ABSTRACT

Title of Document: GREEN AND BLUE SCHOOLS: THE USE OF ENVIRONMENTALLY SENSITIVE RAINWATER DESIGN AT GEORGETOWN VISITATION PREPARATORY SCHOOL IN GEORGETOWN, WASHINGTON DC.

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The artful management of stormwater has a capability to create educational arenas by combining environmentally sensitive rainwater design with education. School settings provide great opportunities for integrating on-site stormwater treatment into many aspects of the curriculum from the sciences to the arts. Presently, urban settings have new initiatives for creating green schools, which covers all levels of sustainability for the campus. This research project focuses on the development of stormwater and water-related designs for Georgetown Visitation Preparatory School in Georgetown, Washington DC. The main research is an assessment of the school's existing stormwater usage and runoff and also evaluating possibilities for new stormwater management techniques to be a supplement to curriculum.

GREEN AND BLUE SCHOOLS: THE USE OF ENVIRONMENTALLY SENSITIVE RAINWATER DESIGN AT GEORGETOWN VISITATION PREPARATORY SCHOOL IN GEORGETOWN, WASHINGTON DC.

By

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Acronyms

ARD	Artful Rainwater Design
CSO	Combined Sewer Overflow
CSS	Combined Sewer System
CWA	Clean Water Act
CWSRF	Clean Water State Revolving Fund
DC	District of Columbia
DC GIS	District of Columbia Geographic Information Systems
DDOE	District Department of the Environment
EIC	Environment as an Integrating Context
EPA	United States Environmental Protection Agency
ERU	Equivalent Residential Unit
ESD	Environmental Site Design
GIS	Geographic Information Systems
LEED	Leadership in Energy and Environmental Design
LID	Low Impact Development
MAEOE	Maryland Association for Environmental and Outdoor Education
MDE	Maryland Department of the Environment
MS4	Municipal Separate Storm Sewer System
NEEF	National Environmental Education Foundation
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NRDC	Natural Resources Defense Council
NWF	National Wildlife Federation
OWM	Office of Wastewater Management
PGDER	Prince George's County Department of Natural Resources
SEER	State Education and Environment Roundtable
TMDL	Total Maximum Daily Loads

Introduction

This thesis explores how stormwater management can be best implemented in a school setting to achieve stormwater and educational benefits. First, stormwater is a significant ongoing problem with increased impervious surfaces that contributes to lower water quality of the natural waters. Second, school children today are losing touch with their natural environment and not only is environmental awareness decreasing, but an overall lack of interest in the environment is growing. Stormwater treatment can serve these two purposes by combining stormwater management and education in a school campus.

The application of the research is a proposed redesign of selected stormwater features located on the Georgetown Visitation Preparatory School campus in Georgetown, Washington DC. The research creates an assessment of the school's existing stormwater usage and runoff and evaluates possibilities for new stormwater management techniques to be a supplement to curriculum.

This thesis is organized into five chapters. The first chapter discusses the background for stormwater management and green schools. The second chapter introduces the design site and the site analysis for the school campus. The third chapter details the design site selection process. The fourth chapter explains the final designs for the four selected design templates. Lastly, the final chapter is a summary and conclusion.

Chapter 1: Literature Review

This chapter is divided into three sections. The first section discusses problems with stormwater and how to best manage it in an environmentally sensitive manner. Another element of stormwater management is to design in a way that users have a more positive perception of stormwater features. The second section discusses how the District of Columbia manages stormwater. The third section discusses the green school movement and specifically how stormwater could be integrated into the school campus and curriculum.

Stormwater Management

The following stormwater management section of the literature review is organized into three sections. The first section covers the problems associated with improper stormwater management. The second section explores the history of stormwater management, national regulations, low impact development (LID), and stormwater management practices. The third and last section explores the concept of artful stormwater design and the idea of adding additional benefits to traditional stormwater features that can provide positive public perceptions and benefits.

Stormwater and Problems

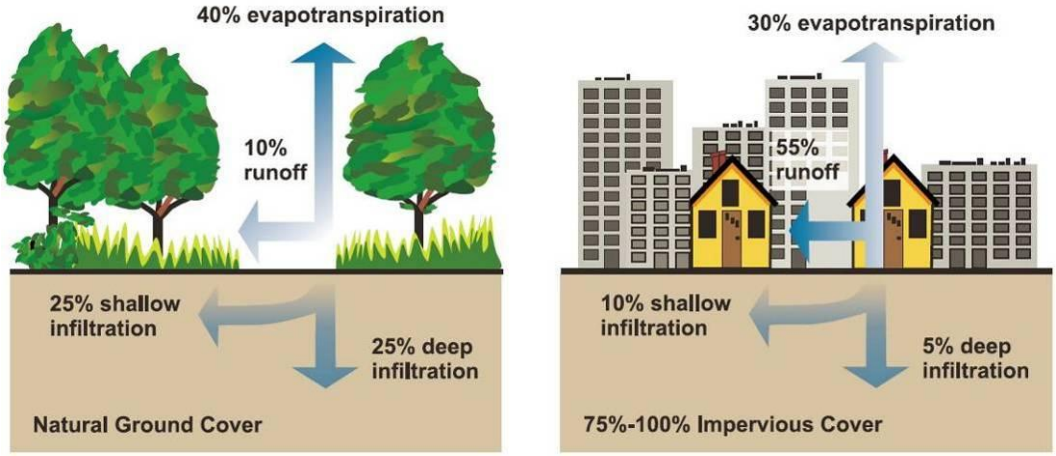
Stormwater is rainwater and melted snow that runs off streets, lawns and other sites. Problems that can result from stormwater can include downstream flooding, stream bank

erosion, increased turbidity, habitat destruction, changes in the stream hydrograph, combined sewer overflows in older cities, infrastructure damage, and contaminated streams, rivers and coastal water (EPA 2012b). Stormwater is an issue because pollutants on the surface become carried by the water or dissolved into the water. These pollutants include sediments, nutrients, and increased temperature of the water (Ferguson 2002).

In a natural environment, the stormwater could go through the local vegetation and soils to be purified before being taken up by plants or flowing into the local water bodies. In urban areas, there are very high amounts of impervious surface such as pavement and roofs which increases the speed that the stormwater enters the local water bodies without having any time for infiltration and purification.

Increased development throughout the landscape has led to increased amounts of impervious surfaces. Impervious surfaces in a watershed result in increased surface runoff, less infiltration into the water table, and less evapotranspiration (EPA 2003). The impacts of stormwater pollution are not static and the negative impacts increase with more development and urbanization (EPA 2007). Figure 1.1 illustrates the differences between the natural and urban infiltration.

Figure 1.1: Natural and Urban Infiltration



(Source: EPA 2003)

Impacts on Natural Processes

Urbanization negatively affects streams and results in water quality problems such as loss of habitat, increased temperatures, sedimentation and loss of fish populations (EPA 2000). The downstream waters can be inundated with oil, bacteria, excess nutrients, and sediment (Ferguson 2002). Pollutant loadings are concentrated in the first flush which is the first half inch of precipitation in a rain event from impervious surfaces and contain grease and oil, nutrients (nitrogen and phosphorous), sediments and heavy metals (EPA 2000). In natural systems, floods are moderate, erosion and sedimentation are in equilibrium, pollutants are degraded, the wetlands are sustained, and public water supplies are more secure (Ferguson 2002).

Impacts on Society

Stormwater impacts on local populations are becoming more of an issue with increasing impervious surfaces. Issues such as local water shortages, combined sewer overflows (CSOs), infrastructure damage, and lack of public understanding are some of the cultural

impacts from stormwater. Water leaves the natural system by running off all the impervious surfaces and not entering the water table; this lowers the base flow of streams which results in local water shortages (Ferguson 2002).

CSO events are caused as a result of older cities having combined sewer and stormwater systems. In a wet-weather event, the high volumes of stormwater overwhelm the system resulting in the need to use emergency outfalls which deposits raw sewage into the local water rivers and streams. Sediment and nutrient contaminants are the greatest concern for the pollutants (Black & Veatch Corporation 2010). Black & Veatch Corporation in 2010 found that regulatory requirements pertaining to the mitigation of CSO issues are only treated by 79 percent of the utilities surveyed. Stormwater utilities are attempting to find ways to treat CSOs by raising funding, but the CSO mitigation costs are often higher than the amount collected by the raised funding (Black & Veatch Corporation 2010).

Another facet of stormwater mitigation is assessing residents for the full cost pricing for all the water treatment. In older cities, the stormwater currently goes with the sewage to the wastewater treatment plants and is returned to the residents for potable water. The full cost pricing would include the entire suite of costs associated with water delivery which includes operations and maintenance for all the water facilities and treatment (EPA 2008). An increased price of potable water would encourage investment in rainwater harvesting systems because they offer a long-term inexpensive supply of water after the initial capital investment (EPA 2008).

Stormwater Treatment History

While examples of incorporating stormwater, flood control and other water related objectives into a design are not recent, e.g. the Emerald Necklace by Frederick Law Olmstead in Boston, stormwater regulations addressing sediment reduction and peak flow reduction concerns arose in the 1980s following the passage of the Clean Water Act (CWA) (OWM 2011).

National regulations

The CWA establishes the basic structure for regulating discharges of pollutants into the waters of the United States and regulating quality standards for surface waters (EPA 2011c). Components of the CWA, e.g. the National Pollutant Discharge Elimination System (NPDES) permitting, have been instrumental for making local municipalities move to action. As of 2011, two-thirds of the nation’s surveyed waters are safe for fishing and swimming (Office of Wastewater Management 2011). This is a vast improvement from the historical poor condition of water quality in the United States.

Clean Water Act

The CWA has a long history. The earliest federal action toward protecting the nation's water was the Refuse Act of 1899. The act outlawed the "dumping of refuse that would obstruct navigation of navigable waters, except under a federal permit." (EPA Region I 2011). The 1948 Water Pollution Act was the first move for environmental protection for water resources (OWM 2011). This act allotted funds to state and local governments for water pollution control but did not yet have federal-scale guidelines. The Water Pollution

Control Act Amendments of 1956 and the Federal Water Pollution Control Act Amendments of 1961 were created by Congress to give additional funding to municipalities for wastewater treatment (OWM 2011). The Water Quality Act of 1965 required states to develop water quality standards for interstate waters by 1967 (OWM 2011). This was not completely successful with only about half of the States developing standards by 1971. In response to environmental concerns, the Environmental Protection Agency (EPA) was created in 1970 to enforce environmental compliance and consolidate federal pollution control activities (OWM 2011). The water that is classified in the control of the CWA is "waters of the United States" refers to navigable waters, tributaries of navigable waters, interstate waters, and intrastate lakes, rivers and streams (EPA 2011d). This also includes wetlands and ephemeral streams but does not include groundwater. The groundwater is managed by the states individually (OWM 2011). The EPA and Army Corps of Engineers worked on the Refuse Act Permit Program together and required any facility discharging wastes into public waterways to obtain a federal permit. This program was revoked in 1971 after a ruling by the Federal District Court (OWM 2011). However, the concept of the permit program remained. In 1972, the Federal Water Pollution Control Act Amendments put emphasis on end-of-pipe technological monitoring control strategies (OWM 2011).

Sections 402, 319, and 404 of the CWA impact stormwater directly. Section 402 of the Federal Water Pollution Control Act Amendments of 1972 established the NPDES program (OWM 2011). This required that all facilities which discharge pollutants from any point source into waters of the United States are required to obtain a permit (EPA

2012e). Section 319 requires that states, territories, and delegated tribes are required to develop nonpoint source of pollution management programs (EPA 2012d). Common pollutants are phosphorus and nitrogen, pathogens, sediments, oil and grease, salt and pesticides (EPA 2012b). Section 404 regulates the placement of dredged or fill materials, which has been mostly related to protecting wetlands (EPA 2011c).

In 1976, the Natural Resource Defense Council (NRDC) entered in a consent decree with the EPA in order for the EPA to reconsider addressing toxics within water pollution (OWM 2011). This resulted in the 1977 amendments of the Federal Water Pollution Control Act now formally called the Clean Water Act (OWM 2011). The main difference was a shift in emphasis from controlling conventional pollutants to controlling toxic discharges (OWM 2011). In 1987 Congress also passed the Water Quality Act which called for increased monitoring and assessment of water bodies to ensure that water quality standards were not just on paper, but were actually being realized in the nation's waters (EPA Region I 2011). The Water Quality Act established meeting water quality standards to be set by the states (OWM 2011). The most common type of standards for meeting water quality standards as dictated by the CWA are the Total Maximum Daily Load (TMDL) standards (EPA 2011e). These determine what level of pollutant load is acceptable in meeting the water quality standards (EPA 2012a). January 5, 2010, President Obama signed into law "An Act to Amend the Federal Water Pollution Control Act to clarify Federal responsibility for stormwater pollution," to clarify that reasonable service charges payable by federal agencies, as described in Section 313(a), include storm water assessments (EPA 2011d).

National Pollutant Discharge Elimination System (NPDES)

As previously mentioned, the NPDES Program was established by Section 402 of the Federal Water Pollution Control Act Amendments of 1972 (OWM 2011). This required that all facilities which discharge pollutants from any point source into waters of the United States are required to obtain a permit (OWM 2011). This only relates to point-source pollution. Also, industrial and commercial dischargers are under the National Pretreatment Program for their point-source discharges (EPA Region I 2011). The NPDES programs include the National Pretreatment Program, the Municipal Sewage Sludge Program, Combined Sewer Overflows, and the Municipal Storm Water Program (OWM 2011). Phase 1 NPDES permits are for population of 100,000 and over and Phase 2 NPDES permits are for populations under 100,000 (EPA 2011c). The NPDES program only applies to "waters of the United States" as defined by the (OWM 2011). The EPA directly implements the NPDES program but the EPA can authorize states, territories, or tribes to implement parts of the national program (OWM 2011). The NPDES program has two types of permits, individual and general. The individual permits are unique per discharger, and the multiple permits are for a large number of similar dischargers (EPA 2012a).

Low Impact Development (LID)

In the early 1990s, LID was developed by the Prince George's County, MD, Department of Environmental Resources (PGDER), with grant funding from the U.S. Environmental Protection Agency (EPA) (Coffman 2002). In 1999, PGDER developed a two-volume set of national guidance manuals on the LID approach (Coffman 2002). The first projects

were retrofitting parking lots with bioretention basins of curb cuts and depressed planting beds (Clar 2002). The goal of LID is to create a more hydrologically functional urban landscape to better maintain or restore an ecosystem's hydrologic regime (Coffman 2002). A mix of subdivision codes, zoning regulations, parking and street standards and other local ordinances that determine development procedures are often obstacles for LID construction (EPA 2000). Negative community perception of LID may also prevent implementation.

The advent of LID created a benchmark that other municipalities could mirror, such as Seattle and Portland, who have excelled in the development of LID techniques. Currently, in Maryland, Environmental Site Design (ESD) is gaining attention for further developing LID techniques while also integrating regulations requiring the use of LID techniques (MDE 2012).

The primary goal for retrofitting old construction or properly designing new construction is to have a positive impact on the environment. Many handbooks and manuals have been published since the PGDER 1999 handbook. The handbooks often lay out different design elements that can be built to meet the LID goals. There are many benefits to using these new techniques that can be categorized into environmental and cultural benefits. The key for LID is to create many micro-scale treatment areas while also preserving existing less disturbed landscapes and reducing the amount of impervious surface construction.

Environmental Benefits

Environmental benefits of LID practices include pollution abatement, protecting downstream resources, groundwater recharge, water quality improvement, reduced treatment costs, and habitat improvements (EPA 2007). Protecting existing features is the first step for successful environmental benefits. The environmentally sensitive areas to be protected are mainly riparian buffers, wetlands, steep slopes, mature trees, floodplains, woodlands, and highly permeable soils (EPA 2000). Hydrology and vegetation are the next main components for LID design. Four basic ecological functions result from LID design; water infiltrating into the soil and vegetation, water flowing over the soil and vegetation, water transpired by vegetation, and precipitation intercepted by vegetation and evaporated (Liptan and Murase 2002). LID design also effectively counteracts the urban heat island effect by removing impervious heat absorbing materials and replacing them with vegetation and soil that will create shade and emit water vapor (EPA 2009). As vegetation absorbs gaseous air pollutants and absorbs particulates, overall air quality is improved (EPA 2009). A recent set of reports showed that forty percent of the impaired waters were affected by nonpoint sources alone while only ten percent were by point sources (EPA 2012c).

Six hydrologic functions should be considered when investigating the effectiveness of LID practices. These hydrologic functions on a site are 1) time of concentration, 2) retention, 3) detention, 4) soil type, 5) land cover, and 6) amount of impervious surfaces. Time of concentration (Tc) refers to the amount of time it takes for water to travel from the most distant point to the watershed outlet (Coffman 2002). Retention is permanent

storage areas that treats for volume and peak flow control (Coffman 2002). Detention is temporary storage that also assists with peak flow control or prevents flooding (Coffman 2002). Soil types are determined from soil maps created by the National Resource Conservation Service (NRCS). The soil types are represented by four hydrologic groups: A, B, C, or D indicating the soil's infiltration capacity (American Fork City 2008). Appendix 5 has further contains about the hydrologic groups. Hydrologic group A is considered to have the greatest infiltrating capacity while Hydrologic group D is considered to have the lowest. Land cover type is a classification such as forested, grass, or paved, among many other types. Impervious surfaces are areas of the landscape that do not infiltrate water.

Successful LID practices can be achieved by many approaches, among them, maintaining pre-development flow path lengths, increasing surface roughness, detaining flows, minimizing disturbances at the site, flattening grades in impact areas, disconnecting impervious surfaces, and connecting pervious areas (EPA 2000). A main component for any stormwater treatment is to be able to treat the first flush of water because it carries most of the accumulated pollutants compared to runoff later in the storm event (Ferguson and Debo 1990).

Cultural Benefits

In most cases, LID practices were shown to be both fiscally and environmentally beneficial to communities. In the vast majority of cases, significant savings were realized for new construction due to reduced costs for site grading and preparation, stormwater

infrastructure, site paving, and landscaping (EPA 2007). More research is needed to further quantify the environmental benefits that can be achieved through the use of LID techniques. More research is also needed to monetize the cost reductions that can be achieved through improved environmental performance, reductions in long-term operation and maintenance costs, and/or reductions in the life cycle costs of replacing or rehabilitating infrastructure (EPA 2007). Cost savings are typically seen in reduced infrastructure because the total volume of runoff to be managed is minimized through infiltration and evapotranspiration (EPA 2007). One difference between conventional stormwater management and LID techniques is that the LID practices can be incorporated into the landscaping of yards, roadsides, parking lots, and in other areas already designed into the overall site layout (EPA 2007). The conventional systems, detention and retention ponds require additional land which ultimately takes from possible lot yield for property sales (EPA 2007).

Stormwater Management Practices

Stormwater management has many goals. In 2007, the EPA created a document that detailed current LID strategies and projects. These categories were conservation designs, infiltration practices, runoff storage practices, runoff conveyance practices, filtration practices, and low impact landscaping (EPA 2007). Conservation designs minimize runoff generation by preserving open space; this includes cluster development, open space preservation, reduced pavements widths, shared driveways, and reduced setbacks for shorter driveways (EPA 2007). Infiltration practices are engineered structures or landscape features designed to capture and infiltrate runoff (EPA 2007). This includes

infiltration basins and trenches, porous pavement, disconnected downspouts, and rain gardens (EPA 2007). Runoff storage practices capture runoff from impervious surfaces and store the water for reuse by infiltration, evapotranspiration, or irrigation (EPA 2007). This includes rain barrels and cisterns, depressional storage in landscaped islands, and green roofs. These can be located in parking lots, streets, sidewalks, or roofs (EPA 2007). Runoff conveyance practices are systems that can be used to slow flow velocities, lengthen runoff time of concentration, and delay peak flows that are discharged off-site (EPA 2007). This includes eliminating curbs and gutters, creating grassed swales, roughening surfaces, creating long flow paths, installing smaller culverts and pipes, and creating terraces and check dams (EPA 2007). Filtration practices are designed to capture pollutants through natural processes by filtering the water through a filtering media (EPA 2007). This includes bioretention cells, rain gardens, vegetated swales, vegetated filter strips and buffers (EPA 2007). Low impact landscaping is careful plant selection by planting native, drought-tolerant plants, converting turf areas to trees and shrubs, reforestation, encouraging longer grass growth, planting meadows, and soil amendments to improve infiltration (EPA 2007).

The specific practices fall into three broad categories: 1) alternative surfaces, 2) non-structural practices, and 3) micro scale practices. While it is beyond the scope of this thesis to document an exhaustive list, Table 1.1 indicates the basic current list of practices.

Table 1.1: Stormwater Management Practices

Alternative Surfaces	
Green roofs	Green roofs are an alternative surface in place of a flat or pitched roof. The benefits include stormwater runoff control, improving the energy performance of buildings, air quality improvement, and potential habitat. Simple vegetated roof covers, with approximately three inches of substrate can reduce annual runoff by more than fifty percent in temperate climates. Green roofs and other vegetation incorporated on and around buildings help shade and insulate buildings from wide temperature swings which decreases the energy need for heating and cooling.
Permeable pavements	Permeable pavements allow stormwater to infiltrate into underlying soils promoting pollutant treatment and recharge, as opposed to producing large volumes of rainfall runoff requiring conveyance and treatment. Permeable pavement takes care of the water at the source and is able to handle the frequent smaller one-inch storms. In urban watersheds, pavements cover one third of the land and they produce two-thirds of the runoff and almost all the petroleum-based pollution.
Reinforced turf	Another alternative surface is a grassed or gravel area with open load-bearing matrix for structural integrity to serve the same function as existing grassy areas.
Non-Structural Practices	
Filter strips	A planted band of vegetation located between the runoff location and the receiving channel or water body is a filter strip. Overland flow allows for infiltration and filtering of storm water into the water table. Filter strips should have a minimum area of fifteen feet while wooded areas are thirty five feet.
Vegetated buffers	Vegetated buffers are vegetation around sensitive areas such as water bodies that provide infiltration, slow and disperse storm water, and allow some trapping of sediment. These also protect the existing resource from further degradation. They disperse stormwater flows over a wide area.
Increased tree cover	Added tree canopy planting additional trees to capture a portion of the rainfall. Tree canopy in also aids in cleaner air, urban heat island reduction, and animal habitat.
Micro-scale Practices	
Bioretention cell Rain gardens	Bioretention cells and rain gardens serve similar functions with the main difference being the size. Typically, rain gardens are smaller and bioretention cells are larger with more hard structures. The purpose is to infiltrate water into the water table and slow the peak flow rate. Rain gardens also serve as excellent habitat areas. Design guidelines recommend that bioretention systems occupy 5-7% of the drainage basin. Bioretention cells and rain gardens have six typical components: 1) Grass buffer strips – reduce runoff velocity and filter

	particulate matter 2) Sand bed – provides aeration and drainage of the planting soil and assists in the flushing of pollutants from soil materials 3) Ponding area – provides storage of excess runoff and facilitates the settling of particulates and evaporation of excess water 4) Organic layer – performs the function of decomposition of organic material by providing a medium for biological growth to degrade petroleum-based pollutants. It also filters pollutants and prevents soil erosion. This mulch should be replaced annually. 5) Planting soil – provides the area for stormwater storage and nutrient uptake by plants. The planting soils contain some clay which adsorbs pollutants such as hydrocarbons, heavy metals and nutrients. Soils begin filtering pollutants immediately and can lose their ability to function in that capacity over time. Nutrients and heavy metals eventually disrupt normal soil functions by lowering the cation exchange capacity (CEC). The CEC is the soil's ability to adsorb pollutant particles through ion attraction and will decrease over time. 6) Vegetation – functions in the removal of water through evapotranspiration and pollutant removal through nutrient cycling. A minimum of three species of trees and three species of shrubs should be selected to insure diversity because different rates of transpiration and ensure a more constant rate of evapotranspiration and nutrient and pollutant uptake throughout the growing season.
Swales	Swales are linear depressions designed to collect, treat, and retain runoff from a storm event. Swales can be designed to be dry or wet (with standing water) between rain events. Wet swales typically contain water-tolerant vegetation and use natural processes to remove pollutants. Sedimentation is the primary pollutant removal mechanism with additional secondary mechanisms of infiltration and adsorption. In slowing the water, sediments and pollutants will drop from suspension in the water. In 1998, a traditional structural conveyance cost two to three times higher than a grass swale. This is conveyance, which is the oldest stormwater management approach.
Dry wells	Dry wells are an excavated pit, backfilled with granular material to assist with peak flow reduction by temporary water storage and water infiltration. They are used to control surfaced pollutants.
Infiltration trenches	Infiltration trenches are an excavated trench backfilled with stone to create a subsurface basin that provides storage of water and allows infiltration. These can be used at the border of impermeable surfaces to capture the sheet runoff for temporary storage.

Level Spreaders	Level spreaders are an outlet used to convert concentrated runoff to sheet flow. The lower edge of the level spreader must be level for the spreader to work properly.
Rain barrels	Rain barrels are a separate entity placed at the end of a roof downspout to capture and hold runoff from roofs. The water in the barrel must be manually released onto the ground, where it can be put to beneficial use to water vegetation. The barrel top typically has a protective screen to inhibit mosquitoes. This technique serves to capture and use the stormwater on site. In the Portland Rainwater Harvesting Code Guide, it requires that the first 10 gallons of roof runoff during any rain event to be diverted away from the cistern to an Office of Planning & Development Review (OPDR) approved location. The Portland Code also requires that rainwater can only be harvested from roof surfaces and then used for toilets and hose bibs. In Colorado, the Western water rights prohibit rainwater capture and reuse because it is seen as restricting the downstream user's allotted water right.
Cisterns	Cisterns are underground tanks to store runoff and stored for non-potable uses.

(Sources: Casey Trees 2012, Cheng et. al. 2001, Coffman 2002, EPA 2000, EPA 2008, Ferguson 2002, Ferguson and Debo 1990, Liptan and Murase 2002, MDE 2011 and, Snodgrass and McIntyre 2010)

Perceptions about Stormwater

Most conventional stormwater practices are focused on water conveyance and aesthetic design objectives are not a primary consideration. Echols and Pennypacker (2008) have used the term 'artful rainwater design' or ARD which means that stormwater can be an art form and that the consideration of aesthetic objectives in stormwater practices can be an additional amenity to the landscape. The argument for the focus on design is that the stormwater practices will be more successful if the stormwater is seen as an additional amenity. Amenity is understood as a feature that increases the landscape's attractiveness or value (Echols and Pennypacker 2008). The traditional urban drainage system is to treat water quantity only, but the sustainable urban drainage system treats quantity, quality, and as an amenity (Echols and Pennypacker 2008). Dreiseitl and Grau (2005) suggest that

the next generation of networked city infrastructure should have multiple benefits, including habitat and recreational space, and at the same time fulfilling a structural function. This is achieved by having the elements publicly visible and also aesthetically attractive (Dreiseitl and Grau 2005). One of the highest ranking programs for improving stormwater quality is public education (Black & Veatch Corporation 2010) and artful rainwater design can contribute to goal.

The design goals of ARD can be divided into convenience (location, ease, or comfort), education (favorable conditions for learning), recreation (favorable conditions for play and/or relaxation), safety (freedom from exposure to danger or risk), social interaction (commingling of individuals or groups), public relations (semiotic expression of values by the designer and/or owner), and aesthetic richness (beauty or pleasure as a result of design composition) (Echols and Pennypacker 2008). Some specific programs and practices used in urban environments are erosion/sediment controls, street sweeping, inlet stenciling, detention-retention basins, stormwater quality monitoring, commercial/industrial regulation, public volunteer involvement, residential toxins collection, constructed wetlands, and lawn herbicide/pesticide controls (Black & Veatch Corporation 2010).

Public education is crucial for a changing perception for stormwater management. Utility companies are using their customer bills as a venue to add informational inserts about stormwater management and its benefits. Other techniques used were websites, public hearings, public school presentations, newspaper articles, open houses, television,

neighborhood associations, brochures, direct mail and storm drain markers (Black & Veatch Corporation 2010). Numerous non-profit organizations are also involved in water or stormwater education as part of their mission.

Conclusion

This portion of the literature review discussed stormwater as an overarching subject. The first section covered the problems associated with improper stormwater management. The second section explored the history of stormwater management, LID, regulations, and specific stormwater management practices. The final section explored how stormwater can also be an artful amenity that can provide perceived by the public as positive and can also be used as an educational tool in the landscape.

Stormwater in the District of Columbia

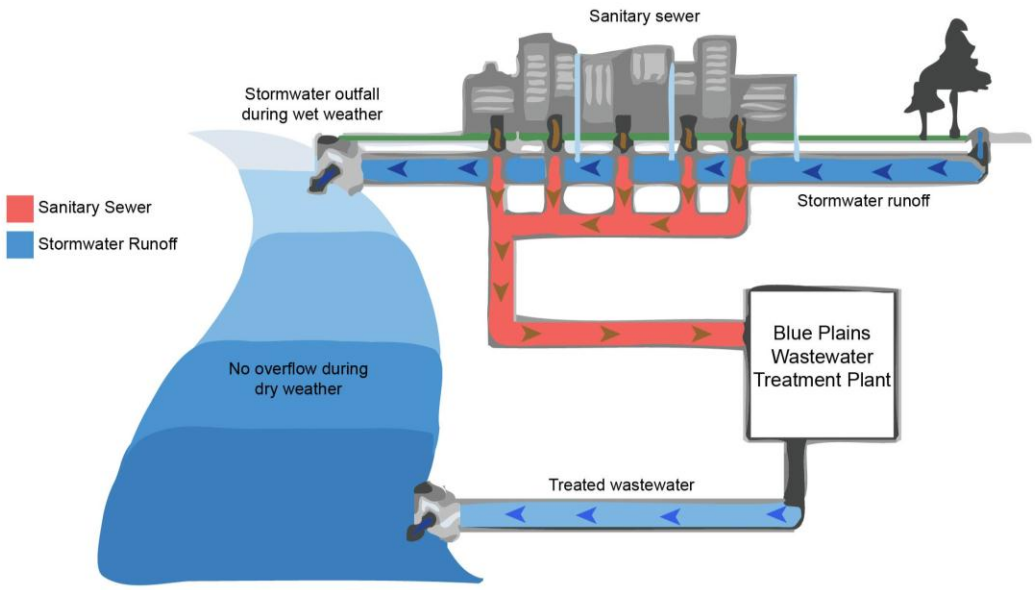
The following section discusses the District of Columbia's stormwater systems, organizations involved with stormwater, permitting requirements, stormwater regulations, fees, and funding opportunities.

Combined and Separate Storm Sewers

The District has both combined and separate stormwater and sewer systems within the city limits. Most of the combined sewer systems (CSS) are in the center of the District with the Municipal Separate Storm Sewer Systems (MS4) in the suburbs. Appendix 1 is a map showing the location of the CSS and MS4 areas. There are fifty three CSS outfalls

throughout the District with fifteen to the Anacostia, ten to the Potomac, and twenty eight to Rock Creek (DC Water 2011a). With increasing amounts of impervious surface in the District, more water flows into the CSS with wet-weather events which results in increased amounts of Combined Sewer Overflows (CSOs). As of 2002, sixty five percent of the District's natural groundcover is impervious surface which yields greater volumes of runoff (Woodworth 2002). Approximately two-thirds of the District of Columbia is served by separate sewer systems (DC Water 2010). Separate systems are illustrated in Figure 1.2:

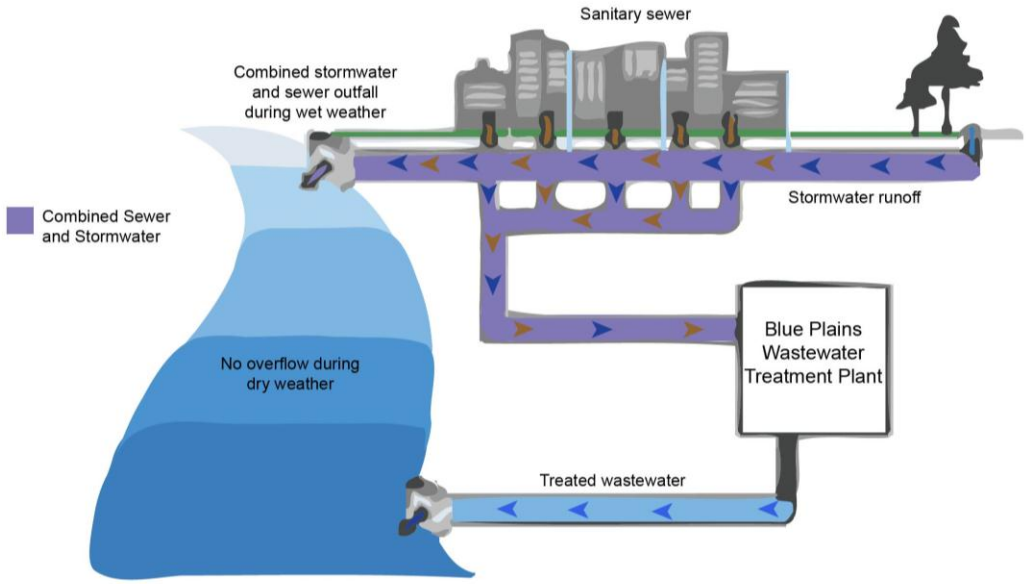
Figure 1.2: Separate Sanitary and Stormwater Sewer Systems



The remaining one-third of the District is served by a CSS, which was built before 1900 (DC Water 2010). The CSS was constructed when there was a smaller population so problems with overflows were not even considered as a possible future problem (DC

Water 2011c). A combined sewer system conveys both sanitary sewage and storm water in one piping system and is illustrated in Figure 1.3:

Figure 1.3: Combined Sewer Systems



The water treatment plant for both sewage and stormwater is the Blue Plains Advanced Wastewater Treatment Plant which is the largest advanced wastewater treatment facility in the world (DC Water 2011a). The stormwater pipes and the Blue Plains facility are managed by DC Water. Areas in the District that are in a MS4 area have separate discharges for the stormwater into local water bodies. Areas with a CSS transport all sewage and stormwater to the Blue Plains facility. Pollutant discharges from separate storm sewers and combined sewer systems account for as much as seventy percent of the pollution in the Rock Creek, Anacostia, and Potomac rivers (Woodworth 2002). The overflows are especially problematic with the Anacostia River because it is a slow moving tidal estuary which does not flush out pollutants as quickly as the Potomac or

Rock Creek (Woodworth 2002). These problems instigated the Clean Rivers Project to help manage the CSO problems. The Clean Rivers Project will be discussed in more detail in an upcoming section.

Involved Government Organizations

Currently, the main agencies that are charged with stormwater management authority in the District are the District Department of the Environment (DDOE) and DC Water. DDOE and DC Water both work under policies and regulations established by the EPA. In 2000, the "Storm Water Permit Compliance Amendment Act of 2000" authorized the DC Water and Sewer Authority (now called DC Water) as the District's stormwater administrator (Spangler and Lewis 2008). This now includes responsibilities for monitoring and coordinating the activities of the District agencies to ensure compliance with the city's MS4 Permit requirements (Spangler and Lewis 2008). DC Water serves two million people within its borders that cover the District and portions of Maryland and Virginia (DC Water 2011a). The District of Columbia City Council passed the "District Department of the Environment Establishment Act of 2005" to establish DDOE as a separate agency and to transfer the stormwater administration authority to DDOE (Spangler and Lewis 2008). The transfer of authority from DC Water to DDOE now results in the District government having control for agencies executing storm water management activities (Spangler and Lewis 2008). The main agencies that work with MS4 Permit compliance are DDOE, DC Water, Department of Public Works, and the District Department of Transportation (Spangler and Lewis 2008). In February 2007, DDOE took over responsibility from DC Water for managing the District's Stormwater

Management Administration and maintaining compliance with the MS4 Permit (Spangler and Lewis 2008).

