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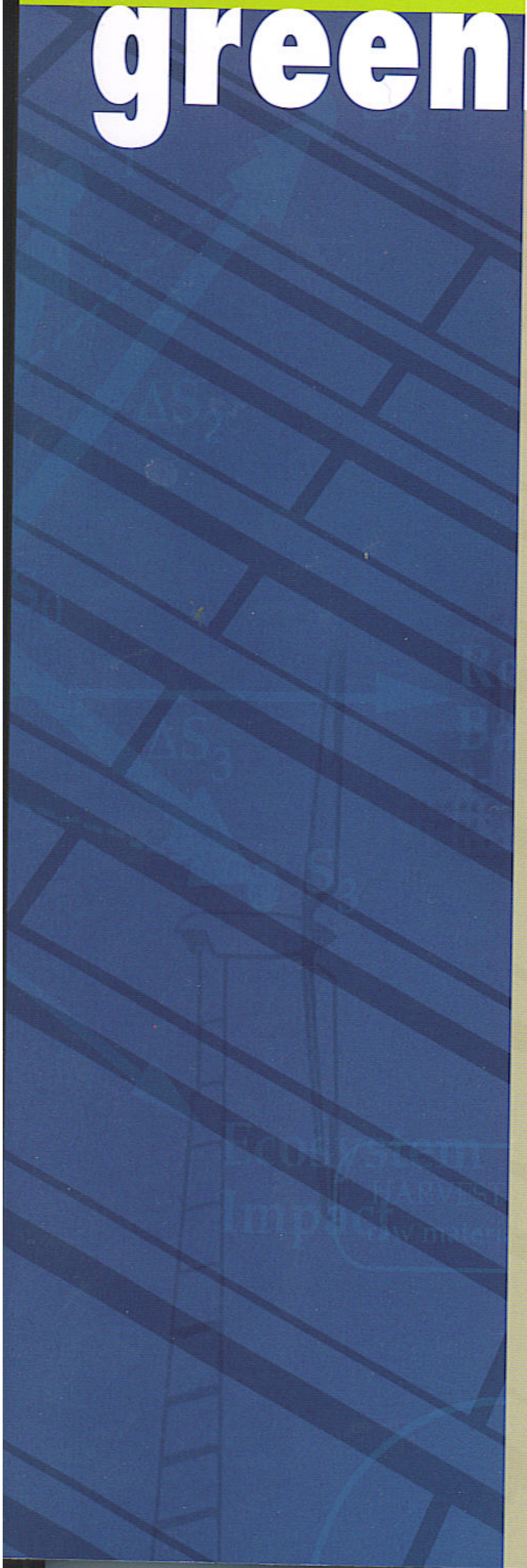

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INDUSTRY CORNER

RESEARCH ARTICLES

THE UNIVERSITY OF DELAWARE RAIN GARDEN: ENVIRONMENTAL MITIGATION OF A BUILDING FOOTPRINT

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INTRODUCTION

Green technology best management practices such as rain gardens are often used to retrofit and mitigate the footprints of buildings and impervious cover in watersheds. Rain gardens are a recent technology created to help remedy water abuses. A rain garden promotes the environmental benefits of storm water mitigation, water conservation, groundwater recharge, and reduced waterbody pollution. This research documents the process of implementing a rain garden from initiation through completion on the campus of the University of Delaware in the White Clay Creek National Wild and Scenic River watershed. The design considered the surrounding drainage area, infiltration rates, and plant selection. Through this project the researcher sought to create a demonstration that could inspire the public to create rain gardens. Initial goals of the research included preventing standing water from remaining in the garden after a four-day period, avoiding amendments to the native soil, and foregoing the removal of excavated soil from the rain garden depression off the site. In addition, no plant species were to be planted within the rain garden depression that were not native to within a five-hundred mile radius of Newark, Delaware. From this research, recommendations were generated for those wishing to install a rain garden. These include establishing initial goals, involving stakeholders, considering alternative overflow outlets, and inspecting soils to at least a 6-foot (1.83 m) depth. Further recommendations include stabilizing the contributing drainage area; utilizing aged, triple shredded hardwood mulch; and considering berms for use in capturing runoff and regulating outflows. In addition to mitigating the impacts of stormwater runoff from the buildings and parking lots in the watershed, the rain garden also serves as an outdoor education and research laboratory on campus.

THE HYDROLOGIC CYCLE

When Coleridge's Ancient Mariner said, "Water, water everywhere, nor any drop to drink," he was pretty accurate. Seventy-five percent of the earth's surface is water, 97.1 percent of which is salt water in the oceans. Approximately 2.9 percent of the total water on the earth is considered "fresh" water, with 76 percent of that bound up in ice caps and glaciers. That leaves 22.8 percent of the earth's fresh water supply in groundwater, 1 percent in surface freshwater, and .02 percent in the atmosphere (English & Smith 2003).

The earth's hydrologic cycle shows that water is evaporated into the atmosphere, and then falls as precipitation (Figure 1). The sun provides energy, and together with gravitational forces, keeps the water in a continual cycling motion. Soils may absorb a certain amount of water over a period of time. The ability of soil to absorb water is called infiltration capacity, and is dependent on the soil type as well as the amount of moisture previously existing in the soil. Rainfall that does not cycle to the atmosphere by evaporation and transpiration, or enter groundwater through infiltration, becomes surface runoff. When the rate of rainfall exceeds the ability of the ground surface to absorb or store water, the excess pools on the surface, or runs down to the lowest gravitational point, usually a stream, that ultimately leads to an ocean. The amount of runoff entering a stream depends on the rainfall intensity and duration, type and amount of vegetation cover, soil type, and slope of the land surface.

