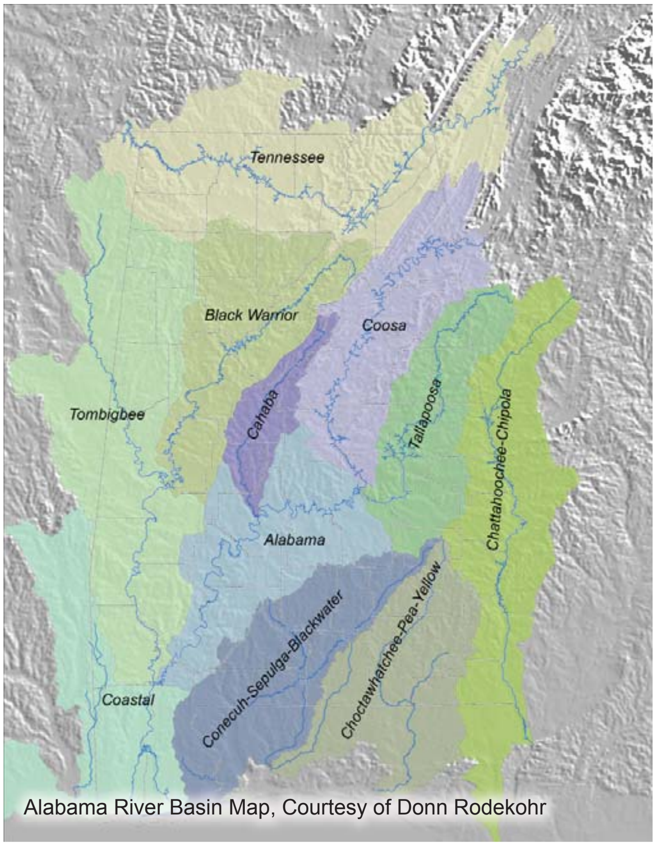
Temperature – Shows a reduction in temperature.

11. References

This lists any source(s) that was used to gain knowledge or information regarding the practice section.

Overview

Low Impact Development Overview



Alabama River Basin Map, Courtesy of Donn Rodekohr

Alabama is blessed with abundant water resources including over 77,000 miles of streams and rivers, diverse wetland ecosystems, coastal waters, reservoirs, and groundwater. These resources are critical for maintaining Alabama's amazing plant and animal biodiversity, drinking water supplies, opportunities for ecotourism, water sources for irrigation, and transportation networks. The quality of water that flows through our communities is a reflection of our quality of life.

Interest in and awareness of the need to better manage stormwater runoff in urban and suburban landscapes has increased in recent years. Multiple studies have identified the negative impacts of poorly managed post construction stormwater on our nation's waters. As landscapes become more urbanized, there is a corresponding increase in the amount of impervious surfaces that limit the ability of stormwater to infiltrate into the ground. In some watersheds, as much as 55% of rainfall runs off an urban landscape that is covered by parking lots, roads, and buildings and only 15% of rainfall soaks into the ground. In comparison, a more natural landscape will infiltrate 45% of the rainfall with only 10% running off. The negative environmental impacts of an increase in stormwater runoff and subsequent peak instream flows in developed landscapes leads to increases in its delivery of pollutants such as nutrients, pathogens, metals, and sediment.

Careful consideration of stormwater management is critical for planners, environmental program managers, elected officials, homeowners, business owners, developers, contractors, design professionals, and others; however, it is rare that these groups have an opportunity to work together in planning for future development and redevelopment, particularly on a watershed level. Low impact development or LID is an interdisciplinary systematic approach to stormwater management that, when planned, designed, constructed, and maintained appropriately, can result in improved stormwater quality, improved health of local water bodies, reduced flooding, increased groundwater recharge, more attractive landscapes, wildlife habitat benefits, and improved quality of life.

Low impact development minimizes runoff and employs natural processes such as infiltration, evapotranspiration (evaporation and transpiration from plants), and storage of stormwater at multiple fine scale locations to be as near to the source of stormwater as possible. Successful implementation of LID recreates a more natural hydrologic cycle in a developed watershed.

The first step in LID is to consider the landscape that will be developed. What are the natural features of the area that may be used or mimicked to promote stormwater infiltration, evapotranspiration, or storage? This may include sensitive areas such as steep slopes, wetlands, and streamside forests that should be retained. See Table 2.4 in Site Selection for a checklist that can be used by developers and designers during construction plan review. Understanding the opportunities and limitations of a landscape to be developed will help with the strategic placement of LID stormwater control measure practices at multiple locations so that stormwater is slowed, stored, and soaked in near to its point of origin.

It is critical to understand local soils, size constraints, groundwater level, native vegetation options, and other potential constraints so that the appropriate LID stormwater control measure practices can be selected to meet the project goals. The LID stormwater practice should be designed to effectively store, infiltrate, or spread out stormwater in its landscape setting, ideally working as a system with the other practices in the development and watershed. Understanding local hydrology and function of a specific stormwater management practice within a particular setting will make stormwater management design more efficient and cost effective.

Auburn University Soil Resources and Conservation Class, Turf Research Unit; Auburn, AL

As with any built practice, LID requires a schedule of maintenance tasks to promote long-term pollutant removal efficiencies. The concern that this maintenance burden will be greater than conventional "grey" stormwater practices should not be a barrier – it is different maintenance, not necessarily more maintenance. In fact, the US EPA has noted that LID life cycle costs are usually less than traditional practices. Traditional stormwater practices may have a greater initial capital investment, use valuable land area for stormwater storage, and incur operation and maintenance costs such as dredging, inlet pumping, and residuals disposal. LID practices typically have lower initial investment, but require more maintenance in the first years of establishment. Once established, they may be maintained in a manner similar to other landscaped areas. Additionally, these practices may help reduce the cost of mowing and irrigation post establishment. Additional LID elements to include in a cost/benefit comparison include improved aesthetics, wildlife habitat, community quality of life, citizen involvement and engagement, and the pride of implementing practices that allow economic and community development to proceed with minimized impacts on water resources. These elements are part of the overall picture of LID that encourages a connection by all stakeholders to transform stormwater into being viewed as a valuable resource.

Recently, Green Infrastructure (GI) has emerged as the term to describe planning and implementation of projects that use vegetation, soils, and natural processes to manage water and create healthier urban environments. On a broad, watershed scale GI may encourage the linking of new and existing greenways, promotion of canopy cover to assist with energy reductions and carbon sequestration, and the preservation of natural areas. As the scale becomes finer, GI encompasses the stormwater management approach recommended by LID to treat stormwater close to its source through infiltration, evapotranspiration, and storage.

Technological advances in LID are helping to fine tune elements of the planning, design, construction, and maintenance of LID stormwater practices. This handbook presents current research and design recommendations to assist all interested groups in setting goals for their development and re-development projects. Goals may include maximizing pollutant load reductions, incorporation of low maintenance, attractive native vegetation, and/or community involvement in understanding connections between what we do in our landscapes and the health of local streams. We strongly recommend seeking input from all stakeholders as we move forward with LID in Alabama so that we understand what is needed to successfully achieve improved water quality and community quality of life.

References

Arnold C. and J. Gibbons. 1996. Impervious Surface Coverage: The Emergence of a Key Environmental Indicator. Journal of the American Planning Association, 62(2): 243-258.

US EPA. Fact Sheet #1. Benefits of LID: How LID Can Protect your Community's Resources. Last accessed April 2013. http://water.epa.gov/polwaste/green/upload/bbfs1benefits.pdf

US EPA. Fact Sheet #5. Maintenance of Low Impact Development. Last accessed April 2013. http://water.epa.gov/polwaste/green/upload/bbfs6maintenance.pdf

US EPA. What is Green Infrastructure? Last accessed April 2013. http://water.epa.gov/infrastructure/greeninfrastructure

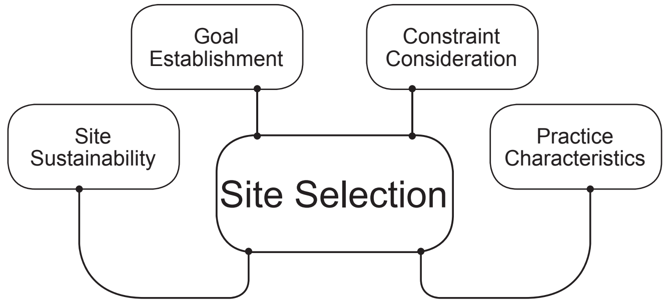
Walsh, C. J., A. H. Roy, J. W. Feminella, P.D. Cottingham, P. M. Groffman, and R. P. Morgan II. 2005. The Urban Stream Syndrome: Current Knowledge and the Search for a Cure. Journal of the North American Botanical Society, 24(3): 706 - 723.

Site Selection

Site Selection

Project Partners Evaluate a Site; Smiths Station, AL

The selection of a site for stormwater control measure (SCM) installation is often the most important step in meeting pollutant removal goals. Site selection should follow four primary, general steps.



Goal Establishment

Site selection should consider constraints of a selected site and the overall project goals. Well-defined and established goals of a particular project are important to identify the best practice for a given location.

Goals may include:

- Conservation or preservation of a site
- Reduced impervious cover
- Reduced impact on water resources
- Water quality improvement
- Use of natural features for stormwater management
- Education about stormwater management or a particular practice
- Demonstration of a particular SCM for technology transfer

Prior to implementing a structural SCM, other means of reducing impervious surfaces and minimizing runoff should be considered in meeting an established goal.

Constraint Consideration

Site Layout: A site layout should be created to show resources and features on site that should be protected as well as site constraints. These include existing buffers, transplantable native vegetation, existing infrastructure, and pretreatment mechanisms.

Constraints: Establishing a list of constraints for a site is crucial to assigning a SCM that will perform efficiently. Site constraints may be natural or man–made structures and are listed in Table 2.1.

Natural Constraints

In-Situ Soils: Use the USDA Web Soil Survey to identify soil map units and to make initial interpretations for potential uses and limitations of a site. However, since most soil map units have inclusions of other soils that may be quite different, detailed evaluations should be made at the proposed site by a professional soil scientist or soil classifier. On-site evaluations should properly identify a soil or the hydrologic soil group (HSG) and the final decision for use should be made based on the detailed determination of soil series or HSG. For a detailed list of HSG properties, see Table

Table 2.1

Natural	Man-made
Steep Slopes	Existing Infrastructure
Compacted Soils	Right of Ways
Jurisdictional Wetlands*	Electrical Lines
Stream Channels*	Fiber Optic Cable
100-Year Floodplains*	Sewer Lines
Existing Riparian Buffers*	Water Lines
Forest Conservation Areas*	Other Utilities
Critical Areas*	Roads
Endangered/Threatened Species*	Septic Drain Fields
Water Table depth	Wells
Shallow Depth to Bedrock	

*Potential Environmental Regulatory Constraints

A.3 in Appendix A on Stormwater Hydrology. A roster for Alabama Professional Soil Classifiers can be found at http://alabamasoilclassifiers.org/.

Compacted Soils: Compacted soils are an issue for many structural SCMs because their compressed structure causes an inability to properly hold and conduct water, nutrients, and air. Compacted soils can be a result of natural forces such as rain, agricultural forces such as tillage operations or crop rotation, and urban forces such as wheel traffic, especially heavy equipment or construction traffic. Compacted soils can limit the function of SCMs, particularly practices whose primary function is stormwater infiltration. When soil is heavily compacted, it contains very few large pores and has a reduced rate of water infiltration and drainage. Once a surface layer is compacted and pore spaces are compressed, runoff occurs resulting in increased soil and water losses.

Poorly Drained Soils: Poorly drained soils may not be suitable to practices relying on infiltration without the use of an underdrain. An infiltration test should be performed on site to determine soil infiltration rates (see Chapter 5.1 on Rain Gardens for information on how to perform an infiltration test). A double ring infiltrometer can also be used to test soil percolation.

Steep Slopes: Steep slopes increase water velocities that may exceed the designed velocity for a particular practice, resulting in increased erosion and decreased residence time and infiltration. Practices such as constructed stormwater wetlands (CSWs) that require larger land areas may not function where slopes constrict the available area for the practice site. Smaller SCMs in series that follow existing site contours may be necessary to overcome steep slopes. Slopes can be graded, but soil moving (especially if not used for another purpose on site) can be expensive and should be considered during site selection. For the purpose of this handbook, a steep slope refers to any slope > 3:1.

Shallow Slopes: Conversely, shallow slopes can also affect SCM selection. Practices that require pretreatment basins, forebays, or an elevation difference to drive the practice function (e.g. water movement throughout a practice) may be expensive to construct on flat sites. In shallow sloped or low relief areas, practices that require a hydraulic head may not be optimal. See Minimum Head under Additional Goals for more information.

Sun/Shade Tolerance: Sunlight availability is limiting for vegetation selection or when there is a need to treat pathogens using sunlight. Practices such as bioretention and rain gardens usually function best in full sun to dry down efficiently between rain events. Conversely, some portions of CSWs require partial shade.

Water Table Depth: Infiltration practices, such as bioretention may be limited by water table depth. For CSWs, the seasonally high water table may be used to maintain the permanent pool elevation in the wetland.

Groundwater Contamination: Groundwater contamination is a risk for practices that intercept the water table. SCMs should never release runoff filtering a "hotspot" into groundwater. Hotspots are defined as commercial, industrial, or other operations that produce higher levels of stormwater pollutants and/or have concentrated pollutants.

Shallow Depth to Bedrock: SCM options can be greatly limited by a shallow depth to bedrock due to infiltration and excavation constraints. Shallow depth to bedrock may also prevent the excavation of pretreatment devices, such as forebays, or the SCM itself. When a shallow depth to bedrock is present, the site may be limited to the use of grassed filter strips, restored riparian buffers, or rooftop runoff management techniques.

Potential Environmental Regulatory Constraints

Jurisdictional Wetlands: Jurisdictional wetlands are areas that support hydric soils, wetland hydrology, and hydrophytic vegetation and are connected to waters of the United States. These wetlands are regulated by the Army Corps of Engineers and require a permit (Section 404 of the Clean Water Act) to work within their proximity. SCMs that discharge or have the potential to overflow polluted effluent should not be located in the vicinity of jurisdictional wetlands. Wetland delineation to define the wetland area may be necessary. Many local county and municipal entities have regulatory setbacks for delineated wetlands, some as much as 100' for designated subwatersheds.

Endangered/Threatened Species: The Alabama Natural Heritage Program's list of Rare, Threatened, or Endangered Plants and Animals of Alabama should be consulted to determine any species of concern for the site (http://www.alnhp.org/).

Stream Channels and Existing Riparian Buffers: Stream channels should not be impacted by LID as this goes against its overall goal of improving and protecting water quality. Impaired watersheds, local buffer ordinances, and environmental regulations limiting development adjacent to stream channels may limit site selection. Existing riparian buffers should only be improved by the addition of a SCM to the site. Most municipalities have their own streamside buffer ordinance that limits land disturbance and construction adjacent to a waterbody.

100-year Floodplains: The 100-year floodplain is the land area adjacent to a waterbody that would flood or be covered by water during a 100-year flood. These areas may affect development and SCM placement.

Forest Conservation Areas: Forest conservation areas and wildlife management areas have been created across the state to prevent habitat loss for threatened and endangered species. These areas are protected and should not be impacted during or after construction.

Alabama Regulatory Requirements: The National Pollutant Discharge Elimination System (NPDES) program was developed in 1972 under the authority of the Clean Water Act. This program controls water pollution by regulating point sources, including but not limited to Municipal Separate Storm Sewer Systems (MS4s), construction activities, industrial activities, and multi-sector general permits, which discharge into the waters of the United States. The Water Permits Division within the United States Environmental Protection Agency (USEPA) Office of Wastewater Management leads and manages the NPDES permit program in partnership with USEPA Regional Offices, States, Tribes, and other Stakeholders. Through the NPDES program, Alabama has approval by USEPA for the State NPDES Permit Program, Regulation of Federal Facilities, the State Pretreatment Program, and General Permit.

One component of the NPDES program focuses on stormwater discharges from MS4s. Stormwater runoff is most commonly transported through MS4s and deposited in local waterbodies.

This regulation was implemented in two phases:

Phase I (1990) - requires areas (cities/counties) with populations of 100,000+ to obtain permit coverage for point discharges.

Phase II (1999) - requires small MS4s >50,000 but <100,000 population to obtain permit coverage for their discharges.

Each jurisdiction is required to develop and implement a stormwater management plan that includes the following six minimum measures:

- Public education
- Illicit discharge detection and elimination
- Construction
- Post construction
- Pollution prevention
- Good housekeeping

A particular storm event (return period) and criteria are established for the following standards: (1) remove pollutants from runoff to improve water quality, (2) prevent erosion of downstream streambank and channel, (3) provide overbank flood protection, and (4) safely pass or reduce the runoff from extreme storm events. Table 2.2 illustrates the sizing criteria and a description for each standard.

Table 2.2

Sizing Criteria	Description
Water Quality	Treat the runoff from 80% of the storms that occur in an average year. This is the runoff resulting from a rainfall depth of approximately 1”-1.5” (first flush) depending on the location in Alabama. For more information on the first flush, see Appendix A on Stormwater Hydrology.
Channel Protection	Provides extended detention of the 1-yr storm event released over a period of 24 hours to reduce bankfull flows and protect downstream channels from erosive velocities and unstable conditions.
Overbank Flood Protection	Provides peak discharge control of the 25-year storm event such that the post- development peak rate does not exceed the predevelopment rate, resulting in reduced overbank flooding.
Extreme Flood Protection	Evaluates the effects of the 100-year storm on the management system, adjacent property, and downstream properties and facilities. Manages the impacts of the extreme storm event through detention controls and/or floodplain management.

Man-made Constraints

Existing Infrastructure: Existing infrastructure is often costly to relocate or remove. Consequently, any damage to infrastructure should be avoided. Existing infrastructure may also impact factors such as soil permeability due to imported fill, area constraints and restrictions (e.g. practice size), location of the SCM on site, and many others. Existing infrastructure should be located prior to site design by calling Alabama 811 (for more information, visit: www.al1call.com). Common infrastructure concerns are presented below.

Right of Ways: Right of ways (ROW) should be considered for maintenance access and may affect SCM location, construction, and maintenance. If a city or municipality installing the practice intends to manage the SCM "in-house," often a municipal ROW is beneficial and the practice is designed to a standard allowing maintenance access for vehicles and equipment required to perform annual maintenance. However, when ownership of the ROW is not the same as the entity charged with SCM maintenance, a Memorandum of Understanding (MOU) may be necessary to guarantee access in all phases of SCM development as well as post-construction maintenance.

Electrical Lines: To allow for maintenance without interfering or damaging the SCM or electrical lines, avoid locating SCMs within 100' of electrical lines. Occasionally a SCM may be located within a 100' radius of electrical lines and in these cases, maintenance practices must be scrutinized to avoid damage and selected vegetation should not encroach vertically on electrical lines. Low growing shrubs or herbaceous perennials are suggested when vegetation height is constrained.

Fiber Optic Cable: Fiber optic cable lines that carry data and communication may run above or below ground. Call Alabama 811 to locate any fiber optic cable lines that may be impacted during construction or post-construction during maintenance.

Water and Sewer lines: Avoid damage to water and sewer lines. These can be located using site plans, Alabama 811, or local utilities companies. As-built plans should be used whenever possible for more accurate locations of these lines. By using Alabama 811 assurance can be given that water and sewer lines are avoided.

Irrigation Lines: Irrigation lines may also be found on site and may need to be removed and replaced following construction. Irrigation is useful in establishing plants for the practice post construction.

Roads: Existing roads and future roads planned for the site should be considered during planning. Future roads may contribute additional runoff to the SCM as well as create erosion and sediment control concerns.

Septic Drain Fields: A general rule of thumb is that SCMs should not be sited within 25' or above septic drain fields.

Wells: SCMs should be located a minimum of 10' from well heads, but local ordinances should be consulted.

Additional Goals

Once constraints are considered, the list of SCMs best suited for a site typically diminishes. Next, determine the treatment needs or requirements of a particular site. The treatment requirement or capability is often determined by regulatory requirements and/or watershed impairment (e.g. peak flow control, total suspended solids reduction, nutrient removal, etc.).

Size of Drainage Area: The size of the drainage area is a primary consideration in SCM selection especially when the practice's performance relies on a permanent level of water. Practices that are designed to handle smaller flows do not perform efficiently and often cannot treat pollutants if sited at the outlet of a larger drainage area or system.

Table 2.3
Comparison of Drainage Area and Size of Practice

Practice	Size of Drainage Area	Size of Practice/ Space Required
Riparian Buffers	S-M	Medium - Large
Level Spreaders and Grassed Filter Strips	S	Small
Constructed Stormwater Wetlands	M-L	Medium - Large
Curb Cuts	S	Small
Bioretention	S	Medium - Large
Rain Gardens	S	Small
Grassed Swales, Infiltration Swales, and Wet Swales	S	Small
Permeable Pavement	S-M	Small
Disconnected Downspouts	S	N/A
Rainwater Harvesting	S	Small - Meduum
Green Roofs	S	Medium - Large

Practice Size (Required Space): Reducing impervious surface cover has the potential to decrease SCM size for the site. Some practices, such as CSWs, require large land areas and aren't applicable in many cases. High-density areas may be a concern; width or depth of a practice may be important for function and/or safety. Various practices, although smaller in size, may be more expensive or lack maximum treatment capability compared to others.

Both the size of the drainage area and the size of the practice can be shown in Table 2.3.

Minimum Head: For SCMs to function properly, a minimum head or elevation difference is often needed to move stormwater through the SCM. The elevation difference on site will affect which practice is selected. For example, CSWs require more change in elevation (hydraulic head) over the length of the SCM to promote flow of water and prevent mosquito breeding habitat. Depending on existing site conditions, excavation or fill to obtain the head required may be costly.

Depth of Ponding: Depth of ponding refers to the amount of standing water present in a SCM. Depth of ponding is used for stormwater storage and may be more or less depending on the practice. For example, bioretention practices typically have 6 – 9" of ponding for a brief period of time following a rain event, but CSWs utilize various hydrologic zones and deep pools may have up to 36" of water at any given time. Ponded water may be a safety concern and should be considered during practice selection. Fencing may be used as long as it does not limit SCM function.

Paired Practices: Paired practices may allow for treatment of larger drainage areas.

Cost: Cost of design, construction, and maintenance often determine feasibility. Consider site goals and pollutant removal efficiencies of each practice when cost may limit practices for a site.

Site Sustainability

Maintenance Level: When practices require extensive maintenance, identifying maintenance personnel early during planning is crucial. Some practices such as CSWs may require a high level of maintenance initially, but may become low maintenance after plant establishment.

Safety: Safety concerns may relate to standing water on site or to wildlife attracted to conditions in a practice. Consider who will utilize the site (humans or animals) and use this list to determine any safety concerns for long-term function and safety of the site.

Community Acceptance: Community acceptance is crucial for long-term adoption of LID practices. A practice with high community acceptance can easily become poorly accepted when a practice is not sited or maintained properly. Community acceptance is key to foster feelings of ownership among community members and to promote these practices as demonstration and educational opportunities.

Table 2.4
Site Selection & General Charactristics by Practice

Practice	BRC	CSW	PP	GR	RH	GS, IS, WS	RB	LS, FS
Sediment	Y	Y	Y	N	N	Y	Y	Y
N	Y	Y	Y	N	N	Y	Y	Y
P	Y	Y	Y	N	N	Y	Y	Y
Metals	Y	Y	Y	N	N	Y	Y	Y
Pathogens	Y	Y	N	N	N	Y	Y	N
Quantity Control	Possible	Yes	Possible	Possible	Possible	No	No	No
Drainage Area	Small	med-large	small	small	small	small	small-med	small
Space Req'd	large	large	small	large	small-med	small	med-large	small
Const Cost	med/high	med	high	high	med	low	med	low
Maint	med/high	med	med	med	med	low	low	low
Comm Acc	med/high	med	high	high	med/high	high	high	high
Habitat	med	high	low	low	N	low	med-high	med

Habitat: Practices that rank high for habitat are likely to attract animals that may be seen as a drawback by the general public.

Signage: Signage may be applicable especially when practices as are used for learning tools. Signage can also be directional or used as a warning when safety is a concern.

Construction Plan Review

Table 2.5 shows a sample check list (courtesy of City of Auburn) that can be used by developers during construction plan review.. This sample checklist can be tailored to fit the needs of a city, county, or municipality.

Table 2.5
Low Impact Development Planning and Design Check List

	1. Natural Resource Assessment
	Natural resources and constraints are identified and shown on the plan (wetlands, rivers, streams, flood zones, meadows, agricultural land, tree lines, steep slopes, and soil types.
	Endangered species of plants and animals on the site are shown on the plan.
	Development is designed to avoid critical water courses, wetlands, and steep slopes.
	Soils suitable for septic & stormwater infiltration have been identified on plans.
	Onsite soils have been assessed to determine suitability for stormwater infiltration.
	Existing natural drainage patterns have been delineated on the plan and are proposed to be preserved or impacts minimized.
	2. Preservation of Open Space
	Calculation of percent (%) of natural open space has been performed (% =_____).
	An open space or cluster subdivision design has been used.
	Open space/common areas are delineated.
	Open space is retained in a natural condition.
	Reduced setbacks, frontages, and right-of-way widths have been used where practicable.
	3. Minimization of Land Disturbance
	Proposed building(s) is/are located where development can occur with the least environmental impact.
	Disturbance areas have been delineated to avoid unnecessary clearing or grading.
	Native vegetation outside the immediate construction areas remains undisturbed or will be restored.
	Plan includes detail on construction methods and sequencing to minimize compaction of natural and future stormwater areas.
	4. Reduce and Disconnect Impervious Cover
	Impervious surfaces have been kept to the minimum extent allowed (check methods used):
	Minimized road widths
	Minimized driveway area
	Minimized sidewalk area (one-side of roadway)
	Minimized cul-de-sacs
	Minimized building footprint
	Minimized parking lot area
	Impervious surfaces have been disconnected from the stormwater system, and directed to appropriate pervious areas, where practicable. Pervious areas may be LID practices, or turf areas.
	5. LID Practices Installed
	Sheet flow is used (level spreader) to the maximum extent possible to avoid concentrating runoff.
	Vegetated swales have been installed adjacent to driveways and/or roads in lieu of curb and gutter.
	Rooftop drainage is discharged to bioretention, rain garden or other LID practice.
	Rain water harvesting methods such as rain barrels or cisterns have been installed to manage roof drainage.
	Driveway, roadway, and/or parking lot drainage is directed to Bioretention, rain gardens or other LID practice.
	Cul-de-sacs include a landscaped bioretention island.
	Vegetated roof systems have been installed.
	Pervious pavements have been installed.

A list of suggested items to be considered by developers when submitting site plans for a low impact development subdivision. All items will apply to each individual property due to individual site differences. Check items that have been applied, or explain why the items have not been used.

This checklist can be found online at: http://clear.uconn.edu/projects/TMDL/library/papers/Eagleville%20Brook_draftLIDchecklists.pdf

References

North Carolina Department of the Environment and Natural Resources. 2009. Selecting the Right BMP. From BMP Stormwater Manual.

University of Minnesota. 2001. Soil Compaction: Causes, Effects, and Control. WW-03115.

USEPA. 2009. About NPDES.

Tennis, P. D., M. L. Leming, and D. J. Akers. 2004. Pervious Concrete Pavements. Portland Cement Association, Skokie, IL, and National Ready Mixed Concrete Association, Silver Spring, MD.

::This page::
::intentionally left blank::

Community Planning

Low Impact Development and Community Planning

LID Workshop; Prichard, Alabama

Low Impact Development (LID) is still a relatively new concept in Alabama. Very few plans submitted to city and county planning offices have water resource elements that specifically address LID. Moreover, LID is not consistently addressed in the comprehensive planning process.

As authorized by the Clean Water Act, the National Pollutant Discharge Elimination System (NPDES) permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States. Administered by the USEPA, NPDES is driving the use of LID measures especially in new development. In most areas, the State is the delegated authority charged with implementation.

Smart Growth is another USEPA development strategy seeking to balance economic growth, urban renewal, and conservation. In new development, Smart Growth advocates compact, village-centered communities composed of open space, commercial areas, and affordable housing, interconnected by pedestrian paths and bicycle lanes. Smart Growth stresses "walkable communities" and alternative forms of transportation that can help lessen the environmental and social consequences of urban sprawl. While not explicitly mentioned as a principal, stormwater management, nevertheless benefits from Smart Growth policies. Compact, high-density development reduces imperviousness at the watershed scale to help reduce overall stormwater runoff. USEPA encourages both LID and Smart Growth as stormwater control measures.

A Holistic Approach to Planning

Planners can support stormwater runoff mitigation by promoting development designs that reduce impervious surfaces and urban sprawl. Communities employing conservation development techniques have found that natural features like undeveloped landscapes, vegetation, and buffer zones effectively reduce and filter stormwater flows. There are also additional benefits such as recreation, wildlife habitat, and increased property values. LID integrates environmental considerations into each stage of development, from design to construction and post-construction. LID practices are also known to improve air quality, reduce the heat island effect, and enhance community appearance. LID measures used individually can produce measurable improvements in stormwater runoff management. Used in combination, they can help local governments and institutions address significant sources of stormwater pollution, and meet NPDES stormwater regulations.

Incorporating LID into the Planning Process

The comprehensive plan is the cornerstone of the Alabama planning process. A comprehensive plan dictates public policy in terms of transportation, utilities, land use, recreation, and housing. The comprehensive plan typically encompasses a specific geographical area and covers a long-term time horizon. Comprehensive planning is an attempt to establish guidelines for the future growth and welfare of a community. Local governments may also voluntarily adopt elements addressing topics of local interest. Cities and counties could adopt an optional LID element in their comprehensive plans, but few have done so. Water is typically addressed only in terms of water supply, and water quality issues have most often been addressed in a separate stormwater management plan. The range of issues addressed in the comprehensive plan and areas covered is left to the decision-making body of the City or the County adopting the plan.

There are several methods to incorporate LID into comprehensive plans. One approach involves amending existing comprehensive plans to incorporate LID language on principals, goals, and policies. Since the land use element is the focus of land use decisions, language on LID should be added to the element. LID language should also be added to other elements that concern water such as Natural Resources. A second approach would be an optional water element to the comprehensive plan. Not many such elements exist in Alabama. The city of Semmes, AL is a good example of how to include watershed protection in a municipal comprehensive plan. Watershed protection and management, protecting and improving water quality, and managing water resource supply and demand are components that should be addressed in comprehensive plans. Such a model element would address the links between water and land use. LID principals, goals, and policies should be added to the jurisdictional stormwater management plan and cross-referenced between these two documents for consistency.

LID may be implemented using an "overlay" specific plan. Such plans are flexible and scalable by design. They are typically used to address the comprehensive development or redevelopment of a defined area (overlay zone) and include LID requirements among the standard and implementation measures applicable to the area.

Conditions of Approval

One method of addressing LID early in the planning process is to develop and apply both standard and non-standard conditions of approval. Most municipalities apply "conditions of approval" to the approval of development projects. These conditions often relate to a broad range of topics, including grading, drainage, landscaping, and water quality. Conditions of approval normally state what is to be done, who is to do it, when it is to be done, and who is responsible for determining compliance. Conditions are applied to discretionary planning permits and subdivision maps at different levels in the approval process. Many jurisdictions in the northeast and on the west coast of the United States have developed water quality conditions of approval. Such conditions often relate to pollution prevention during construction and planning for the installation of post-construction structural and non-structural water quality control measures. Attending and speaking up at your community's comprehensive plan update review is one way to get involved in this process.

New conditions requiring consideration and planning for the implementation of LID measures should be added to the list of standard conditions of approval. LID conditions of approval should be applied as early as possible in the project approval process and repeated at subsequent levels of approval to ensure compliance, timely implementation, and long-term maintenance.

LID and Jurisdictional Codes

Jurisdictional codes can support LID in several ways. Cities and counties can adopt separate ordinances that require the use of LID principals in development projects and provide standards for their use of LID. A LID ordinance can specify when LID implementation plans are due and specify compliance with criteria and standards in a manual or handbook such as this document.

Existing jurisdictional codes may contain barriers to LID implementation. Many types of codes and ordinances can influence the implementation of LID, and impact LID differently at varied scales. At the site scale, building codes, landscape codes, parking codes, and zoning ordinances can influence site coverage, building dimension, parking requirements, and landscaping. A variance, or legal permission from the local governing authority to depart from the code or ordinance, may be needed to implement LID under these codes.


Consensus Building Excercise

Removing Barriers to LID in Current Codes

Removing barriers to LID in existing codes, including zoning codes, is likely to be a time consuming process and vary from jurisdiction to jurisdiction. Perceived barriers to implementation of LID measures are often the result of multiple requirements from multiple departments within a municipality. Not all perceived barriers need to be removed from existing codes. It may actually be easier, at least initially, to apply for a variance or use overlay zones to facilitate implementation of LID practices in both new development and redevelopment projects. As more experience is gained with implementation of LID, the municipal ordinance could then be modified and updated to be more LID inclusive.

New Ordinances to Facilitate LID

A direct way to facilitate LID is to adopt a specific LID ordinance that requires the use of LID principals in development projects. The easiest way to write such a LID ordinance is to use a "model ordinance" as a template. A model LID ordinance for Alabama wound need language that is implementable under State Code of Alabama law. The City of Auburn, AL Conservation Subdivision Development Ordinance and Stream Buffer Ordinance, the Subdivision Regulations for Semmes, AL and Daphne, AL Land Use and Development Ordinance, are good examples of model ordinances that support LID principals. Examples of model ordinances can be found in Appendix B. The Center for Watershed Protection Code and Ordinance Worksheet (found in Appendix B) is based on 22 model development principals for the state of Maryland published in Better Site Design: A Handbook for Changing Development Rules in Your Community (August 1998). This handbook is an excellent guide to facilitate local discussion on Model Development Principals in Alabama communities striving to make their codes and ordinances more LID friendly. The Center for Watershed Protection, Inc. is headquartered in Ellicott City, Maryland, and is a national repository for best practices in stormwater and watershed management.

Conservation Development

Like LID, Conservation Development attempts to moderate the effects of urbanization. It places an added importance on protecting aquatic habitat and other natural resources. Conservation Development subdivisions are characterized by dense clustered lots surrounding common open space. Conservation Development's goal is to make a small footprint, thus disturbing as little land area as possible while simultaneously allowing for the maximum number of residences permitted under zoning laws. Here developers evaluate natural topography, drainage patterns, soils, and vegetation prior to construction. Designs should implement LID practices to alleviate flooding and protect natural hydrology. Conservation Development creates conditions that slow, absorb, and filter stormwater runoff on site by maintaining natural hydrological processes. Conservation Development provides for long-term and permanent resource protection. Additionally, conservation easements, transfer of development rights, and other "in perpetuity" mechanisms ensure that protective measures are more than just temporary. A LID Site Planning and Design Checklist can be used to assist municipalities and developers in the planning and design of LID developments (See Table 2.4 in Site Selection).

LID, LEED and Sustainable Sites Initiative

LID practices can accomplish stormwater management goals, while aiding in obtaining LEED (Leadership in Energy and Environmental Design) certification. LEED is an internationally recognized green building rating system. There are nine LEED building rating systems. Projects that are landscape-only, such as parks, cannot be LEED certified (see Sustainable Sites Initiative below). LEED is voluntary, consensus-building and market-driven. The systems are categorized by building type, and internally divided into credit categories. The credit name, number, and LEED point-worth are provided, as well as the credit's intent, requirements, options, and in some cases, potential strategies. Some credit categories have prerequisites that must be met before credit certification can be achieved. The United States Green Building Council (USGBC) provides information about all of the LEED rating systems including lists of prerequisites, possible credits, and points.

The USGBC administers LEED certification for all commercial and industrial projects. The certification process begins with a determination of whether LEED is right for a project. The project must then be registered, signifying intent to develop a building which meets LEED certification requirements. Resources will be provided at this time that will assist with the building application for certification. Once all materials are assembled, the designated LEED Project Administrator is eligible to submit the application online.

The two LEED rating systems most relevant to LID are LEED for New Construction and Major Renovations (including LEED for Schools), and LEED for Neighborhood Development. For commercial buildings and neighborhoods to earn LEED certification, a project must satisfy all LEED prerequisites and earn a minimum 40 points on a 110-point LEED rating system scale. Homes must earn a minimum of 45 points on a 136-point scale. The LEED for New Construction and Major Renovations Rating System is designed to guide high-performance commercial and institutional projects including offices, libraries, churches, hotels and government buildings. The intent is to promote healthful, durable, affordable, and environmentally sound practices, in building design and construction. Credit categories relating to LID include: Sustainable Sites, Water Efficiency, and Materials and Resources. See Table B.1 in Appendix B.

The LEED for Neighborhood Development Rating System integrates the principals of Smart Growth, urbanism, and green building into a plan that relates the neighborhood to its larger region and landscape. LEED for Neighborhood Development is developed in collaboration with Congress for the New Urbanism and the Natural Resources Defense Council. The rating system emphasizes elements that bring buildings and infrastructure together and relates the neighborhood to its local and regional landscape. This partnership was created to encourage developers to revitalize existing urban areas, reduce land consumption, reduce automobile dependence, promote pedestrian activity, improve air quality, decrease polluted stormwater runoff, and build more livable and sustainable communities for people of all income levels. Credit categories relating to LID include: Smart Location & Linkage and Green Construction & Technology. See Table B.2 in Appendix B.

The Sustainable Sites Initiative (SITES) is an interdisciplinary effort by the American Society of Landscape Architects, the Lady Bird Johnson Wildflower Center at The University of Texas at Austin, and the United States Botanic Garden to create voluntary national guidelines and performance benchmarks for sustainable land design, construction and maintenance practices. It has established Sustainable Sites Initiative Guidelines, to certify sustainable landscape projects. The guidelines are modeled after the LEED program, offer certification based on the use of prerequisites and credits for specific sustainable design practices, and are constantly being updated.0 Ratings are based on a 250-point system. A minimum of 100 credits must be earned in order to be awarded one star. In addition to earning credits, projects must follow several prerequisites in order to qualify as sustainable sites. Up to 127 of these credits can be earned by following the LID site design process. See Table B.3 in Appendix B.

References

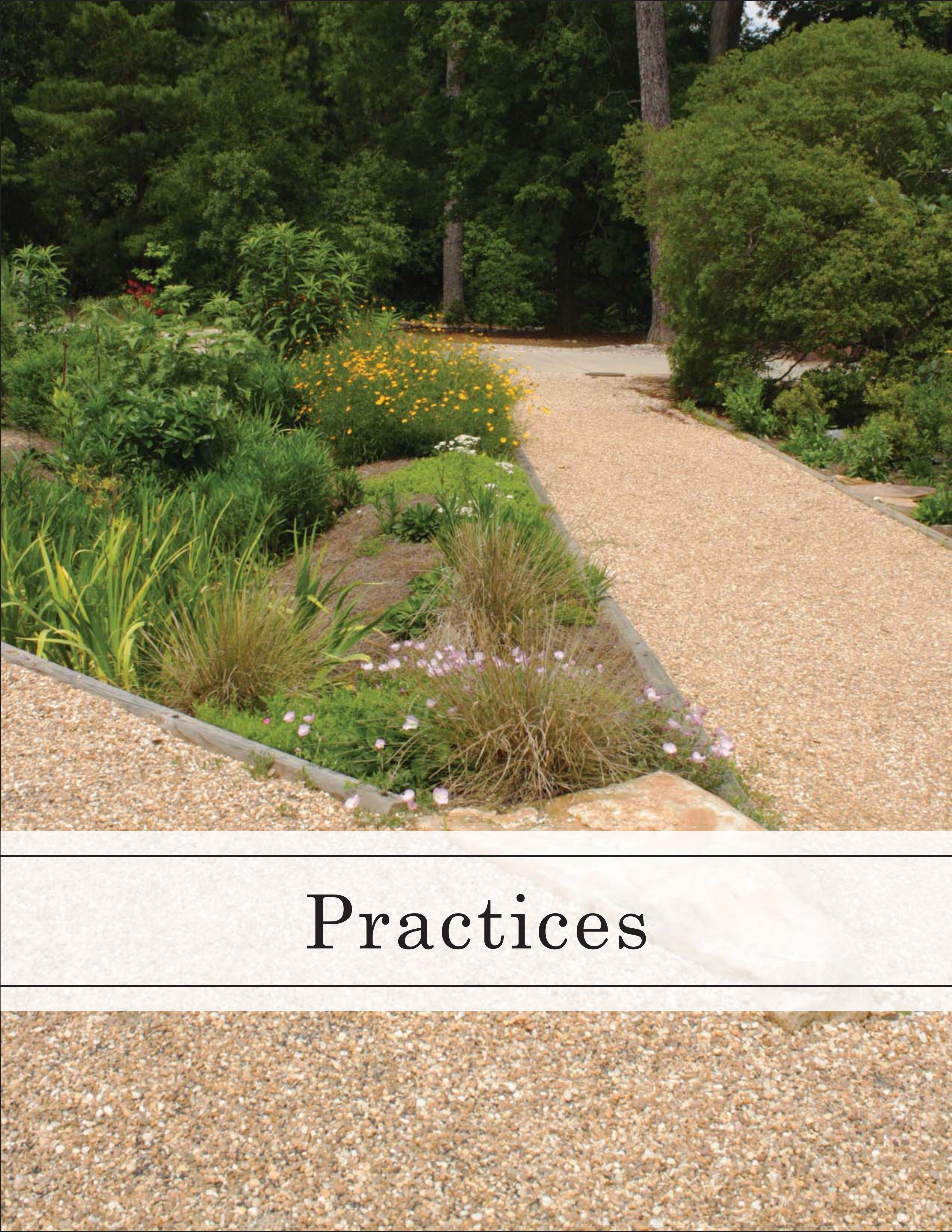
Arendt, Randall. 1996. Conservation Design for Subdivisions: A Practical Guide to Creating Open Space Networks. Island Press, Washington, D.C.

Daphne, Alabama Land Use and Development Ordinance. Last accessed: July 7, 2013. http://www.daphneal.com/wp-content/uploads/2011/08/ord-land-use.pdf

Low Impact Development Center, Inc. Low Impact Development Manual for Southern California: Technical Guidance and Site Planning Strategies. 2010. World Wide Web. Last accessed: Feb. 13, 2013. http://www.casqa.org/LID/SoCalLID/tabid/218/Default.aspx

Semmes, Alabama Sudivision Regulations. Last accessed: July 7, 2013. http://www.cityofsemmes.org/PlanningCommission/Subdivision%20Regulations/SUBDIVISIONREGULATIONS-Adopted-Jan242012.pdf

Sustainable Sites Initiative. Last accessed: Feb. 18, 2013. http://www.sustainablesites.org/



Practices

Bioretention (BRC)

Bioretention in Railroad Park; Birmingham, AL

Site Selection

Quantity Control	possible
Drainage Area	small-med
Space Required	med

Works with:

Steep Slopes	---
Shallow Water Table	---
Poorly Drained Soils	---

General Significance

Construction Cost	med/high
Maintenance	med/high
Community Acceptance	med/high
Habitat	med
Sun / Shade	sun to p.shade

Synonyms: Bioretention basin

Bioretention cells (BRCs) remove pollutants in stormwater runoff through adsorption, filtration, sedimentation, volatilization, ion exchange, and biological decomposition. A BRC is a depression in the landscape that captures and stores runoff for a short time, while providing habitat for native vegetation that is both flood and drought tolerant. BRCs are stormwater control measures (SCMs) that are similar to the homeowner practice, rain gardens, with the exception that BRCs have an underlying specialized soil media and are designed to meet a desired stormwater quantity treatment storage volume. Peak runoff rates and runoff volumes can be reduced and groundwater can be recharged when bioretention is located in an area with the appropriate soil conditions to provide infiltration. Bioretention is normally designed for the water quality or “first flush” event, typically the first 1”-1.5” of rainfall, to treat stormwater pollutants. In certain situations, BRCs can also provide stream channel protection through minimizing peak discharges.

Site Selection

Bioretention works well in dense, urban developments because of the flexibility of its space constraints. Conventional stormwater treatment systems may be inefficient in treating first flush events due to large acreages needed to capture the required volume of stormwater. However, BRCs are versatile systems that store stormwater beneath the media surface, addressing the spatial constraints of ultra-urban areas.

Sizing: BRCs are most effective when used to treat small to moderate quantities of stormwater or small drainage areas that are close to the source of stormwater runoff. These qualities make this SCM an excellent candidate for retrofits (for more information on retrofits, see Retrofits under Construction). The maximum drainage area recommended for bioretention is 5 acres, but 0.5 to 2 acres is preferred. Larger drainage areas can be treated by distributing multiple, decentralized BRCs throughout a watershed. Sizing criteria may depend on the infiltration characteristics of the media, flood mitigation, and pollutant removal needs. This practice does not require a large space; however, a minimum of 200 ft^2 footprint is recommended or approximately 5 – 8 % of the contributing impervious area draining to the system. BRCs perform well when treating small storm events and are well suited for small lots, such as parking lot islands, both as an initial installation practice or retrofit.

Table 4.1.1
Site Selection: Constraints & Limitations for Bioretention

Shallow Water Table	Locations where the seasonally high water table is less than 6' from the surface or less than 2' from the bottom of the cell are not suitable
Slope	Locations with 5% or less slope are recommended and flatter locations work best
Utilities	Call Alabama 811 before construction to locate utilities (for more information, visit: www.al1call.com)
Unstable Soils or High Sediment loads	Locations that are not under active construction, changing soil conditions, or will not experience high sediment loads are recommended; clayey soils can clog media
Continuous Flow	Locations that will not experience continuous flow and are allowed to drain are recommended
Regional Stormwater Control	Bioretention is best suited in small drainage areas; if regional stormwater control is necessary, another SCM should be selected

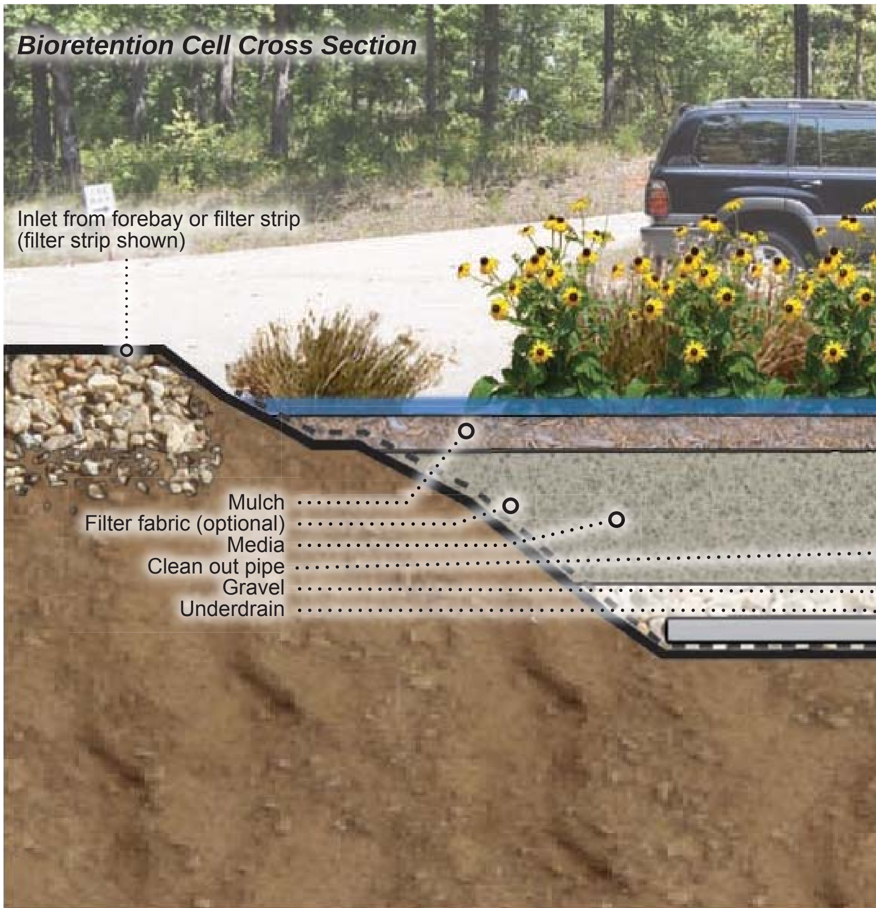
Evaluating Soils: Use the USDA Web Soil Survey to identify soil map units and to make initial interpretations for potential uses and limitations of a site. However, since most soil map units have inclusions of other soils that may be quite different, detailed evaluations should be made at the proposed site by a professional soil scientist or soil classifier. On-site evaluations should properly identify a soil or the hydrologic soil group (HSG) and the final decision for use should be made based on the detailed determination of soil series or HSG. For a detailed list of HSG properties, see Table A.3 in Appendix A on Stormwater Hydrology.

USDA's online Web Soil Survey (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm) can be used as a guide to determine the needed soil information for the site, such as the hydrologic soil group (HSG) and depth to water table.

In-situ Soil: BRCs perform best when sited in well-drained soils such as hydrologic soil group (HSG) A or B (see Chapter 5.1 on Rain Gardens for more information on infiltration testing). In particular, the internal water storage (IWS) layer requires well-drained surrounding soils to function properly. The HSG and an infiltration test will determine if a BRC is a good fit for the soils on site.

Depth to Groundwater: BRCs are suited to sites where the depth to water table is > 6' or where the seasonally high water table is at least 2' from the bottom of the cell to decrease the chance of groundwater contamination. BRCs or any SCM should not release runoff filtering a "hotspot" into groundwater. Hotspots are defined as commercial, industrial, or other operations that produce higher levels of stormwater pollutants and/or have concentrated pollutants.

Site Specific Constraints: The layout of a BRC depends on site-specific constraints such as underlying soils, existing vegetation, drainage, utility location, safety, sight distances, aesthetics, maintenance ease, and equipment access. Bioretention is not recommended in areas with slopes > 5% or where mature trees must be removed. Large trees have extensive root systems and removing them is a time and energy consuming process. If BRCs are sited adjacent to "messy trees" such as sycamore, water oak, or magnolia, it should be clearly understood that more frequent maintenance will be required to minimize clogging of the cell media. Messy trees have excessive leaf litter, fruiting structures, and other debris compared with other trees. A BRC should not be sited in



areas where it will receive high sediment loads, as this will also lead to clogging of the cell media. The contributing drainage area should be stabilized prior to construction of all SCMs, and this is especially imperative for bioretention to prevent clogging and promote proper infiltration rates.

Design

Appropriate watershed and site information should be collected before beginning the design of any SCM. Layout should consider the pretreatment device, IWS layer, and overflow devices. Future maintenance should also be considered, particularly access to a pretreatment device such as a forebay.

Components

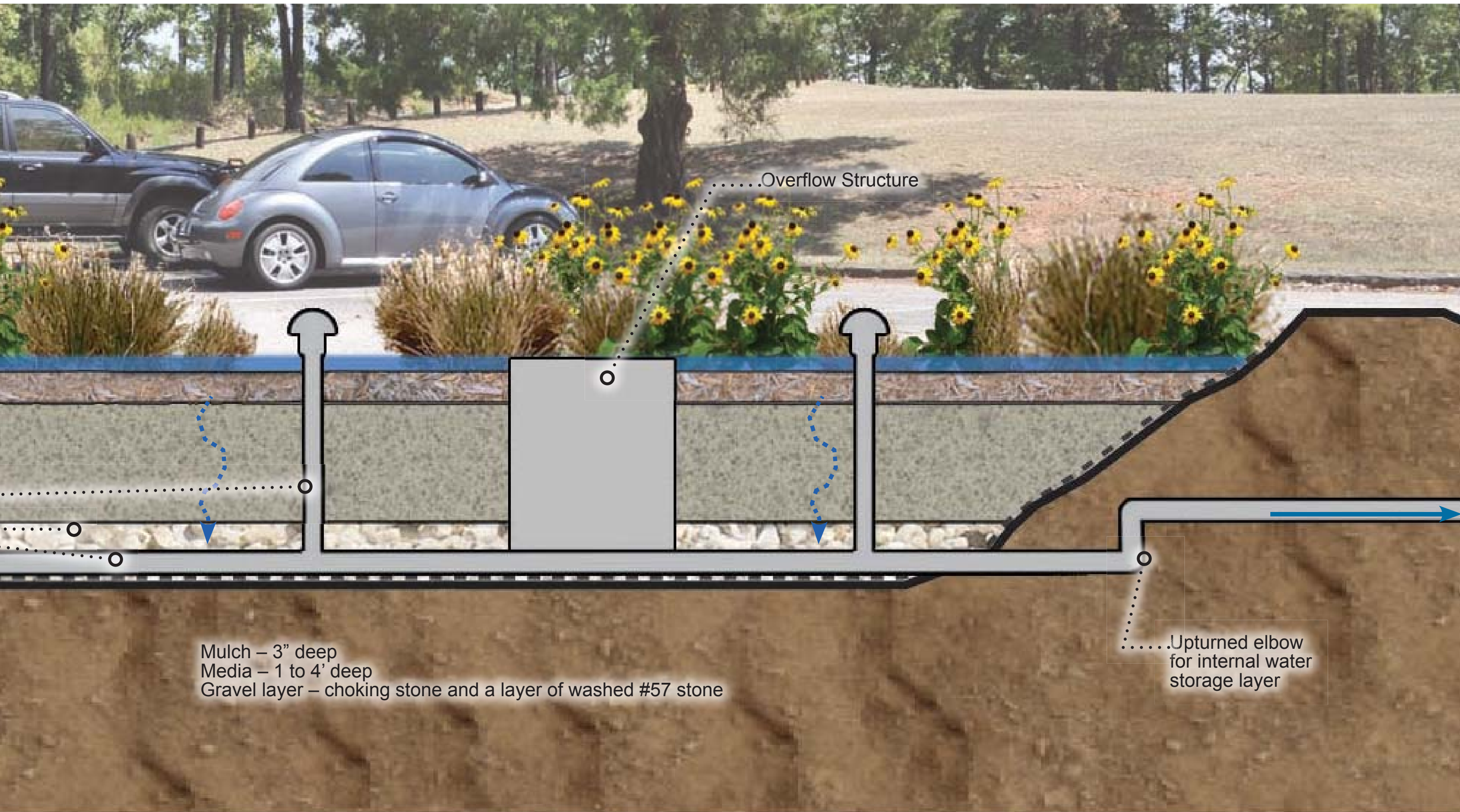
The bioretention system is made up of three primary components: a pretreatment device, BRC, and an overflow or bypass structure.

Pretreatment: Pretreatment devices serve as preventative maintenance for SCMs. Pretreatment devices slow runoff velocities, provide easier maintenance access, and reduce total suspended solids (TSS) in the system by encouraging sedimentation. If pretreatment is not used with bioretention, the mulch layer will require more frequent replacement due to sediment capture and settling on the mulch surface.

Stormwater runoff should sheet flow into a BRC. Swales, forebays, or a minimum of 3' wide sod filter strips are recommended as pretreatment devices for energy dissipation and an even distribution of runoff flow. When selecting a pretreatment device for bioretention, the number of inlets or directions from which stormwater will enter the cell, should be considered, as well as maintenance access and frequency.

Grassed filter strips: Grassed filter strips are recommended if stormwater enters the system via sheet flow over a parking lot or other impervious surface into the cell from all sides of the system (multiple inlets). The filter strip pretreatment system is made up of an 8" wide strip of gravel followed by 4' of sod. For more information on designing filter strips, see Chapter 5.5 on Level Spreaders and Grassed Filter Strips.

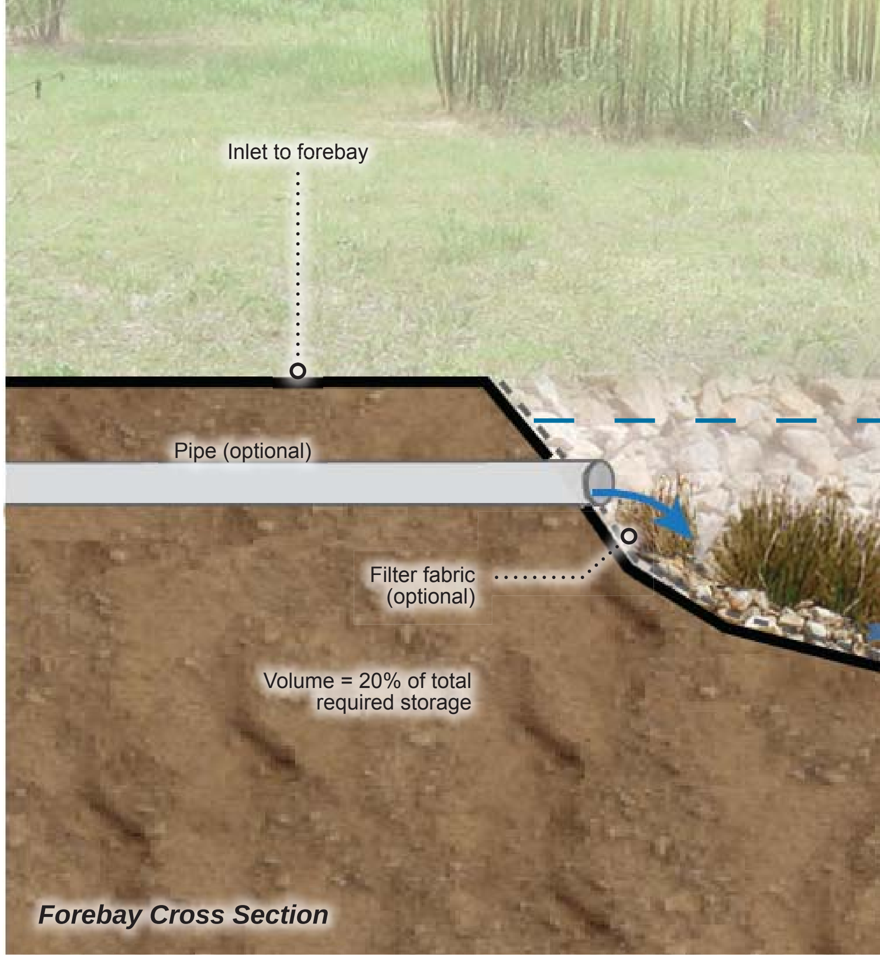
Forebay: A forebay is the best form of pretreatment when runoff is concentrated, channelized, or constricted, such as discharge from a pipe. A forebay is an 18 - 30" deep pool and is used in situations where standing water is not considered a safety concern. The forebay is deepest at the point of runoff entry and is shallowest at the exit point, which dissipates energy throughout the forebay and provides diffuse flow into the BRC.



Additional Components

Underdrain: A perforated pipe is used as the underdrain to promote draining of the cell completely within 48 - 96 hours. The underdrain should be placed in a 3' wide bed of ASTM #57 aggregate at a minimum thickness of 3", covered with 6" of #57 aggregate, and topped with an additional layer of #89 aggregate (layer thickness shall be 2", minimum). Double-washed stone is preferred. Wrapping the underdrain pipe in silt sock or textile is discouraged to prevent clogging from smaller silt particles. The range of pipe diameter used for underdrains is 4 - 8". Due to the potential for clogging, multiple underdrains and clean out pipes are recommended.

The need for underdrains is driven by permeability of the in-situ soil surrounding the BRC. In-situ soils with a saturated hydraulic conductivity less than 2"/hr require underdrains to help drain effluent from the media, which is discharged to another SCM or the stormwater conveyance network. If the saturated hydraulic conductivity is 2"/hr or greater, underdrains are not required. More information about the determination of saturated hydraulic conductivity and its properties can be found in Stormwater Hydrology in Appendix A.



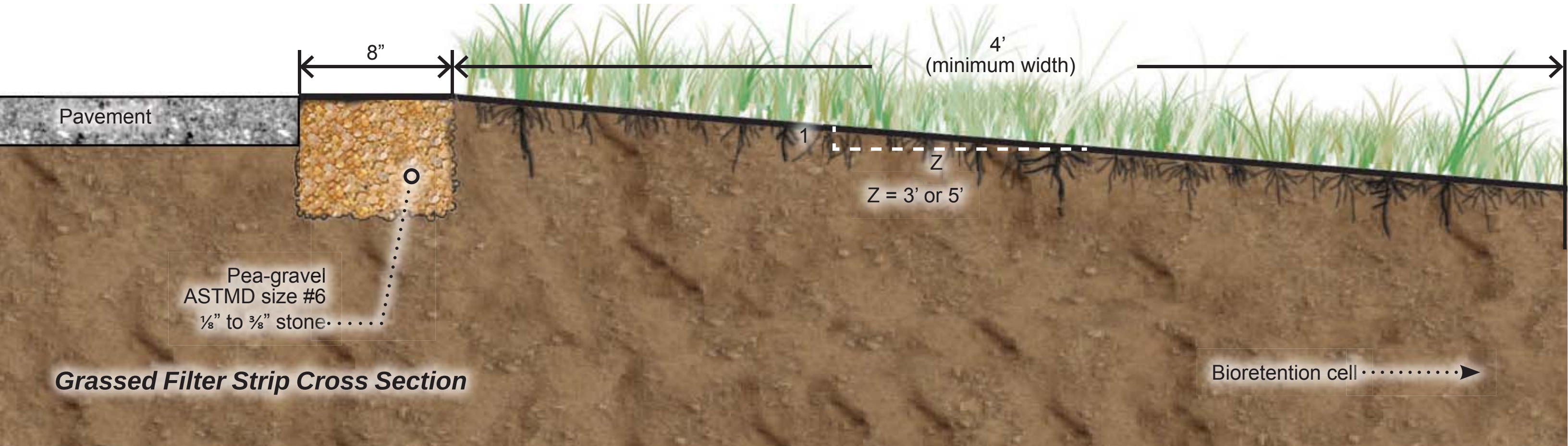
Forebay Cross Section

Clean Out Pipes: Clean out pipes are used to maintain the underdrain system when it is clogged. The addition of clean out pipes can decrease future maintenance costs associated with media excavation.

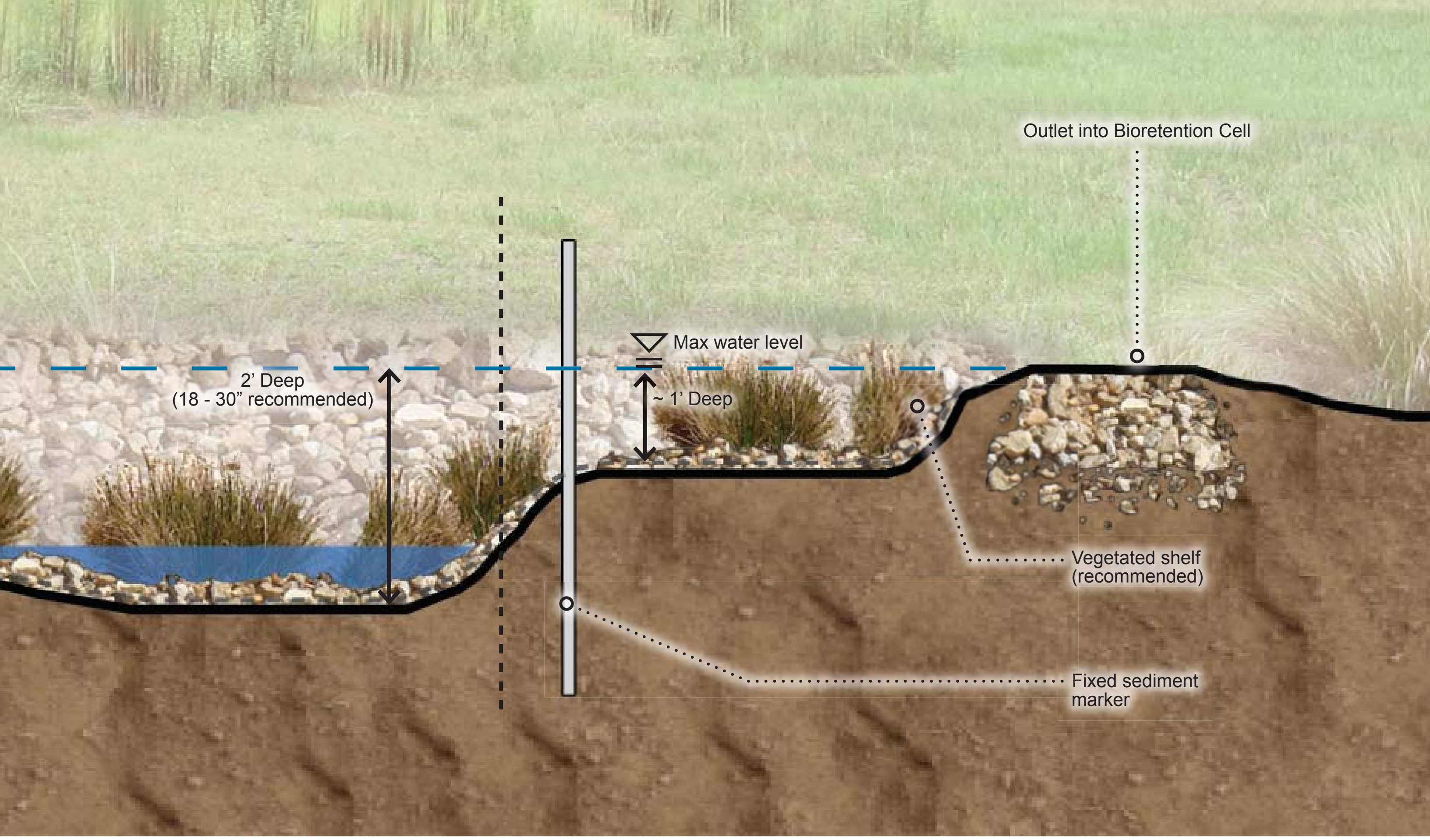
Soil Media Type: The soil media is to be a homogenous soil mix of 85 - 88% washed sand (by volume), 8 - 12% fines (silt and clay) and 3 - 5% organic matter (hardwood mulch or other aged organic component). The mix should be uniform and free of debris greater than 1" diameter. The amount of fines determines the percentage of other media materials. An increased fines content (12%) should be used when targeting a nitrogen reduction and decreased fines content (8%) should be used when targeting phosphorus. See the Construction Section for information on soil testing of the BRC media.

Ponded water should drain within 12 hours, and stormwater should infiltrate the cell to 2' below the surface within 48 hours. The pore-spaces of the media should drain completely with the exception of the volume used for the internal water storage (IWS), which should drain within 96 hours (4 days) based on the design storm.

Internal Water Storage: The IWS layer is created in the bottom of the cell by adding a 90° upturned elbow to the underdrain. This elbow is arranged perpendicular to the horizontal underdrain, and forces water to remain in the lower portion of the media, creating a saturated, anaerobic zone that promotes increased nitrogen reduction (through dentrification) and infiltration. The IWS layer holds water following a rain event, but should drain within 4 days. The addition of an IWS layer may reduce the frequency of outflow in exceptionally permeable soils, such as sandy soils of the Coastal Plains. The use of IWS also allows for temperature reduction benefits because the coolest water is the first to exit the cell as it is pulled from the bottom of the BRC.

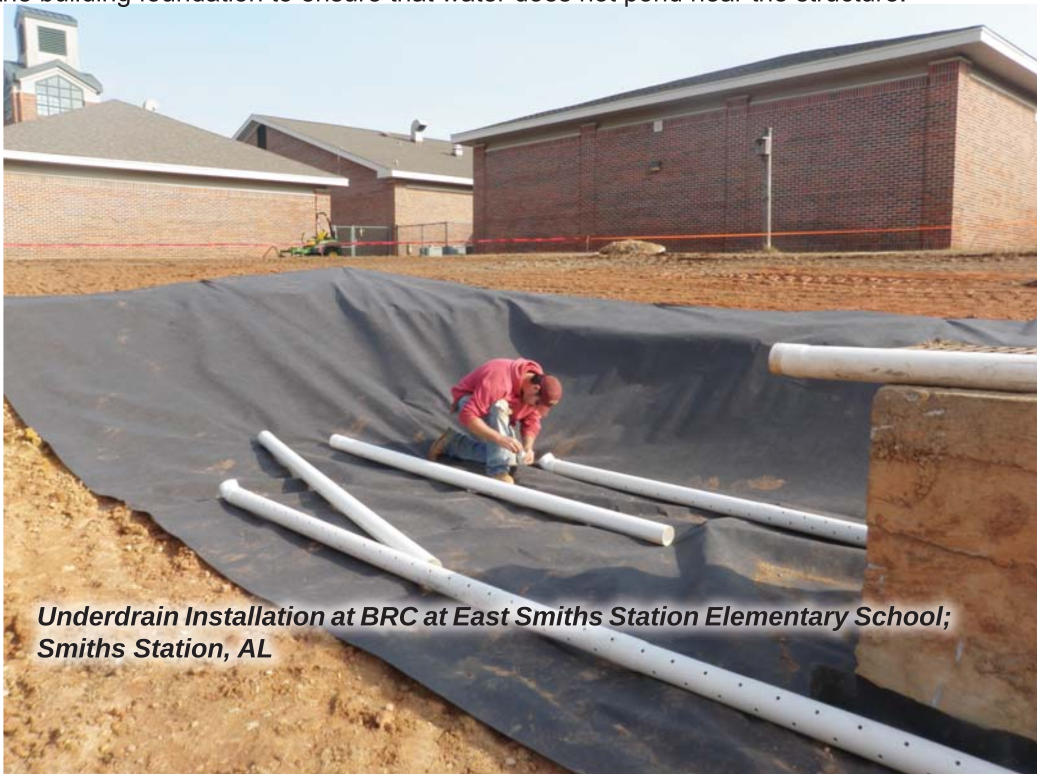


Grassed Filter Strip Cross Section



Similar to underdrains, the use of IWS is dependent on the permeability of the underlying soils. The underlying soils must have a hydrologic soil group (HSG) A or B with limited clay content, to be effective. Media depths above the underdrain layer must be at least 3' to use IWS, with at least 12 - 18" separating the outlet and bowl surface depths (see Internal Water Storage Cross Section). BRCs with a properly designed IWS and acceptable surrounding soil conditions may have increased nutrient reduction rates ranging from 40 - 60% nitrogen and 45% - 60% phosphorus depending on location and in-situ soil. For more information, see the Pollutant Removal Section.

Overflow Structure: BRCs are designed to use an overflow structure such as a bypass or stormwater conveyance overflow. This allows water in excess of the treatment volume to overflow into the existing stormwater conveyance network or to another appropriate SCM such as a filter strip, infiltration swale, level spreader/ grassed filter strip system, or grassed swale. If the BRC is sited adjacent to a building or other structure, the overflow device should release overflow downhill from the building foundation to ensure that water does not pond near the structure.



Underdrain Installation at BRC at East Smiths Station Elementary School; Smiths Station, AL

Design Guidance

The following steps and equations can be used for basic BRC design.

1. **Determine runoff volume to be treated (Design storm)**

    In this handbook, the Discrete Curve Number Method is used to determine the runoff volume or the water quality volume required for treatment. Bioretention is a water quality SCM and these calculations do not consider water quantity or stormwater volume control. BRCs may provide some volume control and standard calculations would apply. For a detailed explanation of the Discrete Curve Number Method and other methods that can be employed, please refer to Stormwater Hydrology in Appendix A.

    Information needed for use in the Discrete Curve Number Method include: **drainage area, pervious and impervious land area, curve numbers (CN), maximum potential retention after rainfall begins (S), precipitation depth (P), and runoff depth (Q).**

    The Discrete Curve Number Method is outlined in EQN 4.1.1 and 4.1.2.

2. **Determine required surface area**

    A BRC is designed to hold approximately the first inch of runoff (first flush) from the entire drainage area. For more information on the first flush, see Appendix A on Stormwater Hydrology. Ponding depths should be no more than 12” for safety reasons. The ponding depth is dependent on the cell’s ability to drain and a deeper maximum ponding depth may be acceptable as long as vegetation is tolerant.

    To determine the required **surface area (SA)**, an assigned **average ponding depth (Avg. Pond)** is divided into the required **treatment volume (V)**, as shown in EQN 4.1.3. The required **treatment volume (V)**, is equal to the runoff depth calculated in EQN 4.1.2.

    Once the required SA is determined (with existing site constraints considered), the dimensions (length and width) of the SA can be determined.

EQN 4.1.1

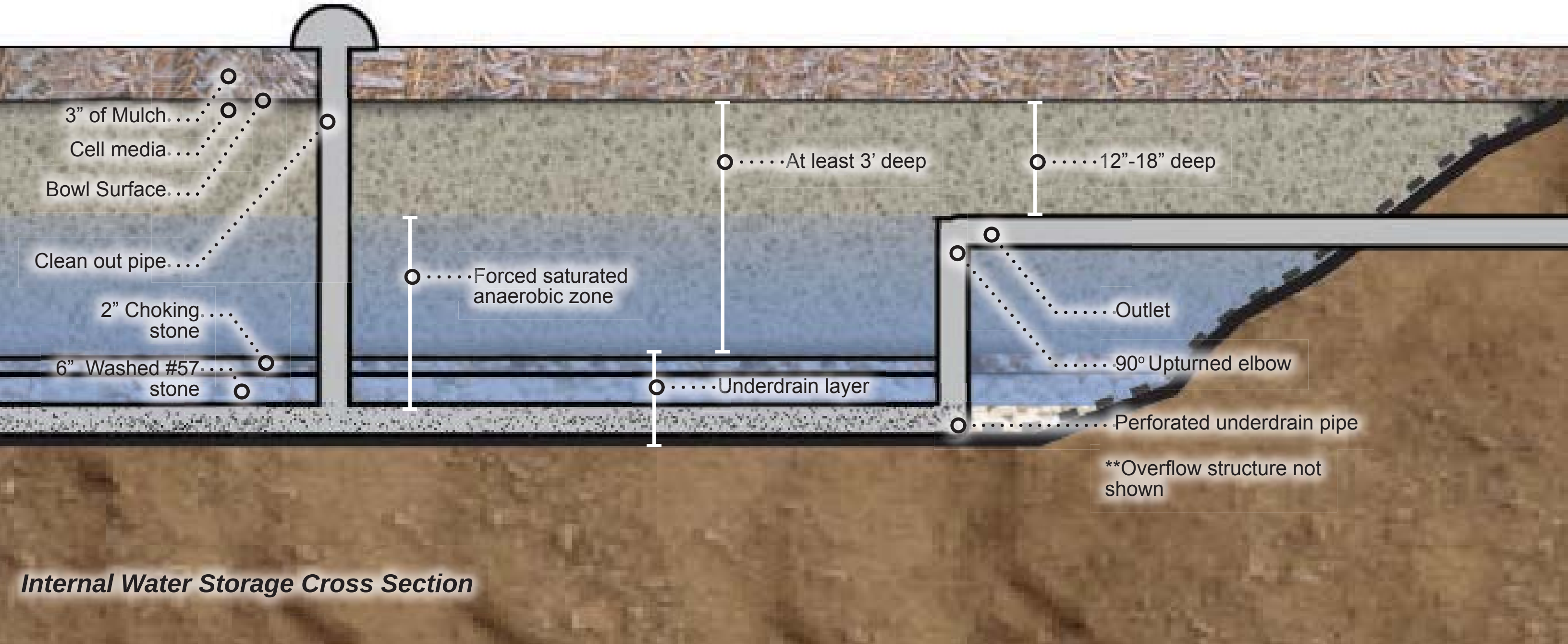
$$S = \left(\frac{1000}{CN}\right) - 10$$

EQN 4.1.2

$$Q = \frac{[P - (0.2S)]^2}{P + (0.8S)}$$

EQN 4.1.3

$$SA = \frac{V}{Avg.\ Pond}$$



Internal Water Storage Cross Section

EQN 4.1.4

$SA = l * w$

l = length of BRC
w = width of BRC

EQN 4.1.5

$\text{Base Length } (L) = l - 2(s)$

$\text{Base Width } (W) = w - 2(s)$

s = side slope dimension (i.e. for 3:1 side slopes, s = 3)

EQN 4.1.6

$\text{Base Area } (A) = L * W$

EQN 4.1.7

$\text{Quantity} = A * d$

3. **Determine dimensions (length and width) of the BRC based on site constraints.**

   Surface area (SA) is the top surface of the bioretention area. SA calculated by these equations is the minimum size required to capture the design storm event. It is recommended that no dimension should be less than 10' to allow for vegetation and aesthetics. To prevent erosion, a side slope of 3:1 or flatter is recommended. The base of the BRC is calculated using the dimensions determined and subtracting the side slope dimensions. The length and width of the base is determined using EQNs 4.1.4 and 4.1.5. This calculation is assuming a rectangular BRC. If other shapes are used EQN 4.1.4 is not applicable.

   The calculated base length and width can be used to determine the base area. The base area is calculated using using EQN 4.1.6.

   The base area is used to calculate soil media depths. The side slope is only applied to the bowl of BRC and affects up to the first foot of depth.

4. **Determine soil media depth**

   The soil media depth is typically determined by the pollutant to be removed and the depth of media needed to support vegetation. Table 4.1.2 illustrates the minimum depth of media required for pollutant removal effectiveness. Selected vegetation type for the cell may require that the media depth be greater than the depth required for pollutant removal (Table 4.1.3).

5. **Determine quantity of BRC media and aggregates needed**

   The quantity of BRC media is calculated using the **base area (A)** and the depth of media, washed sand, choking stone, and #57 stone desired (Table 4.1.4). Quantity of a material (cubic feet) equals the **depth of the material, d** (feet) multiplied by the **base area, A** (square feet), as shown in EQN 4.1.7.

   Using EQN 4.1.8, the quantity in cubic feet can be converted to cubic yards; which is typically the unit of quantities when ordering material.

6. **Determine number and size of underdrains**

Table 4.1.2

Target Pollutant	Media Depth (ft)
Metals and Oils	1
Pathogens	2
Nutrients	3
Temperature	4

**There is no recommended media depth for TSS removal because sedimentation occurs before runoff infiltrates the BRC.

Table 4.1.3

Recommended Depth (in)	Vegetation Type
≤24	Herbaceous perennials and grasses
≥24	Shrubs
≥36	Small trees

Table 4.1.4

Material	Recommended Depth (in)
Bioretention Media	36 or pollutant dependent
Washed Sand	4
Choking Stone	2
#57 Stone	6

All fill materials should be washed and generally void of debris, to prevent clogging of the system.

Depending on the permeability of in-situ soil, BRCs require underdrains to function properly. Typically 4" – 8" pipes are used. To calculate the number of underdrains required to drain a BRC within 48-96 hours EQNs 4.1.9, 4.1.10, 4.1.11, and 4.1.12 are used.

First, the **total ponding (TP)** is calculated using EQN 4.1.9.

Next, the **peak inflow**, Q_p is calculated using EQN 4.1.10. where, **k is the permeability** of the surrounding soil in inches per hour, **TP is total ponding** in feet, and **d is total depth of material**. The media composition is the primary factor in determining permeability. The values determined in the infiltration test can be used for permeability.

Before the number of pipes can be determined the flow, $\mathbf{Q_{BRC}}$ must be calculated. Flow can be calculated using EQN 4.1.11.

Using a modified Manning's equation, EQN 4.1.12, the number of pipes is calculated.

7. **Check drawdown time**

BRCs should completely drain within 48 - 96 hours for the design rainfall volume captured. Ponded water on the surface of the cell is required to drain to 2' below the surface within a maximum of 48 hours. Using the **Volume, V** calculated in EQNs 4.1.2/4.1.3 on page 24 and the **flow** $\mathbf{Q_{BRC}}$, calculated in EQN 4.1.12, the time it takes for the BRC to drain or the drawdown time can be calculated. EQN 4.1.13 illustrates this calculation.

8. **Select the appropriate overflow or bypass**

Overflow devices should be sized to pass rainfall events in excess of the water quality volume. These can be attached to existing infrastructure or a weir can also be used for overflow into a large grassed area or adjacent SCM.

EQN 4.1.8

$$\text{Quantity to order } (yd^3) = ft^3 * 0.037037$$

EQN 4.1.9

$$\text{Total Ponding } (TP) = d + \text{Avg. Ponding}$$

EQN 4.1.10

$$Q_P = \frac{k * TP}{d}$$

EQN 4.1.11

$$Q_{BRC} = \frac{\left(\frac{Q_P}{3600}\right)}{12} * SA$$

EQN 4.1.12

$$N = \frac{\left(16 * \left\{\frac{Q_{BRC} * n}{s^{0.5}}\right\}^{3/8}\right)}{D}$$

Q_{BRC} = flow
n = manning's n
s = slope
D = diameter of pipe (in.)

EQN 4.1.13

$$\text{Time } (hr) = \frac{\left(\frac{V}{Q_{BRC}}\right)}{3600}$$

Bioretention Design Example

For the design example, a location in central Alabama has been selected. The site is **1.6 acres** total, with **0.65 acres** of parking lot (**curve number 98**) and **0.95 acres** of lawn that is in fair condition (**curve number 69**) draining to the BRC. The water quality design storm event precipitation depth is **1.2" (P)**. The soil has a HSG B and a depth to water table greater than 6'. **For this design example numbers are rounded to two significant digits**

1. To calculate runoff, use EQNs 4.1.1 and 4.1.2, for the Discrete Curve Number Method.

EQN 4.1.1

$$S = \left(\frac{1000}{CN}\right) - 10$$

EQN 4.1.2

$$Q = \frac{[P - (0.2S)]^2}{P + (0.8S)}$$

Using the provided curve numbers (CNs), precipitation depth, and equations, the following runoff depths are determined:

Parking Lot (CN=98): S = 0.20", Q = 0.99"= 0.08'

Fair Condition Lawn (CN=69): S = 4.49", Q = 0.02" = 0.00'

To determine the runoff volume, the calculated runoff depths are to be multiplied by their respective areas and summed. Using calculations to two significant digits the Fair Condition Lawn does not contribute any significant runoff volume.

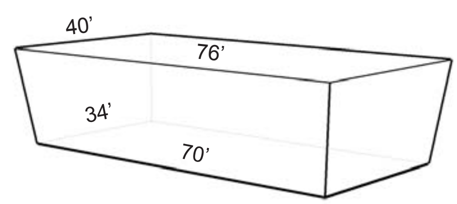
Parking Lot: $0.08\ ft * 0.65 * \left(\frac{43{,}560 ft^2}{1ac}\right) = 2{,}265 ft^3$

Total Runoff Volume = 2,265 ft^3

2. Calculate the surface area (SA) of the bioretention cell using EQN 4.1.3. Average ponding depth **(Avg. Pond)** is typically 9".

EQN 4.1.3

$$SA = \frac{V}{Avg.\ Pond}$$



V= 2,265 ft^3; Avg.Pond = (9"/(1ft/12") = 0.75ft

SA = 3,020 ft^2

*SA should be 3 - 10% of the total watershed area.

3. Dimensions that can be easily constructed should be prioritized. For this example, a 40'x 76' cell is to be used.

Using EQN 4.1.4 the length, 40' and the width 76' can be used to determine if the required **SA** of 3,020 ft^2 is met.

EQN 4.1.4

$$SA = \text{(length)}\ l * \text{(width)}\ w$$

SA = 40*76 = 3,040, which is greater than the calculated required SA of 3020 ft^2.

Continued on next page

Using the dimension 40' and 76' and a side slope of 3:1 the base length and base width can be calculated using EQN 4.1.5. To accomodate for the 9" of ponding and 3" of mulch a 1 foot depth is used to calculate the base footprint.

EQN 4.1.5

$$\text{Base Length } (L) = l - 2(s) = 40-(2*3) = 34'$$
$$\text{Base Width } (W) = w - 2(s) = 76-(2*3) = 70'$$

The BRC **bottom surface area (A)** or footprint dimension is 34' by 70'. The **Base Area (A)** can be calculated using EQN 4.1.6.

EQN 4.1.6

$$\text{Base Area } (A) = L * W = 34*70 = 2,380ft^2$$

4. The soil media depth chosen is 3' for nutrient removal and to support desired vegetation. See the Vegetation section for more information on Vegetation Design.
5. The footprint calculated in EQN 4.1.6 is needed in order to determine the quantity of media fill (aggregates) that is required.

For the design example, with a bowl depth of 12" (9" Avg.Pond and an additional 3" of mulch) and 3:1 side slopes (minimum recommended), the bottom surface area of the cell is 40' x 74' (as calculated in EQN 4.1.6).

Table 4.1.5

Material	Recommended Depth (in)	Amount Needed (yd³)
Bioretention Media	36 or pollutant dependent	280*
Washed Sand	4	31
Choking Stone	2	16
#57 Stone	6	47

*Using 36" depth of media

For example the Bioretention media quantity was calculated using EQN 4.1.7.

EQN 4.1.7

$$\text{Quantity} = A * d = 2,380ft^2 * 3' = 7,140\ ft^3$$

Material quantities are usually specified in cubic yards. Using EQN 4.1.8 bioretention media quantity will be converted to cubic yards.

EQN 4.1.8

$$\text{Quantity to order } (yd^3) = ft^3 * 0.037037$$
$$7140 * 0.037037 = 264.44yd^3 \sim 265yd^3$$

6. The saturated hydraulic conductivity for this HSG B soil is greater than 2"/hr; therefore, underdrains are not necessary. However, a 4" perforated pipe is used in the bottom of this cell for IWS. The underdrain is connected at 1 foot higher than the media material stone base. Often an 18" high density polyethylene (HDPE) pipe with Nyloplast® grate is connected to an existing overflow structure.

Even though underdrains are not necessary the following calculations illustrate underdrain calculations and drawdown time.

EQN 4.1.9

$$\text{Total Ponding } (TP) = d + \text{Avg. Ponding} = 36+9 = 45'' \text{ or } 3.75'$$

EQN 4.1.10

$k = 2''/hr$, $TP = 3.75'$, and $d = 3'$

$$Q_P = \frac{k * TP}{d} = \frac{2 * 3.75}{3} = 2.5in/hr$$

Continued on next page

The flow is calculated using the peak flow, Q_p and the SA calculated in EQN 4.1.4. (For this calculation three significant digits are used due to the magnitude of the variables).

EQN 4.1.11

$$Q_{BRC} = \frac{\left(\frac{Q_P}{3600}\right)}{12} * SA = \frac{(2.5/3600)}{12} * 3020 = 0.175cfs$$

The number of pipes is calculated using flow, Q, manning's n, the pipe slope and the diameter of pipe.

EQN 4.1.12

$$N = \frac{\left(16 * \left\{\frac{Q_{BRC} * n}{s^{0.5}}\right\}^{3/8}\right)}{D} = \frac{\left(16 * \left\{\frac{0.175 * 0.011}{0.0125^{0.5}}\right\}^{3/8}\right)}{4} = \frac{\left(16 * \left\{\frac{0.002}{0.112}\right\}^{3/8}\right)}{4} = \frac{(16 * 0.221)}{4} = 0.88$$

with N<1 this confirms that an underdrain is not required.

