Registration #M93 **Master Plan Category** **December 15, 2017**

The Champion Gateway

Infiltrate. Re-create. Celebrate.

Team Members

- Avantika Dalal, *Landscape Architecture*
- Joshua Franklin, *Landscape Architecture*
- Jason Poole, *Landscape Architecture*
- Jen Ren, *Landscape Architecture*
- Laura Robinson, *Landscape Architecture*
- Tuana Philips, *Environmental Science & Technology*
- Gabriel Donnenberg, *Environmental Science & Policy*
- Joshua Nichols, *Environmental Science & Technology*

Advisory Team

Victoria Chanse, *Plant Science and Landscape Architecture*
Peter May, *Environmental Science and Technology, Biohabitats*
Michael Carmichael, *Facilities Management*
Stephen Reid, *Facilities Management*

Additional Advisors

Dennis Nola, *Plant Science and Landscape Architecture, UMD Architectural & Landscape Review Board*
Mitch Pavao-Zuckerman, *Environmental Science and Technology*
Cy Keener, *Dept. of Art*
Allen Davis, *Civil and Environmental Engineering*
William Mallari, *Facilities Management, UMD Architectural & Landscape Review Board*
David Allen, *Executive Director, UMD DOTS*
David Cronrath, *Architecture, Planning, and Preservation, UMD Architectural & Landscape Review Board*
Darwin Fuerstein, *Facilities Management, UMD Architectural & Landscape Review Board*
Diane Cameron, *Ecologix Group*
John McCoy, *Watershed Management-Columbia Association*
Kelly Fleming, *Low Impact Development Center*
Meghan Spigle, *National Capital Planning Commision*
Mary Abe, *Office of Engineering & Project Management at Prince George's County Dept. of Public Works & Transportation*

ABSTRACT

With the advent of a proposed light rail, the Purple Line, running through the University of Maryland College Park campus, the campus will be transforming itself from an auto-oriented campus to a transit-oriented urban campus. An interdisciplinary team of students worked together to transform a surface parking lot into an urban stormwater park by using the Purple Line as a catalyst for sustainable and environmental innovation on campus. In keeping with the Facilities Master Plan, The Champion Gateway addresses multiple goals, including:

- Capture, treat, and infiltrate stormwater runoff
- Enhance ecosystem services by restoring habitat and plant communities
- Create a campus gateway that celebrates sustainability and community

Working closely with university stakeholders, interdisciplinary faculty and professionals, and using pollution source data , the team created a design that uses multiple LID techniques to create a treatment train for on-site stormwater. Urban forest, Silva Cells, wet meadows, bioswales, permeable surfaces, rain gardens and bioretention area LIDs work as a treatment train to:

- Reduce runoff by 52%
- Reduce impervious cover by 73%
- Increase infiltration by 170%
- Add 1.2 acres of restored soils to an urban area
- Restore native plant communities on 3.7 acres of the site
- Add 367 trees on-site
- Sequester 20,160 lbs of carbon per year

The area becomes a gateway that provides education, research, and recreational opportunity for the community. The Champion Gateway unites campus communities with sustainable practices to infiltrate stormwater, re-create habitat and celebrate the University of Maryland as a champion of green infrastructure techniques.

INTRODUCTION & SITE SELECTION

The Champion Gateway's location resulted from an analysis of five factors: future development of the purple line, the number of people entering campus by the site, future mixed use development planned around the site, its location in the 'performance neighborhood,' and the site being a hotspot for stormwater runoff and pollution.

The Purple Line as a Catalyst

The D.C. metro region of Maryland is developing the "Purple Line:" a light rail system that will connect Bethesda to New Carrollton (MDoT Transit Administration, 2017). This new mode of transportation acts as the catalyst for our design, and helps UMD transform from a vehicular campus to an urban campus using sustainable transportation tactics. The Purple Line creates many opportunities for our site: it reduces the number of cars entering campus as more commuters will use the Purple Line and it also creates view-sheds that showcase the LID practices used in the Champion Gateway that will entice more users onto the site.

Gateway

The Southwest entrance to campus sees on average 29, 101 cars per day (Figure 1). These vehicles either park on the existing site or drive by it. While almost 30k are entering campus from this entrance, there is no official gateway or representation of campus upon arrival. This site will become the "Champion Gateway" that represents all of UMD's sustainability efforts as it welcomes visitors to campus. As transportation to campus switches from vehicular to public transport, the site will function as a new form of gateway not centered around automobiles like the rest of campus entry but one celebrating champion green infrastructure practices.

