PENN STATE UNIVERSITY

UNIVERSITY PARK CAMPUS SUSTAINABLE LANDSCAPE IMPLEMENTATION PLAN

February 2024

ACKNOWLEDGMENTS

This report was prepared by:

Stephen Stimson Associates Landscape Architects, inc.

Phyto Studio

Climate Positive Design

The Pennsylvania Horticultural Society

Penn State University Stakeholders:

Steering Committee:

Erica Smithwick - Professor and Director of the Earth and Environmental Sciences Institute

Eric Burkhart - Ecosystem Science and Management, College of Agriculture

Mike Toolan - Agricultural Operations Specialist, PACE, Shaver's Creek Administration

Grace Wills - President, Eco Action Student Club

Carlin Blash - Treasurer, Eco Action Student Club

Ken Tamminga - Distinguished Professor of Landscape Architecture

Casey Sclar - H.O. Smith Endowed Director of The Arboretum at Penn State

Marek Pundzak - Director of Horticulture and Operations at The Arboretum at Penn State

Krista Bailey - Sustainable Campus Strategist at Penn State Sustainability

Tracey Olexa - Stormwater Engineer at OPP

Todd Zook - Supervisor of Grounds Services (Nittany)

Neil Sullivan - University Planner at OPP Planning, Design, and Properties

Tom Flynn - Manager of Grounds Services Planning, Design, and Properties

Laurie Henry - Sr. Grounds Planner Estimator at OPP

Derek Kalp - Landscape Architect Planning, Design, and Properties

Kurt Coduti - Project Manager at OPP Design & Construction

OPP Executive Committee:

Bill Sitzabee - Vice President for Facilities Management and Planning & Chief Facilities Officer

Steven Watson - Director of Planning, Design, & Properties

Phillip Melnick - Senior Director of Buildings & Grounds

Bruce Smith - Senior Manager of Building Services & Interim Grounds Maintenance Supervisor

Mark Selivan - Supervisor of Grounds Services (Horticulture)

Neil Sullivan - University Planner Planning, Design, and Properties

Other Contributors:

Matt Wolf - Supervisor of Grounds Services (Pollock)

Norm Parks - Supervisor of Grounds Services (Arboriculture)

Theresa Barger - Horticulture Technician

Nate Cromley - Horticulture Technician

Dan Frechen - Horticulture Technician

Adam Craw - Horticulture Technician

Kate Hallin - Horticulture Technician

Ted Zeljak - Horticulture Technician

Kim Fanucci - Horticulture Technician

Rychele Stipcak - Horticulture Technician

Jason Doksa - Horticulture Technician

Abby Kouneski - Plant Production Technician

John Richendrfer - OPP GIS Analyst

BLOCK-STYLE PLANTING NEAR THE EISENHOWER CHAPEL | 2023

TABLE OF CONTENTS

1 INTRODUCTION

1. INTRODUCTION

PROJECT BACKGROUND

Penn State takes great pride in providing a high-quality landscape setting for the over 70,000 students, faculty, and staff who live and work at the expansive University Park campus. These constituents and other members of the Penn State community utilize the campus as a public park and revere its heritage trees, iconic lawns, and historic landscapes. Considering the growing global climate crisis and realities of shrinking University budgets, the Sustainable Landscape Implementation Plan (SLIP) is a planning exercise to reevaluate and recalibrate Penn State's expectations and operations to better meet these demands, while preserving and enhancing the aspects of the campus landscape that are valued most.

The SLIP focuses and directs the efforts of OPP Landscape Services and University Landscape Architects towards a more holistic, ecological management approach. As this planning transitions to implementation, it will provide students, faculty, and staff with myriad research and service opportunities in the long-term, such as measuring changes in biodiversity or labor inputs, and participation in the planting or stewardship of these landscapes. As the campus shifts towards a more ecological landscape through the implementation of the SLIP recommendations, typical maintenance practices will need to become more nuanced and responsive. Personnel training will be required as a prerequisite for implementation of the planting typologies provided in the SLIP.

For efficiency throughout this report, the use of "Penn State" shall refer to the University Park campus, unless otherwise noted.

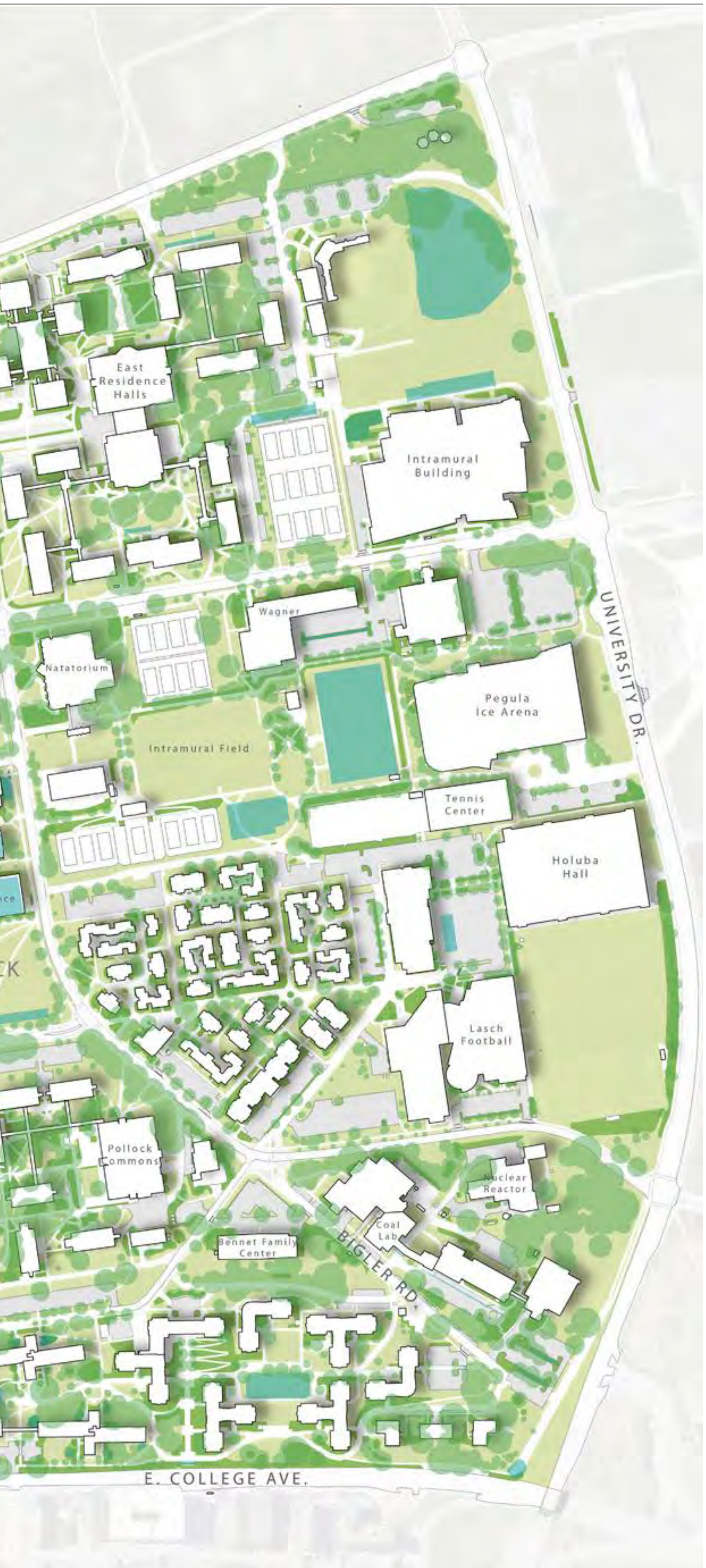
Funding proposal

In Winter 2022-2023, Penn State's Eco Action Club partnered with Office of Physical Plant's landscape design and management staff to prepare a proposal for the Environmental Sustainability Fund, which is sponsored by the University Park Student Fee Board (SFB). The proposal sought a funding match to develop a "Sustainable Landscapes Implementation Plan" and help fund the first phase of implementation. The amount requested was $75,000, with a contribution of $100K from OPP for a total project budget of $175,000. This was based on the estimated fees for hiring a consultant to prepare the plan and the projected construction cost for the first phase. The stated goal for the SLIP was to help develop a clear vision and outline the various strategies and steps forward that can be implemented or phased as resources allow. It also identified future opportunities for research and evaluation to better determine if the anticipated benefits of the planning study are realized and to what capacity.

Steering Committee

This planning process was guided by an engaged steering committee comprised of students, professors, and stakeholders from Penn State's Physical Plant who are responsible for the design, funding, and maintenance of the campus landscape. The primary drivers for this planning exercise included the development of strategies that are fiscally responsible, realistically implementable, and operationally sustainable. The steering committee provided productive dialogue and engagement throughout the process.

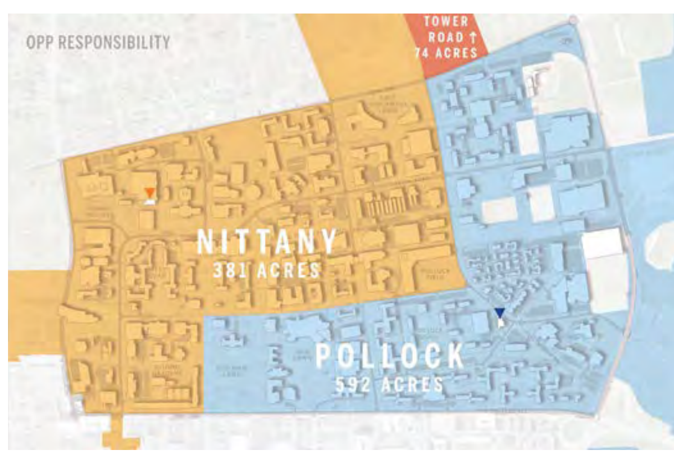

PARK AVENUE
EAST SUBCAMPUS LAWN
Forest Resource
Business Building
HORT WOODS
Ford
Mateer
Robinson Hall
Agricultural Science
East Parking Deck
Agricultural Engineering
Food Science
CURTIN ROAD
ATHERTON ST.
Nittany Lion Inn
Nittany Parking Deck
Moore
Theatre
Music
Forum
Computer Building
Chambers
Spiritual Center
ARTS & SCIENCES QUAD
Rec Hall
Irving
Pattee Library
Paterno Library
Chem/Bio Engineering
Eisenhower Auditorium
Eisenhower Parking Deck
Chemistry
Life Sciences
Millennium Science Complex
Hepper Fitness
Warring Commons
WEST QUAD
Whitmore Lab
POLLOCK FIELD
Harrington
Davey Lab
Osmond Lab
Thomas
Westgate
Hosler
Steidle
Willard
Hub-Robeson Center
Mcelwain
POLLOCK QUAD
Old Main
Deike
HUB LAWN
White Building
ALUMNI GARDENS
OLD MAIN LAWN
Simmons
Applied Research Lab
Power Plant
Nursing
Schreyer
Redifer Commons
Hammond



AREA OF STUDY

For the purposes of this Sustainable Landscape Implementation Plan, the study area has been limited to core campus, as defined by Park Avenue, University Drive, College Avenue, and Atherton Street. This is a primary focus area for OPP's Landscape Services and receives more labor hours and inputs than other areas of campus. This core campus is also most impacted by students, faculty, and staff, and is the most visited part of campus by the community. The study area is 426.50 acres and is made up of +/-50% "soft" landscape features (lawn, planting beds, etc.) and +/-50% "hard" landscape features (buildings, roads, sidewalks, etc.). The focus of this planning effort is to identify opportunities to reduce operations inputs and increase the performance of the landscape.

The dedicated staff and resources in the Nittany and Pollock maintenance shops actively manage this area of campus. It was determined that parts of campus further afield may be more complicated to effect change for a variety of reasons that are beyond the scope of this study.



Current OPP distribution of core campus landscape maintenance shops and responsibility areas

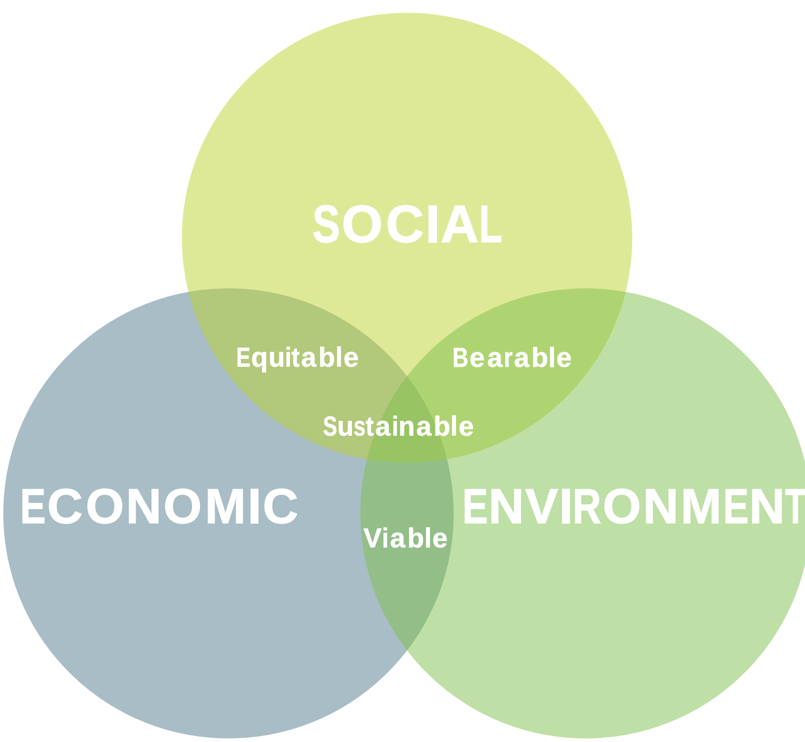
1. INTRODUCTION

PROJECT PURPOSE

This planning effort aims to look at how ecological landscape management strategies can be implemented to transition the predominately tree and lawn landscape to a more ecologically intense, lower input series of landscape typologies. This is in support of broader Penn State objectives to:

Increase overall campus sustainability and support Penn State's goal to reach net zero carbon emissions by 2035.

The design team used the widely accepted principles of sustainability as a guide for this comprehensive approach. In pursuit of improved campus sustainability, this planning approach must incorporate solutions for observed environmental, social, and economic issues to be successful.



Principles of Sustainability

Environmental

* Ecological performance & health
* Carbon emissions reduction
* Biogenic carbon sequestration
* Climate + pest resiliency
* Invasive management
* Soil health

Social

* Community engagement and education
* Be a model for students, the Commonwealth, & other institutions
* Training of staff and management

Economic

* Balancing operations and shrinking budgets
* Minimizing high-input landscapes
* Plant procurement self-reliance (maximize use of greenhouse and nursery facilities to support the SLIP)

SIMPLE MATRIX-STYLE PLANTINGS AT THE RECITAL HALL | 2023

1. INTRODUCTION

GUIDING PRINCIPLES

With guidance from the Steering Committee, the design team developed a series of principles to guide the transformation the campus landscape through design and management to enhance social, environmental, and economic sustainability at Penn State.

Strategies shall be **practical** and incrementally **implementable** as resources allow

Strategies shall **promote economic sustainability** and operational self-sufficiency

Strategies shall aim to **reduce greenhouse gas emissions** and **increase carbon sequestration**

Strategies shall aim to **ecologically intensify campus** while conserving resources

Strategies shall aim to **educate** and **engage** the Penn State community

STRATEGIC GOALS

The guiding principles have guided us to 3 overarching strategic goals for the Sustainable Landscape Implementation Plan. In order to achieve these highlighted goals, a range of objectives are defined for each:

Optimize landscape management through ecological intensification of the campus landscape

a. Transition underutilized lawns over time to a landscape typology that has higher ecological value and aims to lower inputs.

b. Reduce greenhouse gas emissions from landscape operations and maintenance.

c. Promote resilient and implementable landscapes by simplifying and clarifying a system landscape typologies across campus that provide ecological complexity.

d. Increase self-reliance in plant procurement (grow what you need, when you need it).

e. Facilitate periodic reviews & updates to the Landscape Management Guidelines that promote this overall goal.

Increase landscape performance and ecological health

a. Modify/edit existing planting types to increase food and habitat access for wildlife.

b. Protect existing and expand & diversify habitat areas.

c. Increase biogenic (vegetation and soils) carbon sequestration.

d. Reduce embodied carbon emissions from future campus construction projects.

Be a model for sustainable landscape innovation and education

a. Develop pilot project(s) for implementation with support from the Penn State community.

b. Foster long-term stewardship through the development of a landscape management engagement program.

c. Develop protocols for interpretive signage, information, and real-time data about new landscape typologies to communicate the project values and impetus for change.

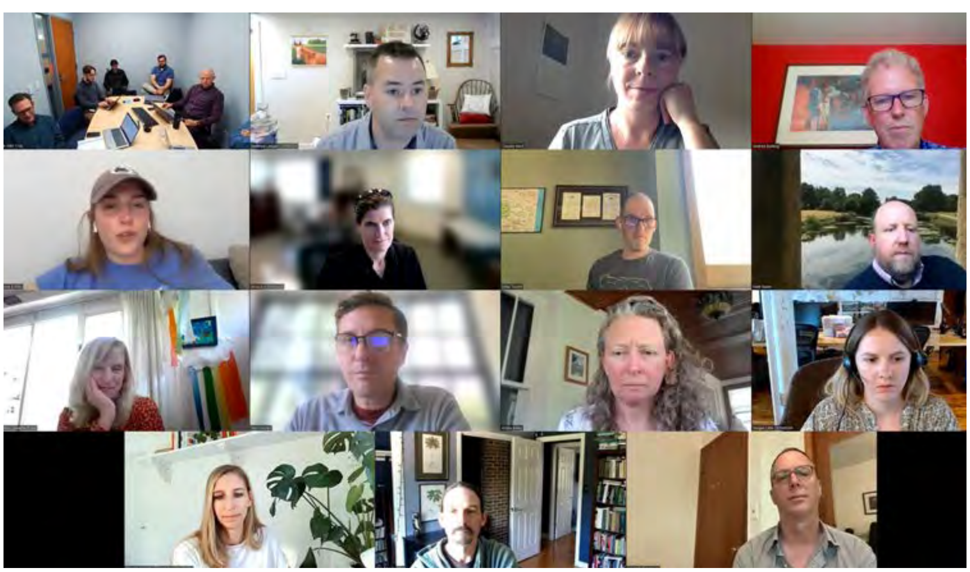
STAKEHOLDER ENGAGEMENT SUMMARY

Steering committee

The Steering Committee was engaged, energetic, and impactful throughout the planning of the Sustainable Landscape Implementation Plan. The committee was strategically comprised of students, professors, and stakeholders from OPP to ensure that the design team had guidance coming from multiple perspectives within the Penn State community. Throughout the process, the committee framed their guidance in acknowledgment of a need for fiscal responsibility and operational sustainability. An important piece of early feedback from the committee that helped define the overall planning approach was acknowledging the importance of making a direct connection to carbon and aligning our project goals & objectives to the Penn State's broader carbon reduction goals developed by Penn State's Carbon Emissions Reduction Task Force (CERTF). The committee also advised that ecological and environmental issues should always be evaluated with aesthetics considerations to ensure that improvements to the overall landscape footprint are both measurable and sympathetic to the existing landscape context. Steering Committee discussions pointed out the need for the design of landscape improvements to acknowledge context and account for potential factors in the built environment, such as bird-friendly building design and light pollution.

The full Steering Committee participated in the following milestone meetings:

* 05/10/23 - Project Kickoff Meeting, focused on project opportunities & challenges
* 06/23/23 - Information gathering findings, vision statement, guiding principles, & goals
* 09/07/23 - Project goals & objectives update and landscape transformation vision
* 11/15/23 - Carbon metrics methodologies & application strategies of landscape typologies
* 02/13/24 - Pilot projects and final report review



Student Engagement

The design team presented a high-level overview to students in September 2023, with the intention of seeking feedback about how the values of the planning effort may align with the sustainability values of the student body. The discussions with students focused on the importance of making their voices heard among the University leadership. The design team identified that this planning effort would not have happened without financial support from the Student Fee Board (SFB) and moving forward will definitely require continued student support in order to secure funding for implementation. The design team met with the students again in November 2023, who noted their overwhelming support of the strategies identified in this report, and were clearly energized about the environmental improvements that these strategies could yield. The change in the traditional campus landscape aesthetic was welcomed by the students, who are very interested in helping to spread the word about the importance of this project, and are willing to help secure funding and support implementation of the strategies identified herein. The primary engagement events included the following:

* 09/07/23 - Project overview presentation & casual outdoor discussion around display boards
* 11/15/23 - Project summary presentation, engagement discussion, & participation survey

Refer to APPENDIX A for stakeholder engagement feedback details

2

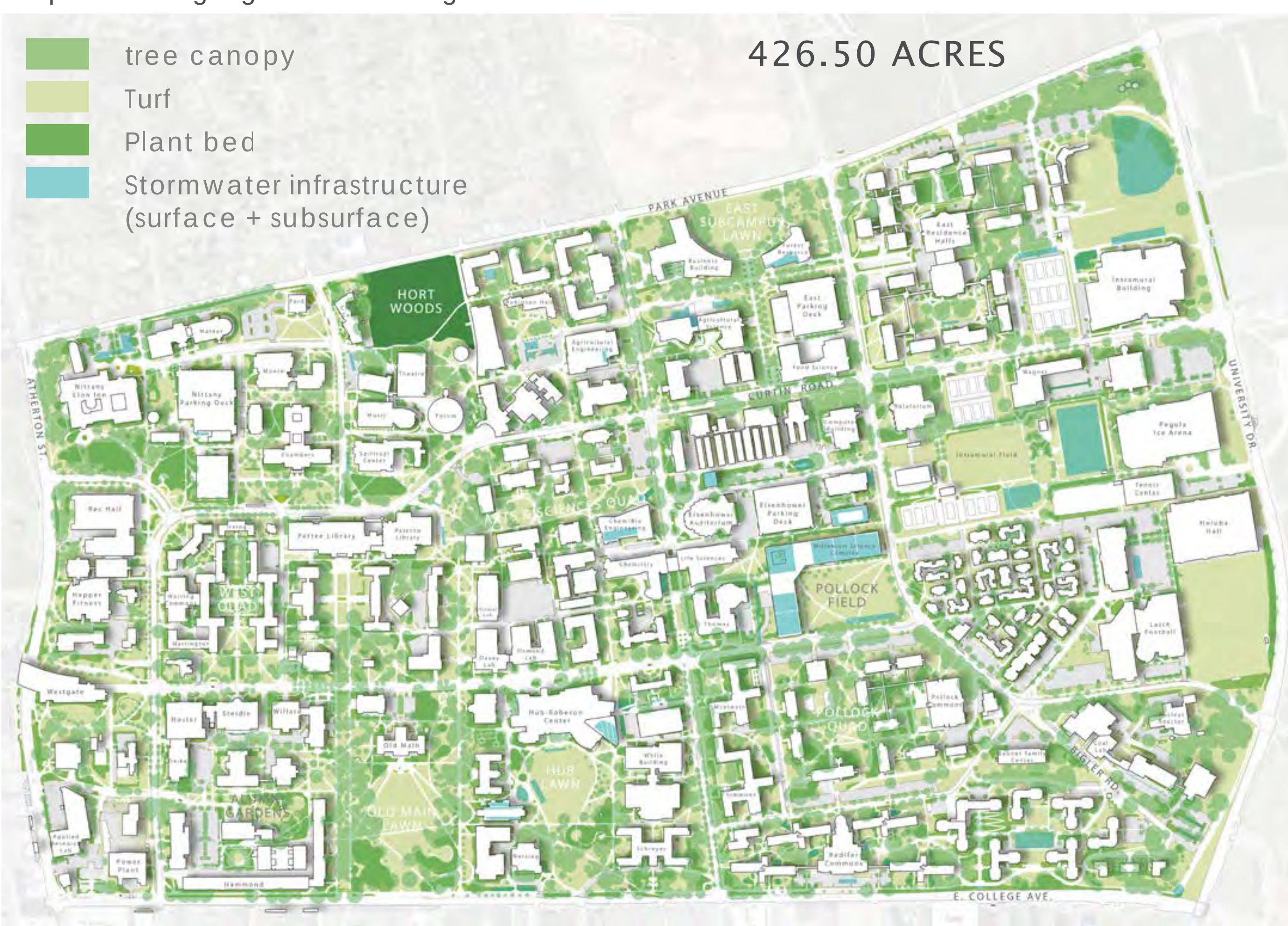
KEY FINDINGS & REC

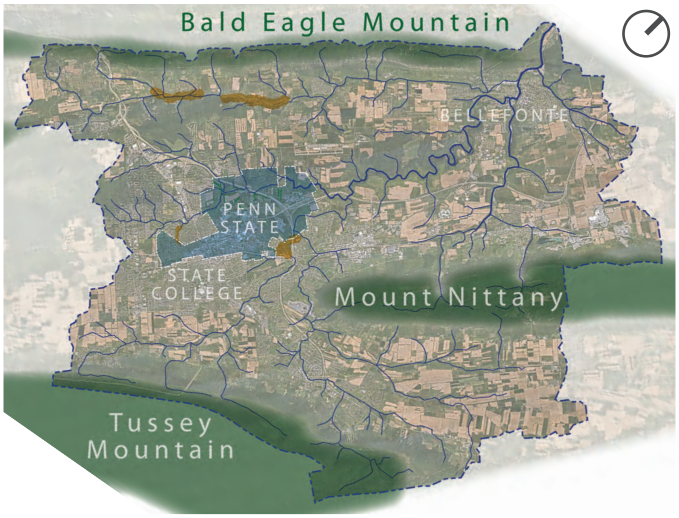
COMMENDATIONS

INFORMATION GATHERING SUMMARY

Working with John Richendrfer, a GIS Analyst with OPP, the design team focused on establishing a thorough understanding the existing conditions of core campus. The extent and depth of available and accurate GIS data curated by Penn State has provided a substantial jump-start to the design team's understanding of the existing conditions.

Using the maps created from this data, the design team established a baseline understanding of the existing campus conditions and used these maps during our campus visits to observe and assess current landscape patterns and associated maintenance regimes. This existing conditions map below highlights the existing "soft" landscape features, including tree canopy cover, lawn, planting beds, and stormwater infrastructure (green roofs, rain gardens, and subsurface stormwater facilities). This, along with other existing conditions mapping illustrated later in this chapter and in Appendix A, was the basis for establishing existing environmental footprint baseline measurements. Proposed sustainable landscape improvements to these conditions were measured and compared to this baseline for evaluation on the efficacy of the planning proposals. This chapter lays out our process for defining and measuring success, and culminates in a series of recommended actions for application.





Campus Hydrology & Irrigation

Penn State is part of the Fox Hollow Watershed that drains towards Spring Creek ultimately making it's way down the Susquehanna River to the Chesapeake Bay. There are not many cost-effective opportunities for widespread stormwater infiltration on campus, due to the Karst geology and susceptibility to sink holes.

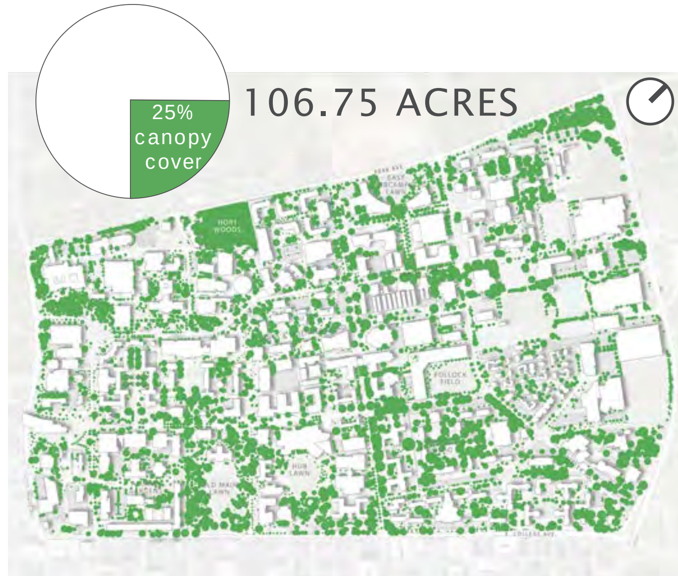
Existing Tree Canopy

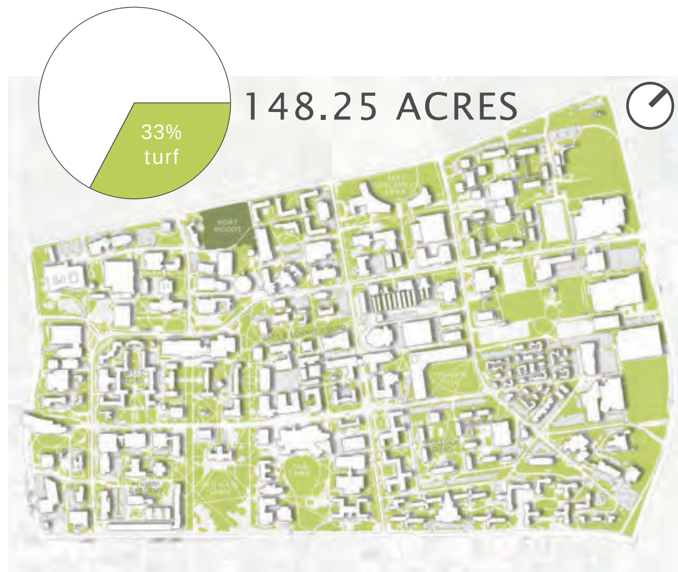
Penn State's campus landscape is the overall extent, diversity, and health of the tree canopy throughout core campus. The existing tree canopy covers just over 25% of core campus, contains over 6,500 trees, and is comprised of nearly 150 different tree species.

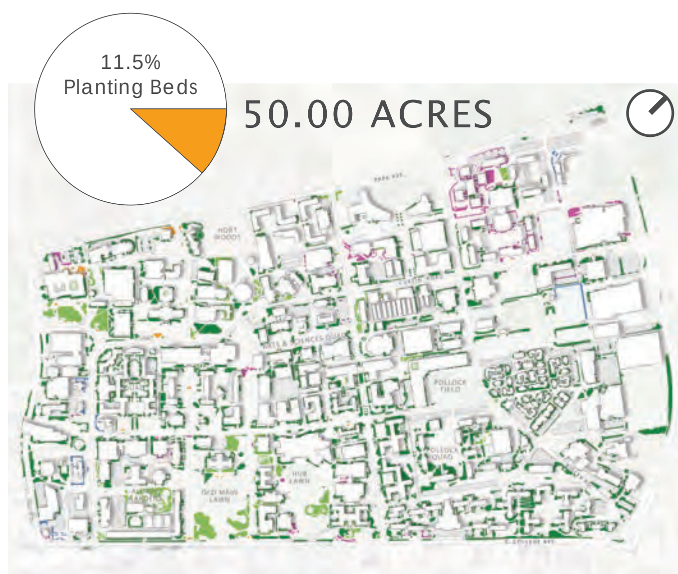
Existing Groundplane

One-third of core campus is currently maintained as traditional lawn, but synthetic fertilizers have been phased out and Penn State's approach to irrigation is minimal. The existing plant beds within core campus have been mapped according to the predominant plant type in each bed. In total, plant beds represent roughly 11.5% of core campus, covering approximately 50 acres.

Annual beds: 0.50 ac.
Horticultural beds: 8.00 ac.
Non-OPP Beds: 0.75 ac.
Shrub Beds: 37.50 ac.
Un-assigned Beds: 3.25 ac.







Refer to APPENDIX B for more existing conditions assessment details

2. KEY FINDINGS & RECOMMENDATIONS

KEY OBSERVATIONS

After a thorough information gathering effort, multiple site visits, field observations, and discussions with the Steering Committee and other project stakeholders, the design team has identified the following key findings regarding the existing landscape conditions:

Operations + Maintenance

- Extensive mowing observed.
- Extensive use of gas powered vehicles.
- Proposed adjustments to operations and maintenance will need to align with planned and anticipated annual budget cuts.
- Lack of communication about and education of non-traditional and more progressive landscape typologies.

Biodiversity

- Lack of herbaceous plant diversity
- Prevalence of non-native plant material and missed opportunities to showcase high-performing plants in overall planting palettes.
- Herbicide over-use on campus was observed.
- Herbicide use and lack of high performing plants are contributing factors to the lack of biodiversity observed on campus.

Water

- Minimal irrigation is being used on core campus.
- The majority of stormwater is being collected subsurface due to karst geology.

Environmental Footprint

- Existing hardscape (roads and sidewalks) accounts for an overwhelming percentage of overall embodied carbon emissions within the campus landscape.
- Frequency of lawn mowing is the primary net greenhouse gas emitter from a landscape operations perspective.
- Ongoing transition toward fully electrified equipment will help to keep operational emissions down significantly from "business as usual" practices.
- Expanded tree canopy and planting areas can positively impact campus environmental footprint.

During the course of the information gathering phase of the study, the design team couldn't help but to identify a series of observed patterns that were consistent across the study area. While disturbance (whether by recreation, maintenance, or development) is acknowledged as part of the core identity of the campus landscape, the design team sees opportunities to reduce the intensity of maintenance in many underutilized and low-performing landscape areas throughout core campus.

The consistent patterns of underutilized lawns, expansive mulch beds, low-density planting areas, and eroded pathway edges are all opportunities to improve the ecological performance of the landscape, while also reducing inputs. The mapping of these patterns throughout core campus presents a substantive acreage of landscape that is ripe for a transition to a higher-performing use.

