

# Sustainable Landscape Systems for Managing Storm Water 2<sup>nd</sup> Edition



Steps for Getting Off  
the Storm Water  
"Grid"



# Authors and Editors



## Authors:

- Dave Dyke: Extension Educator, Commercial Floriculture, The Ohio State University (OSU) Extension, Hamilton County
- Joe Boggs: Extension Educator, Commercial Horticulture, OSU Extension, Hamilton County
- Bill Shuster: Research Hydrologist, National Risk Management Research Laboratory, Office of Research and Development, United States Environmental Protection Agency
- Stephen Foltz: Director of Horticulture, Cincinnati Zoo and Botanical Garden
- Parwinder Grewal: Center for Urban Environment and Economic Development, OARDC Research Internships Program, The Ohio State University
- Kevin Power: Program Coordinator, Urban Landscape Ecology Program, The Ohio State University/Ohio Agricultural Research and Development Center
- Holly Utrata-Halcomb: Administrator, Hamilton County Soil & Water Conservation District & Representative, Hamilton County Storm Water District
- Jeffrey Koehn, Senior Vice President, ME Companies
- Brian J. Bohl: Stream Specialist, Hamilton County Soil & Water Conservation District
- Yang, Hanbae: Ph.D. student, Environmental Science Graduate Program, School of Environment and Natural Resources, The Ohio State University
- George D. Derringer: NRCS, Resource Soil Scientist

## Editors:

- Dave Dyke: Extension Educator, Commercial Floriculture, OSU Extension, Hamilton County
- Joe Boggs: Extension Educator, Commercial Horticulture, OSU Extension, Hamilton County
- Bill Shuster: Research Hydrologist, National Risk Management Research Laboratory, Office of Research and Development, United States Environmental Protection Agency
- Stephen Foltz: Director of Horticulture, Cincinnati Zoo and Botanical Garden
- Holly Utrata-Halcomb: Administrator, Hamilton County Soil & Water Conservation District & Representative, Hamilton County Storm Water District

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# TABLE OF CONTENTS

## Introduction – Page 2

- Overview of the purpose, need, and design of rain gardens and other green storm water management systems in the Metropolitan Sewer District of Greater Cincinnati (MSDGC) service area – p. 2

## Chapter A – Site Selection and Soils: Page 4

- Site selection checklist – p. 6
- Design features of a typical rain garden – p. 8
- The importance of soils in determining infiltration rates in rain garden design – p. 9
- Soil surveys – which soil type(s) do you have? – p. 9
- Determining the infiltration rate of soils used in a rain garden – p. 10
- Determining the area and depth of a rain garden – p. 12
- Rain garden depth – p. 13
- Rain gardens and slopes – p. 13
- Steps for measuring and calculating the slope – p. 13
- Soil texture and amendment – p. 14

## Chapter B – Contour Infiltration Plantings (CIP's) – Page 18

## Chapter C – Rain Garden Design and Construction – Page 22

- Glossary – p. 22
- Designs – p. 24
  - Mixed soil medium design (enhanced infiltration) – p. 24
  - Underdrainage design (enhanced infiltration) – p. 25
  - Saturated zone design without a liner (enhanced infiltration and recharge) – p. 26
  - Underdrainage design with a liner (enhanced infiltration and hot spot) – p. 27
  - Gravel Infiltration Zone with Water Monitoring Pipe (no underdrain) – p. 27
- Building a rain garden – p. 27
  - Drainage – p. 28
  - Soil Amendments – p. 28
  - Underdrains – p. 30
  - 10 steps for building a rain garden's site, soil, and planting bed – p. 31
  - Planting – p. 31

## Chapter D – Rain Garden Maintenance – Page 32

- Soil fertility management – p. 33
- Watering – p. 34
- Mulching – p. 34
- Weed management – p. 34
- Pest and disease management – p. 35

## Chapter E – Plant Selection and Use – Page 38

- Plant selection – p. 38
- Recommended plants for green storm water management controls in Southwest Ohio – p. 40

## Chapter F – Best Management Practices for Turfgrass – Page 44

- Introduction – p. 44
- 5 points for turfgrass success – p. 46
  - Step 1: Assess the soil – do a soil test – p. 46
  - Step 2: Use turfgrass in appropriate locations – p. 48
  - Step 3: Select and appropriate species and quality cultivars – p. 49
  - Step 4: Use appropriate procedures to establish turfgrass – p. 54
  - Step 5: Properly maintain the turfgrass – p. 59

## Chapter G – Regulatory Notes – p. 67

## References – Page 69

## INTRODUCTION

Rain gardens are designed to capture and infiltrate rainwater in the landscape. These gardens are also called "rain water gardens". Rainwater is routed to the garden and filtered naturally by the plants and soils in the garden. This filtration process removes nutrients and pollutants. In its simplest form, a rain garden is a relatively small area of plantings near the drain spout of a building or paved area. However, large highly engineered gardens employing engineered soils and underdrains of varying designs may be required for gardens that receive runoff from a larger impervious area.

While water quality is always important, another primary purpose of installing rain gardens in the MSD service area is to reduce the quantity of rain water entering the combined storm sewer system. The Cincinnati and Hamilton County area is unique in that it was the first in the country to have a sewer system. The system was originally entirely a combined system, but it is now combined only in some areas. In a combined system sewage from toilets, washing machines, etc. and storm water go into the sewer system together. That can be a problem when heavy rain events occur. The system overflows, spreading whatever is in the system into areas where it is neither wanted nor appreciated, such as streams (Mill Creek, Little Miami River, Ohio River). There is another problem with the entire sewage transport system – it is very old with many problems that cannot be easily remedied. Replacing the system would be impractical, costing billions of dollars.

Due to the problems associated with the combined system, the MSD is under a consent decree with the U.S. EPA to mitigate the overflow that goes into our streams. The program established under the consent decree to accomplish this reduction in storm water quantity is the Wet Weather Improvement Program (WWIP). This program will require the establishment and development of "grey" and "green" solutions, including an array of landscape-level storm water management systems and designs that mitigate surface water runoff, such as rain gardens, contour plantings, tree plantings, rain barrels, green roofs, and bio-swales.



Fig. 1: Multiple rain gardens installation  
Photo by Dave Dyke



Fig. 2: Multiple rain gardens installation  
Photo by Joe Boggs



Fig. 3: Residential rain garden  
Photo by Joe Boggs

Some good publications on rain gardens are available, including, "The Blue Thumb Guide to Raingardens, Design and Installation for Homeowners in the Upper Midwest", Schmidt, Shaw, and Dods. Several cities have established substantial rain garden programs. These include Maplewood, MN; Burnsville, MN; and Kansas City, MO. The Wisconsin Department of Natural Resources provides a good rain garden educator's kit [<http://dnr.wi.gov/runoff/rg/kit.htm>]. However, the combination of climate, topography, and soils in the greater Cincinnati metropolitan area differs significantly from other areas for which landscape storm water management manuals have been written. Therefore, the authors concluded that a manual written specifically for Southwest Ohio was required.

All governmental entities, developers, builders, and landscape companies should be cognizant of the Sustainable Sites Initiative (SSI) [<http://www.sustainable-sites.org/report.html>]. The Initiative is an interdisciplinary partnership between the American Society of Landscape Architects, the Lady Bird Johnson Wildflower Center, the United States Botanic Garden and a diverse group of stakeholder organizations to develop guidelines and standards for sustaining landscapes in terms of form, aesthetic value and provision of ecosystem services (e.g., storm water management, wildlife habitat, etc.). The Initiative's purpose is to provide standards for those who want to create sustainable landscapes, much as there are for green building.

The initiative's first report, the "Preliminary Report on the Standards and Guidelines for Sustainable Sites", November 1, 2007, is an interdisciplinary partnership to develop national voluntary standards and guidelines for sustainable land development and management practices as well as metrics to assess site performance and a rating system to recognize achievement. The U.S. Green Building Council, a major stakeholder in the initiative, has committed to incorporating these guidelines and standards into the future evolution of the LEED (Leadership in Energy and Environmental Design) Green Building Rating System.

The SSI describes 2 hydrology goals that directly relate to the goals of the MSD and the content of this publication. The first is - "Value all water on the site. Water should not be treated as a waste product to be captured and quickly conveyed offsite." Of course, the goal of landscapers and developers is often to do just that, remove all water offsite as quickly as possible. This goal will require that landscapers reverse that paradigm and instead endeavor to keep the water onsite.



Fig. 4: Pervious pavers in a parking lot  
Photo by Dave Dyke



Fig. 5: Pervious paver installation to enhance water infiltration  
Photo by Joe Boggs

The second hydrology goal is that a site should be designed to achieve a target water balance. Under target water balance water conditions, the proportion of water inputs to the site (by precipitation, surface flow, and piped-in supply) and outputs from the site (from evapotranspiration, runoff, and water that infiltrates into the soil) have no negative effect - and even create a positive effect - on the environment. A site should identify goals for the post development water balance based on the target conditions and local and or regional issues of concern.

This manual is designed to provide guidance on the design, construction, planting, and maintenance of rain gardens and associated plantings which can impact the runoff of rain water. While the focus of this publication is primarily on rain gardens, the authors would like to emphasize that a holistic approach must be employed in order to efficiently and effectively mitigate rain water runoff. To do so, an array of “grey” and “green” methods must be used. The latter includes rain gardens, turf, rain barrels, green roofs, tree and shrub plantings, contour infiltration plantings (CIPs), bio-swales, and pervious surfaces

Guidance on the construction and employment of rain gardens, turf, and CIPs in rain water mitigation is provided in this publication. However, the authors intend for this publication to be a living document. Additional information on current subjects and additional chapters on using trees and shrubs and other landscape storm water management strategies and designs necessary to implement and conduct a comprehensive holistic rain water mitigation strategy will be added over time.

It should be noted that rain garden science is relatively new. Significant research needs to be done in a variety of areas, especially on plants and how soils native to Hamilton County respond to amendment. Amending soils to provide infiltration rates required for various rain garden situations and yet be conducive to vigorous plant growth is also subject to a lack of consensus by horticulturists and soil scientists.

## CHAPTER A - SITE SELECTION AND SOILS

Every city or plot of land that has undergone development has at least one impervious area, which may be an asphalt road, sidewalk, or any other surface that does not allow water to soak in. When rain falls on an impervious area, almost all of the water will run off.

There are two kinds of impervious areas, connected and disconnected. A connected impervious area collects runoff and routes it to a stream, wastewater treatment plant, or to grey infrastructure where flows might contribute to an undesirable combined sewer overflow. A disconnected impervious area drains to a grassy, wooded, or other pervious area where some of the runoff can soak in.



Fig. A-1: Elevated overflow drain in rain garden  
Photo by Dan Ross, USDA NRCS

We have a perennial runoff problem in Southwest Ohio, as we do not have infinite capacity to direct, nor treat, all this storm water. One option to help to reduce runoff is to add infiltrative surfaces, though this must be done in a structured manner.

A rain garden operates on the principal of infiltration, which is the hydrologic process through which water moves into soil through the pores that separate soil particles. The rain garden is an intentional patch in a landscape that has favorable infiltration and redistribution features. The specific design of, and expectations for, a rain garden depends heavily on the type and condition of native soils. Soils function not only as an appropriate planting medium for rain garden plants, but also the porous media through which water is stored and transmitted.



Fig. A-2: Parking lot curb cut-out, stones to slow water movement, and elevated overflow drain  
Photo by Joe Boggs



Fig. A-3: Residential rain gardens installation to infiltrate water runoff from a street  
Photo by Joe Boggs

Rain gardens have also been built as a landscape feature. A rain garden for storm water management offers plenty of aesthetic benefits. However, there are important design features that require much forethought and planning to get the maximum storm water detention benefit possible.



Fig. A-4: Community rain gardens installation to infiltrate water runoff from streets  
Photo by Joe Boggs



Fig. A-5: Rain gardens using shrubs and incorporating established trees for water uptake and removal  
Photo by Joe Boggs

The primary goal of rain gardens in Hamilton County is to receive excess storm water runoff volume from impervious areas and give it a place to go where it can recharge groundwater and does not enter and overload the storm sewer system and/or cause local flooding or damage to streams and other aquatic ecosystems. Rain gardens should also provide pleasing landscape features, catching water to nourish a variety of plants adapted to a rain garden environment. This approach transforms rainfall runoff into a resource rather than a nuisance. A secondary service provided by rain gardens is the improvement of some aspects of storm water

quality as it is infiltrated and redistributed. The potential for rain gardens to improve aspects of storm water quality will be discussed in a subsequent chapter of this manual.

Rain gardens should: 1) Be relatively easy to build and maintain. 2) Reliably capture runoff water quantity throughout the warm season and also runoff generated from the majority of cold weather thaws. 3) Sustain their performance with few inputs (minimal additions of fertilizer, seasonal pruning, etc.) over the long term.

## Site Selection Checklist

Not all landscapes are given to rain garden installation. It is critical to determine if a setting is appropriate. We provide a checklist to help disqualify areas that are not optimal.

The following restrictions should be considered when siting a rain garden:

- ◆ Prior to excavating for a rain garden in the state of Ohio, you will need to contact the Ohio Utility Protection Service (1-800-362-2764) to first determine if there are any underground lines or utilities in the location where you wish to site the rain garden. If so, you will need to select another location.
- ◆ If there is a private, on-site wastewater treatment system or a leach field for a septic system, then the rain garden shall be located a minimum of 50 feet from any of these wastewater treatment systems AND shall not in any way be hydraulically-connected to these treatment systems so as to avoid cross contamination.
- ◆ Slopes equal to or more than 20% need to be evaluated by a geotechnical engineer prior to incorporating a rain garden on-site. Ideally, rain garden designs on slopes greater than 12% should also be evaluated by a geotechnical engineer. (See **Steps for Measuring and Calculating the Slope**, page 13.)
- ◆ Site is not located on a flood plain or fringe flood areas – you can view flood plain maps at the Hamilton County Soil & Water Conservation District (HCSWCD).
- ◆ Refer to the county soil survey to familiarize yourself with the soil setting in the area and how water can infiltrate in the soils native to the area. You may receive a free copy of the Hamilton County Soil Survey by calling 513-772-7645, or you may view the soil survey online at <http://www.dnr.state.oh.us/soils/surveydata/tabid/9090/Default.aspx>. For other counties, contact the County Soil and Water Conservation District or access the website. This does not replace the importance of conducting at least a simple infiltration test (see sections on soils and infiltration tests below) at the intended site for the rain garden. If limitations for drainage are indicated in the soil survey, then find another spot that has better prospects for drainage, or you will need to install an underdrain.

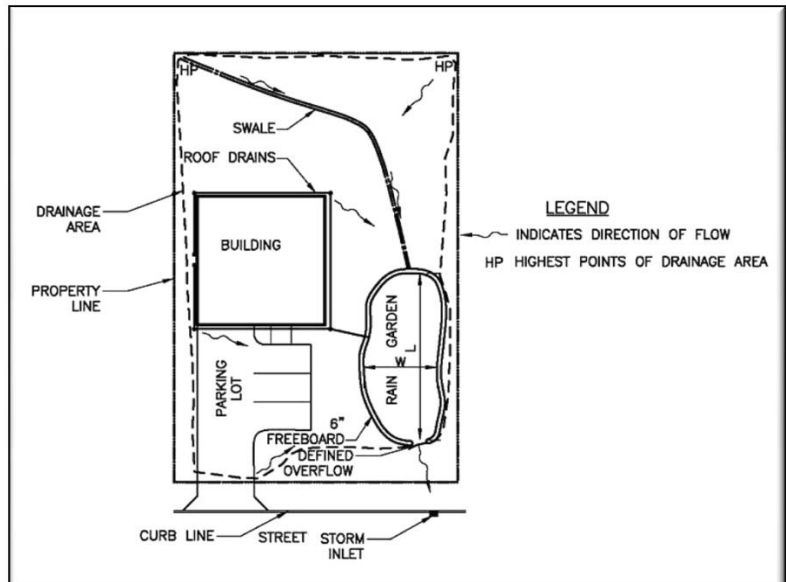


Fig. A-6: Diagram showing the positioning of a rain garden relative to directed drainage  
Graphic Courtesy of Jeffrey Koehn, ME Companies



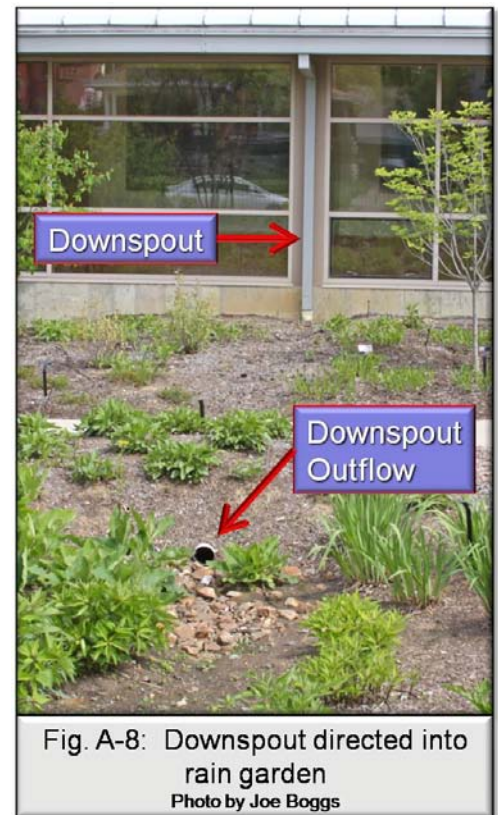
- ◆ No rain gardens are to be implemented in hydric soils. These soils are found in mucky, wetland areas and are typically wet the year around.
- ◆ Determine seasonally high (maximum) groundwater depth through observation, interviews with local residents, or direct measurement – the county soil survey can serve as an excellent guide.
- ◆ No closed hazardous waste remediation or Resource Conservation and Recovery Act (RCRA) sites within 500 feet of site.
- ◆ No endangered species habitat.
- ◆ Site does not fall within a source water protection area.
- ◆ Site should not be located within 100 feet from drinking water wells or waterways.
- ◆ The base of the rain garden should be located 2 – 5 feet above the seasonally high ground water table. This is, particularly important in areas where there are potential pollutants that might find their way into a rain garden. This is usually not a problem for residences.
- ◆ No obvious flooding or erosion impacts to adjacent properties.
- ◆ Rain gardens should be located at least 10 - 15 feet from a home or structure with a basement, and situated in such a way that the rain garden is slightly down slope of the house so that surface or subsurface flow is directed away from the home.
- ◆ Surface infiltration rate in the range of 0.5 to 1 inch per hour prior to amendment or management.
- ◆ Does not impact trees and shrubs. The construction of a rain garden can require a considerable amount of soil disturbance, and the function of a rain garden is to concentrate rain water runoff. Both can have serious negative effects on existing trees and shrubs. Rain gardens should not be located near existing mature trees and shrubs, unless these plants are tolerant of wet conditions and root disturbances. Note that tree roots often extend to 3 times the diameter of its canopy.



The following are considered “optimizers” to help you select the site that will be most environmentally effective:

- ◆ Locate the rain garden so as to take runoff from impervious surfaces, rain barrel overflow, or sheet flow from lawn areas. Oftentimes the roof downspouts or sheet runoff from lawns are routed into storm sewers. One objective of rain gardens is to disconnect a source of runoff from the storm sewer system. Extended downspouts, bio-swales, and contour infiltration plantings can be used to route and spread runoff into the rain garden.

- ◆ Drainage area – the rain garden can be located close to the house (not closer than 10 - 15 feet), but only if the rain garden accepts runoff from the roof downspouts or other sources of runoff (Fig. A-8). Otherwise, the area draining to the rain garden will be too small to generate much runoff; in which case the garden should be located down slope in an area that receives more runoff.
- ◆ If none of the aforementioned restrictions are found then target the poorer soils (lower infiltration rate, higher clay content) – if you have several soils types on your property, try to place the rain garden on a soil that has the lesser infiltration rate or capacity. The idea of a rain garden is to improve on a relatively small patch in the landscape. (Rain garden design will be critical here – a bermed rain garden with poor soils may back-up water in the yard more than desired unless an underdrain is installed.) Such an area may be an ideal place to plant low-maintenance moisture-loving trees or shrubs, such as bald cypress.
- ◆ If you live near a stream, try to place the rain garden between your house’s runoff sources to prevent runoff from going into the stream. By soaking up the excess storm water runoff in a rain garden, there is greater potential for that water to move underground and become what is called base flow for the stream. This is the more permanent flow component in a stream flow regime, and it is an important part of sustaining stream life.



After going through this list, you may find that your site is not particularly suitable for a rain garden. Do not despair, because some areas are just not suitable for rain gardens. In this case it is time to start looking at other storm water management measures. These would include; rain barrels or cisterns for detention, green roofs, small retention ponds, contour infiltration plantings, or moving across the landscape to search for more appropriate soil conditions. Consult with the Ohio DNR storm water manual for more insights as to alternative practices (“Rainwater & Land Development Manual” the BMP manual developed by ODNR, Div. of Soil & Water. This manual is the guide used for the Hamilton County Earth Work Regulations). For a copy of the manual, go to <http://www.dnr.state.oh.us/water/rainwater/default/tabid/9186/Default.aspx#Manual>

**Design features of a typical rain garden:** Storm water capture capacity in a rain garden involves surface storage, soil water, and drainpipe storages, each of which is described briefly below:

- ◆ Surface storage – water is stored in the surface concave (depressed) area of the rain garden.
- ◆ Soil water – The structure of the rooting zone and soils surrounding the rain garden is composed of voids and solids. As long as all of the voids are not full of water (i.e., saturated), there is storage capacity in soil for infiltrated water.
- ◆ Drain storage – if the rain garden has an underdrain, the rooting zone will be drained of excess soil water in a shorter time period, and some of this water will be stored in the drain pipe. The drain pipe conveys excess soil water as trickle flow to a day-lighted area that is down slope of the rain garden.
- ◆ The ponding zone (Fig. A-9) provides the greatest amount of surface storage per increment of depth and regulates the amount of runoff that “stays-on” the rain garden, as this is the water that will eventually infiltrate into the garden and redistribute. Increased depth in the ponding zone will also increase the time of draw-down. We therefore recommend no more than a maximum 10” depth at the

deepest point in the convex bowl that characterizes the shape of the rain garden surface (Wisconsin DNR 2004). Keep in mind that this 10" depth is not the total depth of the rain garden – just the depth of the catenary (the curved cross sectional area at the surface of the rain garden - the "bowl") area at the surface that provides temporary storage of storm water runoff.

- ◆ The defined overflow is the specific area of the garden through which water flows out of the garden when the ponding area has been filled. This can be a pipe. If it is a low spot in the berm of the garden, it should be lined with rocks or other surface that resists erosion.
- ◆ The freeboard is the height of the walls of the rain garden above the defined overflow. The freeboard of a rain garden should be 6 inches.
- ◆ The rooting zone provides much storage in soil pore space and thereby accounts for the second most significant gain in “stay-on” runoff storage per unit depth increment. The “stay-on” water is infiltrated into the soil, and then is redistributed throughout the soils that surround it. Guidance from other states often recommends the use of a sand storage area beneath the rooting zone, but that requires a greater total depth (and therefore expense) for the rain garden. Overall, it is possible that the effects of an underdrain and storage zone may provide little net benefit in terms of increased stay-on. Our recent experience with rain gardens set into soils common to the Mt. Airy – Green Twp. area indicate that a storage zone may not be necessary where underdrains (which moderates stay-on volume) are used and the maximum design specification for runoff capacity is not exceeded.



Fig. A-9: Ponding area in a rain garden  
Photo by Dave Dyke

### **The importance of soils in determining infiltration rates in rain garden design.**

The central goal of a rain garden is to move surface water into the soil horizon, where it is then further absorbed and redistributed to shallow groundwater and taken up by plant communities. The texture of a soil dictates in large part the ability of a soil to transmit water. The proportional amounts of sand, silt, and clay (i.e., texture) will determine whether the soil has more large pores (as in sandy soils) or small pores (as in clay soils), and thus predict its ability to transmit water.

The rate at which a soil transmits water is its hydraulic conductivity (or  $K_{sat}$ ), which is also called permeability, infiltration rate, or percolation rate. Clay soils typically have a much lower hydraulic conductivity than a soil that has a larger proportion of sand or silt than clay. Clay creates very small pores, and clay minerals actually expand or grow in size when wetted, so one can imagine that clay content has a profound impact upon how fast water might move through a soil. Recall that the goal of a rain garden is to infiltrate excess storm water runoff off impervious surfaces, turf, and/or other landscape areas. Therefore, rain garden soils often must have a higher hydraulic conductivity than that found in most SW Ohio soils.

### **Soil surveys – which soil type(s) do you have?**

Out of the 99 soil types that we have here in Hamilton County, only *15 percent* of these soils have good infiltration characteristics and are considered optimal as a rain garden sites. That leaves a many soils in the county that are not quite adequate for use in a rain garden and which therefore will require some management. It is also more than likely that we will have to temper our objectives for the soil accordingly to take advantage of its attributes and manage for its limitations.

The state Natural Resource Conservation Service (NRCS) and local SWCD have at various times mapped soils across Hamilton County and published this information in the Hamilton County Soil Survey. This resource helps the user locate and identify soil types in our county. The text version is available from the Hamilton County Soil and Water Conservation District.

The typical county-level soil survey is a great resource that can be used to get general characteristics of soils; however, it has a margin of error of about 1,000 feet. Also, in most developed areas, i.e. subdivisions, the horizons of soil have been impacted and compacted to such a degree that they are often referred to as Urban Land Complexes. Therefore, county-level soil surveys should not be used as the sole source of information to determine predominant soil types in an area.

The Hamilton County Soil survey maps present a coarse estimation (also called Order-2) of soil types, their extent across Hamilton County landscapes, and their general features. In the case of rain garden design, one may use these soil surveys to determine if the site is NOT a good candidate for rain garden installation, yet it cannot be used as a confirmation that the site IS appropriate. Since soils in SW Ohio are highly variable from one location to another, there must always be some degree of on-site soils evaluation prior to rain garden design or installation.



Fig. A-10: Soil compaction during home construction  
Photo by Joe Boggs

For larger-scale installations of rain gardens, a sub-watershed or watershed-level soil re-survey may be cost-effective. The cost for NRCS to perform an Order 1 soil survey for a 1.8 km<sup>2</sup> watershed was about \$12,000 in 2004, which brings this sort of data within the grasp of many municipalities. This updated survey work used the Hamilton County Soil Survey as a basis. A re-survey was made to account for urban development that occurred after the last soil survey; representative soil pits were identified and classified, and infiltration tests were run on these representative soils areas.