7. A properly designed BRC will drawdown in <96 hours. To calculate drawdown time EQN 4.1.13

EQN 4.1.13

$$Time\ (hr) = \frac{\left(\frac{V}{Q_{BRC}}\right)}{3600} = \frac{\left(\frac{2265ft^3}{0.175cfs}\right)}{3600} = 3.6hrs$$

8. A stormwater conveyance drop inlet will be raised and used as the overflow or bypass to the BRC.

Construction

The BRC should be installed in a stable drainage area to minimize sediment entry into the cell. If construction is to occur nearby, the BRC should be protected from sediment clogging by lining the perimeter of the cell with silt fencing, straw bales, or other appropriate sediment control measures.

Please review proper sediment control practices in the Alabama Handbook for Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas (http://swcc.alabama.gov/pages/erosion_handbook.aspx).

Excavation: Construction should never occur on saturated soils. Furthermore, construction of the cell should be sequenced where precipitation does not fall on the area excavated for the cell as this will decrease infiltration by causing soil surfaces to seal. Preferably, excavation should be done following several consecutive warm and dry days. If a storm is predicted before the cell media will be installed, the cell should be covered.

Compaction: An excavator or backhoe with a bucket that has teeth should be used to excavate the area for the cell. The bottom of the cell should be loosened or scarified (using the teeth on the bucket to rake it) to a depth of 12" below the required bottom elevation with care taken to avoid compaction. Any soil compaction on the bottom of the cell will cause future exfiltration problems and the internal water storage (IWS) layer may not be able to drain sufficiently between rain events. An experienced operator should be hired and it is the responsibility of the designer to communicate to them the importance of minimizing compaction on the bottom of the cell and on the existing surrounding soil.

Media Recipe: The BRC media "recipe" recommended is 85 – 88 % washed sand (by volume), 8 – 12 % fines (clay and silt), and 3 – 5 % aged organics. The percentage of each media component is dependent on the target pollutant to be treated by the cell. If treating nitrogen, 12% fines are recommended to achieve an infiltration rate of 1"/hr. For cells treating phosphorus and metals, 8 % fines are suggested to achieve an infiltration rate of 2"/hr.

Soil Testing: A routine soil test should be performed on a sample of the cell media prior to installation. The soil test will determine the amount of extractable phosphorus present in the media. It is important that the extractable phosphorus of the media be low to very low regardless of the pollutant targeted. When media is used with a high phosphorus content, the BRC is likely to export phosphorus rather than reduce it. Soil media can be sent to the Auburn University Soil Testing Lab (http://www.aces.edu/anr/soillab/) to be analyzed.

Mulch: Triple or double shredded hardwood mulch is recommended for BRCs because it has fewer tendencies to float away and clog overflow structures. However, other mulch types such as pine bark are acceptable when hardwood mulch is not available. Do not use grass clippings for mulch, as this will increase nitrogen loading into the BRC. Mulch should be aged a minimum of six months. Using mulch that has not been properly aged or composted results in the depletion of soil nitrogen during mulch decomposition and can lead to a nitrogen deficiency in plants. Mulch inhibits weed growth, prevents erosion, encourages microorganism activity, provides a surface for excess water to evaporate, and keeps the underlying media from drying out completely during periods of drought. The mulch layer reduces cell media compaction during heavy rains and prevents the spread of fungal disease or other soil borne pathogens that might spread by water splashing from the soil to plants. Sediment is deposited on the mulch surface as stormwater enters the BRC and thus, the mulch serves as pretreatment for the cell to prevent clogging.

Retrofits: Retrofitting an existing facility with bioretention will require different design and construction techniques compared to bioretention in new developments. An IWS layer can be used in bioretention retrofits. An IWS layer reduces the amount of trenched pipe, uses fewer materials, and reduces the cost of the system outlet. This is not only economically appealing, but makes retrofits an option at locations with restricted outlet depth, where the stormwater conveyance is shallow, or when an overflow system is already in place. Existing infrastructure such as a catch basin can also be used as an overflow structure for retrofits.

Vegetation

Plants installed in the BRC should be selected based on the cell media depth in accordance with Table 4.3.1. In addition, plants should be tolerant of short term flooding and extended periods of drought. Vegetation used in BRCs should be tolerant of fluctuating hydrology ranging from extremely wet during heavy rainfall conditions to extremely dry during periods of low rainfall. Most bioretention plants have a facultative (FAC) or facultative wet (FACW) wetland indicator status. FAC and FACW plants are able to withstand short duration floods and maintain root growth that increases the root surface area available for water and mineral uptake. Surrounding soil and annual rainfall will affect the vegetation selection. For example, more drought tolerant plants should be placed in BRCs located in sandier soil conditions as these tend to be drier compared to more clayey soil sites. See Vegetation in Appendix D for more information on wetland indicator status.

Plant Sizes: Recommended plant container sizes include 3-gallon shrubs, 1-quart or larger herbaceous perennials, and trees that are at least 2.5” diameter. Cost will often determine size of plants installed; younger and smaller plants are less expensive than mature, larger plants. In general, using larger plant container sizes reduces plant mortality rates since these plants have stronger root systems and may establish more quickly. Less common species may also be more expensive than commonly produced plants. Prior to design, nurseries should be contacted for a list of available species, price list, and any available price breaks for large purchases. Mulch and plants should be inspected upon delivery and be free of weed seeds to reduce future maintenance and weed removal. Plants should also be inspected for general health, insects, and disease problems prior to installation. To aid in installation, plants can be tagged by species and laid out according to the planting plan.

Plant Establishment: Vegetation in the BRC can be planted at anytime of the year, however, timing can determine water inputs necessary for plant establishment and overall chances for survival. Vegetation installation is recommended for fall because this season requires less irrigation. Planting in the spring is acceptable, but plants will require more irrigation compared to a fall installation. Summer installation is not recommended because plants will require weekly watering and the chance for plant mortality is greater during this time due to heat and drought experienced. Small trees may need staking until they are established. Organic matter in the cell media will aid in plant establishment and help jump-start the nitrogen removal process.

Lime and Fertilizer: The soil test performed on the bioretention media will indicate any lime requirements that should be mixed into the media prior to installation. Current findings suggest that nutrients present in stormwater runoff are sufficient to aid in establishment of plants.

Plant Spacing: Plants should be spaced based on their mature plant width. In most cases, a triangular spacing grid is used so that plants are equally spaced within rows, but the rows are staggered. The triangular grid plant quantity equation can be used to estimate the number of plants per area. The equation utilizes the maximum amount of available space and is sometimes an overestimate as it does not take walking space or maintenance access into account. See Chapter 5.1 on Rain Gardens for more information on design using a plant quantity equation.

It is recommended that the BRC be sketched to scale in order to place plants. Sketching using a circle template will help to eliminate overcrowding because mature plant sizes are used. The circle template method allows the designer to design the cell at a bird's eye or plan view. Vegetation plans that use plants that colonize or reseed areas should allow for plants to spread and include extra space per plant. Also, empty mulched areas within the cell will allow surface water evaporation from mulched surfaces, pathogen die off, and maintenance access.

Turfgrass Bioretention: Turfgrass BRCs have been used successfully, but their long-term functionality is unknown due to thatch buildup and decreased infiltration into the cell. Turfgrass BRCs should be sodded using bermudagrass or centipedegrass.

Vegetation Design Guidelines

- Woody vegetation such as shrubs or trees should not be sited near the inlet to the BRC.
- Local landscape ordinances should be abided by, and this may affect the vegetation plan.
- A diverse plant community is recommended to decrease insect and disease infestations.
- If pathogens are a target pollutant, plants should be loosely spaced to allow for increased sunlight and pathogen die off.
- Plants with taproots should not be used due to their potential to damage underdrain pipes.
- Do not specify noxious or invasive plants that may displace other vegetation and create dense monocultures.
- Contract specifications should require the use of native vegetation instead of exotic plants. When native plants are not available, non-native ornamental varieties may be used when they are not considered invasive. Contact the Alabama Invasive Plant Council if you are unsure whether a plant is invasive (http://www.se-eppc.org/alabama/).
- A mixture of evergreen and deciduous vegetation should be used to ensure nutrient uptake occurs throughout the year. Using all deciduous vegetation can result in clogging due to leaf debris inhibiting infiltration into the mulch layer and may also require more frequent maintenance.

Table 4.1.6
Bioretention Plant List

Botanical Name	Common Name	Habit	Prefers
Clethra alnifolia	summersweet clethra	deciduous shrub	sun to part shade
Conoclinium coelestinum	mistflower	herbaceous perennial	sun to part shade
Ilex glabra	inkberry holly	evergreen shrub	part shade
Ilex verticillata	winterberry	deciduous shrub	sun to part shade
Ilex vomitoria	yaupon holly	evergreen shrub	sun to part shade
Itea virginica	sweetspire	deciduous shrub	sun to part shade
Liatris spicata	blazing star	herbaceous perennial	sun
Lindera benzoin	spicebush	deciduous shrub	sun to part shade
Morella cerifera	wax myrtle	evergreen shrub	sun to part shade
Muhlenbergia capillaris	muhly grass	herbaceous grass	sun to part shade
Panicum virgatum	switchgrass	herbaceous grass	sun to part shade
Rudbeckia fulgida	orange coneflower	herbaceous perennial	sun to part shade
Stokesia laevis	stoke's aster	herbaceous perennial	sun to part shade
Vernonia gigantea	giant ironweed	herbaceous perennial	sun
Vernonia novenboracensis	New York ironweed	herbaceous perennial	sun
Viburnum dentatum	witherod	deciduous shrub	sun to part shade
Viburnum nudum	possumhaw	deciduous shrub	sun to part shade

Vegetation Design Example 1

This bioretention cell is 46' x 80' and uses a mixture of small trees, shrubs, and perennials. It is symmetrical and can be viewed from all sides with the tallest plants located in the center of the cell. The vegetation provides year round seasonal interest.

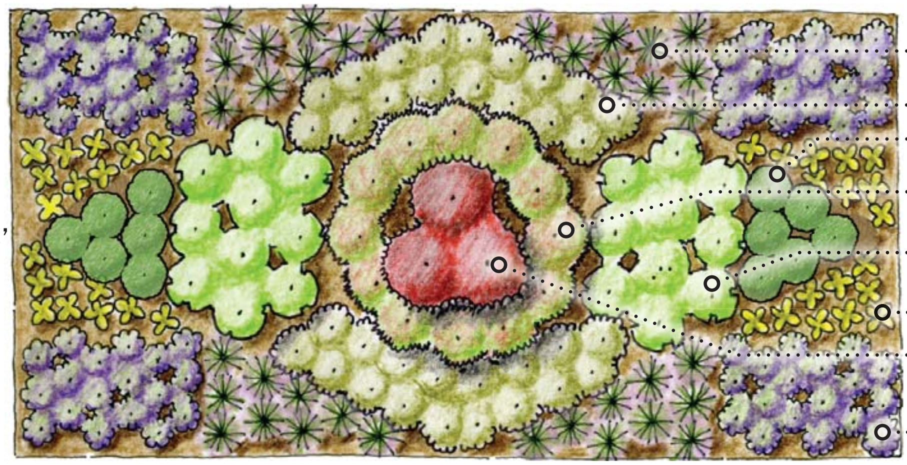


Table 4.1.7
Design 1 Plant List

Botanical Name	Common Name	Seasonal Interest	Quantity
Clethra alnifolia 'Ruby Spice'	'Ruby Spice' summersweet	Summer bloom	12
Ilex glabra 'Shamrock'	'Shamrock' inkberry	Evergreen	6
Ilex verticillata 'Winter Red'	'Winter Red' winterberry	Red berries in late fall and winter	3
Itea virginica 'Henry's Garnet'	'Henry's Garnet' sweetspire	Spring bloom, red fall color	20
Morella cerifera 'Tom's Dwarf'	'Tom's Dwarf' waxmyrtle	Evergreen	34
Muhlenbergia capillaris	muhly grass	Fall bloom	36
Rudbeckia fulgida	orange coneflower	Summer and fall bloom	36
Stokesia laevis	Stoke's aster	Spring and summer bloom	72

Vegetation Design Example 2

The BRC is 46’ x 80’ and uses a mixture of shrubs and perennials. It can be viewed from all sides and has year round seasonal interest.

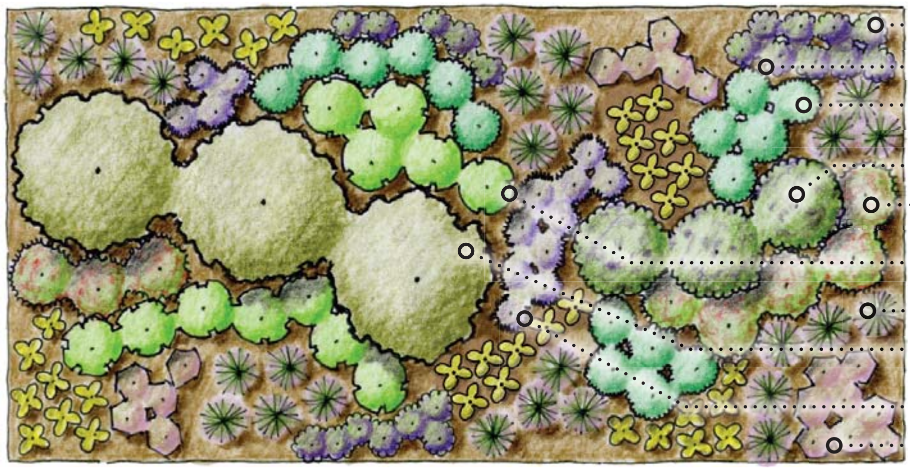


Table 4.1.8
Design 2 Plant List

Botanical Name	Common Name	Seasonal Interest	Quantity
Clethra alnifolia ‘Ruby Spice’	‘Ruby Spice’ summersweet	Summer bloom	8
Conoclinium coelestinum	mistflower	Summer and fall bloom	18
Ilex glabra ‘Shamrock’	‘Shamrock’ inkberry	Evergreen	16
Itea virginica	sweetspire	Spring bloom, red fall color	12
Morella cerifera	waxmyrtle	Evergreen	3
Muhlenbergia capillaris	muhly grass	Fall bloom	27
Rudbeckia fulgida	orange coneflower	Summer and fall bloom	21
Stokesia laevis	Stoke’s aster	Spring and summer bloom	21
Viburnum nudum	possumhaw	Summer bloom, berries in fall	3
Vernonia novenboracensis	ironweed	Summer bloom	15

Maintenance

Clogging: The most common failure mechanism of a BRC is clogging of the cell media. The underdrain pipe can be unclogged via the clean out pipe(s). However, if water remains ponded on the cell surface and clogging persists, it may be necessary to remove and replace the top few inches of media. Following this replacement, if the cell surface continues to remain ponded for longer than 12 hours, then the cell media is likely clogged and will need to be completely replaced. Extended surface ponding provides favorable conditions for mosquito breeding and is detrimental to plants unaccustomed to extended flooding.

Mulch: The top 1 to 2” of mulch and 4” of media have been shown to accumulate sediment and metals. Periodic replacement of these top layers can facilitate removal of sediment bound phosphorus and metals. Upon the need to dispose of any potentially contaminated mulch or media associated with BRCs, the ADEM Environmental Services Branch should be contacted for guidance associated with the requirements for waste determination and disposal procedures. For more information, please call 334-271-7700 or 1-800-533-2336.

Table 4.1.9
Maintenance Schedule

Task	How Often	Comments
Mulching	As needed, full replacement every 2 to 3 years	Bare areas from erosion should be replaced as necessary. Mulching can be done any time of the year, but the best time is late spring after soil has warmed. Mulch should be replaced annually if the watershed is high in heavy metals.
Re-planting	When plants die	If plants consistently suffer from mortality consider using more appropriate plant species for the area.
Weeding	Twice a year	Weeding should decrease over time as vegetation establishes.
Inspect plants	Monthly until establishment, then twice a year	Inspect for diseased or insect infested vegetation.
Inspection	After 0.5” or greater rainfall event	Visually inspect all components including any pretreatment, pipes, or IWS where applicable.
Fertilization	At planting	Most BRCs are used in nutrient sensitive watersheds. Fertilizing beyond plant establishment will increase nutrients leaving the BRC.
Unclog Underdrain Pipes	As needed	Ponded surface water should drain away within 12 hours or less (i.e. eliminate standing water conditions). If water remains ponded on the surface of the cell for longer than 12 hours this may indicate that the underdrain pipe or cell media is clogged.
Pruning	Annually	Pruning will help maintain plant shape. See Vegetation in Appendix D for pruning recommendations.
Sediment Removal	As needed	If sediment clogs the media, the top few inches may need to be removed and replaced. Removed sediment should be properly disposed of as it may contain toxic materials such as heavy metals. Contact the ADEM Environmental Services Branch for guidance at 334-271-7700 or 1-800-533-2336.
Trash Removal	As needed	In high traffic areas, frequent trash removal will be necessary.
Mulch removal from outlets	As needed	Mulch may collect in the outlet or overflow during heavy rains.

Mulch should be maintained at a 3" depth. Plants may grow roots into mulch that is too deep which causes stress to the plant during dry weather conditions. Mulch should be replaced when it decomposes or becomes matted. Some erosion may occur at the inlet and in other areas of the cell. However, if designed properly, erosion should only occur occasionally following extreme wet weather conditions. If erosion occurs frequently, the design should be reworked and flow velocities, drainage areas, and sizing should be considered.

Plant Replacement: Plants should be replaced when mortality occurs. Up to 10% of plants may die in the first year and over time, survival rates should increase. Stem surfaces can be scraped using a razor blade or other sharp tool to determine whether a plant is still alive. The plant is considered to be alive when green tissue is found after scraping the stem. Dead plants are not only unsightly, but can provide favorable environments for insects and diseases to overwinter.

Pollutant Removal

Table 4.1.10
Pollutant Removal Table

Sediment	Nutrients		Metals	Pathogens
	N	P		
a.85%	40%	45%	No Data	No Data
b.80%	50%	60%	MOD	No Data
c.80%	50%	60%	MOD	No Data

a. NCDENR, 2007*
b. City of Auburn, 2011
c. Georgia Manual, 2001

* Research has demonstrated pollutant removal efficiencies of 60% for both N and P in the Coastal Plains.

Bioretention pollutant removal is dependent on the presence of plants, microorganisms, specialized cell media, and mulch; the absence of one of these components decreases the pollutant removal efficiency associated with the BRC. Bioretention shows greater than 35% reduction in nutrients and a minimum of 80% reduction in total suspended solids (TSS). Nutrient removal is more variable compared to TSS, which is likely due to the complexities of chemical breakdown processes and the behavior of nutrients.

Total Suspended Solids: Although most TSS is removed through sedimentation, some suspended fine particles are removed via filtration through the top layer of media and mulch.

Total Nitrogen: An IWS layer creates anaerobic conditions to a facilitate reduction in nitrogen through denitrification. Nitrogen is removed 30" below the media surface. Nitrogen uptake by plants is increased when plant tissue is harvested frequently.

Total Phosphorus: It is critical to soil test cell media prior to installation to determine that the extractable phosphorus is low to very low, especially if phosphorus reduction is a primary concern. Research has shown phosphorus removal depends on the phosphorus content originally found in the BRC media. Media with high extractable phosphorus is likely to leach phosphorus from the BRC. Two-thirds of phosphorus is bound to sediment and is deposited on the mulch layer and surface layer of media as stormwater enters the BRC; thus, mulch can be removed and replaced to assist in phosphorus reduction. The remaining third is soluble phosphorus, which is removed at a depth of 12" or more below the media surface. Phosphorus has the most variable range of pollutant reduction.

Metals: Studies have shown a reduction in metals, but an average pollutant removal efficiency has not been assigned. Most metal removal occurs in the surface/mulch layer of a BRC since metals are often bound to sediments and may be removed by filtration and adsorption processes.

Pathogens: Pathogens are killed on the surface of the cell through sun-exposure and drying, and can be removed throughout the cell through sedimentation and filtration. For pathogens, a range of 70 - 92% removal of fecal coliform or *E. coli* has been reported, but a pollutant removal average is not assigned.

Temperature: When temperature reduction is a goal, media depth is an important factor of planning and design. Temperature is reduced at approximately 48" below the media surface.

Vegetation: Vegetation in these systems has the vital role of transpiration cooling effects, nutrient uptake, and pollutant removal. Most importantly, vegetated BRCs are more efficient in breaking down, removing, and mineralizing harmful pollutants such as hydrocarbons, pesticides, chlorinated solvents, and surfactants compared to cells lacking vegetation. Vegetated BRCs show higher phosphorus reduction compared to non-vegetated cells. BRCs with at least 2.7' of media can retain up to 92% of phosphorus because vegetation increases BRC media sorption (binding) capacity. Deep root systems, high growth rates, and plant maturity are reported to have the highest rates of pollutant removal.

Plant Roots: Plant roots aerate soils and exude nutrients and carbon, which favors microorganism habitat and growth. Roots also contribute to chemical and physical processes that improve soil structure, increase infiltration capacity, and cell media permeability in the BRC.

Transpiration: Through transpiration, plants in BRCs create cooler microclimates. On a daily basis, plants can transpire amounts nearly equal to their total water content. This is significant since herbaceous and woody plants may contain up to 70 and 50%, respectively, of water in their fresh weight.

Microorganisms: Microorganisms present in the media degrade petroleum-based products as well as other organic materials such as decomposing plant leaves. Additionally, microorganisms can aid in nutrient uptake.

Bioretention cell 3 months post installation, East Smiths Station Elementary School; Smiths Station, AL

References

Alabama Soil and Water Conservation Committee. 2009. Alabama Handbook for Erosion Control, Sediment Control, and Stormwater Management on Construction Sites and Urban Areas. Montgomery, AL.

Brown, R.A., W.F. Hunt, and S.G. Kennedy. 2009. Designing Bioretention with an Internal Water Storage (IWS) Layer: Design guidance for an innovative bioretention feature. North Carolina Cooperative Extension. AG-588-19W.

Brown, R.A. and W.F. Hunt. 2009. Improving Exfiltration from BMPs: Research and Recommendations. North Carolina Cooperative Extension.

Christian, K. J., A. N. Wright, J. L. Sibley, E. F. Brnatley, J. A. Howe. and C. LeBleu. 2012. Effect of Phosphorus Concentration on Growth of Muhlenbergia capillaris in Flooded and Non-Flooded Conditions. Journal of Environmental Horticulture 30(4): 219-222.

City of Auburn Manual. 2011.

Davis, Allen P., William F. Hunt, Robert G. Traver, and Michael Clar. 2009. Bioretention Technology: An Overview of Current Practice and Future Needs. Journal of Environmental Engineering. March.

Davis, Allen P. 2007. Field Performance of Bioretention: Water Quality. Environmental Engineering Science, 24(8) 1048-1063.

Davis, A. P., M. Shokouhian, H. Sharma, and C. Minami, C. 2006. Water Quality Improvement Through Bioretention Media: Nitrogen and Phosphorus Removal. Water Environment Research 78 (3), 284–293.

Davis, A. P., M. Shokouhian, H. Sharma, and C. Minami. 2001. Laboratory Study of Biological Retention for Urban Storm Water Management, Water Environment Research 73(1), 5-14.

Dylewski, K. L., A. N. Wright, K. M. Tilt, and C. LeBleu. 2012. Effect of Previous Flood Exposure on Flood Tolerance and Growth of Three Landscape Shrub Taxa Subjected to Repeated Short-term Flooding. Journal of Environmental Horticulture 30:58-64.

Dylewski, K.L., A. N. Wright, K.M. Tilt, and C. LeBleu. 2011. Effects of Short Interval Cyclic Flooding on Growth and Survival of Three Native Shrubs. HortTechnology 21(4): 461-465.

Evans, Erv. Mulching Trees and Shrubs. Consumer Horticulture Fact Sheet. Raleigh, NC: NC State University Cooperative Extension, 2000. http://www.ces.ncsu.edu/depts/hort/consumer/factsheets/trees-new/text/muching.html. Accessed August 8, 2012.

Georgia Stormwater Manual. 2001.

Henderson, C., M. Greenway, and I. Phillips. 2006. Removal of dissolved nitrogen, phosphorus and carbon from stormwater biofiltration mesocosms. In A. Deletic and T. Fletcher, eds. Proceedings, 7th International Conference on Urban Drainage Modeling, and 4th International Conference on Water Sensitive Urban Design, Melbourne, Australia, 2-7 April 2006.

Hinman, C. Low Impact Development: Technical Guidance Manual for Pugent Sound. Olympia, WA: Puget Sound Action Team, Washington State University, Pierce County Extension, 2005.

Hunt, W.F., J.T. Smith, S.J. Jadlocki, J.M. Hathaway, P.R. Eubanks. 2008. Pollutant Removal and Peak Flow Mitigation by a BRC in Urban Charlotte, N.C. Journal of Environmental Engineering. 134(5) : 403-408.

Hunt, W.F. and N. White. 2001. Designing Rain Gardens (Bio-Retention Areas). North Carolina Cooperative Extension. AG-588-3.

Hunt, W.F. and W.G. Lord. 2006. Bioretention Performance, Design, Construction, and Maintenance. North Carolina Cooperative Extension. AGW-588-05.

Jernigan, K. J. and A. N. Wright. 2011. Effect of repeated short interval flooding events on root and shoot growth of four landscape shrub taxa. Journal of Environmental Horticulture 29(4) 220-222.

Li, Houng, and A. P. Davis. 2008. Urban Particle Capture in Bioretention Media. I: Laboratory and Field Studies. Journal of Environmental Engineering. 134.

Low Impact Development Center, Drainage, Bioretention Specifications http://www.lowimpactdevelopment.org/epa03/biospec.htm

Lucas, W.C. and M. Greenway. 2008. Nutrient retention in vegetated and non-vegetated bioretention mesocosms. Journal Irrigation and Drainage Engineering. 134: 5.

North Carolina Department of the Environment and Natural Resources. 2007. Stormwater Best Management Practices Manual, Ch 12: Bioretention (Chapter revised 2009). North Carolina Division of Water Quality, Raleigh, NC.

Passeport, E., W. F. Hunt, D. E. Line, R. A. Smith, R. A. Brown. 2009. Field study of the ability of two grassed BRCs to reduce stormwater runoff pollution. Journal of Irrigation and Drainage Engineering. 135(4): 505-510.

Rendig, V. and H. Taylor. 1989. Principles of Soil-Plant Interrelationships. McGraw-Hill Publishing Company. New York.

Roseen, R.M., T. P. Ballestero, J.J. Houle, P.Avellaneda, J. Briggs, G. Fowler, and R. Wildey. 2009. Seasonal Performance Variations for Storm-Water Management Systems in Cold Climate Conditions. Journal of Environmental Engineering. 135(3):128-137.

Rusciano, G. M. and C.C. Obropta. 2007. Bioretention column study: fecal coliform and total suspended solids reduction. Transactions of the ASABE, 50(4): 1261:1269.

US Environmental Protection Agency. 2006. 2006 Summer Report. Section 319 National Monitoring Program Projects, NCSU Water Quality Group, Raleigh, NC.

US Environmental Protection Agency.. 1999. Stormwater Technology Factsheet: Bioretention. Washington, D.C.

US Environmental Protection Agency. 2000. Introduction to Phytoremediation. EPA-600-R- 99-107. Cincinnati, OH.

::This page::
::intentionally left blank::

Constructed Stormwater Wetland (CSW)


Constructed Wetland at Hank Aaron Stadium; Mobile, AL

Synonyms: Constructed wetland, stormwater wetland, pocket wetland, traditional constructed stormwater wetland, shallow marsh wetland

Constructed stormwater wetlands (CSWs) are created wetland areas designed to treat stormwater and function similarly to natural wetlands. These systems use complex biological, chemical, and physical processes to cycle nutrients, and breakdown other pollutants for treatment of stormwater runoff.

Site Selection

Quantity Control	yes
Drainage Area	med - large
Space Required	med - large

Works with:

Steep Slopes	---
Shallow Water Table	✓
Poorly Drained Soils	✓

General Significance

Construction Cost	med-high
Maintenance	med
Community Acceptance	med
Habitat	high
Sun / Shade	either

Natural wetlands are often referred to as "nature's kidneys" due to their ability to transform or filter compounds. CSWs mimic the filtration and cleansing capabilities of natural wetlands while providing temporary storage of stormwater above the permanent pool elevation (PPE) and because of this, are often used for water quantity control. These systems are large (unless a small CSW/pocket wetland is used) and use shallow pools, complex microtopography, and both aquatic and riparian vegetation to effectively treat stormwater. The use of CSWs or any other SCM does not promote the discharge of stormwater into natural wetlands.

Advantages:

- Visual amenity for natural community greenspace
- Enhanced biodiversity and ecological benefits to urban areas
- Flood attenuation for improved water quality, reduced erosion, and downstream habitat
- Reduced peak flows downstream assist with decreased sediment loads entering streams and a reduction of downstream bank erosion
- Filtration of pollutants and nutrient uptake from plants further improves water quality
- Relatively low maintenance costs

Limitations:

- Requires more surface area than some other conventional stormwater practices; not suitable for space-limited ultra-urban environments
- May release nutrients in the fall
- May be difficult to establish plants under a variety of flow conditions
- Geese may become undesirable residents if natural buffers are not included in the design
- If not designed properly, water leaving the system may have higher temperatures
- Until vegetation is established, pollutant removal efficiency rates may be lower than anticipated
- Higher construction costs when compared with other practices

Site Selection

CSWs are not typically recommended for ultra-urban developments because they usually require more surface area (SA) than conventional stormwater control measures (SCMs). However, they may be suited to large residential, suburban, or commercial developments where space is not limited.

Evaluating Soils: Use the USDA Web Soil Survey to identify soil map units and to make initial interpretations for potential uses and limitations of a site. However, since most soil map units have inclusions of other soils that may be quite different, detailed evaluations should be made at the proposed site by a professional soil scientist or soil classifier. On-site evaluations should properly identify a soil or the hydrologic soil group (HSG) and the final decision for use should be made based on the detailed determination of soil series or HSG. For a detailed list of HSG properties, see Table A.3 in Appendix A on Stormwater Hydrology.

In-Situ Soil: CSWs are appropriate for the USDA hydrologic soil group (HSG) C and D soils that have slow to very slow infiltration rates. Other soils may also work with the addition of a clay or synthetic liner or may be perched.

USDA's online Web Soil Survey (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm) can be used as a guide to determine the needed soil information for the site, such as the hydrologic soil group (HSG) and depth to water table.

Compaction Guidelines

****based on soil permeability***

0.06 - 0.2"/hr - minimal compaction necessary

0.2 - 0.6"/hr - compaction necessary

>0.6"/hr - needs importation of clay and/or liner

Depth to Groundwater: CSWs are well suited for areas where the depth to groundwater is two feet or less. Excavation to the seasonally high water table may be used to maintain the permanent pool elevation (PPE) in the wetland.

Continuous Flow: CSWs are more easily sited in areas where sufficient water or continuous base flow is present to maintain the PPE in the wetland.

Sizing: A minimum drainage area of 10 acres is recommended for a CSW and 5 acres or less is recommended for a small CSW. The wetland footprint will be approximately 3 - 5% of the contributing drainage area.

Commercial or Industrial Sites: If CSWs are sited adjacent to commercial or industrial land uses, contributing pollutants have the potential to harm fish and wildlife populations over time as these pollutants accumulate.

Perching/Liners: CSWs sited in areas with HSG B or where the seasonaly high water table is not near the ground

Table 4.2.1
Site Selection: Constraints and Limitations for Constructed Stormwater Wetlands

Drawdown	Appropriate locations should draw down 2 – 5 days.
Slope	No more than 8% is conducive for a CSW.
Utilities	Call 811 before construction to locate utilities (For more information, visit: www.al1call.com).
Minimum Head	There must be an elevation difference of 2 - 5' from inflow to outflow to ensure water movement throughout the wetland.
High Sediment loads	Drainage Areas under construction or with high sediment loads should be avoided.
Non-native Invasive Vegetation	Non-native, invasive vegetation can be difficult to eradicate. See Vegetation in Appendix D for more information on nonnative, invasive plant removal.
Continuous Flow	Continuous flow is necessary to maintain the permanent pool elevation (PPE) in the wetland.

surface can be perched using a clay or synthetic liner. The clay or synthetic liner should have an infiltration rate of less than 0.01"/hr to keep water from percolating into the surrounding soil. Synthetic liners are considered more expensive and more likely to become damaged compared to clay liners. Perching is generally more risky as perched wetlands rely solely on stormwater to maintain the PPE and extended drought conditions can result in vegetation losses. With or without a liner, soil compaction may be necessary to achieve the desired infiltration rate (See callout box for **Compaction Guidelines**).

Common Constructed Wetland Variations

Traditional Constructed Stormwater Wetlands: CSWs have large surface areas and require a reliable source of base flow or groundwater supply to maintain hydrology to support emergent wetland plants. Deep water zones are concentrated in the forebay, deep pools, and outlet pool. The traditional CSW design is presented in this handbook. All other variations only differ slightly from this design.

Small CSW/Pocket Wetlands: Small CSWs follow the traditional CSW design, but treat much smaller drainage areas (5-10 acres) and are smaller systems. These systems are perfect when all site conditions are met for a CSW, but constraints limit the SA footprint. Water levels tend to fluctuate the most in a small CSW, making it more of a risk in areas prone to extreme drought conditions.

Retention Basins: Retention basins are similar to the traditional design with the exception of additional storage above the marsh. This increase in the temporary pool depth for additional vertical storage and a slightly smaller footprint limits vegetation selection, thus reducing some pollutant removal and available habitat.

Pond/Wetland Systems: These systems utilize two cells for treatment. A wet pond is used to reduce sediment and incoming velocities before entering a shallow marsh wetland. The pollutant removal capability of this system is less than the traditional CSW design.

Gravel-based Wetlands: This rock filter design variation uses one or more wetland treatment cells filled with gravel. The primary contributors of pollutant removal for these systems are algae and microorganism growth that occurs on the gravel.

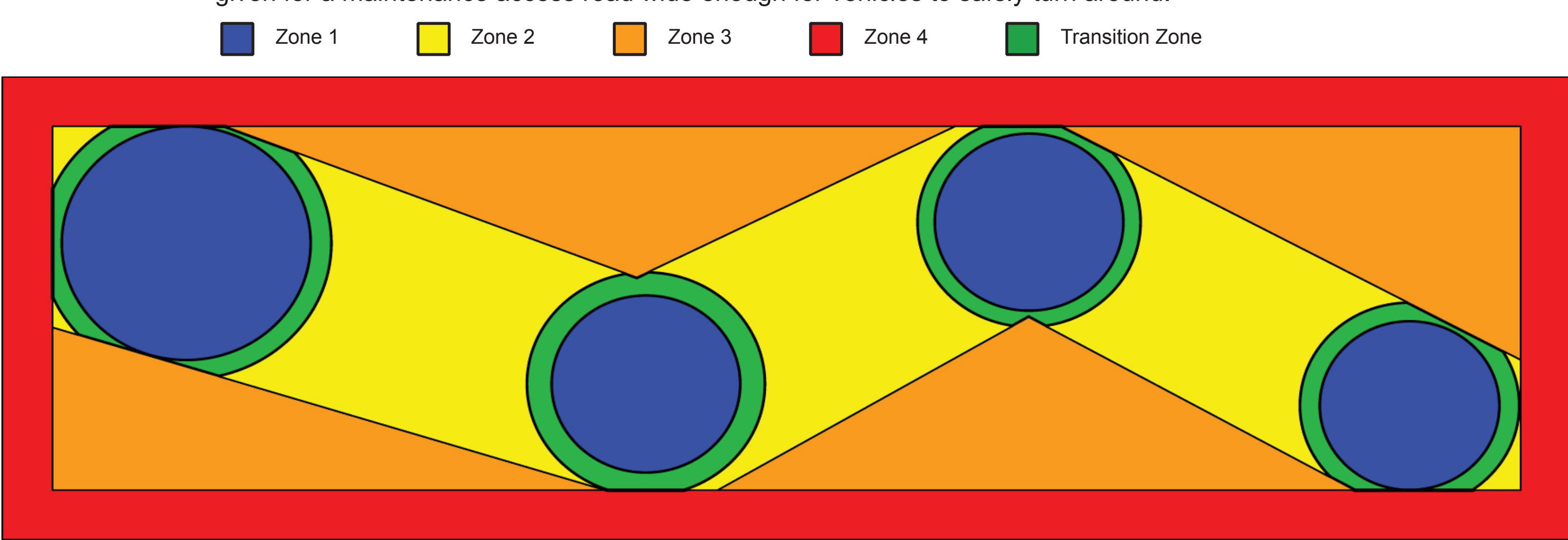
In-line and off-line wetlands: Inline and offline wetlands are not recommended due to their potential to degrade stream habitat and quality. In-line wetlands are wetlands constructed in the stream channel. Off-line wetlands divert stream flow into a constructed wetland and then release it back into the stream. The water source for a CSW should be a combination of stormwater and groundwater interception.

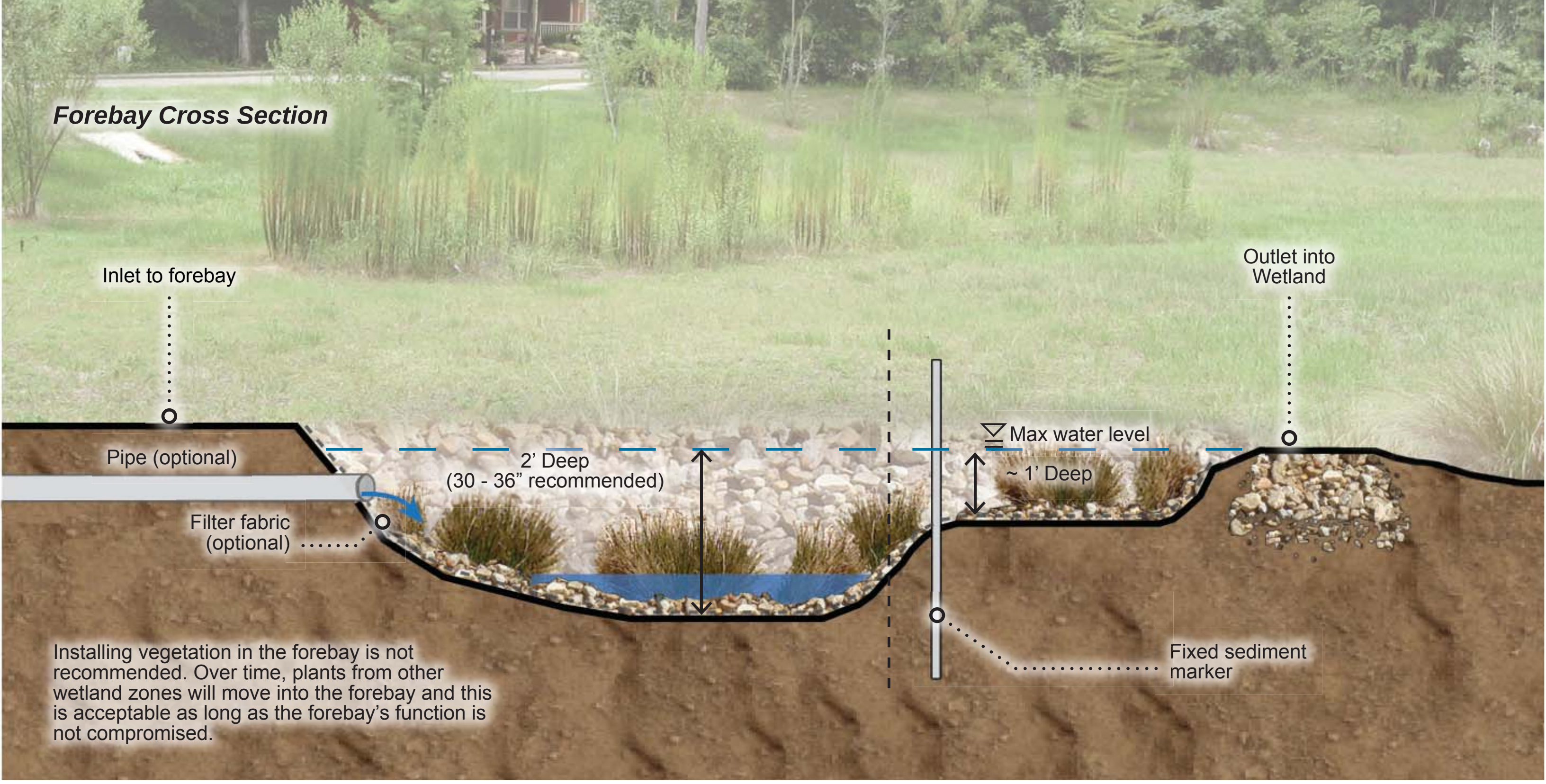
Design

CSWs have many components and zones; therefore, planning and site layout is even more critical for this practice compared to smaller stormwater control measures (SCMs). Components of a CSW include the forebay, inlet, deep pools (Zone 1), shallow water (Zone 2), transition zone, shallow land (Zone 3), upland (Zone 4), and the outlet structures.

The distance that stormwater travels from the entrance to the exit of the CSW should be maximized so that contact time in the wetland is increased to allow for greater pollutant removal. Flow paths can be enhanced using parallel berms and deep pools that are perpendicular to the flow path direction to slow water and increase residence time.

The wetland design should account for maintenance access to plants, forebay, deep pools, outlet pool, and the outlet structure. Since heavy equipment is necessary to clean out the forebay and deep pools, consideration should be given for a maintenance access road wide enough for vehicles to safely turn around.





Components

Zone 1 (Deep Pools)

The total deep pools topographic zone should be divided into several deep pools with one at the inlet (forebay) and outflow (outlet pool) and the rest dispersed between these pools. Deep pools allow for sediment deposition, energy dissipation, and nitrate treatment. Deep pools are designed to hold water throughout the year and can provide habitat for fish and other aquatic organisms during a drought. Deep pools can be planted with floating or submerged plants that grow in standing water.

Inlet: The inlet is the structure where flow or stormwater enters the CSW and should be designed to handle the runoff entering the system. Inlets may be in the form of a swale, pipe, diverter box, or sheet flow device such as a grassed filter strip. The velocity of flow entering the inlet should be considered. Any conveyance bends that could cause erosion or turbidity should be avoided. Erosion and scour should be minimized through the use of armor or vegetation.

Safety Precautions

Safety should be considered due to deep standing water conditions. Creative engineering and design techniques should be used to discourage children from entering the wetland area unless a site goal is to use the wetland as an educational tool. Observation decks, walking paths, and other safe viewing areas may be included in the design to prevent injuries. Trash racks, grates, or pipes may need to be sized such that children cannot enter them. Check local regulations to determine that appropriate safety precautions have been met.

Forebay: The forebay is a pool located at the inlet of the wetland system. It is deepest at the point of runoff entry and shallowest at the exit point. This design dissipates energy throughout the forebay and provides diffuse flow into the CSW.The primary function of the forebay is to allow large debris and sediment to settle out so that pools and ecologically sensitive areas are not clogged, flow velocity is not decreased, and sheet flow is created over the weir into the flow path throughout the wetland. CSW forebays are not vegetated and can be up to 36" deep.

Deep pools: Vegetated deep pools occur between the forebay and outlet pool. Vegetated deep pools are planted with submerged, floating, and occasionally emergent plants. These pools can provide continuous habitat for mosquito predators, such as fish, that require flooded conditions for survival. Dispersing deep pools throughout the wetland decreases distances fish must travel.

Outlet Pool: The outlet pool should not be vegetated to minimize clogging. A clogged outlet structure can result in extended flooding throughout the wetland and decreased drawdown time to the PPE. Decreased drawdown time is detrimental to wetland plants in Zone 3 (shallow land).

Transition Zone

The transition zone is located between the deep pools (excluding the forebay) and the shallow water zone. The transition from these two zones should be a gentle slope and hold 6 – 9” of water at the PPE. Similarly to deep pool vegetation, few plants can tolerate the transition zone due to the increased water depth present in this zone.

Zone 2

Shallow Water: The shallow water zone (also called low or shallow marsh) includes all land within the wetland that has a constant level of 3 – 6” of water when the wetland is at its PPE. Occasional drying in this zone may occur during periods of extreme drought, but should not occur on a regular basis. The purpose of the shallow water zone is to provide a continuous hydraulic connection between the inlet and outlet structures and, during low flows, the shallow water channel should convey water from the inlet to the outlet pool. The water surface level in this zone is considered the PPE. Rooted herbaceous vegetation tolerant of constant inundation is planted in this zone.

Zone 3

Shallow Land: The shallow land zone (also called the high marsh) is the temporary inundation zone that provides necessary storage during and after a rainfall event. This zone functions similarly to a floodplain in a natural wetland. The highest elevation of this zone is referred to as the temporary pool elevation (TPE). Rooted vegetation that is tolerant of temporary flooding and drought is present in this zone. The shallow land zone provides some shade, pollutant uptake, and wildlife habitat.

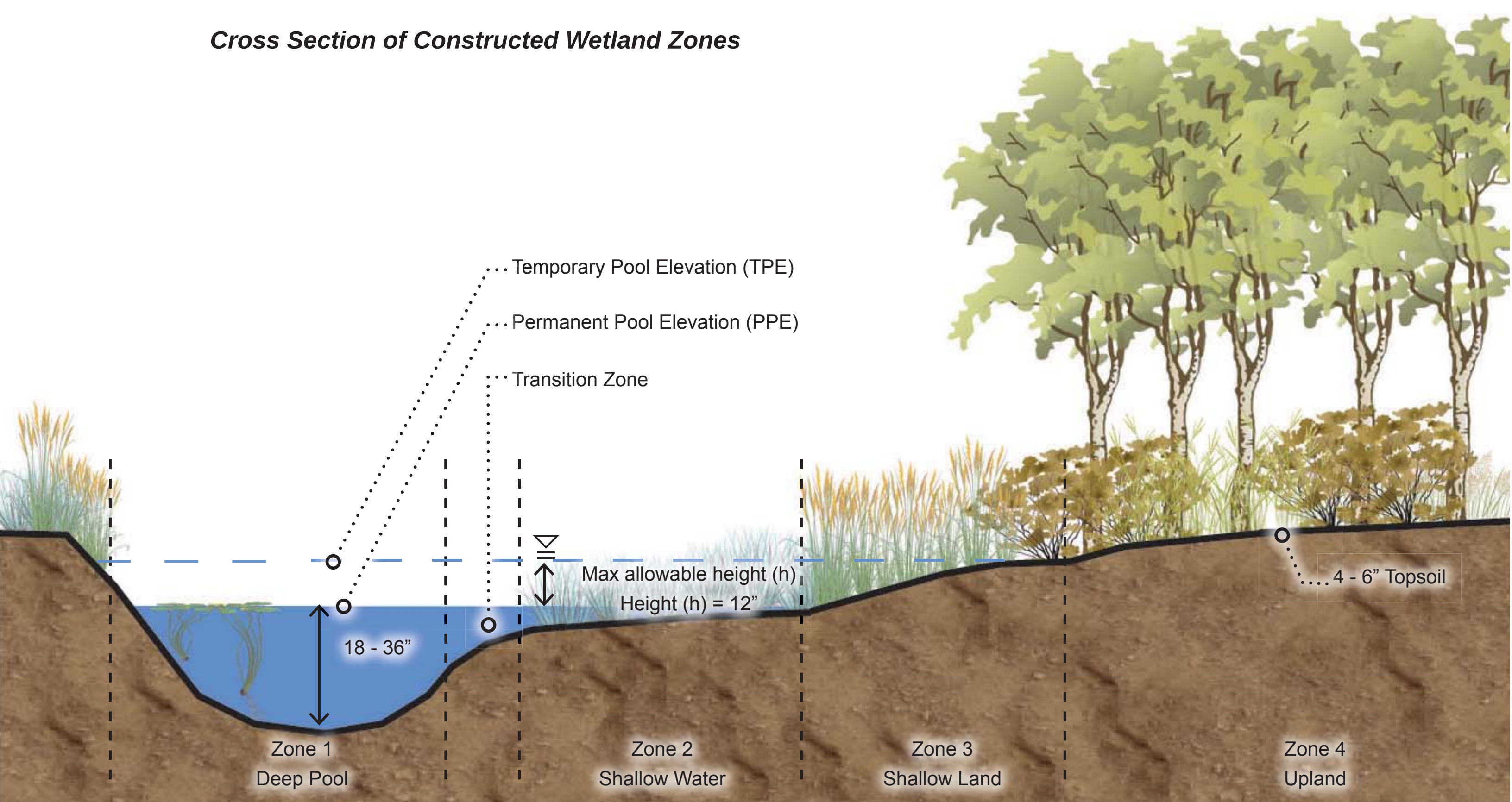
Zone 4

Upland: The upload zone is rarely wet and is not required for a CSW design, especially when space constraints exist. In some cases, an existing buffer can be utilized as the upland zone in the design. The upland zone can aid in tying the CSW to adjacent land, can be used for maintenance access, or to house an observation deck. This zone should not have a slope steeper than 3:1 in order to reduce erosion, allow for maintenance, and to support vegetation.

Outlet Structure

The outlet structure for the CSW serves three primary functions: 1) to contain the water quality volume within the wetland, 2) to release water when a rain event exceeds the first flush, and 3) to allow for manipulation of the pool elevation in order to conduct maintenance activities and therefore, should be easily accessed. The outlet contains a drawdown orifice that is placed at the top of the TPE or at lower depths to either prevent clogging or to release water at a cooler temperature. This allows the temporary pool to slowly draw down from the wetland, but still retains stormwater within the wetland for a minimum of 48 hours. There should not be public access to end walls at outfall pipes since CSWs are designed to pass large rain events and can be safety hazards. These areas may require fencing or warning signs for safety depending on the location of the wetland and responsible entity.

Cross Section of Constructed Wetland Zones



Design Guidance

1. **Determine Volume of Runoff Treated**

The volume of water typically treated by the CSW is based on the first flush of the design storm, see Appendix A on Stormwater Hydrology for more information on first flush. The volume of water below the PPE is constant and remains at all times, except during extreme drought. The first flush, or design storm volume, is the volume of water stored within the PPE and the TPE. The volume of runoff treated by a CSW is determined by two different methods, depending on the amount of impervious cover and land use.

- For areas with connected impervious and mixed land uses, the volume of runoff is calculated using the **Discrete Curve Number Method**.

  Variables needed for use in the **Discrete Curve Number Method** include: **drainage area, pervious and impervious land area, curve numbers (CN), maximum potential retention after rainfall begins (S), precipitation depth (P), and runoff depth (Q)**. The Discrete Curve Number Method is outlined in EQNs 4.2.1 and 4.2.2. For more information on the Discrete Curve Number Method and other methodologies, see Stormwater Hydrology in Appendix A.

  A runoff depth is calculated for each land use with a different corresponding **CN (pervious) and pervious cover**.

  The **total volume treated, calculated in acre inches (ac-in)**, is determined by multiplying runoff depth, **Q (in)** by area, **A (ac)** for all surfaces, pervious (different land uses) and impervious. To determine the volume in cubic feet, use EQN 4.2.3.

  The **Composite Curve Number Method** is used for areas with minimal impervious cover and a single land use. The same variables used for the Discrete Curve Number Method are used for the **Composite Curve Number Method: drainage area, pervious and impervious land area, curve numbers (CN), maximum potential retention after rainfall begins (S), precipitation depth (P), and runoff depth (Q)**. The two areas (one pervious and one impervious) are multiplied by their corresponding CNs to calculate a product, as shown in EQN 4.2.4.

  A **composite curve number (CCN)** can be calculated using the two products, as shown in EQN 4.2.5, where **TA is total area.**

  The **CCN** is then used in calculating the **retention after rainfall begins (S) and runoff depth (Q)**, shown in EQNs 4.2.1 and Y.2. Once runoff depth is determined in inches it can be multiplied by **TA** to determine a total volume in ac-in, which is converted into cubic feet using EQN 4.2.3.

  It is important to note that to calculate the overall surface area of the wetland, it is best for volume to remain in ac-in.

EQN 4.2.1

$$S = \left(\frac{1000}{CN}\right) - 10$$

EQN 4.2.4

$$Product_{impervious} = A_{impervious} * CN$$

$$Product_{pervious} = A_{pervious} * CN$$

EQN 4.2.2

$$Q = \frac{[P - (0.2S)]^2}{P + 0.8S}$$

EQN 4.2.5

$$CCN = \frac{(Product_{impervious} + Product_{pervious})}{TA}$$

EQN 4.2.3

$$Volume = \_\_\_\_\_\_ \; ac - in * 3630 = \_\_\_\_\_\_ \; ft^3$$

2. **Determine SA and Zone Depth**

Since the CSW is designed to hold approximately the first inch of rainfall from the entire drainage area, the SA is calculated as the volume (ac-in) divided by the allowable height (in), as shown in EQN 4.2.6. A **maximum allowable height of 12" for TPE** is recommended. Once SA is calculated, it is converted to square feet by multiplying the SA in acres by the conversion factor 1ac = 43560 ft^2.

The flow path from the inlet to outlet points within the CSW should be maximized in order to maximize the retention time within the system. Often, berms and irregular shapes can be used to obtain the optimal flow path. A 3:1 minimum length to width ratio is suggested.

Even though flow path and retention time is to be maximized, it is crucial to reduce the potential for cutoffs or changes in flow path to reduce nick points or weak areas in the topography that allow for water to short circuit the desired flow path. Deep water zones perpendicular to the flow direction and internal berms parallel to overall flow are recommended.

In contrast to other SCMs, the permanent volume of water, or water below the PPE, will remain in the CSW at all times, and is not part of the design calculations. This pool is maintained through natural or engineered hydrologic zones that are dependent on characteristics such as HSG, saturated hydraulic conductivity (K_{sat}), wetland liners, depth to water table, and many other factors.

The SA of each zone within in the CSW is a percentage of the total SA. Table 4.2.2 contains a recommended distribution for SAs of individual zones. This distribution can vary depending on targeted treatment pollutant to be treated.

Deep Pools (Zone 1): A deep pool should be located at the inlet (see Forbay Cross Section) and another at the outlet (outlet pool). A water balance using monthly rates for rainfall, infiltration, and evapotranspiration can be used to verify the depth of water in Zone 1. Conducting a water balance will help the designer to verify the probability of water following a month long drought, with the exception of extended drought periods.

Shallow Water Zone (Zone 2): This zone should not be designed too deep; this will help ensure plant survivability and habitat.

Shallow Land (Zone 3): The depth of shallow land is equal to or less than the **maximum allowable height (h)** used in the SA calculation, EQN 4.2.7. This depth will also set the elevation of the TPE and is the maximum storage volume in the CSW at any given time. If the CSW targets pathogens, the shallow land zone should comprise a large portion (40% of the total SA) of the wetland to allow for pathogen die off from ultra-violet light exposure.

EQN 4.2.6

$$SA = V / h$$

EQN 4.2.7

$$Q = N * [C_d * A * (2 * g * H)^{0.5}]$$

Table 4.2.2
Recommended Distribution for Surface Areas of Individual Zones

Zone	Surface Area Recommendation	Recommended Water Depth
Zone 1, Deep Pools	20 - 25% of total surface area (10% allocated to forebay, remaining to other deep pools)	18 - 36"
Zone 2, Shallow Water	40% of total surface area	3 - 6"
Zone 3, Shallow Land	30 - 40% of total surface area	12" at TPE
Zone 4, Upland	This zone is optional and is not included in the surface area calculation. Determine the amount of area remaining in overall site and use this area for upland.	This zone is rarely wet.

3. **Determine the Appropriate Outlet Structure**

This practice is unique because the outlet structure has both low and high capacity features.

High Capacity: The high capacity feature is used to bypass storms that are in excess of the first flush volume.

Low Capacity: The low capacity feature is used as a drawdown structure to slowly release the volume of water within the temporary pool over 2 – 5 days.

Examples of outlet structures are shown in Table 4.2.3. Manual drawdown valves or flashboard risers can be installed to drain the wetland for maintenance purposes.

For ease of maintenance, trash racks are recommended for weir boxes and metal mesh is recommended for drawdown orifices to prevent clogging of the outlet structure. The drawdown orifice should be turned downward toward the permanent pool to ensure that it does not clog; this will help to prevent "floatables" from clogging the orifice.

Orifice (low capacity): Factors such as the **number of orifices (N), the coefficient of discharge (C_d), area of orifice(s) [(A) (ft^2)] and driving head [(H) (ft)]**, affect the flow that will exit the system via the drawdown orifice, and ultimately the time required to draw down the temporary pool. The flow rate leaving the orifice can be calculated using the Orifice Equation, EQN 4.2.7, where **g** is **Gravity (32.2ft/s^2) and maximum head is equal to the depth of the temporary pool**.

The orifice flow rate determines how quickly the temporary pool will drain, with a target of 2 - 5 days drawdown time. To calculate the drawdown time, EQN 4.2.8 is used.

In EQN 4.2.8, **V** is the **volume calculated in EQN 4.2.3, Q is the flow rate calculated in EQN 4.2.7, and time is in seconds**. A simple conversion can be used to determine if the temporary pool will drain within five days.

Weir (high capacity): The Weir Equation, EQN 4.2.9, can be used to determine the flow rate over a broad-crested weir or the top of a broad-crested weir box outlet structure. Characteristics of the weir, such as the **weir coefficient (C_w - 3.0 for broad-crested weirs), the length of the weir [(L) (ft)], and the driving head [(H) (ft)] are used in EQN 4.2.9.**

It is important to check the capacity of the network that the overflow will enter after leaving the CSW. It should be verified that the system can handle the peak flow and maximum flows anticipated from the high capacity weir.

Table 4.2.3

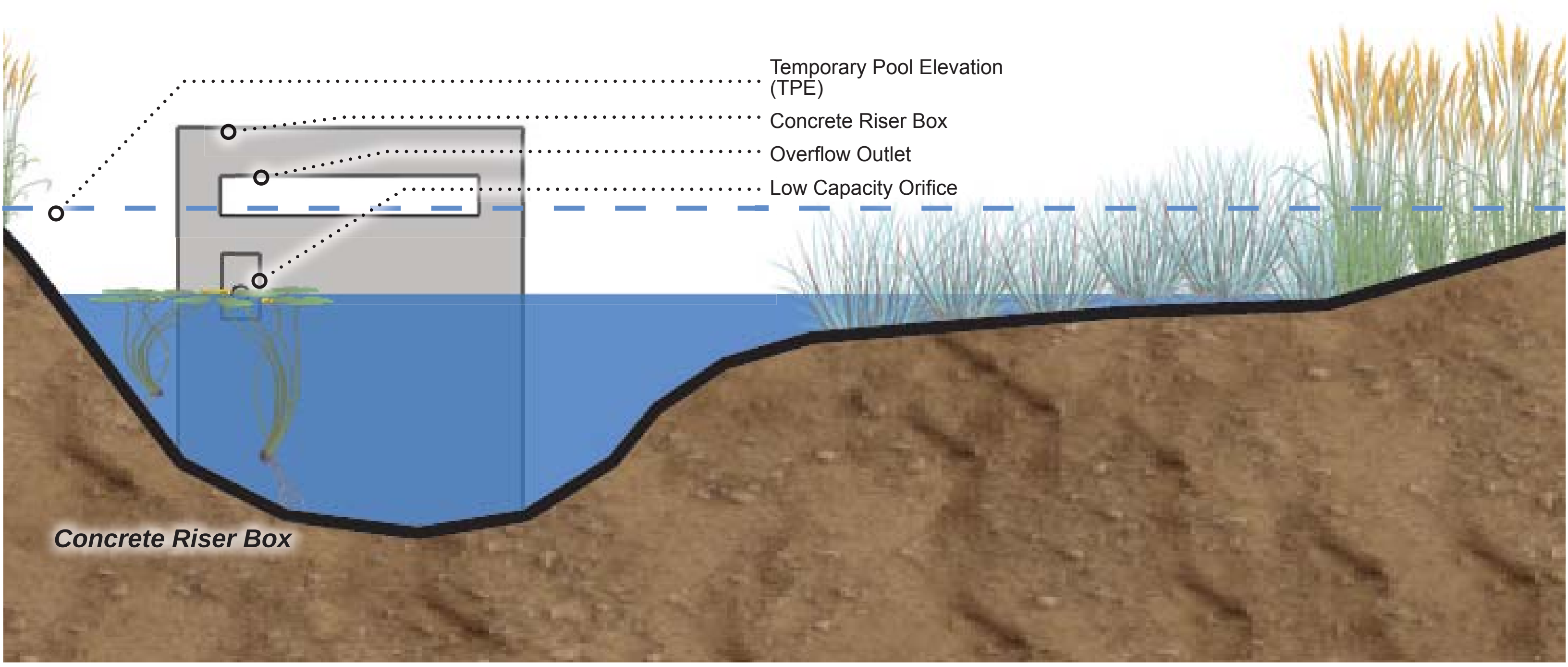
High-capacity	Low-capacity
weir box	drawdown orifice
broad-crested weir	
broad-crested spillway	

EQN 4.2.8

$$\frac{Volume}{Flow\ rate} = Time$$

EQN 4.2.9

$$Q = C_w * L * H^{1.5}$$



Concrete Riser Box

Constructed Stormwater Wetland Design Example

This design example below is for a **small CSW** that was planned for a site in Auburn, Alabama. The site conditions reflected ideal circumstances for a CSW with one exception; the location had a relatively small **total drainage area of 1.5 acres**. The soil on site is a Kinston silt clay loam series that has moderate permeability but is considered to be moderate to poorly-drained, which classified the soil as a HSG D. **For this design example numbers are rounded to two significant digits**

1. **Determine Volume of Runoff Treated**

EQNs 4.2.1 and Y.2 are used to determine the runoff depth based on land use areas and the corresponding CNs. In addition to being a relatively small site, the site is predominately pervious with **1.2 acres of pervious land**; however, this land is in poor condition. Using the NRCS Curve Number Table A.4 found in Stormwater Hydrology in Appendix A, **a CN for the pervious land cover is determined to be 89**. For all **impervious areas** consisting of parking lot, paved surfaces, and driving lanes, a **CN of 98** is assigned. The **precipitation depth (P)** desired for the water quality storm event in the Auburn area is **1.25”**.

EQN 4.2.1

$$S = \left(\frac{1000}{CN}\right) - 10$$

EQN 4.2.2

$$Q = \frac{[P - (0.2S)]^2}{P + 0.8S}$$

Using the provided CNs, precipitation depth, and Equations, the following runoff depths are determined:

Parking lot: S=0.20, Q= 1.04”, 0.09”

Poor Condition Pervious Area: S=1.24, Q= 0.45”, 0.04”

The **total volume (ac-in)** treated is determined by multiplying **runoff depth [(Q (in)] by area [(A) (ac)]** for all surfaces, pervious (different land uses) and impervious. To determine the runoff volume, the calculated runoff depths (Q) are multiplied by their respective areas and summed.

Parking lot: 1.04in*0.3=0.31 ac-in

Pervious Area: 0.45in*1.2=0.45 ac-in

Total runoff volume: 0.76 ac-in

To calculate the **volume in cubic feet**, use **EQN 4.2.3** to determine a volume of 2758.8 ft^3 or 2758 ft^3.

EQN 4.2.3

$$Volume = \_\_\_\_\_\_ ac - in * 3630 = \_\_\_\_\_\_ ft^3$$

For areas with minimal impervious cover and a single land use, the **Composite Curve Number Method** should be used. However, this site has a single dominant pervious land use and the **impervious area is 20% of the total drainage area**, so the **Discrete Curve Number Method** is used.

However, to illustrate the **Composite Curve Number Method**, it is used in this example to calculate the desired volume of treatment. Using **EQN 4.2.4**, the land use areas are multiplied by their corresponding CNs to calculate a product.

EQN 4.2.4

$$Product_{impervious} = A_{impervious} * CN$$

$$Product_{pervious} = A_{pervious} * CN$$

$$Product_{impervious} = 0.3*98 = 29.4$$

$$Product_{pervious} = 1.2*89 = 106.8$$

Continued on next page

A **composite curve number (CCN)** can be calculated using the two products, as shown in **EQN 4.2.5**, where **TA** is the **total area**.

EQN 4.2.5

$$CCN = \frac{(Product_{impervious} + Product_{pervious})}{TA}$$

$$CCN = \frac{(29.4 + 106.8)}{1.5} = 90.8 \approx 91$$

The **CCN** is then used in calculating the **retention after rainfall begins (S) and runoff depth (Q)**, shown in **EQNs 4.2.1 and Y.2**.

EQN 4.2.1

$$S = \left(\frac{1000}{CN}\right) - 10$$

EQN 4.2.2

$$Q = \frac{[P - (0.2S)]^2}{P + 0.8S}$$

S=0.99, Q= 0.54", 0.05'

Multiplying the **runoff depth (Q)** by the **TA** gives a runoff volume in ac-in. The total volume equals 0.81 ac-in. The volume can be **converted into cubic feet using EQN 4.2.3**. The total treatment volume is 2940.3 ft^3.

Since this site has 20% impervious cover, the **Discrete Curve Number Method** volume calculation of 0.76 ac-in or 2759 ft^3 will be used.

2. Determine Surface Area and Zone Depth

Since the CSW is designed to hold approximately the first inch of rainfall (first flush) from the entire drainage area, the SA is calculated as the **volume (ac-in) divided by the allowable height (in)**, as shown in **EQN 4.2.6**. The **maximum allowable height (h)** used for this site location is **9"**.

EQN 4.2.6

$$SA = V / h$$

$$SA = \frac{(0.76ac\text{-}in)}{9in} = 0.08ac = 3678.4ft^2$$

To convert SA calculated using EQN 4.2.6 into square feet, multiply the SA in acres by the conversion factor 1ac = 43560 ft^2.

Next, the SAs and depths of each zone are determined. For the example, the recommendations from Table 4.2.2 are followed (All areas for zones are rounded to the nearest whole foot).

Deep Pools, Zone 1: 25% of the total SA (10% allocated to forebay, remaining to other deep pools)

Zone 1:

10% = 368 ft^2 in forebay ~radius of 11'

15% = 552 ft^2 allocated to other deep pools, with recommended depths of 18"

Continued on next page

Shallow Water, Zone 2: 40% of total SA

40% = 1472 ft^2 for shallow water (Zone 2), with recommended depths ranging from 3-6”

Shallow Land, Zone 3: 30 - 40% of the total SA

30% = 1104 ft^2 for shallow land (Zone 3), with recommended depth equal to the maximum allowable height of 9”.

Upland, Zone 4: This zone is optional and is not included in the surface area calculation. Determine the amount of area remaining in the overall site and use this area for upland. The area at the site for the proposed small CSW is approximately 5000 ft^2; therefore, the remaining 1321 ft^2 will be used to connect Zone 3 to an Upland area (Zone 4).

A liner is not necessary for this site; however, proper documentation of soil media type is strongly recommended.

3. Determine the Appropriate Outlet Structure

This site is adjacent to a riparian buffer and a manufactured weir box is not necessary. A combination of high-capacity and low-capacity outlets is used to drain into the densely vegetated riparian buffer. For this site, a drawdown orifice is used to set the PPE and to draw down the temporary pool. The orifice is designed using **EQN 4.2.7** and the following characteristics are used:

N = 1, C_d = 0.6, g = 32.2, H = 0.75’, and A= 0.003 ft^2 (¾” diameter pipe).

EQN 4.2.7

$$Q = N * [C_d * A * (2 * g * H)^{0.5}]$$

$$Q = 1 * [0.6 * 0.003 * (2 * 32.2 * 0.75)^{0.5}] = 0.01cfs$$

The orifice flow rate determines how quickly the temporary pool will drain, with a target of 2 - 5 days drawdown time. To **calculate the drawdown time, EQN 4.2.8** is used.

The **volume is 2759 ft^3** and **flow rate** was calculated as **0.204 cfs**.

EQN 4.2.8

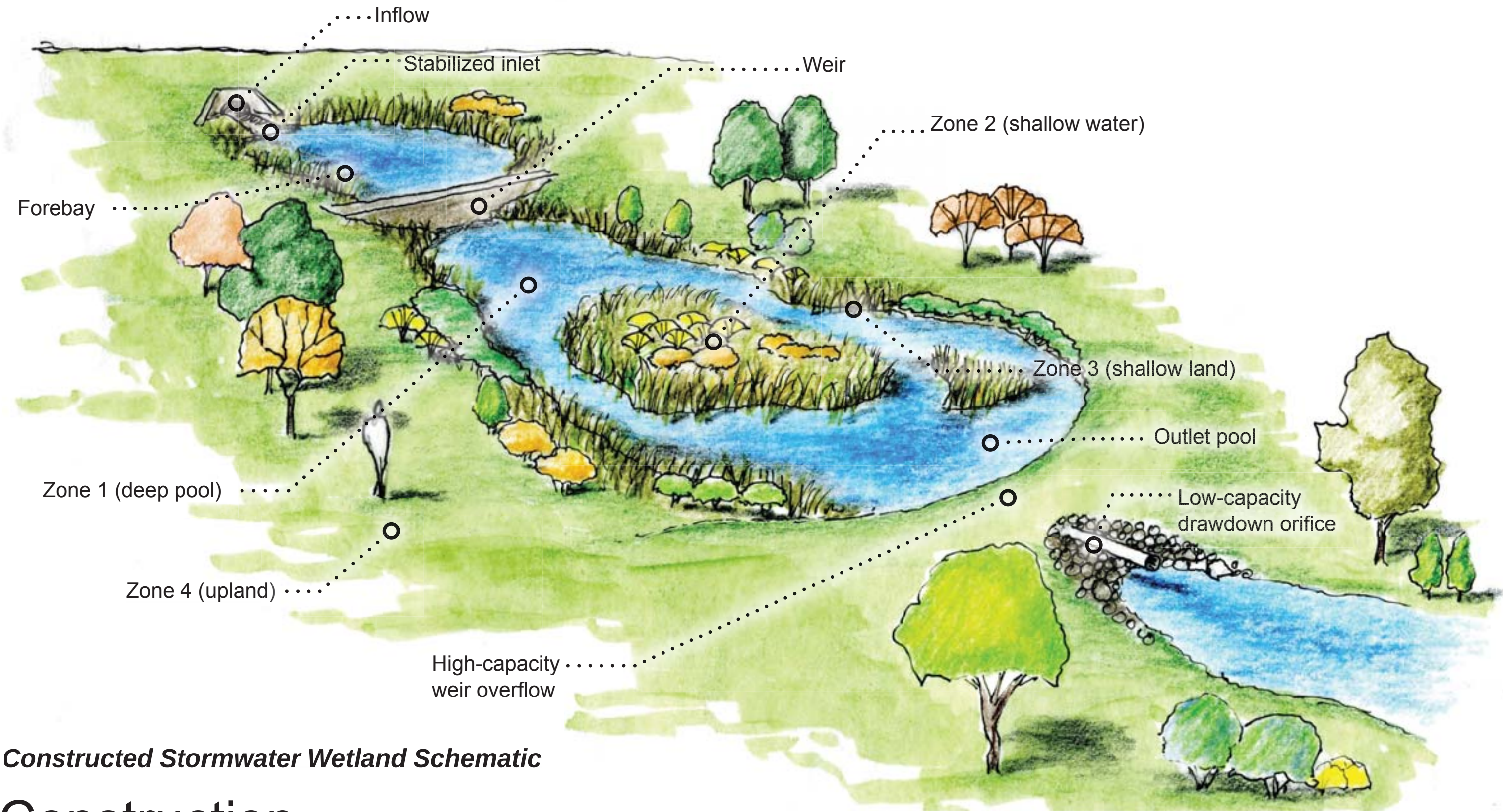
$$\frac{Volume}{Flow\ rate} = Time$$

$$\frac{2759ft^3}{0.01ft^3/s} = Time = 275900s = 76.6\ hrs = 3.2\ days$$

The high capacity weir should be sized to handle the peak flow event and the **length of the weir** can be determined using **EQN 4.2.9**.

EQN 4.2.9

$$Q = C_w * L * H^{1.5}$$



Constructed Stormwater Wetland Schematic

Construction

For more information on soil test protocols, go to the Alabama Cooperative Extension System website at www.aces.edu/pubs/docs/A/ANR-0006-A/ANR-0006-A.pdf. Soil samples can be sent to the Auburn University Soil Testing Lab (www.aces.edu/anr/soillab/) or to other soil testing facilities to be analyzed.

Planning: A well-planned construction schedule and construction oversight can minimize mistakes that negatively impact wetland functions. Construction discharge permit coverage may be required and should be considered early in the planning process. The designer and contractor should make a site visit so that logistics, sequencing, safety concerns, and techniques can be discussed to minimize costs and maximize efficiency.

Surveying: Before excavation, utilities should be marked and the construction surveying and staking of the layout completed to identify the zones of the wetland. During construction, elevations of graded features should be checked often so that wetland vegetation zones do not remain too dry or too wet.

Excavation: The outlet structure should be constructed first to control the water level in the wetland during construction. Excavation should begin at the outlet and move backwards toward the inlet. Tracked excavators are recommended, especially on wet sites. Toothed buckets are recommended to avoid smearing and unintended soil compaction. A hydraulic thumb attachment for the bucket is especially useful for removing debris, placing structures, and scarifying soil surfaces.

Compaction: Care should also be taken to ensure the appropriate level of soil compaction meets the requirements of the wetland design after construction is finished. During construction, the wetland base soil may need to be tamped to prevent excessive seepage. See call out box for **Compaction Guidelines** in the Site Selection Section.

Surface Scarification: Following excavation and soil amendment placement, the site should be prepped for permanent vegetation installation. Use a hydraulic thumb to rough up the soil. Scarification, chiseling, or ripping the top layer of soil is recommended especially if unintentional compaction occurred during construction or the site has suffered drought conditions. Scarification will help plants establish by providing an environment conducive to root growth.

Topsoil: At least 4” of topsoil should be added to all systems (including lined systems) regardless of the hydrologic soil group (HSG). Grading should take into account the 4” layer of topsoil to be added to the subsurface grade. Topsoil on site may be stockpiled for final grading. Harvesting topsoil on site is less expensive, but may result in the introduction of nonnative, invasive plants if they were present prior to construction.

Soil Testing: Before planting, a routine soil test should be performed to determine any nutrient and lime recommendations needed for plant establishment. Any organic matter incorporation, topsoil, clay liner components, or lime should be installed or mixed during or immediately following excavation.

Fertilizing: CSWs tend to lose organic matter during construction and excavation, and adding nutrients back into the soil is important not only for plant establishment, but for performance. A one-time fertilizer application (top dressed on soil surface) prior to planting may be needed to aid in plant establishment, but ongoing fertilization should not be required.

Please review proper sediment control practices in the Alabama Handbook for Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas

(http://swcc.alabama.gov/pages/erosion_handbook.aspx).

Geotextile Fabric: The inlet and forebay should be stabilized with a layer of non-woven geotextile fabric and riprap to dissipate energy from stormwater.

Stabilization: The wetland must be stabilized using permanent seed and appropriate mulch cover as soon as possible, but no later than 13 days from when the site is no longer undergoing active construction. A wetland hydroseed mix is recommended for initial stabilization. Soil scarification to half an inch will help promote quick germination. Once erosion and sediment control measures are installed, they should be inspected following rainfall events to ensure that they are functioning properly.

Retrofits: CSWs are an alternative retrofit option for sediment and erosion control basins used in construction when sediment is removed, properly disposed of, and the appropriate modifications are made to the basin. Retrofits can sometimes make sizing the stormwater wetland difficult due to lack of available space. In these cases, a bypass is needed so the wetland is not inundated with too large of a volume of stormwater, which can damage or "blow out" vegetation. A good rule of thumb is that a bypass is needed if the available space to retrofit is less than 67% of the total SA needed for an appropriately sized wetland.

Vegetation

Permanent vegetation should be installed when construction is complete. Ideal plants for CSWs are native perennials and shrubs with dense root systems to trap sediments and solids. Plants must be tolerant of the stress of flooding and drying associated with these systems. Native plants that colonize quickly should be used. Nonnative, invasive species should never be planted as these can result in dense monocultures that do not foster insect, animal, or plant diversity. If an upland area exists on site, trees may be salvaged to maintain a buffer surrounding the wetland area. Vegetation zones should be staked, flagged, or marked using marking paint for ease of plant installation. See Table 4.2.4 for recommended planting season guidelines for each wetland zone.

Seeding: Seeding of the wetland alone is not recommended due to poor success rates and slow establishment. Established plants can be obtained from nurseries that carry native wetland vegetation.

Plant Sizes: Recommended herbaceous plants should be a minimum of 4" tall, shrubs in a minimum of 1-gallon containers, and trees in a minimum of 3-gallon containers. It should be noted that using larger container plants can yield quicker establishment, but installing larger plants is more expensive and can be time consuming.

Plant Installation: In many cases, using a hydraulic auger attachment to drill holes for 3-gallon plants can speed the process, but attention should be paid to the amount of compaction that this equipment may cause.

Planting Time: Time of year plays an important role in plant establishment. Most herbaceous wetland plants establish best when planted at the onset of the growing season and should be installed from April to mid-June. Wetland plants need an entire growing season to accumulate root reserves needed to survive the upcoming winter. Trees and shrubs are best planted from November to mid-March. An early planting date allows plants to get acclimated before the heat and drought of summer begins.

Water Level During Establishment: Soil should be kept moist without the presence of flooded conditions at planting

Table 4.2.4

Plant Type	Recommended Planting Season
Deep pool plants, Zone 1	Spring or after last frost, preferably not in Summer*
Herbaceous wetland plants, Zones 2 and 3	Spring or after last frost, preferably not in Summer*
Shrubs and trees, Zones 3 and 4	Winter (when dormant), Spring or after last frost, Fall, preferably not in Summer*

* A fall planting season is recommended for coastal CSWs.

and for the first six weeks. Cyclic flooding or occasional inundation followed by aerated conditions is helpful when establishing vegetation in these systems. The soil should never completely dry out during plant establishment. Water levels throughout the wetland can be manipulated using the outlet device to ensure that plants establish before receiving large quantities of stormwater. A common mistake made is assuming wetland plants can immediately withstand flooded conditions when plants lack developed root systems and structural adaptations against waterlogged conditions. Leaves, stems, and other plant parts must be held above the water surface to avoid plant drowning (unless a submerged plant).

Plant Spacing: Plant spacing is a very important factor in a CSW vegetation plan. Planting at greater densities is more expensive, but will result in a more rapidly colonized wetland and can reduce the chance for invasive species colonization. If > 60% plant cover is desired following the first growing season, herbaceous plants should be spaced at a minimum of 3' apart. However, for quicker herbaceous plant cover, spacing as close as 1.5 - 2' apart is recommended. Planting herbaceous plants 3' apart may result in a fully colonized wetland after two years of growth while planting 6' apart may require two or more growing seasons before considered fully functional. Planting broad-leaved emergent plants (*Sagittaria* sp. and *Pontederia* sp.) too far apart can result in the invasion and colonization of undesirable plants such as cattails (*Typha latifolia*). Shrubs should be spaced at a maximum of 5' apart, but 3' is preferred. Trees will volunteer in the CSW, and only 2 – 4 trees/10,000 ft^2 are recommended. Plant spacing recommendations from other LID manuals and available research have been synthesized and compiled in Table 4.2.11.

Shading: Though some shading is desired to reduce water temperatures and to improve habitat for fish and macroinvertebrates, trees should not be clustered together and should only be planted around the perimeter of the wetland to reduce shading and discourage mosquito growth.

Nuisance Species: Cattails should never be planted in the CSW. Although cattails are native to Alabama, they are considered invasive and once they invade, can quickly form dense mats, choking out other native vegetation. Monocultures such as cattails decrease habitat for native wildlife resulting in decreased diversity and species richness. Canada geese are a nuisance to newly establishing plants since they dig up and disturb seedlings and increase nutrients and fecal coliforms in the wetland. Geese are attracted to open water areas and a well-designed upland area can discourage them from settling in the wetland.

The following plant lists are not exhaustive and other plants may be appropriate for use in CSWs in Alabama. Extension specialists, horticulturists, or wetland scientists should be consulted for plant recommendations outside this plant list.

Table 4.2.5
Deep Pools, Zone 1 Plant List

Botanical Name	Common Name	Habit	Prefers	Comments
Nelumbo lutea	American lotus	aquatic herb, floating	sun	Very cold and heat tolerant; once established this plant needs lots of space
*Nuphar lutea**	spadderdock	aquatic herb, floating	part shade	Can be hard to establish; attracts birds; spreads by rhizomes; colonizing
*Nymphaea odorata**	American water lily	aquatic herb, floating	sun to shade	Can be hard to establish; waterfowl eat the buoyant seeds; good fish cover; colonizing
Vallisneria americana	American eelgrass	aquatic herb, submerged	sun to part shade	Grows in stoloniferous clumps; good food source for turtles and other aquatic wildlife

* Transition zone plant.

Deep pool (Zone 1) plants are floating or submerged plants that have an obligate wetland indicator status and grow under continuously standing water conditions. Obligate plants always occur as hydrophytes (water loving plants) in their native habitats. The depth of water ranging from 18 - 36" severely limits the number of native species that can grow in these conditions. The purpose of vegetated deep pools is to absorb nutrients from the water column, encourage sediment deposition, improve dissolved oxygen concentrations, and provide habitat or food sources for aquatic life.

Table 4.2.6
Shallow Water, Zone 2 Plant List

Botanical Name	Common Name	Habit	Prefers	Comments
Carex crinita	fringed sedge	Grass like, evergreen	part shade	Can be divided; colonizing
Hibiscus moscheutos	rose mallow	herbaceous perennial	sun to part shade	Attracts birds, hummingbirds, and ducks
Iris virginica	Southern blue flag iris	herbaceous perennial	sun	Do not plant the nonnative invasive yellow flag iris (I. pseudacorus); I. versicolor is the Northern blue flag iris
Juncus effusus	Common rush	Grass like, evergreen	sun to part shade	Can be divided; colonizing
Peltandra virginica	arrow arum	herbaceous perennial	part shade	Attracts birds, not eaten by muskrats or geese
*Pontederia cordata**	pickerelweed	herbaceous perennial	sun to part shade	Attracts dragonflies, attracts ducks, reliable colonizer
Sagittaria lancifolia	bulltongue arrowhead	herbaceous perennial	sun	Attracts ducks; colonizing
Sagittaria latifolia	duck potato	herbaceous perennial	sun to part shade	Starchy rhizomes attract ducks and snapping turtles; colonizing; high nutrient uptake
Saururus cernuus	lizard tail	herbaceous perennial	part shade to shade	Colonizing; dominates during drought; attracts wood ducks
Schoenoplectus americanus	three square	herbaceous perennial	sun to part shade	Seeds eaten by waterfowl
*Schoenoplectus tabernaemontani**	softstem bulrush	grass like perennial	sun	Seeds eaten by waterfowl; nesting cover
Scirpus cyperinus	woolgrass	herbaceous perennial	sun	Seeds eaten by waterfowl; colonizing
Sparganium americanum	bur-reed	herbaceous perennial	sun to part shade	Tolerates flowing water

* Transition zone plant.

Plants in the Shallow Water Zone (Zone 2) also have an obligate wetland indicator status. This zone holds approximately 3 – 6" of water at all times unless subject to a drought. This zone is typically a channel that connects deep pools to the outlet. A common concern with Zone 2 is that plants in this zone may not be suited to occasional drought. However, even in drought conditions, most CSWs will contain water within a foot below the soil surface and most plant roots in this zone can intercept this water to survive during drought conditions.

Zone 2 plants are herbaceous, considered more efficient in pollutant removal, and are less likely to promote mosquito proliferation. These plants are obligate, emergent plants that always occur as hydrophytes in their native habitats. The use of emergent plants can also reduce algal blooms in deep pools. Zone 2 provides habitat for mosquito predators that can control mosquito populations through a natural means. Emergent plants in this zone will migrate throughout the wetland based on plant successional patterns, or changes to vegetation present in the plant community over time. Some species may be eliminated all together and others may dominate certain areas of the wetland based on the conditions they most prefer.

The transition zone connects Zone 1 to Zone 2 and holds approximately 6 – 9" of water at all times. Some plants for Zone 2 are appropriate for the transition zone and are noted in the plant list.

Table 4.2.7
Shallow Land, Zone 3 Plant List

Botanical Name	Common Name	Habit	Prefers	Comments
Acorus americanus	sweetflag	herbaceous perennial	sun	Does not colonize quickly
Alnus serrulata	hazel alder	deciduous shrub	sun to shade	Colonizes easily; fixes nitrogen
Asclepias incarnata	swamp milkweed	herbaceous perennial	sun to part shade	Attracts butterflies
Cephalanthus occidentalis	buttonbush	deciduous shrub	part shade to shade	Good for fringe of zone 2; attracts bees, birds eat fruit
Chelone glabra	white turtlehead	herbaceous perennial	sun to shade	Attracts butterflies and hummingbirds
Clethra alnifolia	summersweet clethra	deciduous shrub	sun to part shade	Moderate growth rate
Conoclinium coelestinum	mistflower	herbaceous perennial	sun to part shade	Attracts birds and butterflies
Cornus amomum	silky dogwood	deciduous shrub	part shade to shade	Attracts butterflies; birds eat berries
Cyrilla racemiflora	swamp titi	deciduous tree	part shade	Fruit attracts birds and small mammals; bee attractant
Eragrostis spectabilis	purple love grass	native grass	sun	Compact native grass
Eupatoriadelphus fistulosis	Joe Pye weed	herbaceous perennial	sun to part shade	Attracts butterflies and birds
Fothergilla gardenii	dwarf witch alder	deciduous shrub	part shade	Can be damaged by prolonged flooding; good for the edge of the wetland
Helianthus angustifolius	swamp sunflower	herbaceous perennial	part shade	Seeds attract birds; white tail deer browse
Ilex glabra	inkberry	evergreen shrub	sun to part shade	Attracts birds
Ilex verticillata	winterberry	deciduous tree	sun to part shade	Attracts birds and butterflies
Ilex decidua	possumhaw	deciduous tree	sun to part shade	Used as a nesting site by birds; fruit attracts birds and small mammals
Ilex vomitoria	dwarf yaupon holly	evergreen shrub	sun to part shade	Birds and small mammals eat fruit
Itea virginica	sweetspire	deciduous shrub	sun to part shade	Medium to fast growth rate
Lindera benzoin	spicebush	deciduous shrub	sun to part shade	Attracts birds
Lobelia cardinalis	cardinal flower	herbaceous perennial	sun to shade	Butterfly and hummingbird attractant; self sows

Continued on next page

Botanical Name	Common Name	Habit	Prefers	Comments
Magnolia virginiana	sweetbay magnolia	evergreen to semi-evergreen tree	part shade	Attracts sweetbay silkmoths; moderate growth rate
Morella cerifera	wax myrtle	evergreen shrub	sun to part shade	Attracts butterflies and birds; fixes nitrogen
Muhlenbergia capillaris	muhly grass	native grass	sun to part shade	Flood and drought tolerant
Panicum virgatum	switchgrass	native grass	sun to part shade	Flood and drought tolerant
Stokesia laevis	Stoke's aster	herbaceous perennial	sun to part shade	Attracts butterflies
Tradescantia virginiana	spiderwort	herbaceous perennial	sun to shade	Attracts bees
Vernonia gigantea	giant ironweed	herbaceous perennial	sun to shade	Attracts bees
Vernonia novenboracensis	New York ironweed	herbaceous perennial	sun	Attracts birds and butterflies
Viburnum dentatum	witherod	deciduous shrub	sun to shade	Attracts butterflies
Viburnum nudum	possumhaw	deciduous shrub	sun to part shade	Berries consumed by birds
Viburnum obovatum	Walter's viburnum	evergreen shrub	part shade	Berries consumed by birds

Plants in the Shallow Land Zone (Zone 3) are herbaceous plants or shrubs that have a facultative or facultative wet wetland indicator status. Facultative plants can occur as hydrophytes (water loving plants) or non-hydrophytes (plants intolerant of flooding). Plants in this area should be placed in a manner that discourages public access because this zone is a critical habitat area for wildlife. However, this zone can also be used for strategic maintenance access. Establishing plants in Zone 3 can be difficult due to alternating hydroperiods (periods of time this zone remains wet) of flooded and drought conditions based on stormwater runoff entering the wetland. Plants should have robust root systems that can stabilize the area to minimize erosion that may occur after a heavy rain. Vegetation for this zone should have high wildlife value, provide food, and shelter to insects (not mosquitoes), birds (not Canada geese, See Nuisance Species), and other desirable small animals.