Lawns between Thomas & Millennium Science Complex

Underutilized Lawns

Lawns are the primary groundcover across the study area - more than 1/3 of the total core campus. Some lawns have ceremonial or recreational value, while others may have no meaningful function at all.

Mulch area behind Music II Building

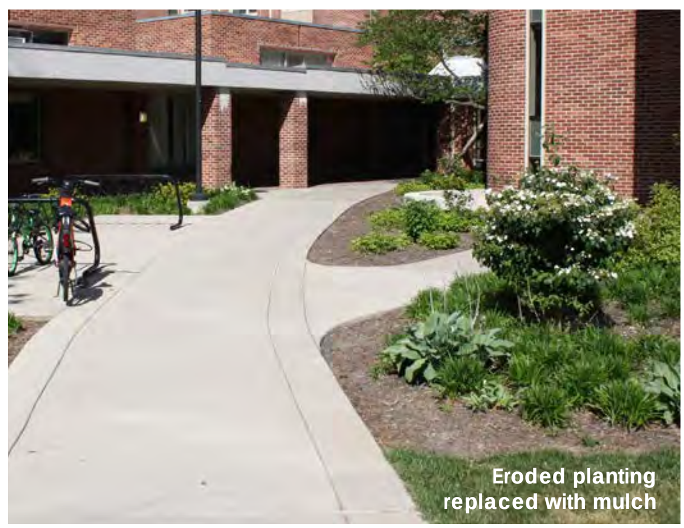
Expansive Mulch Beds

Large mulch beds are pervasive across the campus. While these mulched areas may provide some minor benefits to the existing mature trees, such as protecting soil biota, these areas are providing limited ecological value to the campus landscape.

Low density planting infilled with mulch

Shrub+Herbaceous Beds

Shrub and herbaceous beds make up the majority of plant beds found on campus.



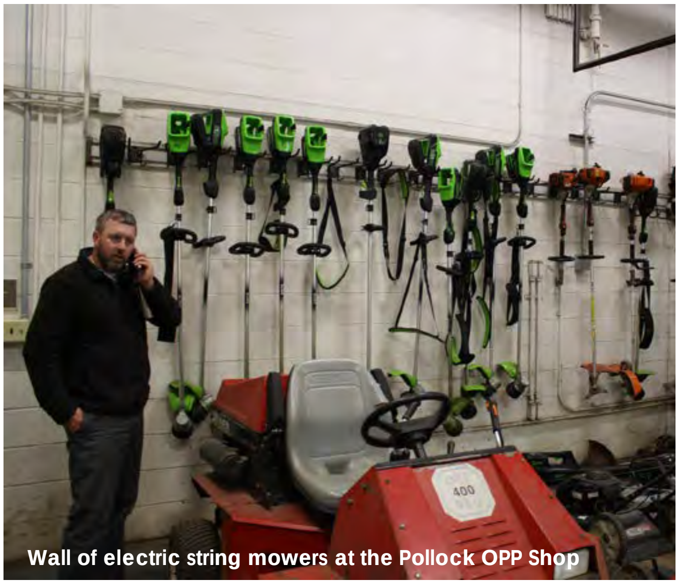
Eroded planting replaced with mulch

Pathway Edges

Eroded pathway edges can be found throughout the campus especially along highly trafficked pathways.

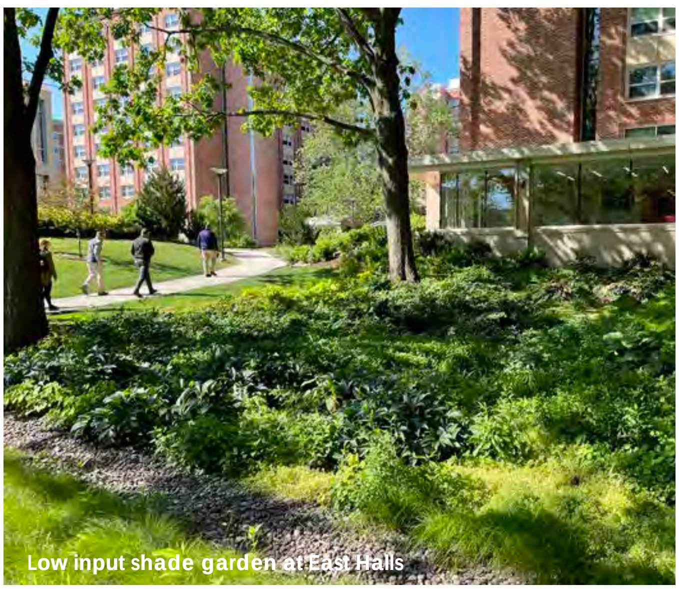
Refer to APPENDIX B for more existing conditions assessment details

2. KEY FINDINGS & RECOMMENDATIONS



Wall of electric string mowers at the Pollock OPP Shop

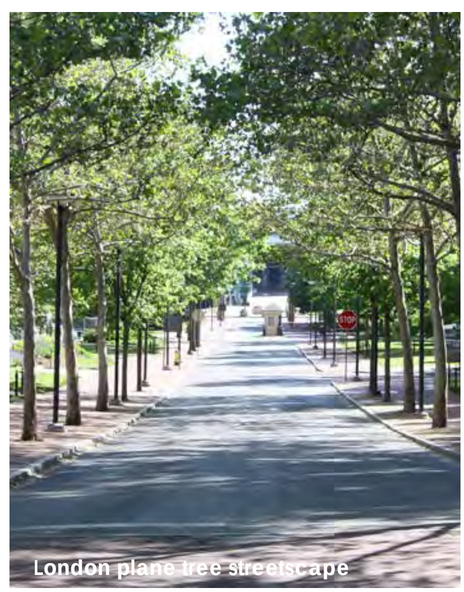
Electric mower at the Pollock OPP Shop



Low input shade garden at East Halls

No-mow fescue lawn near Hort Woods

Hort Woods educational signage



London plane tree streetscape

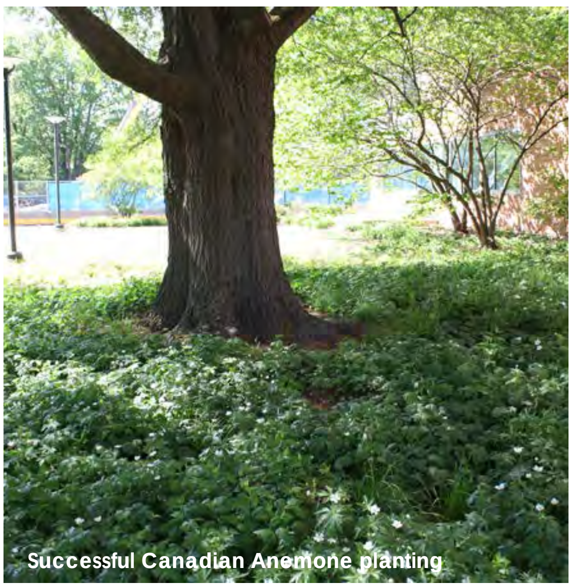
Low input garden near Shortlidge Road

LANDSCAPE HIGHLIGHTS

During the course of this study, the design team observed several landscape highlights, including:

- **Electric lawn equipment**
- **Low-input landscape typologies**
- **Simplified matrix-style plantings**
- **Mature and diverse tree canopy**
- **Examples of interpretive signage**

These are building blocks for the continued transformation of the campus landscape toward a more sustainable future.



Successful Canadian Anemone planting

Successful Geranium planting below a mature canopy tree

Simplified low input matrix-style plantings

Refer to APPENDIX B for more existing conditions assessment details

2. KEY FINDINGS & RECOMMENDATIONS


Lack of plant density and excessive mulching


Visible soil compaction at disturbed landscape edges


Extreme soil compaction


Poor plant selection / marginal success below mature trees


Lack of plant density in bioswales


Underutilized lawns require frequent mowing & weed control

Mineral mulches replace highly compacted edges

AREAS OF CONCERN

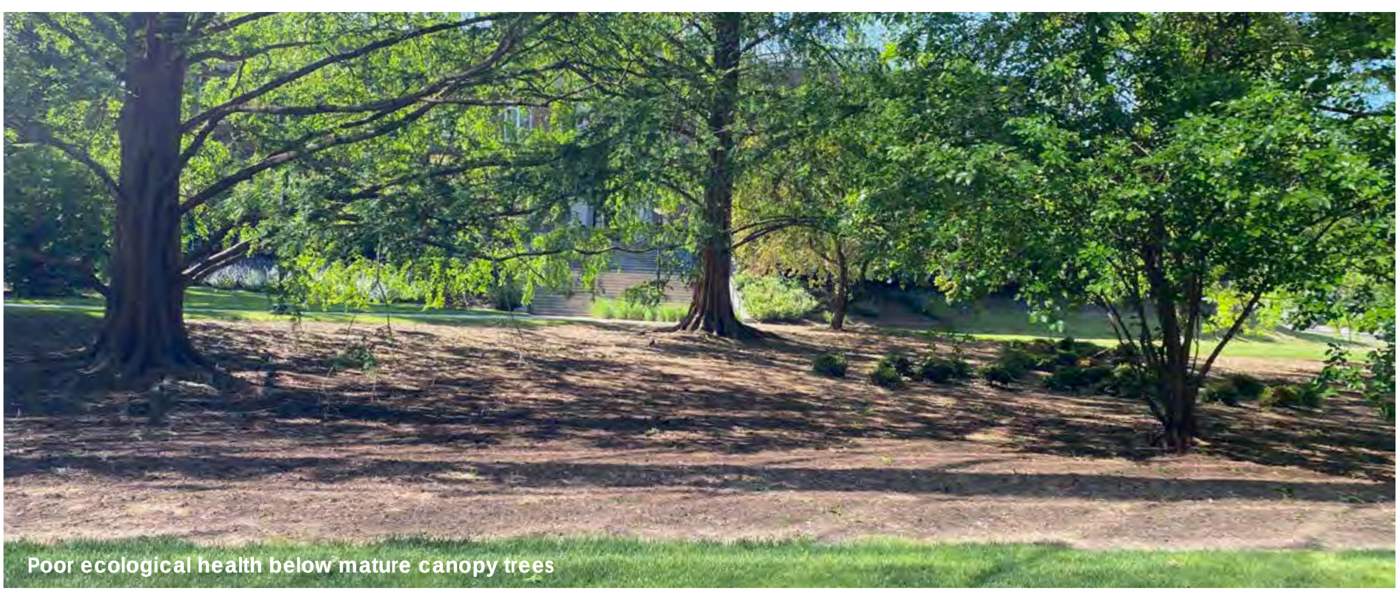
During the course of this study, the design team identified several areas of concern due to the following reoccurring observed patterns:

- **Widespread use of chemicals**
- **Expansive mulching**
- **Extent & frequency of mowing**
- **Gas-powered equipment**
- **Lack of biological life**
- **General Lack of plant density**

These are opportunities to improve the sustainability of the campus landscape.

Widespread use of chemicals leaves pervasive bare spots

Lack of plant density contributes to expansive mulching



Poor ecological health below mature canopy trees

Refer to APPENDIX B for more existing conditions assessment details

DEFINING & MEASURING SUCCESS

The Biodiversity Crisis

When it comes to environmental crises, most attention is paid to climate change, but the reality is that we are in the midst of a series of concurrent, related environmental crises. Expert perspectives on global biodiversity loss suggest that there will be a substantive decrease in ecosystem function as more species become globally threatened or driven to extinction. It is estimated that more than 30% of all living species have either become globally threatened or been driven to extinction in the last 500 years[1], many of which have occurred in the last half century.

The loss of species is clearly documented, but equally alarming is the fact that species not at immediate risk of extinction are also observed to be thinning out, which imperils other species that depend on them. Species diversity helps to make the earth habitable for humans, and it should be noted that all living beings have just the same right to existence as humans do.

Thus, failing to protect species diversity is not only a planetary injustice, but also a detriment to our own existence. So how can the SLIP help to address the biodiversity crisis?

The design team has identified a need to increase stability in the campus landscape by reducing inputs (minimizing disturbance, eliminating chemical pollution, etc.), while preserving and expanding food sources and habitat areas throughout campus.

It is generally understood that chemical pollution, such as the use of pesticides in particular, is a driving cause for insect populations to collapse, which are critical for most of the ecosystem services on which we depend.

The “Application” chapter of this report lays out a series of sustainable landscape implementation strategies that can make a positive impact on biodiversity on campus. The design team has identified a series of proposed landscape typologies that, once established, will require less frequent and less intensive disruptions to the plants and animals in the landscape through the “ecological intensification” of both existing and transformed landscape areas. The planting strategies will increase plant diversity, promote a range of food and habitat, and increase stability by reducing weed competition, and therefore the reliance on chemical use and annual mulching.

Ecological intensification

The SLIP aims to create and nurture healthier and more abundant ecosystems on campus. As a first step to achieving this goal, this report proposed the installation and proper management of carefully crafted planting systems around campus. The proposed plantings are built on the following core attributes:

1. Isbell, Forest and others (2022, July) *Expert perspectives on global biodiversity loss and its drivers and impacts on people. Frontiers in Ecology and the Environment, Ecological Society of America.*

High species diversity

All proposed typologies maximize the addition of site-appropriate species to campus while focusing on regionally native plants.

Density through spatial & temporal layering

Proposed typologies aim to fill as many niches in planting as possible, creating denser and overall more abundant planting systems. Current mulch, for example, is replaced with evergreen ground covers.

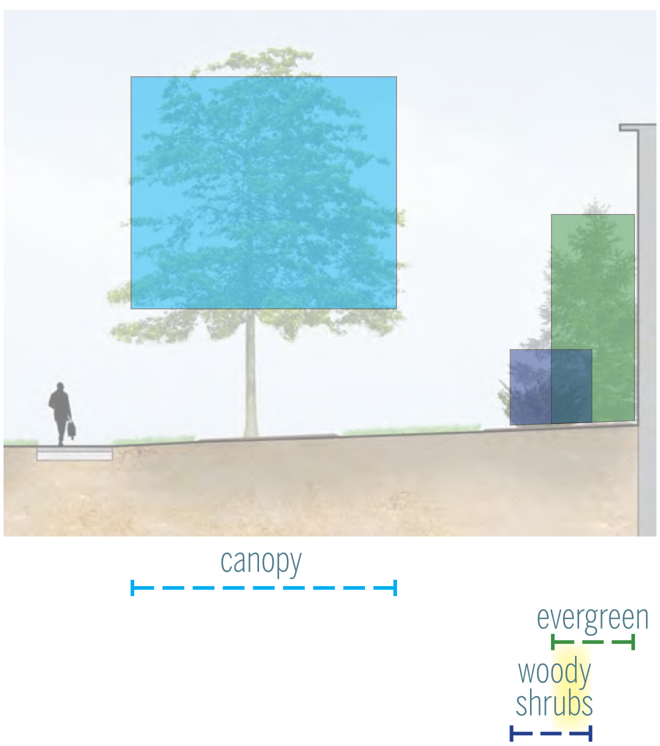
High percentage of flowering plants

Flowering plants are essential for pollinators and will make up the majority of plants on campus. This includes mostly wind-pollinated species (such as willows) that feed early flying pollinators.

Large number of high-performing species

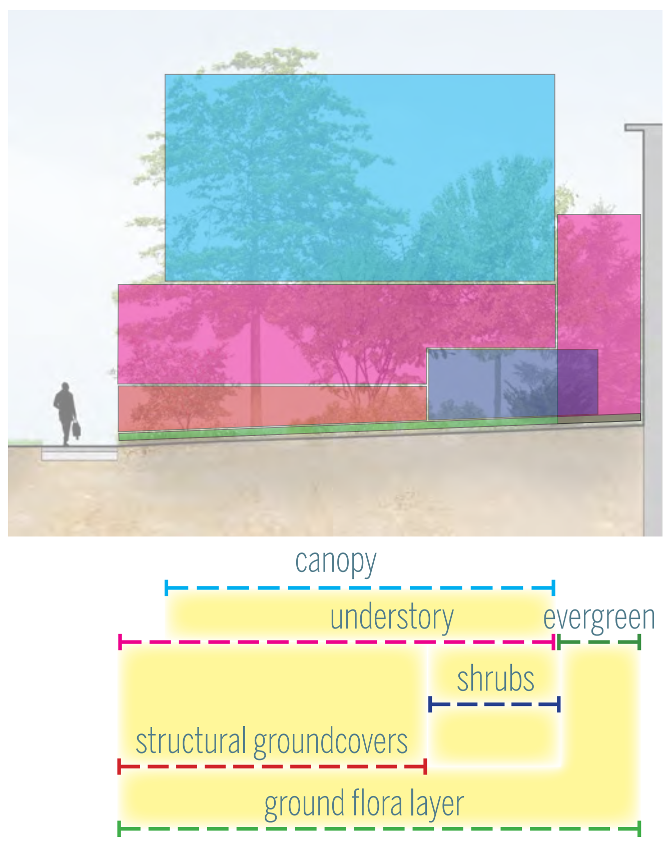
Not all flowering plants or fruits and berries are created equal. Based on data provided by the Center for Pollinator Research and ornithologists, some species offer more nutritious food to pollinators and birds. These species are prioritized in the proposed plant palettes.

Existing Condition



A simple sectional diagram illustrating ecological intensification by spatial and temporal layering.

Ideal Condition



DEFINING & MEASURING SUCCESS

With a critical eye on both the landscape highlights and the areas of concern, the design team worked diligently toward establishing accurate and reliable existing conditions metrics for the performance of the landscape as a baseline for comparison. Our focus on metrics-based planning helped to facilitate group discussions, goal setting, life-cycle cost analyses, and decision-making tools that lead to successful, flexible, and values-based outcomes.

Establishing a baseline condition helped to understand what existing landscape typologies and operations should be subject of more scrutiny, and which should be expanded or tweaked to improve the performance of the landscape.

An important driver for this planning effort is measuring the carbon equivalent (CO2e) footprint of the campus landscape and subsequent operations to maintain the landscape. While many of the calculations are focused on carbon, biodiversity is a related criteria that is more challenging to define and measure. The design team's approach to increasing biodiversity on campus is largely to focus on substantially expanding plant and habitat diversity through a range of landscape typologies in core campus, acknowledging that implementation of these will yield increased biodiversity over time [ideally supporting a 10% net biodiversity gain on campus and protecting 30% of the world's habitats by 2030 (30 x 30) to align with global biodiversity targets]. The intent of these landscape typologies is to drastically reduce the operational inputs (mowing, pesticides, labor, etc.) to maintain them, and to rely on them to sequester carbon from the environment at the same time. Here, the design team lays out how the SLIP defines and measures success for the project.

Existing Campus (Baseline) Emissions

The following serves as a summary assessment for the existing campus landscape greenhouse gas (GHG) emissions to inform the Pennsylvania State University Sustainable Landscape Implementation Plan. The process for establishing the baseline current emissions and sequestration are identified below along with the current performance of the campus landscape.

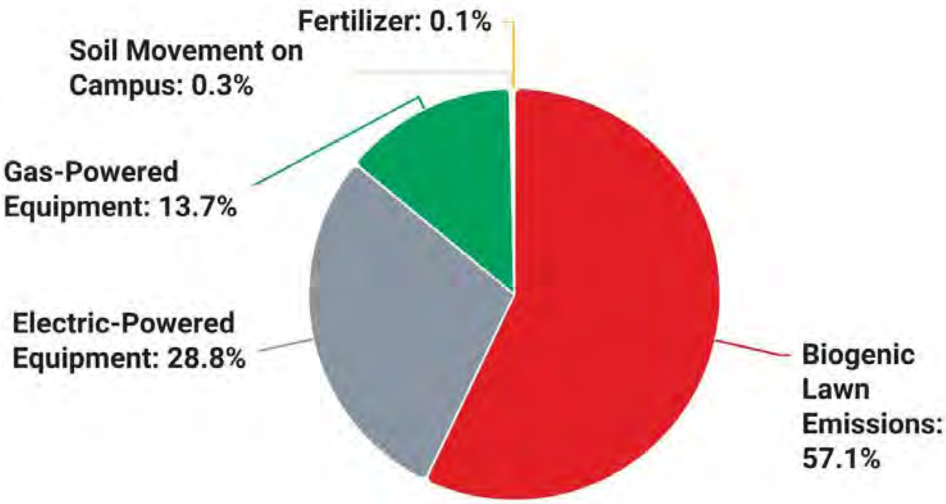
How does the campus landscape within the study area currently perform (carbon, water, biodiversity, etc.)?

What existing landscape typologies have the potential to change over time?

What are potential landscape transformation strategies and metrics for success?

Based on those strategies, how can landscape performance be improved in the following areas?

What are the final recommendations (landscape transformation and operations) for the plan to carry forward?



A project baseline of Penn State's current 2023 landscape operational emissions from Climate Positive Design's Pathfinder Tool.

Climate Positive Design **Scorecard**

Plants

Element	**Total impact**
Minimal management lawn	2,078,063.2 kg
Subtotal	**2,078,063 kg**

Operations

Element	**Total impact**
Soil Movement Off and Back onto Campus in 2022	9,188 kg
Lawn-mowers (electric)	978,334.2 kg
Trimmers/Edgers (electric)	70,256 kg
Leaf blowers (gas)	339,877.8 kg
Lawn-mowers (gas)	158,474.3 kg
Applied NPK to shrubs	3,277.3 kg
Subtotal	**1,559,408 kg**
Net Impact over 50 Years	3,637,471 kg CO2-eq
Annual Impact	72,750 kg CO2-eq

Landscape Operational Greenhouse Gas (GHG)Emissions

Emissions that occur regularly over the lifespan of the project are often referred to as 'operational carbon.' Typical operational GHG emissions associated with landscapes includes mowing and pruning performed using machinery and fertilizer use for trees and shrubs. Mowing and pruning using machinery consumes either gasoline or electricity as fuel, both of which result in emissions. Fertilizer production results in carbon dioxide (CO_2) emissions due to consumption of resources, and its application also results in nitrous oxide (N_2O) emissions as the applied nitrogen is fixed and released to the atmosphere.

The majority (57.1%) of the study area's landscape operational emissions are from the management of lawn, which accounts for 33% of its landscape coverage. Despite the fact that Penn State only uses organic fertilizers on its lawns and does not irrigate, greenhouse gas emissions still originate from lawn clipping decomposition and denitrification alone. Depending on the age of the lawn and its ability to sequester carbon and process nitrogen, a percentage of the carbon and nitrogen found within decomposing lawn clippings is released back into the atmosphere.

The second largest source of emissions (28.8%) is from electric-powered lawn mowers and trimmers. Because the campus still relies on fossil fuel sources for their energy generation, there are GHGs associated with the use of electric equipment.

Utilizing gasoline-powered equipment is responsible for 13.7%, and is from gas-powered lawn mowers and leaf/clipping blowers.

In 2022, 13,880 cubic feet of soil was removed from campus and brought back in 2022, which accounts for 0.3% of total emissions and includes the emissions associated with organic matter decay and biogenic GHG release into the atmosphere.

The remaining emissions of 0.1% are from fertilizers applied to the Hort beds.

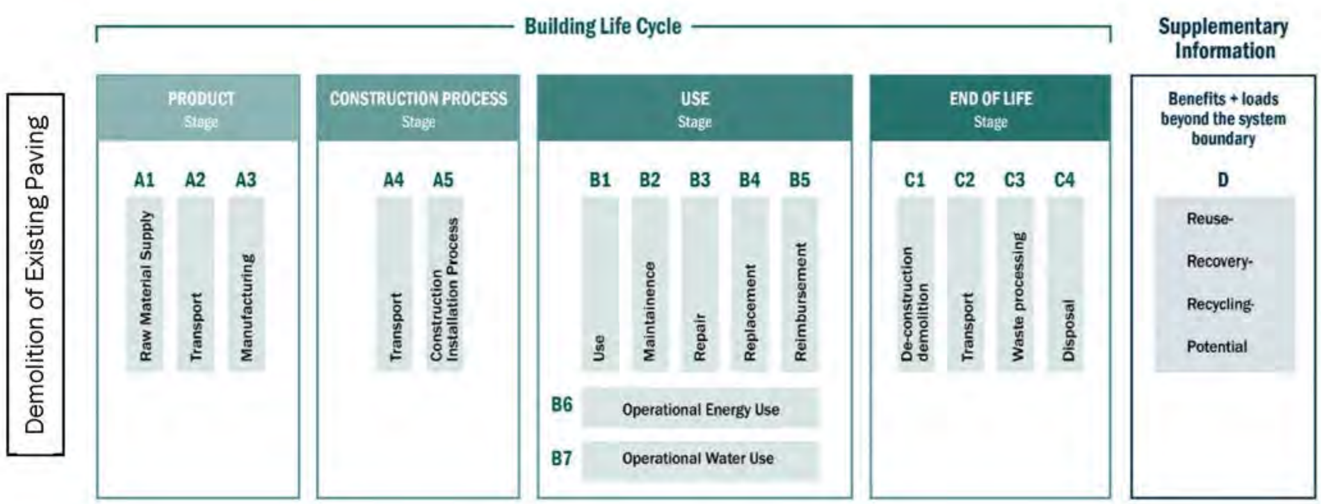
In total the emissions over a projected 50 years equals 3,637,471 kgCO2e (3,674 tonnes) or 72,750 kg/CO2e (72.75 tonnes) per year.

Refer to APPENDIX C for more baseline measurement methodology details

Embodied Greenhouse Gas Emissions

GHG emissions from the extraction, transportation, manufacturing, installation, use/maintenance and replacement of construction materials (see figure below) are referred to as the "embodied carbon" of the project. Pathfinder, the primary life cycle assessment tool for this project, accounts for all life-cycle stages below. Stages B6 and B7 are included in the "Operational Carbon" section. It also includes emissions associated with the demolition of existing paving before the installation of new landscape.

Moving forward it is recommended that Penn State follow proactive guidance to reduce embodied emissions on future site renovation and development projects. While the SLIP recommended guidance is focused on planting and operational strategies that can be addressed in managing the existing landscape, a summary of recommended revisions to OPP's *Design and Construction Standards* is provided in *Chapter 3 Application* to reduce embodied emissions on future landscape construction projects.



Life cycle stages

Over time, the development of Penn State's campus landscape, including site materials such as paving, piping, aggregates, rubberized surfacing, walls, and reinforcements have contributed a significant amount – estimated 94,270,011 kg CO2e (94,270 tonnes). This excludes replacements and demolition as that information was not available.

Active Biogenic Carbon Sequestration

Carbon Sinks

Carbon dioxide (CO2) is the largest anthropogenic source of greenhouse gases in earth's atmosphere.

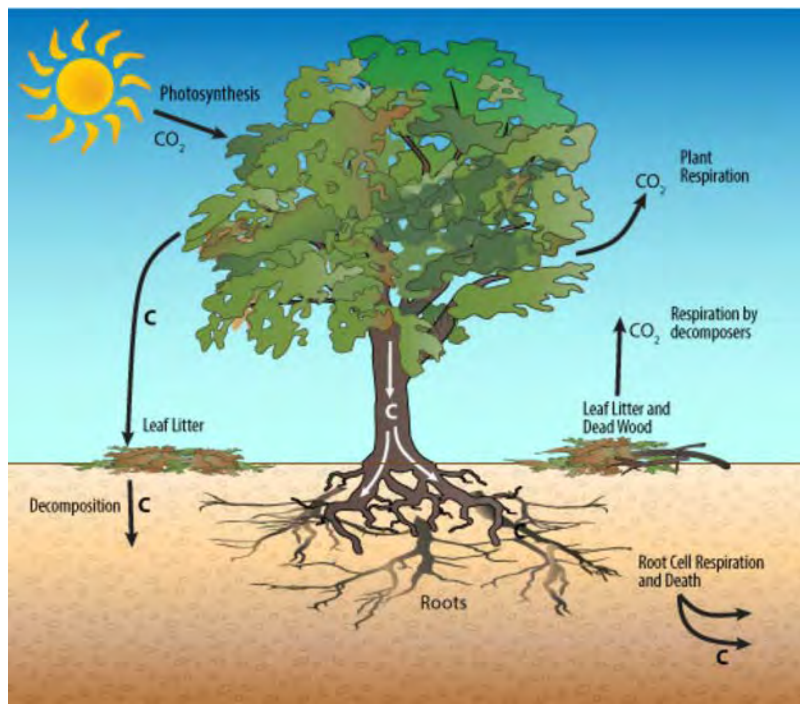
Science Behind Sequestration[1]

Plants 'sequester' carbon dioxide from the air through the process of photosynthesis, during which CO2 is converted to cellulose, sugars and other materials in a chemical reaction catalyzed by sunlight. These are then mostly stored as biomass – wood, roots and leaves, while some CO2 is respired back into the atmosphere. This active, natural process is called carbon sequestration and the amount of CO2 that remains locked up in biomass is referred to as carbon stored or a carbon sink.

Process

Factors affecting Sequestration Rate – The amount and rate of CO2 storage is directly related to the size and growth rate of a plant which depends on species, geographic location, and age. Warmer regions with more sun exposure have longer growing seasons so trees/shrubs in those regions sequester more CO2.

Decomposition and Mortality – Storage of CO2 in trees and shrubs is not permanent; as trees die, most of the CO2 stored in above-ground biomass is released back to the atmosphere through decomposition when the wood is chipped and mulched. A small percentage of the CO2 sequestered by the tree/shrub is fixed into the soil for the long term, unless the wood itself is converted to a wood product. This storage of carbon dioxide in the soil is not counted explicitly in the tool; however, the 'net sequestration' at a given point in time during does account for the CO2 stored in the un-decomposed biomass of dead trees. Since dead trees are assumed to decompose slowly, projects are still able to claim significant sequestration during the project lifespan.



The carbon cycle in trees | *Obtained from https://serc.carleton.edu/eslabs/carbon/1a.html. Last accessed 04/17/2019*

Penn State's core campus of 426.5 acres is approximately 50% planted and consists of both evergreen and deciduous trees, shrubs, perennial beds and grasses, lawn, stormwater gardens and natural forest areas.

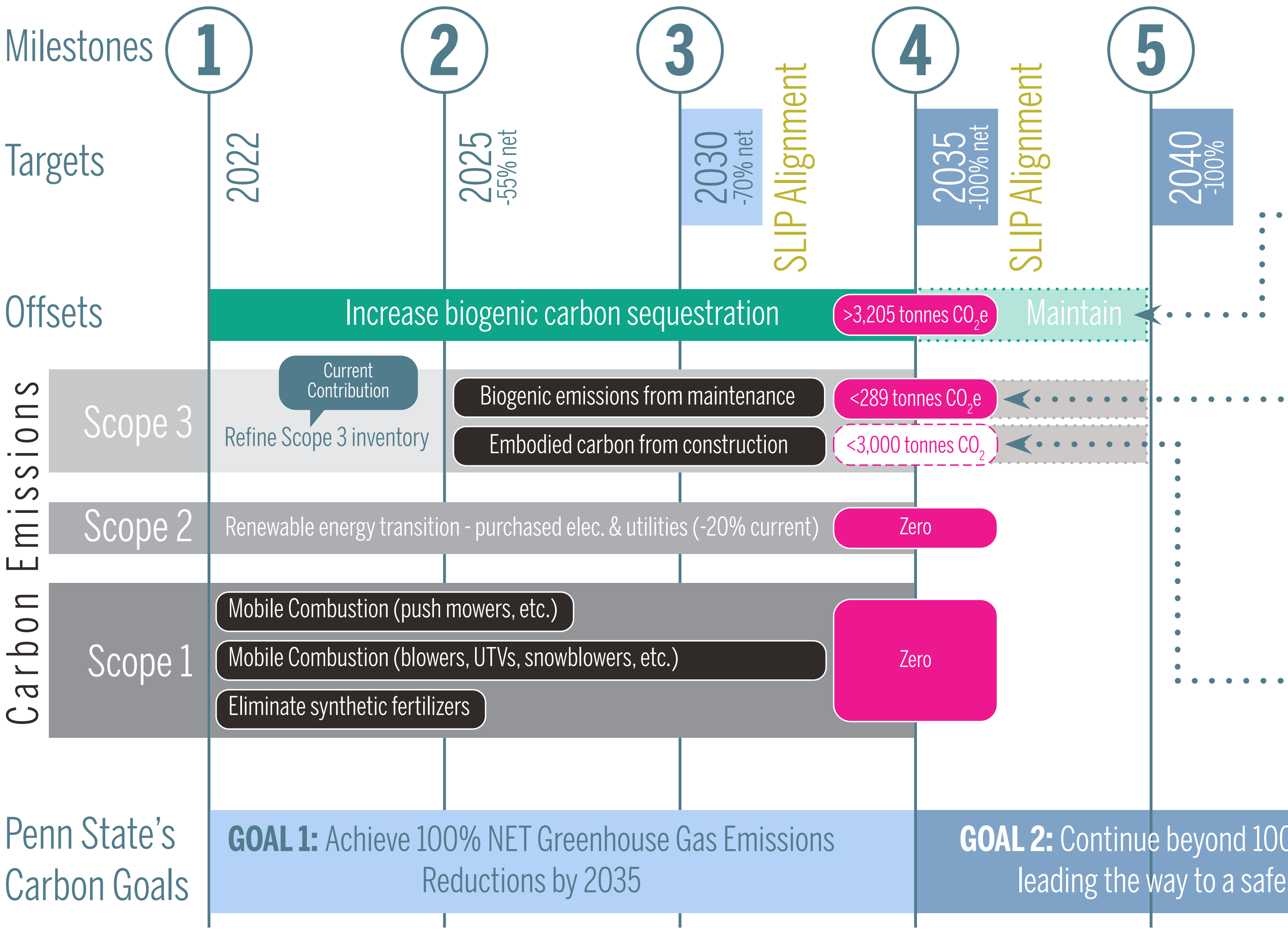
The campus landscape is estimated to sequester an average of 191,901 kgCO2e (191 tonnes) annually and 9,595,030.1 kgCO2e (9,595 tonnes) over 50 years, including typical replanting, replacement, and natural respiration.