Non-Profit Organizations

The following is a non-comprehensive list of organizations that are involved in water and stormwater activities in the District and the Potomac River. Organizations that work in the District are mostly non-profit and use grassroots activism. Casey Trees, the Potomac Conservancy, Potomac Riverkeeper, and the NRDC are examples of organizations that work towards the Potomac River becoming less polluted

Casey Trees

Casey Trees is a non-profit organization based in the District that promotes and restores urban tree canopy. They engage thousands of volunteers to plant and care for trees and provide year-round education courses. They also monitor the District's tree canopy and have developed interactive online tools to work with elected officials, developers, community groups, and residents to promote existing care for the trees and planting new trees to add to the health of the District's tree canopy (Casey Trees 2012).

Potomac Conservancy

The Potomac Conservancy is an advocate for water quality policy and thoughtful land management in the Potomac River watershed. The Conservancy protects and restores the Potomac landscape and teaches river recreation that fosters a conservation ethic (Potomac Conservancy 2012).

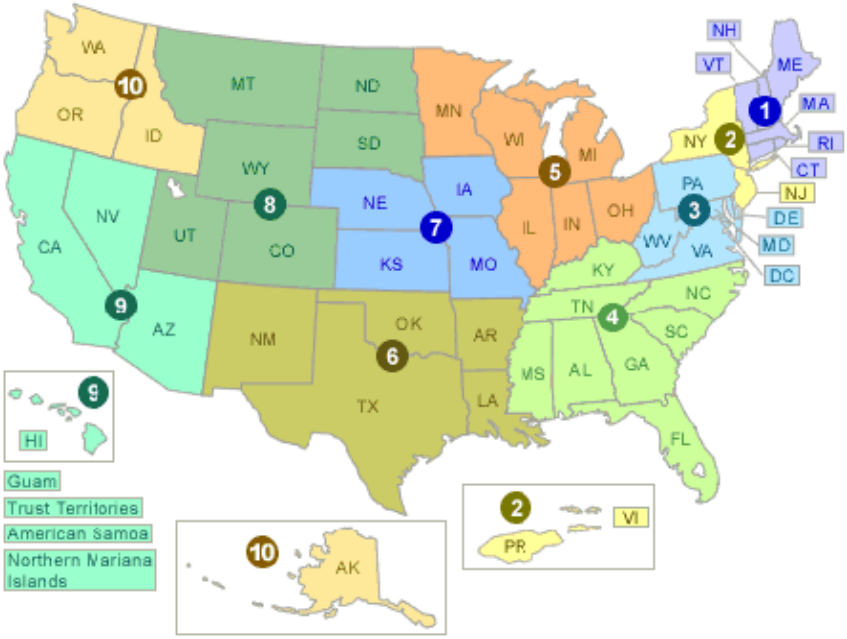
Potomac Riverkeeper

Potomac Riverkeeper is an organization that fights against large-scale polluters in the Potomac River watershed. They use existing environmental laws such as the CWA as their basis for action. A major aspect of the organization is outreach to local communities to teach about local water quality and how they can be better stewards of the environment (Potomac Riverkeeper 2012).

National Pollutant Discharge Elimination System (NPDES) Permit

On November 27, 2007, DDOE submitted the District of Columbia MS4 Best Management Practices Enhancement Package to the US EPA Region III. EPA Region III includes the District, Maryland, Virginia, Delaware, Pennsylvania, and West Virginia (EPA 2011b).

Figure 1.4: National EPA Regions



(Source: EPA Region III 2011)

It was one of the most aggressive storm water management plans in the Chesapeake Bay region (DDOE 2007). The current NPDES permit for the District was issued on October 7, 2011. In section 4.1.1, the permit discusses stormwater controls to "achieve on-site retention of 1.2 inches of stormwater from a 24-hour storm with a 72-hour antecedent dry period through evapotranspiration, infiltration and/or stormwater harvesting and use for all development greater than or equal to 5,000 square feet." (EPA Region III 2011). The 1.2 inch storm requirement was derived because historically 90% of the District's storms produced 1.2 inches of rainfall or less in the storm event (DDOE 2011). In 2009 most of the storms recorded are below the 1.2 inch requirement (Van Wye, et.al. 2011). Treating the first half inch of precipitation is very important because pollutant loadings are highly concentrated with grease and oil, nutrients (nitrogen and phosphorous), sediments and heavy metals (EPA 2000).

Consent Decree

The Anacostia Watershed Society, Kingman Park Civic Association, American Canoe Association, Friends of the Earth, Sierra Club, and Mary Stuart Bick Ferguson ("Citizen Plaintiffs") filed against DC WASA (DC Water) and its general manager, Jerry Johnson pursuant to Section 505 of the CWA in early 2005 (US District Court for the District of Columbia 2003). Section 505 of the CWA allows for citizens to initiate civil suits against any person including any government agency for violating the CWA (EPA 2010). In a judicial context, settlements are embodied in consent decrees signed by all parties to the action and filed in the appropriate court (EPA 2011a). The Consent Decree was entered by court on March 23, 2005 with a specific schedule for implementing the Long Term

Control Plan (LTCP) (DC Water 2011d). The objective of the consent decree is to ensure that DC Water complies with the CWA, the terms and conditions of DC Water's NPDES Permit, and meet the objectives of the EPA's 1994 CSO Policy (US District Court for the District of Columbia 2003). The consent decree deadline for starting the facility plan is for 2015 and placing in operation by 2025 (DC Water 2011d). Additional features in the consent decree is for installing public notification signs and creating programs to educate the public about the dangers of CSO events (US District Court for the District of Columbia 2003).

Current Regulations

Many current regulations are being updated to allow for LID construction to meet new regulation and to address the 1.2 inch storm requirement. There are several current codes and ordinances that can hinder LID retrofits and new stormwater sensitive construction. These include the DC Plumbing Code, Zoning ordinances, Public Space and Safety Codes, and Building Codes. Current DC Plumbing Code regulates all runoff from "roofs, paved areas, yards, courts and courtyards" in section 1101.2. This requires that when there is access to a storm drain, all the runoff must be directed into that drain. The Plumbing Subcommittee of the District of Columbia Building Code Advisory Committee is proposing an amendment that would grant approval for stormwater discharges into vegetated areas (Woodworth 2002). The District of Columbia Zoning Ordinance requires that all parking spaces and driveways use all-weather surfacing which in the existing Public Space and Safety Code is defined as concrete (Woodworth 2002).The current goal is to change the code from "all-weather impervious surface" to having the purpose of

“supporting vehicular traffic” which would allow for installing permeable pavements or pavers. However, in historic districts such as Georgetown, the sidewalk pavement is required to be comprised of brick and sand on a sand-cement bed of Portland cement (Woodworth 2002). Landscaped roofs and roof gardens are currently permitted under the District of Columbia Building Code. There are currently no codes that specify time requirements for ponding retention times (Woodworth 2002).

Construction Permitting Requirements

There are currently two primary permits, both administered by DDOE, that are needed for stormwater design and construction in the District (Champion 2012). The first is the Erosion and Sediment Control plan that is required for an area greater than fifty square feet of land disturbance. The second are the Storm Water Management requirements that are triggered by 5,000 square feet of proposed land disturbance (Champion 2012).

Stormwater Fee Programs

There are many incentive programs around the United States currently in use. These incentive mechanisms can be grouped into five primary types; 1) stormwater fee discounts, 2) development incentives, 3) grants, 4) rebates and instillation financing, and 5) award recognition programs (EPA 2009).

A stormwater fee discount is based on the area of impervious surface on the property and when the amount of impervious surface is reduced, the municipality reduces the fee (EPA

2009). Development incentives are for developers if they have sustainable site design and green building practices and they can move through the permitting process faster or have approval for increased floor area ratios (EPA 2009). As a local example, Montgomery County, MD has the RainScapes Rewards program which offers up to $1,200 per single-family lot or up to $5,000 per multi-family or commercial lot for installation of rain gardens, cisterns, green roofs, native plants, shade trees, and permeable pavement (EPA 2009).

Grants provide funding to property owners to implement a range of stormwater projects and practices (EPA 2009). Rebates and installation financing provide further funding, tax credits or reimbursements to property owners for specific practices (EPA 2009). The awards and recognition programs are to reward exemplary projects which provide additional marketing and public outreach opportunities (EPA 2009).

The most common sources of funding for stormwater projects include stormwater fees, loan programs, and grant programs (EPA 2008). Stormwater fees are used instead of line-item taxes because they more easily target properties that generate the most runoff and also fees do not require a vote by the public to be started (EPA 2008). Loan programs are possible at a variety of scales from the state level to the community (EPA 2008). These loans are low-interest and although not federally required, are often paid off over 20 years or the useful life of the project, whichever is less (EPA 2008). The most readily available source for funding is the EPA Clean Water State Revolving Fund (CWSRF) (EPA 2008). National basis grant programs are mostly meant for small, local projects

(EPA 2008). CWA Section 319 or through the Department of Housing and Urban Development's Community Development Block Grant Program are useful for demonstration projects or as seed money to build local political and community support for green infrastructure practices (EPA 2008).

Black & Veatch Corporation is a global engineering, consulting and construction company who has conducted stormwater utility surveys since 1991(Black & Veatch Corporation 2010). Black & Veatch completed their eighth national Stormwater Utility Survey in 2009. Responses were received from 70 utilities in 20 states which are funded whole or in part by user fees. For utilities that charged based on gross property area, the Equivalent Residential Unit (ERU) ranged from 2,090 square feet to 14,500 square feet of total parcel area (Black & Veatch Corporation 2010). Utilities that base charges on impervious area, an ERU ranged from 305 square feet to 3,600 square feet. Most of the utilities surveyed (81%) were cities (Black & Veatch Corporation 2010). Updating customer parcel information, e.g., impervious surface calculations and classes, is not undertaken at a regular frequency for almost half of the utilities surveyed (Black & Veatch Corporation 2010). Of the utilities that do have a regular interval for updates, it is an annual update (Black & Veatch Corporation 2010). Payment of the stormwater utility is enforced by putting a lien on the property or shutting off the water by about 80 percent of the utilities surveyed (Black & Veatch Corporation 2010).

District Impervious Surface Fees

There are two stormwater fees that exist for the District's residents. Both fees are collected through the monthly DC water bill, of which the DDOE fee is placed in an enterprise fund to be used for infrastructure upkeep or permitting. Both of the stormwater fees for DC Water and DDOE are based on the ERU which is defined as 1,000 square feet of impervious area on a property (DDOE 2011 and DC Water 2011b). The DDOE stormwater fee program started in May of 2009. Effective November 1, 2010 the DDOE charge for one ERU is $2.67 per month which is charged in the customer's monthly water and sewer bill (DDOE 2011). In 2010, the Board of Directors for DC Water made the decision to raise the monthly Clean Rivers Impervious Area Charge (CRIAC) to $6.64 per ERU starting in the 2012 fiscal year (DC Water 2011b). See the below table for the monthly costs from DDOE and DC Water.

Table 1.2: Monthly Costs for the DDOE and DC Water Stormwater Fees

Impervious Area (Square Feet)	ERU	DC Water ERU Rate	DC Water Monthly Cost	DDOE ERU Rate	DDOE Monthly Cost
100-600	0.6	$6.64	$3.98	$2.67	$1.60
700-2,000	1	$6.64	$6.64	$2.67	$2.67
2,100-3,000	2.4	$6.64	$15.94	$2.67	$6.41
3,100-7,000	3.8	$6.64	$25.23	$2.67	$10.15
7,100-11,000	8.6	$6.64	$57.10	$2.67	$22.96
11,100 and more	13.5	$6.64	$89.64	$2.67	$36.05

(Source: DC Water 2011b and DDOE 2011)

The cost of maintaining and replacing the aging infrastructure is projected to rise while federal funding in this area is decreasing (DC Water 2011a). Most of the DC Water stormwater fee funds will be spent towards the Clean Rivers Project.

Discount Program

DDOE expects discount programs to be operational in January of 2012 (Champion et. al. 2011). For installing one or more approved stormwater retention practices, the customer would be able to have a maximum of 55% discount on their monthly sewer and water bill (DDOE 2011). The cap on the discount is due to the possibility of very large storm events that will render the smaller systems to capacity and also supporting the District's costs for stormwater management and administration for the MS4 permit (DDOE 2011). In a 1.2 inch rainfall event, each ERU produces approximately 710.75 gallons of stormwater runoff (DDOE 2011). The discount assessment is given at three year intervals at which point the application must be re-submitted for reevaluation by DDOE (DDOE 2011). Currently there is no discount program with DC Water.

Clean Rivers Project

The Clean Rivers Project was initiated as part of the US District Court for the District of Columbia's Consent Decree between DC Water and the Anacostia Watershed Society. The Potomac River Consent Decree requirements are for the Potomac Tunnel construction (DC Water 2011a). The Anacostia and Rock Creek projects are beginning before the Potomac River projects due to their more severe pollution problems. Under the current consent decree, it does allow for downsizing of the tunnels, but it does not allow complete elimination (DC Water 2011d). The Clean Rivers Project is currently under construction which will build a huge network of tunnels to hold the combined stormwater and sewage until the storm passes (DC Water 2011a). After the storm passes, the combined stormwater and sewage will be passed to Blue Plains. This project requires

$2.6 billion in spending over the next fifteen years (DC Water 2011a). When completed in 2025, the three tunnels will reduce combined sewer overflows to the Anacostia River by 98 percent and to all three waterways – Rock Creek and the Anacostia and Potomac Rivers by 96 percent (DC Water 2011a). The Blue Plains treatment plant is also upgrading its facilities to include a thermal hydrolysis and anaerobic digestion system to generate power to help operate the plant (DC Water 2011a). It will also save as much as $10 million per year in electricity (DC Water 2011a). The end product of the new system are Class A biosolids which can be used in many recycling applications including agriculture, reclamation, forestry, and products for gardening, landscaping, and green roofs (DC Water 2011a). The Clean Rivers Project should be operational by mid-2014 (DC Water 2011a).

Funding in the District

Stormwater management funding opportunities are offered by many independent organizations as well as federal sources. One federal funding source is the Green Project Reserve that DDOE has been using to install stormwater projects. RiverSmart Homes, RiverSmart Schools, and RiverSmart Rooftops are smaller programs through DDOE that homeowners or small organizations could use for starting projects. Casey Trees is a non-profit agency that supports tree plantings and tree health and provides funding to attain those goals.

Green Project Reserve

The Green Project Reserve is a fund established by the American Recovery and Reinvestment Act (ARRA) (Clark and Reiling 2011). The ARRA added $4 billion to the Clean Water State Revolving Fund (CWSRF) and put an emphasis on rapid fund distribution by introducing the Green Project Reserve (GPR) requirement (Clark and Reiling 2011). To be eligible for the GPR, there are four distinct categories. They are 1) energy efficiency projects, 2) water efficiency projects, 3) green infrastructure projects, and 4) environmentally innovative projects (Clark and Reiling 2011).The GPR program will be maintained for the District in future fiscal years but will be reduced by 50% until requirements are better understood (Clark and Reiling 2011).

RiverSmart

The RiverSmart program in the District has three main components; RiverSmart Homes, RiverSmart Schools, and RiverSmart Rooftops. RiverSmart Homes is a program that gives homeowner incentives of up to $1,200 for planting trees, installing rain barrels, planting with native species, rain gardens, or installing permeable pavers (DC Water 2011d). The RiverSmart Schools program provides funding for school yard greening and outdoor classrooms, ranging in amount from $3,500 to $70,000 (DC Water 2011d). RiverSmart Rooftops is a rebate program that will give five dollars per square foot of green roof installed (DC Water 2011d).

Tree Rebate Program

In April 2009, the District adopted an Urban Tree Canopy Goal of obtaining 40 percent tree canopy cover by 2035 (Casey Trees 2011b). The District is currently at a 35 percent canopy cover and in order to achieve the 40 percent goal, 8,600 trees will need to be planted each year over the next two decades (Casey Trees 2011b). The tree rebate program by Casey Trees gives fifty dollars per tree planted (DC Water 2011d).

Conclusion

This portion of the literature review discussed how stormwater is managed in the District. This included six sections; 1) the District's existing systems of combined and separate storm sewers, 2) organizations involved with stormwater, 3) permitting requirements for retrofit and new construction, 4) legal regulations managing environmental impacts of stormwater, 5) stormwater fees and how the District has their fee structured, and 6) funding opportunities for stormwater management projects from local and federal funds.

Green Schools

This section discusses the development of the green school movement and why the movement has rapidly evolved. This includes the benefits of green schools, stormwater management in the school curriculum and how a sustainable campus can be designed for the instruction of many subjects. Also, this section discusses specific concepts for design on the campus, how the community can be involved with the design and financial and

award assistance for construction. Lastly, this section documents selected precedent examples.

Background

The concept of green schools includes both the use of the landscape as a learning tool and the focus on having a holistic campus to have a minimal impact on the environment. The idea to use the school grounds as an educational tool is not a new concept. The newer realization is that children are losing their connection with nature (Louv 2008). Designing schools and school grounds with the specific purpose to use the landscape as a learning tool is what is gaining greater attention from educators, parents, students and designers. Some of the subjects that are emphasized in green school designs are water efficiency, energy performance, transportation, community outreach, and food production. Stone (2009) provides four guiding principles for sustainable schooling. First, nature is our teacher. Second, sustainability is a community practice. Third, the real world is the optimal learning environment. In addition, sustainable living is rooted in a deep knowledge of place. Greening the campus involves many features, which include buildings used for teaching, connecting the outdoor and indoor environment, and schoolyard habitats (Stone 2009). These schools employ a vast variety of building techniques and landscape features. The Center for Green Schools which is part of the US Green Building Council created a list of the main characteristics of a Green School (USGBC 2012a):

- Conserves energy and natural resources
- Saves taxpayer money
- Improves indoor air quality
- Removes toxic materials from places where children learn and play
- Employs daylighting strategies and improves classroom acoustics

- Employs sustainable purchasing and green cleaning practices
- Improves environmental literacy in students
- Decreases the burden on municipal water and wastewater treatment
- Encourages waste management efforts to benefit the local community and region
- Conserves fresh drinking water and helps manage stormwater runoff
- Encourages recycling
- Promotes habitat protection
- Reduces demand on local landfills

The Need for Greener Schools

E.O. Wilson's concept of 'biophilia' and 'Yi-Fu Tuan's concept of topophilia' describe the human innate connection with nature in the 1970s and 1980s (Orr 2004). More recently Louv (2008) has argued that present-day children are lacking opportunities to interact with nature, resulting in nature-deficit disorder. Louv (2008) describes that nature is essential for a child's healthy physical and emotional development. The nature-deficit disorder results in diminished use of the senses, attention difficulties, and higher rates of physical and emotional illness (Louv 2008). The ripple effect will cause major problems to society as a whole if this problem continues to expand (Louv 2008). Children are being restricted by not only the lack of access to nature with high-population areas, but by the huge amounts of rules and regulations that exist with the initial intent to protect the environment (Louv 2008).

History of the Green School Movement

In August of 1981, the National Commission on Excellence in Education was created by the Secretary of Education T. H. Bell (The National Commission of Excellence in Education 1983). This commission was created because the Secretary saw a serious

problem with the education system in the U.S. (The National Commission of Excellence in Education 1983). The report, A Nation at Risk, detailed how the United States has a rising tide of mediocrity that is leading to no longer achieving a top country in education in the world ranking (The National Commission of Excellence in Education 1983). The report describes how not only the United States is showing lack of involvement in competing in the world's economy, but that the fabric of the country is eroding intellectual, moral, and spiritual strengths (The National Commission of Excellence in Education 1983). A Nation at Risk has set a standard for the problem with today's education system (NEEF 2000). With this report; the National Commission on Excellence in Education began its movement for driving school change today (NEEF 2000). In 1994, Congress passed a set of benchmarks titled 'Goals 2000' (NEEF 2000). In 1994 a follow-up report was written, A Nation Still at Risk, that detailed how very few of the goals from Goals 2000 were met and even some of the problems have gotten worse. As detailed by the National Environmental Education Foundation (NEEF) in 2000, Goals 2000 had a set of eight goals:

- Create a student population that is ready to learn (Goal 1) and will complete all four years of high school (Goal 2)
- Rigorous, measureable benchmarks for student achievement and active citizenship (Goal 3)
- Properly prepared and trained teachers (Goal 4)
- Being first in the world in math and science (Goal 5)
- Developing in students the traits that will lead them to become literate adults and lifelong learners (Goal 6)
- Safe, disciplined, drug-free schools (Goal 7)
- More parental participation in the schools (Goal 8).

The EPA, authorized by that National Environment Education Act, has taken action for educating the public about environmental threats and how actions can be taken to protect

the environment (NEEF 2000). In the District, the Healthy Schools Act: Healthy Schools Fund was passed in 2001 with the main purpose for having more nutritional food in the District's public schools (Council of the District of Columbia 2001). There is also a section of the Act that addresses creating an environmental literacy plan and plans to work within the Office of Public Education Facilities Modernization to establish campus-wide sustainability goals (Council of the District of Columbia 2001).

In 2007, the Elementary and Secondary Education Act also known as the No Child Left Behind Act was passed (Chesapeake Bay Foundation 2011). The No Child Left Behind Act fundamentally changed the way that education is delivered in this country by requiring specific standards to be met for reading, math and science which led to the implementation of more standardized testing. In response to the No Child Left Behind Act, the full House of Representatives passed the No Child Left Inside Act in September 2008 and the bill was introduced to Congress on July fourteenth (Chesapeake Bay Foundation 2011). The No Child Left Inside Act supports environmental and outdoor education for the nation's pre-kindergarten through 12 public schools (Chesapeake Bay Foundation 2011). It provides incentives for states to create and implement State Environmental Literacy Plans in order for students to have a basic understanding of the environment before graduation (Chesapeake Bay Foundation 2011). The grants also are to help with teacher professional development. On October 21, 2011 the No Child Left Inside Legislation was approved by the Senate Committee. This is a continuation of the original act that places continued emphasis on environmental literacy and field experiences incorporated into the regular instruction (Chesapeake Bay Foundation 2011).

Currently, the District does not have an environmental literacy plan (Chesapeake Bay Foundation 2011). Locally however, the Maryland Association for Environmental and Outdoor Education (MAEOE) was initiated in Maryland with a mission to encourage, train, and support Maryland educators. The District has coalition members in MAEOE which are the following:

- Appalachian Mountain Club DC Chapter
- Capital Region Earth Force
- Clean Air Partners - MWCOG
- District of Columbia Environmental Education Consortium
- Friendship Public Charter Schools
- George Washington Carver Outdoor School, Inc.
- Groundwork Anacostia River DC
- Touching Earth
- Washington International School
- Washington Parks and People
- Xoana Educational Institute

See Appendix 2 for a list of more national and international organizations that assist with green school programs.

Benefits of Green Schools

Higher education can incorporate environmental literacy, social responsibility and sustainability topics into degree requirements in order to yield students who have the understanding to instigate positive societal changes (Rowe 2002). It is a new shift to teach students the “change agent” skills required for positive societal changes instead of just producing analytical thinkers (Rowe 2002). The root of the word education is “educe” which means to “draw out”. Students need to be outside experiencing the natural world to draw out curiosity and connect with nature (Orr 2004). There are many

education concepts being developed by several different organizations, Environment as an Integrating Context for learning (EIC) and place-based education follow the same overarching goals as listed above but have different focuses. The first is more centered at the school, and the second is to focus on the community as the main venue for education.

Environment as an Integrating Context for learning (EIC)

The Environment as an Integrating Context for learning (EIC) defines a framework for education involving interdisciplinary, collaborative, student-centered, hands-on learning (Lieberman and Hoody 1998). It was developed by the State Education and Environment Roundtable (SEER) which is a cooperative endeavor of education agencies across the nation from 12 states which includes Maryland State Department of Education (Lieberman and Hoody 1998). EIC focuses on using the school's surrounding environment and community as a platform for successful education. Since schools around the nation are in such varying surroundings, these environments may range from a forest to a small garden in an asphalt playground (Lieberman and Hoody 1998). The fundamental strategies for EIC are to break down traditional boundaries between disciplines, provide hands-on learning experiences through project-based activities, rely on team teaching, adapt to individual students and their unique skills and abilities, and assist the students to develop knowledge, understanding, and appreciation for the environment and community (Lieberman and Hoody 1998). The benefits of EIC are; better performance on standardized measures of academic achievement, reduced discipline and classroom management problems, increased engagement and enthusiasm for learning, and greater pride and ownership in accomplishments (NEEF 2000).

Place-based education

Place-based education is founded on the principle to use the local community and environment as the main teaching arenas for arts, mathematics, social studies, science, and many other subjects through the curriculum (Sobel 2005). This system emphasizes real-world projects which maximizes ownership through partnerships because more people working together leads to a sense of community which creates active and contributing citizens (Sobel 2005). For sequential learning, movement from close and familiar to distant and strange accurately mirrors the developmental transitions of a growing child which is exactly what place-based education strives to achieve (Sobel 2005). For example, learning at the small scale before learning about the entire solar system is the main teaching schedule for community-based education and is used in the Chesapeake Bay Foundation Schools Project (Sobel 2005).

Students that are given the freedom to explore their surroundings can begin to formulate their own questions about the functions and interrelationships of the world around them. A major component of EIC is that the projects are completed in a holistic fashion and in groups so each student is involved with all aspects of the project. In so doing, the students begin to recognize the value of each individual's perspective and will develop strong interpersonal skills (Lieberman and Hoody 1998).

Stormwater Curriculum and Artful Rainwater Design

One of the most important features for teaching about stormwater is to make stormwater processes visible. However, students must also be able to interact and gather around the

stormwater features in the landscape in order to learn from them (Echols and Pennypacker 2008), thus requiring comprehensive site design. An example of this concept is creating a physical watershed model of the schoolyard or the community so students could watch how the rainwater interacts with different landforms (Danks 2011). ARD includes two main ways to learn from a stormwater feature. The first, the most straightforward, is installing signs and the second is design and programming (Echols and Pennypacker 2008). Signage must be clear and brief in order to hold the reader's attention and also teach about the site to be the most productive (Echols and Pennypacker 2008). Treatment systems can also be programmed is the so that they invite educational games or activities (Echols and Pennypacker 2008).

There are countless ways that the schoolyard landscape can be connected to other science curriculums. These connections include ecology, habitat, water systems, energy systems, and edible gardens (Danks 2011). Geology can also be taught by placing rocks around the schoolyard so instead of learning about geology with a microscope, the students can see it at full scale while plant ecology can be taught by observing plant growth (Danks 2011). Weather can be monitored by having schoolyard weather stations (Danks 2011). This leads to an improvement in science thinking because the students were involved in real-world and project-based activities that refined their skills in scientific observation, data collection, analysis, and developing conclusions (Lieberman and Hoody 1998).

Schoolyard agriculture and gardens can also provide educational opportunities that help to reconnect the gap that has formed between agriculture and urban people. Culinary

gardens could also be a landscape where students and teachers can discuss health and nutrition. Another advantage to gardens is that raised beds are excellent for areas that need clearly defined beds, or on sites that have drainage issues. They are also useful for terracing in steep areas, bench seating, and for students who cannot sit on the ground (Danks 2011).

Additional Curriculum

While green school campuses can provide a landscape where instructors can teach science concepts, the green school environment can also offer opportunities to provide for the instruction of fine art, language arts, mathematics, and social studies. The green school movement is further developing with teachers and students experimenting with new ideas. These curriculum additions include art, language art, math, and social studies.

Arts are innately messy, so having classes meet outside enables the students to be unhindered by a fear of making a mess (Danks 2011). The schoolyard can also provide new materials to draw or paint, or write about in a poem (Danks 2011). The performing arts can use an outdoor stage or pavilion for small concerts (Danks 2011). The schoolyard can also become a new area that the art classes or performing arts can go during class time (Danks 2011). There can also be artwork within the school grounds by painting maps such as the entire world, or the local community on the walls of the building or pavement on the grounds (Danks 2011).

Benefits for language arts classes is that the students develop a greater interest in the subject thereby making them more interested in learning how to best represent their feelings (Lieberman and Hoody 1998). If they are interested in writing about a special plant, they will be interested in learning the proper format and style to write about their plant. When students enjoy reading about nature and their community they develop an interest in the subject resulting in a desire to better strengthen skills to express themselves (Lieberman and Hoody 1998). Poetry or even just letters are often painted on the walls as artwork is another method to incorporate language arts on a campus (Danks 2011). For literature and language, the best feature is having an outdoor classroom area for the students to be able to sit and talk with one another (Danks 2011).

Math skills could be strengthened because instead of thinking that math is only abstract, the students are able to use math as a tool to quantify and analyze connections among their surrounding environment (Lieberman and Hoody 1998). For example, math students could calculate the area of a path and calculate how many bricks are needed for construction (Danks 2011).

With social studies, the students could examine society in the context of local environment thereby developing connections between the economic, political, legal and cultural systems (Lieberman and Hoody 1998). A garden with a wide variety of plants gives the opportunity to expose the students to unfamiliar landscapes (Danks 2011). Schools can recognize other cultures purely by planting trees, flowers and shrubs from those cultures (Danks 2011).

Design Concepts

Each school landscape will develop its unique design that addresses its site, climate, and students. Site design elements for a green schoolyard include multipurpose design, space definition, place-making features, curriculum connections, legibility, outdoor classroom spaces, signage, and community participation (Danks 2011). A key for success for a schoolyard is to have passive areas, active areas, and outdoor classrooms (Furio 2011).

Overall design concepts for the grounds are to have defined spaces with clear legibility (Danks 2011). A series of outdoor rooms can be created by separating areas with walls, fences, or vegetation while connecting them with easy-to-follow paths (Danks 2011). Signs are incredibly useful because they are not only immediately informative, but also assist in sharing with teachers, family members, and the community what the school is doing currently, and its future goals for making the school better (Danks 2011).

Stormwater design is the same as any design for treating the water on site, increasing infiltration, using as little potable water as possible, careful plant selection, and using captured rainwater on site (Danks 2011). Elements that are different from a stormwater wetland at a school or a wetland outside a parking lot are that there is a greater possibility for educational benefits for students if connected with curriculum and designed with the intent as a learning landscape feature.

Stormwater Management

Design elements that can be utilized for meeting the stormwater treatment goals include green roofs, cisterns, rain gardens, and permeable pavers. Stormwater treatment is part of the Leadership in Energy and Environmental Design (LEED) Green Building Rating System. There are five points that relate to stormwater and curriculum integration in the LEED for Schools system (USGBC 2007). The LEED Green Building Rating System was first introduced in 1999 and LEED for Schools was first developed in 2004 and published in November of 2007 (USGBC 2007). There are 79 points possible for the LEED for Schools system. The ranking is in four categories; certified, silver, gold, and platinum. To be certified, the school must earn 29 to 36 points, silver is 37 to 43 points, gold is 44 to 57 points, and platinum is 58 to79 points (USGBC 2007). The point categories are in sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, and innovation and design process (USGBC 2007). Schools have the opportunity for five credits (Appendix 3) for stormwater management. Schools can register for LEED certification on the LEED website at www.leedbuilding.org (USGBC 2012b). The website has information about the certification process and all other information associated with becoming LEED certified (USGBC 2012b).

Involvement

A major aspect for a successful green schoolyard is to include the teachers, students, and parents in the landscape maintenance. The sharing of landscape maintenance promotes the idea of stewardship for children as they participate in caring for their schoolyard

(Furio 2011). Schoolyards are also useful for the community because they are typically large public spaces that add to the educational opportunity to reach a wider audience than just the students at that school (Danks 2011). Green schools create a strong sense of community around the school that the students can tap that energy (Lieberman and Hoody 1998). For teachers, it is very simple; if the teachers are enthusiastic, the students will be enthusiastic (Lieberman and Hoody 1998).

Funding and awards for promoting construction or retrofits of schools is most typically encouraged by financial funding or award programs. There are many sources for small grants or other types of funding available for schools interested in implementing green school techniques. Non-profit organizations such as private schools can apply for small "seed" grants to help develop local environmental education programs from the EPA (EPA 2011f). The EPA also has Environmental Education Grants program which is sponsored by the EPA's Office of Environmental Education to support environmental education projects with annual funding that ranges between two and three million dollars depending on funding appropriated by Congress (EPA 2012f). DDOE offers funding to schools with the RiverSmart Schools program and Casey Trees offers rebates for newly planted trees as was discussed in an earlier section.

Several opportunities for awards are possible for schools interested in greening their campus. Most of the awards are for a campus-wide approach. Often, states will have their own awards and organizations that manage green schools. The Maryland Association for Environmental and Outdoor Education (MAEOE) is an example of a local state-wide

organization. Awards are offered by the US Department of Education and the National Wildlife Federation (NWF). The Green Ribbon Schools recognition award is a federal program for schools that show progress towards a net zero environmental impact, improve the health and performance of students and staff, and ensuring the environmental and sustainability literacy of all the graduates (US Department of Education 2011). On April 23, 2012, President Obama, the U.S. Secretary of Education Arne Duncan, and the Environmental Protection Agency Administrator Lisa Jackson to announced the first-ever U.S. Department of Education Green Ribbon Schools (U.S. Department of Education 2012). The two schools awarded in the District were Stoddert Elementary School and Sidwell Friends Middle School (Department of Education 2012). The NWF has the Eco-Schools USA program that strives toward teaching environmental awareness for the students and the community (NWF 2012). Below is a list of schools that are registered in the District with the Eco-Schools USA program:

- John Eaton Elementary School – Elementary School
- Smothers Elementary School - Elementary School
- Maury Elementary School - Elementary School
- Columbia Heights Educational Campus - Middle School
- E. L. Haynes Public Charter School - K-12

Precedent Examples

There are numerous schools that are pursing the green school concept in order to use the grounds as an educational tool. The following sections provide a brief overview of selected schools that have specifically utilized their stormwater treatment as an educational tool and as an element that serves as precedents for design ideas.

Sidwell Friends – Washington, DC (Stone 2009 and Danks 2011)

Sidwell Friends was the first LEED Platinum K-12 School in the United States. On April 23, 2012 Sidwell Friends was awarded a Green Ribbon School award (Department of Education 2012). The site includes a large blackwater treatment system from the building's toilets, sinks, floor drains and janitor basins to later use it in urinals, toilets, and the buildings cooling tower. The system includes an underground settlement tank for the liquids and solids to separate. Then the liquids proceed through several wetlands full of plants that remove nutrients from the water. The water also goes through a trickling filter that aerates the water to remove ammonia. The last step is a UV disinfectant system in the building's basement.

The school grounds also include a separate stormwater harvesting system from the roof runoff that creates a pond and rain garden. Excess water from very large storms goes into the rain garden and then if the rain garden overflows, the water is channeled into the municipal stormwater treatment systems. During dry periods, the pond can be filled using water from the 3,000-gallon cistern that is also fed by rooftop stormwater runoff. Plantings on the campus emphasize using native plants that are naturally adapted to the local climate which results in the plants needing very little irrigation. The grounds have an artificial turf field that does not require irrigation water.

The new middle school's roof has a very intricate green roof that assists with stormwater treatment and organic gardens for the students to tend. The older sections of the roof that could not support a green roof were utilized as a location for solar panels and a weather

station. As an added educational tool, signs made by the students are posted throughout the building. The signs are painted with explanations of each unique feature of the school building.

Willow School - Gladstone, NJ (Stone 2009)

Willow School is a kindergarten through eighth grade school that installed a constructed wetland that treats the school's wastewater. Surrounding the wetland are vegetative swales with native grasses. Another stormwater feature is a 57,000-gallon recycled plastic tank which is disinfected with ozone and used for irrigation and toilets. They also retrofitted a grass field with twenty inches of gravel below the surface which will retain all runoff from that field. Each year the students inventory invertebrate species in the wetland and compare their results to previous years and then share their data online for other classes or the community.

Tarkington School of Excellence – Chicago, IL (Stone 2009)

Mayor Richard M. Daley from Chicago has a motto, '*Urbs in Horto*', which means 'city in a garden'. The Tarkington School of Excellence used that motto to create a living roof with tundra plants that can withstand the harsh Chicago winters. This green roof meets all stormwater quantity and quality treatment requirements, and in addition the school integrates the green roof into their curriculums. The green roof is the most visible feature from many classroom windows. Classes will be held on the rooftop where students will draw or just talk about why the green roof is good for the environment. The instructors also discuss important questions such as how the land, technology, and our economics

affect our own culture and other cultures with their classes. One class includes a study of materials and technology where the students discuss what things are made of and how it overlaps into the historical development and economics lessons about scarcity.

