STLCC Forest Park Center for Nursing and Advanced Health Sciences Methods

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The full case study can be found at: https://landscapeperformance.org/case-study-briefs/STLCC-Forest-Park

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Environmental Benefits

- ***Reduces average annual stormwater runoff by 6.3%, from 435,160 cu ft to 407,560 cu ft, for a 98th percentile rain event.***

Background:

The renovated landscape has a total of 1.38 acres of vegetated area (including bioretention and lawn areas). The site saw a 15% decrease in pervious area since approximately 0.76 acres of former lawn became an impervious area. Although the renovated landscape contains a larger impervious area, it includes three bioretention basins (Figure 1) in the remaining vegetated area that help with reducing runoff more than the former lawn.

Figure 1. One bioretention basin in the renovated landscape.

Method and Calculations:

The rational method was used to calculate stormwater management, and LEED and construction documentation provided key information. The landscape was designed to achieve a LEED Gold standard, and therefore the site was planned to treat a 98th percentile rainfall event, and the rainfall depth used for calculation is 2.4 in[1]. The annual average rainfall used is 41 in[2]. The soil type is sandy loam. The designed bioretention basin (C/D soil, with internal water storage underdrain) is set to reduce 55% of the runoff volume[1]. The annual average runoff volume is calculated for the site before and after construction. In calculating the post-construction runoff, we calculated and subtracted the amount of water that the bioretention basins absorb (87,538.71 cu ft) which is a 6.3% reduction in the amount of runoff. The details of the areas are in Table 1.

Table 1. Sizes of the areas on the site and the general values

Item	**Pre-Renovation**	**Post-Renovation**	**Note**
Total Drainage Area	5.22 ac	5.22 ac	
Impervious Area	1.38 ac	2.14 ac	
Pervious Area	3.84 ac	3.08 ac	
Impervious Ratio	26 %	41%	1.38 / 5.22 * 100% = 26 % 2.14 / 5.22 * 100% = 41%
General Value			

Annual Ave. Rainfall (P)	41 in[2]	
Runoff Coefficient (Rv)	0.95 for impervious area 0.42 for pervious areas over limestone bedrock 0.05 for pervious areas over river alluvium	Most upland areas in St. Louis City are limestone bedrock. Most river floodplains are river alluvium.

Pre-Construction Annual Runoff Volume ($V_{A,\ Pre}$)[3]

$V_{A,\ Pre} = (P * R_{v\text{-}impervious} * A_{impervious} / 12) + (P * R_{v\text{-}pervious} * A_{pervious} / 12)$

= (41 * 0.95 * 1.38 / 12) + (41 * 0.42 * 3.84 /12)

= 9.99 ac ft. = 435163.80 cu ft

V = Runoff volume

Rv = Runoff Coefficient

A = Area (ac)

P = Annual Ave. Rainfall (in)

Post-Construction Annual Runoff Volume ($V_{A,\ Pos}$)[3]

$V_{A,\ Pos} = P * R_{v\text{-}impervious} * A_{impervious} / 12 + P * R_{v\text{-}pervious} * A_{pervious} / 12$

= (41 * 0.95 * 2.14 / 12) + (41 * 0.42 * 3.08 /12)

= 11.37 ac ft = 495097.87 cu ft

Runoff Reduction Volume of Best Management Practices (BMPs)[3]

$V = P * R_{v\text{-}impervious} * A_{Timpervious} / 12 * 0.55$

= 41 * 0.95 * 1.17 / 12 * 0.55

= 2.09 ac ft = 91040.26 cu ft

V = Runoff volume

$A_{Timpervious}$ = Total impervious area of three BMPs (ac)

55% runoff reduction retrieved from 6.a. Bioretention, Volume Reduction Calculator Spreadsheet and User Instructions (MSD)[3]

Total BMP Volume Reduction Provided (RR) Calculation[4]

RR = Runoff Reduction Volume of BMPs / RR_v

=91040.26 / 1.04

= 87,538.71 cu ft

$RR_v = (P - 0.2\ S)^3 / P + 0.8\ S$

$=[2.4 - (0.2)(1.9)]^3 / [2.4 + (0.8)(1.9)]$

=1.04

RR_v = Runoff depth (in)

P = Rainfall depth (in)

S = Potential maximum retention after rainfall begins (in)

Potential maximum retention after rainfall begins (in) (S) Calculation[4]

CN = Curve number (unitless) = 84[2]

S = 1000 / CN - 10

= 1000 / 84 - 10

=1.9

Net Decrease in Runoff after the Construction[3]

$=(V_{A,\ Pos} - RR_v)^a - V_{A,\ Pre}$

$= (495097.87 - 87538.71)^a - 435163.80 = 407559.16 - 435163.80$

= -27,604.64 cu ft

[a] The estimated annual average runoff after applying bioretention basins.

Comparison between pro- and post-renovation

(After - Before) / Before * 100%

(407559.16 - 435163.80) / 435163.80 * 100%= **-6.3 %**

Sources:

[1.]Junior College District of St. Louis, Stormwater Management Facilities, Report: Calculations, February, 15, 2018

[2.]Rebekah Frankson, Kenneth E. Kunkel, Sarah M. Champion, Brooke C. Stewart, *Missouri State Climate Summary 2022, NOAA Technical Report NESDIS 150-MO* (Silver Spring: NOAA/NESDIS, 2022), https://statesummaries.ncics.org/chapter/mo.

[3.]Metropolitan St. Louis Sewer District, “Calculation and Report Preparation Tools”, MSD Project Clear, Metropolitan St. Louis Sewer District, October 19, 2016, https://portal.laserfiche.com/Portal/DocView.aspx?id=447754&repo=r-a96260ce

[4.]North Carolina Department of Environmental Quality, “Stormwater Best Management Practices Manual,” North Carolina Division of Water Quality, North Carolina Department of Environmental Quality, July, 2007, https://files.nc.gov/ncdeq/Water%20Quality/Surface%20Water%20Protection/SPU/SPU%20-%20BMP%20Manual%20Documents/BMPMan-Ch03-SWCalcs-20090616-DWQ-SPU.pdf.

Limitations:

- This benefit is only based on an estimation and calculations; there might be gaps between the result and the actual performance.
- The annual runoff estimation generalizes the runoff around a year which does not account for the peak precipitation period in a year or a day. Hence, we cannot understand the performance of these bioretention basins when heavy rainfall happens in a short time.
- The calculation of the annual runoff is based on ideal situations in which the bioretention basins are located at low points and collect water as designed. The actual situation might be different, and therefore, the amount of stormwater managed would be less than this calculation.

- ***Saves an estimated 670,400 gallons of water monthly through reduced irrigation as compared with the site before the renovation.***

Background:

Reduction in water usage is expected based on the application of native plants in the bioretention basin in the new landscape and the absence of automatic irrigation systems across the site. This aligned with our observations during our site visits, although plants and turf outside the bioretention areas exhibited signs of distress. According to the Landscape Management Guide[1] created by the landscape architects, the planting design with native plants only requires irrigation for a while after installation and during drought. (This is also what researchers heard from the campus facilities supervisor during the site visits.) The irrigation frequency and the duration requirements after the installation are suggested as follows: water every three or four days for the first three weeks and once per week until the roots have grown out of the container, which usually takes about a year for large trees. Afterward, basins with native plants will barely need irrigation except during droughts.