Refer to APPENDIX C for more baseline measurement methodology details

ALIGNMENT WITH INSTITUTIONAL GOALS FOR CARBON EMISSIONS

The overall goal of Penn State's Carbon Emissions Reduction Task Force (CERTF) is to achieve NET ZERO emissions by 2035, continuing to improve beyond 100% GHG emissions reduction, leading the way to a safe, healthy, and just future. Aligning with global climate action goals, the SLIP recommends striving for ZERO emissions by 2040, no longer relying on carbon sequestration offsets but actually eliminating GHG emissions altogether.

Since Scope 3 emissions were excluded from the Penn State CERTF, meeting the 55% net reduction at Milestone 2 across all emission scopes will not likely be possible. However, by starting to address these Scope 3 emissions, the SLIP aims to sync up with the CERTF goals for all emissions to accomplish a 70% net improvement from 2022 by 2030 and continue to align with the CERTF goals into the future.



Aligning the Sustainable Landscape Implementation Plan with the Institutional carbon emissions goals.
Scope Emissions are defined by the international standard - the Greenhouse Gas Protocol[3].

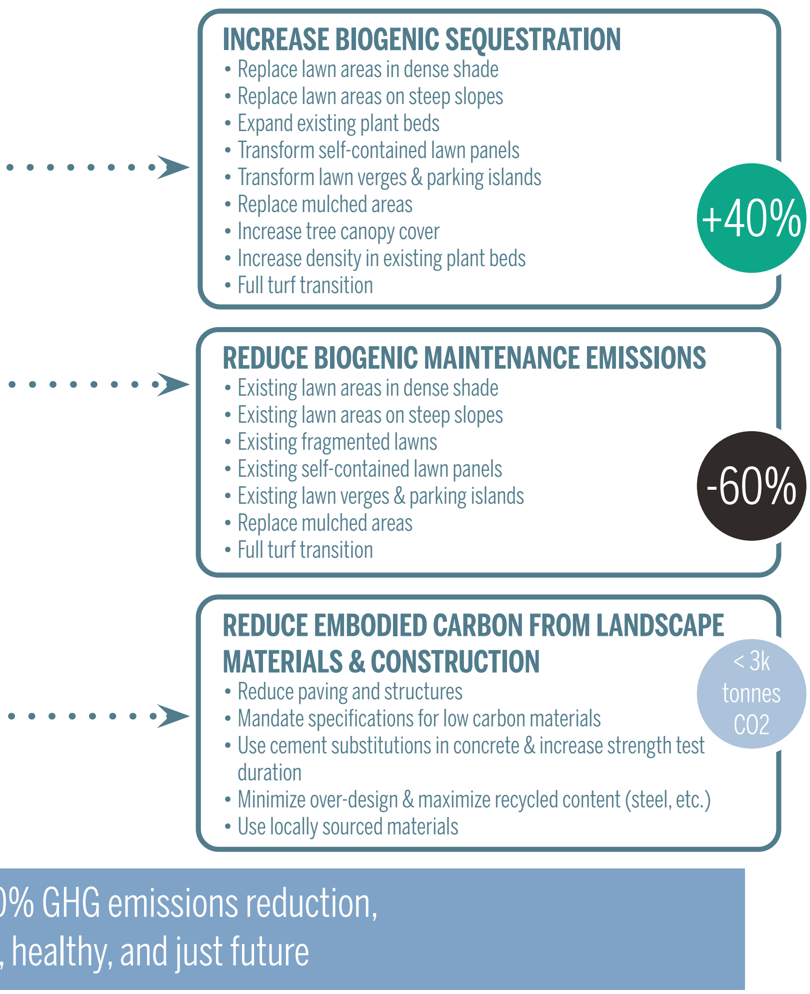
SLIP CARBON EMISSIONS REDUCTION RECOMMENDATIONS

It is worth noting that the quantity of overall campus embodied carbon emissions and sequestration is significantly higher than that of operational emissions. While it is necessary to reduce the operational emissions as shown below to ultimately reach zero by 2040, the sequestration potential is higher than needed to offset the operational emissions alone, therefore should be factored in the overall campus CERTF scenario for meeting the net offset goals. By implementing the these recommendations below, it is estimated that Penn State can accomplish an overall 60% (max. emissions of 289 tonnes CO2 by 2035) operational emissions decrease by 2035 and zero-out operational emissions by 2040.

1. **Continue to phase-out Scope 1 emissions by 2035, such as the use of mobile combustion equipment and synthetic fertilizers.**

2. **Continue to phase-out Scope 2 emissions by 2035 by completing Penn State's transition to 100% renewable energy sources**

3. **Reduce biogenic carbon emissions from lawn maintenance by transitioning underutilized lawns to higher performing plantings to increase sequestration from the baseline by 40% (capturing at least 3,205 tonnes CO2 by 2035), which will continue sequestering into the future.**



In combination, this will allow Landscape Services to achieve a carbon emissions reduction goal of net zero by 2035 within the identified study area. However, the campus landscape will continue to be impacted by construction projects to fulfill the mission of Penn State. In order achieve the ultimate goal of zero operational emissions, Scope 3 embodied carbon from future landscape construction projects must emit less than 3,000 tonnes CO2e. If that is not feasible, additional offsets must be purchased or campus landscape sequestration further increased.

Refer to APPENDIX C for more baseline measurement methodology details

3 APPLICATION

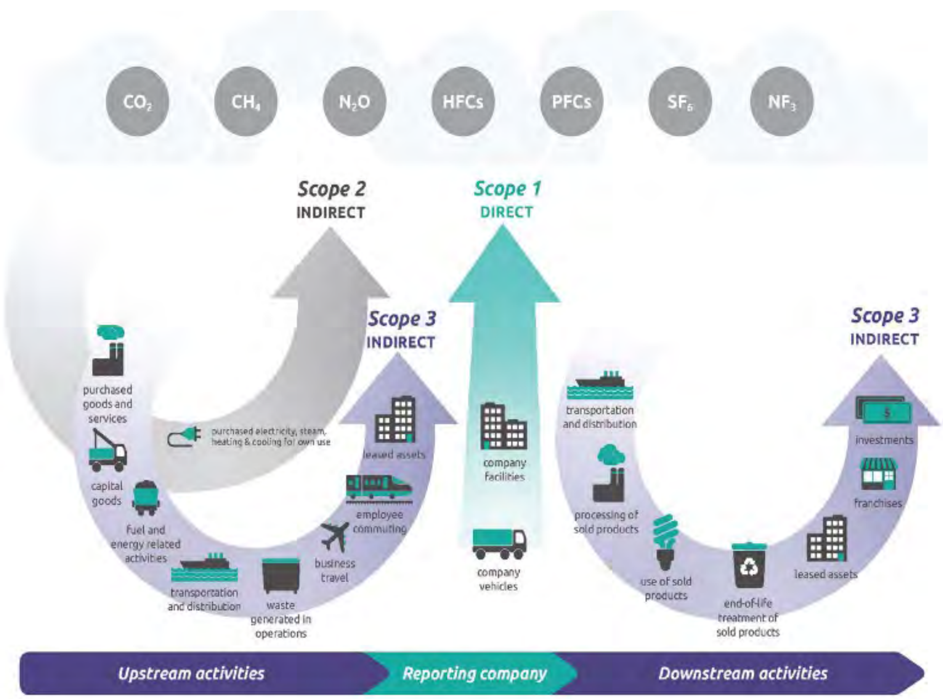
MATRIX PLANTING AT COLLEGE AVE & SHORTLIDGE ROAD | 2023

CONTINUE SHIFT TO RENEWABLE ENERGIES & ELECTRIC EQUIPMENT

Penn State continues to demonstrate leadership in inventorying its GHG emissions, establishing milestones for GHG emissions reduction, and following through on their commitment towards a climate positive future that benefits all. The 2021 Report from the President's Carbon Emissions Reduction Task Force (CERTF) clearly identifies that Penn State has already made substantial progress, and are ahead of schedule toward meeting their carbon reduction goals for Scope 1 and Scope 2 carbon emissions. Moving forward, continued emissions reductions, particularly Scope 3 Operational Emissions, will become more challenging because of the substantial financial commitment and urgency of the climate crisis. Therefore, the 2021 report set goals that are not only ambitious, but also achievable. It is this mentality that the Penn State SLIP planning effort is also taking to contribute to Penn State's GHG emissions reduction goals for all Scope Emissions, as defined by the international standard - The Greenhouse Gas Protocol[3].

Scope 1

The GHG Protocol defines Scope 1 Emissions as being "from operations that are owned or controlled by the reporting company." As Penn State has already been phasing



Overview of GHG Protocol scopes & emissions across the value chain, from the Technical Guidance for Calculating Scope 3 Emissions out mobile combustion equipment, the SLIP recommends continuing this approach until fully transitioned to electric or phased out completely – push mowers and similar between 2025 and 2030, and blowers, UTVs, snowblowers and similar by 2035, or as soon as possible.

Penn State has been substantially reducing synthetic fertilizer use as well and should strive to eliminate them between 2025-2030, or as soon as possible.

Scope 2

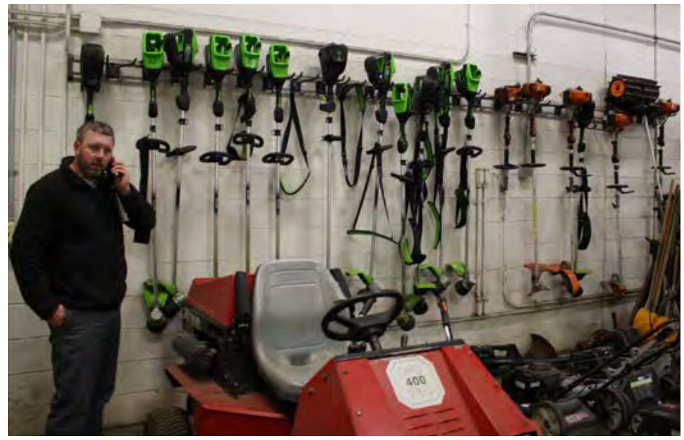
The GHG Protocol defines Scope 2 Emissions as "indirect emissions from the generation of purchased or acquired electricity, steam, heat or cooling consumed by the reporting company."

While Penn State has already transitioned more than 20% of current energy sources to renewable ones, the SLIP supports a full transition by 2035 to meet the goals of the CERTF.

Scope 3 (Operational)

The GHG Protocol defines Scope 3 Emissions as "all indirect emissions (not included in Scope 2) that occur in the value chain of the reporting company, including both upstream and downstream emissions."

As Scope 3 emissions were largely excluded from the CERTF, this SLIP takes the necessary next step by creating an inventory of Scope 3 emissions from the campus landscape (excluding building related emissions).



Facilities Supervisor Todd Zook next to a wall of electric string trimmers in OPP's Pollock Shop

One of many electric ride-on mowers in the Pollock Shop, which are nearly universally embraced by Landscape Services staff.

Despite the progress, there is a mix of gas and electric equipment at the Pollock Maintenance Shop, such as most push mowers, blowers, and snow removal equipment.

Embodied GHG Reduction (Scope 3, continued)

The overall SLIP goal is to reduce 70% net by 2030, net zero emissions by 2035, and ideally zero out by 2040.

Approximately 75 percent of designed landscape emissions come from materials and construction, and the other 25 percent is from operational emissions (CPD 2021). Most embodied carbon emissions come from the extraction, transportation, and manufacturing of concrete, steel, aluminum, and imported stone.

There are many available resources and strategies that Penn State can consider to reduce the campus's embodied carbon emissions. The design team has identified some initial recommended revisions to the OPP Design and Construction Standards as an important next step toward addressing the embodied carbon for future campus landscape and construction projects. The following spread in this report identifies an initial non-exhaustive list of items from related Divisions of the OPP Design and Construction Standards that should be considered for immediate revision.

A more thorough and detailed review of the OPP Design and Construction Standards as a follow-up effort to this report will likely result in substantive improvements toward minimizing embodied carbon in future campus landscape and construction projects. For more detailed considerations, refer to The Climate Positive Design Toolkit[4].

Carbon Sequestration

By transitioning the following landscape areas using strategies recommended in the SLIP, there is anticipated to be a 40% sequestration increase by 2035.

- Lawn areas in dense shade
- Lawn areas on steep slopes
- Lawn verges & parking islands
- Self-contained lawn "island" panels
- Expansive mulched areas
- Limited tree canopy cover areas
- Low desnity plant beds

Best Practices for Increasing Sequestration

The following is a non-exhaustive list of general strategies that Penn State can consider to increase the project's sequestration capability:

- Planting more trees that can grow to taller heights (35+ ft)
- Selecting species that have longer growing seasons in that region
- Planting woody shrubs and groundcovers
- Ensuring proper care during establishment periods to increase survival rates
- Selecting trees with known long lifespans
- Salvaging wood from fallen trees
- Selecting lawn types that require lesser fertilizer application and maintenance
- Constructing wetlands
- Maintaining vegetative coverage on soils
- Protecting and enhancing soil biota

Future Considerations

- Development of a phased implementation Plan and requirements for measuring progress and pilot projects

REVISIONS TO THE OPP DESIGN & CONSTRUCTION STANDARDS

Changing technology and changes in University requirements will require continuing revisions and updates to the Office of Physical Plant's Design and Construction Standards. Penn State has a commitment to environmental stewardship and requires the maximum possible use of sustainable and energy-efficient designs and specifications, for architectural, site, utility, structural, mechanical, electrical, and plumbing work.

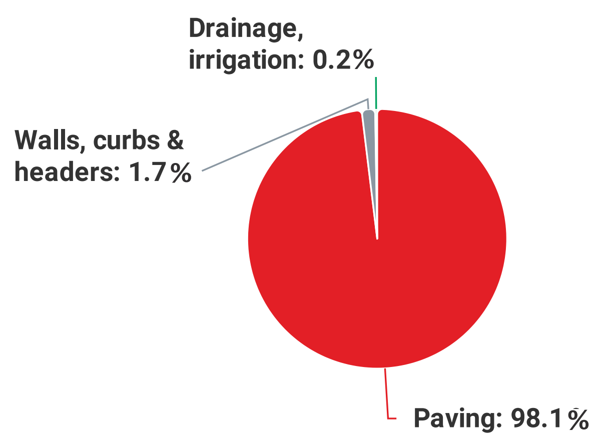
Penn State's more recent commitments to carbon reduction and improved sustainability in the campus landscape are opportunities for OPP to revisit related Divisions of the Design and Construction Standards with a critical eye towards improved sustainability. The Design Team recommends that the following items shall be considered as goals or prerequisites for all future landscape developments on the University Park Campus and other Commonwealth Campuses, including those embedded in broader capital projects:

- Maximize the salvage, storage, and re-use of landscape materials (wood from felled trees, rocks, unit paving, etc.)
- Minimize proposed paving within the landscape to only that which is essential for circulation, assembly, and service.
- Minimize or eliminate the use of traditional lawn on all capital projects.
- Maximize the use of high-performing ecological plants
- Maximize the use of materials with smaller environmental footprints and lower embodied carbon, relying on materials or products with published Life Cycle Assessments (LCAs), which measure the environmental impacts of a product or service or Environmental Product Declarations (EPDs), which signal a manufacturer's commitment to measuring and reducing the environmental impact of its products and services. LCAs are a prerequisite for EPDs, and are independently verified.
- Maximize the use of local materials to cut down on the substantiative impacts of material transportation
- Establish a soil renovation policy to preserve, protect, and enhance the soils on campus
- Minimize the over-design of site elements
- Reduce embodied carbon emissions from landscape materials:
    - Specify a minimum of 50% recycled content for all steel products
    - Consider replacing steel elements with wood, where it will meet necessary structural demands
    - Specify green steel and aluminum that substitute raw and fossil fuel-based materials (with recycled materials and fossil-fuel alternatives such as hydrogen) and use renewable energy for processing

- Maximize supplementary cementitious materials (SCMs), cement substitutions in concrete (slag, fly ash, glass pozzolan, or silica fume, etc) and maximize the use of admixtures to reduce cement demand
- Consider changing the 28-day concrete curing period to 56 days to allow for the slower curing timelines of cement substitutions
- Consider carbon sequestering concrete or low-carbon alternatives for paving, such as crushed stone, wood decking, etc.
- Utilize recycled aggregates and or aggregates
- Consider the addition of wax to asphalt to reduce embodied carbon
- Use organic or eco-friendly binders in materials like stabilized crushed stone paving, where appropriate
- Eliminate or reduce the extent of PVC piping, and consider HDPE piping as a new baseline standard
- Prohibit the use of landscape materials that are mined from natural ecosystems, such as sphagnum peat moss, virgin topsoil, and river gravel

The embodied carbon within the study area hardscape (paving, walls, curbs, infrastructure, etc.) is a significant factor in the overall carbon footprint of the campus landscape. This disparity is exacerbated by the fact that ongoing landscape operations have made many sustainability-focused operations decisions in recent years, such as the shift to electric equipment and organic fertilizers, as well as the substantial reduction in annual plantings and near elimination of irrigation.

Embodied Carbon Landscape Baseline



This chart identifies existing paving as the primary source of embodied carbon within the campus landscape. Revisions to the OPP Design & Construction Standards is an important first step in reducing the embodied carbon within the campus landscape.

SHIFT TO A MORE SUSTAINABLE CAMPUS LANDSCAPE

The design team's investigation and assessments revealed how the strategic sustainability goals outlined in Chapter 1 can be achieved. The following pages describe a number of landscape interventions that should significantly increase ecological function and species diversity on campus, will reduce both biogenic and operational carbon emissions from lawn maintenance, will reduce herbicide use, and will increase biogenic carbon sequestration. The approach can be summarized in three big moves:

1. Maximize Tree Canopy Cover

2. Revive the Legacy of Hort Woods

3. Maximize Sustainable Ground Flora

Proposed landscape changes should be in line with the traditional campus vernacular. The current campus aesthetic can be described as an open savanna archetype, created primarily through trees set in turf. Existing planting beds with typically low herbaceous ground covers under trees and some shrubs fall into this general campus aesthetic.

In order to achieve project goals, proposed landscape changes should be applied as quickly and completely as possible. They are not listed in hierarchical order, but should be implemented simultaneously. Important information about typology installation and long-term management are given in the following pages.

Maximize Tree Canopy Cover

Add as many trees as possible to increase carbon sequestration, cooling shade, canopy rain water interception, habitat, and food sources for wildlife. There are many areas on campus where tree canopy can be increased. However, the robust utility infrastructure throughout core campus is a limiting factor for tree plantings.

The highlighted areas represent opportunities for increased tree canopy cover en masse, with minimal subsurface utility conflicts.

Revive the Legacy of Hort Woods

An open horticultural woodland typology is dually inspired by Penn State's history as a pioneer in forestry education as well as the historic footprint of Hort Woods, which stretched all the way down the spine of campus to Old Main. Restoring and expanding this typology will help increase the regional diversity of native plant and animal species and can be a building block for the growing body of research on the human and physical benefits of stratified woodland typologies.

The highlighted areas represent opportunities for increased tree canopy cover en masse, with minimal subsurface utility conflicts.

Maximize Sustainable Ground Flora

Improve existing planting beds or convert to new vegetation typologies to reduce maintenance needs, improve aesthetic appeal, and increase ecological function and carbon sequestration.

The dark green areas represent opportunities to maximize sustainable ground flora by transitioning underutilized landscape areas to higher performing landscape typologies.

Existing sustainable landscape typologies, such as rain gardens, existing meadows, and green roofs, are not subject to this report and should be analyzed and improved simultaneously to this effort to decrease maintenance needs and improve overall function and aesthetics.

Green Roof at the Forest Resources Building
Image Credit: BLTa-A Perkins Eastman Studio

Rain garden at the Chemical & Biomedical Engineering Building

MAXIMIZE TREE CANOPY COVER

Penn State's campus has an outstanding and exceptionally well maintained tree collection. Current canopy cover is approximately 25% (see diagram) and holds a wide variety of site-adapted trees of varying sizes.

Site investigation and conversations with Penn State staff revealed that there are opportunities to significantly increase canopy cover by strategically adding trees of varying sizes. The diagram to the right shows where more expansive future tree additions may be possible.

Individual tree placement should be carefully evaluated by campus landscape architects or Hort Techs to avoid underlying utilities and structures, consistent with current practices. Important sight lines and the open savanna-like character of campus should generally be preserved.

Priority should be given to large canopy trees. If an area is too small or placement of canopy trees is not possible due to utilities or other constraints, place smaller understory tree species. If no trees can be fitted in, use large shrubs and limb them up if needed.

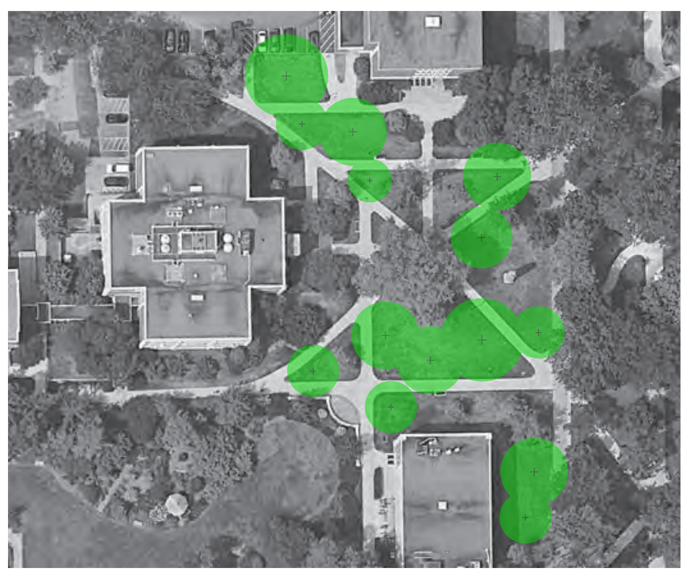
Tree Addition Guidelines

Tree spacing and vertical layering should be carefully evaluated to preserve campus safety and ensure tree additions are in line with overall campus aesthetic. Avoid thick shrub massings where visibility and perceived safety are important, for example directly adjacent to walkways.

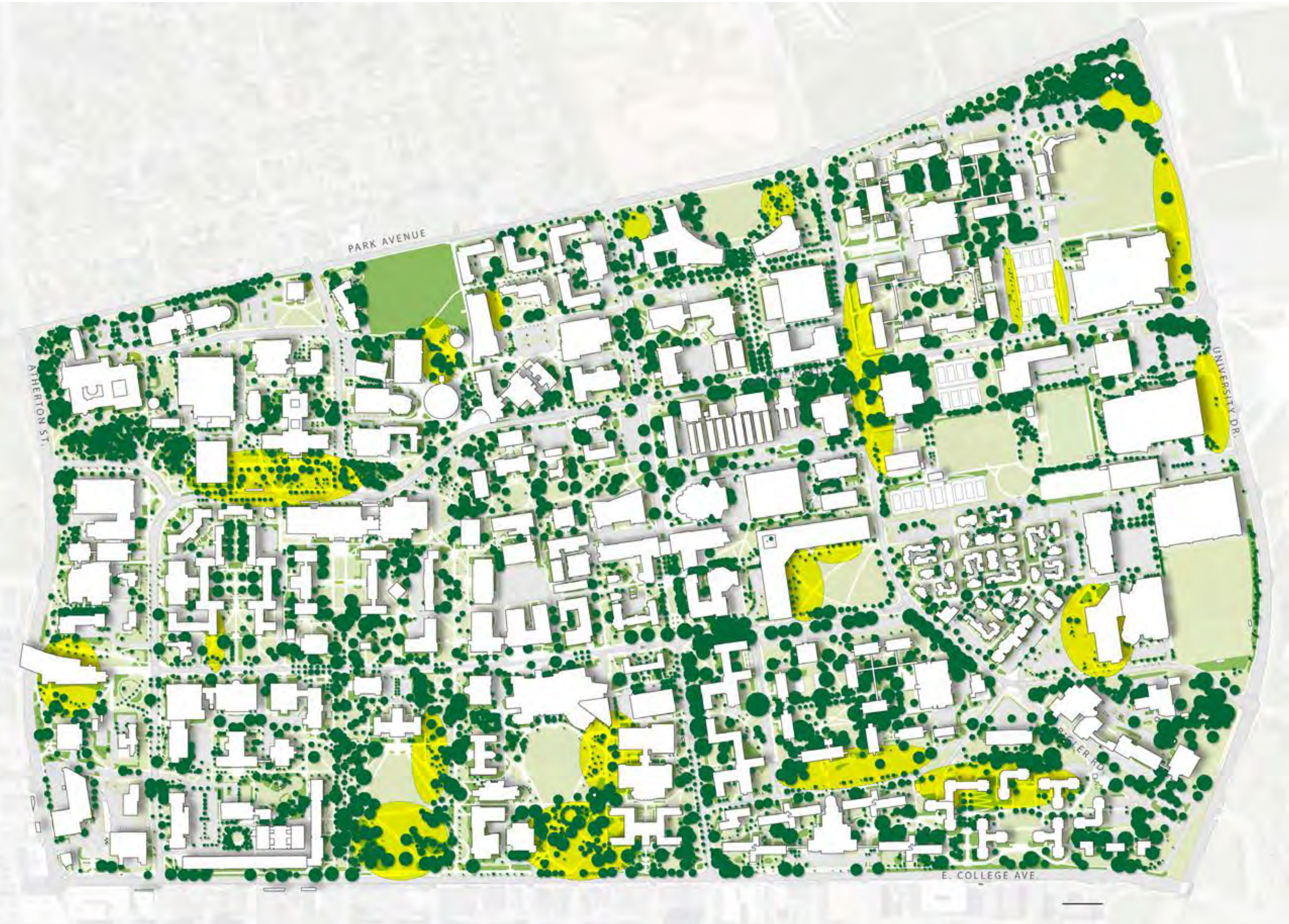
Create more evocative landscape moments by repeating some tree and shrub species within a view shed. While monocultures should be avoided, stronger, more designed clusters can create spectacular flower and fall color events on campus.

Select only most adapted species and cultivars. Use a majority of American native trees and consider the shifting plant hardiness zones. Focus on more heat and drought adapted mid-Atlantic and southeastern US ecotypes and species. Ensure trees are not invasive or have the potential to become invasive in the future.

Collaborate with national arboreta, ecologists, and plant collectors to expand species and genetic diversity of campus trees and understand their impact on indigenous fauna.



An example showing an expanded existing tree canopy by nestling in canopy and understory trees of varying sizes, where possible.



Existing canopy cover illustrated in green, with yellow highlighted areas indicating opportunities for additional tree canopy en masse due to limited utility conflicts and ample, underutilized open space.

Refer to APPENDIX E for more ground flora typology details

REVIVE THE LEGACY OF HORT WOODS

As illustrated in the historic image on the facing page, the footprint of Hort Woods was drastically larger than it is today. It is generally accepted that species richness follows a consistent pattern of an increasing number of species with increasing size of the area. Unfortunately, development follows the same pattern in reverse.

While it is not feasible within core campus to consider full forest restoration, the aim of this approach begins with the preservation of spaces such as Hort Woods and Chapel Woods. The next step is to expand smaller patches of open woodland with characteristic species and associates of the dominant ecological communities of the region throughout the footprint of the original Hort Woods and along the edges of the campus core, where some of the mature legacy trees still remain extant. Restoring these areas as open woodlands and small forest patches will expand the network of native plant community corridors (or closely associated patches), ultimately leading to increased species diversity.

Attention should be paid to maximizing the structural diversity of vegetation to maximize the variety of habitats available for animals and plants, while also maintaining awareness of human safety and security concerns.

Within this open woodland typology, reduced management and maintenance are necessary to provide the opportunity for increased diversity. Dead leaves, twigs, and other debris are food sources and nest cavities for trophic interactions. Decreased management intensity will increase the complexity of the environment and ultimately will cost less than intensive management.

The aesthetic impacts of this shall be considered as well. The landscape language shall communicate human intention and care in these areas, so that these areas can be widely accepted and appreciated. Refer to Joan Iverson Nassauer's "Messy Ecosystems, Orderly Frames" research for additional context on the importance of design in improving ecological quality in the public realm.

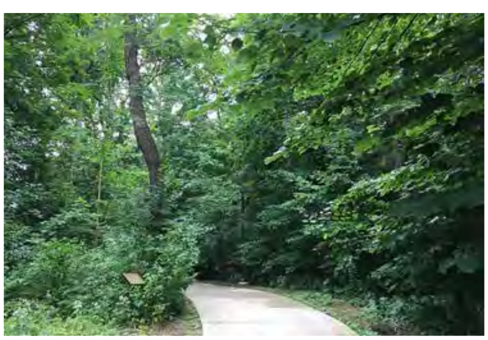
Principles for Restoring Diversity

In the context of an open woodland typology, the design team is seeking expanded opportunities to maximize biological diversity through the implementation of a network of interconnected open woodlands throughout core campus. While the predictive powers of ecology are limited, it is understood that the application of the following ecological principles (adapted from the *Landscape Restoration Handbook - Harker & Evans*) will result in increased diversity:

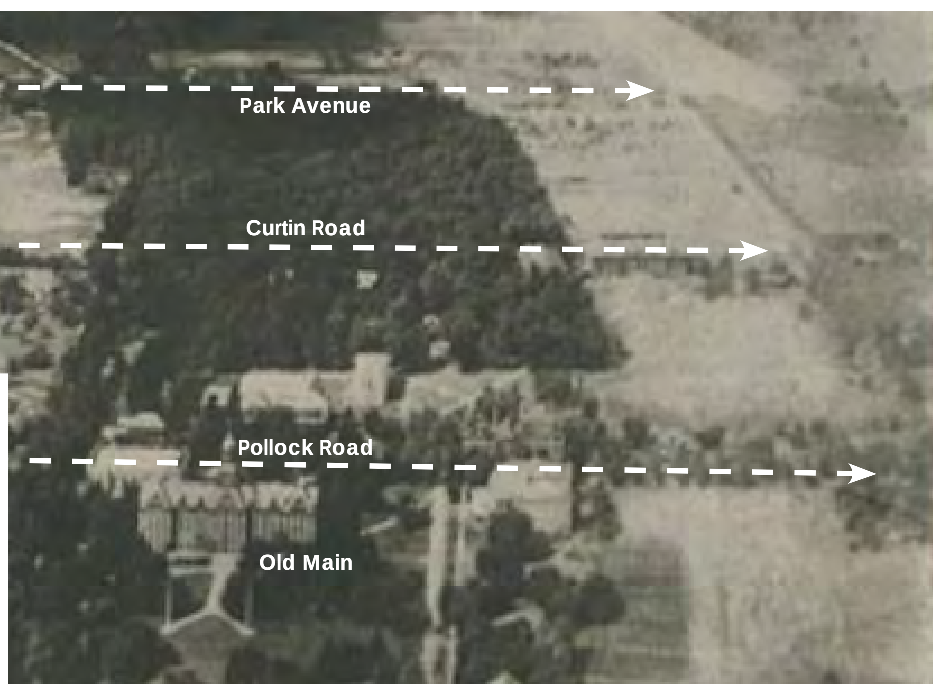
- Preserve as many large natural communities as possible
- Increase the size of existing patches to the minimum size needed to sustain viable wildlife populations
- Avoid fragmentation where possible while creating new open woodland patches, with attention paid to maximizing interior habitat
- Where fragmentation is necessary, minimize isolation of patches by developing broader corridors

A diagram of opportunities for restoring natural diversity through the preservation and expansion of existing woodland remnants within core campus.

A character example of an open horticultural woodland typology, with limited understory for clear sight lines.



A paved walk through Hort Woods, with structural diversity of vegetation at its edges, and interpretive signage to communicate the history and value of this important landscape.



Historic photo showing the extent of Hort Woods after construction of Old Main and other early campus buildings. Present-day roads overlaid to illustrate the scale of the woodland.

Refer to APPENDIX E for more ground flora typology details

Revive the Legacy of Hort Woods

Mature forest once covered larger areas of campus. Hort Woods is one of the only sizeable fragments of woodland that still remains, but it is isolated and too small to sustain a healthy forest ecosystem. Underused turf areas and mulch beds can be converted to woodland ecosystems greatly enhance habitat diversity on campus and create large enough areas for more resilient woodland ecologies.

The proposed woodland is open, inviting, and bright. Dense layers of ground flora erupt in seasonal flower events and are mostly winter green for optimal weed suppression. It is important to develop a plan for curating an uneven age stand of trees (a variety of species at seed/seedling/whip/sapling and even small caliper sizes) to kick-start and maintain tree age diversity.

Suitability

- Medium to large areas in lower visibility parts of campus.
- Proximity to existing Hort Woods is desirable to connect to existing woodland ecologies.
- Suitable for areas with or without existing trees.

Installation

- De-compact soils if needed, based on a soil scientist's recommendations. Tilling should be avoided.
- To the extent that resources allow, enhance soil tilth and drainage to improve conditions for plant success.
- Enrich soils with organic matter, such as good quality (low nitrogen, high carbon) compost.
- Install trees, shrubs, and herbaceous ground flora. Overseed area to build up seed bank of desirable species.

