Rain Gardens

Iowa Rain Garden Design and Installation Manual

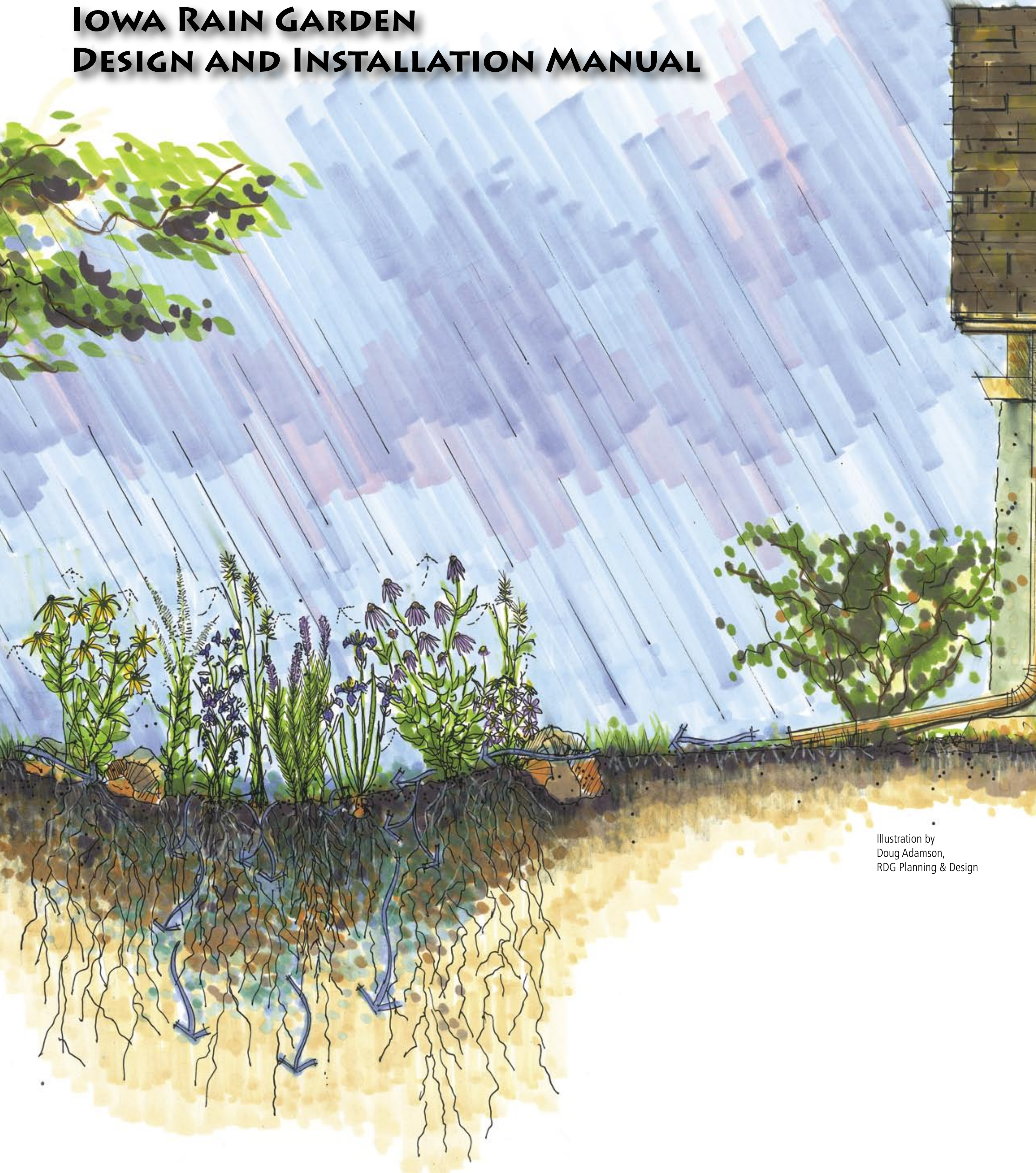


Illustration by Doug Adamson, RDG Planning & Design

Rain Gardens

Iowa Rain Garden
Design and Installation Manual

This Rain Garden Design Manual is the first of its kind in Iowa and can be used as a resource document. It is a work in progress that will be periodically updated to reflect new knowledge and techniques. Please visit www.iowastormwater.org for more information.

The Iowa Rain Garden Design and Installation Manual was assembled in cooperation with the following conservation partners:

Iowa Storm Water Education Program

www.iowastormwater.org

Iowa Stormwater Partnership

www.iowastormwater.org

USDA NRCS
United States Department of Agriculture
Natural Resources Conservation Service

www.ia.nrcs.usda.gov

Iowa Department of Agriculture and Land Stewardship

www.iowaagriculture.gov

Table of Contents

Connection to Water Quality

What is a Rain Garden? A rain garden is a garden that captures rain from roofs, driveways or yards. A rain garden is a depression or a shallow bowl made in the landscape that is level from side to side and end to end. Runoff that travels to a rain garden is temporarily ponded - but it doesn't stay ponded for long. Capturing runoff in a rain garden allows water to infiltrate into the soil rather than run into streets and storm drains. Dirty runoff that enters storm drains is sent directly to "receiving waters" - our rivers, streams, lakes, ponds or wetlands.

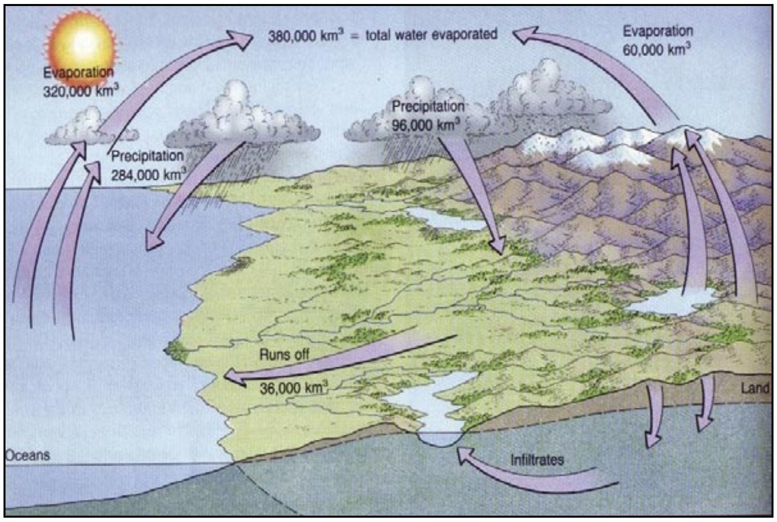
Rain gardens are an infiltration-based storm water management practice that relies on soils with good percolation rates to help manage rainfall to protect water quality. By installing rain gardens, homeowners can create landscapes that add beauty, wildlife habitat and interest to a yard while helping manage storm water more sustainably. Rain gardens are a key practice for creating landscapes that are both beautiful and hydrologically functional - that is - landscapes that hold and infiltrate rainfall rather than generating runoff that causes water quality problems and contributes to flooding.

Why Install A Rain Garden?
Homeowners would be surprised to learn that hundreds of thousands of gallons of rain falls on an urban lot in a year. In Iowa, rainfall averages anywhere from 28-36 inches per year. That means an acre of land in Iowa will receive anywhere from 760,000 to 977,500 gallons of rain in a typical year. The owner of a half acre urban lot in central Iowa would receive approximately 434,500 gallons of rain each year (a little less in western Iowa; a little more in eastern Iowa).

It is hard to visualize how much water 434,500 gallons actually is. Imagine capturing all that rainfall in 50 gallon barrels. You'd need a row of barrels more than 4 miles long to hold all the rain a typical lot receives. To calculate how many gallons of rainfall a property receives, go to www.jcswcd.org. You'll find a tool to perform a rain water audit. The audit will calculate how many gallons of rain a property receives and how much of that rainfall might be leaving the property as runoff.

An urban property generating storm water runoff contributes to water quality degradation. Storm water runoff from roofs, driveways or yards carries pollutants such as hydrocarbons, heavy meals, sediment, bacteria, grass clippings, floatable liter, or nutrients. Storm water runoff carries these pollutants directly to receiving waters without any treatment.

Storm water runoff also causes frequent bounces in stream flows. These "flashy" flows or high flows/low flows cause stream corridor erosion, which contributes sediment to stream flows. Storm water also increases flood potential. Installation of rain gardens is one way to capture and infiltrate storm water and reduce a property's contribution to water quality degradation, flashy stream flows and flooding.