Vegetation Design Guidelines

- A vegetation plan should include delineated planting zones with a corresponding plant species list, plant establishment schedule, plant maintenance guidelines, and the nursery where plants will be ordered.
- Construction sequencing should be outlined as it relates to plant installation.
- Details for any necessary plant replacement should be outlined.
- If plant establishment and survival is a concern, two thirds of plants can be installed the first year followed up by installation of the last third in the second year. The last third of plants can be planted in areas of the wetland that may not have established or need additional vegetation for adequate cover.
- The plant list should include a minimum of at least ten different total species, with five of these being emergent wetland plants, and no more than 30% of one species in the entire wetland. These are minimum guidelines, and more plant diversity is encouraged.

Table 4.2.8
Upland, Zone 4 Plant List

Botanical Name	Common Name	Habit	Prefers	Comments
Asimina parviflora	dwarf paw paw	deciduous shrub	shade	Fruit attracts small mammals
Callicarpa americana	beautyberry	deciduous shrub	sun to part shade	Attracts birds, rodents, butterflies and deer
Calycanthus floridus	sweetshrub	deciduous shrub	part shade	Colonizing, very insect and disease resistant, adapted to many soils
Cercis canadensis	redbud	deciduous tree	part shade to shade	Attracts birds
Cornus florida	dogwood	deciduous tree	part shade to shade	Fruit attracts birds, small mammals, and deer
Echinacea purpurea	purple coneflower	herbaceous perennial	sun to part shade	Self sows; attracts butterflies and hummingbirds
Fagus grandifolia	American beech	deciduous tree	part shade to shade	Nuts attract birds, rodents, mammals; used as a nesting site and larval host for moths
Fraxinus americana	white ash	deciduous tree	sun to shade	Seeds attract birds, used as larval host for butterflies; used as a nesting site and for cover
Liriodendron tulipifera	tulip poplar	deciduous tree	sun to shade	Used as a nesting site, attracts butterflies, hummingbirds, and birds
Pinus taeda	loblolly pine	evergreen tree	part shade	Fast growing, used as a nesting site, seeds attract birds and small mammals
Quercus alba	white oak	deciduous tree	sun to shade	Acorns attract birds and rodents, attracts butterflies, and used as a larval host
Rudbeckia fulgida	orange coneflower	herbaceous perennial	sun to part shade	Self sows; spreads by offsets; attracts birds
Tilia americana	basswood	deciduous tree	sun to shade	Attracts bees and butterflies

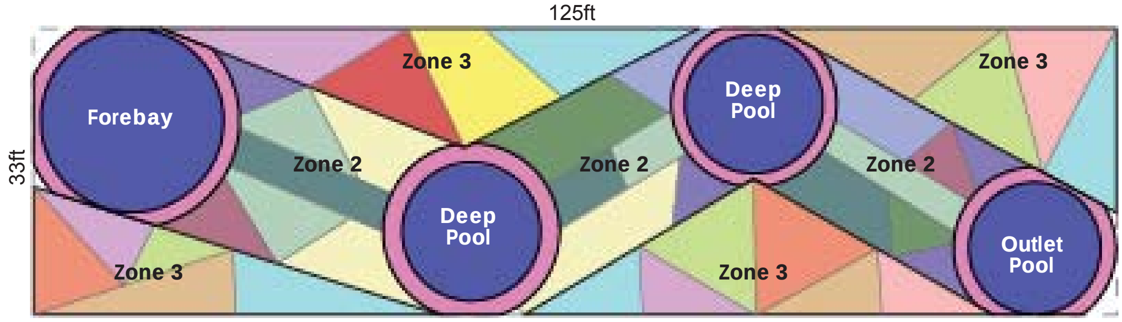
Upland (Zone 4) plants have either a facultative upland or upland wetland indicator status. Upland plants are almost always found in dry areas, but facultative upland plants can be found as hydrophytes (water loving plants), although they usually occur in uplands. Many plants are tolerant of conditions present in the upland zone and because of this, the upland zone provides much biodiversity to the wetland and can provide nesting sites and other valuable wildlife habitat, food sources, and shade.

Vegetation Design Example

The following recommendations are based on a small CSW that is 125' x 33'. Vegetation for this small CSW should be native and low maintenance. The SA breakdown is as follows:

Table 4.2.9

Zone	Description	Radius (if applicable)
Forebay, Zone 1	411ft^2	~ 11ft
Outlet Pool, Zone 1	200ft^2	~ 8ft
Deep Pool, Zone 1	410ft^2, ~ 200ft^2 per pool for 2 pools	~ 8ft each
Shallow Water, Zone 2	1,646ft^2	
Shallow Land, Zone 3	1,234ft^2	



A drawing or sketch of the CSW drawn to scale is needed to layout the vegetation plan. A specific plant list can be made using the above plants lists for each zone.

Most small CSWs cannot accommodate large trees. Ornamental plants that attract butterflies may be desired if the CSW will be located in a highly visible area. Plants that tolerate the transition zone should be noted and placed appropriately between Zones 1 and 2. Moreover, plants that establish quickly or colonize should be prioritized to reduce the chance for nonnative invasives to move into the wetland area. Plants such as *Sparganium americanum* that tolerate flowing water should be placed appropriately in the path of flowing water in Zone 2.

Table 4.2.10
Design Example Plant List

Zone 1	Zone 2	Zone 3
Nelumbo lutea	*Carex crinata*	*Conoclinium coelestinum*
	Hibiscus moscheutos	*Eupatoriadelphus fistulous*
	Iris virginica	*Lindera benzoin*
	Juncus effusus	*Lobelia cardinalis*
	Pontederia cordata *	*Ilex glabra*
	Sagittaria latifolia	*Ilex vomitoria*
	Saururus cernuus	*Itea virginica*
	Sparganium americanum	*Viburnum nudum*

* Transition Zone Plant

Option 1: Calculating Plant Quantity Based on a Drawing

Outline where each species will be planted on a layout plan. Each zone can be divided into geometric shapes to calculate areas (See next page). Use the plant list for each zone to place plants throughout the zone. If plants prefer part shade, be sure that these will be shaded from afternoon sun by taller plants when established.

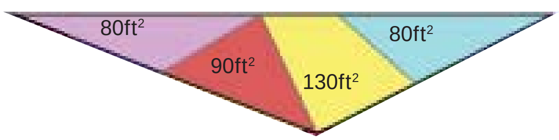
Continued on next page

Table 4.2.11
Plant Spacing Recommendations

Plant Type	Recommended Quantities	Recommended On-Center Spacing
Floating plants for deep pools, Zone 1	6/100 ft^2	8'
Herbaceous plants for shallow water and shallow land, Zones 2 and 3	25/100 ft^2	2'
Shrubs and small trees for shallow land and upland, Zones 3 and 4	4/100 ft^2	12.5'
Trees for upland, Zone 4	1/200 ft^2	100'

Quantities can be calculated based on the recommended spacing for each plant type as shown in Table 4.2.11. Quantities shown below are suggested for maximum cover and establishment; however, depending on the vegetation budget, quantities may be more or less per square foot.

A portion of zone 3 will be used as an example for how to calculate plant quantity:



Ilex glabra has 80 ft^2 that it will inhabit. Based on 4/100 ft^2 planting recommendations, a quantity is determined:
80 ft^2 * 4 ÷ 100 ft^2 = 3.24, so **3 plants**

Eupatoriadelphus fistulosus has 90 ft^2 that it will inhabit. Based on 25/100 ft^2 planting recommendations, a quantity is determined:
90 ft^2 * 25 ÷ 100 ft^2 = 22.5, so **22 plants**

Itea virginica has 130 ft^2 that it will inhabit. Based on 4/100 ft^2 planting recommendations, a quantity is determined:
130 ft^2 * 4 ÷ 100 ft^2 = 5.2, so **5 plants**

Conoclinium coelestinum has 80 ft^2 that it will inhabit. Based on 25/100 ft^2 planting recommendations, a quantity is determined:
80 ft^2 * 25 ÷ 100 ft^2 = 20, so **20 plants**

The same process should be followed to calculate quantities for the remainder of the vegetation plan

Option 2: Create a Landscape Drawing

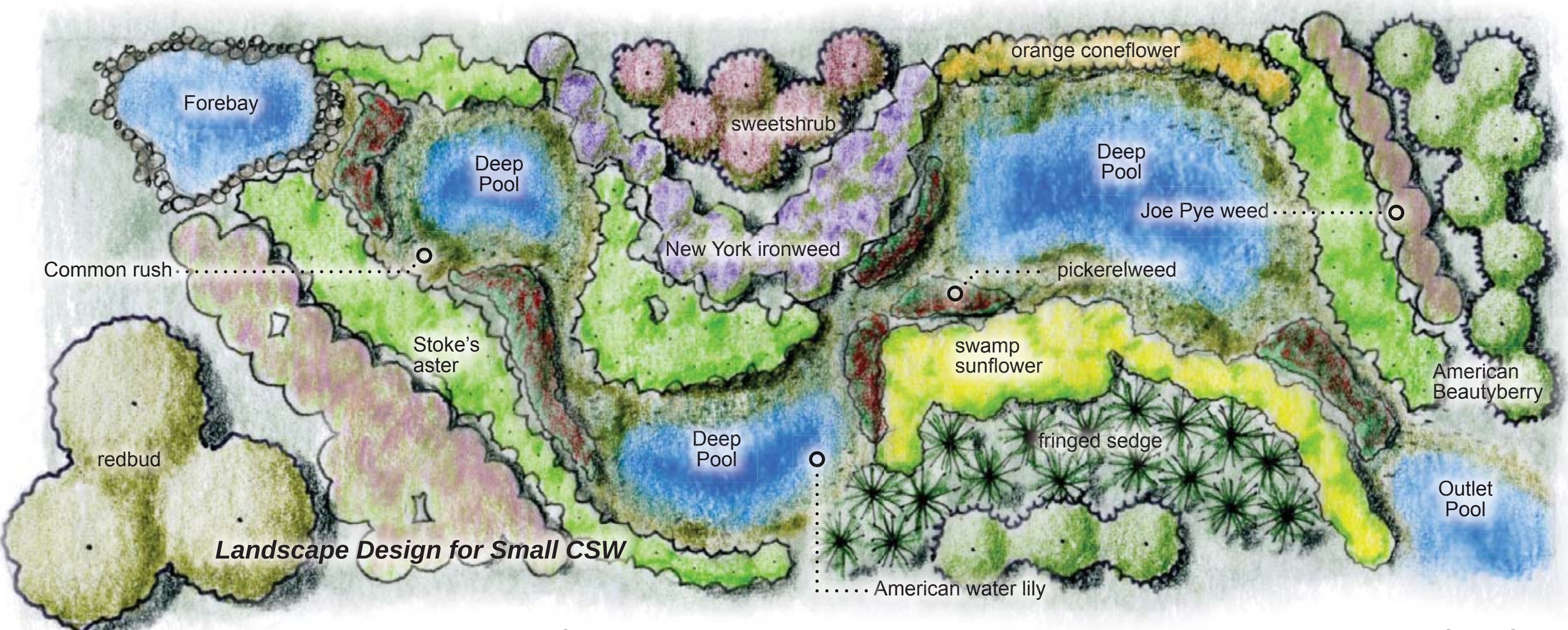
This option is only appropriate for a small CSW draining < 1.5 acres.

This drawing, on next page, is made to scale, shows each individual plant, and is similar to a conventional landscape plan. Much like Option 1, the zones should be drawn on the plan based on the square feet per zone. After creating a plant list, each plant can be added using a circle template. The circle template is used to show the plant's size at maturity, which will help to avoid overcrowding of plants.

Maintenance

CSWs can function effectively for 20 years or longer if designed and maintained properly. Most maintenance tasks for CSWs focus on efficient hydraulic flow, plant health, aesthetics, safety, and mosquito control.

Sediment Removal: Sediment depth in the forebay should be measured and recorded consistently at the same time of year using a rod or other measuring tool. A fixed sediment marker can be installed to determine when dredging is necessary. Sediment removal is recommended when the functionality of the forebay has diminished, when it is half full, or when the average depth of sediment is within a foot of the water surface. Sediment removal from the outlet



pool is also needed, but it will fill much less quickly and should be cleaned out when sediment is within one foot of the water surface.

Clogged Outlet Structure: The outlet structure should be monitored monthly and after storm events. A clogged outlet structure can result in extended flooding throughout the wetland and decreased drawdown time to the PPE. Decreased drawdown time is detrimental to wetland plants in Zone 3 (shallow land). Floating trash and plant debris can easily clog smaller diameter orifices, and the addition of a trash rack or grate can facilitate easier clean out. A clogged orifice can damage wetland vegetation because the temporary pool will not draw down in the recommended 2 - 5 days. Storage volume for later storms is lost when the temporary pool is full. Turning the drawdown orifice pipe downward below the PPE can decrease maintenance frequency and ensure that it is not clogged with floating vegetation, debris, or other trash. It is important that only maintenance professionals have access to drawdown orifice pipes.

Removed Sediment Disposal: Once removed, sediment can be land applied on the banks of the wetland (Zone 4), and should be immediately stabilized using permanent seed and appropriate mulch cover. If the wetland receives runoff from a commercial or industrial setting, the sediment may be hazardous and will need to be tested. Upon the need to dispose of any potentially contaminated or hazardous sediment, the ADEM Environmental Services Branch should be contacted for guidance associated with the requirements for waste determination and disposal procedures. For more information, please call 334-271-7700 or 1-800-533-2336.

Emergency Spillway: The embankment, dam, and emergency spillway should be free of any woody vegetation. When vegetation is found growing on these structures, it should be removed. The dam can be mowed to retard growth. Plants growing on the dam can be controlled using a systemic herbicide; this may be a labor-intensive task and a professional may be required to complete the job especially if a pesticide applicator's permit is needed for commercial applications.

Plant Inspections: Plant establishment and care should be a priority as they are critical to maximizing wetland functions. The task of plant establishment and maintenance should be carefully outlined prior to construction of the wetland area. Weekly plant inspections may be necessary during the first six weeks following planting, followed by bi-weekly inspections for the remainder of the first growing season to observe plant growth and soil moisture levels.

Water Level in the CSW: Naturally lower water levels throughout the wetland during the first growing season (spring and summer) allows new plants to take advantage of more oxygen (decreased oxygen causes stress to plants) in the rootzone resulting in increased SA coverage by plants. Water levels can be raised during the winter months since plant roots require less oxygen for metabolism during this time. If conditions are dry, plants may require irrigation during establishment and access to a water source or a water truck should be considered during planning.

Surface Area Coverage: Plant SA coverage in the 90 - 95% range is preferred and in general, higher SA coverage is better. Following the second growing season, if plant cover has not reached a minimum of 70%, additional plant installation is needed. Plant succession (changes in species present on the plant community is a natural occurrence, but can also be indicative of a problem. When invasive plants move into the established wetland, it is often a sign that conditions in the wetland are no longer favorable for the native plants that were previously established. For example, when submerged aquatic plants disappear, it may be a sign of diminished water clarity, increased sediment, or high turbidity since these plants rely on light penetration throughout the water column for survival.

Table 4.2.12
Maintenance Schedule

Task	How Often	Comments
Erosion Inspection	During and after major storm events for first 2 years, annually thereafter	Ruts, holes, or gullies should be repaired with soil and vegetation cover.
Inspection	After 0.5” or greater rainfall event	Visually inspect all components including forebay, weir, embankment, orifices, or channels where applicable.
Plant Inspection	Weekly for first 6 weeks, then bi-weekly for rest of first growing season; once to twice per year thereafter	Plants should be inspected and irrigated (if necessary) weekly for the first 6 weeks following plant installation. Following the first growing season, plants should be inspected twice per year for the first 3 years and once annually thereafter.
Inspect for/Remove Pests	When the wetland is visited	Inspect for beavers, muskrats, or other pests that may inhibit flow patterns or clog the wetland. A professional trapper may need to be hired.
Dam/Embankment Inspection	Annually	A dam safety expert should inspect the embankment.
Trash Removal	Twice a year, once a week, or once a month depending on location	Trash or debris should be removed from the entire wetland area. Trash should be removed from any trash grates or debris collection mechanisms. Trash removal frequency should be tailored to the site and adjacent land use. CSWs draining commercial areas may require more frequent trash cleanup.
Remove Woody Vegetation from Dam Face	Annually	All woody plants should be removed from the dam face or emergency spillway. A dam safety expert may need to be consulted.
Sediment Removal from the Forebay	When the forebay is half full or within 1’ of surface	Sediment removal may be more frequent if construction is underway in the drainage area.
Sediment Removal from Deep Pools	When they are half full or within 1’ of surface	Deep pools should be dredged before a shift in vegetation or aquatic life occurs due to increased flooding within the wetland.
Sediment Removal from the Outlet Pool	When the outlet pool is half full or within 1’ of surface	Sediment in the outlet pool can inhibit water from leaving the CSW, creating unintentional extended flooded conditions.
Measure Sediment in Forebay	Minimum of once a year	A rod or other tool can be used to check sediment accumulation depth.
Removal of Invasive Plants	Twice a year during the first 2 years, once a year (in spring) thereafter	Weeds or other invasive plants should be removed as they crowd and rob native plants of water, sunlight, and nutrients. Invasive species removal will decrease in frequency when native plants have dominated the CSW.
Replanting	Following the second growing season if necessary	If SA coverage has not reached a minimum of 70% following the second growing season, additional planting may be necessary.
Inspect/Unclog Orifice or Outlet Device	Once per month or following a 2” rain event	The outlet structure is clogged when Zone 3 remains flooded for more than 5 days. Check for trash in the drawdown orifice.

Invasive Plants: Invasive plants can be spread through seeds or other vegetative parts. When invasive plant species become established, their seeds can be easily discharged from the wetland to spread these species downstream. Certain native species may also become noxious. For example, cattails that establish themselves in CSWs adjacent to commercial or residential settings should be removed immediately due to threats of mosquitoes and decreased plant diversity. If caught early, hand removal may prove effective. However, it is very difficult to remove a large clump of cattails by hand and if any portion of the plant is left, the plant will regenerate. In this case, a systemic herbicide such as glyphosate labeled for aquatic use should be wiped onto the foliage. See Appenix D on Vegetation for more information on using herbicides.

Nuisance Species Damage: Animals such as muskrats and beavers can damage the CSW. Muskrats feed on vegetation, and these discarded plant pieces can clog the orifice. Holes burrowed by muskrats in the outlet pool can result in increased turbidity of water leaving the system. Holes burrowed into the dam can diminish its structural integrity and be a safety issue. Muskrat holes should be filled during site visits. Beavers are also known to be attracted to flowing water and can become a nuisance because they remove woody vegetation from the perimeter of the wetland and build dams throughout, which can raise water levels and damage vegetation. If muskrats or beavers become problematic, a professional trapper or relocator may be needed.

Maintenance History: Maintenance records should be kept at a single location throughout the life of the practice. Datasheets or checklists should be used for each inspection during site visits. Problems noted during inspections should be immediately repaired. Maintenance professionals should note erosion, channelization, bank stability, and any sediment accumulation during inspections. It is also important to note plant distribution and wildlife presence. See Table 4.2.12 Maintenance Schedule for additional recommendations.

Pollutant Removal

Table 4.2.13
Pollutant Removal Table

Sediment	Nutrients		Metals	Pathogens
	N	P		
a.85%	40%	40%	No Data	No Data
b.80%	30%	40%	50%	70%
c.80%	30%	40%	50%	70%*
d.80%	30%	40%	50%	70%*

a. NCDENR, 2007
b. City of Auburn, 2011
c. Georgia Manual, 2001
d. Iowa State University, 2009
* If no resident waterfowl are present

Like a natural wetland, plants in a CSW are vital to system processes. When designed and constructed properly, CSWs have the best median pollutant removal rates for total suspended solids (TSS), nitrate-nitrogen, ammonia-nitrogen, total phosphorus, phosphate-phosphorus, and metals compared with bioretention and other stormwater control measures (SCMs). The ability of CSWs to effectively treat TSS, nutrients, and the biochemical oxygen demand (BOD) does not decrease over the life of the wetland. The CSW can be designed to meet particle size removal efficiencies and treatment volume criteria.

Nutrients: Nutrient transformations occur in both aerobic and anaerobic processes within the CSW. The four wetland zones offer both aerobic and anaerobic soil conditions along with the organic matter or topsoil layer that provides exchange sites necessary for nutrient removal. In Zone 1, the deep pools promote an anaerobic environment associated with increased denitrification (nitrogen reduction). Transitional zones aid in nutrient removal through nitrification and denitrification cation processes. Shallow water zones have higher oxygen concentrations compared to deep pools and promote nitrification through aerobic processes.

Total Suspended Solids: Plant stems and pool variations create a slower laminar flow that allows the settling of particulates and sediment. This allows the CSW to treat pollutants such as phosphorus, trace metals, and hydrocarbons that are adsorbed to sediment, suspended solids, or to plant tissues. Reduction of total suspended solids (TSS) is generally at least 80% unless the CSW is undersized or has been improperly designed.

Undersized Wetlands: Undersized wetlands may increase the velocity of inflow and may cause re-suspension of sediments and decreased removal of attached pollutants.

Dissolved Oxygen: Water discharged from these systems may contain low concentrations of dissolved oxygen (DO) (<1 mg/L). If this is a concern for downstream water bodies, an aerating structure may be included to create turbulence and increased DO concentrations of water exiting the wetland.

Temperature: If temperature is a concern, the drawdown orifice should draw from the bottom of the outlet structure to ensure that the coolest water is discharged. This can be especially important in protecting aquatic animal communities that require cooler water temperatures.

Vegetation: CSW plants provide attachment areas and habitat for microorganisms that serve as filtering mechanisms and aid in denitrification. Emergent plants aid in trapping and stabilizing sediment to reduce resuspension of TSS and can attract mosquito predators to inhibit mosquito growth. Plant roots assist in microbial breakdown or the chemical transformation of organic matter, heavy metals, and pesticides by releasing oxygen from their roots to create oxidized sediment surrounding their root systems. The rich organic layer formed through plant decomposition fosters beneficial bacterial growth and traps solids. In order to increase pollutant removal potential, it is important to consider and maintain both the health and diversity of plants in these systems.

References

Alabama Department of Environmental Management. National Pollutant Discharge Elimination System (NPDES) Construction, Noncoal/Nonmetallic Mining And Dry Processing Less Than Five Acres, Other Land Disturbance Activities, And Areas Associated With These Activities. Field Operations Division – Water Quality Program. Chapter 335-6-12.

Bonilla-Warford, C.M. and J.B. Zedler. 2002. Potential for Using Native Plant Species in Stormwater Wetlands. Environmental Management. 29:3.

Burchell, M.R., W.F. Hunt, K.L. Bass, and J. Wright. 2010. Stormwater Wetland Construction Guidance. North Carolina Cooperative Extension. AG-588-13.

Carleton, J. N. T.J. Grizzard, N. Godrej, and H. Post . 2001. Factors affecting the performance of stormwater treatment wetlands. Water Research, 35(6), 1552-1562.

Carr, D. and B. Rushton. 1995. Integrating a Herbaceous Wetland into Stormwater Management. Southwest Florida Water Management District Stormwater Research Program.

Center for Watershed Protection. 1995. Pollutant Dynamics Within Storm Water Wetlands: I. Plant Nutrient Uptake. Techniques, Vol. 1, No.4. Silver Spring, MD.

City of Auburn Stormwater Manual. 2011

Dodson, R.D. 1999. Stormwater Pollution Control: Municipal, Industrial, and Construction NPDES Compliance. Second Edition. McGraw-Hill, New York.

Georgia Stormwater Management Manual. 2001.

Hammer, D.A. (Ed.). 1989. Constructed Wetlands for Wastewater Treatment. Lewis Publishers, Chelsea, MI.

Hunt, W.F., C.S. Apperson, and W.G. Lord. 2005. Mosquito Control for Stormwater Facilities. North Carolina Cooperative Extension. AG-588-4.

Hunt, W.F. and B. Doll. 2000. Designing Stormwater Wetlands for Small Watersheds. North Carolina Cooperative Extension. AG-588-2.

Hunt, W.F. and W.G. Lord. 2006. Maintenance of Stormwater Wetlands and Wet Ponds. North Carolina Cooperative Extension. AG-588-07.

Hunt, W.F., M.R. Burchell, J.D. Wright, and K.L. Bass. 2007. Stormwater Wetland Design Update: Zones, Vegetation, Soil, and Outlet Guidance. North Carolina Cooperative Extension. AG-588-12.

Jones, M.P. and W.F. Hunt. 2007. Stormwater BMPs for Trout Waters. North Carolina Cooperative Extension. AG-588-10.

Iowa State University. 2009. Iowa Stormwater Management Manual, Ch 2H-1: General Information for Stormwater Wetlands. Transportation Institute, Ames, IA.

Kadlec, R.H. and R.L. Knight. 1996. Treatment Wetlands. Lewis Publishers, Boca Raton, FL.

Lichvar, R.W. and P. Minkin. 2008. Concepts and procedures for updating the national wetland plant list. U.S. Army Corps of Engineers, Engineer Research and Development Center, ERDC/CRREL TN-08-3.

Moore, T.L. and W.F. Hunt. 2011. Stormwater Wetlands and Ecosystem Services. North Carolina Cooperative Extension. AG-588-22.

North Carolina Department of the Environment and Natural Resources. 2007. Stormwater Best Management Practices Manual, Ch 9: Stormwater Wetlands (Chapter revised 2009). North Carolina Division of Water Quality, Raleigh, NC.

Pennsylvania Stormwater Best Management Practices Manual. 2006. Appendix B Pennsylvania Native Plants.

Stevens, M. and C. Hoag. 2000. Broad-Leaved Cattail. US Department of Agriculture, Natural Resources Conservation Service, Aberdeen, ID.

United States Department of Agriculture and Natural Resources Conservation Service. 1996. Guidelines for Establishing Aquatic Plants in Constructed Wetlands. NRCS, Athens, GA.

US Environmental Protection Agency. 1999. Stormwater Technology Fact Sheet: Storm Water Wetlands. Office of Water, Washington, D.C.

US Environmental Protection Agency. 1996. Protecting Natural Wetlands: A Guide to Stormwater Best Management Practices. Office of Water, Washington, D.C.

::This page::
::intentionally left blank::

Permeable Pavement (PP)

Permeable Interlocking Concrete Pavers; Orange Beach, AL

Site Selection

Quantity Control	possible
Drainage Area	small
Space Required	small

Works with:

Steep Slopes	---
Shallow Water Table	---
Poorly Drained Soils	---

General Significance

Construction Cost	high
Maintenance	med
Community Acceptance	high
Habitat	low
Sun / Shade	either

Synonyms: Pervious pavement, modular paving systems, enhanced porosity concrete, porous pavement, modular plastic permeable paving

Permeable pavement is a pervious surface used in place of traditional concrete or asphalt to infiltrate stormwater. Permeable pavement provides a volume reduction of stormwater runoff through temporary storage. It can be used to reduce peak flows and promote stormwater infiltration in urbanizing watersheds. The application of permeable pavement reduces impervious surface area runoff, which has been linked to streambank erosion, flooding, nonpoint source pollution, and other water quality impairments.

Permeable pavement refers to any pavement that is designed to temporarily store stormwater in a gravel base layer. Stormwater is held in the gravel base layer, or subbase, before leaving the system through exfiltration into surrounding soils or through an underdrain. These systems are suitable for residential driveways, walkways, overflow parking areas, and other low traffic areas that might otherwise be paved as an impervious surface. Permeable pavement can be less expensive than conventional stormwater management practices (i.e. detention basins) due to the decreased need for curb and gutter, stormwater ponds, and catch basins. The failure potential is high when these systems are not designed, constructed, or maintained properly.

Site Selection

Low Traffic Areas: Areas with less than 100 vehicles traveling on them per day are best suited for permeable pavements, as most types cannot structurally support constant traffic or heavy vehicles. When pervious concrete (PC) is sited on high traffic areas, surface raveling or degradation can occur due to vehicles frequently driving back and forth over the surface.

Evaluating Soils: Use the USDA Web Soil Survey to identify soil map units and to make initial interpretations for potential uses and limitations of a site. However, since most soil map units have inclusions of other soils that may be quite different, detailed evaluations should be made at the proposed site by a professional soil scientist or soil classifier. On-site evaluations should properly identify a soil or the hydrologic soil group (HSG) and the final

USDA's online Web Soil Survey (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm) can be used as a guide to determine the needed soil information for the site, such as the hydrologic soil group (HSG) and depth to water table.

Table 4.3.1
Site Selection: Constraints and Limitations for Permeable Pavement

Constraint	Recommendations
Insufficient Sub-grade Infiltration Rate (<0.5"/hr)	Use other SCM; poorly drained soils are not appropriate for permeable pavement
High Traffic Areas	Use other SCM that can structurally support heavy vehicles, or check with manufacturer of permeable interlocking concrete pavers (PICPs) for structural support limits
Slope	Slopes greater than 2% are not recommended
High Sediment loads	Permeable pavement should not experience high sediment loads that risk clogging system
Heavily Landscaped Areas Adjacent	Maintenance frequency must increase when permeable pavement is sited adjacent to messy vegetation since the system has a higher potential to clog
Regional Stormwater Control	Use another SCM
Reduction in Total Suspended Solids (TSS)	Due to the risk of surface clogging, permeable pavement is not currently designed to capture sediment or reduce TSS

decision for use should be made based on the detailed determination of soil series or HSG. For a detailed list of HSG properties, see Table A.3 in Appendix A on Stormwater Hydrology.

In-situ Soil: Soils should have a minimum infiltration rate of 0.5"/hr as determined by an infiltration test at the initial site visit (see Chapter 5.1 on Rain Gardens for more information on an infiltration test). An underdrain should be used when soils have an infiltration rate of ≤ 0.5"/hr. Suitable soils for this practice are well-drained and have a texture no finer than a loamy very-fine sand. Sandy soils are preferred for permeable pavements because finer textured clay soils do not provide enough structural support. To compensate for clay soils, the gravel base layer can be thicker to provide increased structural support. Placing permeable pavement on fine textured soils (high clay content) can also result in standing water on the surface of the pavement due to inhibited infiltration, which will degrade the surface over time and pose a safety hazard. United States Department of Agriculture (USDA) and Natural Resources Conservation Service (NRCS) hydrologic soil groups (HSG) C and D are not appropriate for permeable pavements, as these usually have greater than 30% clay content and are not well-drained. Sites with a high clay content of 20% or more should be designed with adequate underdrains.

Depth to Groundwater: The runoff volume captured by the system should drain away from the underlying soil within 24 to 48 hours. Additionally, the seasonally high water table should be a minimum of 2' below the permeable pavement base to allow water to properly exfiltrate from the system and to avoid leaching of captured pollutants into groundwater. To prevent groundwater contamination, permeable pavement is not recommended to treat runoff from a "hotspot", industrial, or commercial areas that may have potentially high concentrations of soluble pollutants or pesticides.

Commercial or Industrial Sites: Areas considered unsuitable for treatment using these systems include: commercial plant nurseries, industrial rooftops, fueling stations, marinas, loading or unloading zones, vehicle service or maintenance areas, public works storage areas, auto recycle facilities, and similar locations.

Impervious Surface Area: Runoff directed to permeable pavement should be from impervious surface areas. The ratio of impervious surface area to the permeable pavement surface area should not be greater than 3:1.

Site Specific Constraints: Permeable pavement should be sited at least 10' downslope from buildings and 100' from drinking water wells.

Slope: Slopes greater than 2% are not recommended for permeable pavement. In some jurisdictions, recommendations are less stringent with suggestions of 6% slope or less in North Carolina (less than 0.5% bottom slope) and no greater than 5% in Knox County, Tennessee. Steep slopes can limit storage capacity of permeable pavement systems; however, partitions or baffles can be used to terrace the subgrade to promote infiltration throughout the entire system.

Adjacent Vegetation: Vegetated or other nearby pervious surfaces should be stabilized and not contribute sediment to the permeable pavement surface. Heavily wooded areas adjacent to permeable pavement systems can also be problematic due to excessive debris such as sticks and leaves being ground into the pavement by vehicles and foot traffic. For the same reason, permeable pavement should not be sited near or under extremely messy or high maintenance vegetation. Designers of these systems should be aware that siting permeable pavement near vegetation results in increased maintenance, especially during fall and winter months.

Common Permeable Pavement Variations

Permeable pavements have similar layers of structural support storage and filtering mechanisms including a choker course, subbase layer (reservoir), filter fabric, and underlying soil. The primary difference in each type of permeable pavement cross section is the top layer or the specific type of porous material selected.

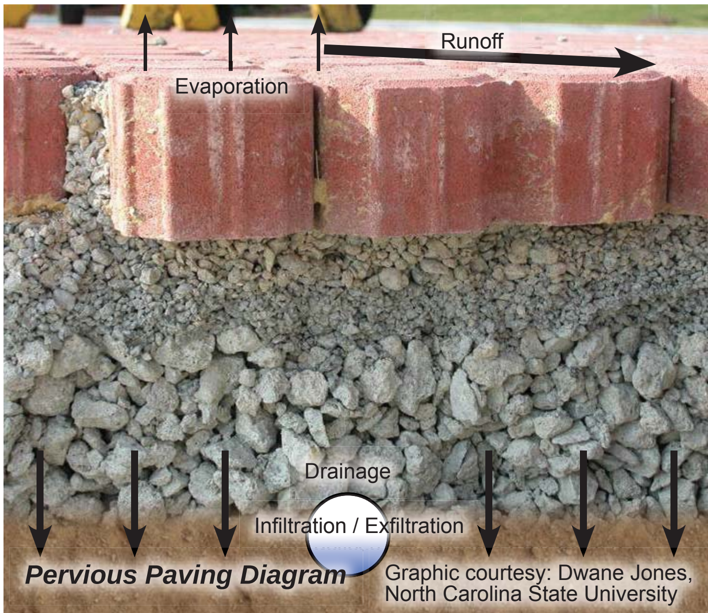
Pervious Concrete (PC): PC is a mixture of coarse washed aggregate, Portland cement, fly ash, and water. The mixture does not contain fine aggregates and their absence creates interconnected void spaces or pores in the mixture to allow for stormwater infiltration, thus making void content a primary component of PC function. Void space for PC should range from 15 – 25% compared to the 5% void space found in traditional concrete. Due to void content, PC does not exhibit compressive strength found in conventional concrete. Following seven days of curing, PC with adequate void content should have a compressive strength of approximately 3,000 pounds per square inch (psi) and an infiltration rate of at least 300"/hr. PC is more widely used in warm climates because it is reported to maintain its consistency during extremely hot weather. PC is appropriate throughout the state of Alabama especially where sandy soils are present.

Porous Asphalt (PA): PA uses fine and coarse aggregates mixed in a bituminous-based binder. Similarly to PC, infiltration occurs in PA through interconnected void spaces. It is suitable to climates that experience winter freezing and thawing due to its ability to hasten snow and ice melt, reducing the amount of salt used during the winter months. Void content should range from 15 – 20% to ensure adequate infiltration. When PA freezes, the void space is maintained and rather than forming a solid block, PA freezes into a porous surface. Continuous infiltration of stormwater aids in reducing freezing and thawing within the subbase layers of the PA, which is expected to decrease frost heaving frequently associated with conventional asphalt. PA is not as strong as conventional asphalt and therefore its placement, design, construction, and installation are essential to its long-term functionality. PA is installed using the same equipment as conventional asphalt; however, compaction should be minimized in order to avoid closing pore spaces. Following installation, PA should not receive traffic for 24 to 48 hours. PA is more expensive compared to conventional asphalt due to the extra cost associated with admixtures; however, PA has shown a lifespan of 30 years, which is double that of conventional asphalt. PA has also been noted to be less expensive compared to PICPs and PC.

Permeable Interlocking Concrete Pavers (PICPs): PICPs are concrete blocks placed with void space between them that are filled with a permeable joint material to encourage infiltration. Void space should range between 8 – 20% of the surface area. These systems are more suited to high traffic areas because they offer the greatest structural strength compared to other permeable pavement types. PICPs do not require any curing and are traffic-ready immediately following installation. The type of PICPs specified is dependent on the strength required by the traffic load of the site. PICPs are available in a variety of shapes, sizes, and colors, and thus are more aesthetically diverse than other permeable pavements. Because the pavers are manufactured and can be installed mechanically, PICPs tend to be more uniform in size and function. Installation is not weather dependent because there is no "plastic" mix that must be monitored for consistency or temperature limitations. PICPs are less expensive compared to conventional concrete and asphalt. Installation and supply costs are noted to be similar for PICPs compared to PC and PA, however, costs spread out over the life of PICPs are noted to be less expensive than PC and PA.

Concrete Grid Pavers (CGPs): CGPs are concrete forms with surrounding void space filled with a fine textured aggregate, sandy loam topsoil and turfgrass, or sand to aid infiltration. Void content ranges from 20 – 50% of the surface area and is dependent on the fill media. Turfgrass is used for these systems due to their shallow roots systems and low overall height. In low traffic situations, CGPs have shown structural support and durability comparable to conventional asphalt.

Plastic Reinforcement Grids (PRGs): PRGs are modular plastic grid units that may be round or honeycomb shaped. These plastic grids provide void spaces, which are either filled with gravel or support turfgrass. Void content is dependent on the fill media. Over time, PRGs may shift



Pervious Paving Diagram Graphic courtesy: Dwane Jones, North Carolina State University


Pervious Concrete


Porous Asphalt
Courtesy National Center for Asphalt Technology


Permeable Interlocking Concrete Pavers


Concrete Grid Pavers


Plastic Reinforcement Grids

and become lifted out of the soil, especially in parking areas where rear tires sit.

Design

Permeable pavement is typically designed to treat the first flush of the selected water quality design storm. The first flush contains the highest concentration of pollutants, see Appendix A on Stomrwater Hydrology for more information on the first flush. The design storm may be dependent on regulatory requirements.

The porous surface selected should be suitable for its intended application. If it is a load-bearing surface, then the pavers, concrete, or asphalt selected should be designed to support the maximum load. It is preferred that the manufacturer make the site design. Specific design requirements for structural stability are beyond the scope of this handbook. A model such as the Interlocking Concrete Pavement Institute's (ICPI) Permeable Design Pro Software (http://www.icpi.org/node/1298) should be used to determine if the system could structurally perform as needed. The American Association of State Highway and Transportation Officials (AASHTO) Flexible Pavement Method for structural design requirements should also be referenced.

Components

Pretreatment: Pretreatment devices such as vegetated swales or filter strips should be used to capture sediment before it enters the permeable pavement surface. See Chapter 4.4 on Grassed Swales, Infiltration Swales, and Wet Swales.

PC Components: The top layer of PC may be as thick as 8" depending on the design and site requirements. Coarse aggregate that is roughly 3/8" (#8 or #89 stone) should be used in the mixture. The absence of fine aggregates provides the void content necessary for infiltration. Next, there is a top filter layer of choking stone (0.5" diameter aggregate) at a depth of 1 to 2" to help stabilize the PC and provide rapid infiltration into the layer below. The next layer is the subbase/reservoir layer for temporary storage of stormwater. The subbase layer is comprised of 1.5 – 2.5" diameter aggregate (#3 or #2 stone) and typically ranges from 2 – 4' deep, but can be a minimum of 9". The depth of the subbase layer is based on the desired storage volume and on-site infiltration rates. The bottom filter layer consists of either 6" of sand or 2" of 0.5" diameter crushed stone; this layer stabilizes the subbase layer and protects the underlying soils from compaction. All aggregates used in the PC mixture and other layers should be washed. A layer of filter fabric should be placed before any aggregate layers are laid to discourage the migration of soil particles.

PA Components: The first layer is the PA layer and it may be as thick as 7", although 2 – 4" is typical. This layer is followed by a 1 – 2" choker course, which provides a level surface and is comprised of small open-graded aggregate. A subbase or base course (reservoir) beneath this layer helps to increase strength and storage capacity of the PA and is usually 18 – 36" deep. Depth of the subbase is dependent on the amount of storage desired and the expected traffic load. The first 3 – 4" of the subbase should contain ¾" (#57) diameter stones to initiate a high infiltration rate into the lower layer of the subbase. The rest of the subbase should contain ¾ to 2.5" diameter stone. All aggregates used in the PA mixture and other layers should be washed. A layer of geotextile fabric is used as a filter between the subbase and underlying soil, similarly to PC.

PICPs Components: The concrete pavers in PICPs are approximately 3" thick. Spacer bars on PICPs are recommended for mechanically installed pavers and for high traffic areas. Pavers installed manually do not require spacer bars. The openings between the pavers are filled with a 3/8" (#8 or #89) stone; the bedding course below the pavers is typically 1.5 – 2" thick layer of the same size stone. The bedding and joint material should be washed, free of debris, and symmetrically shaped. Below the bedding course is a 4" layer of ¾" (#57) stone to provide an open-graded base. The subbase below is comprised of 2.5" (#2) stone and this depth varies based on the design and existing soil conditions on site. All aggregates used in the layers of PICPs should be washed. A layer of filter fabric is placed between the subbase and the underlying soil.

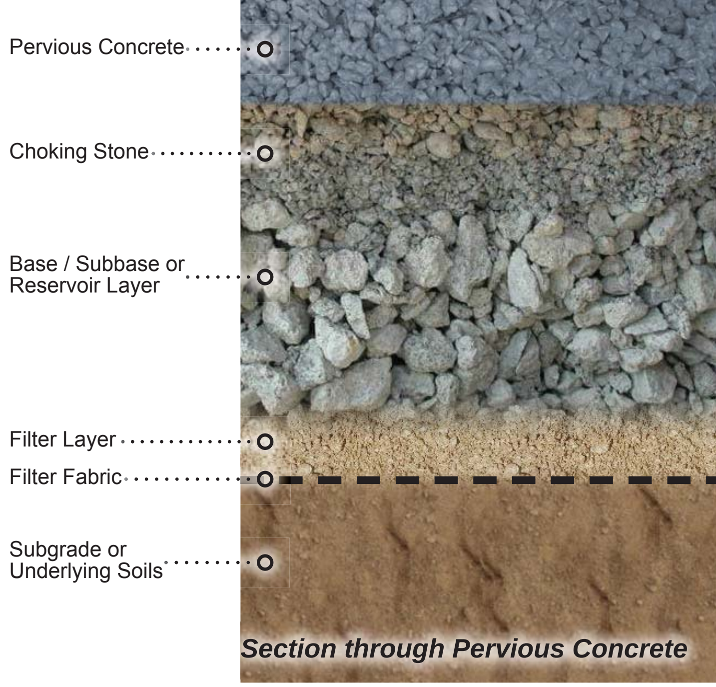
CGPs Components: Grid pavers may use masonry sand or a #10 stone dust with an 8"/hr infiltration rate between the grids for stormwater infiltration. If turfgrass is desired between grids, a sandy loam with a minimum infiltration rate of 1"/hr should be used. Below this layer is a 1" filter layer of masonry sand or #10 stone dust. The reservoir layer is a minimum of 9" and is comprised of 1.5 – 2.5" (#3 or #2) diameter stone. All stone and sand components should be washed and free of debris. The last filter layer is 8" of masonry sand followed by a layer of filter fabric.

PRGs Components: PRGs are placed over fine textured gravel or a sandy loam soil when turfgrass is used. The subbase below uses a well-draining, washed aggregate. The depth of the subbase layer is site dependent and may be a minimum of 9". Filter fabric is placed between the subbase and underlying soil. The structural specifications for these products are highly varied. Most manufacturers can provide specific design and construction information based on their product specifications.

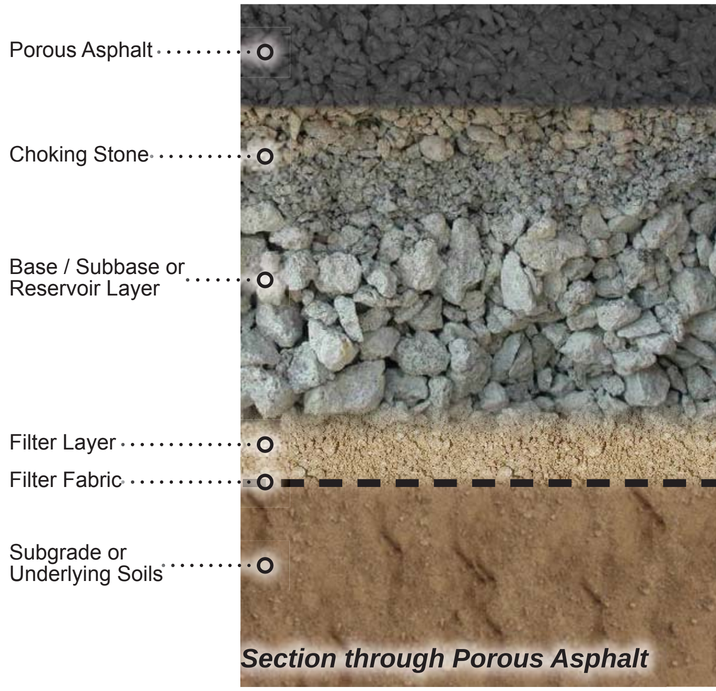
Underdrain: A perforated underdrain system with clean outs should be used for soils with infiltration rates less than 0.5"/hr. Underdrains are typically used when there is a desire to tie into existing stormwater conveyance networks. Perforated PVC pipes are used for underdrains and placed at the subbase layer. A 4-6" perforated or slotted PVC pipe (Schedule 40). A filter fabric "sock" over the underdrain is optional per the design engineer.

Overflow: Stormwater conveyance inlets can be raised above the pavement surface to allow minimal ponding before high flows bypass the permeable pavement system during major storms.

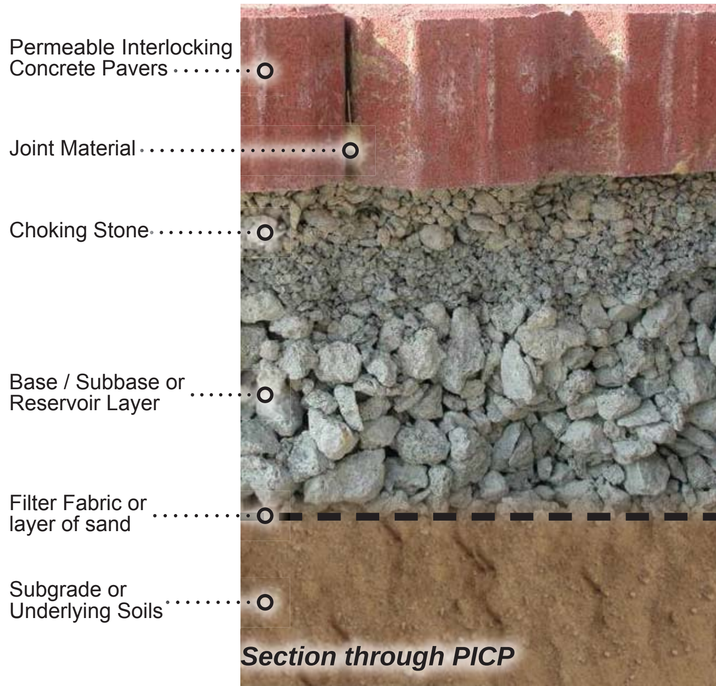
Subbase: The subbase of these systems has the potential to provide enough water storage to reduce stormwater quantity and significantly reduce the peak flow of larger storm events when the subbase is level. This is the layer that the underdrain is placed within. An aggregate base must be used for most permeable pavements types. Aggregates used should be washed, bank-run gravel, 1 - 2.5" diameter, with a void space of approximately 40%. Alabama Department of Transportation (ALDOT) #3 stone and #57 stone are acceptable. Crush and run should not be used for the pavement base due to the tendency of



Section through Pervious Concrete



Section through Porous Asphalt



Section through PICP

fine particles to clog the bottom of the pavement section. This material should have a porosity of approximately 0.32 or greater. Fine particles should not be present as they will clog the system.

Top Course/Choker Layer/Bedding Depth: This layer should be a fine gravel or layer of sand, ASTM C-33 concrete sand or ALDOT fine aggregate size #10 stone dust, to serve as a filter. Filter fabric is placed under the permeable pavement and above the gravel base, around this entire layer.

Interlocking Concrete Paver Infill: The infill is selected based on application and desired infiltration rate. Similar to the top course layer, ASTM C-33 concrete sand or ALDOT fine aggregate size #10 sand can be used when no vegetation is desired (infiltration rates of 8"/hr). If grass cover is desired, a sandy loam soil is recommended; however, the infiltration rate decreases to approximately 1"/hr.

Design Guidance

The following is a series of design steps based on current research, design, and installation. Consult manufacturers or other resources for additional design information.

1. **Determine Treatment Volume or Peak Flow**

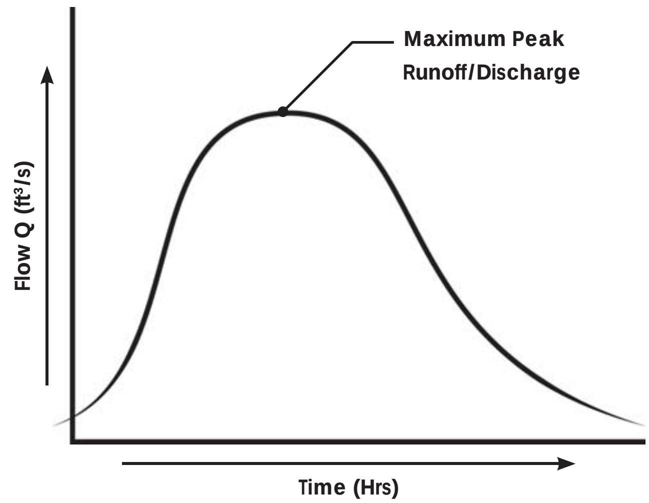
   The Rational Method, as shown in EQN 4.3.1, is used to calculate the peak flow, where the **estimated design discharge (Q)**, is equal to the product of **the Composite Runoff Coefficient (C)**, **Rainfall Intensity (i)**, and **watershed area (A)**. The **Rainfall Intensity (i)** is for a designated design storm for the particular geographic region of Alabama where the site is located.

   The **Composite Runoff Coefficient (C)** is based on the land use and surface for the total contributing watershed area. Increased impervious surface cover results in a higher coefficient. For a table of Rational Runoff Coefficients and a more detailed explanation of hydrological calculations, see Stormwater Hydrology in Appendix A.

2. **Calculate the Runoff Volume**

   To calculate a peak flow reduction, or a volume reduction of stormwater, many sources recommend assigning a "reduction in imperviousness" to the pavement or treating the pavement as a percentage of pervious surface. This percent of pervious surfaces assigned is dependent on the quantity of gravel base the system has and the type of pavement used. For Alabama, if the gravel base depth is greater than 6" of washed stone base, the system will assume a 60% credit for reduction in imperviousness. Systems with less than 6" of base will assume a 40% credit.

   These credit assumptions allow designers to



EQN 4.3.1

$$Q = CiA$$

C = Runoff coefficient (dimensionless) See Table A.2 in Appendix A on Stormwater Hydrology
i = Rainfall intensity (in/hr)
A = Watershed area (ac)

EQN 4.3.2

$$R_v = 0.05 + (0.9 * I_a)$$

R_v = Rational runoff coefficient (in/in)
I_a = Percent impervious / total drainage area

EQN 4.3.3

$$V = 3630 * R_d * R_v * A$$

R_d = Design rainfall depth (in)
R_v = Rational runoff coefficient (in/in)
A = Area (ac)
V = Peak runoff volume (ft^3)

EQN 4.3.4

$$S = \left(\frac{1000}{CN}\right) - 10$$

CN = Land use curve number
S = Maximum potential retention after rainfall begins

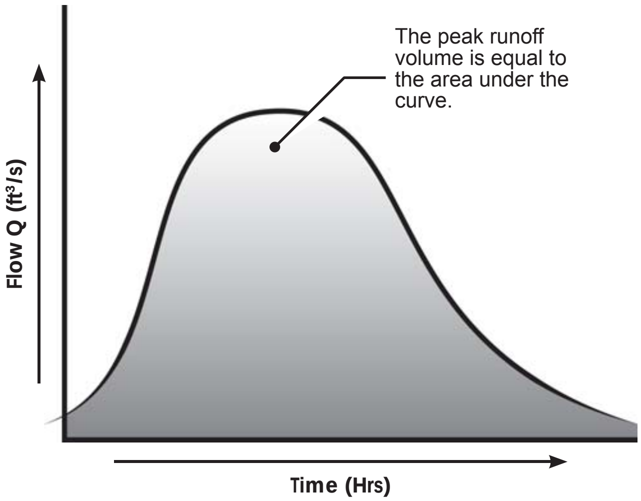
EQN 4.3.5

$$Q = \frac{(P - (0.2S))^2}{P + 0.8S}$$

S = Maximum potential retention after rainfall begins
P = Precipitation depth (in)
Q = Runoff depth (in)

EQN 4.3.6

$$Volume \_\_\_\_\_ \; ac - in*3630 = \_\_\_\_\_ ft^3$$



determine the peak runoff volume using either the Simple Method (EQN 4.3.2 and Y.3) or the Discrete Curve Number Method (EQNs 4.3.4 and Y.5)

The **runoff coefficient (R_v)** is calculated for the Simple Method, EQN 4.3.2.

I_a is the percent impervious (%) or impervious area divided by the total drainage area. The peak runoff volume is then calculated using EQN 4.3.3.

R_d is the design rainfall depth (in), R_v is the rational runoff coefficient (in/in), and A is area in acres.

To calculate the runoff volume using the Discrete Curve Number Method, a curve number of 61 is assigned for managed grass or the pervious credit and a curve number (CN) of 98 for impervious areas. EQNs 4.3.4 and Y.5 are used to calculate a **maximum potential retention after rainfall begins (S)** by using corresponding land use curve number (CN). Then use the **maximum potential retention after rainfall begins (S)** and **precipitation depth (P)** to calculate the **runoff depth (Q)**.

The **runoff depth, Q** (in) calculated for both the impervious and pervious drainage area fraction can be multiplied by their respective areas (ac) and summed for a total runoff volume, as shown in EQN 4.3.6.

Both the Rational Method (EQNs 4.3.2 and Y.3) and the Discrete Curve Number Method (EQN 4.3.4 and Y.5) can be applied using the weighted credits/ratios.

3. **Calculate the Depth of Subbase**

Calculating the depth of gravel base course (subbase/reservoir) is one of the more important aspects of permeable pavement design regardless of the type of permeable product selected. The gravel base course should have a minimum of 9" depth. This minimum depth does not include the top or choker course layers. The minimum storage requirement of the base layer should be the water quality volume. The **water quality volume (V)** can be calculated using EQNs 4.3.2 and Y.3. Once **V** is determined, the **surface area (SA)** and **porosity (n)** of the base layers can be used to calculate base depth. EQN 4.3.7 is used to compute the depth of base.

EQN 4.3.7

$$d = \frac{V}{SA} * n$$

V = Peak runoff volume (ft^3)
SA = Total surface area of pavement (ft^2)
n = Porosity of aggregate
d = Depth of base (ft)

The depth of base (d), is equal to the **water quality volume (V)**, as calculated using the Simple Method or the Discrete Curve Number Method, divided by the total **surface area (SA)** of the permeable pavement, and then multiplied by the **porosity of the aggregate used (n)**. The porosity value is the void space divided by the total volume of fill material. A value of **0.32** is recommended.

4. **Check Actual Storage**

Once the layers and materials are determined, EQN 4.3.8 can be used to determine the actual storage of the system. This is a check to ensure that the depth of storage needed for the water quality storm is met.

It is important to note, that the design presented above is not complete, but these steps will allow a designer to determine whether the design meets the standards to handle the peak flow in storing the water quality volume. While pavement capacity has been calculated, structural integrity needs to be determined.

EQN 4.3.8

$$\text{Act. Storage} = \sum \left(\text{Material (s)} * \frac{\text{\% porosity}}{100} \right) + \left(\text{thickness} * \frac{\text{joint space \%}}{100} * \frac{\text{porosity \%}}{100} \right)$$

Strike off and compression at Duck Samford Park; Auburn, Alabama. Photo Courtesy Michael Hein

Construction

Industry standards and manufacturer specifications should be consulted in the implementation of permeable pavement practices.

Compaction: Construction should be sequenced to avoid clogging and compaction that may inhibit functionality of permeable pavements. During construction, compaction of the underlying soil should be avoided.

Please review proper sediment control practices in the Alabama Handbook for Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas

(http://swcc.alabama.gov/pages/erosion_handbook.aspx).

Slope: The grade of the subgrade layer should not be less than 0.5% (slope) to maintain the storage capacity of the system. If slopes greater than 1% must be used for the subgrade, a series of perpendicular barriers or dams can be used to keep the subgrade from washing away.

Clogging: Once installed, care should be taken to avoid surface clogging of the pavement. If construction begins upslope, erosion and sediment control best management practices (BMPs) are imperative to reduce sediment entering the permeable pavement. Permeable pavements are not designed to treat concentrated flows or runoff from unstabilized areas. Newly developed residential areas are particularly at risk for sediment clogging due to the construction of new home sites and sequencing of these activities. Permeable pavement should never be taken advantage of as a temporary sediment control measure during construction.

Testing: Any testing should be done prior to installation to determine density, compressive strength, void content, and mixture consistency.

Retrofits: Permeable pavement can be incorporated into an initial site design or as a retrofit alternative to conventional pavement; however, retrofits can be expensive and are generally only suggested when resurfacing is necessary.

Pervious Concrete (PC) Construction

Moisture: The subgrade should be moist (without standing water) at PC placement in order to prevent moisture loss from the bottom of the concrete layer. PC is prone to drying during placement due to the amount of void spaces present.

PC Mixture: PC mix can be difficult to place due to its rigidity. An experienced concrete company or contractor is recommended to install permeable pavement, especially PC. The consistency of PC can be tricky, specifically the amount of water in the mix can be difficult to determine. The mix of fly ash, Portland cement, aggregates, and water makes mixing difficult and this can result in the desire to add water while mixing on site. However, when too much water is added, the mixture becomes too wet and pores are likely to become sealed. A dry mixture with too little water cannot bind together and may result in surface raveling later.

Admixtures: PC is difficult to work with due to the absence of sand in the mixture, thus creating necessary void spaces. This causes the mixture to dry out quickly on site and the timeframe to install it becomes slim. A chemical admixture regimen can aid in the mixing, handling, and overall performance of PC. These chemical admixtures include a hydration stabilizer, water reducing agent, and a viscosity-modifying agent to aid in placement of PC (See Table 4.3.2).

Ready Mix Truck: A ready mix truck with rear discharge and one chute is typically used for PC. The chute should be steep and angled down to facilitate PC removal from the truck. The mix may need to be manually removed from the chute using shovels or other tools. Using admixtures can alleviate some of the strain associated with mix removal from the truck because these additives increase workability and flow of the mix from the truck.

PC Placement: Once placement begins, it should be continuous and the surface should be struck off using a vibrating screed. Temporary boards can be added to the forms so that striking off can be 0.5 – 1" above the forms to compensate for compaction that will occur later. After striking off, PC should be consolidated or compacted to the top of the forms (temporary boards are removed) using a steel or weighted roller. The use of hydraulic roller screeds is common for PC installation. A hydraulic roller screed uses stainless steel tubes that rotate in the opposite direction the concrete was placed. It is recommended that consolidation take place within approximately 15 minutes after placement as PC can dry out quickly. Edge raveling is avoided by using a float or steel tamp that is approximately 1' x 1' to compact the edges. Having a sufficient construction crew in place is necessary so that one group can be placing and the other group striking off and consolidating.

Curing: PC should be misted following its placement and it should be covered using plastic sheeting for at least 7 days to cure. The curing process begins 20 minutes or less following compaction and jointing. Plastic sheeting may be held down using lumber, stakes, or rebar. When not cured properly, PC can be prone to surface deterioration and excessive raveling.

Striping: Once cured, striping of PC can be completed. Striping paint does not appear to reduce infiltration or seal pores.

Control Joints: Although cracking of PC is unlikely, control joints can be spaced a minimum of 20' apart to combat concrete shrinking, which may lead to surface cracking.

Cutting Joints: A rolling joint tool or "pizza cutter" should be used soon after PC is placed. Cutting joints with a saw is not recommended because the slurry created from cutting can clog void spaces and saw cut joints generally suffer from surface raveling.

Table 4.3.2

Chemical Admixture Type	Purpose
Polycarboxylate-based Mid-range Water Reducer	Minimizes the need to add water on site, decreases the amount of water needed for the mixture, thus increasing and maximizing the compressive strength of the coarse mixture
Hydration Stabilizer	Extends time frame of plasticity by slowing the rate of hydration in the mixture
Viscosity-modifying	Lubricates the mixture to aid in discharge from the truck and placement

Bury et al., 2006

Maintenance

Several preventative maintenance steps such as proper maintenance access, site selection, and mixture consistency of PC can be taken to circumvent future maintenance obstacles. Any eroded areas or soil wash out should be immediately stabilized.

Clogging: Over time, some level of clogging is expected to occur from sediments and other materials deposited from vehicles, wind, runoff, and surface deterioration. Regularly performed maintenance activities can preserve infiltration rates. Clogged surfaces are easily noted by pouring a gallon of water on the pavement surface. Clogging does not always result in sealed pores. Clogged (not sealed) permeable pavement has been shown to still exhibit infiltration rates exceeding 1”/hr. Underlying soils have been shown to influence surface infiltration rates of clogged permeable pavements.

Clogged PC or PA: When PC or PA fails due to improper mixture consistency or extreme clogging, 0.5” diamiter holes can be drilled every few feet to facilitate infiltration; however, holes too close together can damage structural integrity of the pavement.

Clogged PICP: If PICPs become severely clogged, joint material replacement is necessary to restore infiltration. A vacuum street sweeper can be used to remove joint material to a depth of 4”. Be sure to vacuum a test section to verify that only joint material or aggregate is being removed rather than the gravel base layer.

Maintenance Access: A 20’ wide maintenance access road or right of way should be provided for maintenance of permeable pavement. The access road should be stable, strong enough to hold heavy vehicles such as a street sweeper, and have a minimum drive path of 12’.

Raveling: Slight raveling of surface particles of PC is expected during the first few weeks following installation, but any additional raveling can be problematic for infiltration. As surface particles are loosened, void spaces may be filled with these particles leading to decreased infiltration rates.

Mechanical Street Sweepers: Mechanical street sweepers are the most common and use multiple brushes to loosen particles that are lifted onto a conveyor for temporary storage.

Regenerative Air Street Sweepers: Regenerative air street sweepers are the second most common and are used to remove surface particles through air that is blown onto the surface of the pavement, thus creating a vacuum between the bottom of the truck and pavement surface.

Vacuum Street Sweepers: Vacuum street sweepers are the most expensive street sweeper, and therefore, less common. Vacuum street sweepers have a strong vacuum system that can remove particles from above and below the paver surface.

Preventative Street Sweeping: Preventative street sweeping should be performed at least annually, but quarterly

Table 4.3.3
Maintenance Schedule

Task	How Often	Comments
Street Sweeping	Quarterly	Street sweeping will remove surface debris that can potentially clog the permeable pavement surface. Quarterly street sweeping is suggested, but increased frequency is recommended.
Inspection for Surface Deterioration	Quarterly	Inspections should be made once a quarter or following a 0.5” or greater rain event.
Inspect for Sediment	Monthly	Confirm that permeable pavement surface is free of sediment and debris.
Weed Removal	When they appear	Weeds should be eradicated using glyphosate. Hand pulling can disturb joint material in PICPs.
Mowing of Adjacent Land Areas	When needed	Clippings should be collected and removed from the site.
Stabilize Surrounding Land	When needed	Surrounding land should always be stabile to minimize sediment entry into the permeable pavement.

is better. Preventing clogging through street sweeping will eliminate the need for more stringent, restorative measures. Preventative street sweeping for PICPs, PC, and PA is generally done using a regenerative air street sweeper.

Restorative Street Sweeping: A mechanical street sweeper has shown to be effective for restorative cleaning of concrete grid pavers filled with sand. Restorative cleaning of PC, PICPs, and PA should be done using a vacuum street sweeper.

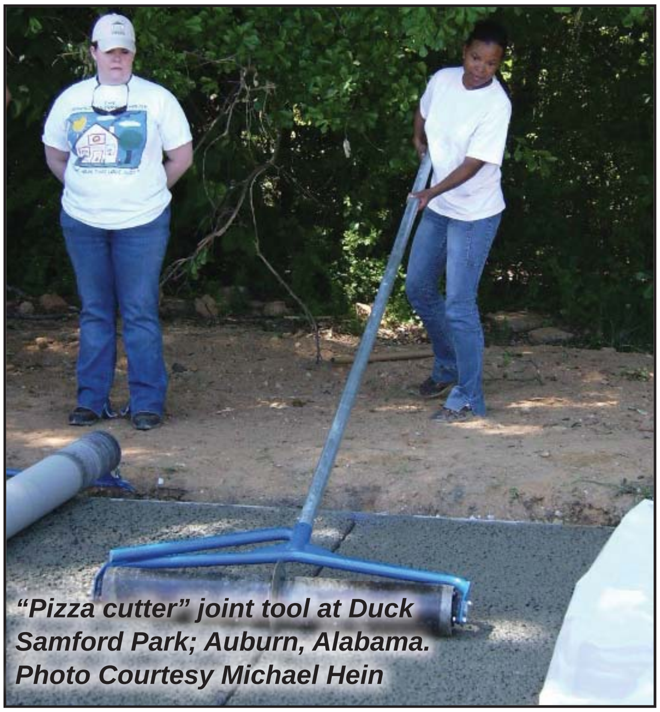
Pressure Washing: Pressure washing using a narrow, cone shaped nozzle is recommended for PC, and a wide spray nozzle is recommended for PICPs. In some cases, pressure washing has restored 80 – 90% of permeability.

Power Blowing: Power blowing is helpful to remove surface debris such as leaves or other plant material that may have collected on the pavement surface.

Combined Forms of Maintenance: Pressure washing and vacuum sweeping are frequently performed together for PC maintenance. These regenerative cleaning methods can restore infiltration capacity by 200%. Combined pressure washing and power blowing has shown a 200-fold increase in infiltration rates on PC.

Surface Raveling; Auburn, Alabama

Placing plastic sheeting over pervious concrete at Duck Samford Park; Auburn, Alabama. Photo Courtesy Michael Hein



"Pizza cutter" joint tool at Duck Samford Park; Auburn, Alabama. Photo Courtesy Michael Hein

Weeds in PICP; Orange Beach, Alabama

Mixture Consistency (Left to Right): A dry mixture, an ideal mixture, and a wet mixture.
Source: Tennis, Paul, D.; Leming, Michael, L.; and Akers, David, J., Pervious Concrete Pavements, EB302.02, Portland Cement Association, Skokie, Illinois, and National Ready Mixed Concrete Association, Silver Spring, Maryland, USA, 2004, 36 pages

Nuisance Species: Permeable pavements utilizing vegetation and PICPs will require removal of unwanted plants or weeds. Weed eradication should be done using glyphosate or other systemic herbicide, followed by actual removal of weeds one week later. Pulling weeds by hand without the use of herbicide can result in dislodging or disturbance of joint material or sand. When PRGs are used with turfgrass, mowed clippings should be bagged and disposed of off site.

Maintenance Agreements: Maintenance agreements should be in place prior to installation of any type of permeable pavement. Equipment availability, labor, and the responsible party should be outlined. Specific maintenance activities and frequency should be outlined in a maintenance schedule. Site inspections and record keeping are important to document the functionality of permeable pavements. All data sheets should be kept in one location for reporting purposes. For more information, see Appendix C on Maintenance.

Pollutant Removal

Table 4.3.4
Pollutant Removal Table

Sediment	Nutrients		Metals	Pathogens
	N	P		
a. No Data	No Data	No Data	No Data	No Data
b. - -	80%	80%	90%	- -
c. - -	65%	50%	60%	- -
d. - -	80%	80%	90%	- -
e. - -	80%	80%	90%	Insufficient Data
f. 99%	No Data	42%	97%*	No Data

Sources:
a. North Carolina Department of Environment and Natural Resources, 2007
b. City of Auburn, 2011
c. Georgia Manual, 2001 - Pervious Concrete
d. Georgia Manual, 2001 - Modular Paving Systems
e. Knox County, 2008
f. Roseen and Ballestero, 2008 - Porous Asphalt

Unlike other structural low impact development (LID) stormwater control measures (SCMs), permeable pavement does not rely on the use of vegetation for pollutant removal; any pollutant removal that occurs is due to the volume reduction of surface stormwater runoff. As a result, soluble and particulate pollutants are often removed by these systems through deposition, absorption, and filtration in underlying soil layers. Research has shown permeable pavements to decrease concentrations of heavy metals, motor oil, sediments, and nutrients in stormwater runoff from a site.

Quantity Reduction: Due to high surface infiltration rates, permeable pavements reduce both water quantity and peak discharges. Any surface runoff from permeable pavement should only occur during high intensity storms when the pavement cannot infiltrate stormwater quickly enough to capture it completely. A North Carolina study examined surface infiltration rates and found that most permeable pavements exhibited infiltration rates greater than 2”/hr. Under these conditions, in order for surface runoff to occur a storm would need to have an intensity exceeding 2”/hr.

Total Suspended Solids (TSS): TSS reductions were not quantified because it is not recommended that these systems trap sediment due to their propensity to clog.

Sediment Bound Pollutants: Both phosphorus and metals are known to be bound to sediments and will naturally accumulate on the pavement surface. Metals are captured in the top 1 – 2” of the pavement void space, and standard street sweeping should remove most heavy metals when the void space consists of sand. Removal of sediment particles from the surface of permeable pavement improves functionality, infiltration, and can also enhance pollutant removal. In an Auburn University study, surface runoff from impervious areas was found to have five times the amount of TSS compared to the leachate from a PC parking lot on campus, indicating the removal or filtration of sediment particles.

CGPs: Additionally, permeable pavements that employ the use of sand as a filter, for example CGPs, have been shown to exhibit higher overall total nitrogen reductions.

Underlying Soils: Underlying soils can affect pollutant removal efficiency of permeable pavements. In general, sandy soils boast higher infiltration rates but offer less treatment of stormwater pollutants. In contrast, clay soils show decreased infiltration, but their higher cation exchange capacity can aid in pollutant capture. Additionally, bacteria that assist in the treatment process are present not only in the underlying soils, but have also shown growth in gravel base layers.

Temperature: Although not quantified, water temperature reductions are assumed because runoff is immediately infiltrated into the pavement surface rather than remaining on the surface where it would be heated by the sun before being discharged into a stormwater conveyance network. Moreover, stormwater stored in the gravel layer subbase or reservoir is held before being released into the surrounding soil, or underdrain system, allowing water to cool before discharged.

References

Alabama Soil and Water Conservation Committee. 2009. Alabama Handbook for Erosion Control, Sediment Control, and Stormwater Management on Construction Sites and Urban Areas. Montgomery, AL.

Bean, E. Z., W. F. Hunt, and D. A. Bidelspach. 2007. Field Survey of Permeable Pavement Surface Infiltration Rates. Journal of Irrigation and Drainage Engineering. 133(3): 247-255.

Brattebo, B.O. and D.B. Booth. 2003. Long-term Stormwater Quantity and Quality Performance of Permeable Pavement Systems. Water Research 37:4369-4376.

Bury, M. A., C.A. Mawby, and D. Fisher. 2006. Making Pervious Concrete Placement Easy Using a Novel Admixture System. Concrete in Focus, Fall 2006.

City of Auburn Stormwater Management Design Manual. 2011.

Dougherty, M., M. Hein, C. Lebleu. 2011a. Evaluation of Stormwater Quality Through Pervious Concrete Pavement. American Society of Agricultural and Biological Engineers Annual Meeting Proceedings.

Dougherty, M., M. Hein, B. Martina, and B. Ferguson 2011b. Quick Surface Infiltration Test to Assess Maintenance Needs on Small Pervious Concrete Sites. Journal or Irrigation and Drainage Engineering, ASCE: 1-13.

Georgia Stormwater Management Manual. 2001.

Gunderson, J. 2008. Pervious Pavements: New Findings About Their Functionality and Performance in Cold Climates. Stormwater.

Hunt, W. F. 2011. Maintaining Permeable Pavements. North Carolina Cooperative Extension. AG-588-23W.

Hunt, W.F. and K. A. Collins. 2008. Permeable Pavement: Research Update and Design Implications. North Carolina Cooperative Extension. AG-588-14.

Interlocking Concrete Pavement Institute (ICPI). 2008. Permeable Interlocking Concrete Pavement: A Comparison Guide to Porous Asphalt and Pervious Concrete. Interlocking Concrete Pavement Institute, Herndon, VA.

Interlocking Concrete Pavement Institute (ICPI). 1995. Section 23 14 13: Interlocking Concrete Pavers. Interlocking Concrete Pavement Institute, Herndon, VA.

Kevern, J., K. Wang, M.T. Suleiman, and V.R. Schaefer. 2006. Pervious Concrete Construction: Methods and Quality Control. National Ready Mix Concrete Association Concrete Technology Forum, Nashville, TN.

Knox County Tennessee Stormwater Management Manual. 2008. Knox County, TN.

LeFevre, J. 2007. Pervious concrete is popular concrete. Concrete InFocus 6(2): 45-48.

Mississippi Concrete Industries Association (MCIA). 2002. Pervious Concrete: The Pavement that Drinks. Ridgeland, MS.

North Carolina Department of the Environment and Natural Resources. 2007. Stormwater Best Management Practices Manual, Ch 18: Permeable Pavement (Revised 2010). North Carolina Division of Water Quality, Raleigh, NC.

Roseen, R.M. and T.P. Ballestero. 2008. Porous Asphalt Pavements for Stormwater Management in Cold Climates. Hot Mix Asphalt Technology, May/June, 2008.

Smith, D. R., K. A. Collins, and W. F. Hunt. 2006. North Carolina University Evaluates Permeable Pavements. Interlocking Concrete Pavement Magazine.

Stormwater Center (SWC). Stormwater Management Fact Sheet: Porous Pavement. Accessed November 2, 2011. http://www.stormwatercenter.net/Assorted%20Fact%20Sheets/Tool6_Stormwater_Practices/Infiltration%20Practice/Porous%20Pavement.htm.

Tennis, P. D., M. L. Leming, and D. J. Akers. 2004. Pervious Concrete Pavements. Portland Cement Association, Skokie, IL, and National Ready Mixed Concrete Association, Silver Spring, MD.

University of New Hampshire Stormwater Center. 2010. 2009 Biannual Report.

USEPA. 2009. Porous Asphalt Pavement. NPDES Fact Sheet.

USEPA. 1999. Porous Pavement. Stormwater Technology Fact Sheet. Office of Water, Washington, D.C.

USEPA. 2010. Surface Infiltration Rates of Permeable Surfaces: Six Month Update (November 2009 through April 2010). Office of Research and Development, National Risk Management Research Laboratory – Water Supply and Water Resources Division, Edison, NJ.

Grassed Swales (GS), Infiltration Swales (IS), and Wet Swales (WS)

Site Selection

Quantity Control	---
Drainage Area	small
Space Required	small

Works with:

Steep Slopes	✔
Shallow Water Table	✔
Poorly Drained Soils	✔

General Significance

Construction Cost	low
Maintenance	low
Community Acceptance	high
Habitat	low
Sun / Shade	either

Synonyms: Vegetated swale, bioswale, wetland channel, dry swale, wet swale, conveyance channel, reinforced swale, grassy swales, biofilter

A water quality swale is a shallow, open-channel stabilized with grass or other herbaceous vegetation designed to filter pollutants and convey stormwater. Swales are applicable along roadsides, in parking lots, residential subdivisions, commercial developments, and are well suited to single-family residential and campus-type developments. Water quality swales presented in this handbook are designed to meet velocity targets for the water quality design storm, may be characterized as wet or dry swales, may contain amended soils to infiltrate stormwater runoff, and are generally planted with turfgrass or other herbaceous vegetation.

Site Selection

Swales can reduce infrastructure costs by eliminating the need for curb and gutter and traditional stormwater piping. Swales are applicable along roadsides, in parking lots, residential subdivisions, or commercial developments, and are well suited to single-family residential and campus-type development. Any type of swale design can be paired with other structural Low Impact Development (LID) stormwater control measures (SCMs) to increase pollutant load reductions and to capture excess stormwater leaving the swale. Swales are typically paired with level spreaders, filter strips, bioretention cells, constructed stormwater wetlands, or permeable pavement to meet treatment needs. However, swales are also used as a stand-alone practice in many applications and work well as retrofits.

Drainage Area: Swales are designed as conveyance channels that capture and treat stormwater runoff in smaller drainage areas. Swales are recommended for drainage areas of 5 acres or less and should capture runoff from approximately 10-20% of the contributing impervious surface area.

Evaluating Soils: Use the USDA Web Soil Survey to identify soil map units and to make initial interpretations for potential uses and limitations of a site. However, since most soil map units have inclusions of other soils that may be quite different, detailed evaluations should be made at the proposed site by a professional soil scientist or soil classifier. On-site evaluations should properly identify a soil or the hydrologic soil group (HSG) and the final decision for use should be made based on the detailed determination of soil series or HSG. For a detailed list of HSG properties, see Table A.3 in Appendix A on Stormwater Hydrology.

In-Situ Soil: The topography and in-situ soil characteristics, particularly the soil texture and hydrologic soil group (HSG), will determine the applicability of a wet or dry swale design. An infiltration test should be performed to determine

Table 4.4.1

Site Selection: Constraints & Limitations for Swales

Slope	Locations with less than 5% slopes where possible
Utilities	Call Alabama 811 before construction to locate utilities (for more information, visit: www.al1call.com)
Limited Volume Control	If storage volume is a primary objective - may need to use another SCM
High Sediment Loads	Swale location should not experience high sediment loads that may clog system; when sediment is introduced there is a risk of possible sediment re-suspension
Continuous Flow	Locations that will not experience continuous flow and are allowed to drain are recommended for dry swales
Not Regional Stormwater Control	If regional stormwater control is desired, use another SCM
Lower Pollutant Removal Rates	An infiltration swale is recommended for highest pollutant removal; increase media/fill material depth for temperature reductions
Undersized Swale, Site Size Constrained	If the site will not support swale size required for design storm treatment, use another SCM or use in conjunction with another SCM, an undersized swale will not adequately reduce total suspended solids

infiltration rates (for more information on an infiltration test, see Chapter 5.1 on Rain Gardens). Dry swales (grassed swales and infiltration swales) are appropriate for HSG A and B that are well-drained to moderately well-drained, respectively (see Table A.3 in Appendix A on Stormwater Hydrology for more information on HSG properties). A dry swale should have an infiltration rate greater than 0/5"/hr and may require that soils be amended to achieve the desired infiltration rate. Infiltration swales may require that soils be amended to achieve desired infiltration rates. Wet swales are conducive to HSG C or in areas where the water table is close to the soil surface.

USDA's online Web Soil Survey (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm) can be used as a guide to determine the needed soil information for the site, such as the hydrologic soil group (HSG) and depth to water table.

Depth to Groundwater: The seasonally high water table should be a minimum of 1' below the bottom of any type of swale and the swale should never intercept groundwater. However, if an aquifer or "hotspot" is present, there should be a minimum of 2' between the bottom of the channel and the seasonally high water table. Hotspots are defined as commercial, industrial, or other operations that produce higher levels of stormwater pollutants and/or have concentrated pollutants.

Slope: Swales should be sited so that they have a mild entrance slope to avoid high velocity flows, and channel dimensions that allow for non-erosive velocities (less than 4' per second or fps). The longitudinal slope should not exceed 5% where possible. Longitudinal slope is important to create conveyance, but should not increase the velocity of the system greater than 1 fps for a 10 - year design storm.

Flow Regime: The designer should evaluate grade transitions to consider the flow regime and range of discharges up to the design flow rate. Hydraulic jumps caused by changes in flow regime should be avoided due to potential erosion and scouring that may occur at locations of undulating flow. Grading to ensure a uniform slope and surface will minimize erosion, sediment re-suspension, and additional maintenance.

Turf Reinforced Matting: Velocities greater than 4 fps may result in eroded grassed swales, and a turf reinforced matting (TRM) under the sod can be used to hold turfgrass in place during high flows.

Common Swale Design Variations

Dry Swales: Dry swales consist of grassed swales and infiltration swales. Dry swales are designed to convey or infiltrate only the "first flush" (water quality volume) or to handle the peak flow volume. See Appendix A on Stormwater Hydrology for more information on first flush. Dry swales may have underdrains that convey stormwater into an outlet, use an overflow device, or a combination of these. Dry swales are designed to have standing water for a maximum of 48 hours, however, 24 hours is preferred. Depending on the type of dry swale, these designs may have shallow,

Table 4.4.2
Types of Swales

Swale Type	Soil/Media	Comments
Grassed Swale	Well-drained in-situ soil or a 50/50 sand/soil mix	Dry swale planted with turfgrass sod
Infiltration Swale	50/50 sand/soil mix or bioretention media mix	Dry swale planted with flood and drought tolerant vegetation; when a bioretention media is used, a layer of gravel is typically placed below the media and an underdrain may be utilized
Wet Swale	Native poorly drained soils	Wetland vegetation

open-channels over a fill material of well-drained in-situ soils, a 50/50 sand/soil mix, or a bioretention media mix.

Grassed Swales: Grassed Swales are dry swales planted with turfgrass and are often used along roadsides where mowing is the primary form of maintenance. Grassed swales are typically used for conveyance, but when placed over well-drained soils (or amended soils), these may provide infiltration of runoff and water quality improvement. In-situ soil can be amended with a 50/50 sand/soil mix to enhance infiltration.

Infiltration Swales: Infiltration swales typically have at least 30" of amended soil (50/50 sand/soil mix or bioretention media mix) beneath the bottom of the swale to aid in infiltrating runoff. See Chapter 4.1 on Bioretention for more information on the recommended media recipe for targeted pollutant removal. Infiltration swales that use a bioretention media mix typically have a layer of gravel beneath the media and an underdrain may or may not be utilized. Infiltration Swales are dry swales that are planted with native grasses, herbaceous perennials, and small shrubs. Infiltration swales are easily integrated into the landscape and can be attractive and aesthetically pleasing in residential and commercial developments, parking lot islands, and medians. Small woody shrubs can be planted in swale channels when their mature height and width does not exceed landscape requirements of the site.

Wet Swales: A wet swale design consists of a shallow, open channel that is placed over poorly drained soils or in areas with a high water table. Amended soil media is not necessary for wet swales. Wet swales are retention structures that are designed to handle the peak flow event and retain all or a portion of the water quality volume. By retaining stormwater, wet swales use increased residence time to provide water quality benefits. They are planted with wetland plants to facilitate pollutant removal.

Pretreament Swales: When used as pretreatment for other SCMs, the swale should be at least 20' in length.

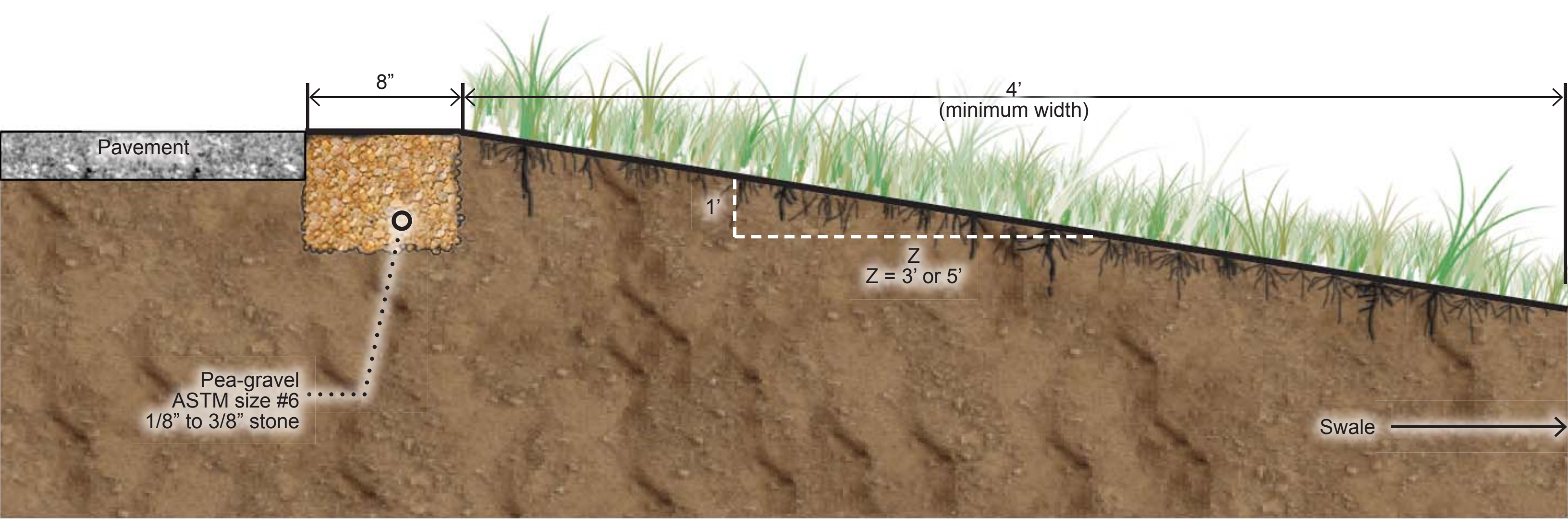
Design

All swale designs consist of three primary components: pretreatment, swale, and overflow. The size of each of these components is based on the volume or design storm to be treated. Swale location should be based on site topography to allow for the integration of natural drainage patterns within the swale drainage way.

Components

Pretreatment: A forebay, grassed filter strip, or grassed inlet is used as a pretreatment device for swales.

