Implementing Sustainable Stormwater Initiatives at Eco-U

2008 Capstone Class
Environmental Science and Policy

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University of Wisconsin – Green Bay

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ABSTRACT

The goal of this year's graduate capstone class in Environmental Science and Policy was to build upon past works and collaborate with campus coordinators with the intent of implementing sustainable initiatives on the University of Wisconsin-Green Bay campus. The main focus of this section was to help the university exceed the requirements of its Municipal Storm Water permit of 40% Total Suspended Sediment by 2013. We targeted three areas: education & outreach, design of control devices, and modeling stormwater pollution. In the first section we focused on stormwater education and remediation. We established a basic educational lecture that was delivered to numerous general education classes and we performed a series of outreach programs intended to create awareness of stormwater impacts on the waters of Wisconsin. Now established, these programs can be replicated annually. In order to ameliorate the impacts of stormwater pollution running off the campus, we designed numerous control devices. The first is a green roof over the Instructional Services building. Pending approval of funding, this is scheduled to be implemented in the spring of 2009. We also designed and planned several additional control devices that could potentially be placed on campus to meet future stormwater requirements. Finally we analyzed the cost and effectiveness of each control device to develop optimal management strategies. These proactive measures combine educational awareness with sustainable management strategies and will serve to meet future stormwater regulations as well as exemplify the University's commitment towards environmental sustainability.

INTRODUCTION

Our 2008 Capstone graduate class decided to review stormwater recommendations made by the 2005 class, whose report (Forsberg, et. al. 2005) contains background on permitting regulations and delineates the process that UWGB will follow as it becomes its own stormwater permitting body. The students focused on ways to help the University meet the required reductions in total suspended solids (TSS) of 20% by 2008, and 40% by 2013, as stipulated by MS4 permit requirements. They investigated best management practices that include use of rain gardens, bioretention cells, treatment trains, wet detention ponds, constructed wetlands, infiltration basins and trenches, and porous pavement. A few of these options were recommended for use on the UWGB campus. We decided to evaluate the effectiveness of several of these best management practices and supplement current education and outreach efforts.

MS4 background and Clean Water Act

MS4 permits were created by a section of the Clean Water Act of 1987, with Phase I communities going into effect in 1990, and Phase II communities going into effect in 2000. Phase I permits were for municipalities which had populations greater than 100,000, and Wisconsin began regulating these municipalities in 1994. In August of 2004, as part of NR216 (WDNR 2004) Phase II changes, any entity with a population over 100,000 became its own MS4 permitting body. UWGB was discharging its stormwater directly into Green Bay or into Mahon Creek, which flows into Green Bay (Forsberg 2005). As a result, UWGB was required to become its own MS4 permitting body, instead of having it handled through the City of Green Bay as was previously done.

Additional Regulations

The purpose of the MS4 stormwater permit, as well as the Natural Resources Codes 216 and 151, is to help control non-point source pollution and improve water quality. These codes are important because recently, municipalities have built their stormwater systems to get rid of water as quickly as possible. As a result, any pollutants carried along with the water, such as oils, litter, fertilizers, salts, phosphorous, nitrogen, and soil particles were carried without treatment as into the nearest water body. Natural Resources Code 216 deals with Municipal stormwater as part of the Wisconsin Pollution Detection and Elimination System (WPDES) stormwater permits.

Implications for Municipalities

The most recent version of the MS4 permit, requiring the 20% reduction in TSS, became effective January 19, 2006 and will expire on December 31, 2010. The required 40% TSS removal will take effect in 2013. The University of Green Bay has already met their 40% TSS reduction. However, it is expected that this requirement will become even more stringent in the future, compelling UWGB to implement additional stormwater best management practices.

Capstone 2008 Project Goals

The 2008 Capstone stormwater group decided to focus on three different areas: education, design, and SLAMM modeling/Cost analysis. The education section identified different opportunities to inform students about all aspects of stormwater management and funding was sought for the Instructional Services Green Roof project. The design group investigated various designs for the green roof over UWGB IS building, porous pavement for part of Wood Hall parking lot, and bioretention cells to treat stormwater from Wood Hall parking lot and Weidner Center parking lots. The final objective was to use WinSLAMM, an urban stormwater modeling program, to model the various control devices developed by the previous group and evaluate their effectiveness in removing pollutants.

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Chapter 1

Stormwater Management -

Public Education, Outreach, Participation & Involvement

Lindsay Calvert
Katherine Disterhaft
Trisha A. Cooper

Introduction

Stormwater management is quickly becoming critical as municipalities attempt to maintain and manage declining fresh water resources. Municipalities now find that increasingly, these water supplies are contaminated with chemical compounds from fertilizers, herbicides, pesticides, animal wastes, car oils and fluids, and many household hazardous wastes. New water quality restrictions and regulations are taking effect through federal and state mandate. As part of changes to the Clean Water Act and Wisconsin Administrative Codes NR 216.07 and NR 151, the UWGB campus must meet stormwater runoff permitting requirements as a Municipal Separate Storm Sewer System (MS4). These codes focus on stormwater especially because in the past, municipalities built stormwater systems with the specific objective of removing stormwater runoff as quickly as possible. Only within the last ten years has it become apparent that stormwater runoff picks up many pollutants and sediment that is then carried directly into "waters of the state." In the case of the University, stormwater runoff adds total suspended solids, phosphorus, nitrogen and other pollutants into the bay of Green Bay and into Mahon Creek. The purpose of MS4 permitting is to help improve the water quality from this nonpoint source pollution. Compliance of MS4 permitting requires the university to meet several criteria. These stormwater permit criteria consist of the following:

A) Public education and outreach.

B) Public involvement and participation.

C) Illicit discharge detection and elimination.

D) Construction site pollution control.

E) Post-construction site storm water management.

F) Pollution Prevention.

G) Development and maintenance of a storm sewer system map.

Graduate students began work on achieving some of these stormwater management guidelines. Three key objectives for the public education team were:

1) Assist the UWGB campus in achieving MS4 compliance.
2) Achieve measurable results that comply with general permitting requirements.
3) Achieve funding to cover expenses of campus sustainability projects that meet the pollution prevention criteria of MS4 compliance.

Toward that end**,** Team 1 (Public Education, Outreach, Participation and Involvement) began taking several steps to achieve public education and outreach and implement public involvement and participation activities on stormwater issues on the University of Wisconsin - Green Bay campus.

Methods

As previously listed, the MS4 regulations include a stipulation that the institution should engage in education and outreach on stormwater issues. Our team took a multi-pronged approach to this goal. Although the results have sometimes been mixed, public education campaigns have resulted in measurable improvements in stormwater quality in residential areas (Dietz et. al., 2004). We chose to target students both inside and outside the classroom with in-class presentations and information tabling which have been shown to be some of the most effective methods at reaching students (Silverman, 2007). For education inside the classroom, we identified mandatory general education courses offered in the fall semester of 2008 at the University of Wisconsin-Green Bay. In order to cover the maximum number of students in a minimum amount of time, we targeted those courses with the highest student enrollments, between 115 to 250 students. Twenty letters of request for donation of class time (3-5 minutes) were emailed to professors (Figure 1). Thirteen professors responded, and 14 classes were visited. Graduate students gave power point presentations that gave students a basic background on stormwater issues and addressed simple actions students could take to prevent and control water pollution (Figure 2). The length of the presentation and the amount of material provided was restricted in order to respect the professor's limited class time. It is difficult to assess the exact number of students that were present for the presentations since many professors do not take enrollment on a daily basis and, for various reasons, students may not attend the class on the day of the presentation. For the class presentations, we have estimated presenting to between 1200 to 1780 students, if one uses 70% attendance and 100 % attendance for classes that varied in enrollment numbers.

Dear Professor:

As part of the 2008 graduate capstone course Seminar in Environmental Sciences and Policy, second-year graduate students have been working with campus staff and faculty in order to help the UWGB campus meet required guidelines as a Municipal Separate Storm Sewer System (MS4).   Compliance of these guidelines requires the university to conduct public education and outreach on stormwater issues.   As part of other steps the students are taking to assist the campus in meeting these guidelines, we are also seeking permission from selected professors for a donation of classroom time. We would like to come in during your class and spend 3-5 minutes talking to students on stormwater issues. We realize the inconvenience this may cause, but please consider this interruption not as part of a class project only, but also as a conscientious effort benefiting the campus through environmental education and meeting state requirements.

Attached please find our public education stormwater power point. This short power point covers some of the main stormwater topics that we would want to discuss.   We will be following up soon with a phone call to set up dates and times. Please consider donating class time for this effort.

Figure 1 - Letter to Professors

Figure 2 - Slides from Presentations

In addition to directly addressing classes, an outreach event was organized for public participation and involvement. Press releases and email notices inviting students to the stormwater event and asking for participation were sent out during the previous week (Figures 3 and 4). The event included two different activities organized for the same date. First, a special public appearance was made by "Ronnie Raindrop" a mascot to the stormwater group. The mascot idea was developed to create the public's association of rain and stormwater. Used several times throughout presentations, educational material, background photos in flyers and posters, as well as a public appearance of Ronnie, we believe the mascot helped to create a tie-in of stormwater to rain (see Figure 5). The mascot also increased public attention and initiated stormwater inquiries and discussions. Additionally during the outreach event, an information booth and poster were set up in a central location during high student activity. Informational brochures were distributed by Ronnie Raindrop and other graduate students. Approximately 250 stormwater brochures were distributed to the UWGB public (Figure 6). Capstone students also spoke with students, staff, and faculty about stormwater issues, answering questions and offering additional stormwater information.

For Immediate Release

November 5, 2008

The University of Wisconsin-Green Bay - Beginning Monday, November 10, 2008, The University of Wisconsin-Green Bay will be holding a Storm Water Event Week on the University campus sponsored by the Environmental Science and Policy second-year graduate students in collaboration with Public and Environmental Affairs Council. Events will include –

- Storm Water drain stenciling – Graduate and undergraduate students will be spray-painting storm sewer drains on the University campus with the message "Dump No Waste – Drains to Bay" or "Dump No Waste – Drains to Stream" since the campus storm water drains directly into these water sources.
- Special public events include student engagement by the "Storm Water Raindrop" on Monday at the Student Union between 11:30 and 1:00. "Raindrop" will be passing out informational literature on storm water and graduate students will be on hand to answer questions and discuss storm water issues and concerns.
- Graduate students will also be addressing undergraduate students during regular class time in order to increase awareness of new and stricter water quality guidelines.

Figure 3 - Press Release

ALL HANDS ON DECK – here is a request for all Capstone and Perspectives students to come and support our own efforts on campus.

WE NEED PEOPLE TO HELP WALK AROUND TO THE STORM SEWER DRAINS ON CAMPUS AND PAINT THE DRAINS WITH THE "DUMP NO WASTE" STENCILS! <u>THIS MEANS YOU OF COURSE!</u> It will be a great opportunity to get something done for the campus and the community. So if you are available, please send an email and tell us what time you are available to help get this job

Figure 4 - Email to Graduate ES&P Students and PEAC members

Figure 5 - Ronnie Raindrop Mascot (in various appearances)

Storm drain stenciling, a complimentary stormwater activity, was planned and organized for the same day as the Ronnie Raindrop appearance and the stormwater tabling event. Storm drain stenciling was an activity arranged and conducted in collaboration with the UWGB student organization Public and Environmental Affairs Council (PEAC). PEAC had been working on the details of stenciling the storm drain when student members, who were also capstone students, decided to work on the project in cooperation, meeting environmental objectives from both PEAC and capstone. PEAC covered the costs of printing colored stormwater handouts that were prepared for the special event. Several students responded to the public announcements and emails and volunteered their time. Approximately 120 UWGB storm drains were stenciled with the phrase "Dump No Waste, Drains to Bay." In applicable cases, stenciling stated "River" or "Stream" depending on the water resource. Some professors gave extra credit to students participating in the stenciling event and this increased participation and awareness.

Some funding opportunities were researched to assist covering the expenses of campus environmental projects as well. Specifically, funding was sought for the Instructional Services

Green Roof project which was being researched by other team members within the stormwater group. A formal request was made to the Student Government Association (SGA) meeting using a short explanatory presentation covering the details of the design and layout aspects of the IS green

RAIN DROPS KEEP RUNNIN' DOWN THE DRAIN

Storm water on campus runs down storm drains and into streams, rivers, and the bay of Green Bay - UNTREATED

Storm water picks up….

- oil
- grease
- fertilizers
- pet wastes
- lawn clippings
- other contaminating particles
- soil & sediment
- leaves

Contaminants and sediment lead to….

- increased algae growth
- unpleasant odors
- beach closings
- decreasing fish and wildlife
- health warnings
- drinking water restrictions
- fish consumption restrictions

(How You Can Help →)

We all need to work toward the goal of cleaner water. We can have an impact on water quality. Here are some ways that you can have an impact.

HOW YOU CAN HELP!!

- Never dump anything into storm sewers or ditches! It goes directly into our water!
- If you spill fluids from a vehicle use cat litter to absorb it and then place that material into the garbage.
- Use phosphorus-free soaps, detergents, and fertilizers.
- Compost leaves and grass clippings and do not put them into the street.
- Consider using non-toxic cleaners such as baking soda, lemon juice, and vinegar.
- Be careful not to over-use fertilizers, pesticides, herbicides, or cleaners.
- Consider going pesticide and herbicide free. It's healthier for you and nature!

roofing and followed by a short question and answer period. We expect SGA to take a vote on funding the project in January when they resume after winter break.

Figure 6 - Stormwater Education Handout (Front & Back)

Discussion

In 1976, the United Nations created a goal statement for environmental education. Environmental education's purpose is to create a world population who is aware and concerned about environmental problems; global citizens who have knowledge, skills, attitudes, motivations, and commitment to work towards solving existing environmental problems while preventing new ones. In 1978 during the world's first intergovernmental conference on environmental education the following objectives were created:

- To foster clear awareness of and concern about economic, social, political, and ecological interdependence in urban and rural areas;
- To provide every person with opportunities to acquire the knowledge, values, attitudes, commitment, and skills needed to protect and improve the environment;
- To create new patterns of behavior of individuals, groups, and society as a whole towards the environment (North American Association for Environmental Education, 2000).

These ideas have been the founding guidance of environmental education programs occurring globally. Environmental education is often about social actions and learning to make a difference (i.e. choosing to buy sustainable, local produce because it benefits a community on multiple levels rather than simply returning immature fish to the lake when caught because it is against the law to keep them). Understanding the rationale for environmental choices and behavior are critical to the education process in environmental education. An example of the strength of this type of learning is made clear in "Exploring the Environment and Issues of Social Concern." This article explains how children teach adults, their parents, about sustainability practices (Griffin-Wiesner & Maser, 2008). Griffin-Wiesner and Maser observe that children learn new concepts such as stormwater and how they can help prevent stormwater pollution. These same children then return home and tell their friends and family about their new discovery. This creates awareness and produces potential change in the behavior of others. Creating change in the behavior of individuals is the imperative in environmental education; so too it is the critical point in teaching students about stormwater at a higher education facility.

In talking to students during the stenciling and stormwater events, we found that most students did not know what stormwater was and did not know they could play a part in protecting the water quality of stormwater. One important point was that most students did not understand the differences between stormwater and sewage water. Many students do not understand that stormwater flows directly into water resources; once it disappears down the storm drain, it effectively disappears from thought as well. Also, we found that there was a wide range of interest levels in water quality issues. Some students simply did not care about water quality or stormwater. We did find that many students were interested in water issues for environmental reasons.

It was surprising to learn how often educated adults did not know what stormwater was, did not understand the importance, and did not know the impact their actions at home had on water quality. Continued stormwater and water quality education would certainly have a positive effect on facilitating change in individual actions and behaviors toward water management. One cannot change behaviors if there is no understanding of the need to change.

Additionally, we found that most professors were open to having graduate students come into their classes for short presentations. An explanatory letter was necessary for some professors to understand that presenters were assisting the university in attaining mandatory public education rather than that students were only looking to attain individual class credits. Comments from professors and lecturers were always positive. Many were surprised at how well the topic fit into the subject matter of health, economics, and business. More than one professor thought presenting during each new semester course would be a positive action.

Class presentations were almost always positively received by the students. Keeping the discussion short and to the point seemed critical in maintaining students' attention and interest. While we did not have the benefit of additional time for questions and answers, comments by professors and lecturers indicated that students appreciated the presentation and seemed to benefit from it. We suggest that these presentations continue each semester and an additional two or three minutes for more in-depth coverage be sought from the lecturing professor, if at all possible.

Recommendations

Through the efforts and accomplishments of this year's capstone group, the Public Education team would like to offer several recommendations related to education, outreach, and funding.

- Continue class presentations. We consider it important that classroom education efforts are continued on an annual basis. This effort will inform and educate students and will help to change behaviors that may cause stormwater pollution. Not only is there evidence that this approach has an impact (Dietz et al., 2004) but there are some unique advantages to continuing this effort in a university environment.

- First, because of the inherent turnover in a university, continuing education efforts are not only required to achieve and maintain a high level of awareness, but also to provide a continuous stream of educated individuals into the community.
- Second, it is an indirect method of incorporating sustainability education into Eco-U's "green" objectives.
- Third, it will assist the UWGB campus in attaining MS4 permit requirements.

- Survey student body. As a way to refine and target the information provided in classrooms and at information tables, we suggest surveying the student population to determine the current level of knowledge and understanding of stormwater and water quality issues. This survey would also create a baseline of student knowledge and allow future public education and outreach efforts to be more effectively defined and tailored to fit the level of understanding and the general perspective of the student.

- Conduct annual stormwater public events. Maintenance and renewal of storm drain stenciling must continue yet consistent budget cuts leave limited funds available to accomplish this goal. An annual event contributes to overall stormwater awareness as well as providing a means of accomplishing storm drain maintenance and stenciling efforts by Eco-U.

- Incorporate sustainability into a project based course. The incorporation of sustainability into other project based courses could offer significant advantages to campus sustainability. Project based classes provide practical learning opportunities and a chance to expand UWGB's green mission. Depending on the purpose of the class, project based coursework can provide students with concrete insights into specific processes, introduce new material through discovery learning, or the chance to integrate the concepts of a subject while learning to implement those concepts (Helle et al., 2006). In a time where students have greater access to raw information than ever before, project based learning provides opportunities for using information in useful ways and teaching critical problem-solving skills that will make our graduates better prepared.

