Campus Hydro Redesigned

From Parking Lot to Integrated Stormwater Treatment Design

Abstract

Situated just south of the South Quad on the University of Illinois Urbana-Champaign campus, parking lot F4 is used daily by staff and community members. Though lot F4 is functional, it floods during and following rain events. Additionally, the lot suffers from lack of shade and plant diversity, as well as poor design and unappealing aesthetics. These factors combine to produce costly energy and stormwater expenses, a compromised ecological habitat, and an unsafe pedestrian thoroughfare. To remedy these problems, we propose a solution consisting of a treatment train that integrates bioswales, a mulched gathering space, a green roof, porous pavement, and a rain garden. Together, these systems are designed to completely disconnect the impervious area, while also setting an example for future parking lot renovations on our campus. Besides effectively managing stormwater, our design educates both students and the local community about green stormwater management using descriptive signage and a welcoming area for outdoor learning and recreation. The design also provides a much safer and more accessible path for pedestrians and cyclists traveling near the F4 lot. Plus, our project features a high likelihood of implementation, as the campus Parking Department plans to renovate the F4 lot in the near future. Subsequently, we worked closely with Facilities and Services to create a design that may be used for the future renovation of parking lot F4.

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Site Selection

Figure 1 shows standing water and other debris in the westmost section of parking lot F4.

Due to the extensive flooding problems displayed in Figure 1, the campus parking department already has plans to redo parking lot F4 within the next couple of years. Just south of the main part of campus, this parking lot is used daily by people that work in nearby buildings, and students traveling through the area to get to class. The metered parking spots in parking lot F4 are used by visitors of the Art East Annex Studio 2, commonly referred to as “the Fab Lab,” a collaborative workspace where campus and community members visit to design and fabricate innovative projects.

Site Problems

The current layout of the parking lot, including pedestrian and bike paths, shown in Figure 2, is disorganized and incoherent. This leads to vehicles, cyclists, and pedestrians wandering through the parking lot in inefficient and dangerous ways. Additionally, the lack of uniformity in the layout leads to an increase in impervious area. Due to the age of the lot and ongoing construction, this site suffers from potholes, loose gravel, mud, and other debris. The poor drainage in the area leads to pooling around buildings. The severe flooding issues make this area difficult to navigate during and after a rainfall event. The site houses some trees, but they are not allowed enough space to grow to their full potential. The lack of shading on the lot makes it prone to the heat island effect. Since it is a parking lot, oil and other pollutants from cars collect on the ground and can mix into the runoff during rainfall.

Figure 2 is a satellite view of the site from Google Maps. It is oriented so that the top of the view is north.

Champaign-Urbana has a municipal separate storm sewer system (MS4); meaning stormwater is discharged directly to the environment without being treated. In this case, the stormwater gets discharged directly into Boneyard Creek, which runs through the campus. This creek has been listed on the Illinois EPA 303d list in the past, due to the pollution problems.

Design Solution

Goals:

1. Increase parking lot safety and accessibility, while reducing impervious pavement
2. Add green infrastructure to increase infiltration and reduce peak runoff
3. Improve the area aesthetically
4. Set an example for future parking lot renovations on our campus
5. Address campus objectives
6. Educate students and community members about green infrastructure

Goal One

We redesigned the layout of the parking lot to make it safer and more accessible. Our project aims to straighten Goodwin Avenue; it currently curves around the east side of the parking lot, as shown in Figure 2. Straightening the street would increase visibility and create a more maneuverable space for users. This new layout would also provide space in the parking lot, giving cars more room to navigate through it. Pedestrians tend to cross through the middle of the north-eastern part of the parking lot, due to the segmented path. The new layout adds a pedestrian path that cuts through the rain garden, allowing pedestrians to safely cross the northern part of the parking lot. The addition of a wider multi-use path, bordering the parking lot from the east, would make it safe and comfortable for cyclists and pedestrians to share the space. Moreover, large trucks that need to access nearby buildings would still be able to easily navigate the redesigned parking lot. A gate off the roadway south of Art East Annex 2 allows trucks to come through, but keeps regular traffic out of the area, thereby protecting pedestrians. The new design of the parking lot also utilizes the space more efficiently to reduce the impervious area from 101,085 square feet to 82,955 square feet; an 18% reduction in the impervious area. In addition to redoing the parking lot, there are plans, as shown in the Campus Master Plan, to tear down the building on the southeast side of the lot, leaving us more space to expand the parking lot.