Forebay: The forebay is a pool located at the inlet of a system. It is deepest at the point of runoff entry and shallowest at the exit point. This design dissipates energy throughout the forebay and provides diffuse flow into the swale. A forebay



is recommended when there is a single, concentrated flow entering the swale. It serves as a sediment sink for runoff entering the system to prevent clogging of the swale channel and subsequent damage to vegetation.

The forebay should be 18 - 30” deep and is designed to be 0.2% of the watershed drainage area. If standing water is a concern, a grassed filter strip may be used as a pretreatment device. Wet swales typically have a forebay for pretreatment and stormwater is released into the wet channel.

Grassed Filter Strip: A minimum width of 3’ of a grassed filter strip is recommended for the entire length of the swale. See Chapter 4.5 on Level Spreaders and Grassed Filter Strips for more information.

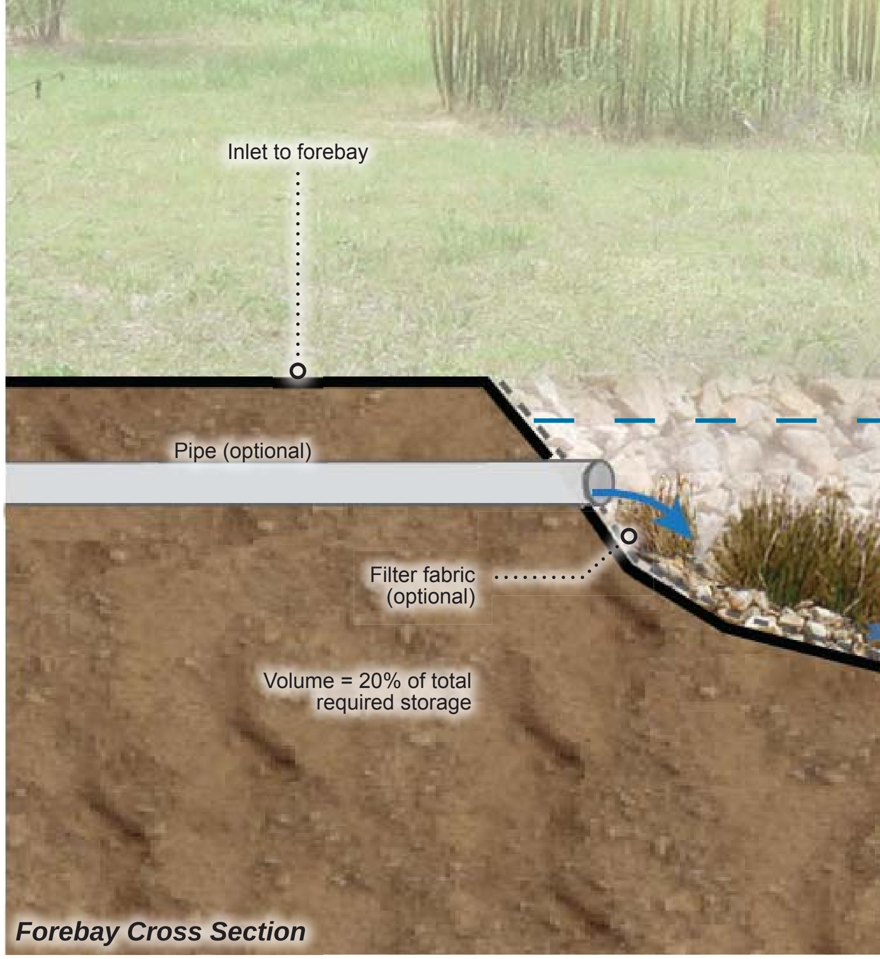
Grassed Inlet: A grassed inlet uses the side slopes of the swale as pretreatment. Grassed inlets are planted with dense turfgrass and have a gentle slope (3:1 or greater, 5:1 is recommended) to prevent erosion. A grassed inlet allows water to enter the system from all sides of the swale, which slows stormwater velocity, and serves as a sediment trap for larger particles.

Swale: The swale is designed to be triangular or trapezoidal in shape, with a minimum of 3:1 side slopes (5:1 is recommended), and a length that does not exceed 100’. Whether the swale is designed to be wet or dry, it is ultimately designed as an infiltration, filtration, and conveyance structure.

Additional Components

Underdrain: Infiltration swales may include the use of underdrains to drain the swale within 48 hours and minimize standing water conditions. Underdrains are corrugated or smooth wall perforated pipe and should be configured to tie in with the overflow or discharge into the stormwater conveyance network. Underdrains are not used in wet swale designs.

Curb Cuts: Curb cuts can be used to direct flows into the swale and are easy retrofits to traditional curb and gutter. Curb cuts do not treat stormwater runoff, but can function as the inlet to a swale system while minimizing erosion (for more information, see Chapter 5.2 on Curb Cuts).



Forebay Cross Section

EQN 4.4.1

$$T_c = \frac{\left(\frac{L^3}{H}\right)^{0.385}}{128}$$

L = Longest length of water path in drainage area (ft)
H = Change in Elevation throughout drainage area or watershed (ft)
T_c = Time of Concentration (minutes)

EQN 4.4.2

$$Q_p = CiA$$

C = Rational coefficient (dimensionless)
See Table A.2 in Stormwater Hydrology Appendix A
i = Rainfall intensity (in/hr)
A = Watershed area (ac)
Q_p = Peak flow (ft^3/s)

Overflow Structure: Overflow structures should be designed to safely pass runoff from rainfall events greater than the peak flow event.

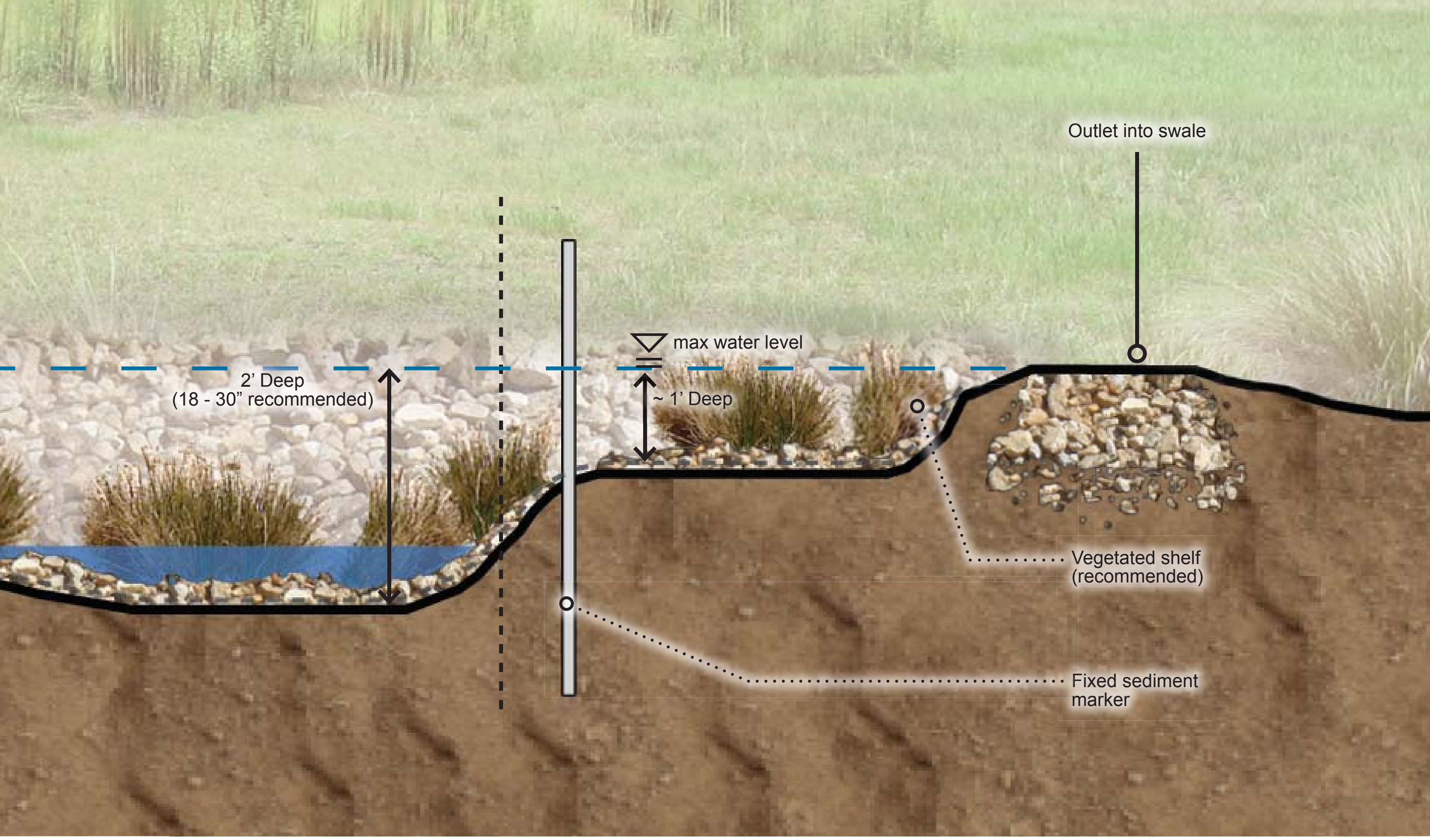
Design Guidance

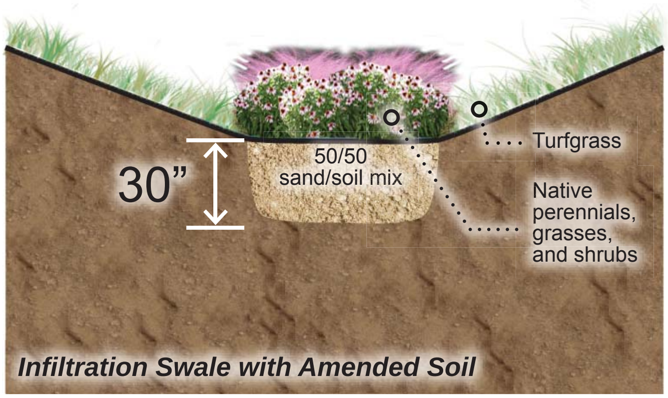
Information should be collected for watershed size, soil texture, HSG, slope, and depth to water table. The design layout or swale location is specific to the site. When determining the best location for the swale, site constraints, retrofit opportunities, aesthetics, and maintenance should be considered. Swales may be designed to be trapezoidal or triangular, see Design Guidance for more information.

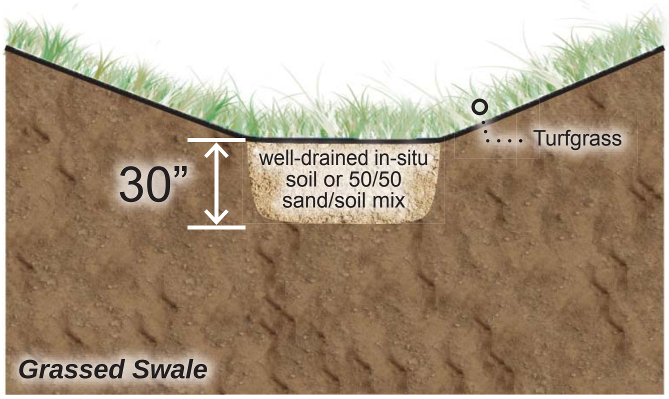
1. **Determine Treatment Volume or Peak Flow**

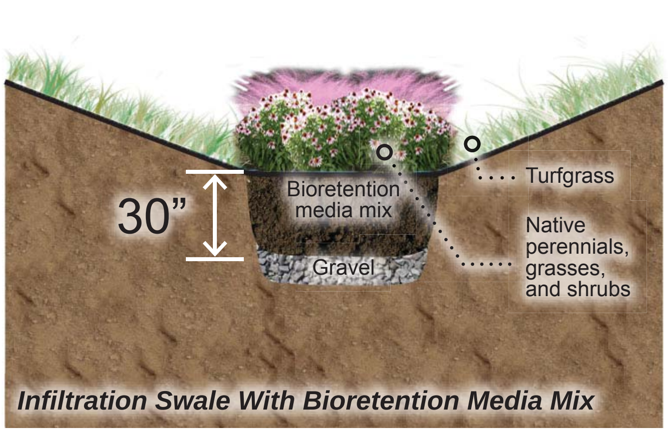
   Swales are designed to treat the first flush volume and control peak flow. The peak flow event is runoff from the primary design storm and is used because it is often the greater of the two.

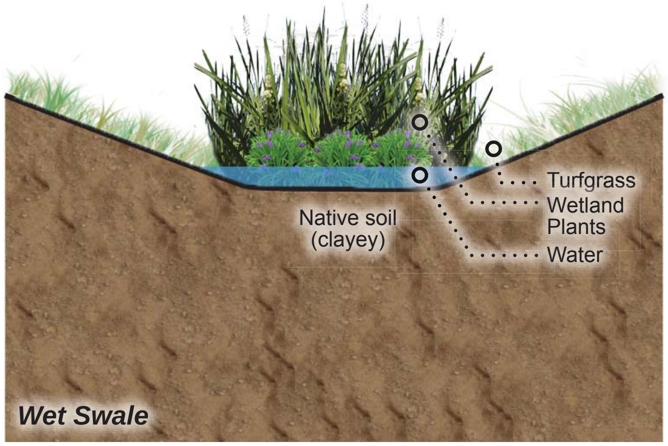
   The Kirpich Equation and Rational Method are used to determine peak flow and swale geometry is calculated to provide sizing recommendations and determine flow equations. The Kirpich Equation shown in EQN 4.4.1,


Outlet into swale
max water level
2' Deep
(18 - 30" recommended)
~ 1' Deep
Vegetated shelf
(recommended)
Fixed sediment
marker


30"
50/50
sand/soil mix
Turfgrass
Native
perennials,
grasses,
and shrubs
Infiltration Swale with Amended Soil


30"
well-drained in-situ
soil or 50/50
sand/soil mix
Turfgrass
Grassed Swale


30"
Bioretention
media mix
Gravel
Turfgrass
Native
perennials,
grasses,
and shrubs
Infiltration Swale With Bioretention Media Mix


Native soil
(clayey)
Turfgrass
Wetland
Plants
Water
Wet Swale

uses the **Longest Length in the Watershed (L)** and the **Change in Elevation (H)** to calculate the **Time of Concentration (T_c)**.

Intensity (i) is derived using the **Time of Concentration** and a selected design storm. **Peak Flow (Q_p)** is calculated using the Rational Method, EQN 4.4.2.

EQN 4.4.3

$$Q_p = \left(\frac{1.486}{n}\right) * A * R^{0.667} * S^{0.5}$$

n = Manning's n (dimensionless) – *see in Stormwater Hydrology Appendix A.*
A = Swale channel cross sectional area (ft^2), based on swale geometry
R= Hydraulic radius (ft)
S = Swale channel slope (ft/ft)

2. **Determine Swale Geometry**

Calculating swale geometry may require several design iterations using Manning's Equation, EQN 4.4.3. It should first be determined whether the swale will be trapezoidal or triangular; if vegetation other than turfgrass is to be used, a trapezoidal channel is recommended.

Swale geometry affects the **Swale Channel Cross Sectional Area (A)**, therefore affecting the **Hydraulic Radius (R)**; both of which are used to calculate the **Swale Depth (D)**. Next, the **steepness of the side slope (S)** should be specified. A 5:1 slope is recommended when side slopes are used to optimize pollutant removal as pretreatment filter strips or when mowing is used to maintain vegetation. Side slopes, which are not the same as swale channel slope, are also used in the calculation of swale channel geometry.

Depth (D) is determined using Peak Flow (Q_p) calculated from EQN 4.4.2. in Manning's Equation, EQN 4.4.3.

Triangular Channels: A modified Manning's Equation for a triangular channel with 3:1 and 5:1 side slopes is shown in EQNs 4.4.4 and Y.5.

Trapezoidal Channels: Once **D** is calculated, side slopes and channel geometry can be altered to calculate the swale width. This iterative process is especially useful when a fixed dimension is necessary.

3. **Check Channel Velocity**

The Continuity Equation, EQN 4.4.6, can be used to validate the velocity within the swale and determine if there is a need for turf reinforced matting (TRM) or additional vegetation to prevent erosion and scour within the swale channel. If velocity exceeds 4 fps, TRM is necessary.

4. **Determine Number and Size of Underdrains**

To calculate the number and size of underdrains, EQNs 4.4.9 – Y.12 found in Chapter 4.1 on Bioretention can be used.

Swale Geometry

(illustrations are exaggerated)

for triangular swale geometry:

$$Area,\ A = 0.5(b*h)$$

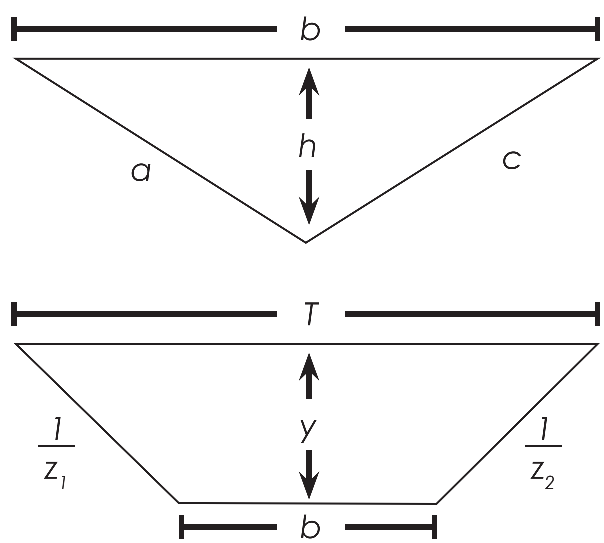
$$Wetted\ Perimiter,\ P = a + b + c$$

for trapezoidal swale geometry:

$$Top\ Width,\ T = b + y(z_1+z_2)$$

$$A = \frac{y}{2}(b + T)$$

$$P = b + y\left(\sqrt{1 + z_1^2} + \sqrt{1 + z_2^2}\right)$$



Note: typically $z_1 = z_2$

EQN 4.4.4 *for 3:1 side slopes*

$$Q_p = \left(\frac{2.71}{n}\right) * D^{2.67} * S^{0.50}$$

-or-

$$D = \left(\frac{Q_p * n}{2.71 * S^{0.5}}\right)^{\frac{1}{2.67}}$$

EQN 4.4.5 *for 5:1 side slopes*

$$Q_p = \left(\frac{4.62}{n}\right) * D^{2.67} * S^{0.50}$$

n = Manning's n
D = Depth (ft)
S = Swale channel slope (ft/ft)
Q_p = Peak flow (ft^3/s)

EQN 4.4.6

$$Q = V * A$$

Q = Flow (ft^3/s)
V = Average velocity in channel (ft/s)
A = swale channel cross sectional area (ft^2), based on swale geometry

Design Example

A site in south central Alabama was chosen for an infiltration swale design. This site has a watershed area of **2.5 acres**, with a Kinston soil series, and HSG B. Most of the site is impervious with **2.0 acres in concrete and pavement. Only the impervious portion of the site is to be treated by the swale (2.0 acres)**.

1. Determine Peak Flow

The swale is designed for the peak flow event, using the Kirpich Equation.

EQN 4.4.1

$$T_c = \frac{\left(\frac{L^3}{H}\right)^{0.385}}{128}$$

The length (l), width (w), and longest length of water path in the drainage area (L) are 480', 180', and 512', respectively. The **Longest Length** of water path in the drainage area, **L is 512'** and **Change of Elevation, H, is 8'**.

Therefore the **Time of Concentration** is $T_c = \frac{\left(\frac{512^3}{8}\right)^{0.385}}{128} = \frac{605}{128} = 4.7\ min$

T_c is 4.7 minutes and will be rounded to the nearest whole number, 5 minutes.

The T_c is used to calculate rainfall **Intensity (i)** in the Rational Method. The design storm or rainfall intensity is determined using the 10 - year flow event and closest estimate of the T_c, 5 minutes. The lowest calculated T_c is 5 minutes so the **10 – year, 5 - minute Intensity (i) is used**. For more detail on how to determine storm intensity using Intensity-Duration-Frequency (IDF) curve refer to Appendix A on Stormwater Hydrology.

The Rational Method, EQN 2, is used to determine **Peak Flow (Q_p)** from the 10 - year, 5 - minute event.

EQN 4.4.2 $Q_p = CiA$

A **Rational Coefficient (C)** of **0.95 for parking lot runoff (impervious), Intensity (i) of 7.36 in/hr** (from appropriate IDF curve, determined using the 10 - year, 5 - minute event), and an **Area (A) of 2.0 acres** for the impervious surface is used for this equation.

$$Q_p = 0.95 * 7.36 in/hr * 2.0 ac$$

Converting the intensity, I, 7.36 in/hr to ft/s $7.36 in/hr \left| \frac{1 ft}{12 in} \right| = 0.613\ ft/hr \left| \frac{1 hr}{3600 s} \right| = 0.00017037\ ft/s$

Converting 2 acres into square feet $2ac \left| \frac{43560 ft^2}{1 ac} \right| = 87120 ft^2$ Therefore

The swale should be able to handle **peak flows of 14 cubic feet per second (cfs)**.

$$Q_p = 0.95 * 0.00017037 * 87120 = 14\ ft^3/s$$

Continued on next page

2. Determine Swale Geometry

A trapezoidal geometry for the swale is desired for maintenance. Calculating the geometry for a trapezoidal swale is often an iterative process; however, in some instances, site constraints limit the dimensions.

For this example, the **Swale Channel Bottom Width (b)**, needs to be a **minimum of 4'** to accommodate the desired herbaceous vegetation. A 5:1 side slope is desired; however, site constraints limit the side slopes to 3:1. These site constraints create limited swale geometry. Using the equations to calculate **Top Width (T), Area (A)**, and **wetted perimeter (P)**, the variables in the modified Manning's Equation, EQN 4.4.3 can be used to confirm $\mathbf{Q_p}$.

$$\textbf{EQN 4.4.3} \qquad Q_p = \left(\frac{1.486}{n}\right) * A * R^{0.667} * S^{0.5}$$

For the trapezoidal geometry: $T = b + y(z_1 + z_2)$, **where b is 4' and z is 3' and a depth of 1' is assumed.**

$$T = 4ft + 1ft(3ft+3ft) = 10\ ft$$

The **top width (T) of 10'** is then used to calculate cross sectional area. The following equation is used.

$A = \frac{y}{2}(b + T)$, where y is an assumed depth of 1', b is 4', and T is the calculated 10'.

$$A = \frac{1}{2}(4ft + 10ft) = 7\ ft^2$$

In order to calculate peak flow using EQN 4.4.3, **Hydraulic Radius (R)** must also be calculated. **Hydraulic Radius (R)** is defined as the **Cross Sectional Area (A)** divided by the **Wetted Perimeter (P)**.

$$R = \frac{A}{P}$$

Wetted Perimeter (P) is first determined. For a trapezoidal channel, **P** is calculated as:

$P = b + y\left(\sqrt{1 + z_1^2} + \sqrt{1 + z_2^2}\right)$, where b is 4', y is assumed to be 1', and $z_1 = z_2 = 3$.

$P = 4ft + 1ft\left(\sqrt{1 + 3ft^2} + \sqrt{1 + 3ft^2}\right) = 10.3ft$ Therefore, $R = \frac{7.0ft}{10.3ft} = 0.68ft$

From the channel geometry calculation, the trapezoidal channel variables of **Area (A) and Hydraulic Radius (R) are 7ft² and 0.68', respectively.**

Additionally, Manning's Equation requires a **Manning's n** and **Swale Channel Slope (S)**. Herbaceous vegetation has an estimated Manning's n value of **0.04** and the **Channel Slope** of the design example is 0.005 ft/ft.

Using EQN 4.4.3 and the calculated variables, peak flow is calculated as follows:

$$Q_p = \left(\frac{1.486}{0.04}\right) * 7 * 0.068^{0.667} * 0.005^{0.5}$$

$$Q_p = 14.2\ ft^3/s$$

The calculated Q_p using the Manning's Equation is compared to the Peak Flow (Q_p) determined by the Rational Method Equation. If the peak flow determined by the Manning's Equation is equal to or greater than the peak flow calculated in the Rational Method, the swale geometry is sufficient for peak flow. However, if peak flow calculated in the Manning's Equation is less, then the swale geometry is insufficient and swale dimensions need to be altered. In this example, due to site constraints, the only available dimension for alteration would be the swale depth.

3. Check Channel Velocity

The Continuity Equation (EQN 4.4.6) can be used to verify that the velocity in the swale channel does not exceed what the vegetation can sustain without resulting in erosion. $Q = VA$, where $\mathbf{Q_p}$ is used to determine the maximum velocity within the designed channel.

The peak flow for the designed system is $\mathbf{Q_p}$ determined using the Manning's Equation, **14.2 ft³/s**.

Continued on next page

Transposed to solve for the maximum velocity:

EQN 4.4.6 $$Q = V*A \quad Q_p = V_{max}*A \quad \frac{Q_p}{A} = V_{max}$$

$$V_{max} = \frac{14.2\ ft^3/s}{7\ ft^2} = 2.03\ ft/s$$

Since $\mathbf{V_{max}}$ is less than 4 fps, turf reinforced matting (TRM) is not necessary.

This design example is for an infiltration swale. The soil was amended with a 50/50 sand and existing soil mix to a depth of 3' below the swale bottom and was planted using vegetation described in the Vegetation Design Example. Additionally, a wet swale vegetation plan is shown in the Vegetation Design Example; however, like the vegetation, the SCM engineering and design would change based on channel geometry and site constraints.

Construction

Compaction: Heavy equipment used to excavate the swale should not be operated within the swale channel to minimize compaction. The bottom of the swale should be scarified, chiseled, or ripped prior to placing any media or soil mix to further enhance infiltration especially when native, well-drained soils are used. If constructed properly, post construction infiltration rates should be similar to pre-construction infiltration rates.

Erosion and Sediment Control: Erosion control blankets should be used if the swale will receive runoff before vegetation has become established. (Refer to the *Alabama Handbook for Erosion Control, Sediment Control and Stormwater Management on Construction* Sites *and Urban Areas* for guidance on erosion matting.)

Vegetation: To prevent scour, vegetation should be established prior to diverting runoff into the swale.

Underdrains: If underdrains are desired, a gravel layer should be considered. The gravel layer is comprised of #57 stone at a depth of 2" greater than the diameter of the underdrain pipe.

Bioretention Media: Infiltration swales that use a bioretention media should have a minimum infiltration rate of 0.5"/hr. To achieve this, the bioretention media uses 85-88% washed sand, 8 - 12% fines, and 3-5% aged organics. For more information on targeted pollutant removal using this mix, see Chapter 4.1 on Bioretention.

Mulch: Infiltration swales have a 3" layer of double- or triple-shredded hardwood mulch. Hardwood mulch is recommended, but other mulches such as pine bark or pine straw have been successfully used although they may require more frequent replacement. All mulches float, however, coarser textured mulches such as pine bark are more likely to float throughout the swale and can clog the overflow device. Mulch should be aged at least 6 months.

Retrofits: Swales used during construction as components of a site's erosion and sediment control plan can be retrofitted to function as a water quality swale. Regrading of the channel and slope may be necessary as well as complete sediment removal within the channel and the establishment of the proper vegetation.

Vegetation

Channel vegetation is dependent on the type of swale design (i.e. grassed, infiltration, or wet swale).

Grassed Swales: Grassed swales using sod are less likely to encounter establishment issues as sod provides a quick and dense cover.

Infiltration Swales: Infiltration swales support drought tolerant plants that thrive under brief flooding during and after a rainfall event. Most of these plants have a facultative (FAC) wetland indicator status.

Wet Swales: Wet swales utilize wetland plants in the channel and may have turfgrass or native grasses planted on the side slopes. Wet swale channel plants usually have a facultative wet (FACW) or obligate (OBL) wetland indicator status since the channels of wet swales have standing water present the majority of the time. (For more information on wetland indicator status, see Vegetation in Appendix D.)

Seeding: The side slopes can be seeded with native grass if stormwater will be conveyed into the swale channel from a forebay pretreatment device or if runoff is diverted until seeds are established. Depending on time of year, temporary seeding of the side slopes may be necessary. Seeding the swale channel or any part of the swale that will receive stormwater is not recommended unless paired with an erosion control blanket (see the *Alabama Handbook for Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas* for details regarding erosion control blankets and seeding recommendations).

Plant Sizes: Most native grasses, herbaceous perennials, and shrubs can be purchased as containerized plants ranging in sizes from plugs or liners (~ 2 - 4” pots) up to 3-gallons. Using containers provides quick cover since containers establish more quickly than seeds. Wet swale plants can be harvested locally or ordered from wetland plant nurseries as plugs or 1-gallon containers.

Harvesting Plants: Harvesting locally is labor intensive and may require a permit to ensure legality. To harvest, wetland plants are divided and tubers or rootballs are transplanted on site. While harvested plants are beneficial because of quick establishment and prior adaptation to local climate conditions, invasive plant species can be introduced.

Plant Height: Plants for swale channels should never be completely submerged, thus plant height in the channel should be no less than the maximum ponding depth. When plants are fully submerged or bend to accommodate high flows, swale channel roughness is reduced resulting in higher flow velocities and reduced filtering contact of plants.

Plant Establishment: Infiltration swale vegetation can be installed any time of the year when using containerized plants. However, installing plants during the summer requires more frequent irrigation until plant establishment regardless of the size plant used. High temperatures and decreased rainfall during summer months reduce the chance for survival of plants. Fall installations are also appropriate as this is the ideal time of year for division or transplant of most perennial plants and a milder climate is experienced during this season. Wet swale plants should be installed from April to October.

Turf Establishment: For June to September installation, newly planted turf should be irrigated at planting so that the surface does not dry out. Sod should be watered daily for the first one to two weeks to keep it evenly moist. As the sod begins to grow new roots, irrigation frequency can be decreased, but a larger volume of water should be applied at each watering. Rainfall should be supplemented so that turfgrass receives about 1 – 1.5” per week from all irrigation sources. Turfgrass sod planted during dormancy will require less irrigation for establishment. In some cases, a dormant planting will not need any supplemental irrigation because rainfall during these months is sufficient for turf to establish. However, dormant plantings may benefit from irrigation during spring months when sod begins to produce new growth.

Table 4.4.3
Infiltration Swale Plant List

Botanical Name	Common Name	Habit	Prefers	Comments
Asclepias tuberosa	butterfly weed	herbaceous perennial	sun	Used as host and nectar source for Monarch butterfly
Baptisia alba	white false indigo	herbaceous perennial	sun to part shade	
Clethra alnifolia	summersweet clethra	deciduous shrub	sun to part shade	‘Sixteen Candles’ is a good dwarf
Conoclinium coelestinum	mistflower	herbaceous perennial	sun to part shade	‘Wayside Form’ is a good compact growth cultivar
Echinacea purpurea	purple coneflower	herbaceous perennial	sun to part shade	Long bloom season
Eragrostis spectabilis	purple love grass	native grass	sun	Compact native grass
Gaillardia pulchella	firewheel	herbaceous perennial	sun	Very heat and drought tolerant
Fothergilla gardenii	dwarf witch alder	deciduous shrub	sun to part shade	Not tolerant of extended flooding
Hypericum densiflorum	bushy St. John’s wort	deciduous shrub	sun	‘Creel’s Gold’ is a good dwarf
Ilex glabra	inkberry holly	evergreen shrub	part shade	‘Shamrock’ is a good dwarf

Botanical Name	Common Name	Habit	Prefers	Comments
Ilex verticillata	winterberry	deciduous shrub	sun to part shade	'Red Sprite' is a good dwarf
Ilex vomitoria	dwarf yaupon holly	evergreen shrub	sun to part shade	'Stoke's Dwarf' or 'Schillings' are good dwarfs
Itea virginica	sweetspire	deciduous shrub	sun to part shade	'Little Henry' is a good dwarf
Liatris spicata	gayfeather	herbaceous perennial	sun to part shade	Narrow form
Lindera benzoin	spicebush	deciduous shrub	sun to part shade	
Morella cerifera	wax myrtle	evergreen shrub	sun to part shade	'Tom's Dwarf' is a good dwarf
Muhlenbergia capillaris	muhly grass	native grass	sun to part shade	Very drought tolerant
Panicum virgatum	switchgrass	native grass	sun to part shade	Flood and drought tolerant
Physostegia virginiana	obedient plant	herbaceous perennial	sun to shade	Can be aggressive
Rudbeckia fulgida	orange coneflower	herbaceous perennial	sun to part shade	Long bloom season
Schizachryium scoparium	little bluestem	native grass	sun to part shade	
Sorghastrum nutans	indian grass	native grass	sun to part shade	
Stokesia laevis	Stoke's aster	herbaceous perennial	sun to part shade	Long bloom season
Tradescantia virginiana	spiderwort	herbaceous perennial	sun to shade	
Vernonia gigantea	giant ironweed	herbaceous perennial	sun	
Vernonia novenboracensis	New York ironweed	herbaceous perennial	sun	
Viburnum dentatum	arrowwood	deciduous shrub	sun to part shade	
Viburnum nudum	possumhaw	deciduous shrub	sun to part shade	

Table 4.4.4
Wet Swale Plant

Botanical Name	Common Name	Habit	Prefers	Comments
Carex crinita	fringed sedge	Grass like, evergreen	part shade	Can be divided
Hibiscus moscheutos	rose mallow	herbaceous perennial	sun to part shade	Attracts birds, hummingbirds, and ducks
Iris virginica	Southern blue flag iris	herbaceous perennial	sun	Do not plant the nonnative invasive yellow flag iris (*I. pseudacorus*); *I. versilcolor* is the Northern blue flag iris
Juncus effusus	common rush	Grass like, evergreen	sun to part shade	Can be divided
Lobelia cardinalis	cardinal flower	herbaceous perennial	Sun to shade	Butterfly and hummingbird attractant; self sows
Peltandra virginica	arrow arum	herbaceous perennial	part shade	Attracts birds
Pontederia cordata	pickerelweed	herbaceous perennial	sun to part shade	Attracts dragonflies
Sagittaria latifolia	duck potato	herbaceous perennial	sun to part shade	Starchy rhizomes attract ducks and snapping turtles; colonizing
Saururus cernuus	lizard tail	herbaceous perennial	part shade to shade	Colonizing; dominates during drought
Sisyrichium angustifolium	blue eyed grass	herbaceous perennial	sun to part shade	If allowed to dry out, will decline
Sparganium americanum	bur-reed	herbaceous perennial	sun to part shade	Tolerates flowing water

Table 4.4.5
Turfgrass List for Grassed Swales, Swales Side Slopes, and Grassed Inlets

Name	Prefers	Drought Tolerance	Comments
Bermudagrass	Sun	Excellent	Tolerates foot traffic, spreads above and below ground, fast growth rate, use statewide
Centipedegrass	Sun to Part Shade	Good	Slow growing, sensitive to some herbicides (check label), may be susceptible to cold injury in North AL
St. Augustinegrass	Sun to Shade	Good	Adapted better to the bottom third of the state, spreads above ground, fast growing, can be sensitive to herbicides, most shade tolerant turf, used in Central and South AL
Zoysiagrass	Part Shade	Excellent	Used statewide, most cold tolerant of warm season turfgrasses, slow growing

*Adapted from Han and Huckabay, 2008

Vegetation Design Guidelines

- Swales are long and linear and because of this, it can be helpful to sketch channel vegetation in 10’ or 20’ sections.
- Low growing perennials, grasses, and shrubs are planted in the channel if not grassed.
- Swale side slopes are planted with turfgrass or native grass.
- Low maintenance native grasses are sometimes used because mowing is needed only once per year.
- Non-turfgrass swale vegetation should have varied seasonal interest and growth patterns.
- Dwarf cultivars are suitable for smaller channel widths.

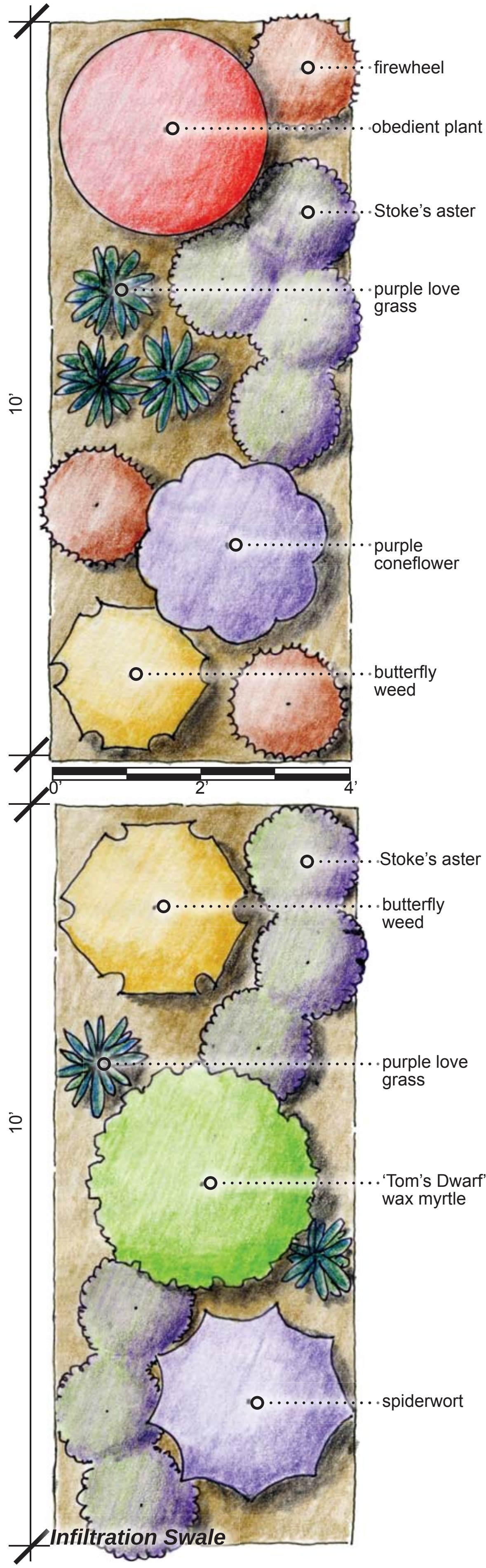
Infiltration Swale Design Example

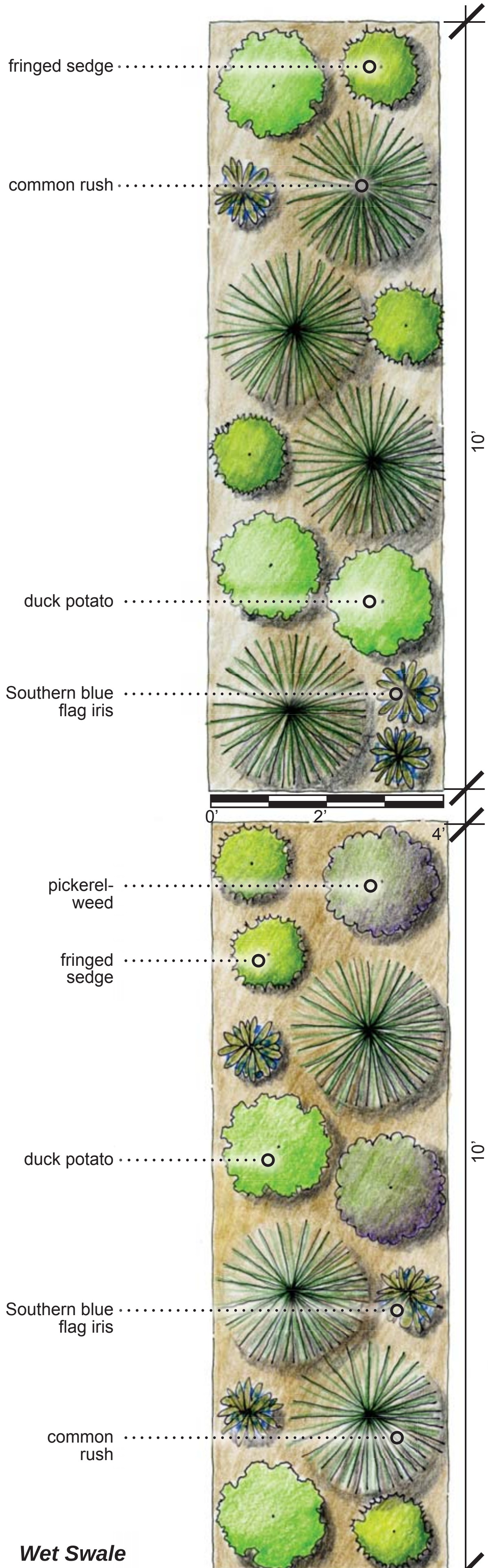
An infiltration swale is designed to capture runoff from the backside of a parking lot. In this example, the channel is 4’ wide. Visibility from the road and parking lot may limit the use of taller growing vegetation in the channel. This vegetation plan can be used for an infiltration swale using a 50/50 sand/soil mix or a bioretention media mix.

This design was sketched using a circle template and drawn to scale to reflect mature plant sizes. Woody shrubs used are dwarf cultivars with a maximum width of 4’. For more information on cultivars, see Appendix D on Vegetation. The length of the infiltration swale is 50’ and because of this, it is helpful to only draw a vegetation plan for a couple of 10’ sections that can be repeated throughout the length of the swale. The side slopes can be planted with bermudagrass to be used as pretreatment into the swale.

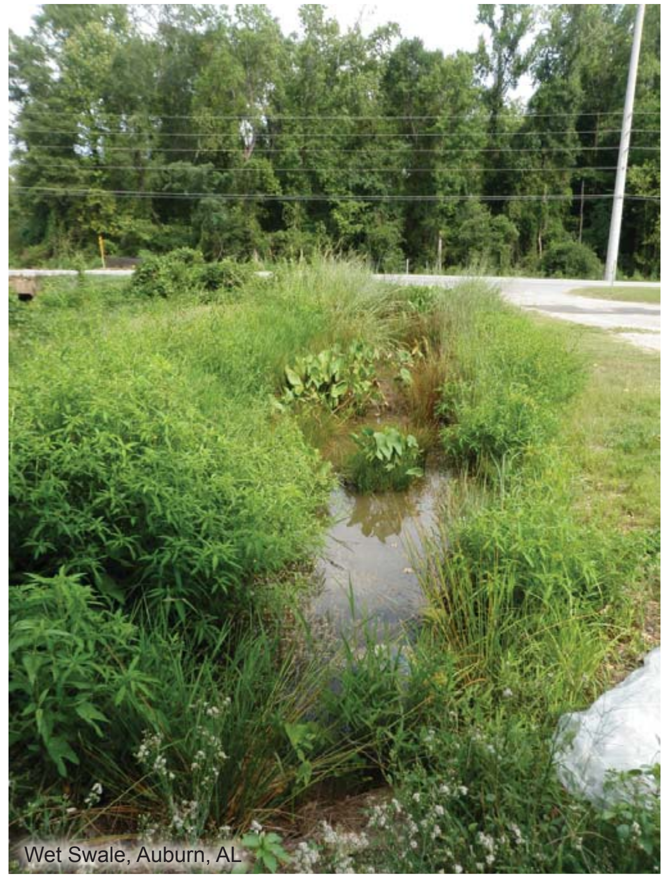
Wet Swale Design Example

For this example, a wet swale is located downslope of a trash compactor site. A forebay is utilized as pretreatment. The channel width is 3’ and the swale is 50’ in length. Wetland vegetation is planted in the channel with some herbaceous and semi-evergreen species. *Panicum virgatum* (switchgrass) is planted on the side slopes since the site is mowed only once per year. Due to the site location at a trash compactor site, weekly trash cleanup is needed to remove stray trash and large items from the forebay and channel.





Wet Swale



Wet Swale, Auburn, AL

Maintenance

Long-term functionality of swales is directly equivalent to the frequency in which maintenance is performed. Although maintenance of infiltration swales can be more frequent, over its life cycle it is still considered less expensive compared to traditional curb and gutter maintenance.

Trash and Litter: Swales in commercial or industrial settings tend to collect more litter and may need monthly or even weekly trash removal for aesthetics and to avoid clogging.

Sediment Removal: Accumulated sediment can form sandbars that inhibit flow patterns and have the potential to be re-suspended, transported throughout the swale, and eventually transported off site. Excess sediment can also smother swale vegetation. For small channel widths, sediment is best removed by hand using a flat shovel and metal rake. If excessive sediment clogs the swale often, check upslope for loose or bare soil areas that need to be stabilized.

Plant Maintenance: Where plant aesthetics are important, more frequent plant maintenance will be required. Wet swales and infiltration swales using a mixture of native grasses, small shrubs, and herbaceous perennials should not be mowed or cut back more than once a year. Vegetation should be maintained at the maximum height appropriate to the plant and site requirements, striving for a dense cover. Additional plants should be installed when plant replacement is needed.

Mowing: Grassed swales with turfgrass require mowing during the growing season and clippings should be removed from the swale to minimize clogging and nutrient release. Turfgrass should be maintained at a height no lower than 5" or the design depth. At lower mowing heights, velocities are not adequately slowed in the swale channel and plants may become completely submerged causing damage and possibly mortality.

Pickerelweed can be planted to attract dragonflies; Phenix City, AL

Nuisance Species: Unwanted plants, or weeds, should be removed from the swale channel and side slopes. In wet swales, cattails (*Typha latifolia*) can become a nuisance as they quickly displace other native plant species to form dense monocultures. Moreover, cattails promote mosquito infestation and have high mosquito counts. Herbaceous plants that attract mosquito predators such as dragonflies should be used in wet swale applications to minimize mosquito populations.

Table 4.4.6
Maintenance Schedule

Task	How Often	Comments
Erosion Inspection	During and after major storm events for first 2 years, annually thereafter	Ruts, holes, or gullies should be repaired with soil and vegetation cover
Inspection	After 0.5” or greater rainfall event	Visually inspect all components including any pretreatment device, channel, overflow structure, and vegetation for damage.
Trash Removal	At least annually, twice a year is better	Trash removal frequency is dependent on location of the swale
Sediment Removal from the Channel	When it reaches 4”	Sediment should be removed from the channel when it reaches a depth of 4” or when vegetation is covered
Sediment Removal from the Forebay	Site dependent	Sediment and other debris should be removed from the forebay when the storage volume is greatly decreased or when the forebay is half full
Mowing of Turfgrass	Every other week in growing season	Mowing should be done more often during the growing season; dense, low growing vegetation is best to maintain diffuse flow. Maintain at a height no lower than 5” or the design depth.
Mowing of Native Grasses	Annually	Most native grasses should be mowed before new growth appears in Spring.
Herbaceous and Woody Vegetation Pruning	Annually	Leaves dropped from deciduous shrubs and herbaceous plants should be collected to decrease clogging of mulch or any damming that might occur in the channel. Woody shrubs should be pruned based on the May Rule (see Appendix D on Vegetation)
Removal of Invasive Plants	Twice a year	Weeds or other invasive plants should be removed as they crowd and rob native plants of water, sunlight, and nutrients
Mulch Replacement	Every 2 years	Infiltration swales and vegetated swales will require mulch removal and replacement. Replenish bare areas as they occur
Irrigation	During plant establishment	Channel vegetation will require irrigation during plant establishment. The frequency is largely dependent on the time of year of plant installation and precipitation. Plants should not require any irrigation beyond establishment
Plant Replacement	When dead plants are noted	Sod or other plants should be replaced when they are choked out by sediment. Replant as needed to maintain dense cover

Pollutant Removal

Table 4.4.7
Pollutant Removal Table

	Sediment	Nutrients		Metals	Pathogens
		N	P		
Grassed Swale	a. 35%	20%	20%		Low
	b. 80%	50%	50%	40%	No Data
Enhanced Swale	c. 80%	50%	50%	40%	No Data
	c. 80%*	40%*	25%*	20%*	
	d. 50%	20%	25%	30%	Insufficient Data

* Represents data for a wet swale. All others are for dry swales.
Sources:
a. North Carolina Department of Environment and Natural Resources, 2007
b. City of Auburn, 2011
c. Georgia Manual, 2011
d. Iowa State University, 2008

Swales are most effective when channels are broad, slopes are not steep or flat, and when vegetation is dense. The ability of swales to reduce runoff volumes is largely dependent on the drainage area size, surrounding land use, slope, underlying soil, and vegetation density and type. Swales remove pollutants primarily through sedimentation but also through infiltration, filtration, and biofiltration. As with most LID practices, increased removal efficiencies are dependent on their design, soils, vegetation, and maintenance.

Enhancing Pollutant Removal: Dense vegetation increases the pollutant removal capabilities by increasing runoff contact time; coupled with small storm events and well-drained soils, the pollutant removal efficiency may be increased even more.

Check Dams: Check dams or other depressional storage areas within the channel can aid in enhancing pollutant removal by improving storage and slowing runoff from steep longitudinal slopes on site.

In-Situ Soil: Infiltration swales with a bioretention media mix typically have higher pollutant removal capabilities due to the specialized soil media designed to filter pollutants. Function and treatment capabilities are increased when in-situ soils are well-drained. Additionally, it has been reported that alkaline soils may facilitate the retention of metals in the swale.

Phosphorus: A soil media with a low phosphorus concentration and high phosphorus sorption is recommended so that phosphorus is not exported from the system.

Wet Swales: Standing water conditions in wet swales foster higher pollutant removal than typical dry grassed swales. In the channel, native wetland plants are used to uptake nutrients and promote biological processes that filter excess nutrients and other pollutants. Wet swales function similarly to a small, shallow constructed stormwater wetland. These linear “wetland areas” foster anaerobic conditions favorable to nutrient cycling processes such as denitrification.

Seasonal Variations: Seasonal pollutant removal efficiency variations can be expected in swales due to winter dormancy of vegetation. It should be noted that plant die back and subsequent reduced plant cover can result in increased erosive forces during wet weather associated with winter months, which can lead to downstream sedimentation.

Vegetation: For increased pollutant removal efficiency, a mix of herbaceous, deciduous, and evergreen vegetation is recommended for all types of swales; however, each project site may have different aesthetic value and needs associated with it.

References

Alabama Soil and Water Conservation Committee. 2009. Alabama Handbook for Erosion Control, Sediment Control, and Stormwater Management on Construction Sites and Urban Areas. Montgomery, AL.

California Stormwater Quality Association. 2003. California Stormwater BMP Handbook: New Development and Redevelopment Ch TC-30. Menlo Park, CA.

City of Auburn Stormwater Management Design Manual. 2011.

Georgia Stormwater Management Manual. 2001.

Han, D. and E. Huckabay. 2008. Selecting Turfgrasses for Home Lawns. Alabama Cooperative Extension System. ANR – 92.

Hunt, W.F. 1999. Urban Stormwater Structural Best Management Practices (BMPs). North Carolina Cooperative Extension. AG-588.

Hunt, W.F., C.S. Apperson, and W.G. Lord. 2005. Mosquito Control for Stormwater Facilities. North Carolina Cooperative Extension. AG-588-4.

Iowa State University. 2008. Iowa Stormwater Management Manual, Ch 2I-2: Grass Swales. Transportation Institute, Ames, IA.

Iowa State University. 2010. Iowa Stormwater Management Manual, Ch 2I-2: Dry Swales. Transportation Institute, Ames, IA.

Lichvar, R.W. and P. Minkin. 2008. Concepts and procedures for updating the national wetland plant list. U.S. Army Corps of Engineers, Engineer Research and Development Center, ERDC/CRREL TN-08-3.

North Carolina Department of the Environment and Natural Resources. 2007. Stormwater Best Management Practices Manual, Ch 14: Grassed Swale (Chapter revised 2009) and Ch 9: Stormwater Wetlands (Chapter revised 2009). North Carolina Division of Water Quality, Raleigh, NC.

Pennsylvania Department of Environmental Protection. 2006. Pennsylvania Stormwater Best Management Practices Manual Ch 6.4.8. Pennsylvania Bureau of Watershed Management, Harrisburg, PA.

Stevens, M. and C. Hoag. 2000. Broad-Leaved Cattail. US Department of Agriculture, Natural Resources Conservation Service, Aberdeen, ID.

University of Florida. 2008. Bioswales/Vegetated Swales Fact Sheet. University of Florida Extension, Program for Resource Efficient Communities. In: Florida Field Guide for Low Impact Development.

US Environmental Protection Agency. 1999. Stormwater Technology Fact Sheet: Vegetated Swales. Office of Water, Washington, D.C.

Virginia Department of Forestry. 2008. Rain Gardens Technical Guide. Virginia Department of Forestry, Charlottesville, VA.

::This page::
::intentionally left blank::

Level Spreaders (LS) and Grassed Filter Strips (FS)

Level Spreader; Auburn, AL

Synonyms: Water spreader, grass filters, grassed buffer strips, filter strips, engineered buffer strips, engineered filter strips

Level spreaders are devices that create diffuse or sheet flow that is evenly distributed or dispersed to decrease flow velocity and discourage erosive forces associated with concentrated flows. Most commonly, level spreaders are paired with grassed filter strips, riparian buffers, or a combination of the two to provide pollutant removal. The primary purpose of a level spreader is to disconnect impervious surfaces by creating non-erosive stormwater connectivity with grassed filter strips.

A grassed filter strip is a linear strip of dense vegetation that receives sheet flow of stormwater runoff from a nearby impervious surface or level spreader in order to reduce peak discharge rates, encourage sediment deposition, and provide limited infiltration. Grassed filter strips are planted with turfgrass, which is easy to maintain and blends seamlessly into urban landscapes. Grassed filter strips are most effective when combined with level spreaders.

Site Selection

Quantity Control	no
Drainage Area	small
Space Required	small

Works with:

Steep Slopes	---
Shallow Water Table	---
Poorly Drained Soils	✔

General Significance

Construction Cost	low
Maintenance	low
Community Acceptance	high
Habitat	med
Sun / Shade	either

Site Selection

Evaluating Soils: Use the USDA Web Soil Survey to identify soil map units and to make initial interpretations for potential uses and limitations of a site. However, since most soil map units have inclusions of other soils that may be quite different, detailed evaluations should be made at the proposed site by a professional soil scientist or soil classifier. On-site evaluations should properly identify a soil or the hydrologic soil group (HSG) and the final decision for use should be made based on the detailed determination of soil series or HSG. For a detailed list of HSG properties, see Table A.3 in Appendix A on Stormwater Hydrology.

Poorly Drained Soil: An underdrain is recommended when infiltration rates are < 1”/hr. See Chapter 5.1 on Rain Gardens for information on infiltration testing.

Practice Pairing: The purpose of a level spreader is to create diffuse flow; therefore, the level spreader is commonly paired with another stormwater control measure (SCM) to provide pollutant removal. Runoff from an impervious drainage area may be directed to level spreader and grassed filter strip systems or they may receive overflow from another SCM, such as a swale or bioretention cell.

Table 4.5.1
Site Selection: Constraints and Limitations for Level Spreaders and Grassed Filter Strips

Regional Stormwater Control	Level spreader/grassed filter strip combinations do not provide regional stormwater control, select another SCM
Slope	Slopes greater than 6% do not allow for adequate treatment in grassed filter strips
Utilities	Call 811 before construction to locate utilities (for more information, visit: www.al1call.com)
Large Drainage Areas	Draining larger watersheds requires longer level spreaders that are difficult to construct
High Sediment loads	Avoid high sediment loads if possible, particularly on sites with active construction

Riparian Buffers: Level spreader/ grassed filter strip systems are commonly sited upslope of riparian buffers where they create sheet flow of stormwater and reduce peak flows into streamside forests.

Drainage Area: Level spreaders are intended to capture runoff in small watersheds; flow volumes from larger watersheds require longer level spreaders that are difficult to construct.

Velocity: No more than 10 feet per second (fps) should be directed into a level spreader/grassed filter strip system. Diffuse flow occurs at velocities of less than 2 fps. Turf reinforced matting (TRM) is recommended if velocities are greater than 4 fps. A flow splitter to divert larger flows to a swale or other SCM can be incorporated.

Slope: Grassed filter strips are designed for areas with a 2 – 6% slope; greater than 6% slope is too steep for effective stormwater treatment and less than 2% slope may result in standing water.

Filter Strip Width: A minimum width of 25' is recommended for grassed filter strips.

Local Ordinances: Local government stream buffer regulations and ordinances should be consulted prior to design and construction of these systems.

Design

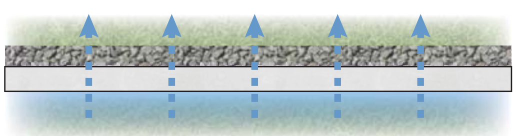
Information should be collected for watershed size, in-situ soil, hydrologic soil group (HSG), slope, and depth to water table. The design layout or level spreader location is specific to the site. When determining the best location for the level spreader/ grassed filter strip system, constraints, retrofit opportunities, and aesthetics should be considered.

The level spreader/grassed filter strip system consists of four primary components: forebay, channel, level spreader lip, and the grassed filter strip. The size of each of these components is based on the volume or design storm to be captured.

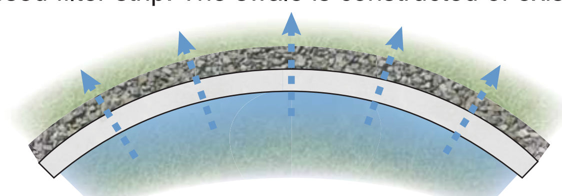
Components

Forebay: A forebay is used as a pretreatment device for level spreader systems. A forebay is a pool that is used for initial storage and as a sediment trap for runoff entering the system, which prevents clogging of the channel behind the level spreader lip. The forebay for this system should be 12 - 18" deep and is used only in situations where standing water is not considered a safety concern. It is deepest at the point of runoff entry and shallower at the point of exit, which allows for energy dissipation within the forebay. If soils on site are poorly drained (<1"/hr), an underdrain may be needed below the forebay, to prevent standing water for extended periods of time. The forebay should be designed to be 0.2% of the watershed drainage area.

Level Spreader Channel/Blind Swale: The level spreader channel or "blind swale" (because of terminal ends) is located directly upslope of the level spreader. This swale is designed so that water fills the swale and spreads evenly over the level spreader creating diffuse flow into the grassed filter strip. The swale is constructed of existing earth



Straight Level Spreader Plan View



Convex Level Spreader Plan View

and soils and may be lined with turfgrass. In urban settings, a concrete channel may be desired for ease of trash and sediment removal. In clayey soils, an underdrain may need to be installed beneath the swale.

Level Spreader: The level spreader is a poured concrete weir constructed level (0% slope), and placed on an appropriate concrete footer. The level spreader should be designed and constructed to remain level. Level spreaders may be straight or convex in plan view, but not concave. This is primarily to prevent concentrated flows downslope.

Level Spreader Lip: The lip of the level spreader on the downslope side should be at least 3” higher than existing grade.

Filter Fabric: Downslope of the level spreader, a minimum 3’ wide strip of geotextile filter fabric (40 oz nonwoven is recommended, but should be selected based on in-situ soil conditions) and 3” layer of aggregate stone should be applied (#57, #1, or designer preference).

Grassed Filter Strip: A grassed filter strip is graded to have a consistent and uniform slope. The filter strip is planted with turfgrass and the length of the filter strip may be dependent on local government stream buffer regulations.

EQN 4.5.1

$$T_c = \frac{\left(\frac{L^3}{H}\right)^{0.385}}{128}$$

L = Longest length of drainage area or watershed (ft)
H = Change in Elevation throughout drainage area or watershed (ft)
T_c = Time of concentration (minutes)

Design Guidance

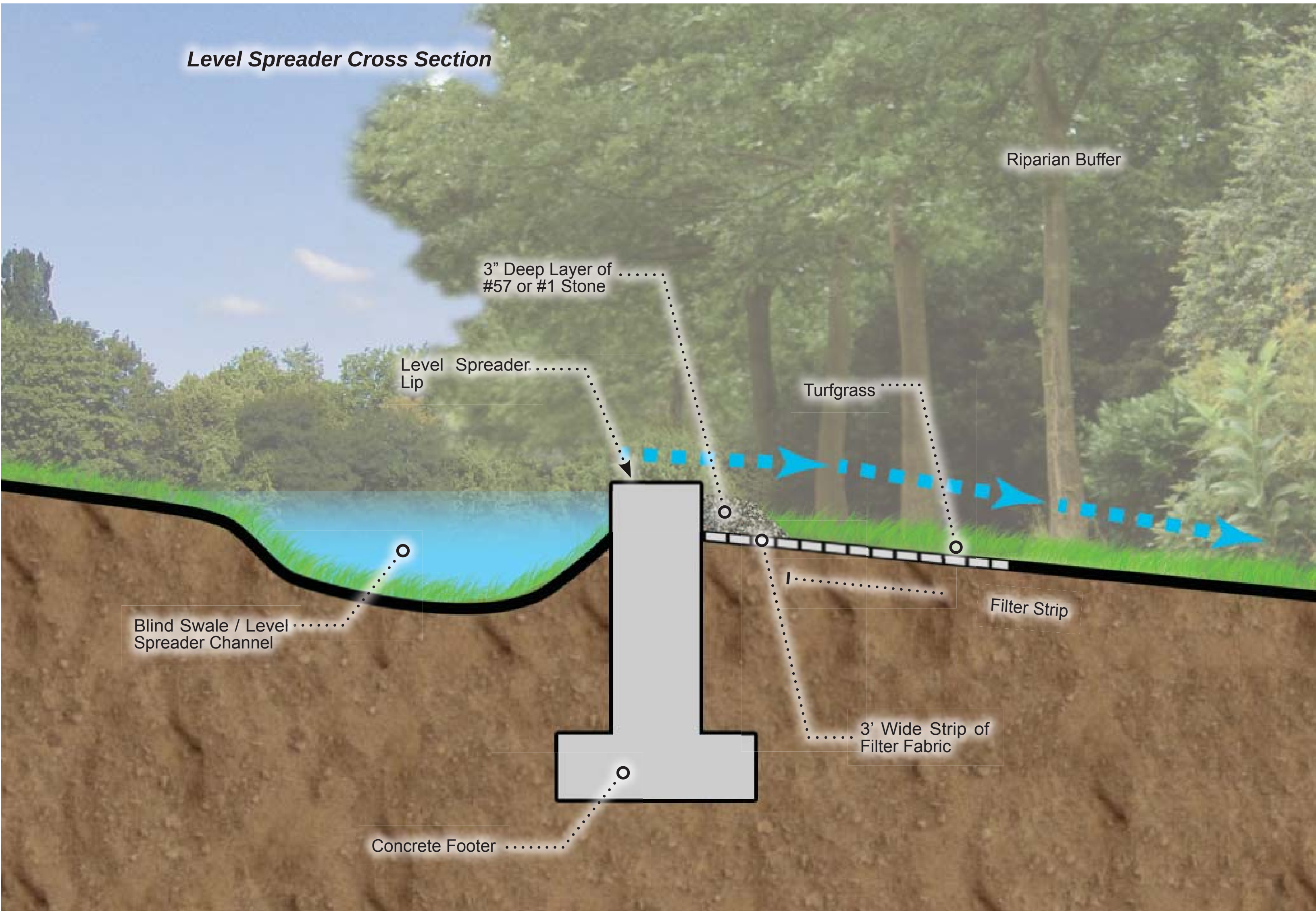
1. **Determine Peak Flow**

    Level spreaders are designed to treat peak flow; the peak flow event is the primary design storm used to design the level spreader channel. The Kirpich Equation and Rational Method are used to determine **Peak Flow (Q_p)** and to calculate level spreader channel geometry. The Kirpich Equation

EQN 4.5.2

$$Q_p = CiA$$

C = Rational coefficient (dimensionless) See Table A.2 in Stormwater Hydrology, Appendix A
i = Rainfall intensity (in/hr)
A = Watershed area (ac)
Q_p = Peak flow (ft^3/s)



shown in EQN 4.5.1, uses the **Longest Length in the Drainage Area (L)** and the **Change in Elevation (H)** to calculate the **Time of Concentration (T_c)**.

Using the **Time of Concentration (T_c)**, a design storm can be determined and the rainfall **Intensity (i)** is derived. If **T_c** is 4.6 minutes, round to the nearest given unit of time, 5 minutes. **Peak Flow (Q_p)** is calculated using the Rational Method, EQN 4.5.2.

Q_p = Peak flow (ft^3/s)

2. **Determine Level Spreader Channel Geometry**

Calculating level spreader channel geometry may require several design iterations using Manning's Equation (EQN 4.5.3). Triangular channels are easy to construct and work well in small drainage areas treated by level spreaders. If a trapezoidal level spreader channel geometry is desired, please refer to Chapter 4.4 on Grassed Swales, Infiltration Swales, and Wet Swales.

The **Level Spreader Channel Cross Sectional Area (A) and Hydraulic Radius (R)** are affected by level spreader channel geometry.

Side Slope: A 5:1 side slope is recommended, however a 3:1 is acceptable.

Channel Slope: The level spreader channel slope is not the same as site slope, or side slopes. The channel slope is the slope in the bottom of the level spreader channel and should be as flat as possible. Since the level spreader channel employs a blind swale, the channel slope should be minimal to avoid erosion, scour, and potential breach of the level spreader channel.

Depth (D) is determined using **Peak Flow (Q_p)** calculated from EQN 4.5.2. in Manning's EQN 4.5.3.

A modified Manning's Equation for a triangular channel with 3:1 and 5:1 side slopes is shown in EQNs 4.5.4 and 4.5.5.

Once **D** is calculated, side slopes and channel geometry are used to calculate the swale **Top Width (b)**.

The Continuity EQN 4.5.6, can be used to validate the velocity within the level spreader channel and determine if there is a need for turf reinforced matting (TRM) or additional vegetation to prevent erosion and scour within the swale channel. If **Velocity (V)** exceeds 4fps, TRM is necessary.

EQN 4.5.3

$$Q_p = \left(\frac{1.486}{n}\right) * A * R^{0.667} * S^{0.5}$$

n = Manning's n (dimensionless) – for more information see Appendix A on Stormwater Hydrology.
A = Swale channel cross sectional area (ft^2), based on swale geometry
R= Hydraulic radius (ft)
S = Swale channel slope (ft/ft)

EQN 4.5.4 *for 3 : 1 side slopes*

$$Q_p = \left(\frac{2.71}{n}\right) * D^{2.67} * S^{0.50} \quad \text{-or-} \quad D = \left(\frac{Q_p * n}{2.71 * S^{0.5}}\right)^{\frac{1}{2.67}}$$

EQN 4.5.5 *for 5 : 1 side slopes*

$$Q_p = \left(\frac{4.62}{n}\right) * D^{2.67} * S^{0.50}$$

n = Manning's n
D = Depth (ft)
S = Swale channel slope (ft/ft)
Q_p = Peak flow (ft^3/s)

EQN 4.5.6

$$Q = V * A$$

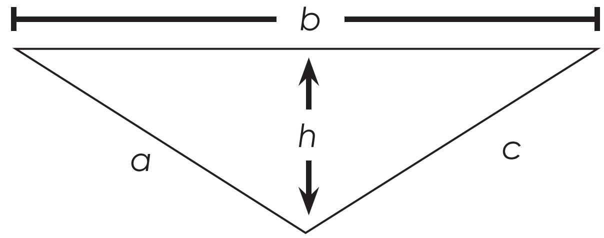
Q = Flow (ft^3/s)
V = Average velocity in channel (ft/s)
A = Swale channel cross sectional area (ft^2), based on swale geometry

Swale Geometry

(illustrations are exaggerated)

for triangular swale geometry:

$$A = 0.5(b*h)$$
$$P = a + b + c$$

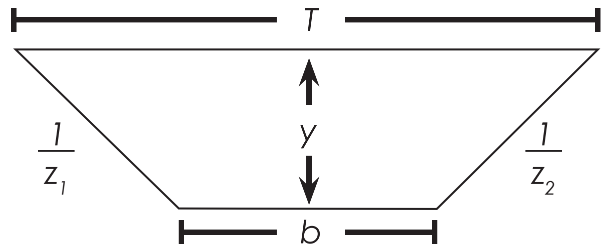


for trapezoidal swale geometry:

$$T = b + y(z_1+z_2)$$

$$A = \frac{y}{2}(b + T)$$

$$P = b + y\left(\sqrt{1 + z_1^2} + \sqrt{1 + z_2^2}\right)$$



Note: typically $z_1 = z_2$

Design Example

1. **Determine Peak Flow**

A residential site in northwest Alabama is used for this design example. The level spreader is treating a small, **1 acre** parking lot that holds a pool house.

A level spreader and grassed filter strip will capture parking lot runoff prior to entering a riparian buffer on the backside of the property. For this example, a triangular level spreader channel will be designed and turfgrass will be planted in the grassed filter strip. The design of the concrete footer, level spreader detail, and grassed filter strip dimensions are not included in this example.

The level spreader channel is designed for the peak flow event, using the Kirpich EQN 4.5.1.

The **Longest Length in the Drainage Area (L)** is 400' and the **Change of Elevation (H)** is 4'.

Therefore the **Time of Concentration** is

EQN 4.5.1

$$T_c = \frac{\left(\frac{L^3}{H}\right)^{0.385}}{128}$$

$$T_c = \frac{\left(\frac{400^3}{4}\right)^{0.385}}{128} = \frac{594}{128} = 4.6\text{~}5 \text{ min}$$

The T_c is used to calculate rainfall **Intensity (i)** in the Rational Method (Peak Flow Equation). The design storm or rainfall **Intensity (i)** is determined using the 10 - year flow event and closest estimate of the T_c. Since the lowest calculated T_c is **5 minutes, the 10 - year 5 - minute intensity** will be used. For more detail on how to determine storm intensity refer to Appendix A on Stormwater Hydrology.

To determine **Peak Flow (Q_p)** from the **10 - year, 5 - minute event**, the Rational Method (EQN 4.5.2) is used.

EQN 4.5.2

$$Q_p = CiA$$

Continued on next page

A **Rational Coefficient (C) of 0.95 for parking lot runoff (impervious), Intensity (i) of 7.2 in/hr** (from appropriate IDF curve), determined using the **10 - year, 5 - minute event,** and **Area (A)** of **1 acre** for the impervious parking lot are used.

$$Q_p = 0.95*7.2in/hr*1.0ac$$

Converting the **Intensity (i)** 7.2in/hr to ft/s,

$$7.2in/hr \left| \frac{1ft}{12in} \right| 0.6ft/hr \left| \frac{1hr}{3600in} \right| = 0.00016666ft/s$$

Converting 1 acre into square feet,

$$1ac \left| \frac{43{,}560ft^2}{1ac} \right| = 43{,}560ft^2$$

Therefore,

EQN 4.5.2 $Q_p = CiA$

$$Q_p = 0.95*0.00016666*43560 = 6.8ft^3/s$$

Therefore, the level spreader channel needs to be able to handle peak flows of 6.8 cfs.

2. Determine Level Spreader Channel Geometry

The level spreader channel will have 3:1 side slopes and a triangular shape. Manning's EQN 4.5.3, can be used to confirm the calculated geometry.

EQN 4.5.3

$$Q_p = \left(\frac{1.486}{n}\right) *A*R^{0.667}*S^{0.5}$$

Since the level spreader channel has these dimensions (3:1 side slopes and triangular shape) a modified Manning's EQN 4.5.4 can be used to calculated channel **Depth (D)**.

EQN 4.5.4

$$D = \left(\frac{Q_p*n}{2.71*S^{0.5}}\right)^{\frac{1}{2.67}}$$

Using the calculated $\mathbf{Q_p}$, a **Manning's n 0.03 for grass**, and a **slope of 0.005ft/ft (0.25ft/50ft)**, a level spreader channel **Depth (D)** can be calculated.

$$D = \left(\frac{Q_p*n}{2.71*S^{0.5}}\right)^{\frac{1}{2.67}} = \left(\frac{6.8*0.03}{2.71*0.005^{0.5}}\right)^{0.375} = \left(\frac{0.204}{0.192}\right)^{0.375} = 1ft$$

Using a calculated **Depth (D)**, of 1', a channel **Top Width (b)** can be determined by multiplying **D** by the side slope and 2, as shown: $b=1ft*3*2=6ft$

Using the area of a triangle equation as shown in EQN 4.5.7 and 6' as the calculated base,

$A=0.5*b*h,$ where b=6ft and h=D=1ft, area can calculated as $A=3ft^2$

Using **Peak Flow ($\mathbf{Q_p}$)** and the calculated **Area (A)** of 3 ft^2, the Continuity EQN 4.5.6, can be used to verify that the velocity in the level spreader channel does not exceed what can be sustained by vegetation, without causing erosion.

$Q = V*A,$ where $\mathbf{Q_p}$ **i**s used to determine the **Maximum Velocity ($\mathbf{V_{max}}$)** within the designed channel.

$$Q_p = V_{max}*A, \quad \frac{Q_p}{A} = V_{max} = \frac{6.8ft^3/s}{3ft^2} = 2.3ft/s$$

Since $\mathbf{V_{max}}$ is less than 4 fps, TRM is not necessary in the channel.

The channel and filter strip will be planted with bermudagrass sod. See the Vegetation section below for information on turf establishment.

Construction

Construction sequencing will ensure that water quality improvement is the primary function of the level spreader and grassed filter strip. Prior to construction, the designer should examine ground contours and specify that the level spreader be parallel to contours to minimize grading.

Existing Riparian Buffers: The designer should visit the site to confirm that the width of the level spreader and grassed filter strip system does not encroach on an existing riparian buffer or wetland areas.

Erosion and Sediment Control: The level spreader system should be protected from sediment deposition and runoff during construction to prevent erosion, compaction, and clogging of the system.

Compaction: Equipment should be operated outside of the proposed grassed filter strip to prevent compaction. Any compacted soil should be loosened to depth of at least 4" and sod should be installed on the filter strip.

Level Spreader Channel: Following completion of the grassed filter strip, the level spreader channel should be constructed according to the design depth.

Please review proper sediment control practices in the Alabama Handbook for Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas

(http://swcc.alabama.gov/pages/erosion_handbook.aspx).

Level Spreader Lip: It is recommended that the level spreader lip be constructed using concrete for long-term functionality. Earthen level spreader lips are erodible and likely to encourage vegetation growth on the lip, which inhibits sheet flow. Moreover, earthen and gravel lips often fail in urban settings.

Level Spreader: The level spreader should be cast in place using industry standards for concrete, and constructed on undisturbed soil whenever possible. Forms should be built to cast the level spreader. The top of the forms should be level and approximately 3" higher than soil downslope. The surface of the level spreader lip should be made level using a screed such as a wooden dowel or other tool. The level spreader should be allowed to set up overnight and should be protected during this process. Once forms are removed, the remaining level spreader channel configuration can be constructed.

Underdrain: An underdrain may be necessary under the level spreader channel and forebay if in-situ soil drainage is poor (<1"/hr). Underdrains are corrugated or smooth wall perforated pipe and should be configured to tie in with overflow or discharge into the stormwater conveyance network.

Forebay: Lastly, the forebay should be constructed, typically using a small excavator. Once the forebay is complete, the level spreader channel should be sodded.

Topsoil: If soils on site are poor and lack organic matter, topsoil can be added at a depth of 6" in the filter strip and on any other slope created by grading to aid in plant establishment. Topsoil can be harvested on site during construction or brought in from an external source.

Soil Testing: Prior to planting, a soil sample should be collected for a soil test to determine any fertilizer or lime requirements needed for plant establishment. The soil sample should be submitted to the Auburn University Soil Testing Laboratory or other comparable soil testing lab. The grassed filter strip may be fertilized at planting based on soil test recommendations, but should not be fertilized following initial fertilization as this can result in the export of nitrogen and phosphorus from the filter strip. For more information on soil test protocols, see http://www.aces.edu/pubs/docs/A/ANR-0006-A/ANR-0006-A.pdf.

Sod Installation: Similarly to grassed swales, grassed filter strips should be established using sod rather than seed. Sod should be cut fresh and installed as soon as it is delivered, preferably in the early morning before temperatures rise. Sod should be installed horizontally across a slope and the seams of sod should be alternated similar to a brick pattern to ensure stability and reduce erosion. Refer to the *Alabama Handbook for Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas* (http://swcc.alabama.gov/pages/erosion_handbook.aspx) for more information on sod installation. Sod may be harvested on site, temporarily stored in the shade, and kept evenly moist until planting.

Irrigation Systems: Irrigation systems should be calibrated (see Alabama Smart Yards Manual, Chapter 3) to minimize excess irrigation applications. A common mistake made during plant establishment is applying a small volume of water too frequently.

Vegetation

Vegetation for the level spreader channel and filter strip should be a dense coverage to be effective. Although not native, turfgrass is utilized because it is dense and fine textured, promotes diffuse flow when maintained at a low mowing height, can be sodded for quick cover, and is easy to maintain.

Turfgrass should be specified for the portion of the filter strip immediately following the run of aggregate (#57, #1, or designer preference). Warm season turfgrasses that actively grow during warmer months and are dormant during the winter are available in Alabama. Generally, turfgrass will not perform well under fully shaded conditions. As with other LID practices such as bioretention and grassed swales, turfgrass selected for grassed filter strips should be tolerant of brief flooding and most importantly, drought (See Table 4.5.2 for a Turfgrass List).

Turf Establishment: For June to September installation, newly planted turf should be irrigated at planting and watered daily for the first one to two weeks to keep it evenly moist. As the sod begins to grow new roots, irrigation frequency can be decreased, but a larger volume of water should be applied at each watering. Rainfall should be supplemented so that turfgrass receives about 1 – 1.5" per week from all irrigation sources. However, dormant plantings may benefit from irrigation during spring months when sod begins to produce new growth. Sod flourishes best when installed in the spring because this gives the turf an entire growing season to get established before the winter months arrive and the grass goes dormant. Sod will establish better when it is not going into or coming out of dormancy (i.e. not in late fall or late winter).

Table 4.5.2
Turfgrass List*

Name	Prefers	Drought Tolerance	Comments
Bermudagrass	Sun	Excellent	Tolerates foot traffic, spreads above and below ground, fast growth rate, use statewide
Centipedegrass	Sun to Part Shade	Good	Slow growing, sensitive to some herbicides (check label), may be susceptible to cold injury in North AL
St. Augustinegrass	Sun to Part Shade	Good	Spreads above ground, fast growing, can be sensitive to herbicides, most shade tolerant turf, use in Central and South AL
Zoysiagrass	Sun to Part Shade	Excellent	Use statewide, most cold tolerant of warm season turfgrasses, slow growing

*Adapted from Han and Huckabay, 2008a

Maintenance

Sediment Removal: Built up sediment can inhibit sheet flow by forming sandbars and dams throughout the filter strip or grassed channel. Sediment, trash, and debris should be removed twice a year from the level spreader channel, forebay, and vegetated filter strip. Accumulated sediment covers up vegetation, chokes it out, and results in plant die off.

Plant Maintenance: Dead plants should be replaced to maintain a consistent cover. Some areas may need to be re-sodded after accumulated sediment has been removed. Plants growing on the run of aggregate (#57, #1, or designer preference) and in the forebay should also be removed, as these can inhibit flow patterns.

Turf Maintenance: Grassed filter strips will require typical turfgrass maintenance including thatch removal and aeration (for more information on these activities, see Appendix D on Vegetation). Grassed filter strips should be kept at an even, low, dense growth where diffuse flow is desired. Turfgrass requires mowing at least once a month (every other week is better) during the growing season. A general rule of thumb is never to remove more than one third of the leaf during mowing. Turfgrasses such as bermudagrass respond well to frequent mowing. Mowing should not be conducted immediately following a rain event or when the ground is saturated to prevent ruts that can cause areas of compaction or re-concentration of diffuse flow.

Table 4.5.3
Maintenance Schedule

Task	How Often	Comments
Erosion Inspection	During and after major storm events (0.5” or greater) for the first 2 years, annually thereafter	Inspect for eroded areas and determine that flows are properly distributed into the filter strip, check for gulley formation in the channel and grassed filter strip.
Inspection	After 0.5” or greater rainfall event	Visually inspect all components including the level spreader lip, channel, and grassed filter strip for any damage.
Sediment and Trash Removal	At least annually, twice a year preferred	Remove deposited sediment, especially at inlet areas, such as the forebay, where it is most likely to collect, sediment should be removed annually or after a 2 yr 24 hr storm event.
Mowing of Turfgrass	Every other week in growing season	Mowing should be done more often during the growing season; dense low growing vegetation is best to maintain diffuse flow. Maintain at a height of 3 to 6”.
Thatch Removal	As needed	Thatch removal should be done when the thatch layer is ¾” or thicker and when grass is actively growing. For more information, see Appendix D on Vegetation.
Aeration	As needed	Core aeration is needed when turfgrass has become compacted and infiltration has slowed. Aeration should only be done following spring green up or when grass is actively growing in summer months.
Plant Removal	Annual minimum	Remove all plants growing on the level spreader lip, in the forebay, or in the run of aggregate stone downslope of the lip.

Pollutant Removal

Table 4.5.4
Grassed Filter Strip Pollutant Removal Table

Sediment	Nutrients		Metals	Pathogens
	N	P		
a.40%	30%	35%	No Data	No Data
b.50%	20%	20%	40%	No Data
c.50%	20%	20%	40%	Insufficient Data

a. NCDENR, 2007
b. City of Auburn, 2011
c. Georgia Manual, 2001

Level spreaders provide minimal pollutant removal, however, when paired with a grassed filter strip, these systems receive reductions in total suspended solids (TSS) and nutrients, such as nitrogen and phosphorus.

Vegetation: The grassed filter strip reduces pollutants through infiltration and filtration processes associated with plants and soil. Dense vegetation cover is expected to increase pollutant removal efficiency, which is why turfgrass is recommended for these practices.

Sedimentation: Grassed filter strips are more effective at reducing runoff velocities and TSS concentrations when stormwater enters from a water-spreading device such as a level spreader or flat surface that encourages sheet flow. When grassed filter strips are used as a stand alone SCM, they reduce TSS loads because their primary pollutant removal mechanism is sedimentation. As sediment drops out, other pollutants attached to sediment particles, such as phosphorus and metals, are removed. Pollutant removal relies heavily on slowing the velocity of stormwater in the filter strip to facilitate sedimentation. Sedimentation has been noted to increase with increasing filter strip widths. Although an average of 25 to 30' is recommended for filter strips, longer strips are likely to have higher pollutant removal efficiencies.

References

City of Auburn Stormwater Management Design Manual. 2011

Georgia Stormwater Management Manual. 2001.

Han, David and Ellen Huckabay. 2008a. Selecting turfgrasses for home lawns. Alabama Cooperative Extension System, ANR-92.

Han, David and Ellen Huckabay. 2008b. Bermudagrass lawns. Alabama Cooperative Extension System, ANR-29.

Hathaway, Jon M. and William F. Hunt. 2006. Level Spreaders: Overview, Design, and Maintenance. North Carolina Cooperative Extension. AGW-588-09.

Hathaway, Jon M. and William F. Hunt. 2008. Field evaluatation of Level Spreaders in the Piedmont of North Carolina. Journal of Irrigation and Drainage Engineering. Jul/Aug issue. 538-542.

Knight, E.M.P., W.F. Hunt, and R.J. Winston. 2013. Side-by-Side Evaluation of Four Level Spreader-Vegetated Filter Strips and a Swale in Eastern North Carolina. Journal of Soil and Water Conservation (In Press - March/ April 2013)

Lee, K. H., T. M. Isenhart, and R. C. Schultz. 2003. Sediment and Nutrient Removal in an Established Multi-Species Riparian Buffer. Journal of Soil and Water Conservation. 58(1): 1.

Minnesota Pollution Control Agency. 2000. Protecting Water Quality in Urban Areas. Saint Paul, MN.

North Carolina Department of the Environment and Natural Resources. 2007. Stormwater Best Management Practices Manual, Ch 8: Level Spreaders (Chapter revised 2010). North Carolina Division of Water Quality, Raleigh, NC.

Winston, R. J. and W. F. Hunt. 2010. Level Spreader Update: Performance and Research. North Carolina Cooperative Extension. AGW-588-21W.

Winston, R. J., W. F. Hunt, W. G. Lord, and A. C. Lucas. 2010. Level Spreader Update: Design, Construction, and Maintenance. North Carolina Cooperative Extension. AGW-588-20W.

Yu, S. L., M. A. Kasnick, and M. R. Byrne. 1993. A Level Spreader/Vegetated Buffer Strip System for Urban Stormwater Management. In Integrated Stormwater Management, ed. R. Field, O'Shea. M. L., and Chin, K., Boca Raton, FL, Lewis Publishers.

Rainwater Harvesting (RH)

Cistern at Little River Canyon; Mentone, AL

Synonyms: Rooftop runoff management, stormwater collection system

Rainwater harvesting is the collection of rainwater for reuse, typically from a rooftop, and can be used as a form of rooftop runoff management to reduce runoff from impervious surfaces. Rooftop systems typically collect stormwater through a connection to a rain gutter system. Rainwater harvesting systems may be above or below ground systems and can be large or small depending on the site, application, and intended use. When designed and used properly, these systems are an excellent way of saving water, energy, and money.

Rain barrels: Rain barrels are systems used for small-scale applications such as residential areas.

Rain barrels are generally 50 – 60 gallons and can be connected to one another to collect larger volumes of water. Rain barrels work well for a residential homeowner as a stormwater collection system, but due to their limited volume collection, rarely contribute to sizeable watershed-wide runoff reductions. However, targeted promotion of rain barrel use raises awareness of stormwater runoff issues, and can also help homeowners to reduce localized stormwater runoff issues and erosion in their yards.

Cisterns: Cisterns are larger storage tanks that are better suited to commercial or agricultural settings where large volumes of water need to be collected.

Cisterns are discussed in this handbook and can be used above or below ground to collect rainwater and store it for later use. Cisterns may range from less than 100 gallons to over 10,000 gallons in size and the water is intended for non-potable water uses. Water collected by these systems may be used for flushing toilets, irrigation, vehicle washing, and laundry. It is recommended that the harvesting system be labeled and identified as non-

Site Selection

Quantity Control	✔
Drainage Area	small
Space Required	small-med

Works with:

Steep Slopes	---
Shallow Water Table	✔
Poorly Drained Soils	✔

General Significance

Construction Cost	med
Maintenance	med
Community Acceptance	med-high
Habitat	---
Sun / Shade	---

More information about rain barrels can be found on the Alabama Rain Barrel Project page at www.alabamarainbarrelproject.com.

Connected Rain Barrels Capture More Rainwater; Auburn, AL potable water to prevent any confusion and to deter anyone from consuming collected water.

Large cisterns typically need to be purchased directly from a supplier, and due to their size and weight, freight charges can be costly.

Site Selection

Above Ground Cisterns: Above ground cisterns are easier to install and maintain, are comparatively less expensive, but can be regarded as unsightly.

Below Ground Cisterns: The primary benefit of a below ground cistern is that it is out of sight and does not take up valuable land. However, below ground cisterns require the addition of a pump, can be harder to maintain after installation, and are generally more difficult to install because they require excavation and significant structural support. Underground cisterns should not be sited adjacent to buildings due to intensive construction and excavation during installation, which can damage foundations.

Downspouts: The cistern should be located near gutter downspouts to make installation modifications easier.