The hydrologic cycle has been in motion since the earth first cooled and condensed. The water that cur-

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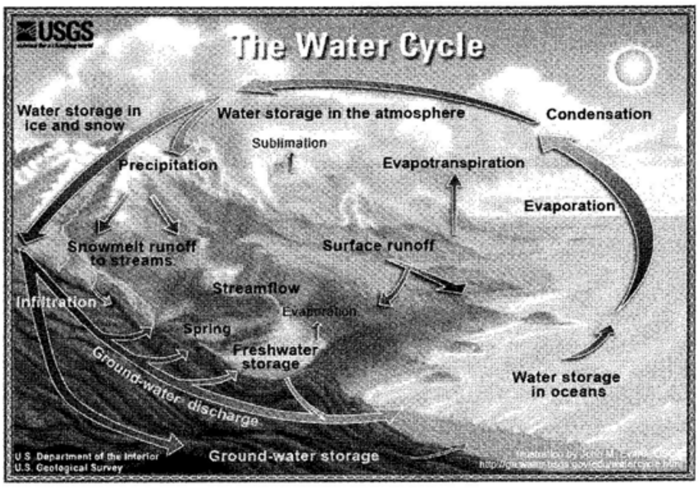


FIGURE 1. The hydrologic cycle. (Source: USGS.)

rently cycles through rivers, lakes, oceans, plants, and animals, is the same water that was formed millions of years ago. "Water can be polluted, abused, and misused, but it is neither created nor destroyed; it only migrates" (de Villiers 2000). The paradoxical reality is that water is merely recycled. Only the elements contained in it, and the amount present at any one place in time is variable. This variability is precisely what makes the hydrologic cycle so delicate and vulnerable. Disruptions to the hydrologic cycle, such as excessive runoff and consumption, affect the already scarce potable water available on Earth.

These trends of hydrologic disruptions and water abuses must be addressed to insure the continued availability of much needed potable water. As evidenced, what we do today impacts what will happen in the future. Native American, Chief Seattle once said, "We do not inherit the earth from our ancestors, we borrow it from our children." The best protection for water now and in the future, is to conserve, and reduce the demand, while preventing the transfer of pollutants into the water in the first place. These preventative measures are often called Best Management Practices or BMPs. One such BMP is the use of rain gardens (Figure 2), which aim to conserve water, promote runoff infiltration and groundwater recharge, and reduce waterbody pollution.

Rain gardens conserve water by reducing the need for supplemental irrigation of landscape plantings. Landscape plantings may include turf, which has a high demand for water, as mentioned earlier. Rain gardens are designed to capture and infiltrate water that occurs naturally from a storm. Using plants native in the area may result in their ability to adapt to natural fluctuations of stormwater inundation and drought. The roots of native plants used in a rain garden will usually grow deeper, following the stormwater as it percolates into the soil, thus enabling it access to water in drought conditions. By replacing shallow rooted turf grass with deeper rooted native plants, supplemental irrigation should no longer be necessary.

Rain gardens promote stormwater infiltration and groundwater recharge by collecting runoff from impervious surfaces that do not allow such activities. Capturing stormwater runoff in a shallow, landscaped depression allows the water time to percolate slowly into the ground, thus recharging groundwater.

FIGURE 2. Rain garden illustration.

Because water should not remain in a rain garden for more than four days, this BMP is not an end-all solution to mitigating all stormwater runoff. Due to the potential of creating mosquito habitats and the safety concerns of long standing water, a rain garden should capture only as much runoff as can be infiltrated in a four-day period. However, *any* stormwater infiltration and groundwater recharge is a benefit, and may mitigate disruptions to the hydrologic cycle.

Rain gardens reduce waterbody pollution by addressing some of the pathways of pollution such as nonpoint source pollution, excessive runoff, and natural soil and vegetative manipulation.

Nitrogen and phosphorus are often contained in turf fertilizers as nonpoint source pollution. By replacing turf areas with rain gardens planted with native plants, the demand for turf fertilizer is no longer necessary. Thus, the opportunity for nitrogen and phosphorus pollution to enter runoff leading to waterbodies is reduced.

Excessive runoff is often a conduit to polluted waterways by carrying surface contaminants, and encouraging sedimentation and streambank erosion. By installing a rain garden, designed to capture and treat runoff, this pollution pathway is diminished. Runoff collected in a rain garden can infiltrate, evaporate, or be absorbed and utilized by plants.

Rain garden plantings play an important role in water resource management. An example cited in Irwin P. Ting's *Plant Physiology*, a 47-foot (14.3 m) tall maple tree with 177,000 leaves and a total leaf surface area of 675 square meters, lost about 220 kilograms of water per hour in the summer sun. That amounts to about 465 gallons (1760.2 l) of water in an eight-hour summer day that must be made up for continued health of the plant by absorbing more water. Thus, plants have the potential to contribute to the mitigation of collected stormwater runoff. Plants also utilize nutrients like nitrogen and phosphorus for healthy growth. A plant's root system can act as a soil stabilizer, reducing erosion in streams and rivers (Tsukamoto 1987). Microbes in the soil surrounding the plant's root system may also aid in filtering and detoxifying nutrients before they reach waterbodies. Hardwood mulch, a plant product, can even biodegrade at least 90 percent of oil and grease runoff occurring from parking lots and roadways (Hong et al., in press).

While rain gardens are positioned to benefit water resources in various ways, additional benefits of rain gardens may include:

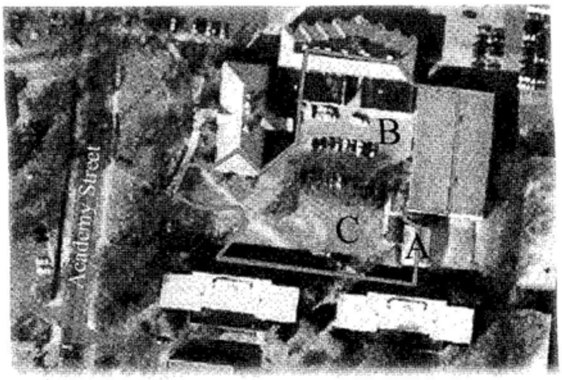
- Reduced landscape maintenance
- Reduced flooding
- Enhanced aesthetic appeal
- Enhanced bird and butterfly habitat
- Conserved energy
- Conserved money

Setting an example through the implementation of a rain garden may educate and motivate the public to consider future generations by installing them on their sites as well. Rain gardens are an attractive way of incorporating gardening, one of Americans' favorite hobbies, with water conservation and environmentally sustainable practices.

METHODOLOGY

This research documents the process of implementing a rain garden from initiation through completion on the campus of the University of Delaware in the White Clay Creek National Wild and Scenic River watershed. The rain garden was retrofitted into the landscape to mitigate the deleterious impacts of stormwater runoff emanating from the DGS Annex Building, Ocean Engineering Laboratory, the Geography Department building, and other buildings on the UD campus (Figure 3).

FIGURE 3. Site of the University of Delaware rain garden near the WRA/DGS Annex Building.