The LEED requirements for outdoor water reduction have four options[2]. They are: 1) using non-vegetated surface; or 2) using vegetated surface but with no permanent irrigation system (2 points), 3) 50% water usage reduction from the baseline (calculated with the equation of landscape water requirement (LWR); 1 point), and 4) 100% reduction from the baseline (2 points). On this site, the landscape design eliminated the permanent irrigation system to meet the strict LEED requirement. Quick couplers are distributed around the entire site[3] for manual irrigation during establishment and drought periods and accommodates other needs from infrequent events.

Method:

We used the Water Budget Tool[4] to estimate the water usage of the previous landscape. The types of green space in the previous campus landscape were turfgrass, shrubs, and trees. We assumed a traditional maintenance application with a fixed spray irrigation system designed for turfgrass and medium water use. The total area of the turfgrass area was 167,336 sf. The new campus landscape utilizes a manual irrigation system of 13 quick couplers to satisfy LEED requirements for water use. Manual watering is assumed to establish plants and to mitigate any periods of drought.

Calculations:

The equation in the Water Budget Tool[4] is used to calculate the landscape water requirement for the hydrozone (LWR_H, gallons per month) for the pre-renovated situation:

$$LWR_H = 1 / DU_{LQ} * [(ET_o * K_L) - R_a] * A * C_u$$

DU_{LQ} = Lower quarter distribution uniformity, 65% for fixed spray

ET_o = Local reference evapotranspiration (in per month), 7.14 for the zip code area 63110

K_L = Landscape coefficient for the type of the plants, 0.7 for medium water required turfgrass

R_a = Allowable rainfall, 25% of the average peak monthly rainfall (R), 25% * 3.28

A = Area of the hydrozone (sf)

C_u = Conversion factor, 0.6233, converting results to gallons per month

The water requirement of the pre-renovated site:

= 1 / 0.65 * [(7.14 * 0.7) - 0.25*3.28] * 167336 * 0.6233

=670,412 gallons per month

The outcome calculated by the Water Budget Tool showed that the landscape water requirement was 670,412 gallons per month. The calculation was based on a medium water requirement. We learned from the facilities supervisor at STLCC that the post-renovated landscape did not irrigate after the plants were established; therefore, the water usage is zero for the post-renovation condition.

Sources:

[1.] dtls & Shaw Nature Reserve, *Landscape Management Guide,* 2020

[2.] U.S. Green Building Council, "LEED v4 for Building Design and Construction," LEED v4.1, U.S. Green Building Council, October., 2019, https://www.usgbc.org/leed/v41

[3.] KAI Design & Build, "Irrigation Plan, Pricing Set", December 21, 2017.

[4.] United States Environmental Protection Agency, "Water Budget Tool," United States Environmental Protection Agency, accessed May 17, 2022, https://www.epa.gov/watersense/water-budget-tool.

Limitations:

- Researchers were not able to obtain the water bill nor the maintenance methods from STLCC for the pre-renovated condition. Therefore, we could only estimate the monthly saved water usage with equations developed by the EPA, and the actual water usage before renovation is unclear. The monthly estimation assumed the medium water usage - when it is a dry or wet year, the actual water usage might differ.
- Although the design shows a 100% reduction in water usage, it is not a perfectly realistic way of maintaining the vegetation, in particular the turfgrass and trees. Two years post-installation, we observed that the turf grass and many trees are distressed due to a lack of water and nutrients. The facilities supervisor at STLCC plans address the turf issue by seeding different grass species - such as Bermuda grass and bluegrass - to replace the originally specified tall fescue mix (*Festuca arundinacea*, 90%) and Kentucky bluegrass (*Poa pratensis*, 10%). In contrast, the three bioretention gardens survived well with no signs of significant plant distress.
- During field visits, we found that most of the trees on the site did not have slow-release watering devices installed, a deviation from the contract documents. The absence of these slow-release devices (gator bags) could be another cause of tree distress. Trees with slow-release watering devices differed in their overall health condition, as they appeared greener and fuller. The amount of sunlight may contribute to better health

outcomes for the trees as well. We observed the healthy trees in locations of less direct sunlight with slow-release devices and reasonably concluded these conditions contributed significantly to their overall well-being (See Figure 2); however, this conclusion needs more testing and observation to understand the actual reasons.

Figure 2. Comparison of tree conditions
(On the right: healthy tree with gator bag located in between buildings; on the left: wilted trees without gator bags in the open area)

- We also found that the current soil condition is not ideal by testing the nitrogen content of the installed soil. We used the Luster Leaf 1601 Rapitest Test Kit and found the nitrogen is at the level between deficient and depleted (Figure 3). Lack of nitrogen causes wilt, yellow leaves, and poor growth could contribute to unhealthy plant condition.

Figure 3. The result of the soil test on nitrogen

Social Benefits

Overall Background for Social Benefits:

The old building connected the west and the east end of the campus. A corridor at the basement level provided students, staff, and faculty access to walk across the campus. One of the renovation goals was to create a campus that encouraged users to utilize outdoor walkways and spend more time outdoors. The design changed the campus as follows. Before the construction, buildings A, B, and C linked by a long indoor corridor allowed people to remain indoors to access all the buildings. This was especially useful in the winter, with temperatures at and below freezing. The renovation dismantled building A and B and the portion that was rebuilt and became the new building did not keep the subterranean pathway in between. Connecting pathways were moved outdoors, and a seating area with furniture was placed next to the building entrance, providing spaces for people to pause on the renovated campus.

We did investigations, observations, and surveys to evaluate the social benefits. The investigation methods are specified for each benefit item and are explained individually within that benefit section. The observations and surveys were used for multiple benefit assessments; therefore, the methods are explained up front.

Observations: The observations were conducted several times on site: 10:00 - 12:00 and 16:00 - 17:00 on June 8; 7:15 - 8:15 and 11:00 - 13:00 on June 9, 2022. The weather conditions were sunny. On June 8, it was 77 °F, 64% humidity, 16 mph wind, and 6/10 UV. On June 9, it was 76 °F, 51% humidity, 3 mph wind, and 5/10 UV. The source of the weather report was from zip code 63110 from the Weather Channel (https://weather.com/).

Surveys: The survey questionnaire included four parts: frequency and transportation to campus, usage of outdoor spaces, feelings and experiences of the current and pre-renovated campus landscapes, and personal information. We distributed the survey questionnaires online and on-site. The questionnaire was delivered through Google Forms and advertised by posting the link in the campus newspaper and sending through emails to faculty and staff, posting flyers in the building, and approaching pedestrians on site (visited on July 6, 2022, from 10:00 to 14:30). We received 21 responses from July 5 to July 18, 2022.

Limitations of the questionnaire survey:

- The research team did not have access to email addresses for students from the school; therefore, we could only reach students in person. We visited the campus for the survey on July 6, which was in the last week of the summer semester, and there were much fewer students around than during our previous visits.
- We posted flyers on bulletin boards on each floor in the new building. Flyers did not seem effective in recruiting people to complete the survey. However, they did get people's attention, as when we approached people on site, they knew about the survey from flyers.