Evaluating Soils: Use the USDA Web Soil Survey to identify soil map units and to make initial interpretations for potential uses and limitations of a site. However, since most soil map units have inclusions of other soils that may be quite different, detailed evaluations should be made at the proposed site by a professional soil scientist or soil classifier. On-site evaluations should properly identify a soil or the hydrologic soil group (HSG) and the final decision for use should be made based on the detailed determination of soil series or HSG. For a detailed list of HSG properties, see Table A.3 in Appendix A on Stormwater Hydrology.

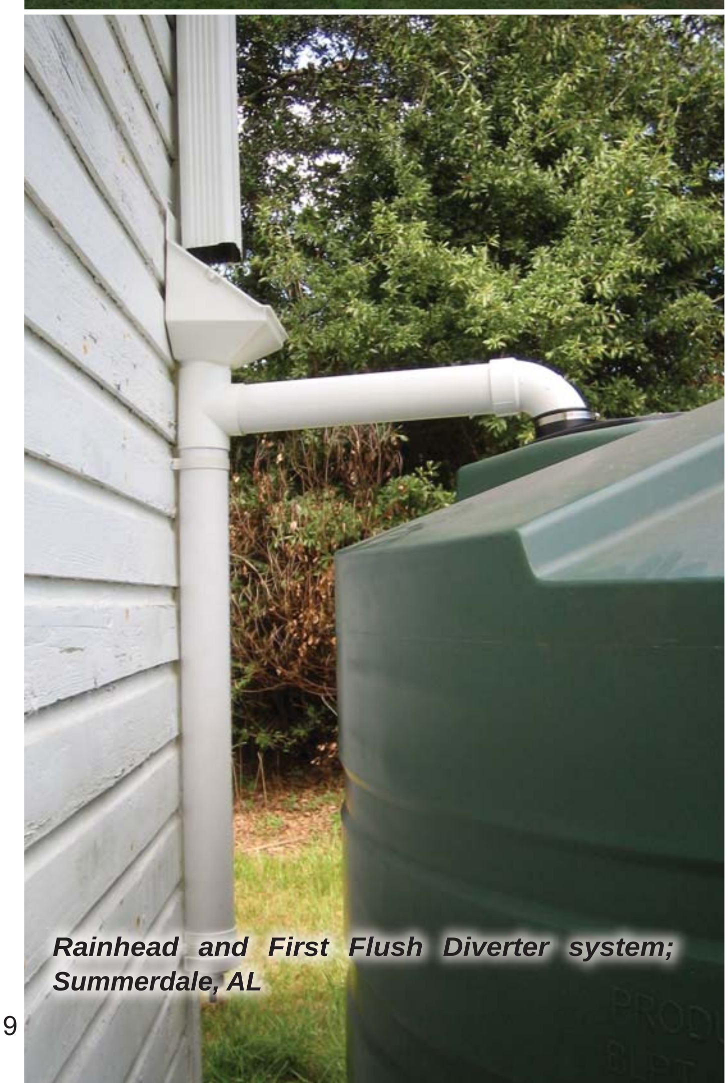
In-situ Soils: Cisterns should not be sited where underlying soils are unstable.

Underground Utilities: Cisterns should not be sited over underground utilities or septic systems.

Water Use: Cistern location should also be in the vicinity of where the harvested rainwater will be used; this will alleviate the need to transport water over long distances.

Call 811 to locate utilities before you begin any type of excavation (www.al1call.com)

Rainwater Harvesting System at Boykin Community Center; Auburn, AL



Rainhead and First Flush Diverter system; Summerdale, AL

Design

It is important that cisterns are designed to capture the correct volume of stormwater for on-site needs and the available collection area. When harvested rainwater goes unused, cisterns overflow and can no longer reduce runoff or collect stormwater.

Components

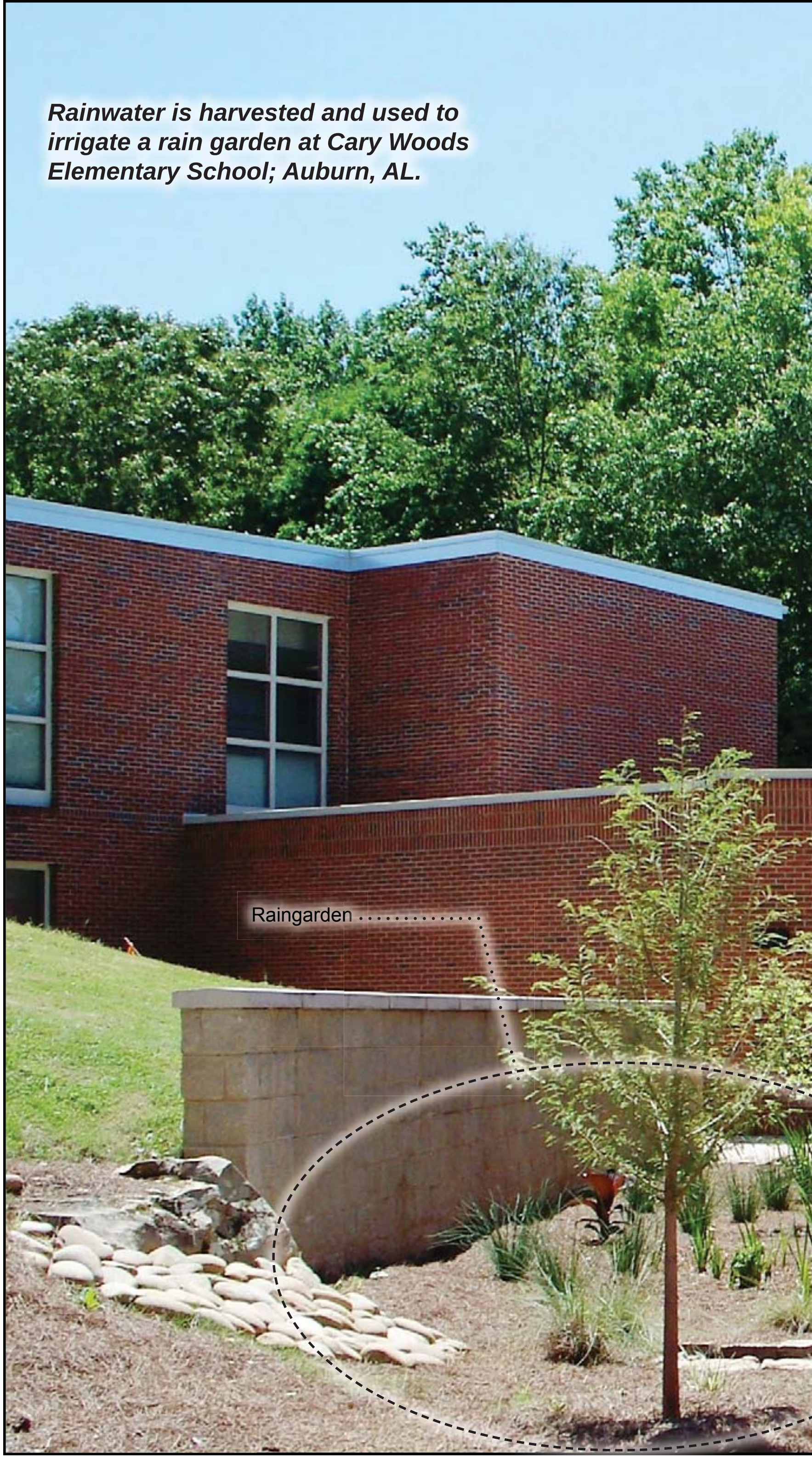
First Flush Diverter: A first flush diverter is a pretreatment device designed to collect and dispose of the first inch of runoff from a rooftop system. The first inch of runoff has the highest concentration of pollutants from atmospheric deposition and other contaminants collected in the runoff process. Once capacity is met, a valve closes to allow the remaining runoff to move through the routing system and into the cistern. In many cases, the first flush diverter valve is made up of a ball and choked section of pipe. The first flush chamber fills, which causes a ball to float and restrict flow into the first flush chamber. The collected water is slowly released from a check valve at the bottom of the chamber. The rate at which the first flush is released is determined by the size of the check valve opening. The diverter should discharge to a stormwater control measure (SCM) or vegetated area for treatment. First flush diverters are especially beneficial when rainwater collected is to be used to irrigate edible plants or crops.

Rainheads: Rainheads can be attached to the gutter system to filter debris before water enters the cistern. These devices have mesh screening so that water passes easily through them, while blocking leaves and other particulate matter. The mesh screening sits roughly at a 45° angle so that debris can be easily discarded to the ground. Incorporating a rainhead can help to reduce cistern maintenance. Rainheads are also useful for the prevention of mosquitoes when 1 mm or smaller screen is used.

Cistern: Cisterns are made of hard plastic, galvanized metal, concrete, or fiberglass. White or light colored cisterns are not recommended due to their propensity to foster algae growth, however, these can easily be painted. Cistern selection should be based on material, size, and whether it will be located above or below ground. Plastic cisterns are lightweight, aesthetically appealing, have minimal assembly, and any modifications can be made using standard tools. Metal cisterns are usually constructed of corrugated or galvanized metal, are commonly made from discarded grain bins, and may require an internal waterproof bladder to minimize leaks.

Structural Support: Gravel, concrete, or stone foundations are recommended as structural support of cisterns especially in situations where underlying soils cannot support the weight.

Underground Cisterns: Underground cisterns will most likely require anchoring by backfilling sand or gravel



Rainwater is harvested and used to irrigate a rain garden at Cary Woods Elementary School; Auburn, AL.

Rainhead clean of debris

around the cistern.

Overflow: As the cistern reaches capacity, it will need a mechanism to release excess water collected. The overflow should accommodate the same flow rate as the gutter system, which is a 100 year, 1 hour storm event. For Alabama, this can range between 3.25” to 4.5” of rain depending on location within the state (see Appendix A on Stormwater Hydrology for more information). It is recommended that the cistern be sized such that overflow is no more than 14% of annual average historical rainfall. Overflow is ideally directed into another SCM, but should always discharge to a vegetated or natural area, not to an impervious surface where it will create more runoff. As a general recommendation, overflow pipes for 1000 ft^2 of rooftop should be a minimum of 2.5” diameter and rooftops > 3000 ft^2 should have overflow pipes with a minimum diameter of 4”.

Outlet: A faucet or outlet pipe should be installed at the bottom of an above ground cistern so that water can be easily retrieved. The outlet should be approximately 6” from the bottom of the cistern to allow for sediment collection in the cistern base. A bulkhead fitting should be installed to prevent leaks since the faucet will experience high water pressure. The bulkhead fitting should be installed from the inside of the cistern and for this reason, it is generally cost effective and safer for the cistern vendor to install it.

EQN 4.6.1

$$V_{req} = SA_{roof} * R_d$$

SA_{roof} = Surface area of roof or flat plane (ft^2)

R_d = Rainfall depth (in) or 1-yr storm event

EQN 4.6.2

$$V = V_{req} * FoS$$

Gutters: Larger quantities of water can be collected when multiple downspouts contribute to the cistern. In this case, some gutters may need to be piped to the cistern. If piping is not an option, gutters can be tied together and directed to a single downspout. However, this can lead to structural failure and unintended overflows during heavy storms.

Pumps: The addition of a pump will help draw water from the cistern and can increase utilization in cases where constant pressure is needed. If the cistern is housed below ground, it will require a pump to move the water. Recommended pumps for cisterns are usually low-head and high-flow centrifugal pumps. These pumps are generally inexpensive, available in various flow rates and heads, and are easy to install. The pump should be submersed in the bottom of the cistern to make the priming process easier.

Pump Selection: A pump should be selected based on the flow rate and total head desired. The flow rate is the rate at which the water moves through the pipe and it is usually expressed in gallons per minute (gpm). Total head is the amount of energy needed to push the water through the pipe and is measured in pounds per square inch (psi).

Secondary Water Supply: A secondary water supply may be set up to provide supplemental water to the system during drought conditions, if desired for irrigation.

Design Guidance

The design calculation of a rainwater harvesting system volume is quite simple. Additional design will be required if the system is underground (e.g. buoyancy calculations are needed) and may be necessary for overflow sizing, pump sizing, and irrigation purposes.

The **cistern volume required (V_{req})** to capture rooftop runoff can be estimated using EQN 4.6.1.

Often a **factor of safety (FoS)** is also added to the equation to ensure critical volumes are captured. A **FoS of 1.2** is suggested.

Maintenance

Sediment and Debris: The most common maintenance concern is keeping debris and sediment out of the cistern. Roof maintenance is imperative to minimize sediment and debris loads such as roof shingle particles from entering the cistern. It is important to maintain gutters to minimize debris entering or clogging the inlet of the cistern. Sediment will build up in the bottom 6” of the cistern, and may need to be cleaned out after a few years. A valve can be installed at the cistern base to regularly drain away built up sediment.

Rainhead: Use of a rainhead will aid in reducing sediment and debris in the cistern and the rainhead should be cleaned periodically so that flow into the first flush diverter and cistern is not inhibited. Mosquito screens should also be cleaned of blocked debris, especially during warm weather conditions when mosquito breeding is likely to occur.

First Flush Diverter: The first flush diverter may clog and cause water to remain in it for long periods of time. As this occurs, it may be necessary to remove the bottom portion of the diverter and discard any built up debris.

Pump: Check pump function regularly and perform any pump maintenance based on the manufacturer’s recommendations.

Safety: The cistern should never be entered for any type of maintenance due to risks associated with drowning and toxic gas exposure.

Table 4.6.1
Maintenance Schedule

Task	How Often	Comments
Clean Out First Flush Diverter	Routinely	Should be performed regularly, preferably after each rainfall event.
Clean Rainhead	Routinely	Should occur frequently to prevent clogging.
Inspection of Gutter Connections	Quarterly or after heavy rainfall events	Check for any damage and remove any trash or vegetation debris.
Unclog Gutters	Routinely	When gutters become clogged, water may back up and inhibit flow into the cistern. Gutter screens can be installed to prevent future clogging.
Check System for Clogging	When unnecessary overflows occur	The system may be clogged when the cistern overflows following a rain event less than or equal to the design rainfall.
Inspection	After 0.5” or greater rainfall event	Visually inspect all components of the rainwater harvesting system for damage or clogging. This is especially important for any pipes or gutters used in the system.
Sediment Removal from Cistern	Every 3 years or as needed	Remove sediment from the bottom 6” of the cistern.

Pollutant Removal

Rainwater harvesting can reduce flooding and stream erosion problems due to the reduction in stormwater volume entering stormwater conveyance networks. The cistern captures rooftop runoff that contains nutrients from rain and atmospheric deposition, which aids in reducing nonpoint source pollution.

References

Hunt, W.F. and L.L. Szpir. 2006. Permeable Pavements, Green Roofs, and Cisterns. North Carolina Cooperative Extension. AG-588-06.

Jones, M. P. and Hunt, W.F. 2006. Choosing a Pump for Rainwater Harvesting. North Carolina Cooperative Extension. AG-588-08.

Jones, M. P. and Hunt, W.F. 2008. Rainwater Harvesting: Guidance for Homeowners. North Carolina Cooperative Extension. AGW-588-11.

North Carolina Department of the Environment and Natural Resources. 2007. Stormwater Best Management Practices Manual, Ch 19: Rooftop Runoff Management. North Carolina Division of Water Quality, Raleigh, NC.

North Carolina Division of Water Quality. 2008. Technical Guidance: Stormwater Treatment Credit for Rainwater Harvesting Systems. North Carolina Division of Water Quality, Raleigh, NC.

Texas Water Development Board. 2005. The Texas Manual on Rainwater Harvesting. 3rd Edition. Texas Water Development Board, Austin, TX.

Green Roofs (GR)

Green roof at UAB Hulsey Center; Birmingham, AL

Site Selection

Quantity Control	possible
Drainage Area	small
Space Required	med-large

Works with:

Steep Slopes	---
Shallow Water Table	---
Poorly Drained Soils	---

General Significance

Construction Cost	high
Maintenance	med
Community Acceptance	high
Habitat	low
Sun / Shade	sun to p. shade

Synonyms: Vegetated roof cover, vegetated roof tops, roof gardens, landscaped roofs, eco-roofs, living roofs

Green roofs are landscaped roofs that use a specialized growing substrate, storage, drainage mat, and vegetation that is tolerant of extreme climates experienced on rooftops. Green roofs mitigate stormwater runoff, reduce the heat island effect of impervious surfaces from rooftops, extend roof membrane life, conserve energy, reduce noise and air pollution, provide wildlife habitat in urbanized settings, and improve fire resistance of buildings. These systems have been used in Europe for decades and are becoming more prevalent in the U.S. as stormwater retention practices that provide aesthetic value. As a stormwater control measure (SCM), green roofs are more effective at reducing runoff volumes resulting from small storms rather than providing pollutant load reductions from impervious surface runoff.

Long-term Investment: Green roofs are considered a long-term investment because they are one of the most expensive structural low impact development (LID) practices per square foot to construct. Depending on the depth of substrate and volume of runoff retained, vegetated roofs can be quite heavy. Construction alone is considered an expensive capital cost when building structure reinforcement is needed. Although green roofs are an expensive practice, the layer of vegetation and substrate protect the roof membrane from ultraviolet (UV) radiation and harsh temperatures, and can extend the lifespan of roofing membranes. In the absence of green roofs, roofing membranes experience sharp temperature fluctuations causing them to expand and contract, resulting in damage and eventual replacement. Data from Europe have shown green roofs to double the life span of roofing membranes.

Table 4.7.1
Site Selection: Constraints and Limitations for Green Roofs

Constraint	Recommendations
Water Quality	If pollutant load reductions are the primary objective, use another practice.
Slope	A roof slope of 8% or less is recommended and flatter slopes work best
Limited Volume Control	Green roofs may have reduced capacity for large quantity retention. No curve number (CN) is assigned and Discrete Curve Number Method cannot be used.
Roof Pitch	Pitches greater than 1:12 do not function for water quantity treatment
Building Code	State and local building codes may prevent retrofit or use of green roof

Site Selection

Footprint: Green roofs have been used on industrial, commercial, and residential rooftops. The installation of a green roof is well-suited to ultra-urban areas because it offers stormwater benefits and ecosystem services, but does not result in any additional land usage.

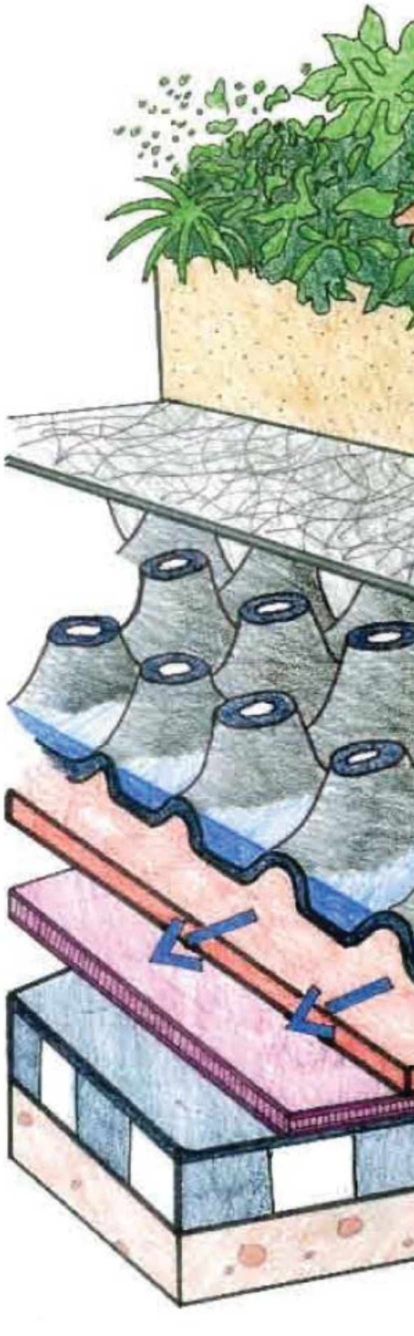
Slope: The ability of a green roof to retain rainwater will decrease with increasing roof slope, typically flat roofs are used for green roofs. A roof slope of 8% or less is recommended when green roofs are planned for water quantity or potential water quality benefits. Green roofs at < 2% slope are not recommended because of poor drainage resulting in standing water that can damage vegetation and increase the need for structural support.

Retrofits: Not all retrofit applications will require structure reinforcement, and it is critical to consult with a structural engineer to determine this early in the planning process. Most flat-roofed buildings can bear the load of an extensive green roof retrofit. Building height, location, sun exposure, and wind exposure should all be considered when planning a green roof installation or retrofit. Surrounding buildings may shade the green roof surface and this has the potential to impact vegetation selection and evapotranspiration rates. A shaded green roof retains water for longer periods of time and could result in stress to the building structure because of heavy, water-soaked substrate.

Common Green Roof Variations

Intensive Green Roofs: Intensive green roofs are similar to landscapes found at ground level. Intensive green roofs have a substrate depth usually > 8” and can support a diverse plant community with deeper root systems. Although intensive green roofs are generally more attractive due to their garden-like appearance, they are also more expensive and require the building to support the increased weight of the substrate depth. Maintenance tends to be more expensive for this type of green roof due to overall aesthetics and maintenance required by the diverse plant community. Intensive green roofs can be designed to accommodate foot traffic and used as an outdoor space with garden paths throughout. Visitor access not only makes aesthetics an important amenity, but also means that safety concerns should be addressed early in the design process. Extreme temperatures of green roofs can be a hazard for humans using it as a recreational space.

Extensive Green Roofs: An extensive green roof installation is more common because it is ideal for retrofits and less expensive. An extensive green roof system requires less structural support because its substrate depth is usually < 8”. The typical substrate depth ranges from 3 – 5” thick with 4” of substrate recommended in the Southeast. Extensive green roofs offer all the environmental benefits associated with intensive green roofs but are designed to be low maintenance and do not usually allow public access. These systems can provide undisturbed habitat for insects, birds, and microorganisms because access is limited.



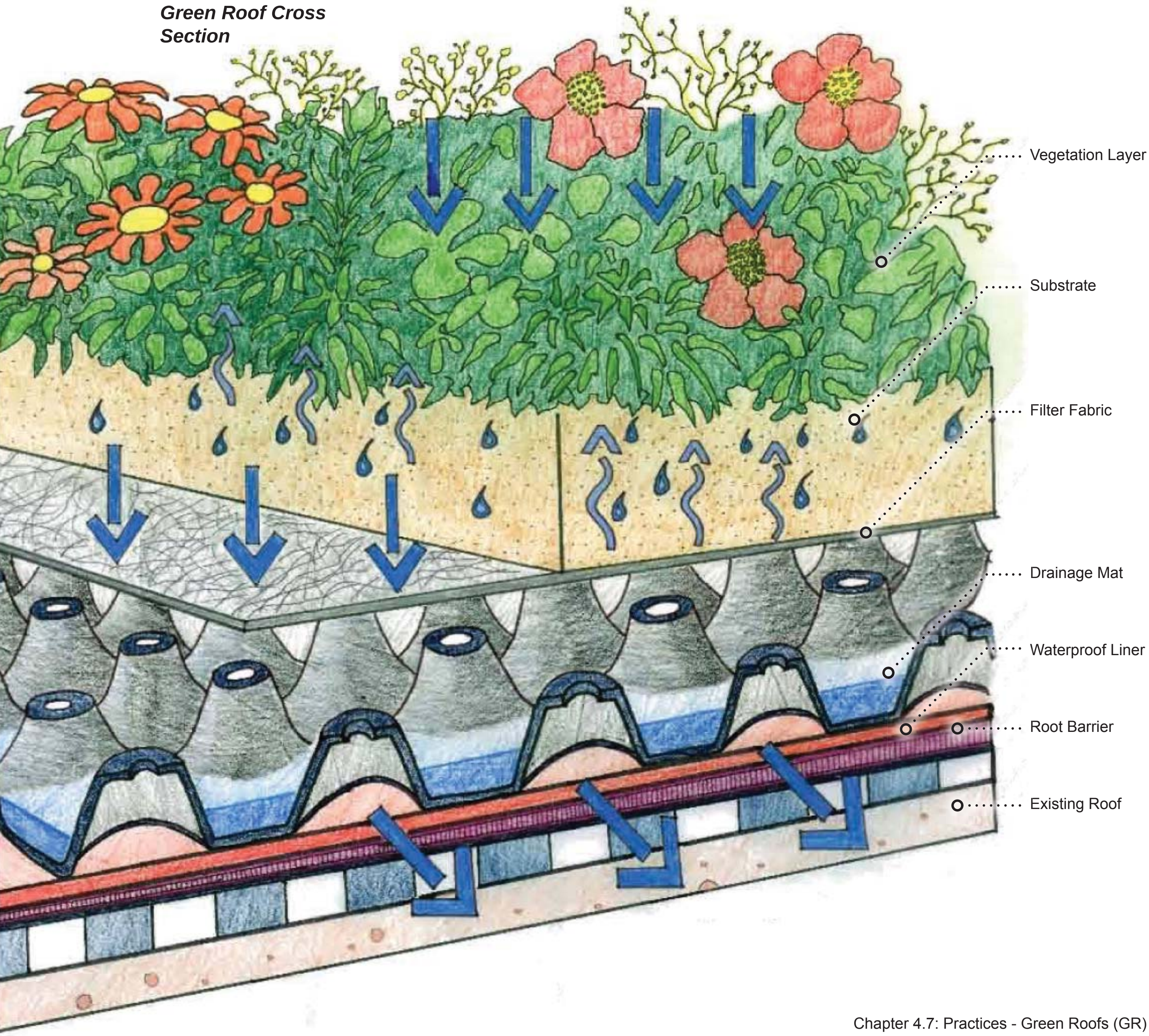
Design

This handbook focuses on the design and construction of extensive type green roofs due to its growing popularity and decreased costs.

Components

Substrate: A green roof substrate should be relatively lightweight, retain nutrients for plant growth, and be persistent. Topsoil should not be used as a green roof growing medium because it is too heavy and remains too wet. The substrate should be composed of a lightweight mineral compound such as shale, slate, clay, or terra cotta. The substrate should hold approximately 40 to 60% water by weight and have a bulk density (dry) range of 35 to 50 lb/ft^3. Though vegetation roots and shoots intercept rainfall, the substrate should manage the release rate of stormwater. A target water holding capacity of 40 to 60% is ideal for plant survival and to release and drain enough water to maintain the appropriate weight on the building structure. Capture volumes ranging from 0.5” to 1.2” have been reported on several green roofs.

Green Roof Cross Section



Substrate Depth: Substrate depth is largely based on local climate and precipitation patterns. Although research out of Michigan shows substrate depths of at least 2.75” can successfully support succulents and provide adequate coverage, 4” of substrate is recommended in Alabama to support succulents and perennials. It should also be noted that when irrigation is installed, decreased substrate depths have been successful.

Substrate Organic Matter: Organic matter in the substrate should be 15% or less. High organic matter components are not recommended because of increased decomposition resulting in substrate shrinkage. Substrate replacement is expensive and not practical, therefore, the substrate components should have minimal decomposition rates.

Fertilizer: Some fertilization is needed for plant establishment, however too much can result in nutrient leaching and increased levels of nutrients in stormwater runoff. Controlled release fertilizers (CRF) have shown to be effective for plant establishment at rates as low as 3.5 oz per 20ft^2 (13N-6P-11K).

Compost: Other research has utilized low rates of compost (up to 20%) in the substrate mix to provide nutrients and organic matter. High rates of compost in green roof substrate may leach nitrogen and phosphorus, which can be problematic in nutrient-sensitive watersheds. Future research at the University of Alabama at Birmingham is planned to analyze water quality impacts associated with the use of both compost and fertilizer.

Filter Fabric: A layer of geotextile filter fabric is placed between the substrate and drainage mat. The filter fabric protects the drainage mat by preventing the substrate from clogging it and deterring root growth into the mat and roof surface.

Drainage Mat: The drainage mat, layer, or net prevents water from ponding by conveying it off the roof to protect and preserve the roof surface. Rapid drainage of the substrate will reduce the weight of the green roof. The drainage mat selected should adequately drain the roof from the design storm. Drainage mats should drain at a rate of 15 gal/min/ft or higher.

Membrane/Waterproof Liner: The impermeable roof membrane is made of tar or another waterproofing liner that creates watertight conditions between the drainage mat and the building structure. This layer is similar to conventional roofing liners. If the membrane contains organic matter, there is danger of roots penetrating it and eventually growing into the underlying structure.

Design Guidance

It should be noted that the design presented in this handbook is limited for Green Roofs because of structural standards that limit their application. A licensed structural engineer should be consulted to verify the use of a Green Roof. Structural upgrades can be cost-prohibitive to a project.

Roof Weight: Green roof weight should be considered during the design process. The weight of saturated media, live or dead loads, and any snow accumulation should be scrutinized to ensure that structural support requirements are met. Dead loads for green roofs consist of the substrate, drainage mat, and water in the pore spaces. These loads must meet state and local building codes. The State of Alabama conforms to the International Building Code (IBC). Under IBC Table 1607.1, roofs used for gardens or assembly purposes must be designed for a 100 pounds per square foot (psf) uniform live load. The substrate used must have the capacity for rainfall retention and balance runoff retention with loading (weight).

1. Calculate Runoff Volume

The Discrete Curve Number Method cannot be used because a curve number has not been specified for green roofs.

However, the Simple Method can be used to calculate the volume of water necessary for water quantity and volume reduction. The Simple Method uses two equations (EQNs 4.7.1 and Y.2) to calculate the runoff coefficient.

Typically, when calculating the **runoff coefficient (R_v)**, **impervious fraction (I_a)** is determined as the impervious area divided by total area. However, in this case, the **impervious fraction (I_a)** is 50% of the impervious fraction for a standard roof and this is a standard assumption for green roof design.

Once the **runoff coefficient (R_v)** is calculated, it

EQN 4.7.1

$$Q = CiA$$

C = Runoff coefficient
i = Rainfall intensity (in/hr)
A = Watershed area (ac)
Q = Peak flow (ft^3/s)

EQN 4.7.2

$$R_v = 0.05 + 0.9 * I_a$$

R_v = Runoff coefficient
I_a = Impervious fraction

EQN 4.7.3

$$V = 3630 * R_d * R_v * A$$

V = Peak runoff volume (ft^3)
R_d = Design rainfall depth (in)
R_v = Runoff coefficient
A = Rooftop area (ft^2)

can be used in EQN 4.7.3 to determine the **total runoff volume (V)**.

The hydrologic properties specific to the substrate or growing medium are used to determine the capacity for rainfall retention. Porosity, moisture content at field capacity, moisture content at wilting point, and saturated hydraulic conductivity (K_{sat}) are all needed to determine water retention and the rational runoff coefficient.

R_d is the design rainfall depth (in), R_v is the rational runoff coefficient (in/in), and A is area in acres.

Forty percent by weight or greater retention is needed to intercept and retain the water quality storm event. This characteristic is imperative for peak attenuation. A runoff hydrograph and numerical modeling can be approximated using these properties. For storms larger than the design storm, runoff will occur and downspouts should be designed accordingly.

Construction

Check Membrane: Prior to installation, the water-proofing membrane should be checked to determine that it is leak-free. Although this may be a time-consuming task, it should be done as a preventative maintenance measure. If leaks to the membrane are found following installation, complete vegetation and substrate removal may be required to mitigate leaks.

Preventing Root Penetration: Membranes or waterproof liners specific for green roof applications should contain a root deterrent chemical or metal foil at membrane seams. Although not required, a copper-based root retardant can also be included in the filter fabric to prevent root growth beyond the substrate layer.

Irrigation: Irrigation should be installed for plant establishment and periods of extreme drought. Hand watering or overhead irrigation has been used effectively during plant establishment, but irrigation for seasonal drought conditions should use micro-irrigation emitters. Soil moisture probes or sensors can be an inexpensive investment for the irrigation system and they ensure that irrigation only occurs during extreme drought conditions.

Roof Access: Frequent roof access will be necessary for inspection and maintenance operations following installation. Substrate loading and unloading or plant replacement to and from the rooftop surface may be labor intensive. Exterior or interior elevators are helpful to carry materials to the roof. A blower truck or shingle lift can be used for 1 – 3 story buildings.

Safety: Safety can be a concern both during construction and after installation due to the possibility of a fall. Safety issues may include high temperatures, being trapped on the roof, and decreased roof structure integrity causing injury.

Vegetation

Plant Characteristics: Vegetation suggested for extensive green roofs are native perennials, grasses, or succulents. Plants for these systems are typically low growing, establish quickly, and are cold, heat, and drought tolerant. Vegetation selection can be difficult due to decreased rooting depth available to plants. Green roof plants that are readily established, spreading, and propagate easily have shown to be successful. Annual and perennial plants can be used, although perennial plants are preferred as the sustainable choice. Other preferred characteristics include persistent plants that are long-lived, self-propagate, or reseed themselves.

Stress Tolerance: Selecting plants for green roofs can be difficult due to the extreme weather conditions experienced on a rooftop. Required stress tolerances results in vegetation that is low-growing, compact, mat-forming, tough foliaged, and any other characteristics that allow plants to efficiently avoid drought. Most green roof vegetation will need to tolerate mildly acidic and poor soil conditions present in the growing substrate.

Irrigation: Irrigation of extensive green roofs is not required, but irrigation has proved effective in aiding in plant establishment as well as plant survival during periods of long-term drought. The initial cost of irrigation system installation is usually less than replacing vegetation.

Plant Placement: Vegetation near gutters and downspouts may remain wet for longer periods of time and should include plants that are tolerant of extended wet conditions. A horticulturist or landscape architect should be consulted for specific vegetation recommendations.

Examples of Green Roof Vegetation at the University of Alabama at Birmingham; Birmingham, AL

Additional Vegetation Design Guidelines

- Areas of the green roof that will remain wet or dry for longer periods of time should be planted with the appropriate species for these conditions.
- The nursery or plant supplier should be contacted prior to green roof design to determine species and quantities that are available.
- Although native species are preferred for LID practices, a mixture of nonnative succulents and native perennials may be necessary to ensure adequate coverage.
- Follow plant label instructions for spacing recommendations.
- Succulents appear to be more suited to extensive green roof environment, but native perennials and grasses can be used in conjunction to provide aesthetic appeal.

Table 4.7.2
Green Roof Plant List*

This is a suggested plant list for green roofs in Alabama.

Botanical Name	Common Name	Native	Habit	Seasonal Irrigation
Antennaria plantaginifolia	pussytoes	yes	perennial	yes
Coreopsis auriculata	mouse-ear tickseed	yes	perennial	yes
Elymus hystrix	Eastern bottlebrush grass	yes	grass	yes
Phemeranthus calycinus	limestone fameflower	yes	perennial	yes or no
Phlox bifida	starry glade phlox	yes	perennial	yes
Sedum album ‘Jellybean’	‘Jellybean’ white stonecrop	no	succulent	yes or no
Sedum album ‘France’	‘France’ white stone-crop	no	succulent	yes or no
Sedum kamtschaticum	orange stonecrop	no	succulent	yes
Sedum rupestre ‘Angelina’	‘Angelina’ stonecrop	no	succulent	yes or no
Sedum spurium ‘Fuldaglut’	‘Fuldaglut’ two-row stonecrop	no	succulent	yes or no
Viola egglestonii	Eggleston’s violet	yes	perennial	yes

*Adapted from Price et al., 2011

Maintenance

Access: Maintenance can prove difficult simply due to the location of the practice. Access to the roof is imperative and walkways or paths for maintenance purposes are recommended for ease of plant inspection, weeding, or irrigation system maintenance.

Vegetation Maintenance: Plant maintenance is expected since the majority of the green roof will be covered by vegetation. Dead plants should be removed and replaced during early spring. Dead vegetation should remain over winter months as cover for the roof before being replaced in the spring. Most vegetation for green roofs will undergo winter dormancy, but should experience bud break when temperatures warm. Maintenance professionals and horticulturists can assist in determinations of whether plant replacement is necessary.

Troubleshooting Roof Ponding: Because the green roof is designed to retain stormwater, leaks are possible and may be challenging to repair. If ponding occurs on the substrate surface, the source of ponding should be quickly determined. Substrate or surface ponding can damage vegetation through extended saturation that may promote fungal growth and plant dieback. In addition, sediment tends to collect in the outlet causing it to clog and should be periodically cleaned out to avoid roof flooding. Ponding may also occur due to clogging of the gutters or drainage layer. Complete substrate removal and replacement should be a last resort and only occur when all other ponding causes have been refuted.

Table 4.7.3
Maintenance Schedule

Task	How Often	Comments
Inspection of Green Roof	Once a quarter	Inspections should be made once a quarter or within 24 hours following a 0.5” or greater rain event. This is especially important during plant establishment.
Inspect Outlet for Sediment and Debris	As Needed	Drainage spouts, gutters, and other components of the roof drainage system should be cleaned out as debris appears. If clogged, the substrate can remain too wet and damage vegetation.
Inspect for Weeds	Every Two Weeks Until Establishment, Then Twice a Year	Vegetation should be inspected for weeds and if present, weeds should be removed by hand. Weeding is most important during plant establishment and should be done every two weeks to minimize plant competition.
Inspect Vegetation	Weekly then 2 or 3 times per year	Inspect vegetation for insects or disease. Replace dead plants at the appropriate time of year (early spring for sedum).
Irrigation	During plant establishment and periods of drought	Weekly inspections are necessary to determine the need for supplemental irrigation.

Pollutant Removal

Practice Pairing: Currently, green roofs are not considered a stand-alone water quality practice primarily because there are not documented reductions in nutrients and other pollutants. However, routing green roof discharges into other structural SCMs such as bioretention has the potential to provide both water quantity and quality treatment.

Retention: Green roofs can be utilized to effectively decrease runoff and peak flows through the retention of stormwater. Rooftop runoff can be even further reduced through evapotranspiration, especially during small storms when the majority of rain absorbed is released back into the atmosphere. Discharge or runoff from the green roof should occur only when the growing medium or substrate has reached field capacity.

Nutrient Leaching: Higher percentages of compost in the substrate can lead to nutrient leaching. Even with low rates of 15% compost, both nitrogen and phosphorus have been leached and were significantly higher compared to rainfall from a conventional rooftop. It is possible that determining the ideal recipe or formula for the growing media could eventually result in water quality benefits or at the very least, a leveling off of nutrient leaching.

Energy Use Reduction: Besides retention of stormwater, green roofs can also provide other benefits. A reduction in energy consumption is provided because green roofs insulate the building through the use of vegetation and substrate that dissipates solar radiation to buffer temperature extremes. Green roofs cool through an increase of reflectivity, or albedo. Heat reduction can be high as 70 – 90% during the summer. Energy savings may be even greater for retrofitted green roofs on buildings that have poor insulation.

Noise Reduction: Green roofs also reduce external noise; five inches of green roof media can reduce noise from building surroundings by 40 decibels.

References

Castleton, H.F., V. Stovin, S.B.M. Beck, and J.B. Davidson. 2010. Green Roofs: Building Energy Savings and Potential for Retrofit. Energy and Buildings. 42: 1582-1591.

Getter, K. L., D. B. Rowe, J. A. Anderson. 2007. Quantifying the Effect of Slope on Extensive Green Roof Stormwater Retention. Ecological Engineering. 31 : 225-231.

Getter, K.L. and D. B. Rowe. 2006. The Role of Extensive Green Roofs in Sustainable Development. HortScience. 41(5):1276-1285.

Getter, K.L. and D.B. Rowe. 2009. Substrate Depth Influences Sedum Plant Community on a Green Roof. HortScience. 44(2):401-407.

Getter, K.L., D.B. Rowe, and B.M. Cregg. 2009. Solar Radiation Intensity Influences Extensive Green Roof Plant Communities. Urban Forestry and Urban Greening. 8:269-281.

Gregoire, B.C. and J.C. Clausen. 2011. Effect of a Modular Green Roof on Stormwater Runoff and Water Quality. Ecological Engineering. 37:963-969.

Hunt, W. F. and L. L. Szpir. 2006. Permeable Pavements, Green Roofs, and Cisterns. North Carolina Cooperative Extension. AG-588-23W.

Köhler M. 2003. Plant survival research and biodiversity: Lessons from Europe. Paper presented at the First Annual Greening Rooftops for Sustainable Communities Conference, Awards and Trade Show; 20–30 May 2003, Chicago.

Lui, K. and J. Minor. 2005. Performance evaluation of an extensive green roof. Green Rooftops for Sustainable Communities, Washington, DC.

Monterusso, M.A., D.B. Rowe, and C.L. Rugh. 2005. Establishment and Persistence of Sedum spp. And Native Taxa for Green Roof Applications. HortScience. 40(2):391-396.

Moran, A., B. Hunt, and J. Smith. 2005. Hydrologic and Water Quality Performance from Green Roofs in Goldsboro and Raleigh, North Carolina.

North Carolina Department of the Environment and Natural Resources. 2007. Stormwater Best Management Practices Manual, Ch 19: Rooftop Runoff Management. North Carolina Division of Water Quality, Raleigh, NC.

Oberndorfer, E., J. Lundholm, B. Bass, R.R. Coffman, H. Doshi, N. Dunnett, S. Gaffin, M. Köhler, K.K.Y. Lui, and B. Rowe. 2007. Green Roofs as Urban Ecosystem: Ecological Structures, Functions, and Services. Bioscience. 57(10):823-833.

Price, J. G., S. A. Watts, A. N. Wright, R. W. Peters, and J. T. Kirby. 2011. Irrigation Lowers Substrate Temperature and Enhances Survival of Plants on Green Roofs in the Southeastern United States. HortTechnology. 21(5): 586–592.

Price, J. G. 2011. Personal communication via email on November 16, 2011.

Rowe, D.B., M.A. Monterusso, and C.L. Rugh. 2006. Assessment of Heat Expanded Slate and Fertility Requirements in Green Roof Substrates. HortTechnology. 16(3) 471-477.

Snodgrass, E.C. and L.L. Snodgrass. 2006. Green Roof Plants A Resource and Planting Guide. Timber Press, Portland, OR.

USEPA. 2008. Stormwater Menu of BMPs: Green Roofs. National Pollutant Discharge Elimination System. Washington, D.C.

VanWoert, N.D., D.B. Rowe, J.A. Andreson, C.L. Rugh, and L. Xiao. 2005. Watering Regime and Green Roof Substrate Design Affect Sedum Plant Growth. HortScience. 40(3):659-664.

::This page::
::intentionally left blank::

Riparian Buffers (RB)

Aerial photo of streamside forest, courtesy of Greg Jennings

Site Selection

Quantity Control	---
Drainage Area	small-med
Space Required	med-large

Works with:

Steep Slopes	---
Shallow Water Table	✔
Poorly Drained Soils	✔

General Significance

Construction Cost	med
Maintenance	low
Community Acceptance	high
Habitat	med-high
Sun / Shade	sun to p. shade

Synonyms: Filter strips, streamside vegetation, streamside forest, aquatic buffers, corridors, greenways, riparian zones, engineered buffers, buffer strip, water pollution hazard set backs, vegetated buffers, biological buffer zones

Riparian buffers are permanently vegetated transition zones that connect upland areas to streams. Prior to development, most streams in the Southeast had naturally occurring riparian buffers. These streamside forests slow runoff velocity, create diffuse flow, and reduce nonpoint source (NPS) pollution concentrations before runoff enters nearby streams or other water bodies. Buffers filter pollutants from agricultural, urban, suburban, and other land cover through natural processes such as deposition, infiltration, adsorption, filtration, biodegradation, and plant uptake. Riparian buffers also stabilize streambanks and provide food and shelter to wildlife to connect otherwise fragmented wildlife communities in a watershed. Riparian buffers are often recommended as part of a holistic watershed management plan aimed at reducing NPS pollution.

Site Selection

Riparian buffers are sited adjacent to surface waters such as perennial, intermittent, and ephemeral streams. To be considered a LID practice, a riparian buffer should be restored and enhanced. Restored riparian buffers work well in high density, urban areas, such as residential subdivisions and can be used in conjunction with other stormwater control measures (SCMs) that help reduce flashy urban flows.

Permanent Easements: A long term or permanent easement is recommended to protect the restored buffer from development, clearing, or unnecessary extensive plant maintenance that might limit buffer functionality.

Right of Way: The restored riparian buffer should not be in a current right of way (ROW) for sewer, power, or other infrastructure.

Buffer Width: Buffer width may be a function of surrounding land use, land availability, or topography and may vary throughout the watershed. Check local ordinances on buffer width as these regulations can vary across the state from 25’ to 150’. Narrower buffers can be just as effective as wider buffers in removing sediment in environments where rainfall events are consistently light; however, buffers in regions that experience heavy or frequent rain events in urbanized settings may require wider buffers to adequately reduce sediment and other pollutants.

Slope: Slope can greatly affect buffer width and a slope of < 6% is recommended to slow runoff through riparian buffers. Steeper slopes may require larger buffer widths due to increased runoff velocities that decrease residence

Table 4.8.1
Site Selection: Constraints and Limitations for Riparian Buffers

Constraint	Recommendations
Width	Effectiveness is minimized in buffers < 25' wide
Slope	Preferred < 6%, may need to be wider if > 6%
Flow	Flow should not be concentrated. Use a level spreader to disperse concentrated flow entering the buffer. Flow entering the buffer should also not exceed 3 cubic feet per second (cfs).
Sediment	Does not work with high sediment inputs
Right of Way (ROW)/ established buffer	Only replaces impaired buffers, must have an access easement

time in the buffer and reduce infiltration or filtration. It is generally noted that increased buffer width can help to reduce sediment loads.

Flow: Flows into the buffer should not exceed 3cfs.

Design

The design of restored riparian buffers includes site selection, determining the dimension of the buffer, and proper vegetation selection and placement. Improvements to riparian buffers may include replanting native vegetation to reduce erosion and eradicating nonnative, invasive plants.

Components

Pretreatment: A grassed filter strip for pretreatment is encouraged, but not required for restored riparian buffer functionality. Grassed filter strips can aid in nutrient and sediment load reductions by reducing runoff velocities and dissipating energy. Grassed filter strips are planted with turfgrass for ease of maintenance and to create diffuse flow into the buffer to allow sediment to settle out of suspension.

Practice Pairing: Often restored riparian buffers are paired with other structural SCMs, such as level spreaders to aid in creating diffuse flow into the riparian buffer. See Chapter 4.5 on Level Spreaders and Grassed Filter Strips for more information.

Dimension: A restored riparian buffer typically has two zones with an optional third zone. A minimum of 100' buffer width is recommended for stream protection; however, some areas of Alabama recommend smaller widths.

Zone 1: Zone 1 is closest to the water body and is designed to create, preserve, and protect physical and ecological functions. This floodplain zone is crucial to the physical and ecological integrity of the stream ecosystem and often has wetland characteristics and critical habitats. Zone 1 should have restricted human use and is planted with native vegetation that protects streambank stability. This zone may range from 25 – 30' wide perpendicular to the stream or water body and is primarily made up of a mix of wetland herbaceous, and woody vegetation.

Zone 2: Zone 2 is the transition area between the upland and Zone 1. Zone 2 is the primary treatment area for pollutant removal. This zone is designed to infiltrate runoff and promote filtration of pollutants. The width of this zone ranges from 20 - 50' perpendicular to the stream additonal to Zone 1, depending on stream and floodplain characteristics. Woody vegetation is the primary vegetation in this zone. Intrusions into this zone should be minimized.

Zone 3: An optional transition to a 25' wide filter strip of grassed or herbaceous plant species is recommended to create diffuse flow into Zone 2. Zone 3 is typically planted with native grasses.

Construction

Construction of a restored riparian buffer should consider stream channel stabilization, vegetation, soil preparation, floodplain or buffer stabilization, and planting.

Permits: Proper permits must be obtained if stream channel stabilization is needed.

Stream Channel Stabilization: Stream channel stabilization combines vegetative and structural techniques. Two recommended vegetation techniques to stabilize streambanks are the use of live stakes and brush mattresses. Structural measures or in-stream features, such as rock vanes, log vanes, or sills, may be necessary to improve streambank stability. Hard armoring streambanks using riprap or gabion baskets is not as desirable compared to more natural, biological engineering techniques, but can be used in situations where applicable. A biological or agricultural engineer should be consulted when stream channel stabilization is necessary.

Invasive Plant Removal: The amount of site preparation is dependent on the amount of existing native vegetation and the need for invasive, nonnative plant removal. A vegetation assessment inventory should be conducted prior to construction to identify both native and nonnative invasive plants on site. Vegetation treatment and soil preparation may require the use of herbicides or mechanical elimination of invasive, nonnative plants (see Appendix D on Vegetation for more information on invasive plant removal).

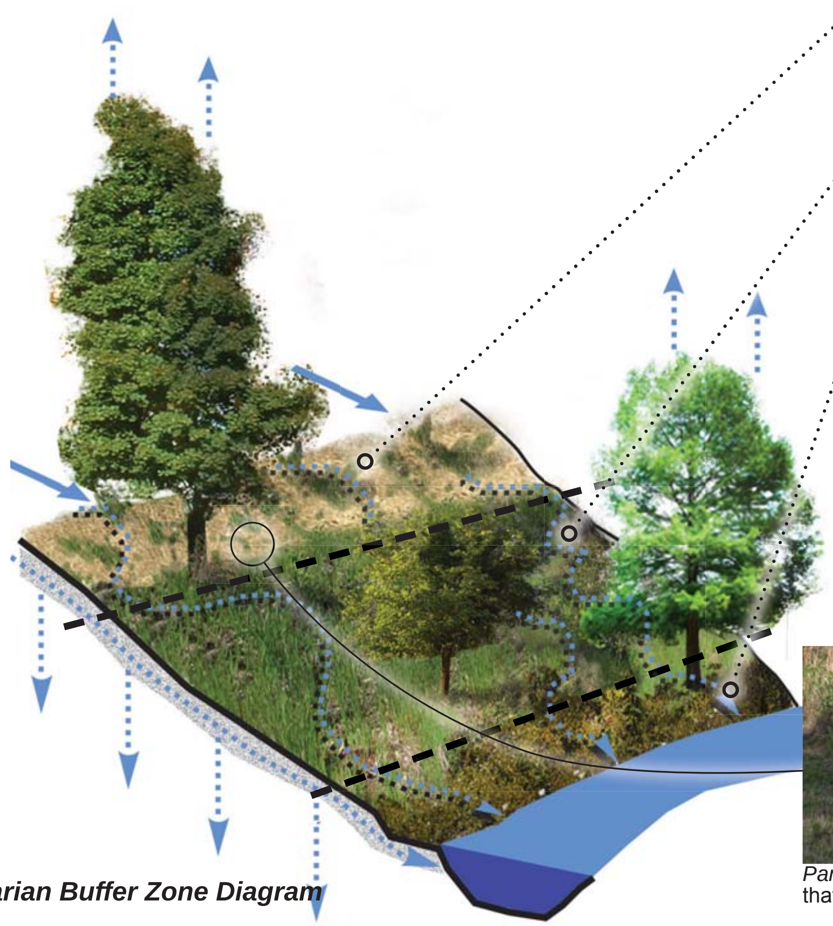
Plant Establishment: Any compacted soil should be chiseled or ripped before adding topsoil necessary for plant establishment and plant growth. Soil amendments such as lime and fertilizer should be added based on soil test results.

A 2" layer of organic mulch such as a hardwood mulch or pine straw may be used to aid in plant establishment.

Erosion and Sediment Control: Areas of bare soil must be stabilized immediately using native grasses, permanent seeding, and erosion control blankets (if necessary) following any soil disturbance according to the *Alabama Handbook for Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas* (**http://swcc.alabama.gov/pages/erosion_handbook.aspx**). Vegetation species used in stabilization should not compete with proposed native planting within the buffer.

Vegetation

Habitat Value: Vegetation has the vital role of stabilizing soil and providing habitat to wildlife in streamside forests. It is recommended to plant riparian buffers with a variety of woody and herbaceous vegetation to maximize wildlife benefit, species richness, and nutrient uptake efficiency. Leaves and twigs provide woody debris, or detritus, to the stream and are a food source to aquatic insects. Bird communities in diverse, planted or restored riparian buffers have been reported to be similar to established natural buffers. Vegetation that provides wildlife with a viable food source should be selected for the buffer. See Appendix D for the Alabama Native Plant List.



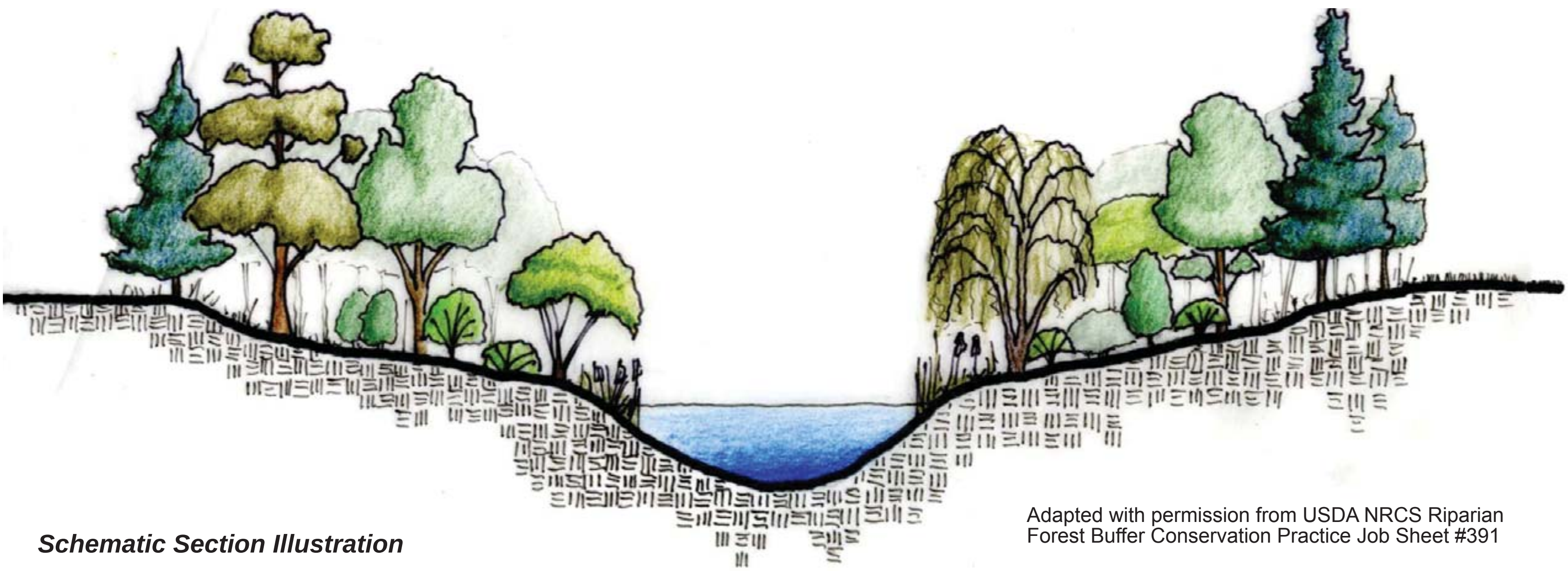
Riparian Buffer Zone Diagram

Panicum virgatum (switchgrass) is a native grass that may be used in the outer third of a filter strip

Table 4.8.2
Recommended Live Stake Species

Botanical Name	Common Name
Cephalanthus occidentalis	buttonbush
Cornus amomum	silky dogwood
Itea virginica	sweetspire
Salix sericea	silky willow
Sambucus canadensis	elderberry
Physocarpus opulifolius	ninebark

Live Stakes: Live stakes are woody stakes (0.5” diameter) harvested and installed during the winter months. Live stakes should produce roots and shoots following one growing season. Live stakes are recommended for streambank stabilization and are planted at the toe of the slope where they intercept stream base flow.



Schematic Section Illustration

Adapted with permission from USDA NRCS Riparian Forest Buffer Conservation Practice Job Sheet #391

Ida Bella Young; Montgomery, AL

Table 4.8.3
Zone 1 Plants

Botanical Name	Common Name	Type
Acer saccharinum	silver maple	tree
Alnus serrulata	hazel alder	shrub
Asimina triloba	paw paw	shrub
Aronia arbutifolia	red chokeberry	shrub
Arundinaria gigantea	river cane	grass like
Asclepias incarnata	swamp milkweed	herb
Betula nigra	river birch	tree
Carex sp.	sedge	herb
Cephalanthus occidentalis	buttonbush	shrub
Chamaecrista fasciculata	patridgepea	herb
Chasmanthium latifolium	inland sea oats	grass
*Clethra alnifolia**	summersweet	shrub
Fagus grandifolia	beech	tree
Euonymus americanus	hearts-a-burstin	shrub
Fraxinus pennsylvanica	green ash	tree
*Helianthus angustifolius**	swamp sunflower	herb
Hibiscus moscheutos	rosemallow	herb
Ilex glabra	inkberry	shrub
Ilex verticillata	winter berry	tree
Illicium floridanum	Florida anise	shrub
*Itea virginica**	sweetspire	shrub
Juncus sp.	rush	herb
Lindera benzoin	spicebush	shrub
Liquidambar styraciflua	sweetgum	tree
Liriodendron tulipifera	tulip poplar	tree
Lobelia cardinalis	cardinal flower	herb
Nyssa aquatica	swamp tupelo	tree
*Panicum virgatum**	switchgrass	grass
Platanus occidentalis	sycamore	tree
Prunus serotina	black cherry	shrub
Taxodium distichum	bald cypress	tree
Viburnum dentatum	arrowood	shrub
*Viburnum nudum**	possumhaw	shrub
Viburnum obovatum	Walter’s viburnum	shrub

*Can be used in Zone 1 or Zone 2
Zone 1: Plants in this zone experience floodplain conditions and it is planted with trees, shrubs, and perennials that tolerate periodic inundation.

Table 4.8.4
Zone 2 Plants

Botanical Name	Common Name	Type
Aesculus pavia	red buckeye	shrub
Asclepias tuberosa	butterfly weed	herb
Asimina parviflora	dwarf paw paw	shrub
Callicarpa americana	beautyberry	shrub
Calycanthus floridus	sweetshrub	shrub
Cercis canadensis	redbud	shrub
Coreopsis lanceolata	tickseed	herb
Hamamelis vernalis	witchhzael	shrub
Hamamelis virginiana	witchhazel	shrub
Lindera benzoin	spicebush	shrub
Magnolia virginiana	sweetbay	tree
*Schizachrium scoparium**	little bluestem	native grass
*Sorghastrum nutans**	indian grass	native grass
*Panicum virgatum**	switchgrass	native grass

* Can be used in optional Zone 3.

Zone 2: Zone 2 is generally considered an upland area that rarely is flooded. Plants best suited for this zone are shrubs and perennials.

Herbaceous Plants: Herbaceous vegetation is best planted in the spring, after the last frost.

Native Grasses: Tall, stiff, fine-textured native grasses such as switchgrass (*Panicum virgatum*) have deep roots compared to turfgrass and work well to stabilize riparian buffers and provide diffuse flow.

Dormant Plantings: Woody vegetation including live stakes, bare roots, and containers will benefit from a winter installation. See Appendix D on Vegetation for more information.

Summer Plantings: If summer plantings are a necessity, plants should be monitored closely for signs of drought stress and irrigated if necessary.

Plant Establishment: Newly planted vegetation will need time to adjust to the shock of being transplanted. It is recommended that transplants be watered twice a week for the first six weeks after planting, especially in the growing season.

For more information on installing live stakes, please visit: http://www.aces.edu/extcomm/timelyinfo/Ag%20Soil/2012/March/2012Live_Stakes.pdf

Tagging Plants: During planting, it may be helpful to tag or flag plants so they are easier to locate for maintenance purposes or vegetation survival monitoring.

Maintenance

Primary maintenance tasks of riparian buffers are associated with vegetation and erosion. Maintenance should be carried out such that minimal impact occurs to the buffer itself, particularly Zone 1 closest to the stream.

Nuisance Species: Wildlife may hinder plant establishment as they browse and this damage should be inspected for and corrected when possible.

Plant Replacement: Plants should be replaced when mortality occurs. Dead plants provide favorable environments for insects and diseases to overwinter and should be removed. However, it is natural that over time, plant succession will occur and plant communities in the buffer may shift.

Livestock Access: When buffers are adjacent to agriculture, fences should be maintained and repaired as needed to control livestock access to the stream.

Erosion: Gullies resulting from concentrated flow should be filled and any resulting streambank erosion should be repaired.

Mulch: Natural leaf litter should not be removed from the buffer as this provides necessary organic matter to the soil. After establishment, plants will provide leaf litter and twigs for a natural organic mulch layer in the buffer.

Thinning Trees: Trees can be thinned in the buffer, but trees with > 2" trunk diameter should not be removed. Proper tree density or cover should be present before trees or undergrowth are thinned.

Table 4.8.5
Common Invasive Nonnatives for Riparian Buffers in Alabama

Botanical Name	Common Name	Type
Ailanthus altissima	tree-of-heaven	tree
Albizia julibrissin	mimosa	tree
Hedera helix	English ivy	vine
Imperata cylindrica	cogon grass	grass
Ligustrum sinense	Chinese privet	shrub/small tree
Lonicera japonica	Japanese honeysuckle	vine
Lygodium japonicum	Japanese climbing fern	vine
Pueria montana var. lobata	kudzu	vine
Rosa multiflora	multiflora rose	shrub
Triadica sebifera	Chinese tallow	tree

Invasive Plant Removal: Invasive, nonnatives should be scouted for and removed from the riparian buffer, especially during plant establishment. As buffers colonize with native shrubs, trees, and herbaceous plants, nonnative, invasive plant removal frequency may decrease; however, annual to semi-annual surveys for nonnative, invasive plants are critical for management of these undesirable plants. See Appendix D on Vegetation for more information on invasive plant management.

Table 4.8.6
Maintenance Schedule

Task	How Often	Comments
Irrigation	After planting and during severe drought	Twice per week for 6 weeks after planting
Replace dead vegetation	Annually	Diseased or infested vegetation should be removed
Check for streambank erosion or incision	Annually	May need to replant vegetation or look upstream for causes of erosion
Inspection	After 0.5" or greater rainfall event	Visually inspect all zones of the buffer for erosion or damage.
Mowing of turf grass	More often in summer months	Should not be cut below 3 to 5" and can be grown to a maximum of 12"
Check for invasive nonnative plants	Annually	See Appendix D on Vegetation for invasive plant management guidance

Pollutant Removal

Table 4.8.7
Pollutant Removal Table

Sediment	Nutrients		Metals	Pathogens
	N	P		
a. 60%	30%	35%	-----	Med
b. 85%	30%	40%	~50%	~70%

Sources:
a. North Carolina Department of Environment and Natural Resources, 2007
b. City of Auburn, 2011

Although restored riparian buffers alone cannot provide complete surface runoff treatment (quality and quantity), buffers can filter various pollutants, particularly nutrients and sediment. Streamside vegetation transforms nutrients such as nitrogen and phosphorus into less harmful forms through nutrient cycling, plant uptake, and microbial processes.

Reduced Runoff: Restored riparian buffers provide passive volume control as stormwater is slowed by vegetation and allowed to infiltrate to groundwater.

Buffer Width: Wider buffers are generally noted to be more effective in removing pollutants, such as nutrients and sediment from surface runoff, although removal effectiveness is dependent on soil type, texture, hydrology, and biogeochemistry of underlying soils.

Total Suspended Solids: Suspended solids and turbidity are reduced through soil stabilization and erosion prevention, which can improve water quality of receiving streams. Dense grass cover in Zone 3 has been shown to be effective in filtering sediment due to increased roughness.

Nitrate Removal: Increased nitrogen reduction in wider riparian buffers is due to greater root surface area and increased nitrogen uptake through plant roots and microbial processes. Soils with subsurface anaerobic (without oxygen) conditions promote denitrification, which results in greater nitrate removal, but may result in decreased infiltration. Grass-only buffers are less effective at reducing nitrogen than forested buffers.

Vegetation: Vegetated riparian buffers shade streams, reducing water temperatures that, in turn, increase dissolved oxygen concentrations and improve water quality.

Plant Roots: Plant variety offers diversity in root morphology, which can be beneficial in soil stabilization. Riparian buffers stabilized with deeply rooted vegetation help retain soil during large rain events by reducing erosion and sedimentation. Tap-rooted plants and other deeply rooted species uptake nutrients from deeper soil horizons, stabilizing these deeper soil layers, while fibrous rooted species influence surface soil horizons. Woody plant species should be used for stabilization as these species are generally more deeply rooted compared to herbaceous plants. Native grasses are an exception to the rule. For example, switchgrass (*Panicum virgatum*) has been shown to have roots as deep as 10.8’ at maturity.

Evergreen Vegetation: The presence of evergreen vegetation is desirable for nutrient removal because these plants retain their leaves and do not return nutrients to the soil during the autumn months. Fast growing plant species are suggested for areas where nutrient removal is the primary goal.

References

Castelle, A.J., A.W Johnson, and C. Conolly. 1994. Wetland and Stream Buffer Size Requirements — a Review. Journal of Environmental Quality. 23(5):878-894.

City of Auburn Stormwater Management Design Manual. 2009.

Dabney, S.M., K.C. McGregor, L.D. Meyer, E.H. Grissinger, and G.R. Foster. 1993. Vegeetative Barriers for Runoff and Sediment Control. P 60 – 70. In: J.K. Mitchell (ed.) Integrated Resources Mangement and Landscape Modification for Environmental Protection. ASAE. St. Joseph, MI.

Dosskey, M.G., P. Vidon, N.P. Gurwick, C.J. Allan, T.P. Duval, and R. Lowrance. 2010. The Role of Riparian Vegetation in Protecting and Improving Chemical Water Quality in Streams. Journal of the American Water Resources Association.

Lee, K.H., T.M. Isenhart, R.C. Schultz. 2003. Sediment and Nutrient Removal in an Established Multi-Species Riparian Buffer. Journal of Soil and Water Conservation. 58(1):1-9.

Ma, Z., C.W. Wood, and D. I. Bransby. 2000. Impacts of Soil Management on Root Characteristics of Switchgrass. Biomass and Bioenergy. 18:105-112.

Mayer, P.M., S.K. Reynolds, T.J. Canfield, and M.D. McCutchen. 2005. Riparian Buffer Width, Vegetative Cover, and Nitrogen Removal Effectiveness: A Review of Current Science and Regulations. National Risk Management Research Laboratory, Office of Research and Development, Cincinnati, OH.

Minnesota Pollution Control Agency. 2000. Protecting Water Quality in Urban Areas. Saint Paul, MN.

National Research Council. 2002. Riparian areas: Functions and strategies for management. National Academy Press, Washington, DC.

Natural Resource Conservation Service. 2001. Conservation Practice Standard: Riparian Buffer (Code 391).

North Carolina Department of the Environment and Natural Resources. 2007. Stormwater Best Management Practices Manual, Ch 15: Riparian Buffers. North Carolina Division of Water Quality, Raleigh, NC.

Simon, A. and A.J.C. Collison. 2002. Quantifying the Mechanical and Hydrologic Effects of Riparian Vegetation on Streambank Stability

Smith, T.A., D.L. Osmond, C.E. Moorman, J.M. Stucky, and J.W. Gilliam. 2008. Effect of Vegetation Management on Bird Habitat in Riparian Buffer Zones. Southeastern Naturalist. 7(2):277-288.

Sudduth, E.B. and J. Meyer. 2006. Effects of Bioengineered Streambank Stabilization on Bank Habitat and Macroinvertebrates in Urban Streams. Environmental Management. 38(2):218-226.

Environmental Protection Agency. 1995. Ecological restoration: a tool to manage stream quality. EPA/841/F-95- 007. Office of Water, Washington, DC.

U.S. Environmental Protection Agency. 2006. Riparian/Forested Buffer Fact Sheet. Office of Water, Washington, DC.

Vidon, P.G.F. and A.R. Hill, 2004b. Landscape Controls on Nitrate Removal in Stream Riparian Zones. Water Resources Research 40, W03201, doi: 10.1029/2003WR002473.

Wenger, S. 1999. A Review of the Scientific Literature on Riparian Buffer Width, Extent and Vegetation. Office of Public Service and Outreach, University of Georgia, Athens, GA.

Young-Mathews, A., S.W. Culman, A. Sanchez-Moreno, A.T. O'Geen, H. Ferris, A.D. Hollander, and L.E. Jackson. 2010. Plant-Soil Biodiversity Relationships and Nutrient Retention in Agricultural Riparian Zones of the Sacramento Valley, California. Agroforest Systems. 80:41-60.111

::This page::
::intentionally left blank::

Retrofits / Alternatives

Rain Gardens (RG)

Entrance to Benjamin Russel High School; Alexander City, AL

Site Selection

Quantity Control	---
Drainage Area	small
Space Required	small

Works with:

Steep Slopes	✔
Shallow Water Table	✔
Poorly Drained Soils	✔

General Significance

Construction Cost	low
Maintenance	low
Community Acceptance	high
Habitat	med-high
Sun / Shade	sun to p. shade

Synonyms: There are no synonyms for this practice.

A rain garden is a shallow depression in a landscape that captures water and holds it for a short period of time to allow for infiltration, filtration of pollutants, habitat for native plants, and effective stormwater treatment for small-scale residential or commercial drainage areas. Rain gardens use native plants, mulch, and soil to clean up runoff.

As urbanization increases and pervious surfaces decrease, rain gardens are an excellent practice to promote infiltration of up to 30% more stormwater than traditional lawns. Residential stormwater management can often help homeowners save money on lawn irrigation when lawns are converted to rain gardens. These areas are designed to capture 3 to 6” of runoff after a storm, which allows water to infiltrate and return to groundwater, rather than being discharged to a stormwater conveyance system.

Site Selection

Potential Rain Garden Locations: Rain gardens can be located throughout the landscape to disconnect impervious surfaces and treat runoff from rooftops, driveways, sidewalks, existing landscapes, or a combination of these surfaces. Rain gardens are most effective at reducing stormwater runoff when disconnecting two impervious surfaces such as a rooftop and a street.

Practice Pairing: Rain gardens can also be connected to other residential stormwater control measures (SCMs) for more effective stormwater treatment. For example, rain barrels can be used to capture rooftop runoff and overflow from these barrels can be directed to rain gardens and used as a water source. A landscape designer or other professional should be consulted for projects that incorporate curbing or curb cuts, storm drains, any type of under drain, or when drainage areas are larger than 2000 ft^2.

Pinch Point: The rain garden should be located between the runoff source (rooftop, driveway, etc.) and the destination of runoff, also known as the “pinch point.” A “pinch point” is an area in which water is already converging, moving through, or exiting a property.

Observe the Site: It is often helpful to watch water flow patterns throughout the landscape on a rainy day. Snapping a few photos will also help note problem areas. Look for eroded areas and sediment accumulation both in the landscape and at curbs. Check where gutters, downspouts, or roof valleys deposit roof runoff as potential rain garden locations.

Collecting From a Rooftop: A good rule of thumb is to place rain gardens approximately 10’ downslope of the downspout. A simple swale or rock-lined ditch can be used at the roof drip line as the inlet to the rain garden to direct stormwater if gutters or downspouts are not available.

Planning for Overflow: Consider how runoff will enter the garden, how it will be captured and held, and how it will exit the rain garden during heavy rain events. Alabama frequently experiences high intensity storms rather than slow, soaking rain events and because of this, overflow of the rain garden should be expected. Overflow should be directed to grassed or vegetated areas and never to the home foundation or a neighbor's property.

Infiltration Test: An infiltration test is performed to determine the optimal rain garden location. Using a post-hole digger, auger, or other tool, dig at least two 4 - 6" diameter, approximately 1' deep holes in each potential rain garden location. Fill each hole with water and let drain completely to prime the hole for more accurate results; this is especially important during drought conditions. Next, fill the hole so that water is within 1" of the top of the hole. Use a ruler or other measuring tool to monitor the depth of the water. Record the start time in order to calculate the drain time. Monitor the amount of time required for water to infiltrate completely. Check the hole once an hour for at least 4 hours. The rate of drain time will determine the most appropriate type of rain garden for the landscape (see table below).

Example of Infiltration Testing.

In./Hr.	Drain Time	Rain Garden Type
≥ 1"	<12 Hours	*Standard Rain Garden*
0.25 to 0.9"	12 - 36 Hours	*Zoned Rain Garden*
< 0.25"	>36 Hours	*Wet Rain Garden*

Follow Up Infiltration Test: Once a specific location and rain garden type have been determined, an additional deeper infiltration test can be performed if there are any concerns about hard pans, bed rock, or other constraints that may limit stormwater percolation. Dig two to three holes at a depth of 2' and fill with water, similarly to the standard infiltration test described above. These holes should drain within 48 hours to ensure that the rain garden will not create a mosquito breeding ground.

Soil Test: Perform a soil test using the soils from the holes dug for the infiltration test. Soil sample boxes, information sheets, and other supplies for soil testing are available from the local County Extension Office. A soil test should be performed to determine lime and

For more information on soil test protocols, go to the Alabama Cooperative Extension System website at www.aces.edu/pubs/docs/A/ANR-0006-A/ANR-0006-A.pdf. Soil samples can be sent to the Auburn University Soil Testing Lab (www.aces.edu/anr/soillab/) or to other soil testing facilities to be analyzed.

Table 5.1.1
Site Selection: Constraints and Limitations for Rain Gardens

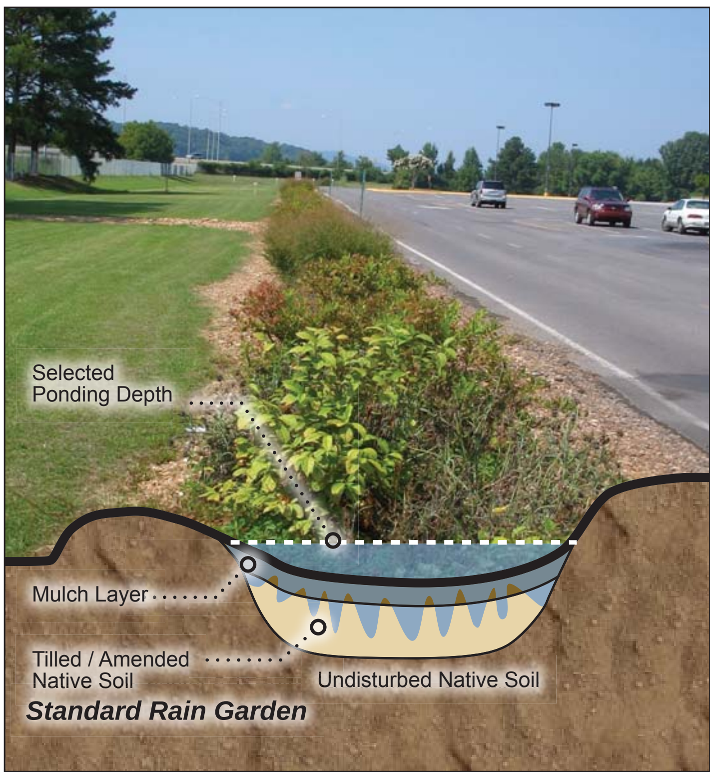
House Foundation	Do not locate within 15' of building foundations with basements; otherwise 5' from the foundation is acceptable.
Slope	Rain gardens should not be located on slopes > 12% due to the inability to hold runoff in the rain garden without a really steep berm. Flatter slopes will also require less digging.
Septic System and Drain Field	Should be located > 25' from septic system and upslope of the drain field.
Utilities	Call 811 when selecting a site for the rain garden and before construction to locate utilities (for more information, visit: www.al1call.com). Rain gardens should not be placed within 5' horizontally or 1' vertically from utilities.
Seasonally High Water Table	If the seasonally high water table is within 2' of the bottom of the rain garden, a different location should be chosen for a standard rain garden or a wet rain garden should be considered.
Large Flow Volumes	Decrease percentage of impervious area for treatment.
Wellhead	Should be located at least 10' from wellhead.
Shaded areas	Locate in full sun to part shade if possible; dense shade will cause the rain garden to remain wet longer than intended and can promote mosquito breeding.
Soggy Areas in the Landscape	These areas are not good locations for a rain garden. Instead, consider capturing runoff before it settles in these spots of the yard.
Existing Trees	Rain gardens should not be located within the drip line of existing trees so that tree roots are left undisturbed and water they uptake will not affect runoff the rain garden should capture.
Existing Retaining Wall	Do not locate a rain garden upslope of a functional retaining wall. Encouraging water to collect in these areas could damage the retaining wall structure.
Heavy Foot Traffic	Foot traffic compacts soil and may damage plants. Consider locating the rain garden in areas where pedestrians do not frequent or incorporate footpaths around the rain garden.

nutrient recommendations for initial plant establishment and quality. Many plants prefer specific pH ranges and the soil test will recommend lime requirements if an increase in pH is necessary for optimal plant growth.

In-situ Soil: Ponding depth is also a function of in-situ soil. Slower draining soils should be designed with decreased ponding depths compared to well-drained soils. The time required to draw down or infiltrate this volume of water will also directly affect vegetation selection.

Types of Rain Gardens

Rain gardens can be designed in a variety of ways and may use different shapes, vegetation, and sizes to meet the needs of a particular site. All rain gardens should hold water after a rain event and infiltrate collected water within 36 to 48 hours. The primary differences in rain garden type refer to the time required for the rain garden to draw down the volume of stored water after a rain event, which is determined by the infiltration test.



Standard Rain Garden: A standard rain garden uses a uniform ponding depth (3” or 6”) of water across the entire base of the rain garden. Native soils are used and can be amended if necessary based on the infiltration rate found by the infiltration test. In these systems, the bottom of the rain garden area is raked level with no variation in elevation within the rain garden footprint.

Wet Rain Garden: If existing soils are more clayey and an infiltration test confirms that a particular site within the landscape does not draw down in 36 hours, a wet rain garden may be necessary. Poorly drained soils do not limit the use of a rain garden in the landscape, but may require a more specific vegetation plan to ensure plant survival, aesthetics, and mosquito prevention. Wet rain gardens can have standard (flat across the bottom) or zoned (variable) topography.

Zoned Topography: Zoned topography provides changes in elevation so that some areas within the rain garden pond more or less, thus requiring a more diverse plant community with aquatic plants occupying deep pools and vegetation that prefers drier conditions in higher areas.

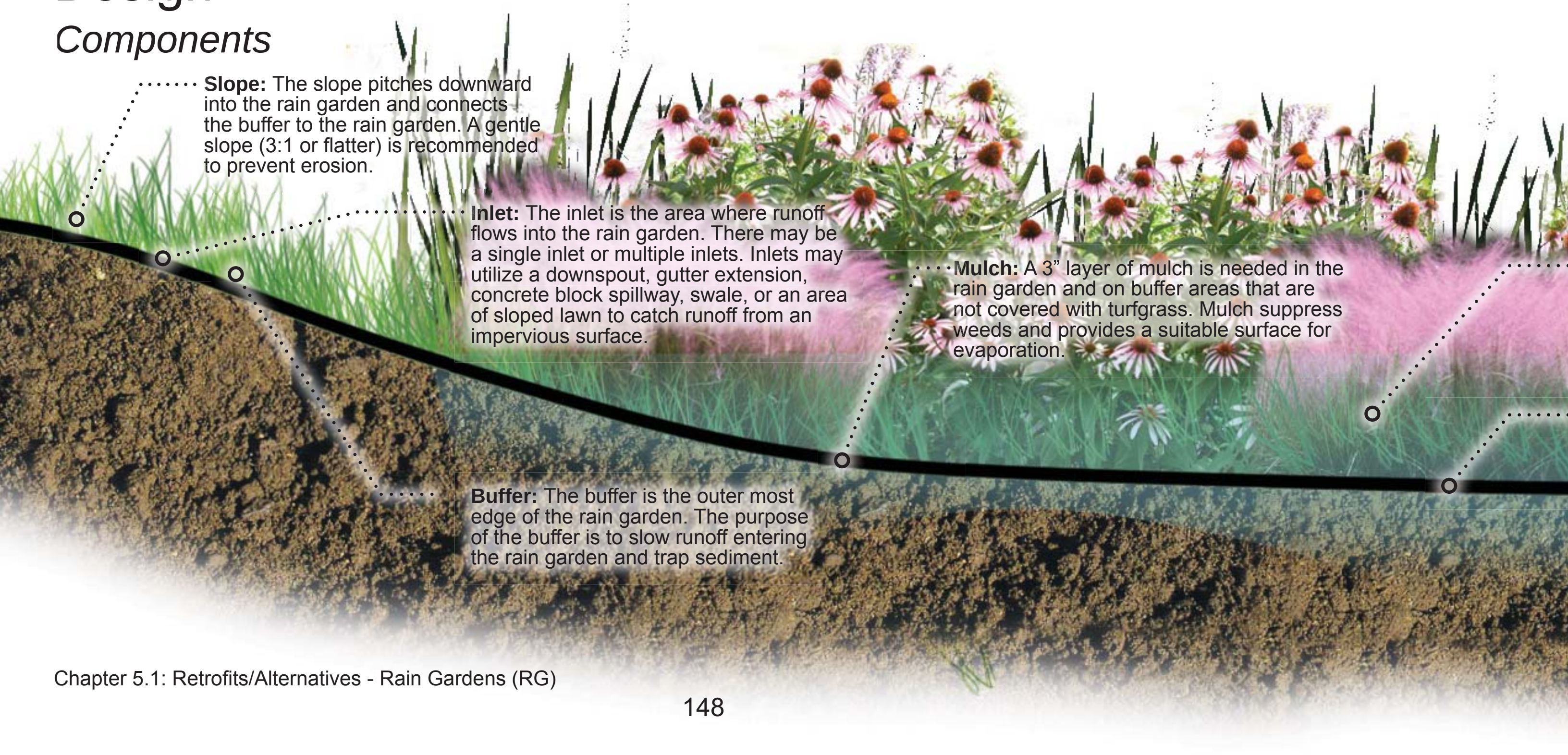
Design Steps

1. ***Determine Sub-watershed Boundaries***

   Consider your property and the source(s) of runoff for the rain garden.

   - How does rainwater move on your property?
   - Do you receive runoff from your neighbor’s property?
   - Are there areas that stay wet for long periods of time following a rain event?
   - Examine pinch points on site (see Chapter 2 on Site Selection for more information). Treating the entire area may require the use of multiple rain gardens especially if you receive runoff from neighboring properties as well as your own.

Design
Components



2. **Estimate the Amount of Impervious Area (IA)**

   Calculate the square footage of impervious surfaces (IA) within the boundaries you have established. Include all portions of rooftops, driveways, sidewalks, roadways, etc. that will be draining to the rain garden. If two roof areas drain to a single downspout that will be used to direct flow, these roof areas are added together.

   Curb Cuts: If the rain garden will collect roadway runoff, determine the flow pattern and in areas where curb is present, a curb cut will be needed. Contact the local Municipal or County office if a curb cut is needed but not already in place.

   Grassed Filter Strip: When there are no curbs, a 2' minimum grassed filter strip and optional 1' wide notch filled with rock is recommended to help slow runoff, trap sediment, and prevent erosion into the rain garden.

3. **Choose a Runoff Capture Depth and Ponding Depth**

   The amount of rainfall to be treated by the rain garden is the **runoff capture depth.** Typically, the rain garden should treat the "first flush" or the first inch of rainfall, which has higher concentrations of pollutants in comparison with runoff later in the storm. See Appendix A on Stormwater Hydrology for more information on stormwater runoff calculations.

   Ponding Depth: The rain garden ponding depth refers to the depth at which water will pond in the rain garden before overflowing. Typically ponding depths are 3 or 6" and either of these depths can be used in sandy soils, but a 3" ponding depth is appropriate for clayey soils as these will drain more slowly.

4. **Determine the Size of the Rain Garden**

   A good rule of thumb is to design the rain garden so that it is twice as long as it is wide, perpendicular to the flow into the garden. Using the desired ponding depth and the total **impervious area (IA)**, the size of the rain garden can be determined with the following equations.

