Celebration of Raindrops:
An Innovative, Interactive Approach to Rainwater Management

University of Illinois at Urbana-Champaign
Student Team D15

Abstract

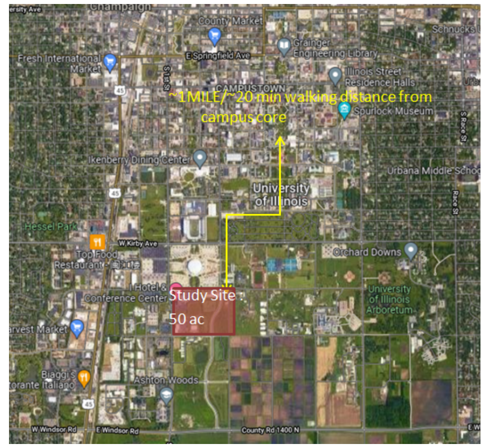
Located at the south-western area of University of Illinois at Urbana-Champaign, the site is part of the UIUC Research Park. Despite its noticeable location near the State Farm Center arena and the iHotel (the university's official hotel), the area remains an unappealing space because of lack of canopy shade and plant diversity as well as an discontinuous pathway. The runoff from unutilized fields and impervious parking lots is discharged directly to the existing retention pond that is connected to the Embarras River, a waterway beginning in Urbana-Champaign. This runoff has high concentrations of phosphorus, nitrogen, and suspended solids, and eventually leads to the Gulf of Mexico where these contaminants harm its rich ecosystem and create a large deadzone where dissolved oxygen is minimal.

"Celebration of Raindrops: An Innovative, Interactive Approach to Rainwater Management" is designed to remedy those problems and to provide a space where students, staff and visitors all can enjoy the interaction with nature and learn more about green infrastructure. The design proposal consists of a constructed wetland, several retention/recreation ponds, a rain garden, experimental farmland, and the transformation of an abandoned silo into a water center. Tying these features together are a rainwater treatment and purification system, a clean water recycling and redistribution system, as well as a greenway system. Furthermore, our project can assist in achieving the University's Illinois Climate Action Plan (iCAP) goal of achieving long-term carbon neutrality by providing an infill design example at underutilized open space.

Team Members
Jingjing Xu- Master of Sustainable Urban Design, Master of Architecture
Yuqing Liu- Master of Landscape Architecture
Will Napier- Master of Landscape Architecture
Chenfei Cai- Master of Landscape Architecture
Sichen Li- Master of Landscape Architecture
Jianing Zhao- Master of Landscape Architecture
Jianming Li- Master of Landscape Architecture
Tonia Andreina- Master of Landscape Architecture
Matthew Andre Krauss- Civil and Environmental Engineering
Aditi Chockalingam- Civil and Environmental Engineering
Arannya Roy- Civil and Environmental Engineering

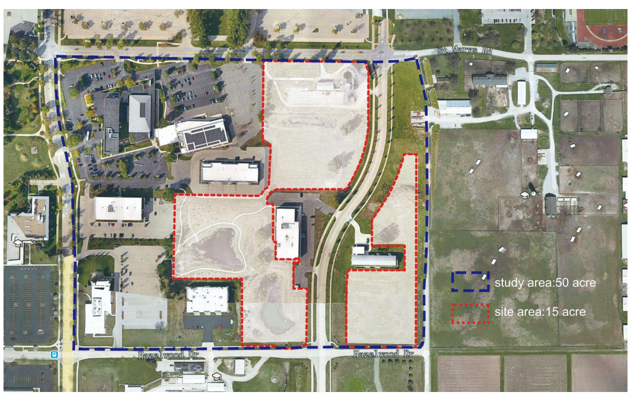
Faculty Advisors
Professor Arthur R. Schmidt, P.E., Department of Civil and Environmental Engineering
Professor Jie Hu, PLA, Department of Landscape Architecture

Project Context



The site is part of the UIUC Research Park, which is positioned for continuous expansion on campus.The growth reinforces the need for a demonstration project that addresses the critical issues of: land use, circulation, infrastructure, parks and recreation. We chose the underutilized area in the north-east block of the research park as our site, to create a distinct identity and to enhance a sense of place for the Research Park and to reinforce its connection with the campus core.

The study area is 50 acres including the surrounding buildings and parking lots while the site of the project is 15 acres. In the north of our site, there is State Farm Center, the third largest Illinois arena, which holds games and conferences every season. The iHotel and conference center are located in the west of the site, providing services for every Illinois game day, alumni reunion, wedding, celebration, community event, or staff meeting. The other buildings inside the study area are office buildings and research labs. A large greenhouse on the east of Fourth Street is operated by a crop research lab across the street.



In terms of topography, our site is situated on a ridge line that divides the whole campus into two watersheds. The rainwater runoff of the study area will be drained to the East Branch of the Embarras River floodplain to the South. The flow of nitrogen and phosphorus from nearby farms and untreated wastewater into the Embarras River, part of the greater Mississippi River watershed, contributes to the growing hypoxic zone in the Gulf of Mexico.

Site Analysis

A number of problems and some advantages are presented based on several site visits and interviews with local users. The large area of impermeable paving for parking lots and the lack of tree canopy in the study area creates heat island effects that make the site measurably warmer than surrounding areas on summer days. Combined with soil types that have a high runoff potential, there are serious environmental factors to consider.

The majority of the site, adjacent to beautiful farmland to the east, is not accessible to bikers and pedestrians. The existing retention pond is a great place for relaxation and recreation, according to Benjamin, a manager who works in the crop research lab, however, there are no few amenities to enjoy there. The pathway around the retention pond is not connected or continuous. Furthermore, it is difficult for Benjamin to check on the greenhouse to the east of Fourth Street after working in the research lab across the street because there is no pedestrian crossing. The Research Park is bisected by Fourth Street, which has led to inefficient and dangerous pedestrian circulation.