The work of Shuster et al. (2007) summarizes the results of a detailed soil survey (more commonly known as an Order 1 survey) conducted in a small urbanized watershed in Cincinnati OH, and compared the extent of different soils with that given in the Hamilton County Soil Survey. They found that for the most part, the soil distributions across the landscapes were consistent with the coarse evaluation. However, they also performed infiltration tests in representative soils to measure  $K_{sat}$  values, and found that these key rain garden design parameters differed greatly from those which were given in the soil survey manual. As a result of these investigations, it was concluded that it is important to measure infiltration rates specifically at the intended location of the rain garden.

### **Determining the infiltration rate of soils used in a rain garden.**

The term infiltration rate is often used interchangeably with percolation rate ("perc" test), water flow, soil hydraulic conductivity, and saturated hydraulic conductivity. This document will refer to infiltration rates as the amount of time that it takes for a certain depth of water to soak into the soil. Infiltration rates are measured at the surface of the native soil, and if possible, the proposed bottom (deepest) elevation of the rain garden. This is because the hydraulic properties of the subsoil are generally the limiting factor for rain garden designs.

With respect to obtaining an understanding of year round infiltration rates, you may want to conduct infiltration tests during seasons when there is a high water table or perched water table, which acts as a

restrictive layer for groundwater recharge. This will provide the greatest insight regarding the effectiveness of rain garden drainage year round. The county soil survey can provide guidance concerning the presence and seasonality of a high or perched water table.

A simplified infiltration test can be performed by excavating a cylindrical hole dug to the proposed depth of the rain garden in dry soil, pouring 3 inches of water into the hole, then allowing it to completely infiltrate (to provide a reference point for measurements, stick a pencil or other object into the side of the hole at the top of the water column when starting). The time required for the initial infiltration should be noted. After the initial 3 inches of water has infiltrated, add another 3 inches of water to the hole. Record the amount of water that infiltrates in 3 hours. This second value is the infiltration rate (determine inches per hour) for soils close to saturation. This process and time period allows sufficient amounts of water to soak in so that the surrounding soil is saturated, and the measurement is what we call an estimate of field-saturated hydraulic conductivity.



Fig. A-11: Measuring water infiltration rate  
Photo by Dave Dyke

For those with more extensive resources or know-how, the ASTM D3385 protocol for double-ring infiltrometry can be followed to ensure consistency in determination of infiltration rates. This is especially important where multiple rain gardens are planned for installation across a given landscape. A geotechnical engineer or other competent professional should be hired to do this work, especially for larger rain garden installations. While double-ring infiltrometry is a good recommendation for the commercial and consulting sector, most private land owners are not going to go to this trouble to determine how fast their soils take in water. The simplified infiltration or percolation test given above is a viable alternative for homeowners interested in devising an appropriate design.

The resulting infiltration rate from the test described above can be used as an objective test to determine if the soil at the site you are considering is usable for a rain garden. When you think about infiltration rate from the rain garden's point of view, consider that the rain garden will be responsible for moving surface water into the soil, and eventually to the surrounding soils. The extent to which the soils at the bottom of a rain garden can move water within a certain amount of time is one of the main limiting factors that govern how it will operate in practice.

If the native soil tends towards saturated conditions, or the infiltration rate is close to zero after three hours, it is best to find another soil type on the property, or failing that, use alternative storm water management practices to mitigate against runoff (rain barrels, green roofs, long bio-swales, contour infiltration plantings, etc.). If you measured an infiltration rate of 0.5" per hour in the soil cylinder that you dug, then the soil has potential for functioning as a rain garden after proper management and construction. Placement of an underdrain beneath the rooting zone composed of sub-par soils can help correct poor drainage in rooting zone soils.



## Determining the area and depth of a rain garden.

The next most critical design parameter is the area of the rain garden. There are many sizing methods used in rain gardens, but most of the most popular methods have focused on larger-scale designs, which are more appropriate for commercial applications. Available area, time, and cost for the rain garden will always be important considerations in sizing decisions. Almost any rain garden that is properly sized against the impervious area will provide some storm water runoff control and treatment. The footprint of the rain garden will mainly depend on:

1. Depth of the rain garden.
2. Type of soil medium used in the garden (water infiltration rate).
3. Size of the drainage area and the volume of the runoff draining into the garden. The rain garden must have enough capacity to handle all of the runoff water that is routed to the garden.
4. Slope.

An optimum ratio between the size of a rain garden and the size of the impervious area (e.g. roofs, driveways, etc.) to be drained is 0.15 – 0.20. In other words, the size of the rain garden should be at least 15% to 20% of the size of the impervious area that drains into the rain garden. Figure A-12 illustrates an example of the calculations for determining the proper size of your rain garden

**Fig. A-12: Calculating the Right Size for a Rain Garden**  
Graphic by Joe Boggs

A house has a total roof area of 50 ft. by 40 ft. The rain garden for this home will receive water from two downspouts. Together, the two downspouts collect about half (50% = 0.5) of all the water that falls onto the roof. How large should the rain garden be for this situation?

**Step 1:** Calculate the drainage area for the water flowing into the rain garden

- a) The total roof area is 50 ft. x 40 ft. = 2,000 sq. ft.
- b) The rain garden will receive water from about half (50% = 0.5) of this area.
- c) Total Drainage Area: 2000 x 0.5 = 1,000 sq. ft.

**Step 2:** Calculate the size of the rain garden based on the size of the drainage area. A rain garden should 15% – 20% the size of the drainage area.

- a) We will use 20% = 0.2
- b) Size of the Rain Garden: 1,000 sq. ft. x 0.2 = 200 sq. ft.

**Note:** A rain garden that is 10 ft. wide and 20 ft. long will cover an area of 200 sq. ft.:  
The area of a rectangle = length x width; 20 ft. x 10 ft. = 200 sq. ft.

You will need to consider a different sizing for different types of landscape designs and land-use types. Rain gardens that primarily drain rooftops, driveways, and "hardscapes" such as concrete patios will need to be larger than rain gardens that primarily drain "greenscapes" such as turfgrass, flower beds, and tree and shrub plantings. An optimum ratio between the size of a rain garden and the size of the greenscape area to be drained is typically 10 to 15%.

The University of Wisconsin offers software for rain garden design. This program is called RECARGA (from the Spanish verb "to recharge"), and has a relatively accessible user's interface and many valuable technical features, including the ability to experiment with actual rainfall data, implement an underdrain in the model, etc. The program along with a user's guide, can be found at:

<http://www.dnr.state.wi.us/Runoff/models/>

The program is limited in some respects. One important limitation is that root zone soils are not freely-selectable. When working with native soils, the RECARGA model can accept a user-selectable infiltration rate, but due to the impact of texture on other functions in the program, the model will not yield good

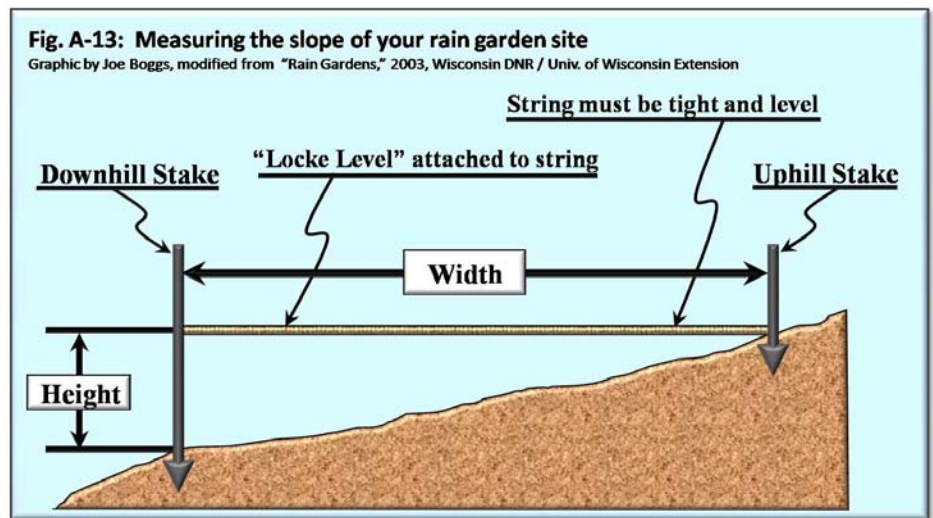
estimates. However, the RECARGA model is useful as a tool to trial different designs and get used to the different impacts that sizing can have on rain garden function and reliability.

**Rain Garden Depth.** In general, your rain garden should be flat in the center and sloped around the inside edges. This modified bowl-shape provides for water ponding above the rooting zone. The maximum ponding depth should be 10", with a rooting zone no shallower than 24" if an underdrain is installed. If an underdrain is not installed, the rooting zone should be no shallower than 12".

**Rain Gardens and Slopes:** The depth of a rain garden depends on the slope of the site and whether or not you intend to install an underdrain. As noted above, where existing or proposed slopes are 20% or steeper, the rain garden site design should be evaluated by a geotechnical engineer. Even a 12% slope may need to be evaluated depending on factors such as the project size and scope. Figure A-13 illustrates an easy and effective way to measure the slope of the site.

**Steps for Measuring and Calculating the Slope:**

1. Drive two stakes, one at the top of the slope (the "uphill stake") and one at the bottom of the slope (the "downhill stake"). The distance between the two stakes should be slightly greater than the planned diameter of your rain garden.
2. Tie a string to the uphill stake at ground level and stretch the string to the downhill stake. Stretch the string tight and tie it to the downhill stake in such a way to allow it to be moved up and down on the downhill stake.
3. Attach a "locke level" to the string and move the string up and down on the downhill stake until the string is level. A locke level is a type of "bubble level" that uses an air bubble floating in a horizontal tube to indicate when the device is level. Locke levels that attach to a string are also referred to as a "string level." An inexpensive string level can be purchased at most hardware stores.
4. Measure the height between ground level at the downhill stake and the point where the level string attaches to the stake.
5. You now have all the information needed to calculate the slope.



**Fig. A-14: Calculating the Slope**  
Graphic by Joe Boggs

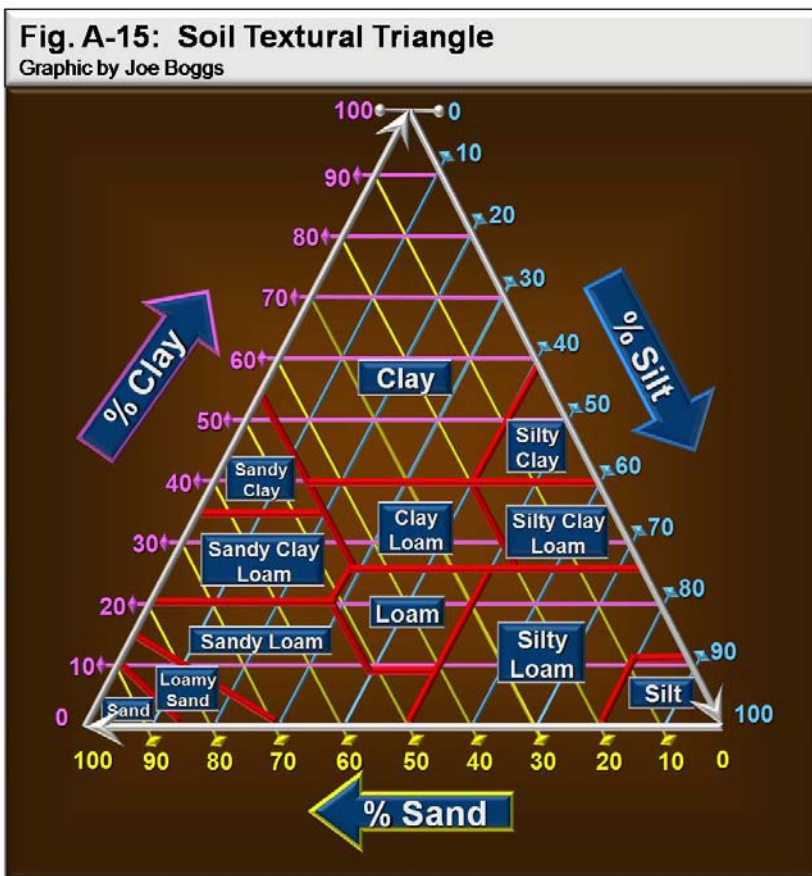
The distance between an "uphill stake" and a "downhill stake" is 20 ft. (240 inches). The height between ground level at the downhill stake and the point where a level string marks the ground level at the uphill stake is 19.5 inches.

<p>The Formula:</p> $\frac{\text{Height}}{\text{Width}} \times 100 = \% \text{ Slope}$	<p>The Math:</p> $\frac{19.5}{240} \times 100 = 8.12 \% \text{ Slope}$
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When you're creating a garden on a slope, you will be digging out soil from the uphill side and adding it to the downhill side as a berm. Of course, the amount of soil that you must dig out on the uphill side, and that you will use to construct the downhill berm, will be directly correlated with the slope. A steeper slope means more digging on the uphill side, and a higher berm on the downhill side, compared to a shallower slope. Remember that the bottom of your rain garden must be level.

### Soil texture and amendment.

Native soils in the SW Ohio area typically have textures ranging from silt-loam to silty-clays. Soils in this area consequently tend toward low infiltration rates, and therefore they can require careful management, which may involve amendment (adding certain soil components such as sand or loam topsoil and organic matter), or in rare and extreme cases, the replacement (where the soil is actually excavated and entirely replaced) of native soils. Research by McCoy (1998) suggests that all soil factors related to its infiltration (and transmission of water) behavior are due to added sand (which was spent foundry sand in this case), and all soil factors related to its retention behavior (CEC and available water) are due to added organic matter (which was muck peat in this case). The paper goes further to say that one needs to add sand so that the final mix is around 65% total sand. In this case, one can approach permeability values of 2-inches per hour, which is a good infiltration rate insofar as rain garden applications.



Herein is the problem: our native soils have only about 20-30 percent sand content. To get the percentage sand up above 50 or 60 percent requires a lot of sand, and also requires the removal of native soil to make room for the new materials. Soil amendment often recalls that old adage “you can’t get there from here”, meaning that this process can often become financially challenging, logistically impossible - or both - to get to an ideal soil mix. Most state, regional, or local rain garden construction guides do not touch on the specifics of soil amendment. This is because conditions vary so much from place to place and soil to soil. There is no golden rule for this process, which means that careful consideration of a number of factors is required.

The addition of sand to influence and increase infiltration rates has been tried in certain Hamilton County rain gardens. The addition of sand to native soils usually does not make much difference until the mass percentage of sand exceeds 50-65%, which calls for a lot of sand and quite a bit of effort to bring up, for example, Hamilton County silty clay loams from their typical 20 percent sand content. Furthermore, to go from 20 to 50% sand by volume for even a plot the size of a rain garden would present the builder with significant material and labor costs (Chalker-Scott 2005).



On the other hand, we do not want a highly sandy soil either, as these do not retain nutrients as well; and may complicate the attainment of water quality objectives that involve keeping storm water in the rain garden for a certain period of time. Since sand has low cation exchange capacity, this material does not hold nutrients. Sands also do not provide nutrients (and rain gardens should ideally require little or no fertilization). Sand storage zones set below the rooting zone soil have been recommended in Wisconsin rain garden guidance, though this approach has not been tested in Hamilton County soils, which tend to be more finely-textured than Wisconsin soils. If we have not convinced you to drop sand additions from your soil amendment plan, then the actual composition of the sand that you will use to add to a rain garden should be considered. Coarse, sharp quartz builder's sand should be used (ASTM C33 Fine Aggregate Coarse sand or USDA coarse sand (that falls into the range of 0.02 – 0.04 in.) and finer sands or mixes with finer sands should be avoided.

For fifty rain gardens installed in western Hamilton County, native silt loam soils were amended with one ton of sand and four bales of dry coarse peat moss. In practice, the addition of these moderate amounts of sand (e.g., one ton) will not increase percent sand over native soils ... never mind increasing percent sand to >50%. However, the median surface infiltration rate for soils amended in this way was measured at close to 2" per hour (from a sample set composed of 47 rain gardens), which is a very acceptable infiltration rate.

The value of the amendment process here is the combined result of excavation (which fluffs the soil and leaves some large voids amongst soil aggregates that can pass or store water), early plant root establishment (which tends to promote soil aggregation and the creation of voids as roots push into the soil), and the addition of sand and organic matter. The jury is still out on whether adding nominal amounts of sand has a positive effect on infiltration and drainage, making this a questionable expense. Therefore, this matter is the subject of ongoing study. At this time we do not recommend the use of sands due to the fact that the process of amendment of native soils with sands is not straightforward.

We will therefore focus on an approach to rain garden design that involves careful excavation and turning of native soils, then amendment of native soils with organic matter (e.g., peat moss, pine bark fines, or compost). This amendment procedure is done to improve the infiltration characteristics of native soils. As we alluded to above on the issue of sand amendments to native soils, regarding replacement of native soils, please understand that it is not always possible to excavate and replace soils with engineered soil mixes. The science of engineered soils is beyond the scope of this guidance. This is because it is an invasive, expensive process and also requires another place to dispose of excavated native soils as fill.

Replacement of soils is generally a "last-resort" approach to be used only when soils cannot be amended to produce the desired infiltration rate. The prospects for building a rain garden under these circumstances should be re-evaluated. However, it has been common experience in this region that soil replacement has often been both necessary and very beneficial. If engineered soils (which are commonly available from landscape and soil businesses) are to be used, the user is cautioned to carefully examine the content of a soil mix, standards for quality control and assurance, and whether cost merits this approach. Although all tilled soils will tend to slump, where soil mixes are used to replace native soils some allowance in your order should be made to replace soil depth lost due to settling of the soil material.

As for amending soils, the key issue is to amend soils when soil moisture conditions are moist to dry. If the soil is too moist, smearing of the soil surface (rain garden wall, bottom) can occur. That creates a new limiting layer, as a smear prevents water from seeping out of the rain garden rooting zone, thus hampering redistribution of the infiltrated runoff. In addition, amendment of clayey soils while wet tends to produce a collection of soil lumps that dry to a concrete-like state. For homeowners, businesses, or companies that have a budget for a full geotechnical assessment with data available on Atterburg limits and plasticity metrics, it is possible to measure soil water content and judge when it is best to excavate and otherwise

manipulate soils. If you do not know what these soil engineering terms mean, do not worry, as these are meant for interpretation by skilled personnel likely involved in larger scale projects in municipal settings.

One approach to amendment is to use a small walk-behind excavator to loosen the soil to 18-24" depth (which requires "double digging" - see "10 Steps for Preparing a Rain Garden's Site, Soil, and Planting Bed", page 31). This is something that would have to be done anyway for rain gardens that are equipped with a drain pipe; since the drain pipe usually sits in a trench or just above the bottom soil layer of the rain garden. Soils often have a limiting layer, which makes the soil less permeable at a shallower depth that one would normally expect. A limiting layer is formed when clay and silt particles are leached through the soil, settling at a point in the soil where it concentrates and through wetting and drying cycles becomes quite hard and impervious to the flow of water. Yet, the limiting layer is often shallow enough that excavation of the rain garden will break-up or otherwise obviate this otherwise restrictive layer.

Rain garden construction provides an opportunity to add organic matter to soils and improve the overall level of tilth and provide an additional source of fertility for these soils. Most SW Ohio soils vary between 2 and 5 percent organic matter content. A beneficial attribute of organic matter content in soil is that it can promote the formation of soil aggregates, which imparts good soil structure and improves infiltration. However, organic matter will not "magically" improve a depleted native soil, nor will moderate or massive additions of organic matter inspire similar and purely magical improvements to better soils.

The question of what to add for organic matter amendment, and in what quantity, is more of an open-ended and conditional question than anyone would want to admit. Therefore, be suspicious of a "one-size fits-all" prescriptive approach. It is important to consider sources of organic matter that are renewable or recycled, such as composted barks or woodchips from local sources. We must not deplete, for example, limited reserves of peat moss for the sake of widespread rain garden construction projects. In such cases, we trade one resource or ecosystem service for another, and the trade is not fair to all involved as peat bogs provide a large number of services insofar as maintenance of water quality.

Coarse fibrous organic matter, such as compost, bark fines (1/2" and less), and coarse sphagnum peat have been found to be very effective in improving the porosity of clay soils. Coarse peat will provide a greater porosity but will also retain water. An alternative is pine fines, which provide porosity, degrade relatively slowly (although not as slowly as peat), and do not retain water. Horticulturalists from Minnesota have tried many amendment combinations in their soils (where native soils can range from sandy to clayey soils) and have come to the conclusion that compost added to native soils has consistently given the best results.

Composts are also valuable sources of boosting soil organic matter by amendment. There are many types of compost available (municipal sludge compost, leaf compost, among a myriad of other types and compositions). Horticulturalists have become used to working with planting mixes that are 50-100% organic matter, and recommendations of a target soil texture have been found that promote this high proportion of organic materials. As with any amendment, however, it is important to consider the status of the native soil, how far one must go to achieve desirable characteristics of that soil, and carefully consider whether the cost and effort is worthwhile. Therefore, the rain garden installer must also know which type of compost is available, its quality, and that its consistency is reliable. Due to the wide range of composts available, there is no comprehensive recommendation that can be made on the



Fig. A-16: Organic matter to be mixed with topsoil in a landscape installation  
Photo by Joe Boggs

proportion of compost (or other types of organic matter) that should be used in a given situation. As far as sourcing quantities of compost in the amounts needed for a residential-sized rain garden, it is often the case that local landscapers import or make their own composts.

After choosing the types and amounts of organic matter, the next step is to incorporate (e.g., roto-till in) these materials. There is usually some preoccupation with overusing a powerful tool such as a roto-tiller by mechanically tilling soil until its structure is fine, powdery, and composed only of very small aggregates. This is not recommended, because when water infiltrates clogging of the already smaller soil pores can readily take place. This is because the smaller aggregates will tend to dissociate into yet smaller particles and ultimately the textural separates of clays and silts will worsen clogging issues. It is best to maintain some degree of soil structure (i.e., larger soil aggregates and clumps), and better yet to err on the side of conserving more large aggregates than might seem prudent. Experience is the best guide here, and tilling up some trial plots or a smaller area of the rain garden for practice may be the best way to gain ultimately satisfactory results.

Once the rooting zone soils have been composed, it is time to manage risk of compaction from excessive trampling or foot traffic on any soil surface. Compaction is defined as a decrease in bulk density, which translates to a soil mass with smaller pores, and therefore a decreased ability to efficiently transmit or infiltrate water. Compaction of the soil surface is often best addressed by the application of approximately 2 inches of mulch to the soil surface.

When working on parcels that are the product of recent development, the likely circumstance is that most of the topsoil has been removed and spread elsewhere, and sod was laid down to create a lawn over the subsoil (B horizon). The B horizon lies directly below the topsoil layer (generally called the A horizon). Clays and other substances wash down into the B horizon, so it is often the case that this soil layer has a smaller infiltration rate due to the tighter structure and increased proportion of clays.

There are two issues to deal with here: low infiltration rate and compaction. A percolation test should be done first to see if the native soil, as it is, has an infiltration rate of 1" per hour. If not, it is advised to look for another location or approach altogether. For compaction issues, loosening the soil by digging or turning it over will help to improve infiltration rates and drainage. We note that there is likely a tillage effect from excavating and mixing soils that will improve (perhaps temporarily) infiltration rates. This is because soils that are carefully excavated and turned over will tend to have a larger number of void spaces among soil particles (what soil scientists call "structural macroporosity"), which promote infiltration and water storage. The downside of this favorable soil structural condition is that it is temporary at best. From a systems perspective, the establishment of plant roots and other soil flora and fauna is of primary importance, as the resulting soil aggregation can promote good infiltration when the larger voids in the soil start to shrink due to natural slumping and compaction because of the overburden weight of the soil itself.

As long as good plant establishment proceeds and roots start to penetrate to and through the lower soil layers in the rain garden, then we might anticipate the following: 1) root penetration will create new conduits for water storage and drainage; 2) rhizomal (near the root) processes will promote good soil structure which is usually accompanied by higher infiltration rates.



# CHAPTER B - CONTOUR INFILTRATION PLANTINGS (CIP's)

## DESCRIPTION AND USES

Contour Infiltration Plantings (CIP) should be considered where slopes and/or limited water infiltration prevent the installation of effective rain gardens. CIP installations actually use the topography of the land to detain and infiltrate rain water runoff by employing berms (raised beds), terraces, and other landscape features that follow the contour of the landscape. Therefore, the hilly and sloping topography in much of the MSD service area often makes CIP installations a very viable option for storm water management, particularly in combination with rain gardens and other landscape rain water runoff management plantings.



Fig. B-1: Contour Infiltration Planting (CIP)

Photo by Dave Dyke

It should be noted that the efficacy of CIP's as a storm water management tool is largely speculative at this time since virtually no research has been conducted in this region on their utilization in that role. However, contour plantings have long been recognized by the agricultural community as a primary means of soil conservation when farming on slopes. They are also used in arid western U. S. areas as a means to capture scarce water for plantings. Jake Schneider's rain garden research at the University of Wisconsin-Madison, in which he found that, "the presence of a berm appears to be the major determining factor behind rain garden effectiveness, regardless of vegetation type", would seem to support the efficacy of using contour plantings for that use.

A quick survey of landscapes in the area will reveal a significant percentage of lawns that slope towards impermeable surfaces such as streets, parking lots, and roads, with little or no landscaping, other than turf, to impede the flow of water directly onto them and then into storm sewers. Most of the landscape plantings in this area that are on slopes are not positioned and/or raised enough to maximize the capture of water. Indeed, the design of many, perhaps the majority, actually results in channeling water around and/or over the installation rather than capturing it for plant use and infiltration. The round or oval design of plantings on slopes also makes mowing them much more difficult than one or several longer plantings that follow the contour.



Fig. B-2: Landscape installation that channels water around the planting area

Photo by Dave Dyke

Like rain gardens and all other plantings, CIP's should be an attractive and integral part of the landscape. Annuals, perennials, trees, and shrubs all can be used. As is the case for all gardens, soil and bed preparation is critical and is essentially the same as for any other type of planting, with the exception that the beds are raised. When a substantial water flow is directed to the bed and/or there is limited subsoil permeability, underdrains, such as those designed for rain gardens, may be installed to maximize their storm water capture capacity.

CIP's, berms, or raised beds, can potentially offer several advantages for areas found inappropriate for rain gardens or when used in place of or in addition to rain gardens as part of a holistic sustainable landscape storm water management strategy.