  The capstone class, for example, has been designed to encourage active integration and implementation of knowledge. As an example, part of the capstone project this year has focused on designing modifications to the green roof over the IS building. Included in this project was significant research on stormwater issues, mitigation strategies, green roof designs, mapping, and specific site characteristics, among many other related research avenues. Because of this project based course, capstone students will gain hands-on experience while the university will benefit from a green roof that works more efficiently, provides more aesthetically-pleasing and useful open green space and also demonstrates green roof technology for the community. This type of project based learning could be useful both at the graduate and undergraduate level and would benefit both the students and the university. This would also provide the UW Green Bay Sustainability Committee with a constant stream of ideas for improvements and a method for them to carry out projects.

- Incorporate sustainability as a general education requirement. As sustainability becomes an imperative, UWGB administration should consider offering sustainability courses as part of the general education requirement. More and more, sustainability is becoming very much a part of our daily lives through business, economics, education, health, and global awareness. The understanding of human impact and the mitigation of that impact on our limited natural resources should be a required learning objective within general education, especially when attending "Eco-U."

- Continue acquirement of outside funding specifically for sustainability and water quality issues. It is recommended that the UWGB campus seek outside funding specifically for sustainable projects on campus. Due to state budget restrictions, this additional stream of funding could enable more ambitious and long-term projects, and would allow students and staff the freedom to implement projects and programs that may be otherwise restricted by state administrative regulations and policies. Allocation of state funding is necessary to cover mandatory stormwater expenses as an MS4 yet we found that there was little flexibility in funding to accomplish these goals; alternative funding methods must be developed.

  Additionally, because students have a wealth of imagination, energy, and ability to think "outside the box" it is suggested that students have the opportunity, through project classes, to pursue creative funding opportunities. Project classes that are focused on grants and funding for sustainability projects would not only give students hands-on experience in researching, preparing, and writing grant proposals but also present opportunities for the campus to be an environmental leader. As a higher education facility that offers undergraduate and graduate degrees in environmental sciences and as a campus that is the only environmental campus in the northeast Wisconsin area, UWGB should aggressively seek opportunities to implement and highlight its environmental curriculum.

Conclusion

The capstone class of 2008 is proud to be a part of Eco-U. We acknowledge the limitations of state funding for environmentally progressive projects and programs, and we understand the difficulties of achieving and maintaining environmental leadership, yet as part of a higher education facility it is our deep conviction that UWGB should strive to attain certain goals as part of retaining the Eco-U moniker. Since we are discussing sustainability, we would like to take this opportunity to remind the administration that students represent unlimited sources of energy, imagination, creativity, and determination. A certain type of renewal resource that is still relatively untapped, so to speak. Past capstone classes have developed incredible ideas, concepts, and recommendations. And while capstone students continue on into the future, we hope that Eco-U's administration and faculty will carry UWGB into the future as well and implement some of these ideas and concepts and not just leave them to the archives.

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Appendix A

Submission of Request for Funding to Student Government Association

Storm Water at the University of Wisconsin Green Bay

WHEREAS the University of Wisconsin, Green Bay needs to meet its MS4 permit requirement from the Department of Natural Resources (DNR), as well as, Governor Doyle's campus sustainability challenge, and

WHEREAS education of the campus community is an integral part of meeting these MS4 permit requirements, and

WHEREAS the Environmental Science, Policy & Planning Graduate Capstone class hopes to provide an ongoing educational and storm water management opportunity to the UWGB campus by installing a green roof over part of the Instructional Services building, thereby facilitating UWGB's ability to remain in compliance with the DNR's MS4 permit, and

WHEREAS the Graduate Capstone class believes that providing financial assistance to the UWGB Facilities Management team will allow the green roof project to proceed in the spring of 2009, despite budgetary constraints, thereby meeting DNR MS4 requirements for education, as well as helping UWGB move towards meeting Governor Doyle's environmental sustainability challenge for our campus.

THEREFORE BE IT RESOLVED that SGA will request from SUFAC five thousand dollars to be allocated towards the creation of a green roof and educational sign.

THEREFORE BE IT RESOLVED the UWGB student senate will receive quarterly updates from the UWGB Facilities Management team in order to make sure the fees are being allocated according to the original intent of the project.

Author: UWGB Graduate Capstone Storm Water Group

Sponsor: Molly Collard and Shea Sternhagen

Chapter 2

Instructional Services Green Roof Project

Alice Billings

Abstract

Greenroofs have been used throughout human existence. Greenroofs reverse the effects of human development by restoring the pervious footprint of a building. This allows the building to exist for the benefit of society at the same time that it restores the ecosystem for the benefit of the larger environment. Greenroofs remediate stormwater runoff problems and reduce a building's carbon footprint. We currently have an opportunity to bring the benefits of greenroof technology to the UWGB campus. We are planning to create a greenroof over the IS building which is low maintenance but which is also accessible to the public. The recommended plot is a very suitable site for the installation of the amended current greenroof best management practices (BMP). This will be beneficial as the improved site will be very attractive with less work than is currently required.

Introduction

Greenroofs have been used throughout human existence. Norwegians long ago covered their homes with sod for insulation and planted them with grasses to make them more stable. During the middle ages, roof gardens were an important feature in wealthy homes, and one of the wonders of the ancient world was the hanging gardens of Babylon. By recalling the rich history of greenroof use for human habitation, and by pointing to the environmental benefits gained by employing this sustainable building technology, it is hoped that this trend will gain momentum in both urban and rural settings in the United States (Getter 2006).

In the industrial world, modern building practices have introduced significant amounts of impervious surface area into our ecological landscape. In the United States, it is estimated that 10% of residential developments and 71% to 95% of industrial areas and shopping centers are covered with impervious surfaces (Ferguson 1998). Before human development began disturbing natural habitats, soil and vegetation constituted part of a balanced ecosystem that managed precipitation effectively (Getter 2006). Greenroofs reverse the effects of human development by restoring the pervious footprint of a building. This allows the building to exist for the benefit of society at the same time that it restores the ecosystem for the benefit of the larger environment. Several aspects of greenroof design create this balance. One of the most important aspects is the drainage and water storage layer.

A standard roof surface replaces a natural habitat's pervious footprint with a man made impervious one, resulting in an increased volume and rate of stormwater runoff. In rural settings this can lead to swiftly flowing rivulets or streams which are more likely to create erosion events in their stream banks. In urban settings, an increased stormwater flow rate can overwhelm local sewer systems, causing them to overflow and spill untreated sewage into human habitats. In New York City, about half of all rainfall events result in a combined sewage overflow event (CSO). These CSO events dump 40 billion gallons of untreated wastewater into New York's surface waters annually (Cheney 2003). Whether the stormwater runoff is occurring in urban or rural settings, it is collecting pollutants from the impervious surfaces it contacts and, regardless of any other damage caused, it is carrying those pollutants untreated into our sources of potable water.

One way in which greenroofs remediate stormwater runoff problems is by reducing the volume of the runoff. Stormwater is soaked up by the soil and the plants, and if there is more water than these can hold, it is held temporarily in the water storage layer. Kolb reported that 45% of all rainfall which hits greenroofs is recycled through evaporation and transpiration. This means that the amount of stormwater from rainfall events which reaches the ground off of a greenroof is reduced in volume by approximately half compared to the amount which reaches the ground off of an impervious standard roof (Kolb 2004). Another way in which greenroofs address the stormwater runoff problem is by delaying the runoff. The water must flow through the soil barrier before it can get to the storage layer, and this process reduces the flow rate compared to the runoff rate from an impervious roof (Kolb 2004). By slowing the stormwater flow rate, we can greatly reduce the amount of stream bank erosion and the number of sewer overflow events.

Another way in which greenroofs remediate problems from modern building practices is by reducing a building's carbon footprint. This happens through extending the life of the existing roof by reducing its UV exposure. Ultra violet rays are one of the main sources of roof deterioration. Sometimes the life of the roof can be doubled compared to what it would be without greenroof remediation. Replacing a roof less often means a reduction in the amount of materials and man hours required to maintain a roof, and this equates to a lower carbon footprint. Lowering a building's carbon footprint also happens through deflecting the sun's light, and through plant transpiration. Greenroofs provide an opportunity for sunlight to be absorbed by plants instead of hitting and warming the building. Greenroofs also allow stormwater to be stored in the greenroof soil. The absorbed light causes the plants to transpire the stored water which cools the building resulting in reduced energy consumption and also in a reduced carbon footprint for that building. Greenroof components such as planting media, shade from plants and transpiration can reduce solar gain for a building by 90% compared to buildings without greenroofs (Cheney 2003).

Habitat loss for wildlife is also remediated by greenroofs. As is the case with stormwater, a standard roof surface replaces a building's living footprint with a nonliving one. When a greenroof is installed, that living footprint is restored (Getter 2006). While larger animals will probably not migrate to a green rooftop, many birds, insects, spiders, butterflies and squirrels are happier up there as the rooftop habitat is often more secluded from human contact than ground level habitat is. Keeping these aspects of the ecosystem strong goes a long way toward keeping the resources we depend upon secure.

We currently have an opportunity to bring the benefits of greenroof technology to the UWGB campus. The Instructional Services (IS) building has a rooftop sitting at ground level and planted with grass. This roof is not designed to current best management practices and is planted with turf grass which is not thriving in this location. Campus facilities management director Chris Hatfield would like to retrofit best management practices into this location and replace the dead grass with plants which will thrive there. To facilitate the retrofitting of best management practices, a preliminary test plot has been designated, and all of the planned work will occur there. When the retrofit of BMP's has proved successful, then as State budgets allow, greenroof technology will be expanded to the rest of the UWGB campus. Modern green roofs are categorized as either intensive or extensive. Intensive green roofs require intensive maintenance similar to ground level landscaping. Extensive green roofs require more minimal maintenance and are typically not accessible to the public. We are planning to create a combination of these two ideas in an extensive greenroof which is accessible to the public.

Methods

Current best management practices include several different layers (Figure 1). The first layer is the roof membrane which keeps water away from the building. The second layer is the membrane protection and root barrier which protects the integrity of the roof membrane. These layers are followed by an insulation layer which keeps condensation from forming over the roof. Next a drainage and water storage layer, the soil or growing medium and the plants chosen specifically to thrive in the chosen site.

Figure 1. Current Best management practices model (www.greenroofs.com)

Here we see the designated test plot location. The line of dead grass is obvious and marks the location of the IS roofline.

Figure 2. Picture of test plot site.

A UWGB alumnus, Neil Diboll, owns Prairie Nursery which has established many greenroofs in Wisconsin. He has recommended we draw appropriate plant species from the sand prairie plant list and refine the plant choice when soil samples are completed.

Diboll Prairie Nursery figure

Wildflowers:
Butterflyweed, Sky Blue Aster, Smooth Aster, Frost Aster, White Aster, Canada Milk Vetch, Lanceleaf Coreopsis, Purple Prairie Clover, Pale Purple Coneflower, Showy Sunflower, Downy Sunflower, Rough Blazingstar, Lupine, Dotted Mint, Beardtongue, Black Eyed Susan, Stiff Goldenrod, Showy Goldenrod, Ohio Spiderwort, Hoary Vervain

Grasses:
Sideoats Grama, Little Bluestem, Prairie Dropseed

Soil samples tests such as ribboning for clay content, sedimentation, pH and mineral analysis will be performed, with the help of Dr. Fermanich, on ten 2 inch soil cores from the test plot site to determine soil characteristics and continuity of characteristics across the whole site. These results will be used to finalize plant choices.

Community involvement will be an important factor in the success of this greenroof. Professors, alumni, graduate and undergraduate students and community members are taking part in making this project happen. This is an unexpected bonus, and a good sign for the greenroof's success, however it is also an important part of UWGB's efforts to meet its MS4 stormwater permitting goals.

Because of the current budget difficulties facing the State of Wisconsin, alternative funding for this greenroof has been sought. A presentation has been made to the UWGB SGA, and at the beginning of the spring 2009 semester the project will be proposed to SUFAC for funding through their Naturewise program. Other sources of funding are also being investigated.

Funding for the greenroof has been requested from the SGA. Here is an itemized list of expected expenses.

1. Removal of existing dead grass and preparation of the site = $ 0.00
2. Addition of soil to the prepared surface

   127 cubic yards of soil at a cost of $12.00 per cubic yard = $ 1,500.00
3. Addition of mulch to the soil surface =$ 0.00
4. Addition of plants to the site

   Cost of seed, potting soil, containers = $ 500.00

   Cost of purchased mature plants = $1500.00
5. Addition of a stone border at the west facing edge of the plot = $1,000.00
6. Addition of a sign = $500.00

Total = $ 5000.00

Results

Current best management practices will have to be modified in order to improve the IS greenroof performance while accommodating existing conditions. The siting of the IS greenroof test plot and the state of current conditions in that area were determined with the help of Chris Hatfield of Facilities Management. The existing roof membrane has been determined to be in good condition during recent construction in another area. The planned modifications will not disturb this membrane for fear of tearing it, therefore the protection layer and the insulation layer will not be installed. The IS greenroof at its western edge slopes down toward the Bay of Green Bay, and this slope functions as a natural drainage for the site. Because of this natural benefit, it is difficult to justify the expense of adding the drainage and storage layer, and it will be left out. The current plan calls for removal of the dead grass, addition of soil to total nine inches, the addition of mulch for weed control and moisture retention, and the addition of appropriate plants.

Soil tests will be used to determine the best plants for the proposed site. Clay content, pH, mineral content and continuity of consistency of the soil will be examined. Based on the performance of the existing grass, the expectation is that the best approximation of site conditions is described as sand prairie. The appropriate choice of plants for this site and the retrofitting of current BMP's will create a site which has a lower carbon footprint as it will require no watering, pre-emergent weed treatments, fertilizer or mowing and only minimal maintenance.

Community involvement has been an unexpected bonus of this project. Former UWGB alum, Neil Diboll, who owns Prairie Nursery in Westfield Wisconsin, has offered to assist us in choosing the best possible plant species to thrive in our site conditions. Dr. Dornbush has offered to have students assist in growing the greenroof plants in the Lab Sciences greenhouse. Dr. Fermanich has offered to have a community planting of the site included in the scheduled 2009 UWGB Earth Day events. Elements of the plant growing process will coincide with research which another graduate student is doing and so our work will benefit other research projects on campus. There is even a local Eagle Scout who will earn one of his final merit badges by building the information sign for us. All educational efforts surrounding this greenroof will count for the educational component of UWGB's MS4 stormwater permitting requirements which will aid Jill Fermanich in her work here on campus. Student involvement has also been requested through Student Government funding which will involve the UWGB student body in this project. Other sources of community funding and involvement are being explored.

Discussion and Conclusion

Facilities management would very much like to replace the existing grass and trees with a more sustainable option; however, doing this over the whole of the existing IS plaza presents some formidable problems. First, the height of the curbs surrounding the planting beds might have to be raised in order to accommodate the appropriate depth of soil. They would certainly have to be rebuilt in order to allow for adequate drainage from the planters. Also, full sized, beautiful trees would have to be removed in order for the new plantings to be installed. This would raise legitimate objections and would be difficult to justify when the proposed BMP’s are untested for retrofitting in this location. Removing large trees is also not a recommended step in maintaining carbon neutrality. In order to move forward with implementing successful new green roof technology unhampered by the previously mentioned difficulties, a test plot was recommended.

There is a rectangle of land over the west part of the IS roof which is an ideal place to create a green roof test plot. Current best management practices will be adapted to this site's specific conditions. Because it is preferable not to disturb the existing well functioning roof membrane, excavation for grass removal will be done to as shallow a depth as possible. Also, because the natural grade of the land allows stormwater to run off to the west down a gentle grass covered slope, it is difficult to justify the expense of the drainage/water storage layer. This layer will therefore not be retrofitted to this site. The test plot retrofitting will include removal of dead grass, addition of soil, addition of mulch and addition of drought tolerant, shallow rooting, low growing, low flammability plants.

In conclusion, the recommended plot is a very suitable site for the installation of the amended current best management practices. Current best management practices can easily be amended to fit the existing site without compromising the existing membrane performance. This will be beneficial for Facilities Management as the improved site will be very attractive with less work than is currently required. The successful implementation of current BMP's in this site will be a useful springboard for more adaptive greenroof retrofitting at other locations on the UWGB campus.

Recommendations

Our recommendations are to implement the modified best management practices in the Spring of 2009, using the recommended plant species suggested by Mr. Diboll and purchased through SGA Naturewise funding.

To prepare for a spring 2009 installation of the proposed greenroof, the following steps should be undertaken:

1. Soil cores taken in January 2009 to determine soil type, and consistency of that type within the overall site.

2. From the soil test results, plan which plant species to use, create a specific plan and present this plan for the approval of Chris Hatfield and all of Facilities Management staff.

3. When approval is granted, planting seeds in the Lab Sciences greenhouse before classes resume in January 2009 in preparation for planting on Earth Day in April, 2009.

4. When the snow melts and before planting day apply soil and mulch to the site, arrange final preparation of the paths and stone borders.