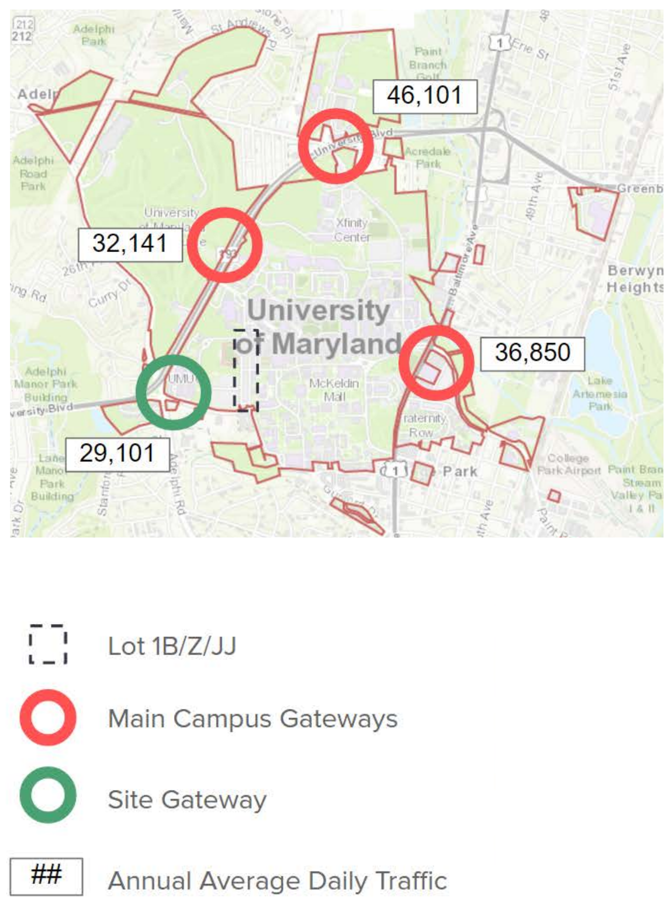

Figure 1. Campus gateways and daily traffic counts

Mixed-Use Development

Future campus plans include creating an urban corridor surrounding our site (UMD Facilities Management, 2011). To the south and southeast of the site is a mixed-use building with apartments and restaurants and other services. Creating a large urban park central to the new development will increase property value and increase usage of the businesses.

The Performance Neighborhood

The UMD football stadium is located directly north of our site and the new Cole Field House and health center is located to the northeast of the site. In the works are two new football practice fields that will be directly adjacent to our site on the northeast corner.
To the north is the Performing Arts center and a new soccer stadium will be erected directly adjacent to our site on the northwest. This combination of sports and arts performance creates a unique "Performance Neighborhood." Our site will add environmental performance to the neighborhood (see "Performance Neighborhood" on accompanying board).

SWAT Hotspots Modeling

The Soil and Water Assessment Tool (Wang, 2014; Wang et al. 2016) was used to model nonpoint source pollutant runoff hotspots for the entire campus. The results showed that four hours after a rain event, our site was a hotspot for excessive: surface runoff, total suspended solid yield, nitrogen yield and phosphorus yield (see "Hotspots" on accompanying board). The model determined that the parking lots on campus were contributing to significant nitrogen loads (11.83-14.69 Kg/HA) and the impervious surfaces were producing substantial surface runoff (504mm-649mm). Converting this impermeable surface that results in excessive runoff and pollution into a stormwater treatment facility and park is in line with UMD's commitment to sustainability and the environment.

INVENTORY & ANALYSIS

Context

College Park is located in the coastal plain physiographic region. It is approximately eight miles northeast of downtown D.C. and 28 miles west of Annapolis. The chosen site is a surface parking lot located on the West side of campus that is planned to become a large green space (University of Maryland Facilities Management, 2011). It measures 225 feet wide and 1550 feet long and covers 6.5 acres.

Watersheds and Catchment Area

The site is located within the Northeast Branch and Paint Branch sub-watersheds within the greater Anacostia watershed (Figure 2). The two catchment areas combined are 6.5 acres with a 3% slope within each catchment (see "Catchment" on accompanying board).

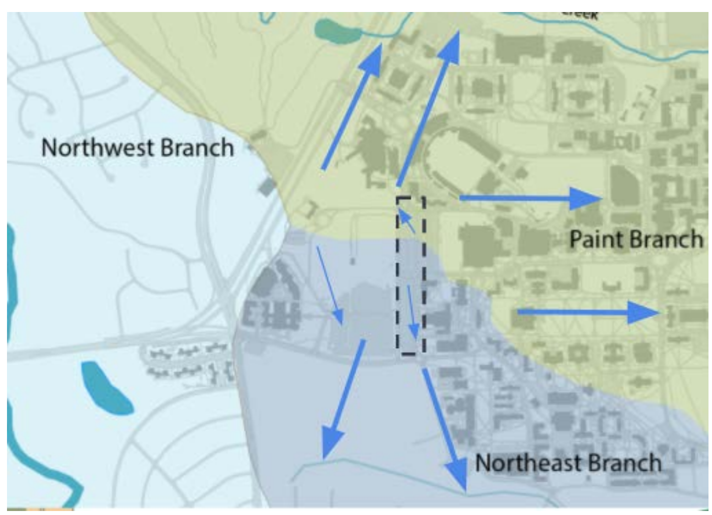

Figure 2. Site-specific sub-watersheds

Topography, Hydrology, Stormwater, and Drainage

The site is located at the high point of campus and slope analysis shows the slopes are between 0-3% (Figure 3).

Surface runoff flows to the northwest of the site and to the southeast end (see “Hydrology” on accompanying board) into the existing stormwater drainage. There are seven stormwater management systems on the west of campus including sand filters, bioretention cells, and cisterns, however there are zero systems on the site. On-site observations before and after a rain event showed evidence of flooding and erosion.