In addition, the rainwater on our site is discharged directly to the existing retention ponds, which smell bad on rainy days, especially due to the service vehicles of the iHotel and the abandoned silo to the north. The majority of the rainwater management system is closed and buried so that visitors have little knowledge or awareness about the process and green infrastructure.

Local Acts and Plans

Several current local regulation acts and action plans apply to the site. The City of Champaign requires all new development and redevelopment to provide for rainwater detention on site and drainage designs that minimize impervious surfaces, attenuate flows via open vegetated swales, and preserve natural waterways.

The Illinois Nutrient Loss Reduction Strategy, developed by the Illinois Environmental Protection Agency, Illinois Department of Agriculture, and University of Illinois Extension proposes and helps implement measures to improve water quality in the region and downstream by reducing nitrogen and phosphorus levels in runoff, promoting sustainable agricultural practices such as cover crops and reduced fertilizer application, and the installation of green infrastructure features like green roofs and green urban rainwater practices like street sweeping and leaf collection.

The University has approved two landmark plans that affect our design: the Illinois Climate Action Plan (iCAP) and the Resilient Landscape Strategy. iCAP sets sweeping sustainability goals for the entire campus, including becoming carbon neutral by 2050. Furthermore, it sets several nearterm land and water management goals, including: reducing the campus's use of potable water by 40% by 2030; doubling pollinator-friendly spaces by 2024; and, doubling green infrastrastructure installations by 2024.

The Facilities & Services department approved its Resilient Landscapes Strategies in 2018, which aims to make the campus an exemplar of resilient rainwater management. It recommends the addition of bioinfiltration cells with native plantings and bioswales for parking lots and roadways; increasing tree planting; and, rainwater harvesting. It also places emphasis on community education surrounding rainwater management to increase awareness and participation in campus stewardship.

The current master plan for the Research Park recommends infill development and that new development be clustered around rainwater management facilities and be right-sized to discourage excessive parking, reducing impervious surfaces and the heat island effect.

Project Goals

The goal of this project is to provide a dynamic, sustainable, and innovative space for the local community, to set an example for future infill development on campus, and to advocate for sustainability and green infrastructure worldwide. We identified six design objectives to address social, environmental, and economic concerns:

1. Reduce rainwater runoff and prevent flooding
2. Improve water quality of the Embarras River
3. Reduce potable water consumption
4. Improve plant diversity and enhance the broader ecosystem
5. Increase accessibility to green space
6. Educate students, staff, and visitors about sustainability and green infrastructure
7. Provide an aesthetic, accessible, and continuous space for relaxation and recreation

Design Solutions

The design is composed of six zones to provide a dynamic experience on the site: Terraced Wetlands, Central Lake, Hook Pond, Mediation Garden, Education Farmland and an Aquatic Tower. Several green infrastructures have been implemented in the six zones to create an innovative, interactive approach for rainwater management. To achieve the design objectives, we propose four strategies:

1. Greywater Treatment and Purification System

The greywater treatment and purification system makes use of the existing topography of the site and purifies the rainwater collected from surrounding building roofs and parking lots by plants in a multi-step system consisting of a constructed wetland, several retention and recreation ponds, and a rain garden.

1.1 Terraced Wetlands

Located in the northern section of the site, Terraced Wetland is a constructed wetland that uses natural processes involving wetland vegetation, soils, and their associated microbial assemblages to improve water quality. The site topography gradually decreases from north to south, with three small curved pools of water distributed along the main roadway of the site. Rainwater is collected in this pool and then flows downward with the topography. The rainwater is purified by layers of wetland plants between the steps by the wetland plants, flows into a circular strip pond in the middle of the wetland, which then converges into an oval-shaped pond.

On the north side of the circular pond, three large, curved steps are set up, which are hidden among the wetland plants. In the center of the circular band pond is a stage on which people can perform or conduct group activities. To the south of the oval-shaped pool, shorter curved steps are set up on which visitors can sit and view the landscape. The pond and wetland plants, the stage in the middle of the site, and the water tower form a richly layered picture for visitors. At the southeast corner of the constructed wetland is a landscape bridge that connects the constructed wetland to the Vegetated Bioswale, giving the entire site a sense of unity. At the same time, the bridge adds to the visitor experience.

1.2 Central Lake

Central Lake redesigns the edges of the existing retention pond on site to connect with Terraced Wetlands and Hook Pond. Two weirs slow the flow from Terraced Wetlands before entering Central Lake. An open, vegetated bioswale extends from the large parking lot of the iHotel's conference center allowing runoff to flow into the main basin between the weirs, trapping sediment, suspended particles, and debris. West of these weirs a tallgrass prairie buffer strip provides similar functions for parking lot runoff not channelled into the bioswale.

Surrounding Central Lake is a loop pathway which connects to the broader greenway system, with two bridges crossing the streams that connect it to Terraced Wetlands to the north and Hook Pond to the south. The path widens south of the tallgrass prairie strip to form a plaza with two large planters with trees fitted with seat walls facing the water. Between the path and the water's edge is densely planted wetlands, cleaning the water and creating vital aquatic habitat. Together the plantings in this section of the design are evocative of the two dominant ecosystems in the region: wetland and prairie.

Just off the path on all sides of Central Lake are three sunken, outdoor classrooms, which can be used for educational events, social functions or casual enjoyment. The floor of each classroom is two feet below grade, creating enough depth for a built-in seat hugging the perimeter, inviting visitors to view their surroundings from a new perspective, closer to the earth and water. Their shape is reminiscent of the organic flow of water drops, echoing the central theme of the design.

1.3 Hook Pond

Hook Pond functions as both a recreation pond and part of the larger rainwater reuse system. After a series of rainwater treatments, clean water resources will be collected in the recreation pond and transformed into the water features. The water feature in this area includes a small crescent-shaped pool and a large pea-shaped pool.