Management

- Regularly monitor for invasive trees, vines, and perennials and remove.
- Structurally prune trees if needed to increase tree health and resistance to storms.
- Enhance ground flora with more shade tolerant species once canopy has filled in.

Challenges

- Visibility for increased safety can be created by limbing up trees and shrubs above sight lines. Ground flora species should be low in height.
- Dense tree spacing at installation speeds up growth and reduces weed pressure on the ground.
- Soils should be amended with low nitrogen organic matter to provide maximum nutrition for trees.

Inviting, open and bright upland chestnut oak forest.

Spring beauty theme.

Wintergreen Christmas ferns.

Refer to APPENDIX E for more ground flora typology details

MAXIMIZE SUSTAINABLE GROUND FLORA

Sustainable ground flora is simply a way of describing designed low input plantings that effectively cover the ground and provide some sort of ecological or environmental function, such as habitat, food source, or carbon sequestration. Ground flora can be a combination of woody plants, herbaceous perennials, biennials, annuals, graminoids (grasses & grass-like plants), and bulbs. Sustainable ground flora is differentiated from "groundcover" in that it provides an important ecological service, above and beyond (or in addition to) its aesthetic attributes.

The sustainable ground flora typologies proposed here are specifically designed to succeed in the unique conditions on campus, such as high soil compaction, high alkalinity, and no irrigation to name a few. The design team has proposed only a limited number of typologies to be used campus wide, in order to:

- Visually unite the campus aesthetic
- Simplify the implementation of recommendations
- Streamline plant procurement (and possibly in-house production of select items)
- Optimize maintenance

Large scale conversion

Large scale turf conversions are perfect for seeded meadows.

Medium scale conversion

An example of a medium scale turf conversion to planting opportunity on campus.

Small scale conversion

Plant smaller, highly visible beds around buildings.

Replace fragmented, hard to mow turf patches.

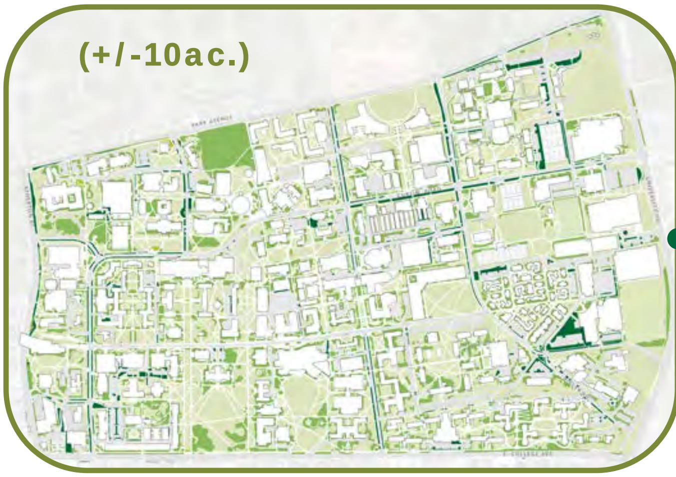
Refer to APPENDIX E for more ground flora typology details

Lawns in Dense Shade

There are examples across campus of struggling lawn areas in moderate to dense shade conditions that make it difficult for lawns to flourish. These areas are typically not sought out for recreational use and should be considered for change.

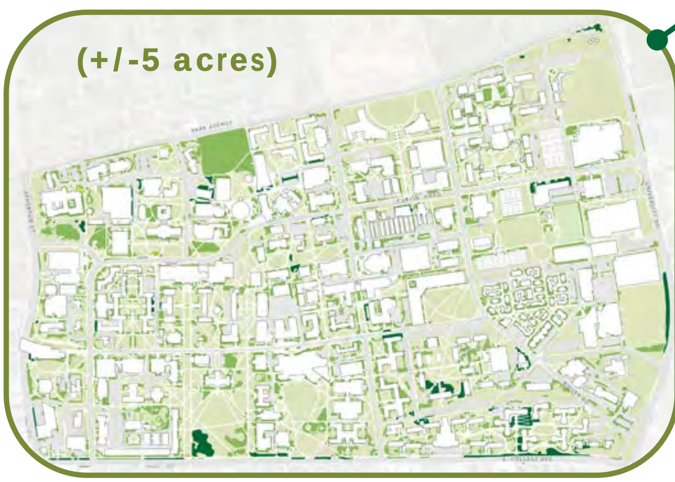
Opportunity areas to Maximize Sustainable ground flora

Improved landscape performance will be achieved by replacing higher-emitting landscapes with lower-emitting ones, while concurrently increasing the carbon sequestration potential of those areas. To meet the SLIP sustainability goals, input reductions & increased sequestration must occur on all +/-85 acres of the identified areas. The focus areas for maximizing sustainable ground flora shall include the following:



Lawn Verges and Parking Islands

Lawn verges and parking islands are impacted by annual snow & salt loads, and severe soil compaction. These areas are time-consuming to maintain and require annual repair from winter damage.



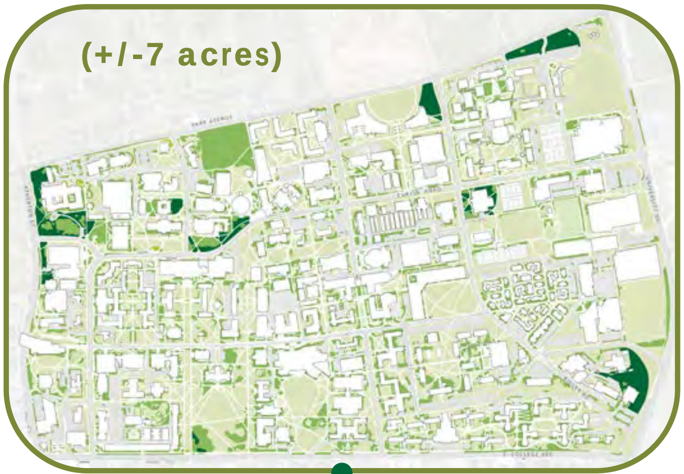
Composite diagram of all existing underutilized lawn areas proposed to be transitioned to another type of ground flora

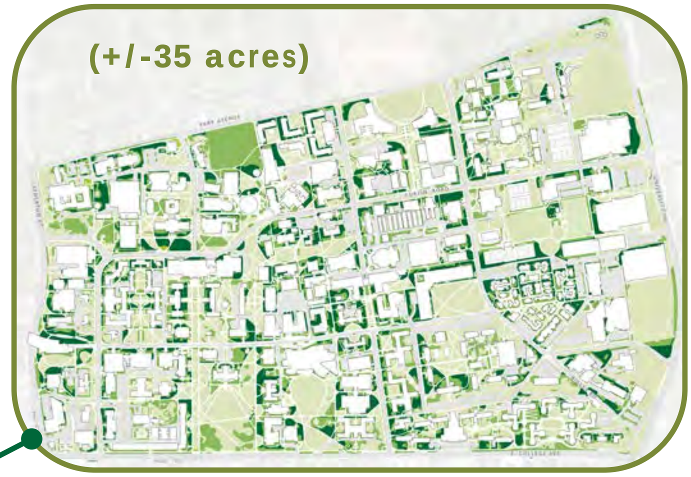
Steep Lawn Slopes

Steep lawn slopes are difficult to maintain and are essentially unusable. Changing these challenging sites to a more sustainable landscape typology can lower maintenance inputs and provide environmental benefits.

Expansive Mulched Areas

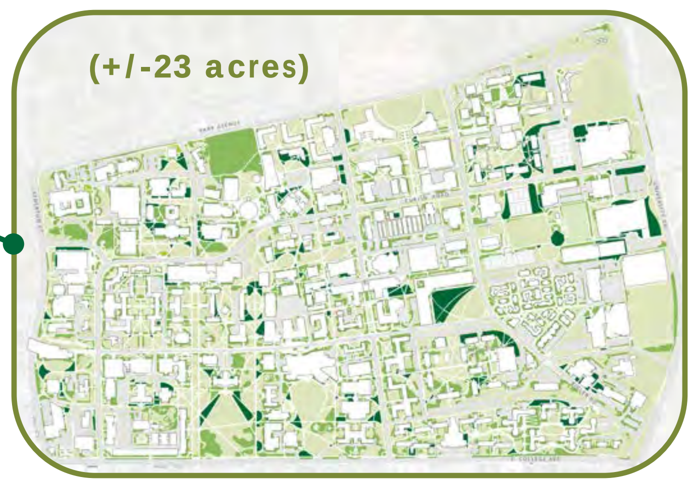
Large mulch beds are pervasive across the campus, adding little ecological value to the campus landscape.





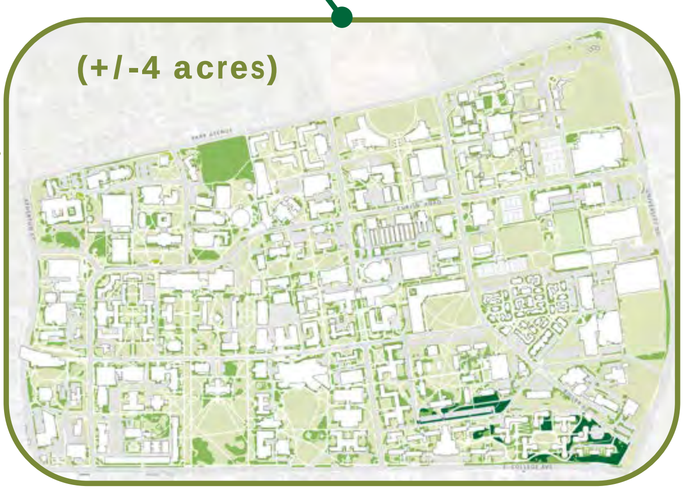
Expansion of Existing Planting Beds

There are innumerable examples of lawn fragments as a result of multiple tree saucers, utilities, furnishings, and encroachment from plantings. These areas are difficult to mow and are unusable for recreational purposes. In many instances, an expansion of existing planting beds out to existing paving will eliminate these fragments and will reduce the tedious tasks of lawn trimming and push-mowing around a variety of obstacles.



Self-Contained Lawn Panels

There are many examples across core campus of lawn panels framed by circulation routes on all sides. These self-contained islands of lawn have no relationship to any particular building or planting, and therefore have no context in many cases. These may present opportunities to experiment with new and unique landscape types.



Refer to APPENDIX E for more ground flora typology details

Ground flora typologies

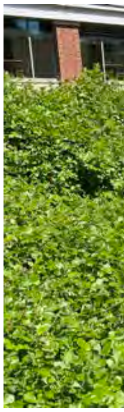
The diagram illustrates the general gradient between proposed ground flora typologies and planting area size. The allocation of ground flora typologies across campus is the responsibility of Hort Techs and Landscape Architects. The described typologies can be improved upon over time as Hort Techs gather more experience implementing these, and as climate and species availability changes.

Larger areas

Stylized sun meadow

Turf conversion to meadow

Stylized shade meadow

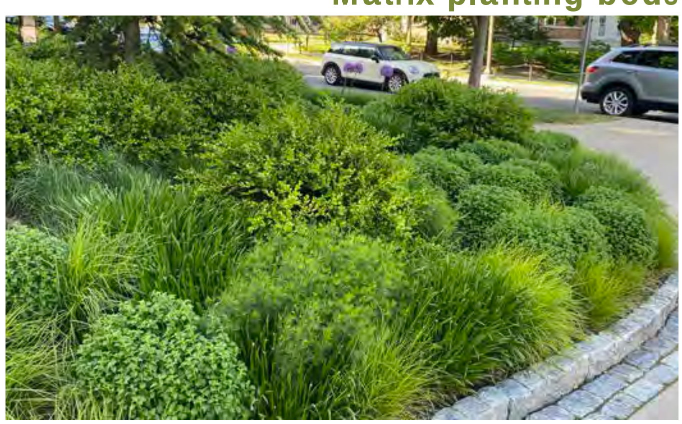


Smaller areas

Block planting beds

Low shrub massing

Matrix planting beds



Stylized Sun Meadow

This typology consists of a short meadow with several showy bloom events throughout the growing season. A high percentage of grasses ensures attractive winter appeal while naturalizing bulbs bring the meadow to life in spring. Integrated high-performing forbs throughout the growing season are the foundation of abundant pollinator populations and bring this meadow to life.

Suitability

- Full to part sun.
- Large to medium scale turf conversions.
- Low to medium productivity soils.
- Areas with limited soil depth and moderate to high levels of compaction.
- High to low visibility areas.
- Locations with nutrient rich, moist soil typologies must be avoided.

Installation

- This meadow is installed through a combination of seeding, plugging, and bulb planting.
- Only use custom seed mixes for ideal species composition. Seeds sustainably procured from local or regional ecotypes are encouraged.
- Installation should be performed by experienced meadow installers with appropriate equipment, like specialized seeders.
- Tilling soils ahead of installation should be avoided. The need for, and extent/depth of decompaction should be established by a soils expert using a penetrometer. If decompaction is required prior to seeding, the soils expert will specify the appropriate equipment to loosen up soil while minimizing damage to soil particles.
- Areas with extensive invasive plant populations should be properly treated prior to seeding.
- Temporary erosion matting may be needed to increase seed germination and prevent erosion.

Management

- Mow annually before bulbs come up. Remove organic debris and compost if possible. See Appendix E for additional mowing requirements during establishment.
- Spot treatment for invasives such as Canada thistle, mugwort, autumn olive, and oriental bittersweet may be necessary in perpetuity.
- Strategic cutting with land management equipment and organic debris removal may be needed to control any unwanted cool season grasses and weedy forbs.
- Occasional overseeding with custom seed mixes may be necessary to ensure strong flower themes and resistance to weed invasion.

Challenges

- Tall grasses and forbs must be avoided to ensure low height and maximum aesthetic appeal. Only use custom seed mixes of predominantly regionally native forbs and graminoids.
- Put up signage educating the public about meadow establishment, especially in the first year(s) when plants are still small.
- Discourage people from stepping into and playing in meadow to avoid plant trampling, unsightly foot paths, and soil compaction, which invite weed incursion.

Attractive stylized sun meadow on medium productivity soil. Emerging Coreopsis flower event in summer, taking over after a robust spring meadow phenology, attracts pollinators and adds visual interest.

Asclepias tuberosa flower theme in summer.

Attractive meadow grasses in fall and winter.

Refer to APPENDIX E for more ground flora typology details

Stylized Shade Meadow

This ground flora typology is a dense tapestry of low graminoids inter-planted with long-lived forbs and bulbs. The selected species thrive in part shade near buildings or under trees. Colorful seasonal flower themes erupt out of this lush, green carpet several times during the growing season. The majority of species are winter green and high in ecological function.

Suitability

- Designed to replace bare areas, mulched beds, or struggling turf in part to full shade.
- Suitable for medium to large areas with high to low visibility.
- Not suitable for very deep shade on the north side of buildings or immediately under large, mature trees. Refer to the “Recommendations for challenging sites”section of this chapter for detailed recommendations for very deep shade.

Installation

- If soils are highly compacted, core aerate or spot auger to loosen soil while minimizing impact on roots. Tilling soils ahead of installation should be avoided, especially if area is near trees.
- Most ground covers for shade cannot be seeded. Therefore, the majority of this typology must be installed from containers. Small to medium size containers, such as landscape plugs and quarts, are preferred.
- Species that can be seeded should be seeded after live plant installation is complete.
- Add bulbs and strategically situated forb plugs after seeding for enhanced aesthetic and pollinator values throughout the growing season.

Management

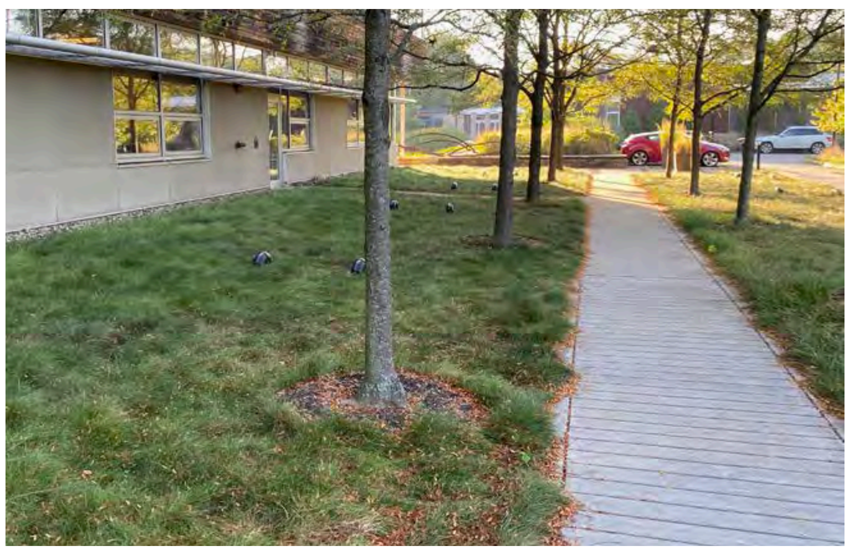
- Regular manual weed management required. Tree seedlings and invasive vines should be removed as soon as they are detected.
- Spot treat invasive weeds, such as Canada thistle and mugwort.
- Wintergreen grasses and forbs should not be mowed.

Challenges

- Installation and maintenance methods must minimize impact on existing trees.
- Will go dormant during serious drought. Emergency irrigation may be needed during extreme drought to ensure survival.
- Higher installation cost due to larger number of live plants. Use small container sizes to minimize installation cost.

Young shade meadow a few weeks after installation.

Sesleria shade meadow under trees.



Fine fescue shade meadow.

Refer to APPENDIX E for more ground flora typology details

Turf conversion to stylized meadow

Where soils are lean and dry enough, existing turf can be converted into an attractive, stylized meadow. This process requires overseeding and planting of showy forbs, grasses, and bulbs into existing turf. Mowing is reduced to occasional strategic cuts that minimize competition from existing turf grasses and ensure a more attractive meadow aesthetic.

Suitability

- Areas with low-productivity soils in full sun to light shade.
- This typology is not suitable for high to medium-productivity soils.
- Especially suitable for medium to low visibility sites of moderate to large scale.

Installation

- Invasive and undesirable species should be removed prior to meadow conversion.
- Turf should be cut low to ensure enhancement seed can form sufficient contact with soil.
- Plant showy forbs and grasses into turf. Overseed with custom seed mix.
- Strategic cuts during first growing season reduce competition from cool season turf grasses and allow enhancement species to germinate and mature.

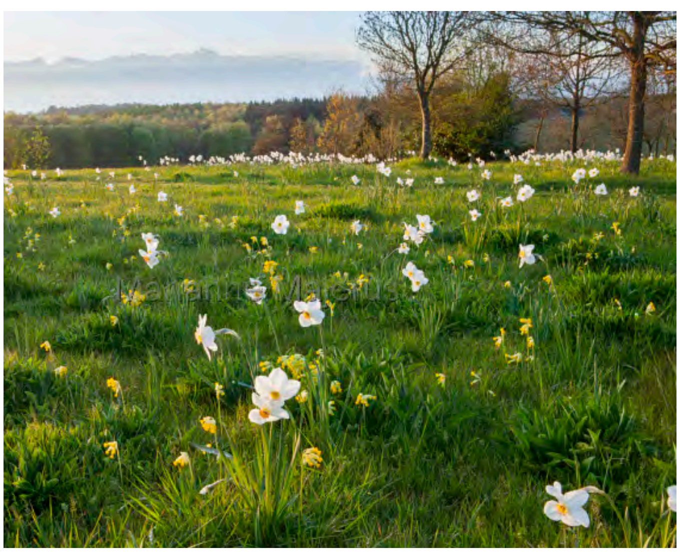
Management

- Regular, strategically timed cutting is essential to reduce competition from cool season turf grasses and ensure the survival of colorful forbs.
- Regular mowing along meadow edges creates a neater appearance and conveys intent.
- Spot treat invasive weeds, such as Canada thistle and mugwort.
- Regular tree seedling and vine removal. Remove them when they are still small.
- Occasional overseeding with desirable species may be necessary to keep seasonal flower themes strong.

Challenges

- Cool season grasses are highly competitive in our climate. Regular cutting and periodic overseeding with colorful forbs is required to preserve desired aesthetic.
- Mowed edges help frame this typology more neatly and convey intent.
- Winter interest can be improved by enhancing this meadow typology with more native warm season grasses, such as broomsedge bluestem (*Andropogon virginicus*).
- Cosmopolitan species composition includes attractive meadow species from Europe and elsewhere. It is not necessary for maintenance staff to know all species in the mix. They should, however, be familiar with problematic weeds that require immediate removal.

Traditional turf enhanced with ecologically productive forbs, such as annual Erigeron spec.



Early seasonal bulb theme after meadow cutback.

Queen Anne's lace theme in summer.

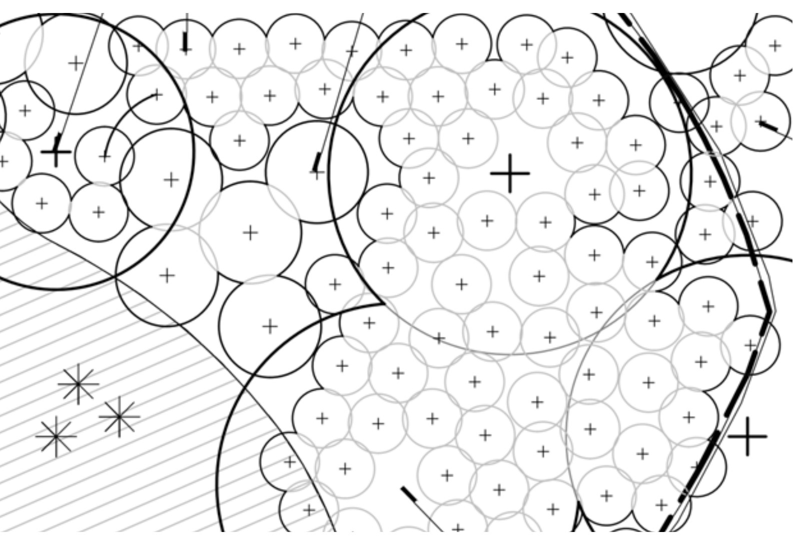
Refer to APPENDIX E for more ground flora typology details

Low Shrub Massings

Single species shrub massings of low to medium height appear to be thriving on campus already. Add more low shrub massings where suitable. To increase overall species diversity on campus, add massings of additional shrub species. Shrubs can be under-planted with tidy, shade-tolerant ground covers to reduce weed pressure and maximize ecological function.

Suitability

- Steep slopes and other hard to access areas.
- Beds where increased vegetation height and winter presence can reduce undesirable foot traffic through planting.
- Suitable for high to low visibility areas of medium size.
- Best in sun to part shade.



Installation

- Beds should be decompacted ahead of planting if needed. Avoid tilling the soil.
- Install shrubs from small to medium size containers, such as one to five gallons.
- Mulch areas between shrubs to suppress weeds.
- Install ground covers between shrubs to suppress weeds. Use small to medium size containers, such as landscape plugs or quarts.

Management

- Shrub massings require little maintenance once established.
- Refrain from excess pruning and allow shrubs to fill in and form a dense, natural-looking carpet.
- Monitor for tree seedlings and vines. Remove when detected and do not let grow tall.

Challenges

- Little seasonal change and limited pollinator value can be balanced by planting ground cover species under shrubs.
- Likely higher installation cost due to larger container sizes should be balanced by lower long-term management needs.
- Avoid taller shrubs massings as they can impact sight lines and security requirements.

Rhus aromatica 'Gro-Low' massing along steep slope.

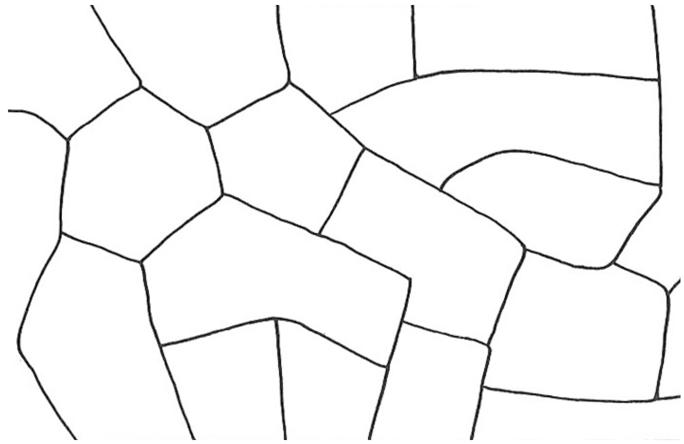
Rhus aromatica 'Gro-Low' massing.

Diervilla lonicera massing in November.

Refer to APPENDIX E for more ground flora typology details

Block Planting Beds

This typology is formed by a mosaic of single-species patches that lock together in an attractive, weed-suppressing carpet. Repetition of flowering species creates strong seasonal flower events. Species patches vary in size. Combinations of medium size blocks form colorful, highly attractive planting for the most visible areas on campus. Larger, single-species blocks are ideal for filling difficult areas with attractive, low-maintenance planting.



Suitability

- Suitable for most visible and representative beds on campus.
- Best for small to medium size beds.
- Full sun to shade.
- Species selection can be adjusted to meet all soil conditions.

Installation

- De-compact soils ahead of installation if needed. Tilling soils should be avoided.
- Install mulch for weed suppression. Do not over-mulch.
- Install block species from live plants.
- Under-plant larger block species with compatible ground covers for additional weed suppression and ecological function.
- Install bulbs.

Management

- Regular manual weed management required. Tree seedlings and invasive vines should be removed as soon as they are detected.
- Spot treat invasive weeds, such as Canada thistle and mugwort.
- Avoid annual re-mulching. If there are gaps in the planting, add more plants to fill them.
- Avoid fertilizer or compost applications unless absolutely necessary. Irrigation should only be needed during extreme drought.

Challenges

- Block plantings require slightly higher maintenance input from trained staff. Use more aggressive, weed-suppressing species or limit number of block plantings to strategic areas to balance management needs with overall maintenance capacity.
- Higher input cost during installation can be balanced by using smaller plant container sizes, such as landscape plugs, quarts, and one gallons.
- Only use long-lived species with appropriate growth behavior to ensure stability and lower maintenance needs. Aggressively spreading species should be used in single-species blocks or paired with species of similar behavior.

Mosaic of medium size blocks.

Attractive yet low-maintenance block of *Sesleria autumnalis* on campus.

Easy to maintain *Geranium macrorrhizum* block on campus.

Refer to APPENDIX E for more ground flora typology details

Matrix Planting Beds

Individual plants are layered together in an attractive, yet resilient carpet. Repetition of flowering forbs creates powerful seasonal bloom events. Bulbs provide spring color and integrated ornamental grasses ensure strong winter interest. Matrix plant palettes are carefully selected to ensure stability and long-lasting flower themes.

Suitability

- Best for smaller size planting beds in high to medium visibility areas.
- Full sun to part shade.
- Species selection can be adjusted to meet all soil conditions.

Installation

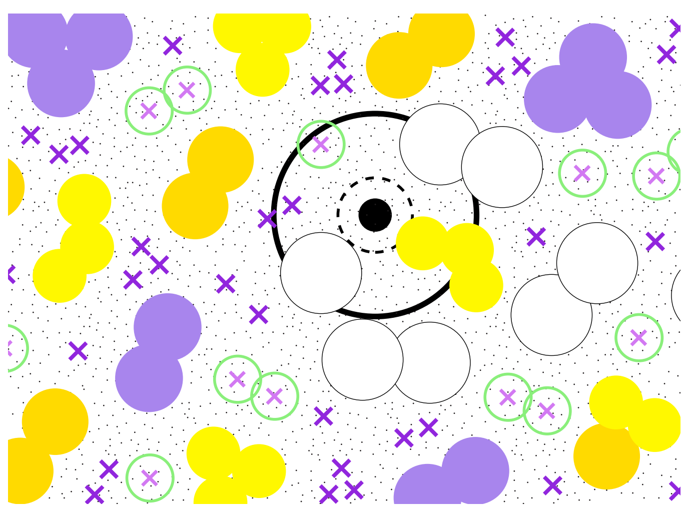
- De-compact soils ahead of installation if needed. Tilling soils should be avoided.
- Install mulch for weed suppression. Do not over-mulch.
- Install block species from live plants.
- Under-plant larger block species with compatible ground covers for additional weed suppression and ecological function.
- Install bulbs.

Management

- Regular manual weed management required. Tree seedlings and invasive vines should be removed as soon as they are detected.
- Spot treat invasive weeds, such as Canada thistle and mugwort.
- Avoid annual re-mulching. If there are gaps in the planting, add more plants to fill them.
- Avoid fertilizer or compost applications unless absolutely necessary. Irrigation should only be needed during extreme drought.

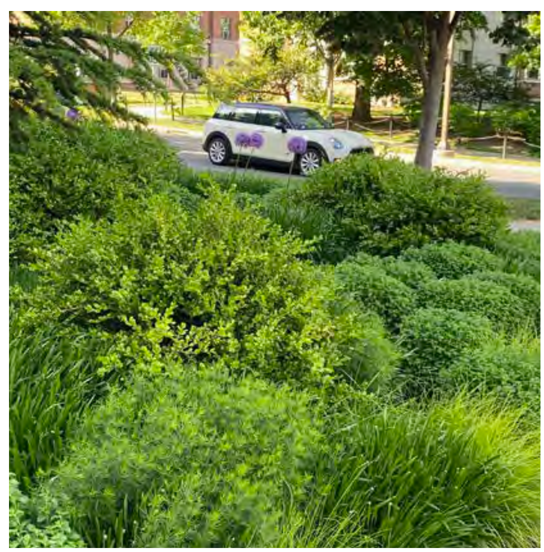
Challenges

- Matrix plantings are more visually complex than traditional block plantings. Management staff should be aware of the planting method to ensure problematic weeds are recognized and removed in a timely manner.



Matrix of shade tolerant species displaying fall aster theme.

Spring *Salvia nemorosa* 'Caradonna' theme in full sun matrix.



Attractive matrix planting on campus.