Understanding Urban Hydrology

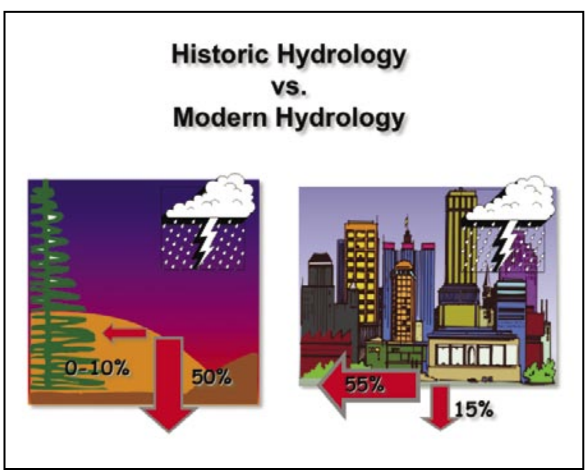
A hydrologically functional landscape holds and infiltrates rainfall. Hydrologically dysfunctional landscapes generate runoff. Urban landscapes generally are hydrologically dysfunctional, because they generate runoff with almost every rainfall event. Because runoff transports pollutants to receiving waters, installing rain gardens helps restore hydrologic functionality to our landscapes.

Hydrologic Cycle

The hydrologic cycle is all about how water moves. When it rains water is either absorbed by the landscape or runs off. Water eventually moves to receiving waters and the oceans. Water also evaporates back into the atmosphere. It rains again and the cycle repeats itself.

Historical Hydrology

Historically, the hydrologic cycle behaved much differently than it does today. Prior to European settlement, infiltration dominated the cycle and runoff was a rare component. Back then, Iowa was dominated by prairie. The prairie ecosystems infiltrated the vast majority of rainfall. Consequently, surface waters were fed by cool, clean groundwater discharge rather than runoff. Before the prairie systems were altered and eliminated, surface waters had good water quality, stable water levels and flooding was minimized.



The tallgrass prairie ecosystem was dominated by grasses and flowering species (forbs) that had deep root systems. Native prairie grasses have fibrous roots that reach six to eight feet deep into the soil profile. Some of the tap rooted forbs send roots twice that deep. Each year a significant percent of the root system of the prairie died off and decayed. Consequently, the prairie developed deep, rich, porous soils. Prairie soils typically had 10 percent organic matter (OM) content or more. About half of prairie soil was pore space—small spaces between granules of soil. These two features – high organic matter content and high porosity – gave the prairie landscapes the ability to infiltrate most rainfall into the soil.

The high organic matter content made the soil act like a sponge and soak up rain. The pore space in the soil allowed the absorbed rain to percolate down through the soil. Consequently, runoff would have been a rare thing on the prairie. About 10 percent of annual precipitation would have moved as runoff, and this would have been mostly from snow melt. More than 90 percent of rainfall would have been infiltrated.

About 40 percent of infiltrated rain was used by growing plants and returned to the atmosphere by a process called "evapotranspiration." About 50 percent of infiltrated precipitation moved down through the prairie soils. Some went to recharge deep aquifers - or reservoirs of water located deep down in bedrock. But at least half would have moved as groundwater flow. Groundwater is water in saturated soils that moves slowly down gradient through the soil to discharge at low points on the landscapes where wetlands, streams, rivers or lakes are located.

The key point is that streams, rivers, wetlands, and lakes were historically fed and maintained mostly by groundwater discharge and not by surface runoff. Historically, the hydrologic system was **infiltration-based and groundwater-driven**. A groundwater driven system would have been a very stable, functional system. A constant supply of cool, clean and slowly released groundwater would have yielded receiving waters that maintained very stable water levels and had very stable (clean) water chemistry.

Rain gardens can help restore hydrologic functionality to our modern urban landscapes and help them mimic the historic hydrology. If we restore hydrologic functionality we will help improve water quality, maintain stable stream flows, and reduce flooding potentials.

Dysfunctional Hydrology in Modern Landscapes

Our modern hydrology is very different from the historic hydrology. Urban landscapes have impervious surfaces such as pavement or rooftops. We also have compacted green space, which often features turf on compacted soils—soils that have little or no pore space. If soil is compacted water can't move into and percolate through it. Urban landscapes that can't infiltrate water generate problematic runoff when it rains. We have changed from the historic infiltration-based and groundwater driven hydrology to a **runoff-driven hydrologic system**. Runoff is the root of water quality problems, stream corridor degradation and flooding. Reducing runoff is the key to restoring a more stable, functional hydrologic cycle and rain gardens can play a key role in accomplishing this important goal.

A hydrologically dysfunctional landscape. Water that can't percolate into the soil profile seeps out into the street two hours after a rain storm occurred.

Eroded urban stream banks result from the flashiness of runoff-driven hydrology.

Rain Garden Location

Location is Critical

Proper location is one of the most important components of successful rain garden installation. The first step in planning a rain garden is walking a property during a rainfall event. It is important to get out in the rain, and watch how runoff moves on the site. **A rain garden must be located so that runoff moves to it.**

If you have a low spot where water ponds, it might be a good site for a rain garden – but maybe not. A rain garden is an infiltration-based storm water management practice that relies on soils with good percolation rates – or soils that allow water to easily move down through the soil profile. If you have a spot that ponds water for an extended period of time (i.e. long enough to kill grass) it does not percolate well enough for a rain garden to work properly.

A rain garden should impound water for about 12 hours (maybe up to 24 hours). If it rains in the afternoon, a rain garden should not have standing water by morning. You do not want water standing in a rain garden for an extended period of time.

(Note: Infiltration refers to the rate that impounded water moves into the soil. Percolation refers to the rate water moves through the soil profile after it has infiltrated. Percolation rates are expressed in inches of downward movement per hour. These terms sometimes are used interchangeably, but there is a difference.)

Soils Investigation

Since adequate infiltration and percolation rates are essential for a rain garden to function properly, a soils investigation must be done at a proposed site for a rain garden. If the soils investigation indicates poor percolation rates, then find an alternative site for the rain garden or install a bio-retention cell. (See Appendix 7, page 24, for information on bio-retention cells.)

A comprehensive soils investigation will allow you to estimate what the percolation rate will be for your rain garden site. You should choose a site that has a percolation rate of 1 inch per hour if possible. The Iowa Storm Water Management Manual requires a minimum of 0.5 inches per hour for infiltration-based storm water management practices.

Analysis Options

Lab Analysis: The best way to ensure adequate percolation rates is a comprehensive soils investigation (see Appendix 2, page 19). The local Extension Service office will have information on how to do soil sampling and provide soil sample kits that can be submitted to Iowa State University for analysis for a modest fee. The lab analysis will determine "soil texture" which is the percent of sand, silt, and clay your soils contain. The soil texture will indicate what the percolation rate will be. Loam indicates a relatively even mixture of sand, silts, and clay. You should have loam soils, or sandy loam soils. Loam has a percolation rate of 0.5 inches per hour. Sandy loam will have percolation rates of about 1 inch per hour. If you have loamy sand or sand, amend the soils with compost to reduce percolation rates. See Appendix 2 on page 19 for more information about soil texture and percolation rates. A soil probe can be used to collect soil samples or dig samples with a shovel.

Sieves are one tool used for lab analysis of soil texture.

Ribbon Test: Another simple way to investigate soil suitability is the ribbon test. This test will estimate clay content, which is usually linked to percolation rates. The higher the clay content the lower the percolation rate, in most cases. Use a soil probe, shovel, or clam shell posthole digger to gather samples of soil from beneath the

Ribbon test used to estimate clay content.

Soil Samples can be collected using a soil probe.

rain garden at 1 foot increments down to at least 3 feet deep. Roll the samples into a cigar shape. Add a little water if the soil is not moist. Pinch the sample between your thumb and finger into a flat ribbon. If the soil won't ribbon and breaks off as you squeeze it, the soils should have low clay content and good percolation rates.

If it extends out no more than an inch before breaking off, the clay content should still be low enough to have adequate percolation rates. If it ribbons out more than an inch before breaking it is questionable that adequate percolation rates exist. If it ribbons out 2 inches the clay content is definitely too high and percolation rates will be too low for rain garden installation.

Percolation Test:

A simple percolation test can be done at a proposed rain garden site. A percolation test will indicate whether water will move down through the soil or not. But, percolation tests are not necessarily a reliable way to predict how water will move through soil, so do the ribbon test too. To conduct a percolation test, remove sod and topsoil. Dig a hole with a clam shell posthole digger. Dig one hole in the center of the proposed rain garden site on the down slope side. Dig this hole about 1.5 feet deep. Dig another hole in the center of the rain garden, but at the upslope edge of the rain garden layout. Make this hole go down to about 3 feet deep. Do the same at the ends of the rain garden.