Sizing Rain Gardens

EQN 5.1.1

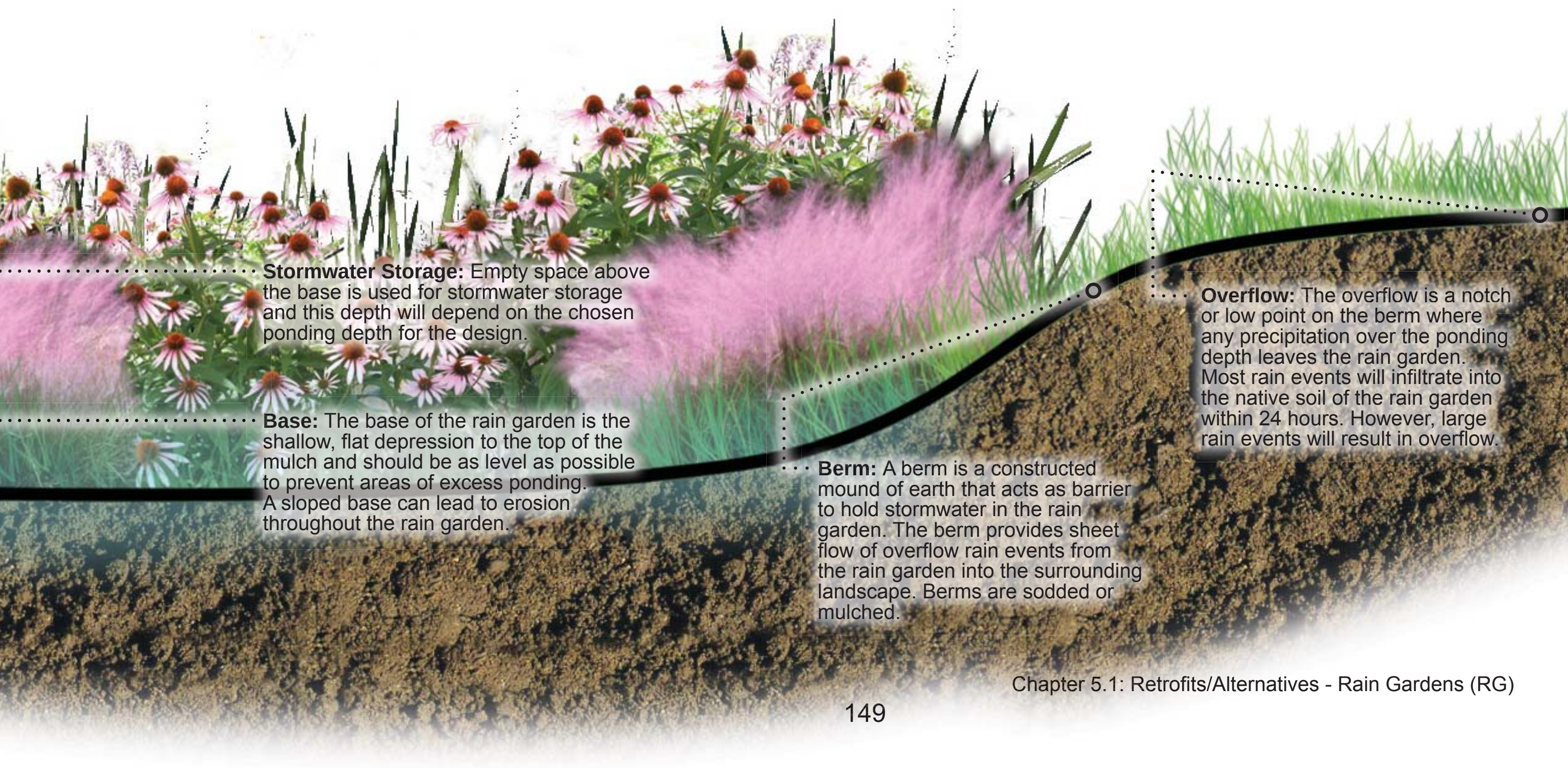
For a 3" Ponding Depth:

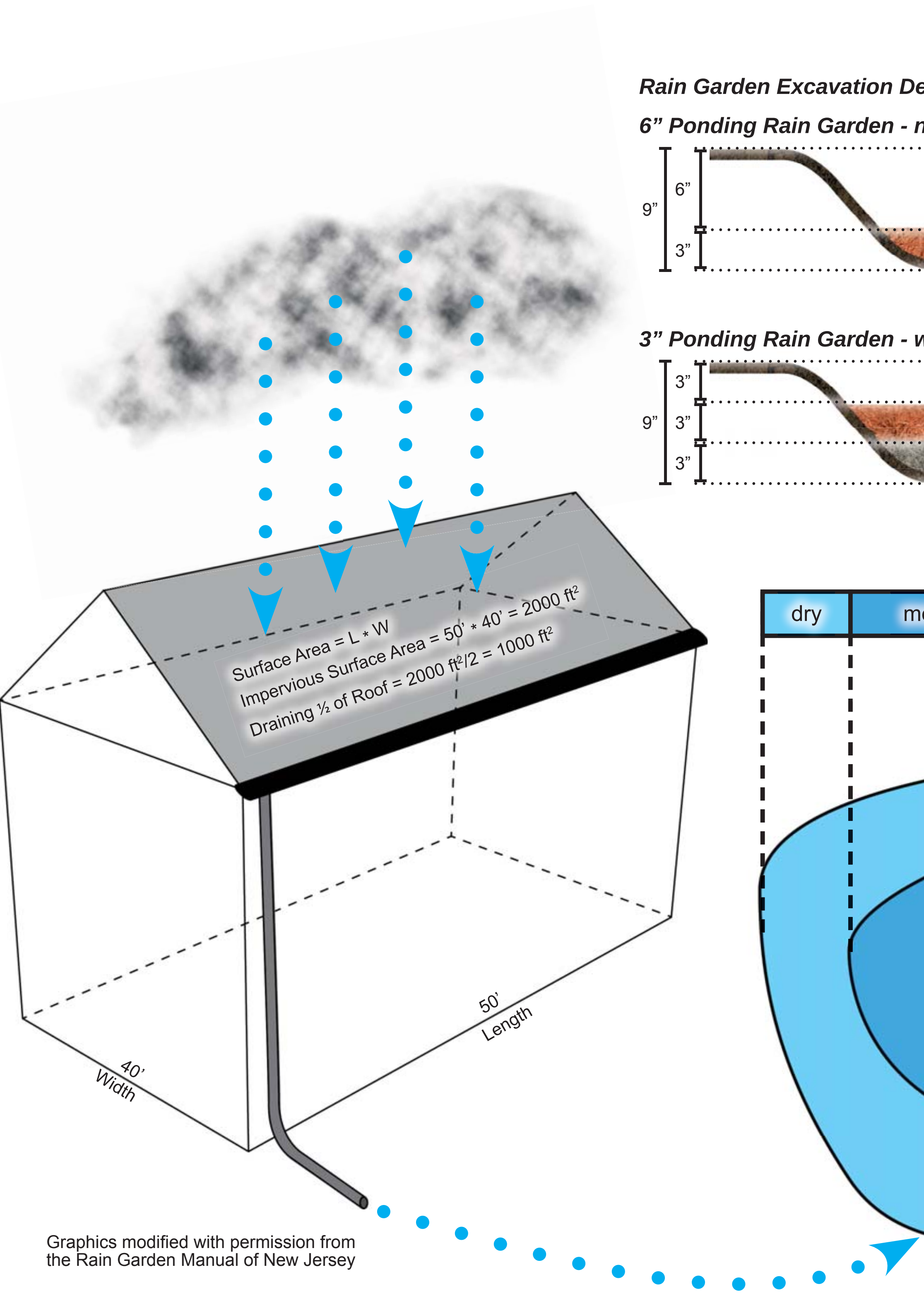
$$\text{Rain Garden Size} = \frac{IA}{10}$$

EQN 5.1.2

For a 6" Ponding Depth:

$$\text{Rain Garden Size} = \frac{IA}{20}$$

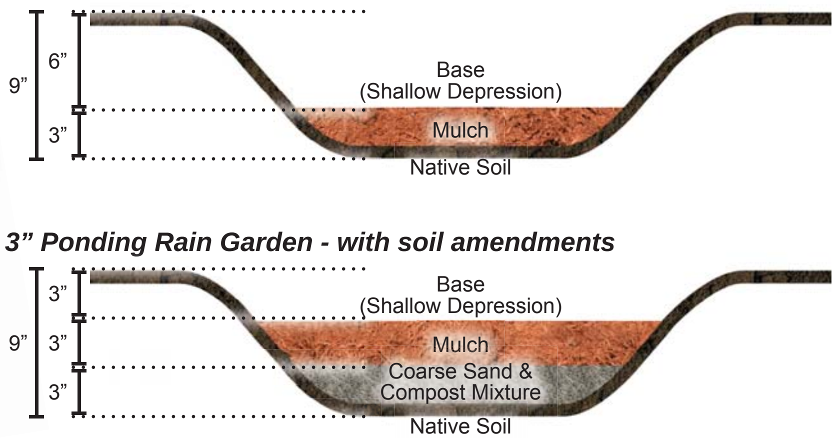


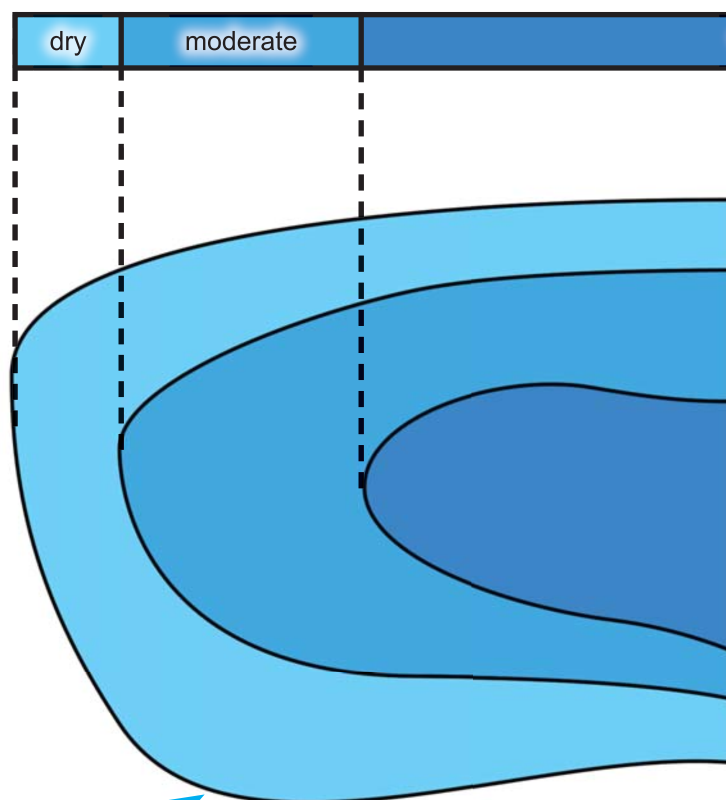


Rain Garden Excavation Depths

6" Ponding Rain Garden - no soil amendments

3" Ponding Rain Garden - with soil amendments





Graphics modified with permission from the Rain Garden Manual of New Jersey

5. **Design a Berm and/or Overflow Weir.**

A berm is sufficient for rain gardens that are treating less than 2,000 ft² of IA.

Call a Professional: If designing a rain garden with a drainage area greater than 2000 ft², it is recommended to consult an engineer or professional landscape architect (PLA) for weir or overflow design options. The **length of the overflow weir** can be determined by the following equation.

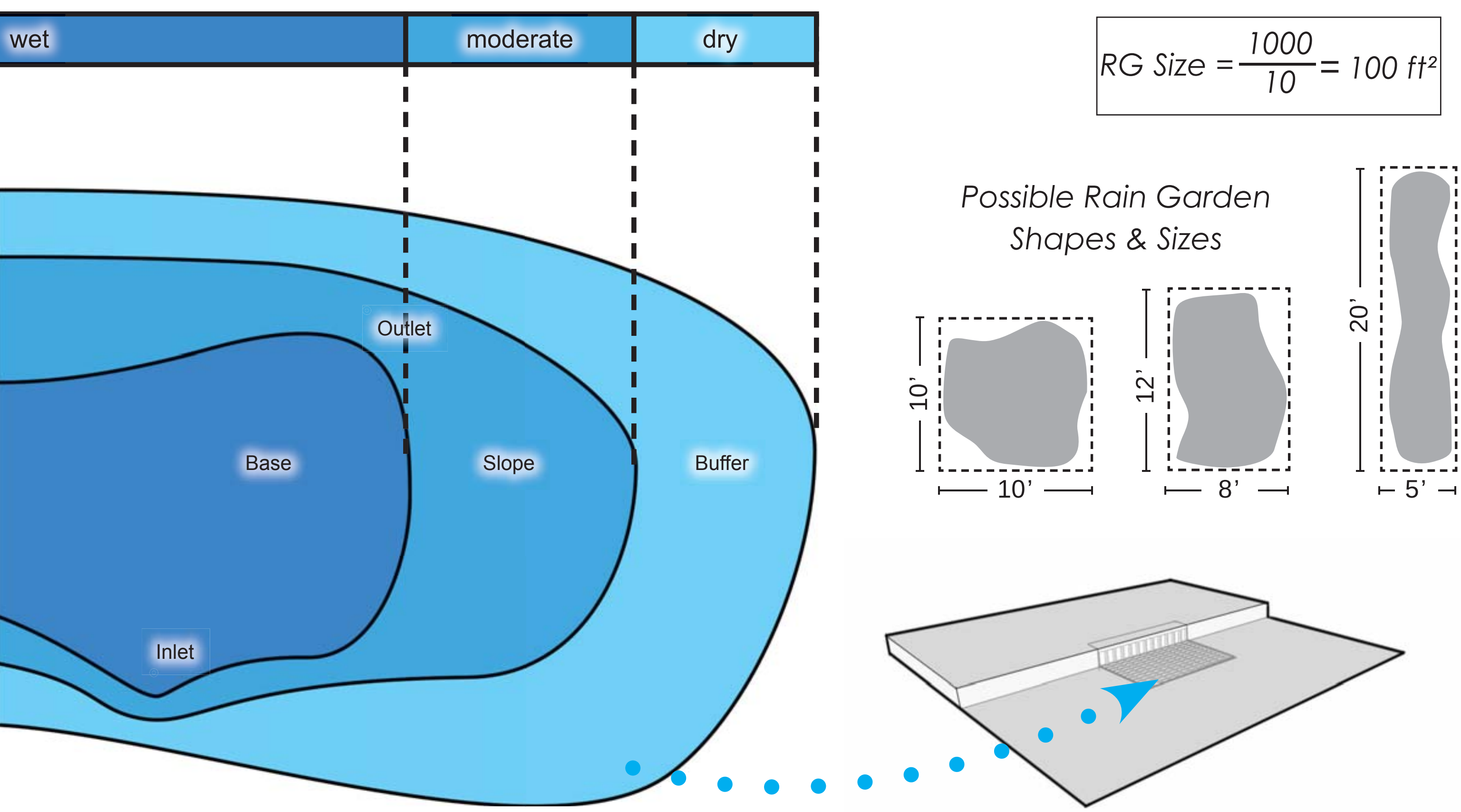
> ***Sizing Over-flow Weir***
>
> ***EQN 5.1.3***
>
> **For a raingarden over 2000 ft²:**
>
> $$\text{Length of Overflow Weir} = \frac{IA}{2000}$$

Design Example

A residential rooftop is 50’ by 40’, for a total of 2,000 ft² of IA. Half of the runoff from the rooftop will be directed to the rain garden. The owner prefers 3” of ponding due to clayey soils on site.

Roof Area = 2,000 ft², treating ½ of the rooftop
Impervious Area (IA) to be treated = 1,000 ft²
Ponding depth = 3”

Using the rain garden sizing EQN 5.1.1. The rain garden is sized to be approximately 100 ft², optional dimensions include a 8’ x 12’ and 5’ x 20’.



Construction

Below are construction steps for a standard rain garden.

1. **Preparation**

Cost: A do-it-yourself (DIY) rain garden typically ranges from $3 – 5 per square foot depending on soil conditions, plant species and size, and planting density. Plant costs are the major expense associated with a DIY hand-dug rain garden. The installer can save on plant costs if a neighbor or friend already has a rain garden or flowerbed with suitable plants that require division. However, depending on the size of transplants, usually at least one growing season is required before a plant size is reached that rivals one purchased.

Utilities: Utilities should be located before digging the rain garden. Call 811 at least two working days prior to any construction. The area of disturbance, including the rain garden and some allowance outside of the rain garden should be outlined using white landscape marking paint to help 811 determine whether the rain garden installation will encroach on any existing underground utilities. In general, rain gardens should not be placed within 5’ horizontally or 1’ vertically from underground utilities.

Erosion and Sediment Control: Active construction activities can increase sediment loading in runoff that will clog the rain garden rendering it ineffective. Rain gardens should be designed to fit into the landscape, but should not be constructed until all on-going construction and land disturbance are complete in the drainage area.

Construction Timeline: Rain garden construction is generally more efficient in early spring because digging will be easier due to seasonal rainfall. Plants will also benefit from an early spring planting due to less stress, milder temperatures, and a better chance for establishment. Summer and fall installations can work but may require more frequent irrigation and care until establishment. Most container sizes can be installed at any time of year as long as adequate irrigation is provided. For more information on plant sizes see Appendix D on Vegetation.

2. **Excavation**

Excavation Depth: The rain garden excavation is based on the chosen ponding depth of 3 or 6” for the design and whether or not your soil requires soil texture amendments. It should be noted that when construction is complete and mulch has been placed in the rain garden, there will be 3 or 6” of empty space in the rain garden that is used for storage of the rain that is captured. Without the ponding depth, or water storage space, the rain garden is not able to capture the desired amount of runoff and will overflow more often than intended. See Rain Garden Excavation Depth graphics on previous page.

Topsoil: Topsoil is the first 4 to 6” of soil that is removed and set to the side to be incorporated with any necessary soil texture and quality amendments before placing plants in the rain garden. Topsoil is usually darker than deeper soil layers and contains high organic matter content that is great for plant establishment and nutrient availability.

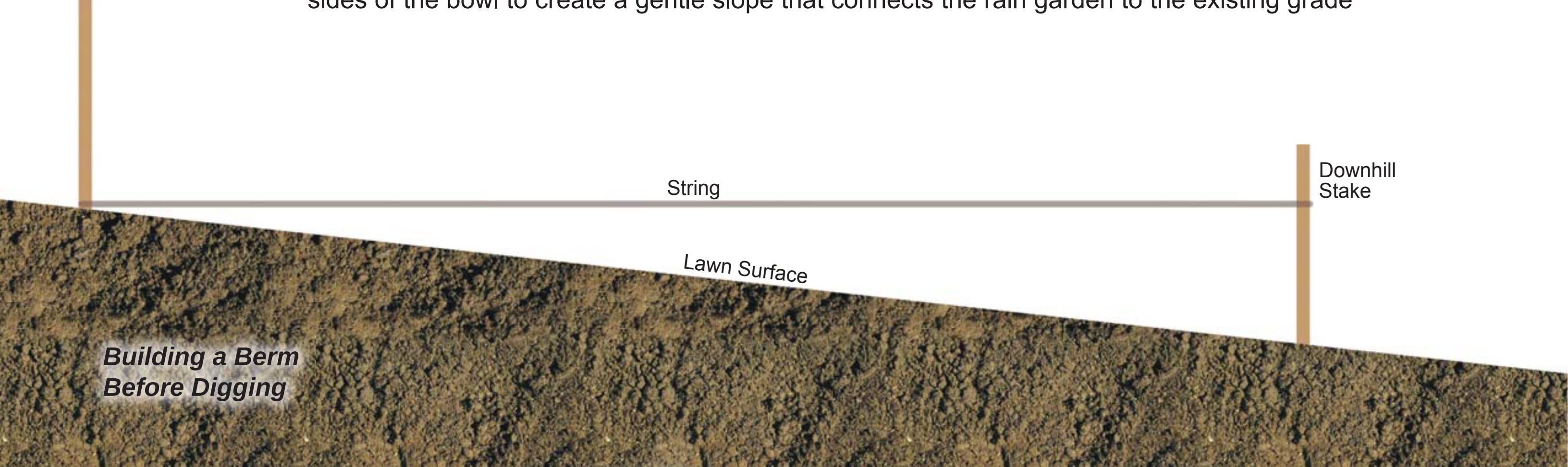
Excavated Soil: Soil that is removed can be stockpiled and placed in other parts of the landscape or can be used make a berm when excavation is complete.

Compacted Soils: If native soils are compacted or a hard pan is reached when digging, up to 8” of soil (including topsoil) may need to be removed or tilled from the soil layer of the rain garden so that plant roots can grow.

Sod Removal: To remove sod, a shovel, sod cutter (rented from local hardware store), or a backhoe can be used. Turfgrass sod should be set to the side for use on the rain garden buffer, berm, or other bare areas of the landscape. Sod should be kept with roots intact, in the shade, and evenly moist until re-planting.

3. **Shaping the Rain Garden**

Buffer and Slope: Once the rain garden has been excavated to the desired depth, work the sides of the bowl to create a gentle slope that connects the rain garden to the existing grade



or ground level of the landscape. A 3:1 slope works well to provide a gradual change in grade between the rain garden and the buffer.

Soil Texture Amendments: Soil texture amendments may be necessary to improve the soil's ability to infiltrate water in the rain garden. Amendments are generally a combination of yard compost or other organic matter and coarse sand. Infiltration rates of 1.5"/hr or greater do not require any soil amendments. For every 100 ft^2 of rain garden, a cubic yard or a 3" layer of soil texture amendments is recommended.

Soil Quality Amendments: Soil quality amendments such as any lime or fertilizer (indicated by soil test results) should be incorporated into topsoil. Animal waste compost is not recommended as an amendment due to typical high nutrient content.

Backfill: Next, use a rake, shovel, or rototiller to break up topsoil that was set aside. This topsoil is mixed with soil amendments (if necessary) and placed back in the rain garden. Begin by mixing in 1" of soil texture amendments and soil quality amendments with some topsoil to create a mix that is about 50/50 topsoil and amendments. If topsoil is poor quality on site, reduce the amount of topsoil added to the amendments for rain garden backfill. Work this soil mixture back into the existing soil in the rain garden until approximately 2 to 3" have been added. Check the depth with a yard stick or ruler to make sure it has not been overfilled. Rake and smooth out the soil so the bottom is level. This will prevent ponding in lower areas. At this point, the empty space should equal to the desired ponding depth plus a mulch depth of 3".

Mulch quantity in cubic feet = 0.25'* x length of rain garden (ft) x width of rain garden (ft)
**** 0.25' = 3" of mulch***

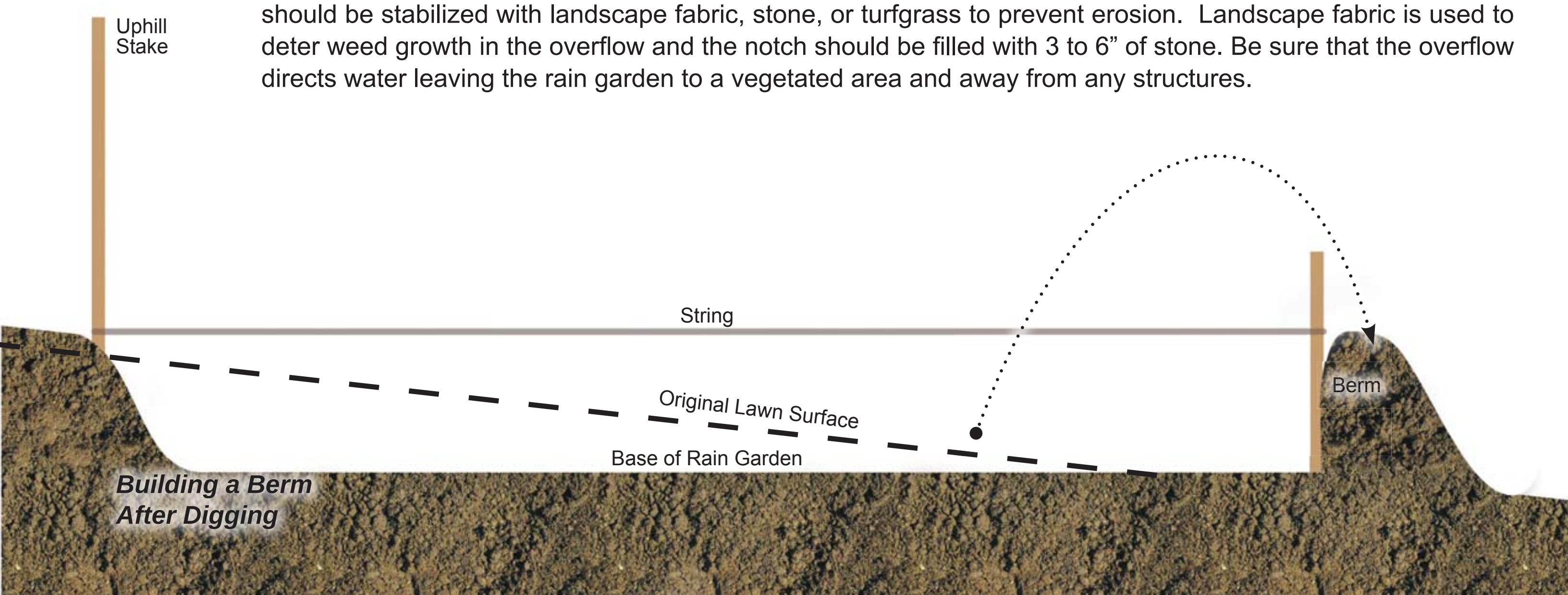
Mulch: A general rule of thumb is 0.5 yd^3 of mulch for every 50 ft^2 of rain garden. Bagged mulch is usually sold in cubic feet; however, if ordering a large quantity, keep in mind that it is sold by cubic yards and will need to be converted accordingly. Small, tender perennial plants can be protected during mulch placement by placing containers over plants to ensure that the mulch layer does not unintentionally cover plants. Mulch should be aged at least six months so it does not rob nitrogen from plants trying to establish. Triple or double shredded hardwood mulch is recommended for rain gardens because it has a decreased tendency to float away. However, hardwood mulch can be difficult to find in Alabama, especially when large quantities are needed. Pine bark or straw has been used successfully, but may require more frequent replacement to maintain a 3" mulch layer. Cypress mulch is not recommended as it is harvested from cypress wetlands and is not sustainable.

4. **Prepare Inlet, Berm, and Overflow**

Inlet: To prevent erosion at the inlet, a 1' wide strip of gravel, rocks, or concrete splash pad can be added to slow down and evenly disperse the flow of water into the rain garden. This is especially helpful when there are not any gutters or a gutter extension cannot be incorporated. More rocks can always be added later if erosion occurs.

Berm: The berm should be mounded on the downhill side of the rain garden where the overflow will exit the rain garden. A berm is not usually necessary when a rain garden is installed on a level landscape. The berm should be mounded as high as the uphill grade of the rain garden (see diagram below). Native grasses or turfgrass sod can be grown (or re-purposed) on the berm to provide cover and stabilize berm soil.

Overflow: A low spot or notch can be created on the berm to serve as the overflow. The overflow area of berm should be stabilized with landscape fabric, stone, or turfgrass to prevent erosion. Landscape fabric is used to deter weed growth in the overflow and the notch should be filled with 3 to 6" of stone. Be sure that the overflow directs water leaving the rain garden to a vegetated area and away from any structures.



Vegetation

Plant Characteristics: Rain garden type will determine which vegetation should be used. Generally, plants for rain gardens should be able to withstand periodic wet and dry periods. Most standing water in a standard rain garden should infiltrate within 24 hours, but during extended periods of rainfall, plants that are unaccustomed to these conditions may suffer. Likewise, periods of extreme drought may also injure plants that are not drought tolerant. Plants selected for all types of rain gardens should be evergreen or perennial and have sturdy root systems at planting.

Native Plants: Native plants are adapted to local environmental conditions and are considered to be low maintenance since they require less fertilizer, water, and pest control inputs, and are usually able to persist during periods of low rainfall or drought once established. Using native plants can also help meet ecological site goals such as providing wildlife habitat, food sources, or breeding sites.

Butterfly Attractors: Many rain garden plants attract butterflies and a combination rain garden and butterfly garden can be created with appropriate plant selection.

Edible Plants: When using edible plants, “eat at your own risk” because rain gardens capture pollutants from impervious surfaces and many of these may be absorbed by plants and held in the tissues.

Standard Rain Garden: A standard rain garden will include plants that prefer moist and dry conditions that have a facultative (FAC or FACW) wetland indicator status, indicating that they are found in both wetland and non-wetland areas.

For more information regarding wetland indicator status, see Appendix D on Vegetation

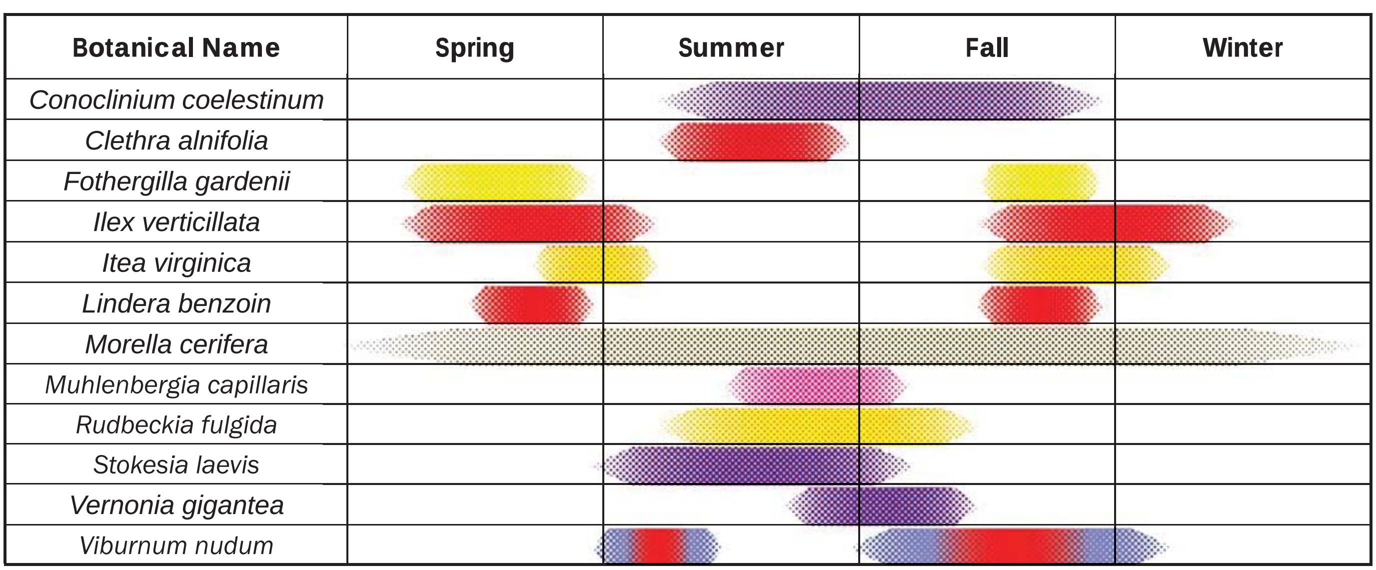
Wet Rain Garden: A wet rain garden will utilize wetland plants that are better suited to mostly wet conditions with facultative (FACW) and obligate (OBL) wetland indicator status.

Zoned Wet Rain Garden: A wet rain garden with zoned topography should have a mixture of plants for dry, moist, and wet conditions based on the topography of the rain garden.

Right Plant, Right Place: Plants more suited for wet conditions should be placed in the center of the rain garden, as this is the area that will typically remain wet the longest. In general, plants that prefer drier conditions should be placed on the slope, or perimeter of the rain garden. Be sure to plant accordingly based on preferred sunlight and water requirements .

Plant Spacing: The plant budget will often drive plant spacing. Dense planting or using larger containers will be more expensive. Perennials may be spaced two or more feet apart to lower plant costs. However, some property owners may prefer an instant landscaped look, and in this case, herbaceous perennial plants are usually spaced more closely. This is not only more expensive, but may lead to additional maintenance in the future as plants spread to colonize an area and encroach on one another’s space. Plants can compete for moisture, nutrients, and sunlight, so it’s best to resist the urge to over plant.

Seasonal Interest: Plan for seasonal interest by including plants that bloom at various times of year. Consider including species that are evergreen or have showy fall color. A seasonal interest calendar can be created to show times of year when plants are most visually interesting to ensure year round aesthetic value.



Rain Garden Plant List

The following plant list contains plants native to Alabama that are appropriate for standard and wet rain gardens.

Botanical name – This column indicates the genus and species assigned to each plant. Botanical or scientific names should always be used to prevent confusion because only one plant has been assigned that particular name; many plants share the same common name which causes confusion. (For example, the common name possumhaw could indicate *Ilex decidua* or *Viburnum nudum*). For more information, see Botanical Names in Appendix D on Vegetation.

Common name – This column is the name applied to a plant based on its botanical name, appearance, or some other characteristic of the plant.

Type – This column indicates the plant's growth habit (shrub, tree, herbaceous perennial or grass, fern, etc.).

Soil Comments – Many plants have a pH range or type of soil they will perform best in and this column shows any soil preferences each plant may have.

Prefers – This column shows moisture and light requirements for each plant. See Table below for moisture and light requirement definitions.

Determining plant spacing for a small rain garden.

Pioneer Museum; Troy, AL

Table 5.1.3
Rain Garden Plant List

Botanical Name	Common Name	Type	*Soil Comments*	Prefers
Acorus calamus	sweetflag	herbaceous grass	acidic, wet	2,3 Sun to Part Shade
*Asceplias incarnata**	swamp milkweed	herbaceous perennial	any	3 Sun or Part Shade
Amsonia tabernaemontana	Eastern bluestar	herbaceous perennial	sandy	3 Part Shade
Baptisia alba	white wild indigo	herbaceous perennial	sandy to rocky, tolerates clay	1,2 Sun
Carex crinita	fringed sedge	grass like	any	2,3 Part Shade to Shade
Carex comosa	bottle brush sedge	grass like	any	3 Part Shade
Carex lurida	lurid sedge	grass like	any	3 Part Shade
Carex tribuloides	bristlebract sedge	grass like	any	2,3 Part Shade
Chasmanthium latifolium	river oats	herbaceous perennial	any	2 Part Shade
*Conoclinium coelestinum**	blue mistflower	herbaceous perennial	any	2 Sun to Part Shade
*Clethra alnifolia**	summersweet	shrub	any	2,3 Sun or Part Shade
*Coreopsis auriculata**	lobed tickseed	herbaceous perennial	rich, acidic	2 Part Shade
*Coreopsis lanceolata**	tickseed	herbaceous perennial	any	1,2 Sun
Coreopsis nudata	Georgia tickseed	herbaceous perennial	rich, acidic	2,3 Part Shade
*Echinacea pupurea**	coneflower	herbaceous perennial	sandy	1,2 Sun or Part Shade
*Eupatoriadelphus fistulosus**	Joe Pye weed	herbaceous perennial	acidic, moist, or wet	2,3 Sun
Helianthus angustifolius	swamp sunflower	herbaceous perennial	any	2,3 Sun to Part Shade
Hibiscus coccineus	scarlet rose mallow	herbaceous perennial	any wet	3 Sun
*Hibiscus moscheutos**	crimson eyed rose mallow	herbaceous perennial	moist, alkaline	2,3 Sun to Part Shade
Ilex glabra	inkberry	shrub	sandy, acidic, peaty	1,2 Sun or Part Shade
*Ilex verticillata**	winterberry	small tree	any, acidic	1,2 Sun or Part Shade
Itea virginica	sweetspire	shrub	any, acidic	1,2,3 Sun or Part Shade
Juncus effusus	common rush	grass like	any, wet	2,3 Sun or Part Shade

Botanical Name	Common Name	Type	*Soil Comments*	Prefers
*Lobelia cardinalis**	cardinal flower	herbaceous perennial	any, will tolerant limestone based soils	2,3 Sun to Part Shade
Muhlenbergia capillaris	muhly grass	herbaceous grass	sandy or sandy loam	1,2 Sun or Part Shade
*Phlox carolina**	Carolina phlox	herbaceous perennial	sandy, loam, acid, will tolerate some lime	2 Sun to Part Shade
*Phlox divaritica**	blue woodland phlox	herbaceous perennial	any	2 Part Shade
*Physostegia virginiana**	obedient plant	herbaceous perennial	humus rich soils	1,2,3 Sun to Shade
Pontederia cordata	pickerelweed	herbaceous perennial	any	3 Sun to Part Shade
Rudbeckia fulgida	orange coneflower	herbaceous perennial	sandy	1,2 Sun or Part Shade
Sisyrinchium angustifolium	blue eyed grass	grass	poor to average moist soils	2,3 Sun to Part Shade
*Stokesia laevis**	Stoke's aster	herbaceous perennial	well drained acid sand preferred	1,2 Sun or Part Shade
*Vernonia novenboracensis**	Ironweed	herbaceous perennial	tolerates clay and acidic soils	1,2 Sun
Viburnum nudum	possumhaw	shrub	prefers acid mucky soils, but is adaptable	1,2,3

*Attracts butterflies, hummingbirds, or both

1. prefers dry conditions and can tolerate drought conditions; to be used on buffer, slope, or berm of standard rain garden and wet rain gardens with zoned topography.

2. prefers moderate or moist conditions and can tolerate occasional inundation. Plants labeled 2 are appropriate for the center of standard rain garden designs or wet rain gardens with zoned topography.

3. prefers wet conditions and are appropriate for wet rain gardens and deep pools of wet rain gardens zoned topography.

Sun – at least 6 hours of full sun per day.

Part Shade – 3 to 5 hours without direct sun per day.

Shade – less than 2 hours of direct sun per day.

Vegetation Design Guidelines

- Mature plant sizes should be considered, particularly if the rain garden is sited where visibility is a concern.
- The design plan should reflect mature plant sizes. Every square foot of the rain garden will not be covered at planting, but over time, the area will naturally fill.
- Large trees are generally not recommended due to the size and canopy cover, which can outcompete and shade out other plants. If you desire the size contrast offered by trees, consider training a shrub such as wax myrtle (*Morella cerifera*) into a tree form.
- Consider the direction a rain garden will be viewed. If it will be viewed from one side, i.e., the rain garden is located in the back of the yard, it may be appropriate to place taller plants in the back. If the rain garden will be viewed from two or more sides, i.e., the rain garden is sited in the front yard, taller plants should be placed in the center of the rain garden.

Create a Landscape Design

Sketch It Out: The rain garden area can be sketched out to help visualize how it will look after planting. A circle template (purchased from the school supply section) can be used to create a bird's eye or plan view of the rain garden sketched to scale. You will need to establish an appropriate scale to use (often decided by your available paper size), such as 1"= 1'. Start by sketching out the footprint of the rain garden. If using a 1"= 1' scale, a 10'x20' rain garden would be sketched on paper to an actual size of 10"x20". See Chapter 4.1 on Bioretention for examples of sketched out landscape designs.

Grouping Plants: Plants are usually grouped in clumps of three, five, or seven to avoid monocultures (plantings with only one plant species).

Extra Space: Be sure to include space between different plantings for maintenance access as well as any reseeding of perennial plants.

For more information on creating a landscape design, contact the local County Extension Office.

Calculating Plant Quantity

Another design option (used in Design Examples 1 and 2 in this handbook) is to calculate a plant quantity. Creating a landscape drawing is best, but a plant quantity can also be calculated so plants can be ordered and placed on the day of planting. Calculating plant quantity will help to avoid over or under purchasing of plants and overcrowding plants. When plants are purchased, nursery tags will denote preferred plant spacing for each species as well as plant height, soil characteristics, and light requirements. Species-specific spacing should always be used when that information is available, but the suggested spacing based on plant type in this handbook provides good general recommendations.

Divide the Space: It is sometimes easiest to divide the area into a mixture of smaller shapes that have easily calculated areas. For example, a rectangular rain garden can be divided into smaller squares, circles, or rectangles. This will make it easier to calculate the quantity of each plant for each part of the rain garden.

Spacing Guidelines: Plants can be spaced based on plant type and a plant quantity for each section of the rain garden can be calculated. This is especially helpful if the rain garden will consist mostly of grasses and perennials because 2' spacing is appropriate for most species of both plant types. By using this method, the total amount of plants needed is known and the rain garden plant selection can be based on what is available at the local nursery.

As a general rule of thumb for rain gardens, plant spacing guidelines based on plant types can be used as seen in Table 5.1.4.

Spacing Patterns: Plant quantity is calculated based on the square feet needed per plant, which is based on whether you plan to arrange plants on a rectangular or triangular grid pattern. For rectangular spacing, the space between plants and between rows is the same. Triangular spacing is generally more visually appealing as it creates a mass-planting look and plants are equally spaced within rows, but the rows are staggered.

Table 5.1.4
Plant Spacing Guidelines

Plant Type	Spacing
Herbaceous perennials	*1.5 - 2'*
Grasses	*2 - 3'*
Shrubs	*4 - 5'*

*Note: These spacing guidelines are meant to create masses of each plant type with sweeps of color. For more space between each plant, the spacing should be increased.

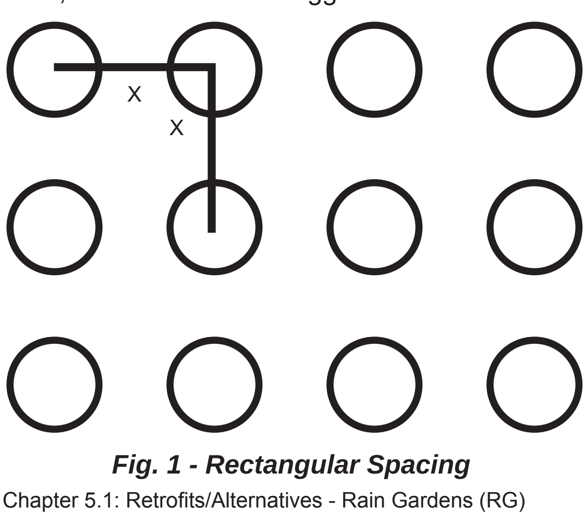


Fig. 1 - Rectangular Spacing

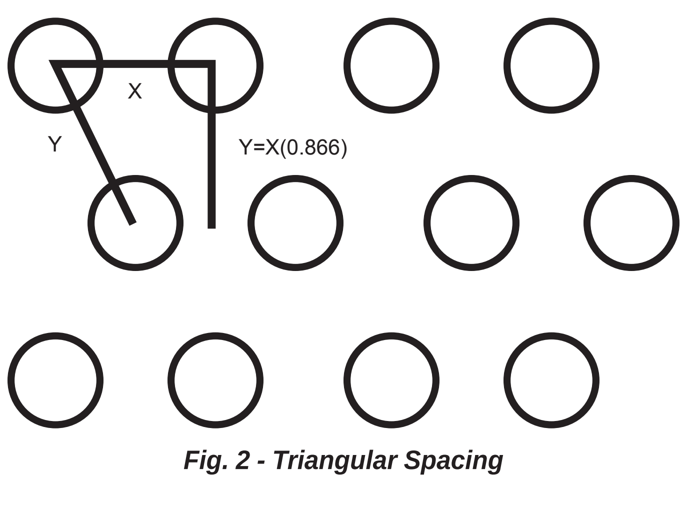


Fig. 2 - Triangular Spacing

An equation can be used to calculate plant quantity based on the selected spacing pattern.

Quantity = Area (ft^2) ÷ square feet needed per plant

So for a 100 ft^2 rain garden planted with herbaceous perennials on 2’ spacing in a rectangular spacing pattern, how many plants would be needed?

Rectangular Spacing Equation

$$ft^2/plant = (X)(X) = X^2$$

$$Quantity = \frac{Area\ (ft^2)}{ft^2\ /\ plant}$$

Triangular Spacing Equation

$$ft^2/plant = YX$$

$$ft^2/plant = [(X * 0.866(X)]$$

$$Quantity = \frac{Area\ (ft^2)}{ft^2\ /\ plant}$$

$$Quantity = \frac{100\ ft^2}{4\ ft^2/plant} = 25\ plants$$

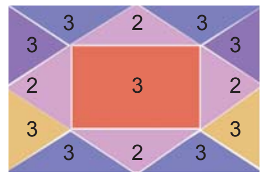
$$Quantity = \frac{100\ ft^2}{3.4\ ft^2/plant} = 29\ plants$$

When using this equation, recall that you will almost never come up with a whole number and since half of a plant cannot be installed, you must decide whether to round up or down. Units of Area should be consistent, so if your

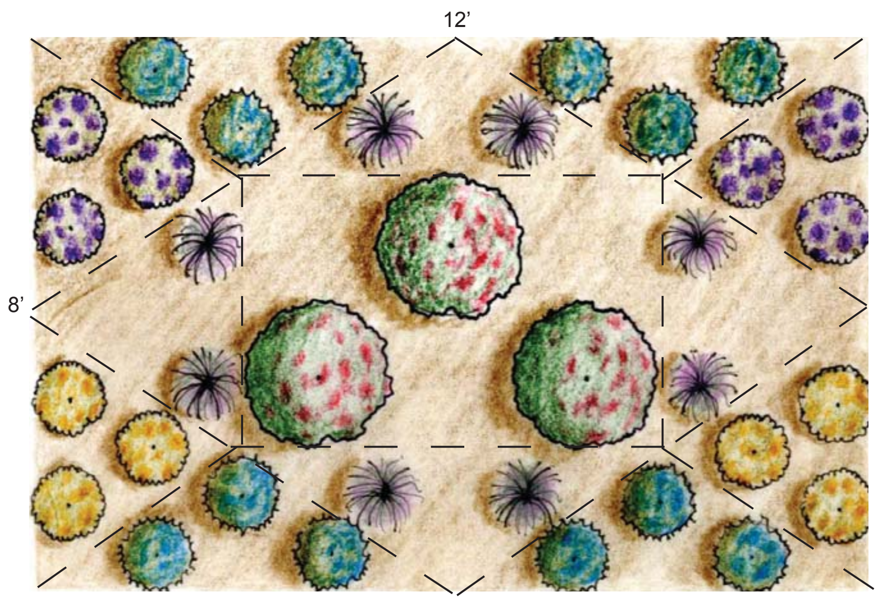
Rain Garden at Pioneer Museum; Troy, AL

Vegetation Design Example 1
Standard Rain Garden

This rain garden vegetation plan was designed for a front yard with showy plants and seasonal interest. The design calls for a 3” ponding depth and is an 8’ x 12’ (96 ft^2) rectangle on a triangular spacing pattern. The slope and buffer are planted with repurposed turfgrass.



Planting Diagram (ft^2)

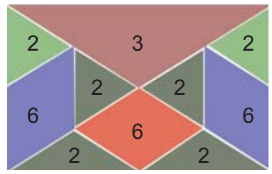


Plant List

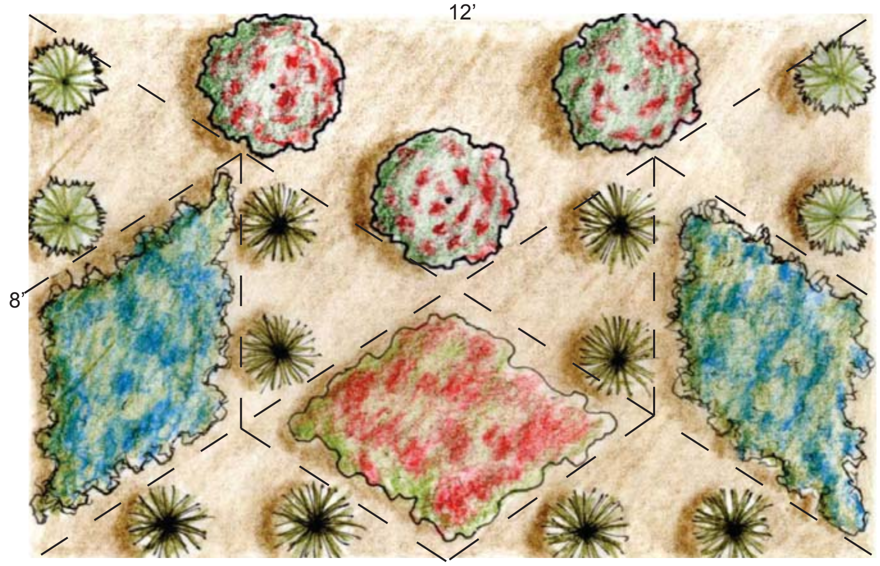
Plant Common Name	Spacing (ft)	Area (ft^2)	ft^2/plant	Quantity
crimsoneyed rose mallow	3	24	7.8	3
muhly grass	2	6	3.4	2
muhly grass	2	6	3.4	2
muhly grass	2	6	3.4	2
muhly grass	2	6	3.4	2
purple coneflower	1.5	6	2	3
purple coneflower	1.5	6	2	3
orange coneflower	1.5	6	2	3
orange coneflower	1.5	6	2	3
Stoke’s aster	1.5	6	2	3
Stoke’s aster	1.5	6	2	3
Stoke’s aster	1.5	6	2	3
Stoke’s aster	1.5	6	2	3

Vegetation Design Example 2
Wet Rain Garden

This rain garden vegetation plan was designed for a residential back yard. The design calls for a 3” ponding depth and is an 8’ x 12’ (96 ft²) rectangle on a triangular spacing pattern with standard (level) topography throughout the rain garden. The slope and buffer of this rain garden are planted with muhly grass.



Planting Diagram (ft^2)



Plant List

Plant Common Name	Spacing (ft)	Area (ft²)	ft² / plant	Quantity
common rush	2	6	3.4	2
common rush	2	6	3.4	2
common rush	2	6	3.4	2
common rush	2	6	3.4	2
cardinal flower	1.5	12	2	6
cardinal flower	1.5	12	2	6
sweetflag	2	6	3.4	2
sweetflag	2	6	3.4	2
swamp milkweed	1.5	12	2	6
scarlet rose mallow	3	2	7.8	3

Maintenance

Sediment and Debris Removal: Rain gardens collect surface runoff from impervious surfaces and as a result, tend to trap sediment and other debris. Although sediment deposition means that the rain garden is functioning, this sediment should be removed periodically. Sediment in the rain garden can cover plants hindering their growth, create a favorable environment for weed seeds to germinate, and clog mulch void space, which may keep the rain garden from drying out between rain events. Trash and other inorganic items should be removed from the rain garden as they collect.

Mulch Replacement: Leaves will degrade and mulch will decompose to replenish organic matter to the soil. Mulch should be maintained at 3" and bare areas should be replaced as needed. Full mulch removal and replacement should occur every two to three years or when mulch has become matted, thus preventing adequate infiltration of stormwater. Mulch depth should never be in excess of 3". Applying excess mulch will limit the storage volume of the rain garden and can potentially lead to problems associated with root rot of plants.

Pruning: Shrubs will benefit from annual pruning to encourage bud break and help maintain plant shape and form. Plants should be pruned based on the May Rule (See Appendix D on Vegetation). Seed heads and spent flowers can be left on herbaceous perennials for winter interest and as a food source for wildlife. It is sometimes helpful to leave the seed heads so these plants are not mistaken as weeds in the spring when new shoots begin growing. Leaving the seed heads can also encourage these plants to reseed themselves.

Table 5.1.5
Maintenance Task List

Task	How Often	Comments
Soil test	Prior to planting and every 3 to 5 years thereafter	Soil quality amendments such as lime and fertilizer should be incorporated prior to planting
Irrigation	At planting and twice per week for 6 weeks after planting	Once established, irrigate only during drought
Inspection	After 0.5" or greater rainfall event	Visually inspect all components of the rain garden for erosion or damage.
Pruning	Annually	Prune based on the May Rule
Replace dead vegetation	After first growing season	Diseased or insect infested vegetation should be removed
Plant Division	Every 2 or 3 years	Plants may become crowded over time and many perennials recommended for rain gardens will need to be divided (See Appendix D on Vegetation for more information).
Remove trash	As needed	Rain gardens in more commercial settings will collect trash more frequently
Remove deposited sediment	As needed or annually	Use a flat shovel to remove
Check for invasive nonnative plants	Twice per year	Hand pull and make sure mulch is in place to prevent weed seeds from germinating
Replace mulch	every 2 - 3 years	May need to replace bare areas to maintain at 3" depth

Pollutant Removal

Rain gardens are designed to uptake nutrients found in runoff, such as nitrogen and phosphorus. To facilitate phosphorus removal, rain garden soil should have a low to very low extractable phosphorus as indicated by a routine soil test. Research has shown that rain gardens planted in soils with high phosphorus actually export this nutrient instead of trapping it. Many Alabama watersheds and waterways already have excess phosphorus. Select a different site for the rain garden if the soil test indicates high or very high phosphorus levels.

References

Bailey, D.A. and M.A. Powell. 1999. Installation and Maintenance of Landscape Bedding Plants. http://www.ce.ncsu.edu/depts/hort/hil/hil-555.html.

Bannerman, R. and E. Considine. Rain Gardens : A how-to manual for homeowners. University of Wisconsin : University of Wisconsin – Extension Environmental Resources Center, 2003. Print.

Dietz, M.E. and J.C. Clausen. 2006. Saturation to Improve Pollutant Retention in a Rain Garden. Environ. Sci. Technol. 40:1335-1340.

Dougherty, M., C. LeBleu, E. Brantley, and C. Francis. 2007. Evaluation of Bioretention Nutrient Removal in a Rain Garden with an Internal Water Storage (IWS) Layer. American Society of Agricultural and Biological Engineers: Meeting Proceedings.

Dunnett, N. and A. Clayden. 2007. Rain gardens: managing water sustainability in the garden and designed landscape. Timber Press, Portland, OR.

Dussaillant, A. R., A. Cuevas, and K. W. Potter. 2005. Stormwater infiltration and focused groundwater recharge in a rain garden: simulations for different world climates. Sustainable Water Mgt. Solutions for Large Cities. 293: 178-184.

Dylewski, K.L. A.N. Wright, K. Tilt, and C. LeBleu. 2012. Effects of Previous Flood Exposure on Flood Tolerance and Growth of Three Landscape Shrub Taxa Subjected to Repeated Short-term Flooding. Journal of Environmental Horticulture. 30(2):58-64.

Hunt, W.F. and N. White. 2001. Designing Rain Gardens (bio-retention areas). North Carolina Cooperative Extension. AG-588-3.

Isaacs, K., J. Tuell, A. Fieldler, M. Gardiner, and D. Landis. 2009. Maximizing Arthropod-Mediated Ecosystem Services in Agricultural Landscape: the Role of Native Plants. Frontiers in Ecology and the Environment. 7:196-200.

New Jersey Rain Garden Manual. Native Plant Society of New Jersey. Assessed May 3, 2013: http://www.npsnj.org/pages/nativeplants_Rain_Gardens.html.

Obropta, C., W.J. Scriarappa, and V. Quinn. 2006. Rain Gardens Fact Sheet. Rutgers Cooperative Research and Extension, New Brunswick, NJ.

Virginia Department of Forestry. 2008. Rain Gardens Technical Guide. Virginia Department of Forestry, Charlottesville, VA.

Curb Cuts (CC)

Curb Cut; Point Clear, AL

Site Selection

Quantity Control	---
Drainage Area	small
Space Required	small

Works with:

Steep Slopes	---
Shallow Water Table	---
Poorly Drained Soils	---

General Significance

Construction Cost	med
Maintenance	low
Community Acceptance	high
Habitat	---
Sun / Shade	either

Synonyms: There are no synonyms for this practice.

Curb cuts convey stormwater into vegetated areas such as roadside swales, parking lot islands, rain gardens, or bioretention areas. Curb cuts are an easy retrofit that can be used in residential or commercial land use areas and are effective in moving stormwater to landscaped areas. Curb cuts are often used to convey stormwater into another low impact development (LID) practice. Curb cuts do not perform any pretreatment, but can minimize erosion by creating diffuse flow into other stormwater control measures (SCMs). Curb cuts can also be installed to redirect stormwater into a grassy field. While this is not directly considered a LID practice, it does reduce stormwater quantity in the receiving water body. Roadside curb cuts usually intercept perpendicular stormwater flow and in many cases multiple curb cuts are needed to adequately collect and move stormwater.

Site Selection

Crested Streets: Roadside curb cuts are best when used on crested streets that have their highest point in the center of the street and carry stormwater to either side.

Site Visit: Prior to design, a site visit during a rainfall event is helpful to note flow patterns that may affect stormwater flows into future curb cuts.

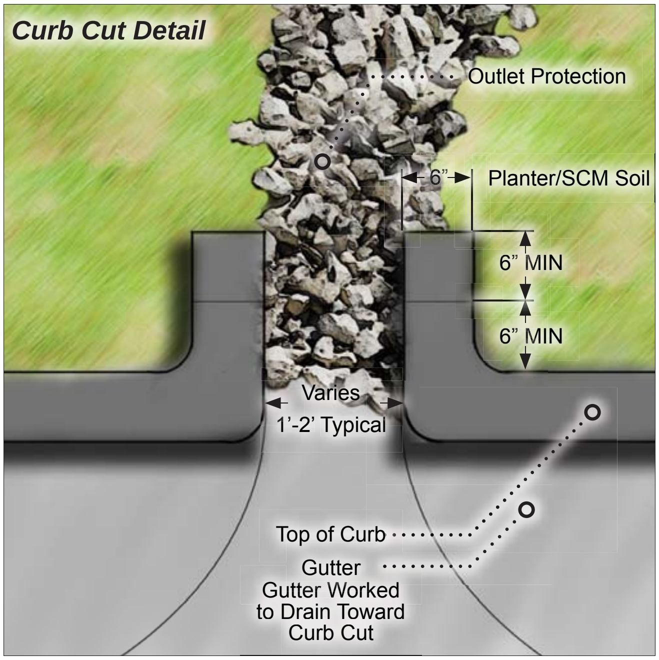
Local Ordinances: It should be noted that city or county codes and ordinances may require a permit application before any ground can be broken for curb cut construction.

Driveways and Intersections: It is recommended that curb cuts are sited at least 5’ from driveway aprons and 20’ from intersections.

Right of Way: When curb cuts are used to direct flow from roadsides into the right of way (ROW), landscaped areas should be a minimum of 6’ wide when street parking is utilized and 5’ wide on streets absent of parking.

Slope: Streets with greater than 5% slope are not recommended for curb cuts.

Submerged Curbs: Curbs that are submerged in water are not recommended for curb cuts.



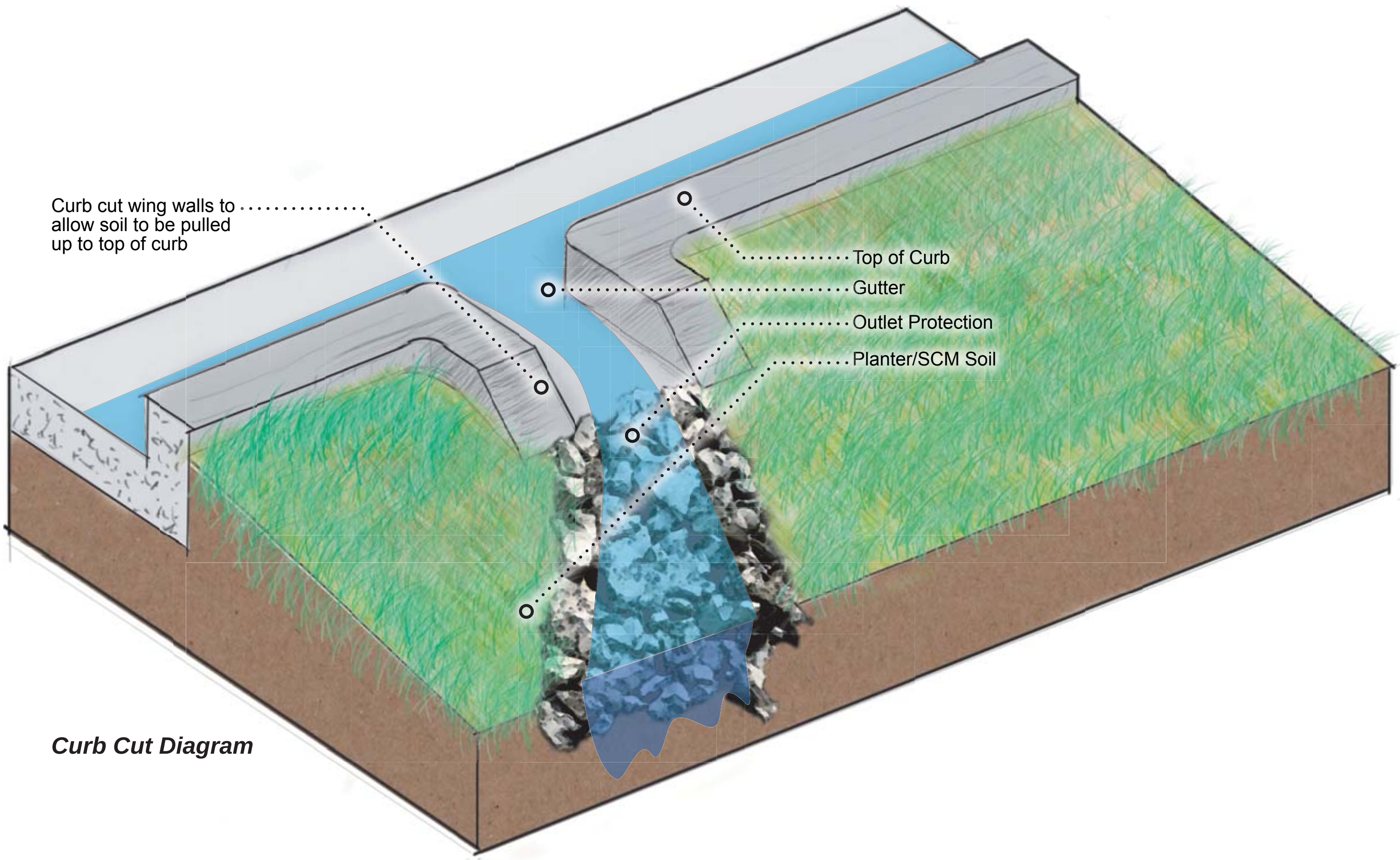
Design

Components

Outlet Protection: A rock apron that is as wide or wider than the curb cut is laid 1 – 2" below the curb cut to prevent soil erosion in the landscaped area that will collect stormwater.

Curb Cut: Curb cuts are generally 18 – 24" wide (a minimum of 12" wide is recommended to reduce the chance of clogging) and the cuts are usually made at 45° angles forming a trapezoidal channel shape. The bottom on the cut should be sloped down toward the area of stormwater collection.

Practice Pairing: When curb cuts are used in conjunction with SCMs, a 2 to 3" drop at the intersection of pavement and the SCM is needed to convey stormwater into the SCM.



Curb Cut Diagram

Table 5.2.2
Maintenance Schedule

Task	How Often	Comments
Remove Debris from Curb Cut	Three to four times per year	Remove trash or debris that may inhibit stormwater flow.
Check Rock Apron	Annually	Repair any erosion to rock apron.
Inspection	After 0.5” or greater rainfall event	Visually inspect all components of the curb cut.

Pollutant Removal

Curb cuts are used to convey stormwater into another SCM or vegetated area. Any associated pollutant removal occurs in the LID practice receiving the redirected stormwater.

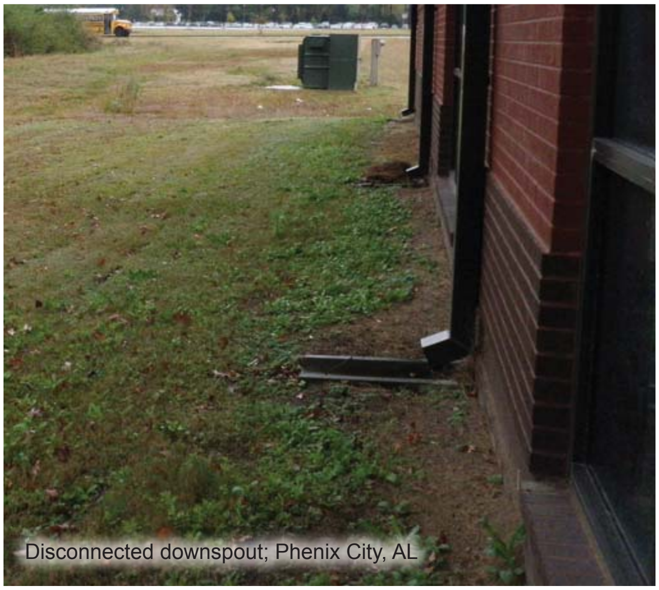
Curb Cut at Hank Aaron Stadium; Mobile, AL

References

City of Tucson. 2010. Green Infrastructure for Public Right of Ways: Curb Cuts and Sediment Traps. Watershed Management Group, Tucson, AZ.

Pennsylvania Department of Environmental Protection. Pennsylvania Stormwater Best Management Practices Manual. 2006. Bureau of Watershed Management, Harrisburg, PA.

Disconnected Downspouts (DD)



Disconnected downspout; Phenix City, AL

Site Selection

Quantity Control	---
Drainage Area	small
Space Required	small

Works with:

Steep Slopes	---
Shallow Water Table	---
Poorly Drained Soils	---

General Significance

Construction Cost	low
Maintenance	low
Community Acceptance	high
Habitat	---
Sun / Shade	either

Synonyms: There are no synonyms for this practice.

Rooftop runoff can be directed to vegetated areas through the disconnection of rooftop downspouts. By redirecting rooftop runoff, stormwater entering the stormwater conveyance network is reduced and groundwater recharge and runoff infiltration is increased. Disconnected downspouts are often used in conjunction with other stormwater infiltration practices by directing runoff to practices such as rain gardens, bioretention areas, and grassed swales. In doing so, the need for curbs, gutters, and conventional collection or conveyance of stormwater can be reduced.

Conventional stormwater practices focus on the immediate removal and conveyance of stormwater from impervious surfaces into storm drain networks. Typically, a stormwater conveyance network transports stormwater to a nearby outfall that is eventually discharged into a local waterway. As urban areas in Alabama expand and redevelop, increases in stormwater flows place tremendous pressures on aging sewer infrastructure. Disconnecting downspouts can help reduce the volume of untreated stormwater directed to waterways and decrease pollution in local streams and waterways.

Disconnected downspouts are applicable in residential or commercial settings. This handbook provides information regarding downspout disconnection for homeowners.

Site Selection Tips

- A good plan should be developed prior to downspout disconnection.
- Disconnecting the downspout should not result in any structural damage to you or your neighbor's property.
- Disconnected downspouts should not be directed to compacted soil that will not infiltrate stormwater. If downspouts are to be directed to poorly drained soils, an infiltration test should be conducted to ensure that standing water conditions will not persist beyond 48 hours as this can lead to mosquito breeding (for more information on how to conduct an infiltration test, see Chapter 5.1 on Rain Gardens).
- Proper execution of downspout disconnection should still allow stormwater to be quickly removed from any roadways and should not result in standing water on impervious surfaces.
- Areas with slopes greater than 10% are not appropriate for disconnected downspouts because steep slopes can result in increased runoff velocities and erosion.

Table 5.3.1
Site Selection: Constraints and Limitations for Disconnected Downspouts

House Foundation	Water should be discharged 5' from basements and 2' from building foundations; water should flow away from structure foundations
Slope	Downspouts should not be disconnected in areas with more than 10% slope
Septic System Drain Fields	Do not direct runoff over a septic system

Design Example

The following steps have been adapted from the City of Portland, 2011.

1. Examine Your Site

The first step is to determine where the downspouts drain to or where the runoff from the rooftop goes. Downspouts may drain to a standpipe or other stormwater conveyance network. It helps to draw or print out an aerial view of the building where rooftop square footage can be estimated and downspouts can be located.

2. Make a Plan

Mark downspouts on the site plan and determine any obstructions such as walkways or impervious surfaces that should be avoided when water is redirected. Extension elbows can be used to direct water around areas that need to be avoided or to direct water away from building foundations. Rooftop runoff can be directed to a rain garden or other landscaped area as long as the landscaped area is at least 10% of the rooftop footprint area. Rain gardens work well to treat rooftop runoff from downspouts because they are bowl shaped landscaped areas meant to capture water and encourage infiltration. See Chapter 5.1 on Rain Gardens for more information.

Check Your Available Landscape Size:

Roof Area		Sizing Factor		Landscape Area Size Needed
1000 ft^2	x	10%	=	100 ft^2 (10' x 10')

Tool List:

- Measuring tape
- Needle nose pliers or crimpers
- Hacksaw
- Drill
- Screwdriver or nut driver

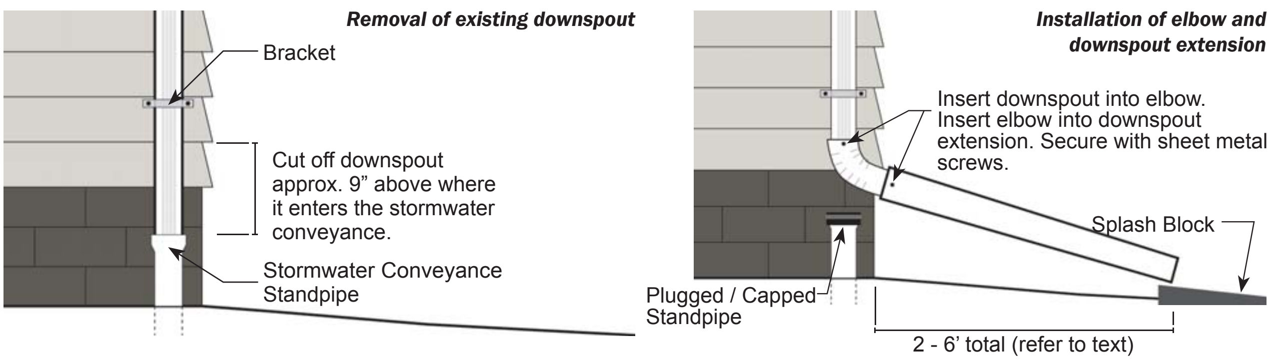
Materials: A materials list will include any downspout elbow or extensions needed plus any materials necessary to seal the standpipe. Be sure to measure the inside diameter of the standpipe so that the correct size rubber cap and hose clamp are purchased. If the downspout is only attached to the standpipe and gutter, a strap or bracket should be used to attach the downspout firmly to the building once it is disconnected. Durable materials should be used for the elbows and extensions. Avoid using corrugated plastic, PVC, dryer hose, or other materials that will degrade quickly.

Extensions can be used to direct runoff away from foundations or under other obstructions, such as a deck, so that flow is directed to a landscaped area. A hinged extension can also be helpful to use so it can be lifted out of the way when mowing the lawn. Concrete splash blocks or decorative rocks can be placed just beneath the downspout to minimize any erosion and direct flow during a heavy rain. A concrete splash block will help spread the runoff to disperse it evenly in a sheet flow pattern.

Continued on next page

3. Disconnecting

The downspout should be cut approximately 9” above where it meets the standpipe. Check the downspout extension length and cut higher if necessary. The standpipe should be sealed or plugged using either an in-pipe test plug or a cap secured by a hose clamp. Do not use concrete or any other substance to seal the standpipe. The elbow should be attached over the downspout; attaching the elbow inside the downspout can cause leakage near the building foundation. Needle nose pliers or crimpers can be used to bend the downspout to ensure that the elbow fits over the cut downspout. Next, the extension should be measured to either 2’, 6’, or to the length necessary to avoid obstructions. Two feet is the minimum amount of extension away from the building foundations and crawl spaces; 6’ is used when there is a basement that could potentially flood. Be sure to attach the extension pieces over the downspout elbow. Do not direct your runoff into neighboring properties. The extension should end at least five feet before the property line. Use sheet metal screws to attach extensions and elbows to one another. Pilot holes can make this an easier process. Add a concrete splash block or rocks below the extension piece to decrease soil erosion.



Maintenance

Gutters: Gutters should be free of debris, pitched, and efficiently direct water to attached downspouts. Flashing on the roof should direct water to the gutter system to avoid home maintenance issues.

Downspouts: Downspout elbows are prone to clogging and these should be checked periodically so that water flows freely. Extension pieces should be checked for proper connection and if these become loose, sheet metal screws should be used to firmly attach one piece to another.

Erosion: Landscaped areas where water has been directed should be checked during and after a heavy rainfall for any erosion, gullies, scour, or extended standing water conditions. If erosion is occurring, check that concrete splash blocks are in place and that vegetation is actively intercepting runoff.

Vegetation Maintenance: Depending on the landscape, plants that were previously unaccustomed to receiving excess runoff may suffer under soggy conditions. In such cases, rain gardens or vegetation that can handle extended periods of wet conditions may need to be used.

Table 5.3.2
Maintenance Schedule

Task	How Often	Comments
Clean Gutters	At least twice a year	Gutters with trees overhead may require cleaning out more frequently.
Caulk Leaks in Gutters	As they occur	Leaks or holes should be repaired as they appear.
Clear Elbows or Bends	As clogging occurs	Debris may collect in elbows or bends, which can inhibit water flow.
Inspection	After 0.5” or greater rainfall event	Visually inspect the downspout, gutters, and splash block for any damage.

Pollutant Removal

Impervious surfaces can contribute nonpoint source (NPS) pollutants to stormwater. Through disconnecting downspouts, stormwater is directed to vegetated areas; thus, stormwater pollutants can be treated by plant and soil filtration processes and runoff quantity is reduced. In slowing and reducing stormwater flows, stream erosion near stormwater outfalls may also be reduced.

References

City of Portland. 2011. How to Manage Stormwater: Downspout Disconnection. Environmental Services, Portland, OR.

Montgomery County MD. 2012. Disconnecting Downspouts. Department of Environmental Protection. Accessed on 1/18/12. http://www.montgomerycountymd.gov/dectmpl.asp?url=/content/dep/water/stormwaterdownspout.asp

Pennsylvania Department of Environmental Protection. Pennsylvania Stormwater Best Management Practices Manual. 2006. Bureau of Watershed Management, Harrisburg, PA.

Seattle Public Utilities. 2011. Rain Wise: Disconnecting Downspouts from the Sewer System – Safely!. Seattle Public Utilities, Seattle, WA.

::This page::
::intentionally left blank::

APPENDIX A: STORMWATER HYDROLOGY

In low impact development (LID), the objective of stormwater control measures (SCMs) is to mimic or replicate the hydrologic function of a natural system. This approach includes the integration of local site conditions, climate, and community with stormwater management to improve resources and quality of life.

By designing SCMs that closely resemble the runoff characteristics of the "undeveloped" site, the storage, infiltration, and pollutant treatment of a drainage area can be maximized. This is accomplished through the following means, where practical:

- minimizing peak flow runoff and volumes,
- removing pollutants,
- promoting infiltration in proper soil conditions,
- disconnecting otherwise connected impervious surfaces that drain directly to infrastructure.

"Where practical" is very important because as discussed in Chapter 2 on Site Selection, the goals and site constraints of a particular location may prevent or be impractical for the construction of some SCMs.

In addition to examining site goals and constraints, stormwater calculations are required in the design of SCMs. These calculations assist a designer in analyzing the effects of proposed stormwater management on hydrology, particularly peak flows and volumes prior to construction. Traditional stormwater management has always considered water quantity and the solution has been to pipe stormwater directly to the stream. LID and current stormwater management strategies have evolved to include not only water quantity treatment and retention to prevent flooding, but also pollutant treatment and water quality improvements. This chapter focuses on the fundamentals of computing stormwater runoff rates and volumes from rainfall using a variety of mathematical methods and models.

This guidance document includes provisions to control and treat a certain volume of stormwater runoff. Some practices/measures also target the control of peak stormwater discharge rates. Additional calculations are necessary to determine proper treatment capacity. It is up to the designer to determine if the calculations support design requirements.

The methodology for stormwater calculations found in this guidance document and allowable methods are found in Table A.1

Designers may adopt different calculation methods, however, the calculation method must meet or exceed the methodology outlined in this guidance document. The act of converting rainfall to runoff is complex and variable; however, by using the equations in this chapter, along with their assumptions and empirical data, an estimated or predicted runoff can be determined. Various methods are used because some of the equations are suitable for large volumes, while others work better for smaller storm events. Furthermore, some methods can be used to determine peak runoff rates, whereas others can determine both volume and peak runoff.

The equations used to calculate these values are presented in the Design section for each SCM presented in this handbook (Chapters 4.1 - 4.8); however, in some cases a model or automated program could also be used. Design guidance and examples are provided in thishandbook and due to rounding, your answers may vary.

Table A.1
Methodology for Stormwater Calculations

Calculation	Method
Peak Flow	Rational Method
Runoff Volume	Simple Method Discrete Curve Number Method
Channel Geometry	Manning's Equation
Hydraulic Performance of Standard Outlet Devices	Weir Equation
Storage Volume	Orifice Equation Stage-Storage Tables
Pollutant Removal	Pollutant Removal Efficiencies

The equations and methodologies presented in this chapter are unique because they require limited rainfall and drainage area data. More sophisticated methods and models have broader data requirements that may not be as available for widespread use. Often, a more data-intense model will produce a more comprehensive and accurate estimation.

Stormwater hydrology, or the science of stormwater and its interaction with the earth, is often depicted through the image of the hydrologic cycle. Stormwater, or runoff, is the by-product of the interaction of precipitation with the land cover or surface in which it comes into contact. Stormwater runoff is one of many pathways that water may take during the hydrologic cycle. Other pathways include precipitation, evaporation, transpiration from plants, and infiltration into the soil. However, due to the relationship between all of these processes, when stormwater runoff increases, other processes tend to decrease causing the cycle to be imbalanced. Rain or precipitation is considered the input of the hydrologic cycle and runoff or other processes are viewed as outputs. The equations used to calculate runoff are considered in a similar manner. The methods used to calculate runoff presented in this guidance document attempt to mathematically simulate processes observed in the hydrologic cycle. These methods treat rainfall as an input and calculate or convert rainfall into runoff volume and/or rate of runoff.

The magnitude, intensity, and frequency of rainfall are all important factors when characterizing the input or design of SCMs. When observing stormwater hydrology or predicting rainfall characteristics for design, the total rainfall that occurs over a particular duration and the likelihood of the reoccurrence of the same storm events is very important. The likelihood of its reoccurrence is called the Recurrence Interval. For instance, a rainfall event that occurs, on average, once every ten years would have an average Recurrence Interval of 10-years and is considered a 10-year storm. A storm's Recurrence Interval can be used to determine the annual probability or the probability of having a given storm event on any given year.

Traditionally, the total amount of rainfall, or runoff volume, for a given storm event has been the primary value of concern. However, a storm event's distribution or intensity variation over a span of time is also of interest, including the peak rate or peak runoff. A storm event's duration can vary dramatically and the peak runoff is dependent on both storm intensity and the surface that runoff encounters.

The equations presented in this chapter compute runoff and address this variability. Methods such as the Rational Method and Natural Resources Conservation Service (NRCS) Soil Conservation Service (SCS) Discrete Curve Number Method depend on a hypothetical rain event, or the design storm for the rainfall input. The design storm event is based on a compilation of local, regional, and statewide data recorded over an extended period of time. Using the design storm, a designer assumes existing waterway conditions and average antecedent moisture conditions. Depending on the existing conditions, these average conditions may case computations to differ from observed current wetter or drier conditions. Hydrologic conditions of the soils in the drainage area as well as the land cover over those soils can also significantly affect both runoff volume and peak runoff. Runoff calculations are impacted by pervious and impervious surfaces, whether those surfaces are connected or disconnected, and the time of concentration or the measure of how quickly or slowly a drainage area responds to rainfall.

The stormwater water quality design storm for Alabama is the rainfall event used to design structural and non-structural SCMs. The water quality design storm has a rainfall depth ranging from 1" - 1.5" depending on geographic location (e.g., coastal locations are 1.5"). See Runoff Volume below for more information. The design storm can be used to design SCMs based on the Rational, Simple, and Discrete Curve Number Methods. The appropriate SCM selection will depend on SCM type and required design data.

Modeling Various Site Conditions

Any given drainage area can have a variety of site conditions that affect the analysis and design of SCMs. This guidance, where applicable, is intended for all of the methodologies discussed above for the computation of runoff volumes and peak runoff. For all sites, a pre-developed land cover at a development site must be assumed to be forested and in good hydrologic condition, unless it can be verified that a different land cover has existed for a minimum of five years prior to the analysis.

Sites will typically have a mixture of pervious and impervious surfaces. Impervious surfaces are defined as any surface that will not allow water to penetrate the surface or infiltrate. Examples of these surfaces include but are not limited to roads, roofs, driveways, and parking lots. Impervious surfaces can be considered connected or disconnected. A connected impervious surface is a surface whose runoff drains directly to a pipe, stormwater conveyance network, or other impervious surface. These types of surfaces do not allow for infiltration or treatment of stormwater. Impervious surfaces, particularly directly connected surfaces, should be modeled and runoff calculated using linear methods such as the Rational Method or the Simple Method. When using the Discrete Curve Number Method to calculate runoff, the impervious and pervious surfaces should be treated separately, calculating runoff from each surface using a weighted average curve number (CN). This is particularly important when calculating runoff for a small rainfall event, with rainfall less than 2", as with using the design storm. It is recommended that runoff volumes be computed using a combined weighted average as a result of separately calculating runoff from the pervious and directly connected impervious portions of the drainage area. For larger storm events and larger rainfall depths, the designer can use his or her discretion in which technique to use.

Peak Flow

When designing practices such as swales, grassed filter strips, and riparian buffers, the calculated flow rate is needed to complete the design. In some states, peak runoff attenuation is required.

The Rational Method is the primary equation used to calculate peak flow.

This method uses an empirical linear equation to compute the peak runoff rate using a period of uniform rainfall intensity. The Rational Method uses a composite runoff coefficient, C, which is correlated with runoff potential and is unitless. A value of 0 is assigned to a surface with no runoff and a value of 0.95 - 1.0 is assigned to completely impervious surfaces. Typically a range of runoff coefficients is provided for a given land use. The designers must use his or her judgment to select an appropriate runoff coefficient value. Generally, larger areas with flat slopes, permeable soils, and dense vegetation are assigned a runoff coefficient from the low end of the range and the opposite is true for small, steep, and impervious areas. On the following page, Table A.2 shows examples if Rational Method runoff coefficients.

The precipitation intensity, i, can be determined using the National Oceanic and Atmospheric Administration (NOAA) Technical Memorandum NWS HYDRO -35 "Five – to 60 – minute precipitation frequency for the eastern and central United States", published in 1977. The maps found in this document can be used to determine precipitation intensity.

NOAA is in the process of using data stations across the state of Alabama to update precipitation intensity data. Rainfall frequency and intensity data from NOAA is currently found at http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=al. Precipitation intensity can be determined for a given annual return interval or specific storm duration. The technical memorandum has a series of graphs that can be used to determine rainfall intensity and equations for the partial duration series for selected return periods. Additionally, Technical Paper #40, "Rainfall

EQN A.1

$$Q = CiA$$

C = Composite runoff coefficient (unitless)
i = Rainfall intensity (in/hr)
A = Area (ac)
Q = Estimated Disign discharge or flow (cfs)

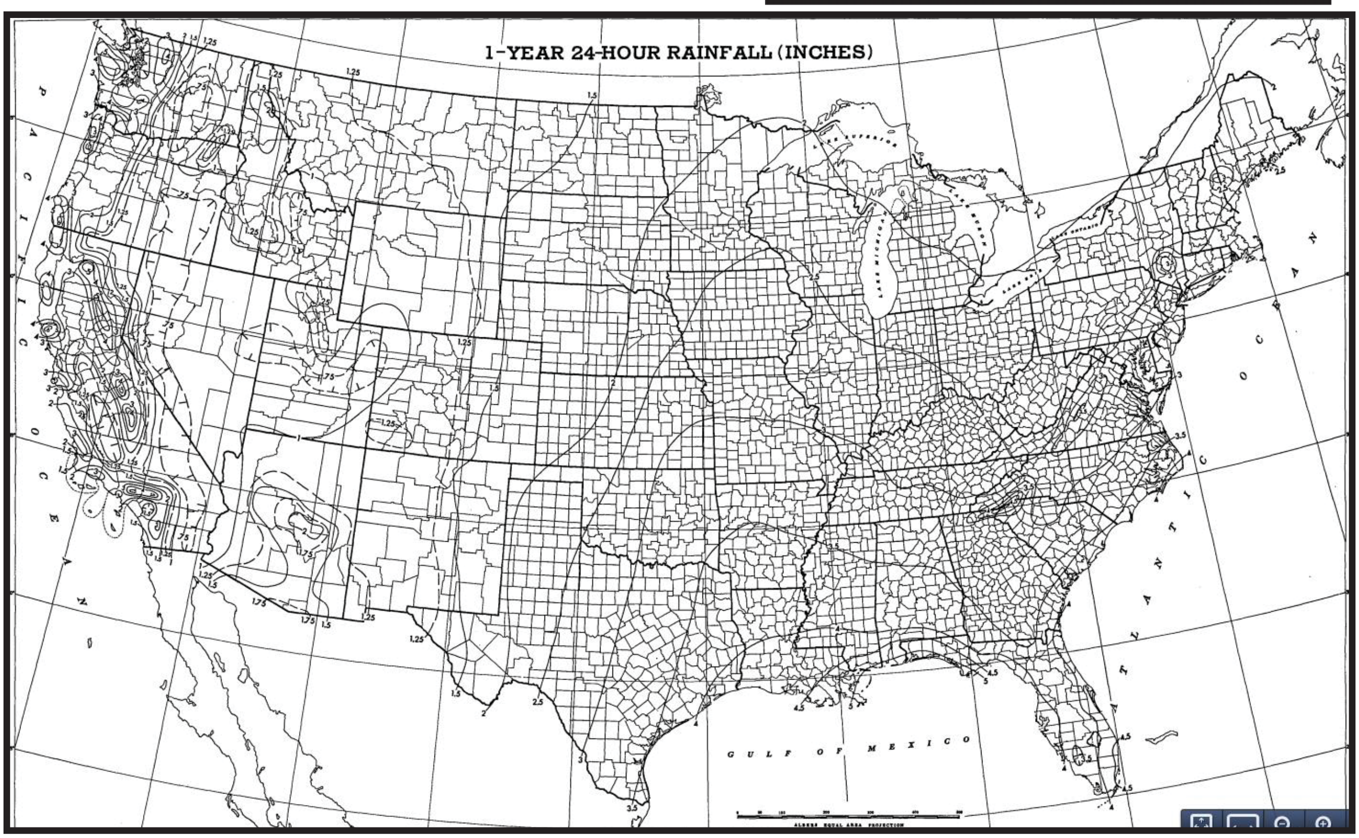


Figure 1. The 1-year 24-hour rainfall frequency graph, an example of graphs found in Technical Paper #40, "Rainfall Frequency Atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years"

Table A.2
Values of Runoff Coefficient (C)* for Rational Formula

Land Use	C	Land Use	C
		Lawns:	
Business:		Sandy soil, flat, 2%	0.05 - 0.10
Downtown areas	0.70 - 0.95	Sandy soil, avg., 2-7%	0.10 - 0.15
Neighborhood areas	0.50 - 0.70	Sandy soil, steep, 7%	0.15 - 0.20
		Heavy soil, flat, 2%	0.13 - 0.17
		Heavy soil, avg., 2-7%	0.18 - 0.22
		Heavy soil, steep, 7%	0.25 - 0.35
		Agricultural land:	
		Bare packed soil	
		-Smooth	0.30 - 0.60
		-Rough	0.20 - 0.50
Residential:		*Cultivated rows*	
Single-family areas	0.30 - 0.50	-Heavy soil, no crop	0.30 - 0.60
Multi units, detached	0.40 - 0.60	-Heavy soil, with crop	0.20 - 0.50
Munti units, attached	0.60 - 0.75	-Sandy soil, no crop	0.20 - 0.40
Suburban	0.25 - 0.40	-Sandy soil, with crop	0.10 - 0.25
		Pasture	
		-Heavy soil	0.15 - 0.45
		-Sandy soil	0.05 - 0.25
		Woodlands	0.05 - 0.25
		Streets:	
Industrial:		Asphaltic	0.70 - 0.95
Light areas	0.50 - 0.80	Concrete	0.80 - 0.95
Heavy areas	0.60 - 0.90	Brick	0.70 - 0.85
Parks, cemeteries	0.10 - 0.25	Unimproved areas	0.10 - 0.30
Playgrounds	0.20 - 0.35	Drives and walks	0.75 - 0.85
Railroad yard areas	0.20 - 0.40	Roofs	0.75 - 0.95

Frequency Atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years" published for the Engineering division of the Soil Conservation Service of the U.S. Department of Agriculture and the Department of Commerce can be used to determine precipitation intensity for smaller duration storm events (see Figure 1).

The Rational Method is most effective for drainage areas less than 20 acres in size and should be limited to drainage areas that are fairly uniform in land cover/land use and topography.

Runoff Volume

The majority of SCMs described in this guidance document are designed as volume control structures. The National Pollutant Discharge Elimination System (NPDES) Permit, General Permit (ALR100000) for Alabama states that "The permittee is encouraged to design the site, the erosion prevention measures, sediment controls measures, and other site management practices with consideration of minimizing stormwater runoff, both during and following construction, including facilitating the use of low-impact development (LID) and green technologies," and in order to comply, some volume control is necessary.

In Alabama, the current recommendation is to capture, retain, and infiltrate the "first flush" (first 1 - 1.5" of stormwater) volume within 2 - 4 days. The "first flush" is the initial surface runoff of a rainstorm. This volume of runoff has higher concentrations of pollutants in comparison with runoff later in the storm. By capturing this volume and treating it - we can account for 80% of the pollution. There is variation in the volume of water and rainfall depth that represents the first flush. This capture depth ranges from 1-1.5" across the state of Alabama, with the Coastal Plain experiencing a high first flush runoff depth (1.5"). When designing for the first flush, the SCM will be sized to appropriately capture, store, treat, or infiltrate this volume of stormwater. Due to the range of first flush depths across Alabama this guidebook uses varying first flush amounts corresponding with site location in the design examples presented. A 1.5" depth is most conservative and will size SCMs to ensure pollutant capture. Designers should check with the municipality they are working in to confirm an appropriate first flush depth. To achieve proper design for the capture, retention, and infiltration of this volume, two methods, the Simple Method and the Discrete Curve Number Method, are used to determine the runoff volume for a specific design storm. Runoff volume calculations are intended for site application and the scale of a single site.