Darrow School - New Lebanon, NY (Stone 2009)

The Darrow School is a 200-year old Shaker campus. The school officials constructed a living machine that treats 7,000 gallons of wastewater per day from dorms, dining halls, academic and athletic facilities. Students in outside science courses study how relationships with the natural environment shape people and events; students in English classes read a book to examine place as a character in the novel; students in math classes devise formulas for tracking food waste in the dining hall; history students reflect on relationships between society use of resources and longevity; students in multicultural courses compare different countries use of environment resources; and photography students document change of seasons on plants in the living machine.

Conclusion

The concept of green schools is to use the landscape as a learning tool and focus on having a holistic campus that has a minimal impact on the environment. The development of the green school concept is a recent trend that includes benefits of both environmental literacy and place-based education for the students, teachers, and community. Selected precedents of green school campuses provided examples of where schools have used their campuses to be educational tools.

Chapter 2: Georgetown Visitation Preparatory School

Methods

The process used for the design application of the stormwater and green school concepts involved three primary steps: 1) site inventory, 2) site analysis, and, 3) design explorations through the creation of design illustrations. The site inventory was completed with site visits and GIS data from DC GIS. The site analysis resulted in template site selections. The design explorations were completed for each template site selections and included incorporating the information gathered with the site inventory and analysis.

Context

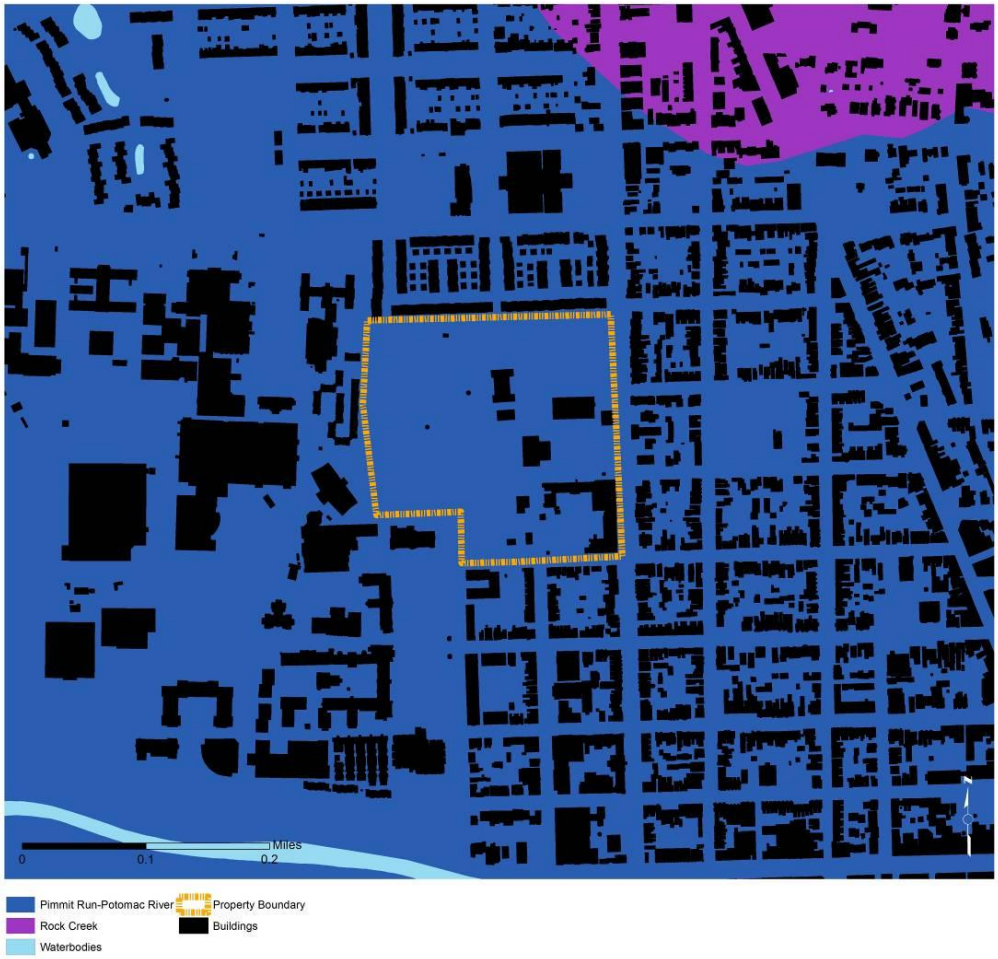
Georgetown Visitation Preparatory School is located in the northwest quadrant of Washington DC. The campus is on 22.28 acres of land within historic Georgetown adjacent to Georgetown University. Figure 2.1 indicates the location of the campus within the District boundary and the property boundary of the campus

Figure 2.1: Site Location

(Data Source: DC GIS and ESRI)

Over a 30-year period, the average rainfall for the District was 43 inches (USGS 2012). The campus is located in the Pimmit Run Potomac River watershed. Figure 2.2 indicates the campus's location within the Pimmit Run Potomac River watershed and also the Rock Creek watershed boundary to the north.

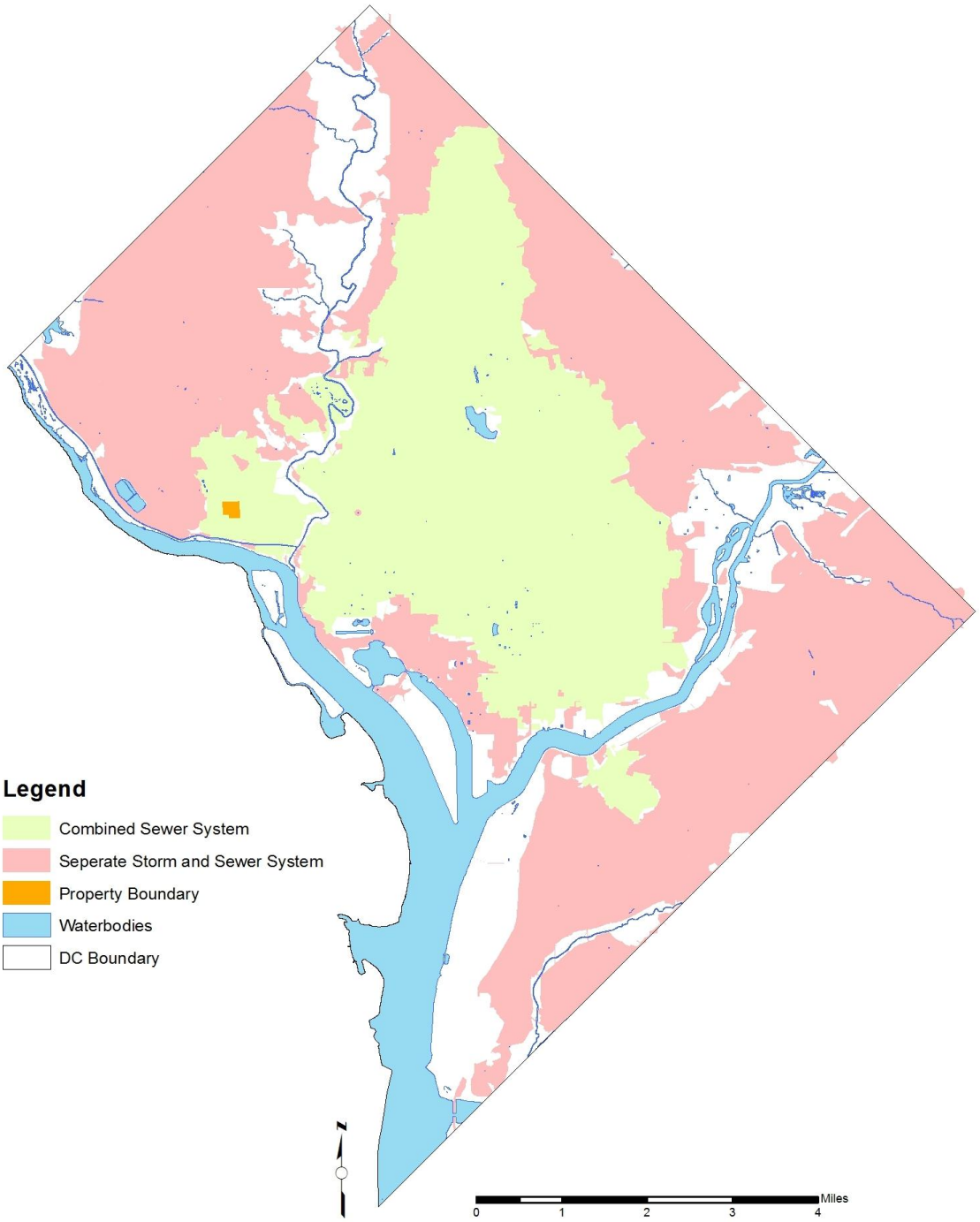
Figure 2.2: Site Watersheds



(Data Source: DC GIS)

The campus is located in the combined sewer system that has outfalls directly into the Potomac River which overflow during large storm events.

Figure 2.3: Combined and Separate Storm Sewer Location in the District



(Data Source: DC GIS)

The campus is currently zoned R-3. Figure 2.4 indicates the zoning of the campus and the adjacent areas. The strip of C-2-A zoning is Wisconsin Avenue and its adjacent businesses.

Figure 2.4: Site Zoning

(Data Source: DC GIS)

History

Georgetown Visitation is a Catholic girl's high school with approximately 480 young women enrolled. The school was founded in 1799 by the Sisters of the Visitation. At that

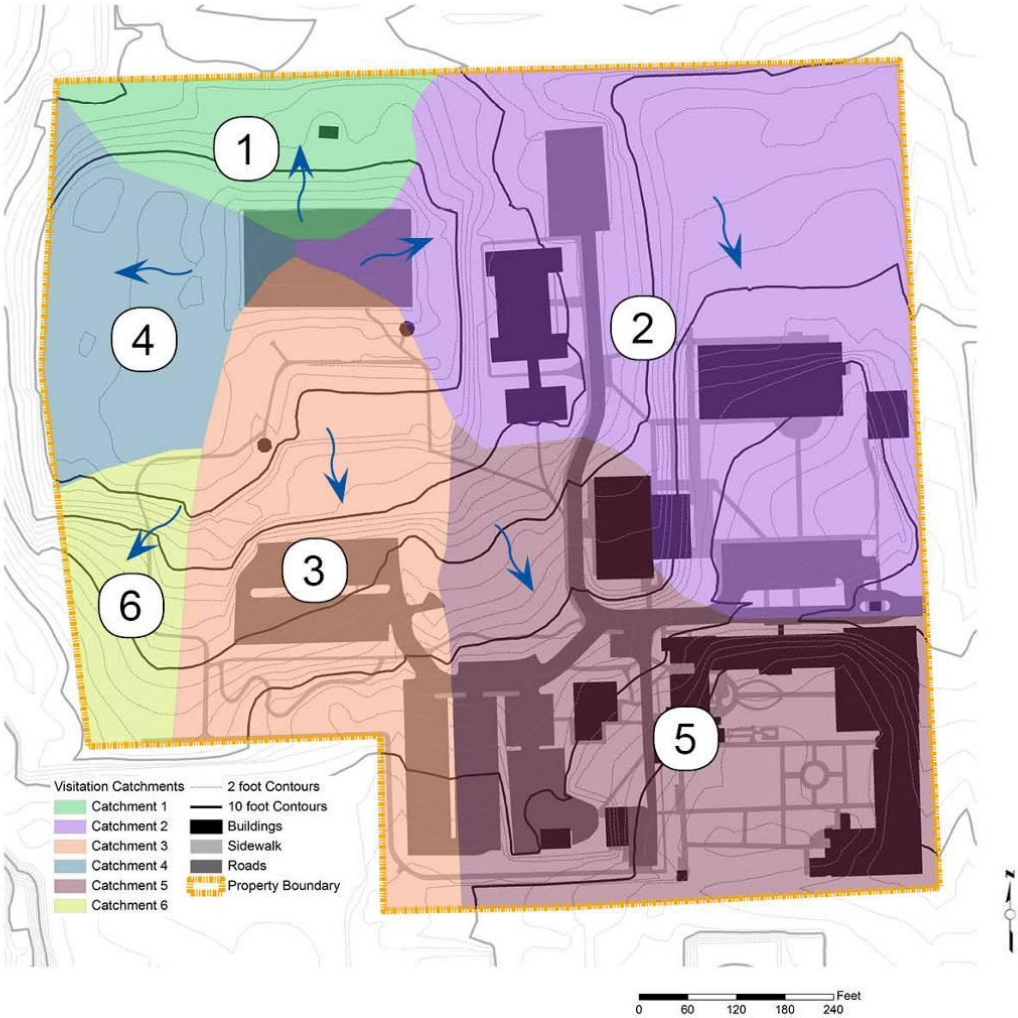
time, free public education was nonexistent and the Sisters of the Visitation offered education to all women. The school survived such historic events as the burning of Washington DC during the British invasion in 1814, and other social and political upheavals that Washington DC has experienced. Throughout these events, the school has maintained its religious beliefs, values and vision. Historic maps of the campus and surrounding areas are noted in Appendix 4.

In 1993, a devastating fire struck Founders Hall. However, with generous donations from parents, friends, and alumnae, Founders Hall was rebuilt with the most current technologies for education. In 1999 the school added the Fisher Athletic Center and Nolan Performing Arts Center as part of the 200-year anniversary for the school's founding.

Hydrology

There are six catchments that divide the campus's water cycle. No significant amounts of water drain onto the site with the tennis courts positioned at the highest elevation. Figure 2.5 indicates the catchment areas for the campus and with the direction of water flow.

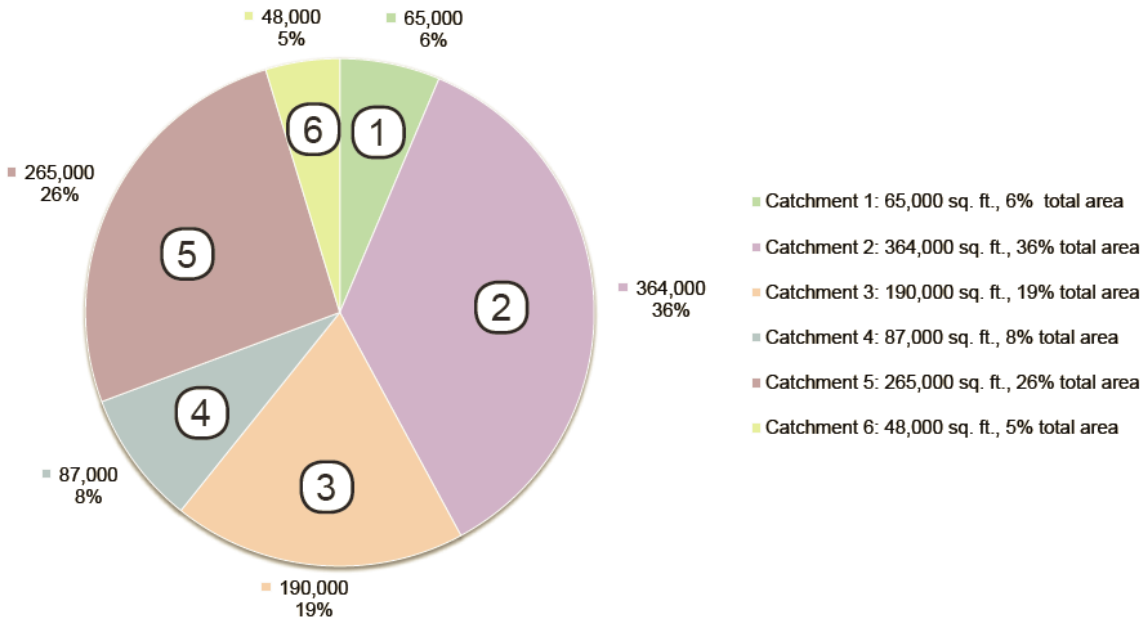
Figure 2.5: Campus Catchments



(Data Source: DC GIS)

Figure 2.6 indicates each catchments acreages and the percent coverage of the total campus acreage. Catchment 2 is the largest and covers 36 percent of the total campus.

Figure 2.6: Catchment Areas



Catchments one, four, and six are primarily dominated by pervious surfaces that drain off-site. Catchments two, three, and five have the highest percentages of impervious surfaces and are also the largest catchments on the campus. Figure 2.7 indicates each catchment with its impervious and pervious cover amounts. Almost half of catchment five is impervious surfaces.

Figure 2.7: Catchment Area Impervious to Pervious Comparison

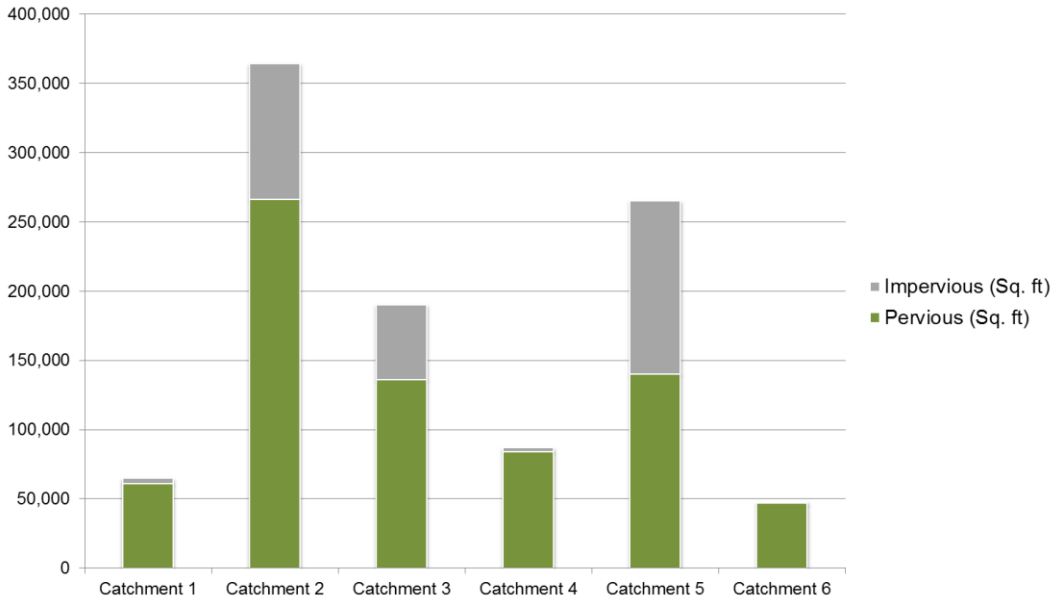
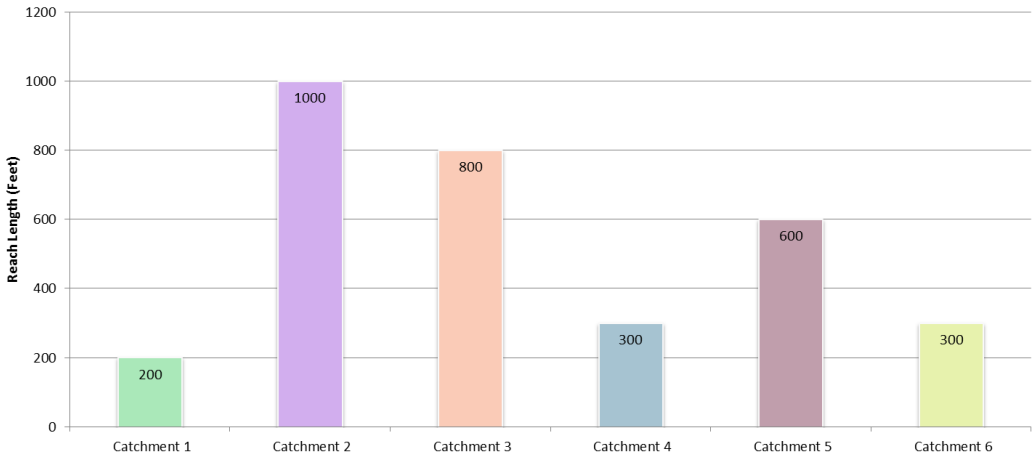


Figure 2.8 illustrates the different reach lengths of each of the catchments. A reach length is the maximum distance for water to travel in a catchment from the highest elevation to the final outfall. The reach length is important to understand the time delay for water to reach the outfall for the catchment area.

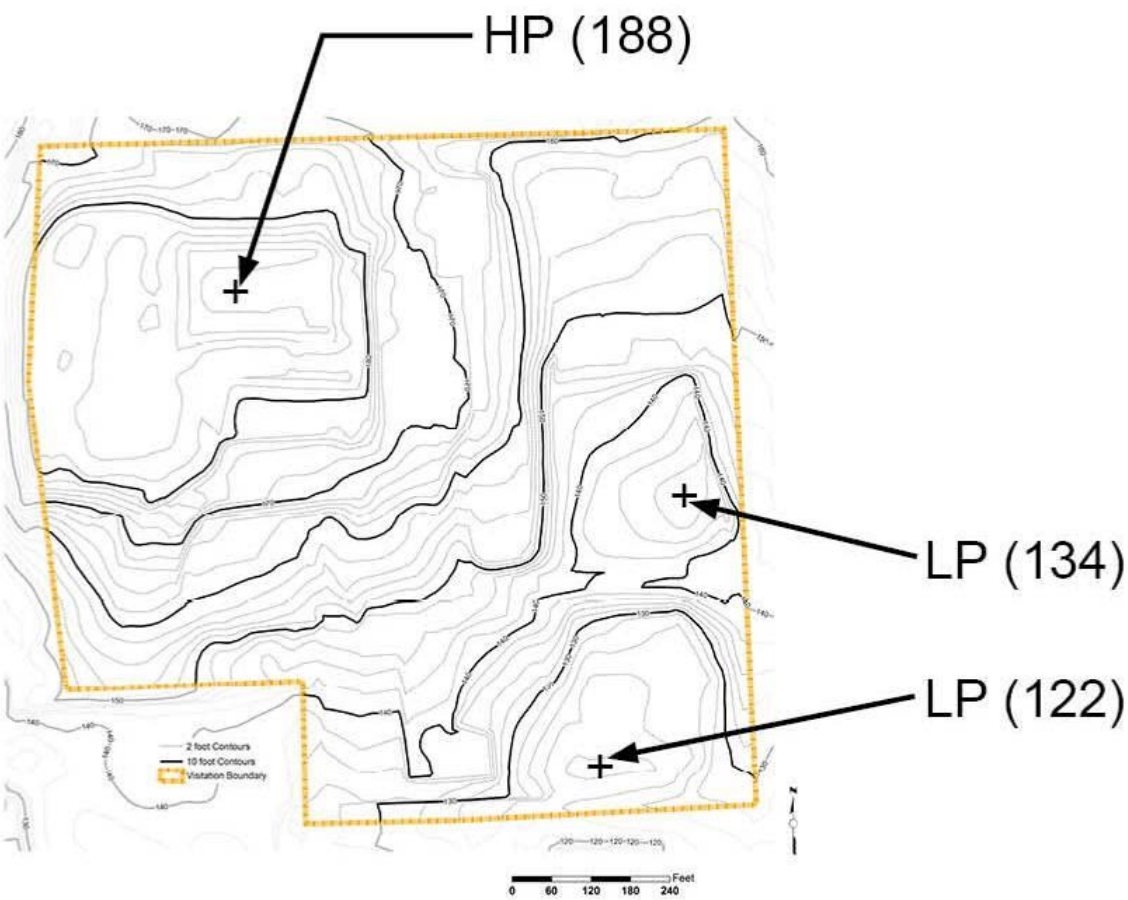
Figure 2.8: Catchment Reach Lengths



Landforms

The tennis courts on the campus are 188 feet above sea level which is the highest point on the campus. The two low points are located in the main entry driveway and also in the Monastery garden. Figure 2.9 indicates the high and low points on the campus.

Figure 2.9: High and Low Points on the Campus



(Data Source: DC GIS)

Calculations were performed with GIS to categorize the campus into three categories to determine slope. Figure 2.10 indicates the extent of three selected slope categories.

Figure 2.10: Slope Map

(Data Source: DC GIS)

A majority of the campus is a moderate slope covering sixty-eight percent of the campus area. There is an equal amount of flat and steep slopes with both occupying sixteen percent of the campus's total area. The flat areas are the playing fields and the parking lots. Figure 2.11 indicates the percentages of the campus with each slope type. Flat slopes are below six percent, moderate slopes are between six and fifteen percent, and steep slopes are greater than fifteen percent.

Figure 2.11: Slope Area Distribution

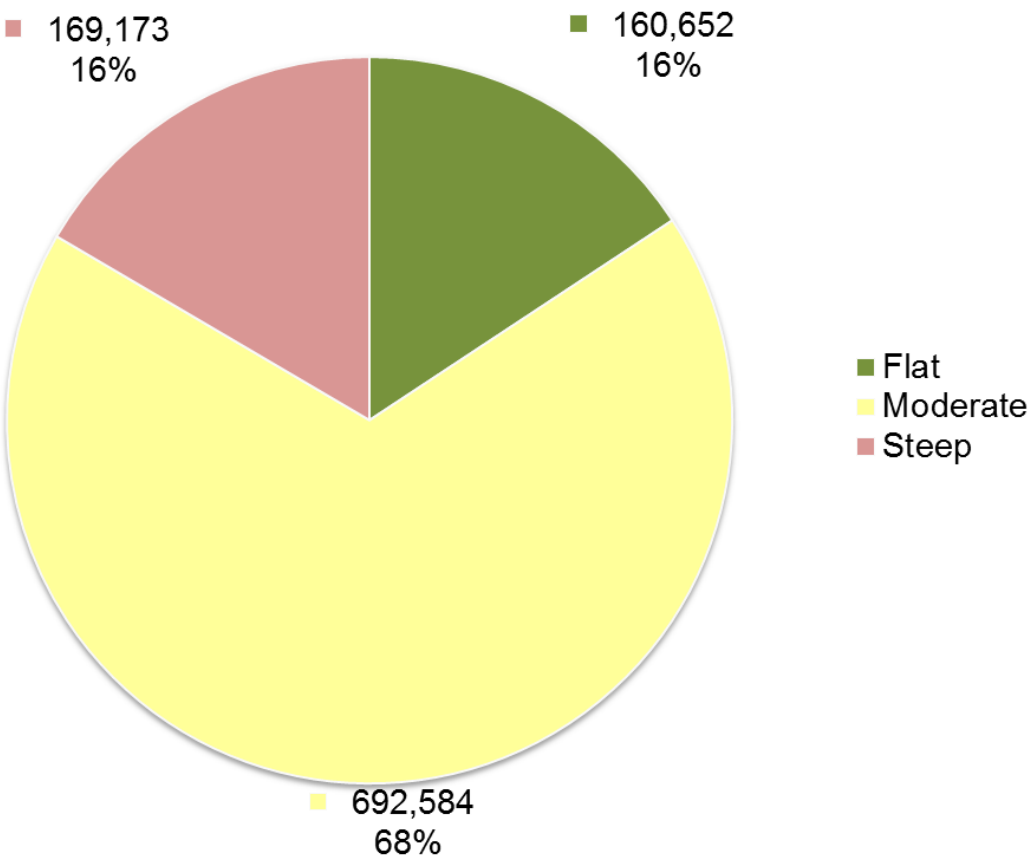
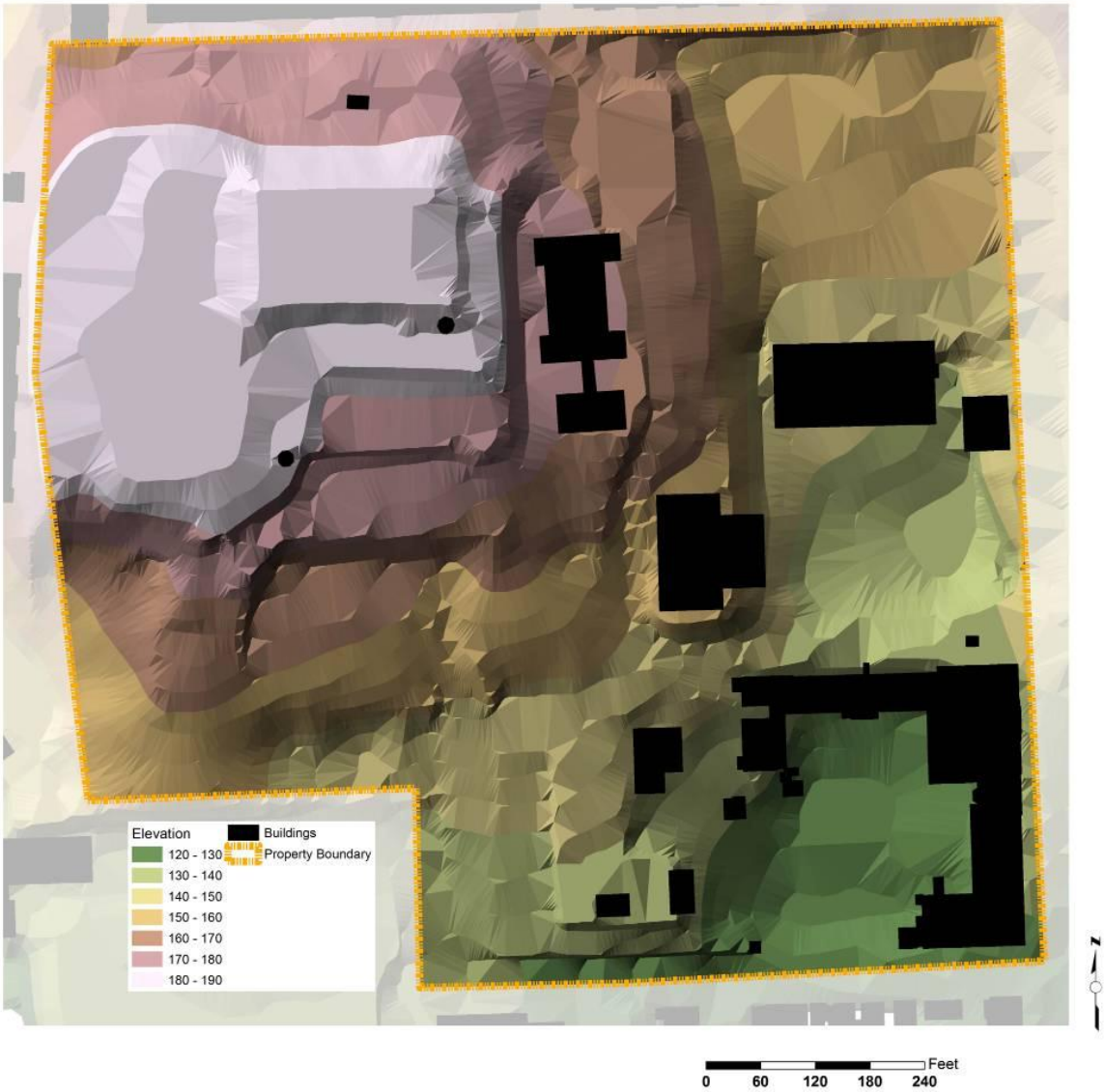


Figure 2.12 indicates the topographic relief on the campus. The overall movement of the rainwater is towards the south east corner of the campus.

Figure 2.12: Relief Map

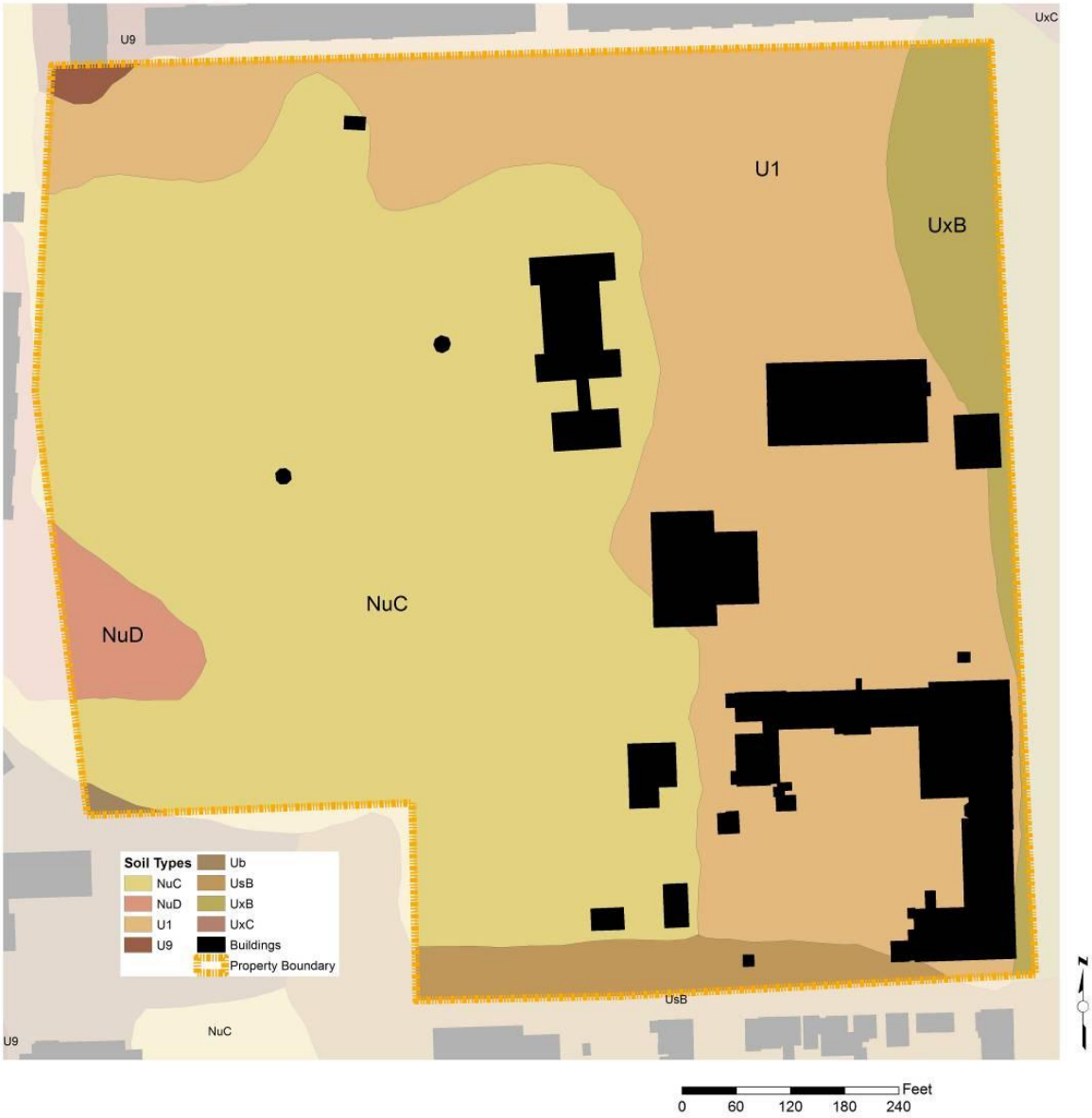


(Data Source: DC GIS)

Soils

The campus has two major soil types on its property; Neshaminy-Urban land complex and Udorthents. Figure 2.13 indicates the locations of the different soil types on the campus.