*A **percolation test** should be conducted at any proposed rain garden site.*

Fill the holes with 12 inches of water. If it drains away in 12 to 24 hours, percolation rates may be adequate. After 24 hours fill the hole with another 12 inches of water and repeat the percolation test. If it drains away again in 12 hours percolation rates should be about 1 inch per hour. If it drains down in 24 hours, percolation rates should be about 0.5 inches per hour. If it doesn't drain down in 24 hours, plan on including a sub drain system (see Appendix 5 on bio-retention cells). An additional percolation test method is described in Appendix 2, page 19. **Soils investigations** are critical to successful rain garden installation. If impounded water in a rain garden does not rapidly drain away, anaerobic conditions can develop – which means oxygen is eliminated from pore spaces in the soil profile. Anaerobic conditions will kill beneficial microbes in the soil that help breakdown pollutants and protect water quality. Extended periods of standing water can also kill plants, create odor problems and provides mosquito habitat.

Seek technical assistance from your local Soil and Water Conservation District (SWCD) if you have questions about the suitability of the soil at a proposed rain garden site.

One Call

Another key item in locating a rain garden is the presence or absence of utilities. While you typically will not be doing deep excavation, you will be doing some digging. Be sure there are no phone lines, gas lines, or other infrastructure in the area you will be digging. **Call "Iowa One Call" at 800-292-8989** to request assistance locating utilities. Call at least 48 hours before you want to start installing a rain garden.

Other Location Considerations

- Rain gardens should never be located upslope from a house or closer than 10 feet from a foundation. Thirty to 40 feet away from a foundation is recommended if the site allows. Roof water can be directed to a rain garden by extending tile from downspouts to the rain garden, or by creating a swale that will convey runoff to the rain garden.

- Avoid locating rain gardens under trees. There will always be some excavation involved with rain garden installation, and excavation under the drip line of a tree canopy will cause damage to a tree's roots. In addition, there is a much wider selection of plant species to choose from in sunnier locations.

- Rain gardens should not be installed in areas with high water tables (some sites in central Iowa), or areas with shallow soils over bedrock (some sites in northeast Iowa). There should be at least 4 feet of soil profile between the bottom of a rain garden and the normal high water table or bed rock. Soil survey information from the Soil and Water Conservation District will indicate whether the potential for high water tables exist or whether shallow bedrock might exist.

- Rain gardens should not be on located on steep slopes that can become unstable when saturated (some sites in deep loess soils of western Iowa).

- If excessive slope exists, installing a rain garden will be more of a challenge. Retaining walls are usually needed to create a level depressional area for a rain garden on steep slopes.

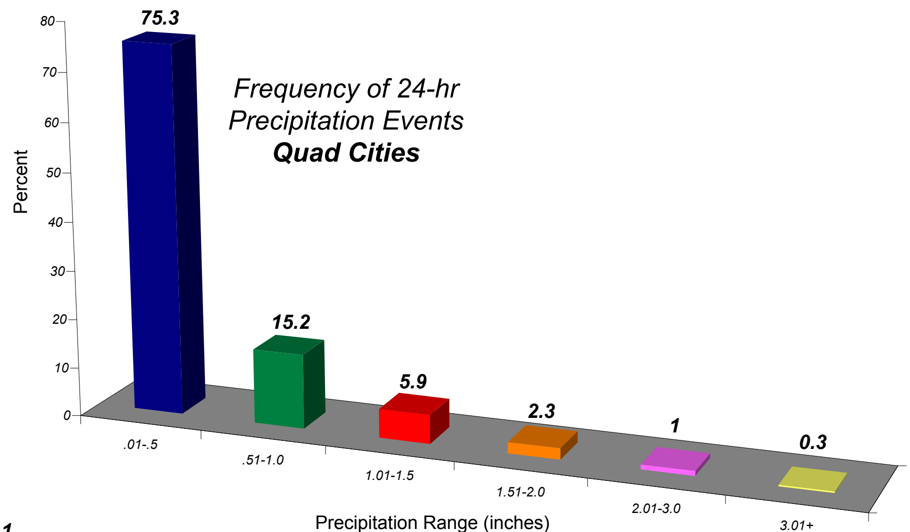
- Rain gardens should only be installed when surrounding landscapes are stabilized and not subject to erosion. If a rain garden will be installed in conjunction with final landscaping of new construction, install the rain garden after everything else is well vegetated. Sediment entering a rain garden will create a crusted surface that will limit infiltration.

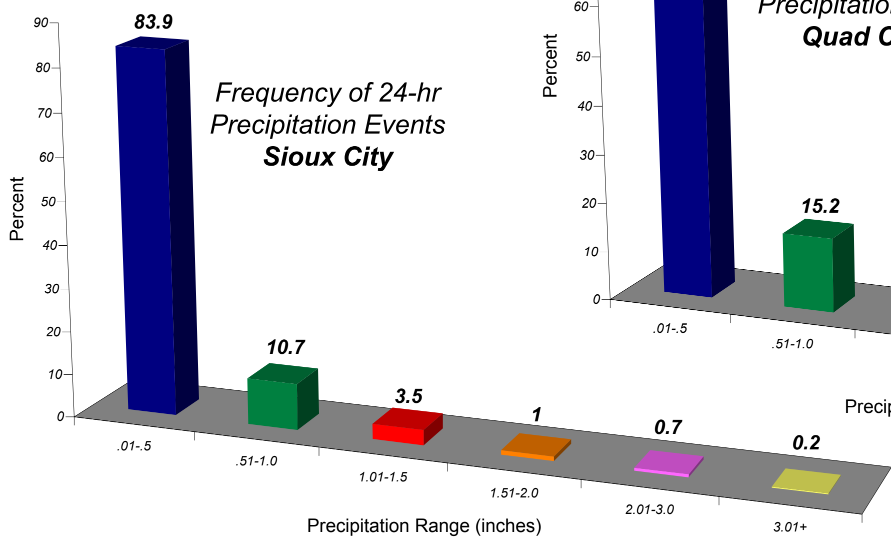
What not to do: *A rain garden located in a city park lacks a mowed border, is not weeded, is not level, does not drain, stands water until the system goes anaerobic and creates odor problems. Park users wanted the rain garden removed, before the parks and recreation department corrected the problems.*

Rain Garden Design

Water Quality Volume (WQv)

The Iowa Storm Water Management Manual requires that infiltration-based storm water management practices be designed to infiltrate 90 percent of rainfall events. Analysis of historical rainfall data for Iowa shows that 90 percent of rainfall events are less than 1.25 inches in 24 hours. Therefore, rain gardens should be designed to handle the runoff from 1.25 inches of rain. This size of an event is called the **water quality volume (WQv)**.





(Rainfall data was summarized for all measurable precipitation from 1948 through 2004 by Ray Wolf of the National Weather Service in Davenport. Note how 90 percent of rainfall is about 1"/24 hrs.)

Rain gardens are generally used in residential settings. It is important for homeowners to manage the WQv because residential property is the major land use in any city. If runoff is not managed properly on residential property, water quality improvement, hydrological functionality, and stabilization of stream flows will not be achieved.

In addition, some cities and Soil and Water Conservation Districts (SWCD) are now offering financial incentive to homeowners who install rain gardens or other infiltration-based practices. To be eligible for this assistance, the installation must follow the design standards in the Iowa Storm Water Management Manual, which requires management of the WQv. Check with your local SWCD to see if cost-sharing is available in your community.

In a single family residence there will almost always be enough space to design a rain garden to handle runoff from a 1.25 inch rain. But if space is limited, a smaller than recommended rain garden can be installed. About 80 percent of rainfall is 0.5 inches or less, according to historical rainfall patterns. However, rain gardens that do not manage the water quality volume will not be eligible for financial assistance programs.

Calculating Size and Depth

Here's the process for determining the correct surface area and depth for a rain garden:

1. Measure the size of the area that will contribute runoff to the rain garden in square feet. If you're capturing roof runoff from a downspout, measure the length and width of the roof that drains to the downspout. (Just pace it out or measure it with a tape on the ground.)

2. Sizing of the rain garden will depend on the depth of the rain garden and the percolation rates you have at the site. Remember – you should have a minimum percolation rate of 0.5"/hr.

3. With a **percolation rate of 0.5"/hr:**

a. Multiply the impervious surface area calculated above by **20%** (0.2) if the rain garden will have **6 inches of depth**.

b. Multiply the impervious surface area calculated above by **16%** (0.16) if the rain garden will have **8 inches of depth**.

c. Multiply the impervious surface area calculated above by **14%** (0.14) if the rain garden will have **9 inches of depth**.