A: WRA/DGS Annex
B: Parking lot
C: Research site
▯: Outlines rain garden drainage area

Planning and design are crucial steps in successfully implementing a rain garden. The more information that is collected and considered before a shovel ever enters the ground, the better prepared and more fruitful the endeavor will be. The initial design concepts must minimally include a proposed site, project approvals from the proposed site authorities, and an estimated budget. Without these early essential elements, time, money, and efforts may be squandered.

Site Selection

In addition to the adequate soil classification (Matapeake-Sassafras silt loam) for a rain garden, the University of Delaware Water Resources Agency/ Delaware Geological Survey Annex (UD WRA) location was superlative because stormwater runoff from the surrounding vicinity was naturally being directed into the area (Figure 4). In addition, a stormwater outlet existed that captured the runoff and treated it via a traditional underground piping system. This is an ideal situation because a rain garden aims to capture and infiltrate stormwater runoff *before* it contributes to traditional outlets, while the very presence of the outlet allows for the treatment of any stormwater flow above the capacity of the rain garden.

The accessibility of the site is important, not just in terms of its ease in allowing heavy equipment access to it, but also for its convenience to visitors. As a demonstration project, the researcher preferred that the rain garden be available to a diverse audience. Locating the rain garden within a public institution such as the University of Delaware—with over 19,000 faculty, staff, and students—provides a broad audience, while demonstrating the University of Delaware Institute for Public Administration Water Resources Agency's mission to ". . . support and enhance the educational experiences of students through the effective integration of applied research. . . ." Part of implementing new technology and innovation is the ability to "sell" it to potential supporters. Since UD is within the City of Newark, a rain garden project supported the City's compliance of Phase II of the Federal Non Point Elimination Discharge System, thus making the project not only allowable, but desirable.

FIGURE 4. Research site prior to installation illustrates runoff from adjacent parking lot.

Once the site, approvals, and funding were secured, the researcher established the following initial criteria for the project:

- Create a demonstration that could inspire the public to create rain gardens.
- Prevent standing water from remaining in the garden after a four-day period.
- Avoid removing excavated soil from the rain garden depression off site.
- Add no amendments to the native soil.
- Allow no plant species to be planted within the rain garden depression that is not native to within a five-hundred mile radius of Newark, Delaware.

Similar to a mission statement, these criteria helped to guide the decision-making throughout the design and implementation of the rain garden project.

Design Process

At this time, buy-in should be received by all parties that may be affected by the rain garden project. For this case study, University departments such as Landscape Engineering, Groundskeeping, Plumbing, Water Resources, and Geology were consulted at the initial stages.

Designing a rain garden includes the specific placement of the garden on the site, the surface area, the depth, and the plant selection and placement. Additional considerations include mulch selection and rain garden enhancements.

Placement

By definition, the rain garden should be placed in an area that receives stormwater runoff. If stormwater does not enter the site naturally, it can be directed to the rain garden using downspouts, drain tile, or surface grading. For this project, stormwater was already being directed into the existing turf area, and then being collected by the existing catchbasin in the center.

One thing to consider in determining the exact placement and dimensions of the rain garden was maintaining a distance of at least 10 feet (3.1 m) away from a building foundation (University of Wisconsin Extension et al. 2003). This reduces the opportunity for directed stormwater to cause damage to structures by seeping or overflowing into a basement or foundation. Another consideration is to avoid placing a rain garden over an existing septic field (University of Wisconsin et al. 2003). A septic field is designed to receive a calculated amount of effluent from a septic tank and slowly dissipate and infiltrate it into the ground. By introducing additional stormwater into a septic field through the placement of a rain garden, the efficacy of the field may be compromised by inundating the septic system beyond its calculated capacity. This may result in the inability of the septic field to perform as designed, potentially causing septic backups and contamination.

It is important to locate the rain garden in a preferably sunny area that is not already prone to water puddling, and is near a stormwater outlet (University of Wisconsin Extension et al. 2003). Since one of the goals of a rain garden is to mitigate stormwater runoff, a sunny location provides a greater opportunity for water evaporation and transpiration by plants. Puddling may indicate that there is no outlet for excessive stormwater to be treated, or that there may be poor soil infiltration capacity in that area.

Locating the garden near an alternate stormwater outlet will insure the treatment of any stormwater runoff above the holding capacity of the rain garden. For this case study, any stormwater entering the garden above its capacity enters the traditional stormwater system through an existing catch basin located in the center of the research site. Treating the stormwater overflow of a rain garden may reduce the opportunity for potentially damaging floods.

The research site is surrounded on three sides by impervious surfaces, such as a sidewalk, a driveway, and a parking lot (Figure 5). The fourth side is partially limited by a curving driveway, and a 25-foot (7.6 m) by 122-foot (37.2 m) turf area that terminates at the street. These parameters, as well as existing underground utilities, determined both the placement and the size of the rain garden.

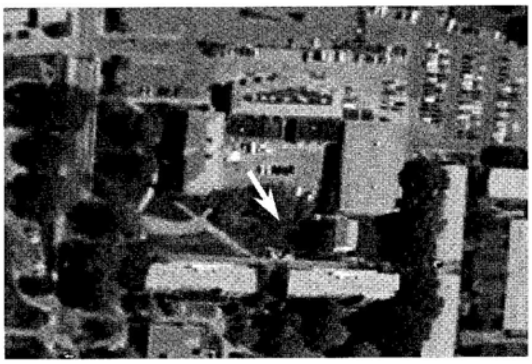
Sizing

The size of a rain garden is designed not only in terms of the area, but also in terms of the depth of the garden space. There are many references, and each suggests a method of calculating the area of a rain garden. Some are very specific to meet precise stormwater engineering and design requirements as illustrated by the *2001 Maryland Stormwater Manual* and *Prince George's County, Maryland Bioretention Manual*. Others resources, like the Wisconsin Department of Natural Resources' *Rain gardens: A how-to manual for homeowners*, and *Building a Rain Garden* from the Rain Garden Network, are geared more toward laypeople for use on a smaller site. While all of these resources are valuable, the approach to this rain garden project was a bit different. The researcher's theory for determining the area of the garden was "the bigger the better." If a moderate rain garden captured and infiltrated a fair amount of stormwater, then a huge rain garden could treat a lot more. All of the available area confined by the surrounding impervious surfaces and underground utilities was utilized, totaling approximately 4000 square feet (371.6 m^2).