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Appendix A

Flowers **Species**	**Common Name**	**Plant Height**	**Rooting Depth**	**Flower Color**	**Bloom Time**	**Notes**
Allium cernuum	Nodding Pink Onion	1 - 2'	1 - 2'	White	July-Aug	Self sows
Allium stellatum	Prairie Onion	1 - 2'	1 - 2'	Lavender	July-Aug	Goes dormant in summer
Coreopsis lanceolata	Lanceleaf Coreopsis	1 - 2'	1 - 2'	Yellow	June-July	Self sows
Coreopsis palmata	Stiff Coreopsis	2 - 3'	1 - 2'	Yellow	June-Aug	Creeps by rhizomes
Dodecatheon meadia	Shooting Star	1 - 2'	1'	White	May-June	Goes dormant in summer
Geum triflorum	Prairie Smoke	6"	1'	Pink	May-June	Slow growing
Helianthus occidentalis	Western Sunflower	2 - 3'	1'	Yellow	July-Aug	Creeps by rhizomes
Liatris aspera	Rough Blazingstar	2 - 5'	2' +	Pink	Aug-Sept.	
Liatris squarrosa	Scaly Blazingstar	1 - 2'	2' +	Pink	Aug-Sept.	
Penstemon digitalis	Smooth Penstemon	2 - 3'	1 - 2'	White	June-July	
Penstemon ovatus	Broad Leaved Penstemon	1 - 3'	1'	Blue	May-July	
Phlox pilosa	Downy Phlox	1 - 2'	1'	Pink	May-June	Short lived (3-5 years)
Ruellia humilis	Wild Petunia	1 - 2'	1 - 2'	Violet	June-Aug	
Solidago rigida	Stiff Goldenrod	3 - 5'	2'	Yellow	Aug-Sept.	Self sows
Solidago speciosa	Showy Goldenrod	1 - 3'	2'	Yellow	Aug-Sept.	
Tradescantia bracteata	Prairie Spiderwort	1 - 2'	1 - 2'	Blue	June-July	Creeps by rhizomes
Tradescantis occidentalis	Western Spiderwort	1'	1 - 2'	Pink	June-July	Creeps by rhizomes
Verbena stricta	Hoary Vervain	2 - 4'	1 - 2'	Blue	July-Sept	Short lived (3-5 years)

Grasses **Species**	**Common Name**	**Plant Height**	**Rooting Depth**	**Flower Color**	**Bloom Time**
Bouteloua curtipendula	Side Oats Grama	2 - 3'	1 - 2'	Straw	Aug-Sept
Eragrostis spectabilis	Purple Lovegrass	1 - 2'	1 - 2'	Pink	July-Sept
Festuca ovina	Blue Fescue	1 - 2'	1 - 2'	Straw	June-July
Koeleria macrantha	Junegrass	2 - 3'	1 - 2'	Gold	May-June

Appendix B

Establishing a green Roof Neil Diboll

FIVE STEPS TO SUCCESSFUL PRAIRIEMEADOW ESTABLISHMENT

Prairie meadows are becoming an increasingly popular alternative to traditional high maintenance landscapes.

the prairie creates a haven for the native plants and animals with which we share this beautiful planet.

Prairie meadows require no fertilizers or fungicides, and few if any herbicides.

With prairie seedlings, significant long term savings result due to greatly reduced maintenance requirements. Any additional initial costs are usually recovered by the second year. Maintenance savings continue to accrue in following years, yielding very low "life cycle" costs for prairie meadows. Because native prairie flowers and grasses are almost exclusively perennials, they return to bloom year after year. A properly installed and maintained prairie meadow is a self-sustaining plant community that will provide landscape beauty for decades to come.

1) **Site Selection** Sunny, well-ventilated, with low weed densities
2) **Plant Selection** Match plants to the soil and growing conditions
3) **Site Preparation** Kill <u>ALL</u> the weeds before planting!
4) **Planting Time & Method** Spring vs. fall, no-till vs. broadcast, nurse crops
5) **Post-Planting Management** Mowing and burning

1. <u>Site Selection</u>

The area to be planted to prairie must be sunny, open, and well-ventilated. Prairie plants require <u>at least</u> a half a day of full sun. Full sun is best, especially for wet soils or heavy clay soils. Good air movement is also critical, as prairie plants are adapted to open sites that are not subject to stagnant air. Poor air circulation in closed in areas can lead to fungal diseases, which are seldom a problem on sunny, open sites. Beware of planting meadows in locations with adjacent weedy vegetation that cannot be eliminated or controlled. Although an established prairie meadow is resistant to invasion by most weeds, three to four years of growth is required for full development.

2. Plant Selection

Every plant is adapted to a certain set of growing conditions. Some will grow only on well-drained sandy or gravelly soils, while others prefer heavy clay. Some require moist soils, while others demand dry growing conditions. A few species can grow in almost any soil, be it dry sand, rich loam, or damp clay.

it is essential to select plants that are adapted to the specific site conditions.

it is very important to include a wide variety of different flowers and grasses to ensure year-round interest in the prairie meadow.

3. Site Preparation

Sod removal on lawns with no weeds, using a sod-cutter is recommended for our site

Irrigating the planting in the spring and summer of the first year during germination can greatly improve seedling development and survival, and is strongly recommended.

4. Planting Time and Method

Prairie seeds can be successfully planted during the following times:

- Spring thaw through June 30
- September 1 through soil freeze-up ("Dormant Seeding")

Planting in July and August is generally not recommended. Drought is common during this time, and late-planted seeds often do not have sufficient time to develop strong root systems before the onset of winter. If irrigation is available, planting can be extended until July 15.

The success of your planting is a direct function of the quality of the seed you plant.

We plan to plant seeds of specific species and grow them ourselves in the Lab Sciences green house to be ready to plant at the end of April 2009.

5.Post-Planting Management

As we are making specific plantings and not broadcasting seed, we will not have the same problems which a seeded prairie faces. We will have to make sure some water is given to the young plants in the summer so they can build their root base, then we will have to prune back dead plant matter each spring.

Results

For Full Sun to One Half Day Full Sun
Criteria for Green Roof Plants

1) Drought Tolerant
2) Shallow Rooting Zone (Note: Plants listed below with roots deeper than 6" can still thrive in green roof situations)
3) Low Growing
4) Low Flammability

Chapter 3

Exploring the Use of Low Impact Development Techniques at UWGB

Linda Filo
Julie Maas
Chandala Nagendrappa
Sarah Wingert

ABSTRACT

We considered porous pavement for part of Wood Hall parking lot and bioretention cells to treat stormwater from Wood Hall parking lot and Weidner Center parking lots. We selected these locations because they are located within Basin 15, which the EarthTech report identified as the largest basin with the least existing amount of stormwater control. We investigated porous pavement and used the RECARGA model to evaluate different bioretention cell designs. We selected porous concrete as the best porous pavement option. For Wood Hall, the best-performing bioretention cell design consisted of a three inch ponding zone, two foot rooting zone, and a two foot storage zone. The design for the Weidner Center was the same except for a three foot storage zone. Recommendations regarding the use of these designs are outlined.

INTRODUCTION

In 2005, EarthTech performed a stormwater pollution analysis for UWGB that estimated the annual sediment and phosphorus loadings for all storm sewer outfalls on campus (Bachhuber and Hanson 2008). This report includes estimates of loading under baseline conditions and existing conditions; the former assumes no best management practices are in place, while the latter includes the influence of existing stormwater best management practices (BMPs). The report found that UWGB's current stormwater BMPs reduce the campus total suspended solids (TSS) load by 42.4% (Bachhuber and Hanson 2008). This means UWGB is already in compliance with the Wisconsin Department of Natural Resources' MS4 General Permit, which states that UWGB must reduce its TSS load by 20% before 2008 and 40% before 2013 (Rasmussen 2005). Despite this success, we discovered that some areas of campus still have little to no stormwater control.

UWGB currently employs three BMPs to control stormwater: impervious surface disconnection, grass swales, and four wet detention ponds (Figure 3.1). Stormwater disconnection refers to the technique of directing runoff from impervious surfaces, such as parking lots, to adjacent pervious surfaces, such as wooded or grassy areas. This technique can increase infiltration of precipitation and reduce stormwater volume. Depending on the size of the pervious area, the runoff may then be funneled into the stormwater sewer system. Grass Swales along roads and parking lots can reduce the pollutant load of stormwater, and allow for some infiltration. They can be directed into the storm sewer or other forms of stormwater treatment, such as wet detention ponds. Wet detention ponds collect and treat stormwater in a constructed basin by allowing suspended solids to settle before the water is discharged into a stream. Thus, wet detention ponds can reduce pollutant loads and stormwater peak volumes during a rain event (Bachhuber and Hanson 2008). UWGB has four detention ponds on campus (Figure 3.1).

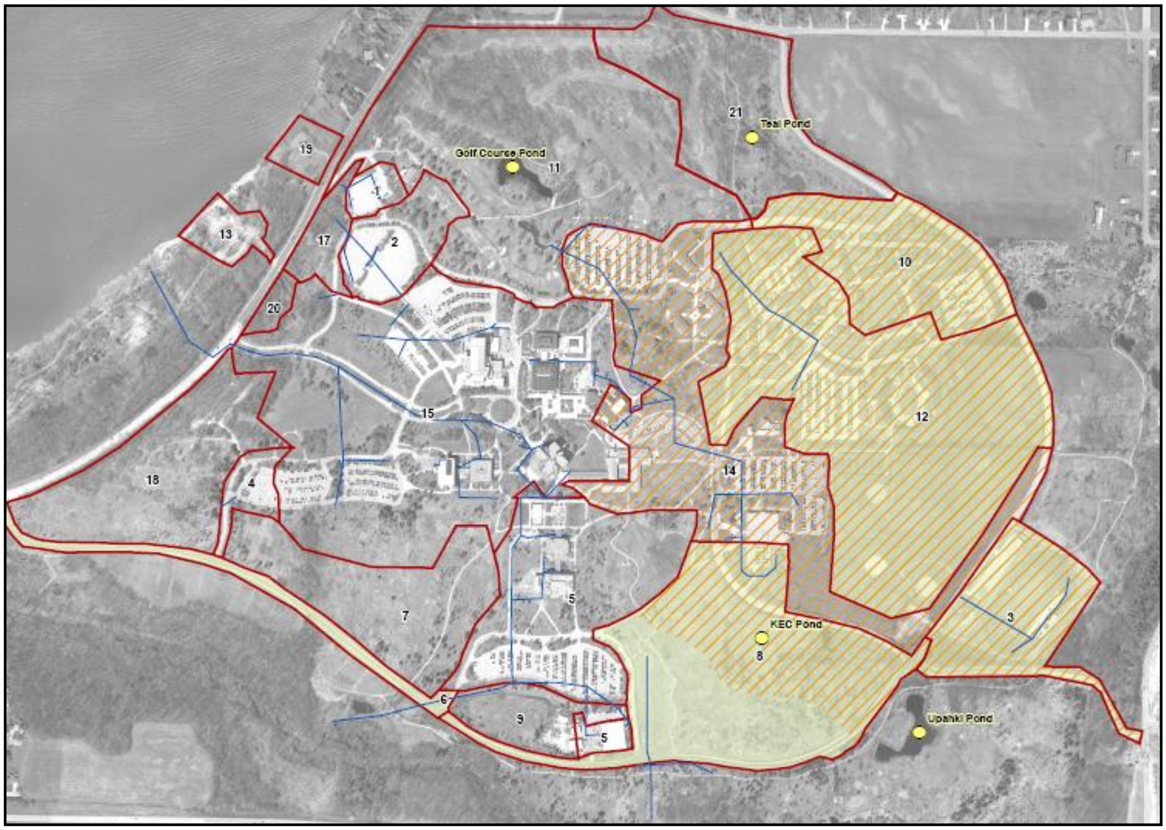
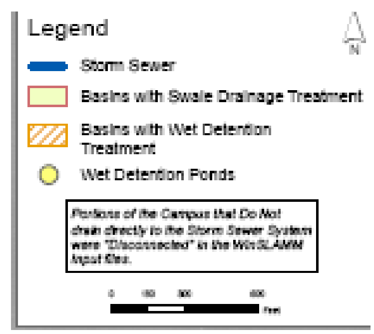
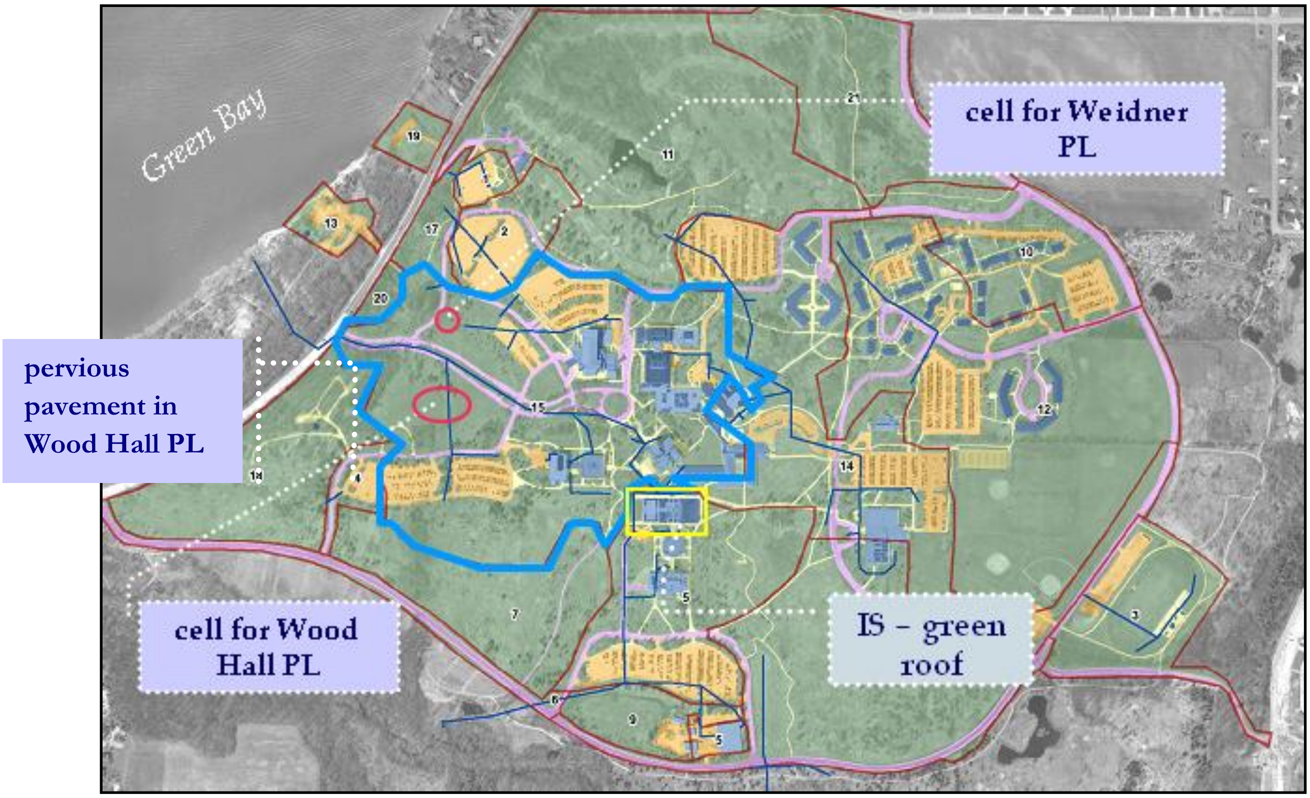


Figure 3.1: Existing Stormwater BMPs and Drainage Basins as Identified by EarthTech (2008)



EarthTech identified 21 drainage basins within the UWGB campus (Figure 3.1). The three stormwater BMPs are not equally distributed within these basins. Basin 15, highlighted in blue on Figure 3.2, is the largest sub-basin (76.5 acres), and is 34.7% impervious (Bachhuber and Hanson 2008). The runoff from this basin eventually drains into a single storm sewer outfall that empties directly into Green Bay. EarthTech found that only 0.1% of TSS and 0.3% of total phosphorus (TP) loadings are controlled by existing management in this basin (Figure 3.3) (Bachhuber and Hanson 2008). The only BMP employed in Basin 15 is impervious area disconnection.



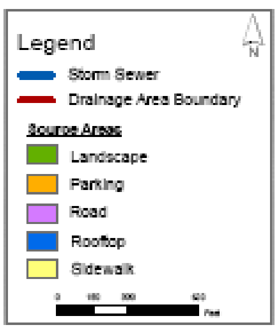


Figure 3.2: Basin 15, highlighted in blue, is the largest sub-basin on campus. Map adapted from EarthTech report (2008).

Table 3.1: Without stormwater control, Basin 15 discharges 9.36 tons per year of TSS and 55.91 pounds per year of phosphorus into Green Bay. Very little of this runoff is controlled by existing BMPs in the basin.

	TSS	TP
Base Condition	9.38 tons/yr	55.91 lbs/yr
Existing Management	9.36 tons/yr	55.76 lbs/yr
Percent Control	0.10%	0.30%

Project Objectives

We decided to investigate the use of two low-impact development techniques in Basin 15, since it is the largest basin with the least amount of stormwater management. The techniques we examined are porous pavement and bioretention, both of which are not currently used on campus. Low impact development techniques are relatively recent developments, but research has revealed promising results for stormwater management (Dietz 2007). Though Basin 15 does not have a wet detention pond, we did not consider this alternative due to input from the campus Facilities Management Department, which was not interested in developing another detention pond on campus at the time this project was conceptualized. A goal of our larger stormwater project was to investigate stormwater control techniques that have a possibility of being used in the future, in Basin 15 or elsewhere on UWGB's campus. Thus, the objectives of the design aspect of this project were to:

1. explore the feasibility of porous pavement and bioretention for use at UWGB;
2. identify possible locations in Basin 15 where these practices could be installed; and
3. tailor the design of the chosen techniques to control stormwater runoff in Basin 15, so they can be further analyzed using Source Loading and Management Model (see Chapter 4)

Low-Impact Development

The concept of low-impact development (LID) was developed in Prince George's County, Maryland, in the early 1990s (EPA 2000). LID is a micro-scale approach that reduces surface water impacts associated with runoff from impervious surfaces by maintaining the pre-development hydrology of a site (Dietz 2007). LID techniques aim to increase infiltration, groundwater recharge, and water storage, and reduce runoff volumes by keeping precipitation on-site (EPA 2000). This decreases the amount of stormwater that enters unimpeded into rivers and lakes through storm drains. Since they are designed to control stormwater at the source, LID techniques differ from conventional stormwater management practices, which tend to utilize large facilities at the base of a drainage basin (EPA 2000). A well-planned site could have several LID practices operating at once. This may completely eliminate the need for a large-scale traditional stormwater management practice, like a wet detention pond.

There are many LID practices. Examples include vegetated roofs, grass swales, cluster development, minimized pavement widths, open space conservation, preservation of existing site conditions, infiltration trenches, disconnected downspouts and sewers, low impact landscaping, pervious pavement, and bioretention (EPA 2007). Of these, bioretention, green roofs, grass swales, and pervious pavement have received the most attention (EPA 2000). For this reason, and also because they were recommended by the 2005 Capstone report, we chose to examine the use of bioretention and pervious pavement in Basin 15.