4. With a **percolation rate of 1"/hr or more:**

a. Multiply the impervious surface area calculated above by **10%** (0.1) if the rain garden will have **6 inches of depth**.
b. Multiply the impervious surface area calculated above by **8%** (0.08) if the rain garden will have **8 inches of depth**.
c. Multiply the impervious surface area calculated above by **7%** (0.07) if the rain garden will have **9 inches of depth**.

(These calculations will yield the square feet of surface area needed to impound and infiltrate runoff from a 1.25" rain. Actually, there is a safety factor built in by following this method. The square footage calculated and the depth specified assumes you will have 100% of a 1.25 inch rain impounded in the rain garden all at once. Typically this won't happen. You'll have infiltration and percolation occurring as soon as runoff enters the rain garden and you'll typically have a small percentage of water retained in gutters. Also, there is a lag time in the runoff reaching the rain garden so it all doesn't arrive at the same point in time.)

5. Once the square footage of surface area is determined, consider various dimensions that yield a length x width that equals the square feet of surface area needed and fits the site. It is best to install long and narrow rain gardens so work can be done from the side when digging, planting, and doing maintenance.

6. Rain gardens should have a designated outlet to convey runoff away safely when a rainfall event occurs that is larger than 1.25 inches. It is guaranteed that this will happen and you don't want water flowing out of a rain garden that causes damage. Outlets will typically be an armored – or reinforced – low spot in a berm or at the end of a rain garden. Be sure that any flows from the rain garden are conveyed in a way that does not cause erosion or damage property or infrastructure below the site.

7. One other thing to consider is whether to include capacity for runoff from the lawn above a rain garden. Ideally, a lawn will have adequate soil quality so that it absorbs and infiltrates the WQv and lawn runoff will not have to be included in the design. Soil quality restoration is recommended for lawns above a rain garden if a lawn generates runoff. This will help create a combination of practices which is always better than reliance on a single practice system. Soil quality restoration guidelines are available in Chapter 2E-5 of the Iowa Storm Water Management Manual. Find it online at www.ctre.iastate.edu/PUBS/stormwater/documents/2E-5SoilQualityRestoration.pdf.

8. On small rain gardens, it is better to increase surface area and stay with the 6 inch depth. Nine inches of depth may look "too deep" in a small rain garden.

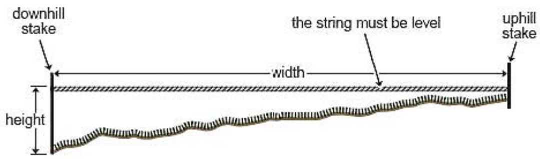
Installation Techniques

Because most rain garden sites have slope and because you need to create a level depressional area for your rain garden, the most common installation approach is the "cut and fill" technique. With cut and fill, a small berm or dam is built at the lower edge of the rain garden, using material excavated from the upper side of the rain garden.

- Lay out the shape of the rain garden with a rope or flags. Give yourself a few days to look at the layout from different perspectives. Adjust the layout to make sure the rain garden fits into the landscape nicely and provides a pleasing addition to the yard.

- Rain gardens should be laid out on the contour– that is across the slope. Long and narrow rain gardens are recommended, so make the long sides lay across the slope and have the narrow ends running up and down the slope.

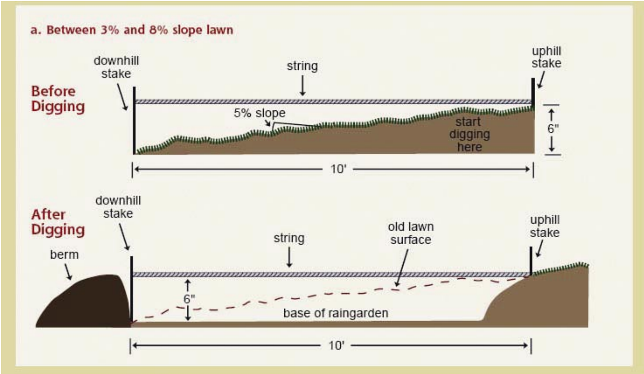
- Place stakes at the upper edge of the rain garden and stakes at perpendicular angles on the lower edge of the rain garden. Tie a rope at the base of the upper stake. Then tie the rope to the lower stake at an elevation that is level with the ground at the upper stake. Use a carpenter's level to make sure the rope is level.



The string should be tied to the base of the uphill stake, then tied to the downhill stake at the same level.

- Now measure the distance from the ground at the lower stake to the rope. This tells you how much the slope has dropped from the upper stake to the lower stake. To get a level surface in the rain garden, you'll have to excavate to that depth at the upper stake.

- It is important that the rain garden be level from side to side and end to end so that water infiltrates uniformly across the bottom of the rain garden. This is important to maximize the capacity for impounding water and for uniformly spreading the infiltration workload evenly over the bottom of the rain garden.



- Before excavation begins, be sure existing turf is killed or removed.

- Remove and stockpile topsoil.

- Excavate subsoil and use it as fill material to create a berm on the lower edge of the rain garden. Stomp the fill down in 2 inch lifts to make sure it's compacted. (You want the berm compacted, but this is the only place in the yard you want compaction.)

- Make sure the berm is constructed level across the top. Use a carpenter's level and a long 2 x 4 board to make sure the top of the berm is level.

To impound 6 inches of water, build a berm 8 inches high on the lower edge of the rain garden. Leave one end or both ends of the rain garden 2 inches below the berm to serve as an overflow outlet. If you want 8 inches of depth, build the berm 10 inches high and leave the end(s) only 8 inches high. If you want 9 inches of depth, build the berm 12 inches high and leave the end(s) only 9 inches high.

***Above:** Rain gardens must be level side to side, end to end, and the berm must be level. Note the low spot on the berm. **Right:** A rain garden installed in a morning by Heard Gardens.*

- The cut slope on the upper edge of the rain garden should be sloped back to a stable slope. Calculate and create a 3:1 slope or flatter. (3 ft back for every 1 ft of depth of cut.)
- Protect the cut slope above the depth of water that will be impounded with erosion control blankets or heavy mulch until vegetation is established.
- Create a designated outlet to accommodate storms that exceed the capacity of the rain garden. Remember – these are designed to capture and manage 90 percent of rainfall events. The storms that exceed design capacity must have an outlet and be conveyed away from the rain garden in a nonerosive, non-damaging manner.

A rain garden with a backdrop retaining wall.

A retaining wall was installed to create a level rain garden on this sloping site in Madison County.

Steep Sites

If steep slopes exist at the site of a proposed rain garden, a retaining wall system will probably be needed. Retaining walls can help overcome steep slopes, but they need to be designed and installed properly. A retaining wall can be built up to create a level depression on a sloping site. A bio-retention cell will be needed if building up a level surface area on steep slopes. A design professional should be hired to ensure proper installation of retaining wall systems. Another alternative is to cut into a slope to create a level depression and have a back drop retaining wall that holds the cutslope soil in place.

Inlets

It is best if runoff can enter a rain garden as a sheet flow, but often it will enter as a concentrated flow from a tile line, downspout, or swale. Watch out for scour erosion where water enters the rain garden, especially in the first year when plants are getting established. The inlet area can be "armored" with flagstones or other protective products. Some rain gardens have continued a flagstone path from the inlet area down the center line of the rain garden. This adds an attractive feature that prevents scour and ensures that foot traffic is concentrated in a designated area when planting, weeding or doing other maintenance. Place a geotextile fabric over the soil before placing rock so erosion doesn't occur below the rocks.

Outlets

Having a proper way to outlet flows from heavy rains that exceed design capacity is important. Leaving one or both ends of the berm lower than the berm at the down slope edge of the rain garden is probably the easiest way to outlet excessive flows. You should "armor" or "reinforce" these outlet areas to prevent erosion. Make the back slope of the outlet a 5:1 slope – that is, it should toe out 5' for every foot of height. In this case, if your notch height is 6 inches (0.5 ft) then it should toe out 2.5 feet from the top edge of the notch. This will allow water to flow out and down in a stable manner. Make sure the area down stream from the outlet is stabilized with strong vegetative cover.

Two common problems with newly installed rain gardens is the flooding of young plants before they are well established, and suffocation of small young plants that get covered by floating mulch when ponding occurs. To prevent flooding and mulch suffocation, leave the outlet site(s) only 1 inch above the bottom of the rain garden so very little ponding occurs until the plants have time to grow taller than the depth of the ponding area. This should take a month or so – maybe longer. When plants are taller than the ponding depth, the outlet can be filled to pond 6"-9" of water so the rain garden will function as it should.

When the opening in the outlet is filled, make sure there isn't a seam between the existing berm and the new fill material. This means you should dig a little trench into the existing berm and as you fill the notch, pack the new fill solidly into the trench.