The Simple Method was developed in the late 1980's and as the name implies, uses minimal site information. Schueler, et. al. developed the equation by collecting/measuring runoff data and plotting the relationship between percent imperviousness and runoff.

The Simple Method uses two equations to calculate runoff volume:

EQN A.2

$$R_V = 0.05 + 0.9 * I_A$$

R_V = Runoff coefficient, unitless
I_A = Impervious fraction, unitless

Upon determination of the runoff coefficient, the runoff volume can be calculated.

EQN A.3

$$V = 3630 * R_D * R_V * A$$

V = Volume of runoff that must be controlled for the design storm (ft^3)
R_D = Design storm rainfall depth (in) Typically 1 - 1.5"
A = Area (ac)

EQN A.3

$$S = \left(\frac{1000}{CN}\right) - 10$$

EQN A.4

$$Q = \frac{[P - (0.2S)]^2}{P + 0.8S}$$

The Discrete Curve Number Method, developed by NRCS, is an excellent fit for designing LID practices. The Discrete Curve Number Method, like the Simple Method, uses two equations to calculate runoff. The curve number, CN, is descriptive of the drainage area land use and the characteristics effecting stormwater runoff. The CN Discrete Curve Number Method uses a hypothetical design storm and an empirical nonlinear runoff equation to compute runoff volumes into runoff hydrographs and is the most widely used method for computing runoff.

Hydrologic soil group (HSG) classifications are crucial in the determination of curve number values. The four hydrologic soil groups are summarized in the Table A.3. Descriptions of saturated hydraulic conductivity for HSGs can be found

Table A.3
Four Hydrologic Soil Groups

	Properties
HSG A	Low runoff potential when thoroughly wet, less than 10 percent clay and more than 90 percent sand or gravel, and have sandy texture
HSG B	Moderately low runoff potential when thoroughly wet, between 10 percent and 20 percent clay and 50 percent to 90 percent sand, and have loamy sand or sandy loam texture
HSG C	Moderately high runoff potential when thoroughly wet, between 20 percent and 40 percent clay and less than 50 percent sand; and have loam, silt loam, sandy clay loam, clay loam, and silty clay loam textures.
HSG D	High runoff potential when thoroughly wet, greater than 40 percent clay and less than 50 percent sand, and have clayey textures.

USDA and NRCS, 2007

Table 2-2a Runoff curve numbers for urban areas [1]

Cover description: Cover type and hydrologic condition	Average percent impervious area [2]	Curve numbers for hydrologic soil group: A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.) [3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only) [4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation) [5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

1 Average runoff condition, and $I_a = 0.2S$.
2 The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.
3 CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
4 Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
5 Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4 based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

Table A.4 Soil Conservation Service Discrete Curve Numbers, Table 2-2a in Technical Release (TR-55), "Urban Hydrology for Small Watersheds" in Chapter 7 of the USDA and NRCS National Engineering Handbook.

Another characteristic effecting CN is land use, or more specifically, land cover. Impervious surfaces have high runoff potential because unlike vegetated open space, they have no means of infiltration. Higher runoff potential correlates to a higher CN. Geographic Information Systems (GIS) can aid in determining land cover, as well as site assessments, aerial photography, and land use.

A site will usually have more than one land use. The SCS Curve Number Method is applied to each land use separately and summed to determine total stormwater runoff. In some cases, such as the constructed stormwater wetland design example (see Chapter 4.2 on Constructed Stormwater Wetlands), an area-weighted composite curve number (CCN) can be used. This is called the Composite Curve Number Method and it should only be used for sites that do not have directly connected impervious surfaces and runoff. Runoff that is not directly connected simply means the runoff is "disconnected" by passing over a pervious surface, such as a lawn, and allowed to infiltrate.

Channel Geometry

Manning's Equation is applicable in determining channel geometry. To justify the use of Manning's steady-state flow, gravitational influences must be assumed. Channel geometry is important for the stability of design, with particular regard to erosion and sediment control. Manning's Equation is used to calculate channel geometry in the case of a grassed swale or level spreader channel and is often an iterative process that assumes channel dimensions to calculate the variables of area, wetted perimeter, and hydraulic radius.

Manning's Equation is:

EQN A.5

$$Q = \frac{1.489}{n} * A * R^{0.667} * S^{0.5}$$

Q = Peak Discharge or flow (cfs)
n = Manning's roughness coefficient (dimensionless)
A = Cross-sectional area (sq.ft.), typically triangular or trapezoidal
R = Hydaulic radius (ft)
S = Longitudinal slope, (ft/ft)

The hydraulic radius can be determined using:

EQN A.6

$$R = \frac{A}{P}$$

R = Hydaulic radius (ft)
A = Cross-sectional area (sq.ft.)
P = Wetted perimeter (ft)

For detailed equations on the calculation of trapezoidal and triangular channel geometry, please refer to Chapter 4.4 on Grassed Swales, Infiltration Swales, and Wet Swales.

Manning's n, is a roughness coefficient assigned to a particular material used to line the design channel, such as grass – n=0.035.

Hydraulic Performance of Standard Outlet Devices

The SCM designs presented in this guidance document are intended to target and treat smaller storm events. These systems require an outlet device or overflow to bypass larger storm events in order to maintain functionality and to meet safety guidelines. These outlet/overflow components must be considered and properly analyzed to determine how overflow from larger events will exit the system. These devices are usually weirs or orifices. Weirs are used to control exit elevations or to divert flow, whereas orifices are typically used to drawdown a SCM detaining stormwater for treatment.

Weir

The broad-crested weir application is most common for practices specified in this handbook. The Weir Equation is:

EQN A.7

$$Q = C_W * L * H^{1.5}$$

Q = Discharge or flow (cfs)
C_w = Coefficient of discharge (dimensionless), 3.0 for broad crested weirs
L= Length of weir (ft)
H = Driving head (ft)

Orifice

For most applications within this guidance document, an orifice is used to control the release of a designed volume of stormwater over an increased time interval. The primary equation is:

EQN A.8

$$Q = C_D * A * \sqrt{2 * g * H_O}$$

Q = Discharge or flow (cfs)
C_D = Coefficient of discharge (dimensionless), default value is 0.60
A = Cross-sectional area of flow at the orifice (sq ft)
g = Acceleration of Gravity (32.2 ft/s^2)
H_O= Driving head (ft) - measured at the centroid of the orifice to the water surface

Storage Volume

Many of the SCMs outlined in this guidance document do not have the capability to provide volume control. SCMs such as bioretention design include a storage volume allowing for some volume control, but the primary function of the SCM is water quality treatment, not water quantity. Each SCM chapter includes the specific calculations for meeting volume control; however, certain SCMs such as constructed stormwater wetlands, involve stormwater detention. These SCMs are designed to provide volume control for the design storm in temporary storage. For SCMs that involve the detention of stormwater, a stage-storage-discharge model is used to determine this relationship for proper design. Examples of models that may be used include but are not limited to HEC-HMS, WinTR-55, SWIMM, and HydroCAD.

Pollutant Removal

Within each SCM chapter there is a discussion of pollutant removal and a table of specified values for each specific SCM according to other jurisdiction. Alabama currently does not assign a specific removal rate of pollutants for each SCM; however, estimated pollutant removal for a designed practice can be assumed using the values found in the Pollutant Removal Table for each practice. In some instances, a municipal entity or a total maximum daily load (TMDL) may require a designer to use a practice that meets a specific pollutant removal standard, such as 85% removal of total suspended solids (TSS). To calculate nutrient removal, an approved removal efficiency can be multiplied by the pollutant loading in the influent to determine the pollutant loading in the effluent (typically in lb/ac/yr).

Pollutant removal can be calculated for each SCM. A given site may include multiple drainage areas and multiple SCMs; however, the overall site must meet the regulatory requirements set forth in the NPDES permit for quantity and quality. If multiple SCMs are used for the same drainage area, they may be weighted to meet the removal requirement of the overall site. For SCMs that do not provide direct input into another SCM, the SCMs can be considered in "parallel" and a flow-weighted removal proportional to the individual removal rate and the fraction of total flow passing through each SCM can be calculated to determine the site's pollutant removal efficiency. Volumes treated for SCMs in parallel are summed for a total volume treated for the site. For SCMs that are placed in a "treatment train" or in series and capture the same drainage area, volume control can be combined, as well as removal efficiency. However, the removal efficiencies are not additive.

The following equation can be used to calculate combined removal efficiency for a given site utilizing a "treatment train":

EQN A.9

$$Q = SCM_1 + SCM_2 - \left[\frac{(SCM_1 * SCM_2)}{100}\right]$$

E = Total pollutant removal efficiency (%)
SCM_1 = Efficiency of first SCM
SCM_2 = Efficiency of second SCM

In cases where the "treatment train" includes more than two SCMs, the equations can be applied iteratively.

References

USDA and NRCS. 2007. Part 630 Hydrology National Engineering Handbook, Chapter 7 Hydrologic Soil Groups. Accessed 05 July 2013. http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17757.wba

New Jersey Department of Environmental Protection Division of Watershed Management. 2004. Best Management Practices Manual. Trenton, NJ.

US Department of Agriculture and Natural Resources Conservation Service. 1986. Urban Hydrology for Small Watersheds. Technical Release 55 (TR-55).

North Carolina Department of the Environment and Natural Resources. 2007. Stormwater Best Management Practices Manual, Ch 3: Stormwater Calculations (Chapter revised 2009). North Carolina Division of Water Quality, Raleigh, NC.

Appendix B: Community Planning Resources

Auburn, Al Model Stream Buffer Ordinance

Section 412. Natural Resource Protection Standards.

A. All residential and nonresidential development shall be preceded by the identification of any environmental or natural feature described in Sections 413 through 420 and shall meet the specified standards of environmental protection.

B. Site alterations, regrading, filling and clearing or planting vegetation prior to approval of the subdivision plats and/or site plans for development shall be a violation of this Ordinance. Reference in this section to "open space" is intended to mean the term as it is defined by Article II and described in Section 421.

Section 413. Stream Buffer.

413.01. Purpose. The purpose of this Section is to establish minimal acceptable requirements for the design of buffers to ensure that the stream and adjacent land will fulfill their natural functions; to reduce land development impacts on stream water quality and flows; and to provide for the environmentally sound use of Auburn's land resources.

413.02. Definitions. For the purpose of this section, the following words or phrases shall be defined as specified below.

A. *Perennial stream:* See Article II, Definitions—Stream, Perennial

B. *Intermittent stream*: A stream that flows at least six months out of a year but does not flow during part or all of the summer and may carry water during or after a rainstorm.

C. *Ephemeral stream:* A stream channel or reach of stream channel that carries surface water runoff for short durations as a result of precipitation events. The channel bottom is always above the groundwater table.

D. *Best Management Practices (BMPs):* Conservation practices or management measures that control soil loss and reduce water quality degradation caused by nutrients, animal wastes, toxics, sediment, and runoff.

413.03. Streams Determination. Perennial and intermittent streams are identified through site inspection by the City Engineer or his designee and/or US Geological Survey (USGS) maps. Perennial streams are those which are normally depicted on a USGS map with a solid blue line. Intermittent streams are normally depicted on a USGS map with a dotted blue line. Perennial and intermittent streams not identified on the USGS map as described herein may be added to a development site plan by the City Engineer and/or his designee based on the determination by a qualified professional that the stream satisfies the USGS definition for said streams. Ephemeral streams are streams assessed and determined by the City Engineer and/or his designee through stream delineation done on the development site as reported by a qualified professional.

413.04. Buffer description, width, and permitted uses. Stream buffers shall be required on each side of all perennial and intermittent streams as defined in Section 413.02 and further described in Section 413.03. Stream buffers width shall vary based on the size of the upstream drainage basin. Table 4.31 specifies the buffer required based on the drainage area for a particular stream above the most downstream point on the development being considered. The USGS 7.5 minute 1":2000' quadrangle maps, in conjunction with the Soil Survey Maps of Lee County and the City of Auburn Geographic Information System (GIS), will serve as tools to delineate the size of drainage basins and specify the corresponding buffer width.

The stream buffer is comprised of three zones: S*treamside Zone, Managed Use Zone, and Upland Zone*. Buffer zones' function, vegetation and permitted uses vary by zone as described in the Table 4.32.

TABLE 4.31

Stream Buffer Width Based on Drainage Area

Drainage Area (Watershed) Designation	**Streamside Zone**	**Managed Use Zone**	**Upland Zone**	**Total Buffer Width on each side of Stream**
< 100 acres	25 feet	None	10 feet	35 feet
≥ 100 acres	25 feet	None	20 feet	45 feet
≥ 300 acres	25 feet	20 feet	10 feet	55 feet
≥ 640 acres	25 feet	50 feet	25 feet	100 feet

If an ephemeral stream remains after construction has been completed, and all or a portion of that stream falls within the stream buffer of an intermittent or perennial stream, then that ephemeral stream shall be revegetated on both sides of the stream in accordance with the targeted vegetation of the corresponding buffer zone. Appropriate stream bank stabilization measures shall be designed if warranted by excessive velocities in the ephemeral stream. If the ephemeral stream remains after construction and falls outside of an intermittent/perennial stream buffer, then that ephemeral stream shall be grassed and/or revegetated in accordance with the surrounding vegetation at a width of 25 feet on each side of the ephemeral stream. Ephemeral stream channels and banks shall be stabilized as appropriate for the predicted stream velocities. These measures are performed in order to preserve and protect water quality.

TABLE 4.32

Stream Buffer Description and Permitted Uses

Characteristics	**Streamside**	**Managed Use Zone**	**Upland Zone**
Function	Protects the physical and ecological integrity of the stream ecosystem	Protects key components of the stream and provides distance between upland development and the streamside zone	Prevents encroachment and filter runoff from residential and commercial development
Vegetative Target	Undisturbed natural vegetation	Mature vegetation and native trees; exotic vegetation and underbrush may be removed and maintained	Lawns, gardens, shrubs, and pervious landscaping features
Uses	Very restricted- Permitted uses limited to: flood control structures, utility easements*, natural footpaths, crossings and approaches for paved roadways, and pedestrian paths and bikeways.	Restricted- Permitted uses limited to: all uses allowed in the Streamside Zone as well as storm water best management practices (BMPs), biking and hiking paths (with natural or pervious surfaces), greenway trails, and limited tree clearing approved by the City Engineer.	Restricted- Permitted uses limited to: all uses allowed in the Streamside and Managed Use Zones, as well as, grading for lawns, gardens, and gazebos and accessory structures. No septic systems, principal structures or impervious surfaces are allowed.

**As deemed necessary and approved by the City Engineer*

413.05. Applicability. The buffer requirements shall apply to all perennial and intermittent streams defined in Section 413.02. Buffer widths for streams are measured horizontally on a line perpendicular to the surface water, landward from the top of the bank on each side of the stream. The top of bank is the landward edge of the stream channel during high water or bank full conditions at the point where the water leaves the stream channel and begins to overflow onto the floodplain.

All properties shall be subject to the buffer width requirements except those properties that are an existing lot of record and/or included on an approved preliminary subdivision plat and the lot or lots cannot meet the requirements described in this Section. *(Effective date 5/02/06 pursuant to Ordinance Number 2389)*

413.06. Minimize Intrusion. Any uses allowed in Table 4.32 shall be designed and constructed to minimize the amount of intrusion into the stream buffer and to minimize clearing, grading, erosion, and water quality degradation.

413.07. Land in the Stream Buffer. Land in stream buffers shall not be used for principal structures. All new platted lots shall be designed to provide sufficient land outside of the stream buffer to accommodate primary structures. Stream buffers should be delineated before streets and lots are laid out to minimize buffer intrusion and to assure adequate buildable area on each platted lot.

Land within the stream buffer can serve to meet the minimum lot size requirements.

413.08. Setback Requirements. For all lots within a development requiring a stream buffer, setbacks can be 100% within the stream buffer.

413.09. Buffer Impact. When the application of the buffer zones would result in the loss of buildable area on a lot (See Section 203 for definition of "lot") that was recorded prior to the amendment of this ordinance, modifying the width of the buffer zones may be allowed, through an administrative process, as determined by the City Engineer.

Modification and mitigation of the stream buffer width are also available to landowners or developers of newly platted lots or subdivisions where there are exceptional situations or physical conditions on the parcel that pose practical difficulty to its development and restrict the application of the regulations of this ordinance. There must be proof of such circumstances by the landowner.

The landowner or his designated representative proposing any of the impacts shall prepare and submit for approval a written request and a site plan showing the extent of the proposed impact and must specify a proposed mitigation technique. Mitigation techniques are included in Section 413.10.

The City Engineer and other appropriate city staff members shall review and render a decision on any buffer encroachment and mitigation technique with regard to the stream buffer requirements. Amendment to the stream buffer width may be allowed in accordance with the following criteria:

A. The proposed encroachment and mitigation is in accordance with the purpose and intent of this section of the ordinance.

B. The proposed lot and structure conforms to all other zoning and development regulations.

C. Encroachments into the buffer areas shall be the minimum necessary to achieve a reasonable buildable area for a principal structure and necessary utility.

D. The landowner or his designated representative submitted an acceptable written statement justifying the need for the buffer impact.

E. The landowner or his designated representative submitted an acceptable mitigation plan in accordance with cited mitigation techniques.

F. Attention has been given to maintaining natural vegetation and eliminating run-off.

In no case shall the reduced portion of the buffer area be less than the width of the Streamside Zone (25 feet).

413.10. Stream Buffer Mitigation Techniques. The following techniques are available to landowners for mitigation of buffer impact.

A. *Installation of Structural BMPs.* The installation of an on-site structural BMP (i.e. bioretention, extended detention/retention, rain gardens, stormwater wetlands, etc.) will allow for stream buffer impacts on the specific site. The structural BMP shall be designed to achieve pollutant (nutrients, herbicides, pesticides, sediment and other illicit discharges) removal to the maximum extent practicable. The BMP shall remain outside the Streamside Zone. A detailed BMP design plan must be submitted to the City Engineer for approval along with a long-term maintenance plan.

B. *Controlled Impervious Surface.* The landowner may commit to and provide a specific site development plan that limits the overall site impervious surface ratio equal to or less than 25%.

C. *Open Space Development.* The landowner may submit a specific site development plan which preserves an undisturbed, vegetative area on-site or near the development site as open space equal to 200% of the buffer encroachment area. The open space preserved must promote water quality protection.

D. *Stream Restoration*: The landowner may restore and preserve the buffer area on any stream of equivalent or greater drainage area the condition of which is determined to be qualified for restoration by the City Engineer on a 1:1 basis in linear feet of stream. This restoration shall include stream bank improvements and Streamside and Managed Use Zone re-vegetation.

E. *Stream Preservation:* The landowner may purchase, fee simple, other stream segments within the city limits at equivalent or greater drainage area on a 1:1 linear foot basis and convey fee simple and absolute title of the land to the City.

F. *Wetland Restoration*: On a 2:1 acreage basis for disturbed stream and buffer area (2 acres of wetland for each acre of disturbed area), the landowner may provide a combination of the preservation and/or restoration of wetlands with protective easements, and the implementation of structural or non-structural BMPs to achieve pollutant removal to the maximum extent practicable.

G. *Greenways*: The landowner may allocate and donate open space within the city limits through fee simple to the City of Auburn for preservation and use as common open space.

H. *Wider Buffer Widths:* A developer may add additional widths to buffer areas where encroachment occurs in other areas on a development site and may obtain an acre for acre credit based on the stream buffer zone impacted. A 2:1 credit could be obtained by determination of the City Engineer in the event additional streamside buffer is set aside for encroachment of the managed use and upland stream buffer zones.

I. *Other Mitigation Techniques:* Other creative mitigation techniques and plans may be considered by the City Engineer.

413.11. Vegetation Preservation. The buffer shall provide for the preservation and enhancement of natural vegetation or planting. No live vegetation may be removed from the Streamside and Managed Use Zones for preparation of land for uses permitted in Table 4.32 unless approved by the City Engineer.

The City Engineer may grant approval of the removal of exotic vegetation (i.e. privet, kudzu, etc.) provided that a vegetation restoration plan is submitted and approved prior to the disturbance of the vegetation. The purpose of such plan is to ensure that native vegetation is restored to the Streamside Zone.

Where a developer or lot owner removes live vegetation from the buffer strip, in violation of this section, the City Engineer shall require native vegetation of reasonable diameter in size to be planted so as to create a buffer area which is in compliance with this section. A vegetation restoration plan must be submitted and approved by the City Engineer prior to restoration.

413.12. Vegetation Restoration Plan. A vegetation restoration plan shall include the following information:

A. Scaled map of lot showing buffer delineation (copy of the survey is acceptable).

B. Square footage of the actual area disturbed or proposed disturbed area.

C. Proposed vegetation to be removed from the buffer.

D. Proposed location, number, and species of plants to be planted in the disturbed area (See list of plant species).

E. Type of ground cover to be placed in the disturbed area (i.e. mulch, pine straw, etc.).

F. Proposed planting schedule and deadline for completion of restoration activities.

413.13. Buffer Delineation. The following buffer delineations are required:

A. Stream boundaries including each buffer zone must be clearly delineated on all grading plans, subdivision plats, site plans and any other development plans.

B. The outside boundaries of the *Managed Use Zone* of the stream buffer must be clearly marked on-site by flagging or fencing prior to land disturbing activities.

C. The outside boundary of the *Managed Use Zone* must be permanently marked at highway stream crossings.

D. Stream and buffer boundaries including the delineation of each buffer zone must be specified on all surveys and recorded plats and noted on individual deeds.

E. Stream buffer requirements must be referenced in homeowners association documents.

413.14. Approved Permits. Where a landowner or his representative obtain permits from Alabama Department of Environmental Management (ADEM) or the U. S. Army Corp of Engineers for proposed impact to the stream or stream buffers then these approved mitigation impacts and plans would supersede the applicable requirements of these sections of the ordinance. The regulations that these permits do not affect shall be applicable to the proposed development site.

Additional information on the Auburn, AL Ordinances may be found at the following link.

http://www.auburnalabama.org/

G. Design Standards for Conservation Subdivisions

1. Dimensional Standards:

Each lot shall have frontage on a public street.

Minimum Lot Area: The minimum lot size is as follows:

Within the Watershed:

Option 1: *Conservation Subdivision*

Minimum lot size for lots without sewer-- 1.5 acres
Minimum lot size for lots with sewer --- 10,890 square feet

Option 2: *Conventional Subdivision*

Minimum lot size for lots without sewer-- 3 acres
Minimum lot size for lots with sewer --- Same as the minimum lot size for specified for the underlying zoning district.

Outside the Watershed:

There is no minimum lot size requirement outside the watershed area. However, the density allowed by the underlying zoning district or specified in these regulations limits the maximum site density.

Minimum Lot Width: 50 feet

Minimum Yards:

Front /Side Street: 20 feet *(porch is included)*
Side: 10 feet
Rear: 20 feet

2. Maximum impervious surface: The overall impervious surface ratio (ISR) of a conservation subdivision in the Lake Ogletree Subwatershed should not exceed 10 percent of the gross area. If the ISR must exceed 10 percent, then appropriate stormwater Best Management Practices (BMPs) shall be incorporated on the development site outside the required Open Space (See Item 8 under this section).

Outside the watershed areas, the overall ISR shall be determined by the underlying zoning district. If the development site is located outside the watershed but within the planning jurisdiction, there shall be no ISR requirement.

3. Street Design

Street Width: Minimum right-of-way (ROW) widths, measured from lot line to lot line; and minimum street width, measured from back-of-curb to back-of-curb, shall be as follows:

Design Factor*	Alley (one way)	Local	Cul-de-Sac	Residential Loop One Way/Two Way
B/C to B/C Width	Not Required	26 feet	26 feet	15 feet/27 feet
Pavement Width	11 feet	22 feet	22 feet	11 feet/22 feet
ROW	25 feet	50 feet	50 feet	varies
Minimum centerline radius	100 feet	200 feet	200 feet	100 feet
Maximum Grade	15%	5%/15%	5%/15%	5%/15%
Design Speed	15 mph	25 mph	25 mph	15 mph
Sidewalk Location	Not Required	Optional/ Pervious	Optional/ Pervious	Optional/ Pervious
Public/Private	Public/Private	Public	Public	Public

*Curb and gutter required where profile grades exceed 5%

All other street classifications shall conform to design requirements found in Article IV, Section C.

Street Layout: The use of interconnected streets and alleys shall be used throughout the development site. Street design such as loop streets is preferred to the use of cul-de-sacs.

4. Cul-de-sac Streets: Cul-de-sacs shall be permitted where topographic features or configuration of property boundaries prevent street connections. In such cases, a planter island shall be incorporated in the center of the terminus. The planter island shall have a minimum radius of 20 feet and shall be reinforced with a mountable rolled curb, at a minimum. Other alternatives to the cul-de-sac shall include an eyebrow or crescent with an island and a one-way loop (See Figure 1).

5. Shared Driveway: Common/shared driveways are encouraged to reduce impervious surface. All shared driveways must be constructed in accordance with standards approved by the City Engineer.

6. Sidewalk/Trail System: Sidewalks shall be installed along one side of the street within a conservation subdivision. Pedestrian trails shall also be permitted in a conservation subdivision. Sidewalks or trails must provide pedestrian access to all existing and planned bicycle and/or greenway networks that run through and adjacent to the development site.

Trails shall be planned, designed and constructed to avoid or minimize degradation of natural resources. Trails shall be soft-surface except where necessary to prevent erosion and/or resource damage. To the extent possible, trails shall provide for pedestrian, bicycle, and/or other non-motorized uses.

All trails and sidewalks shall be designed in accordance with current American Association of State Highway & Transportation Officials (AASHTO) standards. Sidewalks and trails may be constructed of pervious concrete and other porous materials provided the runoff through the material will not be directed towards the subgrade of the traveled lane portion of a roadway. Sidewalks shall be no less than four feet in width.

The City may consider the installation of an alternating sidewalk/trail system in lieu sidewalks. Such system must incorporate well-connected sidewalks and trails that link each residential lot with on-site open space, recreational facilities, and other amenities within the development site. A sidewalk/trail plan for the entire development site must be submitted to the City Engineer for approval. The plan shall include a map depicting the proposed location of all sidewalks and trails throughout the development site. The plan shall be submitted with initial set of construction plans for the proposed development site.

7. Other Design Standards

See Article IV, Design Standards, for other street, sidewalk, block and lot standards.

8. Stormwater Treatment Design Standards.

Within the Lake Ogletree Subwatershed, each development site overall impervious surface ratio (ISR) should not exceed 10 percent of the gross area. Stormwater Best Management Practices (BMPs) shall be required for water quality control if the total ISR is projected to exceed 10 percent for the development site. For development sites with an ISR above 10 percent, stormwater treatment BMPs shall be designed and installed in a manner to achieve the targeted pollutant removal efficiencies found in the City of Auburn Engineering Design Manual.

Outside the watershed areas, the overall ISR shall be determined by the underlying zoning district. If the development site is located outside the watershed but within the planning jurisdiction, there shall be no ISR requirement.

The applicant shall submit a Stormwater Manangement Plan if the total ISR for the development site is projected to exceed 10 percent. The focus of this plan is to describe how the site will be developed in order to achieve the pollutant target removal efficiencies found in manual. The project engineer shall prepare the stormwater plan that includes a water quality/water quantity report, a water quality site development analysis, the location of all structural and nonstructural stormwater treatment BMPs, procedures for implementing non-structural stormwater treatment practices along with a proper maintenance plan. All stormwater management measures shall be incorporated into the design of the conservation subdivision. Stormwater BMP measures shall be designed in accordance with standards outlined in the City of Auburn Engineering Design Manual. The manual includes design standards and target pollutant removal efficiencies for a variety of stormwater BMPs. See of the manual for further details on BMP design guidelines.

The maintenance plan shall contain specific preventative maintenance tasks and an inspection schedule of all stormwater management techniques installed on the development site. The name of a person or persons responsible for preventative and corrective maintenance (including replacement) of the stormwater BMP techniques shall be stated in the maintenance plan. If the maintenance plan identifies a person other than the developer as having the responsibility for maintenance, the plan shall include documentation of such person's agreement to assume this responsibility. Responsibility for maintenance shall not be assigned or transferred to an owner of individual property within a conservation subdivision development, unless such owner owns the entire development.

The Stormwater Management Plan shall be reviewed as a part of the subdivision plat review process and must be submitted with the construction plans.

~~ARTICLE VI.~~ ARTICLE VII. ADMINISTRATION

APPENDIX

How to Design a Conservation Subdivision

A conservation subdivision should be designed in accordance with the following suggested process:

1. Identify all Potential Conservation Areas. Determine which areas will be designated as primary and secondary conservation areas and note these areas as permanent open space. This delineation will help identify where the areas for development are located on the development site.
2. Location of House Sites. Draw the house footprint outside the conservation areas based on the permitted density calculations. House sites should generally be located to enjoy views of the conservation areas but should not be in close proximity to pose negative impacts on these areas. As a general rule, house sites should be at least 100 feet from any Primary Conservation Areas.
3. Alignment of Streets and Trails. Streets should be designed to provide vehicular access to each house and bear a logical relationship to topographical conditions. Streets should be designed outside the conservation areas; however, trails can be located within these areas (See Section E (3)(c)).
4. Drawing the Lot Lines. The final step of the process is to draw the lot lines.

Figure 1 is an illustration of the four-step conservation subdivision design process.

All persons who desire shall have an opportunity of being heard in opposition to or in favor of such ordinance.

Publication Date: Sunday, January 21, 2007

Additional information on the Auburn, AL Ordinances may be found at the following link.

http://www.auburnalabama.org/

ARTICLE I
PURPOSE, REPEALS, ENACTMENT AND SHORT TITLE

1-1 PURPOSE

The City of Daphne, Alabama, pursuant to the authority granted by Title 11, Subtitle 2, Chapter 52, Articles 1 through 4, Code of Alabama, 1975 and 1986 Cumulative Supplement, in order to promote the health, safety, convenience, order, prosperity, and general welfare of the residents; to lessen congestion in the street; to secure safety from fire, panic, and other dangers; to provide adequate light and air; to prevent the overcrowding of land, to avoid undue concentration of population; to facilitate the adequate provision of transportation, water, sewerage, and parks; to facilitate initiation of the Comprehensive Plan, and other public requirements, hereby ordains and enacts into law an official Land Use and Development Ordinance in accordance with the laws of Alabama. In their interpretation and application, the provisions of this Ordinance shall be:

(a) Considered as minimum requirements.

(b) Liberally construed in favor of the governing body.

(c) Deemed to neither limit nor repeal any other powers granted under state statutes.

1-2 REPEALS AND ENACTMENT

An Ordinance of the City of Daphne establishing rules and regulations for zoning, platting, and subdividing land which rules and regulations define the legal authority; classify land; establish zoning districts requirements; prescribe procedures for plat review; set standards and specifications for streets, utilities, and other public improvements in subdivisions; and, prescribe methods for enforcement, exceptions, and amendments.

1-3 SHORT TITLE

This Ordinance shall be known and may be cited as the "Land Use and Development Ordinance" for the City of Daphne.

ARTICLE II
LEGAL STATUS

2-1 AUTHORITY

The rules and regulations set forth herein are hereby adopted in accordance with Title 11, Subtitle 2, Chapter 52, Articles 1 through 4 of the Code of Alabama, 1975, (as amended), and 1986 Cumulative Supplement are as follows:

(a) Zoning:
Zoning authority is specifically contained in Title 11, Subtitle 2, Chapter 52, Articles 1 and 4 of the Code of Alabama, 1975, (as amended), and 1986 Cumulative Supplement.

(b) Subdivisions:
Subdivision authority is specifically contained in Title 11, Subtitle 2, Chapter 52, Articles 1, 2, and 3 of the Code of Alabama, 1975, (as amended), and 1986 Cumulative Supplement.

2-2 JURISDICTION

(a) Zoning:
This Ordinance shall be in force and effect for zoning purposes within the corporate limits of the City of Daphne as presently or hereinafter established.

(b) Subdivisions:
This Ordinance shall be in force and effect for the subdivision of all land which is situated inside the corporate limits of the City of Daphne, as well as, all land which lies in the extraterritorial planning jurisdiction of the City of Daphne, as presently or hereinafter established.

ARTICLE III
OFFICIAL PLANS AND MAPS

3-1 IMPLEMENTATION

This Ordinance shall be implemented in accordance with the Comprehensive Plan. A copy of the plan is filed in the office of the City Clerk and Zoning Administrator and/or Director of Community Development.

3-2 FUTURE LAND USE MAP

The Future Land Use Map as contained in the Comprehensive Plan shall serve as a guide for the future development of Daphne. To the extent practical, it shall be followed in the administration of this Ordinance.

3-3 OFFICIAL ZONING DISTRICT MAP

The Future Land Use Map as contained in the Comprehensive Plan, as well as all official maps, are to be utilized and construed only as visual aids for the City and/or any of its Departments, agencies, or Commissions in the furtherance of City duties and goals and are not solely to be relied upon by any party.

The Zoning District Map, Exhibit A, the latest edition, is hereby adopted and made a part of this Ordinance. It shall be filed in the office of the Zoning Administrator and/or Director of Community Development and the City Clerk to show thereon the date of adoption of said Ordinance. All Official maps shall be used as a tool in determining the permissible use of land. Zoning should always be verified by Zoning Administrator or Director of Community Development.

3-4 AMENDMENTS TO THE OFFICIAL ZONING DISTRICT MAP

If, in accordance with the provisions herein, revisions are made in the zoning district boundaries or any other information portrayed on the Zoning District Map, changes shall be made on the Map immediately following the amendment and upon approval of the City Council. Unauthorized alterations to Zoning District Map shall be considered a violation of this Ordinance and subject to penalties as prescribed herein.

3-5 FILE OF PROPERTIES REZONED, VARIANCES GRANTED, SUBDIVISIONS APPROVED

The Zoning Administrator and/or Director of Community Development shall maintain a file or registry of properties rezoned, variances granted, and subdivisions approved under the authority of this Ordinance in conjunction with all pertinent requirements and/or conditions thereto.

3-6 OFFICIAL OLDE TOWNE DISTRICT MAP

The Olde Towne District Map, Exhibit B, the latest edition, is hereby adopted and made a part of this Ordinance. This map shall be signed by the Mayor and attested by the City Clerk. It shall be filed in the office of the Zoning Administrator and/or Director of Community Development and the City Clerk to show thereon the date of adoption of said Ordinance.

3-7 AMENDMENTS TO THE OFFICIAL OLDE TOWNE DISTRICT MAP

If, in accordance with the provisions herein, revisions are made in the district boundaries or any other information portrayed on the Olde Towne District Map, changes shall be made on the Map immediately following the amendment and upon approval of the City Council. Unauthorized alterations to the Olde Towne District Map shall be considered a violation of this Ordinance and subject to penalties as prescribed herein.

3-8 OTHER OFFICIAL MAPS

The Official Street Map, Exhibit A-2, the latest edition, is hereby adopted and made a part of this Ordinance. The Village Overlay District Map, Exhibit C, the latest edition, is hereby adopted and made a part of this Ordinance. The Official Eastern Shore District Overlay Map, Exhibit D, the latest edition, is hereby adopted and made a part of this Ordinance. The Residential High Rise District Boundary Map, Exhibit E, latest edition, is hereby adopted and made a part of this Ordinance. The Jubilee Retail Overlay District Map, Exhibit F, latest edition, is hereby adopted and made a part of this Ordinance.

3-9 AMENDMENTS TO THE OFFICIAL MAPS

If, in accordance with the provisions herein, revisions are made in the zoning district boundaries or any other information portrayed on the Village Overlay District Map, the Official Eastern Shore District Overlay Map, or the Official Street Map, the Residential High Rise District Boundary Map or the Jubilee Retail Overlay District Map, changes shall be made on the individual map immediately following the amendment and upon Official Maps shall be considered a violation of this Ordinance and subject to penalties as prescribed herein.

Additional information on the Daphne, AL Ordinances may be found at the following link.

http://www.daphneal.com/residents/community-development/documents-information/

1 GENERAL PROVISIONS

1.1 Authority

These regulations are enacted in accordance with the authority granted to the Semmes Planning Commission by the Legislature of the State of Alabama in Title 11, Chapter 52, Code of Alabama, 1975, as amended.

1.2 Jurisdiction

From and after the date of legal adoption and certification to the Probate Judge of Mobile County, Alabama as required by Law, these regulations shall govern each and every subdivision of land within the Semmes corporate limits and expanding 5 miles outside the corporate limits. The 5 mile extra-territorial jurisdiction is subject to change as a result of the following actions:

1. Annexations
2. Jurisdictional agreements entered into with neighboring authorities.

1.3 Purpose

The purpose of these regulations is to establish procedures and guidelines for the development of subdivisions or proposed additions to existing subdivisions within the planning jurisdiction of Semmes, Alabama, in order to regulate the size of lots, the planning and provide for appropriate design and construction of infrastructure and other public facilities. It is the intent of these regulations to harmoniously relate the development of the various tracks of land to the existing community and to obtain the best design possible for each tract of land being subdivided while promoting the public health, safety, economy, good order, appearance, convenience and general welfare within the planning jurisdiction of Semmes.

The Subdivision Regulations are also designed to be used by the Planning Commission to attempt to keep the area compatible with current overall ambience of the area. The purpose of these subdivision regulations is to promote the health, safety, morals, and general welfare of present and future residents alike. It is also the purpose of these regulations to promote coordinated, ecologically sensitive, and aesthetic development in the City of Semmes and its jurisdiction in accordance with the Comprehensive Plan and all other plans and programs adopted by the City. The regulations shall achieve:

1. Govern the subdivision of land within its jurisdiction.

2. Provide for the proper arrangement of streets in relation to other existing or planned streets in accordance with the Comprehensive Plan.

3. Provide adequate open space and provisions for traffic.

4. Provide adequate open space and provisions for utilities.

5. Provide adequate open space and access for fire-fighting apparatus.

6. Provide adequate open space and provisions for recreation.

7. Provide adequate open space and provisions for light and air.

8. Provide minimum standards to avoid congestion of population.

9. Provide appropriate standards for the grading and improvement of streets, water and sewer, other utilities, and other facilities.

10. Establishment of minimum requirements and procedures to control the adverse effects of increased storm water runoff associated with both future land development and existing developed land. Proper management of storm water will minimize damage to public and private property, ensure a functional drainage system, reduce the effects of development on land and stream channel erosion, assist in the attainment and maintenance of water quality standards, enhance the local environment associated with the drainage system, reduce local flooding, maintain as nearly as possible the pre-developed runoff characteristics of the area, and facilitate economic development while mitigating associated flooding and drainage impacts.

11. Promote good civic design and arrangement in accordance with the Comprehensive Plan.

1.4 Policy

It is hereby declared to be the policy of the **City of Semmes** to consider the subdivisions of land and the subsequent development of the subdivided land as subject to the control of the **Semmes Planning Commission** pursuant to the authority granted to the City by Alabama Law.

Any owner of land which lies within the area of jurisdiction of the City of Semmes who wishes to subdivide or re-subdivide such land into two (2) or more lots, parcels, plats, or other divisions of land for the purpose of sale (whether immediate or future), transfer, or lease of lots for building development, shall submit to the City of Semmes Planning Commission a plat of the subdivision which shall conform to the established requirements set forth in these regulations.

No subdivider shall proceed with any improvements or with the installation of utilities in a proposed subdivision until such subdivision plat shall have been reviewed and approved by the City of Semmes Planning Commission.

These regulations shall hereafter be known, cited and referred to as the Subdivision Regulations of the City of Semmes, Alabama.

1.5 Application of Regulations

No subdivider shall proceed with the sale, transfer, or lease of lots, or the erection of buildings, excluding required public improvements and utility structures, within a proposed subdivision until such subdivision has been granted Final Plat approval entered in writing on the plat and signed by the City Engineer, the Chair of the City of Semmes Planning Commission and the Mobile County Engineer (if subdivision is located within the extraterritorial jurisdiction of the City of Semmes) and recorded in the Office of the Probate Judge of Mobile County in accordance with the procedures prescribed in these regulations. Any changes that are required by Mobile County Engineering prior to their Final Plat approval must also be re-routed through the Semmes City Engineer and the Chair of the Semmes Planning Commission for signatures before recording with the Office of the Probate Judge of Mobile County.

1.6 Interpretation

In their interpretation and application, the provisions of these regulations shall be held to be the established requirements for the protection of our rural character and promotion of the public health, safety, and general welfare of our citizens. Where any provision of these regulations impose restrictions different from those imposed by any other provision of these regulations, or any other ordinance, rule or regulation, or other provisions of law, whichever provisions are more restrictive or impose higher standards shall control.

The City of Semmes Definitions of Words as Phrases as amended from time to time and approved by the City shall provide the meanings of all words and phrases in this document. It is hereby adopted by reference.

1.7 Minimum Standards:

The provisions and requirements of these regulations shall be considered minimum standards. There may be cases in the course of subdivision consideration and approval that due to the site characteristics meeting minimum standards may not adequately protect local and public property, residents, public infrastructure, public investment, and the life and safety of the City. Therefore, it is the designer's responsibility to exceed minimum requirements as necessary. Additionally, the City and its staff reserve the right to require that minimum standards are exceeded based on professional judgment and professional engineering standards.

1.8 Responsibilities:

Responsibility of Subdivider:

The subdivider shall be responsible for providing all engineering services, including plans and specifications in conformity with these regulations and construction observation inspection and supervision as is necessary to assure that improvements are installed in conformity with plans, city standards and the requirements of these regulations. The subdivider shall provide the City with all engineering plans required in conjunction with any applicable state, federal or local laws or regulations. Where the Planning Commission deems additional or supplemental engineering data to be necessary for the purpose of assuring the City's interests are protected, all costs shall be borne by the subdivider. The subdivider is responsible for payment of all fees and charges in full.

Responsibility of the City of Semmes:

The City shall, after final plat approval, plat recording and upon receipt of all test reports, maintenance surety, as-built plans and certification and other requirements of these regulations, by resolution of the City Council accept the streets and drainage within the public right-of-way for maintenance. The City Council shall only accept for public maintenance the right-of-ways that are located with the corporate limits of the City of Semmes, Alabama, as may be amended from time to time. The City may cause the inspection of any or all parts of the improvements during and after construction and require the correction of any improvements for maintenance.

Additional information on the Semmes, AL Ordinances may be found at the following link.

http://www.cityofsemmes.org/index.html

Table B.1

LEED for New Construction and Major Renovations Credit Options

Category	Credit Number	Credit Name	Points Possible	Possible LID BMP
Sustainable Sites	5.1	Site Development, Protect or Restore Habitat	1	Appropriate native plant selection, protect sensitive areas
	5.2	Site Development, Maximize Open Space	1	Minimize construction footprint
	6.1	Stormwater Design, Quantity Control	1	Multiple LID BMPs
	6.2	Stormwater Design, Quality Control	1	Multiple LID BMPs
	7.1	Heat Island Effect, Non-roof	1	Shade from trees, light colored pervious paving
	7.2	Heat Island Effect, Roof	1	Vegetated roof
Water Efficiency	1.1	Water Efficient Landscaping, Reduce by 50%	2	Rain barrels, cisterns, select appropriate plant species
	1.2	Water Efficient Landscaping, No Potable Use or No Irrigation	4	Soil amendments, capture/reuse
	2.1	Innovative Wastewater Technologies, Reduce potable by 50%	2	Capture/reuse
	3.1	Water Use Reduction, 30% Reduction	2	Capture/reuse
	3.2	Water Use Reduction, 35% Reduction	3	Capture/reuse
	3.3	Water Use Reduction, 40% Reduction	4	Capture/reuse
	3.1	Material Reuse, 5%	1	Multiple LID BMPs
Materials & Resources	3.2	Material Reuse, 10%	1	Multiple LID BMPs
	4.1	Recycled Content, 10%	1	Multiple LID BMPs
	4.2	Recycled Content, 20%	1	Multiple LID BMPs
	5.1	Regional Materials, 10%	1	Multiple LID BMPs
	5.2	Regional Materials, 20%	1	Multiple LID BMPs
		Total Possible Points:	**22**	

Source: Low Impact Development Center, Inc. Low Impact Development Manual for Southern California: Technical Guidance and Site Planning Strategies. 2010. World Wide Web. Last accessed: Feb. 13, 2013. http://www.casqa.org/LID/SoCalLID/tabid/218/Default.aspx

Table B.2

LEED for Neighborhood Development Credit Options

Category	Credit Number	Credit Name	Points Possible	Possible LID BMP/Strategy
Smart Location & Linkage	8.1	Steep Slope Protection	1	Vegetated swales, native plants
	9.1	Site Design for Habitat or Wetland Conservation	1	Native plants, infiltration basins, dry ponds, constructed wetlands
	10.1	Restoration of Habitat or Wetlands	1	Restore vegetation
	11.1	Conservation Management of Habitat or Wetlands	1	Preserve existing vegetation and sensitive areas
Neighbor-hood Patter & Design	1.1	Compact Development	1-7	Minimize impervious areas
	6.1	Reduced Parking Footprint	2	Decrease size of parking spaces, pervious pavement
	7.1	Walkable Streets	4-8	Planting trees, curb bump-outs
	12.1	Access to Open Spaces	1	Minimize impervious areas
	13.1	Access to Active Spaces	1	Minimize impervious areas
	15.1	Community Outreach and Involvement	1	Informative signs on public LID structures, meetings

Source: Low Impact Development Center, Inc. Low Impact Development Manual for Southern California: Technical Guidance and Site Planning Strategies. 2010. World Wide Web. Last accessed: Feb. 13, 2013. http://www.casqa.org/LID/SoCalLID/tabid/218/Default.aspx

Table B.3

Sustainable Sites Initiative Prerequisite and Credit Options.

Category	Credit Number	Credit Name	Points Possible	Possible LID BMP/Strategy
Site Selection	Prerequisite 1.2	Protect floodplain functions		Protect sensitive areas
	Prerequisite 1.3	Preserve wetlands		Protect sensitive areas
	Prerequisite 1.4	Preserve threatened or endangered species and their habitats		Protect sensitive areas
	Credit 1.5	Select brownfields or greyfields for redevelopment	5-10	LID can be used on these sites
	Credit 1.6	Select sites within existing communities	6	LID can be used for redevelopment
	Credit 1.7	Select sites that encourage non-motorized transportation and use of public transit	5	LID can be used for redevelopment
Pre-Design Assessment and Planning	Prerequisite 2.1	Conduct a pre-design site assessment and explore opportunities for site sustainability		LID site assessment process
	Prerequisite 2.2	Use an integrated site development process		LID site planning strategies
Site Design – Water	Prerequisite 3.1	Reduce potable water use for landscape irrigation by 50 percent from established baseline		Plant adapted vegetation Capture/reuse
	Credit 3.2	Reduce potable water use for landscape irrigation by 75 percent or more from established baseline	2-5	Plant adapted vegetation Capture/reuse
	Credit 3.3	Protect and restore riparian, wetland, and shoreline buffers	3-8	Protect sensitive areas
	Credit 3.5	Manage stormwater on site	5-10	Multiple LID BMPs
	Credit 3.6	Protect and enhance on-site water resources and receiving water quality	3-9	Multiple LID BMPs
	Credit 3.7	Design rainwater/stormwater features to provide a landscape amenity	1-3	Multiple LID BMPs
	Credit 3.8	Maintain water features to conserve water and other resources	1-4	Multiple LID BMPs

Low Impact Development Center, Inc. Low Impact Development Manual for Southern California: Technical Guidance and Site Planning Strategies. 2010. World Wide Web. Last accessed: Feb. 13, 2013. http://www.casqa.org/LID/SoCalLID/tabid/218/Default.aspx

Sustainable Sites Initiative Prerequisite and Credit Options--Continued

Category	Credit Number	Credit Name	Points Possible	Possible LID BMP/Strategy
Site Design – Soil and Vegetation	Prerequisite 4.2	Use appropriate, non-invasive plants		Revegetate disturbed areas
	Prerequisite 4.3	Create a soil management plan		Amend soils
	Credit 4.4	Minimize soil disturbance in design and construction	6	Minimize impervious areas Minimize construction footprint
	Credit 4.5	Preserve all vegetation designated as special status	5	Protect existing vegetation
	Credit 4.6	Preserve or restore appropriate plant biomass on site	3-8	Protect existing vegetation Revegetate disturbed areas
	Credit 4.7	Use native plants	1-4	Revegetate disturbed areas
Site Design – Soil and Vegetation	Credit 4.8	Preserve plant communities native to the ecoregion	2-6	Protect existing vegetation
	Credit 4.9	Restore plant communities native to the ecoregion	1-5	Revegetate disturbed areas
	Credit 4.10	Use vegetation to minimize building heating requirements	2-4	Vegetated roofs
	Credit 4.11	Use vegetation to minimize building cooling requirements	2-5	Vegetated roofs
	Credit 4.12	Reduce urban heat island effects	3-5	Minimize impervious areas Vegetated roofs Light-colored pervious pavement
Site Design – Materials Selection	Credit 5.2	Maintain on-site structures, hardscape, and landscape amenities	1-4	Minimize impervious areas
Site Design – Human Health and Well-Being	Credit 6.7	Provide views of vegetation and quiet outdoor spaces for mental restoration	3-4	Multiple LID BMPs
	Credit 6.8	Provide outdoor spaces for social interaction	3	Vegetated roofs
Monitoring and Innovation	Credit 9.2	Innovation in site design	8	LID Site Design Process
		Total Possible Points:	**127**	

Appendix C: Maintenance

Plan for Maintenance: Maintenance practices, equipment needed, and manpower should be well thought out prior to designing any stormwater control measure (SCM). Planning for regular inspection and maintenance of a SCM is crucial to the long-term effectiveness and aesthetics of each practice. Often maintenance tasks take a back seat until it is too late and the practice is failing.

Send the Right Message: Maintenance of SCMs is especially important - when a practice performs poorly or looks bad, it sends the wrong message to municipal officials and employees, developers, and the general public. Practices left unmaintained can discourage communities from adopting these practices and pose a safety concern. Instead, these practices should encourage and inspire watershed and environmental stewardship.

Maintenance Access: Maintenance easements should be obtained prior to design of the practice and should include the SCM footprint and at least 10' surrounding the SCM. The maintenance access area may need to be larger for tasks such as sediment removal from a forebay. These activities require use of heavy equipment and a maintenance roadway.

SCM Footprint: The SCM footprint includes the SCM, side slopes, forebay or other pretreatment device, outlet, riser structure, dam embankment, and emergency spillway.

Maintenance Easement Ownership: Maintenance easements are typically owned by the entity that owns the SCM. Privately owned maintenance easements should allow for public inspection and maintenance should it be necessary. Private entities may include an individual, Home Owner's Association (HOA), or a corporation.

Maintenance Agreements: Maintenance agreements are completed to guarantee appropriate and timely maintenance of these practices.

Maintenance Agreements should include:

- Maintenance schedule including tasks, frequency, and equipment recommendations
- Responsible parties for any professional or non-professional maintenance tasks to be performed on site
- Any special maintenance concerns, constraints, or site specific information that will aid the maintenance professional
- SCM components that require inspection
- Problems specific to the SCM that may be encountered
- Recommendations for problems that may occur

Non-professional Maintenance: Basic maintenance tasks such as mowing, trash removal, or mulch replenishment can be performed by non-professionals and can be included in grounds maintenance for the overall property.

Professional Maintenance: Professional maintenance refers to tasks that require professional judgment such as inspections of riser structures, dam embankments, outlets, or plant health. Professional engineers, Certified Erosion and Sediment Control Professionals (CPESC), professional landscape architects, horticulturalists, and other specialists should be consulted for recommendations. Repairing eroded areas, grading, and any soil-disturbing activities are best left to maintenance professionals since these tasks can significantly affect SCM function.

Record Keeping: Keeping maintenance records is extremely important to identify effective maintenance strategies and to define site-specific maintenance task frequency. Records or data sheets should be kept in the same location. Maintenance task lists or checklists are most effective to ensure consistency in record keeping and inspection. Any maintenance performed or recommended as a result of the inspection should be noted. Also, maintenance repairs should be added to the inspection task list so they may be regularly evaluated for performance.

Maintenance Professional Education: Workshops or training sessions with the party responsible for maintenance are strongly recommended. Some maintenance divisions experience frequent turnover and annual trainings are helpful to introduce new maintenance procedures and to educate new employees.

Maintenance Expenses: Maintenance expenses are driven by the condition of the drainage area upstream or upslope of the SCM. High sediment loads entering the SCM will increase maintenance frequency and expense. As such, stabilization and any erosion repair upslope will reduce the maintenance cost of the SCM.

Funding Options: Funding mechanisms, such as an escrow account, can be set up to collect fees for regularly performed maintenance. For example, in a conservation subdivision with multiple SCMs, a developer may start the escrow and then transfer it to the HOA so that regular contributions fund routine maintenance or any SCM reconstruction.

DEVELOPMENT REVIEW
Town of Cary
PO Box 8005, Cary, NC 27512

NORTH CAROLINA

WAKE COUNTY

STORMWATER CONTROL STRUCTURE AND ACCESS EASEMENT AND AGREEMENT (Corporate)

THIS STORMWATER CONTROL STRUCTURE AND ACCESS EASEMENT AND AGREEMENT, made this day 1 of 1, 191, **(DATE OF AGREEMENT**) by 2 **(NAME OF OWNER)**, a North Carolina corporation whose principal address is 2a , (hereafter "Grantor"), with, to, and for the benefit of the Town of Cary, a municipal corporation of the State of North Carolina, whose address is P.O. Box 8005, Cary North Carolina 27512-8005 (hereinafter "Grantee" or "Town").

W I T N E S S E T H:

WHEREAS, Grantor is the owner in fee simple of certain real property, situated in the Town of Cary, County of Wake, North Carolina and more particularly described as follows:

3 **(LEGAL DESCRIPTION OF PROPERTY)**

It being the same land conveyed to the Grantor by deed recorded in Book 3a at page 3a in the Office of the Register of Deeds for Wake County (hereafter referred to as "Property"); and

WHEREAS, the property is located within the planning jurisdiction of the Town of Cary, and is subject to certain requirements set forth in the Land Development Ordinance of the Town, (hereafter "Cary LDO"), as such may be amended from time to time; and

WHEREAS, one of the conditions for development of Property is the granting or dedication of a Stormwater Control Structure easement, which includes the implementation of certain stormwater practices such as, but not limited to, the construction, operation and maintenance of engineered stormwater control structure(s) as provided in Cary LDO; the dedication of an access easement for inspection and maintenance of the Stormwater Control Structure easement area and engineered structures; and the assumption by Grantor of certain specified maintenance and repair responsibilities; and

WHEREAS, this Easement and Agreement has been procured in accordance with the requirements of N.C. G.S. Sec 143-211 *et. seq*. and Chapter 4, Part 4.6 of the Cary LDO.

NOW, THEREFORE, for a valuable consideration, including the benefits Grantor may derive therefrom, the receipt of which is hereby acknowledged, Grantor has dedicated, bargained and conveyed and by these presents does hereby dedicate bargain, sell, grant and convey unto the Grantee, its successors and assigns, a perpetual, and irrevocable right and easement in, on, over, under, through and across Property (1) for a STORMWATER CONTROL STRUCTURE easement ("hereafter SCS Easement") of the nature and character and to the extent hereinafter set forth, more particularly shown and described on Attachment 4 **(NAME OF AS BUILT DRAWING)** which is attached hereto and incorporated herein by reference; upon which Grantor shall construct, maintain, repair and reconstruct stormwater control structure(s), including detention pond(s), pipes and water control structures, berms and dikes, and shall establish and maintain vegetative filters and groundcovers; and (2) an access easement more particularly shown and described on Attachment 4a **(ATTACHMENT NUMBER 1 OR 2)**, , for the purpose of permitting Town inspection and, if necessary, maintenance and repair of the SCS Easement and engineered structure(s) as more fully set forth herein and in Cary LDO.

The terms, conditions, and restrictions of the Stormwater Control Structure Easement and Access Easement are:

1. The requirements pertaining to the SCS Easement are more fully set forth in Chapter Chapter 4, Part 4.6 of Cary LDO and the "Operation and Maintenance Manual for 5 (hereafter "Operations and Maintenance Manual"), Cary, NC, prepared by 5a, and dated 5b a copy of which is on file in the Town of Cary Engineering Department. Grantor further agrees Grantor shall perform the following, all at its sole cost and expense:

I. Monthly or after every runoff producing rainfall, whichever comes first:

a. Remove debris from trash rack.
b. Check and clear orifice of any obstructions.
c. Check pond side slopes; remove trash, repair eroded areas before next rainfall.

maintenance of the Stormwater Control Structure easement area and engineered structures; and the assumption by Grantor of certain specified maintenance and repair responsibilities; and

WHEREAS, this Easement and Agreement has been procured in accordance with the requirements of N.C. G.S. Sec 143-211 _et. seq_. and Chapter 4, Part 4.6 of the Cary LDO.

NOW, THEREFORE, for a valuable consideration, including the benefits Grantor may derive therefrom, the receipt of which is hereby acknowledged, Grantor has dedicated, bargained and conveyed and by these presents does hereby dedicate bargain, sell, grant and convey unto the Grantee, its successors and assigns, a perpetual, and irrevocable right and easement in, on, over, under, through and across Property (1) for a STORMWATER CONTROL STRUCTURE easement ("hereafter SCS Easement") of the nature and character and to the extent hereinafter set forth, more particularly shown and described on Attachment 4 **(NAME OF AS BUILT DRAWING)** which is attached hereto and incorporated herein by reference; upon which Grantor shall construct, maintain, repair and reconstruct stormwater control structure(s), including detention pond(s), pipes and water control structures, berms and dikes, and shall establish and maintain vegetative filters and groundcovers; and (2) an access easement more particularly shown and described on Attachment 4a **(ATTACHMENT NUMBER 1 OR 2)**, , for the purpose of permitting Town inspection and, if necessary, maintenance and repair of the SCS Easement and engineered structure(s) as more fully set forth herein and in Cary LDO.

The terms, conditions, and restrictions of the Stormwater Control Structure Easement and Access Easement are:

1. The requirements pertaining to the SCS Easement are more fully set forth in Chapter Chapter 4, Part 4.6 of Cary LDO and the "Operation and Maintenance Manual for 5 (hereafter "Operations and Maintenance Manual"), Cary, NC, prepared by 5a, and dated 5b a copy of which is on file in the Town of Cary Engineering Department. Grantor further agrees Grantor shall perform the following, all at its sole cost and expense:

I. Monthly or after every runoff producing rainfall, whichever comes first:

a. Remove debris from trash rack.
b. Check and clear orifice of any obstructions.
c. Check pond side slopes; remove trash, repair eroded areas before next rainfall.

replacements to the engineered stormwater control structure(s) and appurtenances and conditions as may be necessary or convenient thereto in the event Grantor defaults in its obligations and to recover from Grantor the cost thereof, and in addition to other rights and remedies available to it, to enforce by proceedings at law or in equity the rights, covenants, duties, and other obligations herein imposed.

The Grantor shall in all other respects remain the fee owner of Property and area subject to these easements, and may make all lawful uses of Property not inconsistent with these easements.

The Grantee does not waive or forfeit the right to take action to ensure compliance with the terms, conditions and purposes of this Easement and Agreement by a prior failure to act.

The Grantor agrees that the terms, conditions and restrictions of this easement will be inserted by Grantor in any subsequent deed or other legal instrument by which he divests himself of either the fee simple title to or possessory interests in the subject property. The designation Grantor and Grantee shall include the parties, their heirs, successors and assigns.

TO HAVE AND TO HOLD the aforesaid rights, privileges, and easements herein granted to the Grantee, its successors and assigns forever and the same Grantor does covenant and that Grantor is seized of said premises in fee and has the right to convey the same, that except as set forth below the same are free from encumbrances and that Grantor will warrant and defend the said title to the same against claims of all persons whosoever.

The covenants agreed hereto and the conditions imposed herein shall be binding upon the Grantor and its agents, personal representatives, heirs and assigns and all other successors to Grantor in interest and shall continue as a servitude running in perpetuity with the above described land.

IN WITNESS WHEREOF, the Grantor has caused this instrument to be signed in its corporate name by its duly authorized officers and its seal to be hereunto affixed by authority of its Board of Directors, the day and year first above written.

__________7__________
(Grantor)

__________7a__________
7b President

____7c_____________________

____________Secretary (Corporate Seal)

)RTH CAROLINA
AKE COUNTY

he undersigned Notary Public, do hereby certify and State aforesaid, do hereby certify that __________ _______________ personally appeared before me this day and acknowledged the execution of the egoing instrument.
tness my hand and official seal this __ day of ___________________________, 19___.

/ commission expires: ____

____
Notary Public

fficial Seal]

sement&Deed/Corporate.doc

References

North Carolina Department of the Environment and Natural Resources. 2007. Chapter 7: BMP Inspection and Maintenance.

APPENDIX D: VEGETATION


Muhly grass in rain garden at Donald E. Davis Arboretum; Auburn, AL

Native plant lists for low impact development (LID) practices are located in each chapter along with planting density suggestions and design ideas where appropriate. This chapter explores common characteristics and helpful hints in getting to know why and what species have been included in this handbook.

Native plants are recommended for use in LID practices for both practical and ecological reasons. Alabama native plants are indigenous to the Southeast and occur in the wild without human interaction. This handbook makes use of the United States Department of Agriculture (USDA) plant database (www.plants.usda.gov) to categorize plant species as native or nonnative. Plant selection is often specific to goals of the site and practice. For example, aesthetics and plant availability combined with sunlight and water requirements may limit the use of native plant species for a specific site. In general, native plants are recommended for LID practices, but nonnative plants are acceptable as long as they are not considered to be invasive.

Nutrient Removal

Plants used in LID practices absorb nutrients in stormwater runoff to reduce pollutant loads. Nutrient removal through plant uptake is generally a secondary form of pollutant removal for LID practices. The primary form of pollutant removal occurs through microbial (biological) activity or chemical processes in the soil or growing substrate. As such, the rhizosphere should provide adequate habitat for microorganisms to reduce nutrients loads. A mixture of evergreen and deciduous vegetation is recommended for year round nutrient uptake.

Nutrient Release: There have been some concerns expressed over nutrients released from plants, or discharged, back into systems at the end of the growing season when plants undergo dormancy, especially in constructed stormwater wetlands. When this may be of concern, it is suggested that herbaceous perennials be used because these plants can effectively be harvested (to remove nutrient-laden plant tissues) at the end of the growing season. New tissue will be produced and arise from the root ball the following spring.

Design Considerations

Planning: Client preferences for each project site can determine plant sizes and types, which can limit plant choices for particular sites. For example, if visibility is a concern, plant selection may be limited to low-growing vegetation. Sunlight and hydrologic conditions present on site may also create constraints. Making a list of constraints for the project site and the LID practice you are considering is useful to outline characteristics of plants required. In some cases, native plant species are unavailable or do not fit the site goals and using ornamental nonnative plants is acceptable as long as they are not invasive.

Plant Spacing: Plant spacing should always be based on mature plant size. Some plants work well in mass plantings and should be planted on a tighter spacing pattern. Over time, these plants will create a dense grouping. Resist the urge to crowd plants because it is more expensive and also leads to competition among plants for water, nutrients, and sunlight, which causes stress and weakens plants making them more susceptible to insect and disease infestations.

Plant Preferences: Plants should be specified in the LID practice according to their sunlight preference, water inputs, soil type, and drainage. Plants should always be grouped based on similar preferences to reduce maintenance costs associated with any type of irrigation needed during establishment and plant replacement. For more information on planting the right plant in the right place, see the Alabama Smart Yards Manual at http://www.aces.edu/pubs/docs/A/ANR-1359/ANR-1359.pdf.

Sun – at least 6 hours of full sun per day.

Part Shade – 3 to 5 hours without direct sun per day.

Shade – less than 2 hours of direct sun per day.

Vegetation Plan: A vegetation design for LID should be made to scale to ensure that mature plants sizes are taken into account (for more information, see Chapter 4.1 on Bioretention). Calculating plant quantity is another acceptable form of determining plant placement, although it may not be as precise as a sketch drawn to scale (see Chapter 5.1 on Rain Gardens for information on plant quantity calculations).


Students install plants in bioretention area; Phenix City, AL

Plant Habit

For the purpose of this manual, plant habits, or vegetation types, include herbaceous perennials and grasses, turfgrass, shrubs, and trees.

Herbaceous Plants: Herbaceous perennials, grasses, and turfgrass do not form woody tissue, and instead typically have soft, fleshy tissue. Herbaceous plants are dormant during winter months when they die back to ground level. These plants may be short or long lived ranging from several years to decades based on the species.

Woody Plants: Trees and shrubs are woody plants that form bark and hold woody plant parts above ground. Trees have a central axis and are at least 6' tall (usually much taller), but shrubs are multi-stemmed (i.e. branched from the ground level) and typically smaller than trees. "Small trees" are < 20' tall. Evergreen is a term that refers to a woody plant that remains green and retains leaves throughout the entire year, which is the opposite of deciduous plants that are leafless during winter months.

Installation and Establishment

Installation: Plants should be installed at the top or just above finished soil grade. Plants installed too deep are at risk for disease such as fungal root rot. Remediating compacted soils by breaking them up and amending with organic matter will help plant roots establish more quickly into the surrounding soil. Mulching is also important to improve water retention in the soil and reduce soil temperatures.

Time of Year: Summer plant installations use more irrigation for establishment due to hot weather and low rainfall conditions experienced in Alabama, while a fall planting allows for root growth over the winter prior to spring shoot flush. Spring planting dates are also acceptable, but may require more irrigation until establishment compared to fall planting.

Irrigation: Plants should be watered immediately after planting to reduce transplant shock, ensure soil contact with root ball, and aid in root growth and establishment.

Establishment: Plant establishment generally occurs in one growing season (or longer up to 3 years under extreme drought) depending on the time of year of installation, environmental conditions, and rate of plant growth. Post-transplant root growth is critical for plant survival. Note that drought tolerant plants are not immediately tolerant of dry conditions when planted, but will tolerate these conditions once established.

Calibrating Irrigation: Irrigation systems should be calibrated (see Alabama Smart Yards Manual, Chapter 3) to minimize excess irrigation applications.

Turfgrass

Turfgrass sod should be installed as soon as it is delivered, preferably in the early morning before temperatures rise. Refer to the Alabama Erosion and Sediment Control Handbook for more information on sod installation.

Irrigation: For June to September installation, newly planted turf should be irrigated at planting so that the surface does not dry out. Sod should be watered daily for the first one to two weeks to keep it evenly moist (unless rainfall occurs). As the sod begins to grow new roots, irrigation frequency can be decreased, but a larger volume of water should be applied at each watering. Rainfall should be supplemented so that turfgrass receives about 1 – 1.5" per week from all irrigation sources. Turfgrass sod planted during dormancy will require less irrigation for establishment. In some cases, a dormant planting will not need any supplemental irrigation because rainfall during these months is sufficient for turf to establish. However, dormant plantings may benefit from irrigation during spring months when sod begins to produce new growth (i.e. spring green up).

Plant Sizes

Plant size or maturity of plants used in LID practices are usually driven by economics and time of year.

Containers: Container plants are available in a wide variety of sizes; plugs, 1-gallon, and 3-gallon containers are most commonly used. Larger container plants have the advantage of establishing at any time of the year. Because container substrates can dry more quickly in the landscape, irrigation should be concentrated on the root ball of container plants after planting.

Plugs: Plugs are usually 2 or 3" pots containing a 4" tall plant and are most common for herbaceous plants. This size is ideal when large quantities are planted (e.g. constructed stormwater wetland) due to ease of installation. Plugs can be installed at any time of year, but spring is best since these are very young, small plants.

Bare Roots: Bare root seedlings are an inexpensive option for planting woody plants, but can only be installed during winter months when plants are dormant. Under the right environmental conditions, establishment and cover of bare root seedlings is comparable to container plants after several growing seasons. Upon arriving, bare root seedlings should be inspected for mold and mildew; if roots smell rotten or sour, are powdery, or dry, then the seedlings are likely diseased and should not be planted.

Storing Bare Roots: Bare root seedlings can be stored in a cooler or "heeled in" by digging a V-shaped trench in a moist, shady area. A 10' long trench can hold approximately 1,000 seedlings if they are cut out of the bundles and not overcrowded. The ideal temperature range for storing bare root seedlings is 35 – 38 °F. Seedling roots should be completely covered by backfilling the trench with soil and then watering. Plant bare root seedlings before new leaves

Table D.1
Plant Size Summary Table

Type	Time of Year for Install	Advantages	Disadvantages
Plug	Any but Summer	- Inexpensive - Easy to install	- Limited species availability - Limited plant nurseries carry them
Bare Root	Winter	- Inexpensive - Reduced irrigation needed because they are installed in the dormant season with typically wet weather conditions - Less root injury - Easy to install - Roots can be inspected at planting	- Limited plant nurseries carry them
Container	Any	- Inexpensive - Reduced irrigation needed because they are installed in the wet season - Less root injury - Easy to install - Roots can be inspected at planting	- limited to winter installation - Must store in ground or in cooler until planting - Roots lost or severed in harvest
B & B	Any but Summer	- Larger trees available - Can match soil types if bought locally to ease transplant shock	- Reduced root systems need lots of water

Powell, 1997; West et al., 2005, KSU

appear for better survival. Planting bars or dibble-bars can be used to install bare root seedlings with non-spreading root systems; plants with spreading root systems should be planted using a round shovel.

Cost: Bare root seedlings range from $ 0.20 to $ 0.50 each compared to 1-gallon containers, which may range from $2.50 to $5.00+. Plugs can range from $ 0.50 to $ 1.00.

Seeding

Seeding can be utilized for temporary or permanent cover of bare soil. Seed type and species are dependent on time of year and location within the state of Alabama.

Temporary Seeding: Temporary seeding for erosion control is mandatory on bare soil during construction and guidelines set forth in the Alabama Erosion and Sediment Control Handbook should be followed.

Permanent Seeding: Permanent seeding can be utilized when immediate stabilization is not required. Permanent seeding may be appropriate for riparian buffers (i.e. in areas where seeds will not be washed away), but seeding is not usually recommended for LID practices that are expected to function immediately after they are installed.

Erosion Control Blankets: Erosion control blankets such as a coconut or straw blend blankets are placed over seed and straw to stabilize soil while seeds become established.

For more information on seeding and erosion control blankets, please see the Alabama Handbook for Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas (http://swcc.alabama.gov/pages/erosion_handbook.aspx).

Pure Live Seed: If seeding is chosen as a method of planting, pure live seed (PLS) should be used to adjust seeding rates to achieve a desired plant density. Seeding at too high of a density results in competition for water, nutrients, and sunlight, while seeding at low density can result in invasive plant invasion or decreased cover. Pure live seed expresses seed quality and is the percentage of seed per pound of seed applied that has the potential to germinate (excluding inert material and defunct seeds). Most seeding rates are expressed in pounds of PLS per acre and thus, the following calculation is necessary.

To calculate Pure Live Seed (PLS):

Pounds PLS = number of pounds / percent live seed

Percent live seed = germination percent – inert material percent

For example, to plant 10 lbs PLS of a species with 80% germination and 10% inert material

$$10 \text{ lbs PLS} = \frac{10 \text{ lbs}}{(80\%-10\%)} = \frac{10 \text{ lbs}}{0.70} = 14.3 \text{ lbs}$$

14.3 lbs of seed would be needed to adjust the seeding rate.

Native Plant Benefits

- Encourage diversity of insects, wildlife, and other plants
- Adapted to local environmental conditions and are considered to be low maintenance
- Require less pruning
- Can persist under drought conditions once established
- Tend to withstand lower water inputs because they are adapted the local climate and precipitation patterns of a given area
- Local or already acclimated native plant seedlings are recommended and will perform better

Wildlife Habitat: Plants are sources of food and shelter for wildlife. Birds, small mammals, and other wildlife consume plant fruits and seeds; thus, animal populations are directly related to diversity of plant communities. Shelter is provided both in and under tree and shrub canopies with taller native grasses providing ground-roaming small mammals with overhead cover to travel protected from predators and weather. Native plants are the preferred host for bees, butterflies, and moths. They are easy to establish, low maintenance once established,

Purple coneflower attracts native insects; Waverly, AL and serve as hosts to native insect communities.

Nonnative, Invasive Plants: Nonnative, invasive plants should never be intentionally planted or introduced into landscapes. Unfortunately, most nonnative, invasive plant species have been introduced through the ornamental plant trade and may go unnoticed as problematic for decades or until the negative ecological impacts can no longer be ignored. For example, Chinese privet (*Ligustrum sinense*) was introduced in the 1850s to the U.S. as an ornamental hedge from China; today Chinese privet has become naturalized throughout the Southeast and threatens riparian ecosystems. Homeowners are often surprised when plants become invasive in their own landscapes or when they find these plants have escaped to their neighbor's yard. Nonnative, invasive plants are able to thrive in a variety of conditions such as land disturbance, low nutrient availability, herbivory, grazing, available water, and sunlight exposure making them prone to outcompete native plants. Many nonnative plants become invasive in the U.S. because their native insects and natural enemies are no longer present to keep them in check. Nonnative invasive plants alter plant communities and successional patterns through competition and displacement of native plant species. Other negative consequences include habitat loss, breeding site loss, and alterations to food webs. Nonnative invasive plants spread easily through suckering roots, abiotic (wind or water) and biotic (by animals) seed dispersal, and through other methods of self-propagation, which make these species difficult to control. For more information on controlling nonnative invasive plants see Invasive Plant Removal.

Plants for Low Impact Development

Once established, plants in LID practices should require little maintenance. Turfgrass in pretreatment areas or as part of the LID practice will require some mowing during the growing season and this frequency is site-specific and depends on preferred aesthetics. Native plants are recommended in LID practices because they are low maintenance, sustainable, and already adapted to environmental conditions experienced in these practices. All plants need irrigation until established or if there is a severe drought, but once established, these plants should rely solely on stormwater received.

Sustainability: Native herbaceous perennial plants are sustainable because they usually reseed themselves or spread by vegetative offsets to maintain landscape cover over time. Although native seed plantings may be slow to establish and more expensive compared to nonnative plants, their persistence makes them a cost effective choice.

Wildlife Value: Some LID practices have high wildlife value, provide habitat, and have the added benefit of serving as wildlife corridors that allow for microcosms of plant and animal diversity. These areas provide links between undeveloped land and developed land to balance ecosystems in the face of urbanization and expansion to connect otherwise fragmented native forested areas and landscapes.

Cultivars: Many nurseries may grow native plant cultivars instead of the original plant species because that is what the market currently demands. One criticism is that cultivars of native plants have been mass-produced and lack any genetic diversity. Consider goals of the site or project to determine whether a straight species or a cultivar is appropriate. In a constructed stormwater wetland, genetic diversity and species richness can be prioritized to enhance habitat, insect, and animal diversity. However, in commercial or residential settings, native plant cultivars may be preferred due to specific ornamental qualities they possess. Practices such as bioretention areas, rain gardens, or swales may also utilize a cultivar due to sight or sizing constraints of the site.

Screening Plants: Plant trials or screenings of vegetation in Alabama LID practices are advised to provide sound plant recommendations. Specific soil types and textures as well as local microclimates on site may affect performance of vegetation.


American beautyberry, Smiths Station, AL

Drought Tolerance

In addition to experiencing repeated flood events in LID practices, plants may also be exposed to extended periods of drying in practices such as bioretention, swales, and rain gardens to name a few. LID vegetation should provide evaporative cooling effects as well as maintain plant growth and vigor.

Visual Quality: Many LID practices are in high visibility areas, especially in municipal, commercial, or residential community settings, so plants in these practices need to maintain visual quality. Drought tolerant plants have the ability to maintain photosynthesis and transpiration during a drought and this allows them to continue to efficiently produce carbohydrates necessary for growth, which correlates to plant survival and recovery following a drought.

Evapotranspiration: Evapotranspiration is the combination of water lost from the soil through atmospheric evaporation and water lost from the plant leaves through transpiration. LID emphasizes the importance of evapotranspiration for cooling. It is estimated that about 10% of water in the atmosphere is a result of plant transpiration. In an undeveloped watershed, approximately 50% of precipitation is evapotranspired, while only 30% of is evapotranspired in an urbanized watershed. Thus, the use of LID aims to increase evapotranspiration in urban settings to bridge the gap in evapotranspiration rates.

Transpiration Rates: Transpiration rates vary depending on plant species, season, and plant size. During the dormant season, plants do not require as much water and thus, evapotranspiration is decreased. Larger plants will use more water than smaller ones. For example, a large oak tree may transpire up to 40,000 gal of water per year

Additional Information: To ensure that the plants selected are appropriately drought tolerant, consult plant lists in this handbook, review information on plants labels, plant books, or online. Be advised that you may find conflicting information. It is best to seek an information source that is Alabama specific such as the Alabama Plant Atlas (http://www.floraofalabama.org/). The Alabama Cooperative Extension System will often have the information you are looking for, visit online at www.aces.edu. More information on drought tolerant plants for Alabama can be found at http://www.aces.edu/pubs/docs/A/ANR-1336/ANR-1336.pdf. If you cannot find the information you need from a credible Alabama source, seek information from other Southeastern states with reputable plant science or horticulture departments.

Flood Tolerance

Constructed stormwater wetlands and wet swales require plants that are tolerant of flooded conditions.

Flood Stress: Under flooded conditions, oxygen is decreased because soil pores fill with water. Oxygen is slow to diffuse in water causing an oxygen deficiency resulting in anaerobic (without oxygen) soil conditions. The length of time necessary for anaerobic conditions to occur varies from several hours to a few days and is dependent upon temperature, amount of organic materials in the substrate to be consumed by microbes, and the chemical demand of ions in the soil.

Anaerobic Conditions: Anaerobic conditions are particularly harmful because oxygen is required for root respiration to maintain healthy root tissue and produce new root growth. When oxygen is absent, ions present in the soil become reduced and can be toxic to plants. Wetland plants and flood tolerant plant species adapt to these conditions to transfer oxygen to roots. In doing so, these plants produce oxidized linings around their roots to protect them from reduced ions that may be toxic.

Wetland Plants

Wetland plants are adapted to low oxygen (hypoxic) or no oxygen (anaerobic) conditions where non-wetland adapted vegetation would not survive.

Adaptations: Plants acclimated to flooding usually develop some type of physical adaptations such as lenticels, adventitious roots, surface rooting, shallow root systems, pneumataphores (cypress knees), or aerenchyma tissue. Plants may develop shallow root systems or adventitious roots in the top few millimeters of soil to avoid anaerobic conditions in deeper soil layers. The thickness of the aerated surface soil depends on oxygen transfer from the atmosphere to the soil water surface. Adventitious roots grow on lower stem portions to avoid low oxygen soil layers and to anchor plants. Most flood tolerant plants will exhibit at least some of these adaptations when planted in a constructed stormwater wetland. It is important to understand that all plants cannot tolerate inundated conditions. For more information on specific flood tolerant plants for Alabama, see the Vegetation List in Chapter 4.2 on Constructed Stormwater Wetlands.

Aquatic Plants: Aquatic plants are used in deep pools of constructed stormwater wetlands. These plants are found growing in areas where standing water is present. Aquatic plants are adapted to living under continuous inundated conditions and grow either partially or totally in water. Similarly to terrestrial plants, aquatic plants require sunlight, water, carbon dioxide, and oxygen. These plants are a valuable source of oxygen and carbohydrates to


Aquatic plants in a wet swale; Auburn, AL

animals such as fish and other organisms in and around water.

Many aquatic plants grow in shallow water and can be separated into three groups: emergent, floating leaf plants, and completely submersed.

Emergent Plants: Emergent plants grow in the shallowest water and are rooted in substrate or sediment. Their leaves are held above the water surface. Some examples include pickerel weed, lotus, lizard tail, and arrow arum. Emergent plants are very productive and play a vital role in nutrient cycling and pollutant removal.

Floating Leaf Plants: Floating leaf plants grow at intermediate water depths and may or may not be rooted in sediment. The entire plant may float. Leaves are held at the water surface. An example is water lily.

Submersed Plants: Submersed plants grow completely in the water column and do not have any portion exposed to the atmosphere. These plants are rooted in the sediment. An example is pondweed. Submersed plants need clear water to flourish since suspended sediments in the water column will inhibit light penetration.

Wetland Indicator Status

Wetland indicator status (WIS) can be an excellent guide for moisture conditions preferred by plants in their native habitats. WIS is a helpful designation for plants to define their designation as a hydrophyte, non-hydrophyte, or both. A hydrophyte is defined as plant that is water loving and flood tolerant. Conversely, a non-hydrophyte does not tolerate waterlogged conditions and is not considered flood tolerant.

The National Wetland Plant List has recently been revised by the U.S. Army Corps of Engineers (USACE) based on these designations.

- Obligate (OBL): almost always is a hydrophyte, rarely in uplands
- Facultative Wet (FACW): Usually is a hydrophyte, but occasionally found in uplands
- Facultative (FAC): Commonly occurs as either a hydrophyte or non-hydrophyte
- Facultative Upland (FACU): Occasionally is a hydrophyte, but usually occurs in uplands
- Upland (UPL): Rarely is a hydrophyte, almost always in uplands

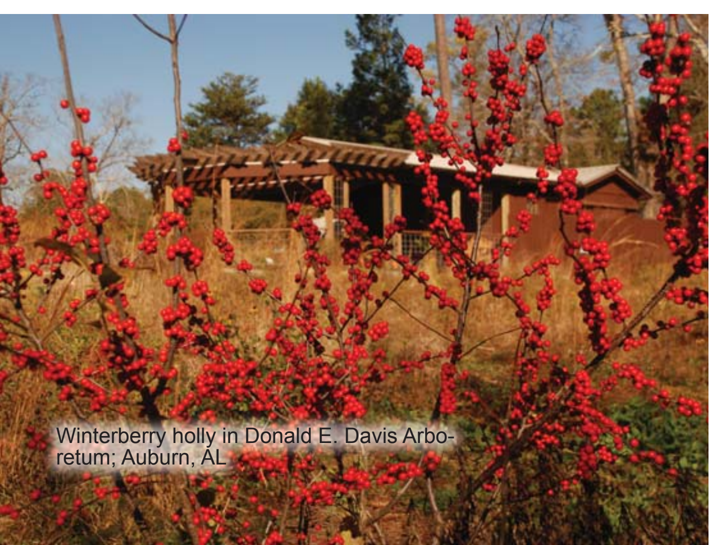
Wetland Indicator Status Lists: These lists are available by ecological region. There are two lists for Alabama, which are the Eastern Mountains and Piedmont and the Atlantic Gulf Coastal Plains. The Alabama lists can be found at: http://rsgisias.crrel.usace.army.mil/NWPL_CRREL//docs/lists//State/AL.pdf. These wetland plant designations are included in the Alabama Native Plant List for this handbook found in Appendix X.

For more information, please see the National Wetland Plant List (http://rsgisias.crrel.usace.army.mil/apex/f?p=703:1).

Use Where Appropriate: Constructed stormwater wetlands use plants from each of the wetland indicator status categories due to the different zones of hydrology. Bioretention cells, rain gardens, and bioswales require plants that are both flood and drought tolerant and may use facultative plants that tolerate alternating hydroperiods in both wetland and non-wetland situations.

Botanical Names

Each plant has been assigned a Latin binomial botanical name consisting of both a genus and specific epithet (collectively known as the species). When ordering plants from a nursery or distributor, refer to plants by their botanical name to reduce the chance of confusion between you and the nursery grower. Referring to plants by their common name is risky since many plants share the same common name, but no two plants share the same botanical name.



Winterberry holly in Donald E. Davis Arboretum; Auburn, AL

Correct Citation: The entire botanical name is underlined or italicized. The genus is capitalized; the species is not. An example is *Coreopsis tinctoria*. *Coreopsis* is the genus and has many species within it (e.g. *Coreopsis nana*, *Coreopsis lanceolata*, etc.), but *tinctoria* is the species, and there is only one *Coreopsis tinctoria*. The cultivar name follows the species name, is not italicized, but is capitalized, and placed in single quotes. *Coreopsis tinctoria* ‘Tiger Stripes’ is an example of a cultivar.

Male and Female Plants

When a plant species does not produce “perfect” flowers (both male and female flower parts in the same flower), that plant species is classified as either monoecious or dioecious. Knowing whether a plant is monoeious or dioecious is important when using plants for ornamental fruit characteristics.

Monoecious: Monoecious means “one house” meaning that male and female flowers occur on the same plant.

Dioecious: Dioecious means “two houses” meaning that one plant has male flowers (a male plant) and one plant has female flowers (female plant). For dioecious plants, you must have both a male and female plant for pollination, fertilization, and fruit production to occur on female plants.

Ornamental Fruit Production: When ornamental fruit production is desired for dioecious plants, often one or two male plants are placed out of sight with female plants placed in front for fruit bearing. For example, *Ilex verticillata* (winterberry holly) needs a male pollinator plant no more than 50’ away and one male plant is sufficient for 10 to 20 female plants. The nursery or grower should be able to provide you with the information necessary to ensure fruit production on dioecious plants.

Vegetation Maintenance

Pruning

Most plants can be pruned once a year to maintain shape, but in some cases, plants may only need pruning every couple of years. Shrubs and other flowering plants should be pruned based on the May Rule.

May Rule: If a plant flowers before May, this means that the plant flowers on old wood and it should be pruned after it flowers. If pruned during the winter, the flower buds would be removed and thus, the plant would not flower that year. If a plant flowers after May, it should be pruned during the winter months because flowers are produced on new wood.

Herbaceous Plants: Stems and leaves of herbaceous perennials die back to ground level during winter months. Leaving the seed heads or spent flower heads may enhance visual winter interest and help encourage seed dispersal since many herbaceous perennials spread by seed. Birds may also eat plant seeds during the winter months and letting the seed heads persist can provide a valuable food source.

Mowing

Mowing should not be conducted immediately following a rain event or when the ground is wet. Mowing under saturated conditions can result in ruts caused by mower wheels or blades and this may inhibit flow patterns especially in pretreatment areas for SCMs where turfgrass is usually specified. Additionally, mowing in wet weather conditions may also cause areas of compaction that decrease functionality and can result in re-concentration of diffuse flow.

Native Grasses: Native grasses are generally mowed at greater heights once or twice per year to remove dead tissue before new growth occurs in early spring. Native grasses will not perform to their potential if mowed or disturbed too often. Mowing creates favorable conditions for exotic species (turfgrass) to outcompete native warm season grasses.

Turfgrass: Turfgrass requires mowing at least once a month (every other week is better) during the growing season. A general rule of thumb is never to remove more than one third of the leaf during mowing. Turfgrasses such as bermudagrass are stimulated to grow through the means of mowing and respond well to frequent mowing.

Thatch: The thatch layer in turfgrass is organic matter made up of stems and leaves that have not decomposed. Thatch develops between turfgrass foliage and the underlying soil layer. Thatch accumulation is increased with excess nitrogen application and infrequent mowing. Thatch build up inhibits water from soaking into soil layers below and can cause turfgrass to mimic an impervious surface, causing runoff. Even when thatch is moistened, it usually remains too wet for healthy grass growth.

