Rain Gardens: Stormwater Solutions Manual for Indiana University Bloomington

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Stormwater Management at the University

The transition from a native landscape to a built environment due to the construction of roads, parking lots, sidewalks, roofs and landscaping increases impervious surface coverage. The process of urbanization has transformed the Bloomington campus landscape; the Jordan River watershed is 44 percent impervious and the Cascades watershed is 36 percent impervious (IU Campus Master Plan, 2010). This change reduces, disrupts or eliminates native vegetation, upper soil layers, and natural drainage patterns that traditionally intercept, evaporate, store and infiltrate stormwater. This affects the ecosystem health of receiving water bodies and downstream communities by changing the timing and volumes of the natural flow regime. The Bloomington campus is divided into four distinct watersheds: Clear Creek, Jackson Creek, Cascade Creek and Sycamore Creek watersheds.

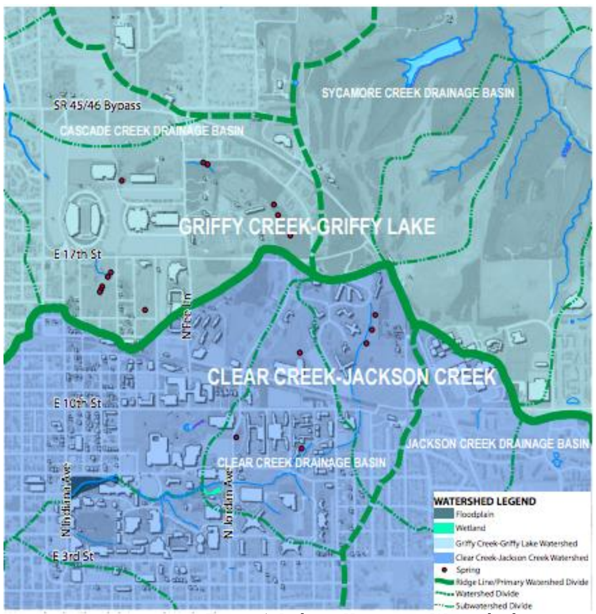


Figure 1. Indiana University Watersheds

A majority of the South half of campus is drained by the Jordan River, a tributary of Clear Creek. In 2010, seven hundred thirty-one acres drained via the Jordan River via storm inlets and underground pipes. Numerous storm drains discharge directly into the river (IUB Master Plan, 2010). Stormwater should not be treated as a waste product needing to be disposed of. In both watersheds, the integrity of the storm sewers is inadequate during large rain events allowing backups to occur. Instead of managing stormwater in large, costly end-of-pipe facilities, LID can address stormwater through more cost-effective methods. These methods can save money and take stress off the campus's infrastructure by implementing small-scale landscape features.

Table 1. Watershed Response to Degradation

Degradation of Watershed Conditions and Stream Response	
Watershed Condition	*Response*
Increased Fine Sediment Deposition	-Reduced dissolved oxygen levels in streambed -Loss of spawning and macroinvertebrate habitat -Eroded stream banks -Decreased water clarity -Alters biotic assemblage structure
Increased Fragmentation of Riparian Areas	-Reduced delivery of woody debris -Reduced bank stability -Loss of bank habitat, structure and complexity
Reduced Shading Loss of Vegetation	-Warmer stream temperatures -Decreases aquatic populations
Increased Pollutant Load	-Synthetic organic compounds can be toxic -Endocrine disruptors -Nutrients cause excessive aquatic plant growth
Loss of Biological Diversity	-Changes in the biological community -Shift towards dominant pollution-tolerant species
Decreased Groundwater Recharge	-Lower stream flows during dry weather -More frequent flooding -Lower water table levels

Hydrologic Cycle and the Effects of Development

The hydrologic cycle is a continuous process. Generally, the movement of water from the atmosphere to the land and back to the atmosphere is through a cycle of precipitation, runoff, evapotranspiration, infiltration, groundwater recharge and stream flow. Changes in the land surface along with inappropriate stormwater management can significantly alter the natural hydrologic cycle.

Naturally, water is stored in puddles, ponds and lakes where it will eventually evaporate. Surface vegetation transpires water into the atmosphere, while most annual rainfall returns to the atmosphere through evapotranspiration. Water can also percolate through soils reaching saturation or the water table (Penn.

Stormwater Manual, 2006). Changing the land surface causes varying changes to the hydrologic cycle (Figure 4). Roads, building, parking lots, and other impervious surfaces prevent rainfall from soaking into the soil and increase the amount of runoff.

Precipitation in Indiana

In Bloomington, Indiana, average annual precipitation is 47 inches, with a 1-year-24 hour storm average of 2.67 inches. Traditionally storm water management has focused on managing flooding from larger but less frequent heavy storm event (Table 2).

Table 2. Frequency of Occurrence for 1-year, 24-hour design storm (NOAA, 2015)

Location	Frequency of Occurrence (Years)				
	2	5	10	50	100
Bloomington	3.07	3.82	4.44	5.31	6.04
Indianapolis	2.92	3.57	4.08	5.3	5.84
Columbus	2.92	3.62	4.2	5.67	6.38
Bedford	3.13	3.89	4.51	6.07	6.81
Terre Haute	3.11	3.83	4.41	5.9	6.6

Stormwater management for these events focuses on peak rate runoff; that is, the maximum rate of flowing water per unit time. Although regulating criteria to manage large storm event is important, it does not account for the change in land surface (Penn. Stormwater Manual, 2006). Not only does peak rate runoff increase, but volume of runoff as well. Monroe County design criteria requires a post development peak discharge for a 2-, 25- and 100-year frequency storm (Monroe County Hwy Dept, 2005). Although a detention facility may slow the runoff, there may still be increased runoff. This approach can be insufficient because it does not address the losses in groundwater recharge and maintenance during low flow periods (Prince Georges County, DER). In addition, the increase of impervious surfaces will increase the frequency of runoff events (Figure 4). For example, little runoff will occur from a woodland wetland site in small rainfall events of less than 1 inch, whereas a parking lot will generate runoff almost immediately (Penn. Stormwater Manual, 2006).

Water Quality

Impervious surfaces convey pollutants in runoff and discharge to surface waters. Runoff that occurs at the beginning of a rain event carries with it concentrations of pollutants that have accumulated during dry periods. These concentrations are generally more pronounced on

<u>Increased Pollutant Loads due to:</u>

- Sediment
- Pesticides
- Viruses
- Bacteria
- Thermal pollution from dark surfaces
- Oil, grease, toxic chemicals
- Nutrients from landscaping
- Road salts
- Heavy metals

impervious surfaces and at the beginning of the storm (Hager, 2001). This concept is referred to as “first flush” (figure 3).

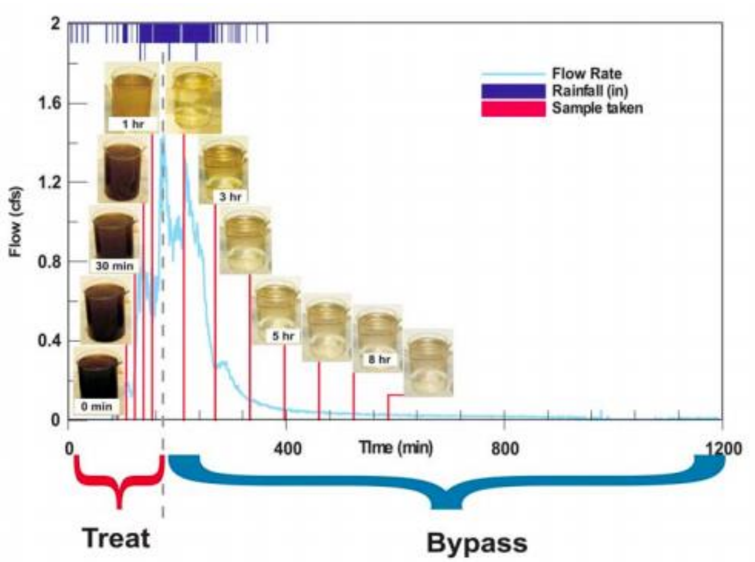


Figure 3. First flush characterization of samples over 700 minutes. Samples contained higher levels of pollutants before peak flow rate, demonstrating the first flush concept (California DOT, 2005)