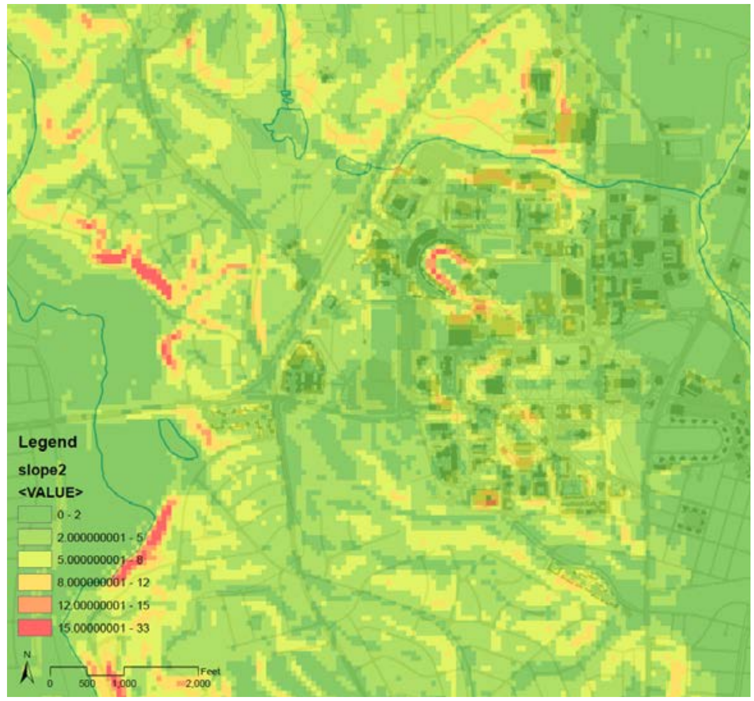

Figure 3. Slope analysis for Northwest campus.

Soil, Compaction, and Infiltration

The site is dominated by urban soils (Un, UrbB) with a hydrologic group rating of D (USDA, 2017). 94.6% of the site is impervious and covered with asphalt. Grassing medians on site were pervious however compaction and infiltration measurements revealed that soils were highly compacted. Team members used hand-held penetrometers to measure soil strength and estimate the level of soil compaction. The soils on our site had high compaction readings ranging from 199-295 PSI which means the soils’ compaction constrains root growth (Table 1) (Coder, 2007; Duiker, 2002). The grassy median in the middle of the parking lot had a 295 PSI penetrometer reading which means root growth is decreased by 60% (Coder, 2007).

Table 1. Soil strength and compaction on various site locations.

	Grassy Median in Parking Lot	Grass areas along sidewalk	Grassy Area where drainage located	Grass Median along Union Drive	Urban Forest Reference on North Campus*
Average Penetrometer (PSI)	295	260	199	208	148
Average Unsat. Hydraulic Conductivity (cm/hr)	2.46 on grass; 0.54 on eroded soil	1.88	4.08	1.22	0.88

*Data for Urban Forest was collected on October 18, 2017 while the other measurements were collected on October 10, 2017. Collecting data on two different days may have introduced more variables.

Infiltrometer readings showed that infiltration rates were highest in large grassy areas than smaller grassy areas (Table 1). This finding supports current research (USDA, 2008; Saxton et al. 1986; Bagarello and Iovino, 2004; Mazaheri and Mahmoodabadi, 2015). These larger grassy areas were surrounded by more trees which could provide more soil organic matter which helps develops stable soil aggregates and increases infiltration (USDA, 2008).

Using a Decagon Mini Disk Infiltrometer, our team measured the surface unsaturated hydraulic conductivity to determine infiltration rates of our site's soils. Infiltration is a good indicator of a soil's ability to allow water movement into the through the soil profile (Decagon Devices, Inc, 2016). Eroded soils on site had low infiltration rates (0.54 cm/hr) with can lead to poor root function, reduced nutrient availability, increased runoff and erosion (USDA, 2008). Our measurements (Table 1) showed that infiltration needs to be increased on site in order to support water storage, root uptake, and plant growth (USDA, 2008).

Air Temperatures and the Heat Island Effect

In hot sun, pavement surface temps can be 50-90º hotter than the surrounding air (Berdahl and Bretz, 1997). These increased temperatures can have negative effects such as impairing water quality. Pavements at 100º F can elevate runoff temps from 70º to 95º F (James, 2002). Heat islands also increase energy consumption & elevated emissions and compromise human health and comfort (EPA, 2017).

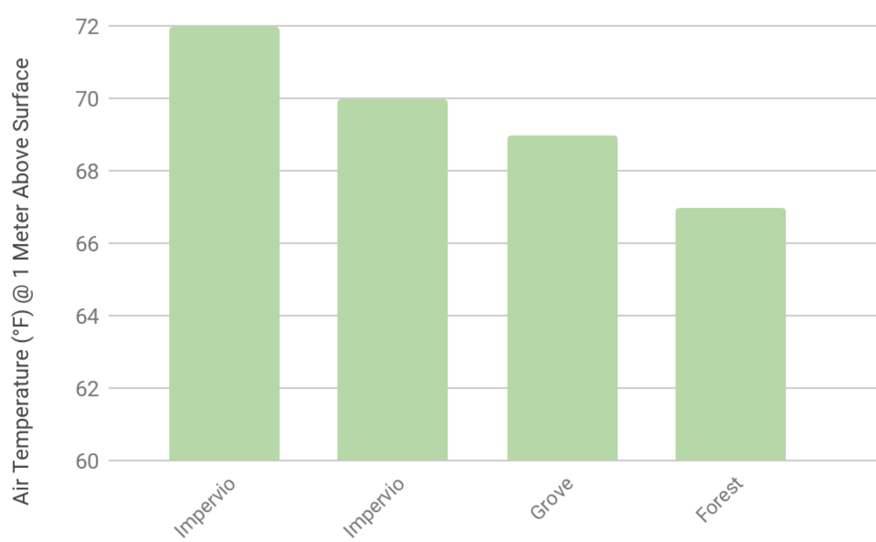

Figure 4. Air temperature at 1 meter above surface vs location.