- Many community college students have other jobs or responsibilities after classes; therefore, they did not have time to stop and answer the questionnaire when we approached them on site. When we realized this, we attached small pieces of paper to the flyers that we put on the boards. People could grab the small flyers and go, and answer the survey when they had time.

- ***Promotes outdoor space occupancy and supports at least 7 types of outdoor activities for students and visitors.***

Methods:

We used observations and surveys (see Overall Background for Social Benefits for details) to understand how much time users spend and what types of activities users do in the outdoor spaces. We observed the time and the duration of users occupying the outdoor spaces and where people usually spend time.

The minimal amount of time spent observing, and the fact that it occurred during summer term, was not sufficient to observe any patterns. Additionally, outdoor space occupancy data is not available from the time before renovation.

We used surveys (see Overall Background for Social Benefits for details) to ask participants about their experiences on the campus including what types of activities they do (multiple choice) and how much time they spend there on average. The findings are added to support our observations during summer term, when fewer people showed up on the campus.

Calculations:

Outcomes of the observations fit the expectation of where people spend time on the campus – the sitting area with cover and movable furniture next to the building entrance. Table 2 shows that we observed five groups staying at the sitting area (area K in Figure 4) and one sitting on the lawn (area L in Figure 4) for a short period (10 - 90 minutes). Five of the groups had only one person and a group of six people. People used the area for working, gathering, dining, and waiting. Most users came to have lunch during noon.

Table 2. Results of the user static behavior observations

Time	Duration (min)	Location	Behaviors
Jun 8 15:30 - 17:00	90	L	Sitting alone using a laptop, in the shade
Jun 9 xx:xx - 09:50	30*	K	Sitting alone using a laptop; left, going inside another building.
Jun 9 11:00 - 12:00	10	K	Waiting alone for someone to pick them up

Jun 9 11:40 - 12:23	43	K	Eating alone, on the phone
Jun 9 11:45 - 12:00	15	K	Eating alone
Jun 9 11:45 - xx:xx	90*	K	A group of 6, eating (They were still there when we left at 12:40)

Note. *An estimated duration; we did not know when they arrived or left.

Figure 4. Locations of the observed static behaviors

We collected a total of 43 responses about the activities that participants do on campuses. Most of the participants (12/43) passed through the campus as their way to use outdoor spaces. Among other intentional activities, what participants did the most was take a break and relax (8/43), walk (8/43), as well as gather with friends (6/43) and have lunch (5/43). Other activities include reading, work, and exercise, with only one answer. Although participants used the campus for plenty of activities, nine of them spent less than 30 minutes in outdoor spaces in a week on average, five spent about half an hour to an hour, and one spent about 60 to 90 minutes a week. The time spent outdoors did not interfere with the types of the activities people do on the campus, even staying for less than 30 minutes a week, people would still do a variety of activities.

Although the observations reported that the actual outdoor space usage occupied mainly one spot, the covered sitting area, the survey outcomes showed that people did multiple types of outdoor activities on the campus and involved the space more than the sitting area. To conclude, the campus landscape supports the general activity needs of the campus members.

Limitations:

- The observation was conducted during the summer term and only during a short period, which is not sufficient to generalize the results year-round.
- We do not know how the outdoor space was occupied during the pre-renovation condition. We could only assume that with the previous landscape design, including trees and lawns with topography changes, but having no furniture, people might have limited ways of using the landscape.
- Students at STLCC commute to campus when they have classes, which may result in students spending little time on the new campus and few activities happening in general.
- This campus is across from a major park: Forest Park in St. Louis. Therefore, the campus may be a less attractive destination for walks to residents, hence, we only observed students using the outdoor space.
- In the survey, we did not specify which part of the campus that they used for their activities.

- ***Increases walkability, with 30% increase in walkability score using a walkability evaluation tool as compared with the site prior to renovation.***

Method:

We assessed the walkability of the renovated campus area to understand the extent to which outdoor spaces invite people to walk through or use them. Walkability is defined by multiple factors, such as street connectivity, quality of the street, safety, aesthetics, and barriers. The appropriate scales in which the details of each factor make sense may be different, so we modified a walkability scale from a previous study[1] that had a comparable smaller-scale site than other walkability studies as a tool to conduct the assessment. This walkability scale[1] was designed to assess spaces in cities at a neighborhood or community scale. Therefore, we excluded factors that do not apply to the size and the traffic situations of the STLCC Forest Park campus – a small-scale campus with a simple pathway system.

Items excluded were social safety (graffiti, abandoned houses or cars, pedestrian flow volume, surrounding security), traffic safety (vehicle flow volume, road safety, traffic sign), physical barrier (scooters occupying sidewalks, street vendors, cul-de-sac), aesthetics (shop window decoration, distinctive business signs), and bus stops. In this walkability evaluation, we focused on the perspectives, including the connectivity of pathways, the environmental quality of the pathway system, the aesthetic quality of the site, and facilities for providing better walking experiences. The final scale is shown in Table 2. There are 14 items and each is scored from 1 to 5 with a total possible score of 70 – the higher the score, the higher the walkability. We investigated walkability on-site for the current situation and assessed the site before renovation with Google Maps using the same scale. Each condition was evaluated by both researchers. We compared the scores of these two evaluations and shared the categories that saw the greatest differences before and after renovation.

Calculations:

Table 3 shows the results of the walkability scale that the post-renovated campus increased the score from 29/70 (41%) to 50/70 (71%), which represents a 30 % improvement. Four categories have significant changes (three- or four-point difference) – the number of intersections, attractive scenery, roadside planting, and pavement smoothness. Among them, pavement smoothness had the greatest improvement. The previous condition as assessed with Google Street View was bumpy with cracks and exposed materials. The current pavement of the sidewalks is smooth and kept in fine condition. The connectivity increased in the post-construction situation due to more pathways connecting an individual spot. These pathways directly link to the destinations (buildings, parking lots, or the garage) and avoid detours. The last point where the two conditions differ most is roadside planting. While pathways in both situations were built on the field where the lawn is the primary land cover, in the post-renovated campus, the vegetation is planted along the pathways so that pedestrians can experience the vegetation closely. The vegetation-related items are in the aesthetics category, which could be more than about visual experience. With the growth of the tree canopy, it can create lush corridors that make the pathways a more pleasant environment to walk during hot days in the long term. Maintenance will be critical to keeping a clear sight to avoid safety concerns. Overall, the post-renovated campus creates a pedestrian-friendly campus where it is a pleasant place to walk.

Nevertheless, five items scored low in both pre-and post-renovated situations: the alternative paths, roadside trees, rain shelter, benches, and accessible ramps. In both situations, there is only one sidewalk in one direction; therefore, the alternative paths scored 1.5 and 2 points. During the on-site observation, we saw pedestrians walking on the main driveway; even though there was a little traffic volume during the summer term, it might cause conflicts during peak traffic. The roadside trees are aggregated toward buildings and driveways in the pre and post situations, which do not provide pedestrians enough shade, and both scored 2 points. There is no free-standing rain shelter designed outdoors in both situations; however, the pre-situation had an indoor corridor, and the post-situation had a covered open space, so both scored 2 points. Regarding benches, according to Google Maps and Google street view, there was no furniture in the previous condition. There is an outdoor sitting area on the post-renovated campus, but that is the only space with furniture around the campus. Lastly, the accessible ramps, although they scored 1 and 2 in the pre and post-situation, had different reasons. For the pre-situation, there were only a few ramps on the site with an obvious topography difference. In the post situation, however, the landscape has made it accessible with flat topography and slopes connecting entrances and the landscape, so there is no need for ramps.

