THE UNIVERSITY OF TENNESSEE
CHATTANOOGA

STUDENT TEAM - D41

Operation C.L.E.A.N.

CAPACITY ENHANCEMENT
WITH
LANDSCAPE MODIFICATION
USING AN
ECOLOGICAL APPROACH
FOR
ABSORBTION
AND
NATURAL RECHARGE

STUDENT TEAM MEMBERS

Carmen Harvey, Civil Engineering: Transportation
Beau Neidich, Civil Engineering: Environmental
Adam Belton, Civil Engineering: Geotechnical
Abbey Burton, Civil Engineering: Structural
Riley Ellis, Civil Engineering: Water Resources
Syed Tareq, Chemical Engineering, Graduate Student

LEAD FACULTY ADVISOR

Dr. Jejal Bathi, Assistant Professor: Civil and Chemical Engineering, UTC

SUBJECT FOCUS TEAM

Kenny Tyler, Director of Engineering and Planning Services, UTC Administrative Services
Bob Jackson, Director of Safety and Risk Management, UTC Administrative Services
Allen Jones, RLA Principal Landscape Architect, ASA Engineering
Dr. Chandra Ward, Assistant Professor, Sociology, UTC

ABSTRACT

The University of Tennessee at Chattanooga is a metropolitan campus located in the heart of downtown Chattanooga and is home to more than 11,000 students and growing. This urban landscape, nestled at the foot of several surrounding mountains and bounded by the Tennessee River, is susceptible to significant flooding and water pollution. These common problems stem from Chattanooga's combined sewer system coupled with the substantial amount of surface runoff generated by stormwater volume that cannot directly infiltrate into the extensive concrete and asphalt regions of the city campus. We thereby propose Operation **CLEAN**: **C**apacity enhancement with **L**andscape modification using an **E**cological approach for **A**bsorption and **N**atural recharge around the Engineering, Mathematics, and Computer Science (EMCS) building on campus. Features of Operation CLEAN green infrastructure (GI) includes interventions such as downspout disconnections, permeable pavement, underground cisterns, and retention areas integrated with real time sensor enabled operations. With active student and community engagement, Operation CLEAN will implement an outdoor environmental lab highlighting the innovative green design elements of the project complete with educational signs, a cost-friendly source of water for irrigating the greenhouse, and a retention basin complemented with picnic tables, benches, and native plant species. Overall, Operation CLEAN meets the current stormwater control regulations set by the City of Chattanooga for new developments while pushing towards an inspiring future of innovative green infrastructure for stormwater management and water pollution mitigation.

INTRODUCTION

The University of Tennessee at Chattanooga (UTC) resides in Chattanooga, TN in the lower Tennessee River watershed of Tennessee Valley (**Figure 1**). While the City of Chattanooga (the City) is known for its natural beauty with steep valleys and rivers, it is also impounded with failing collection system infrastructure. For example, the City's Combined Sewer Overflows (CSO) have led the City to be non-compliant with the Environmental Protection Agency (EPA) National Pollution Elimination Discharge Elimination (NPDES) permit[1]. Currently, the City is operating its collection systems, including its NPDES Municipal Separate Sewer Systems (NPDES MS4) on a consent decree with EPA. There are 34 waterbodies around the City that are listed as 303d impaired waters by EPA[2]. However, the City is progressive in its efforts to combat issues related to both wastewater and stormwater management[3]. The City has developed Resource Rain the Rain Management Guide[4] as part of an initiative to improve surface water quality and reduce runoff entering the combined sewer system[5]. The majority of collection systems on the UTC campus

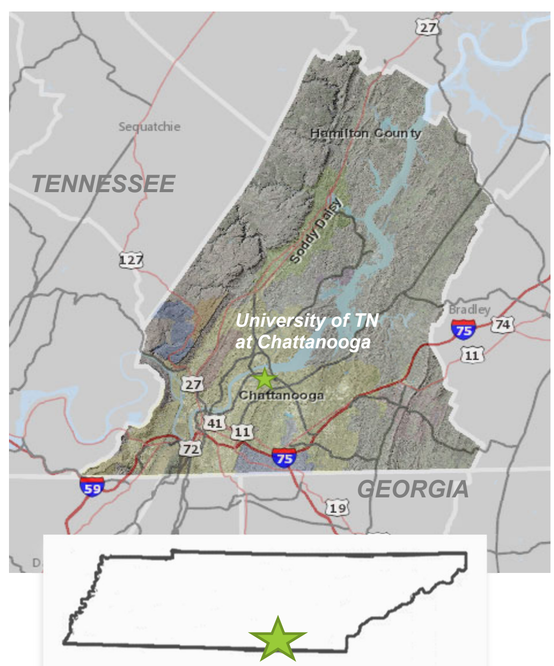

Figure 1 – Location Map of Chattanooga, Hamilton County, TN and UTC (project site)

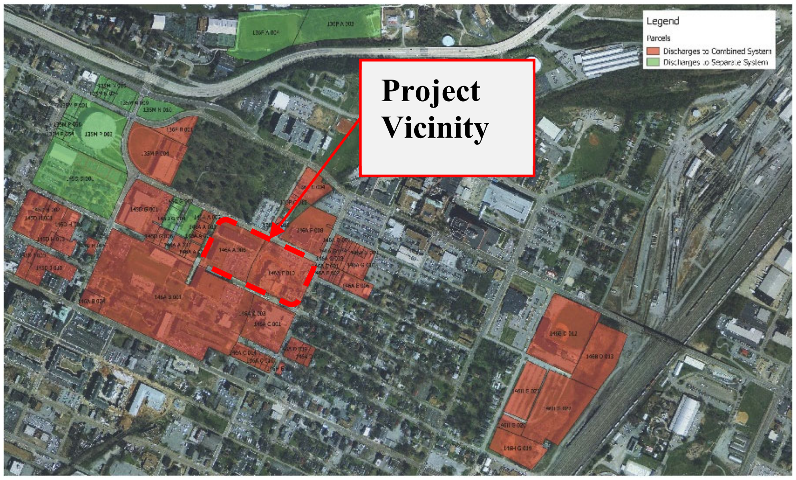

Figure 2 Map of the City of Chattanooga's Combined Sewer on the UTC campus.