Pollutants that are suspended in during first flush, just before peak flow on a hydrograph, typically include high levels of sediment, phosphorus, metals, organic particles and litter. Dissolved pollutants, such as nitrate, salts and synthetic compounds, typically decrease in concentration during a rain event (California DOT, 2005). A common goal of stormwater management involves mitigation to storm water quantity and quality impacts. Monroe Country and Indiana University must take measures to achieve and maintain compliance with Federal, State and Local storm water quality regulations including the National Pollution Discharge Elimination System and County Flood Damage Prevention regulations. In the State of Indiana, Best Management Practices must remove 80 percent of the Total Suspended Solids load from post-construction runoff (IN Stormwater Specifications Manual, 2011). Although the most obvious impact of increased impervious surface and development is increased volume and rate of runoff (figure 4), pollutants transported also pose a significant impact. Green infrastructure strategies can manage both the quantity and quality of storm water surface runoff.

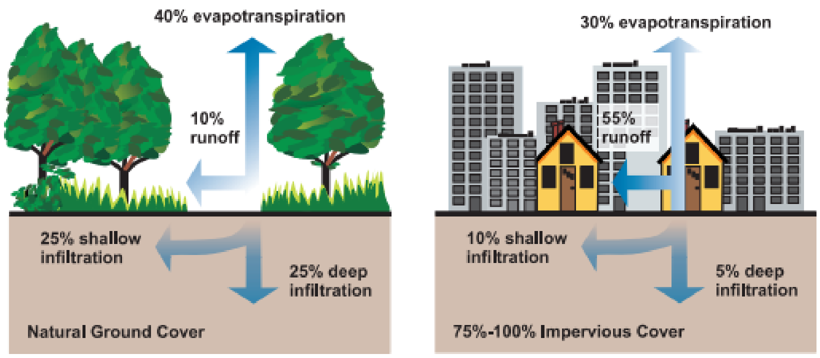


Figure 4. Comparison of runoff in natural groundcover vs. impervious surfaces

Low Impact Development

Low Impact Development (LID) is an alternative and comprehensive approach to stormwater management. It can be used to address a wide range of flow issues including Combined Sewer Overflows, National Pollutant Discharge Elimination Systems, Nonpoint Source Program goals and other water quality standards (Low Impact Development Center, 2007). Instead of a purely structural approach, LID applications emphasize conservation and the use of on-site natural features. Integrating engineered, small-scale hydrologic controls help to mimic a hydrologically functional landscape.

LID strategies focus on evaporating, transpiring, and infiltrating stormwater on-site through native soils, vegetation and bioengineering applications.

LID Management

LID for stormwater management focuses on maintaining or restoring the natural hydraulic functions of a site for the purpose of water resources protection (Anchorage Design, 2008). Managing rainfall at the source using decentralized micro-scale controls mimic a site's predevelopment hydrology. Microscale and distributed management landscape techniques, called integrated management practices (IMPs), are incorporated into LID technology. Incorporating variables such as infiltration, filtration, storage, evaporation, and transpiration, rainwater is detained to keep runoff close to its source (Low Impact Development Center, 2007). This can help control runoff volume, peak runoff rates, flow frequency/duration and water volume control.

- *Volume Control:* A combination of minimizing site disturbance and retention IMPs maintain predevelopment volume. These structures help retain runoff during storm events.

Commented [MP1]: check

- *Peak Runoff Rate Control*: Focuses on maintaining the predevelopment time of concentration. Using retention or detention IMPs distributed across the site will maintain the historic peak runoff discharge rate.
- *Flow Frequency*: Reduced peak flows will minimize sediment, erosion and stream habitat impacts. Through volume and peak runoff rate controls, peak runoff rates will be similar to those during predevelopment conditions.
- *Water Quality Controls*: Modifying the traditional stormwater management approach by placing IMPs in urban environments allows regulators to use LID to reduce the introduction of pollutants and increase environmental benefits (NRDC, 2001).

Native soils and vegetation are strategically distributed throughout the project site to slow, store and infiltrate storm flows. This functional landscape essentially imitates predevelopment detention and retention of a site. (Dietz, 2007) Types of LID techniques include, but are not limited to: bioretention, green roofs, permeable pavers, rain barrels and cisterns, soil amendments, and bioswales, buffers and strips (Figure 5).

Rain Garden	 www.taltree.org	**Green Roof**	
 water.epa.gov	**Permeable Pavement**	 sustainablecommunitysolutios.com	**Rain Barrel**
Soil Amendments	 stpaul.gov	**Bioswales**	 nrcs.usda.gov

Figure 5. Examples of LID Techniques

Instead of University investments in complex and costly centralized stormwater infrastructure, LID allows for simple and effective integration of flexible features. LID is more economical than conventional systems because of fewer pipes, belowground structures and pervious qualities. The types of landscaping used in LID contributes to a higher quality of life, campus livability, add value to a sense of place and aesthetics. From a sustainable stand point, not only does LID improve stormwater runoff quantity and quality, but also improves wildlife habitat, thermal pollution reduction, energy savings smog reduction, and wetland protection enhancement.

Rain Gardens Benefits

Although there are many LID techniques that could be applied on the Indiana University Campus to reduce ecological and economical impacts of traditional stormwater management, rain gardens can be incorporated to tackle peak runoff rates, retention storage and volume conditions. Rain gardens, also called bioretention basins, are shallow landscaped basins that utilize engineered soils and native vegetation to temporarily store and treat stormwater (Figure 6). Bioretention is an extremely flexible and effective LID technique because they function to achieve water quality and water quantity goals.

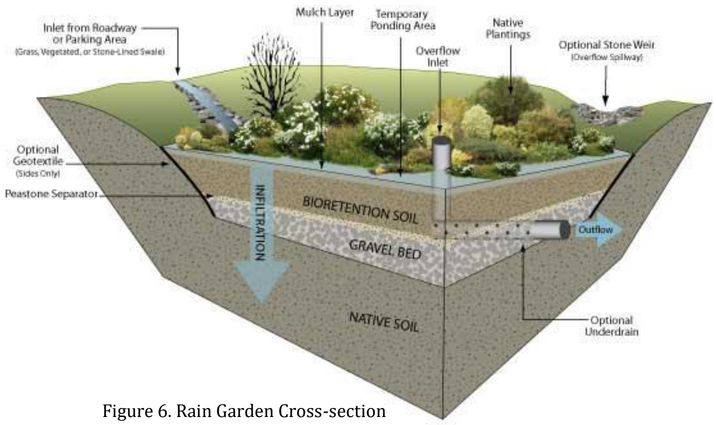


Figure 6. Rain Garden Cross-section

Rain gardens are a successful Best Management Practice that integrates knowledge from a number of disciples including engineering, hydrology and hydraulics, soil science, horticulture and landscape architecture. Rain gardens integrate many properties of other BMPs such as berms, detention ponds and buffer strips (Dietz, 2007). The uniqueness of rain gardens allows them to achieve a wide range of storm water management objectives such as groundwater recharge, pollutant removal, channel protection and peak flow reduction.

Managing storm water runoff by infiltration is one of the simplest ways to actively protect our streams and improve water quality. Storm water management practices should be implemented that rely on natural features by restoring stream beds, reducing impervious ground cover, and treating storm water where it falls instead of channeling it downstream.

Water Quality

The streams and rivers at Indiana University are part of the Clear Creak watershed and are some of the major headwaters that eventually drain into the East Fork of the White River (City of Bloomington, 2015). Inputs to headwater streams, like the Jordan River, ultimately affect the water quality of downstream areas (Karr and Dudley, 2014). Rain gardens can help mitigate water quality issues that evolve up stream orders.