Figure 2.13: Soil Types



(Data Source: DC GIS)

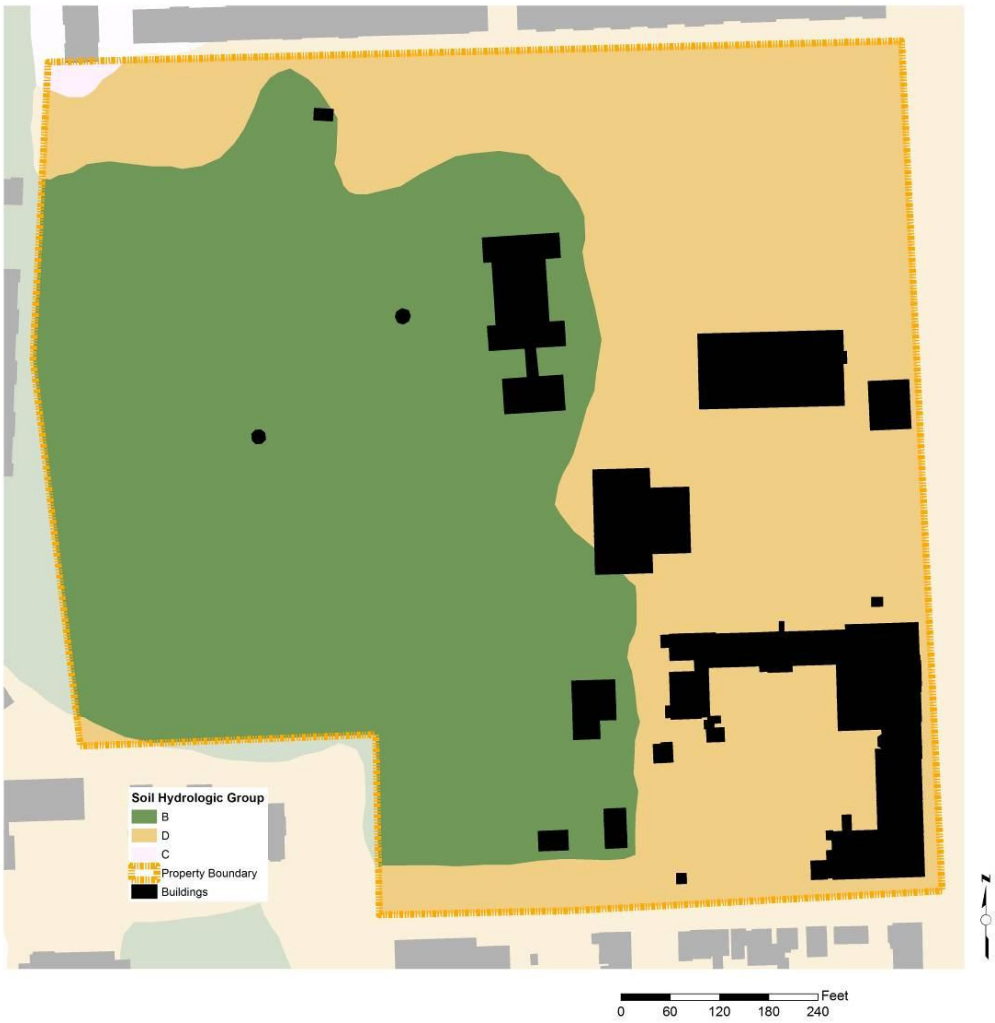
Hydrologic groups were designated by the Natural Resources Conservation Service (NRCS) which are based on measured rainfall, runoff, and infiltration data (USDA NRCS 2007). Details about each hydrologic group are noted in Appendix 5. Table 2.1 lists each of the soil types with their specific name and hydrologic group rating.

Table 2.1: Campus Soils with Hydrologic Group Rating

Map unit symbol	Map unit name	Rating
NuC	Neshaminy-Urban land complex, 8 to 15 percent slopes	B
U1	Udorthents	D
NuD	Neshaminy-Urban land complex, 15 to 40 percent slopes	B
U9	Udorthents, loamy, smoothed	C
Ub	Urban land	D
UsB	Urban land-Manor complex, 0 to 8 percent slopes	D
UsC	Urban land-Manor complex, 8 to 15 percent slopes	D
UxB	Urban land-Sassafras complex, 0 to 8 percent slopes	D
UxC	Urban land-Sassafras complex, 8 to 15 percent slopes	D

The soil types on campus are either under the hydrologic group D or the hydrologic group B rating. A very small piece in the northwest corner is in the C hydrologic group. Figure 2.14 illustrates the locations for each of the hydrologic groups.

Figure 2.14: Soil Hydrologic Groups



(Data Source: DC GIS)

The buildings and parking lots are mostly on the Udorthents soils which have a D rating for the hydrologic group indicating poorly drained soils. This soil typology is often created after construction projects where the naturally formed soils are removed. However, the portion of the campus that is the Neshaminy soils has not been developed with buildings so most of the original hydrology is the same. With the Neshaminy soils, additional construction has been of the two large parking lots and the four tennis courts.

Vegetation

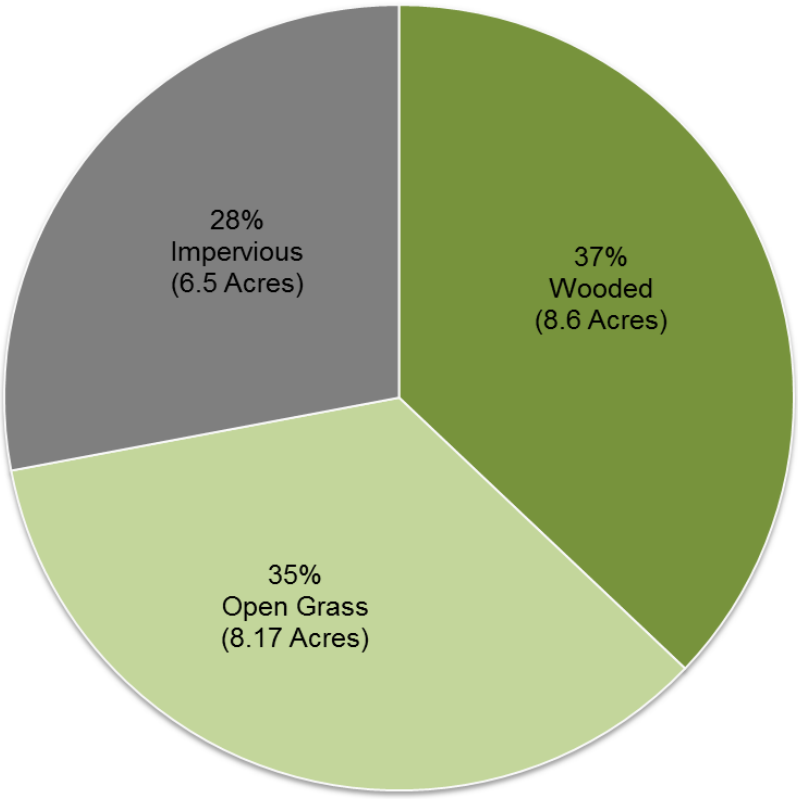
The campus is almost evenly divided between vegetated, impervious paved areas, and open grass. Campus canopy is defined as vegetation that can be viewed from an aerial perspective. Figure 2.15 shows coverage for all the campus vegetation.

Figure 2.15: Vegetation

(Data Source: DC GIS)

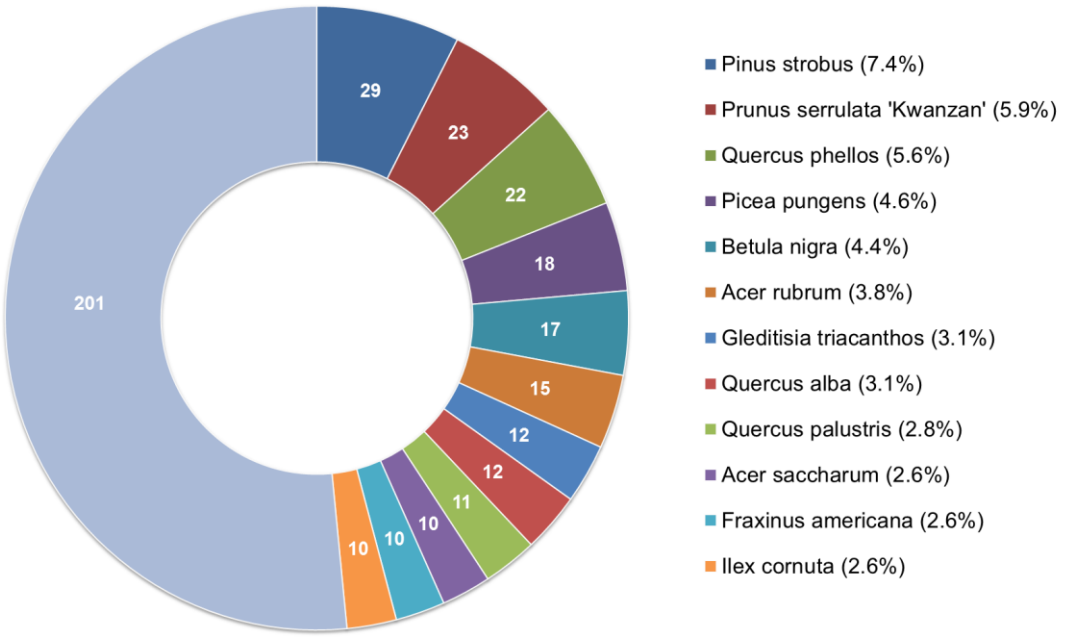
The impervious surfaces include buildings, parking lots, roads, and sidewalks; twenty-eight percent of the campus. Wooded areas account for thirty-seven percent of the campus canopy. Open grass includes all the playing fields and the passive recreation areas; accounting for thirty-five percent of the campus canopy. This is the area outside the tree's drip line. Vegetation over four feet tall or species that will become greater than four feet tall comprises 378,000 square feet (8.6 acres) of the area on the campus. Figure 2.16 illustrates the total campus area and its land types.

Figure 2.16: Canopy Comparison; Impervious, Wooded, and Open Grass



The tree canopy is well cared for except in the area directly north of the cemetery. This area is characterized by a very steep slope and has been left unmanaged to grow more wildly than the remainder of the campus landscape. Most of the vegetative cover under the trees is turf grass, groundcover, or small planted gardens. Beneath the pine trees is a typical pine needle cover. In the forested area, the ground cover is the typical deciduous underbrush with small shrubs and leaf litter. A tree inventory completed in August 2011 identified 390 unique tree species. The highest number of an individual species was 29 specimens of *Pinus strobus* (White Pine). Almost half of the species identified had ten or less specimens on the campus. Figure 2.17 illustrates the actual numerical count and respective percentage for each of the dominant species on the campus.

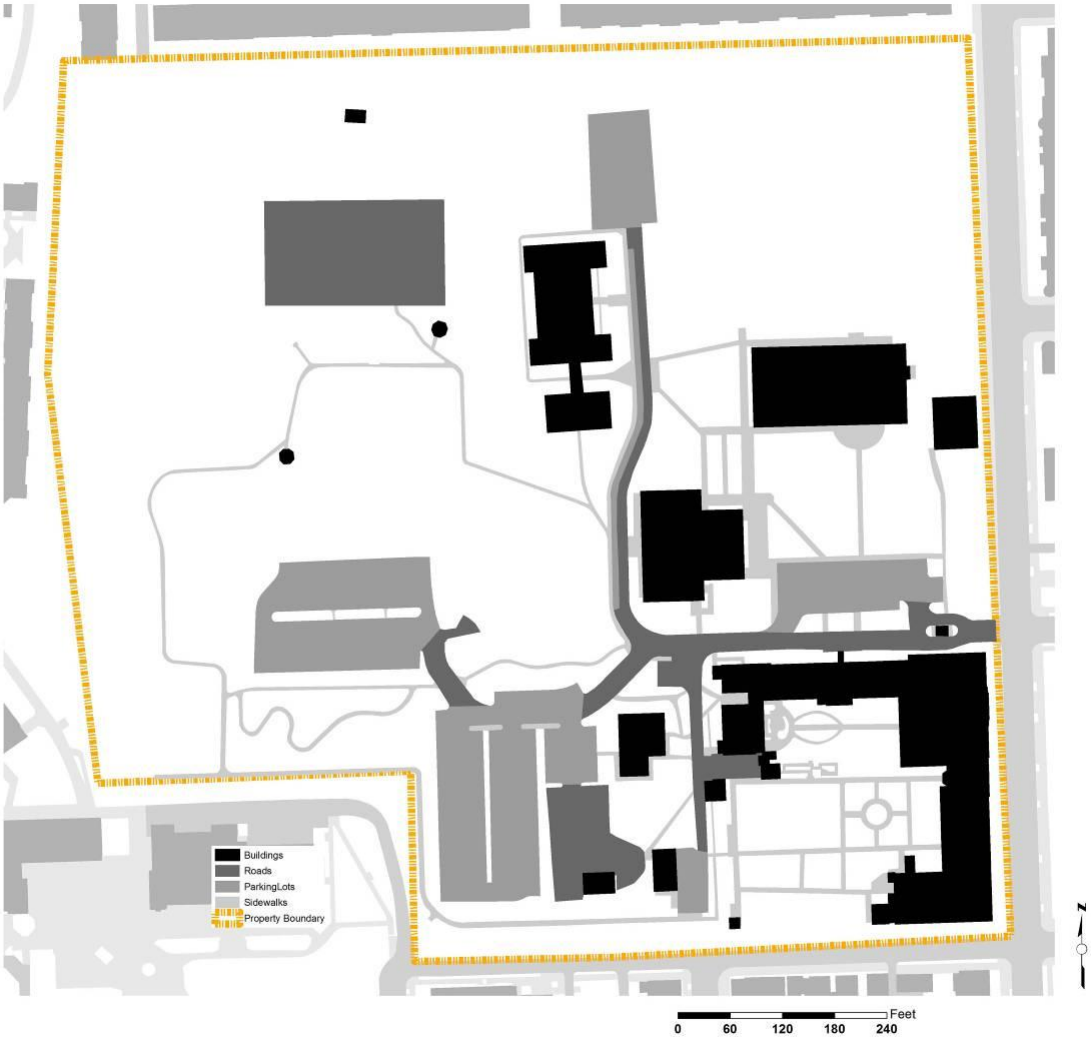
Figure 2.17: Vegetation Species Distribution



Impervious Surfaces

Combining GIS calculations with site visit observations, the campus has 289,000 square feet of impervious surface. The impervious surfaces include buildings, roads, sidewalks, and parking lots. Figure 2.18 indicates the locations of the different types of impervious surfaces.

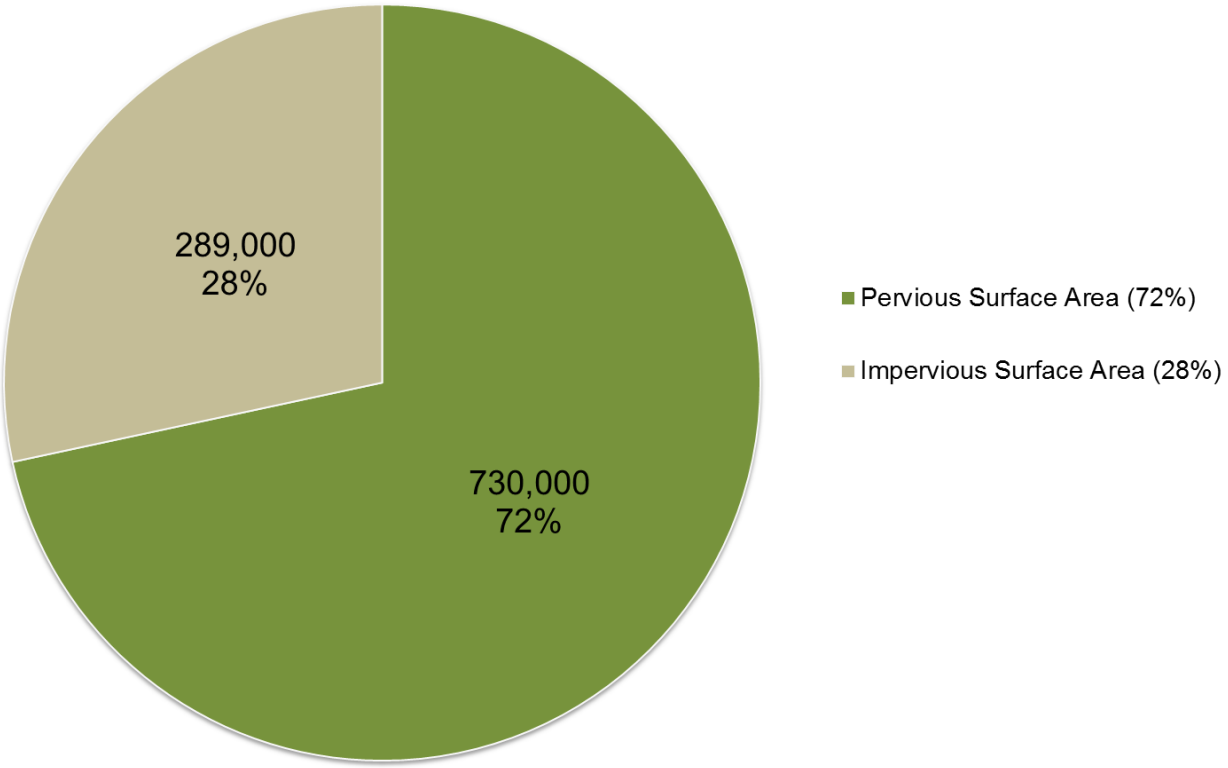
Figure 2.18: Impervious Surfaces



(Data Source: DC GIS)

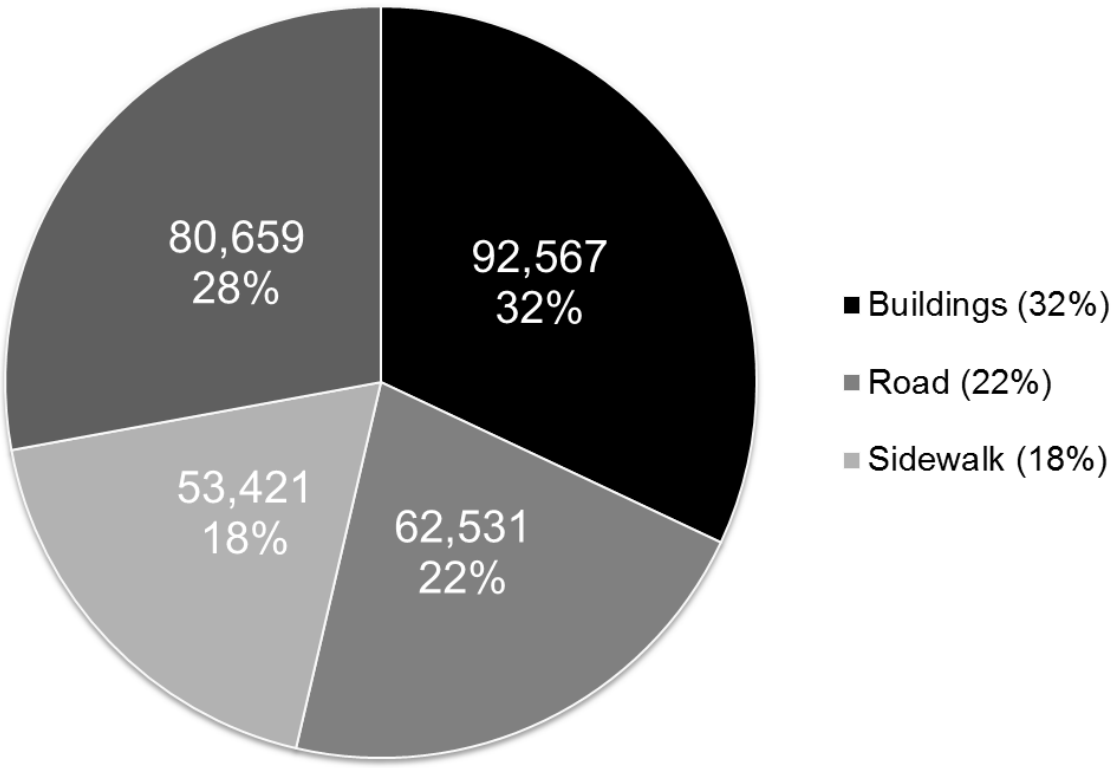
For the entire campus, impervious surfaces cover 28 of the total 22.28 acres (Figure 2.19). The large amounts of pervious surfaces are mostly the sports fields.

Figure 2.19: Pervious and Impervious Surfaces on the Campus



Of the impervious surfaces, buildings comprise 32 percent of the impervious area on the campus. Parking lots are the next largest impervious area. Figure 2.20 illustrates how the total campus impervious surfaces are separated into building, road, sidewalk, and parking lot.

Figure 2.20: Impervious Surface Areas



Of the total campus, the impervious surfaces only cover 28 percent of the campus. However, the quality of the remainder of the campus is mostly turf grass which can have an equal runoff value as the impervious surfaces.

Table 2.2 illustrates that if in the future campus master plan, all roads, sidewalks, and parking lots are converted into pervious surfaces, the monthly fee would reduce from $2,385 per month to $1,526. With the additional 55% reduction offered by DDOE and potential reduction by DC Water, the impervious surface fees could be even further reduced to $386 per month.

Table 2.2: Impervious Surface Fees and Possible Reduction

	Current	Future	Amount Reduced	
Impervious Area	289,000	196,000	93,000	
Monthly Fees	$2,385.22	$859.28	$1,526	
			55% reduced	$386.68

Existing Stormwater Treatment Locations

On this campus, 33 different stormwater treatment locations were identified. They are organized into the following four typologies; downspout, swale, grass area drain, and paved area drain. The exit location of the campus sewer and stormwater pipes into the District's infrastructure is unknown.

Downspouts are on each of the buildings. Exterior downspouts are mostly located on the older buildings. The newer buildings do not have visible downspouts. Most of the visible downspouts are directly piped into the underground system or diverted into a swale of either concrete of grass. For example, downspouts on the Founders Hall are directed into a concrete swale (Figure 2.21).

Figure 2.21: Downspout Example

Most of the swales on the campus are grass. There are several constructed from concrete but they are mostly deteriorating. There are also a few gravel swales that direct the water from a downspout to a grass area drain. For example, the swale located on the eastern border of the campus adjacent to the Monastery Gardens directs the water from the road to a grass drain at the lowest point in the swale where it enters the District's storm sewer system (Figure 2.22).

Figure 2.22: Swale Example

The grass area drains are located mostly in the areas of the campus that are at the lowest elevations. There are five in the entry courtyard alone. These drains are typically one or two foot wide grates. The grass area drain in Figure 2.23 is located in the entry courtyard and drains water from the area immediately surrounding the grate.

Figure 2.23: Grass Area Drain Example

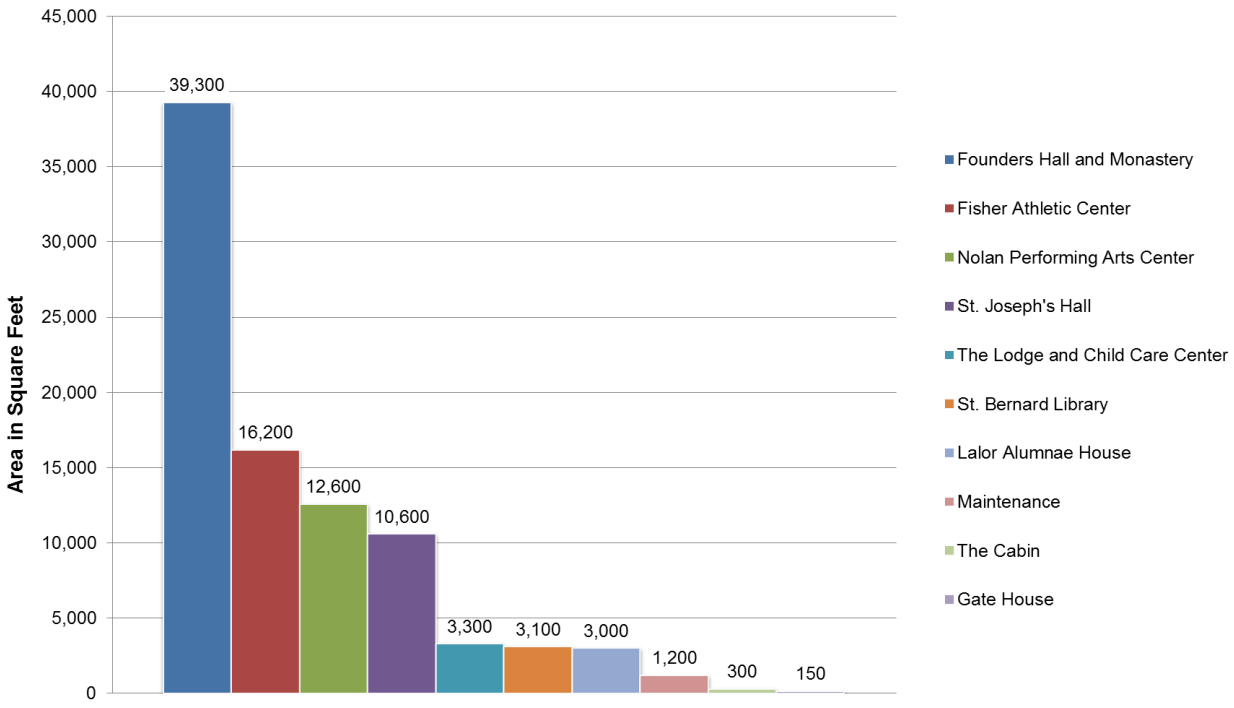
The paved area drains are in the roadways and parking lots. The parking lot drains are large grates and there are a few smaller grates that are in the paved sidewalks of courtyards. Figure 2.24 shows the paved area drain on the southern edge of the South Lot that drains all the water from that parking lot.

Figure 2.24: Paved Area Drain Example

Buildings

The campus has twelve permanent buildings and two open gazebos. The building footprints range from 39,300 square feet of the Founders Hall and Monastery to 150 square feet on the gate house (Figure 2.25). The following sections are a brief explanation of each of the buildings.

Figure 2.25: Building Footprints



Founders Hall

Founders Hall (Figure 2.26) has a 39,300 square foot footprint. This is the main academic building and oldest building on campus dating back to 1873. This building is attached to the monastery on the southern end where students are not allowed to enter. The cafeteria is on the bottom floor which has an exit to the main courtyard in which the students can sit in for lunch. There is no cooking on campus and either the students bring their own lunch or subscribe to the lunch delivery service. Located between Founders Hall and the Monastery is the Chapel of the Sacred Heart which is a quiet place for prayer and reflection.

Figure 2.26: Founders Hall

Monastery

The Monastery (Figure 2.27) is attached to Founders Hall. The Sisters of the Visitation live in this building. Their daily activities include daily prayers and walks around the gardens and campus paths. The Monastery has its own kitchen and chapel for the Sister's nine daily prayers.

Figure 2.27: Monastery

St. Joseph's Hall

St. Joseph's Hall (Figure 2.28) has a 10,600 square foot footprint. This is the academic building for the science, math, art, and history departments. The western portion of the roof has some flat areas that would be ideal for a green roof, but since the building is older, it may not support any additional weight on the roof. This building was renovated in 2004.

Figure 2.28: St. Joseph's Hall

Fisher Athletic Center

The Fisher Athletic Center (Figure 2.29) has a 16,200 square foot footprint. This building houses all the major indoor sports and is used as classroom space for freshmen and sophomore physical education classes which are held twice a week. The building is also used for health classes for the other grades. The most usage occurs after school and during the summer for sport summer camps. This roof is entirely a flat roof which could support a green roof. This building was dedicated in 1998.

Figure 2.29: Fisher Athletic Center

Nolan Performing Arts Center

The Nolan Performing Arts Center (Figure 2.30) has a 12,600 square foot footprint. This is used for performances and Mass is held in the main auditorium on Catholic holidays. The building includes reception rooms, a dance studio, rehearsal space, and a stage. It was created through renovating the school's original gymnasium. A portion of the roof is flat which could support a green roof. This building was also dedicated in 1998.

Figure 2.30: Nolan Performing Arts Center

The Lodge

The Lodge (Figure 2.31) has a 3,300 square foot footprint. This is the location of all the senior lockers and a gathering area during their free period or after school.

Figure 2.31: The Lodge

Child Care Center

The Child Care Center (Figure 2.32) is part of the Lodge building. This program is for children of faculty and other children from the community. It is attached to the Lodge with an outdoor play area.

Figure 2.32: Child Care Center

St. Bernard Library

St. Bernard Library (Figure 2.33) has a 3,100 square foot footprint. This library has computers the students can use during their free period or after school. This building is attached to St. Joseph's Hall by a covered breezeway. One hundred years ago, St. Bernard's Library was home to the Monastery's cows. It became a library in 1958 and was renovated in 2003 with the latest technologies.

Figure 2.33: St. Bernard Library

Lalor Alumnae House

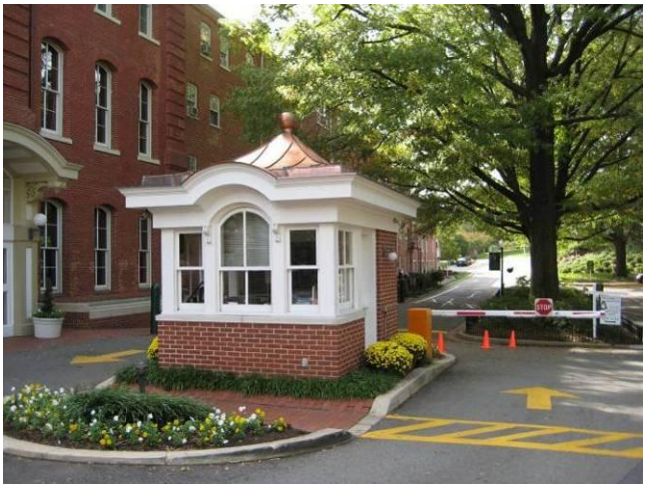
The Lalor Alumnae House (Figure 2.34) has a 3,000 square foot footprint. This building is used for the Development Office and Alumni Affairs. This building holds small receptions, but most of the formal events held indoors are in the Main Parlors of the Academy Building.

Figure 2.34: Lalor Alumnae House

The Gate House

The Gate House (Figure 2.35) has a 150 square foot footprint. The campus is guarded all day and night and throughout the year because the campus is also a home to the sisters who live in the Monastery.

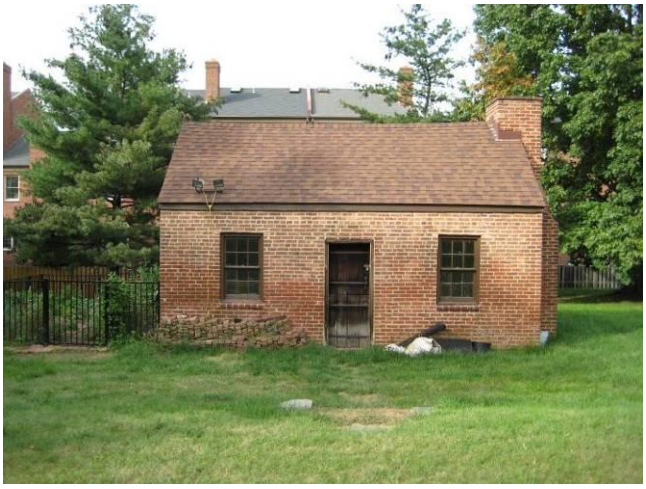
Figure 2.35: The Gate House



The Cabin

The Cabin (Figure 2.36) has a 300 square foot footprint. The building is used for some maintenance storage and also is surrounded by a small vegetable garden.

Figure 2.36: The Cabin



Maintenance

The Maintenance building (Figure 2.37) has a 1,200 square foot footprint. There are 2 maintenance buildings; this is the larger of the two.

Figure 2.37: Maintenance

West Gazebo

The West Gazebo (Figure 2.38) has a 250 square foot footprint. This has a table with chairs and seating for approximately ten people. The foundation is concrete with a raised step.

Figure 2.38: West Gazebo

East Gazebo

The East Gazebo (Figure 2.39) has a 230 square foot footprint. This has a moveable table with chairs with seating for approximately 5 people. The foundation is concrete and level to the ground.

Figure 2.39: East Gazebo

Parking

There are 275 parking spaces on the campus. The total area of the parking is 80,659 square feet (1.8 acres). Figure 2.40 illustrates the comparison between the number of spaces and Figure 2.41 compares the area footprint of each parking lot.

Figure 2.40: Number of Parking Spaces in Campus Parking Lots

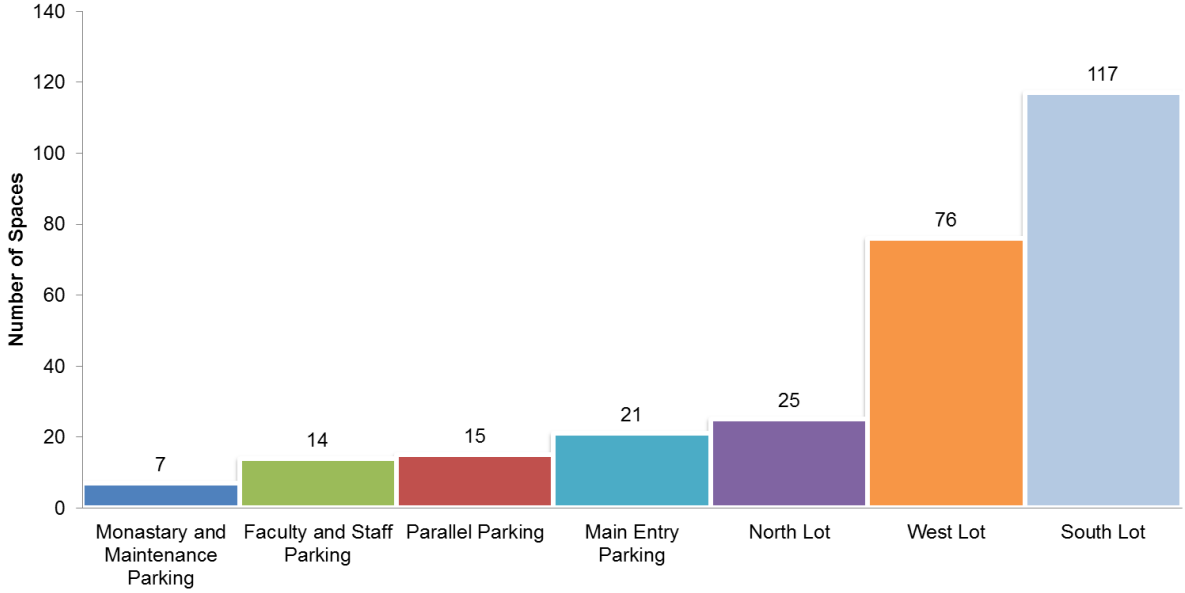
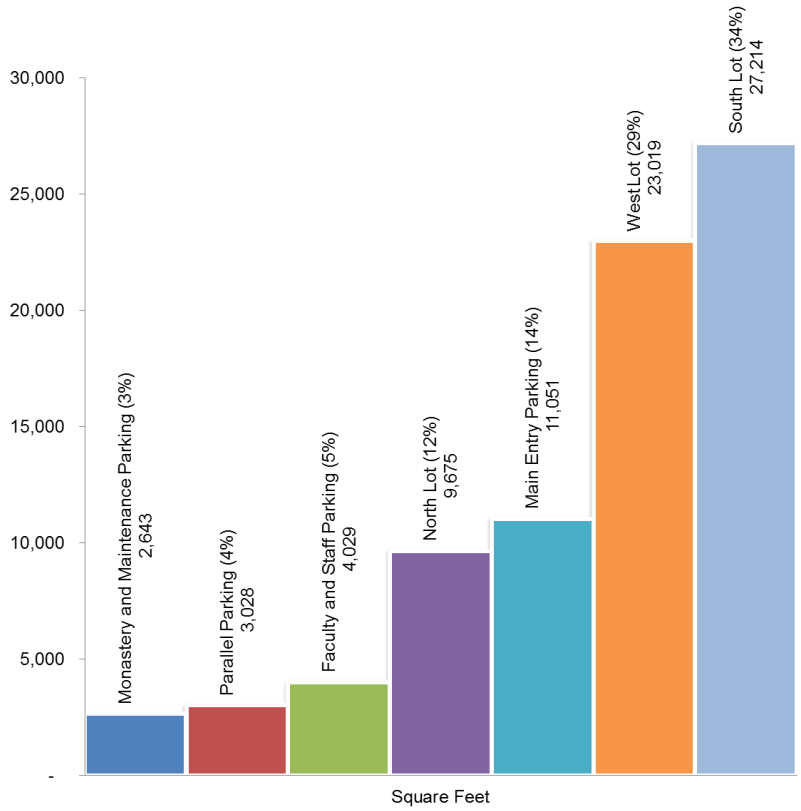


Figure 2.41: Parking Lot Areas



Events on the campus that include all four grades would potentially result in 480 vehicles on the campus. The Christmas Gala also includes neighborhood guests which could result in more vehicles. Sport events also include a large amount of parking need with the other team's transportation. There is some parking possible in the neighborhood streets, but that is not openly advertised. Parking is very restricted in the surrounding neighborhood. A carpool parking discount on parking exists for the students, but carpooling laws prohibit drivers from having too many passengers. Approximately half of the student population has a sibling on campus so most of the carpooling is with family. The following sections are brief descriptions of each of the parking areas.