are combined sewer systems (**Figure 2**). The Resource Rain also offers financial credit to citizens for implementing measures to reduce runoff flows. It is also important to note that high precipitation totals around the City makes stormwater management a challenge. The City's annual average precipitation is about 52.5 inches of rainfall and 4.0 inches of snowfall, the annual average temperatures of high 72° and low 50° (**Figure 3**)[6]. While UTC has initiatives for nature friendly infrastructure development, due to its location as an urban campus and limited space availability, early developments were predominantly composed of grey infrastructure. Due to its significant footprint in close proximity to the City's major drinking water source (Tennessee River), any retrofit to mitigate water pollution on campus would significantly benefit the City as a whole. Our proposed design for managing stormwater will help curtail CSOs while demonstrating nature centered development that takes advantage of technological developments in design and operations of urban infrastructure. While our proposed design allowed us to implement our classroom learnings of modern GI for urban developments, it also gave us the opportunity to demonstrate the potential environmental, social and economic benefits of GI to the community. This report identifies objectives and goals of our proposed project, provides detailed background information on the site existing conditions followed by details of our proposed design, expected benefits and limitations, and discusses funding opportunities for implementing the project.

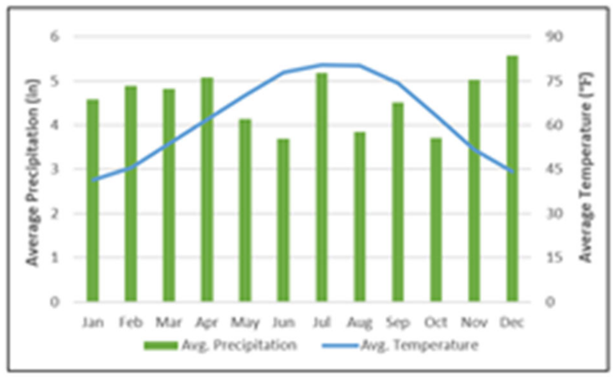

***Figure 3** – Average Climate vs Precipitation of Chattanooga, TN for 20 years*

OBJECTIVES AND GOALS

The 2012 UTC Master Plan outlines the future vision for campus development in terms of buildings and land use, residential student life, campus open space, circulation and parking, transit and bicycle, utility infrastructure, and land acquisition.

1. Promote connections to the environmental city of Chattanooga.
2. Provide leadership as an environmentally sustainable institution.
3. Build the framework for a safe and appealing campus landscape.
4. Support technology infrastructure to promote instruction, learning, scholarship, and service.

Referencing the UTC Master Plan goals, considering the GI survey, and addressing stormwater management issues around the EMCS, Operation CLEAN's project objectives are as follows:

1. Reduce stormwater runoff entering combined collection systems using an **ecological approach** to help alleviate the city of Chattanooga's CSOs.
2. Promote campus water sustainability by implementation and education of green infrastructure elements to clean and reuse stormwater through the processes of **absorption** and **natural recharge**.
3. Revitalize campus aesthetics through **landscape modification** creating exposure to native ecology while advocating a multitude of social benefits such as: encouraged community involvement, enhanced student gathering areas, and overall improved physical and mental wellbeing.
4. Demonstrate potential use of advanced technology for effectively managing water volumes and discharges from urban **capacity enhancement** units (retention basins and cisterns) such that urban flooding can be mitigated and water pollution is minimized.

PROJECT DESIGN

Site Background and Issues

The project area around the EMCS building is about 8.07 acres that is dominated by impervious parking lots, pitched roofs that are directly connected to combined sewer with about 27% pervious areas. The existing grassed islands are raised and confined by a curb that does not allow for runoff to water plants or provide the opportunity for water infiltration. The site is populated with mature trees that support UTC's status as a Level II Arboretum. However, the beds containing these trees are not sufficiently designed to allow their roots to penetrate the subsurface leading to limitations of the designated greenway for campus commute. The greenhouse on the project site is used by the Biological Science Department as their outdoor lab uses portable water irrigation as it does not have a system for harvesting stormwater (**Figure 4**). In addition, the existing dry detention basin collects trash, prevents access to multiple memorial trees, and promotes an unsightly place for mosquitoes to breed.

Figure 4 *– Existing impervious parking lot and green house.*

Site Analysis/Survey

A. Existing Conditions

The impervious and pervious areas of the site were measured using *MicroStation* [7] (Table 1) and a 3D site layout was created using *SketchUp* [8] for demonstrating the proposed design plan. The existing site's topological contours change from an elevation of 760 ft to an elevation of 718 ft (**Figure 5**). In order to determine set design standards, we referred to the

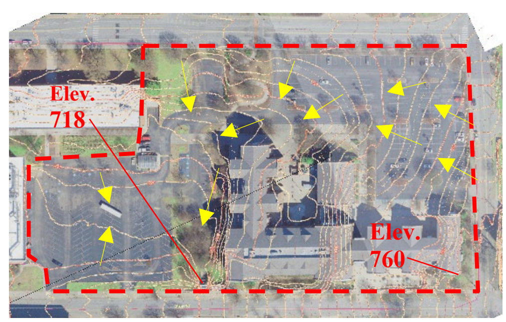

Figure 5 *– Existing Site Conditions with 2' contour interval.*

City design requirements, presented in the City's Rain Management Guide [4], which require that Stay on Volume (SOV) for a 1-inch storm be controlled for any new development site. The site SOV and peak discharges for selected return periods between 2 and 100 years were calculated per the City design calculation standards and are presented in the (**Table 1**).