The recreational pool area has three main activity spaces: a wetland park, terraced seating and a fishing platform. The wetland park is mainly for leisure walks and wetland plants exploration. Terraced seating creates a relaxing space to enjoy the tranquility of the surroundings. The stocked pool is located on the south side of this section where visitors can bring their own tools or rent here to enjoy the fun of fishing.

As part of the rainwater management system, the recreation pond has plans for different water levels in this area, marked by two edges. Between these two edges is a square marked with pebbles. When the water level is low, the square will be exposed. People can touch the treated water in the square and feel the effects of water treatment while having fun. When the water volume is large, this square will be submerged and become a part of the pool, increasing the pool's capacity. Visitors can reach the lakeside square through the trail surrounded by plants and rest on the seats beside the flower beds. After large storm events when the water volume exceeds the capacity of the ponds, it will be discharged into the pond of Education Farmland across Fourth Street to the east.

1.4 Mediation Garden

Mediation Garden consists of a vegetated bioswale and bioretention cell. It is a channel designed to concentrate and transport rainwater runoff while removing debris and pollution. It is also conducive to recharging groundwater. Vegetation reduces the flow rate of water and facilitates treatment and infiltration. Meditation Garden will treat runoff from the nearby roadway and parking lot.

The roughly four acre bioswale is located east of Fourth Street and north of the greenhouse. A large amount of car pollution is deposited on the sidewalk and washed away by the first flush of rain. The bioswale in the project is created at the edge of the parking lot to capture and treat rainwater runoff, and then release it to Education Farmland.

The bioswale is designed to safely maximize the retention time of water in depressions, which helps to collect and remove pollutants, silt, and debris. Therefore, bioswale is designed to be zigzagged according to the site terrain. In depressions with gentle slopes (less than 6%), permeable materials (such as decomposed granite) are laid and gabion parapets are set along it. Various water-loving plants are planted in the depression, including spiderwort, mountain mint, ostrich fern, golden Alexander, red chokeberry, high bush cranberry, New Jersey tea, and blue flag iris. These deep-rooted native grasses and forbs can enhance water infiltration, cooling and purification to improve water quality.

A 100-yard long winding wooden plank road runs through the whole bioswale area, connecting Terraced Wetlands to the west and Education Farmland to the south. The wooden plank road is supported by wooden columns, more than a foot and a half above the ground. To the east of the wooden plank road, three wooden platforms of different heights are set up as open air yoga venues.

1.5 Education Farmland

Education Farmland is a living education center, providing visitors an opportunity to learn about food production and sustainable living. It comprises four zones, including a rain garden, orchard, planting garden, waterfront plaza.

The entrance is a rain garden, capturing and infiltrating rainwater runoff. It is also easy to maintain. There are several native and water-tolerant plants, such as switchgrass, green bulrush, golden Alexanders, culver’s root, wild senna, wild bergamot, sweet coneflower, and New England aster. These plants can attract a variety of birds, butterflies, and small mammals.

The orchard is located at the northwest corner. There are several fruit trees and shrubs, including persimmon, dwarf apple, peach, and black chokeberry. These trees are not only ornamental, but their fruits are edible. Visitors can participate in the whole production process.

The center of the education farmland is the planting garden. Visitors are encouraged to plant produce in the long plant beds by themselves. The garden uses a drip irrigation system to irrigate the farmland.

The waterfront plaza, next to the planting garden is ideal for lectures or workshops. Visitors can sit at seats around the plaza to participate. They can learn about plants, animals, ecosystems, agriculture, food production, and water management. There is also a bridge connected to the plaza where visitors can enjoy the view of the retention pond to the south.

To achieve the design goals, the lawn uses the drought-tolerant tall fescue to reduce the need for irrigation. The planting garden uses the permeable decomposed granite as the pavement material. In addition, a mulch layer was applied to the bare soil surface to reduce water transpiration.

2. Clean Water Recycling and Redistribution

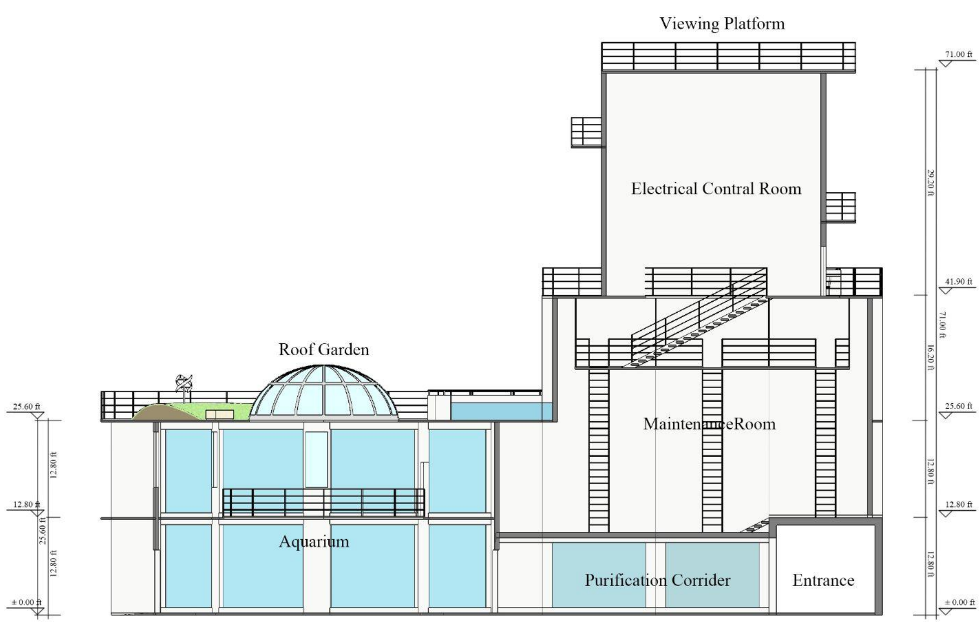
2.1 Off-Site Water Tower

This design contains a complete water circulation system, including water delivery, purification, irrigation, and filtration. The system begins at a lake approximately 5,000 feet southwest of the site at the headwaters of the Embarrass River. It has a water level of about 710 feet above sea level and holds about 482,000 cubic feet of water.