Depth

The depth of a rain garden is largely determined by the infiltration rate of the soil conditions, and the

FIGURE 5. Site of the UD rain garden within the DGS Annex Building complex. (Source: Google Earth.)



amount of area draining stormwater into the garden. The surrounding drainage area helps determine the amount of stormwater that will be entering the garden area, simply by multiplying the area to be drained by the amount of precipitation for a given storm event. Using topographic surveys, it was determined that 1.42 acres or 61,855 square feet (5746.5 m^2) drained into the project site resulting in 8,907,120 cubic inches or 38,559 gallons (145961.7 l) of water from a 1 inch (2.5 cm) rainfall. With this calculation, and the knowledge that the area of the rain garden was fixed at 4,000 square feet (371.6 m^2) more stormwater would enter the site than the rain garden could treat. Given these parameters, the infiltration duration was the limiting factor. One of the objectives was to "prevent standing water from remaining in the rain garden after a four-day period." Therefore, the depth of the rain garden must only allow as much stormwater to be captured that could be treated within the specified amount of time.

For this project, no soil amendments were performed, so the infiltration rate was entirely dependent upon the existing soil types. As a class assignment, students from Civil Engineering 440 Water Resources Engineering conducted an infiltration test. They began by digging a 12-inch (30.5 cm) deep hole, filling it with water and allowing it to drain completely, and then refilling the hole and recording the rate at which the water infiltrated. Pre-construction infiltration rates performed to a 12-inch (30.5 cm) depth were calculated to be .2 inches (.51 cm)/hour. This meant that the top 12 inches (30.5 cm) of soil could soak up to 4.8 inches (12.2 cm) of stormwater in a 24 hour period. In the event that soils may infiltrate more slowly as they become saturated, the depth of the rain garden area was designed to be 8 inches (20.3 cm) deep, to insure that no standing water would be present after four days. The depth of the rain garden was accomplished by building an 8-inch (20.3 cm) berm around the existing catchbasin. After the garden filled up to its 8-inch (20.3 cm) depth capacity, any additional stormwater entering the garden would flow over the berm and directly into the catchbasin. Modifications to adjust the actual depth of the garden were performed, and are further discussed in the "Modifications" section of the "Results" section.

Earthwork

Once the ideal size and shape of any landscape design is determined, it is also up to the designer to determine how it will be realized. The designer must be able to compare the existing conditions with the ideal design and know what steps are necessary to implement it. For example, the original topography of the research site contained a gentle slope that hindered the 4,000 square foot (371.6 m^2) design. The solution was to plan to cut and remove the hill, and install a boulder retaining wall to hold back the newly exposed earth, resulting in the proposed uniform area.

In order to create a 5-inch deep depression in a 4000 square foot (371.6 m^2) area, over 400 cubic yards (305.8 m^3) of soil needed to be excavated and relocated. As a result, the costs of potentially disposing of the soil off site, and the methods of which to perform this task, were considerations. For this project, the soil was designed to be relocated on site, shaped into a mounded overlook, and finely graded into existing turf areas (Figure 6).

Since the infiltration capability is a major component of a rain garden, possible compaction by heavy machinery was a concern. Ideally, any heavy machinery entering the rain garden depression should be avoided. This may be accomplished by utilizing a backhoe with an extendable arm to reach into the center from the edge of the garden, or by the use of simple manual labor. In this case study, the site did

FIGURE 6. Earthwork and excavation at the University of Delaware rain garden.

FIGURE 7. Fine grading at the University of Delaware rain garden.

not allow for the mobility of a backhoe to reach into the garden, and manual labor was cost prohibitive. As a result, a bulldozer and a skid steer were planned to enter the rain garden depression on the condition that they both have rubber-tracking systems instead of tires. Tracking systems displace the weight of the machinery over the entire track instead of concentrating it over four small contact points, as from each wheel, thus reducing the probability of compaction. In addition, after all of the excavating and grading was complete, a skid steer with a subsoiler attachment was to fine grade the site to a 12-inch (30.5 cm) depth to help alleviate negative impacts resulting from the machinery (Figure 7).

Plantings

One goal for this case study was to "create a demonstration to inspire the general public to install rain gardens." In an attempt to attain this goal, the rain garden had to be functional and aesthetically pleasing. To achieve this, the plant selection and placement were important.

Native plants adapt best to fluctuating environmental conditions, like standing water and drought, which reduce their need for supplemental fertilizers and pesticides, support deep root systems that increase infiltration capabilities, and promote biodiversity by attracting a diversity of native insects. Thus, only plants of a genus and species native to within five hundred miles of UD were considered in this research.

An excellent resource titled *Native Species for Use in Vegetative Stormwater BMPs*, published by the Natural Lands Trust and the Brandywine Conservancy, guided the selection of tree and shrub species. Local growers, such as Pinelands Nursery and North Creek Nursery, guided the selection of herbaceous perennial species. Client considerations and aesthetic qualities further narrowed the selections to the existing project planting and mulching plan (Figures 8 and 9). Since the research site is located within a larger institution, the University of Delaware, careful consideration was made to be consistent with the existing campus landscapes. One-hundred percent of the trees and shrubs, and 54 percent of the herbaceous perennials proposed, are plants existing elsewhere on the UD cam-

FIGURE 8. Installing the native plants at the University of Delaware rain garden.

FIGURE 9. Placing the mulch at the University of Delaware rain garden.

TABLE 1. Recommended native plant list for the University of Delaware rain garden.