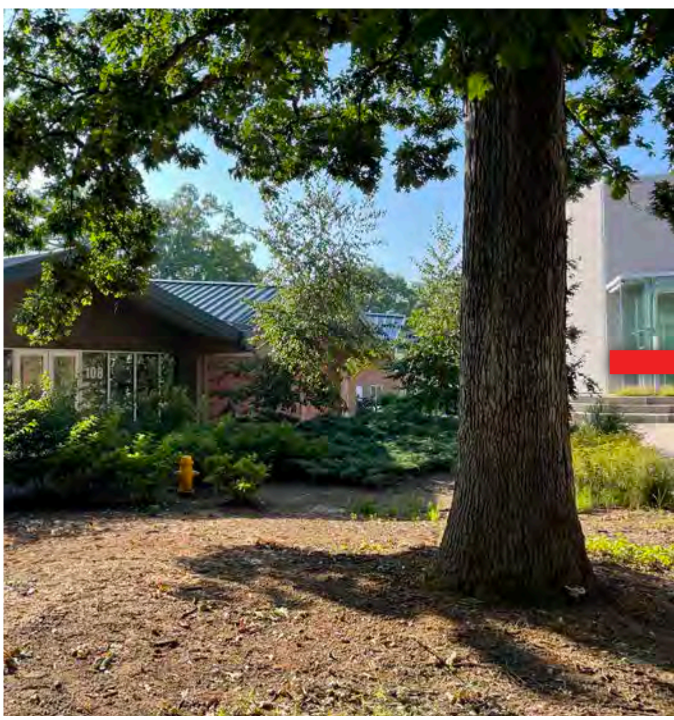
Refer to APPENDIX E for more ground flora typology details

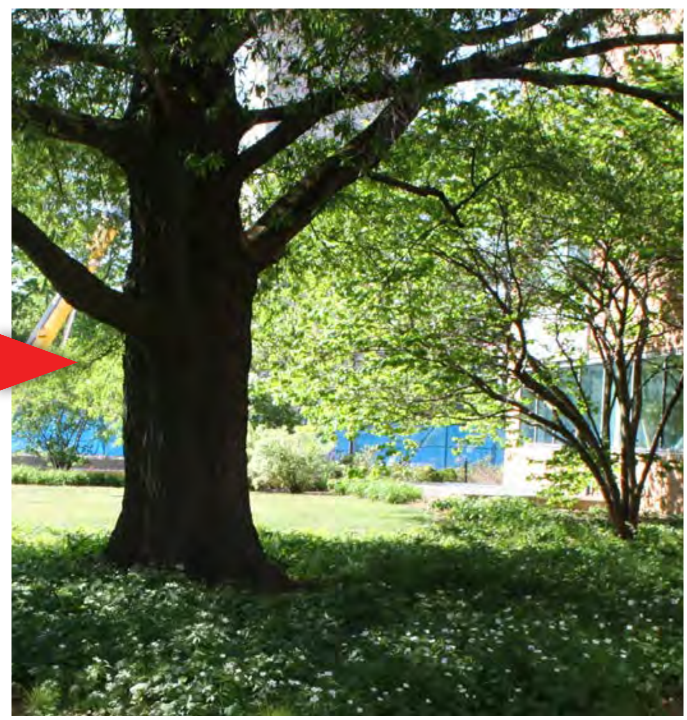
Convert Existing Planting Beds to Sustainable Ground Flora

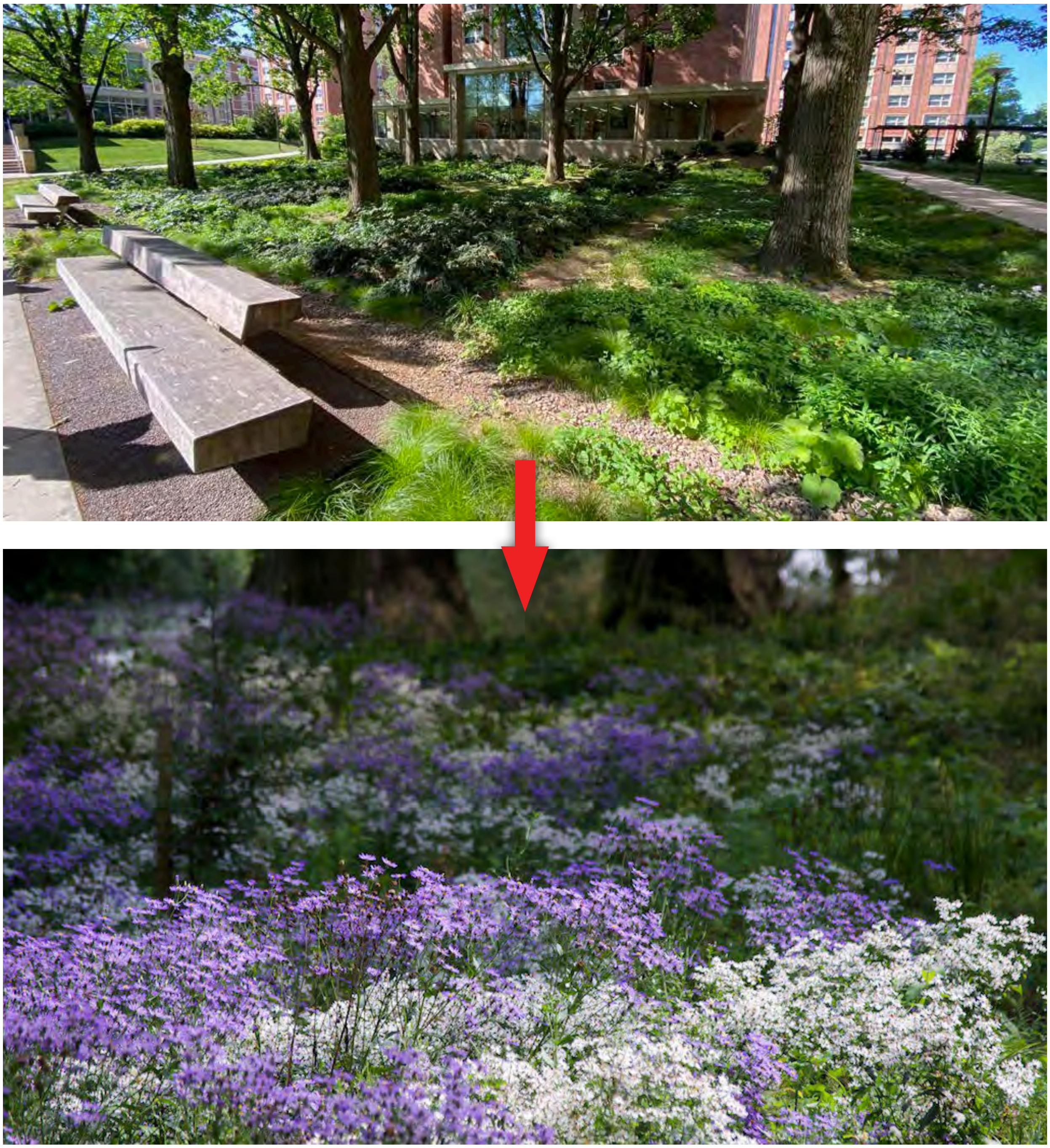
Many existing planting beds on campus could be converted into more sustainable, lower maintenance ground flora typologies. Elements that work can remain and be enhanced by more elements of target vegetation typologies. Campus landscape architects and Hort Techs should begin by evaluating current planting beds and determine if a conversion makes sense, or if total makeover and replacement with new ground flora typologies is a better decision.

Analysis and decision making process:

1. Evaluate if canopy trees can be added.
2. Determine which ground flora typologies is most appropriate based on area size, visibility, soil conditions, etc.
3. Analyze existing ground flora and determine if it can be converted into more sustainable typology or if complete replacement planting is necessary.







The planting bed shown at the top could be converted to an attractive shade meadow by enhancing it with a number of visually appealing forbs.

Refer to APPENDIX E for more ground flora typology details

RECOMMENDATIONS FOR CHALLENGING SITES

The larger vegetation typologies proposed in this report are suitable for campuses general site conditions. However, there are micro-locations with much extreme conditions that can make it challenging to get any planting to thrive. The following recommendations supplement the larger vegetation typologies where needed to establish dense, continuous, and appealing planting throughout.

Bed Edges Next to Walks & Roads

Planting along path edges can fail due to high foot traffic, winter snow piling, salt runoff from winter deicing, or extremely high pH, soil compaction, and drought stress. While no plants will survival all of these conditions in the extreme, the species listed below are known to have high tolerance towards these extreme conditions and look good along path edges.

For Sun

- *Allium* 'Millenium'
- *Antennaria plantaginifolia*
- *Bouteloua curtipendula*
- *Eragrostis spectabilis*
- *Pycnanthemum muticum*
- *Ruellia humilis*
- *Sesleria autumnalis*
- *Sisyrinchium angustifolium* 'Lucerne'
- *Symphyotrichum ericoides* 'Snow Flurry'

For part to full shade

- *Carex cherokeensis,*
- *Carex muskingumensis,*
- *Carex* 'Silver Sceptre'
- *Geranium macrorrhizum* (cultivars)
- *Packera aurea*
- *Packera obovata*
- *Sesleria autumnalis*
- *Solidago sphacelata* 'Golden Fleece'

Antennaria plantaginifolia and *Allium* 'Millenium' thrive next to hot pavement.

Extremely Narrow Planting Beds

Extremely narrow beds require species with high drought tolerance and pre-adaptation to elevated pH ranges. The species below have shown higher than usual adaptability to such conditions.

For Sun

- *Achillea millefolium*
- *Allium cernuum*
- *Allium* 'Millenium'
- *Antennaria plantaginifolia*
- *Asclepias tuberosa*
- *Bouteloua curtipendula*
- *Calamintha nepeta* (and cultivars)
- *Eragrostis spectabilis*
- *Muhlenbergia reverchonii* UNDAUNTED
- *Panicum* 'Cape Breeze'
- *Panicum virgatum* 'Shenandoah'
- *Ruellia humilis*
- *Schizachyrium scoparium* 'Standing Ovation'
- *Sisyrinchium angustifolium* 'Lucerne'

For Sun (continued)

- *Solidago odora*
- *Solidago shortii* 'Solar Cascade'
- *Sporobolus heterolepis*
- *Symphyotrichum ericoides* 'Snow Flurry'
- *Symphyotrichum oblongifolum* 'October Skies'

For part to full shade

- *Ageratina altissima*
- *Anemone canadensis*
- *Carex amphibola*
- *Carex cherokeensis*
- *Carex muskingumensis*
- *Carex* 'Silver Sceptre'
- *Chasmanthium latifolium*
- *Heuchera* 'Autumn Bride'
- *Packera aurea*
- *Packera obovata*
- *Sesleria autumnalis*
- *Solidago caesia*
- *Solidago sphacelata* 'Golden Fleece'

Thriving *Bouteloua* and *Allium* in narrow sun bed.

Healthy *Sesleria autumnalis* in part shade.

Deep Shade Under Trees or Next to Buildings

Deep, dry shade under mature trees or in the rain shadow of buildings is one of the toughest conditions for plants. The species listed below tolerate extremely low light levels while looking good for most of the season. They can be supplemented with spring ephemerals.

- *Asarum canadense, A. europaeum*
- *Carex pensylvanica, C. woodii*
- *Claytonia virginica (spring ephemeral)*
- *Euphorbia amygdaloides var. robbiae*
- *Geranium macrorrhizum (cultivars)*
- *Helleborus foetidus*
- *Packera aurea, P. obovata*
- *Pachysandra procumbens*
- *Polystichum acrostichoides, P. polyblepharum*
- *Solidago sphacelata 'Golden Fleece*
- *Stylophorum diphyllum (spring ephemeral)*
- *Viola sororia*
- *Viola striata*

Euphorbia robbiae var. *amygdaloides* thrives in deep shade.

Seasonally Wet Swales and Bioretention Areas

Resilient planting for seasonally wet area with higher risk for soil erosion. The forbs and grasses below should be under-planted with ground covers for optimal erosion control and weed suppression.

Forbs and Grasses

- *Amsonia hubrichtii*
- *Andropogon virginicus*
- *Asclepias incarnata, A. syriaca*
- *Carex emoryi*
- *Conoclinium coelestinum*

Attractive bioswale with high pollinator value.

Forbs and Grasses (continued)

- *Eryngium yuccifolium*
- *Eupatorium dubium*
- *Eupatorium maculatum*
- *Eupatorium perfoliatum*
- *Euthamia graminifolia*
- *Juncus effusus*
- *Monarda fistulosa* 'Claire Grace'
- *Panicum virgatum* 'Shenandoah'
- *Penstemon digitalis*
- *Phlox paniculata* 'Jeana'
- *Physostegia virginiana* (and cultivars)
- *Pycnanthemum muticum*
- *Pycnanthemum virginianum*
- *Rudbeckia fulgida var. fulgida*
- *Rudbeckia fulgida var. deamii*
- *Ruellia humilis*
- *Sorghastrum nutans*
- *Symphyotrichum laeve*
- *Tradescantia ohiensis*
- *Verbena hastata*
- *Vernonia glauca*
- *Zizia aurea*

Ground covers

- *Carex amphibola*
- *Carex cherokeensis*
- *Carex vulpinoidea*
- *Packera aurea*
- *Prunella vulgaris*
- *Salvia lyrata* (and cultivars)
- *Viola sororia*
- *Viola striata*

Very Steep Slopes

Clonal perennials with semi-evergreen winter foliage are especially suited for stabilizing steep, highly erodible slopes in sun to shade.

For Sun

- *Allium* 'Millennium'
- *Diervilla lonicera*
- *Juniperus chinensis cultivars*
- *Monarda fistulosa* 'Claire Grace'
- *Penstemon digitalis*
- *Pycnanthemum muticum*
- *Rhus aromatica* 'Gro-Low'
- *Rudbeckia fulgida* var. *fulgida*
- *Sesleria autumnalis*
- *Sisyrinchium angustifolium* 'Lucerne'
- *Stachys officinalis* 'Hummelo'
- *Solidago rugosa* 'Fireworks'
- *Symphyotrichum ericoides* 'Snow Flurry'

For part to full shade

- *Carex amphibola*
- *Carex cherokeensis*
- *Carex divulsa*
- *Carex flaccosperma*
- *Carex morrowii 'Ice Dance'*
- *Carex muskingumensis*
- *Chasmanthium latifolium*
- *Eurybia divaricata*
- *Geranium macrorrhizum* (cultivars)
- *Geum fragarioides*
- *Packera aurea, P. obovata*
- *Prunella vulgaris*
- *Sesleria autumnalis*
- *Solidago sphacelata* 'Golden Fleece'

Wintergreen basal foliage on *Pycnanthemum muticum*.

OPERATIONAL ADJUSTMENTS

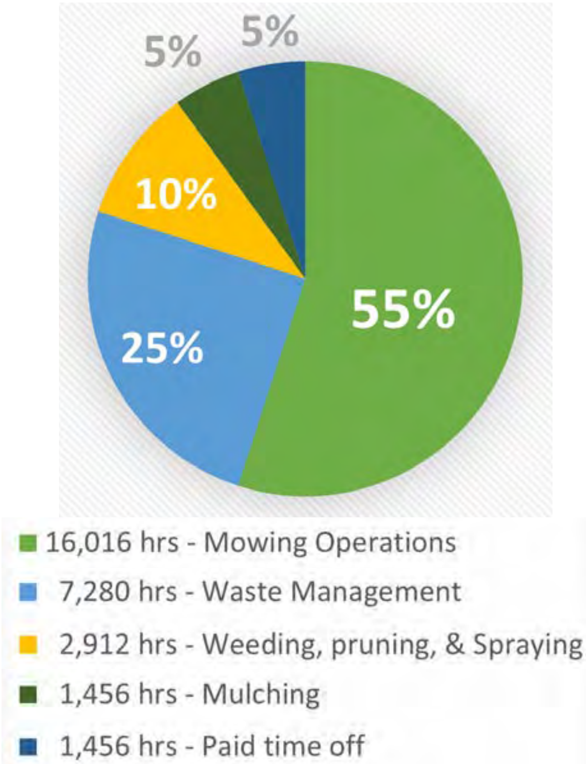
The landscape of core campus is maintained largely out of the Nittany and Pollock landscape shops. It is generally understood that each shop contains similarly sized crews with the same levels of training and expertise. There are some existing OPP Grounds manager and supervisor vacancies that are in the process of being filled, which will help to maximize efficiencies across the maintenance shops.

The primary management procedures for most of the staff in these shops includes turf care, trash and litter management, and snow removal. Landscape bed maintenance is another responsibility, which includes mulching, pruning, plant replacement, leaf removal, and watering as necessary. There are tree care and horticultural team members that operate out of the shops as well. All landscape maintenance equipment is stored and repaired in the shops.

The proposed landscape typologies in this SLIP Report will require new skills and training, and will necessitate broader operational adjustments prior to implementation of these planting strategies. Budget cuts are also real and present, and a certain level of restructuring will be necessary, regardless of the extent to which the SLIP recommendations are implemented. This SLIP Report is just one tool in OPP's toolbox to improve the sustainability in the campus landscape. The SLIP will not solve all OPPs operational and sustainability issues, but it can be a useful resource toward achieving OPP's broader sustainability goals.

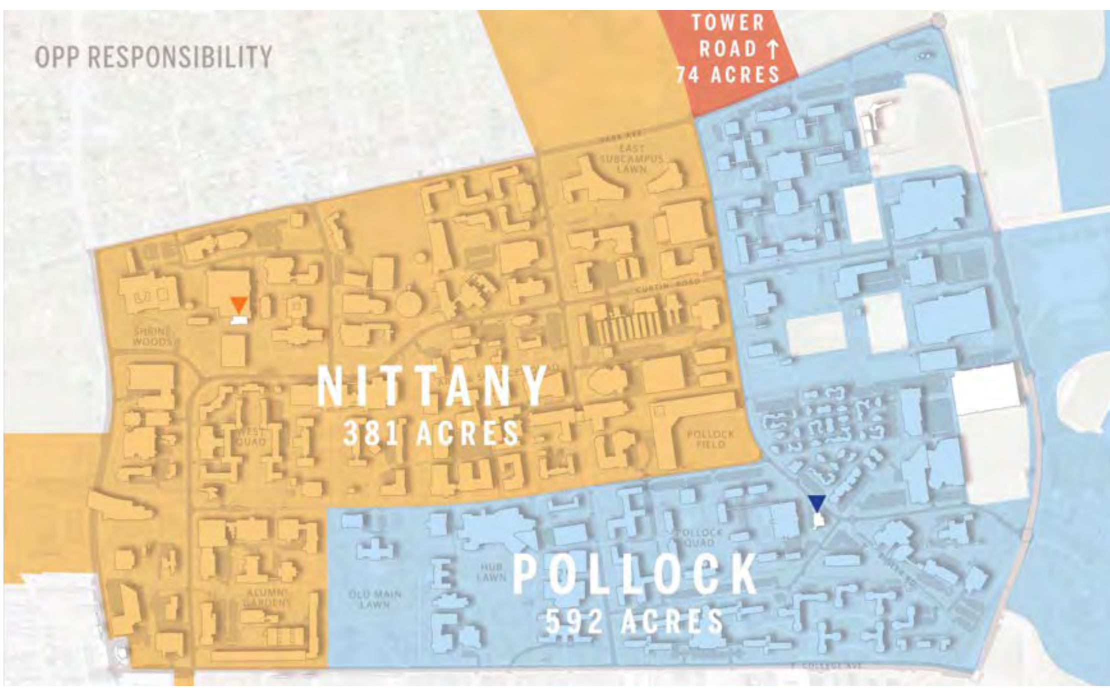
It is understood that all aspects of Landscape Services are currently under review in the context of the budget challenges. It is expected that the implementation of the SLIP recommendations will help to reduce operational labor and equipment

The OPP Landscape Services organizational chart identifies a series of vacancies that were in the process of being filled during the SLIP planning effort

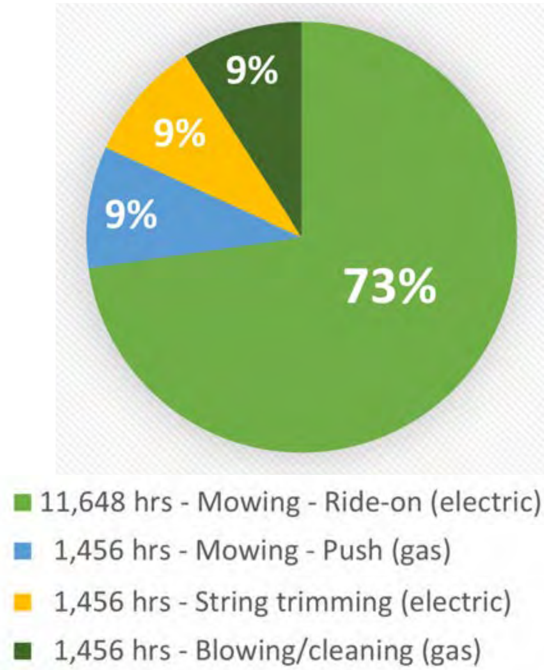


Based on discussions with the Landscape Services Grounds Maintenance Supervisors, this chart highlights the approx. annual labor hours spent performing various Landscape Services tasks within the Nittany and Pollock Landscape Shops

maintenance costs over time, and will reduce the need for herbicide spraying, weeding, and mulching once the planting typologies become established. The pilot projects identified in Chapter 4 are opportunities to track new management costs against current maintenance costs before the recommended planting typologies are implemented at a larger scale. Resulting operational adjustments may necessitate revisions to OPP's Landscape Management Guidelines. It should be noted that the SLIP Report did not take into account waste management or snow removal operations, both of which account for substantial annual labor and equipment maintenance costs as well.



Current OPP distribution of core campus landscape maintenance shops and responsibility



Based on discussions with the Landscape Services Grounds Maintenance Supervisors, this chart highlights the approx. labor hours spent performing the various mowing operations tasks during the +/-6.5 month lawn mowing season

Recommendations For More Sustainable Turf Care

Current turf management practices emit large amounts of greenhouse gases and contribute to noise pollution on campus. The consultant team's investigation identified several opportunities to reduce turf's environmental footprint while preserving the historic campus aesthetic.

Currently Penn State performs lawn mowing operations roughly 6.5 months out of the year, mowing every 5 business days (roughly every 7 days). This results in baseline lawn mowing operations emissions of 3,637,471 kg CO2e/50 yrs (3,638 tonnes).

A diagram highlighting the various ceremonial and recreational lawns within core campus. This represents less than 40% of all existing lawn areas within core campus.

As a conservative estimate, consider the following baseline assumption for annual mowing cycles:

- 6.5 months = 26 weeks.
- 26 weeks = 182 days.
- Within those 182 days are 52 weekend (non-business) days.
- 182-52=130 days of potential mowing.
- 130/5 business days = 26 mows / yr.

An eco-turf example near the Water Tower Terrace

Minimize Mowing Frequency

Option 1: Relax mowing frequency from every 5 business days to every 6 business days, resulting in +/-4 mowing cycles / year

This results in lawn mowing operations emissions of 1,666,785.40 kgCO2e/50yrs.
54.2% emissions reductions

Option 2: Relax mowing frequency from every 5 business days to every 7 business days, resulting in +/-7 mowing cycles / year

This results in lawn mowing operations emissions of 1,440,626.37kgCO2e/50yrs.
60.4% emissions reductions

Additionally, the following strategies to reduce mowing frequency:

- Cut based on height and growth instead of a set schedule.
- Do not cut during drought.
- Consider string trimming of edges only to extend period between mows.

Diversify Species Mix Where Possible

Consider the following opportunities to increase species diversity within underutilized lawn areas that are identified to be transitioned to other more sustainable ground flora typologies when resources allow (consider these strategies for recreational and ceremonial lawns to remain as well):

- Reconsider the 95% weed free threshold for less visible turf grass stands.
- Allow forbs with higher ecological value to mix with turf grasses in less visible areas (eco-turf).

Maximize Lawn Root Systems

- Encourage root depth and density for additional underground carbon storage by applying compost teas, compost top dressing, plug aeration, and giving turf more time to rest after events.
- Protect turf from construction activities and every day vehicular traffic to minimize compaction.

Recommendations For SLIP Communication and Engagement

In order for the SLIP to be successful, it will require awareness, understanding, and support from the Penn State community. Implementation of the pilot projects identified in the following chapter is a next step toward fostering an appreciation for a more ecological aesthetic and measuring the performance of the campus landscape.

OPP has made strides in evolving the traditional campus aesthetic and is far ahead of the curve in terms of transitioning away from GHG-emitting maintenance equipment. However, the general consensus has been that a better job needs to be done toward spreading awareness about the great work Penn State is already doing, as well as the ambitious work that planned for the future, including the implementation of the SLIP.

Coordinated communication and engagement campaigns should be considered as prerequisites for the implementation of the SLIP recommendations, as a way to secure interest, funding, and ultimately stewardship of the campus landscape. While management and maintenance are often not the primary topics of conversation with potential donors or other funding sources, the success of the SLIP requires that design, implementation, and stewardship are three legs that must be considered as essential in order for the SLIP to stand the test of time.

Communicating the goals and desired outcomes of the SLIP University-wide is a great starting point. The design team has identified a series of entities that could support a coordinated communication campaign to highlight the SLIP and forthcoming implementation efforts. Perhaps this effort could be managed by OPP's communications strategist with the support of the SLIP Steering Committee members to connect the following outreach partners:

- Penn State Sustainability
- Shaver's Creek Environmental Center
- The Arboretum at Penn State
- Eco Action Student Club
- Earth and Environmental Sciences Institute
- Alumni Association
- Advancement Office
- Marketing and Communications departments within the various colleges
- Penn State Outreach
- Penn State Today
- Onward State (Penn State's student blog)
- The Centre Daily Times
- The Daily Collegian
- State College.com
- WPSU / Public Radio
    - Living on Earth
    - The Allegheny Front

Students and other volunteers installing plants at the Polinator & Bird Garden. (Photo credits: The Arboretum at Penn State)

In addition to a coordinated communication effort, the SLIP will benefit greatly from an engagement initiative to ensure student involvement in both planning and implementation of the SLIP recommendations. It is in fact Penn State's student-run environmental club Eco Action that partnered with OPP to prepare a proposal for the Environmental Sustainability Fund, which is sponsored by the University Park Student Fee Board (SFB). This proposal's stated goal was to help develop a clear vision and outline the various strategies and steps forward that can be implemented to support improved sustainability in the campus landscape. It was this student interest and effort that enabled the SLIP planning to be undertaken.

The success of volunteer planting projects at the Arboretum are great examples of how students can make an impact in the implementation of the SLIP recommendations as well. The pilot projects in the next chapter are important opportunities to harness the interest and enthusiasm of the students and broader Penn State community.

Examples of landscape signage that can help educate the Penn State community on the SLIP implementation projects. QR codes, such as this one at Penn State York, are simple ways to provide curated information to the general public. More traditional interpretive signs, such as this one at Air Products Headquarters in Allentown, explain why the campus looks different than other traditional corporate headquarters.

Student volunteers assisting in the planting of native seedlings on the Penn State Health Milton S. Hershey Medical Center campus during an annual tree planting ceremony that is held in conjunction with Earth Day. (Photo credit: Penn State Health)

4 PILOT PROJECTS

PILOT PROJECTS

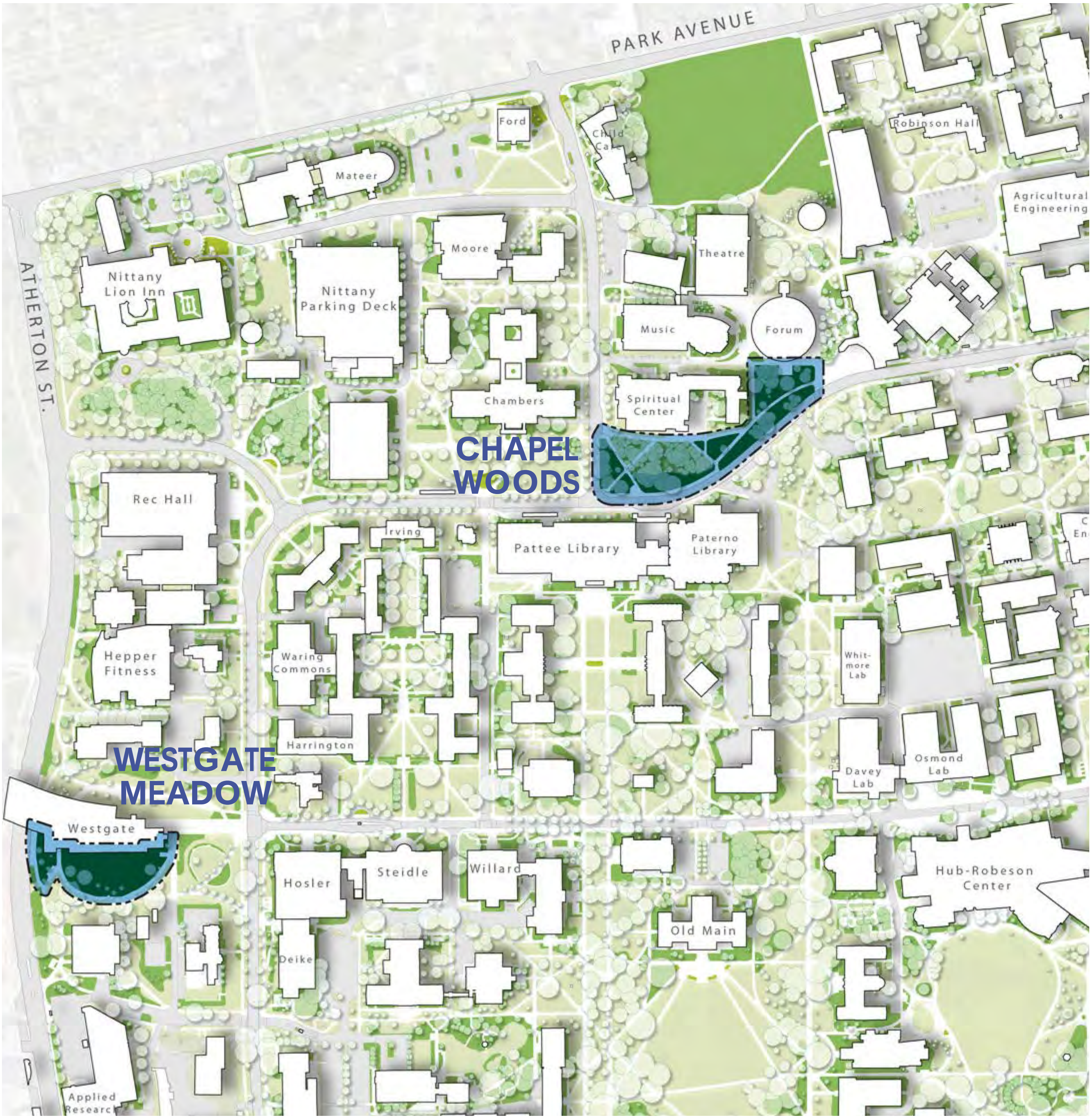
The pilot project areas at Chapel Woods, and Westgate have been selected for their ability to be stand-alone design ideas, building on their context. Both of these areas are unique and provide a variety of environmental conditions and observed landscape patterns that are generally characteristic of the rest of core campus. Selection of these pilot project locations was determined by a range of factors, including but not limited to the following:

- Reducing the footprint of underutilized lawns and high-input landscapes
- Reducing the need for push mowing and string trimming by streamlining or eliminating bed edges and other infrastructure obstacles
- Reducing or eliminating the need for annual mulching
- Opportunities for expansion of existing low-input landscape typologies
- Opportunities for teaching/learning about the campus landscape management practices

Future Implementation Opportunities

In addition to the identified pilot projects, there are a series of other potential opportunities to be considered as additional SLIP pilot project sites and/or implementation sites. These may include:

- Planned capital projects, such as the Waring Commons, Pollock Halls renovations, or new Eberly College of Science building(s)
- Planned utility and infrastructure projects, such as the stormwater improvements proposed near Research East and University Drive
- Planned demolition projects, such as Hammond, Sackett, Engineering Units, or Oswald Tower. As an example this opportunity, refer to Appendix F “Considered Pilot Project Areas” for more details on the Forestry Resources Lab demolition site.
- Other consistent problem areas that require more inputs than others, such as annual planting beds, bare edges along pathways, and sparsely planted beds.



Refer to APPENDIX F for more pilot project details and other considered sites

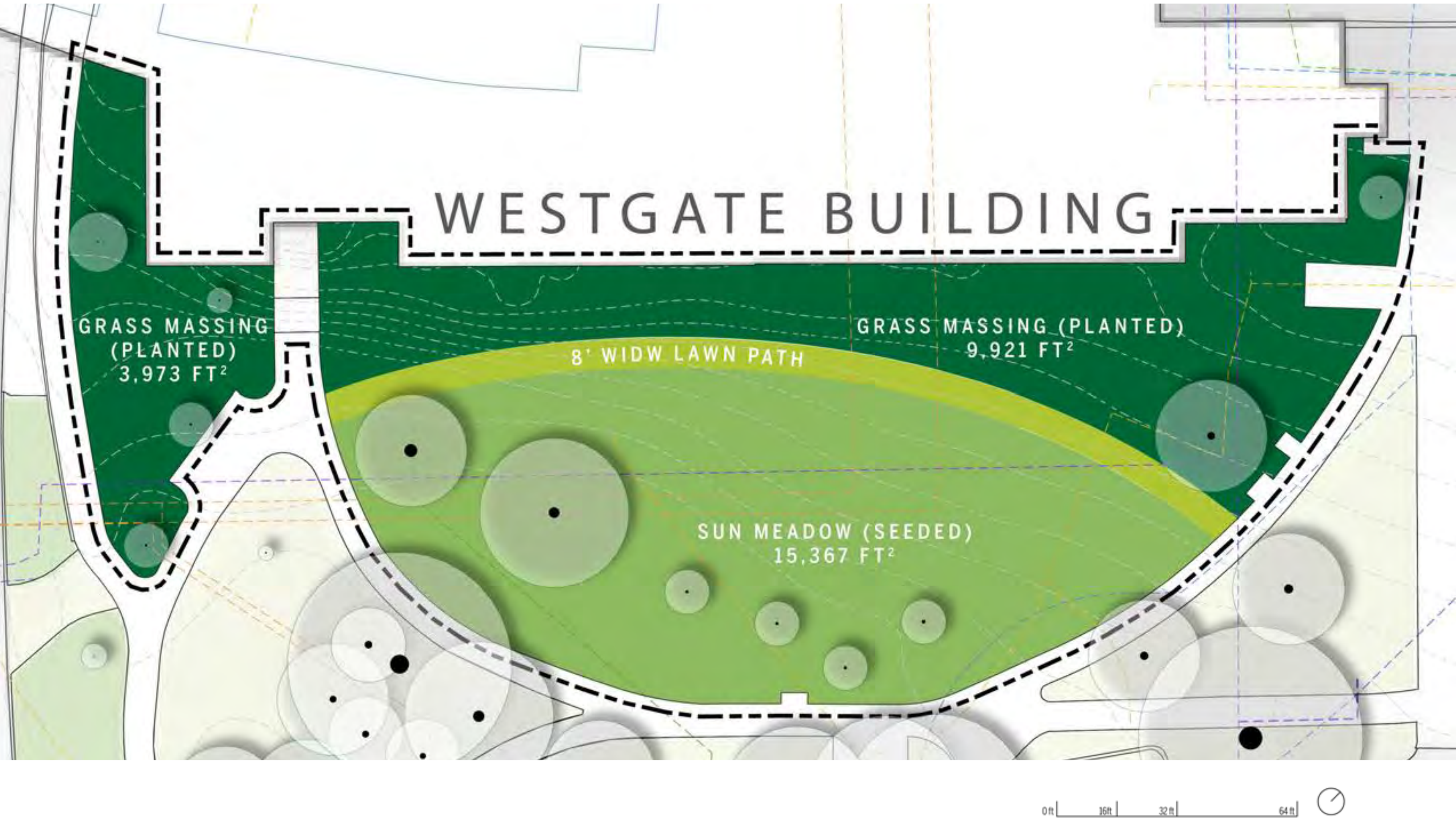
Westgate Meadow

The Westgate Meadow site was selected primarily due to the fact that it is a prime candidate for the "Stylized Sun Meadow" ground flora typology. The site has the appropriate solar exposure, scale, and visibility to be suitable for this typology.

This pilot project will replace over 15,000 contiguous square feet of underutilized lawn with a high-performing ecological short meadow with several showy bloom events throughout the growing season amongst a core of grasses that will provide winter appeal.

Additionally, a 14,000 square foot mass block planting will replace the foundation plantings along the south facade of Westgate Building, where the soils are moderately richer and the slopes are steeper. This area is designed in the spirit of the "Block Planting Beds" ground flora typology. This will provide a dense, weed-supressing groundcover that will provide an attractive and low-maintenance backdrop to the meadow.