In summary, the new arrangement of the building and outdoor spaces has opened up the campus to the outer roads, making the campus more accessible. The pathways added to the campus create good connections between buildings, and the topography change and the smooth surface make it easy to walk outdoors. Moreover, the quality of the pathways is improved, where more vegetation is planted by the pathways, and the aesthetics are enhanced.

Table 3. Walkability measures instruments (modified from Chiang et al., 2017)

Categories	**Attributes**	**Points**	**Pre-renovated campus score**	**Post-renovated campus score**
Street connectivity	Intersection	1 (very few) to 5 (numerous)	1; pathways had less access to places	4.5; many crosswalks
	Alternative paths	1 (very few) to 5 (numerous)	1.5; topography makes alternative paths difficult	2; many pedestrians used the entry drive
Aesthetics	Beautiful views in the surrounding	1 (none) to 5 (common)	2; many views face parking, I-64 and Oakland Avenue	4.5; beautiful views inside of campus, buildings block I-64 and Oakland Ave.
	Attractive scenery	1 (none) to 5 (common)	1; limited trees, building architecture is prominent	4; rain gardens very lush with vegetation
	Roadside planting	1 (none) to 5 (common)	1; none	4; planted medians and vegetation alongside road
	Roadside trees	1 (none) to 5 (common)	2; most trees (Cypress) next to building	2; trees alongside entry drive and are not close enough to some sidewalks.
Sidewalk quality	Sidewalk width	1 (very insufficient) to 5 (very sufficient)	5; sidewalk widths vary from 8-12’	5; sidewalks widths vary from 8’-12’, to match existing walks connecting to other parts of campus.
	Pavement smoothness	1(very coarse) to 5 (very smooth)	1.5; bumpy concrete with exposed gravel aggregate, brick inlays. Cracks present in photos	5; very smooth
	Sidewalk cleanness	1 (very unclean) to 5 (very clean)	5; very clean	5; though few cracks, sprawling present
Amenities	Rain shelter	1 (none) to 5	2; no rain shelter at	2; shelter only at the

		(common)	all outdoor, but they had indoor corridor	building entry
	Benches	1 (none) to 5 (common)	1; no bench seating	2; seating only at building entry
	Lighting	1 (none) to 5 (common)	2.5; pedestrian lighting at walkways	5; pedestrian lighting at walkways, light sculptures
Auxiliary	Accessible ramps	1 (none) to 5 (common)	1; much of the campus is accessible with stairs; difficult for wheelchair users	2; all areas accessible without ramps
	Street signs	1 (none) to 5 (common)	2.5; mostly for vehicular wayfinding to buildings	3; mostly for vehicular wayfinding
Total Points (Total of 70)			29	50

Sources:

[1.] Yen-Cheng Chiang, William Sullivan, and Linda Larson, "Measuring Neighborhood Walkable Environments: A Comparison of Three Approaches," International Journal of Environmental Research and Public Health 14, no. 5, (2017):593, https://doi.org/10.3390/ijerph14060593

Limitations:

- The walkability of the pre-renovated campus was evaluated based on Google Maps and Google Street View and we did not have the chance to experience it ourselves, which might be divergent from the actual condition.

Supplemental Information for Walkability Benefit

- ***Improved outdoor circulation on the campus.***

Method:

To verify the intention of creating an open and welcoming campus, as it was a core concept when redesigning the campus, we used surveys and observations (see Overall Background for Social Benefits for details) to understand students' and other users' circulation on the campus. In the survey questionnaires, we asked participants about transportation, entrance to the campus, parking locations, and the destinations of their routines; we also asked about their preference for the experience commuting among these destinations. With the answers, we can illustrate the possible pathways each participant uses and their preference, as well as consider these routes in the walkability assessment. In the observations, we recorded the routes people used and the number of people using them.

Calculations:

The survey outcomes showed the results of 21 participants' preference for the experience of walking from parking lots and the parking garage to the new health center building through the renovated landscape (brown arrows on Figure 5) was rated generally high, with an average of 4.7 points ((5 + 5 + 4.1) / 3). On the other hand, the routes (yellow arrows on Figure 5) commuting through the original campus showed some unfavorable experiences, and the average score is 2.8 ((1.8 + 4 + 3 + 3 + 2) / 5).

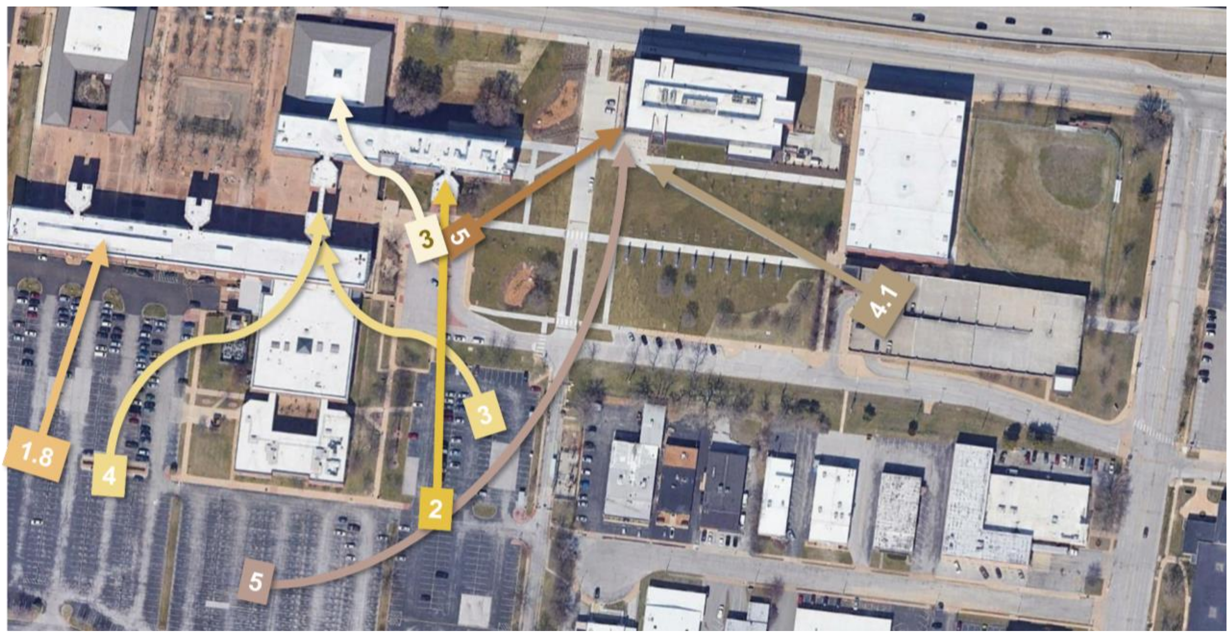

Figure 5. Preference of people walking from parking to their buildings
(The arrows pointing roughly to the parking spaces and the destinations are not the actual routes participants took. The yellowish colors indicate the routes passing through the original campus landscape, and the brownish colors indicate the routes on the renovated campus landscape.)