Soil and plant based filtration in rain gardens remove pollutants through a variety of physical, biological and chemical processes. Rain garden studies have indicated good removal of phosphorus and total Kjeldahl nitrogen. Research involving mass balances demonstrate that rain gardens have a moderate affect on nutrient removal (Davis et al. 2003). In lab testing, copper reduction of up to 90 percent was found along with reduced nutrient concentrations of total Kjeldahl nitrogen by 68 percent, and ammonia-nitrogen at 87 percent (Dietz, 2007). A majority of metal removal occurs in the top couple layers of a rain garden in the mulch and upper soil layers. Heavy metals, like zinc and lead, achieved excellent reduction of 98 and 99 percent (Davis et al. 2006). Total suspended soils removal via rain gardens varies from 59 percent up to 97 percent in studies (Davis, 2007 and UNHSC 2006). Phosphorus studies have been variable, due to the complexity of chemistry of the nutrient. Some studies have found low treatment efficiency due to possible leaching by soil and vegetation whereas others have seen an addition of phosphorus. The variations can be dependent upon initial levels of soil phosphorus and available sorption sites on aluminum, iron and clay minerals in soil (Davis et al. 2009). Adopted from Prince George County's Bioretention Manual, Table 3 summarizes of pollutant removal effectiveness by rain gardens.

Table 3. Pollution Removal Performance Based on Bioretention Studies

Parameter	% Removal	Source(s)
TSS	97	Hsieh and Davis, 2005b; UNHSC, 2006 Ermillio & Traver, 2006
TP	35–65	Davis et al., 2006; Hunt, et al., 2006 Ermillio, 2005
TN	33–66	NHSC, 2006; Hunt et al., 2006 Sharkey, 2006, Davis et al., 2006
Cu	36–93	Ermillio, 2005; Davis, et al., 2006
Pb	24–99	Ermillio, 2005; Davis, et al., 2006
Zn	31–99	UNHSC, 2006; Ermillio, 2005
Oil & Grease	99	UNHSC, 2006; Hong, et al., 2006
Bacteria	70	Hunt, et al., 2007

Water Quantity

Besides pollution reduction goals, rain garden also have the objective of water quantity control, specifically minimizing, detaining and infiltrating stormwater runoff. Typically, rain garden designs are based off of a 1-year, 24-hour design storm. For Monroe Country, this design storm produces approximately 2.56 inches of rain. Rain gardens mitigate flow from infrequent storm events (1-yr, 2-yr or 10-yr design storm), but design for peak flow mitigation studies have been limited. The volume of runoff that needs to be controlled to mimic natural conditions is based of the sites curve number (Prince George's County, 2007). The volume removal capacity of the basin must be considered when designing for peak outflows. Studies have shown that increasing the bowl depth or additional volume capture can mitigate peak flows. Soil media also plays an important role in storm water volume control. For example, if the soil was mainly composed of gravel and/or sand, peak-flow mitigation would be minimized if infiltration rates were 250mm/h or above (Hunt, et al. 2012)

Rain Garden Design for the IU Campus

Rain gardens have many practical uses around the IU Bloomington Campus, but in order for rain gardens to be effective, they must be designed to meet constraints of a site. Although they are not suitable as a pretreatment mechanism or for industrial purposes, rain gardens are applicable for parking lots, rooftops, roadways, building, lawns and sidewalk runoff. In general, rain gardens should be placed as close to the source of runoff generation, smaller than 2 acres, located at least 10 feet away from foundations, and located on slopes less than 20 percent. The layout of a rain garden is determined by site constraints such as soils, utilities, existing vegetation and drainage.

Preliminary Site Evaluation

Soil

The efficiency of a rain garden is dependent on the infiltration rate of the surrounding soil. A majority of the built campus soil is composed of Crider Silt Loam and Crider-Urban Land Complex (Figure 7). Although identified as well-draining, these soil have been subject to major compaction and land-altering patterns (IUB

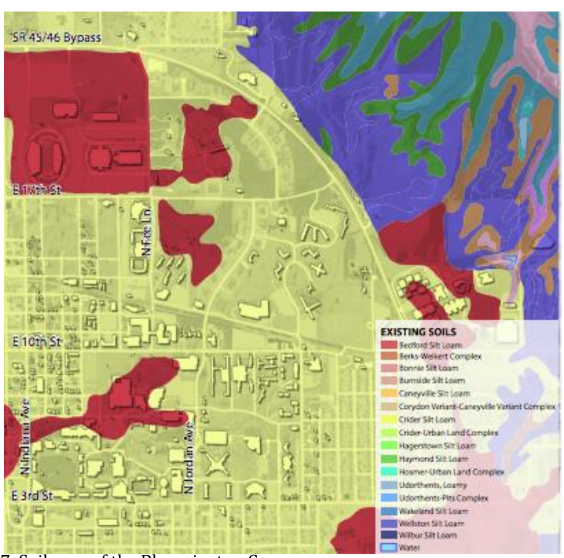


Figure 7. Soil map of the Bloomington Campus

Master Plan, 2010). Central campus is categorized as Hydrologic Soil Group B according to Web Soil Survey. These soils having a moderate infiltration rate when thoroughly wet. Group B soils typically have an infiltration rate of 0.15-0.30 in/hr and have moderate runoff potential. Infiltration test show that many of the soils present near buildings are clay-based and have low levels of percolation (Ploch, 2014). For soils not to be a restriction, rain gardens must have an infiltration rate sufficient to draw down pooled water over a 48 hour timespan or an infiltration rate of at least 0.5 inch/hour. To overcome slow infiltration rates on campus, engineered soils or an underdrain system can be installed.

Utilities and Foundations

The Bloomington campus is composed of many utility lines including chilled water, electrical power, telecommunications, stream, storm water, and sewer. Many of these lines exist underground, with depths as little as six inches (for irrigation). Most utilities are 24-36 inches deep, while lighting is usually 12-18 inches (Campus Division, 2015). With rain garden depths reaching a maximum ponding depth of six inches and total depth reaching 48 inches, it is important to locate existing utilities. Utilities have been mapped on ArcGIS and available through the Physical Plant, Campus Division, and the Landscape Architects Office. Lee Walters in the Utilities Department can grant permission for these GIS layers for academic purposes.

To reduce the any likelihood of flooding foundations, rain gardens should be installed a minimum of 10 feet from buildings (Figure 8). They should not be hydraulically connected to buildings of pavement foundations as they can cause damage to the structures.

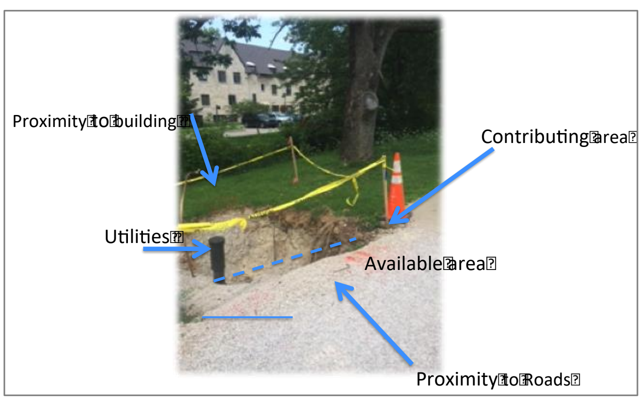


Figure 8. Examples of some design constraints

Existing Vegetation

With approximately 36 percent tree canopy cover and the historic landscaped character, rain gardens should not require the removal of existing vegetation. This is with exceptions; if landscaped areas are degraded, subject to erosion, present heavy ponding or include the presence of dying or dead trees, rain gardens can be installed.