Table 1 *- Existing Conditions (Pavements, Stay-On-Vol., Flow Rates)*

Impervious (sq. ft.)	Pervious (sq. ft.)	SOV (eq.1) (cubic ft.)	Q_2 (eq. 2) (cubic ft./sec.)	Q_5 (eq. 2) (cubic ft./sec.)	Q_{10} (eq. 2) (cubic ft./sec.)	Q_{25} (eq. 2) (cubic ft./sec.)	Q_{100} (eq. 2) (cubic ft./sec.)
257,769	93,911	21,630	23.6	28.7	32.6	38.3	47.2

B. Existing Water Quality

To quantify a base line for existing water quality, five runoff samples were collected on 10/28/20 along the path used to calculate the time of concentration and overland flow distance (**Figure 6**).

Figure 6 *– Water quality testing locations (in order left to right) 1. Student Parking at Palmetto; 2. Curb line Student Parking next to loading docks; 3. Drainage structure at basin area; 4. Inside basin area; 5. Outlet pipe of basin at Vine Street bridge*

The water samples were tested for total suspended solids (TSS), dissolved solids (DS), PH, and turbidity (**Table 2**). While we acknowledge stormwater quality can be highly variable, both temporally and spatially, the collected samples provided an insight into potential water quality levels at different locations on the project site. As illustrated in the (**Figure 7**), clarity of water samples and amount of solids collected on filter papers are different based on the sample location.

Table 2 *- Existing Conditions (Water Quality Test Results)*

Test	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Suspended Solids (mg/L)	15	14	33	20	3
Dissolved Solids (mg/L)	2910	1960	1225	685	1720
P^H	7.63	7.78	7.61	7.56	7.52
Turbidity (NTU)	32.7	12.9	54.2	10.3	13.9

Figure 7 *– (Samples from left to right) 1. Initial water samples collected on site; 2. Test of suspended solids; 3. Final result of all samples showing dissolved solids*

Community Engagement

The team has engaged in discussion with the City of Chattanooga Public Works Department, professional engineers (those who are familiar with local stormwater issues), heads of the Sustainability and Facilities departments at the UTC, and Tennessee Department of Environmental Conservation (TDEC) staff in water services to better understand and mitigate stormwater issues around the campus using green infrastructure. In order to confirm feasibility, we have reviewed our proposed designs with the above mentioned professional and amended based on their feedback.

A. Community Outreach

Community involvement is crucial to the future of our project. Due to Coronavirus challenges, we submitted an earlier version of our design board on a virtual platform to the American Society of Civil Engineers (ASCE) Chattanooga Development Symposium to receive feedback from professionals across different disciplines[9]. Increases in Coronavirus led us to send out an online survey to assess the UTC community's support for our proposed designs. The survey results showed that an overwhelming majority of respondents saw value in investing in sustainable infrastructure (**Figure 8**). Respondents that wished to aid the project's implementation were invited to join a focus group that will discuss the future of the project. In addition we hosted practicing engineers and landscape architects on campus to confirm the feability of site conditions for our proposed design.

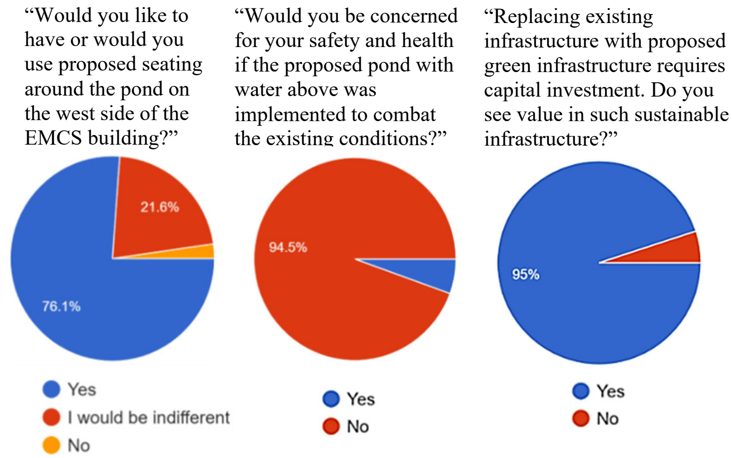

Figure 8 *– Results from campus survey about green infrastructure.*

Site Design Plan

A. Areas of Focus and Description

Area 1: Reserved Parking Lot: Surface pavement of Area 1 parking lot will be replaced with porous asphalt and permeable parking pavers with underdrains. The underdrains will discharge into a cistern proposed to be located close to the green house for irrigation water use. The existing islands will be replaced with recessed islands, bioretention material, and native trees assisting reducing parking lot temperatures, improving resilience. (**Figure 9**)

Area 2: General Parking Lot: Since most of Area 2 exceeds a 6% slope, the existing impervious pavement cannot be replaced with porous asphalt, but permeable pavers will be placed in the disability parking slots that are within 2% slope. Rain gardens are proposed in the medians of parking spaces such that will collecting runoff from adjacent parking areas. Ideally underdrains would be installed and connected to the cistern but due to concern by the UTC facility relating to the installation cost and maintenance access, and need for significant demolition of existing pavements, underdrains are not proposed for infiltered rain garden water.

In addition, existing high raised parking lot island will be converted to rain garden with curb cuts and proposed excavation to create depressions.