We conducted observations on two weekdays during the summer term (the detailed observation time is shown in the method section of the occupancy benefit). Pedestrians arrived during the times between classes, which were in the morning (between 7:00 and 8:00 am) and at noon (between 11:30 am and 12:30 pm). Many of them were those attending classes in the new building. There are generally, however, fewer people around the campus during the summer term, according to the District Division Dean of Health Sciences, Dr. Hubble. The results of the observations are summarized in Figure 6 and the details are shown in Table A1 (Appendix).

According to our observations, most people moved between the new building and the garage in the east on Route B (61% of pedestrians, a total of 140 visits) and the parking lot in the south on Route A (19%, a total of 43 visits). Route I was an alternative path for Route A, especially for those who went from the parking lot to the building, as Route I is the first north-south path they encounter. Route I, however, is the main driveway going through the campus, which might increase potential conflicts between cars and pedestrians. Based on the satellite image before the renovation, the pre-renovated campus did not have a direct sidewalk linking the building to the garage entrance. Route B provides an efficient way of moving around the campus, shown by its high utility. In addition, Route F, a newly created route, connects people on the campus to Oakland Ave., making the campus more accessible for people from the north. Figure 6 shows the main entrance of the campus on Oakland Ave. Our observations demonstrated the pathway design fits the needs of pedestrians' movements, and it created the pathways connecting destinations and enabling people to move efficiently.

The newly introduced pathway system and new entrances opened up to Oakland Ave. did provide a walkable and friendly outdoor landscape for campus members to commute among entrances, buildings, and the parking lots.

Figure 6. Routes of pedestrian movement by observation
The thickness of the arrows demonstrate the frequency of the usage, the thicker, the more frequent visits observed. The frequency is categorized into four levels based on the visit counts.

Figure 7. The entry driveway (on the right) runs through the campus and the main entrance.

***Limitations*:**

- The researchers have no information about the circulation on the pre-renovation landscape. Although we cannot directly compare the differences between the before and after situations, we know that people used the subterranean corridor as the main pathway, which was considered undesirable as getting campus users outside was a primary goal of the renovation.
- Although we can summarize the main routes being used on the campus, what we have observed about pedestrians reflects the situation during the summer term; it is, however, not possible to infer what the usage patterns are during the fall and spring semesters.
- We do not directly ask participants to describe or draw their routines. Because we planned to collect surveys on-site and online, there were technical limitations to asking participants to draw on the map with the online survey tools, especially those using mobile phones to access the survey.

- ***Promotes relaxation and reduces distressed feelings. When 21 site users familiar with the campus before renovation rated their perceptions of the site pre- and post-renovation, average scores for relaxation increased by 36%, and average scores for distressed feelings were reduced by 36% for the post-renovation landscape.***

- ***Increased the attractiveness of the campus. When 21 site users familiar with the campus before renovation rated their perceptions related to the site pre- and post-renovation, average scores for campus attractiveness increased by 45% for the post-renovation landscape.***

Methods:

To understand how the pre- and post-renovated campus landscapes make users feel, we used questionnaires (see Overall Background for Social Benefits for details) to ask about both conditions. We asked about attractiveness, relaxed and distressing emotions, and pleasant and awake feelings[1]. The attractiveness is asked to understand the general and immediate reaction when people see the landscape. The relaxed and distressed feelings are chosen because people wish to relax after classes or appointments to help reduce the feeling of distress. We asked for pleasant and awake feelings to explain the kinds of feelings that the landscapes make users feel. Russell and Pratt (1980)[1] explained the emotions with coordination of pleasant-unpleasant on the X axis and arousing-sleepy on the Y axis. The four quadrants are labeled with the combination of the two emotions, which are exciting, distressing, gloomy, and relaxing in the first to the fourth quadrants accordingly. For these questions, we asked participants to evaluate their pleasant-unpleasant and arousing-sleepy feelings on 1 to 9 scale, with 1 indicating as unpleasant and sleepy and 9 indicating as pleasant and arousing.

Calculations:

As Table 4 shows, participants had more positive feedback toward the renovated landscapes than before. For attractiveness, participants reported feeling that the post-renovated landscape was more attractive (45% increase) than the pre-renovated landscape. For emotional experiences, participants reported feeling more relaxed (a 36% increase in related feeling) and less distressed (a 36% decrease in the distressed feeling) in the post-renovated landscape than in the pre-renovated site.

About the results of the scale of Russell and Pratt, the scale 1 to 9 is converted to -4 to 4 with 5 (out of 9) as 0. The result is shown in Table 4 that the pre-and post- renovated landscapes scored: (-0.89, -0.68) and (1.95, 1.89) for the Unpleasant-Pleasant and Sleepy-Arousing, respectively. Therefore, the pre-renovated landscape made participants feel slightly gloomy, in the third quadrant; the post-renovated landscape made participants feel somewhat excited, the emotion representing the first quadrant. In addition to promoting positive and reducing negative emotions, the findings elaborated that the new landscape provided more energy than the prior passive landscape.

Table 4. Comparisons in the emotions between the pre- and post-renovated landscapes

Items	**Pre-Renovated**	**Post-Renovated**	**Difference***
Attractiveness	2.76	4.00	45%
Relaxed	2.81	3.81	36%
Distressed	2.81	1.81	-36%
Unpleasant-Pleasant[#]	-0.89	1.95	-
Sleepy-Arousing[#]	-0.68	1.89	-

*Difference: (post - pre) / pre * 100%
#The questions were asked with a 9 Likert-scale, which are converted and calculated as -4 - -1, 0, 1 - 4, with 5 (among the 1 to 9) as 0 when calculating the results.

Sources:

1. James A. Russell and Geraldine Pratt. "A description of the affective quality attributed to environments," Journal of personality and social psychology 38.2 (1980):311-322, https://doi.org/10.1037/0022-3514.38.2.311.

Limitations:

- Considering the time users would likely spend on the questionnaire, we asked one question for each feeling to keep the questionnaire short. This might restrain the responses and perspectives that were received.
- By July 18, the questionnaire survey had 21 respondents. It is a small sample size which might cause bias.
- This survey question depended on the memory of surveyed users of the site prior to renovation.

Economic Benefits

- ***Saves an estimated $32,000 annually on maintenance as compared with the site before the renovation.***

Background:

The renovated campus implemented three bioretention basins planting with native plants, which require significantly water and maintenance than the conventional planting design. Although the remaining green spaces are lawns, the lower proportion of the conventional lawn is expected to reduce the maintenance costs of the entire landscape.

Method:

We compared the cost of landscape maintenance (see Table 6 for the included items) before the renovation and two years after the completion of the site. We asked the facilities supervisor at STLCC the types of maintenance the school has done on the new campus landscape and the frequency at which it is conducted. However, we could not access information about the pre-renovated situation, therefore we did the cost comparison based on the area of each land cover type and estimated the cost of the maintenance needed for both situations. The cost of these maintenance items is calculated based on the information found from the below sources: Forbes Advisor[1], Schill Grounds Management[2], and FIXr[3]. The details are included in Table 6.

Calculations:

We summarized the estimated area for each land cover type in Table 5 as the maintenance items vary among different land covers.