- For installation procedures and anticipated challenges, refer to the "Stylized Sun Meadow" and "Block Planting Beds'' ground flora typologies
- Refer to Appendix E for additional site selection, preparation, installation, and management details for these typologies.



Sun meadow seed mix

Area in acres:	0.35
Area in sq ft:	15,367
Total seeds per sq ft:	150
Total seed mix (lb):	10.20
Seed mix per acre (lb):	28.91

Quantity (oz)	**Species**	**Size**
0.39	*Achillea millefolium*	Seed
11.99	*Allium cernuum*	Seed
4.61	*Andropogon virginicus*	Seed
31.61	*Asclepias tuberosa*	Seed
33.53	*Baptisia australis*	Seed
0.12	*Blephilia ciliata*	Seed
4.64	*Bouteloua curtipendula*	Seed
1.38	*Carex molesta*	Seed
1.68	*Coreopsis lanceolata*	Seed
0.11	*Coreopsis tinctoria*	Seed
3.69	*Dalea purpurea*	Seed
1.62	*Daucus carota*	Seed
14.41	*Echinacea pallida*	Seed
0.16	*Eragrostis spectabilis*	Seed
1.77	*Liatris aspera*	Seed
2.74	*Monarda bradburiana*	Seed
0.25	*Monarda fistulosa*	Seed
3.92	*Penstemon digitalis*	Seed
1.10	*Prunella vulgaris*	Seed
0.21	*Pycnanthemum tenuifolium*	Seed
0.35	*Pycnanthemum virginianum*	Seed
0.23	*Rudbeckia hirta*	Seed
30.61	*Schizachyrium scoparium*	Seed
1.95	*Sisyrinchium angustifolium*	Seed
0.65	*Solidago odora*	Seed
3.69	*Symphyotrichum ericoides*	Seed
0.53	*Symphyotrichum pilosum*	Seed
2.38	*Tridens flavus*	Seed
2.10	*Verbena stricta*	Seed
0.77	*Viola sororia*	Seed
163.18		

Cover crop

Quantity (lb)	**Species**	**Size**	**Seed rate (lb/ac)**
15.88	Regreen (sterile cover crop)	Seed	45

Block planting area (Grass Massing)

Area in sq ft:	13,894

Quantity	**Species**	**Size**	**Spacing (inches o.c.)**
500	*Carex amphibola*	LP	Scattered evenly across entire area
1,500	*Packera obovata*	LP	Scattered evenly across entire area
7,086	*Panicum virgatum* 'Shenandoah'	LP	18
9,086			

Estimated Existing Conditions Annual Mgmt. Costs: $30,535.21 ($0.98/SF)

- Based on RS Means 2022 national averages for Site Work & Landscape Costs for mowing, edging, fertilizing, weed control (chemical), aerating, and de-thatching

Estimated Proposed Conditions Annual Mgmt. Costs: $24,691.55 ($0.79/SF)

- Includes management procedures for established plantings, as listed in Appendix E: Planting typology details, and based on RS Means 2022 national averages for Site Work & Landscape Costs

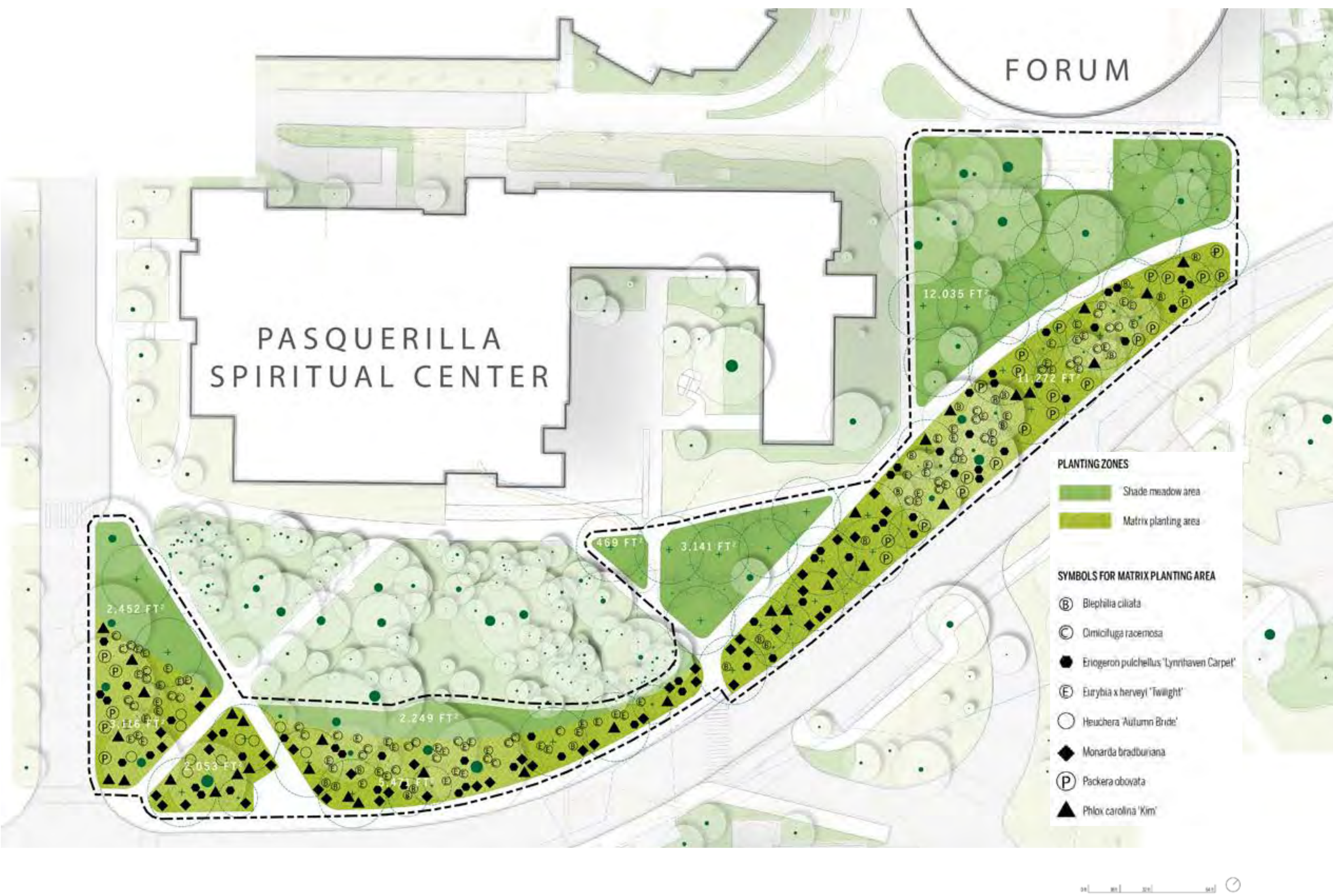
Refer to APPENDIX F for more pilot project details and other considered sites

Chapel Woods

The Chapel Woods site was selected based on its context as a premier opportunity to expand the existing "Legacy of Hort Woods" with a "Stylized Shade Meadow" ground flora typology in the protected areas under the dense tree canopy. The site has the appropriate solar exposure, scale, and visibility to be suitable for this typology.

This pilot project will replace over 20,000 square feet of underutilized lawn with a high-performing ecological shade meadow.

Additionally, an over 22,000 square foot mass matrix planting will replace the lawns along Curtin Road, where the road salts and snow loads are factors. This area is designed in the spirit of the "Matrix Planting Beds" ground flora typology. This will provide a dense, weed-supressing groundcover that will provide an attractive and low-maintenance backdrop to Chapel Woods.



Canopy and understory tree schedule

Code	Species	Quantity	Size
CaGl	*Carya glabra*	4	1 to 2" cal.
CaOv	*Carya ovata*	3	1 to 2" cal.
CeOc	*Celtis occidentalis*	3	1 to 2" cal.
CeCa	*Cercis canadensis*	7	1 to 2" cal.
CoFl	*Cornus florida*	9	1 to 2" cal.
QuAl	*Quercus alba*	7	1 to 2" cal.
QuCo	*Quercus coccinea*	10	1 to 2" cal.
QuMo	*Quercus montana*	6	1 to 2" cal.
SaAl	*Sassafras albidum*	18	1 to 2" cal.
PrSe	*Prunus serotina*	2	1 to 2" cal.
OsVi	Ostrya virginiana	3	1 to 2" cal.
		72	

Shade meadow

Area in acres:	0.47
Area in sq ft:	20,346
Total seeds per sq ft:	150
Total seed mix (lb):	14.04
Seed mix per acre (lb):	30.05

Quantity (oz)	Species	Size
1.02	*Ageratina altissima*	Seed
0.18	*Agrostis perennans*	Seed
5.45	*Anemone virginiana*	Seed
3.88	*Aquilegia canadensis*	Seed
1.14	*Blephilia ciliata*	Seed
13.56	*Carex blanda*	Seed
10.77	*Carex divulsa*	Seed
20.35	*Carex grisea*	Seed
7.32	*Carex molesta*	Seed
4.58	*Carex muskingumensis*	Seed
127.16	*Diarrhena americana*	Seed
2.15	*Festuca rubra*	Seed
2.65	*Festuca subverticillata*	Seed
10.17	*Monarda bradburiana*	Seed
14.19	*Zizia aurea*	Seed
224.58		

Cover crop

Quantity (lb)	Species	Size	Seed rate (lb/ac)
21.02	Regreen (sterile cover crop)	Seed	45

Matrix planting area (shade)

Area in sq ft:	21,912
Total plants:	18,627

Symbols (See plan for symbol locations, place symbol plants first.)

Quantity	Species	Size	Plants per symbol	Spacing (inches o.c.)
300	*Blephilia ciliata*	LP	15	14
120	*Cimicifuga racemosa*	QT/1G	3	24
540	*Eriogeron pulchellus* 'Lynnhaven Carpet'	LP	9	14
567	*Eurybia x herveyi* 'Twilight'	LP	9	18
150	*Heuchera* 'Autumn Bride'	LP	15	14
1,075	*Monarda bradburiana*	LP	25	14
1,350	*Packera obovata*	LP	50	14
875	*Phlox carolina* 'Kim'	LP	25	18
4,977				

Graminoid matrix (Place grass matrix clusters after symbol plants are arranged, then fill in with *Sesleria* .)

Quantity	Species	Size	Layout details
150	*Carex cherokeensis*	LP	Clusters of 3 to 5 plants at 24" o.c. scattered evenly across planting area.
500	*Carex pensylvanica*	LP	Clusters of 3 to 5 plants at 14" o.c. scattered evenly across planting area.
500	*Carex woodii*	LP	Clusters of 3 to 5 plants at 14" o.c. scattered evenly across planting area.
2,500	*Deschampsia cespitosa* 'Goldtau'	LP	Clusters of 3 to 5 plants at 24" o.c. scattered evenly across planting area.
100	*Viola sororia*	LP	Clusters of 3 plants at 36" o.c. scattered evenly across planting area.
9,900	*Sesleria autumnalis*	LP	Place after all other plants are laid out. Fill remaining gaps. Place approximately 14" o.c.

- Refer to the "Reviving the Legacy of Hort Woods" for installation prodecures and anticipated challenges for the open horticultural woodland plantings.
- For installation prodecures and anticipated challenges, refer to the "Stylized Shade Meadow" and "Matrix Planting Beds" ground flora typologies.
- Refer to Appendix E for additional site selection, preparation, installation, and management details for these typologies.

Estimated Existing Conditions Annual Mgmt. Costs: $20,429.19 ($0.51/SF)

- Based on RS Means 2022 national averages for Site Work & Landscape Costs for mowing, edging, fertilizing, weed control (chemical), aerating, and de-thatching

Estimated Proposed Conditions Annual Mgmt. Costs: $16,618.01 ($0.42/SF)

- Includes management procedures for established plantings, as listed in Appendix E: Planting typology details, and based on RS Means 2022 national averages for Site Work & Landscape Costs

Refer to APPENDIX F for more pilot project details and other considered sites

A

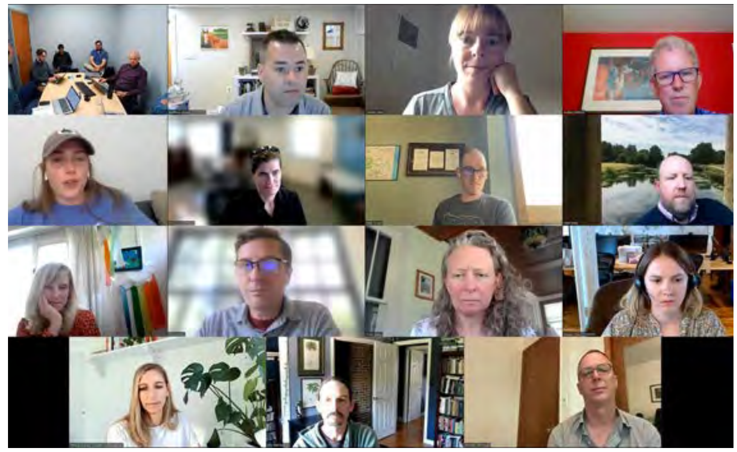
APPENDIX STAKEHOLDER ENGAGEMENT

ARTS & SCIENCES QUAD, NEAR THE ARTS COTTAGE | 2023

APPENDIX A: STAKEHOLDER ENGAGEMENT FEEDBACK

KICKOFF MEETING

The project kickoff meeting occurred on Wednesday, May 10, 2023. The meeting included Design Team and Steering Committee introductions, a brief project background from Derek Kalp, a summary of the mapping and data collected to date, and a facilitated discussion centered around what the meeting participants see as the biggest opportunities and challenges are to this planning effort. The Jam board snapshot below highlights the opportunities, challenges, and other observations that were discussed during the kickoff meeting.



WHAT WE HEARD

- This is an opportunity to shift our values & develop new habits
- Solutions need to be realistic, manageable, & supported by data to enact change
- We must educate & engage the Penn State Community as stewardship partners

CORE CAMPUS WALKING TOUR

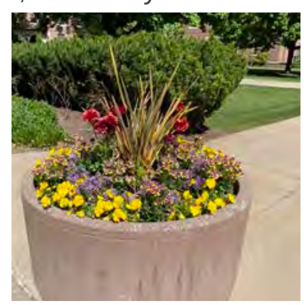
The core campus tour was an opportunity for Penn State's OPP representatives to share their observations with the Design Team in an informal way so that the Design Team could see first-hand the issues that are grappled with on a day-to-day basis. The walking tour route was designed to include the various landscape and program areas in core campus. Beginning at East Halls, the group walked south through athletics venues, Nittany Apartments, Eastview Terrace, Pollock, and South Halls. The group proceeded westbound toward the Hub and Old Main lawns, and to the Alumni Garden. From there, the group walked through West Halls, the Nittany Lion Shrine, and Fisher Plaza. Turning east, the group saw Chapel Woods, the Arts & Sciences Quad, Shortlidge Mall, Millennium Science Complex, and the East Sub-campus.

HORT TECH ONE-ON-ONES

Rather than having a discussion or workshop with all of the grounds leadership, supervisors, horticulture technicians, and staff at once, the Design Team decided to meet with each group independently to understand the opportunities and challenges that are expressed at each level of the grounds management hierarchy. The Design Team met with each horticulture technician independently on campus in an area that they currently manage, so that we could hear and see first-hand the day-to-day issues that they face. The Design team heard many re-occurring themes from each interview:

- The hort. techs appreciate the level of freedom and autonomy with which they are able to work.
- When changing traditional landscape typologies to something different or more progressive, communication and education are important factors, but are rarely done successfully.
- The dispersal of the hort. techs throughout the various maintenance shops has been challenging for most of them. Many miss the ease of communication, idea sharing, and collaboration with their counterparts.
- Pruning and mulching traditional shrub and groundcover beds takes a lot of time.
- Watering annual beds and containers is very time consuming, but the design, install, and impact of these beds is rewarding. There is a general acknowledgment that this is an unsustainable practice, and the extent of annual plantings has been cut in half in recent years.
- Herbicide spraying is a “necessary evil,” a way to save time to get on to other tasks.
- There is minimal collaboration with the rest of the grounds staff, but communication about who does what is generally good, despite occasional misunderstandings.
- Work time is finite, incremental improvements are key.

The woodland shade garden at East Halls is a good example of a more progressive and non-traditional campus landscape typology that gets a lot of questions and comments. Hort. tech Nate sees this as low-maintenance and sustainable, but may be too large of a scale for it to be universally accepted as an appropriate campus landscape typology.



Hort. tech Theresa explains her approach to managing the Alumni Gardens. Generally, her attitude is “more plants, less mulch.” She prefers more compact and dense, spreading herbaceous plantings because this keeps the weeds down. This approach has worked well in these gardens, especially when mixed with evergreens and other plants that provide winter interest. When Theresa is not in the Alumni Gardens, most of her time is spent watering her many annual display beds and containers distributed across campus.

The Schreyer gardens, south of the HUB Lawn, are quite charming out-of-the-way respites that are well-maintained under the majestic trees. Hort. tech Dan tries to create mixed beds with no more than 6-8 perennial species and evergreens for habitat and winter interest. It was observed in these gardens that the shrub, herbaceous perennial, and groundcover species are predominately of Eurasian origin with little to no pollinator value to most North American bees, flies, butterflies, beetles, and hummingbirds.

The mature canopy trees on lower Old Main lawn are an impressive collection of specimen trees. In the shade of these trees, hort. tech Adam notes that it has been a struggle to create successful widespread understory, shrub, and groundcover plantings. The dense, dry shade has been a challenge to successful plantings under these trees. As a result, the cycle of herbicide spraying and mulching in these expansive areas has been the fall-back solution to keep these areas looking clean and maintained.

Hort. techs Abby and Kate gave a tour of the Tower Road greenhouse facilities and landscape shop. Generally, 50% of all annual greenhouse production goes directly to the Arboretum. Abby noted that this makes high numbers and special requests from the other hort. techs a challenge, due to limited space and limited support to address the varying cultural needs of complex requests.

Currently, Abby noted that the greenhouses do not grow perennials for use on campus. Abby and Kate both expressed interest and capacity to expand greenhouse operations to grow perennials for use on campus, but they noted that it would require additional help and careful sequencing with annual production. They are especially keen on growing spring ephemerals, which may fit nicely in the greenhouse scheduling.

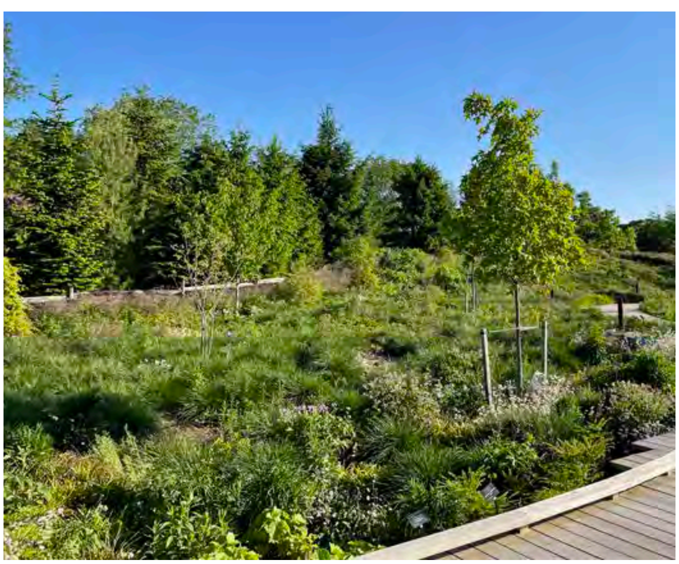
Abby expressed concern with the existing facilities that makes work more challenging. The shade house does not provide sufficient shade levels or air circulation to be used properly. Also, irrigation is a sustainability concern because the facility is not currently connected to beneficial reuse water.

APPENDIX A: STAKEHOLDER ENGAGEMENT FEEDBACK

No mow grasses at Marsh Meadow, with recent sink-hole repairs in the distance

Invasive Asiatic Bittersweet root sprouts are one of maintenance issues that require constant attention

Robust plantings along a pathway edge in the Strolling Garden



View from a boardwalk in the Pollinator & Bird Garden

The Design Team also met with hort. techs Rychele, Ted, and Kim in the Arboretum to better understand the landscape management practices there, in relation to what was observed in core campus. Clearly, the Arboretum affords them more opportunities and resources for specialty plant procurement and experimentation, but the hort. techs still try to be “thrifty” with plants. While there is a lot of rabbit and deer pressure in the Arboretum, they typically do not experience damage to the plant beds from winter plowing because they do not use any snow-melt products and they reduce plowing to narrow corridors along pathways.

The hort. techs in the Arboretum have the resources (and volunteer labor) to be more proactive about scouting for and spraying invasive weeds. Bittersweet is a constant battle, the primary source of herbicide spraying. They believe that the general maintenance crews on core campus would benefit from more training on plant and weed identification, pruning practices (a big concern), and general education on sustainability practices.

OPP BUILDING & GROUNDS LEADERSHIP DISCUSSIONS

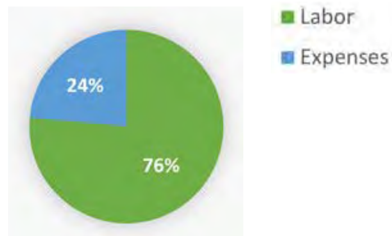
After a comprehensive campus tour and one-on-one meetings with grounds supervisors and horticultural technicians, the Design Team met with OPP's Building & Grounds leadership to review what we hears and to ask some follow-up questions related to campus-wide landscape operations. First and foremost, it became clear that budget cuts are real challenges to operations. There has been a trend of +/- $200k cuts in the annual budget for the past few years, which is projected to continue for the foreseeable future. While these cuts have been strategically addressed without compromising level of service to date, current and future budget cuts will need to impact the level of service currently provided.

In addition to the budget realities, it has been challenging balancing the union and non-union labor on campus. There are differences in the level of training across the crews, and the horticultural technicians have not typically worked directly with the other landscape crews. The dispersal of the hort. techs across the maintenance shops presents an opportunity for them to begin to mentor and educate the landscape crews about appropriate maintenance practices and procedures for shrub, perennial, and groundcover beds throughout campus. This would be especially helpful and productive when lawn mowing labor needs to temporarily be reallocated, such as when mowing is not needed due to weather conditions.

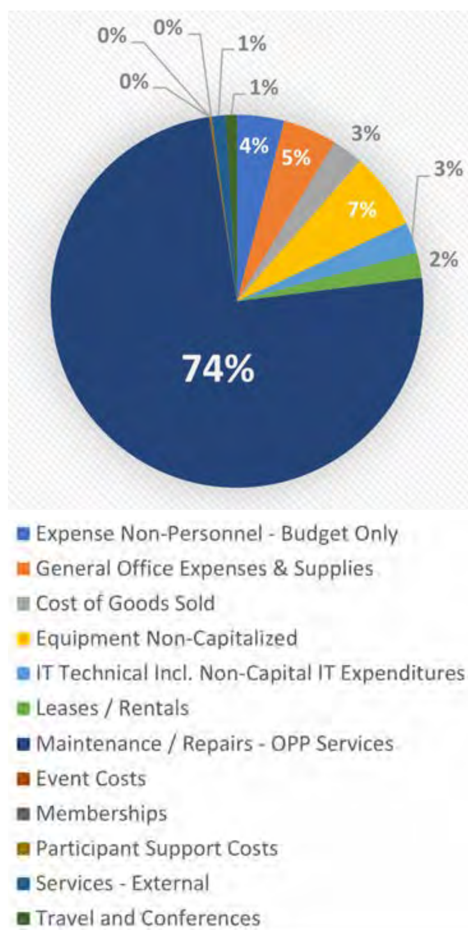
With regard to non-traditional and naturalized landscape typologies, there is serious concern that these landscapes require more labor to maintain and more training for a typical grade 7 or 8 maintenance crew member. Expanding the management responsibilities of the current hort. techs is also more expensive.

It was discussed that proposed changes to the organizational structure of grounds maintenance is a possibility, but that new ideas and strategies must be aligned to specific positions, rather than individuals.

One ideal outcome of this planning process is a desire to standardize plant selection to promote continuity across campus.



The chart above highlights a labor & expenses breakdown, while the chart below highlights the detailed expenses of the Landscape Services annual budget. Current budget challenges will likely require adjustments throughout Landscape Services.



APPENDIX A: STAKEHOLDER ENGAGEMENT FEEDBACK

STUDENT ENGAGEMENT

The design team presented a high-level overview of the SLIP to about 35 students in September 2023. The design team identified that this planning effort would not have happened without financial support from the Student Fee Board (SFB) and that subsequent implementation of the SLIP recommendations will likely require continued student support. The students unanimously expressed their support for the SLIP at this time.

The design team met with roughly 30 students again in November 2023. During this meeting, the design team provided an online survey with the help of EcoAction and LASS to seek additional student feedback. The following is a summary of survey responses from a small group of student respondents:

Would you be interested in signing a petition or letter of support to urge the Student Fee Board (SFB), project stakeholders, or other Penn State leadership to help fund the implementation of the SLIP?

- Yes (100% of respondents)

Would you be interested in participating in outreach events such as a pop-up display in the HUB to get the word out about the SLIP to the broader student body?

- Yes (100% of respondents)

Would you be interested in the stewardship of any of the proposed landscape areas (occasional weeding, monitoring, data collection, bio-blitzes, etc.) during your time at Penn State?

- Yes (100% of respondents)

Additionally, the survey asked more open-ended questions. Here are a range of collected responses to these questions:

Does the SLIP align with your values regarding the environment?

- Yes and I am most excited to see more diverse wildlife taking the place of some of the lawns.
- Yes, I am very excited to see unused lawns be transformed into ecologically and socially impactful spaces.
- Yes - it would help to further advertise the positive impact that it will have on students to administration (grades, mental health, etc.).

Are you generally comfortable with the aesthetic change this may bring to the campus landscape?

- I am. This change will add more dimension to the campus and is for a good, environmentally friendly reason.
- Yes - Right now, the plots of lawn and hardscape sometimes feel harsh and stark when compared to spaces on campus with ample tree cover and groundcover.

Understanding that we are in a climate and biodiversity crisis, does the SLIP make you think differently about how you approach your studies, projects, etc.?

- As a biology student, I think SLIP is a good reminder about the interconnectedness of education, collaboration, emissions, natural landscapes, and human health (mental and physical).
- I think it has helped me be more aware of the spaces I'm designing and what sorts of plants to bring to a space


DISCUSSION

APPENDIX A: STAKEHOLDER ENGAGEMENT FEEDBACK

05/10/23 STEERING COMMITTEE MEETING MINUTES

Meeting Minutes

Project: Penn State Sustainable Landscape Implementation Plan
Date: 05.10.2023
Attendees: Matt Langan, Megan Little (SSA), Claudia West (Phyto Studio), Pamela Conrad (Climate Positive Design), Andrew Bunting, Matt Rader (PHS), Thomas Flynn, Tracey Olexa, Todd Zook, Neil Sullivan, Derek Kalp, Kurt Coduti, Zachary, Erica Smithwick, Erik Burkhart, Mike Toolan, Grace E. Willis, Ken Tamminga, Casey Sclar, Marek Pundzak, Krista Bailey (PSU)

Distribution: Penn State

Agenda: Penn State Sustainable Landscape Kick Off Meeting

Minutes:

Project Background/Study Area:

a. Derek gave an overview of the project background.
b. Neil: Why Not West Campus?
    i. Derek: Maintain clean boundaries for study area. West Campus is a new landscape and is already incorporating sustainable elements.

What Do You See To Be the Biggest Opportunities and Challenges To This Effort?

Opportunities

Casey Sclar (Arboretum): Develop new habits that push forward the way we do things. Boost value of our profession.

Zachary (OPP): Bring tradition of innovation and be a model. Break tradition.

Kurt Coduti (OPP): Biggest opportunity is the people in the room and the consultant team. Teamwork.

Thomas Flynn (OPP): Ready for a new aesthetic. Mindset has changed. People are able to see the beauty in these naturalized landscapes.

Grace E Wills (Eco Action): Student involvement with planting. Volunteer hours.

Erica A H Smithwick (EESI): Living lab context. Habitat quality, research lense. Habitat Quality. Carbon sequestration as metric.

Mike Toolan (Shaver's Creek:) Changing perceptions of native and managed landscape. What does a managed landscape look like? Involving the community is an opportunity. Pride in involving people via education.

Tracey Olexa (OPP): Expand the tool box that she has and share with others.

Krista Bailey (Sustainability Institute): How do we know what success is? Starting to grow some low water, low input, native habitat enhancing plantings. Erode some turf! Education is key - crew, public, trustees, etc.

Kenneth Tamminga (DLA): Vibrant ecology, beauty, inclusive identity are not mutally eclusive. Find ways to reveal truth of that and shift values. Value shift.

Eric Burkhart (Shaver's Creek): Opportunity for introduction of edible forest gardens and those types of landscape typologies. Interesting and novel ways that we can use the psu landscape for educational and environmental purposes.

Neil Sullivan (OPP): Increase biological diversity on campus. Don't let perfect get in the way of better.

Challenges

Casey Sclar (Arboretum): Biggest challenge is "we've always done it that way"

Zachary (OPP): Break tradition.

Kurt Coduti (OPP): Lots of voices to be heard. Teamwork.

Thomas Flynn (OPP): Native planting lasted 1 week b/c of board member perception. People weren't ready for that aesthetic. Challenge is convincing our crews that there is nothing to be scared about. Proving through this design effort what the benefits are and giving these new landscape types the time to yield success.

Grace E Wills (Eco Action): Use this as an opportunity to educate people within each space.

Mike Toolan (Shaver's Creek:) Changing perceptions of native and managed landscape.

Krista Bailey (Sustainability Institute): Education + Engagement. We are investing in our environment.

Tracey Olexa (OPP): Stay within boundary conditions.

Kenneth Tamminga (DLA): Institutional inertia.

Eric Burkhart (Shaver's Creek): Student involvement, agricultural involvement. Longterm landscape projects. Complexity associated with maint. of diverse landscapes.

Neil Sullivan (OPP): Make a business case for these decisions. Fiscal Responsibility.Practical and implementable – realistic with aspirations.

Derek Kalp (OPP): Giving Staff something that they feel is manageable and implementable

Survey:

a. Focus group session may be better than an online survey.
b. Marek should be added to the OPP focus group.

06/23/23 STEERING COMMITTEE MEETING MINUTES

Meeting Minutes

Project: Penn State Sustainable Landscape Implementation Plan
Date: 06.23.2023
Attendees: Matt Langan, Megan Little (SSA), Claudia West (Phyto Studio), Pamela Conrad (Climate Positive Design), Todd Zook, Neil Sullivan, Derek Kalp, Kurt Coduti, Erica Smithwick, Erik Burkhart, Kenneth Tamminga, Casey Sclar, Marek Pundzak, Krista Bailey, Laurie Henry, Lara Garcia (PSU)

Distribution: Penn State

Agenda: Penn State Sustainable Landscape Steering Committee 02

Minutes:

Information Gathering Overview:

a. Matt gave an overview of the Information and Gathering / Findings Report
b. Water:
   i. Derek: PSU was recently involved in an application for headwaters and was turned down because they weren't progressive enough.
   ii. Tracey: Yes to more surficial stormwater management on campus
   iii. Ken: Consider working with Stuart Echols (Landscape Architecture Department) to determine some other surficial stormwater management opportunities on campus.
c. Soil
   i. Laurie: Soil Testing would be beneficial.
      1. Matt: The design team will be putting together a map of suggested soil testing.
      2. Ken: The design team should consider getting in touch with soil scientist Tim Craul to discuss campus soil compaction and realistic possibilities for improvement.
d. Turf Grass
   i. Pamela: We should steer away from percentage reduction goals and just use them as a general guidance. The real focus should be on addressing the problem patterns that we observed.
   ii. Todd: Currently there are only 2 different "priorities" or ways that they approach the turf on campus.
      1. The arboretum gets mown twice a week.
      2. The President's House, Hintz, and the Arboretum are all irrigated, and therefore mowed more frequently.
      3. Everything else is the same – fertilizer, chemical use, aeration, etc. is consistent.
   iii. Laurie: PSU has a hard time keeping the Hub Lawn established to a decent coverage because of the use that is gets from different activities, which is a go to area for people to utilize.
      1. Getting consistent lawn and plant coverage over steam lines is also an issue.
   iv. Pollock field and the lawn near the forestry school does not get scheduled for event use.
   v. Access to the Old Main lawn is bad – PSU tries not to do events there, but it was used for the Arts Festival in years past.
      1. When ESPN comes, the Old Main lawn is the location they prefer.
e. Trees
   i. STIMSON will update the Heritage Trees/Groves based on the most recent designations from PSU.
f. Maintenance
   i. Claudia: Most of the spraying is done in expansive mulch beds to get rid of tree saplings.
   ii. Ken: Don't forget about the impact of gas-powered machines in terms of noise that disrupts learning and research. It's real, and at times quite persistent.
g. Plant Diversity:
   i. Eric: Sees value in the choices that are made for plant diversity and density.
      1. For example: Japanese spirea is invasive and should not be planted on campus.
h. Observed Patterns:
   i. Casey: Many of the areas labelled turf grass have compaction issues. These areas take a lot of input and perhaps are the most unsustainable practice.
   ii. Remediating compaction also involves potentially disrupting utilities.
   iii. Soil compaction is a HUGE issue on campus.
   iv. Laurie: There are issues with steam line areas, PSU can't get things to grow over them. PSU is interested in heat tolerant plants or river stone as a solution.
      1. Derek: Underground utilities are pervasive on campus – this is a huge issue with new trees on campus. Should we consider planting quick growing but not high value trees over utilities?
   v. Eric: Students, faculty, and staff are observing more bird strikes into buildings. We should keep in mind that introducing more species diversity may overlap with existing buildings/large windows.
      1. Derek: This is an intense topic of conversation in our hallways - hoping this can be resolved architecturally. We don't want to have to make any landscape concessions.
   vi. Ken: Should this project side step the issue of invasives on campus? For example big Ailanthus that is used for lots of teaching opportunities – should they get rid of it or stop maintaining it, serving as "mother tree" to other invasives species downstream.
      1. **Derek: It would be great if we emphasized some of these things in the report.**
      2. Eric: We don't need those educational opportunities on campus – the horse is out of the barn. We don't need to see them on campus, most students find ailanthus hard to palette. These are educational opportunities for the wrong reason.