Bioretention

Bioretention cells are planted gardens that infiltrate stormwater from impervious surfaces, such as parking lots and roof tops. They are placed in shallow depressions to encourage the collection of runoff, and often include a pretreatment step to filter out large sediments, such as a forebay or grassy swale (Figures 3.4 and 3.5). Bioretention cells are basically rain gardens, but unlike rain gardens, some bioretention cells have an underdrain that is “online”, or connected to the stormwater sewer system (Atchison, Potter, and Severson 2006).

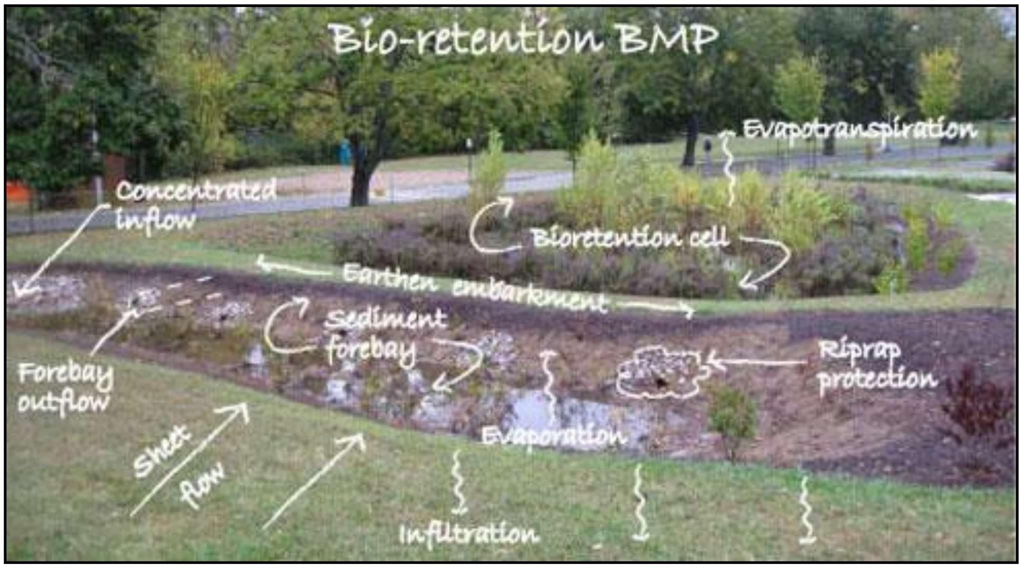


Figure 3.4: Bioretention cell and forebay designed to receive runoff from a nearby parking lot (Virginia Tech University)

Bioretention cells can substantially reduce both the pollutant load and volume of runoff following a rain event through biological, physical, and chemical processes (Winogradoff 2002; Atchison, Potter, and Severson 2006). Such processes include infiltration into the soil media, settling of suspended solids, evapotranspiration through plant leaves, filtration of runoff through mulch and soil, assimilation of nutrients and other pollutants by plants, nitrification, dentrification, and decomposition of organic compounds by bacteria (Winogradoff 2002). Infiltration of stormwater through the soil has the added benefit of recharging the aquifer underlying the bioretention cell. Bioretention cells have been shown to effectively reduce stormwater peak flow volumes regardless of season (*Bioretention System* 2008).

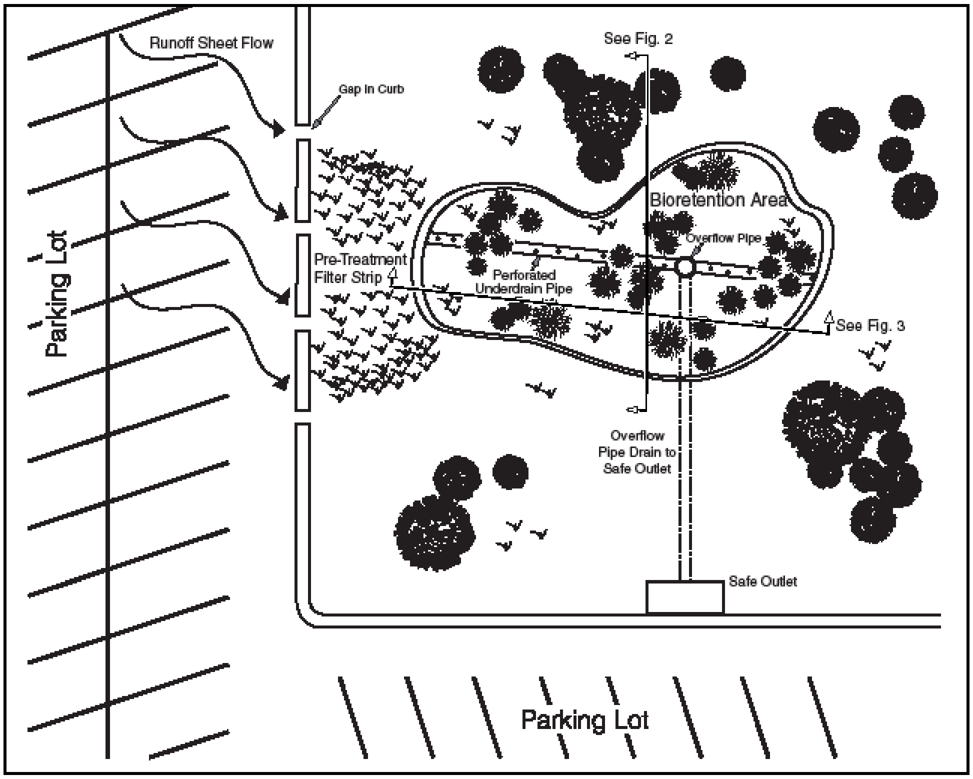


Figure 3.5: Typical layout of a bioretention cell capturing runoff from a parking lot (WDNR 2006)

Not surprisingly, bioretention cells get their name from their ability to retain pollutants (Table 3.2) (Atchinson, Potter, and Severson 2006). Early and recent studies have demonstrated a high retention of metals in bioretention cells, including copper, zinc, and lead (Dietz 2007). On the other hand, the ability of bioretention cells to contain nutrients, such as nitrate and total phosphorus, has received mixed results. Some studies have even documented the net export of total phosphorus (Dietz 2007). The net export of phosphorus from some bioretention cells has been attributed to several sources. These include: 1) high phosphorus content of the surrounding soil, 2) erosion of phosphorus-containing soil after construction of the bioretention cell, and 3) leaching of phosphorus from the mulch and engineered soil media within the bioretention cell (Dietz 2007). To avoid unwittingly exporting phosphorus from a bioretention cell, it is important not to plant vegetation that requires the use of fertilizers.

Table 3.2: Typical Pollutant Removal Rates for Bioretention Cells (Atchison, Potter, Severson 2006)

Pollutant	Removal Rate (%)[1]
Total Suspended Solids (TSS)	90[2]
Metals (Cu, Zn, Pb)	>95[3]
Total Phosphorus	80[3]
Total Kjeldahl Nitrogen	65-75[4]
Ammonium	60-80[4]
Organics	90[2]
Bacteria	90[2]

1. Data Compiled by Wisconsin DNR (Bioretention Tech. Note 1004, draft)
2. Prince George's County, Md., Department of Environmental Resources, 1999
3. Davis et al. 2003
4. Davis et al. 2001

The typical components of a bioretention cell are the pretreatment zone, ponding zone, plant & mulch surface layer, root zone, underdrain, and storage zone. A description of each is as follows (Figure 3.6) (Winogradoff 2002; Atchison, Potter, Severson 2006):

- The *pretreatment zone* typically consists of runoff over grass swales, which allows large particles to settle out before reaching the bioretention cell.

- The *ponding zone* stores water temporarily on the surface of the cell and allows particulates to settle out.

- As mentioned previously, the *plants* are responsible for pollutant and nutrient uptake. Also, their roots aid in maintaining infiltration capacity by loosening the soil and creating pathways for percolating water. Plant selection should include native plants that can tolerate inundated conditions, which excludes most upland plants. Obligate wetland plants are also not recommended due to the possibility of extended dry conditions, especially if the rooting zone soil is sandy.

- Along with the plants, a *mulch layer* can be included on the surface of the bioretention cell to reduce soil erosion and provide a site for microbiological growth and adsorption of heavy metals.

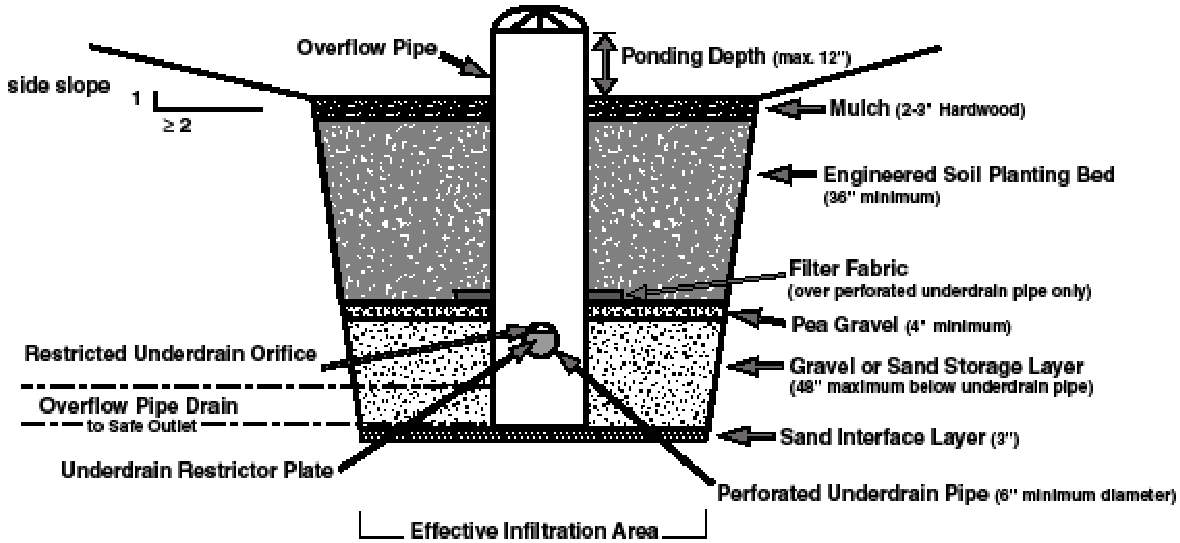


Figure 3.6: Typical Components of a Bioretention Cell (WDNR 2006)

- The *rooting zone* is needed primarily to provide sufficient depth, nutrients, and drainage for plant growth. The rooting zone is typically composed of a combination of topsoil, compost, and sand. Most of the pollutants are removed in this layer.

- The *underdrain* increases the infiltration capacity of the cell in less permeable soils by decreasing the duration of ponding; when the ponding zone reaches its maximum depth, water can overflow through a standpipe into the underdrain. The underdrain can be connected to the existing storm sewer system. An "overflow" event occurs when water enters the underdrain untreated; thus, it is not desirable to have stormwater enter the underdrain, but it can serve as a useful back-up during a heavy rain event.

- The *storage zone* reduces flow into the underdrain by providing additional water storage in the cell. It also reduces the duration of ponding and saturation.

Porous Pavement

Urban development has had an adverse effect on both the quantity and quality of surface waters. During rainfall events, impervious areas, such as roadways, driveways, and rooftops, cause water to run off surfaces faster and in greater amounts than from undeveloped pervious areas, such as grasslands and forests. The increase in runoff can cause an increase in overland and stream bank erosion, as the water rapidly travels to surface water sources. Surface waters, in turn, experience irregular flow rates and higher sediment loadings. Impervious areas also reduce infiltration, impacting groundwater aquifers. The result is an increase in surface water temperature and pollutant load, which have detrimental effects on aquatic habitats. The most common urban storm water pollutants include sediment, nutrients, oil and grease, bacteria, and heavy metals.

As urban areas expand, the problems associated with urban runoff and water quality continue to grow. Because of their ability to allow water to infiltrate into the surface, permeable pavements can be an effective means of approaching a solution to these problems. Permeable pavements, also referred to as porous pavements, are alternatives to the traditional impervious asphalt and concrete pavements. Pervious pore spaces in the permeable pavement surface allow for water to infiltrate into the pavement during rainfall events. Water passes through several layers of pervious material where it is temporarily stored. In areas underlain with highly permeable soils, the captured water slowly infiltrates into the sub-soil. In areas containing soils of lower permeability, water can leave the pavement though an underdrain system. (Pratt *et al*., 1989; Hunt *et al*., 2002; Bratteo and Booth, 2003; Bean *et al*., 2005).

Because of their ability to allow water to quickly infiltrate through the surface, permeable pavements allow for reductions in runoff quantity and peak runoff rates Even in areas where the underlying soil is not ideal for permeable pavements, the installation of under drains has still been shown to reflect these reductions (Pratt *et al*., 1989). As a result, permeable pavements have been regarded as an effective tool in helping with storm water control (Watanabe 1995). The evaporation rates, drainage rates, and retention properties on permeable pavements are largely dependent on the particle size distribution of the bedding material.

Permeable pavements also affect the water quality of stormwater runoff. Permeable pavements have been shown to cause a significant decrease in several heavy metal concentrations as well as suspended solids (Pratt *et al.* 1989). Removal rates are dependent upon the material used for the pavers and sub-base material, as well as the surface void space (Pratt *et a*l., 1989). Metal pollutant concentrations within pavements themselves decrease rapidly with depth.

- A typical cross-section of the pervious pavement used in parking lots consists of a pervious concrete layer with a thickness of 4 to 6 inches, a permeable base with a thickness up to 18 inches, and a permeable subgrade. The surface component of pervious paving can be:
- Porous asphalt or porous concrete.
- Concrete or plastic grid structures filled with unvegetated gravel or vegetated soil,
- Concrete modular pavers with gapped joints that allow water to percolate through.

If the subgrade permeability is low, drainage pipes can be used to drain water, but drainage pipes increase the cost of a pervious pavement system (Figure 3.7). Typical pervious concrete mix designs used in the United States consist of cement, single-sized coarse aggregate (generally a size between one inch and the No. 4 sieve), and a water to cement ratio ranging from

0.27 to 0.43. Reported properties of pervious concrete in the United States indicate that the 28-day compressive strength of pervious concrete ranges from 800 psi to 3,000 psi, with void ratios ranging from 14% to 31%, and permeability ranging from 36 to 864 inches/hour.

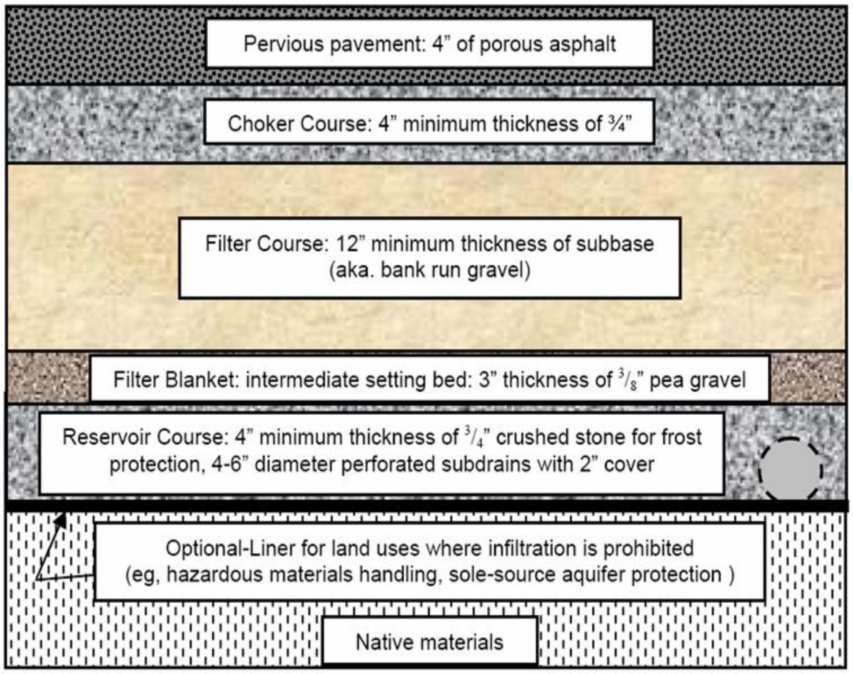


Figure 3.7 Typical Cross Section of Pervious Pavement System (UNHSC 2008)

Basin 15: Control Locations

For our project, we focused on two of the largest sources of stormwater runoff in Basin 15: the Weidner Center parking lots and the Wood Hall parking lot. The Wood Hall parking lot was focused on most extensively because it is slated for repairs sometime between 2009 and 2011 by the Facilities Management 6 Year Plan. We located our bioretention cells near existing storm pipes that drain the respective parking lots. This would allow for the the possibility of "online" bioretention cells (cells connected to the storm system through an underdrain). We placed one bioretention cell in the disc golf course near the Wood Hall parking lot, and another in front of a storm outfall near Weidner Hall (Figure 3.2).

Pervious pavement was investigated as a storm water management technology for the Wood Hall parking lot on the UWGB campus. Because the use of pervious pavement is limited to low traffic areas, we chose an infrequently-used portion of the Wood Hall parking to evaluate as a potential site for installation. At present, pervious pavement is only recommended for low-traffic applications due to a lower load-bearing capacity compared to traditional pavement (Dietz 2007). This portion is located in the west half of the Wood Hall parking lot. Though not located in Basin 15 (this part of the Wood Hall parking lot is in Basin 4), the lot could be re-graded to accept runoff from other parts of the parking lot that are in Basin 15.

METHODS

Bioretention Cells

There are many different components included in the design of a bioretention cell and each one affects the cell's performance. To guide our design of bioretention cells to reduce stormwater runoff from the Wood Hall and Weidner Center parking lots, and to ensure compliance with state requirements, we researched literature, including technical notes and relevant government regulations.

We also used the RECARGA model (Figure 3.8), a software program developed by the UW Madison Department of Civil Engineering and recommended by the Wisconsin Department of Natural Resources, to evaluate different designs.