Drainage and Groundwater

Depth to groundwater below the rain garden should be less than two feet. This can also be said for depth to bedrock, which can be shallow in Indiana with its abundance of limestone bedrock. Determining depth to groundwater can be found on web soil survey or by performing a test pit during seasonal periods. Slopes exceeding 20 percent will cause water velocity entering the garden to be too high and promoting infiltration will be difficult (Prince George County, 2007). It is recommended that grading occur if the site is located on a slope of less than 2 percent to create proper drainage and flow into the site. To determine slope of site a string can be tied to an uphill and downhill stake and measured (Figure 9). Slope can also be determined using Digital Elevation Maps.

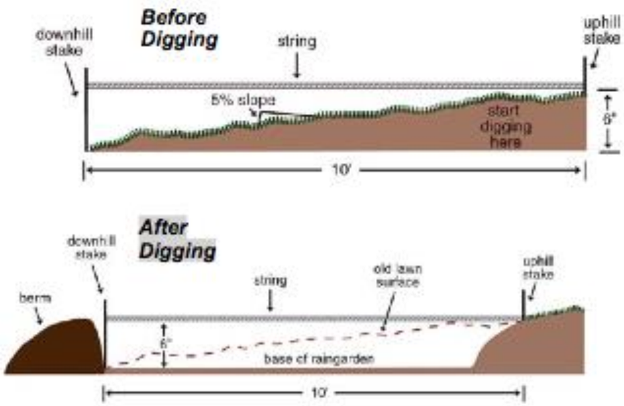


Figure 9. Determine slope using a basic method consisting of stakes and string

Other Considerations

Rain gardens thrive in full to mostly sunny locations due to higher rates of evapotranspiration. Shady locations can still be possible if the species of plants are shade tolerant and infiltration rates are at least a half-inch per hour. Even though a location may seem ideal for a rain garden, it is important to have enough space to capture runoff from the contributing area. A general rule of thumb is that a rain garden will require approximately 10 percent of the total contributing area (PSAT, 2003).

For rain gardens additions on campus to be sustainable, they need to complement the existing landscape. Rain gardens have the opportunity to function as memorable spaces on the Bloomington campus because of their diversity, character and overall function. Rain gardens can be preserved as a natural area on campus due to their environmental, visual and social benefits. As a critical component of the Jordan River Watershed, rain gardens will protect the iconic Jordan River by depositing treated stormwater and reducing peak flows. Rain gardens can add to future campus enhancement, but should be designed with aesthetics in mind. Campus rain gardens need to preserve the existing landscape character by maintaining a groomed appearance with lower plant diversity. Implementing rain gardens in a suitable manner moves the Campus Master Plan forward with the preservation and sustainable management of natural features and enhancement of the campus landscape.

Preliminary Design

In 1993, the first major bioretention design manual was published in Maryland for Prince George's County. This manual has been sited by other states for their design criteria. Many states have their own recommendations for proper design and engineering of rain gardens, including Indiana, which has a Stormwater Specifications Manual. Sizing criteria differs based on rain garden purpose, whether placement is for water quality volume, recharge volume, overbank flood control or channel protection. For the purposes of the IU Bloomington Campus, water quality and volume is the main concern. Recommendations for campus design are a combination of Indiana State specifications, and the Prince George's County manual. For simplicity, there are three main calculations for determining rain garden size. Water Quality Volume can be calculated two different ways depending on total impervious surface present or other runoff coefficients. Water Quality Volume is a one step calculation, whereas Target Treatment Volume is a two-step procedure.

1. Calculate Water Quality Volume

$$WQ_v = \frac{[(P)(Rv)(A)]}{12}$$

WQ_v= Water Quality Volume
P= Target Precipitation (inches), 2.56 for the 1-year, 24-hour storm
R_v= Volumetric Runoff Coefficient
A= Contributing Area (acres)

R_v= 0.05+0.009(I) where, I is the percent impervious surface area

2. Target Treatment Volume
   a. $TIV = \frac{[(A)(P)(C)]}{12}$

      TIV= Target Treatment Volume (ft^3)
      P= Target Precipitation (inches), 2.56 for the 1-year, 24-hour storm
      A= Contributing Area (ft^2)
      C= Rational Runoff Coefficient

   b. Footprint Calculation

      $A_r = \frac{[(12)(TIV)]}{P_d} * (0.26 * I_e^{-0.53})$

      A_r= Rain Garden Footprint
      TIV= Target Infiltration Volume (ft^3), Equation 2a
      P_d= Depth of Ponded Water (inches)

I_e= Infiltration Rate of Engineered Soils (inches/hour)*

* 1 inch/hour

3. Approximate Garden Depth without subdrain
   a. $Dr = \frac{Pd+Fd}{12} + Ed$ where,

   Dr= Total Depth of Rain Garden without Subdrain
   Pd= Depth of Ponded Water (inches), 6 inches maximum
   Fd= Freeboard (inches), 2 inches minimum
   Ed= Depth of Engineered Soils

Two equations are presented because rain gardens are an extremely versatile LID technique. There is a lot of freedom associated with designing the shape of the garden, though it is important to consider how runoff should be spread evenly across the surface. Overall, the size of a rain garden is just the function of the drainage area and runoff generated. Generally, most equations include a rational runoff coefficient (Appendix C) or CN value, the drainage area, precipitation and depth. While some calculations can be complex, others can be relatively simple like the EPA's recommendation on bioretention sizing (figure 10).

Figure 10. EPA calculates bioretention size by area and runoff coefficients:

BIORETENTION AREA SIZING COMPUTATION

DEVELOPMENT	AREA SQ. FT.	"C" FACTOR	C X AREA
PAVEMENT	23,800	0.90	21,400
GRASS	10,100	0.25	2,500
TOTALS	33,900		23,900

BIOTENTION AREA SIZE

1. **With Sand Bed (5% Sum of C x Area)**
   = 05 x 23,900 = 1,195 OR SAY 1,200 sq. ft.
2. **Without Sand Bed (7% Sum of C x Area)**
   = 07 x 23,900 = 1,1673 OR SAY 1,700 sq. ft.

Final Design

Engineered Soils

As mentioned before, IU's campus soils are not ideal for infiltration of storm water runoff. Therefore, engineered soils are a critical component for the overall final design. Although proper balance of soil mixture is essential to pollutant removal, there are several methods that will suffice and are economically sound for campus. The ideal planting medium is highly permeable to allow infiltration, provide adsorption of organic nutrients and has high porosity. According to Prince George's County Bioretention Manual, this can be achieve with a prepared soil mix consisting of 50-60 percent sand, 20-30 percent compost and 20-30 percent topsoil.

If this mix is not obtainable, it is recommended that the soil has a predominantly sandy or granular structure. Soil should have a clay content of no more than 25 percent with an infiltration rate of at least 0.5 inches per hour (City of Indianapolis, 2011). Natural soil can be amended with compost or a compost and sand mixture, and mixed using a rototiller. When *in situ* soils are used that are saturated or have high clay content, an underdrain may help regulate infiltration.

Most soil preparation can take place in house at campus division. Soil preparation can be achieved by thoroughly mixing soil components and amendments using a backhoe, tiller, or front-end loader. *In situ* soils can be prepared when the ground is not saturated, by manually mixing to reduce compaction and aerate the soils. The final soil amendment should have a pH between 5.5 and 7.0 (USKH, 2008). Engineered soils should be free of any material over one inch such as roots, rocks and debris. Soils should be presoaked prior to the planting vegetation to aid in settlement.

Pretreatment

The amount of maintenance associated with sediment deposition can be reduced with pretreatment methods. Grass filter strips or RipRap are a common form of pretreatment. According to Indianapolis Stormwater Specifications, it should be sized to contain 0.1 inches of runoff per impervious acre of contributing drainage (City of Indianapolis, 2011). Sheet flow enters the rain garden through pretreatment controls to slow velocity and allow sediment to settle.