Temperatures were taken one meter above surface at various locations surrounding the site on a sunny October day. There was a 5° difference between the impermeable surface (72°) without shade and the forest stand (67°) located in the West Campus district (Figure 8). During a tailgating observance event in October, many people seeked shade. It will be important to add shade to the design to decrease the heat island effect. As annual average temperatures continue to rise (Runkle et al. 2017), shaded areas will become more vital to enjoy outdoor space.

Tree Survey

There are seven species of trees on site. There are Q. palustris, Q. coccinea, A. rubrum, P. strobus, hybrid elms and hybird crapemyrtles on the current site. There are six P. strobus at the south end of the site that have DBH's (depth at breast height) ranging from 38 cm-53 cm.

Opportunities and Design Goals

- Capture, treat, and infiltrate stormwater runoff
- Enhance ecosystem services on site by restoring habitat and plant communities
- Create a gateway to campus that celebrates sustainability and community

DESIGN SOLUTION

Art + Habitat + Transportation

The Champion Gateway site is located in a visible spot on campus, making it imperative to consider programming that benefits all potential users in the design. As a "Big 10" institution, the University of Maryland takes both education and sports seriously. To showcase the University's dedication to excelling in the physical and academic arenas, the site was designed to suit the needs of both cultures by providing programs for recreation and research.

With the help of Cy Keener, Assistant Professor at the University of Maryland's Department of Art, the north end plaza features artistic installations that react to weather patterns in a visually creative way - spinning with the wind, or lighting up in reaction to moisture.

Open meadow space, though typically limiting pedestrian use, becomes a canvas for swaths of seasonal color, drifting and and changing week by week throughout the year. The open space leaves room for showcasing sculptural works, and the flora in the vast vertical site conduct the movement of butterflies and native bumblebees, providing critical habitat and food, and supporting insect biodiversity.

The Purple Line that bisects our site serves to encourage and celebrate the use of public transportation. This is in line with UMD's initiatives to reduce impervious and environmentally desolate parking lots, and reduce greenhouse gas emissions from individual vehicular traffic to the campus.

Treatment Train

One of the concepts behind our site design is the purposeful management of the flow of stormwater across it (see "Treatment Train" sections on accompanying board). Taking note of site topography, we designed our site so that captured water from the site and surrounding buildings could be conveyed, infiltrated through permeable paving and non-compacted soils, and filtered through bioretention areas before reconnecting with existing storm drainage system.

The south section of our site contains a meadow, urban forest, and bioretention area. Rather than transferring runoff quickly away from the site, on-site runoff will slow down and infiltrate in the meadow and urban forest and ultimately the bioretention area, improving water quality through phytobial remediation (the use of plants and other symbiotic organisms to treat water). Moving from one system to another provides the benefit of a greater amount of organisms and soil conditions for the water to come into contact with, improving its outcome (Tsihrintzis and Hamid, 1997).

Champion Project

The north section of the site is surrounded by sports facilities: two practice fields, a soccer stadium, and the University of Maryland's Capital One football stadium. Currently our site serves as tailgating event space during athletic events. Unfortunately, lack of shade and pedestrian accommodation currently leave attendees crammed under the few existing trees, and standing on thin medians. Under the new proposed design, we have conceptualized *Champion Grove*: an open green space under a grid of canopy trees. This space is designed to be used by pedestrians to gather, celebrate, relax, and enjoy. The *Champion Grove* adds 129 canopy trees. According to the American Forests Organization, one large tree can capture and filter up to 36,500 gallons of water per year. By the time the canopy trees in *Champion Grove* have matured, they would have the potential to capture and filter over four million gallons of water per year (American Forests, 2017). The system would improve year over year as the trees grow.

Because human traffic would easily compact the soil, rendering it less effective at infiltrating water and stunting the tree's growth, we have specified the use of Silva Cells. These cells are placed directly underneath the ground cover surrounding the trees. They absorb impacts made above ground and give tree roots room to grow, even with heavy pedestrian traffic above ground. Silva Cells also improve permeability and the capacity of the soil to filter the water which moves through it. A study by a University of North Carolina researcher found that a Silva Cell treated 80% of runoff and all nutrient, sediment, and heavy metals concentrations were decreased (Page et al. 2015).

Considering the high cost of the Silva Cells, approximately \$14-\$18 per cubic foot (Marritz, 2012), we propose the implementation of "The Champion Project" to seek donations from university alumni. Trees will have personalized dedication plaques available for purchase to help pay for the Silva Cells. This donation structure will foster sustainable engagement and a sense of stewardship toward the *Champion Grove*. It also allows alumni to build champion trees for a champion school.