Goal Two

To analyze our treatment train of green infrastructure, we used the Stormwater Management Model (SWMM) to compare the site's current runoff with the runoff that would occur if our design were to be implemented.

Runoff Model

We used the National Oceanic and Atmospheric, NOAA, point precipitation frequency estimates and a Type II rainfall curve to model a 2 year 24 hour storm for the site using SWMM. According to the NOAA estimates, a 2 year 24 hour storm has a depth of 3.05 inches.

In the model, the site area is divided into subcatchments. Water flows from one subcatchment to the next, as indicated by the blue arrows in Figure 3, to create a treatment train. Downspouts from buildings within the drainage area are disconnected and directed towards pervious surfaces. Runoff from Goodwin Avenue and sidewalks flows into the bioswales and the rain garden by way of curb inlets. Once the stormwater is on the ground, it flows through the site, ultimately going to the rain garden.

Figure 3 shows the 2-dimensional layout of the proposed site.

Downspout Disconnection

We disconnected a total of 40,212 square feet of roof and diverted 10,220 cubic feet (76,450 gallons) of stormwater.

Site Soil and Engineered Soil Mix

The bioswales, educational and recreational area, and the rain garden all have the same basic subsurface layers: a shallow layer of mulch, which overlays a deeper layer of bioretention soil media, followed by the site soil. The organic mulch layer helps maintain soil moisture, prevent erosion and surface sealing, and traps finer sediment. The bioretention soil media, a loamy sand, allows the water to be treated as it percolates through its depth. Pollutants are removed in the soil layer through sedimentation, filtration, adsorption, microbial processes, and plant uptake. Investigations into the soil at the site showed that the silt loam has poor drainage and a low infiltration rate; this necessitates the installation of pipe drainage under green infrastructure. The depth of the soil layer varies in different green infrastructure practices in the design depending on the type (if any) of vegetation above it and the volume of water to be treated.

Green Roof

Art East Annex Studio 1 will have a 2,612 square foot modular extensive green roof. Pre-planted sedum trays, which were chosen based on past use and proposals on campus, will be placed on a waterproofing material on top of the green roof area (see reference #1, 16). The area of the green roof was chosen based off of the SWMM runoff model of the current parking lot F4 layout and the slope of the roof.

Porous Pavement

Service lanes within the parking lot are good sites for permeable pavers as they have minimal traffic. Runoff from rooftops of Art Annex Studio 1 and 2 are directed towards these areas, shown in Figure 3. The design for permeable pavers here is similar to a standard design used by the university in a previous project (reference source # 25).

Bioswales

These 6 foot wide conveyance channels will be constructed along the edge of the parking lot for a total length of 750 feet. The parking lot will be graded so that runoff can flow into these paths. Curb cuts direct runoff onto energy dissipators that allow the runoff to spread evenly over the bioswale. The banks have a gradual slope of 3:1 and a ponding depth of 6 feet. Following the planting plan, which is described under Goal Three, a mixture of prairie plants will be rooted in a 2 to 3 inch layer of mulch, which overlays an 18 inch bioretention soil media layer. Excess runoff is directed towards the rain garden through grates that travel across the road.

Educational and Recreational Area

The educational and recreational area directly north of the Integrated Bioprocessing Laboratory will infiltrate some amount of the disconnected runoff from the Agricultural Bioprocess Laboratory and the Integrated Bioprocessing Laboratory, as well as the flows from higher elevations. It consists of a 2 to 3 inch layer of mulch overlaying an 18 inch layer of bioretention soil media. The educational and recreational area is designed without any ponding depth to avoid flooding. Any excess runoff will flow into the bioswale located downstream. There is also a 6 inch storage layer below the soil with an underdrain located 6 inches from the bottom. This pipe is designed to carry the full capacity of the storage above it within 30 hours.