Our design proposes a 130-foot tall water tower be built adjacent to the lake to store runoff from campus before it reaches the river. At this height, it will be taller than the Aquatic Tower on-site, allowing water to be transported to the Aquatic Tower by atmospheric pressure and gravity through underground pipes. According to NOAA, Urbana-Champaign has an above average annual wind speed; therefore we propose a wind turbine be installed to pump the water from the water tower to the Aquatic Tower.

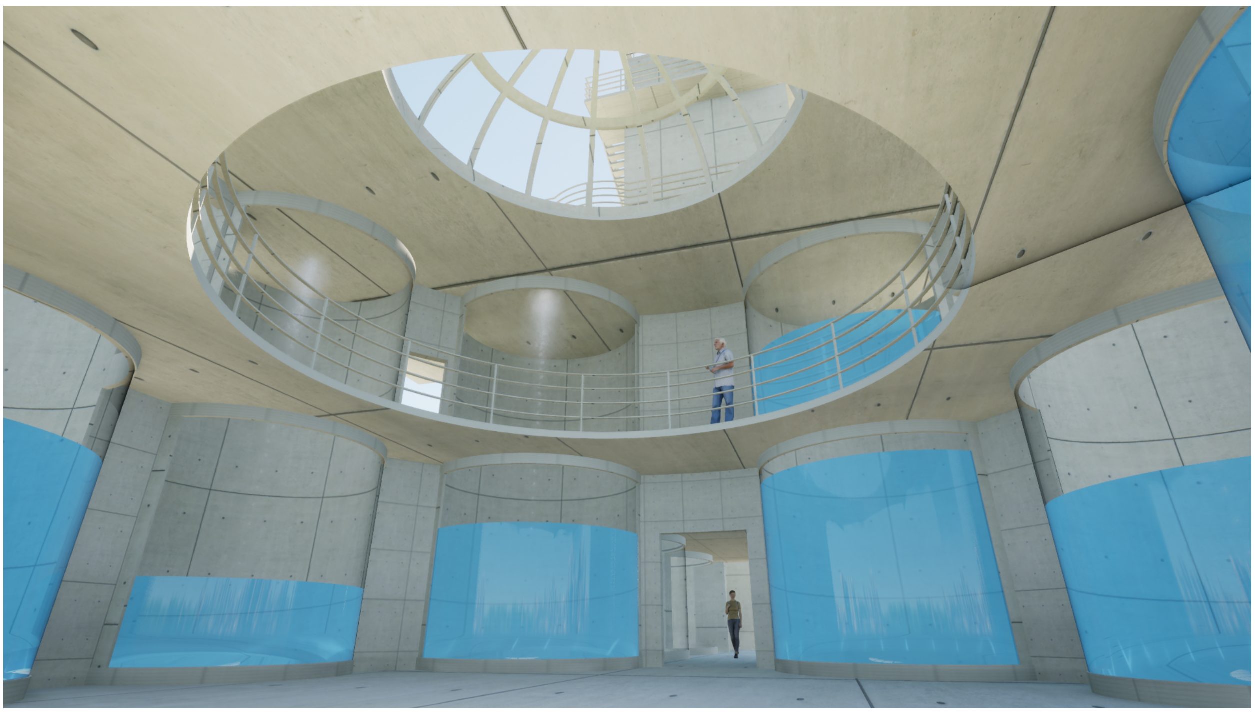
2.1.2 The Aquatic Tower

The core node of the whole water circulation system is the proposed Aquatic Tower, reimagining the existing, abandoned silo as a water purification system, complete with aquarium and outdoor landscape design. The 71-foot tall Aquatic Tower is located at a regional high point (769 feet above sea level) along the ridge that separates the broader campus into two watersheds, and has a maximum storage capacity of about 60,200 cubic feet. Water from the water tower along the lake will be pumped into the Aquatic Tower by pressure, where it is purified and stored. Then, the water will be distributed to the site and surrounding areas for irrigation. Any runoff from the site will be initially filtered by surface vegetation and eventually be collected in the lake downhill and the cycle will start anew.



Section View of Aquatic Tower

The building is divided into two sections: north and south. The southern section of the building is about 71 feet tall and contains six purification tanks. The lake water enters the most southern two water storage tanks at first, undergoing sand filtration, then algae filtration in the next two, and finally protein separation before it enters the aquarium in the north section. The southern section includes three indoor floors and two outdoor floors. The entrance of the interior ground floor is located on the south side of the building, with two exits facing east and west. These exits connect to an outdoor staircase to improve the connection between the interior and exterior circulation for visitors. The purification tanks are made with glass walls and form a corridor from which visitors can observe the different stages of the water purification process.



The second interior floor of the southern part functions as the maintenance room with tanks mirroring the floor below. Both sides of the water tank feature maintenance entrances, ladders and pipeline for easy maintenance and repair. This floor is for employees only and the entrance is located on the third floor of the building. The third interior floor is located above the six water purification tanks. Its function is an electrical control room and has staircases leading to the second floor. This floor is for employees only as well.

The first outdoor floor sits over the six purification tanks and is about 41.9 feet high. This floor functions as an outdoor sitting space with tables and chairs, and an outdoor staircase on the east side leads to a roof garden on the north. Along the eastern guardrail, is a large green wall. The entrance to the third interior floor is also on this floor. The second outdoor floor is 71 feet high, built above the electrical control room. This floor functions as a viewing platform, which is the highest point of the site and provides a bird's eye view of the whole site.