Area 3: Vine Street, Outdoor Lab: Existing impervious pavers in Area 3 will be replaced with permeable pavers. The water from the permeable pavers' underdrains and downspout

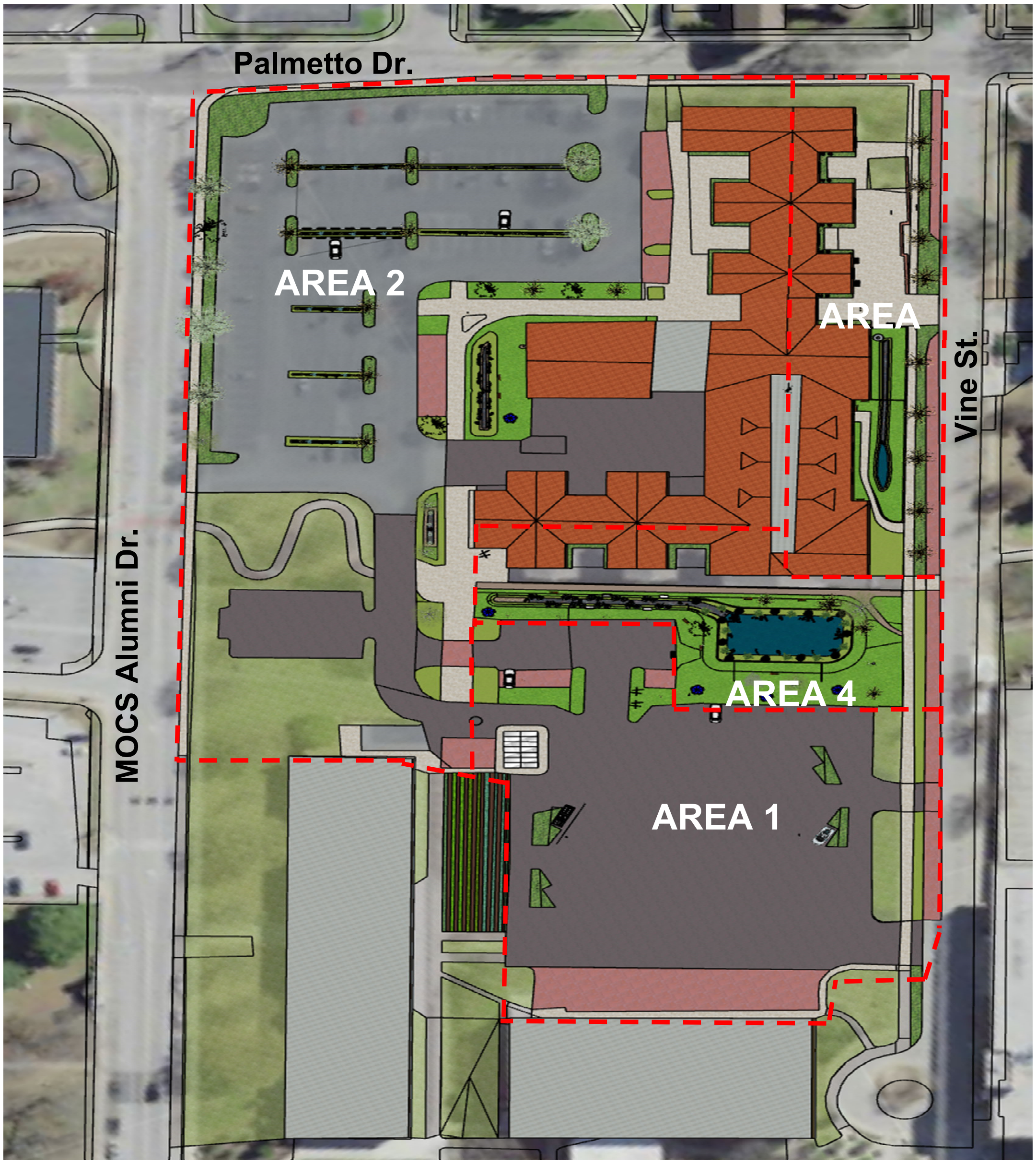

Figure 9 -Project Site Overview including Subdrainage Design Areas 1-4.

disconnections of the north side of the EMCS roof will flow into proposed planter boxes along EMCS building. In addition, a geotextile barrier is proposed to prevent water from entering the ground level of the building. Planter boxes with curb cuts open to runoff are placed along the Vine St. for the existing trees and provide more cover to exposed roots. Underdrains from the patio, sidewalk, small cistern, and downspout disconnections will supply water to the outdoor lab proposed in the open spaces on north side of the EMCS building.

Area 4: Vine Street, Retention Basin: Area 4 will have a bioswale fed by parking runoff and underdrains from a large loading dock (on south side the EMCS) paved with porous asphalt. A retention basin is at the project's lowest point. There will be gradually elevated greenway, about six feet wide, and made of crushed recycled asphalt and concrete from the project site in Area 1. The current connector has stairs that make bicycle travel difficult. There will be seating, native plants, memorial trees, and additional native trees surrounding the basin. A segment of the pathway will also veer off and gradually slope down to connect with the recognized abortorium on the south side of Vine Street, which is also the designated greenway for campus commute.

B. Proposed Controls Summary

Planter Boxes: Planter Boxes totaling 17,293 sq. ft., will be placed next to the buildings, along the roadway, and in parking areas to collect the rain from the downspout disconnects (**Figure 10**). The boxes next to the road and parking lots will be open underneath for infiltration while the boxes next to the building will be lined to keep water from entering the lower classroom levels. Underdrains will allow the excess water to flow either to the outdoor classroom or into permeable paver subgrades away from the building[10].

Downspout Disconnection: Currently, the EMCS roofs are directly connected to combined sewers with no opportunity for the stormwater to infiltrate. The proposed design contains 38 downspouts disconnections that are routed to rain gardens (**Figure 11**) for water harvesting using cisterns or connected to planter boxes (**Figure 10**) along the building[11].

Bioswales: The proposed bioswale is expected to reduce water contaminants, especially TSS, while increasing infiltration time[12]. The 1,391 sq. ft. bioswale (**Figure 12**) will have a waterfall feature that utilizes elevation change to transport runoff (**Figure 13**) from the loading area, parking lots, and downspout disconnections to the retention basin. This will replace the current ditch stripped the grass lining and exposed the bare soils resulting erosion. In addition, benches will also be placed along the bioswale to encourage and provide opportunity for students to spend time in outdoors.