Trees and Shrubs		Herbaceous Perennials	
Botanical Name	**Common Name**	**Botanical Name**	**Common Name**
Aronia arbutifolia "Brilliantism"	Red Chokeberry	*Andropogon virginicus*	Broom Sedge
Cephalanthus occidentalis	Buttonbush	*Asclepias incarnata*	Swamp Milkweed
Clethra alnifolia	Hummingbird Shrub or Sweetpepper Bush	*Aster novi belgii*	New England Aster
Ilex verticillata local seed	Winterberry Holly	*Caltha palustris*	Marsh Marigold
Ilex verticillata "Winter Red"	Winterberry Holly	*Carex vulpinoidea*	Fox Sedge
Itea virginica "Henry's Garnet"	Virginia Sweetspire	*Eupatorium fistulosm*	Joe-pye Weed
Lindera benzoin	Spicebush	*Hibiscus moscheutos*	Marsh Hibiscus
Myrica cerifera	Wax Myrtle	*Iris versicolor*	Blue Flag Iris
Rhododendron viscosum	Swamp Azalea	*Juncus effusus*	Soft Rush
Taxodium distichum	Bald Cypress	*Monarda punctata*	Bee Balm
Viburnum dentatum	Arrowwood Viburnum	*Panicum virgatum*	Switchgrass
Viburnum nudum pollinator	Possomhaw	*Scirpus pungens*	Common Three-square
Viburnum nudum "Winterthur"	Possomhaw	*Vernonia noveboracensis*	New York Ironweed
Viburnum prunifolium	Blackhaw		

pus. Table 1 contains the recommended native plant list for the University of Delaware rain garden.

When implementing any design, it must be understood that events may not go exactly according to the plan. This project was no exception. Underground utilities proved to be a bigger concern than anticipated. The research site is the headwaters for a small tributary. As the University of Delaware campus was developed, this tributary had been manipulated and rerouted, sometimes into an underground pipe, as was the case on the research site. A suggestion by the UD Water Resources Agency to daylight, or simply uncover and remove the pipe exposing the tributary to the light of day, was entertained. It was not until soil borings performed on the site revealing existing utilities in the area, such as a water line, an electrical line, and a 48-inch in diameter sewer line, deemed this to be unfeasible. It is advisable to determine where, what, and to what depth the utilities are located early on in the design process. Most states have a free service that will mark most major utilities lines within five business days after a request has been submitted. In Delaware, the organization is called MISS UTILITY.

RESULTS

The garden was implemented according to the design specifications. However, some adjustments were made due to erosion, unforeseen underground utilities, and poor drainage.

An adjustment to the project was made to address the partial erosion of the rain garden resulting from stormwater sheeting off of the impervious parking lot surface and directly into the planting areas. A 4-inch (10.2 cm) deep, 18-inch (45.7 cm) wide band of cobblestones running the entire length between the parking lot and the garden edge was installed to reduce the erosion (Figure 10). The newly installed buffer absorbed the impact of the sheeting runoff,

FIGURE 10. Installation of cobble erosion control filter strip.

thus reducing the velocity of which water entered the garden area causing the erosion.

Another adjustment to the project was made to address an adjacent, ruptured underground pipe leaking directly into the garden area. The pipe was initially thought to be abandoned, and thus capped and buried. It was later discovered that the pipe was an outfall for air condition condensate, and was simply inactive until the air condition units were in use. To remedy the situation, the pipe was excavated, repaired, and reconnected to a nearby stormwater catchbasin. This disturbance in the soils immediately adjacent to the project, resulted in excessive sedimentation in the rain garden.

The last adjustment pertains to the poor drainage challenges of the rain garden. As previously mentioned, the depth of the rain garden project was determined based primarily on the infiltration capacity of the existing soils. Underneath the topsoil layer is a 4-foot (1.2 m) deep layer of dense clay. Since water was moving laterally, it was not infiltrating the amount of water that it was designed to, resulting in 8 inches (20.3 cm) of water standing in the rain garden for thirty days, far more than the optimal four-day period. By cutting three 3-inch (7.6 cm) notches into the berm surrounding the existing catchbasin, the excessive water was allowed to overflow into it. The depth of the rain garden then became 5 inches (12.7 cm) deep. Even after this adjustment, standing water was still present after four days, so alternate options were explored.

Further soil inspection found that under the 4-foot (1.2 m) layer of clay was a very porous, gritty, 2-foot (.6 m) layer of sand, and underneath that was gravel. To minimize disturbance of the new plantings, it was decided to hand auger 4-inch diameter borings to a 7-foot (2.1 m) depth, through the clay and sand layers into the gravel layer (Figure 11). This allowed for stormwater to travel past the dense clay layer and infiltrate into the sand and gravel layers more quickly and effectively. The overall depth of the rain garden then became 5 inches (12.7 cm), and contained thirteen 4-inch (10.2 cm) wide by 7-foot (2.1 m) deep borings.

Due to the extended duration of 5 inches (12.7 cm) of standing water in the rain garden area, approximately 18 percent of the newly installed plants did not survive such extreme conditions and had to be discarded and later replaced.

DISCUSSION AND RECOMMENDATIONS

The following conclusions and recommendations were found to be important considerations when designing and implementing a rain garden project.

Establish initial goals. As with any task or project, setting goals is essential for communication among stakeholders, determining limitations, and providing a method of evaluating the success of the project. The following are a few questions that may help in guiding the goal-setting process:

- How much runoff will be generated on-site?
- How much runoff will be captured by the rain garden?
- How long will standing water be allowable in the rain garden?

FIGURE 11. Performing soil borings to install pea gravel drains through clay layer.

- Will the rain garden be a public demonstration garden, private garden, or will it be used to meet specific stormwater regulations?
- Will replacing and/or amending the native soil be considered? If not, what is the existing soil type analysis?
- What will the budget be for the entire project?

Table 2 summarizes the expenditures on the rain garden project, which were funded by a grant from the U. S. Environmental Protection Agency through the Christina Basin Clean Water Partnership.

Involve representatives from all stakeholders impacted by the project. The stakeholders include a diverse array of people from designers and engineers to plumbing and groundskeeping staff. Also involved may be funders, residents and/or visitors, and surrounding employees. Only some of the stakeholders may be included initially; the rest should be included as the site selection and design processes get under way. For this case study, including stakeholders led to greater financial support, an improved site design, and prompt and positive responses by University Facilities Department staff.

TABLE 2. Rain garden budget.

Item	Proposed Cost ($)	Actual Cost ($)	Values ($) (estimated & exact)
Design	In-kind	In-kind	2,000
Earthwork	4,255	6,657	6,657
Plantings (tree & shrub)	4,500	5,622	5,622
Plantings (herbaceous)	N/A	1,445	1,445
Plant installation	2,800	In-kind	3,000
Mulch installation	1,040	1,850	1,850
Pipe repair	N/A	1,500	1,500
Drainage Borings by hand	N/A	In-kind	750
Boring stone backfill	N/A	150	150
Initial maintenance (weeding, watering, herbicide)	60	60	1,000
Eco-paver patio (300 sq. ft.)	8,000	7,560	7,560
Interpretation	3,920	*	4,670
Totals for 4,000 sq. ft. rain garden	24,575	24,844	36,254

N/A Not Applicable * Incomplete

Locate the rain garden near an alternative stormwater outlet to treat any overflow above the garden's capacity. This proved vital to the success of this case study, due to the unexpected diminished soil infiltration rates, and the record area rainfall for the month of October 2005. "An alternative stormwater outlet" can be considered any method of treating overflow from a rain garden. Examples may include draintile, a swale or ditch, or an existing stormwater grate or catchbasin.