- ◆ They are normally easier to construct and maintain.
- ◆ They could be efficacious for rain water mitigation for several reasons:
  - They would directly adsorb surface rain water.
  - They would back up water into the uphill turf areas where it could be infiltrated. Research at the University of Wisconsin-Madison, has indicated that, "with its shallow, dense root mass, turf seems to act as a temporary sponge, sopping up rain and then releasing it slowly into the soil" and that "it might therefore be a better choice (than native prairie plants) when groundwater recharge is the goal, although this needs testing." Other researchers have found that un-bermed native mixture treatments produced over two times more runoff than did un-bermed Kentucky bluegrass treatments.
  - The initial surge of rain water would be ameliorated. Surface water that was not infiltrated into the garden area or uphill turf area would eventually work its way through or around the garden and be released downhill in a much more controlled manner after a delay that enabled the first quantities of water to be absorbed into systems. They would have additional advantages over rain gardens in landscapes that cannot accept a rain garden:

◆ A wider array of plant materials and hardscape features can be used. The majority of perennial herbaceous materials, annual plants, and trees and shrubs will grow best in a good, well-drained garden soil. That is just the type of soil that a berm (raised planting bed) should provide. Furthermore, a berm is designed to detain and capture rain water for plant use and infiltration into the subsoil, lessening the need for supplemental water applications if constructed properly and suitable plants adapted to the site are planted.

◆ Berms could also be constructed where it would be difficult or impossible to construct rain gardens, such as in areas with buried utilities.

◆ A very significant additional advantage of berms is that they can be used to direct water to desired areas, such as rain gardens or creeks. They could often be better than using ditches or swales, which are subject to erosion and not as attractive (often appearing unattractive) as a nice flower garden and/or tree or shrub planting.



Fig. B-3: Plant diversity in a landscape planting  
Photo by Dave Dyke



## CIP DESIGN AND CONSTRUCTION

### Laying out bed contour and shape

The upper edge of CIP's should have a slope of 1 – 2% relative to horizontal. That is, the upper edge should drop 1 – 2 feet in elevation for every 100 feet of bed length. [Note that the Soil & Water Conservation Service (SWCS) or Natural Resources Conservation Service (NRCS), which works closely with the SWCS, can lay off the contour lines.] Maintaining that slope throughout the length of the bed is critical. A 1 - 2% slope will allow storm water to gently run along the uphill side of the bed, preventing overtopping and erosion. If a slope is less than 1% water may pond in that area, creating a wet spot above the planting.

The slope can also be used to direct the storm water to desired areas, such as swales or rain gardens. A series of CIP's can be staggered in a “switchback” pattern on a long slope, with the slope of each CIP being the opposite of that above it in order to attain maximum runoff capture and infiltration.

While a variety of methods can be used to establish a base contour line slope for the upper edge of a planting, a laser transit will give the most accurate results. Contour readings should be taken a maximum of every 10 feet, with flags marking the contour line. A curvy, undulating slope may require more frequent readings – a reading should be taken at all changes in the topography.

The beds should be approximately 3 – 5 feet wide and 6 – 12 inches high, depending largely on the slope. Remember that the higher the bed the more quickly it will be to dry out. Therefore, bed heights of 6 – 8 inches (prior to mulching) are usually preferable to higher beds. Contour beds are designed to break up the slope of the landscape, as beds grow wider they begin to lose some of their efficacy as a water infiltrator because the slope of the bed becomes more of a part of the overall landscape slope. Therefore, the ideal bed width should typically be 3 - 4 feet, but may need to be a bit wider if trees or shrubs with large root balls are planted.

### Constructing beds

Once the contour line has been determined for the planting, the garden can be outlined with landscape paint, flags, or other methods. If the area is covered in turfgrass or it is weedy, glyphosate (e.g. Roundup) may be applied at least 1 week prior to tilling the area to kill all existing vegetation.

Till beds to a minimum depth of 8 inches for annuals and perennials. Beds for trees and shrubs with larger root balls must be dug to a depth and width that will allow for proper planting. About 2 – 3 inches of a fibrous organic matter, such as good compost or pine bark fines, should be tilled into the soil. If the native soil in a bed is a very poor “urban complex” or clayey soil, serious consideration should be given to



replacing it with good topsoil. Additional topsoil, amended with approximately 25% - 30%, by volume, of organic matter, should then be added to give the bed the desired height. Settling of the soil subsequent to construction should be considered when determining the initial bed height.



Fig. B-6: CIP tilled to a depth of 8"  
Photo by Dave Dyke



Fig. B-7: Topsoil and amendments added to raise CIP bed to 12" height  
Photo by Dave Dyke

### Planting and mulching.

CIP's should be attractive, low maintenance, landscape feature gardens. A wide variety of annuals, perennials, trees, and shrubs adapted to the site may, and should, be used. Use plants that have demonstrated the ability to do well in the area, as described in Chapter 5. Remember that raised planting beds will tend to dry out relatively quickly. Therefore, it is important that plants that are drought tolerant and/or have deep root systems be used.

Plant all materials as you would in any other garden, water in thoroughly, and mulch with 2 inches of a quality shredded hardwood bark mulch.



Fig. B-8: Mulching CIP with 2" of shredded hardwood mulch  
Photo by Dave Dyke



Fig. B-9: Completed CIP  
Photo by Dave Dyke



Fig. B-10: Water not infiltrated into CIP is routed around picnic area into a rain garden  
Photo by Dave Dyke

## CHAPTER C - RAIN GARDEN DESIGN AND CONSTRUCTION

Rain gardens are designed to reduce the quantity and improve quality of storm water runoff in a natural and aesthetically pleasing manner. Before reading this section, it is assumed that the reader will have read the sections of the manual that pertain to site selection, soil management, rain garden sizing criteria, and plant culture.

### GLOSSARY.

#### Major Components of a Rain Garden.

- ◆ **Flow Entrance.** The flow entrance is an important component of the rain garden. The best way of capturing runoff is to allow the runoff to sheet-flow into the rain garden over grassed areas, which reduce the velocity of the runoff. Accumulated sediment and debris at the flow entrance should be removed if the accumulation obstructs flow into the rain garden itself.
- ◆ **Vegetation.**
  - The major role of plant species in the rain garden is: 1) to uptake nutrients (i.e., N, P) and other pollutants; 2) to enhance the water cycle through evapotranspiration; 3) to increase the infiltration rate by creating water pathways along roots; and 4) to stimulate microbial activity through root development.
  - A diverse mixture of plants is preferred to minimize monoculture susceptibility to urban environmental stresses. Additional potential benefits of a properly designed garden include: Improvement of the site value and aesthetics and wildlife enhancement.
- ◆ **Ponding Area.** The ponding area plays a role as a surface storage of the runoff and provides for evapotranspiration. Ponding design depths are kept to a minimum (a maximum of 10 inches – 6 inches may often be ideal) to minimize any adverse effects on plant growth and to reduce hydraulic overload in the rain garden.



Fig. C-1: Series of residential rain garden installations to infiltrate water runoff from a street

Photo by Joe Boggs



Fig. C-2: Residential rain garden installation to reduce water runoff from a street

Photo by Joe Boggs



Fig. C-3: Plant diversity in rain gardens

Photo by Dave Dyke



- ◆ **Defined Overflow.** The defined overflow is the specific area of the garden through which water flows out of the garden when the ponding area has been filled. This can be a pipe. If it is a low spot in the berm of the garden, it should be lined with rocks or other surface that resists erosion.
- ◆ **Freeboard.** The freeboard is the height of the walls of the rain garden above the defined overflow. The freeboard of a rain garden should be 6 inches.
- ◆ **Mulch Layer.** The mulch layer has several physical and biological functions in the rain garden. The layer acts as a filter for pollutants in the runoff; protects the soil from drying and eroding; moderates the soil temperature (keeping it cool in the summer and protecting plants from severe temperature fluctuations in the winter), helps to control weeds, reduces compaction, and provides an environment for microorganisms to degrade organic pollutants.
- ◆ **Soil Medium.** The soil medium in the rain garden is the zone that provides the water and nutrients for the plants to sustain growth. The rhizosphere (the soil zone that surrounds and is influenced by the roots of plants) in the soil can enhance biological activity, encourage root growth, and increase nutrient uptake and water retention. The microorganisms break down complex organic compounds and transform organic nutrients into usable plant nutrients. Also, clay components in the medium could contribute to adsorbing heavy metals, nutrients, hydrocarbons, and other pollutants in the runoff.
- ◆ **Gravel Diaphragm (optional).** The pea gravel diaphragm is preferred to prevent any clogging in under drain systems. The thickness of the diaphragm should be between 3 to 8 inches to provide enhanced porosity without clogging.
- ◆ **Under drain (or underdrain) (optional).**
  - Under drains are used in rain gardens to increase the ability of the soil to drain quickly and to ensure proper drainage for the plants.
  - Typically, a rain garden located on a private lot will require an under drain system to avoid overflows or other issues when the infiltration rate is low.
  - Under drains typically include a gravel “blanket” encompassing a horizontal, perforated drain pipe. This type of black tile drainage pipe is usually found at hardware stores, and its diameter is typically from 4 to 6 inches.
  - For soils with infiltration rates greater than 1 inch per hour and where water table depths are known to be greater than 2 ft below from the bottom of the proposed rain garden, and if the rain garden does not receive runoff from a large impervious area, then an underdrain is NOT necessary.

### **Control of Storm Water Runoff Quantity.**

- ◆ **Interception:** The collection or capture of runoff on plant foliage or the soil surface.
- ◆ **Infiltration:** The downward movement of water into the soil medium. Percolation denotes the movement of water through a soil.
- ◆ **Evaporation:** Evaporation occurs when sufficient heat is added to water at the soil surface so that it changes from a liquid to a gas and moves into the atmosphere.

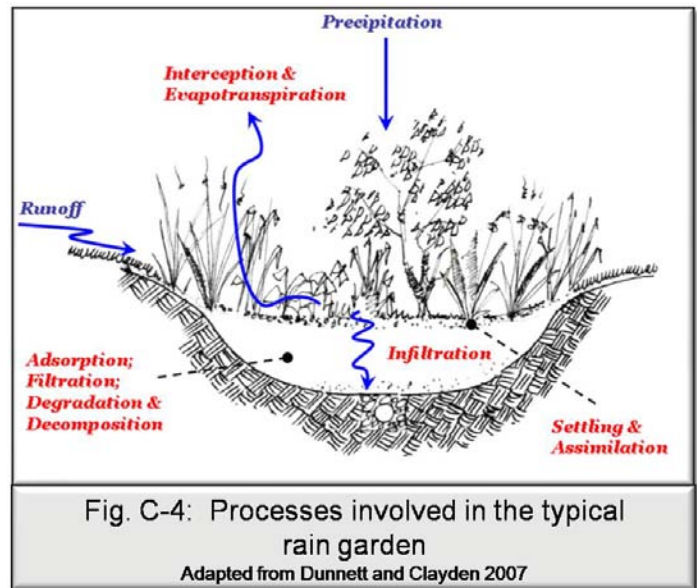
- ◆ **Transpiration:** The movement of water through plant leaves and into the atmosphere.

### Control of Storm Water Runoff Quality

- ◆ **Settling:** When runoff slows and ponds within the rain garden so that suspended solids and particles can settle out.
- ◆ **Filtration:** Soil particles and other debris are retained on the surface of or within the soil medium.
- ◆ **Assimilation:** Nutrients are taken up by plants for their growth.
- ◆ **Adsorption:** The attraction of dissolved substances onto a surface – plant roots, clay soil particles and soil organic matter – can ‘lock up’ contaminants and nutrients by attaching them to their surface.
- ◆ **Degradation & Decomposition:** The breaking down of chemicals and organic matter by soil microorganisms.

Figure C-4 shows the foundational processes that occur in rain gardens to achieve the objectives of quantity control and quality improvement. It should be pointed out that homeowners will look at rain gardens as a way of soaking up excess storm water runoff, with less an emphasis on improving the quality of runoff. There are several reasons for this, though the main reason is that water quality is not a big issue at the scale of a residential parcel. If the case is otherwise, then a rain garden is not the way to deal with the situation.

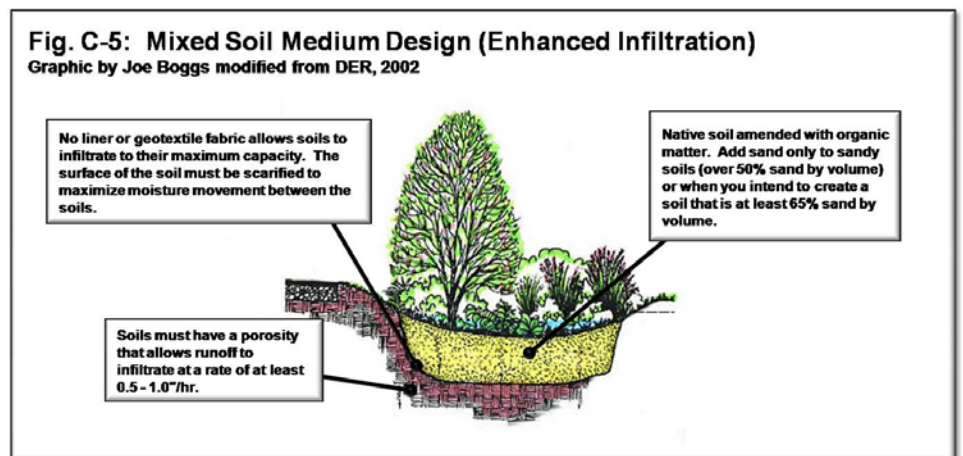
On the other hand, commercial concerns deal with runoff from large impervious areas such as parking lots, and it is probable that metals, oils, and other potential toxins will move with runoff into a commercial-sized rain garden.



## DESIGNS

### Mixed Soil Medium Design (Enhanced Infiltration)

This is the type of rain garden that most homeowners would use as a landscape feature. It is recommended for areas which are expected to generate runoff and where high recharge of groundwater would be beneficial, such as in residential and some commercial landscapes. The soil medium in the rain garden needs to have a



high infiltration rate since there is no underdrain. These gardens should have infiltration rates of 0.5 inches per hour or greater. Since an underdrain is not included in this design, the builder should consider making the growing medium of this type of rain garden deeper (~24") in order to realize greater infiltration capacity.

Figure C-5 shows a rain garden design using a mixed soil medium (DER, 2002). Note that it will often be necessary to amend native Hamilton County soils to achieve reasonable infiltration rates.

### Underdrainage Design (Enhanced Filtration)

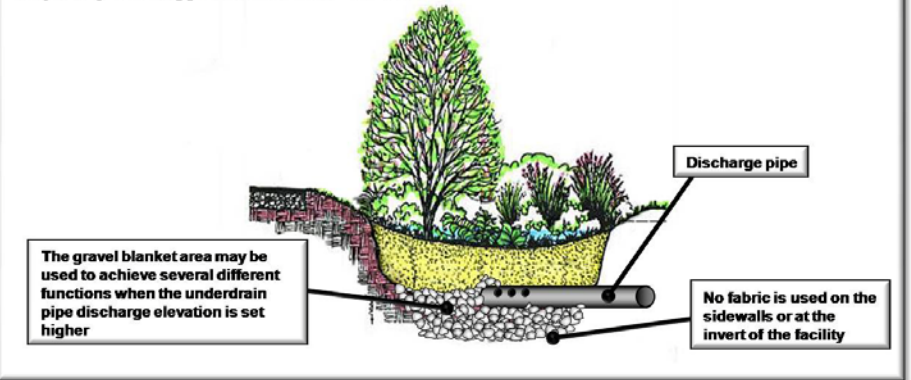
This type of rain garden is designed with an underdrain at the bottom of the planting soil medium to ensure that the rain garden rooting zone drains at a desirable rate. This style is commonly used to receive water from roadway runoff via curb cuts.

When used in that manner it should be sited 5 feet from the roadway and connected to the roadway via a sodded area.

When the rain garden is saturated by a storm, and has not had enough time to redistribute water before another storm comes along, it will produce runoff. Overflow pipes can be installed, which will direct that runoff into storm drains.

**Fig.C-6: Saturated Zone Design Without A Liner (Enhanced Filtration and Recharge)**

Graphic by Joe Boggs modified from DER, 2002



**Fig. C-7: Work Sheet for Calculating the Gravel Depth**

Developed by Jeffrey Koehn

**1. Determine drainage area to the rain garden**

- Roof (a) \_\_\_\_\_ sq. ft.
- Hard Surface (b) \_\_\_\_\_ sq. ft.
- Grass and Vegetation (c) \_\_\_\_\_ sq. ft.
- Total Drainage Area (d) is:  $a + b + c = d$

**2. Calculate Total Run-off for a 1" Rain (g) (1" = 0.083 ft)**

Note: "r" is the "run-off coefficient"

Impervious Area (e): Roof and Hard Surfaces,  $r = 0.9$

$$(a + b) \times 0.9 \times 0.083 \text{ ft} = (e) \text{ cubic feet}$$

Pervious Area (f): Turf and Vegetation,  $r = 0.4$

$$\text{_____}(c) \times 0.4 \times 0.083 \text{ ft} = (f) \text{ cubic feet}$$

$$\text{Total Run-Off (g) is: } \text{_____}(e) + \text{_____}(f) = \text{_____}(g) \text{ cubic ft.}$$

**3. Determine the area of the Rain Garden (h)**

$$\text{Total drainage area } \text{_____}(d) \times 0.15 = \text{_____}(h) \text{ sq. ft}$$

**4. Calculate the Gravel Depth**

$$\text{Depth of Gravel} = \frac{\text{Runoff}}{\text{Area} \times \text{Void Ratio}} = \frac{(g)\text{_____}}{(i)\text{_____} \times (j)\text{_____} \times 0.33} = \text{_____} \text{ ft. (k)}$$

$$\text{Depth of Gravel} = (k)\text{_____} \times 12 = \text{_____} \text{ inches of Gravel}$$

Confirm that depth of gravel is less than 24". If it is not, increase the area of the rain garden



The underdrain provides enhanced drainage of the rooting zone and therefore decreases the amount of time that the rooting zone would be saturated. However, it also decreases the amount of recharge to the surrounding soils. Due to the problems with clogging of the filter fabric recommended in earlier designs, we now recommend that a pea gravel blanket be used around the underdrain pipe instead of filter fabric. Note that the underdrain will need to be installed first, after excavation. The underdrain must be installed so that it slopes away from the rain garden (nominal 1-3% slope) so that water does not back up.

The underdrain pipe is usually a black PVC drainage pipe product, 3-6" in diameter. Depending on the shape of the rain garden, a few sections of underdrain could be tied into a main drain that exits down slope of the rain garden.



Fig. C-8: Curb cut allowing water to flow from a parking lot into a rain garden  
Photo by Joe Boggs



Fig. C-9: Gravel blanket being installed beneath a rain garden  
Photo by Joe Boggs

### Saturated Zone Design without a Liner (Enhanced Filtration and Recharge)

This type of rain garden is designed to have an anaerobic (saturated) zone below the raised underdrain discharge pipe. The saturated zone could convert nitrate ( $\text{NO}_3^-$ ) to nitrogen gas ( $\text{N}_2$ ) by denitrification process. This is recommended for areas where high nutrient loadings are expected. The raised underdrain also provides different functions, which include a storage zone for the runoff and a recharge zone for the groundwater.

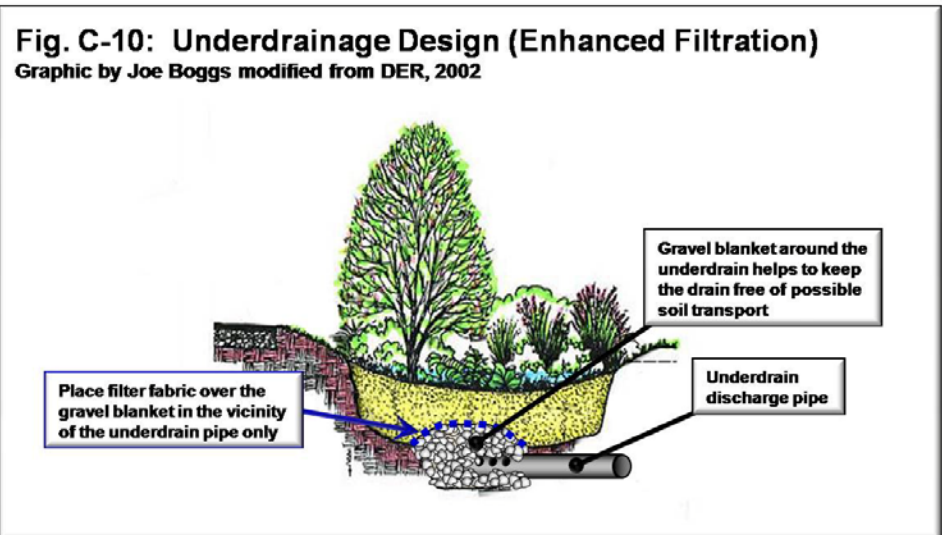
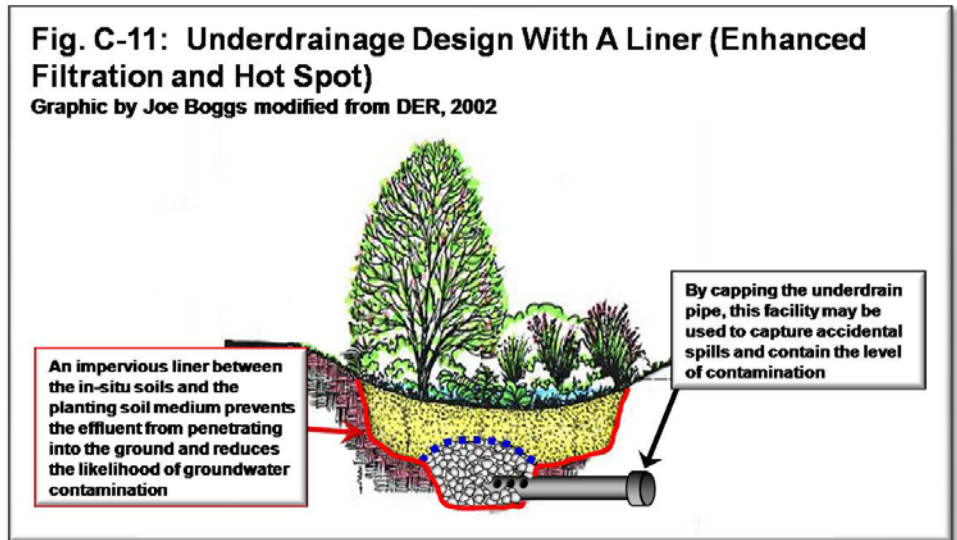


Fig. C-10: Underdrainage Design (Enhanced Filtration)  
Graphic by Joe Boggs modified from DER, 2002



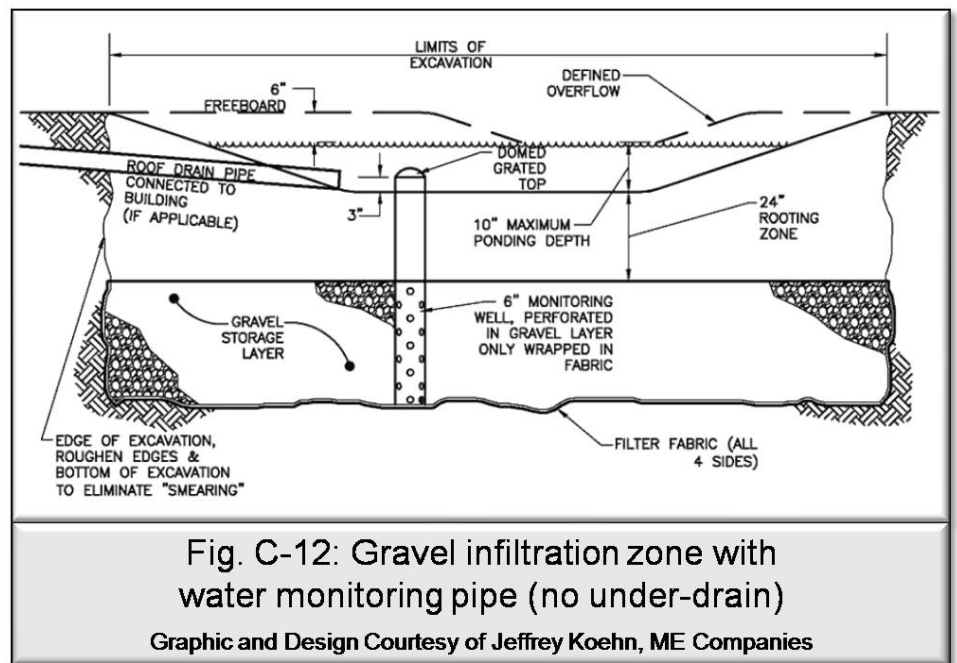
## Underdrainage Design With A Liner (Enhanced Filtration and Hot Spot)

This type of rain garden is designed to prevent groundwater contamination by placing an impervious liner between the in-situ soils and the rain garden medium. This design is recommended for areas that are known as “hot-spots” (i.e., gas stations, transportation depots, and agricultural sites). In the event of an accidental spill, the underdrain can be capped.



## Gravel Infiltration Zone with Water Monitoring Pipe (No Underdrain)

This type of rain garden relies on a gravel infiltration bed to allow water to slowly infiltrate into the soil. The design is similar in principle to a "dry well." A vertical pipe allows monitoring of water infiltration rates. The monitoring pipe is not connected to an underdrain.



## Building a Rain Garden

A rain garden should provide two important functions in the landscaping:

1. All of the water directed into the garden should infiltrate into the soil of your garden within 24 – 40 hours. It should not function as a wetland or water garden! **NOTE:** It is very important that your rain garden drains within 24 – 40 hours in order to avoid problems with biting and nuisance aquatic insects such as mosquitoes and midge flies. A properly functioning rain garden will not contribute to the development of these pestiferous insects.

2. A rain garden should enhance, rather than detract from, your overall landscape design. It should be aesthetically pleasing, support the growth and survival of strong plants, and "fit" into the rest of your landscaping. This function is strongly influenced by plant selection and by plant health management including providing soil conditions that support plant establishment and survival.



Fig. C-13: Soil amendments delivered for use in a rain garden  
Photo by Dave Dyke



Fig. C-14: Adding soil and amendments to a rain garden  
Photo by Bill Shuster, USEPA-RD

**Drainage:** The ability for a rain garden to drain water into the soil can be influenced by the addition of soil amendments and by installing a drainage system (underdrain) beneath it. However, it is strongly recommended that you focus on using soil amendments as your primary method to enhance drainage and only consider using an underdrain as a secondary method that is reserved for solving extreme problems with drainage.