***Figure 11** – Downspout Disconnect to Rain Garden between building and parking lot in Area 2.*

***Figure 12** – Isometric view of the Bioswale between EMCS building and Reserved Parking lot in Area 4.*

***Figure 13** – Front View of Bioswale between EMCS building and Reserved Parking lot in Area 4.*

Rain Gardens: The proposed design includes 16,600 sq. ft. of rain gardens using native species (see plant schedule) [13,14]. Area 2 rain gardens will be placed along the slope as parking dividers to catch sheet flow runoff from the parking lot (**Figure 14**) [15]. While the downhill slope is greater than 6% and not adequate for porous asphalt pavement; therefore, the proposed rain gardens will act as a buffer to slow the runoff. Raingardens adjacent to the parking lot and building will collect adjust area runoff and the water from downspout disconnections.

Figure 14 *– Mini-rain garden parking divider located in the student parking lot in Area 2.*

Cisterns: There are two cisterns proposed as part of the design. Cistern 1 is a large underground cistern between the green house and reserved parking lot looking north at the edge of Area 1 and Area 2 (**Figure 15**). Cistern 1 is designed to hold irrigation needs of greenhouse and rain garden greens in the project area. The design capacity of the cistern is 39,872 gallons, of which 3,000 gallons will come from rooftop disconnection from west side roof of the EMCS, with the remaining will come from porous asphalt underdrains. Irrigation operations are proposed to operate based on moisture sensor feedback based automatic operation which can also be optimized with predicted weather forecast. Cistern 2 in Area 3 (**Figure 16)** will be used to manage stormwater by collecting the runoff for distribution into the nearby Outdoor Lab and retention basin.

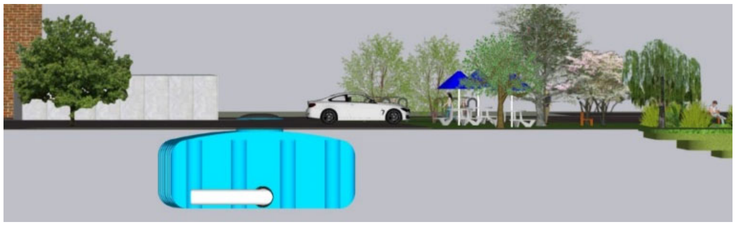

Figure 15 *– The Large underground Cistern between the green house and Reserved Parking lot looking north at the edge of Area 1 and Area 2.*

Figure 16 *– Small above ground cistern in the outdoor lab in Area 3.*

Retention Basin: Alongside bioswales and rain gardens, a retention basin serves the purpose of improving the retentive qualities of an area routinely plagued with excess stormwater and flooding and has the option of being wet or dry[16]. The proposed wet retention basin (**Figure 17),** which is an upgrade of the existing dry detention basin, will be located at the lowest point on the site at the outlet of the project site. The design of the proposed retention is established per design requirements set in the City Resource Rain Manual[4]. The proposed wet retention basin will have a 6:1 overall slope, a 4.5 ft depth, and a surface area of 3,820 sq. ft. The internal basin slope to the outlet is 1.0%. Discharge from bioswale along the west side of the EMCS building enters the proposed retention basins. Riprap will be placed at the entrance of the bioswale and at the inlet pipes from the adjacent parking lots to capture the overflow from the porous asphalt underdrains. A forebay will be constructed at each major inlet to allow for sediment collection and removal. The outlet will be placed above the permanent pool elevation and made with reinforced concrete pipe meeting the 10-year storm design. The emergency spillway handles a 100-year storm event [17, 18].

Recycled Porous Greenway Connector: The proposed design includes construction of a 1,670 sq. ft. greenway connector path (Figure **17)** next to the bioswale and retention basin on the EMCS building side. It will be made from compacted recycled asphalt and concrete removed from Area 1 for permeable pavement retrofit. This will have advantage of higher resistance for erosion during large rain events while still providing opportunity for the runoff infiltration[19].

Permeable Pavements: The proposed design includes installation of 78,940 sq. ft. of porous asphalt paving in the Area 1. Pavers totaling 54,629 sq. ft. shall replace existing sidewalks, patio areas in Areas 1-4 (**Figure 18)** and be added to disabilities parking spots area. The paving layers constructed to follow design standards for permeable pavements in the City's Resource Rain Manual[4]. Removal of existing curbs will allow water to flow directly onto the porous pavement areas from impervious areas. Besides water pollution and water quantity reduction, the proposed permeable pavers will provide several benefits such as preventing ice from building up on parking areas and walkways leading to improved safety and resulting in a longer life span of such pavements versus the traditional counterparts[20, 21].

Figure 18 *– Permeable sidewalk, parking pavers, and porous asphalt next to the EMCS and adjacent to the student parking lot and bioswale in Area 1 and Area 2.*

C. Real time Flow Control

The challenges of urban flooding can be alleviated and proactively controlled with real time sensor feedback technologies for managing water releases[22]. We propose to demonstrate and use the technology to manage releases from our Cistern 1 and wet retention pond. Real time feedback on water levels (L) and water quality (WQ) integrated with a calibrated hydraulic model will provide the opportunity to have controlled release of the water in such way that downstream will not flood while maximizing volume reduction and water quality treatment by the retention facilities. (**Figure 19**) As an example, in a scenario where the retention pond is at maximum capacity pre-rain event, the runoff and releases from upstream drainage areas will combine with the pre-existing water in the pond resulting in an aggravated flood downstream. Instead, on real time basis, if we can set the downstream pond to release its water before the upstream pond overflows, the downstream pond will have the capacity to hold additional water and can safely convey the water avoiding flooding. In addition, given a rain event is predicted to cause water levels to reach capacity, water would be proactively released the days prior to the rain event. The use of such innovative technologies with the proposed project will be beneficial to demonstrate to students and the local

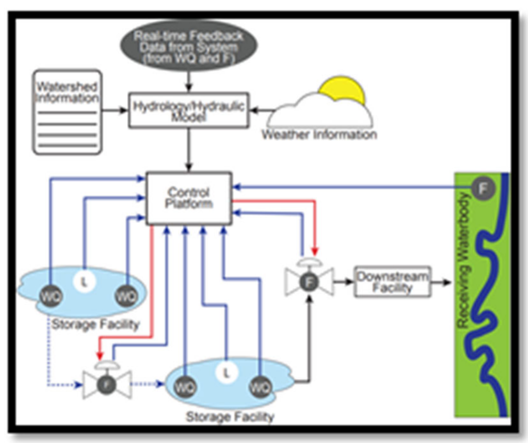

Figure 19 – Sensor Technology weather data collection and cistern/retention basin flow control.

community on the uses of technology to mitigate the most common stressing issue in a typical urban setting.