Rain Garden

In the final step of the treatment train, the excess runoff from the other treatment and infiltration practices will be directed towards the rain garden (a cross section is shown in Figure 4). This bioretention area, which is planted with flowers from the planting plan described in Goal Three, is located at the lowest point of the parking lot. The underdrain is designed to convey the full storage capacity of the layers above within 30 hours. An inlet grate, at an elevation greater than the 6 inch ponding depth, is also provided to capture excess runoff that may be generated during large storms. Both the underdrain and inlet grate direct stormwater towards the existing drainage system.

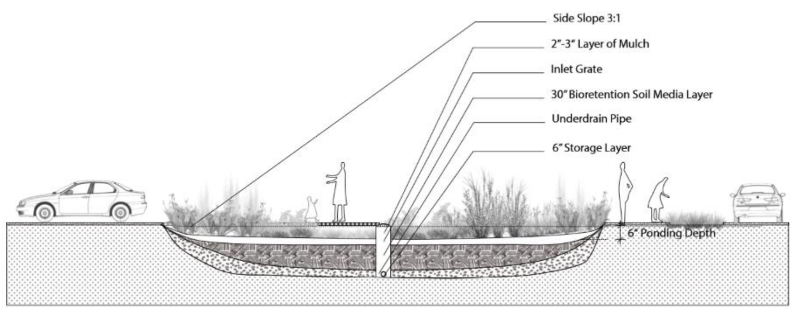

Figure 4 shows the cross section the rain garden.

Other Options Explored

We considered water reuse in the project, but Illinois Plumbing Codes do not permit any indoor water reuse. Even though water reuse may hopefully be implemented in the future, we did not feel as though it would be a good addition to the project at this time. We considered rain barrels as well, but they would not catch all of the roof runoff. Rain barrels are also high maintenance, and have the potential to attract mosquitoes. Subsequently, we decided rain barrels would not be a good fit for this project. Instead, we made sure that each roof's runoff went into a pervious area.

Treatment Summary

With an annual rainfall of 41.38 inches (1980 – 2010 average), we calculated the total pollutant loads, shown in Table 1, that our design would prevent from flowing into Boneyard Creek. To make these calculations, we used the Simple Method from the New York Stormwater Management Design Manual. This great decrease in the external outflow will help keep pollutants out of Boneyard Creek.

Pollutant	Annual Load Reduced
Total Suspended Solids (lbs)	3,583
Total Phosphorus (lbs)	12.7
Total Nitrogen (lbs)	12.69
Escherichia Coli (Billion Colonies)	37,2592
Copper (lbs)	1.059
Lead (lbs)	0.711
Zinc (lbs)	5.549

Table 1 shows the reduction of the annual pollutant load.

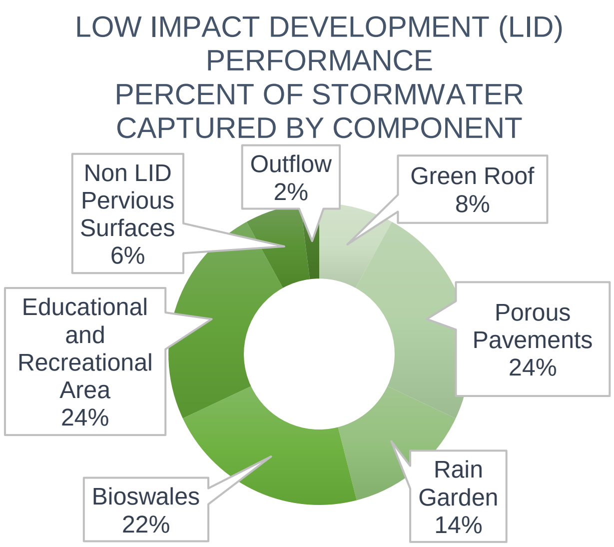

Figure 5 shows the low impact development (LID) perfomance.