Obtain soil classifications and subsequent infiltration ratings of the rain garden site to a depth of at least 6 feet (1.8 m) or refusal. Perhaps if this had been completed in the initial design stages, the modifications performed to improve the drainage may have been unnecessary. Knowing the soil profile may assist in determining any soil amendments required, proximity to the water table, and what drainage design options are feasible.

Ensure that the drainage area contributing to the rain garden is stabilized. This recommendation was discovered when the pipe adjacent to the rain garden had to be excavated and repaired. The disturbance resulted in the loosened soil that entered the rain garden area during rain events. This sedimentation of fine particulates led to diminished infiltration capacity in some areas, thus impairing an overall goal of a rain garden. An area can be considered stabilized when a groundcover such as turf, mulch, a silt fence, or even paving has reduced the opportunity for soil particles to be dislodged and relocated.

Use aged, tripled shredded, larger particulate, hardwood mulch. As discussed earlier, the continued clogging of the overflow catchbasin leading to the poor drainage, and the "bathtub ring" effect may have been avoided.

Utilize berms to capture runoff and regulate outflows. The berms could be stabilized with small plantings having a fibrous root system. This case study was designed so that excavated soil would not have to be hauled off-site, but simply relocated elsewhere on the project. Most rain garden projects can be constructed by using mounds of excavated soil to create a "bowl" in which to capture stormwater runoff. As in this case study, the excavated soil can be used to regulate the depth of the rain garden depression and overflow outlet, simply by adjusting the height of the berm around the stormwater catchbasin. This was advanta-

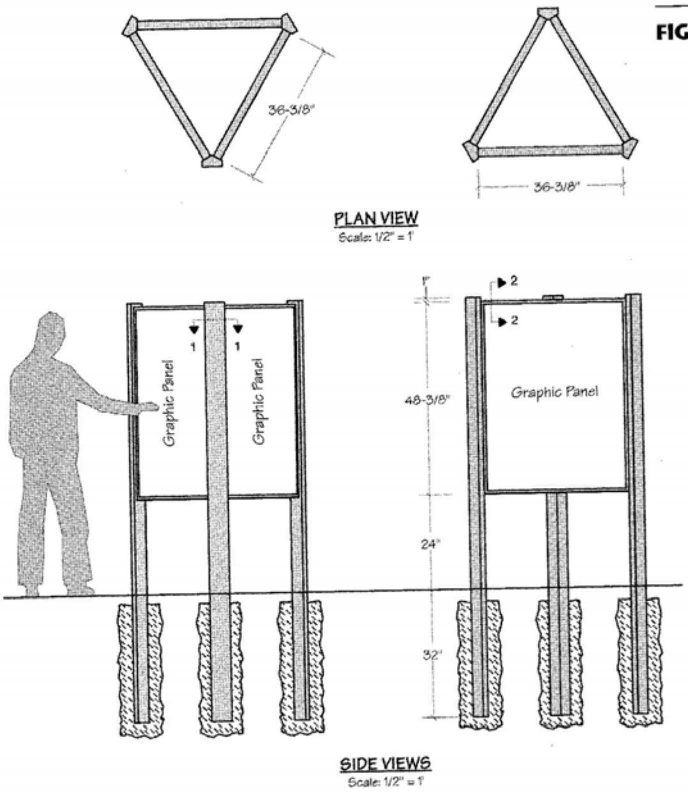


FIGURE 12. Rain garden interpretive sign.

geous, as the depth of the rain garden had to be adjusted due to initially poor infiltration. Leaving all of the excavated soil on-site eliminates the high costs involved in hauling/disposal.

Publicize the rain garden as a building stormwater retrofit project. A rain garden interpretative sign has been installed as a way to educate the students, parents, faculty, staff, and the public regarding the benefits of retrofitting rain gardens as a way to mitigate building footprints on the environment (Figure 12 and Appendix A). Porous eco-pavers were installed at the interpretive sign area as a way to show alternative practices to infiltrate stormwater runoff from the building footprint (Figure 13).

FIGURE 13. UD rain garden porous eco-pavers at the interpretive sign.