Proposed LID Strategies and Benefits

Table 2. Proposed LID Strategies and Benefits*

Green Infrastructure Practices	Area/Amount on Site	Benefits
Bioswales & Raingarden	12,297 sq.ft	Captures, treats, and infiltrates stormwater runoff
Permeable Pavement	93,214 sq.ft	Reduces runoff and peak flow energy, increases infiltration
Wet Meadow	38,788 sq.ft	Mitigates flooding, increases infiltration rates, improves water quality and habitat diversity
Trees	367 new trees	Absorbs air pollutants, sequesters carbon, lowers air temperatures, helps treat and infiltrate runoff
Habitat Restoration	162,124 sq.ft	Improves biodiversity

Soil Amendment	50,425 sq.ft	Prevents soil compaction, increases infiltration rates and improves tree longevity
Rooftop Rainwater Harvesting	216,154 gallons	Captures and stores stormwater runoff, reduces peak flow energy and stress on stormwater sewer system

*Benefit information gathered from (United States Environmental Protection Agency, 2017c)

PERFORMANCE METRICS

Stormwater Runoff

The EPA Stormwater Calculator was used to calculate the results during a 2-year storm event.

Table 3. EPA Stormwater Calculator Statistics

EPA Calculator Statistics	Existing Conditions (2017)	Post-Design (2030)
2-Year Storm Event	94.6% Impervious	26% Impervious
Average Annual Rainfall (in)	44.3	44.3
Average Annual Runoff (in)	37.45	18.04
Days per Year with Rainfall	81.29	81.29
Days per Year with Runoff	59.11	37.42
Percent of Wet Days Retained	27.29	53.96
Smallest Rainfall w/ Runoff (in)	0.1	0.1
Largest Rainfall w/o Runoff (in)	0.22	0.5
Max. Rainfall Retained (in)	0.6	1.76

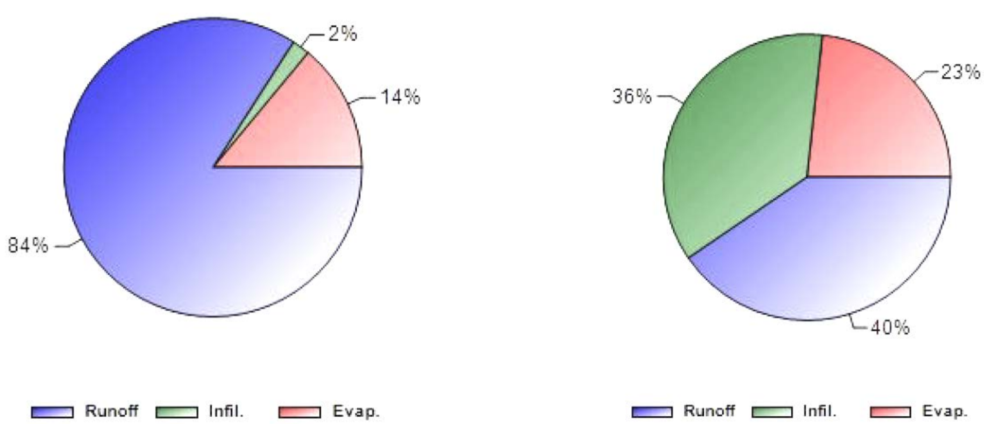

Figure 5. Existing (left) and proposed (right) runoff, infiltration and evaporation amounts (EPA, 2017b).

Stormwater Benefits

- Runoff reduction: 52%
- Infiltration increase: 170%
- Impervious cover reduction: 73%

Stormwater Pollution Assessment with TR-55 Modeling

Pollutants removed on-site will decrease the amount of nutrients entering the Anacostia watershed and ultimately the Chesapeake Bay.

Table 4. North and South catchment combined annual pollutant removal based on TR-55 Modeling

	TP lbs/Acre	TN lbs/Acre	TSS tons/Acre
Total	3.89	34.7	0.483

New Tree Planting Benefits

The increased tree canopy cover on site will greatly reduce heat island effect by providing following benefits (USDA Forest Service 2017):

- New trees planted on site 367
- Increase in canopy coverage 40%
- Hardscape shaded by vegetation 25%
- Carbon sequestration 20,160 lbs/yr
- Removing CO2 from air 273 lbs/yr
- Produce oxygen 53,800 lbs/yr

The design supports the goals of the UMD's Climate Action Plan 2.0 to capture carbon and educate students about sustainability (University of Maryland Office of Sustainability, 2017). The *Champion Grove* also aligns with UMD's future plans because the grove will be a part of larger open space system (see "Facilities Open Spaces" on accompanying board). Significantly increasing the tree canopy mitigates the loss of other tree removal for future campus developments. According to campus facilities management, approximately 250 trees would be removed due to the development of the Iribe Center.

Ecosystem Benefits

- Area of restored soils: 1.2 acres (15%)
- Area of restored native plant communities: 3.7 acres (47%)
- Change in plant diversity: 25 new species added

Planting Plan

The team carefully selected plants based on plant hardiness, low maintenance requirements, and diversity.