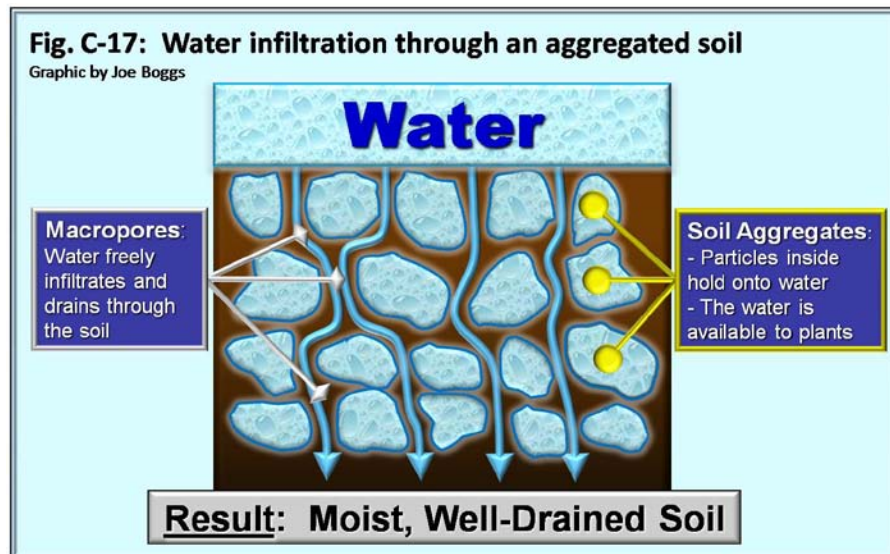
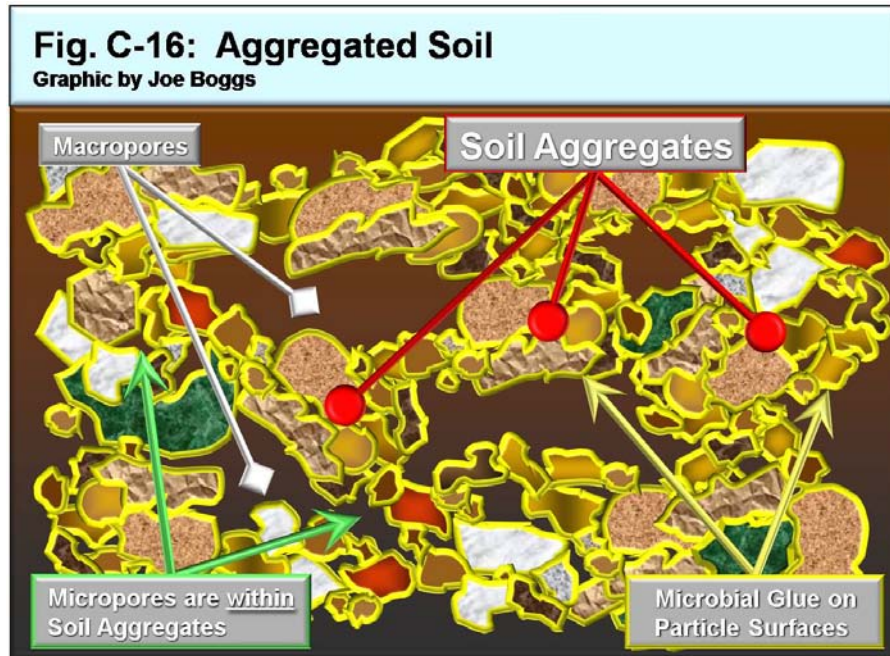
**Soil amendments** are grouped into two general categories: organic (e.g. compost, peat moss, bark fines, etc.), and inorganic (e.g. sand). Organic amendments are preferred for improving drainage because they provide both physical and horticultural benefits. These benefits include:

- ◆ Enhancing water movement and plant root growth by making the soil more porous.
- ◆ Holding some soil moisture to support the continual growth and survival of plants.
- ◆ Releasing nutrients to support plant health and the health of soil micro and macro organisms.
- ◆ Promoting the development of good **soil structure** by supporting the formation of "**soil aggregates**." Soil aggregates are created when soil particles (e.g. sand, silt, clay, organic material, etc.) are held together by sticky substances ("microbial glue") exuded by micro and macro soil organisms (Fig. C-16). The aggregates provide the following benefits:
  - Large pores (macropores) are formed between the aggregates allowing water to more easily flow into and through the soil. Aggregated soil significantly enhances water infiltration.



Fig. C-15. Leveling a rain garden to produce a flat bottom with sloped edges: a modified "bowl-shape"  
Photo by Bill Shuster, USEPA-RD

- The macropores support plant root growth and development by loosening the soil.
- Clay particles within the aggregates will hold onto plant nutrients. The particles will also hold some soil moisture to support plant growth.



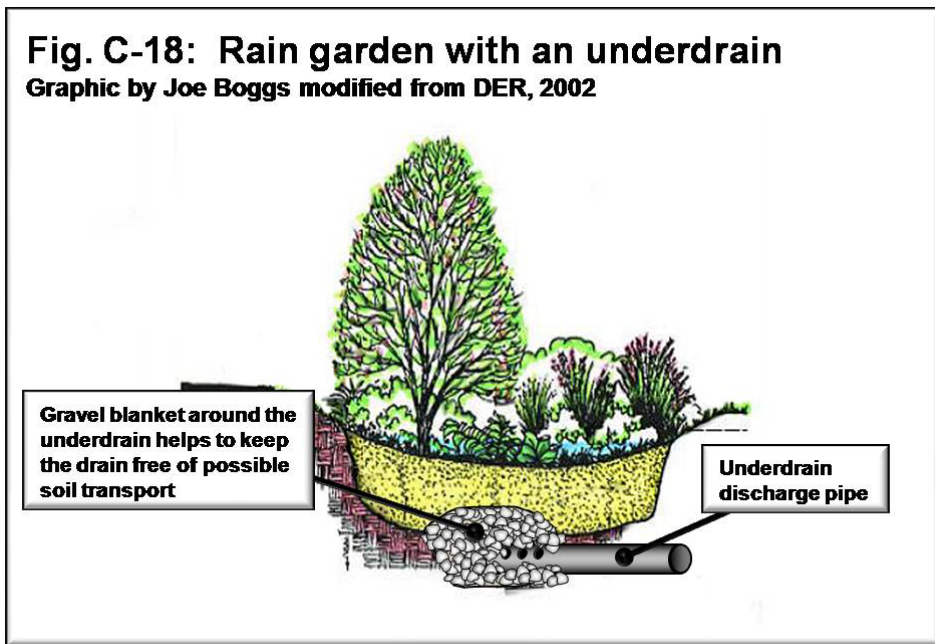
Some rain garden designs recommend the use of sand to achieve good drainage. These recommendations range from amending the existing soil with various percentages of sand to completely removing the existing soil and replacing it with sand. While sand will provide rapid drainage, we do not recommend the use of sand as a soil amendment for the following reasons:

- ◆ Soils in Greater Cincinnati tend to have high percentages of clay. When sand is added to a clay soil, the pore spaces between the large sand particles will become filled with the small clay particles. This produces a soil density that mimics concrete! A soil must consist of 50 – 60% sand by volume before it will enhance water infiltration without becoming negatively affected by the clay particles.

- ◆ Removing the existing soil and replacing it with sand means sand must be purchased and hauled to your rain garden site. The existing soil must be hauled away and disposed. Both add to the costs and overall complexity in constructing your rain garden.
- ◆ Sand has a very low cationic exchange capacity (CEC), which is a measure of the soil's ability to hold onto plant nutrients. This means nutrients must constantly be added to sandy soil. This creates an ongoing risk the nutrients will wash through the sand to contaminate the ground water beneath the rain garden.

**Underdrains** are sometimes installed beneath a rain garden to solve extreme problems with water infiltration and drainage. Underdrains are used to solve the following problems:

- ◆ Water infiltration is extremely slow due to the condition of the subsoil beneath the garden.
- ◆ The garden cannot be sized to accommodate the volume of rain water runoff directed into the garden. For example, the size of your rain garden may be limited by the size of your property, or the amount of space in your landscaping that can be devoted to a rain garden.



The underdrain pipe (Fig. C-18) is usually a 4" – 6" diameter black PVC drainage pipe. It is recommended that a pea gravel blanket is used to surround the underdrain pipe instead of filter fabric. Note that the underdrain will need to be installed first, after excavation. The underdrain must be installed so that it slopes away from the rain garden (a nominal 1 – 3% slope) so that water does not back up.

Underdrains are not generally included in "standard" rain garden designs because the pipe(s) remove some of the water from the site rather than allowing all of the water to recharge the soil beneath the site. Still, a rain garden that includes an underdrain will slow the movement of water off-site so that it does not contribute to problems with urban storm water management. If you plan to include an underdrain in your rain garden design, you will also need to plan for the redistribution of the water that is discharged from the drain pipe.





## 10 Steps for Preparing a Rain Garden's Site, Soil, and Planting Bed:

- (1) Develop a "check-list" of materials and tools that you will need to construct the rain garden. Having all of the materials on-site when you begin construction will save time.
- (2) Select a day when the soil is only slightly moist. Dry soil will be difficult to dig and digging in wet soil will lead to soil compaction. If the soil is too dry, you can add water sparingly to moisten the soil; however, do not overwater!
- (3) Use spray paint to outline the "footprint" of your rain garden.
- (4) Dig the garden to the desired depth, and then dig down an additional 4" – 6".
  - This additional digging is known as "over-digging" or "double-digging,"
  - It will be used to produce a transition zone between the amended soil in your rain garden and the soil beneath the garden. Water does not easily flow between soils with differing textures. This is known as "soil incompatibility." The transition zone will include a mix of the soil beneath the garden and the amended soil in it.
- (5) Use a shovel or coarse rake to roughen the soil in the bottom and along the sides of the rain garden hole. This is known as "scarifying" the soil and it serves to further reduce soil incompatibility by "blurring the boundaries" between the surrounding soil and the soil in the rain garden. No matter how it is done, the sides of the hole should never be smooth.
- (6) Mix the soil amendment(s) into the soil you have dug from the rain garden hole. The mixing ratio should be around 1:3; organic matter to native soil. Remember that the addition of the soil amendment will raise the total volume of the finished amended soil. You will not use all of the amended soil to backfill your rain garden since you want the rain garden to be concave (bowl-shaped), not convex (humped). It is best to mix the amendment into the soil in small batches, and then add the amended mixture to the garden as needed.
- (7) The first soil that you will return to the garden will be a 50:50 mix of the amended soil and the existing soil. This will create the transition zone. Fill the hole with this mixture until you reach the level of desired depth of the rain garden. DO NOT compact the soil.
- (8) Next, fill the garden to the desired depth and contour with the soil that has been amended to the 1:3 ratio. Again, DO NOT compact the soil.
- (9) The excess soil mix from the hole may be used in the construction of a berm along the lower side of the garden to prevent water from over-washing the garden during heavy rain events. The berm should be taller on the downhill side and gradually become lower until it is even with the grade on the uphill side. Do not compact the berm. Plant the berm with dry-tolerant plants, then mulch with 1" – 2" of shredded hardwood mulch.
- (10) If water will enter the rain garden with force, you should consider installing an erosion control mat or a rock swale to disperse some of the power. A thick stand of healthy turf above and below the garden will help to slow down and infiltrate water and greatly reduce erosion.

**Planting.** In general, the planting recommendations for a rain garden are the same as for any other landscape garden. Remember that the rain garden should function both as an aesthetically pleasing landscape feature as well as a tool for managing rain water runoff. The long-term success of a garden depends on providing a good start for the plants installed.

- (1) Design the garden to allow plenty of space between plants because they need room to grow (Fig. C-20). Remember that perennials usually look best when planted in clumps or groups of plants of the same variety.



Fig. C-19: Rain garden design planting grid  
Photo by Joe Boggs

- (2) Dig a hole for each plant large enough to accept its root system comfortably. Lift out each plant from its flat or container with a block of soil surrounding its roots.
- (3) If containerized plants have become root bound, disturb the root system by gently pulling the roots apart before planting.
- (4) Set the soil block in a planting hole and backfill it so the plant sits at the same level as the surrounding soil. Planting depth should be the same as container depth or to soil line on bare root plants; do not bury the crowns. If planted too deeply, crowns and roots may rot; if too shallow, they may dry out.
- (5) Thoroughly irrigate each newly installed plant with a "starter solution" of high phosphate liquid fertilizer.
- (6) Cover a rain garden to a depth of no more than 1" – 2" with high quality organic mulch, preferably shredded bark mulch. Non-shredded mulch tends to float and wash away.



Fig. C-20: Planting a rain garden  
Photo by Dave Dyke



Fig. C-21: Completed newly installed rain garden  
Photo by Joe Boggs

## CHAPTER D – RAIN GARDEN MAINTENANCE

There are few differences between the plant health practices recommended for maintaining rain garden plants and the general horticultural practices recommended for maintaining healthy plants elsewhere in the landscape. The exceptions are related to the special function of a rain garden.

Landscape management practices that interfere with water infiltration will interfere with the rain garden's function. For example, as organic mulch decays, large particles become small particles and the small organic particles can interfere with water movement, particularly if allowed to dry out. In fact, the decayed mulch can become hydrophobic, meaning that it will repel water. Periodically rake and redistribute the mulch to prevent this problem.



Fig. D-1: Rain gardens are maintained like other landscape plantings  
Photo by Joe Boggs

The rapid movement of water into the soil beneath a rain garden also increases the risk for ground water contamination. This should always be considered when making fertilizer and pesticide decisions involving a rain garden.

### Soil Fertility Management

As with all plants in the landscape, the plants in a rain garden will do best if provided with the right amount of nutrients and if the pH of the soil matches their needs. Remember that too much fertilizer can be just as bad as not enough. The best way to learn what is "just right" is to have the soil tested.

A standard soil test will provide information on the status of several important plant nutrients as well as the soil pH, the cation exchange capacity (CEC), and the base saturation (Fig. D-2). Additional tests are available for iron (Fe), zinc (Zn), manganese (Mn). These nutrients move very slowly into and through most soils. The exception is sandy soils. As mentioned earlier, sandy soils have a very low CEC, meaning that they do not hold onto nutrients. Instead, the nutrients are easily washed from the sandy soil, which presents a serious risk to ground water contamination beneath your rain garden. Soil testing labs always provide a fertilizer recommendation specific to the test results. You should carefully follow the fertilizer recommendations.

Standard soil tests do not provide information on nitrogen (N) in the soil. This is because nitrogen can move quickly through soil which makes the test results very time-sensitive. Nitrogen should be added sparingly and only when plants need it. It is generally recommended that perennials be fertilized in spring as new growth emerges, and again eight weeks later. Using a "slow-release" form of nitrogen will reduce the risk of ground water contamination beneath your rain garden.

You should have the soil in a rain garden tested as soon as you complete its construction. Testing the soil prior to adding amendments will not provide accurate results relative to the "finished" product. For instructions on how to take and submit soil samples for testing, refer to the Ohio State University Extension FactSheet HYG-1133-99 titled "Soil Testing is an Excellent Investment for Garden Plants and Commercial Crops" [<http://ohioline.osu.edu/hyg-fact/1000/1133.html>]. The factsheet also lists soil testing labs. In Hamilton County, you can contact the Hamilton County Soil and Water Conservation District (513-772-7645) to acquire a soil testing kit.

**Fig. D-2: Ideal Soil Test Result Values**  
Graphic by Joe Boggs

pH	Phosphorus P lbs. / A*	Potassium K lbs. / A*	Calcium Ca lbs. / A*	Magnesium Mg lbs. / A*	Cationic Exchange Capacity C.E.C. meq./100 gms	Base Saturation		
						% Ca	% Mg	% K
5.5 to 6.5	50 to 100	250 to 400	800 plus	150 to 250	7 to 10 or higher	40 % to 80%	10% to 40%	3% to 5%
* To convert lb/A (pounds per acre) to ppm (parts per million), divide by 2. Example: 100 lb. per A / 2 = 50 ppm								



## Watering

Additional water may be required to keep your rain garden plants healthy during the growing season.

- ◆ In general, plants need 1" of water per week as rainfall and/or applied water.
- ◆ Plants that are recently planted or transplanted may need additional water during the establishment period.
- ◆ Watering should be done in the morning at soil level rather than sprinkled over the top of plants, which may spread disease.
- ◆ When watering, moisten the entire bed thoroughly, but do not water so heavily that the soil becomes soggy. After watering, allow the soil to dry moderately before watering again.
- ◆ Soaker hoses, bubblers, and other watering devices that slowly distribute water to the soil rather than onto the foliage of plants all aid in following proper watering practices.



Fig. D-3: Like other landscapes, rain garden plants must be watered after planting, during establishment, and later during droughts  
Photo by Joe Boggs

## Mulching

Use mulch to help prevent mud-splashed blooms, conserve moisture, moderate soil temperatures, and suppress weeds. Organic mulch will also continually infuse organic matter into the soil as they decay.

- ◆ Mulch can be applied in the spring, after the soil has warmed, or in the fall.
- ◆ Mulch should only be applied to a depth of 1" – 2", and it should be kept away from plant stems.
- ◆ Never use more than 3" unless it is used for winter protection. For example, perennials that are transplanted or newly divided in the fall should have 3" – 4" of mulch applied over the crowns after the ground freezes to prevent soil from freezing and thawing and potentially heaving plants out of the ground. Plants that are marginally hardy should also have 3" – 4" of mulch for winter protection. Pull the mulch back from the crowns once new growth begins to emerge in spring.
- ◆ Compost, chipped or shredded bark, pine needles, etc., are all suitable for rain gardens. However, shredded hardwood bark is best for rain gardens and contour infiltration plantings because it will not easily float or wash away.



Fig. D-4: Hardwood bark mulch  
Photo by Joe Boggs

## Weed Management

It is critical to control weeds in your rain garden. Once established, weeds may be very difficult to control due to weed seed production and the establishment of vegetative structures such as roots and rhizomes.

- ◆ Weeds can be prevented and controlled using several "cultural" methods such as hand pulling, cultivation, and mulching.

- ◆ Perennial weeds are best killed prior to planting using a postemergent, non-residual, non-selective, herbicide (e.g. glyphosate). A postemergent herbicide kills growing plants, and non-residual means the herbicide breaks-down quickly and will not infiltrate through the soil. Non-selective means the herbicide kills almost all plants.
- ◆ Weeds can be prevented from establishing from seed by using a preemergent herbicide. These herbicides will prevent weed seed germination; however, they do not control established weeds. Many preemergent herbicides products are labeled for use around flowering plants. The products are applied to a weed-free soil surface in spring after the bed is planted to control summer annual weeds, and in late-summer to control winter annual weeds. Be very careful when using pesticides that could potentially end up in ground or other water systems. As with all pesticides, read and follow product label directions.



Fig. D-5: Lesser Celandine (*Ranunculus ficaria*), also known as Fig Buttercup, is a non-native highly invasive weed  
Photo by Joe Boggs

### Pest and Disease Management

Perennials, trees, shrubs, and annuals used in rain gardens may have their share of pest and disease problems. Research the plants that interest you and become knowledgeable of specific problems. Selecting plants that have few pest and disease problems is one of the most effective ways to avoid these problems.

- ◆ Large animal pests such as rabbits, squirrels, chipmunks, and deer can be managed using exclusion methods, such as fencing, and by using chemical repellents to directly protect plants. Plant selection is also important. For example, the Cincinnati Zoo and Botanical Garden has a list of plants [[www.cincinnati-zoo.org](http://www.cincinnati-zoo.org)] that have been found to be the most deer resistant.
- ◆ Small animal pests such as insects should be managed using three steps:
  - First, you must identify the pest. This includes separating the "good insects," such as insect predators from the "bad insects," the pests. Contact your county Extension educator or the OSU C. Wayne Ellett Plant and Pest Diagnostic Clinic [<http://ppdc.osu.edu/>] for assistance in plant pest identification.
  - Next, you must decide whether or not the pest is actually causing significant damage to the overall health of the plant(s). There are many pests, such as aphids, that only appear to cause damage to plants; however, they are not harming the health of the plant.
  - Finally, you need to devise a pest management strategy using Integrated Pest Management (IPM) tactics.

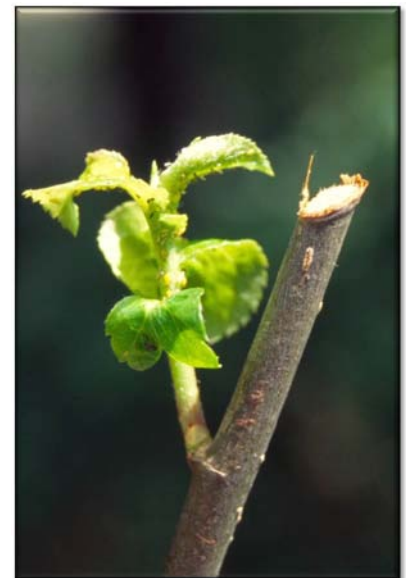
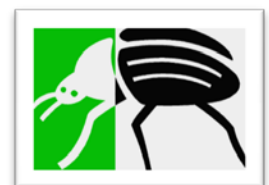


Fig. D-6: Rabbit damage: note the 45° angled cut  
Photo by Joe Boggs



- Figure D-7 shows the IPM tactics:
  - Chemical control includes all forms of insecticides; however, this tactic should be reserved as a "last resort" and the insecticides should have a limited impact on biological control tactics.
  - Cultural control includes plant selection as well as practices that enhance the health of plants, such as proper fertilization.
  - Biological control primarily focuses on actions that enhance beneficial insects, such as selecting plants that provide nectar and pollen to feed adult beneficial insects (e.g. parasitoid wasps). Also, you should avoid actions that limit the effects of beneficials, such as killing them with an insecticide.

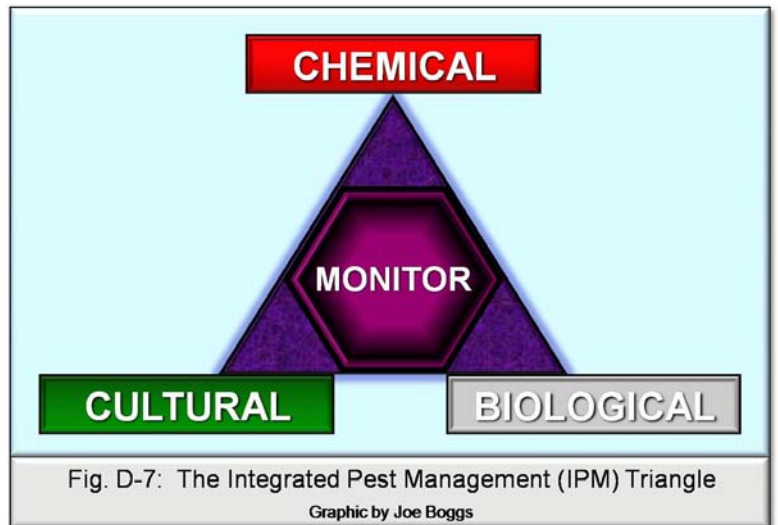


Fig. D-8: Eriophyid rosette damage  
Photo by Joe Boggs



Fig. D-9: Four-Lined Plant Bug, a common pest of perennials  
Photo by Joe Boggs



Fig. D-10: Fiery Searcher Caterpillar Hunter, an important insect predator  
Photo by Joe Boggs



Fig. D-11: Parasitoid wasp cocoons sprouting from a saddleback caterpillar  
Photo by Joe Boggs

◆ Disease Management employs a different triangle; the **Disease Triangle** (Fig. D-12).

○ The Disease Triangle illustrates that a disease can develop only when you have a plant pathogen present at the same time that you have a susceptible host and environmental conditions that will support disease development. If you remove any one of these three conditions, a plant disease will not develop. Here are some examples:

- **Environmental:** A number of fungal diseases require an abundance of water on plant leaves. This condition can be reduced by avoiding wetting the leaves during watering.
- **Host Plant:** Plant diseases often develop on stressed plants. Plant health management practices, such as proper fertilization, are also plant disease management practices. Selecting disease resistant plants will also remove the host from the triangle.
- **Pathogen:** Pruning to remove diseased tissue will help to remove the pathogen.

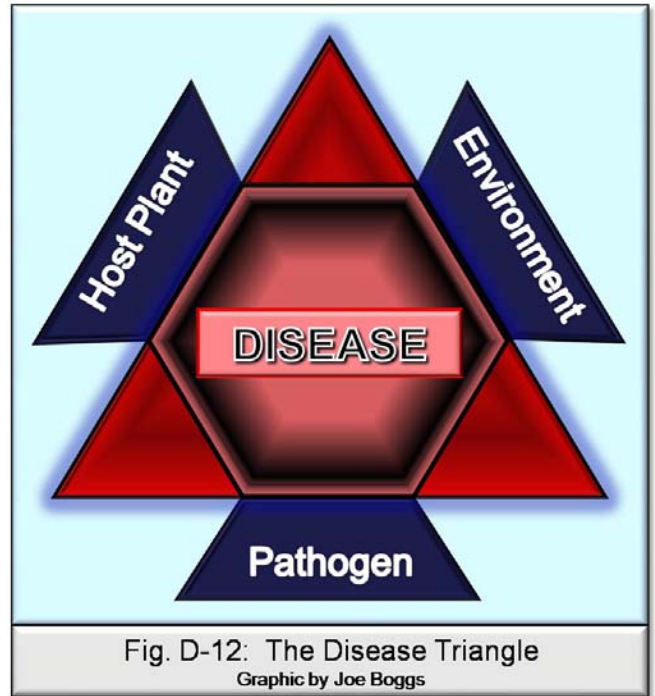


Fig. D-13: Powdery mildew on ninebark 'Diablo'  
Photo by Joe Boggs



Fig. D-14: Slime mold, a nuisance fungus on mulch  
Photo by Joe Boggs

## CHAPTER E – PLANT SELECTION AND USE

**Plant selection.** Plants used in storm water management applications, such as rain gardens, have been typically thought of as those that can tolerate both wet soils in the late winter and spring and dry soils in the summer.

However, what you should be really concerned with is selecting plants that will thrive in the different ecosystems created by the many green storm water management systems. This includes everything from bio-swailes to contour infiltration plantings to rain gardens.

Native plants are often suggested for use in rain gardens based on the belief that they are better adapted to local conditions than non-native plants. Consider using all plants that do well in our area under the soil and site conditions found in the rain garden, or other storm water management systems. Both native and non-native plants should be considered.

We urge that you refer to the list included in this publication for guidance in making your plant selections. Also refer to <http://www.plantplaces.com/>. This outstanding web site, developed by Steve Foltz, Horticulture Director, Cincinnati Zoo & Botanical Garden, has a comprehensive list, with photos, of a very wide variety of all kinds of plants that have done well in Southwest Ohio.