D. Outdoor Environmental Lab

The Outdoor Lab in Area 3 (**Figure 20**) will function not only as a lab for students, but also as a site for tours and community education. Since many students base their university choice on how

Figure 22- *Outdoor lab cross-sectional view of rain garden and infiltration testing.*

Figure 23 *– Outdoor lab in Area 3 with rooftop weather station, small cistern, rain garden, and bioswale.*

a campus feels, the goal is that the Outdoor Lab will also interest prospective students, especially to enhance their interest in environmentally friendly engineering. There will be the opportunity for students to link to the sensor technology and the see what is happening around the EMCS in real-time. In addition, lab students will be able to discuss, test, and improve the GI on campus. The Outdoor The proposed lab to incorporate a treatment train approach that would demonstrate rain water harvesting, bioswale and bioretention in series Lab will include a small cistern, a bioswale, and many explanatory signs (**Figure 20**).

E. Project Limitations: Having steep slopes (>6%) has limited the options to proposed GIs for major portions of the impervious areas. The overall grade change and slope of the of certain area made it futile to proposed porous asphalt paving. Also, for example, due to pre-existing infrastructure, such as paved parking surface, the installation of underdrains was not proposed since the existing pavement would not be removed. Another design element that was initially proposed but eventually dismissed was the installation of a green roof. Most of the existing rooftops are steep-pitched and inaccessible for installing and maintaining a green roof system. Green roofs also require a structural analysis, which can be expensive, and retrofit of an existing roof can be costly as well. The UTC Maintenance Dept. opposed green roofs for this project but was open to installing them on new builds or rooftops accessible to the community could access for social benefits.

BENEFITS EVALUATION

Social Benefits

GI is crucial in spanning the gap between environmental and social goals and will positively impact the welfare of the greater Chattanooga community. Social benefits provided by GI include but are not limited, to feelings of safety, improved physical as well as mental health, and strengthened community ties. While the presence of greenspaces around EMCS can contribute to well-being, accessibility is necessary to have a positive effect on community health. Outdoor seating around the retention basin will encourage community connectedness while the elevated berm with greenway access and nearby bike parking will encourage healthy lifestyles. Although the retention basin could spawn mosquitoes and green habitat could harbor ticks, risk of disease and transmission is diminished if a diverse, healthy ecosystem is guaranteed. Heightened sensitivity to allergens from plants is an additional threat, however, we will propose the use of native species over highly allergenic, non-native species that are often used in GI. Spending time in green spaces has psychological benefits such as relaxation and stress alleviation. rendering these green areas as common places of respite for over-stimulated minds. The Outdoor Lab will increase social capital and cohesion by establishing common values. Such collectiveness will undoubtedly have a positive impact on students' wellbeing. Communication among students and faculty from different departments stimulates socialization and the close relationship between the departments on this project demonstrates the interdisciplinary nature of GI [23].

Environmental Benefits

A. Change in Paved Area, SOV, and Flow Rate (Q)

The current system insufficiently manages stormwater, thus, adding GI will significantly improve overall water quality system. The proposed design will reduce the contributions to the combined sewer system. Post-construction will reduce impervious to 34% from 73% of existing conditions. Improvements will increase the Stay-On-Volume capture allowing more time for infiltration and evaporation. Peak flow discharges are expected reduce significantly with implementation of the proposed design (**Table 3**).

Table 3 *– Projected Results of Impervious vs. Pervious; SOV; and Flow Rates of proposed green infrastructure implementation*

Conditions	Impervious (sq. ft.)	Pervious (sq. ft.)	SOV (eq.1) (cubic ft.)	Q_2 (eq. 2) (cubic ft./sec.)	Q_5 (eq. 2) (cubic ft./sec.)	Q_{10} (eq. 2) (cubic ft./sec.)	Q_{25} (eq. 2) (cubic ft./sec.)	Q_{100} (eq. 2) (cubic ft./sec.)
Existing	257,769	93,911	21,630	23.6	28.7	32.6	38.3	47.2
Proposed	120,408	231,272	BMP 29,620	20.2	24.6	27.9	32.8	40.5
Results	137,361 reduced	137,361 gained	Capture>SOV acceptable	3.5 reduced	4.1 reduced	4.7 reduced	5.5 reduced	6.7 reduced

B. Stormwater Annual Runoff Analysis

EPA's National Stormwater Calculator (SWC) [24] was used to test the annual rainfall runoff control performance. The SWC is regarded as most suitable for performing screening-level analysis of small footprint sites such as those proposed in this project. In order to understand long term performance, the proposed design is analyzed for over a 20-year period using historical data monitored at the Chattanooga Regional Airport. Note, the SWC limits its capabilities to hydrology only analysis. As such, we could only analyze proposed impervious area disconnections, permeable pavers, planter boxes and rain gardens. The SWC prediction results **(Figure 21)** demonstrate a significant reduction in the site runoff when compared to existing conditions while increasing infiltration. The analysis also indicated that average annual runoff has reduced from existing conditions 37.75 inches to 11.8 inches for proposed conditions.