Table 5. Landscape composition of the pre- and post-renovated campus

Land Cover Type	Pre-Renovated Area (%)*	Post-Renovated Area (%)*
Bioretention garden area (densely planted area)	0	11%
Tree and lawn	15%	14%
Number of trees	100	106
Lawn	63%	41%
Path on lawn	12%	12%
Pavement on the plaza	0	10%
Building	10%	12%
Total Area	227,383 sf (5.22 ac)	227,383 sf (5.22 ac)

*The area is calculated as a proportion with the total area as the denominator.

The cost difference is calculated as following when the cost is based on manpower:
$ Cost per hour * Hours * Frequency * [(post area - pre area) / 100]

When the cost is calculated based on area, the comparison calculation is as follow:
$ Cost per area * Frequency * [(post area - pre area) / 100] * 227,383 sf

The calculation for each maintenance item is listed below and summarized in Table 6:

- Trees and bushes trimming: $ 40 * 40 hr * 2 * (106-100) / 100 = $ 192
- Leaf removal (tree + lawn): $ 40 * 240 hr * 1 * (14-15) / 100 * = $ -96
- Fertilization (tree + lawn and lawn): $ 4 / 1000 sf * 3 * (55 - 78) / 100 * 227383 = $ -628
- Lawn aeration (lawn): $ 20 / 1000 sf * 2 * (41-63) / 100 * 227383 sf = $ -2,000
- Weeding (bioretention area and lawn): $ 65 / 10900 sf * 52 * (52-63) / 100 * 227383 sf = $ -7,756
- Outdoor pest control (tree + lawn and lawn): $ 4 / 1,000 sf * 104 * (55-78) / 100 * 227,383 sf = $ -21,756

The total amount of maintenance cost was reduced by $ 32,044 because the area requiring maintenance was significantly reduced. The greatest reduction was shown in maintenance related to lawn, especially weeding and pest control.

Table 6. Maintenance cost comparison

Maintenance Items	**Frequency***	**Cost / Manpower#**	**Area/Num differences (Post/ Pre)**	**Cost Difference**
Tree/ bushes trimming	twice per year	40 hr manpower ($40/hr) [1]	106 / 100	$192
Leaf removal (tree + lawn)	once a year	240 hr manpower ($40/hr) [1] / time	14% / 15%	$-96
Fertilization (tree + lawn and lawn)	Three times per year	$4/time/1000 sf [2]	55% / 78%	$-628
Lawn aeration (lawn)	Twice a year	$20/time/1000 sf [2]	41% / 63%	$-2,000
Weeding (bioretention area and lawn)	Weekly, 52 times per year	$65/10900 sf [3]	52% / 63%	$ -7,756
Outdoor pest control (on tree + lawn and lawn)	Twice a week, 104 times per year	$4/time/1000 sf [2]	55% / 78%	$ -21,756
Equipment repair	As needed	–	–	–
Subtotal				$-32,044

*We assume the frequency of applying the maintenance is the same in the pre- and post-renovated situations, and information on frequency was provided by the current landscape management.

#The cost of maintenance items and manpower is estimated at a medium cost standard and is not location-specific.

Sources:

1. “How Much Does Landscaping Cost?,” Forbes Advisor, accessed June 26, 2022 https://www.forbes.com/advisor/home-improvement/landscaping-cost/

2. “How Much Does Landscape Maintenance Cost?,” Schill Grounds Management, accessed June 26, 2022, https://www.schilllandscaping.com/blog/how-much-does-landscape-maintenance-cost

3. “How Much Does It Cost to Hire a Weed Control Service?,” FIXr, accessed June 26, 2022. https://www.fixr.com/costs/weed-control-service

Limitations:

- The outcome of the reduced maintenance cost is a roughly estimated number without knowing the actual cost, especially when the previous maintenance items and frequency are unknown.

Inconclusive Benefits

- ***Surface temperature is almost the same in the pre- and post-renovation situations.***

Background:

The design aims to enhance usage of outdoor walkways and spaces, which is challenging when environments do not provide comfortable user experiences. While climate change makes summer longer and temperatures higher, to what extent does alteration of the vegetation reduce the air temperature? Vegetation has been reported to be effective in temperature reduction; therefore we sought to make comparisons among different types of vegetation and pavement and examine the temperature reduction effect at the site.

Method:

We used the Actron IR Thermometer Pro, model CP7876, to measure surface temperature. Its distance-to-spot ratio is 10:1. We put the thermometer 4 ft above the ground when measuring, and the area it measures is about 0.13 sf. The measurements were done from 15:00 to 17:00 when the site had been exposed to the sun during the day. We conducted the measures on June 8, and the weather conditions at the time we started the measures was 77°F, 64% humidity, wind speed 16 mph, and 6 / 10 UV, as reported for the zip code 63110 from The Weather Channel (https://weather.com/).

The campus was categorized into five types according to the pavements and the location, including bioretention garden area, tree and lawn area, lawn area, pavement on the lawn, and the pavement areas next to the building. We randomly applied grids on the map to identify the measuring points. The cell dimension is 10 by 10 ft, and points are at least 20 ft away from each other (see Figure 9). We marked four to eight points for each type of surface. When measuring the surface temperature, the shaded area and period were avoided.