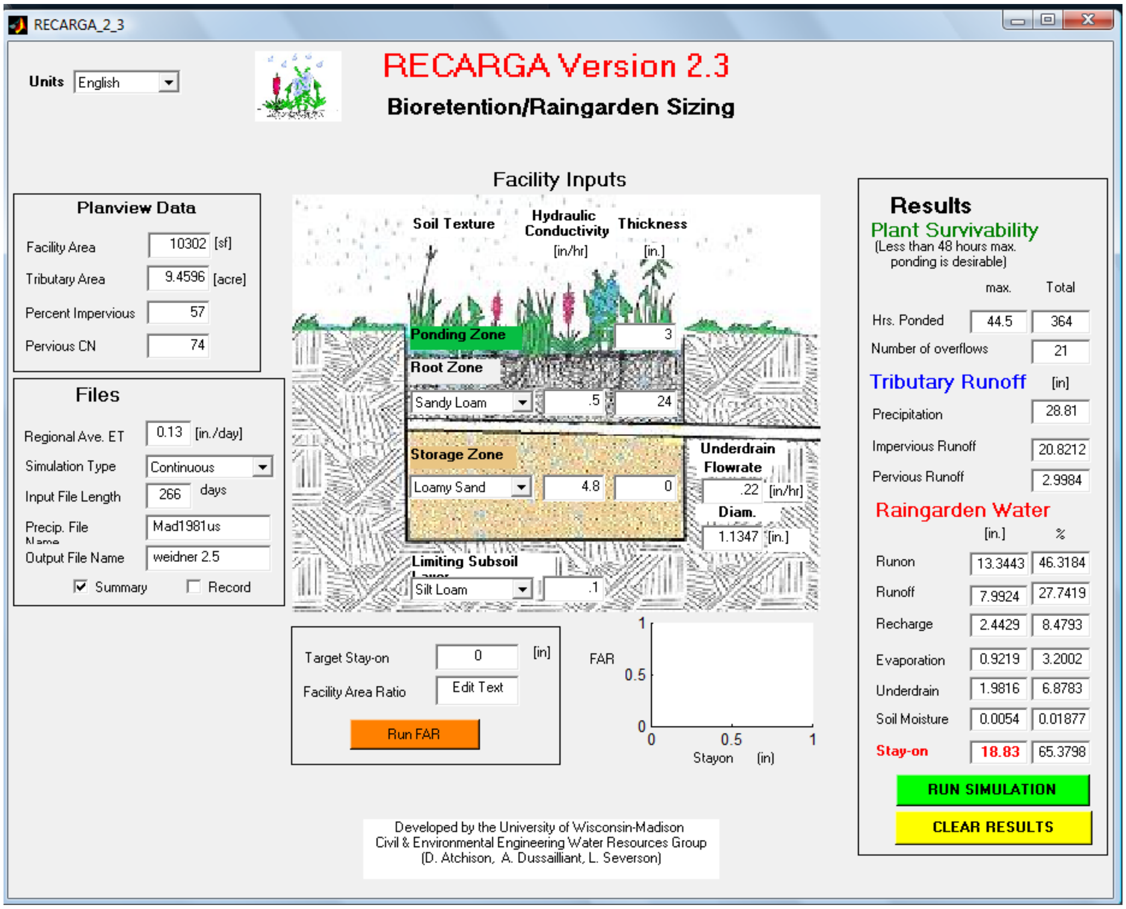


Figure 3.8 The RECARGA Model

The RECARGA model evaluates user-provided inputs to predict how much stormwater a particular design could be expected to retain, i.e., how much runoff would be reduced. We investigated the following required inputs:

- *Tributary Area:* Total area, in acres, of the drainage area ("sub-basin") that we were focusing on during a particular RECARGA run. These values were determined by our colleagues in the SLAMM modeling group, who used ArcGIS to draw the tributary area boundaries onto air photo layers and calculate the area. The areas of our two tributaries, or sub-basins, were:
  - Wood Hall: 14.4625 acres
  - Weidner Center: 9.4596 acres

- *Percent Impervious:* Percent of tributary land surface that is vegetated or undeveloped. The area of impervious surface in each tributary was determined by using the ArcGIS methods described in the previous section. Using this area, we calculated the percent of impervious surface in each sub-basin.
    - Wood Hall: 30.19% impervious
    - Weidner Center: 57.02% impervious
- *Pervious Curve Number (CN):* Value used by RECARGA to estimate run-off. The pervious CN is based on many variables, including soil type, precipitation, and land use. We obtained this value by referring to Technical Release 55 (NRCS 1986). We used a pervious CN value of 74 for each of our sub-basins.
- *Precipitation:* The RECARGA model uses hourly precipitation records to predict how a particular design would perform under specific conditions. We contacted several regional climate specialists to obtain these records and chose to use a dataset that contains 266 days of consecutive hourly precipitation from Madison, Wisconsin in 1981. This dataset was provided with the RECARGA software.
- *Simulation Type*: The RECARGA model offers options to predict bioretention cell performance based on a single precipitation event or a longer, continuous, period of time. We used the continuous simulation type because it predicts performance of our designs over the entire time period contained in our precipitation dataset.
- *Native Soil Properties:* The existing soil at a bioretention site influences the overall effectiveness of the cell. United States Department of Agriculture soil surveys indicate that campus soils are clayey silt loams, however, the soils in our sites, those adjacent to the Wood Hall and Weidner Center parking lots, are classified as “fill”. We made an

assumption that the soil had been excavated from a development project on campus and entered a "silt loam" classification with a hydraulic conductivity of 0.1 inches/hour into RECARGA for this input.

- *Regional Evapotranspiration Rate:* Rate at which water is evaporated from the ground surface and transpired from vegetation. We used a rate of 0.13 inches/day because this is a typical value used in the region (Atchison, et. al. 2006).
- *Ponding Zone Depth, Rooting Zone thickness and properties, Storage Zone thickness and properties:* We consulted literature and WDNR requirements to select appropriate and acceptable materials and specifications for these inputs. For the rooting zone, we indicated that we would use a standard engineered soil mix, primarily sandy loam, with a hydraulic conductivity of 0.5 inches per hour. For the storage zone, we indicated that we would use a typical engineered soil mix, primarily loamy sand, with a hydraulic conductivity of 4.8 inches per hour.

  To determine the ideal thickness for the ponding zone, rooting zone, and storage zone, we ran the RECARGA model many times, which allowed us to evaluate the performance offered by different combinations of these design components for each site. The results of these comparisons are described in the following section.
- *Perforated underdrain:* For bioretention cells, WDNR recommends an underdrain with a diameter that is no less than six inches (2006). To determine the required underdrain diameter, the RECARGA model requires an underdrain flow rate. To calculate the underdrain flow rate necessary to drain the cell within 24 hours after a rain event, we divided the proposed ponding depth by 24 hours and subtracted the hydraulic conductivity of the native soil. RECARGA then calculated the required diameter of the

underdrain to meet this flow rate. For all of the designs we ran, a six inch underdrain was sufficient.

Porous Pavement

To understand how porous pavement might contribute to stormwater management practices at UWGB, we researched literature on the subject and spoke with members of the facilities team to get their input about how management and operations would respond to the product. We determined appropriate values for design components, including cement content, coarse aggregate composition, water:cement ratio, field infiltration rate, compressive strength, and compacted thickness. We then shared these values with our colleagues to enter into the WinSLAMM modeling program to predict the performance of porous pavement on the UWGB campus.

RESULTS

Bioretention

After running the RECARGA model numerous times to compare different design options for each site, we evaluated the output to understand how the different design components interact and affect overall performance.

Wood Hall Bioretention Cell

Increasing the size of the bioretention cell decreases the number of overflows and the amount of runoff in the sub-basin. The current percent of runoff for the Wood Hall sub-basin is about 29%. Increasing the size of the bioretention cell can substantially reduce the amount of runoff. However, a complete reduction would require an extremely large cell (approximately 15% of the sub-basin area). The large size of such a cell can be attributed to the fact that the

Wood Hall tributary area, approximately 14.5 acres, exceeds the 2 acre maximum recommended by the DNR (WDNR 2006). This standard is set to prevent erosion and clogging (WDNR 2006). The smaller cells modeled in RECARGA substantially reduce the amount of runoff, but would likely experience such problems (Figure 3.9).

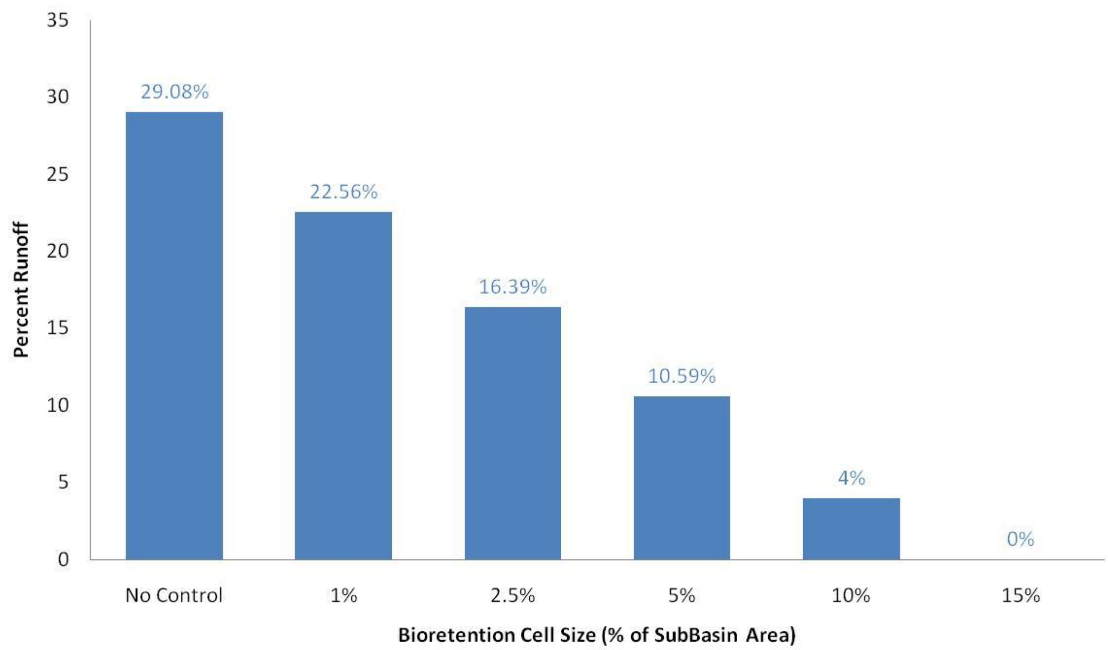


Figure 3.9: Percent of runoff leaving the Wood Hall sub-basin for different size bioretention cells.

Increasing the storage zone, from 2 feet to 3 feet, results in minimal change to ponding duration. Increasing the rooting zone, from 2 feet to 3 feet, also produces a minimal change in ponding duration. Increasing ponding depth, from 3 inches to 9 inches, leads to excessively long ponding durations. Ponding durations lasting more than 24 hours are not recommended, in order to avoid suffocating plants (Atchison, Potter, & Severson 2006).

Weidner Center Bioretention Cell

The current percent of runoff coming from the Weidner Center parking lots is about 46%. Runoff is higher in the Weidner Center sub-basin because there are more impervious surfaces in a smaller area. The percentage of impervious area is 57.02%, compared to 30.19% in the Wood Hall sub-basin. The tributary area for the Weidner Center, which is about 9.5 acres, also exceeds the 2 acre maximum recommended by the DNR. Additionally, the amount of space available for a bioretention cell is more limited, and the 10% and 15% size options are not feasible as a single cell in our identified location. The smaller cells can still reduce runoff but, as with the smaller biorention cells for Wood Hall, would still be subject to erosion and clogging (Figure 3.10).

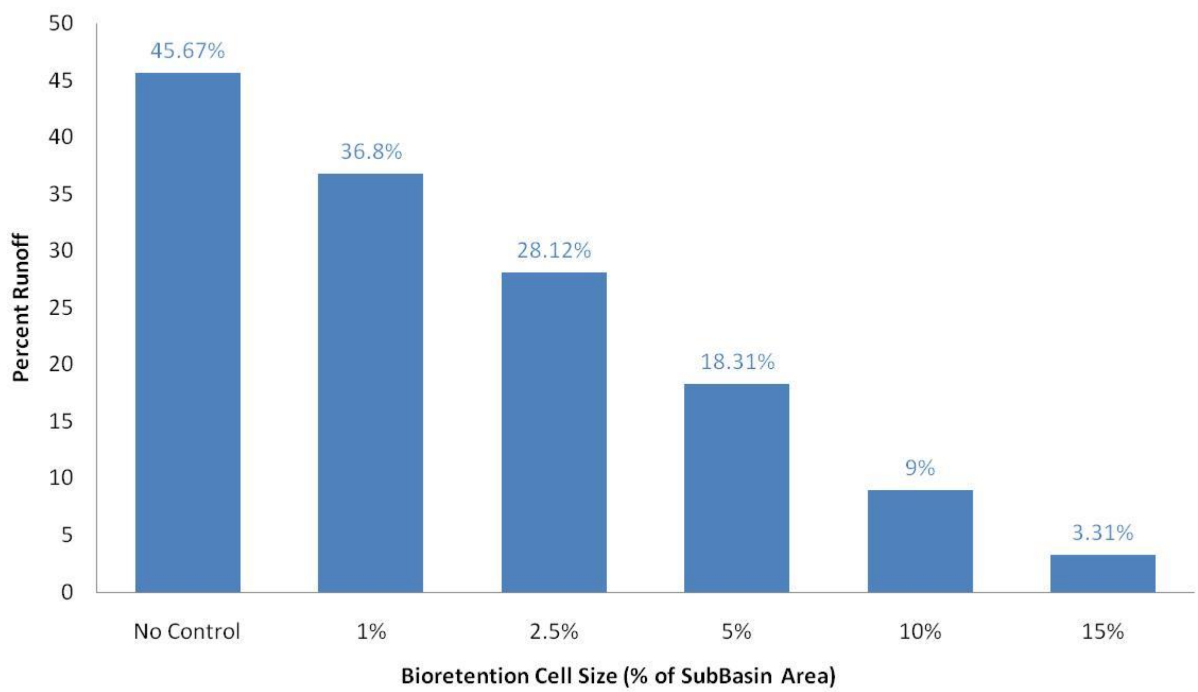


Figure 3.10: Percent of runoff leaving the Weidner Center sub-basin for different size bioretention cells.

Increasing the depth of the storage zone from 2 feet to 3 feet dramatically decreases the ponding duration, but increasing the depth from 3 feet to 4 feet results in negligible change. Increasing the rooting zone from 2 feet to 3 feet produces almost no change in ponding duration. Increasing the ponding depth from 3 inches to 9 inches creates excessive ponding durations, which is detrimental to plant survivability.

Design Summary

Based on the results obtained from the RECARGA model, we selected a 3 inch ponding zone and a 2 foot rooting zone for both locations (Figure 3.11). Additionally, we selected a 2 foot storage zone for the Wood Hall bioretention cell and a 3 foot storage zone for the Weidner Center bioretention cell (Figure 3.11). These designs are only likely be effective in the form of multiple small cells that receive runoff from smaller tributary areas.

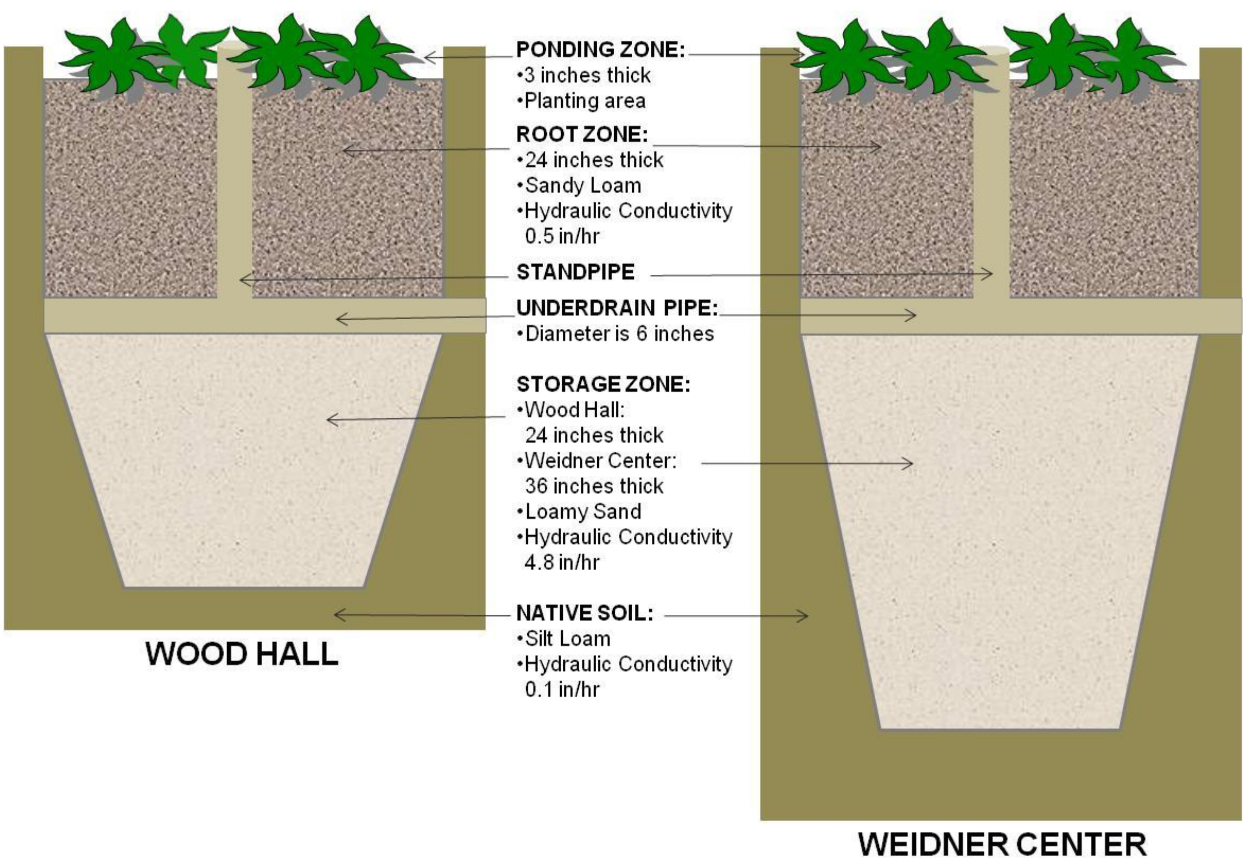


Figure 3.11: Selected designs for bioretention cells

Plants for the bioretention cells should be native species that are tolerant of drought and flood conditions. Salt tolerant plants may also be necessary if runoff contains salt-based de-icers (WDNR 2006). Appropriate plant selections can be made with the help of a guidebook developed by Shaw and Schmidt (2003). Typical maintenance of bioretention cells includes watering plants when necessary during the first year, monthly inspections and debris removal, and yearly additions of mulch (WDNR 2006).