Main Entry Parking

The Main Entry Parking (Figure 2.42) has 21 parking spaces and covers 11,051 square feet. The main use for this parking area is the three lane drop off and pick up area that parents use in the morning and afternoon. The three lanes are fully used during drop off and pick up times. Most of the students travel to campus via carpool by parents or siblings. Some students use the public transportation system and enter campus through this gate. The parking has handicap and visitor parking spaces. This lot is the main entry driveway to the campus with the guard house at the entry drive. The asphalt is bounded with concrete curbs and is in fair condition. There is a large stormwater drain in the second lane of the drop off and pick up area. A sidewalk runs through the lot that connects Founders Hall and the Fisher Athletic Center.

Figure 2.42: Main Entry Parking

Monastery and Maintenance Parking

The Monastery and Maintenance Parking (Figure 2.43) has 7 parking spaces and covers 2,643 square feet. There are two covered parking spaces reserved 24 hours for the Monastery. Farther down the driveway is unmarked parking for the maintenance vehicles. The asphalt is in fair condition and the water runs into a concrete swale away from the building.

Figure 2.43: Monastery and Maintenance Parking

Faculty and Staff Parking

The Faculty and Staff Parking lot (Figure 2.44) has 14 parking spaces and covers 4,029 square feet. The southern portion of the lot is for maintenance and dumpsters are behind the wooden.

Figure 2.44: Faculty and Staff Parking

South Lot

The South Lot (Figure 2.45) has 117 parking spaces and covers 27,214 square feet. This is the main student lot which holds the largest amount of vehicles. There is a center median that has a curb cut on the lowest piece, but there is no inlet so the only water that immediately falls in the median. All the water drains to the south border of the lot where a large inlet is located.

Figure 2.45: South Lot

West Lot

The West Lot (Figure 2.46) has 76 parking spaces and covers 23,019 square feet. This is the second student parking lot. During the day, the students rarely return to their cars so the lot is only used for parking and then walking into the main building. The lot is used during the summer for a drop off area for the summer camps. This parking lot is mostly curbed, but the east and west sides have an open section. A center median has a concrete diverter for water to pass through, but there are no other water uses for the median. The trees planted will become significant shade trees in the next fifteen years. The north border is a steep hill which has been converted to an unmown grass hill.

Figure 2.46: West Lot

Parallel Parking

The parallel parking spaces (Figure 2.47) are along the road that leads up to the St. Bernard Library and St. Joseph's Hall. The spaces are surrounded by curbs and a sidewalk. There are fifteen parking spaces which cover 3,028 square feet.

Figure 2.47: Parallel Parking

North Lot

The North Lot (Figure 2.48) has 25 parking spaces and covers 9,675 square feet. This is the most secluded parking lot on the campus. It is used by maintenance for storage and during the school days for teachers. The northwest corner has a gravel driveway leading farther into the campus grounds. This lot is used during sport events for team bus parking. The lot has curbs on one side, but none on the other. The center has an area drain. The high amounts of gravel and sand would indicate that water slows here and the lot is not used as frequently as other lots on campus.

Figure 2.48: North Lot

Campus Use

This campus is unique from many other high schools because it is primarily the home for the Monastery. The Sisters of the Visitation own the land and school buildings. Due to the school being the guest on the site, they are restricted from growth past the 480 young women currently enrolled. This means that there will be no additional major construction. The buildings have been and will be renovated, but no additional footprint will be added. This is also a campus that has a very unique history which adds special locations on the campus that is restricted for further construction. The campus identity is very important for their unity.

The campus usage maps were created from the student perspective and show how the students and teachers use the campus. The monastery garden is used daily by the sisters, but it is private for the sisters only. Students may go into the garden but only with prior permission. The use intensity is classified on a daily, weekly, and monthly use frequency. These were determined by site observations and understanding of the campus events. The monastery has its own uses and intensity, but for this proposal the monastery was seen as out of the project scope.

Open Space

The open space is classified into active, passive, and conservation areas (Figure 2.49). The active areas are primarily for athletics, but the outdoor child care play space is also very active. The passive areas are mostly open fields where special events are held. These events include the yearly marshmallow roast which is a tradition for all the students to participate. The summer camps also use these areas for gathering during the summer. The remaining open spaces that are not used for sports or open grass are garden areas with low-growing plants. The conservation areas are the forested areas. This includes the very thick forest by the cemetery and the secluded areas at the north end of the campus. The conservation areas are most significantly areas on the campus that are not to be disturbed and if impacted, should be improved.

Figure 2.49: Open Space Diagram

The highest uses are on the athletic fields because they are used heavily for sports. Almost all of the students participate in some team sport (Figure 2.50). The other areas of daily use are immediately adjacent to the academic buildings or the main entrance. The forested areas farthest from the main buildings are used less frequently.

Figure 2.50: Open Space Use Intensity Diagram

Buildings

The buildings are in the categories of teaching, administration, maintenance, religious, iconic, and separately, the student lounge (Figure 2.51). Founders Hall is the building with the most types of uses as it has administration and teaching, and also the iconic street front that was with the original construction of the school in 1799.

Figure 2.51: Building Use Diagram

With having so few buildings on the campus, they are all used with a daily frequency (Figure 2.52). The buildings used least are The Cabin and The Lalor Alumnae House. The maintenance building is used in higher frequency during the growing season. It is

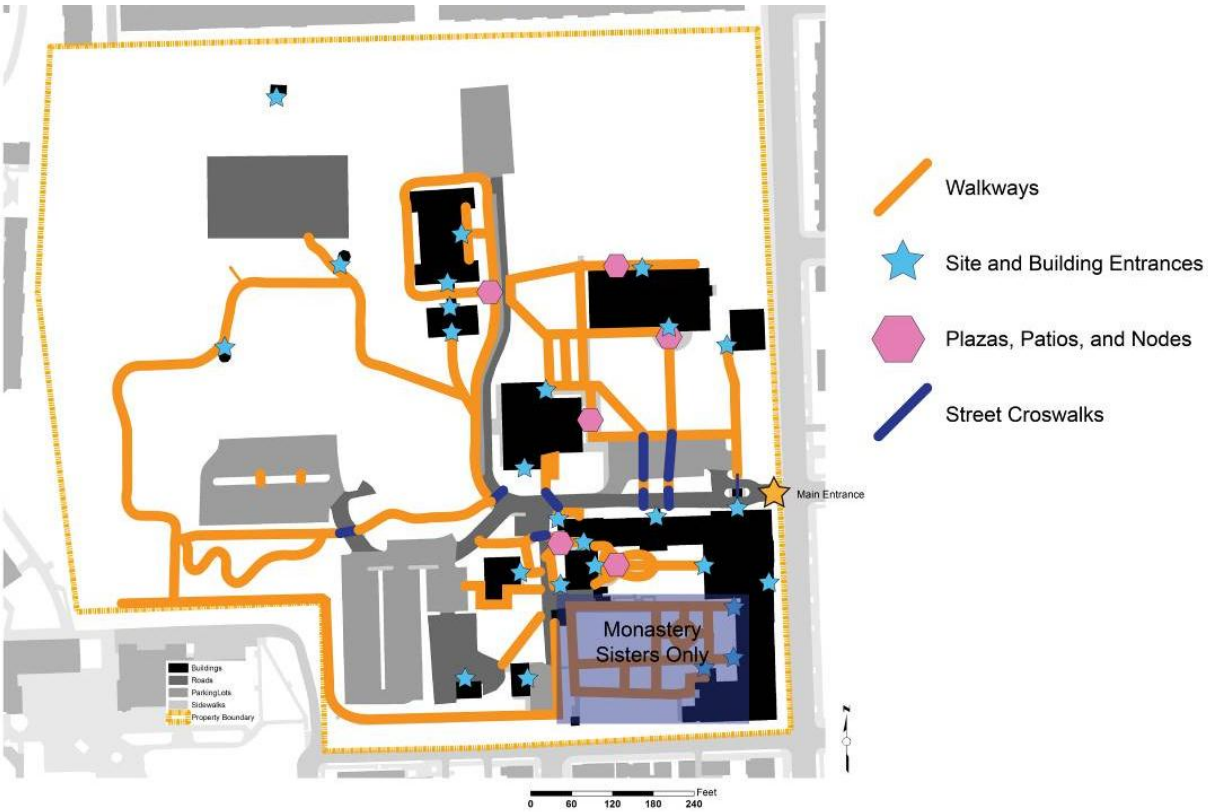
primarily the grounds immediately around the maintenance building that are used the most because that is where the trucks and other tools are stored.

Figure 2.52: Building Use Intensity Diagram

Pedestrian Circulation

The campus has a very extensive pedestrian circulation system since the academic buildings are separated (Figure 2.53). Walking paths are also important to the monastery sisters to go for walks during the day. The elements identified on the diagram are the walkways, site and building entrances, plazas, patios, and crosswalks.

Figure 2.53: Pedestrian Circulation Use Diagram



The use intensity for the pedestrian circulation is very high around the academic buildings (Figure 2.54). The least traveled pathways are farther from the buildings and athletic fields. The least used paths are used by the monastery sisters.

Figure 2.54: Pedestrian Circulation Use Intensity Diagram

Vehicle Circulation

The vehicle circulation has the main purpose to get into the campus and to a parking lot (Figure 2.55). The roadways are indicated in orange on the diagram. The elements identified on the diagram are streets, site entrances, passenger drop-off zones, parking areas, and service areas.

Figure 2.55: Vehicle Circulation Use Diagram

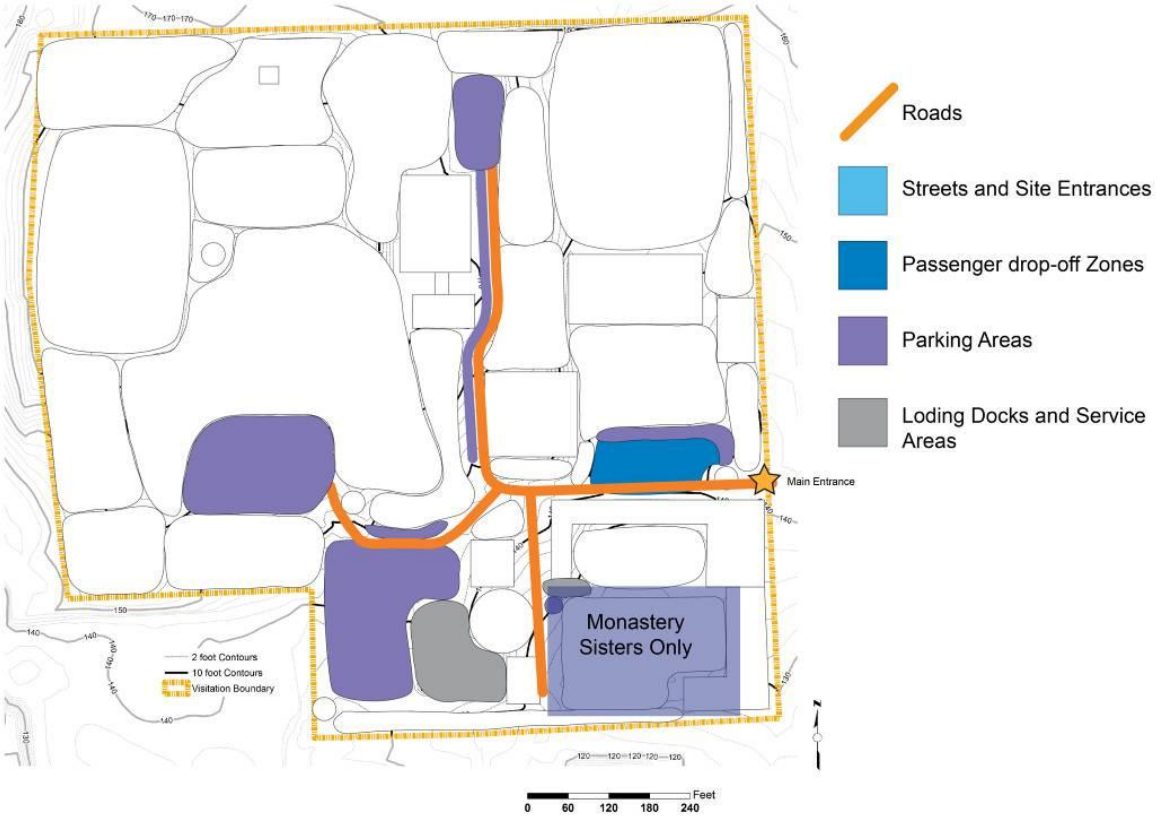


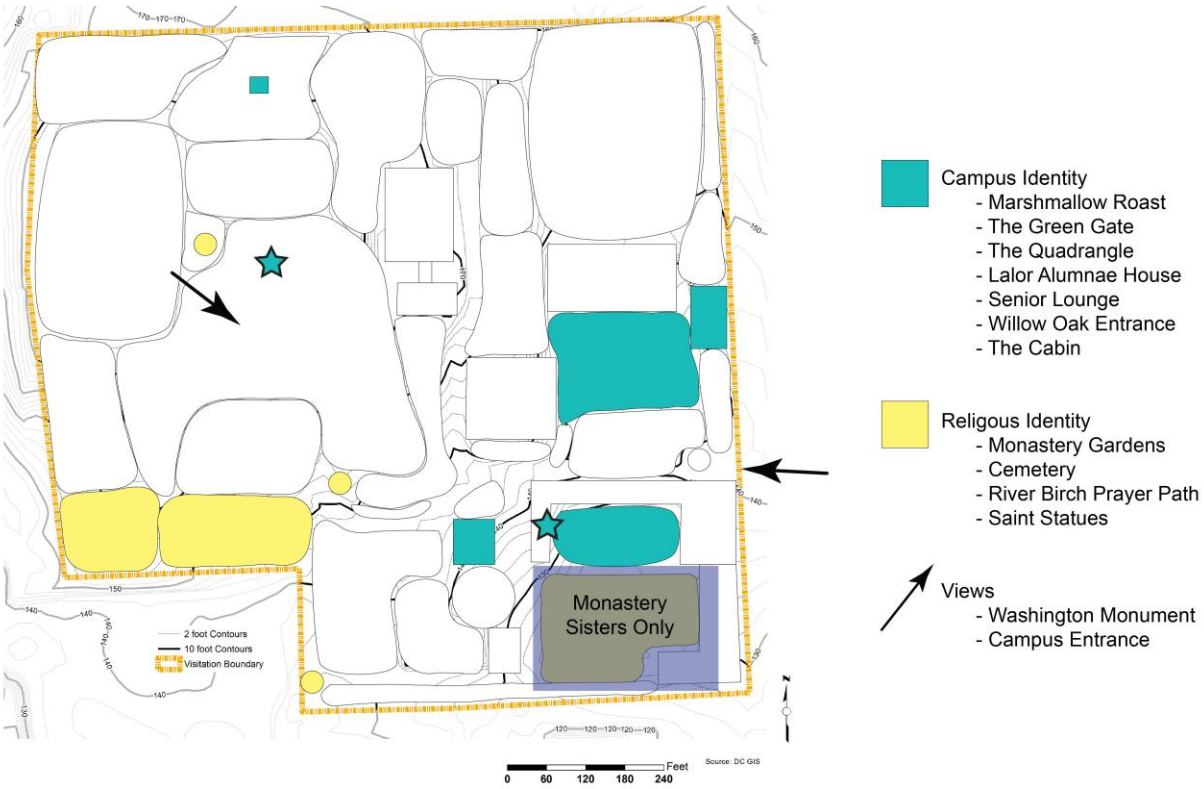
Figure 2.56 illustrates the use intensity of the vehicle circulation on the campus. The roads used daily are between the main entrance and the parking lots. The road that goes north is used less than the main entrance road because the parking lot at the end is much smaller than the other parking lots. This road has parallel parking which is used daily. The main entry parking area is used daily with the drop off and pick up times since there is no bus that will pick up the students.

Figure 2.56: Vehicle Circulation Use Intensity Diagram

Campus Identity

Several locations on the campus are unique for this campus alone (Figure 2.57). The elements have historical or religious significance. This includes the Green Gate, Quadrangle, Willow Oak Grove, Cabin and Lodge. The religious identity is mostly shown through various statues around the campus. Another unique element of this campus is its view to the Washington Monument.

Figure 2.57: Campus Identity Diagram



The Green Gate

The Green Gate (Figure 2.58) was once used as the locked door for the campus. The Gate is especially significant during the graduation ceremony when the seniors walk through the gate as an important rite of passage.

Figure 2.58: The Green Gate

The Quadrangle

Students use this space to sit and eat lunch during the fall and spring months. Figure 2.59 is the view of the Quadrangle from Founders Hall. This area of campus is used for picnics, welcome events, and father's club picnics.

Figure 2.59: The Quadrangle

The Willow Oak grove

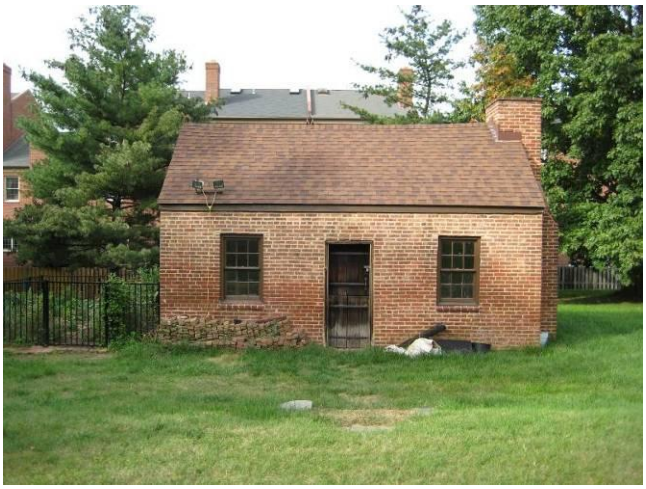
This Willow Oak grove is over the main entry drive and creates a very welcoming environment for new guests (Figure 2.60). Its shade is also ideal during the pick-up and drop off times.

Figure 2.60: Willow Oak Grove

The Cabin

The building has been on the campus as one of the original buildings (Figure 2.61).

Figure 2.61 The Cabin



The Lodge

This is the location of all the senior lockers and a gathering area for them during their free period or after school (Figure 2.62).

Figure 2.62: The Lodge

Religious Identity

Several statues are on the campus with small flower beds surrounding their bases. There is also a cemetery on the west side of the campus where the sisters are buried. It is about three-tenths of an acre. Next to the cemetery is a curvilinear prayer path surrounded by river birch trees. The Monastery has gardens lovingly tended by the sisters. The gardens are not open to the students or public without permission. This garden has wonderful tree specimens which have been carefully tended over the past 200 years.

Statues

All of the statues on the campus are of various religious figures. They are interspersed throughout the campus. Figure 2.63 is the statue by the tennis courts near the high point on the campus. Figure 2.64 is the statue north of the South Parking Lot. Figure 2.65 is the statue by the South Parking Lot. Figure 2.66 is the statue in the cemetery. Lastly, Figure 2.67 is the statue in the entry willow oak courtyard.

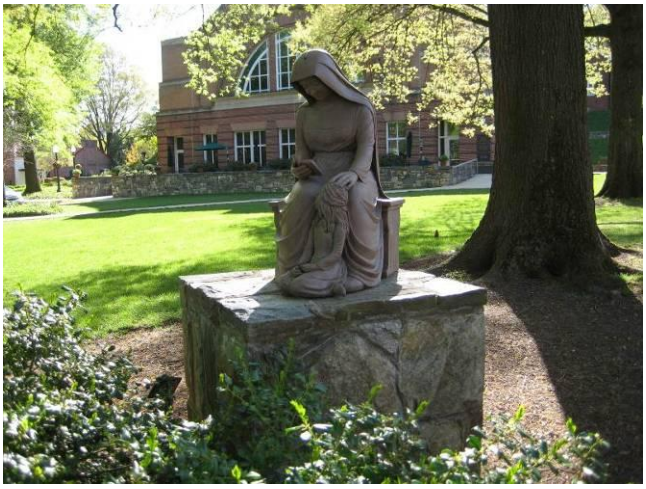
Figure 2.63: Statue by the Tennis Courts

Figure 2.64: Statue North of the South Parking Lot

Figure 2.65: Statue by the South Parking Lot

Figure 2.66: Statue in Cemetery

Figure 2.67: Statue in Entry Willow Oak Courtyard



Cemetery

The cemetery (Figure 2.68) is for the sisters who have passed away during the time the campus has been established. This area is very secluded and is a quiet place for reflection.

Figure 2.68: Cemetery

The river birch prayer path (Figure 2.69) is a recent addition to the campus. Throughout the path are small plaques to read during prayer.

Figure 2.69: River Birch Prayer Path

The monastery gardens (Figure 2.70) are tended by the sisters of the monastery and has a wide variety of plants. The garden is not open for the students to enter, but they can if

granted permission by the sisters. This is the section of the campus that has some of the oldest trees on the campus.

Figure 2.70: Monastery Gardens

Views

The Washington Monument is visible from the tennis court area (Figure 2.71).

Figure 2.71: View to the Washington Monument

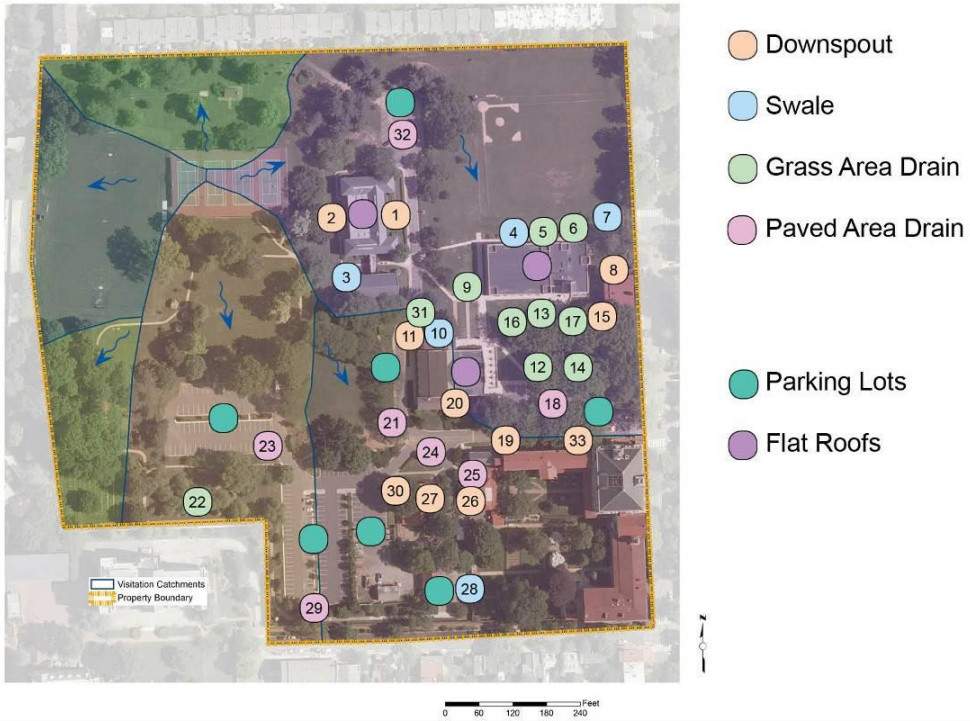
Figure 2.72 is the view into the campus and is the only entrance to the campus. The entrance is guarded by a gate house year-round.

Figure 2.72: View into the Campus

Chapter 3: Template Site Selection for Design

The redesign of all thirty three stormwater features identified on campus (Figure 3.1) is beyond the scope of this thesis. Thus, all stormwater features were organized into four typologies. These four treatment typologies are 1) downspouts, 2) swales, 3) grass area drains, and 4) paved area drains. The objective was to select four locations to serve as a template for the four stormwater landscape typologies. Each represents an example for each of the existing stormwater treatment typologies (downspout, swale, grass area drain, and paved area drain). The three criteria used for selecting the final four locations to be re-designed were site intensity of use, area to disturb, and water catchment area.

Figure 3.1: Treatment Site Locations

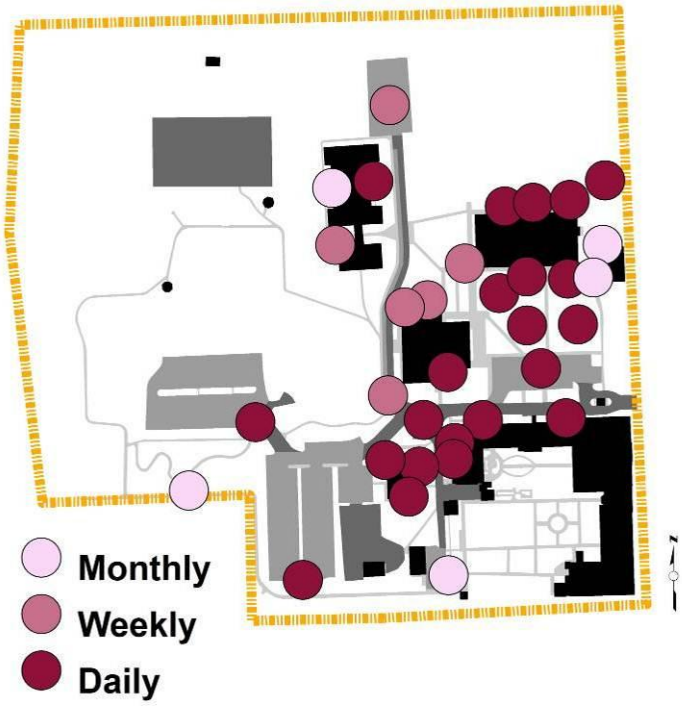


(Data Source: DC GIS, ESRI Basemap)

Site Intensity of Use

Site intensity of use is the frequency a site is used or the number of people that would pass a given site. The usage types analyzed for intensity of use was open space, pedestrian circulation, vehicle circulation, and building use. These different uses were then scored based on a daily, weekly or monthly frequency of use. The total was calculated by averaging all the intensity maps together. High visibility is the most desirable for site selection so daily use was scored a three, weekly use was scored a two and monthly use was scored a one. Figure 3.2 illustrates the site intensity of use with their corresponding sites.

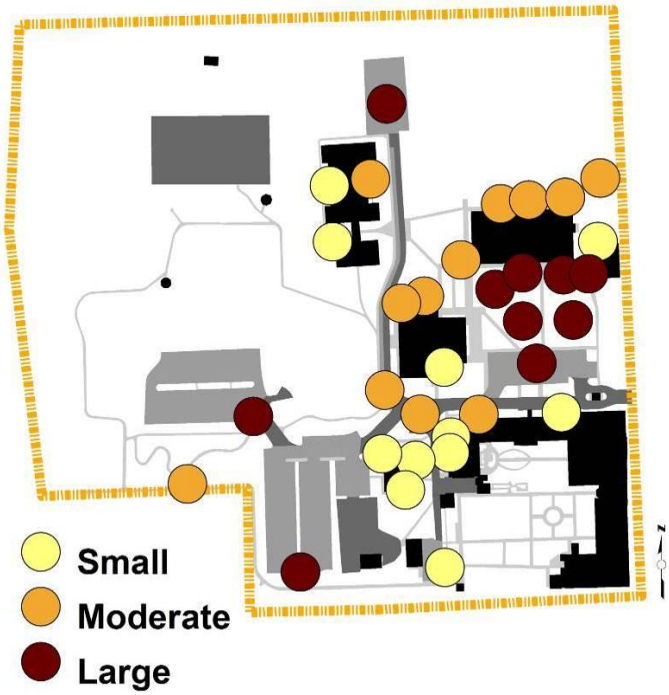
Figure 3.2: Site Intensity of Use



Area to Disturb

Disturbance area is the immediate vicinity that could be used in redesigning the area. For example, the area for a grass area drain location would be the catchment area for that particular site given the topography. All of the sites were ranked in relationship to each other. The larger areas are the most desirable for site selection. Rank one to eleven scored a one and represented the area between 600 and 2,000 square feet. Rank twelve to twenty two scored a two and represented the area between 3,000 and 7,000 square feet. Rank twenty three through thirty three scored a three and represented the area between 9,000 and 25,000 square feet. Figure 3.3 illustrates the area of disturbance possible with their corresponding sites.

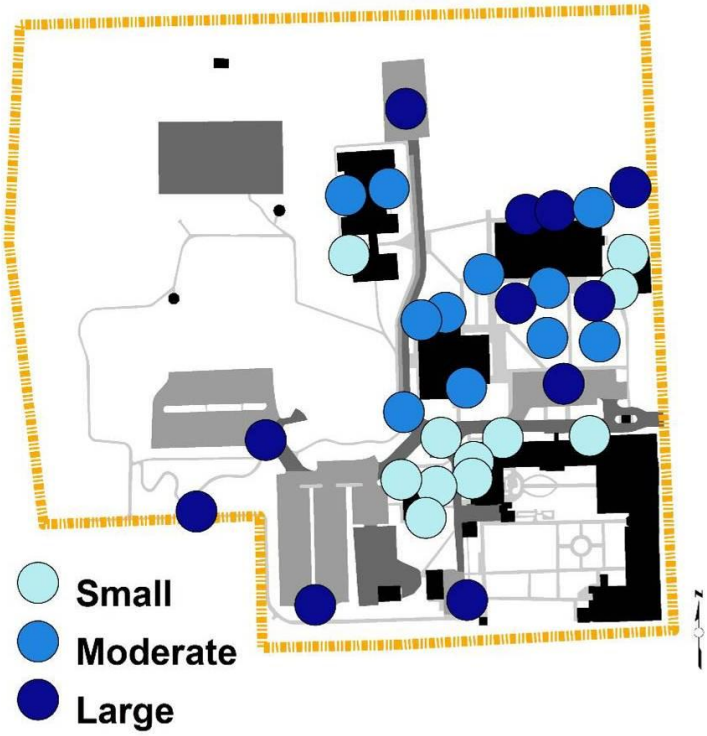
Figure 3.3: Area to Disturb



Catchment Area

This was calculated by using the catchments of water that could enter the site. Sites with larger volumes are the most desirable for the final site selection. Since the sites were ranked in relationship to each other, the catchment area was determined by area and not exact volume. The larger areas are the most desirable for site selection. Rank one to eleven scored a one and represented the area between 600 and 2,000 square feet. Rank twelve to twenty two scored a two and represented the area between 3,000 and 7,000 square feet. Rank twenty three through thirty three scored a three and represented the area between 9,000 and 25,000 square feet. Figure 3.4 illustrates catchment area sizes with their corresponding sites.

Figure 3.4: Catchment Area



Selection Matrix

The main obejecive of the site analysis was to select, from the four typologies of existing stormwater treatment, four sites to serve as templates of better stormwater management and adding educational opportunities. These four templates are intened to serve as models for the four catergoies that were indentified in the analyisis phase of the design project. These categories are 1) downspouts, 2) grass area drains, 3) paved area drains, and 4) swales. The criteria used to determine the four template sites were by the intensity of use, area to disturb, and catchment area. Each of the sites was scored in order to select the location that will be designed for the example of how to treat a downspout, grass area drain, paved area drain, and swale.

The sites selected for the templates were Site 19 and 26 combined for the downspout, Site 17 for the grass area drain, Site 23 for the paved area drain, and Site 7 for the swale. Site 19 and 23 were combined because the water volumes to be treated could be rerouted into one area. Site 17 was selected for the grass area drain because it is less obtrusive to the iconic willow oak grove space and more secluded from the main entry. Site 23 was selected for the paved area drain because it had the largest catchment area and had an additional opportunity for treating the adjacent water from the fields. Site 7 was selected for the swale because it had the highest score which gave it the highest visibility, catchment area, and disturbance area. Table 3.5 indicates the final scores for each of the sites and the final selection comments if there were two sites with the same score.

Table 3.5: Site Selection Matrix

	Name	Intensity Score	Disturbance Score	Volume Score	TOTAL	Selection
Downspout	Site 19				7	✔ Combining the input water volume for 19 and 26, there is more possibility for treatment. Also, directly compared to 1, the combined sites have a higher intensity of use
	Site 26					
	Site 1				7	
	Site 11				6	
	Site 20				6	
	Site 15				5	Site 19 & 26
	Site 27				5	
	Site 30				5	
	Site 33				5	
	Site 2				4	
	Site 8				3	
Grass Area Drain	Site 17				9	✔ Not as obtrusive onto the iconic Mall space, nearer to existing naturalized gardens.
	Site 16				9	
	Site 5				8	
	Site 12				8	
	Site 13				8	
	Site 14				8	Site 17
	Site 6				8	
	Site 9				6	
	Site 22				6	
	Site 31				5	
Paved Area Drain	Site 23				9	✔ Largest area between 18, 29, and 23. Also, 23 can treat water from the water higher in the catchment.
	Site 18				9	
	Site 29				9	
	Site 32				8	
	Site 21				6	Site 23
	Site 24				6	
	Site 25				5	
Swale	Site 7				9	✔ Highest score
	Site 4				8	
	Site 10				6	Site 7
	Site 28				5	

Chapter 4: Final Template Designs

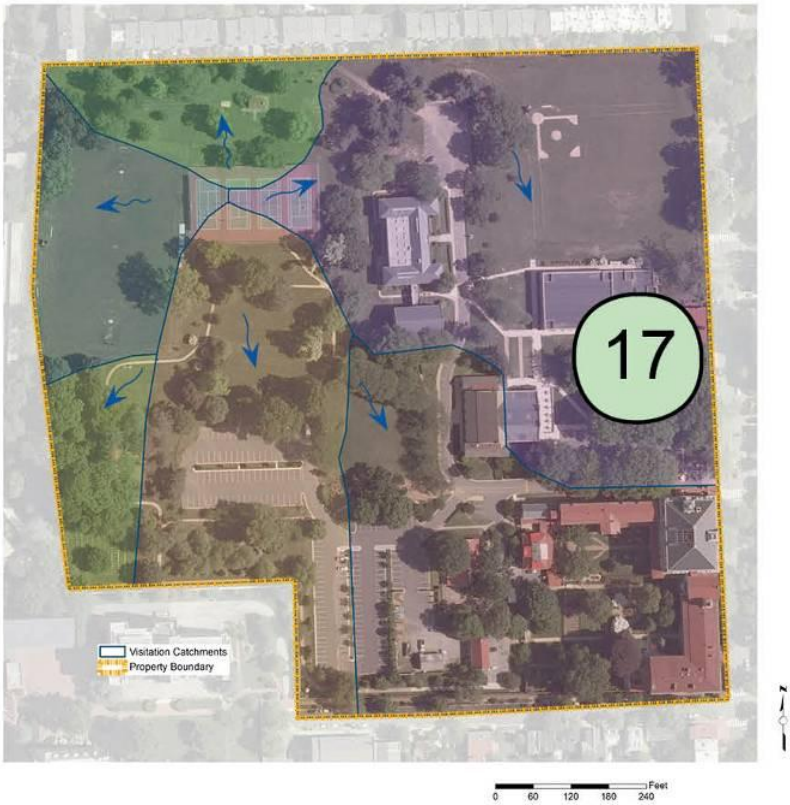
Using the selected template sites from the site selection, designs were developed to best illustrate ideal stormwater management and educational or artful demonstration. The artful design was completed by both creative design and by the inclusion of artful elements. Appendix 6 is a table ranking the stormwater management elements and their possibilities for water, environmental, and education benefits. These specific elements were all incorporated into the specific designs for the four design sites. Appendix 7 is the presentation boards for both the site analysis and site design for the campus and selected design sites.

Template 1: Grass Area Drain - The Lalor House Learning Garden

Site Description and Analysis

This site is located at the end of the largest catchment on the campus and is one of the low points with topography (Figure 4.1). The soils in this area are very poor because this site specifically was a parking lot and therefore has poor drainage. Directly north between the athletic center and the alumnae house is a steep slope. The athletic center was built in 1997 and its downspouts go directly into the underground system. The athletic center has a flat roof which may be able to accommodate a green roof. This site has a very high visibility to guests since it is so close to the main entrance.