Site Preparation

Any sod or other existing vegetation that is not going to be dug up needs to be killed before installation of the rain garden. If you don't eradicate all pre-existing grass you will be fighting it as competing, undesirable vegetation in the future. You can cut, dig and roll the sod and use it somewhere else in the yard; or you can spray it with a herbicide such as Roundup® and wait a couple of weeks for it to die out. You can also lay down plastic, a thick layer of newspaper or cardboard anchored with rocks to kill the grass. These products should kill existing vegetation in a couple of weeks. If time allows, give the site time to allow any weed seeds that may be in the top level of the soil time to germinate. Then kill any regrowth again before installing the rain garden.

Install an edging material along the edge of the rain garden to a depth of at least 4 inches. Edging will provide a barrier that prevents the roots of surrounding sod from creeping back into the rain garden planting. This can be done as a final touch of the rain garden installation. Another alternative is to install a brickwork edge backed by a woven geotextile that will physically block roots from spreading into the rain garden.

Soil Amendments

If a thorough soil analysis indicates good percolation rates (1"/hr or more) and good organic matter content (OM 5%+) exists, you won't need to do any soil amending. But if percolation rates are around 0.5 inches per hour and OM content is low (2% is common), plan on amending the soils with some compost, and possibly sand. If you are amending with compost only to increase organic matter content, over-excavate the site by 2 inches. Then place 2 inches of compost and rototill to a depth of 6 inches. (See Appendix 8, page 25)

A rain garden in Okoboji has brick work edging and a mulch barrier.

If you have a site with low percolation rates of 0.5 inches per hour, you might want to amend the soil mixture in the top 6 inches with sand and compost. Washed concrete sand has more diversity of aggregate size. You want this. Do not use masonry sand, which has uniformly fine sized particles which can actually slow percolation rates. If amending the rain garden with sand, use only washed concrete sand.

Mix a soil matrix that is at least 50% sand, about 30% compost, and about 20% topsoil. Over excavate the bottom of the rain garden by 6 inches. Backfill with 3 inches of sand and 2 inches of compost and 1 inch of topsoil. Rototill to the maximum depth possible (see Appendix 8, page 25).

During this rain garden installation the area was over-excavated in sandy subsoil and backfilled with a soil amended with compost to increase organic matter content.

What to Plant

Native plant species are recommended for rain gardens for a couple of important reasons. First, they will develop deep root systems. (6 ft deep and beyond) The deep roots of the natives will help build and maintain high organic matter content and porosity. The deep roots will also have the ability to go down and find water during dry periods. Once established many native species tolerate temporary impoundment of water and/or extended periods of dry weather. You also don’t have to fertilize native species – in fact you should not fertilize them.

A monoculture border (all one species) will give the rain garden a defining edge and a well kept appearance. Typically the border will be a low growing grass, such as blue or hairy grama or sideoats grama if you are using natives (or turfgrass if a blend of natives and non-natives are used). The border can be planted on the sloping edge of the rain garden.

On the floor of the rain garden plant a variety of species that bloom throughout the growing season. Plant clumps of each species, with spacing of 1 - 1.5 feet apart. Select lower growing native plants that don’t grow more than 3 - 4 feet high.

Install live plants that establish readily during the first year. While natives are recommended some people may want to blend in some of their favorite horticultural cultivars. Select plants that meet your aesthetic values, but consider the amount of input needed to keep any non-natives alive (water during drought, fertilizer), and the effects of those inputs on nearby native species. Some natives will grow unusually large if given fertilizer and others will just die.

A short list of favorite native species for rain gardens is provided in Appendix 9 on page 26.

Many plant lists recommended for rain gardens include species adapted to wet conditions. Since rain gardens should drain down readily, wet loving species will probably not thrive. Some plants that prefer dryer conditions may not thrive in a rain garden that might stay moist during periods of extended rainfall. Over the course of the first 2-3 years of plant establishment, be prepared to supplement plantings until suitable species have established themselves.

When you are planting the rain garden, try to minimize foot traffic. Work from the side if possible. On larger, wider rain gardens build small bridges that span the width of the rain garden and work from them. Screw 2 x 8 foot sheet(s) of plywood board to the 2” ends of long 2 x 4 inch boards to make a nice working platform. Or lay an extension ladder across the rain garden with a 2 x 8 foot piece of plywood board on it to provide a work platform. It will be impossible to eliminate all foot traffic but keep it to a minimum.

Mulching

Mulching the rain garden surface is usually recommended to provide a weed barrier and to conserve moisture for young plants during the first year. Mulching continues to help suppress weeds in following years. You should use a 2-3 inch layer of shredded hardwood mulch. When planting small plugs, it is easier to place the mulch before planting. Then spread the mulch before installing the plug and pull it back around the little plant after it is in place.

Mulch is often sold in bags that cover about 10 sq ft per bag. Calculate the number of bags of mulch needed by dividing the square footage of rain garden surface area by 10 to get the number of bags of mulch needed. A 150 sq ft rain garden would require 15 bags of mulch.

Rain Garden Maintenance

During the first year be prepared to water a rain garden if timely rainfall does not occur. Water at least once a week during establishment if it doesn't rain.

The most important thing about rain garden maintenance is to keep it looking good. Studies have found that rain gardens, especially when native plants are used, are well accepted if they appear to be orderly and well kept. Select lower growing species that stay upright. Keep plants pruned if they start to get "leggy" and floppy. Deadhead (cut off the old flower head) after a plant is done blooming.

Perhaps the most important maintenance item is to keep the rain garden weeded, especially the first couple of years when natives are establishing. Native plants spend much of their energy establishing deep root systems the first year or two. So expect a bit of an "ugly duckling" in year one. Usually in year two and certainly in year three native plants will have developed into a "swan" and will put on a spectacular show of color and texture that attracts butterflies, birds and beneficial insects.

Once established, your rain garden shouldn't require much maintenance. This is especially true if weeds are diligently kept from setting seed the first couple years. When mature, the garden should be free of bare areas except where stepping stones may be located. Reducing weed competition early and getting natives well established is key to low maintenance. Once well established, native species will prevent annual weeds from being a persistent problem – weeds just can't compete with vigorous, deep-rooted native species. Keep an eye out for a build-up of sediment or organic matter where runoff enters the rain garden. If a lip of material begins to build up over time you will have to clean it out to ensure runoff easily enters the rain garden.

Rain gardens should only be installed when surrounding landscapes are stabilized and not subject to erosion. So if you're planning a rain garden in conjunction with final landscaping of new construction, install the rain garden after everything else is well vegetated. Sediment entering a rain garden will create a crusted surface that will limit infiltration. But even with stabilized landscapes, some sediment can move with runoff. So keep an eye out for any build-up of fine sediment on the floor of the rain garden.

A few other maintenance items to watch for:

- Water standing for more than 12-24 hours.
- Vegetation has died and needs replacing.
- Erosion is visible on the berm, the cut slope, the floor of the rain garden, or where the rain garden outlet(s) overflows.
- A low spot has developed on the berm due to settling.

How Much Work Is Installing a Rain Garden?

Each site and each rain garden will be unique, so it's impossible to say how much work or time it will take to install a rain garden. A big part of rain garden installation is the planning and design. Give yourself plenty of time to plan things out before starting to install a rain garden. If you have a good design in hand and the rain garden is laid out and you've got a good crew on hand, you may be able to install a small rain garden in an afternoon. If it's a challenging or larger site, and you're doing the work yourself it could take a full weekend or more to install a rain garden. But regardless of how much time it takes, make sure installing a rain garden is a pleasurable gardening experience.

How much time to budget for maintenance is also site dependant. For the first year, keeping the rain garden weeded will be the biggest time demand. After establishment, weeding workload should go down.

How Much Will A Rain Garden Cost?

Cost of a rain garden will depend on its size and complexity. Obviously, if you're on a steep slope and using a retaining wall system, your costs will be higher than if you're installing a simple cut/fill rain garden on gentle slopes.

Cost will also depend on how much of the work a landowner does. If the site has good soils that need little or no amendment and a landowner is willing to put in the sweat equity, the major costs will be plants and the mulching. Cost could be as low as $3 per sq ft of surface area in this situation. (Figure plant costs of $2 per plant and calculate the number of plants needed by dividing the sq ft of surface area by 1-1.5 ft, which is the recommended spacing for most native plants and many cultivars. Add another$1/sq foot for mulch.)