The northern part of the water tower is 25.6 feet high and is divided into two indoor floors and one outdoor floor. The interior part is enclosed by 8 water storage tanks that are transformed into aquariums. The water inside the aquarium is purified water, which will be enriched by raising ornamental fish and then used for irrigation in the surrounding area. The entrance to the lobby on the interior ground floor is on the north side, while a corridor connects the lobby to the southern part. The second floor of the building is a circular corridor, with two entrances on the east and west sides connecting with the outside. There is no indoor staircase between the first and second floors, but is connected by two outdoor staircases. The interior roof is designed as a glass dome.

The outdoor floor of the northern part is a roof garden 25.6 feet above ground level. The green roof is centered around the glass dome surrounded by an ornamental pool that is not directly connected with the indoor aquarium. Visitors can reach the site via an outdoor staircase or continue to the upper viewing platform to the south. Since the windmill at the starting point of the water circulation system is far from the site, there are four ornamental micro-windmills in the green space of the roof garden. They are used to indicate that the water circulation system of the water tower is driven by the green energy of wind.

2.2 Drip irrigation

Drip irrigation “provides slow, even application of low-pressure water to soil and plants using plastic tubing placed in or near the plants’ root zone” (Shock, 2013). The use of drip irrigation systems in design is for more efficient use of water. Drip irrigation systems are carefully planned for each step in irrigation to maintain the needs of crops or plants.
The existing irrigation system on site is a sprinkler system, which will be replaced with a new drip irrigation system in our design. The major differences between the drip and sprinkler irrigation systems are listed below:

	Drip Irrigation	**Sprinkler Irrigation**
Cost	Dripping valves and pipe - More expensive (Beginning) & Save water - Cheaper (Future)	Spray guns and nozzles - Cheaper (Beginning) & Waste water - More expensive (Future)
Application Method	Set system requires an investment of time and energy - Harder	Set the watering time - Easier
Coverage	Only wets the root area	Cover large areas
Uneven or Even Watering	Irrigate every plant individually - Even	The closer to the sprinklers, the more water will plant get - Uneven
Water Efficiency	Extremely make use of accessible water - Maximum efficiency	Waste as much as 80% of the water - Low efficiency
Irrigation Depth	Irrigate the plants slowly and allow the soil more time to soak water - Deeper watering	Spread out the water to a large surface area - Don’t penetrate the soil deeply
Risk of Invasive Weeds	Low	High
Plant Disease	Deeper and slower watering makes plants grow better - Strong and healthier	Soak the plant - lead the plant easy to get sick

Although drip irrigation can take more time and effort at first and initial cost is greater than sprinkler systems, it makes more efficient use of water, controls weeds, helps plants grow, reduces disease, and increases yields in the long-term, making it worth the extra effort and cost.

3. Greenway System

The existing conditions of the site relegate visitors to sidewalks parallel to the major thoroughfares despite ample open greenspace on the site. The site's design for a connected greenway enhances the campus's existing bikeways, promotes non-carbon transportation, and physical exercise.

3.1 Loop

A continuous loop connects the various features of the design with permeable decomposed granite paths, wooden platforms, and bridges. This will invite visitors to explore all aspects of the educational aspects of the rainwater management design as well as provide useful multimodal connections to important nodes on the site.

3.2 Elevated Corridor

One of the most visible and exciting parts of the loop is the elevated corridor stretching over Fourth Street, connecting Terraced Wetland and Meditation Garden. It will provide a safe, accessible alternative to crossing the busy throughway and will double as a landmark for the site.

3.3 Waterfront Plaza

A large plaza northwest of Central Lake will create an events space integrated into the landscape design of the site. While allowing for continuous circulation along the larger greenway and a secondary loop around Central Lake, the plaza, combined with satellite sunken classrooms, provides space for various social and educational functions.

3.4 Riverfront Platform

The riverfront platform in Meditation Garden, situated between Education Garden to the south and the elevated corridor to Terraced Wetland provides not only a unique vantage point from which to view aquatic flora and fauna but also a serene space for outdoor yoga practice.

4. Public Education

The Research Park is home to high quality projects from many fields and is itself a showcase for innovation. Its location next to the iHotel and State Farm Center means there is a large influx of visitors to the site on a regular basis. The site design includes a signage system that will clearly show visitors where the relevant educational resources are located. At the same time, the educational site will not only provide visitors with an offline real experience, but also extend the dissemination of knowledge online. Through an associated online app, visitors will be able to browse the educational resources even after they return home.

4.1 Sunken Classrooms

This classroom provides an open-air educational space for visitors. Circling Central Lake, three classrooms with built-in seating create semi-enclosed, semi-private outdoor spaces for lectures and events as well as casual enjoyment and relaxation. Their unusual vantage point gives visitors a new appreciation for their surroundings.

4.2 Experimental Farmland

This farmland is a very rich plant resource that encourages people to get involved in the plant growing process. After the plants mature, flowers, vegetables, fruits, and other related produce can be provided to the campus dining hall. People can learn the entire process of food production. At the same time, visitors will also be able to learn about the application of the latest planting technology here. Besides, the experimental farmland is located at the lowest point of the site, which is the outlet of the entire water system. Therefore, the site is also a great location for conducting lectures related to water management.

4.3 Ornamental Garden

The bioswale in Meditation Garden uses a large number of native, flowering, water tolerant plants. Firstly, the variety of plants makes for a seasonal interest that is different but very beautiful all year round. Secondly, the large number of flowering plants attracts native pollinators, including hummingbirds, bees, butterflies, etc., further enhancing the biodiversity of the site. At the same time, these plants provide habitat for animals. Finally, the bioswale helps to slow and absorb some of the rainwater runoff, filtering pollutants and sediments through bioretention. As a result, this garden provides an educational resource for visitors from multiple perspectives.

4.4 Water Treatment Exhibition

The redesign of the tall concrete corn silo is transformed into a sort of aquarium that makes water treatment visible to visitors. It is reactivated as the site's landmark, a welcoming first stop on visitors' educational tour into the Research Park.