In the current design, all of the impervious area is directly connected, but the new design we are proposing eliminates all of the directly connected impervious area.

Figure 5 shows the low impact development (LID) performance on the site by showing the percentage of stormwater captured by the green infrastructure components and other pervious surfaces. The site can successfully capture 98% of the 34,412 cubic feet of water that results from 2 year 24 hour storm. Since only 2% of the stormwater is discharged, the peak discharge for the new site approaches zero.

We quantified the stormwater management of the old site versus the new site to see how the treatment train positively impacted the area. Figure 6 compares the infiltration (groundwater recharge), final storage and external outflow of the two sites. There are clear benefits from the increase in groundwater recharge and site storage.

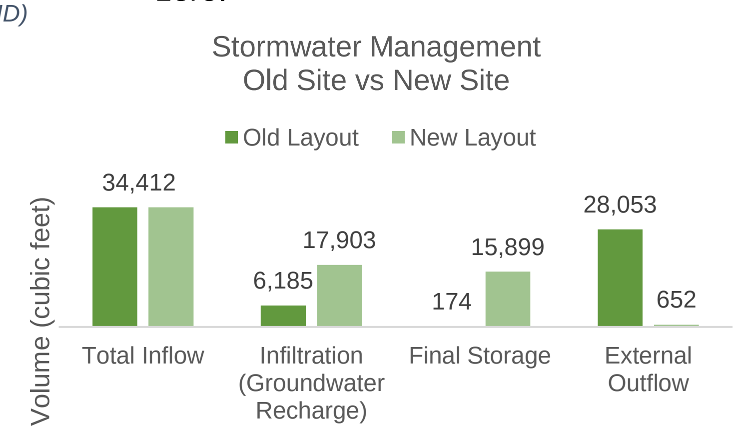

Figure 6 compares the stormwater management in the old site to the new site.

The trees that would be added to the site, discussed in depth in Goal Three, also have benefits. Using the online National Tree Benefit Calculator provided by the Arbor Day Foundation, and assuming a DBH (diameter at breast height) of 24 inches to show the positive short-term effects of planting, we estimated that the newly planted trees would sequester 1,252 pounds of CO_2 in one year, along with some amounts of O_3 particulate matter and NO_2.

Goal Three

To achieve our goal of improving the area aesthetically, we added a variety of well-spaced vegetation to the site. We lined the multi-use bike and pedestrian lane with trees and bioswales, and we added areas to relax while surrounded by nature.

For the trees on site, we chose a combination of swamp white oak, sycamore and eastern cottonwood. The fourteen trees we added to the site line the bioswales, which run along the southern portion of the lot, as shown in Figure 3. We chose to add only two eastern cottonwoods because their seeds could clog the porous pavement (we also placed them far from the porous pavement). We also decided to evenly distribute six swamp white oaks and six sycamores. Considering these trees' preference for medium to wet soils and full sun, we found them fitting to deal with stormwater on site. The eastern cottonwood and swamp white oak are both Illinois natives, and the sycamore is more commonly found throughout Indiana and the southern United States. Currently, most trees on campus are maples and oaks, which are both native and abundant, so we chose the sycamore to add biodiversity to the trees on campus. All three of these trees' large canopies (diameters of the mature crowns range from 50 – 75 feet) increase shade in the area. The swamp white oak's burnt yellow leaves, as shown below in Figure 7, will add to the aesthetics of the area during the fall. The design also adds three ornamental trees to the recreational and educational area for the purpose of improving aesthetics.

Figure 7 swamp white oak

Figure 8 sycamore

Figure 9 eastern cottonwood

Figure 10, below, shows proposed signage in the area (which will be addressed in greater detail in a later section). This example encourages visitors to identify the different flowering plant species in the area via a scavenger hunt. The signage also describes the motivations behind why these plants were chosen.