It also contains the location of rain gardens and other green storm water management installations throughout the area. Consider all types of plant materials, including trees and shrubs that are relatively low maintenance, instead of only selecting the more traditional herbaceous plant materials associated with infiltration plantings. Remember that a garden can provide many functions in addition to storm water management, including shade and wildlife habitat. Finally, it is important that you consider the following when making your plant selections:

- ◆ **Recommendations/local trials.** Use plants that have been successfully grown and/or trialed in this area by reputable non-biased agencies, organizations, companies, or individuals under the conditions for which they will be used. The plants recommended in this publication have been chosen by Steve Foltz subsequent to many years of experience and trials. All plants are trialed at the zoo without the use of pesticides. They are generally trialed over a period of 2 or more years in several garden plantings involving a variety of environmental conditions, including soils and light, and usually receive a minimal amount of fertilizer. In order to be recommended, they must maintain their vigor and a superior appearance over most or all of the growing season with insignificant insect or disease damage.
- ◆ **Hardiness.** Hardiness zone refers to minimum winter temperatures. In general, the northern half of Ohio is in Zone 5 with -10° F to -20° F; southern Ohio is in Zone 6, with 0° F to -10° F minimum temperatures. However, southern Ohio has been as low as -24° F.
- ◆ **Light.** Light exposure is critical for plant growth and bloom. "Full sun" is considered to be 6 hours or more of direct sun. "Partial shade" is a half day of sun (morning sun and afternoon shade) or a filtered shade through high branched trees. "Full shade" is no direct sun exposure. Some plants are particular as to light required while others are more adaptable.
- ◆ **Moisture.** Rain gardens have 3 moisture zones: moist at the bottom of garden, average on the sides, and dry around the top edges. Plants that need saturated soil (e.g. wetland plants) or dry soil should generally be avoided.



Fig. E-1: *Helianthus angustifolius*  
'Gold Lace'  
Photo by Steve Foltz



- Plants to be planted in the lower "moist zone" of a rain garden may be at least partially submerged for 24 hours or more during periods of extended rainfall. The soil may be saturated for extended periods. Soils that drain poorly, especially in winter, cause the death of many perennials due to crown rot. Therefore, it is extremely important that plants you choose for the wet zone be adapted to wet conditions.
- Plants that do well in average moisture conditions should be planted along the sides of the rain garden.
- Use plants that grow well in average to drier conditions around the top edges.
- ◆ **Fertility and pH.** The fertility and pH requirements of plants should be considered when selecting them. The plants on our recommended plant list will do well in the pH ranges most typically found in our area. Some plants, such as certain natives, their cultivars, and others, may do well in a good loam garden soil with minimal or no fertilization. Others may require fertilizer applications to thrive. You should always consult soil test results for guidance in making fertilizer applications.
- ◆ **Planting size.** For best appearance and ease of establishment, plants grown in 4" pots or larger should be selected for planting. If budgetary constraints dictate more inexpensive materials, plugs may be used if they are planted in the spring. As a general rule, the larger the plants the better.
- ◆ **Physical characteristics.** It is best to select plants with a purpose in mind, such as low-growing edging plants, accents, masses of color, etc.
  - Size: Consider the height and width of mature plants. If planted too close, some will be crowded out and plant health and garden appearance will be affected. Plant taller plants in groups in the middle of a garden that is to be observed from all sides and towards the back of those designed to be observed primarily from the front.
  - Aggressiveness: Spreading and fast-growing plants can overpower other plants in the garden. Therefore, it important to group plants that have similar growth rates.
  - Color, texture, and bloom time: A garden can have a very pleasing appearance throughout the growing season with careful planning. Be sure to consider both the color of foliage and the blooms when selecting plants.
  - Clustering plants: When using the same plants in clusters, odd numbers (3, 5, and 7) will generally give a more pleasing appearance than even numbers.
  - Appearance: Native plants may sometimes produce a "weedy" appearance. Select named varieties for a good display from a limited number of plants in a limited space.
- ◆ **Deer resistance.** Deer can be a major problem in Ohio gardens, and they will feed on a wide variety of plants. If deer are a problem in the landscaping, we recommend that you consider selecting plants for a rain garden that are generally resistant to deer damage, unless you can protect the plants with adequate fencing. The Cincinnati Zoo and Botanical Garden [[www.cincinnati-zoo.org](http://www.cincinnati-zoo.org)] has developed a list of plants that have been found to be less attractive to deer. Of course, you must remember that if deer are hungry, they may even feed on "deer resistant" plants.
- ◆ **Special considerations.** You may want use plants in a rain garden that are attractive to butterflies, hummingbirds, birds, etc. There are many lists available that highlight plants that are attractive to wildlife. If you consult these lists, we recommend that you make your final selection based on plants that are also found in the plant selection list included in this publication.



To see photos of plants included in the following plant list, visit [www.plantplaces.com](http://www.plantplaces.com). The website catalogs ornamental plants that are successfully growing in the Greater Cincinnati Region. Also visit [www.planttrials.com](http://www.planttrials.com) to see herbaceous plants that are being trialed around the Greater Cincinnati Region. Both websites can be helpful in selecting plants for the landscape.



Fig. E-2: *Eupatorium maculatum* 'Gateway' (Joe-Pye Weed), *Sedum* sp. (Sedum), and *Echinacea* sp. (Coneflower)  
Photo by Steve Foltz

## Recommended Plants for Green Storm Water Management Controls in Southwest Ohio

### Perennials

Note: ♦ is the symbol used for plants that can tolerate wet soils

#### Full Sun

##### Native Perennials Under 2'

- Asclepias tuberosa – Butterfly Weed
- Amsonia 'Blue Ice' – Blue Ice Bluestar
- Aster oblongifolius –
  - 'Raydon's Favorite' – Raydon's Favorite Aster
  - 'October Skies' – October Skies Aster
- Aster novae-angliae 'Purple Dome' – Purple Dome Aster
- Coreopsis verticillata 'Moonbeam' – Moonbeam Coreopsis
- Coreopsis auriculata 'Nana' – Yellow Coreopsis
- Coreopsis lanceolata – Lance-leaved Coreopsis
- Echinacea tenesseeensis 'Rocky Top' – Tennessee Coneflower
- Echinacea purpurea 'Kims Knee High' – Kim's Knee High Coneflower
- Eryngium yuccifolium – Rattlesnake Master
- Gaillardia 'FanFare' – Fanfare Blanketflower
- Heuchera villosa 'Caramel' – Caramel Alum Root
- ♦ Iris versicolor – Blue Flag Iris
- Liatris microcephala – Dwarf Blazing Star
- Liatris spicata – Blazing Star
- ♦ Lobelia cardinalis – Cardinal Flower
- Oenothera fruticosa 'Fireworks' – Fireworks Sundrops
- Phlox subulata – Creeping Phlox
  - 'Emerald Cushion Pink', 'Emerald Cushion Blue'
- Sedum ternatum – Native Sedum
- Silene regia – Royal Catchfly
- Solidago sphaceolata 'Golden Fleece' – Golden Fleece Goldenrod
- Solidago ohioensis – Ohio Goldenrod
- ♦ Spiranthes cernua v. odorata – Chadds Ford Fragrant Lady's Tresses
- Stokesia 'Klaus Jelitto' – Stoke's Aster
- ♦ Tradescantia ohioensis – Spiderwort

##### Non Native Perennials Under 2'

- Dianthus x gratianopolitanus 'Bath's Pink' – Bath's Pink Dianthus
- Geranium x cantabrigiense 'Biokova' and 'Karmina'
- Geranium sanguineum – Bloodred Geranium
- Hemerocallis 'Happy Returns', 'Stella d'Oro', (many others)

- Iris siberica – Siberian Iris
- Liriope spicata – Creeping Liriope
- Liriope 'Big Blue' – Big Blue Liriope
- Nepeta 'Six Hills Giant' – Catmint
- Salvia 'Blue Hill' – Blue Hill Salvia
- Salvia 'May Night' – May Night Salvia
- Sedum 'Autumn Joy' – Autumn Joy Sedum
- Stachys 'Helen von Stein' – Lamb's Ears
- Thymus serpyllum – Creeping Tyme

##### Native Perennials 2'-4'

- ♦ Acorus calamus – Sweetflag 'Variegata'
- ♦ Asclepias incarnata (swamp milkweed)
- Amsonia tabernaemontana – Blue Star Amsonia
- Amsonia hubrichtii – Arkansas Amsonia
- Baptisia australis – Wild Blue Indigo
- Baptisia australis var. minor – Wild Blue Indigo
- Baptisia 'Purple Smoke' – Purple Smoke Baptisia
- Baptisia sphaerocarpa – Yellow Wild Indigo
- Echinacea purpurea – Coneflower 'Magnus', 'Ruby Star', 'White Swan', 'Fragrant Angel'
  - (Echinacea Big Sky Series)
- ♦ Helianthus angustifolius 'First Light' – First Light Swamp Sunflower
- ♦ Monarda – Bee Balm
  - ('Jacob Cline', Marshall's Delight', Raspberry Wine')
- Phlox paniculata 'David' – David Garden Phlox
  - 'Katherine' – Katherine Garden Phlox
- Rudbeckia fulgida 'Goldsturm' – Goldsturm Black-eyed Susan
- Solidago rugosa 'Fireworks' – Fireworks Goldenrod
- Thermopsis caroliniana – Carolina Lupine

##### Non Native Perennials 2'-4'

- Perovskia atroplicifolia – Russian Sage
- Leucanthemum 'Becky' – Becky Shasta Daisy
- Paeonia – Peony
- Hemerocallis Assorted Cultivars

##### Native Perennials 4' and larger

- Boltonia asteroides 'Snowbank' – Thousand Flowered Aster
- Coreopsis tripteris – Tall Coreopsis (
  - ♦ Eupatorium maculatum 'Gateway' – Gateway Joe-Pye Weed
  - Helenium autumnale – Sneezeweed
  - ♦ Helianthus angustifolius 'Gold Lace' – Gold Lace Swamp Sunflower
  - ♦ Hibiscus moscheutos – Swamp Rose Mallow

(‘Sweet Caroline’, ‘Moy Grande’, ‘Pink Cloud’  
 Ratibida pinnata – Prairie Coneflower  
 ◆ Rudbeckia nitida ‘Autumn Sun’ – Autumn Sun Coneflower  
 Rudbeckia submentosa – Sweet Coneflower  
 Rudbeckia maxima – Great Coneflower  
 Silphium laciniatum – Compass Plant  
 Silphium perfoliatum – Cup Plant  
 Silphium terebinthenaceum – Prairie Dock  
 ◆ Veronicastrum virginicum – Culver’s Root

## Perennials for Shade

### Native Perennials Under 3’

Aquilegia canadensis – Wild Columbine, ‘Corbett’ (Yellow), ‘Little Lanterns’ (red/orange)

Asarum canadense – Wild Ginger  
 ◆ Chelone lyonii ‘Hot Lips’ – Pink Turtlehead  
 Dicentra eximia – Wild Bleeding Heart  
 Dodecatheon meadia – Shooting Star  
 Geranium maculatum – Wild Geranium  
 Heuchera americana – American Alumroot  
 Heuchera villosa – Hairy Alumroot  
 Iris cristata – Dwarf Crested Iris, ‘Alba’, ‘Eco Bluebird’, ‘Powder Blue Giant’  
 Mertensia virginica – Virginia Bluebells  
 Pachysandra procumbens – Alleghany Spurge  
 Phlox divaricata – Wild Phlox, ‘London Grove Blue’, ‘May Breeze’  
 Phlox stolonifera – Creeping Phlox, ‘Blue Ridge’, ‘Sherwood Purple’  
 Stylophorum diphyllum – Celandine Poppy  
 Tiarella cordifolia – Foam Flower  
 Viola labradorica – Labrador Violet

### Non Native Shade Perennials

Anemone japonica – Japanese Anemone  
 Arum italicum – Italian Arum  
 Asarum europeum – European Ginger  
 ◆ Astilbe chinensis ‘Pumila’ – Chinese Astilbe  
 Begonia grandis – Hardy Begonia  
 Brunnera macrophylla – Siberian Bugloss, ‘Langtrees’, ‘Variegata’, ‘Jack Frost’  
 Epimedium x versicolor ‘Sulphureum’ – Yellow Barrenwort  
 Epimedium x rubrum – Red Barrenwort  
 Galium odoratum – Sweet Woodruff  
 Pachysandra terminalis - Pachysandra  
 ◆ Helleborus orientalis – Lenten Rose  
 Helleborus foetidus – Green Hellebore  
 Dicentra spectabilis - Bleeding Heart  
 ◆ Hosta  
 Blue – ‘Elegans’, ‘Blue Umbrellas’, ‘Blue Angel’, ‘Krossa Regal’,  
 Blue Cadet, Yellow – ‘Sum & Substance’, ‘Gold Standard’, ‘Solar Flare’, ‘Lemon Lime’  
 Variegated - ‘Francee’, ‘Patriot’, ‘Sagae’  
 Polygonatum odoratum ‘Variegatum’ – Variegated Solomon’s Seal  
 Rohdea japonica – Sacred Lily

### Native Shade Perennials 3’ and larger

◆ Aruncus dioicus – Goatsbeard  
 ◆ Veronicastrum virginicum – Culver’s Root

## Ornamental Grasses

### Native Grasses

Carex spp. – Many different types to choose from  
 Sporobolus heterolepis - Prairie Dropseed  
 Schizachyrium scoparium – Little Bluestem ‘The Blues’  
 Panicum virgatum - Switch Grass, ‘Hanse Herms’, ‘Northwind’, ‘Cloud Nine’, ‘Shenandoah’, ‘Dallas Blues’

## Non Native Ornamental Grasses

### 1’-3’

Pennisetum alopecuroides ‘Hameln’ – Hameln Fountain Grass  
 Pennisetum orientale – Oriental Fountain Grass

### 3’-5’

Calamagrostis x acutiflora ‘Karl Foerster’ – Karl Foerster Feather Reed Grass  
 Pennisetum alopecuroides – Fountain Grass  
 Miscanthus sinensis ‘Little Nicky’ – Little Nicky Zebra Grass  
 Miscanthus sinensis ‘Adagio’ – Adagio Maiden Grass  
 Miscanthus sinensis ‘Morning Light’ – Morning Light Maiden Grass

### 5’-8’

Miscanthus sinensis ‘Variegatus’ – Variegated Silver Grass  
 Miscanthus sinensis ‘Strictus’ – Porcupine Grass  
 Miscanthus sinensis ‘Gracillimus’ – Maiden Grass

### 8’+

Miscanthus ‘Giganteus’ – Giant Silver Grass  
 Arundo donax – Giant Reed Grass  
 Saccharum (Erianthus) ravennae – Ravenna Grass

### Ferns

Adiantum pedatum (northern maidenhair fern)  
 Athyrium filix-femina (lady fern)  
 Dennstaedtia punctilobula (hay-scented fern)  
 Dryopteris marginalis (marginal wood fern)  
 Onoclea sensibilis (sensitive fern, bead fern)  
 Osmunda cinnamomea (cinnamon fern)  
 Osmunda claytoniana (interrupted fern)  
 Osmunda regalis (royal fern)  
 Polystichum acrostichoides (Christmas fern)

## Trees, Shrubs and Vines

**Note:** ◆ denotes plants that can tolerate wet soils

### Native Large Trees (50’ or more)

#### Maple:

Black Maple (*Acer nigrum*)  
 ◆ Autumn Blaze Maple (*Acer x freemanii* ‘Autumn Blaze’)  
 ◆ Red Maple (*Acer rubrum* ‘Red Sunset’, ‘October Glory’)  
 Sugar Maple (*Acer saccharum*)

#### Birch:

◆ River Birch (*Betula nigra*)  
 ◆ Heritage River Birch (*Betula nigra* ‘Heritage’)

#### Hickory:

Pignut Hickory (*Carya glabra*)  
 Shagbark Hickory (*Carya ovata*)

#### Oak:

White Oak (*Quercus alba*)  
 ◆ Swamp White Oak (*Quercus bicolor*)  
 Scarlet Oak (*Quercus coccinea*)  
 Shingle Oak (*Quercus imbricaria*)  
 Bur Oak (*Quercus macrocarpa*)  
 Chinkapin Oak (*Quercus muehlenbergii*)  
 ◆ Pin Oak (*Quercus palustris*)  
 Red Oak (*Quercus rubra*)  
 Shumard Red Oak (*Quercus shumardii*)

#### Others:

Yellow Buckeye (*Aesculus flava*)  
 Northern Catalpa (*Catalpa speciosa*)  
 Common Hackberry (*Celtis occidentalis*)  
 Persimmon (*Diospyros virginiana*)  
 American Beech (*Fagus grandifolia*)

- ◆ Thornless Honeylocust (*Gleditsia triacanthos* var. *inermis* 'Skyline', *Shademaster*', 'Sunburst', 'Imperial')
- Kentucky Coffeetree (*Gymnocladus dioica* (male clones available))
- ◆ Sweetgum (*Liquidambar styraciflua*)
- Tuliptree (*Liriodendron tulipifera*)
- Cucumber Magnolia (*Magnolia acuminata*)
- Osage Orange (*Maclura pomifera* (Male clone))
- ◆ Black Tupelo (*Nyssa sylvatica*)
- ◆ Sycamore (*Platanus occidentalis*)
- ◆ Bald Cypress (*Taxodium distichum* 'Shawnee Brave')
- American Linden (*Tilia americana*)
- Valley Forge American Elm (*Ulmus americana* 'Valley Forge')

### Non Native/non-invasive Large Trees

- Horsechestnut (*Aesculus hippocastanum*)
- Hardy Rubber Tree (*Eucommia ulmoides*)
- European Beech (*Fagus sylvatica*)
- Ginkgo (*Ginkgo biloba* (male clone))
- ◆ Dawn Redwood (*Metasequoia glyptostroboides*)
- ◆ Bloodgood Londonplane Tree (*Plantanus x acerifolia* 'Bloodgood')
- English Oak (*Quercus robur* 'Regal Prince')
- Japanese Pagoda Tree (*Sophora japonica*)
- Littleleaf Linden (*Tilia cordata*)
- Silver Linden (*Tilia tomentosa* 'Sterling Silver')
- Accolade Elm (*Ulmus* 'Accolade')
- Chinese Elm (*Ulmus parvifolia* 'Allee')
- Japanese Zelkova (*Zelkova serrata*)

### Native Small to Medium Flowering Trees

#### 25'-50'

- American Hornbeam (*Carpinus caroliniana*)
- American Yellowwood (*Cladrastis kentukea*)
- Umbrella Magnolia (*Magnolia tripetala*)
- Bigleaf Magnolia (*Magnolia macrophylla*)
- American Hophornbeam (*Ostrya virginiana*)
- Sassafras (*Sassafras albidum*)

#### Under 25'

##### **Birch:**

- ◆ Weeping River Birch (*Betula nigra* 'Summer Cascade')
- ◆ Sweet Birch (*Betula lenta*)

##### **Hawthorn:**

- Cockspur Hawthorn (*Crataegus crusgalli* var. *inermis*)
- Washington Hawthorn (*Crataegus phaenopyrum*)
- Winter King Hawthorn (*Crataegus viridis* 'Winter King')

##### **Dogwood:**

- Pagoda Dogwood (*Cornus alternifolia*)
- Flowering Dogwood (*Cornus florida* 'Cloud Nine', 'Cherokee Princess')
- ◆ Red-Panicked Dogwood (*Cornus racemosa*)

##### **Others:**

- Red Buckeye (*Aesculus pavia*)
- ◆ Apple Serviceberry (*Amelanchier x grandiflora* 'Autumn Brilliance', 'Princess Diana')
- Allegheny Serviceberry (*Amelanchier laevis* 'Cumulus')
- Common Pawpaw (*Asimina triloba*)
- ◆ Little King River Birch (*Betula nigra* 'Little King')
- Eastern Redbud (*Cercis canadensis* 'Alba', 'Appalachian Red')
- Weeping Redbud (*Cercis canadensis* 'Lavender Twist')
- Fringe Tree (*Chionanthus virginicus*)
- Eastern Wahoo (*Euonymus atropurpureus*)
- ◆ Sweetbay Magnolia (*Magnolia virginiana* 'Northern Belle')
- ◆ Peve's Mineret Bald Cypress (*Taxodium distichum* Peve's Mineret)
- ◆ Weeping Bald Cypress (*Taxodium distichum* 'Cascade Falls')

### Non Native/non-invasive Small to Medium Trees

##### **Maple:**

- Miyabei Maple (*Acer miyabei* 'State Street')
- Japanese Maple (*Acer palmatum* 'Burgundy Lace', 'Bloodgood')
- Girard's Hybrid Paperbark Maple (*Acer griseum x nikoense*)
- Flame Amur Maple (*Acer ginnala* 'Flame')

##### **Magnolia:**

- Saucer Magnolia (*Magnolia x soulangiana*)
- Star Magnolia (*Magnolia stellata*)
- Loebneri Magnolia (*Magnolia x loebneri* 'Merrill', 'Jane Platt')

##### **Cherry:**

- Sargent Cherry (*Prunus sargentii*)
- Yoshino Cherry (*Prunus x yedoensis* 'Akebono')
- Weeping Cherry (*Prunus subhirtella* 'Pendula')
- Snow Fountain Weeping Cherry (*Prunus* 'Snow Fountain')

##### **Others:**

- Horsechestnut (*Aesculus hippocastanum*)
- Columnar European Hornbeam (*Carpinus betulus* 'Fastigiata')
- Chinese Chestnut (*Castanea mollissima*)
- Turkish Filbert (*Corylus colurna*)
- Seven Son's Tree (*Heptacodium miconioides*)
- Golden Rain Tree (*Koelreuteria paniculata*)
- Amur Maackia (*Maackia amurensis*)
- Donald Wyman Crabapple (*Malus* 'Donald Wyman', 'Sugar Tyme')
- Fruitless Mulberry (*Morus alba* 'Strybling')
- Persian Parrotia (*Parrotia persica*)
- Globe Black Locust (*Robinia pseudoaccacia* 'Umbraculifera')
- Korean Mountainash (*Sorbus alnifolia*)
- Ivory Silk Lilac (*Syringa reticulata* 'Ivory Silk')

##### **SHRUBS**

### Native Shrubs over 8'

##### **Sumac:**

- Shining Sumac (*Rhus copallina* 'Prairie Flame')
- Smooth Sumac (*Rhus glabra*)
- Staghorn Sumac (*Rhus typhina*)

##### **Viburnum:**

- Nannyberry Viburnum (*Viburnum lentago*)
- Blackhaw Viburnum (*Viburnum prunifolium*)
- Southern Blackhaw Viburnum (*Viburnum rufidulum*)
- American Cranberrybush Viburnum (*Viburnum trilobum* 'Wentworth')

##### **Others:**

- ◆ Bottlebrush Buckeye (*Aesculus parviflora*)
- ◆ Devils Walking Stick (*Aralia spinosa*)
- ◆ Allegheny Serviceberry (*Amelanchier laevis*)
- ◆ Gray Dogwood.....*Cornus racemosa*)
- ◆ Giant Gray Dogwood (*Cornus drummondii*)
- American Hazelnut (*Corylus americana*)
- Fringe Tree.....*Chionanthus virginicus*)
- Common Witchhazel (*Hamamelis virginiana*)
- ◆ Vernal Witchhazel (*Hamamelis vernalis*)
- ◆ Bayberry (*Myrica pensylvanica*)
- ◆ Ninebark (*Physocarpus opulifolius* 'Summer Wine', 'Diabolo')
- Wafer-ash (*Ptelea trifoliata*)
- Carolina Buckthorn (*Rhamnus caroliniana*)
- ◆ Elderberry (*Sambucus canadensis*)
- Scarlet Elder (*Sambucus pubens*)
- American Bladdernut (*Staphylea trifolia*)

### Non Native Large Shrubs 8'+

- Cornelian Cherry Dogwood (*Cornus mas* 'Golden Glory')
- Japanese Cornell Dogwood (*Cornus officinalis*)
- Smokebush (*Cotinus coggygia* 'Daydream', 'Velvet Cloak', )
- Godsall Pink Deutzia (*Deutzia scabra* 'Godsall Pink')
- Pearlbush (*Exochorda racemosa*)
- Forsythia (*Forsythia x intermedia* 'Meadowlark', 'Northern Sun')

Beauty Bush. (*Kolkwitzia amabilis*)  
 Crape Myrtle. (*Lagerstroemia 'Hopi'*, '*Acoma*' '*Catawba*')  
 Fragrant Honeysuckle (*Lonicera fragrantissima*)  
 Japanese Orixia. (*Orixia japonica*)  
 Assesseppi Lilac (*Syringa x hyacinthiflora 'Assesseppi'*)  
 Fragrant Viburnum (*Viburnum x carlecephalum*)  
 Burkwood Viburnum (*Viburnum x burkwoodii 'Mohawk'*, '*Chanaultii*')  
 Alleghany Viburnum (*Viburnum x rhytidophylloides 'Alleghany'*)

### **Native Shrubs 4' - 8'**

- ◆Indigo Bush (*Amorpha fruticosa*)
- ◆Red Chokeberry (*Aronia arbutifolia 'Brilliantissima'*)
- ◆Carolina Allspice (*Calycanthus floridus*)
- ◆Buttonbush (*Cephalanthus occidentalis*)
- ◆Summersweet (*Clethra alnifolia 'Ruby Spice'*)
- ◆Silky dogwood (*Cornus amomum*)
- ◆Redosier Dogwood (*Cornus sericea 'Baileyi'*, '*Cardinal'*, '*Flaveramea'*)
- Leatherwood. (*Dirca palustris*)
- Large Fothergilla (*Fothergilla major*)
- Oakleaf Hydrangea (*Hydrangea quercifolia*)
- Annabelle Hydrangea (*Hydrangea arborescens 'Annabelle'*)
- St.John's Wort (*Hypericum kalmianum*)
- ◆Sweetspire (*Itea virginica 'Henry's Garnet'*)
- ◆Sparkleberry Winterberry Holly (*Ilex verticillata 'Sparkleberry'*)
- Spicebush (*Lindera benzoin*)
- Shining Sumac (*Rhus copallina 'Prarie Flame'*)
- ◆Hardhack. (*Spiraea tomentosa*)
- ◆Arrowwood Viburnum (*Viburnum dentatum 'Chicago Lustre'*, '*Northern Burgundy'*, '*Blue Muffin'*, '*Red Feathers'*, )
- ◆Smooth Witherrod Viburnum (*Viburnum nudum 'Winterthur'*)