4.5 Education Tour

This site offers visitors a rich and unique educational tour. It starts from the Water Center and ends at the Educational Farmland. Visitors along the water corridor will not only experience the rich ecological landscape of the riverbank, but also learn about the ecosystem.

Design Performance

Runoff

Rainwater runoff is a major factor when looking at the effectiveness and sustainability of our site design. As a storm progresses, the rainwater can either infiltrate the soil in manageable amounts, or cause flooding on a site as it travels across impervious surfaces to an area with high water concentrations. Most of the improvements we propose will help to reduce runoff quantities significantly, as they are able to capture the rainwater and use it to enrich the surrounding ecosystem.

To determine the amount by which runoff is reduced, two preliminary factors had to be considered: the hydrologic soil group and average rainfall on our site. Hydrologic soil groups categories soil groups based on their mineral content and runoff/infiltration potentials. The four groups include group A, B, C, and D, with A having the lowest runoff potential and highest infiltration potential while D has the highest runoff potential and lowest infiltration potential. Based on data from the Natural Resources Conservation Service (NRCS) Web Soil Survey, we concluded that our site is mostly soil group C, suggesting that runoff concentrations are high. The second factor, average rainfall, was determined using the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service. The two types of precipitation events chosen included a 1-year 24-hour precipitation event as well as a 100-year 24-hour precipitation event. These two storm events were chosen in order to see runoff reduction for a typical large storm that happens every one year as well as during a major storm that occurs every 100 years. The average rainfall was calculated to be 6.53 cm for a 1-year 24-hour storm and 17.5 cm for a 100-year 24-hour storm.

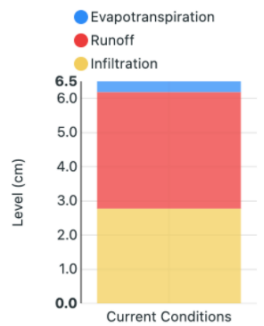
Based on this information, we were able to calculate the change in runoff values for the two hypothetical storms. The values that were estimated are quite significant, and help reduce runoff rates by 54% for the 1-year storm and 88% for the 100-year storm. This high reduction in runoff will help mitigate flooding on the site as well as help with water quality control, another major factor that we considered on our site.

Runoff Calculations for 1-year 24-Hour Rainfall

BEFORE

24-hour hypothetical storm event

Simulated by SLAMM and TR-55 model algorithms

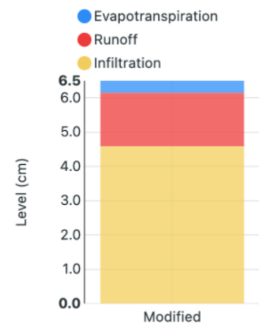


Runoff Partition	Water Depth (cm)	Water Volume (m³)
Runoff	3.410	6,918.96
Evapotranspiration	0.315	639.49
Infiltration	2.774	5,628.70

AFTER

24-hour hypothetical storm event

Simulated by SLAMM and TR-55 model algorithms



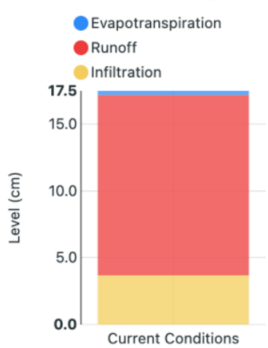
Runoff Partition	Water Depth (cm)	Water Volume (m³)
Runoff	1.563	3,171.23
Evapotranspiration	0.349	707.29
Infiltration	4.588	9,308.64

Runoff Calculations for 100-year 24-Hour Rainfall

BEFORE

24-hour hypothetical storm event

Simulated by SLAMM and TR-55 model algorithms

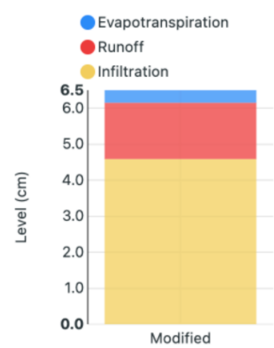


Runoff Partition	Water Depth (cm)	Water Volume (m³)
Runoff	13.503	27,395.17
Evapotranspiration	0.315	639.49
Infiltration	3.682	7,469.22

AFTER

24-hour hypothetical storm event

Simulated by SLAMM and TR-55 model algorithms



Runoff Partition	Water Depth (cm)	Water Volume (m³)
Runoff	1.563	3,171.23
Evapotranspiration	0.349	707.29
Infiltration	4.588	9,308.64

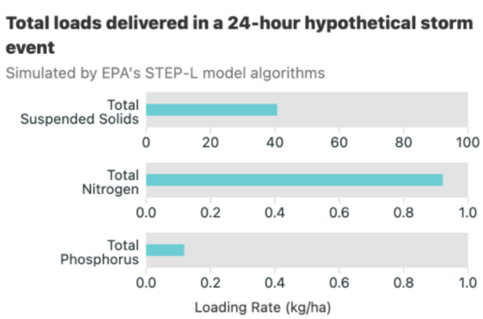
Water Quality

As rainwater flows across impervious surfaces it picks up harmful pollutants including fertilizer, pesticides, and motor oil, most of which contain high concentrations of phosphorus and nitrogen. These nutrients can certainly be beneficial for aquatic ecosystems as they promote the growth of algae. However, when too much of it enters a stream or lake, the excess algae growth can disrupt ecosystems and decrease oxygen levels in the water. Cyanobacteria, a blue-green algae that makes water ways a murky green, can also begin to grow in larger amounts, disrupting aquatic animals and humans. This is an especially prominent issue in Illinois, a state dominated by agriculture, as the high concentrations of nitrogen and phosphorus from the state's waterways eventually ends up in the Gulf of Mexico, one of the most productive ecosystems in the world. Currently, the largest "dead zone" of hypoxic (low oxygen) water in the world is in the Gulf, so finding a way to reduce nitrogen and phosphorus levels across Illinois can greatly help marine life downstream as well here locally.