The edge of the rain garden will be bordered by the smallest of the plants. Toward the inside of the rain garden, there will be two medium height flowers, and the tallest of the plants will be in the middle of the rain garden. With this arrangement, the plants with the deepest roots system will be in the center, which is also the lowest point of the garden. The deep roots will provide a path for excess rainwater to flow away from sidewalks and buildings, preventing pooling and flooding. Over the entire site, there will be 10,500 square feet of native flowering plants.

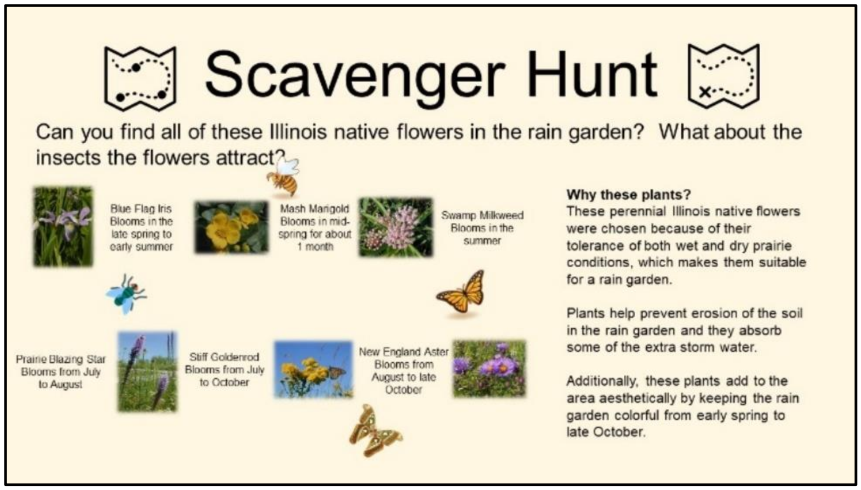

Figure 10 example of signage for the educational and recreational area.

These flowers attract a variety of life, such as insects and hummingbirds, thereby increasing the biodiversity of the area. As one of the first natives to bloom in the spring, Marsh Marigold begins the season by attracting pollen-loving insects such as flies and bees. In the summer, the pink, lavender, and white blooms of the Swamp Milkweed attract butterflies and hummingbirds. Lastly, blooming from mid-late summer to October, the New England Aster and Stiff Goldenrod collectively attract butterflies, moths and bees.

Goal Four

Currently, most campus parking lots are designed to be inexpensive without worrying about making them 'green.' Through this project design, we hope to encourage our campus to design and implement green parking lots in the future, which is something University of Illinois Chancellor Robert Jones is encouraging us to do.

In our Chancellor's own words: "I am pleased to know that our students are working together to envision sustainably designed parking lots. I am very supportive of having permeable pavements, an increase in the tree canopy, and green stormwater infrastructure integrated throughout the University of Illinois at Urbana-Champaign."

We have proposed a few guidelines for future parking lot renovations:

- Have a minimum of 1 tree per 15 parking stalls
- Manage 95% of the local rainfall events on site, as suggested by LEED v4
- Reduce the impermeable cover, either on the parking lot or the surrounding area
- Improve water quality by having it infiltrate through green infrastructure components
- Reduce vehicle, pedestrian, bicycle and delivery truck conflicts by using Complete Streets

Goal Five

The Campus Master Plan incorporates the goals of the 2015 Illinois Climate Action Plan (iCAP). One of the objectives of iCAP is to "Investigate the water quality impacts of stormwater runoff and potential ways to reduce stormwater pollutant discharges by FY18." Our project helps meet this objective by proposing a way to reduce discharged stormwater and by treating the stormwater that is discharged. Because they reduce the heat island effect and sequester CO_2, Tree planting on campus, especially in parking lots, is another goal of iCAP . By redesign the site layout, we address another goal of the Campus Master Plan, which is to increase accessibility and connectivity to improve travel for pedestrians, cyclist and drivers.