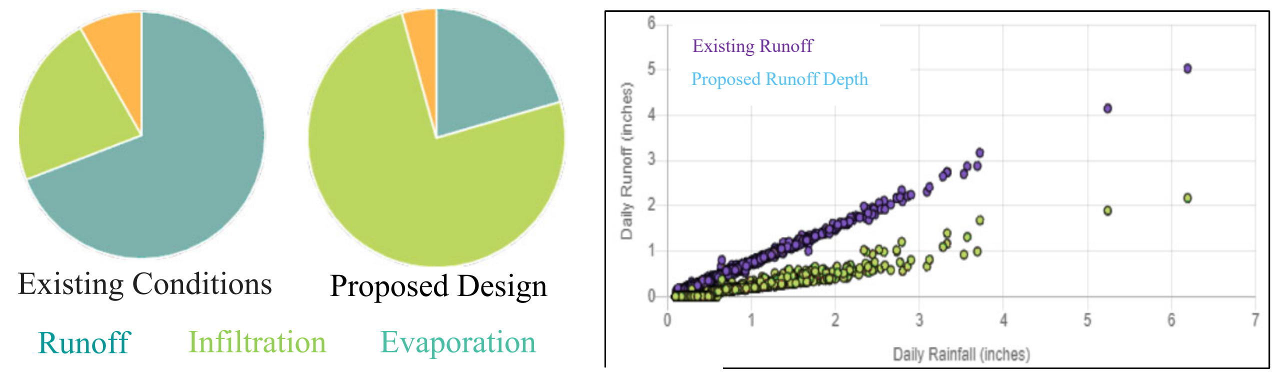

Figure 21 *- Comparison of existing and proposed site hydrology*

C. Stormwater Pollution Control

Developed areas such parking lots are adds significant quantities of pollutants such as TSS; phosphorous, nitrogen, and bacteria, which however can be control with the implementation of pervious pavements, retention basins, rain gardens, and bioswale. Our projected water quality benefits are based on data from the City Guide[4] (Table 7-2 BMP Applicability Matrix for Water Quality Improvement for Specific Pollutants of Concern) (**Table 4**). **Table 4** highlights potential reductions base on our design BMPs.

Table 4 *– Projection of pollutant removal per green device implemented*

BMP/ Pollutant	Total Suspended Solids % Reduction	Total Phosphorus % Reduction	Total Nitrogen % Reduction	Bacteria (E. Coli) % Reduction
Pervious Pavement	40	40	18	N/A
Retention Ponds	78	18	36	71
Vegetative Swales	37	N/A	14	N/A

Economic Benefits:

Economic benefits include improved parking space, maintenance cost, new student recruitment, external funding attraction, and water utilities savings.

A. Irrigation Savings:

The estimated monthly cost of irrigation in **Table 5** is based on 1-inch water over the square footage of irrigated land and calculated using values from the Tennessee American Water for Commercial rates[25] and Moccasin Bend Wastewater Treatment sewer rates[26]. As shown in the Table 9, there is no additional need for water than what can be harvested from the proposed design, avoiding expenditure needed for irrigation.

Table 5 *- Monthly Cost Saving in Irrigation*

Irrigation Conditions	Total area to be Irrigated (SF)	Water (gallons)	Water + Sewer cost per 1000 gallons	Water Collected For irrigation (gallons)	Monthly Cost of Irrigation for the site
Existing	56,123	35,900	$8.31	0	$298.00
Proposed	64,000	39,872	$8.31	69,331	$-244.81

B. Storm Sewer Fee Reduction:

Property owners in the City of Chattanooga are charged $152.33 per 3,200 sq. ft. of impervious area per year on their water bill[4]. Our project's design reduces the impervious area by 53% and hence the cost to the university is expected to go down from $12,270 to $5,732 a year in stormwater fees.

PROJECT SCHEDULE

The Phasing Plan is broken up into three years and the three seasons (**Table 6**). Year One focuses on the acquiring of funds to proceed with project and to ensure that both the University and Contractors can make the needed preparations for the following two years. Year Two and Year Three split the main areas of intensive construction into the parking lot of Area 1 and the sidewalk entry way for Area 3. Smaller projects can be accomplished during the school semester due to low inconvenience to students and low labor intensity.

Table 6- *Proposed Design and Construction Schedule*

Progress	Jan-May	Jun-Aug	Sep-Dec
Year One	Acquiring Funding		
	Release of Bidding Estimates		
	Coordination with UTC and Contractors		
Year Two	Parking Lot (Area 2)	Demolition of Parking Lot (Area 1)	Downspout Disconnections
		Cistern #1	Bioswale (Area 4)
	Rain Gardens	Reinforced Concrete Pipes	Trees at Retention Pond
	Bioswales	Porous Asphalt and Pervious Pavers	Building of Outdoor Lab
	Training Maintenance Personnel for GI management	Grass for Retention Pond	
Year Three	Furnishing of Outdoor Lab	Demolition of Sidewalk (Area 3)	Tiding Up any Construction Debris
		Cistern #2	
		Reinforced Concrete Pipes	
		Planter Boxes	
		Green Roofs	

PROJECT COST

A. **Maintenance:** Like all stormwater management systems, GI requires consistent inspections and maintenance to ensure it will continue to function correctly, produce anticipated water quality, and have environmental benefits[27, 28]. The maintenance cost of the proposed controls are derived from the Green Values National Stormwater Management Calculator[26] and listed in the **Table 7**.

Table 7 *- Annual Maintenance Frequency for Green Infrastructure*

Item	Maintenance Activity	Frequency
Rain Garden/Planter Box/Bioswale	watering	every 4-6 weeks
	weeding, trimming, pruning	semi-annually
	plant replacement	annually
Pervious Paver	vacuuming	every 6 months
	power washing	every 3 years
Cistern	cleaning and inspection	annually
Downspout Disconnection	cleaning and inspection	semi-annually
Retention Basin	remove debris and repair embankments	annually
	remove accumulated sediment	every five years

Table 8 *- Annual Maintenance Cost for Green Infrastructure*[27]

Item	Unit	Area / Amount	Cost / Unit	Average Price	Lifespan [years]
Rain Gardens	Sq. Ft.	16,600	$0.340	$5,644.00	30
Pervious Pavers	Sq. Ft.	54,629	$0.036	$1,966.64	25
Cistern #1	Gallons	40,000	$0.070	$2,800.00	20
Cistern #2	Gallons	10,000	$0.070	$700.00	50
Bioswales	Sq. Ft.	1,391	$0.120	$166.20	30
Rain Planter Box	Sq. Ft.	17,293	$0.800	$13,834.40	25
Downspout Disconnection	Each	38	$0.250	$9.50	50
Retention Basin	Sq. Ft.	3,820	$0.75	$2,865.00	20