Porous Pavement

Studies have shown that porous pavement systems dramatically reduce surface runoff volumes and peak discharge (Dietz 2007). Porous pavement is suitable for cold weather climates, as it will continue to infiltrate through winter months. (Roseen et al. 2008). We selected porous concrete as the best pavement option for UWGB because it is well suited for subsoils with low permeability, due to a higher void content. Research also indicates that, as with any storm water management technique or device, permeable paving performs well over time if properly installed and maintained. Vacuuming twice per year to prevent clogging and plowing snow with the blade slightly higher than normal are recommended (Dietz 2007). Table 3.3 clarifies some common misconceptions about porous pavements.

Table 3.3: Misconceptions about porous pavements (From Roseen et al. 2008).

Misconceptions	Truth
Freezes faster	Has demonstrated increased speed in thawing due to flow through by melt water
No infiltration in winter	Can have increased IR in winter
Weaker material	Pavement system is stronger despite weaker material
Higher Cost	New development can be cheaper
Higher Maintenance	Yes for sweeping, lower winter maintenance for PA
Slippery	Developed to have higher friction than traditional asphalt
Cannot plow, salt, or de-ice	Can be plowed and de-iced, however no sand is recommend
More prone to frost heaving	Reduced compared to traditional asphalt due to vadose zone disconnect
Lower life span	Increased life span due to reduced freeze thaw

CONCLUSION AND RECOMMENDATIONS

Possible Stormwater Control Options Based on Results:

- Install several small bioretention cells around each parking lot to reduce cost
    - would require regrading and new piping infrastructure.
- Combine the use of small bioretention cell with other practices, such as grass swale drainage, disconnection, and porous pavement in low-traffic areas or sidewalks within Basin 15.
- During repair of Wood Hall parking lot:
    - re-grade lot so runoff flows into woods located to the south (disconnected from storm drains) OR
    - re-grade so west half of lot drains into Basin 4 (woods west of the basin)
        - would reduce the contribution of Basin 15 to Green Bay
        - would make bioretention more feasible by reducing runoff volume.

General Recommendations

- Future plans for parking lot construction should incorporate a proactive approach to stormwater control to avoid the hassles of retrofitting
    - i.e. bioretention cell islands within new lots
    - Completely inventory all stormwater drains, including direction of water flow so contributing areas can be estimated accurately
- Incorporate pervious pavement in a test situation somewhere on campus, such as a small, low-traffic section of a parking lot or sidewalk

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Chapter 4

Using Arc-GIS and WinSLAMM to

Determine Optimal Stormwater Treatment Scenarios

Daniel Cibulka

Lawrence Eslinger

Phil Hahn

Abstract

We used a geographic information system (ARC-GIS) and an urban stormwater simulation model (WinSLAMM) to evaluate possible stormwater management options within the University of Wisconsin-Green Bay (UWGB) campus. Arc-GIS was used to determine land use composition and area for two regions on campus – the Weidner Center parking lot and the Wood Hall parking lot. Data regarding these two sub-basins were modeled in WinSLAMM. The model calculated annual Total Suspended Solids (TSS) and Total Phosphorus (TP) yields within each sub-basin under existing conditions. We then tested various pollution control devices to determine optimal management strategies for pollutants. Finally, a cost analysis was used to estimate the most cost-effective management practice for stormwater treatment within the UWGB campus.

WinSLAMM results and the cost analysis suggests that a bioretention device is best suited to remediate stormwater pollution from the Weidner Center parking lot sub-basin. We recommend a bioretention device ranging between 2.5-5% of the contributing sub-basin drainage area. Pro-active steps, such as continual stormwater remediation, will assist in meeting future stormwater regulations as well as exemplifying UWGB's commitment towards environmental sustainability and educational opportunities.

Introduction:

Although the UWGB campus has already met Wisconsin Department of Natural Resources MS4 requirements to reduce pollutant loadings from impervious surfaces, there has been increased interest in further reducing the impact the university has on the Bay of Green

Bay. Besides the campus mission of promoting sustainability, the facilities management department has been exploring ways to reduce stormwater while adopting technology that reduces labor and resources. Following an interest by professors and graduate students in the Environmental Science and Policy Capstone course, a plan of action was adopted to address the possible inclusion of additional stormwater management practices on campus.

In 2005, an EarthTech Inc. report identified 21 drainage basins on the UWGB campus (Bachhuber and Hanson 2005). Through the use of urban watershed modeling, researchers used WinSLAMM (Windows based Source Loading and Management Model) to estimate annual Total Suspended Solids (TSS) and Total Phosphorus (TP) loads from each basin. The report identified Basin 15, which encompasses a large portion of west-campus, as the second largest contributor of TSS (9.38 tons/year) and the largest contributor of TP (55.76 lbs./year) in stormwater pollutant runoff from campus. The report also stated that the basin currently has very little control to reduce pollutant yields (0.1% for TSS and 0.0% for TP).

The modeling program EarthTech used in their 2005 study, WinSLAMM (Windows-based Source Loading and Management Model), is a commonly used stormwater modeling program that was originally developed by Robert Pitt and John Voorhees as part of the Environmental Protection Agency's street cleaning program in the 1970's (Pitt and Voorhees 2002). The urban watershed model has been continuously updated since then to identify and quantify stormwater pollutants exported from numerous types of urban landscapes. WinSLAMM has many functions that allow the user flexibility in analyzing the urban watershed. They include:

- Ability to analyze up to 6 land use types and 14 source areas

- Ability to simulate runoff volume and loading for 16 pollutants
- Numerous BMP options for the user to add to the landscape
- Ability to run simulations of different management scenarios
- Ability to analyze and compare the cost of management scenarios

According to the authors, WinSLAMM is unique from other models in that it is able to more accurately analyze small storm hydrology, which research has shown can contribute towards significant pollutant loading in urban areas (Bannerman, et al. 1983). Along with accurately analyzing smaller storm events, WinSLAMM is also able to calculate a "first flush" relationship for each type of urban landscape. The "first flush" phenomenon holds that large proportions of pollutants are washed off during the initial runoff from a storm event (Deletic 1998). Therefore, the first flush is very economical to target in current storm water management strategies (Goonetillke et al. 2002). From research Pitt and Voorhees (2002) have done, they argue that stormwater models operating without a first-flush structure show a linear increase in pollutant loading, while this relationship is actually exponential in nature. WinSLAMM is able to account for these "first flush" pollution loads and, therefore, can more accurately estimate total pollution reduction from various control devices.

In this component of the Capstone Stormwater Project, we decided to actively concentrate on possible solutions for pollution control in Basin 15, given its high pollutant load and potential for implementation of best management practices. Two parking lots within the basin were specifically isolated as preferred areas to remediate stormwater – the Weidner Center parking lot and the Wood Hall parking lot (Figure 1). These parking lots are fairly large (Table 1) and individually contribute substantial quantities of pollutants during runoff events. Conveniently, both parking lots have storm drains that travel either under or onto the campus' disc golf course. These easily accessible drains were thought to be prime locations for a bioretention device which, along with cleansing the stormwater, would provide a vivid reminder of the University's environmental agenda, provide educational opportunities, and enhance the natural beauty of the campus. Because the Wood Hall parking lot is scheduled to be resurfaced in the near future, we also considered porous pavement options.

The objectives of this study were to:

- Characterize area, land use, and current pollutant yield of UWGB Basin 15, and the Weidner Center and Wood Hall Sub-Basins using Arc-GIS and WinSLAMM.
- Model various sized bioretention devices and porous pavement options to determine reduction of pollutants (TSS, TP) achieved through each control device within respective Sub-Basins.
- Use a Cost Analysis to determine the best management scenario.

Methods:

To begin stormwater assessment, land use from Basin 15 needed to be both characterized and quantified. EarthTech had previously identified the boundaries of Basin 15 in their 2005 study.   We delineated the Weidner Center and Wood Hall parking lot sub-basins within Basin 15 using storm sewer maps, air photos, and field assessments. These areas were then digitized as shapefiles in Arc-Map (ArcMap Version 9.2, ESRI 2006). Land use areas for the entire campus were developed by EarthTech Inc. (Bachhuber and Hanson 2005) and are available as ArcMap shapefiles. We used these files to calculate land use in each sub-basin. Best locations for the bioretention cells were determined using storm sewer maps, air photos, and field assessments.

To model pollutant export from Basin 15 and the two smaller sub-basins, WinSLAMM version 9.3.0 software was obtained through PV & Associates (www.winslamm.com). Parameter files were uploaded through the United States Geological Survey website (USGS 2008). These files simulate rainfall, determine pollutant concentrations on various land surfaces, and direct the pollutant exports from the landscape in WinSLAMM. These files were used by EarthTech Inc. during their 2005 investigation of stormwater on the UWGB campus and are specific to the Green Bay area. Files used in this study include:

- WisReg – Green Bay 1969.ran (1 year rainfall file)
- WI_GEO01.ppd
- WI_SL06 Dec06.rsv
- WI_AVG01.psc
- WI_DLV01.prr
- WI_Res and Other Urban Dec06.std
- WI_Com Inst Indust Dec06.std

After uploading parameter files, land use information was input from Arc-GIS into the model. Existing pollutant yields were established for Basin 15, first to ensure that similar results to EarthTech's 2005 study were achieved, and secondly to develop a baseline for the Basin. Existing conditions were also established for the Weidner Center and Wood Hall sub-basins.

Following the characterization of existing pollutant yields, bioretention cell and porous pavement scenarios were added to the model to determine pollutant reduction from these devices. A total of eight bioretention cells were modeled - four in the Weidner Center sub-basin and four in the Wood Hall sub-basin. The four sizes consisted of 1%, 2.5%, 5%, and 15% of the respective sub-basin. These device sizes were developed using RECARGA (Chapter 3 of this document). WinSLAMM was then used to determine the pollutant reduction that occurred from each device within each sub-basin. The overall pollutant reduction each device had for the entire Basin 15 was calculated as well.

The proposed porous pavement options were located in the western portion of wood hall (Appendix C). This location was selected because it is a relatively unused and the lot is scheduled to be resurfaced between 2009 and 2012 (UWGB Master Plan 2005). The sizes of porous pavement were developed using Duluthstreams.org tool-kit (Duluthstreams.org 2008, Chapter 3 of this document) and air photos. Scenario I was 48,787 $ft.^2$ and Scenario II was 125,000 $ft.^2$. For the WinSLAMM modeling, it was assumed that the entire Wood Hall parking lot would be resloped so that runoff drains into the porous pavement. Since the west portion of the Wood Hall parking lot drains to Basin 4, these scenarios were modeled for Basin 4 plus the area of the Wood Hall parking lot that is in Basin 15.

Following the delineation of sub-basins and modeling of stormwater treatment scenarios, we used a cost analysis to evaluate the efficiencies of the proposed pollution remediation devices. The approximate costs for construction of a bioretention cell were provided by Robert E. Lee and Associates (Jared Schmidt *personal communication*), and are represented in Table 1.

Table 1. Estimated costs of materials needed to construct a bioretention device.

	Cost	Unit
Excavation	$5.00 - $6.00	cubic yard
Bioretention Media (Root & Storage)	$17.50 - $25.00	cubic yard
Gravel (Under-drain bed)	$15.00 - $20.00	cubic yard
Under-drain pipe	$20.00	linear foot
Filter Fabric	$2.00	square yard
Mulch	$35.00	cubic yard
Plants	$3.50 - $5.50	square foot

For total cost calculations of the proposed bioretention cells, we used the highest estimated costs for materials in order to determine the maximum cost of each device. Therefore, the University will be able to identify costly items, and use resources available to the campus in order to reduce costs for some of the needed materials.

We applied the cost of the bioretention media (mixture of soil, sand, etc.) to the root and storage zones in each bioretention device. Therefore, gravel was not incorporated into the cost determination. A thin layer of gravel will be needed to surround the under-drain pipe, however, the exact dimensions of that layer were uncertain, and since the cost of the bioretention media was just five dollars more per cubic yard, we chose to exclude the costs associated with the gravel layer. We assumed that the under-drain pipe would be covered by filter fabric extending two feet outside of the pipe. Therefore, when calculating the cost for filter fabric, we multiplied the length of the under-drain pipe (ft.) by two, which results in the square footage of filter fabric needed. Mulch was not incorporated in any cost calculations, but the associated dollar estimate was included in Table 1 to provide the University with an idea of cost for mulch from an independent supplier. To determine the cost for plants, we assumed one plant would be planted per square foot. Therefore, the surface area of each proposed bioretention device ($ft.^2$) was multiplied by $5.50 to estimate the total cost associated with plants. An example of the total cost calculation for the 1% Weidner Center bioretention device is shown below:

Surface area of Weidner Center 1% bioretention device = 4,121 $ft.^2$

Total depth of bioretention device = 5.75 ft.

Total area ($ft.^3$) = 4,121 $ft.^2$ x 5.75 ft. = 23,695.75 $ft.^3$

    1 yd^3 = 27 ft^3

Total area (yd^3) = 23,695.75 $ft.^3$ / 27 ≈ 878 yd^3

Excavation Cost = 878 yd^3 x $6.00 = **$5,268**

Bioretention Media Area (yd^3) = 4,121 $ft.^2$ x 5 ft. = 20,605 $ft.^3$ / 27 ≈ 764 yd^3

> Note: The top 0.75 ft. (9 in.) of the cell consists of a 6 in. drain pipe and a 3 in. ponding zone which contains no media.

Bioretention Media Cost = $19,100

Under-drain pipe length (ft.) = 45.25 ft. ("Typical Width" from RECARGA) x 2 = 90.5 ft.

Under-drain pipe Cost = 90.5 ft. x $20.00 = **$1,810**

Filter Fabric ($ft.^2$) = 90.5 ft. (pipe length) x 2 ft. (outside of pipe) = 181 $ft.^2$

Filter Fabric Cost = 181 $ft.^2$ x $2.00 = **$362**

Plants Cost = 4,121 $ft.^2$ (surface area of bioretention device) x $5.50 = **$22,665.50**

Total Cost = $5,268 (Excavation) + $19,100 (Bioretention Media) + $1,810 (Under-drain pipe) + $362 (Filter Fabric) + $22,665.50 (Plants Cost) **= 49,205.50**

It is evident that the cost of plants consumes a large portion of the total cost. The associated cost for plants can be dramatically decreased depending upon the size and quality of the plants and the spacing between them (Jared Schmidt *personal communication*). There is also an opportunity for the University to use the on-campus greenhouse to grow some of the plants, which may further reduce costs.

The approximate cost for installation of porous pavement in the Wood Hall parking lot was determined to be $16.25 per square foot, and was derived from a combination of sources including duluthstreams.org and the Environmental Protection Agency (EPA). Therefore, the total cost associated with installing the porous pavement was calculated simply by multiplying the square footage associated with each modeled scenario by $16.25.

To compare the efficiencies of the proposed pollution remediation devices, we calculated the associated cost required for each device to remove one pound of total suspended solids (TSS).

Results:

Basin 15 is Institutional land use type which contains several academic builds and large areas of impervious surfaces, mainly streets and parking lots. The Wood Hall sub-basin is characterized by large proportions of landscaped area and impervious pavement (Table 2, Appendix A). The Weidner Center sub-basin has a smaller total area than the Wood Hall sub-basin and is characterized by a higher proportion of impervious pavement and less landscaped area (Table 2, Appendix A). Both sub-basins are dominated by parking lot and landscaped area and have very small percentages of other land use types. The proposed bioretention cell locations were placed in open, low-traffic, areas along existing drainage pipes (Appendix B).

Table 2. Land use (acres) for Basin 15 and sub-basins.

	Basin 15 (acres)	Weidner Center Sub-Basin (acres)	Wood Hall Sub-Basin (acres)
Landscape	49.98	4.07	10.1
Parking	9.67	4.28	3.92
Road	4.87	0.65	0.26
Roof	6.72	0.06	0
Sidewalk	5.34	0.41	0.19
Total Impervious	**26.6**	**5.39**	**4.37**
Total Size	**76.58**	**9.46**	**14.46**

WinSLAMM was used first to calculate baseline, or existing conditions within Basin 15 and the two smaller sub-basins (Table 3). Although the Weidner Center sub-basin is smaller in size compared to the Wood Hall sub-basin (9.46 vs 14.46 acres), the TSS yield was greater and the TP yield was comparable to that of the larger sub-basin.

Table 3. Baseline pollution conditions of Total Suspended Solids (TSS) and Total Phosphorous (TP) for Basin 15 and the two sub-basins.

WinSLAMM Summary - Existing Conditions

Location	TSS (lbs/year)	TP (lbs/year)
Basin 15	18,799.50	55.91
Weidner Center Sub-basin	3,611.64	7.81
Wood Hall Sub-basin	3,062.86	8.99

The WinSLAMM results show that the small devices can control a substantial amount of TSS and TP from the contributing sub-basins and the larger ponds obtained nearly complete control of both TSS and TP (Figure 1). Next, the model shows pollutant reductions (TSS, TP) from Basin 15 under varying scenarios in which bioretention devices were placed in the Weidner Center and Wood Hall sub-basin, and porous pavement was placed within the Wood Hall sub-basin. A total of 10 scenarios were run – eight bioretention devices (four sizes placed in the Weidner Center sub-basin and four sizes placed in the Wood Hall sub-basin) and two porous pavement options. When placed in either sub-basin, bioretention devices captured a substantial amount of TSS at the smaller device sizes (1% and 2.5% of sub-basin). As device size increased to the larger sizes (5% and 15% of sub-basin), the rate of TSS removal decreased (Figure 2). Devices placed in the Weidner Center sub-basin continuously out-performed devices placed in the Wood Hall sub-basin in all size categories for TSS removal (Figure 2).