Goal Six

In the space to the north of the Integrated Bioprocessing Laboratory, there will be an educational and recreational area. This area features educational signage that focuses on teaching students and the community about the benefits of green infrastructure. An example of the signage, Figure 10, takes the form of a scavenger hunt. Children visiting the area, especially while attending the summer camps hosted by the Fab Lab, will be inclined to search the site for certain flowers and the insect species that are attracted to those flowers. Adults can also participate in the scavenger hunt, or read about the plants featured in the recreational area. Other signage will include ideas for implementing green infrastructure on a smaller scale in residential homes. Both Champaign and Urbana, the surrounding communities, incentivize adding rain gardens and other efforts to decrease peak discharge and stormwater runoff to homes by partially reimbursing the home owners for the construction costs. This area has been designed to be multi-functional; children can play here, adults can learn about green infrastructure, and students can relax or even have an outdoor class.

Figure 11

Our team put together a survey to get an idea of how many people on campus use this area. We had 90 responses and found that 50% of respondents go through our proposed site. The methods of travel through the site are displayed in Figure 12.

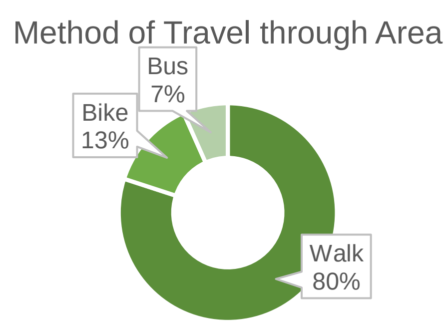

Figure 12

This information helped us realize how important it is to make the area more pedestrian friendly. We also want to make the area more bike friendly so that more people can use the area as a bike route. We took the results from Figure 13 into account when we designed the site. We did our best to find the quickest and most efficient route, while also making sure that it was the most scenic.

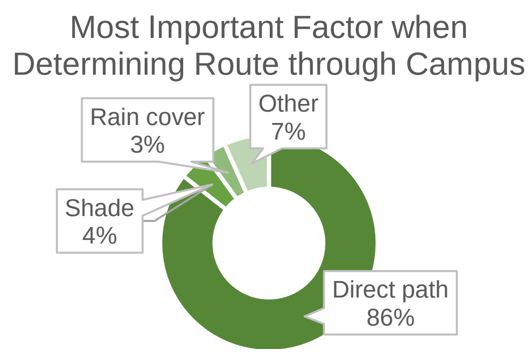

Figure 13

Maintenance

To increase the ease of maintaining the site, we kept our maintenance plans as simple as possible. After completing a draft of maintenance plans for the area, our advisors from Facilities and Services looked over our draft and helped us make some improvements.

Rain garden and bioswales

These should be mowed once a year, either in the fall before winter or after the last frost. Mulch should be added to the area to keep down weeds. During the first three years of being planted, the area should be weeded and treated with herbicide three times a year (April, June and September).

Educational and recreational area

After rainfall or large winds, the mulch will need to be redistributed evenly over the site. The structures in the site will also need to be maintained by repairing or replacing broken poles or benches and keeping the signage clean.

Snow removal

Snow from the parking lot can be placed inside the bioswales or in the north-west corner of the educational and recreational area. Placing the compacted snow in the educational and recreational area gives people the opportunity to use the snow to make snowmen or snow tunnels.

Green roof

Since the green roof is separated out into trays, the individual trays can be repaired or replaced when needed without having to take apart the whole green roof. During prolonged dry periods, the green roof should be watered.

Porous pavement

Similar to other porous pavements parking lots in the community (Champaign-Urbana Mass Transit District’s and C9, another campus parking lot), we did not include any special maintenance for the porous pavement. Since the service lanes that have porous pavement are not used very often, this will help reduce clogging.

Clogged grates

Grates are great for easy and effective maintenance. When they become clogged, the leaves and other debris can easily be removed with a shovel to allow for water flow.