If you're amending soil, you'll need to factor in cost of compost and/or sand. Calculate quantity of material needed and estimate about $10/ton for materials. Add more if you'll be having the materials delivered. If you're doing a more complicated system (soil amendment, fancier inlet/outlets, larger plant stock) costs could range from $5 - $10 per sq ft of surface area. If a vendor/contractor is doing design and installation, costs could run $20+ per sq foot of surface area.

Additional costs associated with rain garden installation can occur. If a rain garden will be installed as part of new construction, then design downspouts, yard slopes, and the slope of a driveway to shed water to a designated rain garden site. But if a site is being retrofitted to add rain gardens there may be extra expense in getting water to a rain garden. Driveways, for instance are generally sloped to direct water into the street gutters and then to the storm sewers. It might be necessary to install a grated gutter that directs water to a rain garden in a setting like this, which obviously adds costs. Or, extra time and expense may be needed to install tile or construct swales to get downspout runoff directed to a rain garden. The cost of renting a rototiller or sod cutter may also be a part of rain garden installation. As with most home improvement projects there may be some unanticipated things that might add to costs.

When Not to Install a Rain Garden

In most settings, a rain garden can be successfully installed. But there may be certain situations where a rain garden might not be the right practice to install. One of the major limiting factors for rain gardens is compacted soils that won't allow water to percolate through the soil profile. This is a special concern where new construction has altered and compacted the soil profile from construction traffic.

In some settings, a high water table may exist and minimize the amount of percolation that can occur. If water table elevations are near the soil surface at your site, turn to an alternative practice such as soil quality restoration to help your landscape better absorb rainfall. A review of soil maps and soil survey information for your site will help you evaluate potential limiting factors such as a high water table. You can get soil survey information from your local SWCD. Soil surveys are not always helpful, though, if the site has been significantly altered by land disturbing activities associated with construction.

There may be a few rare situations where space is limited to accommodate a properly designed rain garden, but in most residential settings this shouldn't be a problem. In western Iowa, you might find sites where the deep loess soils on extremely steep sites or on fill could become unstable if infiltration of rainfall is enhanced by a rain garden. In northeast Iowa, some sites might have shallow soils over fractured bedrock. Percolation of pollutants to groundwater could be a concern on sites like this.

Soil quality restoration is best performed as part of final landscaping with new construction. It involves deep tillage to shatter compacted soils and incorporation of compost to achieve desired organic matter content. Strive for 5% organic matter, which usually can be achieved by incorporating 1 - 3 inches of compost into the soil. On existing landscapes with turf over compacted soils, you can improve soil quality through aeration and the application of compost. You can aerate by either pulling shallow plugs or punching deep holes into the soil profile (8-9 inches) through deep-tined aeration.

Deep tined aeration

Apply a compost blanket after aeration to help fill the holes with the high organic matter content that compost offers (30%-60% OM). Adding grass seed to the compost application will supplement existing patchy turf. You can apply compost by hand, with a small front end loader, or by hiring a pneumatic blower truck to spread compost.

Compost blanket application

Common Mistakes

- Installing a rain garden on soils that lack adequate percolation rates.
- Poor maintenance – mostly insufficient weeding the first year after installation. Annual weeds that are not pulled will re-seed rapidly, creating an unkempt looking rain garden.
- Planting species that are too tall for the area. Carefully note the height ranges for the recommended species; if you have a small bed do not plant the taller species.
- Use of fertilizer. Native species do not need fertilizing, and often will grow too tall and flop over if they encounter rich conditions.
- Improper plant placement – put drought tolerant species on the sides of the rain garden and more water tolerant plants in the wetter areas of the rain garden.
- Improper location of the rain garden; water does not naturally flow to the site, or outflows are

Final Considerations

Rain gardens are a great practice that can be installed in most residential settings. But they are not necessarily a "magic bullet." Remember, there are some settings where limiting factors may affect rain garden design and performance and in some settings you may need to rely on the treatment train concept – a combination of practices working together to manage water sustainably. Rain gardens are usually used to manage water that falls on an urban lot. But when you look at most residential settings, what makes up the majority of impervious surfaces? It's the streets, of course. Transportation surfaces constitute up to 70 percent of imperviousness. So, do everything possible to manage water that falls on roofs and driveways and yards – then take on the challenge of organizing a neighborhood project that manages road runoff.

The right of ways between curbs and sidewalks often have infrastructure that may make it a challenge to retrofit and add rain gardens. But in some settings it may be possible to install rain gardens up slope from storm sewer intakes and make curb cuts that let road runoff enter the rain garden rather than going directly into the storm sewers. In most cases, managing road runoff will require the installation of a rain garden for road runoff on private land. This means an easement or other formal agreement between the property owner and the municipality will be needed that establishes procedures for installing, paying for, and maintaining the rain garden. A public – private demonstration project that manages road runoff has been installed in Okoboji. New developments in Okoboji are now being designed to manage road runoff in this way.

The installation of one rain garden by one homeowner does little to impact the hydrologic instability and the water quality problems we have in Iowa. But the cumulative affect of individual actions will ultimately lead to tangible changes in improved water quality, more stable stream flows, and reduced flooding potentials.

Here is a perfect retrofit opportunity. A curb cut could be installed in the adjacent green space. The polluted street runoff that goes into the nearby lake would be cleaned up, cooled off, and slowly released to improve water quality in the lake.

Appendix 1

Tools Needed (for installation of rain garden by a homeowner)

- Clam shell post hole digger
- Shovel
- Rakes
- Rope
- Wooden stakes
- Flags
- String
- A carpenter's level
- Tape measure
- Materials for killing existing vegetation (Round-up, plastic, cardboard, etc.)
- Work gloves
- Wheel barrow
- Rototiller (not required unless amending soil)

A rototiller is used to prepare a rain garden site in Madison County.

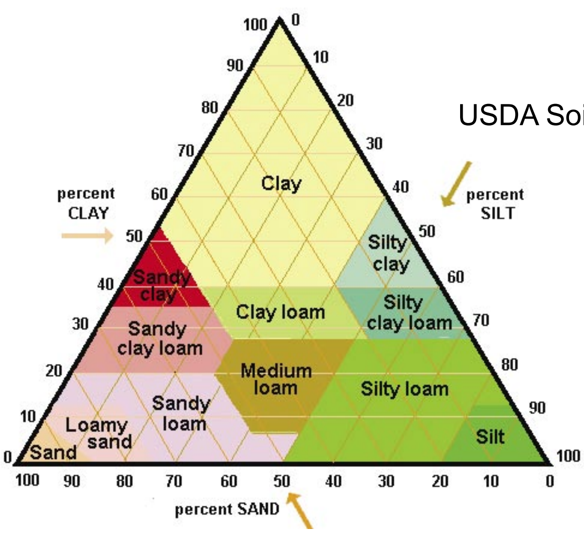
APPENDIX 2

Soil Texture and Percolation Rates

Hydrologic soil properties classified by soil texture

Soil Texture Class	Hydrologic Soil Group	Effective Water Capacity (C_w) (in/in)	Minimum Percolation Rate (in/hr)	Effective Porosity (in^3/in^3)
Sand	A	0.35	8.27	0.025 (0.022-0.029)
Loamy sand	A	0.31	2.41	0.024 (0.020-0.029)
Sandy loam	B	0.25	1.02	0.025 (0.017-0.033)
Medium Loam	B	0.19	0.52	0.026 (0.020-0.033)
Silt loam	C	0.17	0.27	0.300 (0.024-0.035)
Sandy clay loam	C	0.14	0.17	0.020 (0.014-0.026)
Clay loam	D	0.14	0.09	0.019 (0.017-0.031)
Silty clay loam	D	0.11	0.06	(0.026 (0.021-0.032)
Sandy clay	D	0.09	0.05	0.200 (0.013-0.027)
Silty clay	D	0.09	0.04	0.026 (0.020-0.031)
Clay	D	0.08	0.02	0.023 (0.016-0.031)
Note: Minimum rate: soils with lower rates should not be considered for infiltration BMPs				

Source: Rawls et al., 1982



USDA Soil Textural Classification

Note that 50-60 percent sand puts soils in the sandy loam textural class, which has a percolation rate of 1 inch per hour.

Appendix 3

Procedure for Percolation Test Column
(Obtained from Section 2-E7 in the Iowa Stormwater Management Manual)

- Install casing (solid 5-inch diameter, 30-inch length) to 24 inches below proposed BMP bottom (see figure below).