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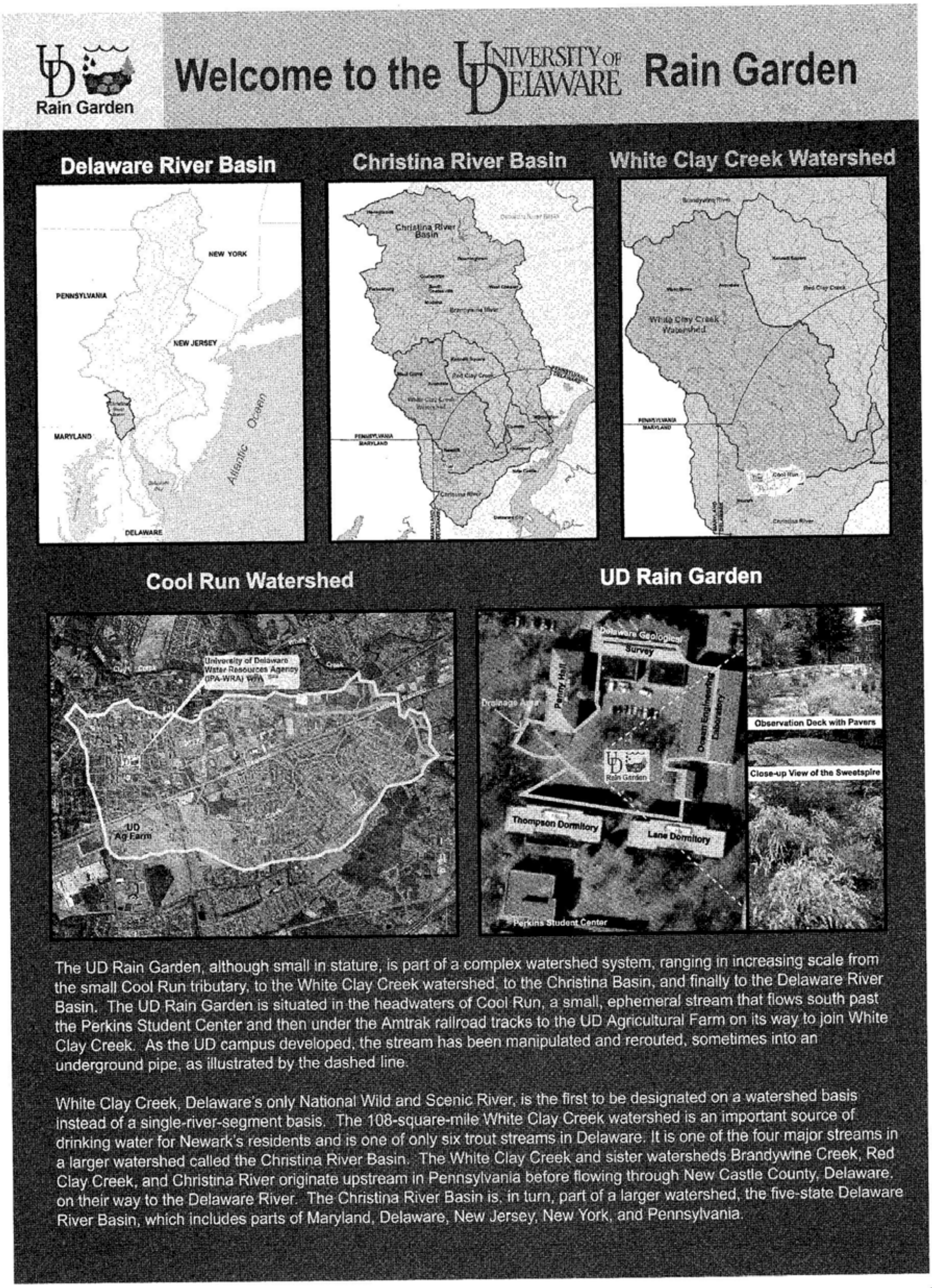
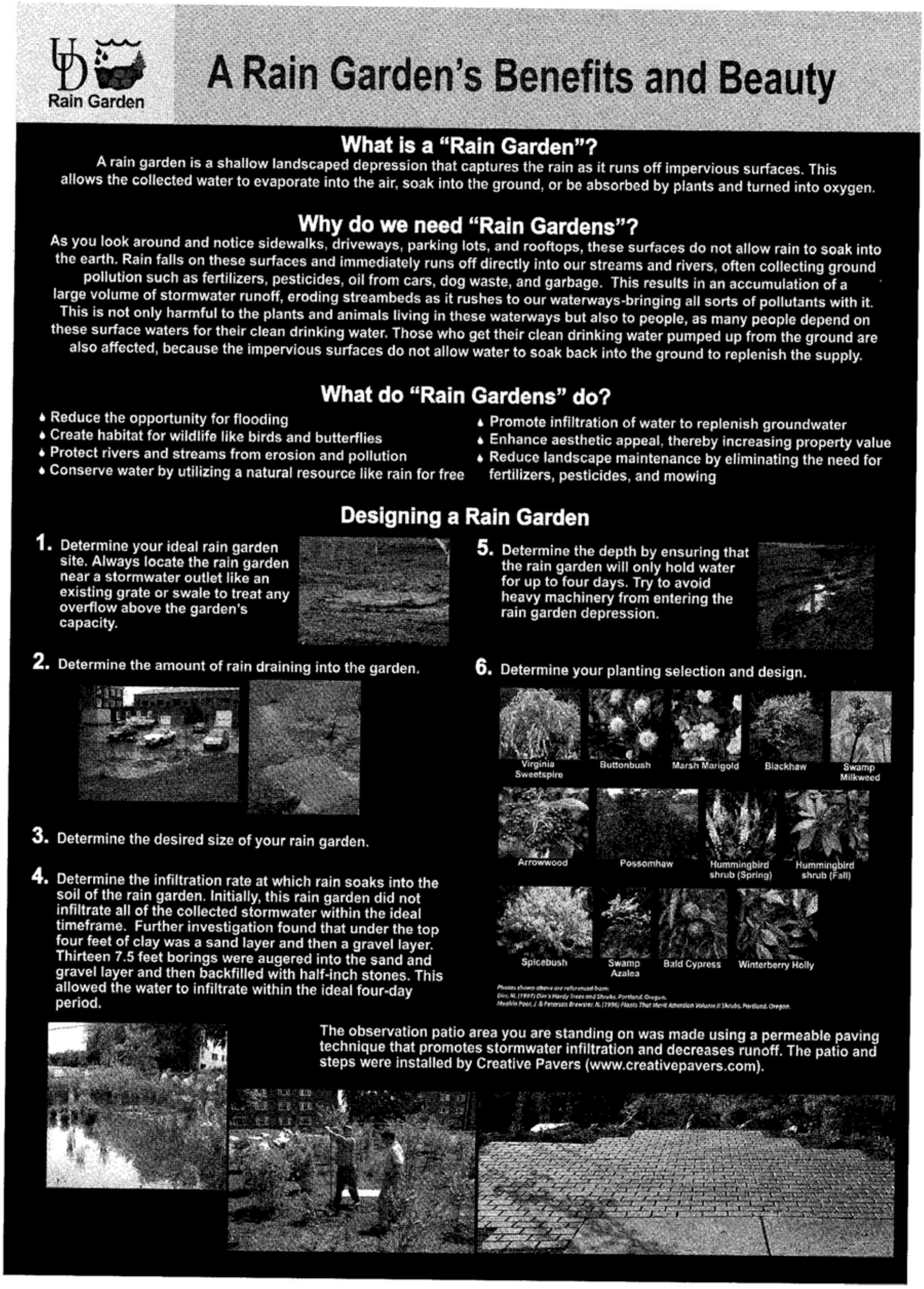
APPENDIX A. RAIN GARDEN SIGN PANELS.