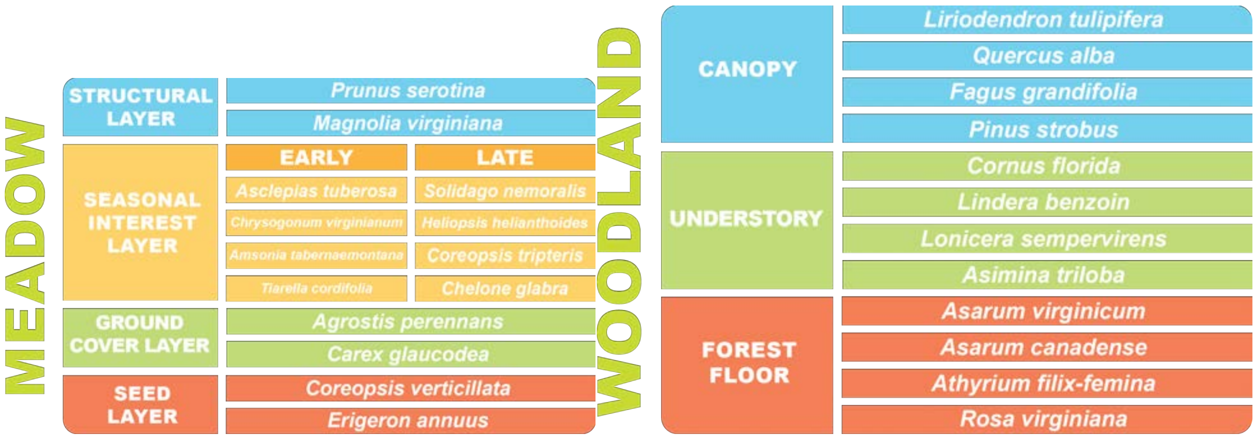

Figure 6. Meadow and Woodland plant species. Graphic based on: (U.S. Fish and Wildlife Service, 2016).

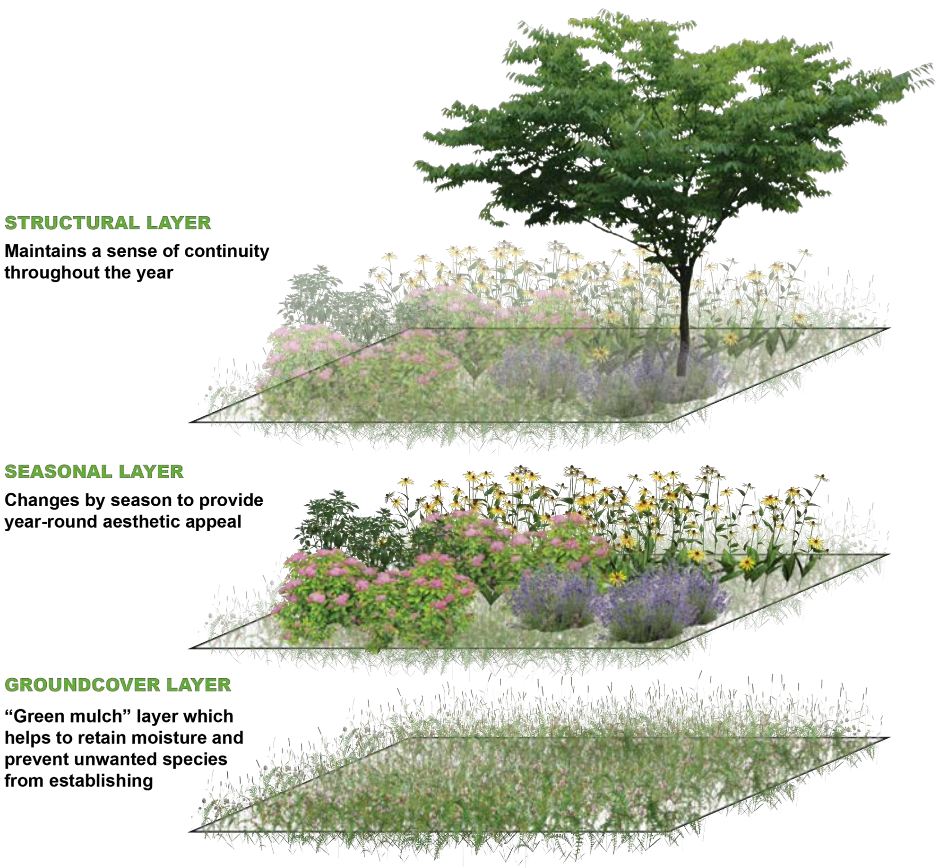

Figure 7. Layers of a meadow. Graphic based on: (Rainer & West, 2017)

Resiliency

Increase in vegetation and tree canopy and reduction of impervious surfaces will help to reduce surface temperatures and combat heat island effect. The site will improve the longevity of the urban forest. The Silva Cells on site will allow for the use of compost from the surrounding area. Many pieces of the site can re-use construction materials from the local area, greatly reducing the waste of demolition and new construction (American Society of Landscape Architects).

Social and Cultural

The Champion Gateway would transform the West District into a green urban oasis where visitors can relax and enjoy the native plant meadows and lush tree canopies (Figure 8). The gateway creates opportunities for social events in the idyllic gathering spaces that celebrate the performance identity of the neighborhood which includes the Clarice Performing Arts Center, football stadium, soccer stadium, and Center for Sports Medicine and Human Performance. Additionally, the proximity to both the football and soccer stadiums make the Champion Gateway an ideal location for tailgating and celebrating the University of Maryland's NCAA Big Ten sports teams.