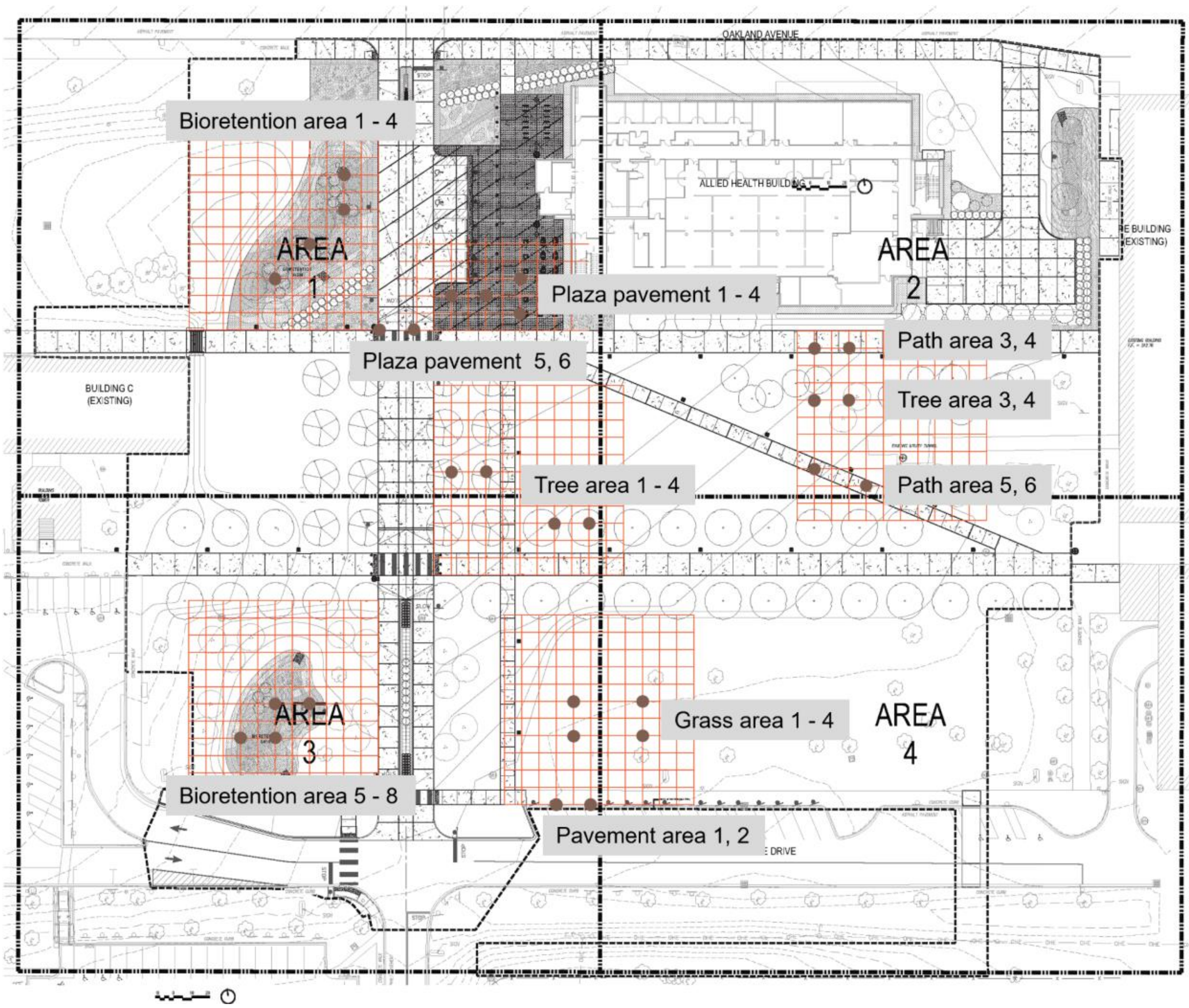

Fig 9. Temperature survey points

Calculations:

For the current situation, we zoned the whole campus into five types of pavements, the bioretention garden, trees, turfgrass, path on the lawn, pavement of roads, and plaza. We used AutoCAD to estimate the areas of each surface type and calculate the area percentage of each type. Weight the measured temperature by the area (%) and calculate the average temperature of the whole site. For the situation before the renovation, we also zoned the previous plan and estimated the area percentage of each type of surface. The calculation of the area-weighted temperature of the site is shown in Table 7 and Table 8. The estimated average temperature of the pre-renovation and post-renovation site is 72.7 °F and 73.1 °F, which is a 0.5% increase.

The renovated landscape has a more densely planted area; however, we measured a rather higher temperature on the 3/8" Meramec gravel cover inside the bioretention area (Figure 10). We had two points measuring this material, the temperature was 84.2 °F and 87.9°F. The temperature was slightly lower than but almost the same as the average pavement surface temperature, 87.7 °F. As a result, the average temperature of the densely planted area increased. This layer, the Meramec gravel, is required by St. Louis City code. Although reducing temperature is not the primary goal of implementing bioretention gardens, it is a point that can be improved to create a comfortable environment.

Fig 10. The 3/8" Meramec gravel cover in the bioretention garden area.

Table 7. The estimated site temperature of the pre-renovation campus

Surface Type	**Area (%)**	**Measured Temperature (°F)**	**Weighted Temperature (°F)**
Bioretention garden area (densely planted area)	0	79.4	0
Tree and lawn	15%	82.0	12.3
Lawn	61%	82.0	50.0
Path on lawn	12%	86.7	10.4
Pavement on the plaza	0	88.7	0
Estimated average temperature for the site			72.7

Table 8. The estimated site temperature of the post-renovation campus

Surface Type	**Area (%)**	**Measured Temperature (°F)**	**Weighted Temperature (°F)**
Bioretention garden area & densely planted area	11%	79.4	8.7

Tree and lawn	14%	82.0	11.5
Lawn	41%	82.0	33.6
Path on lawn	12%	86.7	10.4
Pavement (uncovered sitting area and roads)	10%	88.7	8.9
Estimated average temperature for the site			73.1

Comparison of the estimated temperature between the pre- and post-renovated campus:

(After - Before) / Before * 100%

(73.1 - 72.7) / 72.2 = 0.005 = 0.5%

Limitations:

- The temperature monitoring period was short. Measurements of these days may not be enough to generalize the outcomes of the surface temperature to other sites or the same types of the material.
- We measured the temperature twice, one in the afternoon and the other in the morning. We assumed that in the morning, the building and plaza area did not get as much sunlight as the open landscape area in the south by the time we measured. Therefore the measured surface temperature of the plaza area was much cooler than the vegetated area. The amount of sun difference might cause bias, so we did not include the measurements in the morning to avoid bias.

Cost Comparison

- ***Construction of the three rain gardens cost approximately $9.96 per sf over a total of 1.02 acres (44,431 sf), as compared to a conventionally planted landscape bed, which would have cost about $9.68 per sf. The rain garden construction increased the project budget by approximately $12,440; however, it captures and stores surface water, encourages groundwater recharge, offers improved aesthetics, and requires less maintenance.***

Background:

The bioretention garden is part of the Stormwater Best Management Practice (BMP)[1] for the city of St. Louis. Details of the BMPs are listed below.