Vision / Guiding Principles / Goals + Objectives

a. Vision:
   i. Ken: Why are we excluding "design" from the vision statement?
      1. At any scale, there is a design gesture that needs to come before.
      2. Operations and Maintenance – is management a better term to use instead?
   ii. Claudia: Beauty is a part of sustainability. Seek opportunities to defragment the landscape through beauty.
   iii. Erica: The draft vision statement focuses too heavily on aesthetics. Make sure that ecological and environmental issues are captured in the vision statement and supporting goals.
   iv. Consider economic sustainability too. It is a driver for the decision-makers.

b. Guiding Principles:
   i. Pamela: We should steer away from percentages for our goals.
   ii. We need to double-check our carbon emissions goals align with other initiatives. Zero emissions by 2035 is a common goal that we should align to.
   iii. Neil: Is using the term "reducing carbon" important to this project?
      1. It is a big part of broader campus initiatives and we should take advantage of that, so that our work is also part of broader solutions.
   iv. Casey: We need to make that direct connection to carbon and tie it to PSU's carbon goals from the President.
      1. Economic sustainability is important. Need to be prioritizing lower input solutions with proper turn around times. If we say doing this is going to cost more in the long run than there will be no traction. Reduce carbon footprint.
   v. Invasive Plant Resources:
   vi. Pennsylvania DCNR invasive plant list for reference: https://elibrary.dcnr.pa.gov/GetDocument?docId=2700788&DocName=dcnr_20033786.pdf
   vii. PDA noxious weed list for reference: https://www.agriculture.pa.gov/Plants_Land_Water/PlantIndustry/NIPPP/Pages/Controlled-Plant-Noxious-Weed.aspx
   viii. Ken: "Typology" has multiple "types"
   ix. Erica: https://www.psu.edu/news/administration/story/president-bendapudi-addresses-climate-action/
   x. Derek: The team should be focused on the core campus but should include 1 slide that recognizes contextual connections – food farm on campus, connections to Shaver's Creek, other resources are important to this.
   xi. Another layer for the team to consider – potential pilot project at Fisher Plaza. Derek works hard to create projects on campus and the more layers you can add to justify the purpose and need helps provide funding.
   xii. Student Health and health in general is important. There is a crisis with student mental health. Students love the idea of being in a forest and the opportunity for meditation.
   xiii. Derek & Tom: Another thing to consider is the Land Grant Mission and legacy of Penn State's self-sufficiency and landscape legacy.

c. Goal- Optimize Maintenace & Operations:
   i. Derek - Objective A seems good
   ii. Erica: PSU 100% emissions reduction by 2035. Optimize for what? clarify in title
   iii. Derek - Object C, that would be awesome!
   iv. Laurie: Objective D would help significantly with budget. would also help with availability.
   v. Derek: Objective D , legacy of being self sufficient at PSU. Historic aspect of the landscape legacy from late 1800's, interesting to think about it from that perspective. part of evolution. Could see students planting plants, classes out collecting seed.
   vi. Kenneth: Objective D, we should make sure there are soils in place for plant materials to thrive. Potential to remediate soils.
   vii. Eric: Plenty of plant material that seeds could be propagated from. go next level with native plants. regional ecotypes
   viii. Casey: In different case scenarios, each typology will have a different impact.

d. Goal- Increase Landscape Performance and Ecological Health:
   i. Erica: Objective A, Enhanced biodiversity also promotes resilience to climate change/variability.
   ii. Kenneth: Objective A, love to see some lanscape ecology as part of the ologies at work.
   iii. Kenneth: Objective C, Because the words "groundcover" has its connotations, I try to get my sutdents to think more about ground flora, as a lower level and not to forget about bio continuity into soil layers.

e. Goal: Reduce the Environmental Footprint of Landscape Materials
   i. Kenneth: Paving materials – we need clarification on the requirements of ADA out in the landscape.

f. Goal: Be a Model for Sustainable Landscape Innovation and Education
   i. Erica: Be a model for students. Expand this to Urban Farm?
   ii. Casey: I would appreciate having the Arboretum added to the list. Consider all aspects of student associated activities, student farm growing plants that perform well in riparian areas and also provide food.
   iii. Kenneth: We should think about who we are a model to.
   iv. Casey: Citizens of commonwealth, commonwealth campuses
   v. Derek: Land grant goals, and peers at other universities.

09/07/23 STEERING COMMITTEE MEETING MINUTES

Meeting Minutes

Project: Penn State Sustainable Landscape Implementation Plan
Meeting Date: 09.07.2023
Attendees:

- Matt Langan, Megan Little (STIMSON) Derek Kalp, Kurt Coduti, Tracey Olexa, Neil Sullivan, Casey Sclar, Krista Bailey, Laurie Henry, Kenneth Tamminga, Tom Flynn (Penn State), Pamela Conrad (Climate Positive Design) Claudia West (PHYTO)

Distribution: Penn State, Design team

Agenda: Penn State Sustainable Landscape Steering Committee Meeting Presentation

Project Recap and Presentation of Landscape Transformation Vision

a. The design team gave an overview of the project to date and presented a draft of the landscape focus areas and how they align with the institution's broader carbon emission reduction goals.
b. Neil: What total percentage of campus carbon emissions is from landscape emissions?
c. Tracey: The low-level ground flora "salad" helps with stormwater management and minimizing the watershed.
d. Kenneth: Consider psychological impact from mowing equipment noise. A quiet landscape is better for human ecological health.
e. Krista: The Climate Action "Plan" is not an actual adopted plan, but a set of recommendations. PSU does not have an approved climate action plan.
f. Kenneth: Soil biota and chemistry is integral to ecological health. Change language from groundcover to ground flora.
    a. Matt: The design team is putting together a proposal for soil testing on campus to support the design recommendations for this project.t
    b. Casey: Look at soils in mulch beds to get a baseline. Hort Woods, the Pollinator Garden, mulch beds, and lawns should all be included in the soil samples.
g. Casey: When proposing to expand the existing plant beds, the disruption to views will be the hardest piece to sell.
    a. Derek: Impacts of ongoing disturbance and utilities should be considered.
    b. Tracey: We need to be strategic about the locations of trees.
    c. Tom: Campus is always evolving.
    d. Kenneth: This is an opportunity to enhance viewsheds. Safety, visibility, and communication should guide this effort.
    e. Laurie: We get a lot of work orders for clearing around buildings.
h. Laurie: The campus recreational use layer should be overlayed on the maps the design team are developing.
i. Krista: More habitat = more critters.
j. Casey: Mulch is a high expense for OPP.
    a. Tracey: Mulch gets into utilities/pipes.
k. Derek: Plant pocket forests where it makes sense.
    a. Casey: One area to be conservative is where big trucks need access to buildings.
l. Casey: A map should be developed of where recreation and connection to nature can happen.
    a. Forest bathing – great psychological benefits to this type of landscape experience.
    b. Derek: It would be great to have a map of hort woods and where it used to extend to campus.

Meeting Minutes

Project: Penn State Sustainable Landscape Implementation Plan
Meeting Date: 09.07.2023
Attendees:

- Matt Langan, Megan Little (STIMSON) Phillip Melnick, Derek Kalp, Kurt Coduti, Todd Zook, Mark Selivan (Penn State), Pamela Conrad (Climate Positive Design) Claudia West (PHYTO)

Distribution: Penn State, Design team

Agenda: Penn State Sustainable Landscape Steering Committee Meeting Presentation Preview

Project Recap and Presentation of Landscape Transformation Vision

a. The design team gave an overview of the project to date and presented a draft of the landscape focus areas and how they align with the institution's broader carbon emission reduction goals.
b. Pamela: An additional milestone for the project would be to align with the planetary/global carbon emission reduction goals.
    a. PSU could consider registering campus as a carbon sink – opportunities for funding/credits can be found this way.

    ACTION: Pamela to provide Philip with the information for the Carbon Sink Certification.
c. Philip: Compost – should we look at opportunities to reduce our carbon footprint within PSU's composting operations.
    a. PSU does have an Elm Collection program that makes and sells furniture made from trees cut down on campus.
d. Philip: The design team should consider the recreational impacts of removing turf.
e. Todd: What is our stance on habitat? Currently OPP gets a lot of calls about wildlife sightings.
    a. Claudia: Species selection will be key in filtering what wildlife we are hoping to attract. Emphasize charismatic wildlife.
    b. There are educational opportunities here. Consider signage about food pyramid/natural life cycle.
f. Philip: Public Perception of new planting typologies is key.
    a. Letting nature take over is not the right approach. We need to be very intentional about how we are doing this. For example, letting lawn panels go wild might not be the right approach.
    b. Location on campus also matters. Be thoughtful about where we are implementing the new landscape typologies.
    c. Claudia: These need to be designed, stylized gardens.
g. Todd: Big trees and expansive lawns are what people expect on campus. We need to prepare alumni and donors for this shift.
    a. Philip: Changing the landscape means changing our mindset.
h. Philip: We should provide a place to interact for each building. If there was a way to interact with each new landscape type, that would be a success.
    a. Need to consider the map of reservable campus spaces and compare them with the lawns that we are planning to transform on the proposed map.
i. Todd: Could we consider transforming the lawn at Pattee Mall instead of the lawn panels at Old Main?
    a. The design team should also consider the pavilions at University Dr and Park Ave for transformation.
j. Philip: Potential Funding Options
    a. Student support is critical. Student support gives OPP leverage.
    b. The tree replacement fund could be a source for funding some of these projects.
    c. PSU should consider reviving the class gift program to help fund the SLIP.
    d. The student fee board is another great source of funding.
    e. Campus Beautification Fund
    f. Campus Maintenance Energy Savings Fund.
k. Mark: Maintenance cost and skills need to be considered if we are transforming lawn into landscape with higher horticultural value.
    a. Philip: We will need to convert our labor.
    b. Todd: It is hard to find a workforce that is willing to work on their hands and knees.
    c. Mark: There needs to be a paradigm shift. Perception/informational piece is the most important.
    d. Philip: Staff will find a place that works for them within the new horticultural/natural systems focused landscape approach.
    e. Todd: New laborers will be a blend of 6's and 7's.
l. Todd: Clusters of trees are good! This means less work for his crews.
    a. Lawn verges and parking islands are very tough and will need to be planted with salt tolerant plants.
m. Three Key Steps:
    a. 1. Sell the environmental aspect of the project
    b. 2. Get people past the perception of – Show visuals of what it can be.
    c. 3. Operations – setting expectations, what we do first is critical.
    d. 4. Data/Monitoring is icing on the cake.

11/15/23 STEERING COMMITTEE MEETING MINUTES

Meeting Minutes

Project: Penn State Sustainable Landscape Implementation Plan
Meeting Date: 11.15.2023
Attendees:

Matt Langan, Derek Kalp, Tracey Olexa, Neil Sullivan, Casey Sclar, Krista Bailey, Laurie Henry, Kenneth Tamminga, Tom Flynn, Pamela, Claudia West, Eric Burkhart, Todd Zook, Marek Pundzak, Casey Sclar, Matt Wolf

Distribution: Penn State, Design team

Agenda: Penn State Sustainable Landscape Steering Committee Meeting Presentation

Summary

- Tom was promoted to fill Bruce's interim position, which was positively received by the team.
- The team presented an update on their progress in increasing campus sustainability and reaching net-zero carbon emissions by 2035. They discussed their methodology, key findings, and recommendations, and shared their plans for a pilot project while requesting feedback.
- The next steps include submitting a proposal to the student fee board and finalizing a report in early December.

Landscape Emissions: Methods, Strategies, and Future Plans

- Pamela discussed the operational and embodied emissions of the campus landscape, including the methodology used to calculate them and the impact of different site operations.
- Strategies to reduce operational maintenance emissions and increase carbon sequestration were presented, with a focus on offsetting emissions from future construction projects.
- The discussion also covered the importance of considering nitrogen in the calculations and the potential for legumes to fix nitrogen in land cover.
- The significance of the Fabaceae family trees for carbon sequestration was questioned. Pamela emphasized the importance of using cover crops on barren soil to prevent carbon release into the atmosphere and tip the scale from a net emitter to a net carbon sink.
- The team also discussed the need to deepen their understanding of the landscape services footprint, including the use of diesel, and the strategy for implementation on the labor side.
- The team agreed to further investigate the importance of reducing embodied carbon in the landscape to quickly reduce scope 3 emissions.

Sustainable Landscape Practices

- The team discussed the need for sustainable landscape practices, including minimizing paving, reducing lawn use, and using ecological plans. They highlighted the importance of using materials with smaller environmental footprints and explored the potential of using local materials, detailed soil protection policies, and reducing overdesign of site elements. The emphasis was on reducing carbon emissions in materials used for projects, with possible replacements for steel including wood and other structural elements.
- The team also discussed the life cycle cost of concrete and the importance of considering it for understanding carbon footprint. Tracey requested supplementary material related to storm water storage and inquired about resources that support H. 20 or H. 25 loading.
- The team also discussed maximizing salvage and storage of landscape materials and explored ways to communicate their availability to contractors. They acknowledged the difficulties in reusing materials from salvage yards and discussed the challenges of replacing benches made of wood more frequently than those made of alternative materials.
- The importance of considering the embodied carbon in different materials and the impact of the nursery industry on their choices was also highlighted.
- Lastly, the team decided to focus on identifying a pilot project to illustrate the impact of their strategies, with a focus on maximizing tree cover and open woodland footprint on campus to promote sustainability.

Campus Landscape Maintenance and Design

- The team highlighted the importance of preserving the legacy of the campus's wooded areas and appealing to a conservative group.
- They also discussed the typology of landscapes, ranging from minimal maintenance to higher intensity planting technologies. The team acknowledged that not all areas would become a "Longwood Garden," but rather used a spectrum of technologies to manage the landscapes.
- The group also identified underutilized lawn areas and recreational spaces, concluding that over 50% of the lawn area has potential for change.
- Lastly, they presented a logic that proposes typologies based on the amount of input and management required, with a focus on low-maintenance solutions.
- The team discussed the possibility of reducing mowing frequency on lawns to lessen emissions and labor, with a potential reduction of 60% if mowing takes place every 6-7 business days instead of every 5.
- They also acknowledged the importance of maintaining acceptable standards for athletics fields, which may not be able to accommodate changes to turf management strategies.
- The team considered diversifying species and reducing herbicide use as additional ways to enhance sustainability. The use of eco-friendly fertilizers and micro clover was also suggested. However, the team recognized the challenges of maintaining turf areas with varying management strategies, and the need to balance the desired aesthetic with sustainability.

Meadows on Campus: Challenges and Potential

- The team discussed the challenges and potential of implementing meadows on campus. They acknowledged the need for careful management to prevent invasive species, control weeds, and manage traffic.
- The team also highlighted the importance of understanding the suitability of different locations on campus for these meadows. They stressed that these decisions would be made based on the expertise of the landscape supervisors.
- The team also emphasized the need for a holistic approach, which includes using different techniques and tools to manage the ecosystems.
- The discussion concluded with a reminder that these meadows require a certain level of management and care to maintain their ecological performance.

Woodland Meadow System Creation

- The team discussed the creation of a woodland meadow system on campus, considering the challenges of working under existing trees and full sun conditions.
- They proposed the use of small container sizes to minimize impact on tree roots and the use of compatible flowering species to create a strong visual.
- They also highlighted the potential of converting existing turf into a stylized meadow by interplanting with compatible flowering species.
- Another idea was the creation of bigger shrub massings to stabilize challenging site conditions and discourage foot traffic.
- The team stressed the importance of using species with high pollinator value and avoiding invasive species.
- They also proposed two horticultural approaches for more visible areas of campus, including blockplanting and matrix planting, which aim to create visually stylized and legible plantings with minimal maintenance needs.

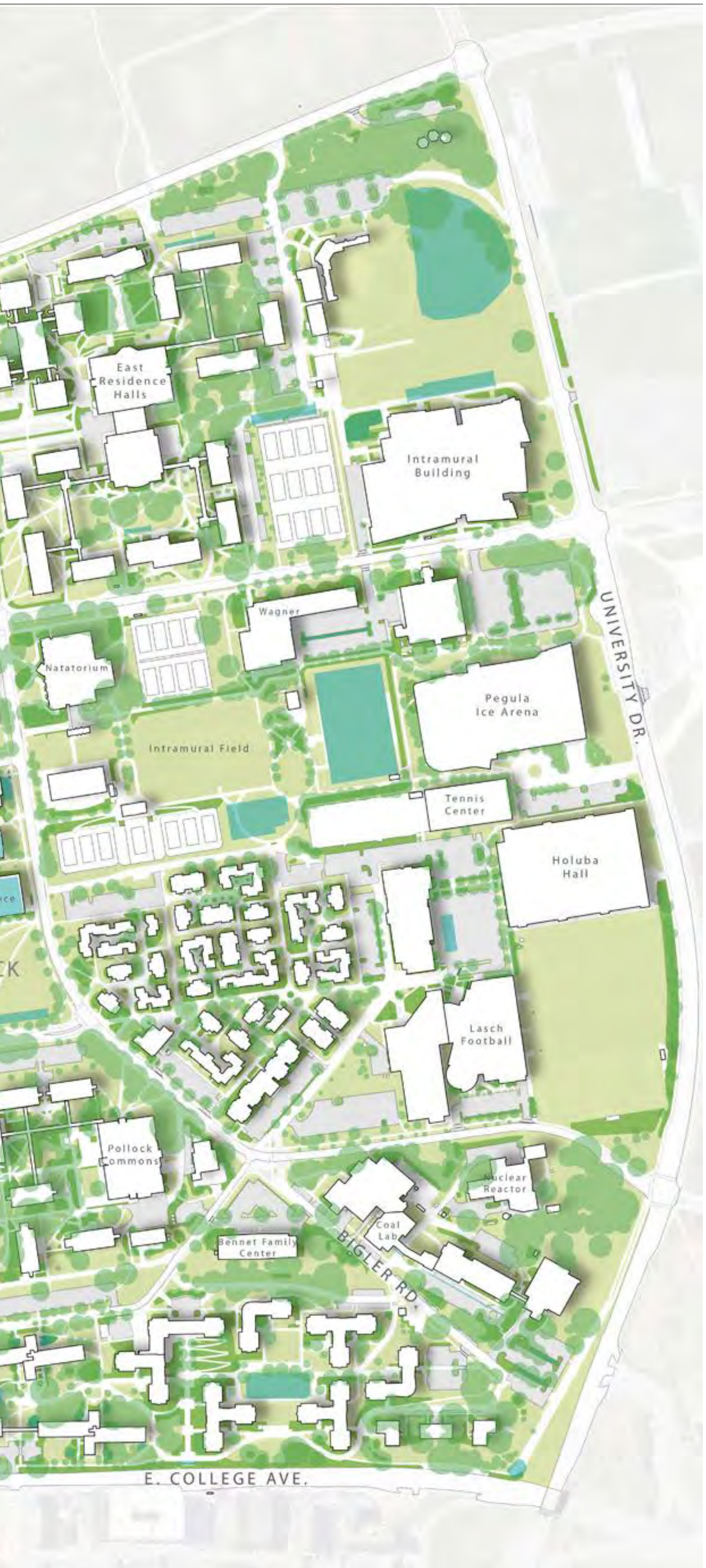
Pilot Project Site Selection

- The team discussed the pros and cons of selecting Fisher Plaza and the Obelisk garden as potential sites for their pilot project.
- Fisher Plaza, despite limited usage, was seen as a good candidate due to its high visibility, potential for tree canopy cover, and alignment with existing technologies. However, the team recognized the need to align any proposed improvements with a bigger master plan for Fisher Plaza.
- The Obelisk garden, despite heavy foot traffic and utilities, was viewed as an opportunity for maximizing plant bed density and converting existing planting beds to more sustainable ground cover. The team also discussed the possibility of using the site for educational purposes, such as comparing traditional horticulture with sustainable land management.
- The idea of incorporating public education and outreach was also suggested, especially in relation to the site's requirements for MS. 4 permit compliance.
- Casey discussed the opportunities arising from the demolition of the Sackett Building and the impacts on the surrounding Hammond building. The team considered the temporary landscape around College Avenue as a significant real estate with potential for various functions, including a ceremonial lawn and recreational space.
- Krista expressed her thoughts on the ecosystem services provided by the proposed planting areas and the potential for research.
- Tracey mentioned a 40% reduction in impervious area being considered for the Hammond project and the potential of using soils that have been under buildings for decades.
- The team also discussed the possibility of expanding this approach to other areas such as the second Hammond demolition and the millennium science site.
- The team debated whether to spread out the pilot project into multiple areas managed by individual hort. techs or group them together. The team also considered the possibility of integrating the design project with the utility project to improve water management and include dense tree growth.
- The team discussed the selection and design of pilot projects for landscaping in high profile areas of the university campus. They agreed on the importance of making the projects highly visible and successful. The team considered focusing on one or two areas for the demonstration, with the possibility of spreading out the projects across the campus. They also discussed the need for a site-specific or generic diagram to guide the design and maintenance of the projects. The team decided to finalize the chosen areas and begin the design process.

B

APPENDIX EXISTING CONDITIONS ASSESSMENT

APPENDIX B: EXISTING CONDITIONS ASSESSMENT



EXISTING CONDITIONS MAPPING

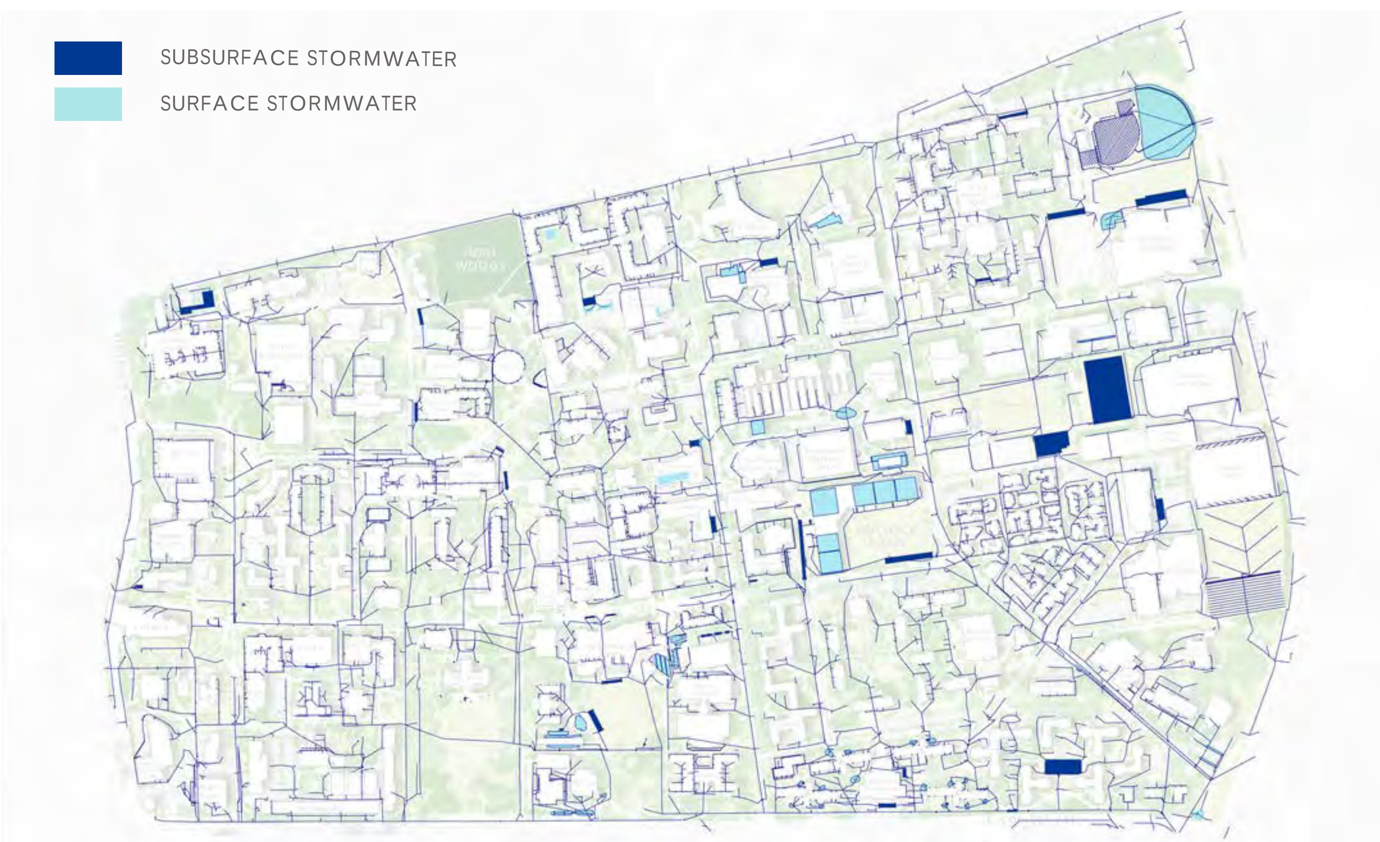
Working with John Richendrfer, a GIS Analyst with OPP, the Consultant Team focused on establishing a thorough understanding the existing conditions of core campus. The extent and depth of available and accurate GIS data curated by Penn State has provided a substantial jump-start to the Consultant Team's developing understanding of these existing conditions.

Using the maps created from this data, the Consultant Team established a baseline understanding of the existing campus conditions and used these maps during our campus visits to observe and assess current landscape typologies and associated maintenance regimes.

This existing conditions map highlights the existing "soft" landscape features, including tree canopy cover, lawn, planting beds, and stormwater infrastructure (green roofs, rain gardens, and subsurface stormwater facilities). This, along with other existing conditions mapping illustrated later in this chapter, will be the basis for establishing existing environmental footprint baseline measurements. Proposed sustainable landscape improvements to this existing condition will be measured and compared to the baseline condition for evaluation on the efficacy of those proposals.

APPENDIX B: EXISTING CONDITIONS ASSESSMENT

Core Campus Drainage



Core Campus Stormwater Infrastructure

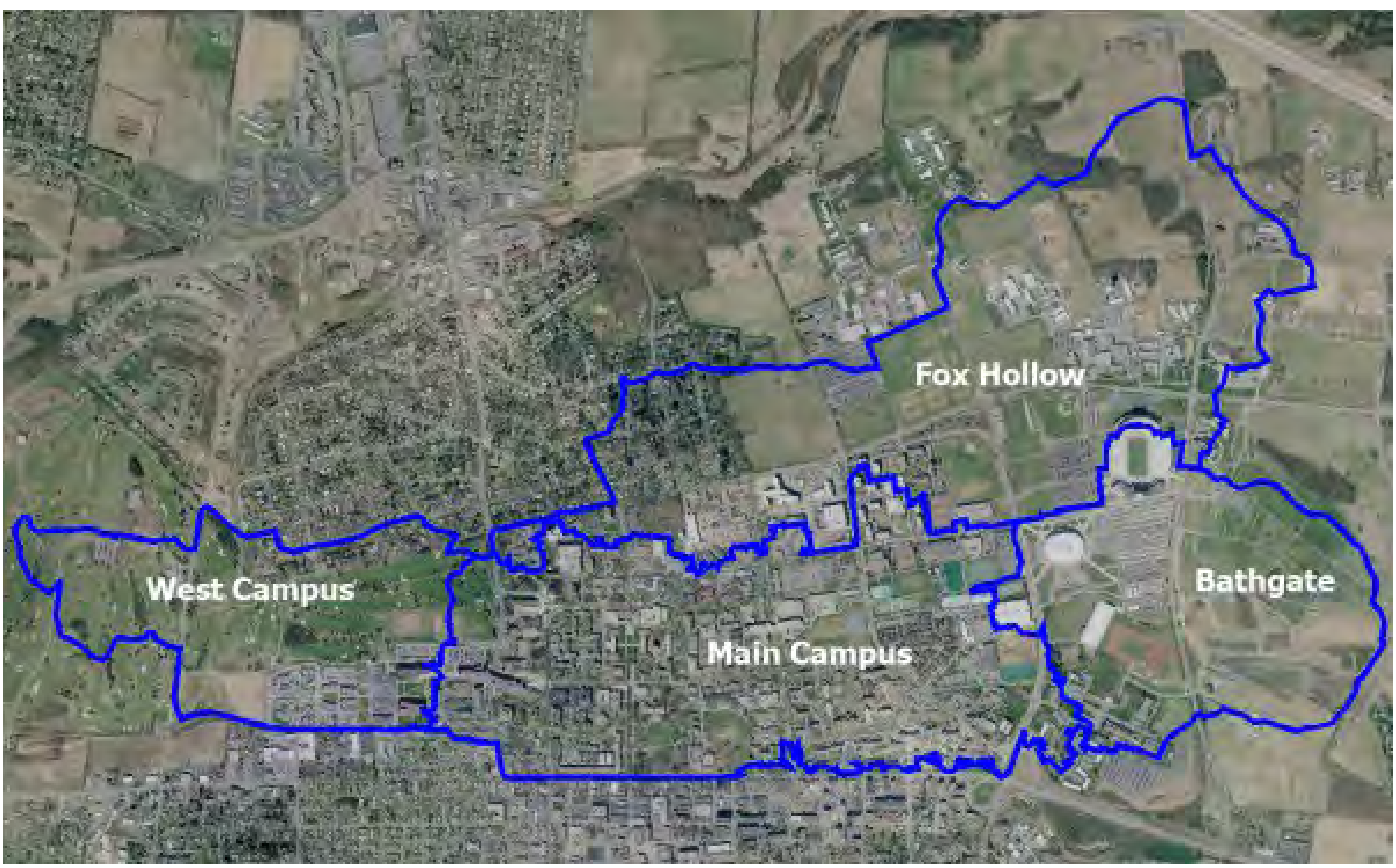
CORE CAMPUS HYDROLOGY + IRRIGATION

Penn State's Core Campus is part of the Main Campus and Fox Hollow Watershed that drains towards Spring Creek ultimately making it's way down the Susquehanna River to the Chesapeake Bay. Due to the Karst geology and the landscapes susceptibility to sink holes, there is little opportunity for stormwater infiltration on campus.

Perched on a hill, most of Core Campus drains south east towards College Avenue. While the majority of stormwater collection happens subsurface through a network of drains, pipes, and cisterns, there are a number of green roofs and lined swales that collect surface runoff.

Penn State's current approach to irrigation is minimal, which is encouraging. Penn State may want to consider planning ahead with increased temperatures and the need for back-up irrigation for plant establishment.

Stormwater Swale at the Stuckeman Family Building



University Park Campus Watershed Map from *OPP's Website*


SPECIAL PLACES - HIGHEST PRIORITY
PUBLIC SPACES - HIGH PRIORITY
CONNECTIVE SPACES - MEDIUM-HIGH PRIORITY
ATHLETIC FIELDS + COURTS - EVENT PRIORITY
PARK AVE.
EAST SUBCAMPUS LAWN
HORT WOODS
CURTIN ROAD
ARTS & SCIENCES QUAD
WEST QUAD
POLLOCK QUAD
HUB LAWN
ALUMNI GARDENS
OLD MAIN LAWN

PRIORITY ZONE MAPPING

OPP has established a series of maintenance priority zones across core campus, to align available resources with this highest profile areas of campus. This network of zones is broken down into Special Places, Public Spaces, Connective Spaces, and Athletics Spaces.

While the Special Places and Public Spaces are typically host to the more memorable landscape experiences on campus, it is those interstitial Connective Spaces that predominate core campus. These landscapes are the connective fabric that holds the campus experience together. While these areas may be maintained to a slightly lesser degree than other areas, they also may have opportunities for more transformational contributions to a more ecologically healthy and sustainable campus landscape.