Figure 11. Gravel swale

Underdrains

Certain characteristics, like impervious subsoils or heavy clay content, may dictate an underdrain system. A rain garden designed this way will function more like a filter system that discharges treated water into an existing drainage system. A gravel and perforated PVC pipe section can be used to collect runoff that has filtered through soil layers. Perforations typically occur in 3/8-inch perforations, 6 inches center to center, with a minimum of four holes per row (City of Indianapolis, 2011). The underdrain system, or subdrain, exists in an 8-inch gravel layer below the planting soil bed, that facilitates groundwater recharged if water in the storage area can not exit via the underdrain (EPA, 2002). The bottom of the rain garden must have a minimum grade of 0.5 percent to allow treated water to flow towards the subdrain for it to function properly. The pipe can be protected by using a drain sleeve to prevent clogging. The filter fabric should have a minimum permittivity rate of 150 gal/min/sq. (Monroe County Hwy Dept., 2005).

Figure 12. Beginning underdrain installation (ILCA,2015)

For rain gardens that will include an underdrain, the following calculation can be used to find total depth of the rain garden:

$$D_{rs} = \frac{P_d + F_d}{12} + E_d + S_d + 0.005 * L_r$$

D_{rs}= Total Depth of Rain Garden with Subdrain (feet)
P_d= Depth of Ponded Water (inches)
F_d= Freeboard (inches)
E_d=Depth of Engineered Soils (feet)
S_d= Depth Required for Subdrain Diameter and Rock, can assume 1.75 during preliminary design
L_r= Length of Rain Garden, along axis of subdriain

Overflow Structures

Overflow structures must be installed to safely convey additional runoff and provide drainage control. Safe overflow paths can take different designs such as a storm drain system, stream channel, bioswales or broad-crested weirs (Prince George County, 2007). Overflow structures may connect to the existing storm water utilities on campus. All rain gardens should include some form of overflow bypass

Figure 13. Overflow structure (ILCA, 2015)

to transmit runoff without overtopping the rain garden. Structures should be capped to prevent clogging by mulch and debris (WI DNR, 2003).

Grading

Rain garden sites must be graded so that runoff is directed to the infiltration trench. These trenches, or filter strips provide a direction of flow and pretreatment. The slope of adjacent land is also important to consider in that seepage may occur from lower elevations. The slope to adjacent down gradient property should not be more than 12 percent (USKH, 2008).

Erosion Control

First, rain gardens should not be constructed until contributing area is stabilized. If construction is underway, rain garden installation should wait until erosion is controlled. Excavation of the rain garden should only be conducted in dry or mostly dry conditions to reduce the likelihood of soil compaction (City of Indianapolis, 2008).

Planted ground cover is key to erosion control, but a mulch layer will improve effectiveness. It is important to slow sheet flow velocity of runoff, and mulch can decrease flow to a maximum of 0.9 meters per second (City of Indianapolis 2008). Unless there is dense herbaceous cover of at least 70 percent, rain gardens should have a protective mulch layer. Mulch can become suspended during heavy storms; therefore, mulch can be covered with an erosion blanket or shredded hardwood chips can be used (figure 14). The mulch layer should be a maximum of 2-3 inches thick. This will enhance plant survival, inhibit weed growth and maintain soil moisture levels (City of Indianapolis, 2008). Studies have shown that soil biota is important in filtering nutrients and pollutants (NRCS, 2001).

Figure 14. Rain garden with shredded mulch (ILCA, 2015)

Plant Species

Although higher biodiversity effects ecosystem functioning, low diversity landscaping should be used in rain gardens at the IU campus. It is critical that species planted are native and noninvasive. Native plant species are not just aesthetically pleasing, but are recommended for rain gardens due to their deep root systems. Theses deep root systems will help build and maintain the high organic matter content and porosity of the soil. In addition to uptake of water, native species can be drought tolerant. Native species typically need little or no fertilization and pesticide/herbicide use. This will reduce the maintenance responsibilities and decrease the amount of water needed during dry periods (INPAWS, 2015). Native wildflowers and grasses to incorporate into rain gardens are listed for Indiana University in Appendix A.

Figure 15. Visual rendering incorporating natives such as Purple Coneflower and Blue Flag

Landscaping plans should clearly specify how vegetation would be established and managed. If trees will be incorporated into the rain garden they should exist around the perimeter of the site, which is subject to less frequent inundation. Plugs should be planted instead of seed to improve survivability and for ease of implementation. Plants should be trimmed and manicure to remain visually appealing. The design of the garden should be more uniform in structure to dispel a "weedy" appearance. Plants selected should be able to tolerate saturated and dry conditions. The Indiana University Landscape Architect, Mia Williams, must approve final plant selection. Campus Division can order plants through an approved nursery such as Country Road Greenhouses. Plants should be ordered in a timely manner so that plugs do not dry out before installation. Landscaping should occur in spring, or late summer/early fall to improve the likelihood for plants to take root. A conceptual landscaped design should be hand drawn and rendered for final approval. The Bloomington Landscape Architects Office performs visual rendering (Figure 15).

Commented [MP2]: check

Maintenance

For every rain garden installed, a thorough maintenance plan shall be developed. Each plan should have an inspection, operation and maintenance objective. Points that should be covered in the plan should detail the following:

- Sediment build-up
- Clogging
- Erosion
- Trash and debris
- Plant health
- pH testing
- Mulch replacement
- Plant health

The first couple years of rain garden maintenance are the most important and require the most frequent attention. Plants will need watering to nurture plugs into establishment. This is especially crucial during droughts. Trees and shrubs should be inspected twice per year to evaluate their health. Pruning or trimming is on an as needed basis maintain appearance. While plants establish, weeds must be removed by hand. Herbicides should not be used to encourage the reduction of these products in accordance to the IU Campus Master Plan. By the third or fourth season, native plants will begin to out-compete weeds (WI DNR, 2003). During the winter, stems and seed-heads can be left for wildlife cover and bird food. In the spring, new growth should be trimmed back 3-5 inches. Dead plant material should be removed and composted. Rain gardens that heavily incorporate native grasses, sedges or rushes, will require growth to be stimulated by mowing or using a weed-whacker (at a height of six inches minimum).

Mulch replacement is recommended when erosion is evident. Every two to three years mulch should be removed and replaced (EPA, 2012), unless heavy metal deposition occurs. In this case, mulch should be replaced annually. Mulch should be amended as needed to maintain a two to three inch depth (Low Impact Development Center, 2007).

In areas where heavy metal deposition is likely, engineered soils should be removed and replaced. Overall, replacing soils every 20 years will prolong the life and services of the rain garden.

Table 4. Bioretention Maintenance Requirements

Maintenance Requirements for Rain Gardens	
Objective	**Frequency**
Watering Plants	Water consecutively the first 14 days once planted (unless there is rain). As necessary afterwards
Watering during droughts	Water in morning as needed at signs of plant stress

Removing trash and debris	Monthly; check overflow structure
Adding Mulch	As needed
Remulching	Once every 2-3 years (annually if heavy metals accumulation. ie parking lot)
Removing and Replacing Soil	Every 20 years
Weeding	Regularly the first four seasons
Pruning and Trimming	Annually
Visual Inspection	Monthly and after storms
pH	Once a year. Add alkaline product if needed

Overview of construction sequence and Rain Garden Processes

The sequence of construction will vary from rain garden to rain garden, and the actual steps of installation will be finalized by the head project coordinator or civil engineer. Generally, the main step for the construction of a rain garden will be as follows:

1. Permit approval and construction permits
2. Install temporary sediment control barrier
3. Site grading and any removing drainage barriers. Construct curb cuts and other inflow entrances.
4. Stabilize disturbed area around rain garden site
5. Excavate rain garden area to specified depth
6. Install underdrain system if needed
7. Backfill rain garden with amended or engineered soil mixture (overfill to account for settling)
8. Presoak planting soil to aid in settlement. Do not compact soils. Leave space for mulch
9. Complete final grading and overflow path/structure
10. Plant vegetation
11. Mulch and install erosion protection

Figure 16. Director of the Office of Sustainability, Bill Brown assist with the construction of the Union Street rain garden (Photo:Eric Rudd, 2014)

Oversight at IU

Rain gardens can range from simple to complex in their design and engineering plans. Whatever the case, all garden plans must be review and approved by the Vice President of Capital Planning and Operations. In gardens that do not require underdrains or daylighting of any pipes, campus division can install the garden with oversight from the EQLU intern. Gardens more complex require oversight from a campus civil engineer. All plans need to be overlooked by a campus engineer and the a landscape architect. Depending on the scope and size of the project contracting the project may be required. The timeline alone for a project to be approved can take months, so it is important to have effective, open communication with all parties involved to make sure progress is made in the right direction.