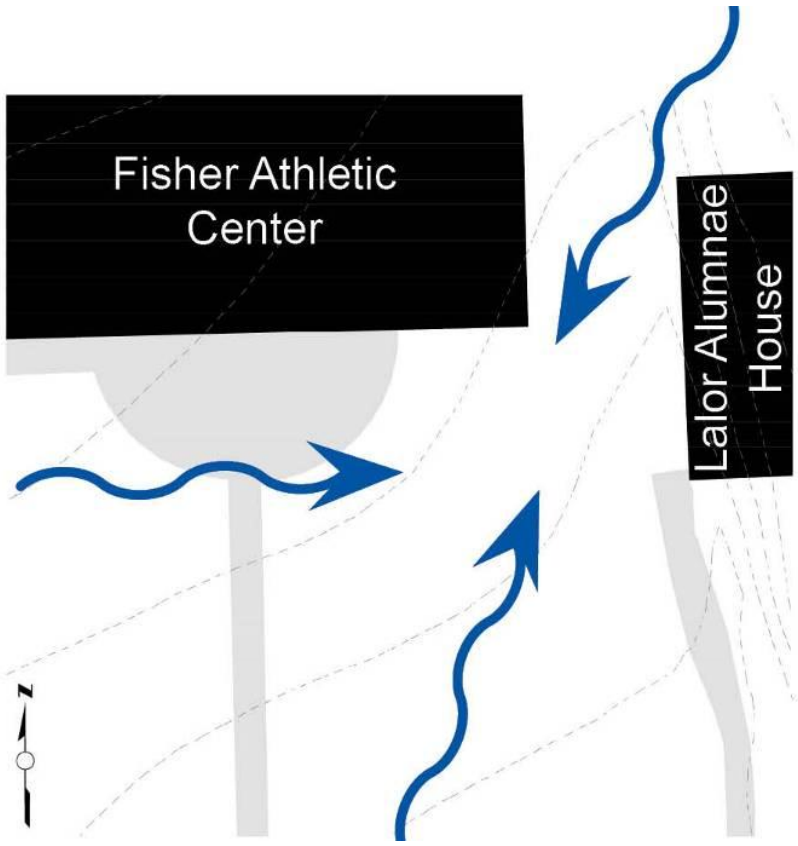
Figure 4.1: Grass Area Drain Site Location



Issues that this site contains are having a lack of infiltration, no educational opportunities, little biodiversity, poor soil quality, and the space is currently blocked from any easy access. Goals for the design of this specific site include increasing infiltration, involving educational opportunities, adding more species diversity, creating connected pedestrian flows, treating all adjacent stormwater, and exposing the stormwater in an artistic design.

This location is the lowest point of the willow oak mall and frequently floods. The mall has five area drains which indicate the high volume of water. This site has an added source of water in that the Lalor Alumnae house has its downspouts all flowing into this area. Figure 4.2 illustrates the general hydrologic flow of this site.

Figure 4.2: Grass Area Drain Hydrology



The catchment area in which the site is located is 47,678 square feet. Figure 4.3 illustrates the grass area drain catchment area. Using formulas designed by the Maryland Department of the Environment's (MDE) Environmental Site Design Standards (July 2010), this catchment will produce approximately 973 cubic feet of water during a 1.2" rain storm. All subsequent calculations for the catchment areas in the template designs follow these calculations methods. This amount of water can be treated in a rain garden that has a 2,860 square foot area. This assumes that the rain garden will have a six inch ponding depth, three inches of mulch with a 0.4 porosity and one foot of added planted soil.

Figure 4.3: Grass Area Drain Catchment Area

Design

The proposed Lalor House Learning Garden incorporates three primary elements: a series of sequential rain gardens, an integrated seating wall, and planting areas of rain gardens. This design of the walk and wall systems is informed by the existing architectural patterns as the new athletic center plaza in front of the main entry (Illustration 4.1). The walkways are raised above the rain garden about one foot (Illustration 4.2). There are three small sets of stairs in the middle of the walkways, but all the areas by the existing sidewalks are level (Illustration 4.3). The circular pattern radiates from the sidewalk and then surrounds the low point. The height from the ground increases when closer to the rain garden. The weirs (Illustration 4.3) step down at the lowest point and channel water

during a rain event to the next rain garden. The students can go into the rain garden easily by entering next to the existing walkway leading to the athletic center (Illustration 4.4). That section of the path is flush with the ground, but then steadily slopes down to the low point. The wall attached to the main path is eighteen inches tall to accommodate a seat wall in order for students to be able to sit, talk and engage in a social or learning opportunity. The center of the rain garden is close enough to the Lalor Alumnae house so that in a rain event, a class could still go to the rain garden and be under the covered porch of the house (Illustration 4.5). This provides an enhanced opportunity for instruction. All the gardens areas surrounding the pathways are planted with native species for increased biodiversity and opportunities for curriculum integration (Illustration 4.6).

Illustration 4.1: Designed Plan View with Water Flow Arrows

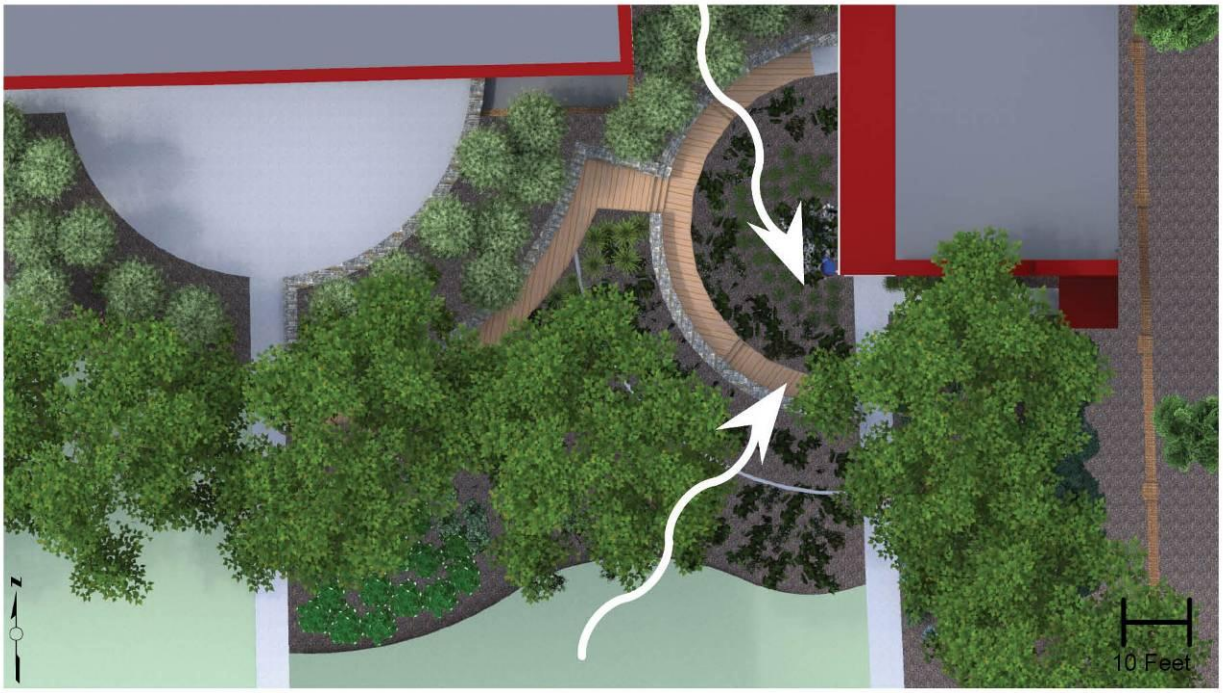


Illustration 4.2: Aerial view of the proposed design with the weir system and elevated decks for water to flow beneath

Illustration 4.3: View towards the athletic center from the Alumnae House sidewalk

Illustration 4.4: View from the connecting sidewalk over the rain garden

Illustration 4.5: View over the rain garden of a class meeting during a storm

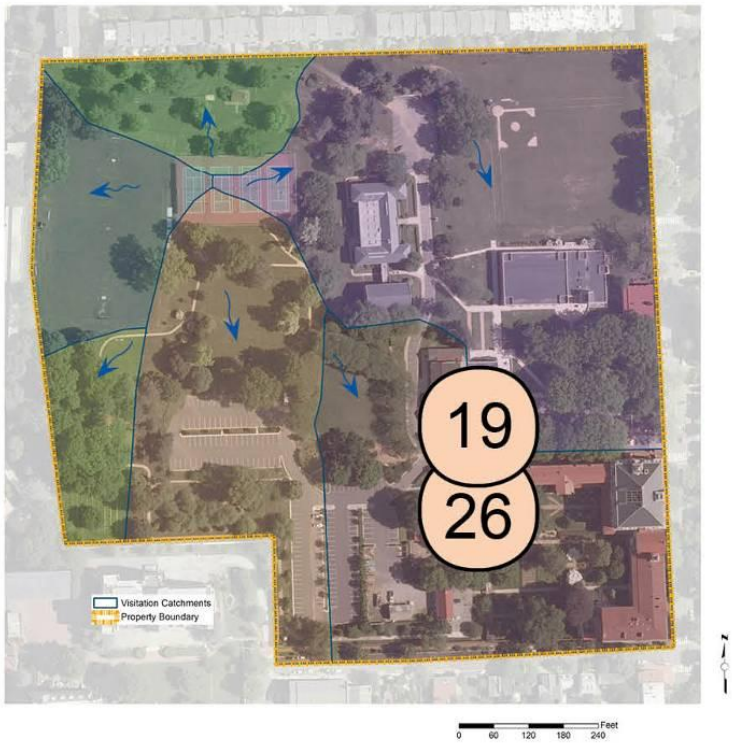
Illustration 4.6: View towards the Lalor Alumnae House from the existing sidewalk

Template 2: Downspout – Green Gate Plaza

Site Description and Analysis

The Green Gate Plaza is located on the east side of Founders Hall across the street from The Lodge (Figure 4.4). This site has a very high visibility for students because it is the main pathway to walk between some of the main academic buildings on the campus. This area has significance for the students because the Green Gate was historically the only entrance to the buildings and it would be locked nightly by the sisters living at the monastery. The Gate is especially significant during the graduation ceremony when the seniors walk through the gate as an important rite of passage. There are four downspouts that immediately enter this area and more water is added from the road runoff.

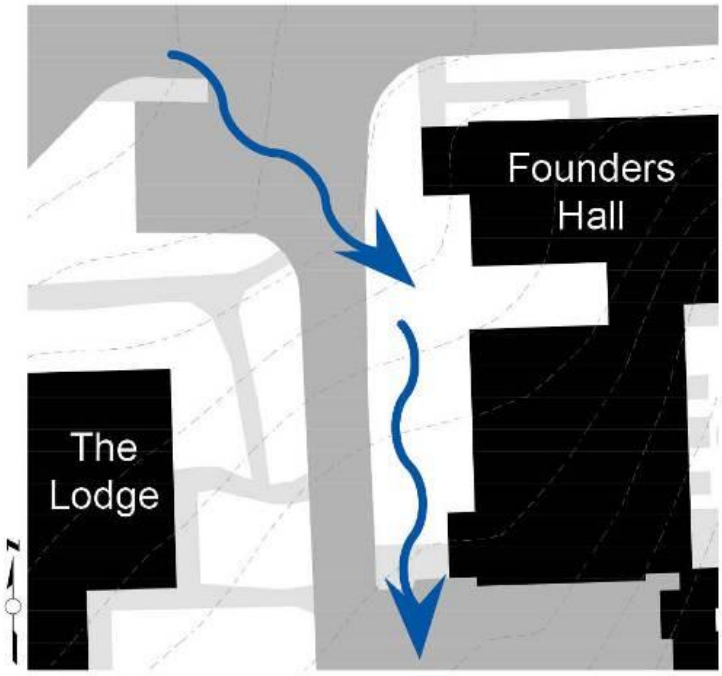
Figure 4.4: Downspout Site Location



Issues that characterize this site include lack of educational opportunities, little biodiversity, lack of aesthetic appeal creating a space where users are not encouraged to linger, awkward pedestrian access with the street crossing, the existing concrete swales are in poor condition, and lack of seating. Goals for the proposed design include adding educational opportunities, increasing species diversity, creating connected pedestrian flows, treating all adjacent stormwater, creating a more iconic and attractive space around the green gate, and exposing the stormwater in an artistic design.

Existing water flow comes from the adjacent street and most significantly from the surrounding buildings. The water flows past the plaza into a concrete swale that moves farther south. Figure 4.5 illustrates the water flow around the site.

Figure 4.5: Downspout Hydrology



The catchment area is 12,297 square feet which includes both roof and ground plane areas. This catchment will produce approximately 799 cubic feet of water during a 1.2” rain storm. This amount of water can be treated in a rain garden that has approximately a 737 square foot area. This assumes that the rain garden will have a six inch ponding depth, three inches of mulch with a 0.4 porosity and one foot of added planted soil. Figure 4.6 shows the catchment area location for the site.

Figure 4.6: Downspout Catchment Area

Design

This proposed design creates a plaza around the Green Gate with seat walls as a new feature that can for student during classes or for students to sit during the lunch break (Illustration 4.7). Trench drains are located at the intersection of the road and plaza to capture any excess runoff from the road. The adjacent road will also be rebuilt with permeable pavers which are the same as in the plaza so that the pedestrian space also continues into the roadway (Illustration 4.8). This new plaza area will also be a new space for the graduation celebrants to take photographs (Illustration 4.9). The movement of water will go beneath the walkway so the patio directly in front of the green gate is completely level with the ground (Illustration 4.10). This space has a direct path for easy pedestrian movement in order for students to move easily from class to class (Illustration 4.11). The stormwater rain barrels are conical shaped urns (Illustration 4.11 and 4.12), which when filled, have small holes for the water to be released (Illustration 4.13). These urns were inspired by the stormwater collection urns at the Powhatan Springs Park in Alexandria, Virginia. These holes will release the water in an arc pattern into a lower urn which then will overflow into the rain gardens. These urns are surrounded by rain gardens so when the water is at a very slow flow the water will trickle directly into the rain garden. Surrounding the plaza are rain gardens at a grade that is below the walkways (Illustration 4.14). The sides of the buildings will also have a trellis for plants to grow upon and help cool the buildings. The walkway from inside Founders Hall through the Green Gate will remain the same, and the view will be of the redesigned open plaza and new center rain garden (Illustration 4.15).

Illustration 4.7: Plan view with water flow direction

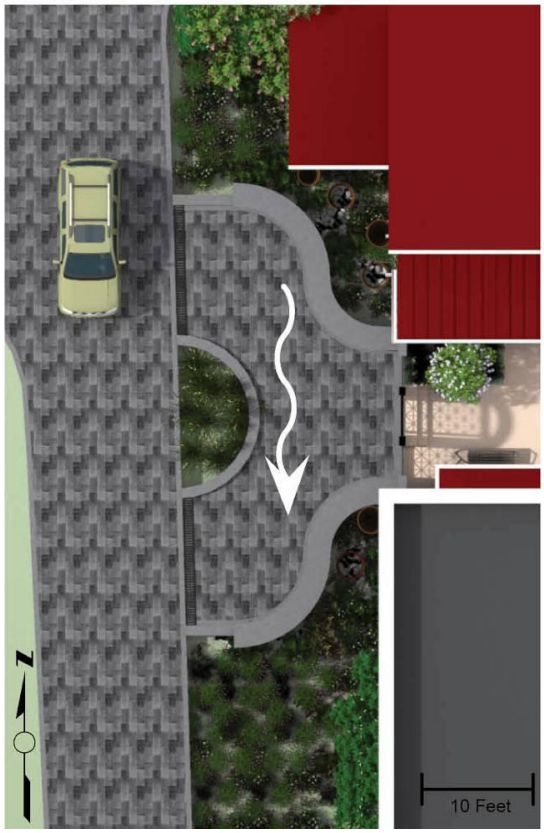


Illustration 4.8: Aerial oblique view of the plaza

Illustration 4.9: Aerial oblique view of the plaza looking north east

Illustration 4.10: Stormwater treatment train

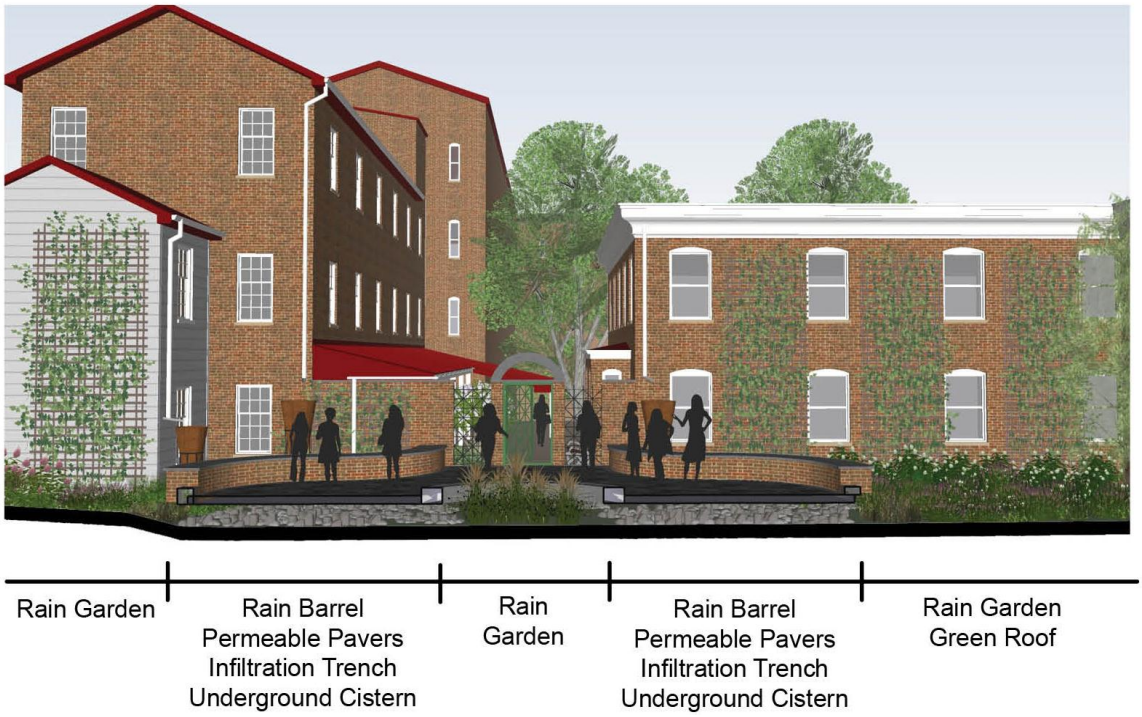


Illustration 4.11: North view of the stormwater treatment train during a storm

Illustration 4.12: North view of the stormwater urns and Green Gate from the street

Illustration 4.13: Stormwater Urns during a storm

Illustration 4.14: South view of the rain garden

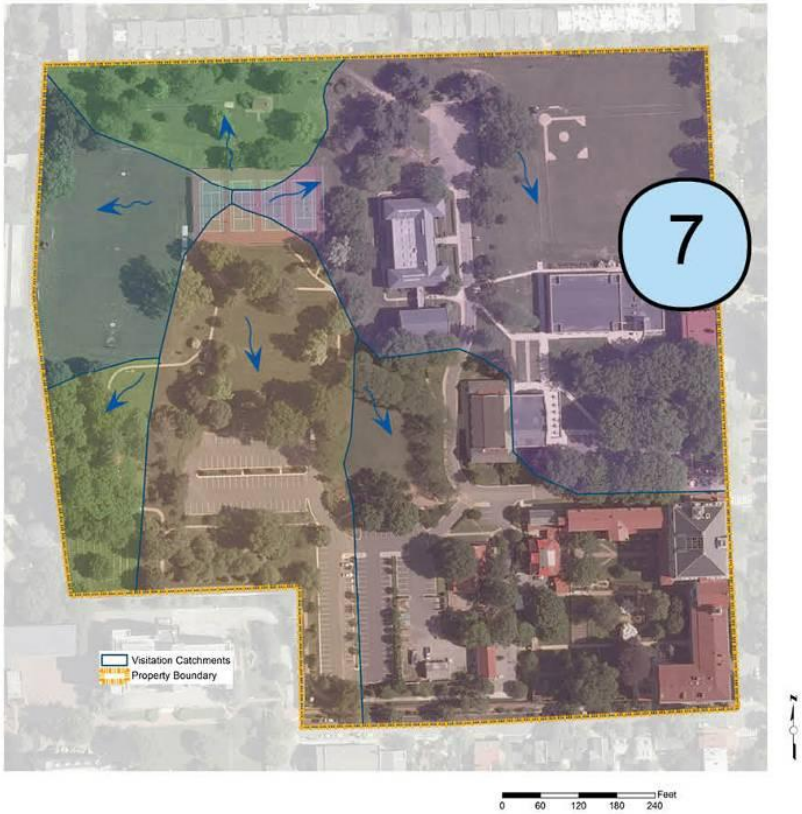
Illustration 4.15: West view to the street through the Green Gate

Template 3: Swale - The 35th Street Water Garden

Site Description and Analysis

This existing swale is on the east side of one of the main athletic fields (Figure 4.7). The field does have an under drain, but still some sheet runoff goes into the swale. The swale has a very good visibility from 35th Street through a metal rung fence. 35th Street has lanes of parallel parking on either side of the road and two lanes of moving traffic. The street is also a main route for buses and traffic noise can be overwhelming. This area can also become very hot with since there no significant shade and seating is limited to one small bench.

Figure 4.7: Swale Site Location



Issues that this site contains are having a lack of infiltration, no educational opportunities, little biodiversity, poor soil quality, little seating, no buffer to 35th Street, and the space is currently lacking significant shade for users. Goals for the design include increasing infiltration, involving educational opportunities, adding more species diversity, increasing tree cover, treating all stormwater from the field, exposing the stormwater in an artistic design, creating a buffer to the street, and adding seating.

Existing water flow comes from the athletic field and the back yards of the townhomes to the north of the campus. Water from the street does not enter the swale due to the curb and gutter system. Figure 4.8 illustrates the general water flow of the site.

Figure 4.8: Swale Hydrology

The catchment area is approximately 59,113 square feet. This catchment will produce approximately 295 cubic feet of water during a 1.2” rain storm. This amount of water can be treated in a rain garden that has approximately a 3,546 square foot area. This assumes that the rain garden will have a six inch ponding depth, three inches of mulch with a 0.4 porosity and one foot of added planted soil. Figure 4.9 shows the catchment area for the swale.

Figure 4.9: Swale Catchment Area

Design

The 35th Street Water Garden design is based on the concept of increasing quantities driven by the increase in the size of the catchment area. The swale was divided into three sections to represent increasing catchment area as the water flows from the top of the swale to the bottom of the swale. Each section has a drop in elevation of two feet which is the same as the existing slope. The three sections will have plants increasing in elevation as the water flow to the larger section which mirrors the increasing amount of water each successive section of the swale will receive. The width of the sections also increases into the higher volume areas. As another feature, the three section pattern is reflected by the number of proposed benches. Illustration 4.16 shows the plan view and ground level view of each of the platforms with a section including 35th Street. Illustration 4.17 shows the three platforms and the relationship between 35th Street and the athletic field. The benches can be used by the sports teams and for users during larger events. The benches can also be used for classroom instruction when these landscapes are being used for instruction. The total length of the swale is 243 feet long with a fifteen foot buffer on either end. Visibility of the 35th Street Water Garden from 35th Street is also important to be able to demonstrate stormwater management to the surrounding community (Illustration 4.18).

Illustration 4.16: 35th Street Swale Template Details

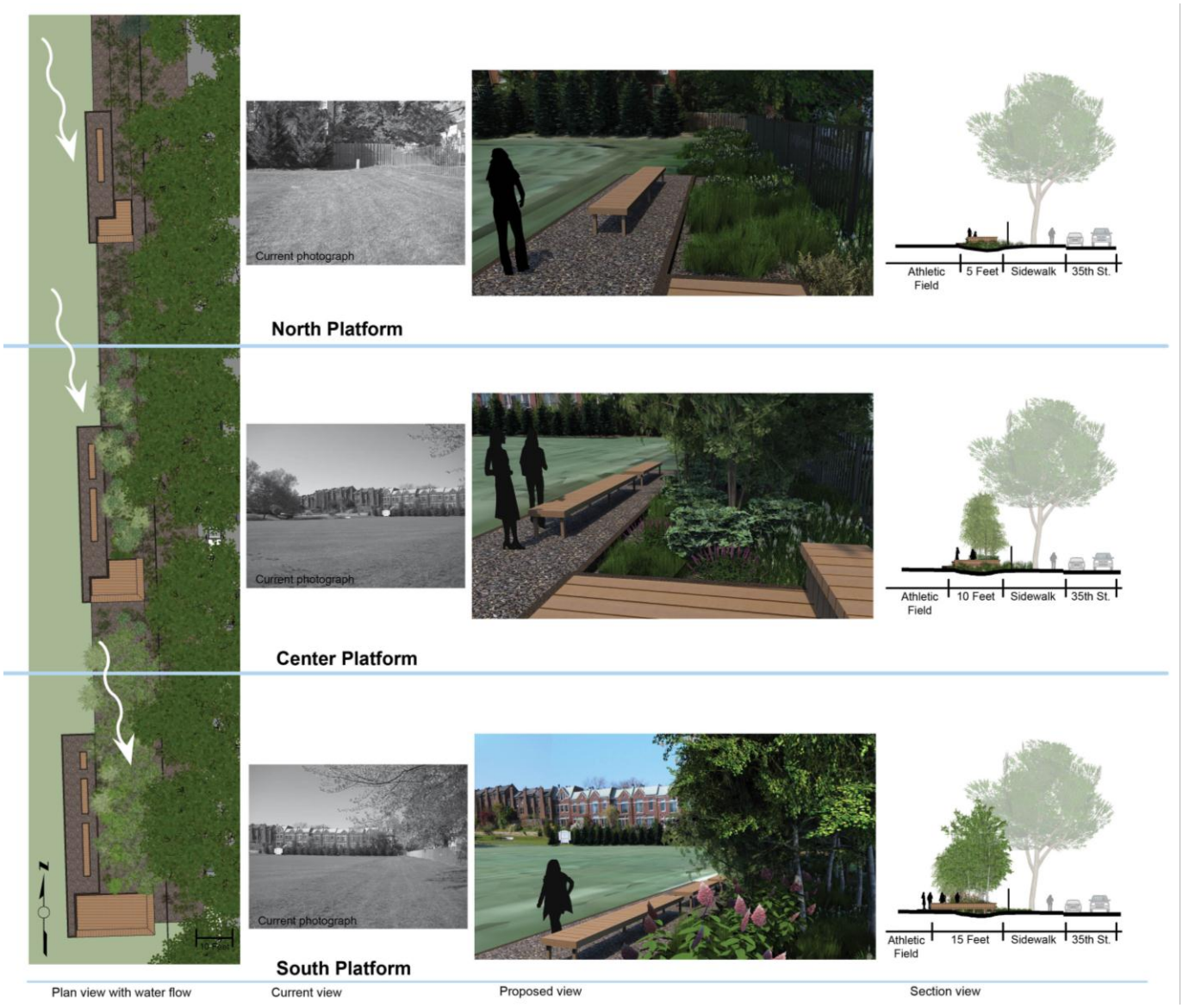


Illustration 4.17: Aerial oblique of the three swale platforms

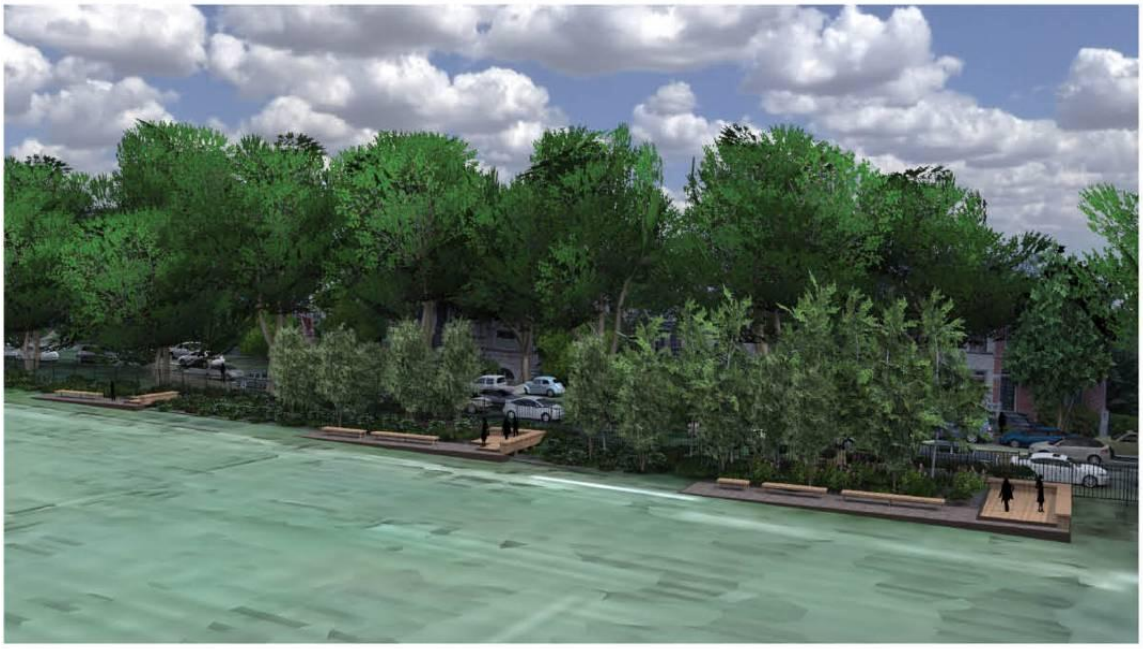


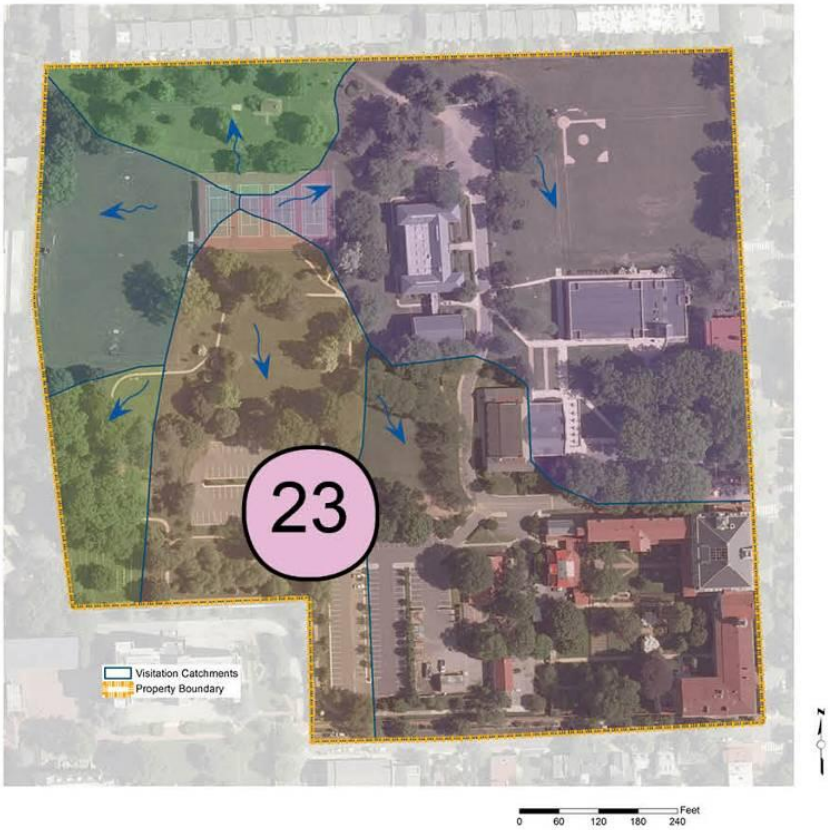
Illustration 4.18: View from 35th Street of the middle platform and Athletic Center

Template 4: Paved Area Drain – West Parking Lot

Site Description and Analysis

The west parking lot is a student parking area. It is the farthest parking lot from all the academic buildings and located on the east side of the campus (Figure 4.10). It currently has 76 parking spaces and covers 23,019 square feet. There is a small grass median but it is raised and water is diverted around it ultimately into a storm drain at the south east end of the parking lot. During the summer, this lot is used by the summer camps as a drop off area.

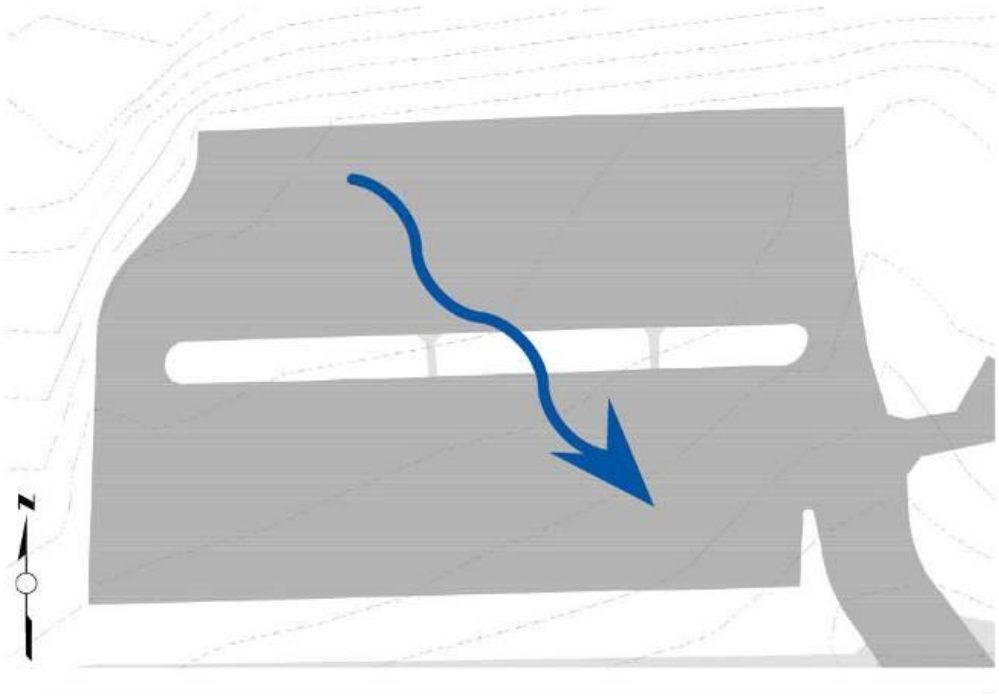
Figure 4.10: Paved Area Drain Site Location



Issues of this site include lack of infiltration, no educational opportunities, little biodiversity, poor soil quality, trees with a restricted root zone, and minimal shaded parking. Goals for the design include increasing infiltration, providing educational opportunities, adding more species diversity in the plantings, treating all adjacent stormwater, exposing the stormwater in an artistic design, and adding appropriate pedestrian paths.