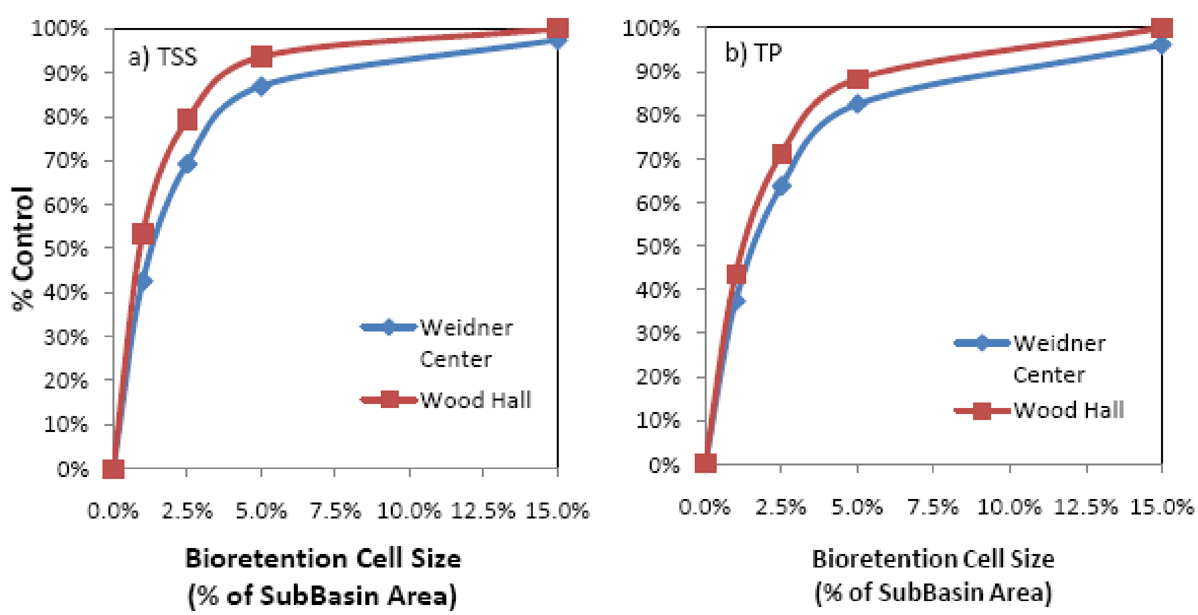

Figure 1. Percent control of a) Total Suspended Solids (TSS) and b) Total Phosphorous (TP) from the contributing sub-basin for each sided control device.

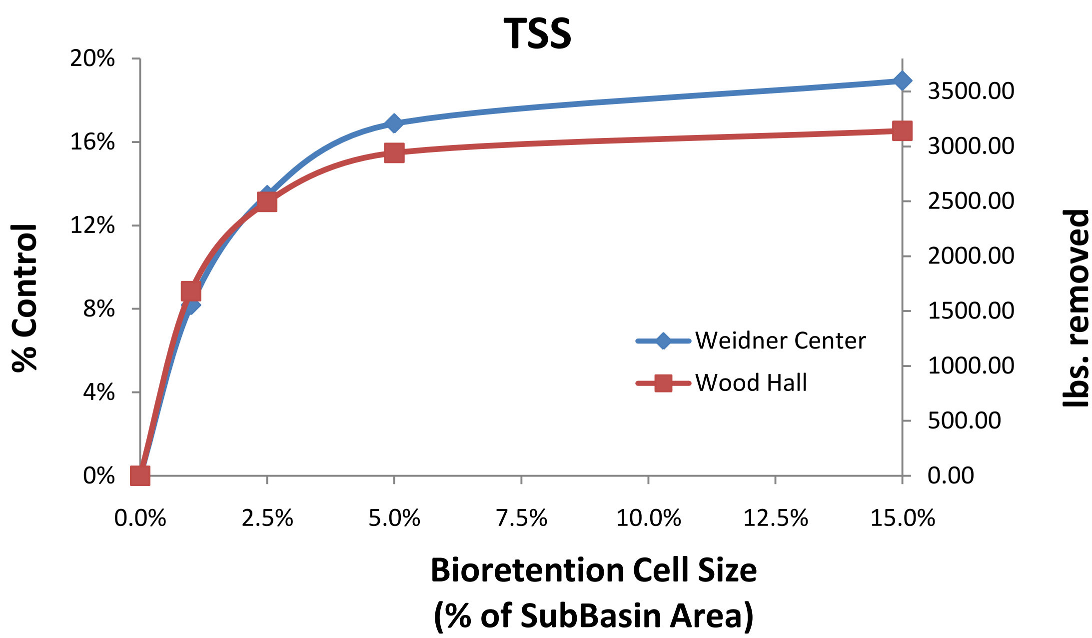

Figure 2. Percent of TSS control and lbs. of TSS removed from 4 sizes of bioretention devices in the Weidner Center sub-basin and Wood Hall sub-basin. Results reflect pollutant reduction within the entire Basin 15.

For TP, a similar relationship to TSS control was seen in which the smaller bioretention devices captured substantial amounts of pollution and the larger sized devices were less efficient (Figure 3). With respect to TP, the Wood Hall devices achieved greater reduction than the Weidner Center devices (Figure 3).

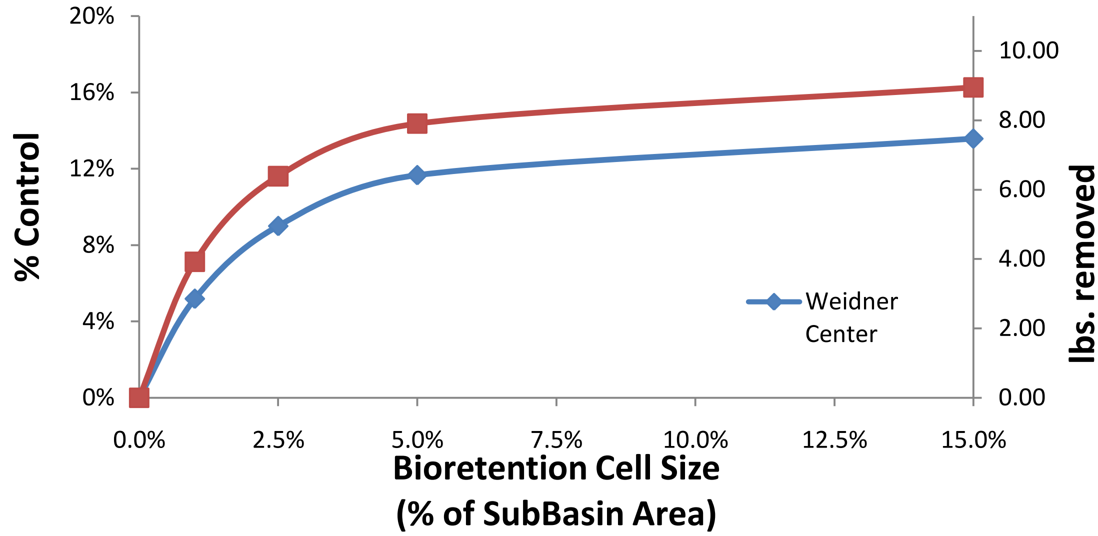

Figure 3. Percent of TP control and lbs. of TP removed from 4 sizes of bioretention devices in the Weidner Center sub-basin and Wood Hall sub-basin. Results reflect pollutant reduction within the entire Basin 15.

The WinSLAMM output was examined closer to identify and quantify contributing source areas for TSS and TP. In Basin 15 streets are the largest contributor of TSS, while the landscaped area within the basin contributes the largest percentage of TP (Table 4). Within the Weidner Center sub-basin, there exists a, proportionally, large amount of parking space. This parking area is the largest contributing source of both TSS and TP for the sub-basin (Table 4). In the Wood Hall sub-basin a proportionally large amount of landscaped land exists. Here, parking space exports the largest percentage of TSS, but landscaped area is the culprit of the largest percentage of TP export (Table 4)

Table 4. Landscape type percent contribution for runoff volume, TSS, and TP as modeled by WinSLAMM. Contribution was calculated for the entire Basin 15, each sub-basin, and Basin 4 plus Wood Hall parking lot.

Basin 15 Source Area Percentage Contribution			
Source Area	Runoff Volume (cu. Ft.)	TSS (lbs.)	TP (lbs.)
Roofs 1	22.8	4.3	9.4
Paved Parking/ Storage 1	19.4	14.2	7.9
Paved Parking/ Storage 2	13.2	9.7	5.4
Sidewalks/ Walks 1	9.8	4.2	5.6
Sidewalks/ Walks 2	0.8	0.3	0.4
Street Area 1	18.2	45.8	25.1
Street Area 2	1	2.6	1.4
Large Landscaped Area 1	11.4	14.6	35.4
Large Landscaped Area 2	2.9	3.7	8.9
Other Dir Cnctd Imp Area	0.6	0.6	0.6
Land Use Totals	100	100	100
Weidner Center Source Area Percentage Contribution			
Source Area	Runoff Volume (cu. Ft.)	TSS (lbs.)	TP (lbs.)
Roofs 2	1.1	0.2	0.6
Paved Parking/ Storage 2	72.2	55.2	42
Sidewalks/ Walks 1	8.1	3.6	6.7
Street Area 2	12.9	33.3	25.1
Large Landscaped Area 2	5.8	7.7	25.6
Land Use Totals	100	100	100
Wood Hall Source Area Percentage Contribution			
Source Area	Runoff Volume (cu. Ft.)	TSS (lbs.)	TP (lbs.)
Paved Parking/ Storage 2	74	59.6	33.4
Sidewalks/ Walks 1	4.2	2	2.7
Street Area 2	5.8	15.9	8.8
Large Landscaped Area 2	16	22.5	55.1
Land Use Totals	100	100	100
Basin 4 + Wood Hall Lot Source Area Percentage Contribution			
Source Area	Runoff Volume (cu. Ft.)	TSS (lbs.)	TP (lbs.)
Paved Parking/ Basin 4	19	0.2	0.2
Paved Parking/ Wood Hall Lot	68.9	29.8	27
Sidewalks/ Walks 1	0.4	0.2	0.4
Street Area 2	9.3	29.7	26.4
Large Landscaped Area 2	2.4	3.2	12.6
Land Use Totals	100	100	100

Following the modeling of bioretention devices in both sub-basins, WinSLAMM was used to analyze pollutant removal by porous pavement in the Wood Hall sub-basin. The baseline conditions for both porous pavement options are identical. The larger scenario achieves higher control of both TSS and TP (Figure 4). This relationship is unlike the bioretention cells in that as the square feet of the device increases, a linear increase in pollutant removal is seen.

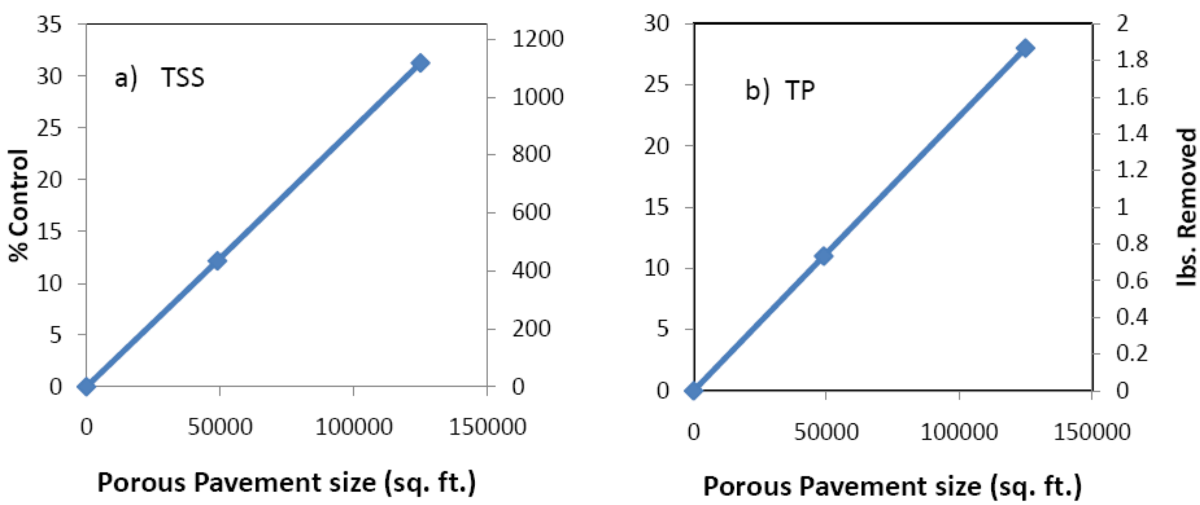

Figure 4. Percent control (primary axis) and lbs. removed (secondary axis) of a) TSS and b) TP for the porous pavement scenarios.

Once modeling of bioretention devices and porous pavement was complete, a cost analysis was performed on the different options. The proposed bioretention devices were much less expensive and more cost-effective at TSS removal than the porous pavement options (Table 5). The Weidner Center sub-basin bioretention devices were more efficient in treating TSS than the Wood Hall sub-basin devices, as evident by the cheaper cost per pound of TSS removal over all bioretention cell sizes (Table 5, Figure 5). The Weidner Center sub-basin bioretention devices were also less expensive than the Wood Hall devices (Table 5, Figure 5).

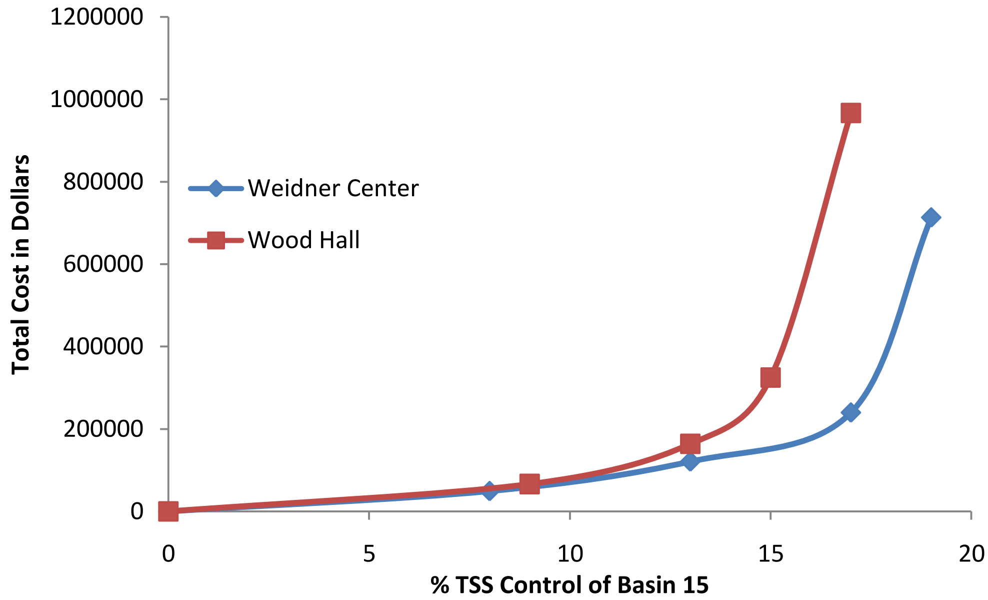

Figure 5. Total cost of each bioretention cell plotted against the percent Total Suspended Solids (TSS) for Basin 15. Data points are each size (1%, 2.5%, 5%, and 15% of the total area of each contributing sub-basin).

Table 5. Cost analysis of the proposed pollution control devices by the cost per pound of Total Suspended Solids (TSS) removed.

Control Type	Control Option	$ per pound of TSS Removal	Total Cost
Bioretention Cell	Weidner 1%	$32.00	$49,205.50
Bioretention Cell	Weidner 2.5%	$47.88	$120,958.00
Bioretention Cell	Weidner 5%	$75.59	$239,869.50
Bioretention Cell	Weidner 15%	$200.50	$713,508.00
Bioretention Cell	Wood 1%	$39.90	$66,383.00
Bioretention Cell	Wood 2.5%	$66.30	$163,620.50
Bioretention Cell	Wood 5%	$111.64	$324,775.50
Bioretention Cell	Wood 15%	$311.02	$966,596.50
Porous Pavement	Scenario 1	$1,826.70	$792,788.75
Porous Pavement	Scenario 2	$1,818.49	$2,031,250.00

Discussion:

The results from the WinSLAMM models show that the larger bioretention cells (>2.5%) meet or exceed the 80% reduction of TSS from the contributing drainage basin, recommended by researchers (Pitt and Voorhees 2002) and the WDNR (2004). The small ponds, however, do not meet these recommendations. A device that does not meet the suggested control may not be a viable option for best management practices.

TSS control was similar for both sub-basins, but slightly greater in the Weidner Center sub-basin for each size device modeled. Pollution control appeared to be most efficient between the 2.5-5% device sizes. The Wood Hall devices achieved greater reduction in TP than the Weidner Center devices. However, this was likely due to the larger landscaped area in the Wood Hall sub-basin.

According to Bannerman et al. (1993), most stormwater pollution comes from streets and parking lots. Our results are similar for the Weidner Center sub-basin in that the majority of TSS and TP come from paved parking, with streets making a substantial contribution as well. In this sub-basin, landscape and parking make up 35% and 37%, respectively, of the total land-use. In the Wood Hall sub-basin, 59% of TSS is exported from paved parking, while 55% of TP is exported from landscaped areas and 33% is exported from parking. This is likely due to the large proportion of landscape in this sub-basin (69%) and smaller amount of parking space (27%).

Based upon the cost analyses, the 1% control device in the Weidner center sub-basin achieves the most cost effective pollution reduction of TSS (Table 2). However, since this device achieves only 43% reduction in TSS within the sub-basin, it may not be the best management decision. Usually very large control devices are not financially or spatially practical, so they may need to be divided into several smaller devices. We did not investigate other locations for bioretention cells, but this may be required if the University decides to implement several smaller devices. Other options may be to implement a multi-chambered "treatment train" (Greb et al. 2000) or a combination of several control devices. A previous Capstone class highlighted different stormwater treatment scenarios that use grassy swales that lead to a bioretention cell or a multi-control treatment train (Forsberg et al. 2005). These options may be worth investigating before the University implements any sort of control device.