Figure 8. New social and cultural spaces

IMPLEMENTATION & PHASING

Phasing

The plan will be implemented in three phases (Figure 9). The first phase will create bioretention areas in the two lowest points on the site so that capture and treatment can begin immediately. It will also initiate the "Champion Project" whose goal is to tie alumni funding into the project and establish a canopy of grand trees. The second phase will continue the champion tree grove. The third and final phase will establish the urban forest and wet meadows, completing the treatment train resulting in 74% pervious surfaces (Table 5).

Table 5. Impervious change with phasing

	Impervious Surface	Pervious Surface
Existing Conditions	94.6%	5.4%
Phase 1: 2017-2020	72%	28%
Phase 2: 2021-2025	63%	37%
Phase 3: 2025-2030	26%	74%

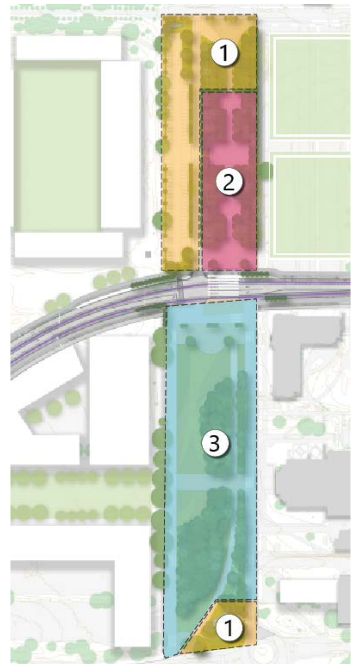

Figure 9. Phasing plan

Funding

Potential funding sources for this project include alumni donations that would sponsor Silva Cells and trees, DOT funds to offset penalties incurred by the establishment of the Purple Line, sustainability grants of up to $200,000 from the UMD Office of Sustainability, and grants from the Chesapeake Bay Foundation, Fish and Wildlife Federation and Chesapeake Bay Trust, as the project will have an overall positive effect on the bay and donations from private citizens.

Likelihood of Implementation

Table 6. Design solution alignment with existing plans and requirements.*

Plan/Initiative	Description	Champion Gateway Alignment
2010-2030 Campus Master Plan	West Mall	Designs West Mall with BMPs to reduce runoff and treat stormwater
UMD Climate Action Plan 2.0	Reduce CO2	Reducing vehicular use reduces CO2 emissions on campus and increase of shade reduces energy usage of surrounding buildings
MS4 Permit Requirements	Implementing BMPs to treat impervious areas	Reducing impervious surface by 73% and treating stormwater through BMPs
UMD Parking Outlook	Reducing vehicular dependence on campus	Reducing parking spaces and promoting light rail, pedestrian, and bicycle commuting

*(UMD Facilities Management, 2011; University of Maryland Office of Sustainability, 2017; United States Environmental Protection Agency, 2017d; University of Maryland Department of Transportation Services, 2015)

COMMUNITY ENGAGEMENT

Design Process

During the design process, the team worked extensively with all stakeholders related to the site. The parking lot is currently under the jurisdiction of UMD's Department of Transportation Services, but surrounded by sports facilities and the performing arts community. The team invited these stakeholders and representatives for meetings to listen to their concerns, expertise, and expectations. Multiple design reviews and stakeholder meetings involved representatives from facilities management, the department of transportation, local professionals in environmental science and civil engineering as well as students from landscape architecture, environmental science and technology, and environmental science and policy. The design evolved through this interdisciplinary stakeholder process and responded to conclusions from all the meetings.

Student Outreach

Engaging the general campus community was an important part of the design process. The design team used precedent images on large boards to gauge the wants and needs of people on campus. Two teams stood outside of the STAMP Student Union and near a high traffic area near the Architecture building. Passersby were asked to rank their favorite types of outdoor spaces they'd like to see on campus by placing stickers for "Good," "Better," and "Best" on the different images.

106 people participated in the survey. Each person was given three choices. The results of the community engagement showed that the students would like to see more tree-shaded areas, a water feature, and public art. These results can be seen in the *Champion Grove*, the artful plazas near the Purple Line, and the views of the bioretention areas.

Future Collaboration Opportunities

The Champion Gateway creates numerous opportunities for future educational, research and social use. The urban forest can be incorporated into the University of Maryland's arboretum. As the *Champion Grove* is implemented, Silva Cell technology can be analyzed and changed as each phase is completed. Porous plazas will have educational interactive art installations. The tiered native meadow will attract pollinators and other wildlife, improve water quality and will act as a living laboratory where students can study landscape performance. Dr. Allen Davis of the Department of Civil and Environmental Engineering can continue his research in the rain gardens and bioswales to explore different techniques related to soil, infiltration, and plant species (Davis et al 2009). Peter May and Mitch Pavao-Zuckerman can use the site for their Urban Ecology and Urban Water Quality courses.

CONCLUSION

The Champion Gateway completes four important milestones important to the EPA and the University of Maryland: it utilizes LID practices on campus, it treats, captures and conveys stormwater, it creates a unique social gathering place for diverse groups of university stakeholders and it creates an innovative landscape for research and performance measurement.

REFERENCES

American Forests (2017). “Forest Facts”. www.americanforests.org/explore-forests/forest-facts/.