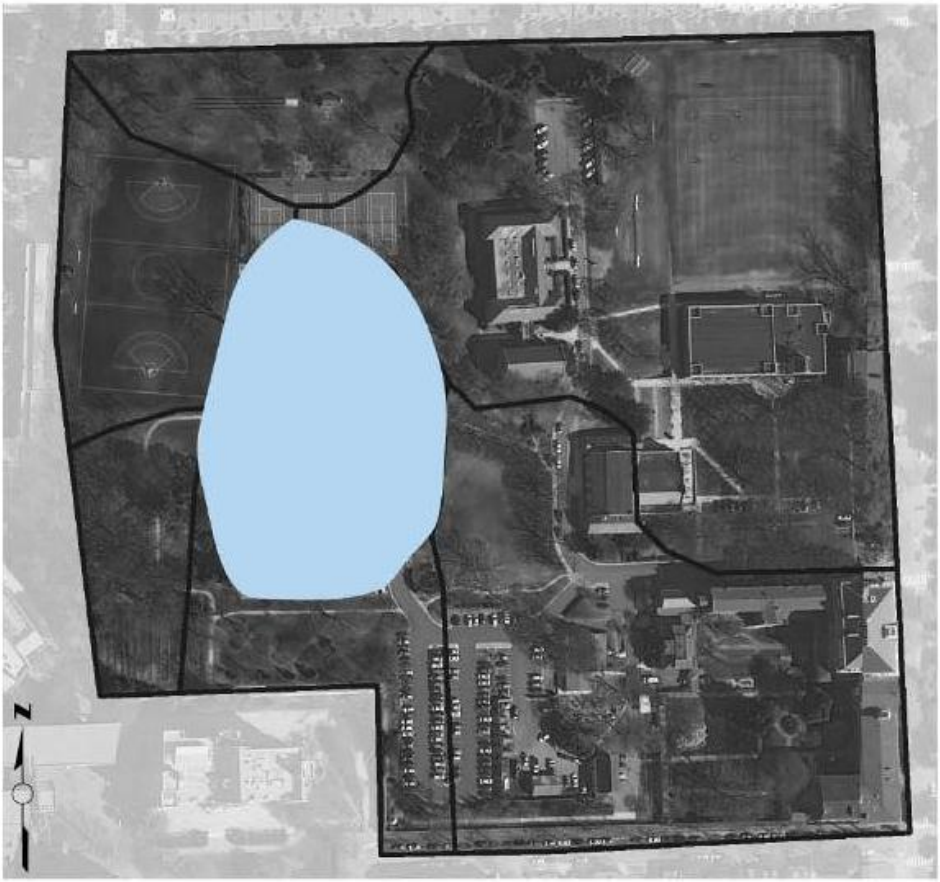
Existing water flow comes from grass areas to the north of the existing parking lot. There is a steep hill at the northern edge that drains onto the parking lot. All of this water flows into a storm drain that connects to the underground system which flows into the District's combined storm sewer system. Figure 4.11 illustrates the water flow onto the site.

Figure 4.11: Paved Area Drain Hydrology



The catchment area is 117,145 square feet. This catchment will produce approximately 3,538 cubic feet of water during a 1.2” rain storm. This amount of water can be treated in a rain garden that has approximately a 7,028 square foot area. This assumes that the rain garden will have a six inch ponding depth, three inches of mulch with a 0.4 porosity and one foot of added planted soil. Figure 4.12 shows the large catchment area for the site.

Figure 4.12: Paved Area Drain Catchment Area



Design

The proposed West Parking Lot treats the parking lot as a new location for education and stormwater visibility. Illustration 4.19 illustrates the site organization and relationship to the existing road. The proposed parking area accommodates sixty eight cars. On the east side of the parking lot is a sidewalk has been added for increased pedestrian safety. The parking lot maintains the existing grade averaging a six percent slope. Artistic elements incorporated into this parking lot design include customized plaques with etched drawings of native plant or animal species (Illustration 4.20). Some parking spaces have been removed in order to place rain gardens to receive overflow (Illustration 4.21). The parking spaces have permeable pavers and the driving lanes are composed of permeable pavement in order to demonstrate different types of methods for stormwater infiltration in a paved area (Illustration 4.22). Patterns were added to the permeable pavement area to illustrate the water flow (Illustration 4.23). The center median is nine feet wide which can support larger trees (Illustration 4.24). Crossing the center rain garden median is accommodated by the inclusion of small boardwalks for pedestrian movement. These also add increased visibility of the stormwater treatment for teachers and students (Illustration 4.25).

Illustration 4.19: Plan view

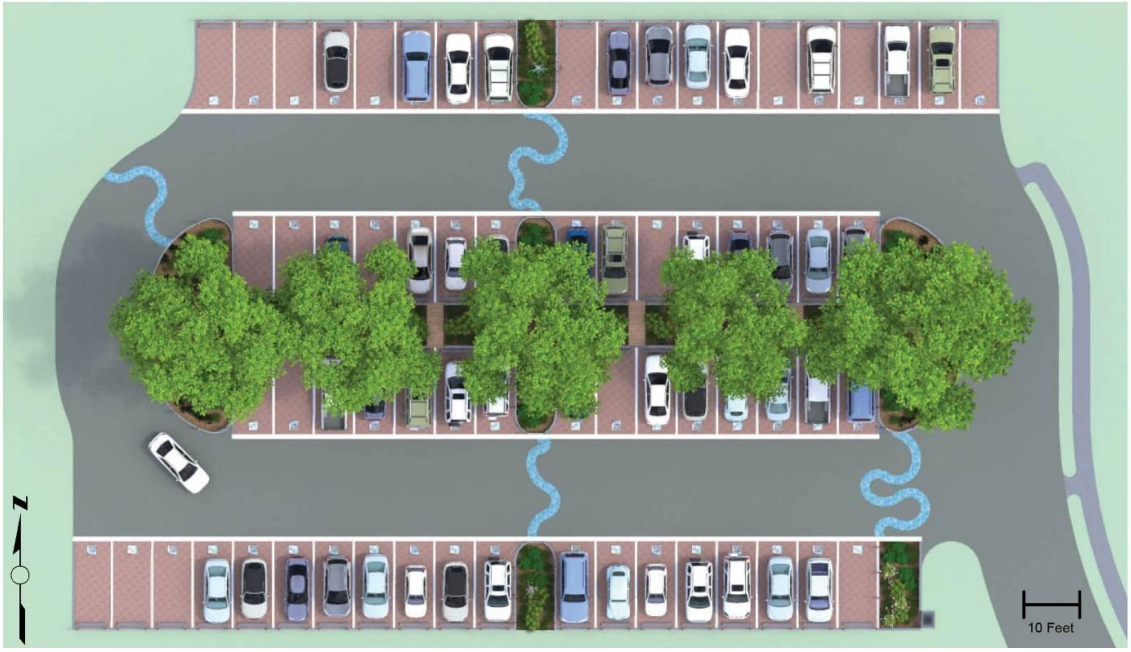


Illustration 4.20: Aerial oblique of the parking areas around the center rain garden

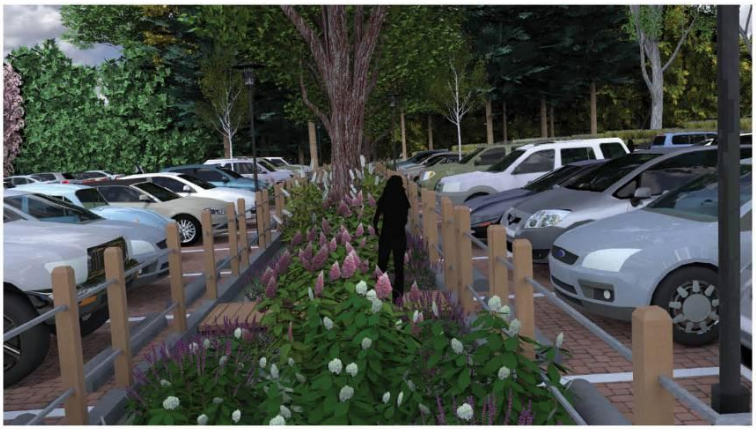
Illustration 4.21: View of the north side of the parking lot

Illustration 4.22: View of the south side of the parking lot

Illustration 4.23: Rain garden and artful pattern in the pavement

Illustration 4.24: Median rain garden with mature tree

Illustration 4.25: Median rain garden with pedestrian boardwalk



Chapter 5: Summary and Conclusion

The objective of this thesis was to integrate stormwater management and education while doing so with artful design principles. The integration of these factors was demonstrated by the creation of designs and plans for selected stormwater features on the Georgetown Visitation Preparatory School campus in Georgetown, Washington DC. This thesis explored the artful management of stormwater on a school campus. Design templates were developed for the campus that illustrates possibilities for diverse stormwater management and artful integration to enhance the school's curriculum for a broad array of educational subjects.

This thesis was broadly divided into two sections: 1) literature review and 2) design application. The literature review explored the foundation of research on the topics of stormwater management and green schools while also researching precedent examples within these sections. The design application used the principles from the literature review to demonstrate the integration of an artful stormwater design with educational curriculum.

The literature review was organized into three areas of investigation: 1) stormwater management and its potential for becoming an asset to the landscape, 2) an overview of stormwater issues and impervious surface fees in the District and 3) the green schools' movement and the objective of teaching the younger generation about the importance of the environment.

Stormwater can be a wonderful asset to a landscape. By treating the water on site, possibilities for using stormwater as an educational tool are numerous. Specific stormwater features, such as green roofs, rain gardens, and permeable pavers, can become avenues for education about the environment and learning about the current problems while treating stormwater. Artful rainwater design is the integration of treating stormwater and making it not only visible but interactive for people who use these designed areas on a frequent basis. The fundamental aspect of the artful rainwater design is having the stormwater be visible. The designs of the templates for the Georgetown Visitation Preparatory School campus are examples where the intent of the design was to provide visibility to stormwater processes

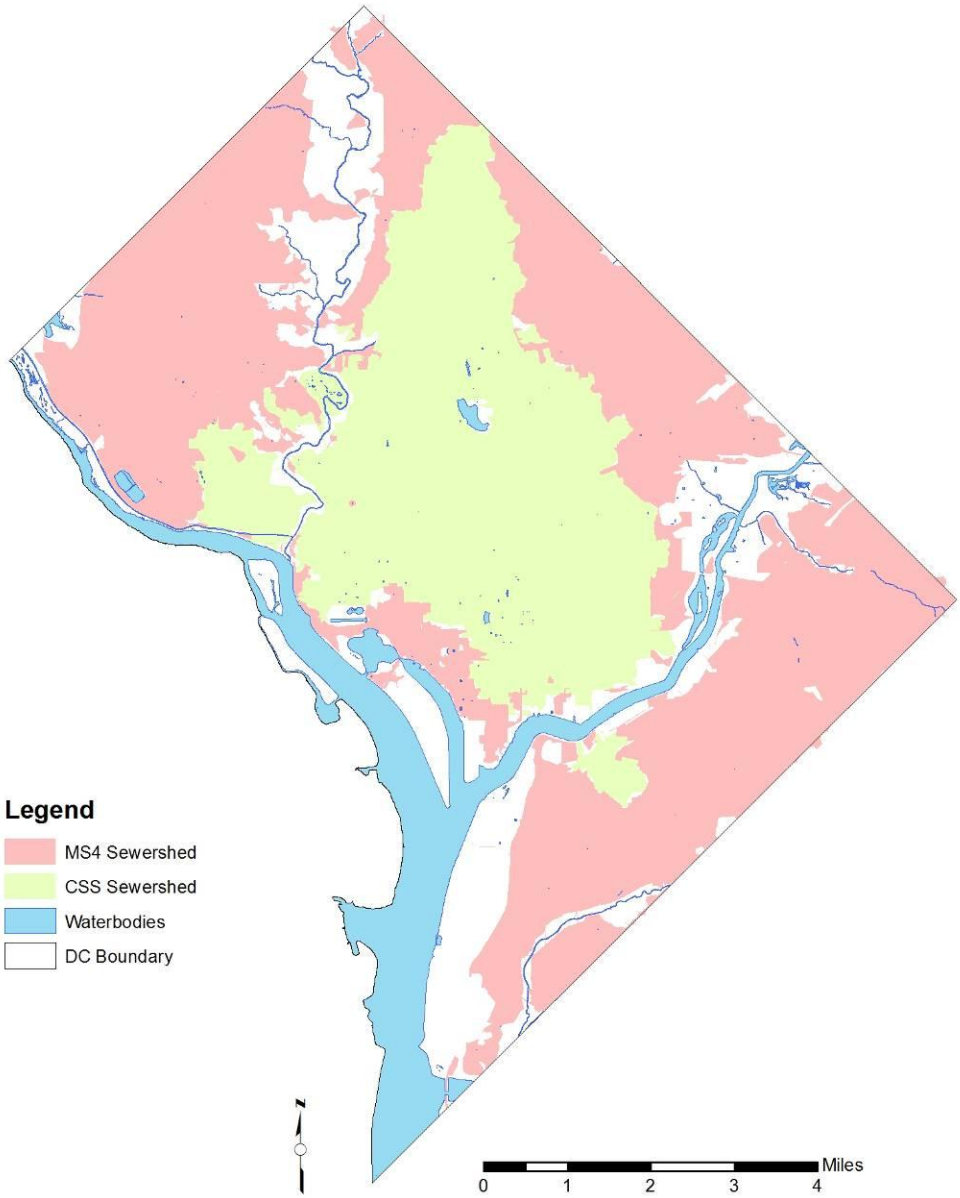
Increased impervious surfaces and stormwater overflows are a significant problem. With the advent of LID, stormwater managers are beginning to implement stormwater fees based on the amount of impervious surface on a property which results in more incentive for individual stormwater management. The growing use of fess for impervious cover and stormwater will encourage property owners, including schools, to consider implementation of LID techniques to reduce costs. School settings are great opportunities for integrating on-site stormwater into many aspects of the curriculum from the sciences to the arts. Environmental education, and reconnecting children to nature is crucial for maintaining the natural environment and education in the primary and secondary school settings offers a tremendous opportunity to teach the students at an age that will result in future environmental sustainability.

In the design application, designs and plans were developed for the stormwater typologies on the campus. These template designs combined the need for stormwater management and opportunities for education in the Georgetown Visitation Preparatory School landscape. Although these template designs are not applicable at all locations, the ideas created in these designs could be utilized in other schools to address environmental sustainability with stormwater management and environmental education. Some limitations of this thesis include not addressing the construction budget or maintenance costs of the proposed designs. Another limitation for the research is how the treatment of the stormwater deposits the toxins into the mulch and rain garden plants could possibly impact the health of students that go into the rain gardens. These issues provide potential areas of research and design exploration for integrating education into the campus landscape. More research could also be done about maintenance of the LID stormwater features and how to best show other aspects of stormwater features to meet educational objectives.

In summary, with the increasing problems of stormwater management and the growing need for place-based environmental education, the redesign of school campuses can provide opportunities to address these issues. The result will be stormwater treatments artfully designed and students having the opportunity to enhance their environmental ethos needed for a more sustainable future.

Appendices

Appendix 1 – MS4 and CSS Sewersheds in the District



(Data Source: DC GIS)

Appendix 2 – Major Organizations for Green Schools

Below are organizations organized by scale that works with green schools.
(Source: Rowe 2002, Stone 2009, Danks 2011, Rodriguez 2012)

Washington, DC Resources

- Alice Ferguson Foundation http://fergusonfoundation.org
- Anacostia Watershed Restoration Partnership http://www.anacostia.net
- Anacostia Watershed Society http://anacostiaws.org
- Bay Backpack http://www.baybackpack.com
- Casey Trees http://www.caseytrees.org/
- Chesapeake Bay Foundation – District of Columbia Resources and Information http://www.cbf.org/page.aspx?pid=469
- Chesapeake Bay Foundation – Education Programs www.cbf.org/education
- Chesapeake Bay Program http://www.chesapeakebay.net
- DC Environmental Education Consortium – Schoolyard Greening http://www.dcschoolyardgreening.org/
- DC Environmental Education Consortium www.dcnaturally.org
- DC Greenworks http://www.dcgreenworks.org/
- DC Schoolyard Greening http://www.dcschoolyardgreening.org/
- DC Water for Kids http://dcwater.com/kids
- DC Water http://www.dcwater.com/
- District Department of the Environment
- Environmental Education Program http://ddoe.dc.gov/education
- RiverSmart Homes http://ddoe.dc.gov/riversmarthomes
- RiverSmart Schools http://ddoe.dc.gov/service/riversmart-schools
- EnvironMentors http://ncseonline.org/environmentors/
- Maryland Association for Environmental & Outdoor Education www.maeoe.org
- National Capital Region Watershed Stewards Academy http://www.ncr‐wsa.org
- National Geographic Field Scope – Chesapeake Bay FieldScope Project http://www.nationalgeographic.com/field/projects/cbfieldscope.html
- NOAA Chesapeake Bay Office www.chesapeakebay.noaa.gov
- Potomac Conservancy www.potomac.org
- RainScaping Campaign: An Environmental Partnership for Stormwater Runoff Solutions for Anne Arundel County http://rainscaping.org
- Washington Aqueduct http://washingtonaqueduct.nab.usace.army.mil/

Local, Regional, and State-wide Organizations

- Boston Schoolyard Initiative (Massachusetts) http://www.schoolyards.org/
- California School Garden Network (California) http://www.csgn.org/
- Chicago Botanic Garden – School Gardening Program (Illinois) http://www.chicagobotanic.org/schoolgarden/index.php
- Earth Partnership for Schools (Wisconsin) http://uwarboretum.org/eps

- Hawai'i Island School Garden Network (Hawaii) http://www.kohalacenter.org/HISGN/about.html
- MIT, the Program on Environmental Education and Research (PEER): a resource for faculty, staff and students who are interested in developing new content for their courses and performing environmentally-related research to directly impact environmental policies, people's behaviors, or educational systems.
- Natural Learning Initiative (North Carolina) http://www.naturalearning.org/
- Pennsylvania Consortium for Interdisciplinary Environmental Policy: (www.paconsortium.state.pa.us)
- REAL School Gardens (Texas) http://www.realschoolgardens.org/
- San Francisco Green Schoolyard Alliance (California) http://www.sfgreenschools.org/
- The Green Schools Initiative (California+) http://www.greenschools.net/
- The State of Michigan's Sustainability and Energy Education Project: for secondary and higher education educators to get information on how to teach change agent skills and actions to help keep the planet healthy (www.urbanoptions.org)
- Tufts Institute for the Environment: (www.tufts.edu.tie)
- University of New Hampshire Center for Sustainability

National Organizations

- Alliance to Save Energy – Green Schools Program http://ase.org/programs/green-schools-program
- American Community Garden Association http://www.communitygarden.org/
- Center for a Sustainable Future: (http://csf.concord.org) provides teacher training, downloadable learning activities and on-line courses in sustainability.
- Center for Ecoliteracy http://www.ecoliteracy.org/
- Center for Environmental Education http://www.ceeonline.org/
- Children & Nature Network http://www.childrenandnature.org/
- Collaborative for High Performance Schools http://www.chps.net/dev/Drupal/node
- Community Built Association http://communitybuilt.org/
- Energy Star – Program for K-12 School Districts http://www.energystar.gov/
- Environmental Literacy Council (DC)
- Environmental Protection Agency – Environmental Education http://www.epa.gov/enviroed/
- HarvestH2O http://www.harvesth2o.com/
- Life Lab Science Program http://www.lifelab.org/
- National Gardening Association – Kidsgardening http://www.kidsgardening.org/
- National Environmental Education Week http://eeweek.org/
- National Science Foundation funded Advanced Technology Environmental Education Center (ATEEC): advances environmental technology education through curriculum development, professional development, and program improvement in the nation's community colleges and high schools

- National Wildlife Federation – Schoolyard Habitats® http://www.nwf.org/Get-Outside/Outdoor-Activities/Garden-for-Wildlife/Schoolyard-Habitats.aspx
- National Wildlife Federation – Eco-Schools USA http://www.nwf.org/Global-Warming/School-Solutions/Eco-Schools-USA.aspx
- National Wildlife Federation's Campus Ecology program: training clinics, fellowships and publications to aid in greening college and university campuses
- North American Association for Environmental Education http://www.naaee.net/
- Partnership for Environmental Technology Education (PETE): provides leadership in environmental education and training for community and technical colleges through partnerships with businesses, industry, government and other educational providers
- Project W.E.T. (Water Education for Teachers) http://www.projectwet.org/
- Second Nature: Boston-based national organization helping institutions of higher education prepare future professionals for the increasingly complex environmental challenges the nation faces (www.secondnature.org)
- The Cloud Institute for Sustainability Education (New York, NY)
- The Foundation for Environmental Education – Solar School Initiative http://solarschools.org/
- The North American Alliance for Green Education: a non-profit consortium of varied higher educational institutions and organizations from diverse bioregions and includes many example institutions
- U.S. Environmental Protection Agency (http://www.epa.gov/):
- Green Building http://www.epa.gov/greenbuilding/
- Office of Ground Water and Drinking Water http://water.epa.gov/drink/index.cfm
- Teaching Center http://www.epa.gov/students/index.html
- U.S. Green Building Council – Build Green Schools Program http://www.centerforgreenschools.org/home.aspx

Other related websites

- Asphalt to ecosystems www.asphalt2ecosystems.org
- Bay Tree Design, Inc. www.baytreedesign.com
- Eco-Schools http://www.eco-schools.org/
- H2O Conserve http://www.h2oconserve.org
- Healthy Landscapes: Clean Water Starts at Home – Sustainable Landscaping http://www.uri.edu/ce/healthylandscapes/index_landscaping.html
- Low Impact Development Center – Sustainable School Projects http://www.lowimpactdevelopment.org/school
- Rain Garden Network http://www.raingardennetwork.com/
- Sustainable Schoolyards Exhibit at the U.S. Botanic Garden http://www.sustainableschoolyard.org/
- U.S. Environmental Protection Agency – Office of Ground Water and Drinking Water http://www.epa.gov/safewater
- U.S. Environmental Protection Agency - WaterSense Program http://www.epa.gov/WaterSense/

- U.S. Environmental Protection Agency – Watershed Academy Webcasts http://www.epa.gov/owow/watershed/wacademy/webcasts
- UNESCO Teaching and Learning for a Sustainable Future report: resource for helping educators integrate sustainability into the curricula
- Water – Use It Wisely http://www.wateruseitwisely.com
- Water Footprint http://www.waterfootprint.org
- Water: H2O = Life http://www.amnh.org/exhibitions/water/

Appendix 3 – USGBC Credits for Stormwater Management in Schools

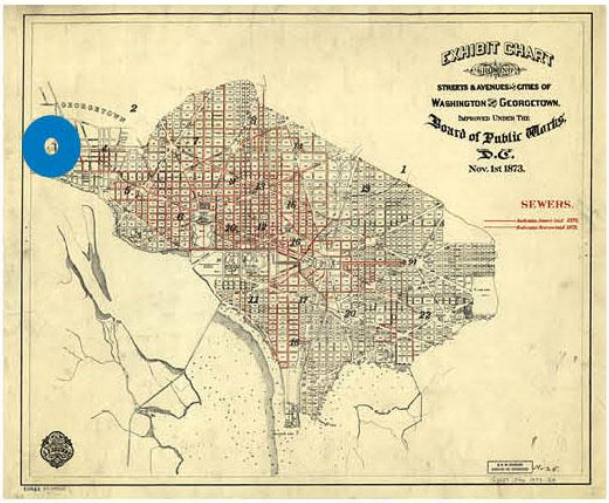
Credits that apply to stormwater management and green schools are the following: (USGBC 2007)

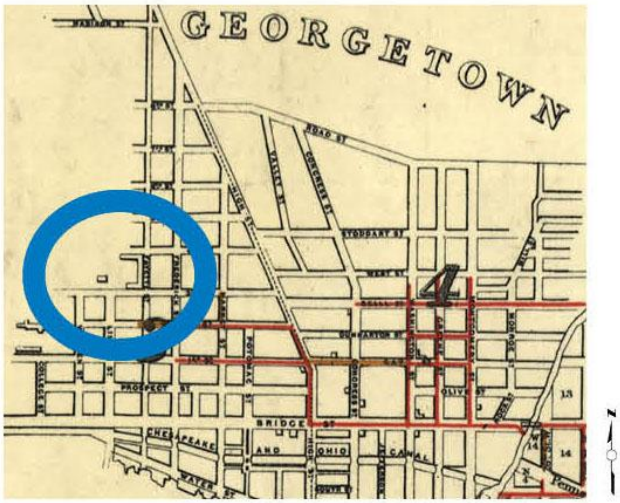
- SS Credit 6.1: Stormwater Design – Quantity Control (1 point)
    - If the existing imperviousness is less than or equal to fifty percent, the stormwater management plan must include treatment to prevent the post-development peak discharge to exceed the pre-development peak discharge for the one and two year 24-hour design storms. If the existing imperviousness is greater than fifty percent, the stormwater management plan must result in a twenty-five percent decrease in the volume of stormwater runoff for the two-year 24-hour design storm. This would be completed by practices such as green roofs, pervious paving, and stormwater reuse.
- SS Credit 6.2: Stormwater Design – Quality Control (1 point)
    - The stormwater management for this plan must capture and treat ninety percent of the average annual rainfall using acceptable and approved best management practices (BMPs). This would be achieved by using alternative pervious surfaces, or nonstructural techniques such as rain gardens, vegetated swales, or rainwater recycling.
- WE Credit 1.1: Water Efficient Landscaping – Reduce by 50% (1 point)
    - Reduction of potable water consumption for irrigation by fifty percent from the calculated mid-summer baseline must be achieved to acquire this point. This would be accomplished by careful plant species selection, irrigation efficiency, using captured or recycled rainwater, or having the source from a public agency that has treated the water for the specific purpose of non-potable uses.
- WE Credit 1.2: Water Efficient Landscaping – No Potable Water Use of No Irrigation (1 point in addition to WE Credit 1.1)
    - This point can only be achieved by also getting WE Credit 1.1. The difference between the points is that in WE Credit 1.2, no potable water is used at all for irrigation or no irrigation is used entirely. An irrigation system can be installed only if it will be removed within one year after installation after the plants have become established.
- ID Credit 3: The School as a Teaching Tool (1 point)
    - This point requires that the sustainable features of the school be integrated with the school's educational mission. The curriculum should not just be a description of the features themselves, but an explanation how these features fit into the entirety of the environment.

Appendix 4 – Historic Maps with Georgetown Visitation Preparatory School

Source: Library of Congress, Geography and Map Division

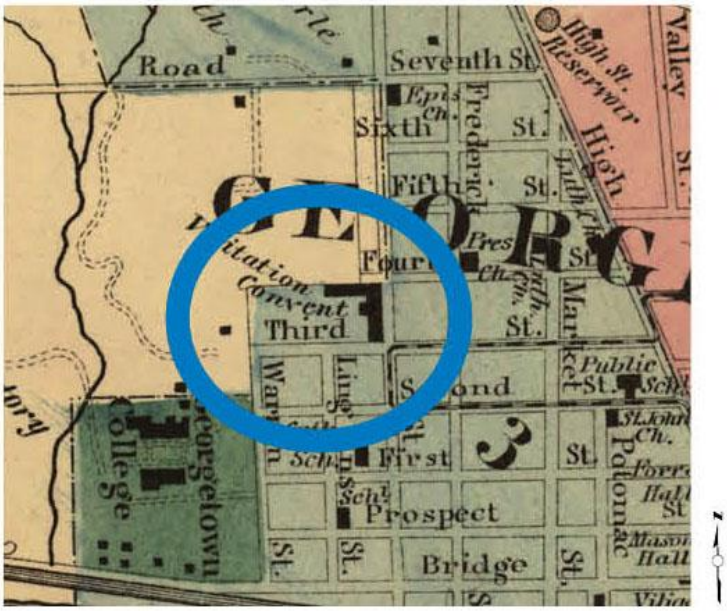
Sewers by the Board of Public Works, DC
1873



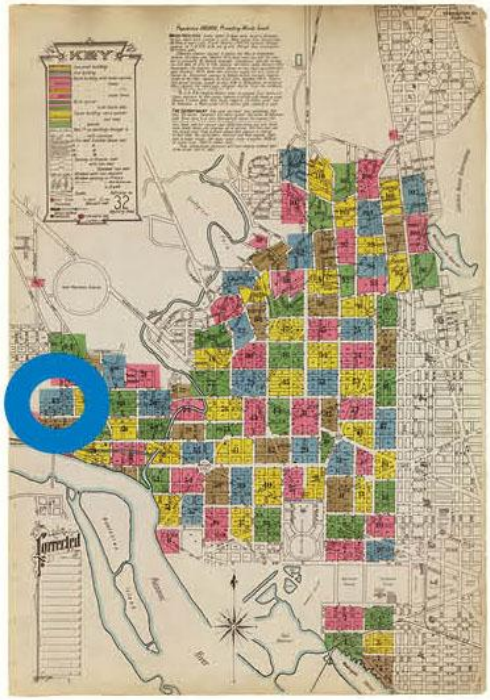


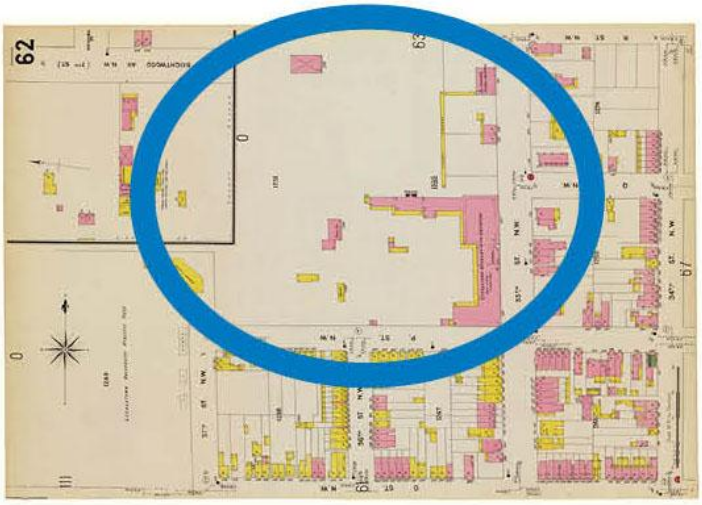
James Keily Map
1851

G.M. Hopkins Survey
1879



Sanborn Map Company Insurance Maps
1903





Appendix 5 – Hydrologic Soil Groups

Source: USDA NRCS. 2007. "Hydrology National Engineering Handbook - Chapter 7 Hydrologic Soil Groups."

Group A—Soils in this group have low runoff potential when thoroughly wet. Water is transmitted freely through the soil. Group A soils typically have less than 10 percent clay and more than 90 percent sand or gravel and have gravel or sand textures. Some soils having loamy sand, sandy loam, loam or silt loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments. The limits on the diagnostic physical characteristics of group A are as follows. The saturated hydraulic conductivity of all soil layers exceeds 40.0 micrometers per second (5.67 inches per hour). The depth to any water impermeable layer is greater than 50 centimeters [20 inches]. The depth to the water table is greater than 60 centimeters [24 inches]. Soils that are deeper than 100 centimeters [40 inches] to a water impermeable layer are in group A if the saturated hydraulic conductivity of all soil layers within 100 centimeters [40 inches] of the surface exceeds 10 micrometers per second (1.42 inches per hour).

Group B—Soils in this group have moderately low runoff potential when thoroughly wet. Water transmission through the soil is unimpeded. Group B soils typically have between 10 percent and 20 percent clay and 50 percent to 90 percent sand and have loamy sand or sandy loam textures. Some soils having loam, silt loam, silt, or sandy clay loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments. The limits on the diagnostic physical characteristics of group B are as follows. The saturated hydraulic conductivity in the least transmissive layer between the surface and 50 centimeters [20 inches] ranges from 10.0 micrometers per second (1.42 inches per hour) to 40.0 micrometers per second (5.67 inches per hour). The depth to any water impermeable layer is greater than 50 centimeters [20 inches]. The depth to the water table is greater than 60 centimeters [24 inches]. Soils deeper than 100 centimeters [40 inches] to a water impermeable layer or water table are in group B if the saturated hydraulic conductivity of all soil layers within 100 centimeters [40 inches] of the surface exceeds 4.0 micrometers per second (0.57 inches per hour) but is less than 10.0 micrometers per second (1.42 inches per hour).

Group C—Soils in this group have moderately high runoff potential when thoroughly wet. Water transmission through the soil is somewhat restricted. Group C soils typically have between 20 percent and 40 percent clay and less than 50 percent sand and have loam, silt loam, sandy clay loam, clay loam, and silty clay loam textures. Some soils having clay, silty clay, or sandy clay textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments. The limits on the diagnostic physical characteristics of group C are as follows. The saturated hydraulic conductivity in the least transmissive layer between the surface and 50 centimeters [20 inches] is between 1.0 micrometers per second (0.14 inches per hour) and 10.0 micrometers per second (1.42 inches per hour). The depth to any water impermeable

layer is greater than 50 centimeters [20 inches]. The depth to the water table is greater than 60 centimeters [24 inches]. Soils deeper than 100 centimeters [40 inches] to a restriction or water table are in group C if the saturated hydraulic conductivity of all soil layers within 100 centimeters [40 inches] of the surface exceeds 0.40 micrometers per second (0.06 inches per hour) but is less than 4.0 micrometers per second (0.57 inches per hour).

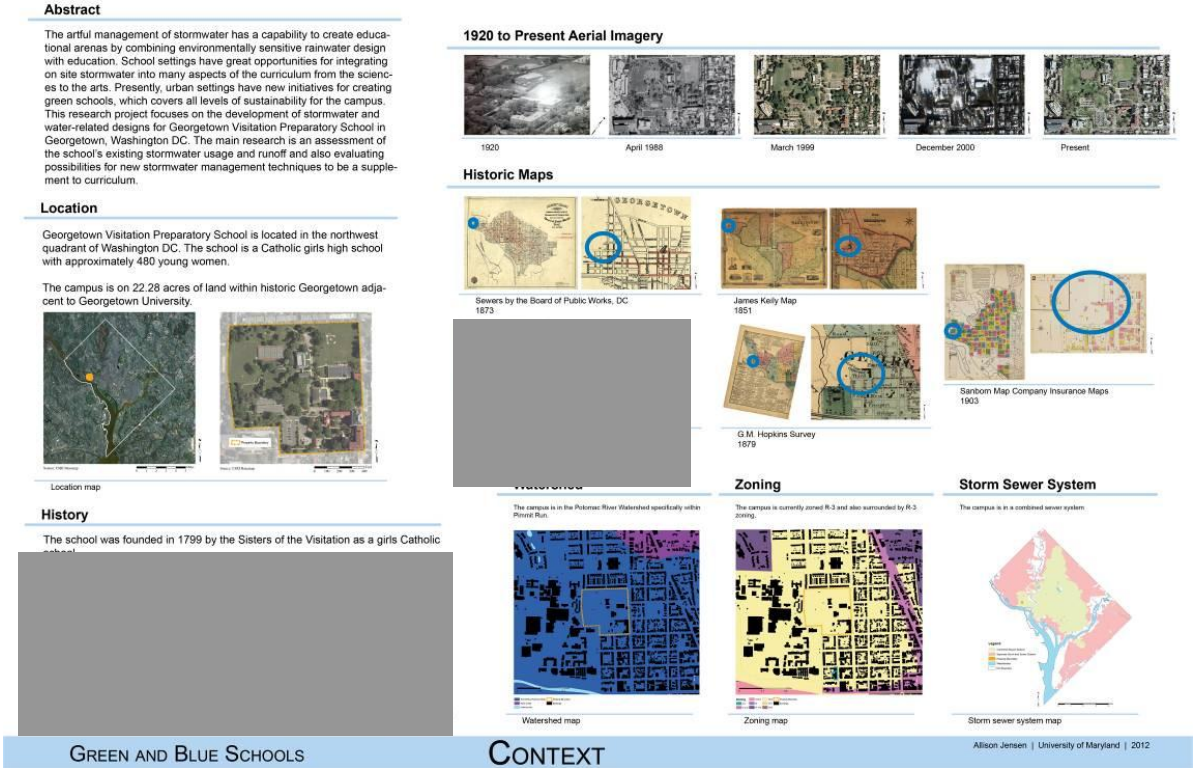
Group D—Soils in this group have high runoff potential when thoroughly wet. Water movement through the soil is restricted or very restricted. Group D soils typically have greater than 40 percent clay, less than 50 percent sand, and have clayey textures. In some areas, they also have high shrink-swell potential. All soils with a depth to a water impermeable layer less than 50 centimeters [20 inches] and all soils with a water table within 60 centimeters [24 inches] of the surface are in this group, although some may have a dual classification, as described in the next section, if they can be adequately drained. The limits on the physical diagnostic characteristics of group D are as follows. For soils with a water impermeable layer at a depth between 50 centimeters and 100 centimeters [20 and 40 inches], the saturated hydraulic conductivity in the least transmissive soil layer is less than or equal to 1.0 micrometers per second (0.14 inches per hour). For soils that are deeper than 100 centimeters [40 inches] to a restriction or water table, the saturated hydraulic conductivity of all soil layers within 100 centimeters [40 inches] of the surface is less than or equal to 0.40 micrometers per second (0.06 inches per hour).