B. Planting Cost: Plant species with extensive, strong roots structures are required to prevent runoff from stripping topsoil and creating large areas of negative infiltration[29,30,31, 32]. For the islands in Areas 1 and 2, grasses such as Blue Grass with strong roots that naturally thrive while inundated are all that is required. Within the planter boxes the aforementioned grass, shrubbery such as the Virginia Sweet spire, and small trees whose roots are not prone to overspreading and destroying the infrastructure of the building will be used (**Table 9**). Using plant species that are native to East TN will contribute to the system as a whole as it not only gives the area a more natural look but keeps the system healthy and flourishing[13,14].

Table 9 *– Proposed Planting Schedule*

Species	Quantity per (6300 sq. ft.)	Average Cost
Grasses[11]		
Blue Grass	19.8 lbs of seed	$6.56 per lb, $124.15 for full coverage
Perennials[12]		
Yellow Yarrow	Covering ⅛ of Garden: 88 plants	$6.35 per ounce
Blue Star	Covering ⅛ of Garden: 28368 plants	For 787.5 sq. ft.: Approx. $80.85
Grey Headed Coneflower	Covering ⅛ of Garden: 197 plants	For 787.5 sq. ft.: Approx. $23.52
Blur Flag Iris	Covering ⅛ of Garden: 88 plants	For 787.5 sq. ft.: Approx. $1061.17
Shrubs[13]		
Virginia Sweet spire	Covering ⅛ of Garden: 88 plants	For 787.5 sq. ft.: Approx. $17.95
Oakleaf Hydrangea	Covering ⅛ of Garden: 12 plants	For 787.5 sq. ft.: Approx. $4.00

C. Green Infrastructure: The cost estimates of the proposed design components are derived using midrange anticipated price values published by Green Values Calculator[33] and Tennessee Department of Transportation (TDOT) Region 2, unit prices[34]. Each price listed was derived from case studies with examples or from awarded projects. The real time feedback sensor technology which is set up in two different components for cost estimates.

Table 10 *- Installation and Material Cost for Green Infrastructure* [27,28]

Item No.	Unit	Area/Amount	Cost/Unit	Price	Installation	SUBTOTAL
Porous Asphalt[26]	Sq. Ft.	78,940	$6.34	$500,479.60	$297,586	$798,065.60
Pervious Pavers[26]	Sq. Ft.	54,629	$7.10	$387,865.90	$112,122.73	$499,988.63
Cistern #1[26]	Gallons	40,000	$1.45	$58,000.00	$341,176.47	$399,176.47
Cistern #2[26]	Gallons	10,000	$1.45	$14,500.00	$85,294.12	$99,794.12
Bioswales[26]	Sq. Ft.	1,391	$15.00	$20,865.00	$33,024	$53,889.00
Rain Gardens[26]	Sq. Ft.	16,600	$7.00	$116,200.00	$67,212	$183,412.00
Rain Planter Box[26]	Sq. Ft.	17,293	$8.00	$138,344.00		$138,344.00
Grass with Bioretention[26]	Sq. Ft.	30,371	$3.00	$91,113.00		$91,113.00
Downspout Disconnection[26]	Each	38	$35.00	$1,330.00	$342	$1,672.00
Sensor Technologies	Each	1	$2,570.00	$2,570.00 **(1)**		$2,570.00
Pavement Removal[26]	Sq. Yd.	15,730	$19.23	$302,487.90		$302,487.90
12" R.C.P. (underdrains) [26]	Linear Ft.	295	$70.00	$20,650.00		$20,650.00
Retention Basin	Sq. Ft.	3,820	$0.93	$3,548.90		$3548.90
					Total Project Initial Cost:	$2,594,711.62

(1) Price Includes 2 Components. 1) Weather analysis: Ambient Weather WS-2902C Smart Weather Station cost $170.00 Each. 2) Bettis EHO Electro-Hydraulic Operator (Smart), produced by the Emerson Automation Solutions Cost $1,200 Each.

PROJECT FUNDING

UTC Green Fee fund is available for GI projects that support the campus sustainability initiative. The Green Fee fund is supported through a $10 per student assessment each term. The green fee funds are collected to support the campus Recycling Program, purchase Green Power, and consider and implement other eco-friendly campus programs and initiatives approved by the Environmental Task Force Committee. Interaction with the campus sustainability staff has orally confirmed potential eligibility of this stormwater management project for the green fee fund[35].

City of Chattanooga Green Grants is another potential funding source for selected GI projects proposed in the master plan. The City of Chattanooga's Water Quality Program (WQP) has created the Green Grants Program for property owners who seek to improve water quality and/or go beyond their Stay-on-Volume (SOV) requirement for GI development or retrofit projects. The grant will provide businesses, institutions, and other non-single-family residential customers partial funding to design and construct green infrastructure projects on private properties. [36]

The City of Chattanooga's RainSmart Program is an incentive program exclusively available for implementing rain garden or rain barrel GI controls on private properties. As part of this program, the city reimburses for installing water quality projects on private properties. The primary goal of the program is to reduce stormwater runoff. Potential eligibility of the proposed stormwater GI controls was discussed with the City RainSmart program staff and secured oral acknowledgment of the projects' eligibility for the incentives [37].

Section 319 is another potential source of funding for implementing the proposed stormwater management plan. The Tennessee Department of Agriculture (TDA) administers the Nonpoint Source Program in Tennessee on behalf of US-EPA. As part of this funding source, the TDA pays for 60% of the cost of a project that controls non-point source pollution. BMP Implementation Projects. Projects of this type receive the highest priority for funding. Eligible applicants for the funding include non-profit organizations, local governments, state agencies, soil conservation districts, and universities [38].

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