Porous pavement would offer reduction in pollution control from Basin 15 by redirecting runoff from the Wood Hall parking lot to Basin 4 (Appendix 3). However, cost analysis of the porous pavement determined that cost per pound of TSS reduction was significantly greater than the bioretention options. The estimated cost to implement porous pavement was also much greater and may not be a feasible option. However, when the Wood Hall lot is resurfaced it may be advisable to redirect the runoff into Basin 4 and 18. These basins have more natural vegetation and are better able to treat runoff naturally. Porous pavement may be cost effective to implement into newly constructed parking lots and this option should be considered in future plans.

Conclusions / Recommendations:

- A comprehensive map of stormwater drains and pipes is needed. The maps that are currently available are outdated and lacking vital stormwater data.
- Porous pavement, although a fascinating method of treating stormwater, is not recommended for the Wood Hall parking lot due to its large cost. It may be a feasible option for newly created parking lots or in a smaller scale to serve as an educational model, but for the purposes of reducing the most pollution with the smallest financial burden a bioretention device is more practical in this location.
- A bioretention device sized between 2.5% and 5% of the contributing area is the most cost-effective and spatially reasonable option for stormwater treatment. To capture the most pollution possible, it is recommended this device be placed within the Weidner

Center sub-basin. This device should be carefully planned as to not interfere with users of the UWGB disc golf course and should be designed to complement the natural beauty of the grounds and the rest of the arboretum.

- Further research should be performed to investigate whether one device between 2.5% and 5% or several smaller devices (adding up to between 2.5% and 5%) would best treat stormwater. A "treatment train" design such as a grassy swale leading to a bioretention device may allow a smaller device to be created and also save money in the process.

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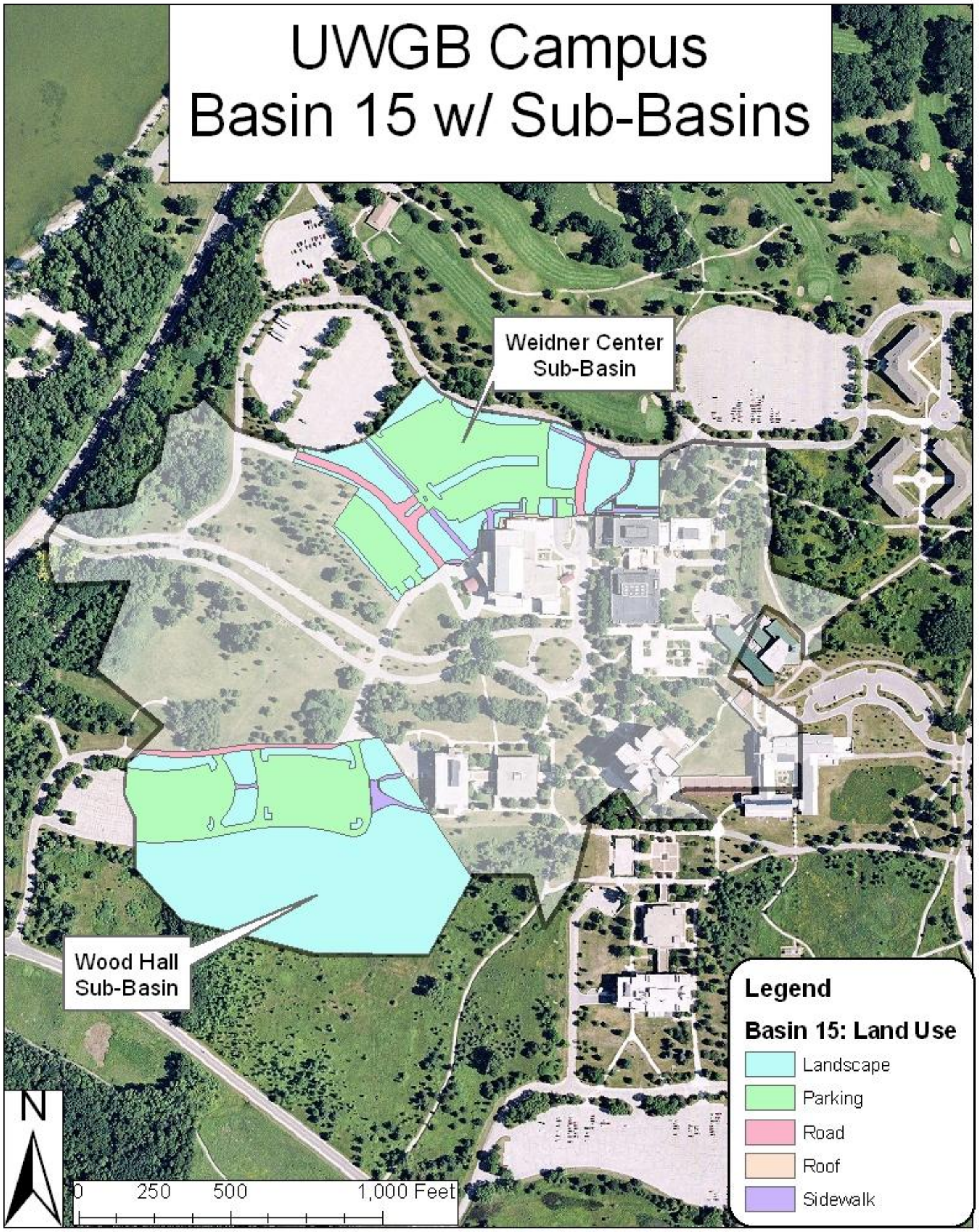
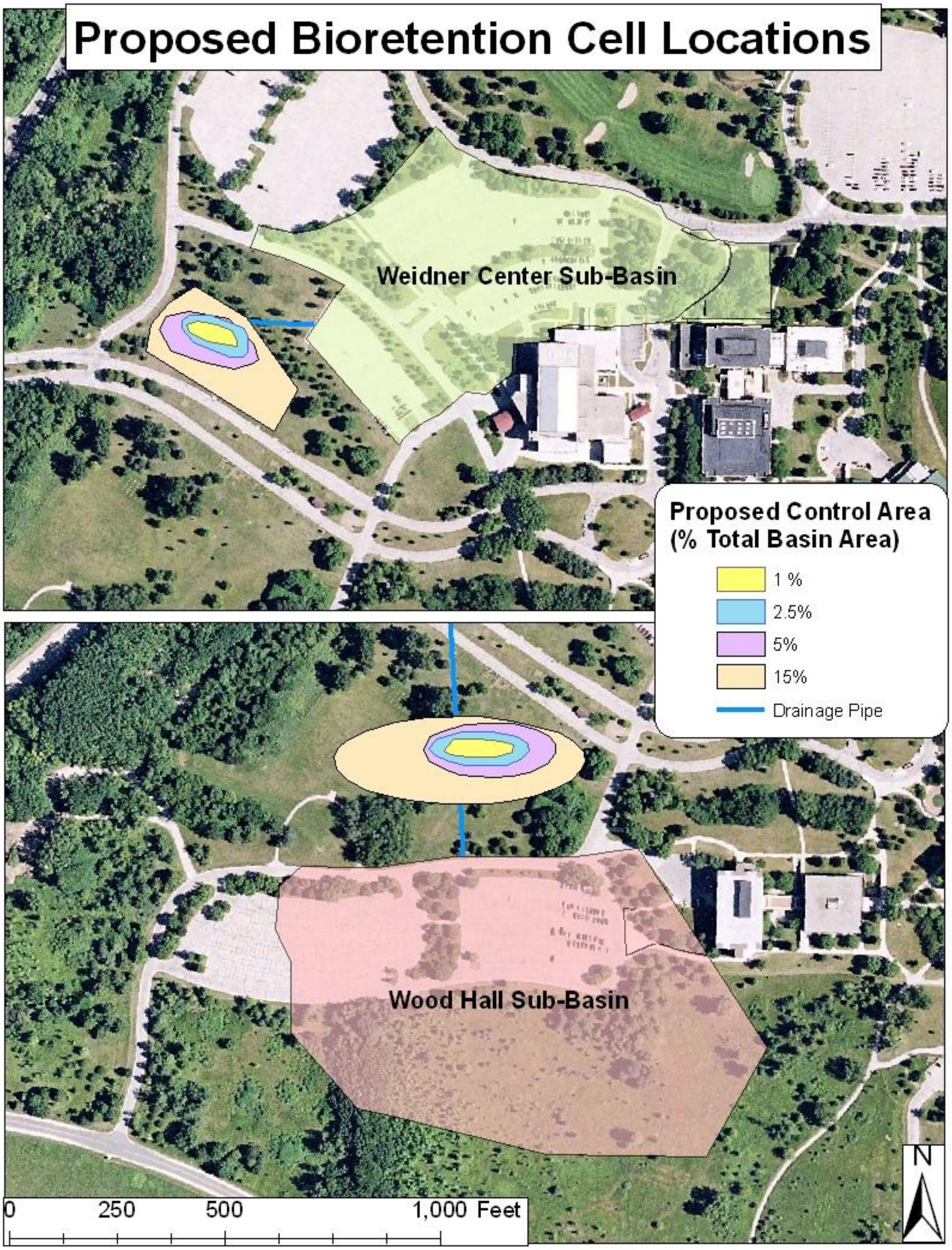
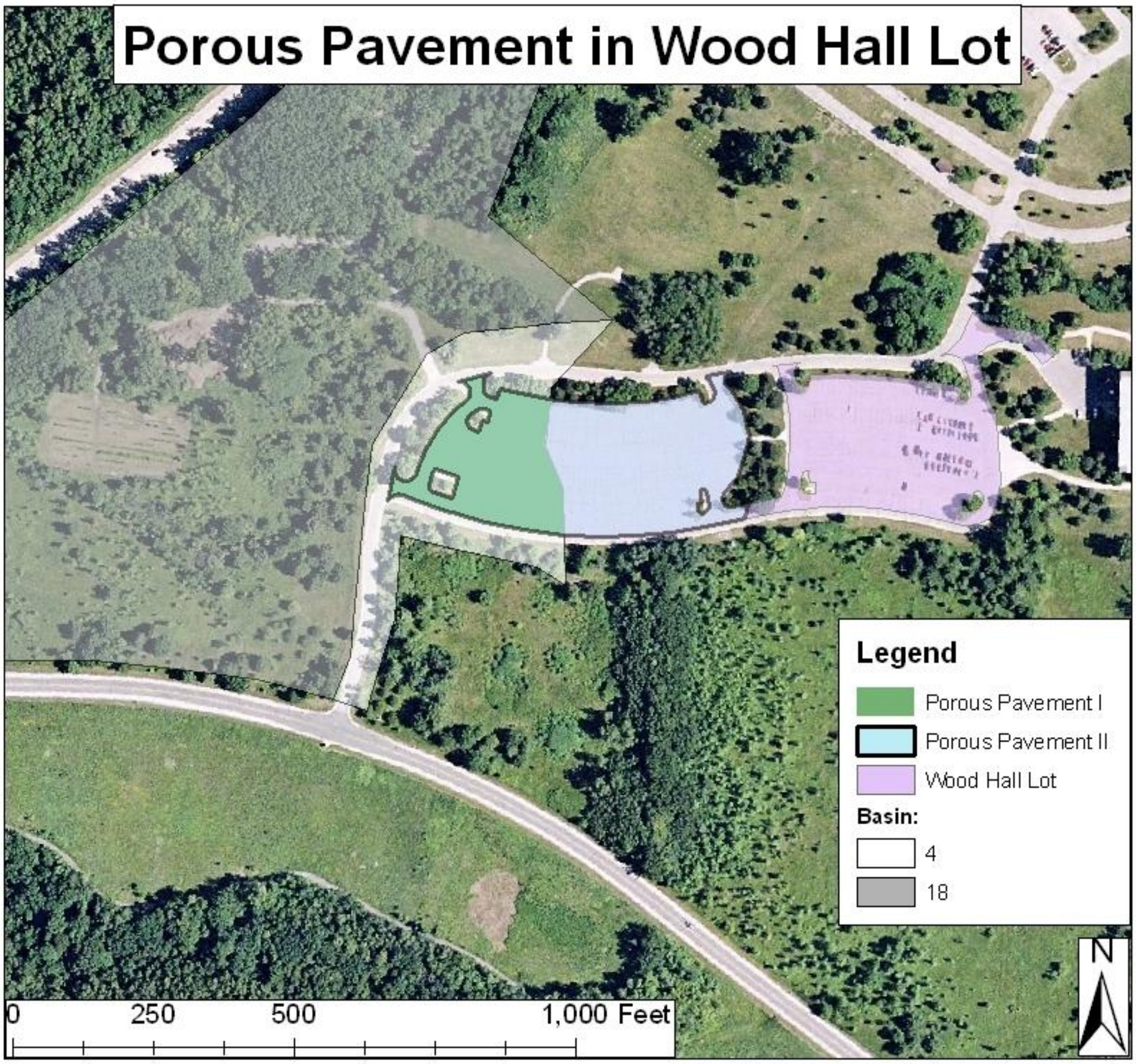
Appendix A: Basin 15 on the University of Wisconsin-Green Bay campus. Land use within the Weidner Center and Wood Hall sub-basins is shown.



Appendix B: Proposed locations and relative sizes for the bioretention cells in the Weidner Center (above) and Wood Hall (below) sub-basins.



Appendix C: Location and relative sizes of the two porous pavement scenarios in the Wood Hall parking lot.



Appendix D: WinSLAMM results for existing condition, and under various scenarios in which bioretention devices were placed within the Wood Hall sub-basin. Modeling results are reported for two scales – Basin 15 and the Wood Hall sub-basin. % Add. Control (Campus) refers to the additional percentage of pollution control the entire campus would receive if such a device were implemented.

Basin 15 - Wood Hall TSS					
Conditions	**Existing**	**Wood 1%**	**Wood 2.5%**	**Wood 5%**	**Wood 15%**
Basin 15 Export	18,799.50	17,135.95	16,331.80	15,890.30	15,691.70
Control (lbs)	-	1,633.27	2,425.82	2,866.36	3,062.86
% Control (Basin 15)	-	8.85	13.13	15.47	16.53
% Add. Control (Campus)	-	1.70	2.60	3.20	3.40
Basin 15 - Wood Hall TP					
Conditions	**Existing**	**Wood 1%**	**Wood 2.5%**	**Wood 5%**	**Wood 15%**
Basin 15 Export	55.91	51.93	49.42	47.88	46.82
Control (lbs)	-	3.98	6.49	8.03	9.09
% Control (Basin 15)	-	7.12	11.61	14.36	16.26
% Add. Control (Campus)	-	1.87	3.05	3.78	4.28
Wood Hall Sub-Basin TSS					
Conditions	**Existing**	**Wood 1%**	**Wood 2.5%**	**Wood 5%**	**Wood 15%**
Sub-basin export	3,062.86	1429.59	637.04	196.5	0
Control (lbs)	-	1,633.27	2,425.82	2,866.36	3,062.86
% Control (Sub-Basin)	-	53.32	79.20	93.58	100.00
Wood Hall Sub-Basin TP					
Conditions	**Existing**	**Wood 1%**	**Wood 2.5%**	**Wood 5%**	**Wood 15%**
Sub-basin export	8.99	5.08	2.6	1.05	0
Control (lbs)	-	3.92	6.39	7.94	8.99
% Control (Sub-Basin)	-	43.54	71.09	88.33	100.00

Appendix E: WinSLAMM results for existing condition, and under various scenarios in which bioretention devices were placed within the Weidner Center sub-basin. Modeling results are reported for two scales – Basin 15 and the Weidner Center sub-basin. % Add. Control (Campus) refers to the additional percentage of pollution control the entire campus would receive if such a device were implemented.

Basin 15 - Weidner Center Sub-Basin TSS					
Conditions	**Existing**	**Weidner 1%**	**Weidner 2.5%**	**Weidner 5%**	**Weidner 15%**
Basin 15 Export	18,799.50	17,261.86	16,272.98	15,626.28	15,420.88
Control (lbs)	-	1,537.64	2,526.52	3,173.22	3,558.62
% Control (Basin 15)	-	8.18	13.44	16.88	18.93
% Add. Control (Campus)	-	1.70	2.80	3.40	3.90
Basin 15 - Weidner Center Sub-Basin TP					
Conditions	**Existing**	**Weidner 1%**	**Weidner 2.5%**	**Weidner 5%**	**Weidner 15%**
Basin 15 Export	55.91	53.01	50.88	49.39	48.32
Control (lbs)	-	2.92	4.98	6.45	7.51
% Control (Basin 15)	-	5.19	9.00	11.66	13.58
% Add. Control (Campus)	-	1.37	2.34	3.03	3.53
Weidner Center Sub-Basin TSS					
Conditions	**Existing**	**Weidner 1%**	**Weidner 2.5%**	**Weidner 5%**	**Weidner 15%**
Sub-basin export	3,611.64	2,071.40	1,110.22	474.32	94.95
Control (lbs)	-	1,540.24	2,501.42	3,137.32	3,516.69
% Control (Sub-Basin)	-	42.65	69.26	86.87	97.37
Weidner Center Sub-Basin TP					
Conditions	**Existing**	**Weidner 1%**	**Weidner 2.5%**	**Weidner 5%**	**Weidner 15%**
Sub-basin export	7.81	4.89	2.83	1.36	0.30
Control (lbs)	-	2.92	4.98	6.45	7.51
% Control (Sub-Basin)	-	37.36	63.75	82.60	96.20

Appendix F: WinSLAMM results for existing condition, and the two scenarios in which porous pavement were placed within the Wood Hall parking lot. % Add. Control (Campus) refers to the additional percentage of pollution control the entire campus would receive if such a device were implemented.

Porous Pavement Basin 4 + Wood Hall Parking Lot

	Existing	Scenario I	Scenario II
TSS Export	3612	3177	2495
TSS (lbs.) removed	-	434	1117
% TSS Control	-	12%	31%
TP Export	6.562	5.85	4.72
TP (lbs.) removed	-	0.72	1.84
% TP Control	-	11%	28%
% Add. TSS Control (Campus)	-	0.5%	1.2%
% Add. TP Control (Campus)	-	0.3%	0.7%