### **Non Native Medium Shrubs 4'-8'**

Five Leaved Aralia. (*Acanthopanax sieboldianus*)  
 Flowering Quince (*Chaenomeles speciosa 'Texas Scarlet'*, '*Cameo'*)  
 Contorted Filbert. (*Corylus avellana 'Contorta'*)  
 Sunrise Forsythia. (*Forsythia 'Sunrise'*)  
 Weeping Forsythia (*Forsythia suspensa*)  
 Panicled Hydrangea. (*Hydrangea paniculata 'Tardiva'*, '*Limelight'*)  
 Gibraltar Bushclover (Lespedeza thunbergii 'Gibraltar', '*Avalanche'*)  
 Chinese Neillia. (*Neillia sinensis*)  
 Gnome Pyracantha (*Pyracantha 'Gnome'*, '*Kasan'*, '*Lowboy'*)  
 Ural False Spirea. (Sorbaria sorbifolia 'Sem')  
 Grefsheim Spirea. (*Spiraea x cinerea 'Grefsheim'*)  
 Vanhoutte Spirea. (*Spiraea x vanhouttei*)  
 Snowmound Spirea. (*Spiraea nipponica 'Snowmound'*)  
 Dwarf Korean Lilac (*Syringa meyeri 'Palibin'*)  
 Miss Kim Lilac (*Syringa patula 'Miss Kim'*)  
 Korean Spice Viburnum. (*Viburnum carlesii*)  
 Judd Viburnum. (*Viburnum x judii*)  
 Eskimo Viburnum. (*Viburnum x 'Eskimo'*)  
 Chaste Tree. (*Vitex agnus-castus*)  
 Old Fashioned Weigela (*Weigela florida 'Variegata'*, '*Wine and Roses'*)

### **Native Shrubs under 4'**

- ◆Black Chokeberry (*Aronia melanocarpa 'Iriquois Beauty'*, '*Viking'*)
- ◆Compact Sweetshrub. (*Clethra alnifolia 'Hummingbird'*, '*Sixteen Candles'*)
- ◆Red Sprite Winterberry (*Ilex verticillata 'Red Sprite'*, '*Afterglow'*. '*Shavers'* (need a male to pollinate female for fruit set.))
- ◆Henry's Garnet Sweetspire (*Itea virginica 'Henry's Garnet'*)
- ◆Little Henry Sweetspire (*Itea virginica 'Little Henry'*)
- Dwarf bush Honeysuckle (*Diervilla lonicera*)
- Southern Bush Honeysuckle (*Diervilla sessilifolia*)
- Dwarf Fothergilla (*Fothergilla gardenii*)
- Fragrant Sumac (*Rhus aromatica 'Gro Low'*; '*Green Globe'*)
- Flowering Raspberry. (*Rubus odoratus*)
- Indian Currant (*Symphoricarpos orbiculatus*)
- Indian Currant (*Symphoricarpos x chenaultii 'Hancock'*)
- ◆Yellowroot (*Xanthorhiza simplicissima*)
- Sunburst St. John's Wort (*Hypericum frondosum 'Sunburst'*)

Jetbead. (*Rhodotypos scandens*)

### **Non Native Shrubs under 4'**

Glossy Abelia. (*Abelia x grandiflora*)  
 Purple Beautyberry. (*Callicarpa dichotoma 'Issai'*, '*Early Amethyst'*)  
 Jet Trail Quince (*Chaenomeles speciosa 'Jet Trail'*)  
 Cranberry Cotoneaster. (*Cotoneaster apiculatus*)  
 Bearberry Cotoneaster. (*Cotoneaster dammeri 'Coral Beauty'*)  
 Golden Peep Forsythia. (*Forsythia 'Golden Peep'*)  
 Kirilow Indigo. (*Indigofera kirilowii*)  
 Japanese Spirea. (*Spiraea japonica 'Little Princess'*, '*Goldmound'*)  
 Bumald Spirea. (*Spiraea x bumalda 'Goldflame'*)  
 Conoy Viburnum (*Viburnum x 'Conoy'*)

### **Native Evergreen Trees**

American Holly (*Ilex opaca*)  
 Eastern Red Cedar (*Juniperus virginiana 'Carnaertii'*; '*Burkii'*; '*Emerald Sentinel'*)  
 Southern Magnolia (*Magnolia grandiflora 'Bracken's Brown Beauty'*; '*D.D. Blanchard'*)  
 Evergreen Sweetbay Magnolia (*Magnolia virginiana var. australis 'Northern Belle'*, '*Henry Hicks'*)  
 White Pine (*Pinus strobus*)  
 Eastern Arborvitae (*Thuja occidentalis*)  
 Canadian Hemlock (*Tsuga canadensis*)

### **Non Native Evergreen Trees**

Nordman Fir (*Abies nordmaniana*)  
 Cedar of Lebanon (*Cedrus libani var. stenocoma*)  
 Needled Juniper (*Juniperus rigida*)  
 Norway Spruce (*Picea abies*)  
 Blue Spruce (*Picea pungens 'Hoopsi'*, '*Fat Albert'*, '*Moerheim'*)  
 Lacebark Pine (*Pinus bungeana*)  
 Swiss Stone Pine (*Pinus cembra*)  
 Tanyosho Pine (*Pinus densiflora 'Umbraculifera'*)  
 Limber Pine (*Pinus flexilis 'Vanderwolf's Pyramid'*)  
 Austrian Pine (*Pinus nigra*)  
 Japanese White Pine (*Pinus parviflora 'Glaucu'*)  
 Scots Pine (*Pinus sylvestris*)  
 Douglas Fir (*Pseudotsuga menziesii*)  
 Western Arborvitae (*Thuja plicata 'Spring Grove'*, '*Green Giant'*)

### **Evergreen Shrubs**

Boxwood (*Buxus 'Wintergreen'*, '*Winter Gem'*, '*Green Velvet'*, '*Green Mountain'*, '*Vardar Valley'*)  
 Blue Holly (*Ilex x meserveae 'Blue Prince'*, '*Blue Princess'*)  
 Grey Owl Juniper (*Juniperus virginiana 'Grey Owl'*)  
 Spreading Juniper (*Juniperus chinensis 'Sea Green'*, '*Old Gold'*, '*Gold Star'*, ....)  
 Blue Pacific Juniper (*Juniperus conferta 'Blue Pacific'*)  
 Blue Rug Juniper (*Juniperus horizontalis 'Wiltonii'*)  
 Oregon Grapeholly (*Mahonia aquifolium 'Compacta'*)  
 Mugo Pine (*Pinus mugo*)  
 Japanese Yew (*Taxus x media 'Runyan'*, '*Wardi'*, '*Densiformis'*)  
 Karen's Azalea (*Rhododendron 'Karen's'*)

### **Native Vines**

Cross-vine (*Bignonia capreolata 'Tangerine Beauty'*)  
 Trumpet Creeper (*Campsis radicans 'Flava'*, '*Mme Galen'*)  
 Virgin's Bower (*Clematis virginiana*)  
 Trumpet Honeysuckle (*Lonicera sempervirens 'Magnifica'*, '*Blanch Sandman'*, '*John Clayton'*)  
 Virginia Creeper (*Parthenocissus quinquefolia*)  
 Amethyst Falls Wisteria (*Wisteria frutescens 'Amethyst Falls'*)  
 Kentucky Wisteria (*Wisteria macrostachys*)

# CHAPTER F – BEST MANAGEMENT PRACTICES FOR TURFGRASS.

## INTRODUCTION

### Turfgrass and Rain Gardens

Turfgrass may be used with rain gardens in two ways. It may be used within the garden as vegetative cover, or it may be used around the garden to serve as a buffer between the garden and an impervious surface, such as a concrete parking lot. The dense vegetative growth of stems and blades found in a healthy stand of turfgrass acts as a physical barrier preventing water sheeting across the soil surface from washing out or overtopping the rain garden. Slowing surface sheeting also allows more water to infiltrate into the soil to recharge ground water.

Of course, turfgrass plants also absorb significant amounts water to be released into the atmosphere through a plant process called evapotranspiration. University research has shown that 8.5 million grass plants in a healthy 10,000 sq. ft. lawn absorb 6,000 gallons of rainwater and an average golf course of 150 acres can absorb 12 million gallons of water during a 3-inch rainfall. Studies conducted at the University of Wisconsin demonstrated that turfgrass species used in lawns will absorb water at rates similar to native prairie plant species. It is speculated the similarity is based on root density. While prairie plants have deeper root systems, turfgrass species have denser root systems; there are more roots per volume of soil to absorb water.

#### A. Turfgrass in the U.S.:

- 50,000,000 acres of managed turfgrass:
  - 80 - 100,000,000 home lawns
  - Over 775,000 sports fields
  - More than 17,000 golf courses
- Turfgrass in Ohio:
  - \$4.6 billion dollars in total economic impact
  - 41,000 employees



Fig. F-1: Storm water catch basin with turfgrass

Photo by Dave Dyke



Fig. F-2: Turfgrass used as a buffer between a parking lot and a rain garden

Photo by Joe Boggs



## B. The Value of Turfgrass:

### ■ Landscape Value:

- Used for aesthetic reasons
  - Deep green carpet-like growth enhances other landscape features
  - Imparts a feeling of spaciousness; gives width and depth to landscapes
- Used for practical reasons
  - No other living groundcover is as durable as turfgrass
  - Growing point rests at ground level allowing turfgrass to thicken and recover from foliar damage

### ■ Environmental Value:

- Reduces water run-off, improving water quality, and enhancing infiltration to recharge groundwater reserves. Aside from the aforementioned direct effects of dense turfgrass growth acting as a physical barrier to water flow and turfgrass plants absorbing and releasing rainwater through evapotranspiration, turfgrass also provides a home to earthworms. Earthworm populations of 200-300 earthworms per m<sup>2</sup> are common in turfgrass lawn: they increase the amount of macropore space within the soil that results in high soil water infiltration rates and water-retention capacity.
- Removes carbon from the atmosphere (carbon sequestering):
  - Every 2.5 acres of golf course turf sequester about one ton of carbon from the air per year
  - U.S. lawns remove 5% of carbon dioxide in the atmosphere
- Improves air quality:
  - Grass traps more than 12 million tons of dust and dirt annually. Trapped particles also include allergens such as plant pollen.
  - A 250 sq. ft. lawn produces enough oxygen for a family of four.
- Reduces energy costs:
  - Eight average size lawns have the cooling effect of 70 tons of air conditioning (1 ton = 12,000 BTU per hour, or 3,517 watts).

## C. What Turfgrass Cannot Do:

- It is not allowed to bloom
- It does not provide pollen or nectar
- It doesn't provide shade
- It has a limited landscape impact relative to form and function

## D. Turfgrass is a HIGH MAINTENANCE plant!



Fig. F-3: Typical Ohio landscape dominated by turfgrass

Photo by Dave Dyke



Fig. F-4: Landscape without turfgrass in southwest Ohio; a "gravel lawn"

Photo by Joe Boggs



## 5 POINTS FOR TURFGRASS SUCCESS:

1. Assess the soil – Do a soil test.
2. Use turfgrass in appropriate locations.
3. Select an appropriate turfgrass species, and the best turfgrass cultivars.
4. Use proper procedures to establish the turfgrass.
5. Properly maintain the turfgrass.

### STEP 1. Assess the Soil - Do a Soil Test

A) Soil tests are used by turfgrass managers like blood tests are used by physicians. Both types of tests disclose vital information this is mostly hidden from view.

#### 1) What a Soil Test Can Do:

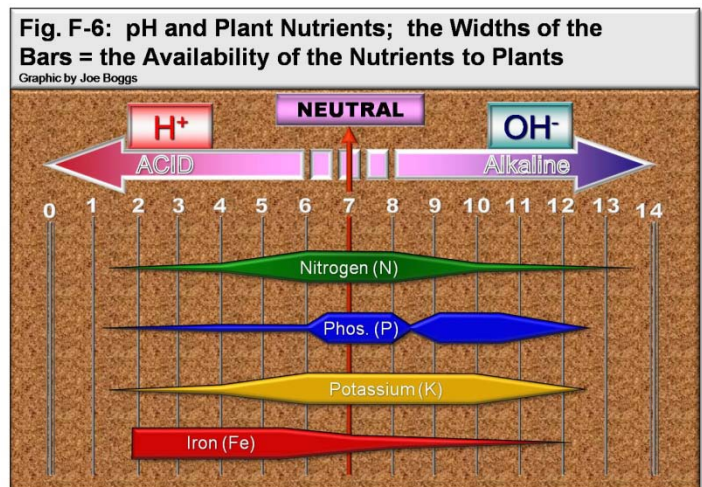
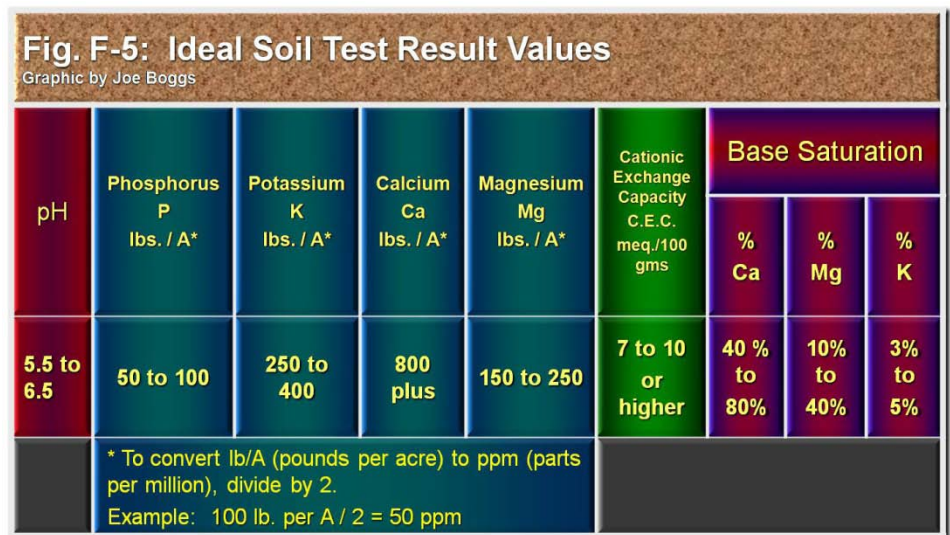
(a) Provides information important to understanding the chemical and physical qualities of the soil.

- Allows us to learn the soil's pH. This is a component of soil chemistry which may interfere with the way nutrients are made available to turfgrass plants.

- Discloses information about the nutrient content of the soil including phosphorus, potassium, calcium, and magnesium.

- The Cation Exchange Capacity (CEC) listed on soil test results provides a snapshot of the ability for the soil to hold onto and exchange positively charged nutrients (cations). Soils with a high CEC will remain fertile over a longer period of time, requiring fewer fertilizer applications, compared to a soil with a low CEC.

- Sand, silt, and clay are known as the "mineral components" of the soil, and the relative percentages of these particles in the soil is known as the "soil texture." Soil tests can allow us to learn the texture of the soil.





- Soil testing labs can also provide information on the organic content of the soil.

(b) Provides recommendations for correcting problems with soil nutrients.

- Problems with soil pH are addressed by lime recommendations to lower the pH, or sulfur (or other soil acidifiers) recommendations to lower soil pH.
- Problems with nutrient deficiencies are addressed by fertilizer recommendations.
- Conversely, a soil test will prevent over-application of nutrients which can be just as detrimental to the health of turfgrass as nutrient deficiencies.

2) What a Soil Test Cannot Do:

- (a) Standard soil testing labs do not provide information on general soil chemical contamination. While most soil testing labs can perform special tests (for an additional fee) to determine the concentrations of certain elements, such as "heavy metals" (e.g. lead, arsenic, etc.), the labs typically do not offer tests for pesticide contamination.
- (b) Soil testing labs can provide information on soil texture (percentage of sand, silt, and clay); however, they normally do not provide recommendations aimed at changing soil texture.
- (c) Standard soil testing labs do not provide information on nitrogen in soils. This element is subject to rapid movement into the soil, and rapid uptake by plants. Nitrogen concentrations change too rapidly for soil tests to provide accurate results for this element.

**B) Soil Testing Tips:**

- 1) "Do-it-yourself" Soil Tests versus Soil Testing Labs: Soil testing kits and equipment can be purchased; however, their overall quality and dependability is strongly associated with, "you get what you pay for." Given the expenses that can be incurred by making fertilizer application errors (e.g. too much or not enough), the expense of using a reputable soil testing lab is usually justified.

2) Equipment Needed:

- (a) A shovel or hand trowel, or a soil testing probe. Soil probes are comparable in price to a good quality shovel; however, they make it easier to take multiple soil samples.
- (b) A clean, plastic bucket. The bucket will be used to collect soil samples. Metal buckets can introduce contaminants into soil samples.

3) When Do You Soil Test?

- (a) A soil test should be performed prior to planting to allow enough time to make corrections based on soil test recommendations.
- (b) Soil testing should be repeated every 3 years for most mineral soils.
- (c) Soil tests can also be performed "as needed" as an aid to diagnosing lawn problems. Diagnostic soil tests target areas of the lawn that show symptoms associated with soil problems.

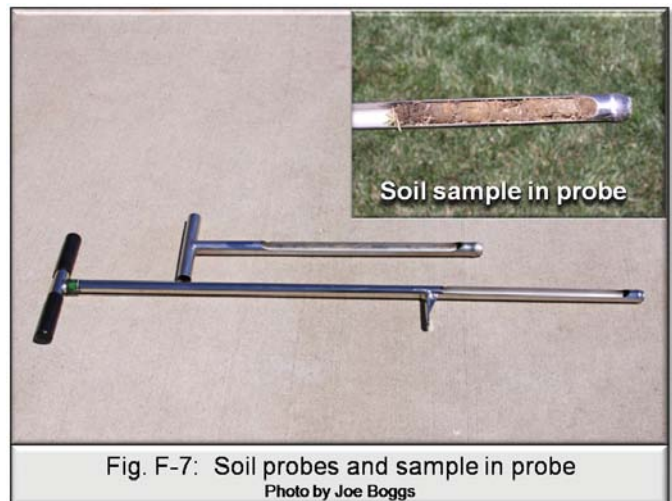
4) How Many Soil Tests?

(a) Different Plants = Different Tests:

- The recommendations from soil test results are based on the type of plants being cultivated.
- A lawn, a flower bed, and a vegetable garden would require three separate soil tests.

(b) Different Areas = Different Tests:

- Individual soil tests should focus on areas in the landscape that have the same soils.
- The front yard lawn of a home may have a different soil compared to the backyard lawn, so the two areas would require two different soil tests.



**5) How Many Samples Per Soil Test?**

- (a) There will be some variability in soils even within small areas. A single sample taken from a spot visited by a neighbor's dog will produce a highly inaccurate test result!
- (b) You should take several soil samples in the area that is covered by a single soil test. A general rule is to take 8 - 10 samples.
- (c) Mix these samples in a clean plastic bucket (do not use a metal bucket!), and remove a single "composite" sample from the bucket to be used for test.

**6) How to Take Soil Samples?**

- (a) Depth: 4 - 6" for turfgrass soil tests.
- (b) Remove the upper 1/4" of the sample to remove organic matter and debris.

**7) Getting More Help:**

- (a) In Hamilton County, OH, soil testing kits are available through the Hamilton County Soil and Water Conservation District. Soil testing boxes and instructions can be obtained from their office for \$10.00/box or \$12.00 if they are mailed to you. Call their office at 772-7645 for further information, or visit their website at: <http://www.hcswcd.org/about/default.asp>

## **Don't Guess, Soil Test!**

### **STEP 2. Use Turfgrass in Appropriate Locations**

*"The lawn is the canvass upon which we paint the rest of the landscape"*

– Alex Cusnow

**A)** While turfgrass has a significant place in landscapes, it should not be the dominant feature of landscapes.

**B)** The proper use of turfgrass should be framed within the overall landscape design to enhance, not detract, from the design.

**1) Trees and Turfgrass do not get along:**

**(a) Tree Root Morphology:**

- Most (>90%) of the tree roots are in the upper 3' of soil.
- Of these, more than 80% of the "feeder roots" are in the upper 6" of soil. This is exactly where the turfgrass roots grow.
- Horizontal root spread is 2.5 - 3.0 times crown spread.
- Most roots (>60%) are outside the drip line.

**(b) Trees**

- Produce too much shade for the healthy growth of most turfgrass species.
- Compete with turfgrass for resources (e.g. water, nutrients, etc.).

**(c) Other plants, such as moss and weeds, will be favored.**

**2) Reducing Tree/Turfgrass Plant Competition**

- (a) Use mulch (mulch rings) around trees.
- (b) Plant non-competitive companion plants around trees.



Fig. F-8: Proper use of turfgrass within the landscaping  
Photo by Joe Boggs

## STEP 3. Select an Appropriate Species and Quality Cultivars

### Some Turfgrass Basics:

#### A) Turfgrass Growth:

- 1) Turfgrass blades grow from a central point of meristematic tissue (meaning cells can differentiate and become new structures) called the "Crown."
- 2) Crowns are positioned on the surface, either the thatch surface, or the soil surface where no thatch exists.

#### B) Based on general turfgrass growth characteristics, there are two types of turfgrasses:

- 1) "Bunch Grasses:" does not spread beyond the width of lateral upright stems called "tillers."
  - (a) Bunch grasses include:
    - Fescues
    - Ryegrasses

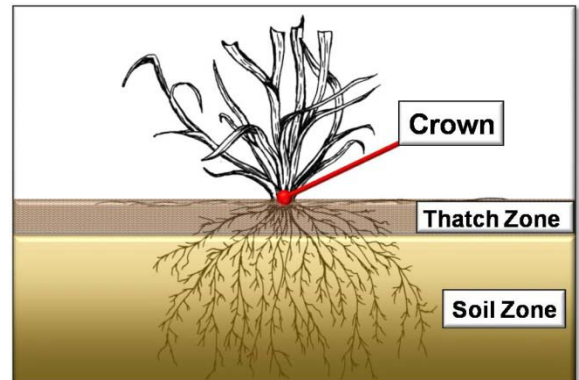


Fig. F-9: Basic structure of a turfgrass plant  
Graphic by Joe Boggs

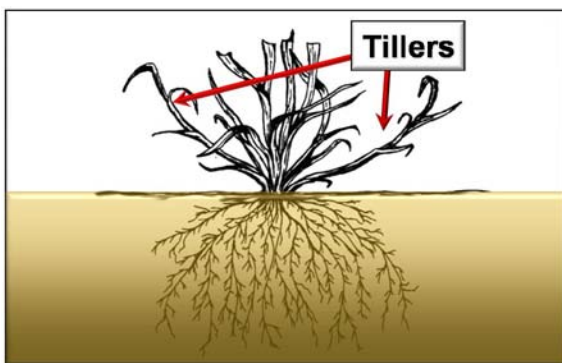


Fig. F-11: A "Bunch Grass"  
Graphic by Joe Boggs

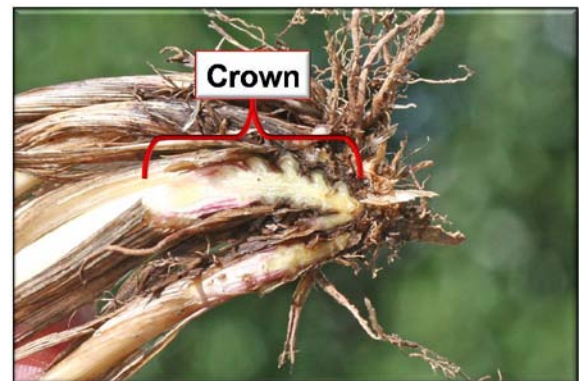


Fig. F-10: Turfgrass Crown, the growing point  
Photo by Joe Boggs

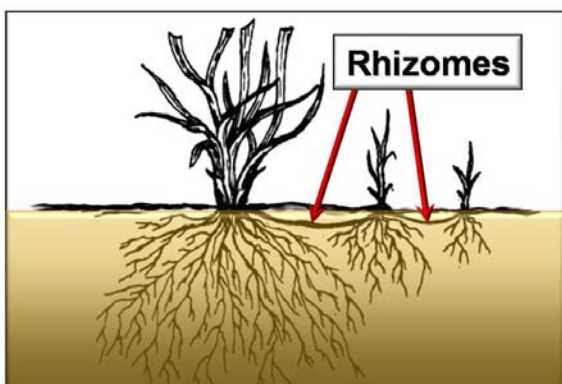


Fig. F-13: A rhizomatous "spreading" grass  
Graphic by Joe Boggs

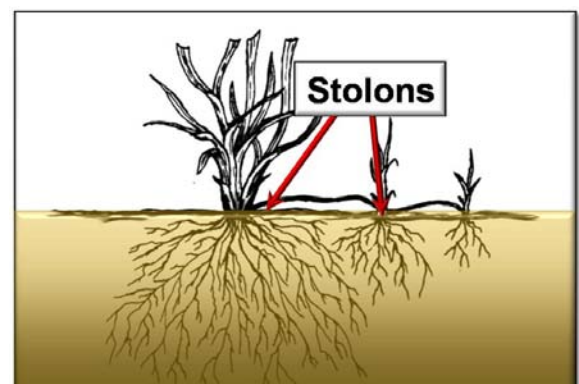


Fig. F-12: A stoloniferous "spreading" grass  
Graphic by Joe Boggs

- 2) "Spreading Grasses:" spread by producing stems
  - (a) Stolon = a stem growing above the ground.
  - (b) Rhizomes = a stem growing beneath the ground.
  - (c) Spreading grasses include:
    - Bluegrasses
    - Bentgrasses
  - (d) **Note:** thatch is non-decayed stems, either non-decayed stolons or rhizomes.

C) Cool-Season vs. Warm-Season Grasses

- 1) Cool-Season Grasses:
  - (a) Grow and look best in the spring and fall.
  - (b) Are able to go dormant in the summer.
- 2) Warm-Season Grasses:
  - (a) Grow and look best in the summer.
  - (b) Are able to go dormant in the fall – winter.

D) Cool-Season Grasses: in general, these are the preferred grasses used as turfgrass in southwest Ohio lawns.

1) The Bluegrasses (*Poa* sp.)

- (a) Three common species:
  - Kentucky Bluegrass (*Poa pratensis*)
  - Rough Bluegrass (*Poa trivialis*): considered an invasive, non-preferred grass.
  - Annual Bluegrass (*Poa annua*): considered an invasive "weed" grass.

(b) Kentucky Bluegrass Characteristics:

- Positives:
  - Dark blue-green color.
  - Fine to medium texture.
  - Capable of going dormant during hot, dry weather. Newer cultivars are highly heat tolerant.
  - Each plant is capable of spreading by producing rhizomes.
  - The rhizomes become thatch which provides a cushioned feel when walking on a bluegrass lawn.