De-Thatching: The thatch layer can be checked in September or October by using a knife or shovel to remove a piece or “plug” of grass and soil. Look beneath the turfgrass plants, thatch will be a dark brown to black color and should be easily distinguished from soil layers. When this layer builds to ¾” or greater, brown patches or spots may be noticeable and de-thatching is necessary. De-thatching should be done after spring green up in early summer from May to August using a vertical mower, power rake, or other spring attachment.

Invasive Plant Removal

Invasive plant species should be removed prior to construction of LID practices and, if possible, before seed production to prevent seeds from spreading during or after plant removal. A list of Alabama invasive plants can be found through the Alabama Invasive Plant Council (http://www.se-eppc.org/alabama/).

Mechanical

Mechanical removal of invasive plants includes hand pulling, digging, or the use of a weed wrench or other equipment. When removing invasive plants through mechanical means it is important to remove as much of the original root system as possible. Many invasive plants have the ability to regenerate from root fragments left behind.

Hand Pulling: Hand pulling is usually successful for small stands of weeds with stems less than 3" in diameter.

Equipment: Weed wrenches can be used for 3" or greater diameter trunks; these tools use leverage to remove above and below ground portions of invasive plants.

Erosion and Sediment Control: Mechanical removal usually causes some soil disturbance to areas making them vulnerable to invasion by other invasive plants. When removing invasives from large spaces, stabilization may be necessary using seed, straw, or other means (See the *Alabama Handbook for Erosion Control, Sediment Control, and Stormwater Management on Construction Sites and Urban Areas*).

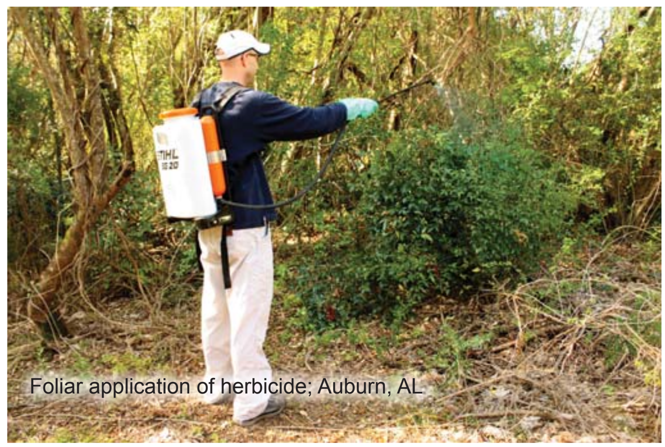
Chemical

Chemical control of invasive plants uses herbicides to manage target plants. Herbicide activity results in yellowing foliage, necrotic (blackened) spots, or necrotic margins and may take a month or longer. Reapplication should occur as new growth appears. There are many chemical treatments and choosing the best one is largely dependent on the target plant species for control.

Herbicide Dyes: Herbicide dyes are also helpful to prevent unneeded reapplication of the herbicide and to keep track of target plants.

Recommendations by Species: Many plant species have specific chemical recommendations and a recommended application window for best control. More information can be found in the Forest Service book, Nonnative Invasive Plants of Southern Forests: A Field Guide for Identification and Control (http://www.srs.fs.usda.gov/pubs/gtr/gtr_srs062/). A summary of chemical herbicide application methods can be found in Table D.2.

Cut Stump Treatments: Cut stump or stem treatments involve cutting an invasive plant stem down to the ground and then applying herbicide to the cut. This method is



Foliar application of herbicide; Auburn, AL

Table D.2
Summary of Chemical Control Measures

Control Type	Size/Vegetation Type	Equipment	Time
Foliar	<8 ft tall nonevergreen woody or herbaceous	Back pack sprayer with metal tip	Mid summer through fall best, but anytime after leaf out is okay
Foliar	<8 ft tall woody evergreen or semi-evergreen	Back pack sprayer with metal tip	Winter
Cut stump or cut-stem	>0.5" diameter stem	Chainsaw, handsaw, or pruning shears and back pack sprayer or pressurized hand sprayer	Anytime, but later summer to fall is best
Basal bark	Any woody vegetation less than 6 to 8" in diameter	Back pack sprayer or handheld pressurized sprayer	Anytime, but late summer to fall is best

(Miller et al., 2010; Enloe et al, 2010) recommended for low-density invasive species removal since the manual labor involved can be extensive when many stems require cutting. These treatments require higher concentrations of the active ingredient and should contain a minimum of 41% of the active ingredient. This method works best on stems that are greater than 0.5” in diameter. Stems should be cut close to ground level, but should still be visible so that you do not lose sight of them; however, in cases where reapplication may be necessary, it is best to cut down to 4 – 6” to leave room for additional cut stem applications in the case of re-sprouting. Herbicide can be applied directly to the cut on smaller stems using a sponge, paint brush, or spray bottle and should occur quickly after stem cuts are made to ensure effectiveness. However, for stumps greater than 6” in diameter, herbicide should be painted or sprayed all the way around the stump and to the areas immediately inside the bark. For more information, please refer to http://www.aces.edu/pubs/docs/A/ANR-1465/ANR-1465-low.pdf

Foliar Applications: Foliar applications are recommended for large monotypic stands of invasive plants and can be a selective or non-selective treatment. Selective treatments target specific invasives and can leave other plants unharmed, but non-selective herbicides (e.g. glyphosate) eradicate any vegetation where they are applied. Rain should not be forecast for the next 24 to 48 hours following foliar sprays. Foliar applications are recommended for nonnative invasive plants that are less than 8’ tall; however, taller woody vines can be cut to 3 - 5’ tall and treated below the cut or basal bark applications may be made. Foliar applications can be sprayed whenever leaves are present, but mid summer to late fall applications are most effective for woody plants. Applications made during winter or spring can be helpful to discourage seed formation and further invasion of plants. Basal bark applications are most effective on trees of 8’ or less diameter breast height (dbh).

Basal Bark Application: Basal bark herbicide applications are appropriate for moderate to low-density nonnative invasive plant control. This method is selective and there is little danger of injuring adjacent vegetation. The application is made using a backpack sprayer and an herbicide-oil-penetrant mixture is applied to the lower stem or trunk of woody vegetation. For more information, refer to http://www.aces.edu/pubs/docs/A/ANR-1466/ANR-1466.pdf

Disposal: Invasive plants should be disposed of properly so that re-rooting does not occur. Weeds should not be pulled and then set immediately back on the ground, instead, weeds should be placed “head” first in the collection bag for disposal to avoid further spread of seeds or plant parts. Bagging on site is best so plant pieces are not spread to other sites. Soft tissue weeds can be placed in black or clear plastic heavy-duty garbage bags to be solarized (i.e. dried in the sun). Plastic sheeting or tarps can be used to dry plants between them, but this method may take several weeks to completely dry weeds. Burning is an acceptable form of disposal, but local codes and ordinances should be checked prior and be aware of some plants such as poison ivy that can cause irritation if inhaled. Composting is not recommended unless weeds are known not to reproduce vegetatively (i.e. through rooting of plant stems, etc.) or there are no flowers and/or seeds present.

Wetland Areas and Aquatic Invasives Control

Most aquatic invasive plants form dense canopies similar to terrestrial invasives plants. Flood prone areas are subject to invasion by invasive plant species that prefer those conditions. Aquatic invasive species should be controlled using a systemic herbicide specifically labeled for aquatic use. Some species can be controlled by water level or by creating conditions unfavorable to the species. Fpr example, cattails (*Typha latifolia*) can be controlled by deep flooding for several weeks during the growing season after stems have been cut. In some cases, the application of these herbicides may require a pesticide applicator’s permit.

Native plant nurseries and resources

The following is a list of Southeast nurseries with native plant stock

- Biophilia, Elberta, AL, 251.987.1200, www.biophilia.net/
- Alabama Nurseries and Orchards, contact Larry Foster, 1.800.222.1280
- Joshua Timberlands, LLC., contact Sam Campbell, Elberta, AL, 251.986.5210
- Tom Dodd Nurseries, Semmes, AL, 1.800.866.3633
- Dodd and Dodd Nursery, Semmes, AL, 251.645.2222, www.doddnatives.com
- Cohn Flowers, contact Rebecca Cohn, 9549 Derby Dr., Birmingham, AL, 205.527.5431
- Mulberry Woods Nursery, Garden City, AL, 205.493.0861, www.mulberrywoodsnursery.com
- Blooming Colors, 1192 S. Donahue Dr., Auburn, AL 334.821.7929
- Nearly Native, 776 McBride Rd. Fayetteville, GA, http://www.nearlynativenursery.com
- Superior Trees, Lee, FL, http://www.superiortrees.net
- Mellow Marsh Farm, Siler City, NC, www.mellowmarshfarm.com
- Foggy Mountain Nursery, Lansing, NC, http://www.foggymtn.com

Table D.3
Alabama Native Trees, Shrubs, Herbaceous Perennials, and Ferns

Genus	specific epithet	Common Name	Sun	Moisture	Height	Bloom Season
Acer	*barbatum*	southern sugar maple	P	D	20 to 25'	spring
Acer	*negundo*	boxelder	S	W	30 to 50'	spring
Acer	*rubrum*	red maple	F	W-D	50-75'	spring
Acer	*saccharinum*	silver maple	F-S	W	50 to 70'	spring
Acer	*saccharum*	sugar maple	F-P	M	50-75'	spring
Achillea	*millefolium*	common yarrow	F-P	W	24 to 36"	spring-summer
Acorus	*calamus*	sweetflag	F-P	W-M	3-5'	summer
Actaea	*pachypoda*	doll's eyes	P-S	M-W	1-2'	spring
Actaea	*rubra*	red baneberry	P-S	M	1-3'	spring
Adiantum	*pedatum*	maidenhair fern	P-S	M	18-36"	N/A
Aesculus	*pavia*	red buckeye	S-P	D	10 to 20'	spring
Aesculus	*parviflora*	bottlebrush buckeye	F-P-S	M	6-12'	summer
Aesculus	*sylvatica*	painted buckeye	S-P	M	6-12'	spring
Aletris	*farinosa*	colic root	F	M-D	2.5-3'	summer
Allium	*canadense*	wild onion	PS	D	8-12"	summer
Alnus	*serrulata*	hazel or tag alder	F-P	W	40'	spring
Amelanchier	*arborea*	serviceberry	F-P	M-D	15-25'	spring
Amorpha	*fruticosa*	indigo bush	F-P	M-W	6-10'	spring to summer
Amsonia	*tabernaemontana*	blue star	F-P	M	2-3'	spring
Anemone	*virginiana*	thimbleweed	S	M	1-3'	summer
Antennaria	*plantaginifolia*	pussy's toes	F	M	.5-1'	spring to summer
Apios	*americana*	groundnut	S	W	vine	summer
Aquilegia	*canadensis*	wild columbine	P-S	M-D	1-2'	spring to summer
Aralia	*spinosa*	devil's walkingstick	F-P	M-D	10-20'	summer

Flower Color	Fall Color	WIS AGCP	WIS EMP	Comments
yellow/green	Y	NL	NL	yellow fall color, resistent to wind and ice
yellow, green, brown	N	FAC	FAC	attracts birds and Cecropia silkmoth, planted widely as a shade tree, fast growing, weak limbs
red	Y	FAC	FAC	Buds and young twigs are red/green, fall color
white, red, yellow	Y	FAC	FACW	fast growth rate, brittle branche, yellow, brown, to red fall color; attracts Cecropia silkmoth
yellow, green, brown	Y	FACU	FACU	Excellent fall color; beautiful large shade tree
white, pink	N	FACU	FACU	flower heads are compact clusters, fragrant foliage
yellow	N	OBL	OBL	perennial, rhizomatous, iris-like herb, grass like
white	N	FACU	UPL	Small white flowers Apr-May; poisonous white berries Aug-Sep
white	N	UPL	UPL	A bushy plant with large, highly divided leaves and a short, thick, rounded cluster of small white flowers
N/A	N	FACU	FAC	Tiny fan-shaped deep blue-green fronds held on black stems
red	N	FACU	FAC	It is normal for this plant to drop its leaves at the end of summer
white	N	NL	NL	A mound shaped thicket forming shrub with picturesque candelabra-like branching.
yellow/green	N	FAC	FAC	Large understory shrub in deciduous forests, unique pear shaped fruits
white	N	FAC	FAC	small white urn shaped flowers
white, pink	N	FACU	FACU	high deer resistance
red, green, brown	Y	FACW	OBL	Can fix nitrogen, yellow to red fall color
white	Y	FACU	FAC	Yellow/orange./red fall color; white flowers in April
purple and yellow	N	FACW	FACW	attracts lots of moths and butterflies
blue	N	FACW	FACW	Blue showy flowers in May
white	N	FACU	FACU	Lovely large white flowers followed by fluffy seed heads
white	N	NL	NL	Forms a low mat of little rosettes of white-wooly leaves
red, pink, and purple	N	FACW	FACW	climbing vine, may take over
red and yellow	N	FACU	FAC	Unique red & yellow flowers attract hummingbirds
white	N	FAC	FAC	Thorny; 3-4" clusters of wht flowers in sum.; birds like berries

Genus	specific epithet	Common Name	Sun	Moisture	Height	Bloom Season
Argemone	*albiflora*	bluestem prickly poppy	P	D	1-3'	spring to summer
Arisaema	*dracontium*	green dragon	P-S	M-D	28"	spring
Arisaema	*triphyllum*	Jack-in-the-pulpit	P-S	M	12"	spring
Aruncus	*dioicus*	goat's beard	F-P	M	4-7'	spring
Aronia	*arbutifolia*	red chokeberry	F	W-M	5'	spring
Arundinaria	*gigantea*	giant cane	P-S	M-W	6-25'	green
Asarum	*canadense*	wild ginger	P-S	M	6"	spring
Asclepias	*incarnata*	swamp milkweed	F-P	M-W	2-4'	summer to fall
Asclepias	*longifolia*	longleaf milkweed	F-P	M-W	1-2'	summer
Asclepias	*tuberosa*	butterfly weed	F	D	1-2'	summer
Asimina	*parviflora*	dwarf paw paw	P	D	6-8'	spring
Asimina	*triloba*	paw paw	P-S	M	40'	spring
Asplenium	*platyneuron*	ebony spleenwort	F-P	M	6-12"	N/A
Athyrium	*filix-femina*	lady fern	S	M-W	18-24"	N/A
Baccharis	*halimifolia*	sea-myrtle	P	W	6-12'	summer to fall
Bacopa	*monnieri*	water hyssop	F-P	M-W	1'	spring
Baptisia	*alba*	white wild indigo	F-P	D	2-4'	spring
Baptisia	*australis*	blue indigo	F	M-D	2-4'	spring/summer
Betula	*lenta*	sweet birch	F-P	M	40-55'	spring
Betula	*nigra*	river birch	F	M-W	40-70'	spring
Bignonia	*capreolata*	cross vine	F-P	M	vine	spring
Boltonia	*asteroides*	white doll's daisy	P	W	3-6'	summer/fall
Botrychium	*virginianum*	rattle snake fern	P-S	M	3'	spring/summer
Callicarpa	*americana*	American beautyberry	P	M	3 to 8'	summer
Calycanthus	*floridus*	sweetshrub	P-S	M	6-10'	summer
Camassia	*scilloides*	wild hyacinth	F-PS	M-D	1-2'	spring
Campanulastrum	*americanum*	American bellflower	P	M	3-4'	summer
Campsis	*radicans*	trumpet creeper	F	M-D	vine	summer

Flower Color	Fall Color	WIS AGCP	WIS EMP	Comments
white	N	NL	NL	plant parts toxic to humans
yellow, green	N	FACW	FACW	Similiar to Jack-in-the-pulpit; goes dormant mid-summer
green, purple, brown	N	FACW	FACW	Spathe appears Mar-May; red berries late summer, fall
cream	N	FACU	FACU	Feathery plumes of cream-colored flowers rise above foliage
white	Y	NL	NL	
spring	N	FACW	FACW	Rarely flowers; wood stems, spreads by rhizomes
red brown to purple	N	UPL	FACU	Evergreen groundcover with heart-shaped glossy leaves
pink	N	OBL	OBL	attracts butterflies and hummingbirds
white	N	FACW	OBL	grows from a taproot
orange	N	NL	NL	Clusters of brilliant orange flowers Jun-Aug
maroon	N	FACU	UPL	maroon axiallry flowers in mid-March, high dry sites
maroon	Y	FAC	FAC	Unique fruit resembles & tastes like banana, light green to yellow fall color; attracts butterflies and moths
N/A	N	FACU	FACU	stalk turns shiny black with age
N/A	N	FAC	FAC	Delicate & lacy arching fronds have dark red stems at maturity
white	Y	FAC	FACW	White to green flowers occur in small dense terminal clusters.
white	N	OBL	OBL	attracts butterflies
white	N	FACU	FACU	leaves turn black in the fall
blue-violet	N	NL	FACU	if started from seed, plants will not flower for 3 years
yellow, green, brown	Y	FACU	FACU	Golden-yellow fall color
green and brown	Y	FACW	FACW	Modest yellow fall color; seed attracts birds
red, yellow	Y	FAC	FAC	reddish purple fall color
white	N	FACW	FACW	Broad flat clusters of generally small flower heads
n/a	N	FACU	FACU	requires more care than other ferns
white, pink	N	FACU	FACU	Axillary berries in fall attract over 40 birds species
brown, maroon	N	FACU	FACU	Interesting brown blooms Apr-July
blue/lavender	N	FACW	FAC	A leafless stem with lavender to blue flowers in an elongated, loose-flowered cluster
blue/purple	N	FAC	FACU	attracts hummingbirds
red, orange, yellow	N	FAC	FAC	A high-climbing, aggressively colonizing woody vine to 35 feet with showy flowers.

Genus	specific epithet	Common Name	Sun	Moisture	Height	Bloom Season
Carex	*comosa*	bottlebrush sedge	F-P	W	3.5'	summer
Carex	*crinita*	fringed sedge	P	M-W	2'	summer
Carex	*lupulina*	hop sedge	P	W	3'	summer
Carex	*lurida*	shallow sedge	F-P	W	2.5'	summer
Carex	*stricta*	tussock sedge	F	M-W	3'	summer
Carex	*tribuloides*	blunt broom sedge	F-P	M-W	3'	summer
Carya	*cordiformis*	bitternut hickory	F-P	M	50-70'	spring
Carya	*glabra*	pignut hickory	F-S	D	50-60'	spring
Carya	*illinoinensis*	pecan	F	M	70-100'	spring
Carya	*ovata*	shagbark hickory	F-S	M-D	60-80'	spring
Carya	*tomentosa*	mockernut hickory	F-S	M-D	50-60'	spring
Castanea	*pumila*	chinquapin	F-S	M	20-25'	spring
Catalpa	*bignoniodes*	southern catalpa	P	M	25-40'	spring
Caulophyllum	*thalictroides*	blue cohosh	P-S	M-W	1-3'	spring
Ceanothus	*americanus*	New Jersey tea	F-P	D	3'	summer
Celtis	*laevigata*	sugar hackberry	F-P	M-D	60-80'	spring
Celtis	*occidentalis*	common hackberry	F	M-D	40-60'	spring
Cephalanthus	*occidentalis*	buttonbush	P-S	M-W	6-12'	summer
Cercis	*canadensis*	Eastern redbud	F-S	M-D	20-30'	spring
Chamaecrista	*fasciculata*	patridge pea	F-P	M-D		summer
Chasmanthium	*latifolium*	river oats	P-S	M	2'	summer
Chelone	*glabra*	white turtlehead	F-S	M-W	1-4'	summer
Chelone	*lyonii*	pink turtlehead	F-P	M-W	24-30"	summer
Chionanthus	*virginicus*	fringetree	F-P	M	12-20'	spring
Chrysogonum	*virginianum*	green-and-gold	P-S	M	8"	spring/fall
Cimicifuga	*racemosa*	black cohosh	P-S	M	1-3'	summer/fall
Cirsium	*discolor*	field thistle	F	D	3-6'	summer

Flower Color	Fall Color	WIS AGCP	WIS EMP	Comments
green	N	OBL	OBL	Prefers mucky soils; a more cultivated sedge variety that can be used in wet rain gardens
green	N	FACW	OBL	grass like evergreen; seeds eaten by waterfowl; transplants easily
green	N	OBL	OBL	spreads by rhizomes; will grow on the edge of streams or ponds
green/yellow	N	OBL	OBL	attracts birds
yellow	N	OBL	OBL	attracts birds, butterflies, and moths; nesting habitat for rails and snipes
green and brown	N	FACW	FACW	Tolerates gravelly and mucky substrates
yellow, green, brown	Y	FAC	FACU	Striking yellow buds; pinnately compound leaves, yellow fall color
yellow, green, brown	Y	FACU	FACU	Golden-yellow fall color; rapid growth rate
yellow	N	FACU	FACU	The largest of the hickories and one of the most valuable cultivated plants origninating in North America.
green, brown	Y	FACU	FACU	golden yellow fall color
yellow, green, brown	Y	NL	NL	golden yellow fall color
white	Y	NL	NL	Slender spikes of strongly scented staminate flowers; yellowish purple fall color
white	N	UPL	FACU	Short crooked branches with heart shaped leaves and clustered flowers.
green	N	NL	NL	Green flowers Apr-May; blue poisonous berries
white	N	NL	NL	Short spikes of tiny white flowers in June
green	N	FACW	FACW	attracts butterflies and moths
green, brown	N	FACU	FACU	attracts butterflies and moths
white	N	OBL	OBL	used for live stakes; attracts birds and butterflies
pink	N	UPL	FACU	Clusters of rosy/pink flowers (Apr); flowers line branches/trunk
yellow	N	FACU	FACU	Seeds are eaten by song and game birs; flowers attract bees and butterflies; an annual that is great used in a mix for stream enhancement projects
green, brown	Y	FAC	FACU	Yellow fall color, perennial grass, clump forming with oat like flowers
white	N	OBL	OBL	Terminal clusters of white and lavendar tinged two lipped flowers; attracts butterflies and hummingbirds
pink	N	FACW	FACW	Showy pink flowers July-Sept
white	N	FACU	FAC	Wispy, creamy wht. fragrant flowers in May
yellow	N	NL	NL	Yellow flowers contrast green foliage in spring & fall
white	N	NL	NL	Slender candle-like clusters of white slowers in summer & fall
pink/purple	N	UPL	UPL	attracts butterflies and seeds attract birds

Genus	specific epithet	Common Name	Sun	Moisture	Height	Bloom Season
Cirsium	*muticum*	swamp thistle	F	W	2-7'	summer
Cladrastis	*kentuckea*	yellowwood	F-P	M	30-50'	spring
Claytonia	*virginica*	springbeauty	P	M	4-12"	spring
Clematis	*crispa*	blue jasmine	F-P	M-W	vine	spring/fall
Clethra	*acuminata*	cinnamonbark	F-P	M	8-15'	summer
Clethra	*alnifolia*	summersweet clethra	F-P	M-W	6-12'	summer
Cliftonia	*monophylla*	buckwheat brush	F	W	12-18'	spring
Clinopodium	*coccineum*	scarlet calamint	F-P	D	1-3'	spring/ summer/fall
Commelina	*erecta*	whitemouth dayflower	P	D	1-3'	summer/fall
Conoclinium	*coelestinum*	mistflower	F-P	M	3'	summer to fall
Coreopsis	*auriculata*	mouse-eared coreopsis	F	M	18"	spring
Coreopsis	*basalis*	goldenmane tickseed	F	D	15"	summer
Coreopsis	*lanceolata*	tickseed	F	M-D	1-2.5'	spring
Coreopsis	*nudata*	Georgia tickseed	P	W-M	3-5'	spring
Coreopsis	*pubescens*	star tickseed	F	M	3-4'	summer
Coreopsis	*tinctoria*	golden tickseed	F-P	M	1-2'	spring
Coreopsis	*verticillata*	threadleaf coreopsis	S	D	1-2'	summer
Cornus	*alternifolia*	pagoda dogwood	P-S	W-D	15-25'	summer
Cornus	*amomum*	silky dogwood	F-S	M-W	6-10'	summer
Cornus	*florida*	flowering dogwood	F-S	D-M	25-30'	spring
Cornus	*foemina*	stiff dogwood	P	M-W	20'	spring
Cotinus	*obovatus*	American smoke tree	F	D	15-30'	spring
Corylus	*americana*	American hazelnut	F-S	M	12-15'	spring
Crataegus	*aestivalis*	May hawthorn	P	W	30-40'	spring
Crataegus	*marshallii*	parsley hawthorn	P	D	12-25'	spring
Crataegus	*phaenopyrum*	Washington hawthorn	F-P	M	25-30'	spring

Flower Color	Fall Color	WIS AGCP	WIS EMP	Comments
pink/purple	N	OBL	OBL	attracts butterflies
white	Y	NL	NL	Clusters of fragrant/wht pea-type flowers (spr); yllw. fall color
white to pink	N	FACU	FAC	tuber, good in patches
white, pink, blue, purple	N	FACW	FACW	Usually blooms mid spring and again in fall; attracts birds and butterflies
white	Y	NL	NL	Twisted racines of white lily-of-the-valley like fragrant flowers; yellow orange fall color
white to pink	Y	FACW	FAC	yellow orange fall color
white to pink	N	OBL	OBL	A thicket forming shrub with white to pink flower clusters; fragrant flowers; evergreen
red	N	NL	NL	A shrub with wiry stems and showy red flowers.
blue	N	FACU	FAC	attracts birds, will usually lay down if not supported by other plants
blue-violet	N	FAC	FAC	very vigorous, can be leggy, attracts birds, bees, and butterflies
yellow	N	NL	NL	Rich yellow flower head spring to frost if dead-headed
yellow	N	NL	NL	Annual; self sows
yellow	N	UPL	FACU	Best in full sun, will take part shade; attarcts butterflies
pink	N	OBL	NL	Notched ray flowers surround a center of small, yellow disk flowers.
yellow	N	FAC	FACU	Bright golden yellow flowers all summer; perennial
yellow/maroon	N	FAC	FAC	Nectar source for bees and butterflies; birds eat seeds; considered an annual, but may perfrom as a short lived perennial in some states.
yellow	N	NL	NL	Perennial; spreads by rhizomes; seeds attract birds
white	Y	FAC	FAC	Clusters of wht. flowers (late sum.); Black berries, dull maroon fall follage
white	N	FACW	FACW	Creamy white flowers May-Jun; no fall color
white	Y	FACU	FACU	White flowers in spring turn into bird-attracting berries; red fall color
white	N	FACW	FACW	Reddish twigs becoing gray with age.
red, purple	Y	NL	NL	A short trunk, open crown with flower panicles that develop long, red or purple, hairlike petioles
white, green	Y	FACU	FACU	Edible nuts; suckering; fall color varies from deep red to bright yellow
white	N	OBL	NL	Clusters of white flowers followed by edible red fruit.
white	Y	FAC	FAC	Dainty, white, five-petaled blossoms are followed by bright-red, persistent fruits.
white	Y	FAC	FAC	Wht. spring flowers; red fall berries; orange/ scarlet fall color

Genus	specific epithet	Common Name	Sun	Moisture	Height	Bloom Season
Crataegus	*spathulata*	little-hip hawthorn	P	M	12-36'	spring
Crinum	*americanum*	swamp lily	P	W	2-3'	summer/fall
Croton	*alabamensis*	Alabama croton	P	M	6-8'	spring
Cypripedium	*acuale*	pink lady slipper	P-S	M-D	12"	spring to summer
Cypripedium	*calceolus*	yellow lady slipper	F-P	M	6 - 12"	spring
Cyrilla	*racemiflora*	swamp titi	S	W	10-15'	spring to summer
Decumaria	*barbara*	wild hydrangea-vine	P-S	W	vine	spring to fall
Delphinium	*carolinianum*	blue larkspur	P	D	1-2'	spring to summer
Delphinium	*tricorne*	dwarf larkspur	P	M	12-30"	spring
Dennstaedtia	*punctilobula*	hay-scented fern	P-S	M	36"	N/A
Dicentra	*cucullaria*	dutchman's breeches	F-S	M	10"	spring
Diervilla	*sessilifolia*	bush-honeysuckle	F-S	M	4-6'	summer
Diodia	*virginiana*	Virginia buttonweed	P	D	6-18"	summer
Diospyros	*virginiana*	persimmon	F-P	D-M	30-50'	spring
Dodecatheon	*meadia*	shooting star	F-P	M	1-2'	spring
Dracopis	*amplexicaulis*	clasping coneflower	P	M	2-3'	spring to summer
Drosera	*rotundifolia*	roundleaf sundew	F	W	<12"	summer
Dryopteris	*marginalis*	marginal fern	P-S	W-M	1-3'	N/A
Echinacea	*purpurea*	purple coneflower	F-P	M-D	3'	summer
Elymus	*hystrix*	Eastern bottlebrush grass	F-P	M-D	2.5-5'	summer
Eragrostis	*spectabilis*	purple love grass	F	M	1 - 1.5'	summer/fall
Erythronium	*americanum*	trout lily	P-S	M	8"	spring
Euonymus	*americanus*	Hearts-a-bustin	P-S	M	4-6'	spring
Euonymus	*atropurpureus*	burning bush	P	M	20-25'	spring

Flower Color	Fall Color	WIS AGCP	WIS EMP	Comments
white	N	FAC	FAC	Slender thorny branches with clusters of white flowers.
white	N	OBL	NL	The fragrant flowers are white, sometimes marked with pink on an erect plant that grows in small clumps.
white, yellow	Y	NL	NL	Orange fall color, crushed leaves smell like banana-apple; likes soil rich in organic matter
pink	N	FACU	FACU	One of the largest native Orchids and is found both in low, sandy woods and in higher, rocky woods of mountains.
yellow	N			Found in boggy areas, not available in the trade
white	Y	FACW	FACW	Starts out as a shrub, but eventually grows into a tree; can grow to be up to 30' tall; red fall color; can be evergreen in mild climates
white	N	FACW	OBL	Blooms on new wood and will only bloom when climbing
violet	N	NL	NL	White to pale blue, spurred flowers in a narrow cluster on a finely downy stalk.
deep blue	N	NL	NL	Attracts large numbers of native bees
N/A	N	UPL	FACU	Fronds smell like hay when crushed
white, yellow	N	NL	NL	Can spread to cover larger areas; perennial; attracts bees
yellow	N	NL	NL	Small yellow flowers on tips of new growth all summer
white	N	FACW	FACW	
yellow/green	N	FAC	FAC	Yellow/orange/mauve color; butterfly larval plant; attracts the luna moth
pink & white	N	FACU	FACU	Delicate white to pink petals, red & yellow center; important pollen and nectar source for honeybees
yellow	N	FAC	FAC	Smooth-stemmed annual coneflower
white	N	OBL	OBL	native to swamps and bogs
N/A	N	FACU	FACU	evergreen clumping fern, sensistive to heat, likes an oak leaf winter covering
pink	N	NL	NL	Self sows and spreads by offsets; clumping perennial; attracts butterflies, hummingbirds, and native bees
green	N	UPL	UPL	
purple, red	N	FACU	UPL	Widely available as contaoners or seed, will spread through seed to reseed an area
yellow	N	NL	NL	Large few-petaled yellow flowers; mottled leaves
yellow/green to purplish	Y	FAC	FAC	Purplish flowers in May; interesting red seed pods in Sept, attracts birds; some red fall color
purple	Y	FAC	FACU	Can be a shrub or small tree; red fall color; showy crimson fruit pods in fall and into winter

Genus	specific epithet	Common Name	Sun	Moisture	Height	Bloom Season
Eupatoriadelphus	*fistulosus*	Joe-Pye weed	F-P	M	5-8'	summer
Eutrochium	*fistulosum*	trumpetweed	F-P	M-W	4-7'	summer
Fagus	*grandifolia*	American beech	F-P	M	85+'	spring
Fothergilla	*gardenii*	fothergilla	F-P	W-M	3'	spring
Fothergilla	*major*	large Fothergilla	F-P	M	6-10'	spring
Fragaria	*virginiana*	wild strawberry	F-P	M-D	6"	spring
Frangula	*caroliniana*	Carolina buckthorn	P	M	12-15'	spring
Fraxinus	*americana*	white ash	F	M-D	80'	spring
Fraxinus	*caroliniana*	pop ash	F	M-D	30'	spring
Fraxinus	*pennsylvanica*	green Ash	F	M-D	60-80'	spring
Gaillardia	*pulchella*	firewheel	F-P	D	1-2'	summer
Gaultheria	*procumbens*	wintergreen	P-S	M	4-8"	summer
Gaura	*angustifolia*	southern beeblossom	F-P	M	4'	spring to summer
Gaylussacia	*dumosa*	dwarf huckleberry	P	W-D	3-15"	spring to summer
Gelsemium	*rankinii*	swamp jessamine	F-P	M-D	vine	spring
Gelsemium	*sempervirens*	Carolina jessamine	F-P	M	vine	early spring
Geranium	*maculatum*	wild geranium	F-S	M	1-2'	spring and summer
Gleditsia	*triacanthos*	honey-locust	F	M-D	30-75'	late spring
Gordonia	*lasianthus*	loblolly bay	F	M	30-80'	summer
Gymnocladus	*dioicus*	Kentucky coffeetree	F-P-S	M-D	60-75'	summer
Halesia	*carolina*	Carolina silverbell	F-S	M	30'	spring
Halesia	*diptera*	silver bell	F-P	M	20-30'	spring

Flower Color	Fall Color	WIS AGCP	WIS EMP	Comments
purple	N	FACW	FACW	Purplish-pink flowers explode in Aug/Sept attracting butterflies
pink/purple	N	FACW	FACW	
yellow, green, brown	N	FACU	FACU	Nuts in fall attract birds/mammals/humans; leaves turn copper colored in fall and remain on the tree throughout the winter
white	Y	FACW	FACW	orange to yellow fall color
white	Y	NL	NL	Showy, fragrant flowers in spring; spectacular fall leaves
white	N	FACU	FACU	Forms groundcover; tasty fruit in early summer; fruit attracts wildlife; flowers attract butterflies
yellow	Y	FACU	FAC	Songbirds and other wildlife consume the berries, which apparently have medicinal properties but can be toxic.
green to purple	Y	FACU	FACU	Can grow larger than 80'; early yellow fall color then changing to burgundy; easily transplanted; attracts many butterflies and moths
green	N	OBL	OBL	Small tree; not available in the trade; transplants well
green to purple	Y	FACW	FACW	Yellow fall color; transplants well; planted in spoil soils after strip mining
red and yellow	N	UPL	UPL	Annual, but is a short lived perennial in coastal settings; reseeds; needs well drained soils
pink	N	FACU	FACU	Pink flowers in summer followed by edible fruit that persists; evergreen; deer browse in winter
pink & white	N	NL	NL	Annual; not avaialble in the trade
white	N	FAC	FAC	Spreads by rhizomes; semi-evergreen to deciduous
yellow	N	FACW		This high-climbing vine is very common in parts of the South
yellow	N	FAC	FAC	Evergreen vine; can have problems with leaf miner; seen growing natively in tops of trees all over; fragrant yellow trumpet shaped flowers
purple	N	FACU	FACU	1" lavender-purple clowers in spring & summer; colonizes by rhizomes but is not aggressive
yellow	N	FAC	FAC	A thornless variety is available - Gleditsia triacanthos inermis; attracts butterflies and moths
white	N	FACW	FACW	Evergreen; fragrant white flowers
white, green, brown	Y	NL	NL	Leaves give the foliage a tropical look.
white	N	FACU	FAC	Drooping large white bell-shaped flowers in early spring; yellow to brown fall cplor is considered poor
white	Y	FAC	FAC	The white, tubular flowers hang on long, pendulous pedicels

Genus	specific epithet	Common Name	Sun	Moisture	Height	Bloom Season
Hamamelis	*vernalis*	vernal witch hazel	F-P	M-D	12-36'	winter
Hamamelis	*virginiana*	common witch-hazel	F-S	M	15-30'	fall
Helianthus	*angustifolius*	swamp sunflower	P	M-W	3'	fall
Hepatica	*acutiloba*	sharp-lobed hepatica	S	M-D	4-9"	spring
Heuchera	*americana*	alumroot	S	D	1-3'	spring to summer
Hexastylis	*arifolia*	little brown jugs	P-S	M	6"	spring
Hibiscus	*coccineus*	scarlet-rose mallow	S	W	4-7'	summer
Hibiscus	*moscheutos*	crimson-eyed rose mallow	F-P	M-W	3-8'	summer
Hydrangea	*arborescens*	snowhill hydrangea	P-S	M	4-6'	summer
Hydrangea	*quercifolia*	oakleaf hydrangea	S	M	3-12'	summer
Hymenocallis	*caroliniana*	Carolina spider lily	P-S	M	1-3'	spring, summer
Hypericum	*densiflorum*	dense hypericum	F-P	W-D	4-6'	spring
Hypericum	*prolificum*	shrubby St. John's wort	F-P	M	1-5'	summer
Ilex	*cassine*	dahoon holly	F-P	W-M	20-30'	spring
Ilex	*decidua*	possumhaw	F-P	M	15-30'	spring
Ilex	*glabra*	inkberry	P	M-W	6-12'	spring
Ilex	*montana*	mountain winterberry	F-P	M	15-40'	spring
Ilex	*opaca*	American holly	F-S	M-D	20-40'	spring
Ilex	*verticillata*	common winterberry	F-S	M-W	6-15'	spring
Ilex	*vomitoria*	yaupon	F-P	W-D	12-25'	spring
Illicium	*floridanum*	Florida anise tree	P-S	W-M	6-12'	spring
Impatiens	*capensis*	jewelweed	F-P	M	3'	summer
Ipomopsis	*rubra*	standing-cypress	F-P	D	2-6'	summer
Iris	*cristata*	dwarf crested iris	P-S	M-D	4-8"	spring
Iris	*fulva*	red flag	F-P	M	1-3'	spring

Flower Color	Fall Color	WIS AGCP	WIS EMP	Comments
yellow	Y	FACU	FACU	A small tree or large shrub to 15 ft. tall with multiple, crooked stems forming an irregular, open crown.
yellow	Y	FACU	FACU	1" fragrant, creamy to bright yellow flowers in fall; yellow fall color
yellow	N	FACW	FACW	browsed by white tail deer; seeds used by birds; reseeds readily
white, pink, purple, blue	N	NL	NL	White, pink, blue, or purple solitary flowers in spring
greenish-purple	Y	FACU	FACU	Greenish-purple bell-shaped flowers bloom on leafless stalks; foliage turns purple, red, and yellow in fall
purple to brown	N	FAC	FAC	Spotty groundcover, heart-shaped leaves, jug-shaped flowers held at ground level beneath the leaves
red	N	OBL	OBL	Deep scarlet flowers over 10 inches in width.
white/red	N	OBL	OBL	Widely available, likes slightly acidic soils
white	N	UPL	FACU	Large clusters of flat, creamy white flowers Jun-Jul; suckers freely
white, green, purple	Y	NL	NL	The foliage, shaped something like that of red oak, becomes colorful in fall.
white	N	OBL	OBL	A smooth, fleshy, fragrant perennial
yellow	N	FACW	FACW	Golden yellow 1" flowers in late spring: semi-evergreen; spreads by stolons
yellow	Y	FAC	FACU	Showy 1" yellow flowers bloom Jun-Sept; yellow green fall color
white	N	FACW	FACW	Inconspicuous greenish white axillary flowers.
white	N	FACW	FACW	Female trees produce red berries in fall
white	N	FACW	FAC	Black berries in the fall that persist into winter
white	N	NL	FACU	Red berries on female plants
white	N	FAC	FACU	To ensure fruit, one male is needed per 2-3 females
white	N	FACW	FACW	Red berries on female plants persist into winter & attract birds
white	N	FAC	FAC	Evergreen; berries produced on female plants
red, purple	N	FACW	FACW	Maroon-purple flowers occur singly and are composed of 20-30 strap-like petals.
orange	N	FACW	FACW	Beautiful orange flowers attract butterflies & hummingbirds; annual; important for honey bees
red	N	NL	NL	Showy red tubular flowers on spikes; attracts hummingbirds
lavender-blue	N	NL	NL	Pale lavender-blue, crested flowers Apr-May
red, orange, yellow	N	OBL	OBL	Showy copper, red or orange, drooping petals and spreading sepals make up the terminal flower

Genus	specific epithet	Common Name	Sun	Moisture	Height	Bloom Season
Iris	*virginica*	Southern blue flag iris	P-S	W	3-6'	early summer
Itea	*virginica*	Virginia sweetspire	F-S	W	3-6'	summer
Juglans	*nigra*	black walnut	F-P	M	50-75'	spring
Juncus	*effusus*	common rush	F-P	M-W	3'	spring
Juniperus	*virginiana*	Eastern red cedar	F-P	M-D	40-50'	spring
Justica	*americana*	water willow	F-P	W-M	1-3'	spring/summer
Kalmia	*latifolia*	mountain laurel	P	M	8-10'	spring
Leucothoe	*axillaris*	doghobble	P-S	M	2-4'	spring
Leucothoe	*fontanesiana*	drooping leucothoe	P-S	M	3-5'	summer
Liatris	*spicata*	blazing star	F	M	3'	summer
Lilium	*canadense*	yellow bell lily	F	W-M	3-8'	summer
Lilium	*superbum*	Turks-cap lily	F-P	M	4-6'	summer
Lindera	*benzoin*	spicebush	P-S	M	6-12'	winter
Liquidambar	*styraciflua*	sweetgum	P	M	70-120'	spring
Liriodendron	*tulipifera*	tulip tree	F	M	70-90'	spring
Lobelia	*cardinalis*	cardinal flower	F-P	W	3-5'	fall
Lobelia	*puberula*	lobelia	F-S	M	2-4'	summer/fall
Lobelia	*siphilitica*	greatlobelia	P-S	W	1-3'	summer
Lonicera	*sempervirens*	trumpet honeysuckle	F-P	M	vine	spring
Lyonia	*ligustrina*	male-berry	P	W	6-12'	summer
Lyonia	*lucida*	lyonia	P-S	M-D	3-5'	spring
Lysimachia	*ciliata*	fringed loosterife	F-P	M-W	2-3'	summer
Magnolia	*acuminata*	cucumber tree	P-S	M	50-75'	spring

Flower Color	Fall Color	WIS AGCP	WIS EMP	Comments
blue/purple	N	OBL	OBL	Spreads by rhizomes; be sure to get this iris and not the nonnative invasive yellow flag iris
white	Y	FACW	OBL	Spectacular long lasting yellow, orange, crimson fall color
yellow, green, brown	Y	UPL	FACU	Yellow fall color; deep tap root makes transplant difficult; certain plants will not grow beneath b;lack walnut due to the juglones it releases into the soil; attracts birds and small mammals; host plant for luna moth
yellow	N	OBL	FACW	Attracts birds, very easily transplanted, can be divided
green, purple, brown	N	FACU	FACU	Offers nesting and cover to birds; fruits used extensively by birds and small mammals; evergreen
pink, purple, violet	N	OBL	OBL	An aquatic with bicolored flowers in dense, head-like or spike-like clusters.
pink, red, white	N	FACU	FACU	Pink, red, or white flowers in late spring; evergreen; difficult to propagate
white to pink	N	FACW	FACW	Evergreen; attracts bees; browsed by deer
white	N	FACW	FACW	Lance-shaped leaves on slender stems; few branches; evergreen
purple	N	FAC	FAC	Tall purple spikes bloom after 2-3 years; attracts butterflies and hummingbirds
red, orange, yellow	N	FAC	FAC	A large, showy lily with recurved petals
orange	N	FACW	FACW	Gorgeous orange flowers; morning sun & afternoon shade
yellow	N	FACW	FAC	Yellow spicily fragrant flowers in late winter; red fruit in fall on female plants
white, green	Y	FAC	FAC	Red to purple fall color; fruit attracts several bird species; used as a nesting site
yellow, green, orange	Y	FACU	FACU	Large tulip-like flowers are yellow/grn./org. in May-June; yellow fall color
red	N	FACW	FACW	Terminal clusters of bright red flowers each 1 1/2" long in fall
blue-violet	N	FACW	FACW	Spikes of flowers range from pale blue to violet
blue	N	OBL	FACW	Elongated clusters of pale to dark blue flowers in late summer
red to orange	N	FACU	FACU	Evergreen vine; flowers followed by red berries that attract birds and other wildlife; flowers attract hummingbirds, butterflies, and bees
white	Y	FACW	FACW	Orange to red fall color; low wildlife value; does attract birds
pink	N	FACW	FACW	Evergreen; suckers easily; flowers attract bees
yellow	N	FACW	FACW	Yellow flowers grow upside-down; good groundcover; tolerates seasonal flooding
yellow/green	N	NL	FACU	Yellow/grn. magnolia-type flowers (spr); pink/red fuit in fall; fruits eaten by ground foraging birds and small mammals

Genus	specific epithet	Common Name	Sun	Moisture	Height	Bloom Season
Magnolia	*grandiflora*	Southern magnolia	F-P	M-D	72-100'	spring
Magnolia	*macrophylla*	bigleaf magnolia	P	W	30-40'	summer
Magnolia	*tripetela*	umbrella tree	F-P	M	15-40'	spring
Magnolia	*virginiana*	sweetbay magnolia	PS	M-D	40-60'	summer
Maianthemum	*canadense*	wild lily of the valley	P-S	M	3-6"	late spring to early summer
Malus	*angustifolia*	southern crabapple	P	M	25-30'	spring
Matteuccia	*struthiopteris*	osterich fern	P	M	3-6'	N/A
Mertensia	*virginica*	Virginia bluebells	F-P	M	1-3'	spring
Mitchella	*repens*	partridge berry	P-S	M	3"	spring to summer
Mitella	*diphylla*	bishop's cap	P-S	M-D	1-2'	spring
Monarda	*didyma*	bee balm	F-P	M	3-4'	summer
Morella	*cerifera*	southern wax myrtle	F-P	M-D	6-12'	spring
Morus	*rubra*	red mulberry	F-P-S	M-D	12-36'	spring
Muhlenbergia	*capillaris*	muhly grass	F-P	M-D	3'	fall
Nelumbo	*lutea*	American lotus	F	W	6'	summer
Nuphar	*lutea*	cow lily	P	W	3'	spring to fall
Nymphaea	*odorata*	American water lily	F-P-S	W	1'	spring to fall
Nyssa	*aquatica*	water tupelo	F	W	50-100'	sping
Nyssa	*sylvatica*	black tupelo	F	M-D	30-60'	spring
Oenothera	*speciosa*	pink evening-primrose	FS	M	1-3'	spring
Onoclea	*sensibilis*	sensitive fern	F-P	W	12-24"	N/A
Osmanthus	*americanus*	devilwood	P	M	30'	spring
Osmunda	*cinnamomea*	cinnamon fern	P-S	M-W	24-48"	N/A
Osmunda	*regalis*	royal fern	P	M-W	2-5'	N/A
Ostrya	*virginiana*	hop-hornbeam	P-S	M	30-50'	spring
Oxydendrum	*arboreum*	sourwood	F-S	M-D	20-30'	summer
Pachysandra	*procumbens*	Allegheny spurge	P-S	M	9"	spring

Flower Color	Fall Color	WIS AGCP	WIS EMP	Comments
white	N	FAC	FACU	Beautiful fragrant large white flowers.
white	N	NL	NL	Largest flowers and largest leaves of all native North American species.
white	N	FACU	FACU	6-8" wht. flowers spring w/unpleasant odor; red fruit in fall
white	N	FACW	FACW	Semi-evergreen to evergreen; lemon scented flowers; attracts sweetbay silk moth; medium growth rate
white	N	FAC	FAC	Spreads by rhizomes to form a colony.
pink	N	NL	NL	Fruit consumed by birds and small mammals
N/A	N	FACW	FACW	2-8 foot tall fronds.
purple	N	FAC	FACW	Nodding clusters of pink buds that open into light blue trumpet-shaped flowers.
pink	N	FACU	FACU	Elegant pink flowers, red edible fruit,dense/ creeping evergreen groundcover
white	N	FACU	FACU	Produces distinctive clusters of tiny white flowers
red	N	FAC	FAC	Edible leaves; red flowers attract bees/ hummingbirds
green	N	FAC	FAC	Fixes nitrogen; should not be used in nitrogen sensitive watersheds; evergreen, attracts birds and butterflies
white, green, brown	Y	FACU	FACU	Habitat, flower and fruit similar to white mulberry; yellow fall color
pink	N	FAC	FACU	Used extensively, a good phosphorous uptake plant
yellow	N	OBL	OBL	Aquatic plant, good for deep pools
yellow	N	OBL	OBL	Aquatic plant, can grow in water up to 16" deep
white/yellow	N	OBL	OBL	Aquatic plant, shallow water
green	N	OBL	OBL	Buttressed base, flood tolerant, deciduous, can grow in standing water
white, green, brown	Y	FAC	FAC	Scarlet-red fall color
pink, white	N	NL	NL	Opens flowers in the evening, closing them by early morning; seeds attract birds and mammals
N/A	N	FACW	FACW	Shelters salamanders and frogs; poisonous to livestock; roots shallow
white	N	NL	NL	Small fragrant white flowers; evergreen
N/A	N	FACW	FACW	Clusters of arching fronds; cinnamon colored fertile fronds
N/A	N	OBL	OBL	Tolerates year round shallow water; pinnae resemble locust tree leaves
white, yellow, green, brown	Y	FACU	FACU	Scarlet red autumn color; some food value to birds and small mammals
white	Y	FACU	UPL	Fragrant flowers in spring; yellow/pink/red in fall
white, pink	N	NL	NL	Mottled purple leaves; flowers are white with pink tinge; semi-evergreen groundcover; spreads by slender rhizomes

Genus	specific epithet	Common Name	Sun	Moisture	Height	Bloom Season
Panicum	*virgatum*	switchgrass	F-P	M-D	3-6'	summer/fall
Parthenocissus	*quinqefolia*	Virginia creeper	F-P-S	W-M-D	vine	spring
Passiflora	*incarnata*	passion flower	S-P	M-D	12-36'	spring to fall
Peltandra	*virginica*	arrow arum	P	W	2-3'	spring
Penstemon	*digitalis*	Foxglove Beardtongue	F-P-S	D	3-6'	summer
Persea	*borbonia*	red bay	P	W-M	36-72'	spring
Phacelia	*bipinnatifida*	fernleaf phacelia	P-S	M	1-2'	spring
Philadelphus	*inodorus*	mock orange	F-P	W	10-12'	spring
Phlox	*amoena*	chalice phlox	F-P	M	2-3'	spring
Phlox	*carolina*	Carolina phlox	F-P	M	3-4'	summer to fall
Phlox	*divaricata*	wild blue phlox	P-S	M	12-18"	spring
Phlox	*glaberrima*	smooth phlox	P	W-M	2-4'	spring
Phlox	*paniculata*	garden phlox	F-P	M	2-4'	summer
Phlox	*stolonifera*	creeping phlox	P-S	M	6-10"	spring
Photinia	*melanocarpa*	black chokeberry	F-P	D-W	3-5'	spring
Physostegia	*virginiana*	obedient plant	F-P	W-D	4'	summer to fall
Pinus	*echinata*	short-leaf pine	P	D	50-100'	spring
Pinus	*elliottii*	slash pine	P	M	75-100'	winter
Pinus	*glabra*	spruce pine	P	M	100-120'	spring
Pinus	*palustrus*	long-leaf pine	F	D	80-100'	winter
Pinus	*strobus*	Eastern white pine	F-P-S	M-D	75-100'	spring
Pinus	*taeda*	loblolly pine	P	D	60-110'	spring
Pinus	*virginiana*	Virginia pine	F-P	M-D	15-40'	spring

Flower Color	Fall Color	WIS AGCP	WIS EMP	Comments
green and brown	N	FAC	FAC	Grows in clumps; a loose sod former; spreads by rhizomes; attracts birds and butterflies
white/green	N	FACU	FACU	A woody, dedicuous vine, Virginia Creeper can be high-climbing or trailing.
purple, pink, white	N	NL	NL	Unusual purple showy flowers; vine with tendrils
yellow	N	OBL	OBL	Flowers are spathe and spadix
white	N	FAC	FAC	
pale yellow	N	FACW	FACW	Evergreen with pale yellow flowers; aromatic; fruit eaten by birds
purple, violet, blue	N	NL	NL	Reseeds readily; contact can cause allergic reaction; biennial - blooms mid-spring of second year
white	N	NL	NL	Attracts large numbers of native bees; white flowers are nearly odorless - Philadelphus coronarious (nonnative) has fragrant flowers
pink	N	NL	NL	Clusters of fragrant rose and white flowers, attracts hummingbirds
white, pink, purple	N	FACU	FACU	Thick leaves & showy flower clusters; attracts butterflies and hummingbirds
lavender	N	FACU	FACU	Fragrant lavender-blue flowers Apr-May
pink/purple	N	FACW	FAC	Attracts hummingbirds
pink, magenta, white	N	FACU	FACU	Clusters of magenta, pink lavender, or white flowers Jul-Sep; powdery mildew can be a problem
white, pink, purple, violet	N	NL	NL	White, pink, purple to violet trumpet-shaped flowers in spring; semi-evergreen groundcover; does not like full sun; slugs can be a problem in wet soils
white	Y	FAC	FAC	Dependable showy orange, burgundy & purple fall color
pink, purple	N	FACW	FAC	Long lasting purple flowers with triangular lobes; can be aggressive; colonizes
yellow	N	NL	NL	Evergreen; used for cover and nesting site; seeds attract birds; attracts butterflies
red	N	FACW	FACW	Evergreen; loses its lower branches with age, forming a open, rounded crown.
green	N	FACW	FACW	Evergreen; spruce pine has bark that resembles a spruce tree.
brown	N	FAC	FAC	Evergreen; an 80-100 ft. tree with short, stout, spare branches forming an open, irregular crown.
green	N	FACU	FACU	Evergreen;largest Northeastern conifer and useful for pulpwood, construction, and countless other items.
yellow	N	FAC	FAC	Evergreen; used for cover and nesting site; seeds attract birds; attracts butterflies
yellow	N	NL	NL	Evergreen; seeds attract birds; attracts butterflies

Genus	specific epithet	Common Name	Sun	Moisture	Height	Bloom Season
Platanus	*occidentalis*	sycamore	F-P	M-W	70-90'	spring
Podophyllum	*peltatum*	may apple	P-S	M	1.5'	spring
Polemonium	*reptans*	Jacob's ladder	S	M	1-3'	spring
Polygonatum	*biflorum*	Solomon's seal	P-S	M	2-3'	spring
Polystichum	*acrostichoides*	Christmas fern	P-S	M	12-36"	N/A
Pontederia	*cordata*	pickerel weed	W	M-W	3'	summer
Prunus	*americana*	American plum	F-P	W-D	12-20'	spring
Prunus	*angustifolia*	chickasaw plum	P	D	15-30'	spring
Prunus	*caroliniana*	Carolina laurelcherry	F-P	M	15-36'	spring
Prunus	*serotina*	black cherry	F-S	D	50-80'	spring
Ptelea	*trifoliata*	hoptree	F-S	M	15-20'	spring
Physocarpus	*opulifolius*	ninebark	F-P-S	D-M-W	6-12'	summer
Quercus	*alba*	white oak	F-P	D	60-90'	spring
Quercus	*bicolor*	swamp white oak	P	W-M	80'	spring
Quercus	*coccinea*	scarlet oak	F	M	60-75'	spring
Quercus	*falcata*	Southern red oak	P	D	100'	spring
Quercus	*georgiana*	Georgia oak	S	D	12-36'	spring
Quercus	*hemisphaerica*	darlington oak	F	D	90-120'	spring
Quercus	*laevis*	turkey oak	F	M-D	30-40'	spring
Quercus	*laurifolia*	laurel oak	P	M	36-80'	spring
Quercus	*lyrata*	overcup oak	F-P	W-M-D	30-45'	spring
Quercus	*michauxii*	swamp chestnut oak	P	M	50-100'	spring
Quercus	*nigra*	water oak	P	W-M	50-100'	spring
Quercus	*phellos*	willow oak	P	W-M	100'	spring
Quercus	*prinus*	chestnut oak	P	D	65-145'	spring
Quercus	*rubra*	red oak	F-P	M-D	60-75'	spring

Flower Color	Fall Color	WIS AGCP	WIS EMP	Comments
yellow, green, brown	N	FACW	FACW	leaves drop all summer; white molted bark; attracts birds; shade tree
white, pink	N	FACU	FACU	Only has two leaves and one flower; leaves, roots, and stems toxic if ingested; colonizes by rhizomes
purple	N	FAC	FACU	A smooth, weak-stemmed plant with light blue to purple, bell-shaped flowers.
greenish white	N	FACU	FACU	1/2" bell-shaped greenish-white flowers hang from leaf axils; attracts birds and butterflies
N/A	N	FACU	FACU	Stiff deep green fronds are once-pinnate
blue/purple	N	OBL	OBL	Easy to grow so long as it does not dry out; attracts bees and butterflies, also attracts dragonflies that eat mosquitp larvae.
white	Y	UPL	FACU	White fragrant flowers in spring; 1" red/yellow fruit in summer; red to yellow fall color
white	Y	NL	NL	Pale yellow fall color; edible fruit; attracts birds and butterflies
white	N	FACU	FACU	Evergreen; attracts native bees; berries attract birds
white	Y	FACU	FACU	Messy tree; small edible berries in summmer attract birds; yellow fall color
white	Y	FACU	FAC	Small, white fragrant flowers; yellow/green fall color; larval host for swallowtails
white/pink	Y	FAC	FACW	Has been used as a live stake, yellow fall color
red, yellow, green, brown	Y	FACU	FACU	Brown/red/ bright red fall color; grows rapidly; attracts birds and butterflies
red, yellow, green	Y	FACW	FACW	Attracts birds and small mammals; yellow fall color
yellow	Y	NL	NL	A beautiful oak best known for its brilliant autumn color.
yellow	Y	FACU	FACU	Reddish brown fall color; used for cover and as a nesting site; attracts birds and moths
green	Y	NL	NL	This species is a conservation concern and is officially listed as threatened.
green	N	FACU	FACU	A short-lived pyramidal-rounded evergreen.
yellow	Y	NL	NL	Leaves resemble a turkey foot; brightly colored Fall foliage.
yellow	N	FACW	FACW	Semi-evergreen; can be short lived
yellow	N	OBL	OBL	Attracts waterfowl
yellow	Y	FACW	FACW	Yellow to red fall color; attracts birds and butterflies
yellow	Y	FAC	FAC	Yellow fall color; attracts moths, birds, and small mammals
yellow	Y	FACW	FAC	Attracts moths and birds; yellow or russet fall color
yellow	Y	UPL	UPL	A medium to large tree with chestnut-like foliage.
yellow, green, brown	Y	FACU	FACU	Russett red to bright red fall color; grows rapidly; attracts birds and small mammals

Genus	specific epithet	Common Name	Sun	Moisture	Height	Bloom Season
Quercus	*shumardi*	shumard oak	F-P	M-D	50-90'	spring
Quercus	*stellata*	post oak	F-P	D	40-50'	spring
Quercus	*virginiana*	live oak	F-P	M-D	40-80'	spring
Rhapidophyllum	*hystrix*	blue palmetto	F-P	W-M	3-6'	spring/summer
Rhododendron	*alabamense*	Alabama azalea	S	M	5-6'	spring
Rhododendron	*arborescens*	smooth azalea	P	M	8-12'	summer
Rhododendron	*austrinum*	Florida flame azalea	P	D	6-12'	spring
Rhododendron	*calendulaceum*	flame azalea	P-S	M	4-8'	spring
Rhododendron	*canescens*	piedmont azalea	P	D	6-12'	spring
Rhododendron	*catawbiense*	mountain rosebay	F-S	M	6-10'	spring
Rhododendron	*periclymenoides*	pinxter azalea	P-S	M	6-10'	spring
Rhododendron	*maximum*	rosebay rhododendron	P-S	M-W	15-40'	summer
Rhododendron	*viscosum*	swamp azalea	P	D	12'	summer
Rhus	*copallinum*	winged sumac	F	D	20-35'	summer
Rhus	*glabra*	smooth sumac	F-P	M-D	9-15'	summer
Robinia	*pseudoacacia*	honey-locust	F	M-D	30-50'	spring
Rosa	*carolina*	Carolina rose	F-P	W-D	3-4'	summer
Rosa	*palustris*	swamp rose	F-P	M-W	4-6'	summer
Rudbeckia	*fulgida*	orange coneflower	F-P	M	3'	summer to fall
Rudbeckia	*hirta*	black-eyed susan	F-P	M-D	2-3'	summer/fall
Ruellia	*caroliniensis*	Carolina wild petunia	P	M	2-3'	summer
Ruellia	*humilis*	fringe leaf wild petunia	F-P	D	1-2'	summer

Flower Color	Fall Color	WIS AGCP	WIS EMP	Comments
white/green	Y	FAC	FAC	Scarlet red fall color; used for cover and as a nesting site; fruits attract birds
yellow, brown	Y	UPL	UPL	Variable fall color; non-showy to golden-brown
yellow	N	FACU	FACU	Evergreen; frequently seen growing with spanish moss in the South; birds and squirrels use this tree for cover
white	N	FACW	FACW	Needle palm is an armed shrub, rarely more than 6 ft. tall, with erect or spreading stems from a short trunk.
white/yellow	N	NL	NL	Decidiuous, flowers before leaves emerge, flowers lemon scented
white	Y	FACW	FAC	Large white flowers, it is the last of the azaleas to bloom in the spring.
orange/yellow/ red	N	FAC	FAC	Beautiful orange, yellow, and red flowers.
yellow, orange, scarlet	N	NL	NL	Yellow, orange, scarlet flowers in late spring
white/pink	N	FACW	FACW	A showy shrub growing up to 8 feet tall.
lilac-purple	N	FACU	FACU	5-6" umbel of lilac-purple to pale pink flowers mid-spring; special value to honey bees; evergreen
pink	N	FAC	FAC	Variable flower color - often pink flowers before leaves emerge; special value to honey bees
white to deep pink	N	FAC	FAC	Huge clusters of white to deep pink flowers with yellow spots; evergreen; should not be ingested by humand or animals
white to pink	N	OBL	FACW	Special value to honey bees
yellow, green	Y	UPL	FACU	Yellowish-green flowers are succeeded by drooping, pubescent, pyramidal fruit clusters
white, green, yellow, brown	Y	NL	NL	Velvety red fruit on female plants that persist into winter; special value to native bees; also attracts parasitic insects that prey on insect pests
white	N	UPL	FACU	Attracts large numbers of native bees and honey bees; attracts butterflies, birds, and hummingbirds
pink	Y	FACU	FACU	Yellow, orange, red fall color; pink flowers May-July; does not have thorns
pink	N	OBL	OBL	Fragrant flowers in summer, red hips in fall; attracts birds
yellow	N	FAC	FAC	Attracts birds; will colonize by offsets and reseeding
yellow	Y	FACU	FACU	2-4" flower heads with 10-20 bright yellow petals summer/fall; annual or short lived perennial; attracts nectar bees and butterflies; attracts birds
purple	N	FACU	FACU	Usually only one or two of the light purple flowers are open per day.
purple	N	FACU	FACU	Its showy flowers are petunia shaped and vary in color from lavender to purple.

Genus	specific epithet	Common Name	Sun	Moisture	Height	Bloom Season
Sabal	*minor*	dwarf palmetto	F-P-S	M-D	5-10'	summer
Sagittaria	*lancifolia*	lance leaf arrowhead	F	W	3'	summer
Sagittaria	*latifolia*	duck-potato	F-P	W	1-3'	summer
Salvia	*coccinea*	Texas sage	F-P	M-D	1-3'	spring/ summer/fall
Salix	*sericea*	silky willow	F-S	W-M	12'	spring
Sambucus	*canadensis*	elderberry	F-S	M-W	5-12'	summer
Sambucus	*nigra*	elderberry	P	W	10-20'	spring to summer
Sanguinaria	*canadensis*	bloodroot	S	M	6-10"	spring
Sassafras	*albidum*	common sassafras	F-P	D-M	30-60'	spring
Saururus	*cernuus*	lizard's tail	P-S	M-W	4'	spring/summer
Schizachrium	*scoparium*	little bluestem	F-P	D	3'	summer to fall
Schoenoplectus	*americanus*	three square	F-P	M	3-6'	spring to summer
Schoenoplectus	*tabernaemontani*	sofstem bulrush	F	W	3-6'	spring
Scirpus	*cyperinus*	woolgrass	F	W	3-6'	summer
Sedum	*pulchellum*	rock stonecrop	F	W	0-1'	spring
Sedum	*ternatum*	wild stonecrop	P	M	4-8"	spring
Serenoa	*repens*	saw palmetto	P	M	10-12'	summer
Sideroxylon	*lycioides*	buckthron bumelia	P	W-M	20'	summer
Silene	*virginica*	fire pink	F-P	M	10-20"	spring/summer
Sisyrinchium	*angustifolium*	narrow blue eyed grass	F-P	W-M	1.5'	spring/summer
Sisyrinchium	*mucronatum*	blue-eyed grass	F-P	M-D	1'	summer
Smilax	*smallii*	jackson vine	F-P	M	8'	spring
Solidago	*altissima*	goldenrod	F-S	M	2-4'	fall
Solidago	*rugosa*	winkle-leaf goldenrod	F	M-D	2-5'	fall
Sorghastrum	*nutans*	indiangrass	F-P-S	M-D	3-8'	summer

Flower Color	Fall Color	WIS AGCP	WIS EMP	Comments
white	N	FACW	FACW	Fruit attracts birds and mammals; used for cover
white	N	OBL	OBL	A tuber that produces rhizomes;
white	N	OBL	OBL	Colonizing; starchy tubers used by ducks and muskrats
red	N	NL	NL	Several whorls of red flowers form an interrupted spike on a square stem.
green, yellow	N	OBL	OBL	Provides good wildlife habitat; used for live stakes
white	N	FACW	FACW	Showy white flowers in July, edible fruit in Sept; commonly used for live stakes
white	N	FACW	FACU	Produces berries that are used in preserves and pies but should never be eaten when fresh and raw.
white	N	UPL	UPL	2" white flowers with yellow centers; roots have red sap; rhizomes toxic and may be fatal if ingested
yellow	Y	FACU	FACU	Yellow flowers (Apr); clear yellow/orange/pink/ scarlet fall color; fruit attracts birds
white	N	OBL	OBL	Prefers up to 4" flooding; colonizing
white	Y	FACU	FACU	clump forming perennial grass with great striking red fall color that remains almost all winter
yellow, brown	N	OBL	OBL	Native to coastal AL but will perform throughout the state; the rhizomes, are a food source of muskrat, nutria, and other animals
red	N	OBL	OBL	Native to central AL
green and brown	N	OBL	FACW	Seeds eaten by waterfowl. Roots eaten by muskrats and geese. Provides cover for nesting birds; colonizing
white/pink	N	UPL	FACU	
white	N	NL	FACU	Rock loving perennial
white	N	FACU	FACU	Small, white, fragrant flowers occur on plume-like branched stalks from leaf axils.
white	N	FAC	FACW	Spiny shrub or small tree with open crown
pink	N	NL	NL	Deep red-pink flowers attract hummingbirds and butterflies; short lived perennial
blue	N	FACW	FACW	Leaves of this perennial form dense, tufted clumps which steadily grow with new foliage during the season.
blue/purple	N	FACW	FAC	Rich blue/purple flowers with yellow centers May-Jul; a member of the Iris family
yellow/green	N	FACU	FACU	Thornless; attracts birds
yellow	N	FACU	FACU	Attracts butterflies and birds
yellow	N	FAC	FAC	Tiny flowers look like strings of yellow beads Aug-Oct
yellow	Y	FACU	FACU	Deep orange to purple fall color; tolerates seasonal inundation

Genus	specific epithet	Common Name	Sun	Moisture	Height	Bloom Season
Sparganium	*americanum*	bur-reed	S-P	W	2.5'	summer
Spigelia	*marilandica*	indian pink	P	D	1-2'	spring
Staphylea	*trifolia*	American bladdernut	S	M	8-15'	spring
Stewartia	*malacodendron*	silky camellia	S	M	10'	spring
Stewartia	*ovata*	mountain camelia	S	M	12-20'	summer
Stokesia	*laevis*	stoke's aster	F	M	12-30"	summer
Stylophorum	*diphyllum*	celadine	S	M	12-14"	spring
Styrax	*americanus*	snowbell	F-P	W-M	8-15'	spring/summer
Styrax	*grandifolius*	bigleaf snowbell	P	M	20'	spring
Symphoricarpus	*orbiculatus*	coral berry	F-S	M	2-5'	spring/summer
Symphyotrichum	*patens*	late purple aster	F-P	M-D	1-3'	summer
Symplocos	*tinctoria*	horsesugar	P	W	36-72'	spring
Taxodium	*distichum*	bald cypress	F-P	W	50-75'	spring
Thelypteris	*kunthii*	Kunth's maiden fern	P-S	M	3'	N/A
Thelypteris	*noveboracensis*	New York fern	P-S	M-D	1-2'	N/A
Thermopsis	*villosa*	bush pea	S	M	3-5'	spring/summer
Tiarella	*cordifolia*	foamflower	P-S	M	6-12"	spring
Tilia	*americana*	American linden	F-S	M	60-80'	spring/summer
Tradescantia	*virginiana*	Virginia spiderwort	F-P-S	D-M	3'	spring/summer
Trillium	*grandiflorum*	white trillium	P-S	M	8-16"	spring/summer
Tsuga	*canadensis*	Canadian hemlock	F-S	M	40-60'	spring
Ulmus	*alata*	winged elm	PS	D	30-40'	spring

Flower Color	Fall Color	WIS AGCP	WIS EMP	Comments
yellow/green	N	OBL	OBL	Seeds used by waterfowl; tolerates flowing water; colonizes by slender underground rhizomes
red/yellow	N	NL	NL	Blooms from the bottom upward and the flowering season can be prolonged by removing the flowers as they wither.
white	N	FAC	FAC	Drooping clusters of cream, bell-shaped flowers and attractive, dark-green, trifoliate leaves.
white	N	NL	NL	Open branched deciduous shrub
white	Y	NL	NL	Large, showy, solitary, white flower with crimped and scalloped edges.
purple	N	FAC	FAC	Showy purple flowers
yellow	N	NL	NL	Known for its large, poppy-like, yellow flowers.
white	N	FACW	OBL	Attracts nectar bees and butterflies; fruit attracts birds
white	N	FACU	FACU	Fragrant white flowers are bell-shaped and hang from the tree in late spring. It needs shade and acid, moist soil.
white/green	N	FACU	FACU	Bell shaped flowers become clusters of large pink berries
violet-blue	N	NL	NL	1 1/2" bright violet-blue flowers with yellow centers, used to be Aster patens
cream/white	N	FAC	FAC	Small, fragrant cream colored flowers.
purple	Y	OBL	OBL	Leaves turn yellow to copper in fall; attracts birds and small mammals; used for cover and nesting site
N/A	Y	FACW	FACW	Arching fronds of this fern are lime to medium-green in color; bronze fall color
N/A	N	NL	NL	Provides shelter for toads
yellow	N	NL	NL	1" yellow flowers crowd long narrow erect clusters spring/sum; needs water during droughty summers
white	N	FAC	FAC	Evergreen groundcover; feathery white flowers Apr-Jun; spreads by underground stems
yellow	N	FACU	FACU	Clusters of creamy yellow fragrant flowers; flowers attract native bees and honey bees; this tree attracts predatory insects that prey on insect pests and supports biological control efforts
blue, purple	N	FAC	FACU	Adaptable to various soil conditions; Juglones tolerant
white	N	NL	NL	A single large, white, long-lasting flower arises above the leaf whorl
yellow	N	FACU	FACU	When grown in sun this evergreen requires consistent watering; attracts showy insects such as butterflies and moths
yellow/green	Y	FACU	FACU	Dull yellow fall color; fast growing shade tree used for cover and as a nesting site; attracts birds, butterflies, and small mammals

Genus	specific epithet	Common Name	Sun	Moisture	Height	Bloom Season
Ulmus	*americana*	American elm	F-P	M	80'	spring
Vaccinium	*arboreum*	farkleberry	PS	D	12-15'	spring/summer
Vaccinium	*corymbosum*	highbush blueberry	F-P	W-D	6-12'	spring/summer
Vaccinium	*darrowii*	evergreen blueberry	P	M	1-3'	spring
Vaccinium	*elliottii*	elliot's huckleberry	F-P	W-M	12'	spring
Vaccinium	*pallidum*	lowbush blueberry	F-P	M-D	12-16"	spring
Vaccinium	*stamineum*	deerberry	F-P	M	10-15'	spring/summer
Vallisneria	*americana*	eelgrass	F-P	W	6-12"	spring to summer
Verbena	*hastata*	swamp verbena	F-P	M	3-5'	summer
Vernonia	*gigantea*	giant ironweed	F-S	M	5-8'	fall
Vernonia	*noveboracensis*	New York ironweed	F	M-W	4-7'	summer
Viburnum	*acerifolium*	maple-leaf viburnum	F-P	M-D	4-6'	spring/summer
Viburnum	*dentatum*	arrowwood	F-P	W-M	6-12'	spring
Viburnum	*nudum*	possumhaw	F-S	W-M	6-8'	summer
Virburnum	*obovatum*	small-leaf arrow wood	P	M	12-18'	spring
Viburnum	*prunifolium*	smooth blackhaw	P	M	12-15'	spring
Viburnum	*rufidulum*	blackhaw viburnum	F-S	D-M	10-15'	spring
Viola	*egglestonii*	glade violet	P-S	D-M	6"	spring
Viola	*papilionacea*	common blue violet	PS	W	4"	spring
Viola	*pedata*	bird-foot violet	F-S	D	4-10"	spring to summer
Viola	*sororia*	blue violet	S-P	M	6-10"	spring
Vitis	*rotundifolia*	muscadine	F-P	M	90'	summer

Flower Color	Fall Color	WIS AGCP	WIS EMP	Comments
red, green	N	FAC	FACW	Was once a common tree, but has been largely eradicated due to Dutch Elm disease
white	Y	FACU	FACU	Red fall color; fruit attracts birds and mammals
white to pink	Y	FACW	FACW	Excellent fall colo that is red, orange, yellow, and sometimes purple; fruit readily eaten by humans & wildlife
pink to white	N	FACU	NL	Small, blue-green leaves with a whitish bloom and pink to white, urn-shaped flowers.
pink	N	FACW	FACW	Flowers appread before the leaves and are bell-shaped; blue black fruit; best in full sun
white/pink	N	NL	NL	Sets some fruit even in shade; has white/pink flowers; fruit attracts birds
white	N	FACU	FACU	Twisted trunks; bell-shaped flowers; sweet, spicy tasting fruit; birds and mammals eat berries
green	N	OBL	OBL	grow from stoloniferous clumps submerged under water. In shallow water, leaves may reach and float on the surface; important food source for turtles
purple	N	FAC	FACW	Used by native bees; reseeds
purple	N	FAC	FAC	Attracts bees
red, purple	N	FACW	FACW	Intense reddish-purple thistle-like heads; flowers attract butterflies and seeds attract birds
white	Y	FACU	UPL	Pie-shaped clusters of creamy-white flowers; beautiful fall color; attracts birds and butterflies
white	Y	FAC	FAC	Creamy-white blooms in spring; yellow to red fall color; attracts many different birds; butterfluy attractant
white	Y	FACW	OBL	Showy clusters of white flowers in May and June; berries turn pink to blue to black; attracts birds and small mammals
white	N	FACW	FACW	White flowers appear while the leaves develop and are followed by red fruits
white	Y	FACU	FACU	Fruit is consumed by songbirds, gamebirds, and mammals and can be made into preserves.
white	Y	UPL	UPL	Showy clusters of wht. flowers that leap out from foliage; attarcts nectar insects, butterflies, and bees
purple, violet, blue	N	NL	NL	
purple	N	NL	NL	
blue, purple	N	FACU	FACU	Clumping; reproduces by seeds unlike other violets that reproduce vegetatively
white, blue, purple, pink	N	FAC	FAC	Attracts birds; leaves and flowers edible; leaves high in vitamins A and C
yellow	N	FAC	FAC	Flowers in June; bark is not exfoliating; purple, black, or bronze berries ripen in Sept or Oct.

Genus	specific epithet	Common Name	Sun	Moisture	Height	Bloom Season
Wisteria	*frutescens*	American-wisteria	F-S	M	25-30'	spring
Woodwardia	*areolata*	chain fern	P-S	M-W	1-2'	N/A
Xanthorhiza	*simplicissima*	yellow-root	F-S	M	2-3'	spring
Yucca	*aloifolia*	aloe yucca	F	D	6-12'	summer
Yucca	*filamentosa*	Adam's needle yucca	F	M-D	2-3'	spring to summer
Zephyranthes	*atamasca*	atamasca lily	P	W-M	8-15"	spring

Sun Exposure: F=Full Sun, P=Part Sun, S=Shade

Soil Moisture: W=Wet, M=Moderate, D=Dry

Wetland Indicator Stats (WIS): OBL=Ogligate, FAC=Facultative, FACU=Facultative Upland, UPL=Upland

NI=No Indicator, insufficient information available to determine indicator status, NL=Not Listed

Flower Color	Fall Color	WIS AGCP	WIS EMP	Comments
white, pink to purple	N	FACW	FACW	Deciduous vine; flowers appear after plant has leafed out unlike nonnative wisterias; less aggressive compared to nonnatives; attracts butterflies
N/A	N	OBL	FACW	Provides cover for frogs, toads, and newts
purple	N	FACW	FACW	Bright green celery-like folliage; racemes of purple flowers
white	N	UPL	FACU	The evergreen leaves are thick and stiff and up to 2 ft. long, with tiny, sharp serrations
white	N	NL	NL	Flower stalk can be as high as 6'; attracts butterflies and moths
white	N	FACW	FACW	Colony forming; will bloom best with 1 to 2 hours of direct sun or 3 or more hours of dappled light; tolerant of seasonal flooding

References

Alpert, P., E. Bone, C. Holzapfel. 2000. Invasiveness, invisibility, and the role of environmental stress in the spread of non-native plants. Perspectives in Plant Ecology, Evolution, and Systematics. Vol 3: 52-56.

Bailey, D.A. and M.A. Powell. 1999. Installation and Maintenance of Landscape Bedding Plants. www.ces.ncsu.edu/depts/hort/hil/hil-555.html.

Bogash, S.M. and Lana Adams (ed.). 2002. Handling and Planting “Bare Root” Plants. Penn State Cooperative Extension.

Brown, P. 2000. Basics of Evaporation and Evapotranspiration. University of Arizona Cooperative Extension. Turf Irrigation Management Series. AZ1194.

Brown, R. and W.F. Hunt. 2009. Improving Exfiltration from BMPs: Research and Recommendations. North Carolina Cooperative Extension System. Urban Waterways.

Chen, Y., R.P. Bracy, A.D. Owings, and D.J. Merhaut. 2009. Nitrogen and Phosphorus Removal by Ornamental and Wetland Plants in a Greenhouse Research System. HortScience 44(6): 1704-1711.

Christian, K. J., A. N. Wright, J. L. Sibley, E. F. Brnatley, J. A. Howe. and C. LeBleu. 2012. Effect of Phosphorus Concentration on Growth of Muhlenbergia capillaris in Flooded and Non-Flooded Conditions. Journal of Environmental Horticulture 30(4): 219-222.

Dirr, M.A. 1998. Manual of Wood Landscape Plants. Stipes Publishing L.L.C., Champaign, IL

Drew, M.C. 1997. Anoxia avoidance by selective cell death and aerenchyma formation. Ann. Rev. Plant Mol. Biol. 48:223-250.

Dylewski, K.L., A. N. Wright, K.M. Tilt, and C. LeBleu. 2012. Effect of Previous Flood Exposure on Flood Tolerance and Growth of Three Landscape Shrub Taxa Subjected to Repeated Short-term Flooding. Journal of Environmental Horticulture 30(2): 58-64.

Dylewski, K.L., A. N. Wright, K.M. Tilt, and C. LeBleu. 2011. Effects of Short Interval Cyclic Flooding on Growth and Survival of Three Native Shrubs. HortTechnology 21(4): 461-465.

Enloe, S., N. Loewenstein, and D. Cain. 2013. Cut Stump Herbicide Treatment for Invasive Plants in Pastures, Natural Areas, and Forests. Alabama Cooperative Extension System, Agronomy and Soils Series ANR - 1465.

Enloe, S., N. Loewenstein, W. Kelley, A. Brodbeck. 2013. Basal Bark Herbicide Treatment for Invasive Plants in Pastures, Natural Areas, and Forests. Alabama Cooperative Extension System ANR-1466.

Floridata. Accessed on 5/2/11. www.floridata.com/ref/I/ilex_ver.cfm

Griffin, J.J., T.G. Ranney, and D. M. Pharr. 2004. Heat and Drought Influence on Photosynthesis, Water Relations, and Soluble Carbohydrates of Two Ecotypes of Redbud (Cercis canadensis). J. Amer. Soc. Hort. Sci. 129(4):497-502.

Griffin, A.B.*, A.N. Wright, K.M. Tilt, and D.J. Eakes. 2010. Post-transplant irrigation scheduling for two native deciduous shrub taxa. HortScience 45:1620-1625.

Han, David and Ellen Huckabay. 2008a. Selecting turfgrasses for home lawns. Alabama Cooperative Extension System, ANR-92.

Han, D. and E. Huckabay. 2008b. Bermudagrass Lawns. Alabama Cooperative Extension System, ANR-29.

Harper, C.A. and P. D. Keyser. 2008. Potential Impacts on Wildlife of Switchgrass Grown for Biofuels. University of Tennessee Biofuels Initiative.

Hobbs, R.J. and S.E. Humphrees. 1995. An integrated approach to the ecology and management of plant invasions. Conservation Biology 9: 761-770.

Jernigan. K. J. and A. N. Wright. 2011. Effect of Repeated Short Interval Flooding Events on Root and Shoot Growth of Four Landscape Shrub Taxa. Journal of Environmental Horticulture 29(4): 220-222.

Krüger, G.H.J and L. van Rensburg. 1995. Carbon dioxide fixation: Stomatal and non-stomatal limitation in drought stressed Nicotiana tobacum L. cultivars. In: P. Mathis (ed.). Photosynthesis: From light to biosphere. Vol 4. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Li, M., J. R. Schutt, J. McFalls, E R. Bargenhagen, C. Y. Sung, and L. Wheelock. 2008. Successional Establishment, Mowing Response, and Erosion Control Characteristics of Roadside Vegetation in Texas. Texas Transportation

Institute, College Station, TX.

Madsen, J. D. 2009. Chapter 1: Impact of Invasive Aquatic Plants on Aquatic Biology. In: Biology and Control of Aquatic Plants: A Best Management Practices Handbook (Gettys, L. A., W.T. Haller, and M. Bellaud, eds.). Aquatic Ecosystem Restoration Foundation, Marietta GA.

Mattrick, C. 2006. Managing Invasive Plants: Methods of Control. Conservation Notes from the New England Wild Flower Society. 20-23.

Mitsch, W.J. and J.G. Gosselink. 2007. Wetlands. 4th ed. Wiley, Hoboken, N.J.

Nilsen, E.T and D.M. Orcutt. 1996. Flooding,362-400. In: E.T. Nilsen and D.M. Orcutt (eds.) Physiology of Plants Under Stress. Wiley, Hoboken, N.J.

North Carolina Department of Forestry and Natural Resources. 2008. Riparian and Wetland Tree Planting Pocket Guide for North Carolina. 2nd edition.

Polomski, B. and D. Shaughnessy. 2003. Aerating Lawns. HGIC 1200. Clemson Cooperative Extension. Revised by T. Hale.

Price, J.G.*, A.N. Wright, K.M. Tilt, and R.S. Boyd. 2009. Organic matter application improves posttransplant root growth of three native woody shrubs. HortScience 44:377-383.

Reichard, S.H. and P. White. 2001. Horticulture as a pathway to invasive plant introductions in the United States. BioScience 51: 103-113.

Rosenweig, M.L. 1995. Species diversity in space and time. Cambridge University Press, New York.

Swank, W.T. and D.A. Crossley (eds.). 1987. Forest hydrology and ecology at Coweeta. Ecological Studies: Vol 66. New York: Springer-Verlag.

Tallamy, D. 2010. Alice M. Leahy Lecture Series: Why Native Plant Species are Essential for Supporting Biodiversity. October 19, 2010.

Tallamy, D. 2009. Bringing Nature Home. Timberpress, Portland, OR.

Tourbier, J.T. and R.N. Westmacott. 1981. Water Resources Protection Technology: A Handbook for Measures to Protect Water Resources in Land Development. Washington, D.C. : Urban Land Institute.

United States Department of Agriculture and the Natural Resources Conservation Service. 2006. Plant Guide: Chinese Privet. http://plants.usda.gov/plantguide/pdf/pg_lisi.pdf, Accessed May 30, 2012.

United States Department of Agriculture and Natural Resources Conservation Service. 1996. Guidelines for Establishing Aquatic Plants in Constructed Wetlands. NRCS, Athens, GA.

Unites States Environmental Protection Agency. 1988. Design Manual: Constructed Wetlands and Aquatic Plant Systems for Municipal Wastewater Treatment.

United States Geological Survey. 2012. The Water Cycle: Transpiration. http://ga.water.usgs.gov/edu/watercycletranspiration.html. Accessed May 31, 2012.

University of New Hampshire Cooperative Extension. 2010. Methods for Disposing of Non-Native Invasive Plants. Ed. Karen Bennet.

West, D. H., K. Tilt, D. Williams, and H. Ponder. 2005. Street Trees: Site Selection, Planting, and Maintenance in the Urban Landscape. Alabama Cooperative Extension System. ANR – 0814.

Williamson, M. 1996. Biological Invasions. London: Chapman-Hill.

Wilson, C. 2010. Denver County Extension: Don't Power Rake to Remove Lawn Thatch. Accessed: 5/6/13, http://www.colostate.edu/Depts/CoopExt/4DMG/Lawns/aerate.htm

Wright, A.N., R.D. Wright, J.F. Browder, and B.E. Jackson*. 2007. Effect of backfill composition on post-transplant root growth of Kalmia latifolia. Journal of Environmental Horticulture 25:145-149.

Wright, A.N., S.L. Warren, F.A. Blazich, and U. Blum. 2004. Root and shoot growth periodicity of Kalmia latifolia 'Sarah' and Ilex crenata 'Compacta'. HortScience 39:243-247.

Wright, A.N., S.L. Warren, and F.A. Blazich. 2007. Root-zone temperature influences root grwth of Kalmia latifolia taxa and Ilex crenata 'Compacta'. Journal of Environmental Horticulture 25:73-77.

Yu, S. L., M. A. Kasnick, and M. R. Byrne. 1993. A Level Spreader/Vegetated Buffer Strip System for Urban Stormwater

Management. In Integrated Stormwater Management, ed. R. Field, O'Shea. M. L., and Chin, K., Boca Raton, FL, Lewis Publishers.