American Society of Landscape Architects. “Building a Park Out of Waste.” Designing Our Future: Sustainable Landscapes, www.asla.org/sustainablelandscapes/Vid_Waste.html.

Bagarello V, Iovino M. (2004). “A simplified falling head technique for rapid determination of field-saturated hydraulic conductivity”. Soil Sci Soc Am J 68:66–73

Berdahl P. and S. Bretz. (1997). “Preliminary survey of the solar reflectance of cool roofing materials”. Energy and Buildings 25:149-158.

Coder, Kim D. (2007). “Soil Compaction Stress and Trees: Symptoms, Measures, Treatments”. Warnell School of Forestry and Natural Resources, University of Georgia. https://georgiaarborist.org/Resources/Educational%20articles-stuff/Dr.%20Coder%20Soil%20Compaction%20Monograph.pdf

Davis, Allen P., William F. Hunt, Robert G. Traver, and Michael Clar. (2009). “Bioretention Technology: Overview of Current Practice and Future Needs.” Journal of Environmental Engineering 135.3

Decagon Devices, Inc. (2016) Mini Disk Infiltrometer User Manual. http://publications.decagon.com/Manuals/10564_Mini%20Disk%20Infiltrometer_Web.pdf

Duiker, S. W. (2002). “Diagnosing Soil Compaction Using a Penetrometer (Soil Compaction Tester)”. A publication from Penn State Extension, The University of Pennsylvania https://extension.psu.edu/diagnosing-soil-compaction-using-a-penetrometer-soil-compaction-tester > Accessed Dec 2017.

James, W. (2002). “Green roads: research into permeable pavers”. Stormwater 3(2):48-40.

Marritz, Leda. (2012). “How to keep silva cells costs down.” Deep Roots. http://www.deeproot.com/blog/blog-entries/keeping-silva-cell-costs-downdesign-guidelines-for-meeting-your-budget

Maryland Department of Transportation, Transit Administration. (2017). “Purple Line.” http://www.purplelinemd.com/en/home

Mazaheri, M.R. & Mahmoodabadi, M. Arab J. (2015). “Study on infiltration rate based on primary particle size distribution data in arid and semiarid region soils”. Geosci (2012) 5: 1039. https://doi.org/10.1007/s12517-011-0497-y

Page, J.L., R.J. Winston, and W.F. Hunt. (2015). “Soils beneath suspended pavements: An opportunity for stormwater control and treatment”. Ecological Engineering, https://doi.org/10.1016/j.ecoleng.2015.04.060

Rainer, Thomas, and Claudia West. (2016). “Planting in a Post-Wild World: Designing Plant Communities for Resilient Landscapes.” Timber Press.

Runkle, J., K. Kunkel, D. Easterling, B. Stewart, S. Champion, R. Frankson, and W. Sweet. (2017). Maryland State Summary. NOAA Technical Report NESDIS 149-MD, 4 pp.

https://statesummaries.ncics.org/md
Saxton KE, Rawls WL, Rosenberger JS, Papendick RI. (1986). Estimating generalized soil water characteristics from texture. Soil Sci Soc Am J 50:1031–1036
Tsihrintzis, V.A. & Hamid, R. Water Resources Management. (1997). 11: 136. https://doi.org/10.1023/A:1007903817943
United States Environmental Protection Agency. (2017d). “Developing an MS4 Program.”Stormwater Discharges from Municipal Sources https://www.epa.gov/npdes/stormwater-discharges-municipal-sources
United States Environmental Protection Agency. (2017a). Heat Island Impacts. https://www.epa.gov/heat-islands/heat-island-impacts#4
United States Environmental Protection Agency. (2017b). National Stormwater Calculator. http://www.epa.gov/water-research/national-stormwater-calculator
United States Environmental Protection Agency. (2017c). Performance of Green Infrastructure. https://www.epa.gov/green-infrastructure/performance-green-infrastructure
University of Maryland Department of Transportation Services. (2015). “University of Maryland 2015 - 2018 Parking Outlook”. http://www.transportation.umd.edu/parking/pdf/ParkingOutlook.pdf
University of Maryland Facilities Management. (2011). Facilities Master Plan 2011-2030. https://www.facilities.umd.edu/documents/fmp/2011-2030%20facilities%20Master%20Plan.pdf
University of Maryland Office of Sustainability. (2017). “Climate Action Plan 2.0.” Sustainable UMD. https://sustainability.umd.edu/progress/climate-action-plan-20
USDA. (2008). “Soil Quality Indicators”. USDA Natural Resources Conservation Service. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_053289.pdf
USDA Forest Service. (2017) i-Tree Design v6.0, www.itreetools.org/
U.S. Fish and Wildlife Service. (2016). “Search for Plants.” Chesapeake Bay Native Plant Center. www.nativeplantcenter.net/
Wang, Y. 2014. Potential Sites for Rainworks Competition: Campus Hotspots Modeling. Report findings of the Soil and Water Assessment Tool results for the UMD Campus.
Wang, Y., Montas, H. J., Brubaker, K. L., Leisnham, P. T., Shirmohammadi, A., Chanse, V., & Rockler, A. K. (2016). Impact of Spatial Discretization of Hydrologic Models on Spatial Distribution of Nonpoint Source Pollution Hotspots. Journal of Hydrologic Engineering, 21(12), 04016047.