Funding

Depending on the size, resources and methods used, rain garden cost will vary. Overall the use of rain gardens will decreased the cost of conventional stormwater infrastructure (EPA, 2002). For example, a rain garden built at a Medical office in Maryland was able to reduce their net drainage cost by 50 percent, or $24,000 (Prince George County, 2007). Generally, simple rain garden construction cost between $3 to $5 per square foot, where as commercial sites can cost between $10 and $40 per square foot (Low Impact Development Center 2007). Each site is unique and requires a specific cost breakdown.

Rain Garden Examples

Rain gardens are an extremely flexible tool and have many applications. They can be installed in new developments and retrofitted into existing environments. Several typical situations that present themselves are described and illustrated below.

On-Lot

This is the most common and traditional rain garden application. Its simple planting and construction sequence is located on lower part of the site to receive runoff. These gardens typically employ many native planting arrangements and have a typical basin design up to six inches deep (figure 17). There is no mounding present, rather the area is depressed to intercept and store water (Low Impact Development Center, 2007).

Figure 17. On-Lot rain garden. (Photo: http://www.lid-stormwater.net/biolowres_home.htm)

Tree-shrub Pit

This technique can help runoff requirements for local drainage interception. Mulched areas around trees or shrubs are "dished" to provide very shallow ponding storage. This is similar to conventional mulching practices, but with the exception being that the mulched area is depressed 2-3 inches rather than mounded. The mulched area is extended to the tree dripline.

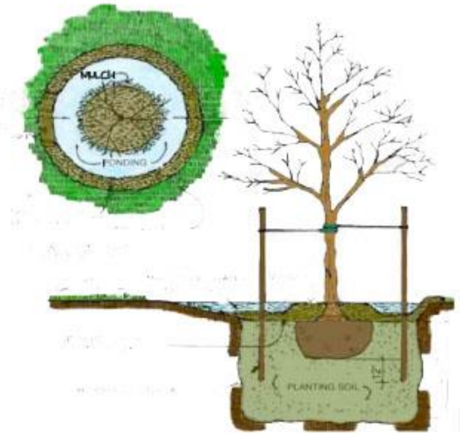


Figure 18. Diagram of a tree-shrub rain garden (Prince George's County, 2007)

Roads

Rain gardens located along a road or traffic circle are much like those of parking lots (figure 19). Cuts can be made into the curb to direct flow under a sidewalk to a rain garden.

Figure 19. Rain garden adjacent to a road (Human Nature Inc.)

Parking lots (Curb and curbless)

A curbless rain garden is located next to a parking lot without curbing (Figure 20). The sheet flow enters directly into the Rain Garden. This method has lower construction cost because there is no addition of cement curbing. Car stops can be installed to protect the area. Sheet flow should enter over level areas or a terraced system may be used. Curbed parking lots have water diverted in to a rain garden using an inlet (Figure 21).

Figure 20. Curbless rain garden (http://stormwater.pca.state.mn.us/)

Figure 21. Curbed rain garden (ceds.org)

Roof

Polyethylene piping attached to a downspout can direct runoff from building's roofs into a rain garden. From here, most designs resemble typical on-lot rain gardens. More difficult construction may be needed if roof runoff is capture and directed in the interior of the building structure (Figure 19).

Figure 22. Rain garden at Cyberinfrastructure building on the IU Bloomington campus captures water from the roof.

Median

Rain gardens existing in medians or traffic islands typically need an underdrain system and a buffer, or filter fabric along the curb (this reduces seepage). If a rain garden is located within a county right-of-way, approval must be permitted.

Figure 23. A rain garden located along a median (Low Impact Development Center)

Swale-side

Some rain gardens can be placed adjacent to a bio-swale. The swale and rain garden are separated by a low berm, and overflow discharge flows into the base of the swale. The depth of the rain garden is greater than the invert of the swale (Prince George's County, 2007).

Figure 24. Rain garden next to a swale (Prince George's County)

Sloped "Weep Garden"

Rain gardens can be appropriately placed in sloped terrain if using a weep garden design. These gardens can accommodate restrictive slope conditions by using a retaining wall. Using stone or wood, the retaining wall allows the soil-filtered water to seep through the wall. These designs can also incorporate an underdrain (Prince George's County, 2007).

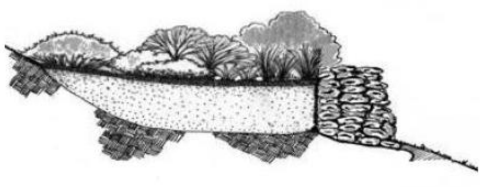


Figure 25. Weep-garden design

Rain Gardens at the Indiana University Bloomington Campus

In the past five years, the IU Bloomington campus has begin to incorporate rain gardens into the existing landscape. Most of these gardens have been installed during construction of new facilities such as the Cyber Infrastructure building, the Kelly School of Business expansion and the new Bart Kaufman Field (figure 26). The rain gardens at these sites were funded through the existing project budgets. A rain garden was installed in the existing landscape near Union Street Apartments in October 2014. During the installation several barriers made proper construction difficult. An existing utilities road was not removed prior to construction, reducing the potential size of the garden by 50 percent. Miscommunication between Campus Division employees led to improper basin design. The garden is being reconstructed Spring 2015.

Figure 26. Rain gardens at Bart Kaufman field (left) and Kelly School of Business (right)

A rain garden has been proposed for installation near Woodlawn Field, and the School of Public Health tennis courts. This project is being funded with a $4000 grant from the Student Sustainability Council. This rain garden will receive runoff from the outdoor sports fields and the lawn surrounding the garden. The existing stormwater pipe will have to be daylighted to allow water from the field to flow into the garden (Appendix C). The garden will capture runoff from approximately 90,000 square feet, and the overflow structure will tie into the existing stormwater piping. The garden should have a pooling

depth of five inches, but will be several feet deep to accommodate the daylighted piping. Visual rendering of the project has been completed and final approval has yet to occur (figure 27). The installation of this garden should occur in August or September 2015.

Figure 27. Proposed SPH site. (Photo: Tristan Johnson)

On-Campus Rain Garden Partnerships

One of the goals during this academic year was to collaborate with classes on campus to increase awareness of rain gardens by involving students. Two classes were selected for the Spring 2015 semester: Melissa Clark's Best Management Practices class and Nancy Obermeyer's Vector-Based GIS class. The progress of each class is described below.

Vector-Based GIS

The initial meeting between Andrew Predmore, Celia Daniels, Nancy Obermeyer and the rain garden intern, Meghan Ploch, was to discuss working with Nancy's class began in mid-December. The goal of working with the class was to give the class a brief introduction to rain gardens and work with them to plot the potential location coordinates in ArcGIS. Unfortunately, there was confusion and disarrangement in the timeline and structure of the original plan. Once the semester started, there seemed to be some confusion on what class the rain garden intern was presenting to and working with.

After several emails, Nancy agreed that Meghan would come to the Vector-Based GIS class that meets on Friday. After several weeks there was still no progress due to misinformation of where and when the classes met, and assumptions that the intern could come on days that she could not. During the last email conversation, Nancy was confused of the goals, in addition to the storing and gathering data. Unfortunately, given the lengthy, inactive progress in the right direction, Meghan went ahead to plot the rain garden data on ArcGIS online without the class.