The inclusion of a vegetated bioswale, water purification system, and a wetlands area, all help to improve the quality of the water that eventually flows downstream in the Embarrass River. Through online simulations, we were able to estimate the improvements in water quality that exist with our design, specifically the changes in nitrogen and phosphorus levels as well as total suspended solids (TSS).

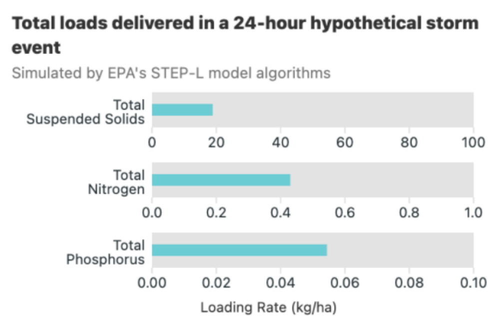
Water Quality Improvements

BEFORE



Quality Measure	Load (kg)	Loading Rate (kg/ha)	Average Concentration (mg/L)
Total Suspended Solids	825.842	40.706	119.4
Total Nitrogen	18.704	0.922	2.7
Total Phosphorus	2.401	0.118	0.3

AFTER



Quality Measure	Load (kg)	Loading Rate (kg/ha)	Average Concentration (mg/L)
Total Suspended Solids	383.109	18.884	120.8
Total Nitrogen	8.727	0.430	2.8
Total Phosphorus	1.104	0.054	0.3

As seen in the table above, the quality of water is also greatly improved with our design. There is around a 50% reduction in the total loads of TSS, nitrogen, and phosphorus. If our design principles and goals were transferred to urbanized sites along the river, there could be major improvements to local waterways across the state of Illinois, helping to restore the suffering ecosystem in the Gulf of Mexico.

Carbon Sequestration of Vegetation

Carbon sequestration capacity of vegetation plays an important role in global carbon emission reduction (Chen, et al., 2020). Due to human activities, the balance of the carbon cycle has been disrupted. At the same time, the process of urbanization has led to the continuous reduction of forests and the weakening of vegetation's ability to fix nitrogen. This can lead to a serious ecological disaster. Therefore, this design will consider the factors that affect the ability of vegetation to sequester nitrogen in order to increase the rate of carbon sequestration.

Vegetation carbon sequestration is the process by which plants photosynthesize to absorb carbon dioxide from the atmosphere and store it as carbon in themselves and in the soil. Trees are the best and most important carbon sinks. When they are destroyed, they lose their ability to sequester carbon, especially when trees are burned as the absorbed carbon will be released into the atmosphere. Therefore, when selecting trees for the site, it is important to plant trees that can grow quickly and survive over time, such as pines, oaks, and sweet gums (Nowak & Crane, 2002). Woody shrubs and perennial grasses and forbs are also important in increasing the carbon capture capabilities. Selecting deep-rooted perennials, of which many are native to Illinois, will also increase carbon sequestration to some extent. The deeper the root system, the more carbon storage is facilitated.

Reduction in Potable Water

Rainwater is collected and treated in the Aquatic Tower, which holds 60,200 cubic feet of water, with a daily purification capacity of about 4,000 tons. The water in the purification process is divided into 4 levels. Among them, Level 4 is unpurified water, Level 3 is initially purified water, Level 2 is completely purified water and Level 1 is fertilized irrigation water. The campus is designed to use drip irrigation, so the use of potable water can be reduced. Since toilet water does not require high quality as portable water, grey water like Level 2 can also be used for toilets in local buildings. As the highest point in the southern part of the campus, the Aquatic Tower provides redistributed water for the site and the broader campus which reduces potable water consumption, saving energy, money and this vital resource.

Canopy Cover

By increasing canopy cover the design offers more seasonal beauty and function, where trees provide shade in hot months and windbreaks in cold months. An increased canopy also sequesters more atmospheric carbon while contributing to habitat and food sources for local wildlife.

Plant Diversity

A diverse plant selection not only extends seasonal interest for visitors' experience of the site but also ensures that a variety of wildlife can survive and thrive on the site. The plant schedule prioritizes their bioremediative function and is designed to address a variety of pollutants. Indiangrass (*Sorghastrum nutans*) reduces agrochemicals' potency from surrounding farmland; American wild celery (*Vallisneria americana*) transforms insecticides in particular; while lanceleaf frogfruit (*Phyla lanceolata*) consumes excessive fertilizers that might make their way through the water system.

Sunflower (*Helianthus spp.*) and Indian mustard (*Brassica juncea*) absorb heavy metals to their roots like magnets. Willows (*Salix spp.*) clean the water and help transform petrochemicals into innocuous substances. Cattails (*Typha spp.*), a quintessential example of a keystone water species for a variety of wildlife and ecological functions, purifies water while providing habitat for a variety of organisms in its vast, complicated root systems. The root systems also help prevent soil erosion and maintain bank stability. Together these plants work to collaboratively and somewhat passively remediate the site.

Pollinator and Wildlife Diversity

Flora and fauna function in networks or ecosystems. By diversifying the planting schedule, the integrity of the natural ecosystems will be enhanced and support related wildlife populations, with each biotic contributor playing their ecologically specialized role. The proposed design dramatically increases biodiversity on site with emphasis on several different ecosystem types (wetland, prairie, vegetated bioswales, etc.), which should increase pollinator and wildlife diversity.

Project Phasing

If the project proposal is approved by the University, the implementation of the design will take five years. The first year will concentrate on construction drawings based on the concept we have proposed and the development of an online app for education as well as advertisement. The first year would also include fundraising efforts, including: applying for funding from the Student Sustainability Committee at UIUC and finding stakeholders who are willing to donate money to the project. The second year would focus on constructing the subterranean piping system for drip irrigation and the drainage system connecting the water treatment system. In the meantime, utility work needs to be done for the project. The third year can be used for constructing landform, pathways and bridges, as well as the renovation of the silo into the Water Center. The following year, trees and other plants can be installed. Finally, signages can be installed and furniture is provided.