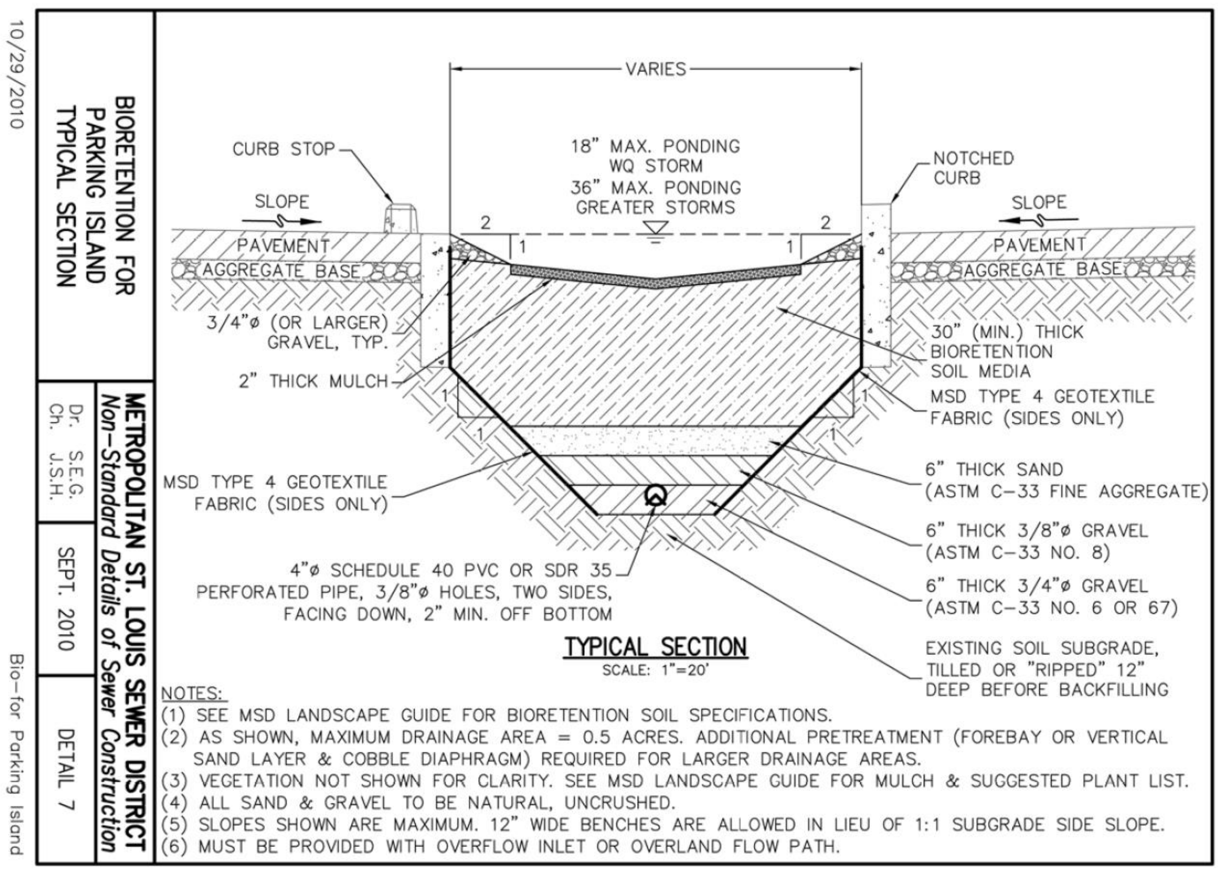

Fig 11. Metropolitan St. Louis Sewer District Bioretention Detail[1]

Method:

We referred to Figure 11 from the Metropolitan St. Louis Sewer District to identify the layers of bioretention gardens, with one modification noted by the diagrams from the landscape liaison. The modification was that they used 2’’ pea gravel on the top layer instead of 2’’ mulch. We compared the cost of materials needed to build a bioretention garden and a conventional landscape. We got the details about the conventional landscapes from our landscape architecture liaison, including the estimated unit price, which was from their previous projects in the same area. For the materials that the landscape architecture liaison did not provide information on, we searched online and referred to Grace Pacific LLC and St. Louis Composting.

Calculations:

The cost of both types of landscapes is calculated based on 100 sf area. Table 8 shows the details. The estimated cost for a bioretention garden is $ 8.3 per sf and $8.07 per sf for a conventional landscape. We added a 20% contingency as an extra for unforeseen situations; therefore, the final cost for the bioretention garden and the conventional landscape are $9.96 and $9.68, respectively. Applying the difference ($0.28) to the site, creating bioretention gardens increased the cost by $12,440 (= $0.28 * 44,431 sf).

Table 9. Materials and the cost of bioretention garden and conventional landscape

Materials	**Cost for Bioretention Garden of 100 sf**	**Cost for Conventional Landscape of 100 sf**
	(layer depth) amount * unit price	(layer depth) amount * unit price
Mulch	-	(3”) 0.93 cu yd * $28[3] = $26
Pea gravel	(2’’) 0.62 cu yd * $57[2] = $35	-
Soil media	(36’’ - 42’’, median 39’’) 12.1 cu yd * $30[3] = $364	(18”) 5.6 cu yd * $30[3] = $168
Thick sand (ASTM C-33 fine aggregate)	(6’’) 1.86 cu yd * $93[2] = $173	-
⅜’’Ø Gravel (ASTM C-33 No.8)	(6’’) 1.86 cu yd * $57[2] = $106	-
¾’’Ø Gravel (ASTM C-33 No.6)	(8’’) 2.48 cu yd * $53[2] = $131	-
Subtotal	$809	$194
Subtotal per sf (/27/100)	$0.3	$0.07
Plant material	18” O.C. 100 * $8[4] = $800 sf	12" O.C. 100 * $8[4] = $800 sf
Per sf (/100)	$8	$8

Total cost per sf	**$8.3**	**$8.07**
Added 20% contingency	**$9.96**	**$9.68**

Sources:

[1] Metropolitan St. Louis Sewer District, *MSD Landscape Guide for Stormwater Best Management Practices. St, Louis.*

[2] "2016 Makakilo Quarry Price List", Grace Pacific LLC, accessed July 23, 2022. https://gracepacific.com/sites/default/files/AGGREGATE-PRICE-LIST-01202016.pdf

[3] "Mulch", St. Louis Composting, accessed July 23, 2022. https://www.stlcompost.com/mulch

[4] dtls, email message to author, March 23, 2022

Limitations:

- This cost comparison includes only the fee for materials, whereas the cost includes service fees in practice.
- The estimated cost will be rough in practice; for example, 0.9 cu yd will be rounded up to 1 cu yd because of the least amount to order for the materials. In this comparison, as we are researching the differences, we do not round up until the final number to keep the actual number to observe the subtle distinction.
- This comparison on the material cost only includes the medium materials, e.g., mulch, soil, plants, etc. Materials needed for constructing bioretention gardens but not included in the calculation are, for example, the additional pipe systems, geotextile fabric on the sides of the basin, and the rocks around the inlet.
- The price for each material is not from the original source of the project and is limited to the availability of the original source. Therefore, the estimated cost might differ as the price of the material changes.

Appendix A: Activity Observations

We conducted observations of the pedestrians on the campus as a supplement for the walkability supporting the design goals of promoting the usage of outdoor spaces. The result of the circulation of pedestrians shows Table A1.

Table A1. Results of the route usage observations

Time	**Location**	**Behaviors**
Jun 8 10:00 - 11:00	A	2 people passing through
Jun 8 10:00 - 11:00	E	1 people passing through
Jun 8 11:00 - 12:00	A	17 people passing through
Jun 8 11:00 - 12:00	B	16 people passing through
Jun 8 11:00 - 12:00	C	8 people passing through
Jun 8 11:00 - 12:00	F	4 people passing through
Jun 8 11:00 - 12:00	G	2 people passing through
Jun 8 16:00 - 17:00	A	2 people passing through
Jun 8 16:00 - 17:00	B	5 people passing through
Jun 9 07:15 - 08:15	A	8 people passing through (1 one them linked to Route I)
Jun 9 07:15 - 08:15	B	64 people passing through
Jun 9 07:15 - 08:15	D	1 person jogging
Jun 9 07:15 - 08:15	F	1 person passing through the campus
Jun 9 07:15 - 08:15	G	1 person passing through
Jun 9 07:15 - 08:15	I	2 people passing through, one then linked to route A
Jun 9 07:15 - 08:15	J	4 people dropped off by someone, 1 person parked bike by the pole
Jun 9 11:00 - 12:00	A	10 people passing through
Jun 9 11:00 - 12:00	B	34 people passing through
Jun 9 11:00 - 12:00	C	6 people passing through
Jun 9 11:00 - 12:00	F	1 person passing through

Jun 9 11:00 - 12:00	G	1 person passing through
Jun 9 12:00 - 13:00	A	4 people passing through
Jun 9 12:00 - 13:00	B	21 people passing through
Jun 9 12:00 - 13:00	C	3 people passing through
Jun 9 12:00 - 13:00	G	8 people passing through, one of them linked to I
Jun 9 12:00 - 13:00	I	1 person passing through