Best Management Practices


Figure 27. Student's WINSLAMM model from the BMP class

Students in the class explored various BMPs, green infrastructure and respective ecological analysis and impacts. Working with Melissa Clark, it was determined that the class project would be an in depth analysis of rain garden design for the IU campus. Using potential rain garden locations graded B or higher from Meghan's original rain garden report, students research their top four choices for implementation. Rain quality and quantity reductions were modeled using EPA SWMM. Top four locations were identified as Teter Residential Hall, the Indiana Memorial Union Parking lot, the Alumni Hall parking lot and the grassy lawn behind the Student Recreation and Sport Center. Final reports can be found in the IUOS box account. The goals of implementing rain gardens were to address visibility, water quality, water quantity, and cost. A list of stakeholders interested in rain garden BMPs were created and as follows:

- Donors
- Trustees
- City Government
- Community
- Alumni
- Campus Division
- Staff
- Faculty
- Students
- Visitors
- Provost office
- Landscape Architects Office
- The Bibble Hotel
- Residence Halls
- University Ranking for beautiful campus/landscaping/architecture
- MS4 permitting
- SPEA
- Streams
- IU Campus Master Plan
- Risk Management

The Future of Rain Gardens and EQLU Working Group Goals on the IU Bloomington Campus

Rain gardens should be implemented throughout the IU campus to reduce storm water runoff. In accordance with campus architecture guidelines that new buildings should meet LEED silver requirements, rain gardens can help achieve surface water management goals (USGBC, 2008). These attractive gardens should be designed to capture runoff from high priority locations such as parking lots, roads and ponding areas. This will require future discussions between parking operations on campus to negotiate proper parking and rain garden allocation. Funding should be allocated for rain garden projects and further research in grant opportunities should be researched. Modeling stormwater management techniques such as rain gardens will provide useful data to examine runoff and pollutant load reductions. Rain garden development is listed as a topic for the Greek Incentive Program. A simple rain garden pamphlet should be created and made accessible by sorority and fraternity organizations.

Educational signage is a major endeavor that should be developed, not just for rain gardens, but any sustainable feature on campus. Signage and social media will increase community awareness of sustainable initiatives on campus. Temporary signage, that doesn't have to meet all IU criteria for signs, should be used more frequently, especially in new or developing projects. Public awareness and participation can be increased through involvement in rain garden workshops, and workdays. An outreach opportunity can occur with the development of the IU Tree Inventory project. Future interns for the Environment Quality Land Use (EQLU) working group may develop working days for students and/or staff. Furthermore, the Jordan River Restoration has the opportunity to be apart of the transitions lab. Although in its developing stages, future interns can start making connections between faculties and gathering research.

Appendix A

Indiana Native Wildflowers

Latin Name	Common Name	Exposure	Bloom Season	Height	Flower Color
Alisma subcordatum	Water Platain	Sun	June- September	2-3 ft	White
Asclepias incarnata	Marsh Milkweed	Sun	July-Aug	3-4ft	Pink
Asclepias incarnate	Swamp Milkweed	Sun	July-Aug	4-5 ft	White, pink
Aster firmus	Shining Aster	Sun	Sept-October	3-4 ft	Lavender
Aster novae-angliae	New England Aster	Sun	Sept-October	3-4 ft	Purple
Aster puniceus	Swamp Aster	Sun-Psun	Sept-October	4-5 ft	Lavender
Aster simplex	Panicled Aster	Sun	Sept-Oct	5 ft	White
Aster umbellatus	Flat-topped Aster	Sun	Aug-Sept	4-5 ft	White
Boltonia latisquama	False Aster	Sun-Psun	June-Sept	3ft	White
Caltha palustris	Marsh Marigold	Sun-Psun	April-June	1-2 ft	Yellow
Cassia hebecarpa	Wild Senna	Sun-Psun	July-Aug	3 ft	Yellow
Chelone glabra	Turtlehead	Sun-Psun	July-Aug	2-3 ft	Purple, Pink, White
Chelone glabra	White Turtlehead	Psun	August-Sept	2-4 ft	White
Chelone obiqua	Pink Turtlehead	Psun	Aug-Sept	2-4 ft	Pink
Echinacea purpurea	Purple Coneflower	Sun-Psun	July-Aug	2-3 ft	Purple
Eupatorium coelestinum	Blue Mist Flower	Psun	Aug-Sept	1-2 ft	Blue
Eupatorium fistulosum	Hollow Joe-Pye Weed	Sun	Aug-Sept	5-8 ft	Pink
Eupatorium maculatum	Spotted Joe-Pye Weed	Sun	Aug-Sept	4-6 ft	Pink
Eupatorium perfoliatum	Boneset	Sun	Aug-Sept	3-4 ft	White
Eutrochium purpureum	Sweet Joe-pye weed	Psun-Shade	July-Sept	7 ft	Pink
Filipendula rubra	Queen-of-the-prairie	Sun	June-July	3-5 ft	Pink
Gentiana andrewsii	Bottle Gentian	Sun-Psun	Sept-October	1-2 ft	Blue
Helenium autumnale	Autumn Sneezeweed	Sun-Psun	Sept-October	3-4 ft	Yellow
Hibiscus moscheutos	Swamp rose mallow	Sun	June-Sept	4-6 ft	Red, White
Iris cristata	Dwarf crested iris	Psun-Shade	March-May	1-3 ft	White, Blue, Purple
Iris virginica	Blue Flag	Sun-Shade	may-June	1-2 ft	Blue
Liatris pycnostachya	Prairie Blazing Star	Sun	July-Aug	3-5 ft	Purple
Liatris spicata	Dense Blazing Star	Sun	July-August	3-5 ft	Purple
Lobelia cardinalis	Cardinal Flower	Sun-shade	August-Sept	2-3 ft	Red
Lobelia siphilitica	Blue lobelia	Sun-Pshade	July-Sept	2-3 ft	Blue
Lobelia siphilitica	Great Blue Lobelia	Sun-shade	August-sept	2-3 ft	Blue
Lycopus americanus	Water Horehound	psun	July-Sept	1-2 ft	White
Mimulus ringens	Monkeyflower	Sun-Psun	July-Aug	2-4 ft	Lavender
Patibida pinnata	Yellow Coneflower	Sun	July-Aug	3-4 ft	Yellow
Penstemon calycosus	Smooth Penstemon	Sun-Shade	May- June	1-2 ft	Purple
Penstemon digitalis	Foxflove Penstemon	Sun-Psun	May- June	1-2 ft	White
Physostegia virginiana	Obedient Plant	Sun	August-Sept	2-3 ft	Pink
Pycnanthemum virginianum	Mountain Mint	Sun	July-August	1-2 ft	White
Rudbeckia fulgida speciosa	Showy Black-Eyed Susan	Sun-Psun	Aug-Sept	3-4 ft	Yellow
Sedum ternatum	Wild stonecrop	Pshade	April-may	0-1 ft	White
Senecio aureus	Golden Ragwort	Sun-shade	April-May	1-2 ft	Yellow
Silene regia	Royal catchfly	Sun-Pshade	July-Aug	4 ft	Red
Silphium perfoliatum	Cupplant	Sun	July-Sept	4-8 ft	Yellow
Solidago gigantea	Late Goldenrod	Sun-Shade	Aug-Sept	6 ft	Yellow
Solidago riddellii	Riddell's Goldenrod	Sun	Sept-October	2-3 ft	Yellow
Solidago rugosa	Wrinkled Goldenrod	Sun-Psun	Aug-Sept	2-3 ft	Yellow
Verbena hastata	Blue Vervain	Sun	July-Sept	2-6 ft	Purplish-Blue
Vernonia fasciculata	Smooth Ironweed	Sun	August-Sept	3-4 ft	Purple
Vernonia gigantea	Ironweed	Sun	Aug-Sept	4-6 ft	Purple
Veronicastrum virginicum	Culver's Root	Sun-Psun	July-August	3-4 ft	White
Zizia aurea	Golden Alexanders	Sun-shade	May-June	1-2 ft	Yellow