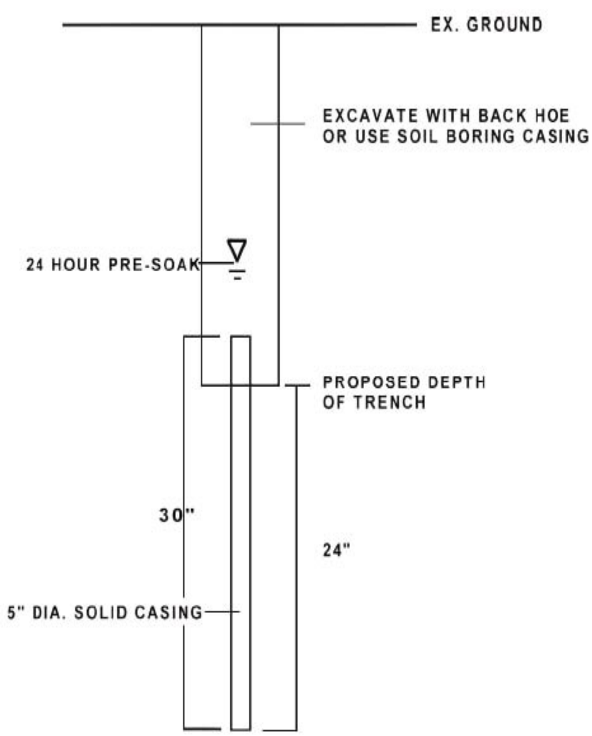
- Remove any smeared soiled surfaces, and provide a natural soil interface into which water may percolate. Remove all loose material from the casing. Upon the tester's discretion, a 2-inch layer of coarse sand or fine gravel may be placed to protect the bottom from scouring and sediment. Fill casing with clean water to a depth of 24 inches, and allow to pre-soak for 24 hours.

- After 24 hours, refill casing with another 24 inches of clean water, and monitor water level (measured drop from the top of the casing) for 1 hour. Repeat this procedure (filling the casing each time) three additional times, for a total of four observations or until there is no measurable change in the readings. Upon the tester's discretion, the final field rate may either be the average of the four observations, or the value of the last observation. The final rate should be reported in inches per hour.

- May be done through a boring or open excavation.

- The location of the test should correspond to the BMP location.

- Upon completion of the testing, the casings should be immediately pulled, and the test pitshould be backfilled.



Appendix 4

Design Exercises

Exercise 1

Assume you have a 2000 sq ft house. You have 4 downspouts taking equal amounts of runoff. Therefore, 2000 sq ft divided by 4 downspouts = 500 sq ft / downspout. Measure it out to confirm. 25 ft L x 20 ft W = 500 sq ft. You can add a safety factor in and account for the slope of the roof by multiplying the measured area by 12% - or 0.12. In this example 500 sq ft x 0.12 would yield an additional 60 sq ft, making the total area to design for 560 sq ft.

Assume you have perc rates of 0.5 in/hr and want a depth of 6 inches:

560 sq ft x .20 (from text) = 112 sq ft of surface area needed for the rain garden.

Now determine the dimensions of the rain garden:

112 sq ft ÷ 10 ft W = 11 ft L x 10 ft W (Try to go longer and more narrow.)
112 sq ft ÷ 7 ft W = 16 ft L x 7 ft W (Not bad...can you comfortably work 3.5 ft in from either side to do planting, weeding, etc. without having to walk and compact the surface of the rain garden?)

Does that length fit the site? (Remember, the roof line you're managing water from is 25 ft long).

112 sq ft ÷ 5 ft W = 22 ft L x 5 ft W (Easy to work from the sides but may be getting too long for the site).

Exercise 2

Assume you have the same house dimensions but have perc rates of 1 in/hr. You want to stay with the 6" of depth for your rain garden.

Once again you'll have 560 sq ft of impervious surface to manage runoff from.

560 sq ft x 0.10 (from text) = 56 sq ft of surface area needed for the rain garden

Now determine the dimensions of the rain garden:

56 sq ft ÷ 10 ft L = 10 ft L x 6 ft W
56 sq ft ÷ 12 ft L = 12 ft L x 5 ft W

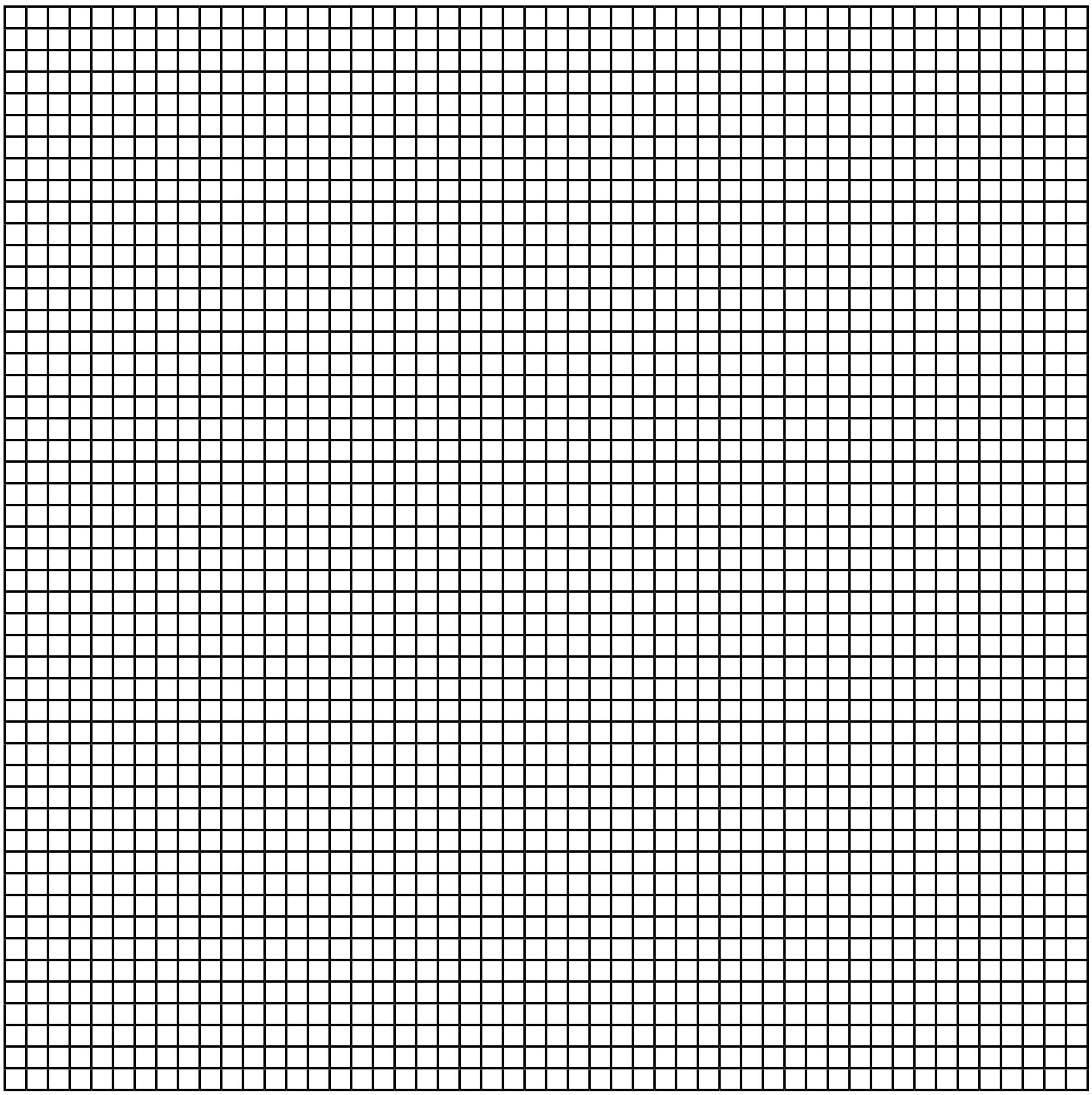
Note: Don't get too worried about going to a shorter and wider layout if it fits the site better. But do pay attention to traffic and compaction on the bottom of the rain garden. You could lay boards across the top of the garden to do planting and weeding or you can create decorative paths through the planting and confine foot traffic to the pathways. And remember, a rain garden doesn't have to be square or rectangular. It can be any shape you desire or that fits the site best. These dimensions are guidelines for sizing, so try to get this square footage even if the rain garden is an irregular shape. If you end up a little larger or a little smaller, that's fine. Remember, you can't make a rain garden too big and you have a safety factor built into the design if you end up a little smaller.

Appendix 5

Design Calculations Worksheet and Site Design Layout Graph

1) Impervious Surface (I.S.): _____ ft L x _____ ft W = _______ sq ft of I.S.

2) Sizing the rain garden: (use the factor from page 8 of the text for the percolation rates of the site and proposed depth of the rain garden)
_____ sq ft of I.S. x ____ (7%-20%) = ______ sq ft of rain garden surface area



Appendix 6

Temporarily Impounded Water Calculations
(The formula on Appendix 5 covers this, but if you're curious about how much water you're managing you can calculate it with this formula):

Sq ft of impervious surface ÷ 43,560 sq ft = _______ acres of impervious surface.