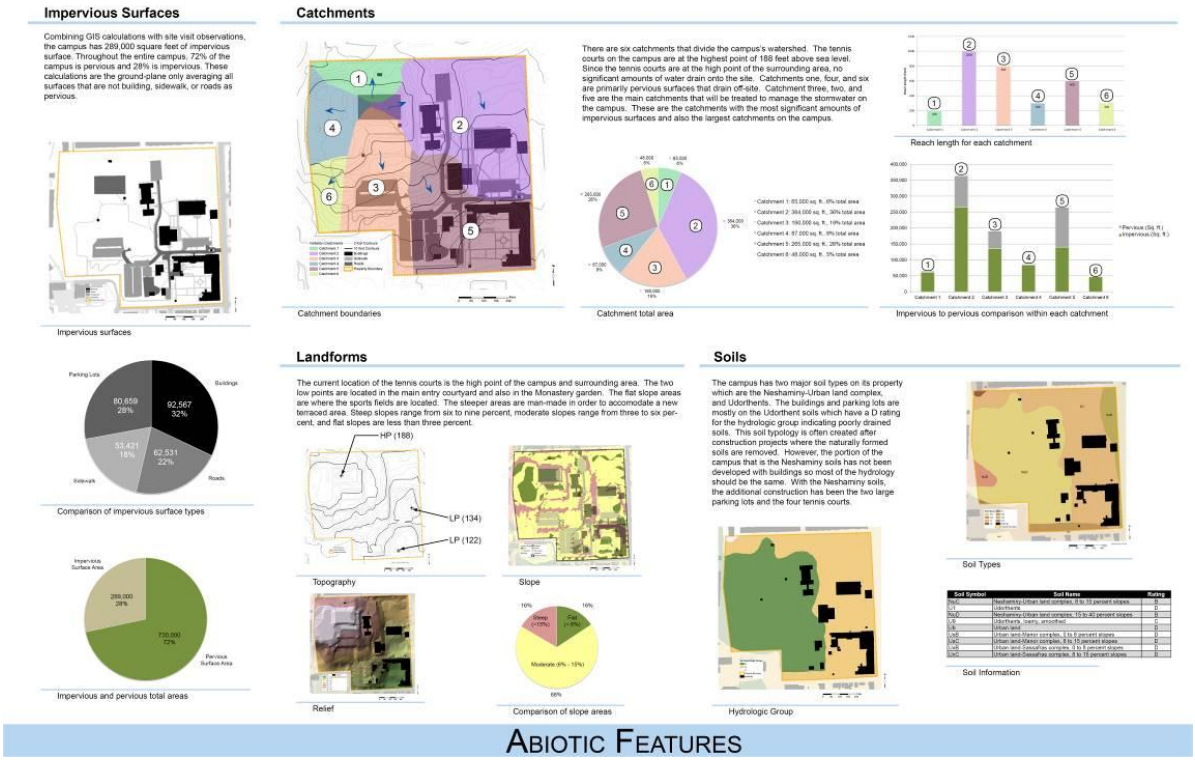
Appendix 6 – Stormwater Treatment Practice Ranking

This table was created to rank the stormwater features identified in the literature review against each other according to possibility for water benefits, environmental benefits, and educational benefits.

	Tool	Water Benefits			Environmental Benefits			Education Benefits		TOTAL
		Retention	Infiltration	Evapotranspiration	Biodiversity	Pollutant Removal	Air quality Improvement	STEM*	Humanities	
Alternative Surfaces	Green roofs (accessible)	💧💧💧	💧	💧💧💧	🌲🌲🌲	🌲	🌲🌲	🍎🍎🍎	🍎🍎🍎	19
	Green roofs (inaccessible)	💧💧💧	💧	💧💧💧	🌲🌲🌲	🌲	🌲🌲	🍎	🍎	15
	Permeable pavers	💧💧	💧💧💧	💧	🌲	🌲🌲🌲	🌲	🍎🍎	🍎🍎	15
	Reinforced turf	💧💧	💧💧💧	💧	🌲	🌲🌲	🌲	🍎🍎	🍎	13
Non-Structural Practices	Filter strips	💧💧	💧💧💧	💧💧💧	🌲🌲	🌲🌲🌲	🌲	🍎🍎	🍎🍎	18
	Vegetated buffers	💧	💧💧💧	💧💧💧	🌲🌲🌲	🌲🌲	🌲🌲🌲	🍎🍎	🍎🍎	19
	Increased tree cover	💧	💧💧	💧💧💧	🌲🌲🌲	🌲🌲	🌲🌲🌲	🍎🍎🍎	🍎🍎	19
Micro-scale Practices	Bioretention cell/Rain Garden	💧💧💧	💧💧💧	💧💧	🌲🌲🌲	🌲🌲🌲	🌲	🍎🍎🍎	🍎🍎🍎	21
	Swales	💧	💧💧	💧💧	🌲	🌲🌲	🌲🌲	🍎🍎	🍎	13
	Dry wells	💧💧💧	💧💧	💧	🌲	🌲	🌲	🍎🍎	🍎	12
	Infiltration trenches	💧💧💧	💧💧💧	💧	🌲	🌲	🌲	🍎🍎	🍎	13
	Level Spreaders	💧	💧	💧	🌲	🌲🌲	🌲	🍎	🍎	9
	Rain barrels	💧💧💧	💧	💧	🌲	🌲	🌲	🍎🍎🍎	🍎	12
	Cisterns	💧💧💧	💧	💧	🌲	🌲	🌲	🍎🍎🍎	🍎	12

Appendix 7 – Presentation Boards





Description

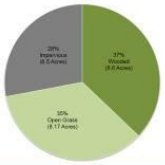
Vegetation over 4 feet tall or species that will become greater than 4 feet tall comprise 378,000 square feet (8.6 acres) of area on the campus. This is approximately 37% vegetation cover for the campus.

The remainder of the open vegetated areas are turf which comprises 8.17 acres which is 35% of the total campus including the area underneath the canopy trees.

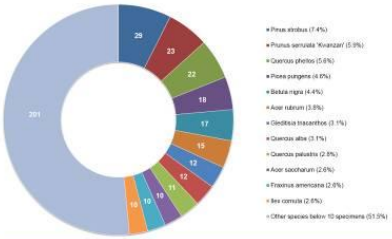
The majority of trees are in an open setting and healthy. There is a small forest located in the area that has a very steep slope. There are 390 tree specimens identified.

The vegetative cover under the trees is turf grass, groundcover, or small planted gardens. Beneath the pine trees is a typical pine needle cover. In the forested area, the ground cover is the typical deciduous tree undertrush.

Vegetation location map



Campus Canopy



Species richness

Pinus strobus
White Pine
29 on campus

Prunus serrulata
'Kwanzan'
Kwanzan Cherry
23 on campus

Quercus phellos
Willow Oak
22 on campus

Betula nigra
River Birch
17 on campus

Fraxinus americana
White Ash
18 on campus

Quercus palustris
Pin Oak
11 on campus

Acer saccharum
Sugar Maple
10 on campus

Quercus prinus
Chestnut Oak
6 on campus

Ulmus parvifolia
Lacebark Elm
6 on campus

Carya illinoinensis
Pecan
2 on campus

Fagus grandifolia
American Beech
1 on campus

Quercus coccinea
Scarlet Oak
1 on campus

VEGETATION

Description

There are 275 parking spaces on the campus. The total area of the parking is 80,659 square feet (1.8 acres). Events on the campus that include all four academic grades would potentially result in 480 vehicles on the campus. The Christmas Gala also includes neighborhood guests which could result in more vehicles. Sport events also include a large amount of parking need with the other team's transportation. There is some parking possible in the neighborhood streets, but that is not openly advertised. Parking is very tight in the surrounding neighborhood. A carpool parking discount on parking exists for the students, but carpooling laws prohibit drivers from having too many passengers. Approximately half of the student population has a sibling on campus so most of the carpooling is among family.

Parking lot location map

Main Entry Parking

21 parking spaces
11,051 Square Feet

The main use for this parking area is the three lane drop-off and pick up area that parents use in the morning and afternoon. The three lanes are fully used during drop off and pick up times. Most of the students travel to campus via carpool by parents. Some students use the Metro system and public transportation and enter campus through this gate. The parking spaces are for visitors. The lot is the main entry driveway to the campus with the guard house at the entry drive. The asphalt is bounded with concrete curbs and is in fair condition. There is a large stormwater drain in the second lane of the drop off and pick up area. A sidewalk runs through the lot that connects Founders Hall and the Father Athletic Center.

Monastery and Maintenance Parking

7 parking spaces
2,943 Square Feet

There are two covered parking spaces reserved 24 hours for the Monastery. Farther down the driveway is unmarked parking for the maintenance vehicles. The asphalt is in fair condition and the water runs into a concrete swale away from the building.

Faculty and Staff Parking

14 parking spaces
4,029 Square Feet

This lot appears to be for faculty and staff. The southern portion of the lot is for maintenance and behind a wooden fence are the dumpsters.

South Lot

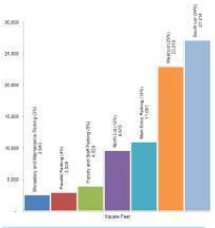
117 parking spaces
27,214 Square Feet

This is the main student lot which holds the largest amount of vehicles. There is a center median that has a curb cut on the lowest piece, but there is no inlet so the only water in the median is the water that immediately falls in the median. All the water drains to the south border of the lot where a large inlet is located.

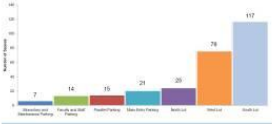
West Lot

78 parking spaces
23,019 Square Feet

This is the second student parking lot. During the day, the students rarely return to their cars as the lot is only used for parking and their walking into the main building. The lot is used during the summer for a drop off area for the summer camps. This parking lot is mostly curbed, but the east and west sides have an open section. A center median has a concrete diverter for water to pass through, but there are no other water uses for the median. The trees planted will become significant shade trees in the next 15 years. The north border is a steep hill which has been converted to an unmowed grass hill. This shows that the maintenance staff is already receptive for changing behaviors.



Parking lot area



Number of parking spaces in each parking lot

Parallel Parking

15 parking spaces
5,028 Square Feet

These parallel parking spaces are along the road that leads up to the St. Bernard Library and St. Joseph's Hall. The spaces are surrounded by curbs and a sidewalk.

North Lot

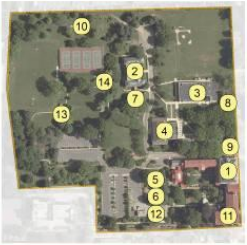
25 parking spaces
8,670 Square Feet

This is the most secluded parking lot on the campus. It is used by maintenance for some storage and the northwest corner has a gravel driveway leading farther into the campus. This lot is used during sport events for team bus parking. The lot has curbs on one side, but none on the other. The center has an area drain. The high amounts of gravel and sand would indicate that water stows here and the lot is not as frequently used as the other lots on campus.

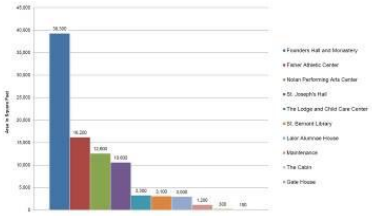
PARKING

Description

The campus has 12 permanent buildings and two open gazebos. The building footprints range from 39,300 square feet of the Founders Hall and Monastery to 150 square feet on the gate house.



Building location map



Building Footprints

1 Founders Hall

39,300 square foot footprint

This is the main academic building and oldest building on campus dating back to 1973. This building is attached to the Monastery on the southern end where students are not allowed to go. The cafeteria is on the bottom floor which has an exit to the main courtyard that the students can sit in for lunch. There is no cooking on campus and either the students bring their own lunch or subscribe to the lunch delivery service. It was severly damaged in 1993 by fire and subsequently has been fully restored. Located between Founders Hall and the Monastery is the Chapel of the Sacred Heart which is a quiet place for prayer and reflection.

2 St. Joseph's Hall

10,600 square foot footprint

This is the academic building for the science, math, art, and history departments. The western portion of the roof has some flat areas, but since the building is older, it may not support any additional weight on the roof. This building was renovated in 2004.

3 Fisher Athletic Center

16,200 square foot footprint

This building houses all the major indoor sports courts and is used as classroom space for freshmen and sophmore physical education classes which are held twice a week. The building is also used for health classes for the other grades. The most usage occurs after school and during the summer for sport practices of summer camps. This roof is entirely a flat roof which could support a green roof. This building was dedicated in 1998.

4 Nolan Performing Arts Center

12,600 square foot footprint

This is used for performances and on holidays, Mass is held in the main auditorium. The building includes reception rooms, a dance studio, rehersal space, and a stage. It was created through renovating the school's original gymnasium. A portion of the roof is flat which could supports green roof. This building was dedicated in 1998.

5 The Lodge

3,300 square foot footprint

This is the location of all the senior lockers and a hangout for them during their free period or after school.

6 Child Care Center

Part of the Lodge building

The program for this building is for children of faculty and other children from the community.

7 St. Bernard Library

3,100 square foot footprint

This library has computers the students can use during their free period or after school. This building is attached to St. Joseph's Hall by a covered breezeway. One hundred years ago, St. Bernard's Library was home to the Monastery's cows. It became a library in 1858 and was renovated in 2003 with the latest technology.

8 Lalor Alumnae House

3,000 square foot footprint

This building is used for the Development Office and Alumni Affairs. This building holds small receptions, but most of the formal events are held indoors are in the Main Parlors of the Academy Building.

9 Gate House

150 square foot footprint

The campus is guarded all day and night and throughout the year because the campus is also a home to the sisters who live in the Monastery.

10 The Cabin

300 square foot footprint

The building is used for some maintenance storage and also is surrounded by a small vegetable garden.

11 Monastery

Attached to Founders Hall

The Sisters of the Visitation live in this building. Their daily activities include daily prayers and walks around the gardens and campus paths. The Monastery has its own kitchen and chapel for the Sister's nine daily prayers.

12 Maintenance

1,200 square foot footprint

There are 2 maintenance buildings; this is the main building.

13 West Gazebo

250 square foot footprint

This has a table with chairs with seating for approximately 10 people. The foundation is concrete with a step.

14 East Gazebo

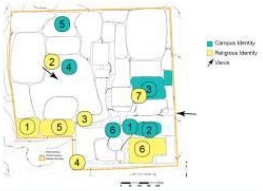
230 square foot footprint

This has a movaeble table with chairs with seating for approximately 5 people. The foundation is concrete and level to the ground.

Buildings

Description

As an urban campus, there are still areas of infrequent use and well-preserved trees. Campus usage is identified from the student persepective and how the students use the campus. The usage was identified mostly by site visits and observation. Intensity levels were by daily, weekly, and monthly use frequencies.



Location map

Campus Identity

The Green Gate was once used as the locked door for the campus. Now it is used during the graduation ceremony as a treasured rite of passage.

The Quadrangle is where the students can sit and eat lunch during the fall and spring months. This area of campus is used for picnics, welcome events, and father's club picnics.

Willow oak canopy over main entry driveway

View from the north west playing field to the Washington Monument on the National Mall

The Cabin has been on the campus as one of the original buildings

The Lodge is the location of all the senior lockers and a hangout for them during their free period or after school

Religious Identity

Statue by tennis courts

Statue north of the south parking lot

Statue south of the south parking lot

Statue south in the cemetery

Cemetery. Approximately 3/10 acre

River birch grove with a prayer path

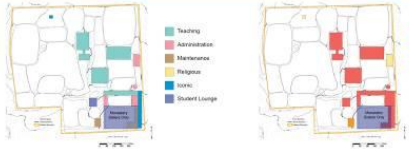
Monastery gardens.

Statue in the willow oak main entry courtyard

Open Space - Use and Intensity of Use

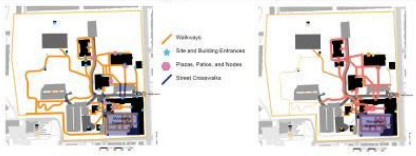
Active, passive, and conservation areas.

Buildings - Use and Intensity of Use



Teaching, administration, maintenance, religious, iconicspaces, and the student lounge.

Pedestrian Circulation - Type and Intensity of Use

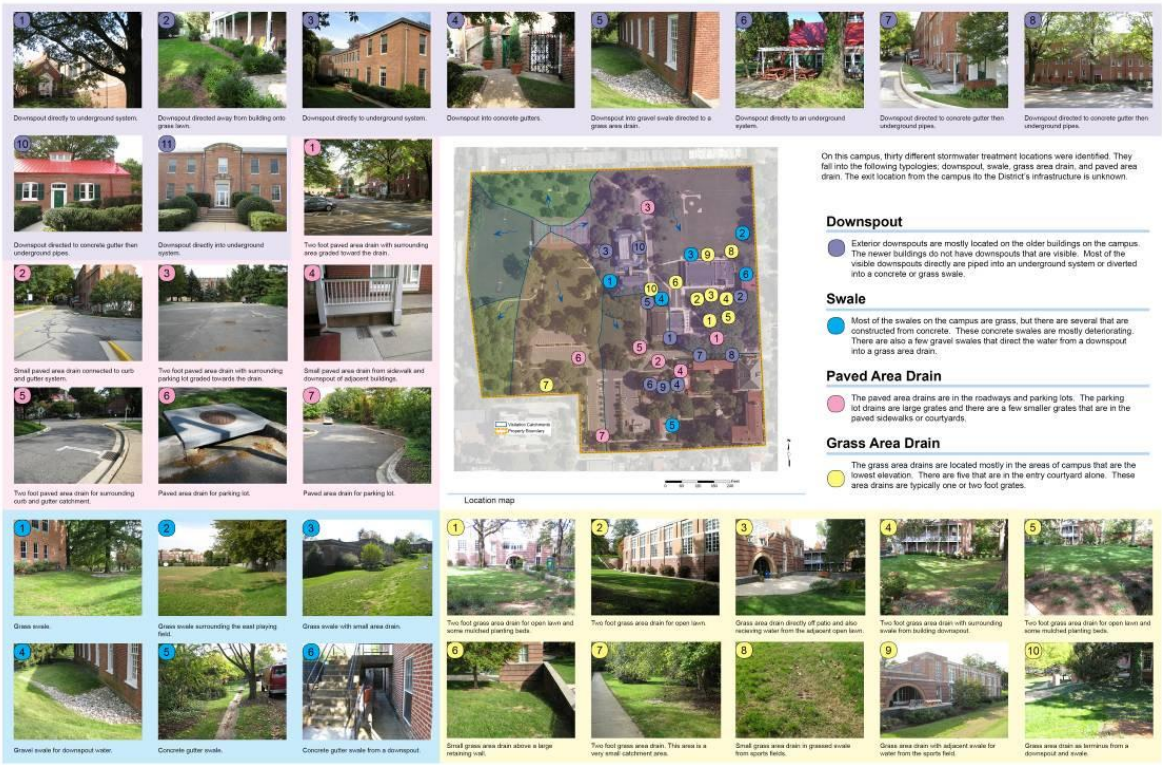


Walkways, site and building entrances, plazas, patios, and crosswalks.

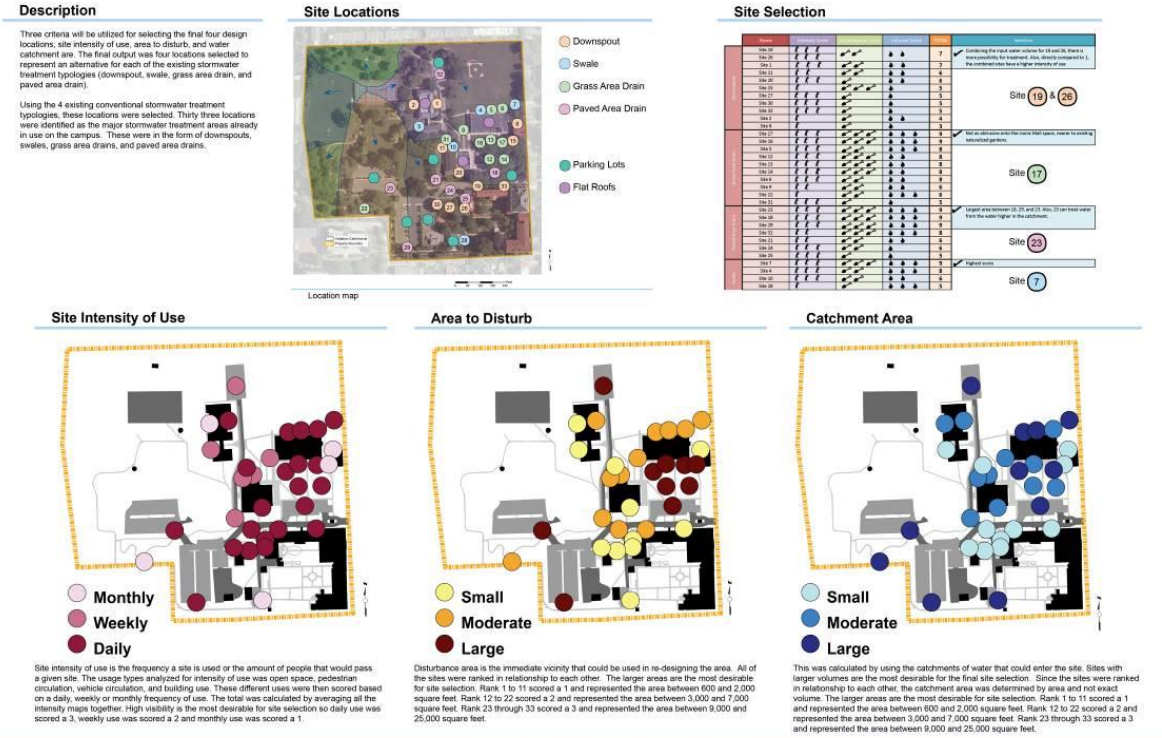
Vehicle Circulation - Type and Intensity of Use

Streets, site entrances, passenger drop-off zones, parking areas, and service areas.

Campus Use



Existing Stormwater Treatment



Design Site Selection

Lalor House Learning Garden

This site is located at the end of the largest catchment on the campus and is one of the low points with topography. The soils in this area are very poor especially because this site specifically was a parking lot and therefore has poor drainage. Directly north between the athletic center and the alumnae house is a steep slope. The athletic center was built in 1997 and its downspouts go directly into the underground system. The athletic center has a flat roof which may be able to accomodate a green roof. This site has a very high visibility to guests especially since it is so close to the main entrance.

Issues

- Lack of infiltration
- No educational opportunity
- No biodiversity
- Poor soil quality due to construction
- Space not usable because disconnected from paths

Goals

- Increase infiltration
- Design education opportunities
- Increase biodiversity, native plants
- Create connected spaces
- Connect with athletic center patio
- Treat all water from mall area
- Expose stormwater in an artistic design

Location

Location map

Photographs of the Site

View north east over the design site

Current grass drain inlet

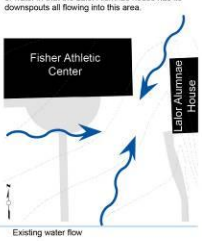
West view towards the athletic center

View from the existing sidewalk

View north between the athletic center and the Lalor Alumnae House

Current Hydrology

This location is the lowest point of the willow oak mall and frequently floods. The mall has five area drains which all address the high amounts of flooding. This location has an added source of water in that the Lalor Alumnae house has its downspouts all flowing into this area.



Existing water flow

The catchment area is 47,678 square feet. Using formulas designed by the Maryland Department of the Environment's Environmental Site Design Standards, this catchment will produce 973 cubic feet of water during a 1.2" rain storm. Using additional calculations, this amount of water can be treated in a rain garden that has a 2,860 square foot area. This assumes that the rain garden will have a six inch ponding depth, three inches of mulch with 0.4 porosity and one foot of added planted soil.

Catchment area

Precedent Images

Sukahanna Rain Garden in Arlington, Virginia

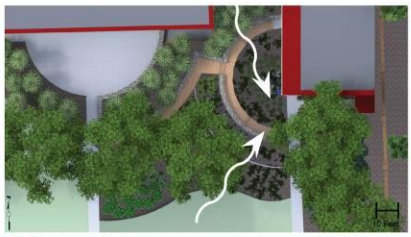
GREEN AND BLUE SCHOOLS — GRASS AREA DRAIN — Allison Jensen | University of Maryland | 2012

Lalor House Learning Garden

This design uses the same forms as with the new athletic center plaza in front of the main entry. The circular pattern radiates from the sidewalk and then surrounds the low point. The walkways are raised from above the rain garden about one foot. The height from the ground increases when closer to the rain garden. The weirs step down to the lowest point. The students can enter the rain garden easily by entering next to the existing walkway leading to the athletic center. That part of the path is flush with the ground, but then steadily slopes down to the low point. The wall attached to the main path is 18 inches tall for a seat wall in order for students to be able to sit. The center of the rain garden is close enough to the Lalor Alumnae house so that in a storm a class could still go to the rain garden and be under the covered porch of the house. There are three small sets of stairs in the middle of the walkways, but all the areas by the sidewalks are level

Stormwater Management Tools

- Permeable Pavers
- Vegetated Buffers
- Increased Tree Cover
- Bioretention Cenn/Rain Garden
- Rain Barrel



Plan View with water flow direction

Aerial oblique showing the pathways and stairs and the weir

View from the sidewalk by Lalor House

View from the sidewalk to the Athletic Center

View into the rain garden from the boardwalk

View from the existing center sidewalk

GREEN AND BLUE SCHOOLS — GRASS AREA DRAIN — Allison Jensen | University of Maryland | 2012

Green Gate Plaza

This site has a very high visibility for students because it is the main pathway to go between the academic buildings on the campus. This area has significance for the students because the Green Gate was historically the only entrance to the buildings and it would be locked nightly by the sisters living at the monastery. The Gate is especially significant during the graduation ceremony when the seniors walk through the gate as an important rite of passage. There are four downspouts that immediately enter this area and more water is added with the road runoff.

Issues

- No educational opportunities
- No biodiversity
- Unattractive
- Pedestrian disconnected with an awkward street crossing
- Concrete swales in poor condition
- No seating

Goals

- Design education opportunities
- Increase biodiversity, native plants
- Treat all water from adjacent rooftops
- Expose stormwater in an artistic design
- Create pedestrian emphasis space
- Exemplify green gate

Location

Location map

Photographs of the Site

View from the south towards the Gate

The Green Gate

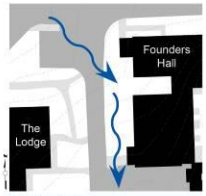
Planting bed between the main walkways

Downspouts from Founders Hall

Downstream swale area

Current Hydrology

Existing water flow comes from the adjacent street and most significantly from the surrounding buildings. The water flows past the plaza into a concrete swale that moves farther south.



Existing water flow

The catchment area is 12,297 square feet which includes both roof and ground plane areas. Using formulas designed by the Maryland Department of the Environment's Environmental Site Design Standards, this catchment will produce 799 cubic feet of water during a 1.2" rain storm. Using additional calculations, this amount of water can be treated in a rain garden that has a 737 square foot area. This assumes that the rain garden will have a six inch ponding depth, three inches of mulch with 0.4 porosity and one foot of added planted soil.

Catchment area

Precedent Images

Plaza at Sidwell Friends Middle School in Washington, DC

Green roof at Sidwell Friends Middle School in Washington, DC

Stormwater Collection in Arlington, Virginia

GREEN AND BLUE SCHOOLS — DOWNSPOUT — Allison Jensen | University of Maryland | 2012

Green Gate Plaza

This design creates a plaza around the Green Gate with seat walls as a new space for classes to meet or students to sit during the lunch break. This space also also has a more even flow for pedestrian movement so that students can more from class to class easily. This new plaza area will also be a new space for the graduation celebrations to take photographs. The movement of water will go beneath the walkway so only the patio directly in front of the green gate is completely level with the ground. Trench drains are put in at the intersection of the road and plaza to capture any excess runoff from the road. The adjacent road will also be rebuilt with permeable pavers the same as in the plaza to illustrate that the pedestrian space also continues into the roadway. The stormwater rain barrels are conical shaped urns thich when they are filled have small holes for the water to be released. These holes will release the water in an arc pattern into a lower urn which then will overflow into the rain gardens. These urns are surrounded by rain gardens so when the water is at a very slow flow the water will trickle durectly into the rain garden. The sides of the buildings will also have a trellace for plants to grow on to help cool the buildings.

Stormwater Management Tools

- Green Roof
- Permeable Pavers
- Vegetated Buffers
- Bioretention Cell/Rain Garden
- Grass Swale
- Infiltration Trenches
- Rain Barrels
- Cisterns

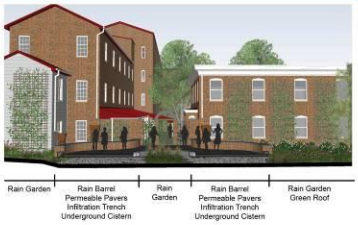
Plan View with water flow direction

Aerial Oblique Views

Aerial oblique view of the plaza

Aerial oblique view of the plaza

Stormwater Treatment Train



North view of the stormwater treatment train during a storm

Current photograph

Stormwater Urns

Current photograph

South View of Rain Garden

Current photograph

North View from Street

Current photograph

West View to Street

GREEN AND BLUE SCHOOLS — DOWNSPOUT — Allison Jensen | University of Maryland | 2012

35th Street Water Garden

This existing swale is on the east side of one of the main athletic fields. The field does have an underdrain, but still some runoff will go into the swale. The swale has a very good visibility from 35th Street through a metal rung fence. 35th Street has two lanes of parallel parking and two lanes of traffic. The street is also a main route for buses and traffic noise can be overwhelming. This area can become very hot with no significant shade and there is only one small bench for seating.

Issues

- Lack of infiltration
- No educational opportunity
- No biodiversity
- No shade, hot grass
- Only one bench for seating for the sports teams
- No buffer to 35th Street

Goals

- Increase infiltration
- Design education opportunities
- Increase biodiversity, native plants
- Increase tree cover
- Expose stormwater in an artistic design
- Treat all water runoff from the field
- Create buffer to the street
- Add seating

Location

Location map

Photographs of the Site

View north east over the design site

Current grass drain inlet

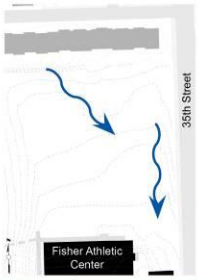
West view towards the athletic center

View from the existing sidewalk

View north between the athletic center and the Lalor Alumnae House

Current Hydrology

Existing water flow comes from the athletic field and the back yards of the townhomes to the north. Water from the street does not enter the swale due to the curb and gutter system.



Existing water flow

The catchment area is 59,113 square feet. Using formulas designed by the Maryland Department of the Environment's Environmental Site Design Standards, this catchment will produce 295 cubic feet of water during a 1.2" rain storm. Using additional calculations, this amount of water can be treated in a rain garden that has a 3,546 square foot area. This assumes that the rain garden will have a six inch ponding depth, three inches of mulch with 0.4 porosity and one foot of added planted soil.

Catchment area

Precedent Images

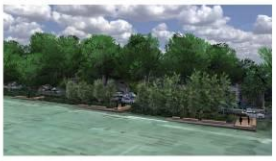
GREEN AND BLUE SCHOOLS — SWALE — Allison Jensen | University of Maryland | 2012

35th Street Water Garden

This design is based off of a division by three. Each section has a drop in elevation of two feet which is the same as the existing slope. The three sections will have plants that are decreasing in elevation which mirrors the increasing amount of water each successive section of the swale will recieve. The width of the sections also increases into the higher volume areas. As another feature, the three pattern is reflected by the benches. These benches are for the sports teams. The total length of the swale is 243 feet long with a 15 foot buffer on either end.

Stormwater Management Tools

- Permeable Pavers
- Filter Strips
- Vegetated Buffers
- Increased Tree Cover
- Bioretention Cell/Rain Garden
- Grass Swale
- Infiltration Trenches

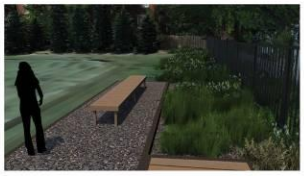


Aerial oblique of the three swale platforms

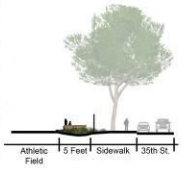
View from 35th Street

Plan view with water flow

Current view

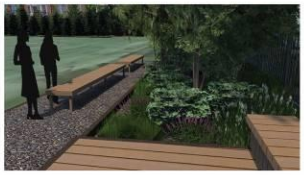


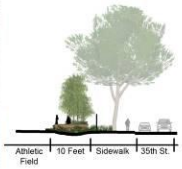
Proposed view



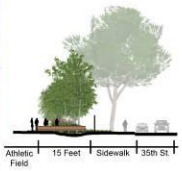
Section view

North Platform





Center Platform



South Platform

GREEN AND BLUE SCHOOLS — SWALE — Allison Jensen | University of Maryland | 2012

West Parking Lot

This is a the west parking lot and is the second student parking area. It is the farthest from all the academic buildings. It has 76 parking spaces and covers 23,019 square feet. There is a small grass median but it is raised and water is diverted around it ultimately into a storm drain at the south east end of the parking lot. During the summer, this lot is used by the summer camps as a drop off area.

Issues

- Lack of infiltration
- No educational opportunity
- No biodiversity
- Trees in the median have a restricted root zone
- No shaded parking
- Steep hill on the north side, access to the north fields is difficult

Goals

- Increase infiltration
- Design education opportunities
- Increase biodiversity, native plants
- Expose stormwater in an artistic design
- Add underground cisterns for field irrigation
- Install pedestrian paths to fields and academic buildings

Location

Location map

Photographs of the Site

View north east over the design site

Current grass drain inlet

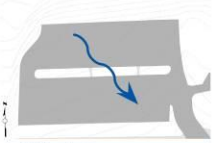
West view towards the athletic center

View from the existing sidewalk

View north between the athletic center and the Lalor Alumnae House

Current Hydrology

Existing water flow comes from grass areas to the north. There is a steep hill at the northern edge that drains onto the parking lot. All of this water flows into a storm drain that connects to the underground system which flows into the District's combined storm sewer system.



Existing water flow

The catchment area is 117,145 square feet. Using formulas designed by the Maryland Department of the Environment's Environmental Site Design Standards, this catchment will produce 3,538 cubic feet of water during a 1.2" rain storm. Using additional calculations, this amount of water can be treated in a rain garden that has a 7,028 square foot area. This assumes that the rain garden will have a six inch ponding depth, three inches of mulch with 0.4 porosity and one foot of added planted soil.

Catchment area

Precedent Images

Stamped concrete in Alexandria, Virginia

GREEN AND BLUE SCHOOLS — PAVED AREA DRAIN — Allison Jensen | University of Maryland | 2012

West Parking Lot

This area treats the parking lot as a new location for education and stormwater visibility. The parking spaces have permeable pavers and the driving lanes are composed of permeable pavement in order to demonstrate different types of methods for stormwater infiltration in a paved area. Crossing the center rain garden median are small boardwalks for pedestrian movement and added visibility for the stormwater treatment. Since the center median is nine feet wide, it can support larger trees. Some parking spaces have been removed in order to place rain gardens for overflow. This parking lot has 68 parking spaces. On the east side of the parking lot a sidewalk has been added for increased pedestrian safety. The parking lot maintains the natural slope averaging a six percent slope. Patterns were added to the permeable pavement area to illustrate the water flow. Another aspect of art added is in each parking space is a plaque with an etched drawing of a native plant or animal species.

Stormwater Management Tools

- Permeable Pavers
- Filter Strips
- Vegetated Buffers
- Increased Tree Cover
- Bioretention Cell/Rain Garden
- Grass Swale
- Infiltration Trenches

Aerial oblique of the parking areas around the center rain garden

View of the south side of the parking lot

View of the north side of the parking lot

Rain garden and artful pattern in the pavement

Median rain garden with mature tree

Median rain garden with boardwalk

Plan view

GREEN AND BLUE SCHOOLS — PAVED AREA DRAIN — Allison Jensen | University of Maryland | 2012

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