Maintenance Plan

Straightforward and sustainable maintenance is critical to the success of any design project. Our proposal aims to create an appealing maintenance to amenities ratio for Facilities & Services at the Research Park.

Constructed Wetlands

By far the most maintenance heavy component of the design, the constructed wetlands will require constant monitoring of water levels and quality, microbial populations, and soil quality. Removing sediment buildup regularly will maintain inlet and outlet valve flows as well as plant and wildlife health. A consistent and slow in- and out-flow will be established to maintain water quality and reduce bank erosion.

Rain Gardens and Bioswales

These areas should be mowed to roughly three inches in late winter or early spring before regrowth in order to maintain winter interest for visitors as well as habitat and food sources for wildlife. After mowing, mulch should be applied to reduce weed growth and maintain moisture during the growing season.

Farmland

This section will be the most intensively managed, though maintenance would be incurred by volunteers and those growing food crops. The orchard will require annual pruning to maximize yields.

Drip Irrigation

While the initial install will be extensive, the maintenance for the drip irrigation system will occur only twice a year, to check for leaks and water pressure. Filters will be changed at the same time. Ongoing care will include making sure that the system is covered by soil or mulch, especially after large storm events.

Pathways and Plazas

The majority of the greenway system is paved with decomposed granite contained by metal edging. This will need to be relayed annually, ideally in spring, and checked after major storm events. Plazas are paved with permeable interlocking pavers, which will require maintenance roughly annually to remove sediment buildup that can reduce their permeability and encourage vegetation growth and disrupt their stability. The wooden walkways will be constructed with local bald cypress, a naturally decay-resistant wood, and should require minimal maintenance for approximately 50 years.

Water Treatment System

The structure of the modified water storage tank is able to cope with the internal water pressure, and additional frame structures are installed on the building facade to distribute the pressure and provide support. The corrosion problem is solved by coating the inside of the tank, which needs to regularly cut off the water supplement for maintenance and renew the coat when it doesn't rain. The top of each storage tank is provided with a maintenance channel for regular maintenance. The filter device in the water storage tank for purification needs to be cleaned and replaced regularly as well, especially when the lake in the south is turbid after heavy rain.

Cost

This project shows economic benefits from two aspects. Firstly, the green infrastructure implemented in the proposal qualifies for credit incentive from the City of Champaign. According to the Stormwater Utility Fee Credit and Incentive Manual of Champaign, there is up to $250 available for our 1.74 acres of vegetated bioswale and rain gardens and up to $750 available for the retention ponds and wetland and 25% of the construction cost for both of them. Our site meets the criteria of 100% direct discharge credit because rainwater on our site drains to either university-owned rainwater pipes or to ditches and creeks not owned by the City.

Furthermore, the project is using drip irrigation with reclaimed rainwater for 8.89 acres of vegetated bioswales, farmland, and lawn area. Compared to the conventional sprinkler system, it costs more for installation but saves money in the long-term. Drip irrigation’s water efficiency saves $34 per acre annually, which provides a breakeven time of 25 years. After 25 years, the cost of drip irrigation becomes lesser than sprinkler irrigation systems.

	Drip Irrigation	**Sprinkler Irrigation**
Installation costs	$3000 per acre - $26670 total	$2150 per acre - $19110 total
Annual Savings	$34 per acre - $302 total	N/A
Breakeven time	25 years	

Funding

The funding resource for our project is the Student Sustainability Committee (SSC). It is the unit of Student Engagement at the University of Illinois that is charged with leading the student body toward building a culture of sustainability on campus. Student Sustainability utilizes the collective agency of students to catalyze pragmatic, solution-oriented, and inclusive change in our community.With the partnership of a team of staff and faculty members, SSC allocates $1.47 million annually toward the development and seed-funding of projects that have a positive environmental impact on the university community. They have six subcommittees that specialize in one section like education, energy, food waste, transportation, land & water, and other. Groups will submit their project proposal to at least one of these committees and they will determine which projects get funding. Our project would be reviewed by the Land & Water committee.

References

Shock, C. C. (2006). Drip Irrigation: An Introduction.

Chen, J., Fan, W., Li, D., Liu, X., & Song, M. (2020). Driving factors of global carbon footprint pressure: Based on vegetation carbon sequestration. *Applied Energy*, *267*, 114914.

Nowak, D. J., & Crane, D. E. (2002). Carbon storage and sequestration by urban trees in the USA. *Environmental pollution*, *116*(3), 381-389.

Frerichs, L., Bleill, L., Faullin, C., Thomas, J., Delorenzo, M., Walden, B., Christy, T., Kim, Q., Knight, B., Schmidt, D., Clark, D., Sokolowski, C., Fox, P. B., Ruedi, A. L., McMillan, E. L., Daly, P., Johnson, R., Stephens, R., & Ghosh, A. (2018). Research Park at University of Illinois Master Plan 2018.

Institute for Sustainability, Energy, and Environment. (2020). Illinois Climate Action Plan [Strategic Framework]. University of Illinois at Urbana-Champaign. https://icap.sustainability.illinois.edu/

Resilient Landscape Strategy. (2019). [Strategic Framework]. Facilities & Services, University of Illinois at Urbana-Champaign. https://fs.illinois.edu/services/grounds/resilient-landscape-strategy

Storm Water Management and Erosion Control Ordinance. (2015). Champaign County National Pollutant Discharge Elimination System.

IEPA, IDOA, and University of Illinois Extension 2021. Illinois Nutrient Loss Reduction Strategy Biennial Report 2019-2020. Illinois Environmental Protection Agency and Illinois Department of Agriculture; Springfield, Illinois. University of Illinois Extension; Urbana, Illinois. https://www2.illinois.gov/epa/topics/water-quality/watershed-management/excess-utrients/Documents/NLRS-2021-Biennial-Report-FINAL.pdf