______ acres of impervious surface x 27,152 gallons/ac/inch of rain = _____gallons/inch.

______ gallons/ac/inch x 1.25 inches = ________gallons/1.25 inches (WQv).

______ gallons x 0.1337 cu ft/gal = ______ cu ft of runoff to manage.

Exercise 1

From the example above we know we have 560 sq ft of impervious surface to manage. So,

560 sq ft ÷ 43,560 sq ft/ac = 0.013 ac of impervious surface

0.013ac x 27,152 gallons/ac/inch = 353 gallons of rain/inch from the downspout

349 gallons/inch x 1.25 inches = 441 gallons for the WQv

436 gallons x 0.1337 cu ft/gallon = 59 cu ft of water

With a rain garden surface area of 112 sq ft x 0.5 ft deep = ~56 cu ft of available storage. That's close enough to the 59 cu ft of water being generated. Remember, not 100 percent of the rainfall will reach the rain garden, and there will have been some infiltration before the last of the runoff arises.

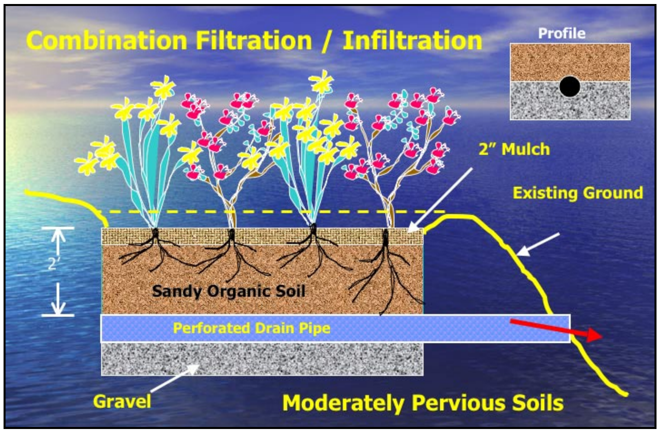
Exercise 2

With perc rates of 1 inch/hr we will have about half the cu ft of temporary storage. We had a surface area of 56 sq ft x 0.5 ft of depth = about 28 cu ft of storage. We still have 59 cu ft of water to manage. So doubling the perc rate offsets the reduced storage we have, compared to what we needed above.

Appendix 7

Bio-retention Cells

A bio-retention cell - or a bio-cell - is designed with a specified square footage of surface area and a specified depth, just like a rain garden. But a bio-cell has an engineered sub-grade that extends to frost line (42-48 inches). The sub-grade of a bio-cell has an 8-12 inch gravel bed with a perforated drain tile embedded in it. It has 24-30 inches of an "engineered" soil mix – typically about 60% sand, 25% compost, and 15% topsoil. Depth of the bio-cell is typically in the 6-9 inch range, like a rain garden.



A bio-retention cell is used where impounded water is not able to infiltrate into the surrounding soils, typically because the natural soils have been altered and compacted. The drain tile in the gravel bed ensures that water moves through the manufactured soil matrix. Bacteria in the soil mixture captures and breaks down pollutants. Water released from the bio-cell is cleaned up and cooled off, after moving down to frost line where the soil maintains a constant temperature of 50-some degrees. Water is slowly released via the drain tile, mimicking the way groundwater releases as it moves down gradient in natural soils.

The tile of a bio-cell needs a place to outlet so water that has moved through the cell can be released. This means that a downhill site is needed to outlet the tile – or in some cases the sub-drain tile is outletted into a storm sewer located near the bio-cell. Typically bioretention cells are used to treat large expanses of impervious surfaces, such as large parking lots in commercial settings, but they may be needed in residential settings, too.

Another consideration for sites with questionable percolation rates is to install a modified bio-cell. This can be accomplished by digging a trench down the center line of the rain garden to frost line. Lay a nonwoven geo-textile in the trench and place a 5" perforated drain tile in the trench. Fill the trench with washed 1" rock to within a foot of the floor of the rain garden. Fold the geo-textile over the rock trench and fill with soil to the floor of the rain garden.

Appendix 8

Calculating Soil Amendments

How much compost to add:

1. Depth of a 2 inch layer of compost is 0.17 feet (2” ÷ 12” = 0.17 ft of compost).

2. Multiply 0.17 ft of compost x ____ sq ft of rain garden surface area = ____cu ft of compost needed.

3. Convert ____ cu ft needed to ____cubic yards by dividing ___cu ft by 27 = ____cu yd needed.

4. Multiply cu yd needed by 1200 lbs to calculate the weight of compost needed. ____ cu yd x 1200 lbs/cu yd of compost = ____ lbs of compost needed.

5. If you’re buying bagged compost from a store divide the ____ lbs of compost needed by the weight of the bag to determine the number of bags needed.

6. If compost is being purchased in bulk from a composting facility it will usually be sold by the ton. Divide ____ lbs of compost needed by 2,000 = ____ tons needed.

A heaping load of compost on a full sized pick up truck will weigh about 1.5 tons. It never hurts to have too much compost. What might not be needed for amending a rain garden’s soil can be used to mulch trees or gardens or simply spread as a light layer on turf, which will increase organic matter content and make a yard better able to absorb rain.

How much sand to add:

1. 3” inches of sand ÷ 12” = 0.25 ft of sand.

2. 0.25 feet of sand x ____sq ft of surface area = ___cu ft of sand needed.

3. Convert to cubic yards by dividing ___ cu ft by 27 cu ft per cu yd = ____ cu yds needed.

4. Sand is usually sold by the ton at sand pits so multiply the cu yd needed by 1.5 to convert your needs to ___ tons of sand.

Appendix 9

Native Plant Favorites for Soils with Good Percolation Rates

Common Name	Height	Comments	Forb/Grass
Blue grama	1-2 ft	makes a good border	grass
Bottle gentian	1 ft	novel purple flowers	forb
Butterfly milkweed	1-4 ft	emerges late spring; no milky sap	forb
Columbine	1-2 ft	orange flower stalk may add 1 ft	forb
Culver's root	3-6 ft	can get tall; for moderatley moist soils	forb
Fox sedge	1-3 ft	may not tolerate drought	grass
Golden alexander	1-3 ft	yellow dill-like flower, mod moist soils	forb
Little bluestem	2 ft	nice rusty color all winter	grass
Mountain mint	1-3 ft	for moist soils	forb
Nodding onion	1-2 ft	for moderately moist soils	grass
Pale purple coneflower	4 ft	most overused native; only in S. Iowa	forb
Prairie blazing star	2-5 ft	for moist soils	forb
Prairie smoke	1 ft	makes a good border	forb
Sideoats grama	2-3 ft	red anthers; not as tidy as little bluestem	grass
Silky aster	1-2 ft	loved by rabbits	forb

Websites with native plant lists for rain gardens:

- http://prrcd.org/inl/recommended_plants.htm
- http://www.dnr.state.wi.us/runoff/rg/plants/PlantListing.html

Rain Gardens

Iowa Rain Garden
Design and Installation Manual

Acknowledgements

This document was created, reviewed, edited, and approved by the Iowa Stormwater Partnership under the direction of Wayne Petersen, Iowa Department of Agriculture and Land Stewardship-Division of Soil Conservation (IDALS-DSC). Thanks to those who reviewed and provided input on content.
Reviewers include:

- Inger Lamb and Anita Maher-Lewis, Prairie Rivers Resource Conservation & Development (RC&D)
- Brenda Nelson, Nelson Design
- Rich Maaske, IDALS-DSC
- Steve Anderson, Dickinson Soil and Water Conservation District (SWCD)
- Kim Proctor, IDALS-DSC
- Rebecca Kauten, Black Hawk SWCD
- Eric Schmechel, Dubuque SWCD
- Amy Johannson, Scott SWCD
- Amy Bouska, Johnson SWCD
- Mark Masteller, Iowa Department of Transportation (IDOT)
- John Paulin, Prairie Rivers RC&D
- Doug Adamson, RDG Planning & Design
- Stacy Schlader, USDA-Natural Resources Conservation Service (NRCS)

Front cover design and review of the first manual were provided by Jennifer Welch, Polk SWCD. Pat Sauer, Kathleet Gibbons, and Karen Hansen of the Iowa Stormwater Education Program formatted, edited and printed the first run of this manual.

Thanks to Jason Johnson, USDA-NRCS, for assistance with formatting the manual for the second printing.

First Printing March 2008
Second Printing May 2008

Notes