Fig. F-14: Kentucky bluegrass  
Photo by Joe Boggs



Fig. F-16: Bluegrass boat-shaped blade tip  
Photo by Joe Boggs



Fig. F-15: Bluegrass blade folded in sheath  
Photo by Joe Boggs

■ Negatives:

- Requires moist, well-drained soils.
- Will not tolerate heavy shade.
- Has a high fertility requirement for maximum performance.
- Seeds require 21 – 27 days to germinate.
- Susceptible to a number of insect and disease problems.
- Thatch accumulation: if rhizomes are produced faster than they decay (e.g. over fertilization with nitrogen), the thatch can accumulate to an unhealthy thickness interfering with water movement, root penetration, and air/soil gas exchange (See "Thatch Management" below).

2) The Fescues (*Festuca* sp.)

(a) "Turf-Type" TALL FESCUE (*Festuca arundinacea*):

■ Positives:

- Highly wear tolerant.
- Capable of performing well across a range of soil conditions, but generally does best in moist, well-drained soils.
- Medium shade tolerance.
- High drought tolerance on deep soils; however, medium to low drought tolerance on heavy soils.
- Some cultivars have endophytic fungi which provide resistance to certain insect pests (see below).
- Highly competitive once it becomes established, usually during the second season.
- Will perform under low fertility, but does best under medium to high fertility.
- Seeds germinate in 7 – 14 days.
- Does not produce rhizomes or stolons, so it is less subject to producing thatch.



- Negatives:
  - A wide color range, but generally medium to light green.
  - Medium to coarse texture; however, this can be influenced by stand density. Insect pest and disease susceptibility has become an issue in recent years.
  - This is a "bunch" grass which means it cannot spread. Lawns must be over-seeded periodically to maintain thick plant density.

(b) "Fine" or "Fine Leaf" Fescues:

- Three common species:
  - Red Fescue (*Festuca rubra*)
  - Chewing Fescue (*Festuca rubra* var. *commutata*)
  - Hard Fescue (*Festuca ovina* var. *duriuscula*)
- Fine Fescue Characteristics:
  - Positives:
    - ✓ Dark green color.
    - ✓ High shade tolerance; one of the highest for cool-season grasses.
    - ✓ Performs well under low fertility.
  - Negatives:
    - ✓ Extremely fine, wire-like blade texture (almost "hair-like").
    - ✓ The blade texture makes fine fescues very difficult to mow.
    - ✓ A "bunch" grass which means it does not spread.
    - ✓ Requires well-drained, slightly dry soils.
    - ✓ **NOTE:** the significant negative characteristics make fine fescues one our least desirable grasses for use as turfgrass in home lawns.

3) The Ryegrasses (*Lolium* sp.)

(a) Two common species:

- Perennial Ryegrass (*Lolium perenne*)
- Italian (annual) Ryegrass (*Lolium multiflorum*): historically used in seed mixes as a "nurse crop" to provide coverage until preferred turfgrass species germinate, but this is no longer a recommended practice.

(b) Perennial Ryegrass Characteristics:

- Positives:
  - ✓ Generally, a dark green color.
  - ✓ Prominent parallel leaf veins make the blades highly reflective. This "sheen" is utilized in athletic fields to enhance mower stripes.
  - ✓ Rapid seed germination (3 – 7 days) and establishment. This is the most competitive cool-season grass species.
  - ✓ Will perform at medium fertility, but does best under high fertility.
  - ✓ Does not produce rhizomes or stolons, so it is less subject to producing thatch.
- Negatives
  - ✓ A small, compact plant coupled with a fine to medium blade texture requires a high plant density to produce thick lawns.
  - ✓ This is a "bunch" grass which means it cannot spread. Lawns must be over-seeded periodically to maintain thick plant density.
  - ✓ Highly susceptible to certain fungal diseases that can kill plants.
- **NOTE:** while perennial ryegrass is used as turfgrass in some lawns, this species is generally viewed as less desirable compared to Kentucky bluegrass and turf-type tall fescue.



Fig. F-20: Perennial ryegrass lawn  
Photo by Joe Boggs

## E) Warm-Season Grasses:

- 1) In general, warm-season grasses are rarely used as turfgrass in southern Ohio lawns. However, there are three species that deserve mention:
  - (a) The Bermudagrasses (*Cynodon* sp.)
  - (b) The Zoysiagrasses (*Zoysia* sp.)
  - (c) Buffalograss (*Buchloe dactyloides*)
- 2) The primary reason these grasses are not used is because they go dormant and turn brown in the fall. They remain dormant throughout the winter, and become green again in the spring.
- 3) Another reason these species are not typically used in Ohio lawns is associated with the invasive nature of these grasses, particularly Zoysiagrass. The three species are "spreading grasses" which means individual plants give rise to additional plants.
- 4) However, some cultivars of Zoysiagrass are highly heat tolerant, and buffalograss is both heat and drought tolerant.
- 5) Several university turfgrass breeding programs are working to develop cultivars of these species that do not go dormant in the fall, or that remain dormant for shorter periods of time. To date, no cultivars these desired characteristics have been developed.

## F) Turfgrass Selection Considerations:

### 1) Species – Varieties – Cultivars

- (a) Species: are naturally occurring with slight inherent genetic variations
- (b) Varieties: are naturally occurring based on a type(s) of genetic variation.
  - There are very few naturally occurring varieties that are used as turfgrass in lawns.
  - Kentucky 31 is a variety of tall fescue discovered in 1931 in Kentucky. This is not a recommended grass for lawns since there have been no improvements through genetic selection since 1931.
- (c) Cultivars:
  - Do not occur naturally. The term means "cultivated varieties."
  - People select desired genetic traits found among varieties. They then "cross" the varieties to produce a new form with the desired traits.
  - While grass seed labels frequently refer to the contents as "varieties," in most cases, the bag actually contains cultivars.
  - This is an important distinction since cultivars represent continual improvement of a grass species based on genetic selection.

### 2) Grass Seed Mixtures vs. Blends:

- (a) A mixture is two or more species.
  - Example: a bag of seed with Kentucky bluegrass and perennial ryegrass would be a mixture.
  - Using a mixture of different species of grass can present challenges in maintaining a consistent appearance throughout the lawn:
    - Different species have a tendency to become segregated over time producing "patchy" lawns.
    - Different species may respond differently to pest, disease, and environmental problems resulting in the loss of one species. This can produce open areas in a lawn.
- (b) A blend is the same species, but two or more cultivars.
  - Example: a bag of seed with two or more Kentucky bluegrass cultivars would be a blend.
  - Blends have become more popular in recent years to take advantage of the continual improvements through plant selection, and to avoid struggles with maintaining consistency in multi-specie lawns.

### 3) National Turfgrass Evaluation Program (NTEP):

- (a) Sponsored by:
  - United States Department of Agriculture, Agricultural Research Service (USDA, ARS).
  - National Turfgrass Federation.
- (b) NTEP trials test turfgrass cultivars at sites located throughout North America. Consequently, the cultivars are subjected to a wide-range of environmental conditions.

- (c) The trials results are considered non-biased, and research based making the NTEP program one of the best sources of non-commercialized information on the performance of turfgrass cultivars.
- (d) Trial results can be viewed on the NTEP website: [www.ntep.org](http://www.ntep.org)

#### 4) Endophytic Fungi: Natural Insect Pest Control

- (a) Endo = within; Phyte = plan
- (b) Grass endophytes are intercellular fungi that live symbiotically within grass plants.
  - The fungi produce no external structures (fruiting bodies), and they occur only as hyphae between cells.
  - The fungi are passed on to the next generation of grass plants only through grass seed (not "contagious").
  - The fungi help to protect their plant hosts by producing toxic alkaloid chemicals that kill "top feeding" insects.
- (c) Insects that are affected by these natural insecticides include:
  - Billbugs
  - Chinch bugs
  - Sod webworms
  - Common armyworm
  - Fall armyworm
  - Greenbug aphid
- (d) Insects that are not affected by endophyte alkaloids include:
  - White Grubs
  - Black Cutworms
- (e) Grass species that are known to have endophytic fungi:
  - Tall fescue
  - Fine Fescue
  - Perennial ryegrass
- (f) Grass species that are unknown to have endophytic fungi:
  - Kentucky bluegrass
  - Bentgrasses



Fig. F-21: Chinch bug damage in southwest Ohio  
Photo by Joe Boggs

- (g) **NOTE:** endophyte alkaloids are known to be toxic to grazing animals. In fact, the fungi were first discovered and identified in New Zealand as causing a condition in sheep known as "blind staggers." Endophytic grasses should not be used in locations where animals may graze.

## STEP 4. Use Proper Procedures to Establish Turfgrass

### A) General Seeding Recommendations:

- 1) Always use a "starter" fertilizer at the time of seeding, and 3 – 4 weeks later. This will provide nutrients at the soil surface to support seedling growth and establishment.
- 2) Apply water immediately after seeding. Water initiates seed germination.
- 3) Know how long it takes for the seed to germinate.
- 4) The best time to seed is in early September:
  - (a) There is a saying: "A bad fall seeding is still better than a good spring seeding."
  - (b) While this may only be partially true, a fall seeding allows the new seedlings to become established in the fall, and to continue to mature the following spring. The well established fall-seeded plants will have a greater ability to handle the hot, dry months of July and August compared to spring-seeded plants.



## B) Herbicides and Grass Seeding:

- 1) If you are planning to spread grass seed, be very careful with using herbicides.
- 2) Herbicides are designed to kill plants, or to prevent plant seeds from successfully germinating (See "Weed, Pest, and Disease Management" below).
- 3) Herbicides do not discriminate between preferred plants, such as turfgrass, and non-preferred plants such as weeds.
- 4) General Recommendations:
  - (a) Always read and follow label directions. This recommendation applies to all pesticides!
  - (b) Do not use an herbicide that affects plant seed germination if you are planning spread grass seed. The herbicide may prevent the grass seed from successfully germinating.
  - (c) If you plan to use an herbicide that kills plants, pay close attention to the label recommendations regarding the length of time between the herbicide application date and the date when it is safe to sow grass seed. Some of these herbicides will kill grass seedlings.

## C) A Word About Seed Spreaders:

- 1) There are two types of spreaders that can be used to spread seed:
  - (a) Drop Spreader:
    - This type of spreader has a seed box positioned between two wheels. Seed drops through a horizontal slot at the bottom of the box, thus the seed only falls between the two wheels.
    - Drop spreaders are used for precise spreading of seed.
    - They are most suitable for small areas.
    - They are often used in conjunction with a broadcast spreader to avoid throwing seed into landscaped areas (e.g. flower beds).



- (b) Broadcast (Rotary or Cyclone) Spreaders:

- Push Type
  - This type of spreader has a seed box positioned above the wheels. Beneath the box is a small slot that allows the seed to fall on a rotating disk. The disk throws the seed ahead and to the sides of the spreader.
  - Seed is cast in a band that is 5 – 8' wide, depending upon the spreader.
  - Used to apply seed over large areas.
- Hand-Held Type:
  - The seed box and rotary disk are contained in a small, hand-held unit.
  - Used for very small areas, or to "spot seed."

(c) **NOTE:** Seed spreaders are also used to apply fertilizer.

## D) Seed Germination Times:

- 1) Knowing how long it takes for seeds to germinate reduces concern that something has gone wrong! Remember that the time it takes for seeds to germinate is related to temperature and moisture.
- 2) Following are germination times for the three main cool-season grasses used in Ohio lawns:
  - (a) Kentucky Bluegrass: 21 - 27 days
  - (b) Turf-Type Tall Fescue: 7 - 14 days
  - (c) Perennial Ryegrass: 3 - 7 days

### 3) Seeding Rates:

- (a) It is also important to know the recommended seeding rate for the species of turfgrass you are seeding.
- Using less than the recommended rate will produce thin lawns.
  - Using more than the recommended rate will:
    - Waste seed.
    - Produce plant crowding which slows turfgrass establishment and maturation.
    - Makes the new grass plants more susceptible to certain diseases.
  - Following are seeding rates for selected turfgrass species:
    - Kentucky bluegrass = 1 to 1.5 lbs. / 1000 sq.ft. (15 - 23 seeds/sq. in)
    - Tall Fescue = 7 to 9 lbs. / 1000 sq.ft. (11 - 14 seeds/sq. in)
    - Perennial Ryegrass = 7 to 9 lbs. / 1000 sq.ft. (11 - 14 seeds/sq. in)
    - Fine Fescue = 3.5 to 4.5 lbs / 1000 sq.ft. (13 - 17 seeds/sq. in)
- (b) **NOTE:** Seeding rates are based on the weight of the seed, and Kentucky bluegrass has very small seeds which weigh less than the seeds of other species. Grass seed is also sold by the pound. This is why Kentucky bluegrass often appears to be more expensive than other species; a 50 lb. bag of bluegrass seed will cost more than a 50 lb. bag of tall fescue. However, the seeding rate for Kentucky bluegrass is much lower than tall fescue, so the 50 lb. bag covers a much larger area.

## E) Methods to Improve Existing Lawns or Establish New Lawns:

### 1) "Rejuvenation"

- (a) This method is used to improve an existing lawn by introducing seed to an existing lawn:
- It is usually done to improve the plant density of a lawn that is thinning due to drought, insects, disease, etc.
  - The existing turfgrass and weeds are not killed.
  - The seed can be applied simply by over-seeding with a spreader; however, it is best to use a "slice-seeder" (also known as a "slit-seeder," see "Renovation" below) to place the seed in contact with the soil.
  - It is best to keep the existing grass mowed lower than normal until the seed germinates to reduce competition between the seedlings and the mature plants.
  - Best time of the year: September



Fig. F-23: Slice seeding a home lawn  
Photo by Joe Boggs

### (b) Winter Seeding:

- This is actually a form of Rejuvenation; however, the seeding occurs during the winter months.
  - The Goals:
    - ✓ To thicken lawns damaged during the fall.
    - ✓ To correct winter damage (freeze; snow molds, etc.).
  - Problems with Winter Seeding:
    - Research shows a 50% success rate; that is a 50:50 chance of good results: bad results.
    - Turfgrass seed has no cold temperature dormancy. The seed can germinate in winter, and the seedlings may be killed by freezing temperatures.
  - Solutions:
    - Delay seeding until March.
    - Rake the lawn to remove dead / matted grass and expose the soil to seed.
    - DO NOT apply a preemergent herbicide in the spring.

## 2) Renovation:

(a) This method is used to reestablish a new lawn because of an excessive loss of turfgrass or a heavy weed infestation.

### (b) Steps:

- The existing turfgrass and weeds are killed using a non-residual, postemergent, non-selective herbicide such as glyphosate (e.g. Roundup®) or glufosinate (e.g. Finale®).
- The effective elimination of existing turfgrass and weeds usually requires at least two herbicide applications. And, the target plants must be healthy and growing.
  - Read and follow label directions closely to determine the length of time between applications.
  - If the plants targeted to be killed by the herbicide are suffering from lack of water, the lawn will need to be irrigated to make certain the plants are healthy and growing ... so they can be killed!
  - Adjust watering and herbicide application timing based on the planned date for sowing the new grass seed. For example, if the seeding date is the first of September, irrigating the old lawn may need to be started in late-July to early August, depending on the recommended time between herbicide applications, and the time before new seed can be sown.
  - Lawn renovation does not usually require the use of straw, except in bare areas. The grass and weeds killed by the herbicide will serve the same function as straw.



(c) Best Seeding Method: Use a slice-seeder (slit-seeder).

- A slice-seeder uses cutting discs to slice through the organic matter at the soil surface to place turfgrass seeds in direct contact with the soil.
- Adjust the depth of the slicing discs to create slits on the surface of the soil. **DO NOT BURY GRASS SEED!** Maximum germination of grass seed occurs when the seed is in contact with the soil, but exposed to sunlight.

(d) Follow the "General Seeding Recommendations" presented above regarding watering and fertilizing the new lawn.

(e) Best Time to Sow Seed: the first of September; however, the herbicide must be applied in August.

## 3) Seeding a New Lawn on Bare Soil:

(a) Seeding a new lawn on bare soil is done under the following circumstances:

- A heavy thatch must be removed using a sod-cutter or by roto-tilling.
- Extensive problems with the soil must be corrected (e.g. heavy clay).
- New construction.

(b) Direct Seeding Onto Bare Soil Requires:

- Extensive grading and site preparation prior to seeding. The soil must be prepared to a "seed bed" quality.
- The grass seed can be sown with a spread, a slice-seeder, or other methods (see "Hydro-Seed" below).
- Some form of a seed/soil stabilization and moisture management material must be used.
  - Straw:
    - ✓ Only use wheat straw. Do not use hay since this material will contain plant seed.
    - ✓ Only apply to 50% coverage.
      - Too much straw will shade the grass seed which inhibits seed germination.
      - Straw does not need to be removed once grass seedlings appear. Too much straw requires straw removal which damages the tender seedlings.

- ✓ It is best to limit the use of straw to gentle slopes to avoid loss of straw and seed by water run-off. Netting can be applied over the straw to provide some stability relative to wind and water run-off.
  - **Seed Mats / Mulch Mats:**
    - ✓ Seed or mulch mats are composed of organic material (e.g. compressed straw, shredded paper, coconut husks, etc.) and the mats are rolled over seeded ground to help stabilize the system, particularly on sloped ground.
    - ✓ This method is useful for seeding extreme slopes.
    - ✓ Most mats are designed to decompose as the grass plants become established; however, some require removal once seeds begin to germinate.
  - **Hydro-Mulching / Hydro-Seeding:**
    - ✓ Hydro-mulch is a mixture of water and processed cellulose (e.g. paper) that is sprayed over seeded ground. Hydro-Seeding means that grass seed is included in the slurry.
    - ✓ This method is useful for seeding extreme slopes or hard to reach areas.
    - ✓ **NOTE:** moisture levels must be closely monitored and maintained because the organic matter may become hydrophobic (repels water!) once it dries out.
- (c) Best time of the year to sow grass seed: first of September.

#### 4) Sodding:

(a) Sod consists of mature turfgrass plants that have their root system removed.

(b) Sodding is used to quickly establish new turfgrass.

■ **Advantages:**

- Produces an immediate result.
- Quickly stabilizes the soil to prevent water and wind erosion.
- Prevents weed seed germination.
- Can be done anytime of the year when turfgrass roots will grow.

■ **Some Considerations:**

- Sodding can be more expensive than seeding.
- Sod will rapidly dry out once it is harvested. Ideally, sod should be installed the same day that it is harvested from the sod farm.
- Success requires experience and close attention to proper installation.
- Sod establishment requires a heavy use of water, and close monitoring to adjust irrigation after the turf roots grow into the soil (called "knitting").

(c) Site Preparation and Installation:

- All existing plant material (e.g. turfgrass, weeds, etc.) must be removed.
- Soil must be leveled and all debris (e.g. roots, stones, etc.) removed.
- A starter fertilizer should be applied prior to sod installation.
- The soil should be dry.
- Sod **MUST** be installed in direct contact with soil. A light rolling helps to assure good sod-soil contact.
- Sections of sod **MUST** be in tight contact with one another. Gaps between sections will not close, and will result in drying and death of nearby grass plants.
- Sod **MUST** be irrigated **IMMEDIATELY** after installation. If a large area is being covered, water should be applied periodically to installed areas so sod does not dry out.

(d) **NOTE:** Kentucky bluegrass sod has a thin thatch layer which helps to hold the sod together during harvest and installation. This layer should be closely inspected and should not be greater than about 1/2" in thickness.



## STEP 5. Properly Maintain the Turfgrass

### A) FERTILIZATION

#### 1) Fertilizer Applications: it's about the macro nutrients

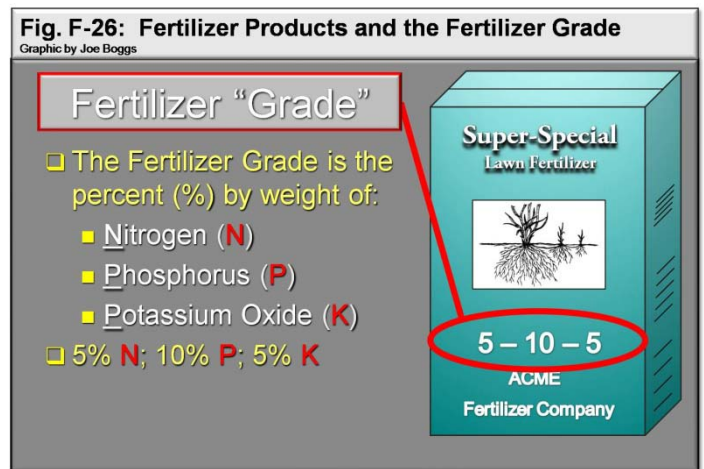
- (a) Macro nutrients are elements that are heavily used by plants. The three most significant macro nutrients are nitrogen (N), phosphorus (P), and potassium (K).
- (b) In turfgrass management, Nitrogen is given the most attention because:
  - It moves rapidly through the soil, consequently N is not normally measure in soil tests.
  - "Preventative" applications are made based on time of year
- (c) Phosphorus and Potassium move slowly through the soil
  - Needs and rates are based on soil test results
  - "Curative" application rates and recommendations are based on soil test results.

#### 2) Fertilizer Grade: the percent, by weight of N-P-K in a fertilizer product.

- (a) 10-6-4 fertilizer would have: 10% nitrogen; 6% phosphorus; and 4% potassium.
- (b) A 100 lb. bag of that fertilizer would have: 10 lbs. of N; 6 lbs. of phosphorus; and 4 lbs. of potassium.

#### 3) Fertilization Schedules:

- (a) Turfgrass quality is significantly enhanced by fertilizer applications. However, too much fertilizer can have the opposite effect.
- (b) Four applications are recommended per year in Ohio. Some lawncare companies make 6 – 8 applications per year. They are not over-applying fertilizer, just applying lower amounts per application to avoid "nutrient spikes."
- (c) Note that the following table provides adjusted rates to account for nitrogen from grass clippings returned by mulching mowers. The aim is to avoid over-fertilization of the turfgrass.



**Fig. F-27: Ohio turfgrass fertilization schedule**  
Graphic by Joe Boggs

Fertilizer Grades	Application Dates			
	March	Late May – Early June	Early Sept.	Oct. / Nov. / Dec.
10-6-4	5 – 10 *	10	10	10 - 20
19-3-3	2.5 - 5	5	5	5 – 10
Changes to rates if CLIPPINGS are RETURNED (Mulching Mower)				
10-6-4	2.5 – 5	5	10	10 - 20
19-3-3	1.25 – 2.5	2.5	5	5 – 10
* Rates: Pounds of actual fertilizer per 1,000 sq. ft.				

#### 4) Fertilizer Applications:

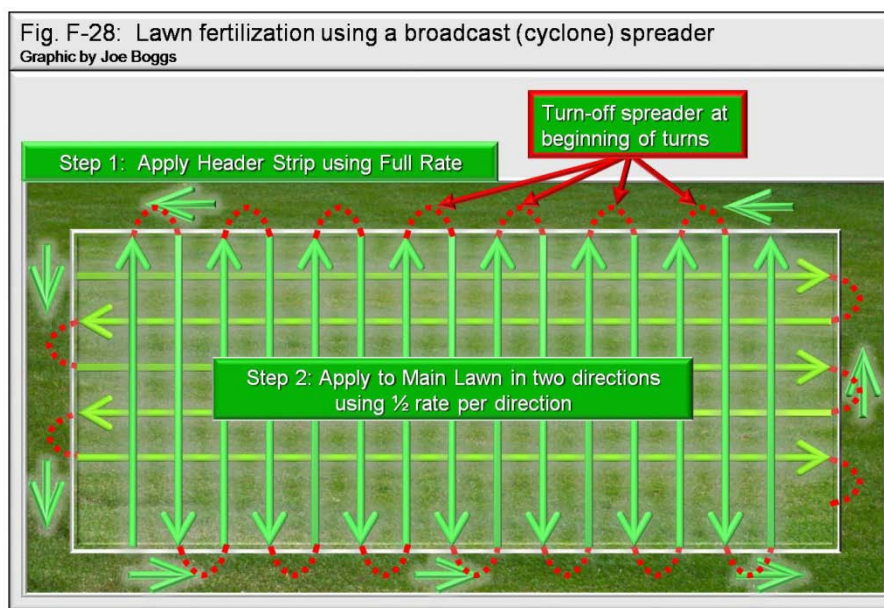
(a) Spreaders: Fertilizer spreaders are the same as the "seed spreaders" described in "A Word About Seed Spreaders" above.

##### ■ Drop-Spreaders:

- Drop-spreaders apply fertilizer in a very precise band measured by the width of the spreader hopper.
- These spreaders are recommended for boundary areas (e.g. near flower beds, sidewalks, etc.) to prevent fertilizer from being applied to non-target areas.
- Drop-spreaders are recommended for small areas. It is very difficult to accurately gauge where the fertilizer is being applied, thus these spreaders frequently produce unsightly "banding" in lawns.

##### ■ Broadcast (Rotary or Cyclone) Spreaders:

- Rotary spreaders can cast fertilizer over a wide band measuring 5 – 8', depending upon the spreader model.
- The spreaders are recommended for applications made to large areas; however, inaccurate overlaps of applications can also produce unsightly banding. The following graphic shows how to avoid fertilizer banding with a rotary spreader:



#### 5) Limiting the Impact of Fertilizers on Water Quality:

(a) Utilize fertilizer products that have a high concentration of a slow-release form of nitrogen.

■ Nitrogen in a quick-release form (e.g. urea) will be released faster than can be absorbed by grass plants.

■ The free nitrogen is subject to being moved off-site by water runoff.

(b) Extreme care should be taken not allow fertilizer to be cast onto non-target hard surfaces, such as onto sidewalks, driveways, and streets.

■ Nutrients will be washed into waterways causing contamination.

■ Such areas should be closely inspected immediately after a fertilizer application, and errant fertilizer gradually swept back into the turfgrass with a broom, or blown back with a leaf blower.

(c) Fertilizer applications should not be made when soils are frozen, or when soils are extremely dry. These soils will allow nutrients to runoff.

(d) Fertilizer applications should not be made directly adjacent to water, such as next to ponds or streams.

■ This will directly contaminate the water with fertilizer-based nutrients.

■ A buffer "no fertilizer" zone of 10 – 25 feet, depending upon the slope, should be maintained between the fertilizer target site and water. If turfgrass fails to thrive in this low fertility zone, consider selecting plants for that thrive at lower levels of soil fertility. Do not let the zone become denuded of plant growth since bare soil can behave like concrete regarding water and nutrient runoff.

## B) MOWING

### 1) There are two types of mowers used in turfgrass management:

#### (a) Reel Mowers:

- These mowers have a helical blade that cuts across a stationary blade called the "bed knife."
- Both sets of blades must be kept razor-sharp to maximize the effectiveness of the mower.
- Reel mowers provide a very precise cut of the turfgrass blades; however, they are most effective on grass blades that are only slightly longer than the height of the bed knife. Thus, they are mostly used on close-cut turfgrass such as on athletic fields and golf courses.