Native Grasses, Sedges, and Rushes

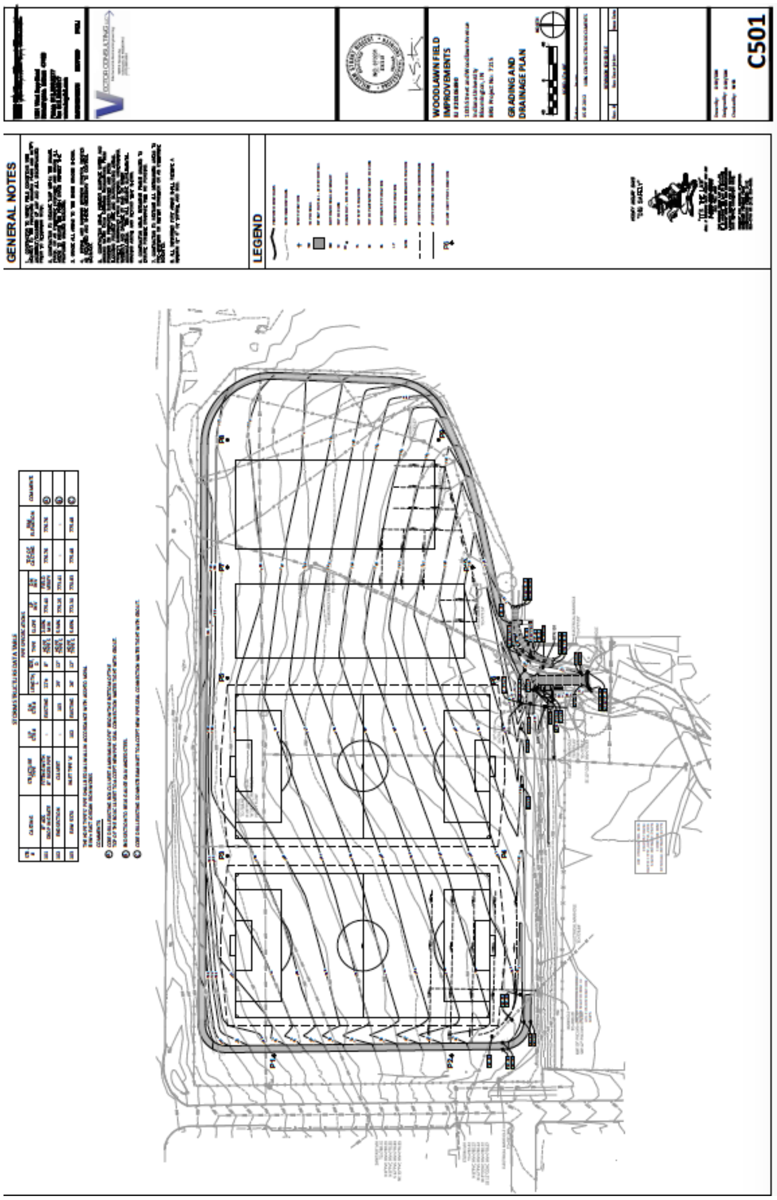
Latin Name	Common Name	Exposure	Bloom Season	Height	Flower Color
Carex frakii	Frank's Sedge	Shade	Apr-June	2-3 ft	Green
Carex hystericina	Porcupines Sedge	Sun	May-June	3 ft	Green/Brown
Carex shortiana	Short's Sedge	Sun-Psun	May	2-3 ft	Green
Carex vulpinoidea	Fox's Sedge	Sun-Psun	May-June	1-2ft	Brown
Elymus riparius	Riverbank Wild Rye	Psun-Shade	July-Aug	3-5 ft	Green
Elymus virginicus	Virginia Wild Rye	Sun-Shade	July-Aug	4-5 ft	Straw
Glyceria striata	Fowl Manna Grass	Sun-Shade	June-Aug	2-3 ft	Green
Leersia oryzoides	Rice Cut Grass	Sun-Pshade	June-Oct	3 ft	Green
Panicum virgatum	Switchgrass	Sun	July-August	3-5ft	Brown
Spartina pectinata	Prairie Cordgrass	Sun-Pshade	July-Aug	4-7 ft	Yellow-Brown
Carex stricta	Tussock Sedge	Sun-Pshade	May-June	1-3 ft	reddish-brown
Juncus effusus	Soft Rush	Sun	June-Aug	2-4 ft	Yellowish-green
Panicum virgatum	Switchgrass	Sun-Pshade	Aug-Sept	3-6 ft	Green/Brown
Sorghastrum nutans	Indian Grass	Sun-Shade	Aug-Oct	3-6 ft	Yellow
Cephalanthus occidentalis	Buttonbush	Sun-Pshade	June	5-12 ft	White
Iiex verticillata	Winterberry Holly	Sun-Pshade	June-July	3-12 ft	Greenish-white
Carex annectans var xanthocarpa	Yellow Fox Sedge	Sun-Psun	May-June	1-2 ft	Brown
Carex bromoides	Brome Hummock Sedge	Sun-Shade	May-June	1 ft	Green
Carex emoryi	Riverside Tussock Sedge	Sun-Psun	May-June	2ft	Green
Carex frankii	Frank's Sedge	Sun-Shade	May-July	1-2ft	Green
Carex granularis	Meadow Sedge	Sun-Shade	May-June	1ft	Green
Carex grayii	Burr Sedge	Psun-Shade	May-July	1-2ft	Green
Carex muskingumensis	Palm Sedge	Shade	May-June	1-2ft	Brown
Deschampsia caespitosa	Tufted hair Grass	Sun	May-June	1-2ft	Brown
Schizachyrium scoparium	Little Bluestem	Sun	July-August	2-3ft	Brown
Scirpus cyperinus	Woolgrass	Sun	July-August	4-5ft	Brown
Scirpus pendulus	Reddish Bulrush	Sun	June-July	3-4ft	Brown
Sporobols heterolepis	Prairie Dropseed	Sun	August-Sept	1-2ft	Brown

Appendix B

Runoff Coefficients for the Rational Method

	FLAT	ROLLING	HILLY
Pavement & Roofs	**0.90**	**0.90**	**0.90**
Earth Shoulders	0.50	0.50	0.50
Drives & Walks	0.75	0.80	**0.85**
Gravel Pavement	**0.85**	**0.85**	**0.85**
City Business Areas	0.80	**0.85**	**0.85**
Apartment Dwelling Areas	0.50	0.60	0.70
Light Residential: 1 to 3 units/acre	0.35	0.40	0.45
Normal Residential: 3 to 6 units/acre	0.50	0.55	0.60
Dense Residential: 6 to 15 units/acre	0.70	0.75	0.80
Lawns	0.17	0.22	0.35
Grass Shoulders	0.25	0.25	0.25
Side Slopes, Earth	0.60	0.60	0.60
Side Slopes, Turf	0.30	0.30	0.30
Median Areas, Turf	0.25	0.30	0.30
Cultivated Land, Clay & Loam	0.50	0.55	0.60
Cultivated Land, Sand & Gravel	0.25	0.30	0.35
Industrial Areas, Light	0.50	0.70	0.80
Industrial Areas, Heavy	0.60	0.80	**0.90**
Parks & Cemeteries	0.10	0.15	0.25
Playgrounds	0.20	0.25	0.30
Woodland & Forests	0.10	0.15	0.20
Meadows & Pasture Land	0.25	0.30	0.35
Unimproved Areas	0.10	0.20	0.30

Appendix C



GENERAL NOTES
LEGEND
WOODLAWN FIELD IMPROVEMENTS
GRADING AND DRAINAGE PLAN
C501

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