By closely following the weeding guidelines for the first few years of the project, the long-term maintenance should decrease because the plants will have spread out enough to keep out weeds on their own. Facilities and Services will perform the same maintenance that they perform on other parts of campus to maintain the multi-use path. Because it does not require striping and restriping the lines, the multi-use path facilitates easier maintenance and lower costs than a traditional bike lane. Finally, the university's Parking Department will follow the same maintenance plan that they would use for any other parking lot.

Project Phasing

After bidding on the project is completed, the implementation of the project will take just over one year. Starting in the spring of the year, pavement and utility work will be done (including any regrading of the parking lot). Following the completion of this work, the green roof and trees will be added to the site in the fall. The following spring, after the change for frost has cleared, the perennials will be planted. Lastly, after all the planting is done, the structures and signage will be added to the site.

April - September
- Pavement and Utility Work

→

September - October
- Install greenroof
- Add trees

→

April - May
- plant perennials
- Add structures and signage

Cost and Funding

In calculating the budget for the project, we accounted for the environmental costs, and the capital and operating cost, shown on the calculations page. We found that the capital and operating cost (including the drainage cost) of the project would come to approximately $532,000.

Since our project site falls within the proposed renovation list of the university's master plan, funding to begin this project can be acquired from the University. Funding for the project could also be acquired from the UIUC Student Sustainability Committee (has previously funded projects some projects up to $500,000), Water Pollution Control Loan Program of the Illinois Clean Water Initiative, and the EPA Source Reduction Assistance Grant (from $20,000 to $260,000). The permeable paving stones will also be a source of funding and support for the project. Alumni, or other supporters of green infrastructure, will be able to pay to have their names engraved on one of the stones. There are also several opportunities for outreach to alumni and potential supporters: University of Illinois Alumni Association, CEE Alumni Association and Moms and Dads Association.

Our project will also reduce costs for the University, further incentivizing the implementation of the project. The University has to pay a stormwater utility fee to both Champaign and Urbana that is based on the total impervious area that drains into the city's sewers. By reducing the impervious area, we will save the University capital. Adding trees to the site will reduce energy bills by providing shade to the surrounding buildings. The green roof can also reduce energy consumption by providing insulation for the building, thereby decreasing the energy used for heating and cooling.

Conclusion

Campus Hydro Redesigned will manage the flooding issue in parking lot F4 using a green infrastructure treatment train consisting of bioswales, a recreational area, a green roof, porous pavement, and a rain garden. The site renovations will leave a lasting positive impact on campus, as they will not only increase safety and improve aesthetics, but also provide an area where students, staff, and community members can gather to learn about green infrastructure. With strong support from Chancellor Jones and Facility & Services, we believe that the new design for parking lot F4 can be used as a reference for future green parking lot renovations on the University of Illinois at Urbana-Champaign campus.

Acknowledgements

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Calculations

Project Cost	Porous Paving13,074 ft^2	Asphalt Paving 24,651 ft^2
Embodied Energy (MJ)	297,590	2,634,105.72
CO_2 Emissions (kg)	17,403.74	154,048.147

Cost ($)	Porous Paving	Asphalt Paving	Sidewalk 10,786 ft^2
Capital & Operating	218,920.76	255,948.89	87,152.39
Social & Environmental	2,628.23	40,500.77	
Total	225,598.96	296,449.66	87,152.39

Table 2. (references sources #2, 3, 13, 14, and 20)

SWMM Model (references sources #7,10,15, and 21)

LID Control	Total Inflow (in)	Infiltration Loss (in)	Outflow (in)	Final Storage (in)
Green Roof	3.05	0	0.01	3.3
Bioswales	59.41	11.45	17.66	34.16
Porous Paving	15.31	14.95	0	0.38
Rain Garden	19.78	5.34	1.23	16
Educational & Recreational Area	22.61	5.96	9.23	8.88

Table 3 shows a summary of LID performance.

Pollutant Loads The Simple Method is used. (reference source #18)

L = 0.226*R*C*A (Chemicals Constituents & TSS)

L = 103*R*C*A (Bacteria)

L=Annual load, R=Annual runoff, C=Pollutant Conc., A=area

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