#### (b) Rotary Mowers:

- These mowers have a rotary blade, or blades, that cut grass by a force that is related to the speed of the blade.
- Rotary mower blades should not be kept razor-sharp since the thin metal edges will be broken and/or rolled during mowing.

### 2) "Bagging" vs. "Mulching" mowers:

#### (a) Bagging Mowers:

- Mowers that collect clippings in a bag are called "bagging" mowers.
- These mowers were originally developed to provide a "clean" look to newly mowed lawns.
- Bagging mowers remain effective in enhancing the appearance of a fresh-cut lawn; however, they also generate yard waste.
- It is recommended that the collected clippings be composted on-site and the organic matter returned to the landscape rather than removed and deposited in a landfill.

### 3) Mulching Mowers:

- (a) These mowers return grass clippings or fallen tree leaves to the soil.
- (b) As noted in the fertilization section, mulching mowers have a beneficial impact on nutrient recycling by allowing the nutrients locked in the grass blades to be returned to the soil.
- (c) Early mulching mowers were challenged by long, wet grass. However, newer, better designed mulching mowers are highly effective across a range of turfgrass conditions.

### 4) Mowing Practices:

#### (a) Mowing Height & Frequency:

- It is recommended that mowers be adjusted to cut grass to a height of between 2 1/2 – 3", and grass is cut frequently enough to avoid removing more than 1/3rd of the blade during mowing. This is commonly known as the "1/3rd Rule."
- These recommendations are based on the way turfgrass distributes carbohydrates in support of plant growth:
  - Turfgrass plants will continually direct the carbohydrates that are produced through photosynthesis towards the re-growth of blades, at the expense of root growth. In other words, blade growth is prioritized over root growth.
  - As a result, high-cut turfgrass develops larger root systems compared to close-cut turfgrass. The close-cut plants are continually trying to re-grow cut blades!



Fig. F-29: Proper mowing height / frequency following the "1/3rd" rule

Photo by Joe Boggs

- 
- (b) Mowing Directions:
  - Turfgrass that is continually mowed in the same direction will eventually start to grow in that direction. This produces an unsightly pattern known as "graining" within the lawn.

To avoid this problem, turf should be mowed in different directions, across the bias, as shown in Figures F-30 and F-31.

Ideally, the weekly changes in mowing direction should be at 90 degree angles to one another; however, even 45 degree changes in mowing directions will effectively prevent the development of graining in turfgrass growth.

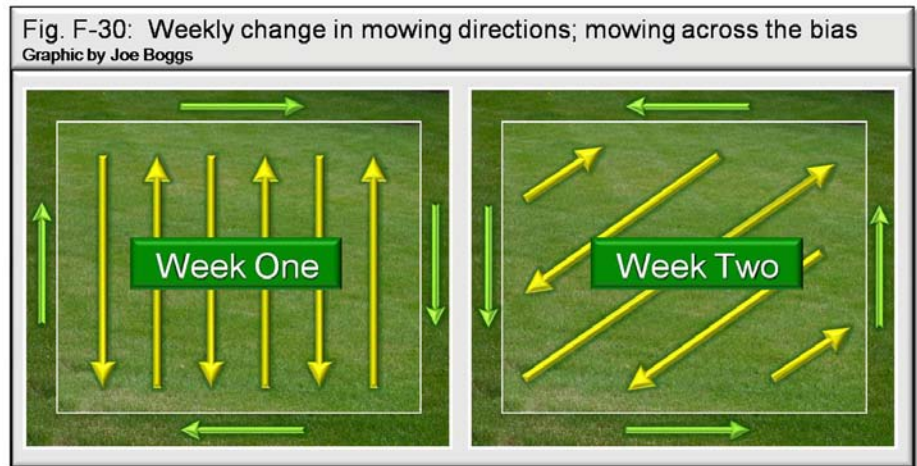


Fig. F-31: Photo of mowing pattern with weekly change in mowing directions; mowing across the bias  
Photo by Joe Boggs

## C) THATCH MANAGEMENT / CORE AERATION

### 1) What is Thatch?

- (a) Thatch is non-decayed stems (stolons or rhizomes).
  - Stolons and rhizomes contain lignin, the same chemical compound that provides structural rigidity to tree wood.
  - Grass blades cut during mowing do not contribute to thatch since the blades are comprised of over 70% water, and they have little to no lignin.
- (b) For certain species of turfgrass, thatch is a naturally occurring part of the turfgrass ecosystem. For example, bluegrass and bentgrass ecosystems always have a thatch layer that is located between the crowns of the plant, and the soil.

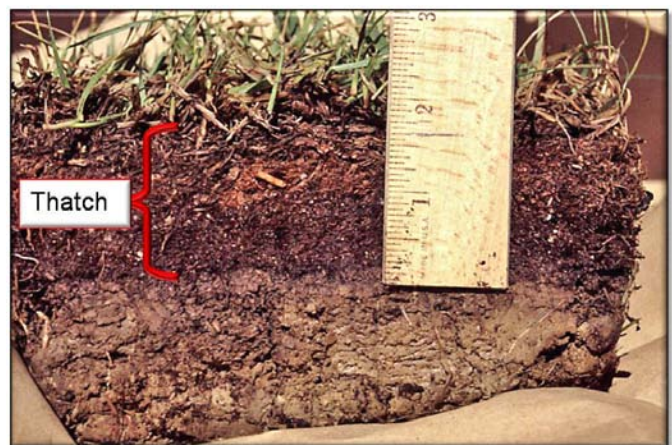


Fig. F-32: Excessive thatch layer  
Photo by Joe Boggs



## 2) What is Wrong with Thatch?

(a) Inherently, there is nothing wrong with thatch until it becomes too thick.

- Thatch that is between 1/2 – 3/4" thick causes no harm to the overlaying turfgrass plants, and the thatch layer actually gives the lawn a pleasant, springy "feel" when walked upon.
- Plant health and even insect problems can occur when the thatch layer thickens beyond 3/4".
- Thatch that is too thick:
  - Interferes with root growth.
  - Reduces water penetration into the soil. Indeed, if thatch becomes too dry, it can actually become hydrophobic, meaning that it repels water.
  - Reduces beneficial exchanges of gasses between the soil and the atmosphere.
  - Begins to undergo anaerobic decomposition which releases gases and fluids that can kill grass plants.



Fig. F-33: White grubs are associated with thatch  
Photo by Joe Boggs

## 3) Thatch Management:

(a) Fertilization:

- Since the rate that thatch accumulates is governed by the rate of stem growth against the rate of stem decay, stimulating rapid stem growth by over-fertilization will result in a more rapid accumulation of thatch.
- Maintaining a consistent fertilization schedule aimed at avoiding over-fertilizer will reduce over-stimulation of stem growth.

(b) De-Thatching:

- There are two types de-thatching equipment:
  - The first consists of a simple set of curved, finger-like, wire tines that can be pulled behind a lawn tractor to "pluck" the thatch from the lawn.
  - The second type is a gas-powered self-propelled piece of equipment that has vertical cutting discs (also called a "vertical mower") that cuts the stems and rips the thatch from the lawn.
- Both are effective in maintaining the thatch layer at a manageable thickness.
- However, if the thatch becomes thicker than about 1", these pieces of equipment can pull entire turf plants from the ground along with the thatch.

(c) Core Aeration (Cultivation):

- Core aeration involves removing plugs from the lawn, leaving behind holes.
  - A mechanical core aeration machine hollow tines or spoons mounted on a disk or drum. It extracts cores that are 1/2 – 3/4" in diameter and deposits them on the lawn. Aeration holes are typically 1 – 6" deep and about 2 – 6" apart.
  - The holes allow oxygen to penetrate the thatch layer which enhances aerobic decomposition of the thatch. The process is much like turning a compost pile to add oxygen to speed decomposition of the organic matter.

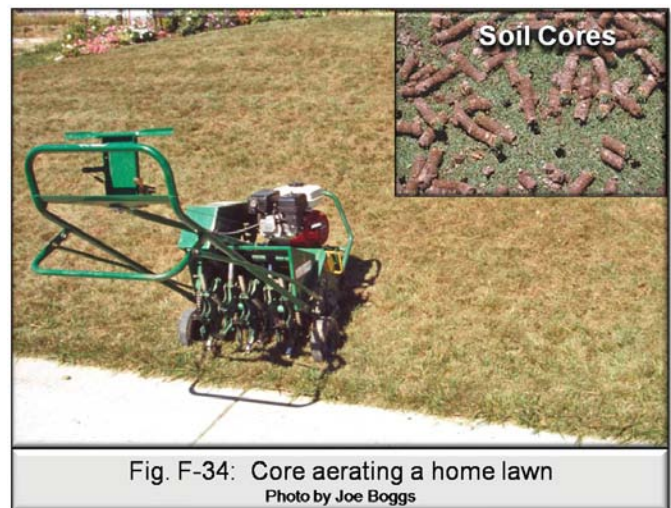


Fig. F-34: Core aerating a home lawn  
Photo by Joe Boggs

- Core aeration 1 to 2 times a year (spring and/or fall) will reduce thatch accumulation. Once the thatch layer thins to a manageable thickness, aeration can be performed once every 2 – 3 years.
- Other Benefits of Core Aeration:
  - The benefits of core aeration extend beyond thatch management. Indeed, it is recommended that all lawns be core aerated periodically whether or not thatch is an issue.
  - Core Aeration:
    - ✓ Introduces oxygen into the soil which improves turfgrass root development.
    - ✓ Increases nutrient movement into the soil.
    - ✓ Enhances water infiltration into the soil.
    - ✓ Reduces fertilizer and pesticide runoff from overly compacted soil.

## D) IRRIGATION AND WATER MANAGEMENT

### 1) Management of Cool-Season Grasses:

- (a) Cool-season grasses are genetically programmed for surviving periods of hot, dry weather in the summer. Their survival does not depend on the availability of water through irrigation.
- (b) In fact, grass plants that are actively growing during the heat of the summer are more susceptible to certain fungal diseases.
- (c) However, there may be the desire to maintain active turfgrass in the summer for aesthetics.

### 2) Tips on Irrigation:

- (a) Water should be applied during the early morning hours to allow the turfgrass canopy to dry during the day. This will make plants less susceptible to disease infection.
- (b) Water should be applied "deeply and infrequently." Irrigation should be applied until the water has infiltrated through the turfgrass root system, and the soil should be allowed to dry between irrigation cycles.
  - There is no "one size fit all": how often and how much depends on soil type and evapotranspiration rates. In other words, irrigation must be adjusted through monitoring.

## E) Weed and Pest Management:

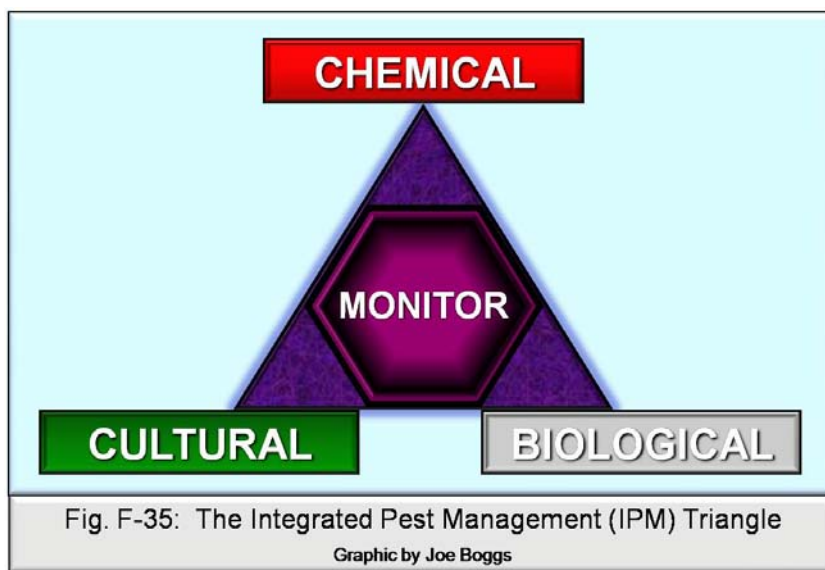
1) Weeds and pests are best managed using Integrated Pest Management (IPM); a strategy represented graphically by the IPM triangle.

2) The IPM triangle shows that Chemical, Cultural, and Biological tactics should be combined to manage weeds and pests

(a) **Weed Management:** Weeds are plants that are growing where they are unwanted. Even turfgrass can be a "weed" if it is growing in a flower bed.

#### ■ Cultural Tactics:

- The most effective approach to managing weeds in a lawn is to focus on growing a thick, healthy lawn.
- ✓ In general, weeds grow in lawns because they are taking advantage of openings in the lawn.
- ✓ Turfgrass plants are very strong competitors. There are very few weed species that can grow in a lawn comprised of a dense stand of turfgrass plants.
- The first line of defense against weeds in a lawn is to apply all that has been covered thus far in this training module to thicken the lawn and enhance the health of turfgrass plants.



■ **Chemical Tactics:**

- Chemical weed control should be viewed as the second line of defense against weeds. Even crabgrass will not grow in a thick, healthy lawn. However, occasionally something goes wrong and chemical management of weeds is required.
- The primary goal in using an herbicide is to maximize the desired results while minimizing undesired results. Undesired results include applying an herbicide that does not affect the target weed, or applying an herbicide that kills non-target plants (e.g. lawn grass!).
- As with all pesticides, **READ AND FOLLOW LABEL DIRECTIONS!** Herbicide labels provide clear information on recommended application conditions and methods, weeds that are controlled, and the length of time the herbicides are active (e.g. when seed can be sown).

**(b) Pest Management:**

■ **Cultural Tactics:**

- The first line of defense against turfgrass pests is to provide an environment for healthy turfgrass while limiting conditions that support pests and diseases.
- Cultural Management Tips:
  - ✓ Plant Selection:
    - Pest management starts with selecting cultivars that are less susceptible to the problems.
    - NTEP trial results (see "Turfgrass Selection Considerations" above) provide:
      - Information on pest susceptibility for Kentucky bluegrass, tall fescue, and perennial ryegrass cultivars
      - Levels of endophytic fungi found in tall fescue and perennial ryegrass cultivars. Endophytic fungi provide a natural defense against a number of turfgrass insect pests.
  - ✓ Plant Management:
    - Fertilizers:
      - Too much, or too little fertilizer can dramatically affect pest problems. Too little will prevent turfgrass from recovering from pest damage. Too much can stimulate excessive growth that actually attracts certain pests. Providing proper plant nutrition can help turfgrass to recover from pest damage.
    - Thatch:
      - As noted above, a dense layer of thatch can stress grass plants by preventing strong root development and limiting water infiltration. Stressed plants are more susceptible to damage caused by pests.
      - Certain white grubs, such as Japanese beetle grubs, can feed on thatch. In fact, some white grub producing beetles actually prefer to lay eggs on lawns with dense thatch. A thatch management program is also a white grub control program.

■ **Biological Tactics:**

- There are few biological control agents available for direct application or release to control turfgrass pests. Nematodes are the exception with certain types available in sprayable formulations to control grubs.
- The best approach to enhance biological control agents is to avoid pesticide applications that suppress these agents. When possible, apply pesticides that are finely targeted to control pests without killing bio-allies.

■ **Chemical Tactics:**

- Chemical applications should be viewed as the second line of defense against pests.
- As with herbicides, the primary goal in using insecticides is to maximize the desired results while minimizing undesired results.
- As with all pesticides, **READ AND FOLLOW LABEL DIRECTIONS!** Insecticide and fungicide labels provide clear information on how and when to apply the chemicals, and application safety.
- Seeking Professional Help:
  - ✓ Many insect problems require application equipment that is not owned by the typical homeowner, and methods that are beyond their scope of experience.

✓ Remember that the best way to limit chemical applications is to make certain the applications are achieving their maximum effect. In many cases, this may require the services of a lawncare professional.

## F) Disease Management:

1) Diseases are best managed using a strategy depicted by the Disease Triangle

2) Two points about the Disease Triangle:

(a) A plant disease can only develop if there is a **susceptible host**, an **environment conducive to infection**, and a **pathogen all present at the same time**.

(b) If only one of these factors is removed, a disease cannot develop.

3) Using the Triangle:

(a) **The Host Plant:**

■ The first line of defense against turfgrass diseases is to provide an environment for healthy turfgrass while limiting conditions that support disease development.

■ Plant selection; using turfgrass that is not susceptible to diseases, is one of the most effective methods for removing "host plant" from the Disease Triangle. NTEP trial results (see "Turfgrass Selection Considerations" above) provide information on disease susceptibility for Kentucky bluegrass, tall fescue, and perennial ryegrass cultivars

■ Fertilizers:

- While some turfgrass diseases (e.g. red thread) are more likely to infect grass plants suffering from low levels of nitrogen, other diseases (e.g. brown patch) nitrogen levels are excessive.
- Disease management is strongly linked to proper fertilization. Both too much or too little can lead to the development of turfgrass diseases.

(b) **The Environment:**

■ Water:

- Most turfgrass diseases are caused by fungi, and many thrive under conditions of excessive moisture in the turfgrass canopy coupled with high temperatures.
- Dormancy: cool-season turfgrass species have the capability to become dormant during the summer which reduces their chances of developing many turfgrass diseases. Watering to prevent dormancy throughout the summer increases the chances of disease infection.
- Timing: if water is applied during hot summer months, the best time to irrigate is during the early morning hours. This allows the turfgrass canopy to dry out before the heat of the afternoon.
- Mowing: maintaining a proper mowing schedule will enhance drying of the foliage by improving light penetration and air circulation.

■ Thatch:

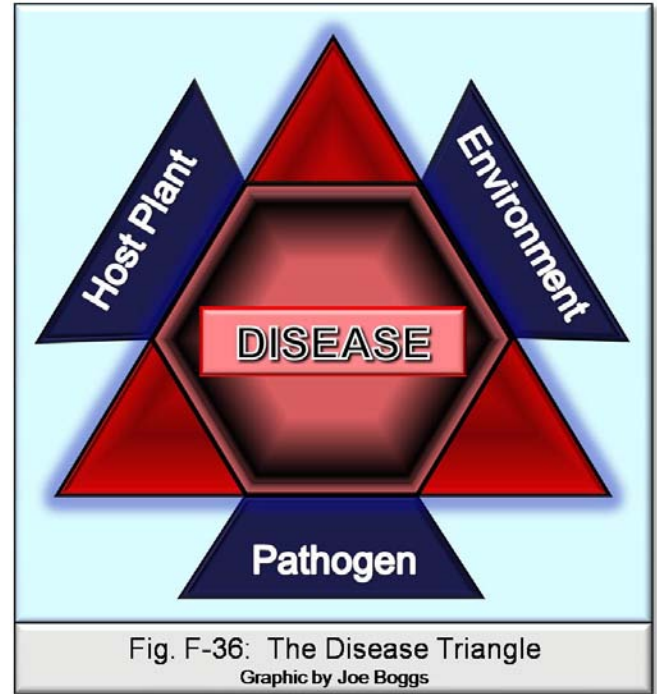
- As noted above, a dense layer of thatch can stress grass plants by preventing strong root development and limiting water infiltration. Stressed plants are more susceptible to disease infections.

(c) **The Pathogen:**

■ "Sanitation" involves removing sources of the pathogen such as "disease inoculum" which is represented by spores or dead, diseased plant tissue. For example, a thick thatch layer can harbor many forms of disease inoculum, so a good thatch management program is also a good disease sanitation program.

■ Chemical applications should be viewed as the second line of defense against diseases.

- As with herbicides, the primary goal in using fungicides is to maximize the desired results while minimizing undesired results.
- As with all pesticides, **READ AND FOLLOW LABEL DIRECTIONS!** Fungicide labels provide



clear information on how and when to apply the chemicals, and application safety.

- Seeking Professional Help:

- ✓ Most disease problems require application equipment that is not owned by the typical homeowner, or fungicides not available for purchase by homeowners. More importantly, application timing and methods may be beyond the scope of homeowner experience.

## Chapter G: Regulatory Notes

It is important to note that rain gardens and other “green” landscape management systems may be used to satisfy various permits and regulations that apply to many development and redevelopment projects within Hamilton County. These permits and regulations establish performance standards and criteria that must be used. These may conflict with the sizing criteria given on page 13 (which is based on the capture of the first one inch of precipitation of a rain event, whereas the MSDGC and Hamilton Country Storm Water District require the capture of the first 0.75 inches of precipitation of a rain event) of this manual and with guidelines in other publications.

Following is information related to the MSDGC draft off-set credit policy and its proposed performance standards that all in the MSDGC service area must be aware of:

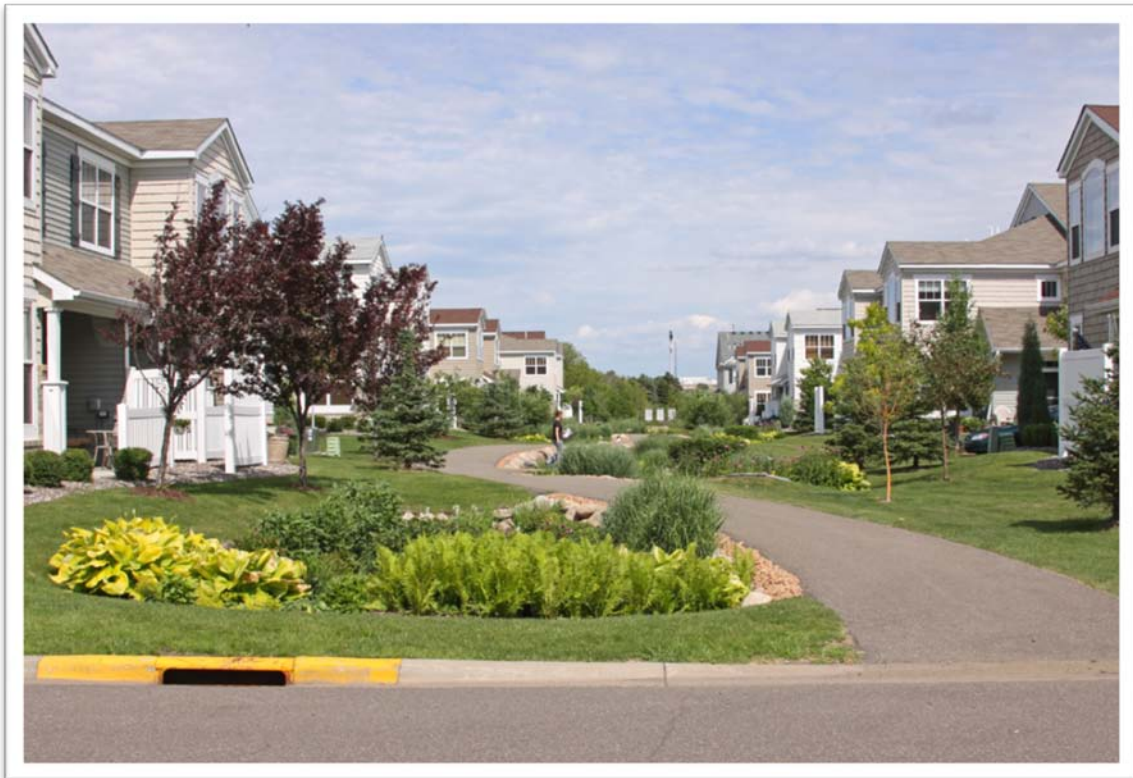
- ◆ **Areas draining directly to streams or separate storm drains** are subject to both Ohio EPA’s Construction General Permit for Storm Water Discharges (Ohio EPA Permit No.: OHC000003) and the Rules and Regulations of the Hamilton County Storm Water District (HCSWD Regulations). Ohio EPA’s permit and the HCSWD Regulations require construction projects disturbing 1 acre or more to install storm water quality controls, and establish performance standards and criteria for these controls that **MUST** be followed. Rain gardens may be used to satisfy Ohio EPA’s permit and the HCSWD Regulations if they are designed to achieve these performance standards and criteria. Since this manual uses different terminology, the following table can be used to determine which criteria apply:

Rain Garden Design	EPA Permit	HCSWD Regulations	Water Quality Volume (inches)	Drawdown Time (hours)
Mixed Soil Medium (Fig. 19)			0.75	24-48
Gravel Infiltration Zone (Fig. 23)				
Various Underdrainage Designs (Figs. 20, 21, and 22)	Bioretention Cell	Filter - Bioretention	0.75	40

- ◆ **Areas draining to combined sewers**, generally found within and adjacent to the City of Cincinnati, are subject to the rules and regulations of the Metropolitan Sewer District of Greater Cincinnati (MSDGC). MSDGC is developing an off-set credit program to prevent increases in existing CSO volumes and frequencies as a result of development. Through this new regulation, off-set credits may be obtained by installing rain gardens and other green storm water management features to control CSOs through removal of storm water from combined sewers and/or release of storm water at a rate that does not exceed the interceptor capacity of the combined sewer system.

The MSDGC's draft guidance to accompany the off-set credit regulation, titled *Off-set Credit Policy for Green Controls: Background and Implementation*, requires that all of the following performance standards must be met for the proposed green storm water control(s):

1. No captured runoff ( $V_{GC}$ ) may pond on the surface of the control more than 48 hrs after the end of a storm event.
2. All captured runoff ( $V_{GC}$ ) must either infiltrate into the soil ( $V_{NI} + V_{EI}$ ) or be discharged from the control ( $V_{ED}$ ) within 72 hours after the end of a storm event.
3. The extended detention volume ( $V_{ED}$ ) discharged to a combined sewer must be released at a rate that does not exceed the CSO interceptor capacity in cfs/ac.
4. The extended detention volume ( $V_{ED}$ ) discharged to a storm sewer or a stream must meet Ohio EPA permit and local storm water discharge requirements.
5. Mulch and/or vegetation must cover all bare ground within the green control(s) year round.
6. Vegetated controls must use plants that have been found to be hardy, attractive, vigorous, and relatively insect and disease free throughout the growing season under local conditions, and must be non-invasive or not overly aggressive. Plants must also not constitute a nuisance according to state and local regulations.
7. All applicable flood control detention requirements ( $V_{FC}$ ) of MSD and local jurisdictions must be satisfied, and no green control shall contribute to an increase in flooding or runoff to neighboring properties.
8. A legally-binding maintenance agreement must be established for the green control(s), with MSD and/or the local jurisdiction provided full rights to access the green control(s), re-establish its full design capacity, and charge all properties served by the green control(s) for remedial repair or maintenance.



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***Keith L. Smith, Associate Vice President for Agricultural Administration and Director, OSU Extension  
TDD No. 800-589-8292 (Ohio only) or 614-292-1868***