Rain Garden
A Rain Garden's Benefits and Beauty
What is a "Rain Garden"?
A rain garden is a shallow landscaped depression that captures the rain as it runs off impervious surfaces. This allows the collected water to evaporate into the air, soak into the ground, or be absorbed by plants and turned into oxygen.
Why do we need "Rain Gardens"?
As you look around and notice sidewalks, driveways, parking lots, and rooftops, these surfaces do not allow rain to soak into the earth. Rain falls on these surfaces and immediately runs off directly into our streams and rivers, often collecting ground pollution such as fertilizers, pesticides, oil from cars, dog waste, and garbage. This results in an accumulation of a large volume of stormwater runoff, eroding streambeds as it rushes to our waterways-bringing all sorts of pollutants with it. This is not only harmful to the plants and animals living in these waterways but also to people, as many people depend on these surface waters for their clean drinking water. Those who get their clean drinking water pumped up from the ground are also affected, because the impervious surfaces do not allow water to soak back into the ground to replenish the supply.
What do "Rain Gardens" do?
♦ Reduce the opportunity for flooding
♦ Create habitat for wildlife like birds and butterflies
♦ Protect rivers and streams from erosion and pollution
♦ Conserve water by utilizing a natural resource like rain for free
♦ Promote infiltration of water to replenish groundwater
♦ Enhance aesthetic appeal, thereby increasing property value
♦ Reduce landscape maintenance by eliminating the need for fertilizers, pesticides, and mowing
Designing a Rain Garden
1. Determine your ideal rain garden site. Always locate the rain garden near a stormwater outlet like an existing grate or swale to treat any overflow above the garden's capacity.
2. Determine the amount of rain draining into the garden.
3. Determine the desired size of your rain garden.
4. Determine the infiltration rate at which rain soaks into the soil of the rain garden. Initially, this rain garden did not infiltrate all of the collected stormwater within the ideal timeframe. Further investigation found that under the top four feet of clay was a sand layer and then a gravel layer. Thirteen 7.5 feet borings were augered into the sand and gravel layer and then backfilled with half-inch stones. This allowed the water to infiltrate within the ideal four-day period.
5. Determine the depth by ensuring that the rain garden will only hold water for up to four days. Try to avoid heavy machinery from entering the rain garden depression.
6. Determine your planting selection and design.
Virginia Sweetspire
Buttonbush
Marsh Marigold
Blackhaw
Swamp Milkweed
Arrowwood
Possomhaw
Hummingbird shrub (Spring)
Hummingbird shrub (Fall)
Spicebush
Swamp Azalea
Bald Cypress
Winterberry Holly
Photos shown above are referenced from:
Dirr, M. (1997) Dirr's Hardy Trees and Shrubs. Portland, Oregon.
Meekin Poor, J. & Peterson Brewster, N. (1996) Plants That Merit Attention Volume II Shrubs. Portland, Oregon.
The observation patio area you are standing on was made using a permeable paving technique that promotes stormwater infiltration and decreases runoff. The patio and steps were installed by Creative Pavers (www.creativepavers.com).

A Special Thank You to the Funders

UD Rain Garden

Funders

US Environmental Protection Agency Targeted Watersheds Initiative

EPA United States Environmental Protection Agency — Targeted Watersheds

CSREES Mid-Atlantic Regional Water Quality Program

CSREES Mid-Atlantic Water Quality Program — Applying knowledge to improve water quality

The UD Rain Garden is funded in part by the EPA as part of the Targeted Watersheds Initiative. A $1 million grant was awarded to the Christina Basin Clean Water Partnership to restore the watersheds in the Christina Basin.

The Targeted Watersheds Initiative Grant Program was proposed in 2002 by the Bush administration to encourage successful community-based approaches to protect and restore the nation's watersheds. The Christina River Basin Clean Water Partnership is a wonderful example of partnerships actively working together to identify real problems in real places and solving them. In the 2003 selection process, the first year of funding in the Targeted Watersheds Initiative Grant Program, the Christina Basin application was the highest ranked application from more than 170 submittals. This impressive milestone–and the award of $1 million in Federal grant funds was a testimony to the multi-state, multi-organizational efforts to improve the water quality conditions in the Christina Basin. At stake is the health of an environmentally and economically significant residential, agricultural, and industrial watershed that provides numerous recreational opportunities and serves as a primary source of drinking water for many of its more than 500,000 residents. However, there is no time to rest. The partners and residents of the Christina Basin must maintain a commitment to achieve the water quality–management goals established for the Christina Basin. Other projects funded by the watershed initiative grant include

A series of Chester County Conservation District Agriculture conservation projects in Pennsylvania and three projects in Delaware

DNREC's Pike Creek Stream Restoration Project - Delaware's largest stream restoration project

Photos shown below are courtesy of the Department of Natural Resources & Environmental Control.

Before restoration on Pike Creek at Three Little Bakers Golf Course, rip-rap was used in some areas to hold the stream banks in place.

After restoration on Pike Creek at Three Little Bakers Golf Course—the same area has been transformed with logs, tree stumps, boulders, and live branch willow layering to stabilize the banks and create habitat for fish and macro-invertebrates.

Delaware Nature Society, Christina Basin SMARTYARDS project - water-friendly native landscaping for homeowners

Photos shown below are courtesy of the Delaware Nature Society.

Planting a variety of native plants in your garden will create a beautiful array of colors year-round that will require less watering, food for native species, a place to raise young, shade, and promote resource conservation.

Installing a rain barrel to collect rain water from your down spout is a great method for conserving water. The collected water be used for watering plants, gardens and grass.

Cool Run Wetland Restoration Project - collaboration between DNREC and UD in the headwaters of the White Clay Creek

Photos shown below are courtesy of the University of Delaware, College of Agriculture and Natural Resources.

The stream running through farm fields will be evaluated for channel modification and buffer enhancement.

DNREC scientists evaluate a rill for enhancement to reduce pollution transport.

Unproductive pasture and crop field acreage will be converted to wetlands that will filter pollutants and provide wildlife habitat.

This button bush is an example of the native species that will be planted in the new wetland and stream corridor areas.

CSREES advances knowledge for agriculture, the environment, human health and well-being, and communities through national program leadership and federal assistance. CSREES' two key mechanisms for accomplishing its mission of "advancing knowledge" are

1. National program leadership. It helps states identify and meet research, extension, and education priorities in areas of public concern that affect agricultural producers, small business owners, youth and families, and others.
2. Federal assistance. It provides annual-formula funding to land-grant universities and competitively granted funds to researchers in land-grant and other universities.

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