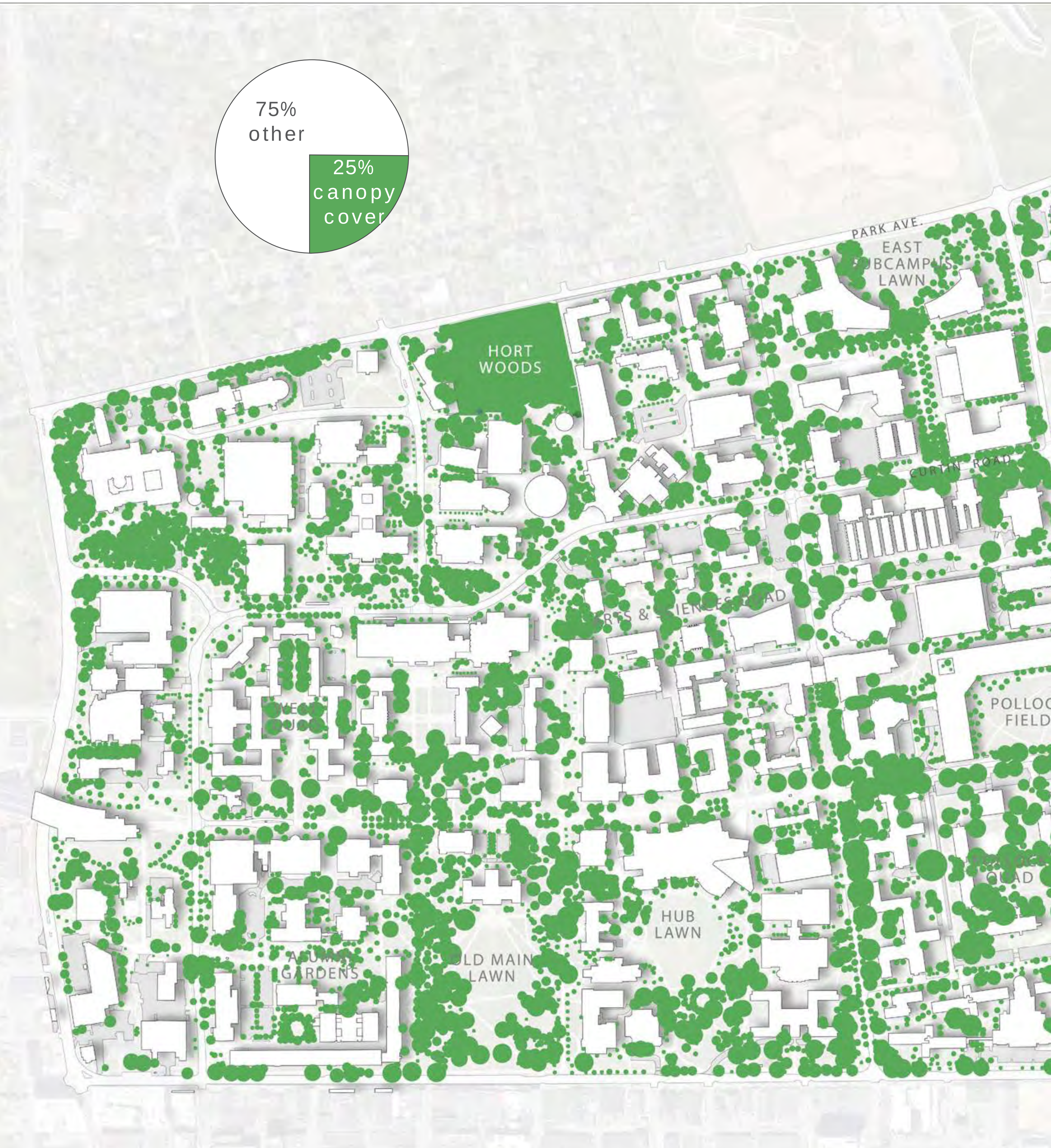
While the campus-wide Athletic Fields + Courts are expansive, their presence is core campus is limited to fragmented pockets toward the eastern edge of the study area, east of Bigler Road. It is understood that Penn State Athletics has maintenance jurisdiction in and around the athletics facilities, and it is clear that the focus of their resources is on the facilities themselves, and on the interstitial spaces between facilities to a lesser degree.

SPECIAL PLACES | ALUMNI GARDENS

CONNECTIVE SPACES | CROSSROADS NEAR MILLENNIUM SCIENCE COMPLEX

PUBLIC SPACES | SHORTLIDGE GARDEN

ATHLETICS | INTRAMURAL FIELD NEAR MCCOY NATATORIUM

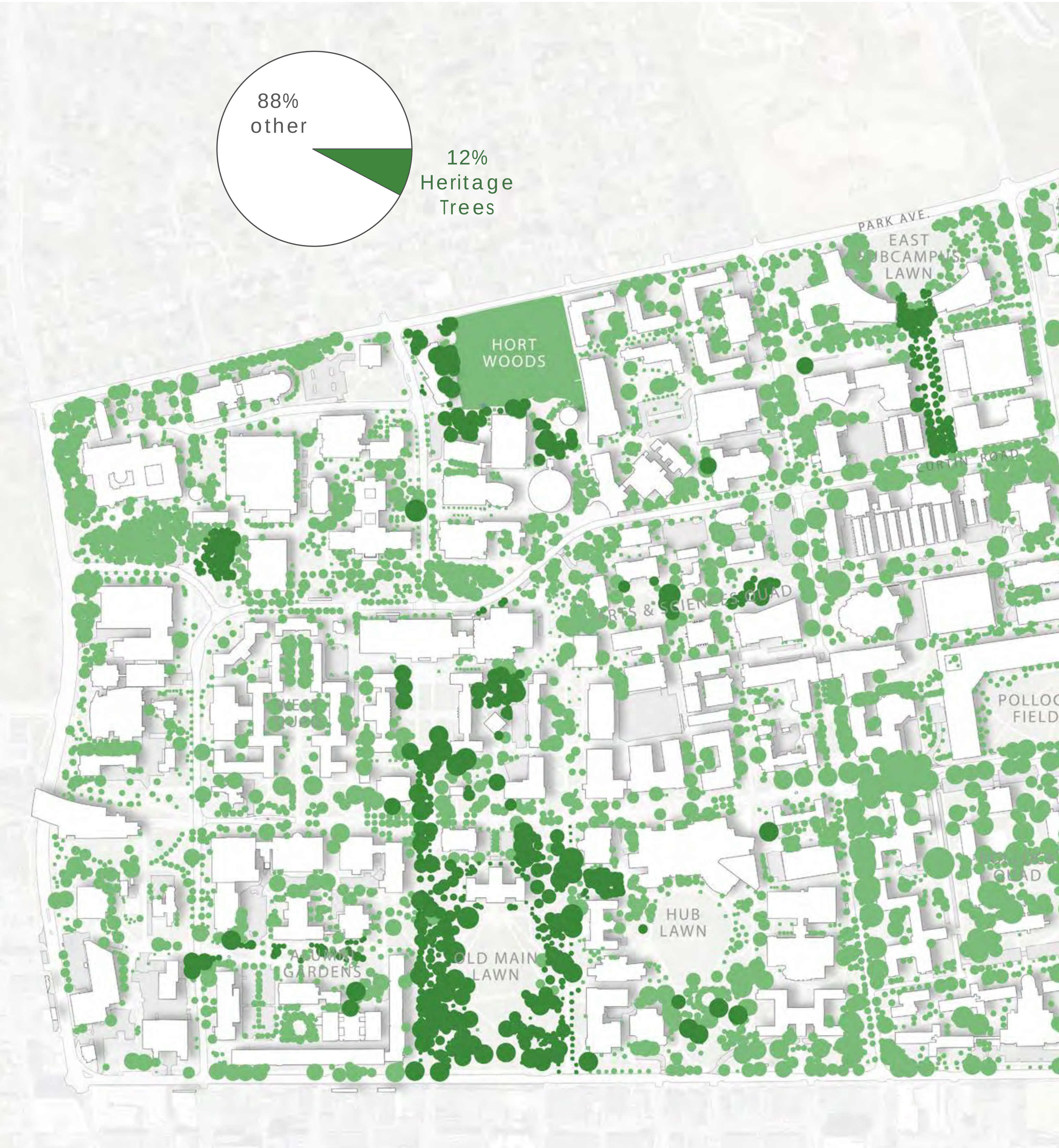

75%
other
25%
canopy
cover
PARK AVE.
EAST
LAWN
HORT
WOODS
CURTIN ROAD
HUB
LAWN
LAWN
POLLOC
FIELD
QUAD

EXISTING TREE CANOPY

Penn State's campus landscape is the overall extent, diversity, and health of the tree canopy throughout core campus. The existing tree canopy covers just over 25% of core campus, contains over 6,500 trees, and is comprised of nearly 150 different tree species.

The University Park campus has an all-encompassing tree care plan identifying the policies, procedures and practices in establishing, protecting, and maintaining trees on campus with the goal of ensuring a safe, attractive and sustainable urban campus forest. The plan's objectives include:

- Ensuring proper species selection, high-quality nursery stock acquisition, and industry-consensus planting procedures
- Promoting species diversity and proper age structure in the tree population
- Protecting high-value campus trees during construction and renovation projects
- Promoting tree health and safety by utilizing best management practices when maintaining campus trees
- Ensuring trees are reasonably replaced when there is mortality due to weather, pest infections, injury or construction displacement
- Encouraging campus community members to respect and value the campus urban forest.


88%
other
12%
Heritage
Trees
PARK AVE.
HORT
WOODS
HUB
LAWN
OLD MAIN
LAWN

HERITAGE TREES

Heritage Trees are individual trees on the Penn State University Park Campus that have developed exceptional historical, cultural, and/or aesthetic value because of their age or their association with an important event or person. To gain “Heritage Tree” status, a tree must meet one of three criteria regarding its historical, cultural, or aesthetic value. In order for age to be a tree’s qualifying factor, the tree must be at least 100 years old. The list does contain younger trees, however, that hold the title because of the irreplaceable aesthetic value they provide or because of some other cultural significance.

The University Tree Commission is a key player in deciding which trees are Heritage Trees. Formed in 2001, the commission includes nine members with expertise in subjects like horticulture or landscape architecture, along with a student representative.

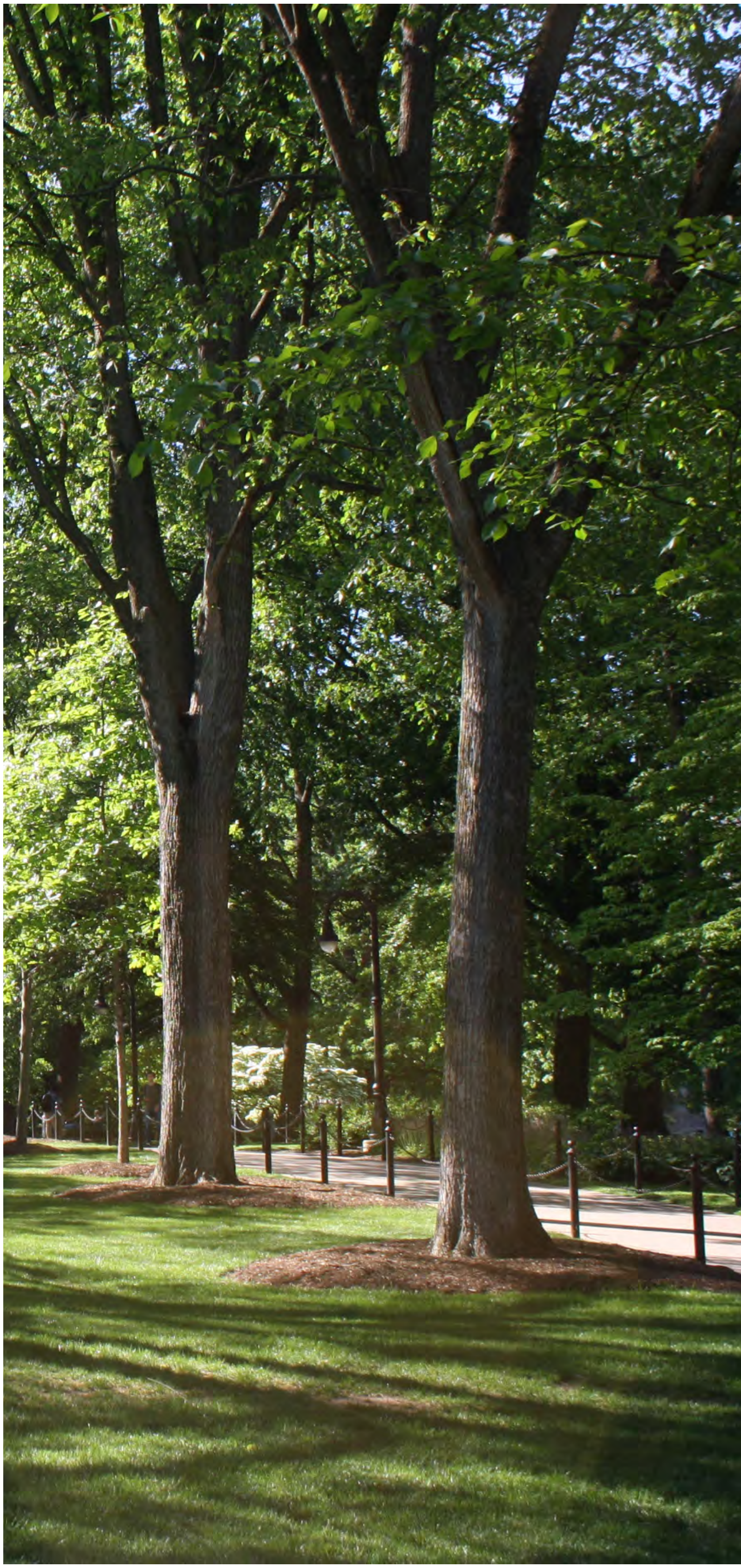
In addition to naming individual trees, the commission identifies groves of trees as Heritage Groves, meaning that the value the group of trees provides as a whole is irreplaceable. The commission is also a decision-maker when it comes to which trees to add or remove to the University Park campus.

APPENDIX B: EXISTING CONDITIONS ASSESSMENT

TREES ON CAMPUS

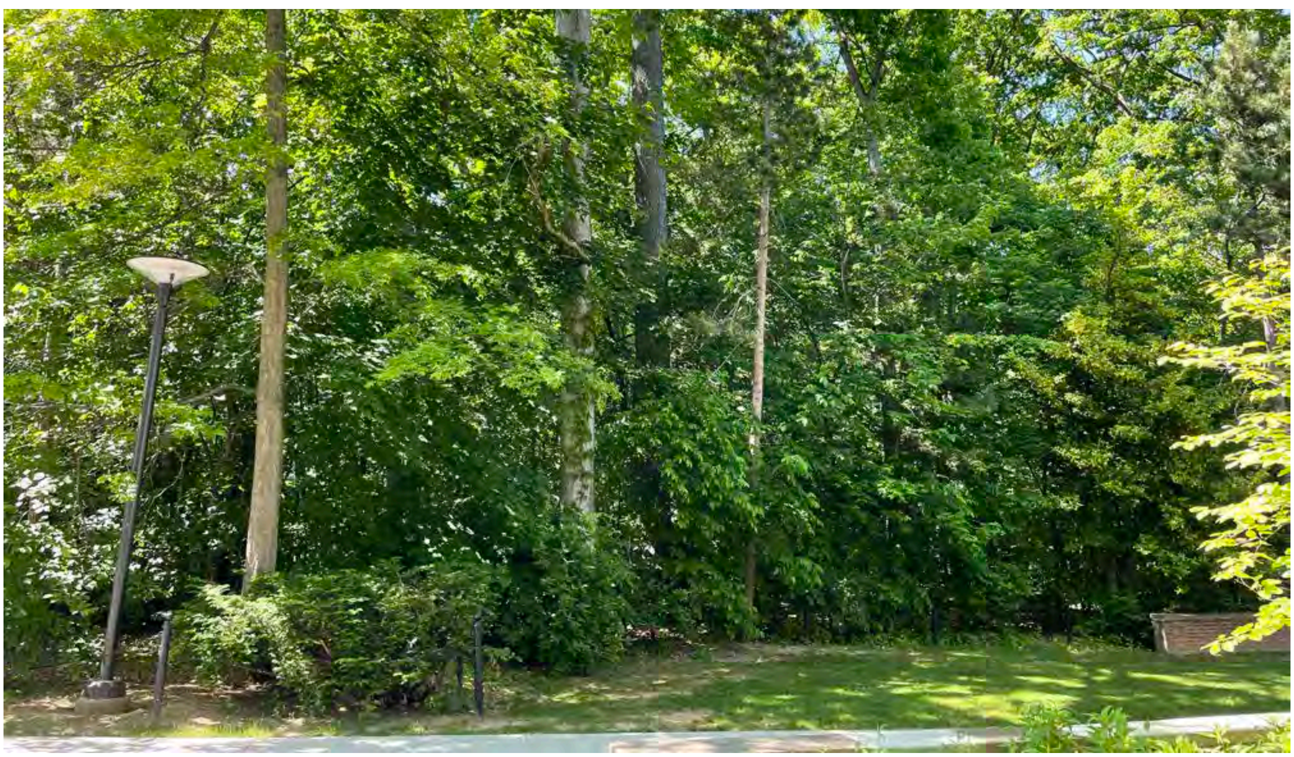
In 2018, Penn State was honored with Tree Campus USA recognition as presented by the Arbor Day Foundation for its continued commitment to effective urban forest management. The Tree Campus USA program was launched in 2008 and honors colleges and universities for effective campus forest management and for engaging staff and students in conservation goals.

Also in 2018, Penn State was awarded a Level II Accreditation by The ArbNet Arboretum Accreditation Program and The Morton Arboretum for achieving particular standards of professional practices deemed important for arboreta and botanic gardens. The ArbNet Arboretum Accreditation Program is the only global initiative to officially recognize arboreta at various levels of development, capacity and professionalism. Penn State is also now recognized as an accredited arboretum in the Morton Register of Arboreta, a database of the world's arboreta and gardens dedicated to woody plants.



HISTORIC ELM ALLEE AT PATTEE MALL
Summer 2023

GROVE OF TREES AT THE PEACE GARDEN
Summer 2023



HORT WOODS
Summer 2023


67%
other
33%
turf
HORT
WOODS
EAST
SUBCAMPUS
LAWN
ARTS & SCIENCES QUAD
WEST
QUAD
POLLOCK
FIELD
POLLOCK
QUAD
HUB
LAWN
OLD MAIN
LAWN
ALUMNI
GARDENS

CORE CAMPUS TURF EXTENTS

Roughly 1/3 of Penn State's core campus is maintained as lawn. While this is expected and thought of by many as a necessity in institutional environs, the sheer acreage, nearly 150 acres, of existing lawn presents a significant and time-consuming perennial maintenance cycle.

According to OPP's Landscape Management Guidelines, all turfgrass is cut to a height of 3" at least once every (5) working days or as needed to maintain height. Exceptions are made if turfgrass is under stress due to lack of soil moisture or conditions are too wet to cut. Mowing occurs for 6-7 months each year, with a maintenance crew of roughly 28 members. During this period, maintenance crew members are actively mowing turfgrass roughly 24 hours per week. It is therefore estimated that lawn mowing alone accounts for approximately 16,000-18,800 labor hours annually.

OPP is in the process of transitioning its lawn maintenance equipment - mowers, trimmers, and blowers - to electric models. The grounds supervisors have indicated that maintenance crews now gravitate to the electric mowers and trimmers, but the technology has yet to make electric blowers practical for institutional use. Edge trimming and removal of clippings from walks (blowing) account for roughly 8 hours per week of each maintenance crew's time. This accounts for 5,375-6,275 labor hours annually.

Lawns are fertilized annually with a microbial, humic acid, and natural plant nutrient enhancement package. NPK fertilizers are no longer used. Broadleaf post-emergence herbicides are applied to keep a 95% weed free turfgrass stand. Pre-emergent herbicides are applied yearly or as needed in established turfgrass areas to control annual grasses and broadleaf weeds.

APPENDIX B: EXISTING CONDITIONS ASSESSMENT

TURF PRIORITY AREAS

OPP had developed a map of turf priority areas with the intention of developing a tiered maintenance approach. It has been determined that in practice, this has not occurred. While the Priority 1 areas are generally the first to be attended to during any given mowing cycle, but it is understood that all lawns on core campus (with few exceptions, such as Alumni Gardens) receive the same treatment in terms of mowing, fertilizer, chemical use, aeration, etc.


ANNUAL BED - >1%
HORTICULTURAL BED - 16%
NON-OPP BED - 1.5%
SHRUB BED - 75%
UN-ASSIGNED - 6.5%
PARK AVE.
HORT WOODS
CURTIN ROAD
ARTS & SCIENCES QUAD
QUAD
POLLOC FIELD
OLLOCK QUAD
HUB LAWN
OLD MAIN LAWN
ALUMNI GARDENS

PLANT BED MAPPING

The existing plant beds within core campus have been mapped according to the predominant plant type in each bed. In total, plant beds represent roughly 11.5% of core campus, covering approximately 50 acres.

There has been a deliberate effort over the past few years to reduce the overall amount of annual beds on campus, due to the fact that they are a drain on the limited landscape operations resources and it is generally accepted as an unsustainable practice. The locations of annual displays have been strategically reduced, now less than 1% of all planting areas, to exist only to frame important campus gateways, important buildings, and some building entrances. OPP regularly receives requests for more annual plantings, especially in the form of container plantings in highly-visible and heavily-used public spaces on campus.

Annual beds are typically re-planted or supplemented with additional plants 3-4 times each year to maintain seasonal displays, which also include container plantings throughout campus. The Hort Techs are responsible for the design, planting, and maintenance of all annual beds within core campus. Watering the annual beds becomes a time-consuming activity in warm weather. Horticultural beds are primarily mixed beds of primarily herbaceous perennials and grasses, with some shrubs and trees. These represent approximately 16% of all planting areas in core campus and are maintained by the Hort Techs on staff. The majority of plant beds in core campus are shrub beds, which account for 75% of plant beds, nearly 38 acres. Shrub beds require less maintenance, with weeding and spraying as the biggest demands. Shrub pruning is done every 2-3 years. Plant beds are not typically fertilized, with the exception of liquid fertilizer used in annual beds and containers on occasion.

APPENDIX B: EXISTING CONDITIONS ASSESSMENT


Lawns south of Westgate Building


Lawns at Chambers / Fisher Plaza


Lawns between Thomas & Millennium


Mulch rings


Narrow lawn strips


Utility and furnishing impediments


Steep slopes at South Halls


Steep slopes at Pollock parking lots


Steep slopes at Nittany Apartments


Thinning lawns near Old Main


Thinning lawns near Chapel Woods


Thinning lawns near Nittany Lion Inn

Open Lawns

While there are many ceremonial and well-used recreational lawns on campus, there are also many examples of under-utilized open lawns that are ripe for a transition to a higher-performing landscape typology that requires lower inputs.

Fragmented Lawns

There are innumerable examples of lawn fragments as a result of multiple tree saucers, utilities, furnishings, and encroachment from plantings. These areas are difficult to mow and are unusable for recreational purposes.

Lawn Slopes

Steep lawn slopes are difficult to maintain and are unusable from a recreation standpoint. Changing these challenging sites to a more sustainable landscape typology can lower maintenance inputs and provide environmental benefits.

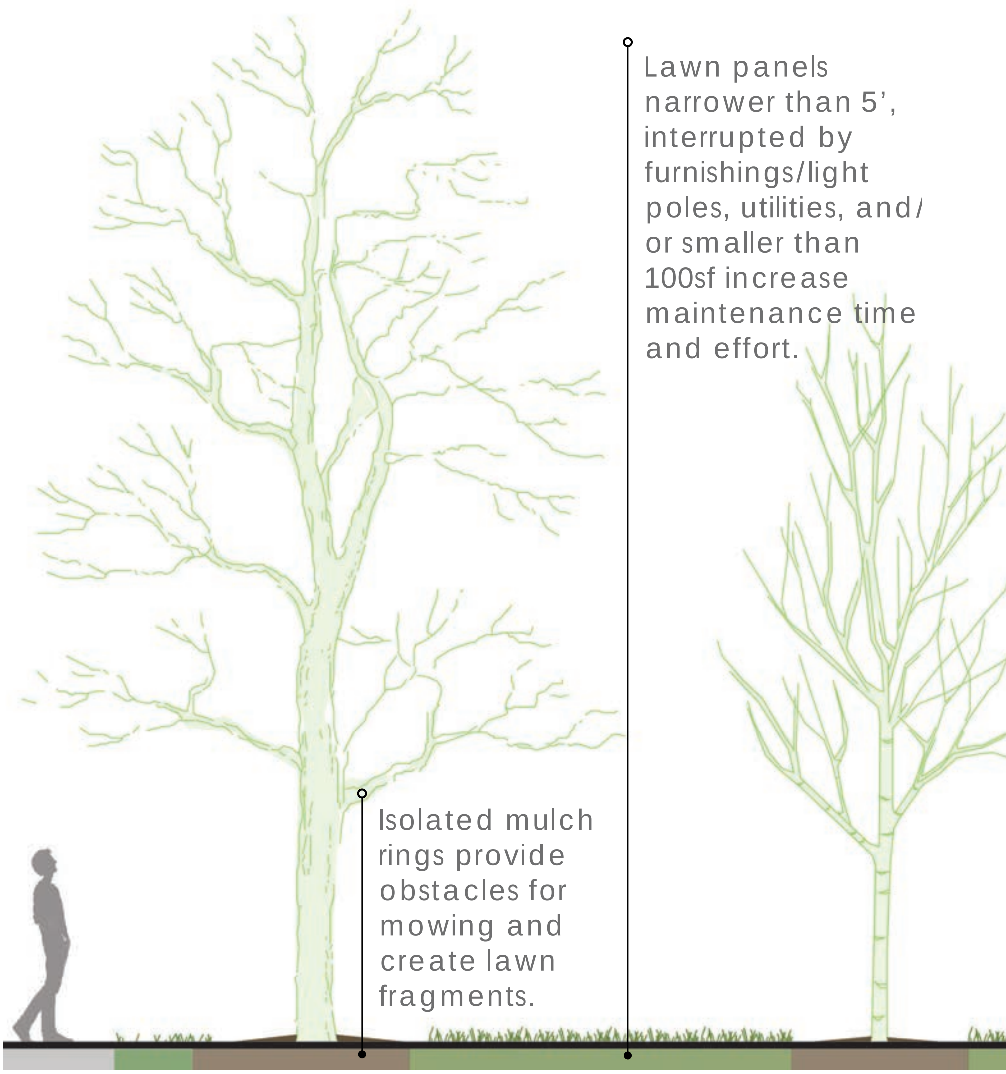
Dense Shade

There are examples across campus of struggling lawn areas in moderate to dense shade conditions that make it difficult for lawns to flourish. These areas are typically not sought out for recreational use and should be considered for change.

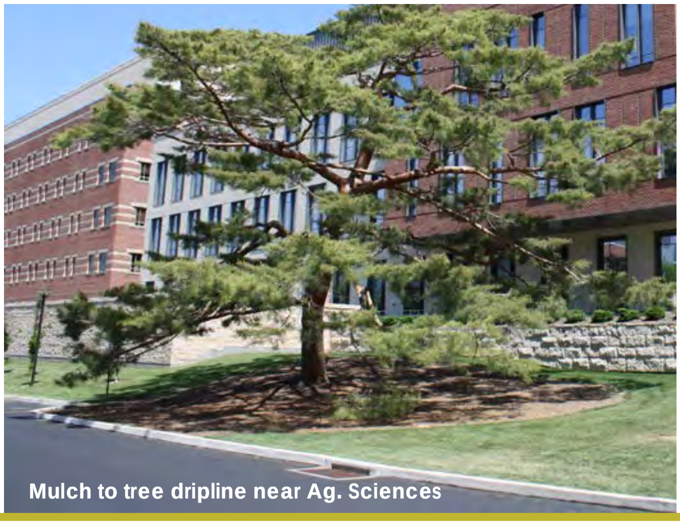
OBSERVED PATTERN 1

UNDERUTILIZED LAWNS

Lawns are the primary groundcover across the study area, representing more than 1/3 of the total core campus at roughly 150 acres. It is estimated that more than half of this lawn acreage is underutilized or not used at all.

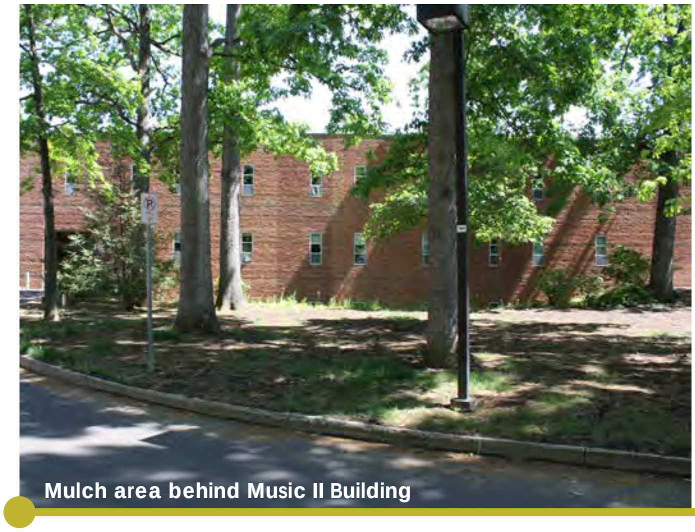



Typical mulch saucer on campus


Mulch to tree dripline near Ag. Sciences


Mulch strip along McKean Road


Mulch bioswale along College Ave


Mulch area behind Music II Building


Mulch area west of Hamilton Hall

Under Trees

While mulch rings are a common treatment for tree root zones, fragmented or unnecessarily large tree rings provide little to no ecological value to the campus landscape.

OBSERVED PATTERN 2

EXPANSIVE MULCH BEDS

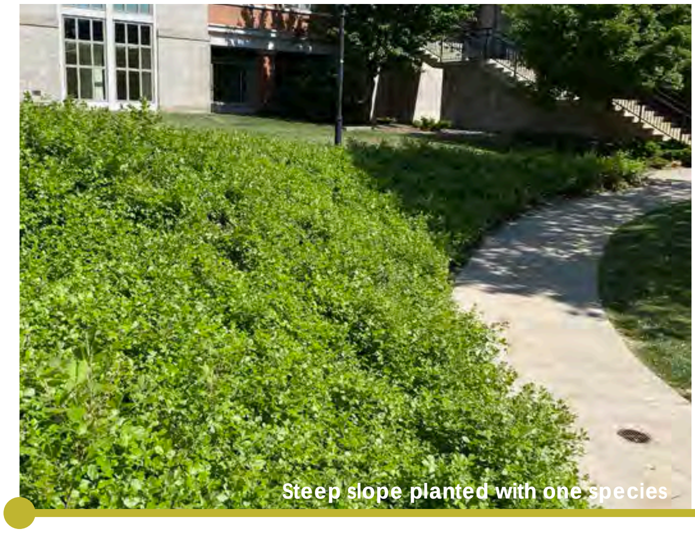
Large mulch beds are pervasive across the campus, adding little ecological value to the campus landscape. The presence of large mulch beds invites the use of chemical treatments to control weeds. The current scale of re-mulching these beds exceeds 2,000 tons (3,500 - 4,000 cubic yards) per year. At $20/CY, this is roughly $70,000 - 80,000 in mulch material costs, excluding labor costs to spread the material.

High Traffic Areas

Large expanses of mulch are often found in high traffic areas where disturbance is common. Salt and snow loads contribute to the physical and chemical degradation of soils in these areas as well.

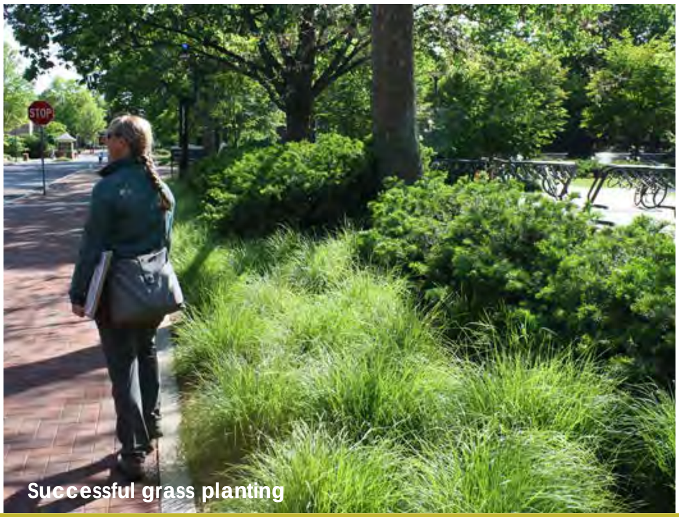
Low Visibility

There are examples across campus of mulch beds in areas behind buildings or on less visible paths. Mulch beds can often be found in dense shade where lawn or herbaceous materials have struggled to survive, or in back-of-house areas that are not highly visible from higher-trafficked areas.

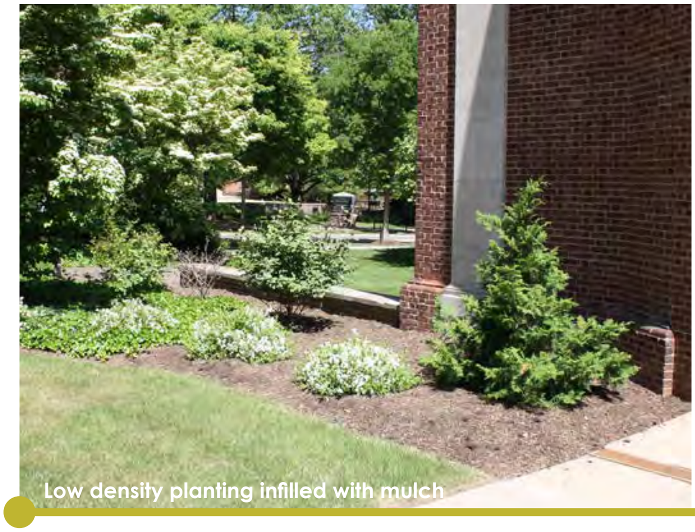

Steep slope planted with one species


Steep slope planted with one species


Matrix planting near East Halls



Successful grass planting


Low density planting infilled with mulch


Low density plant bed infilled with mulch

OBSERVED PATTERN 3

SHRUB+HERBACEOUS BEDS

There are roughly 50 acres of planting beds in the study area. Shrub beds take up +/- 37.5 acres with horticultural (mixed herbaceous perennials) beds making up roughly 8 acres. The lack of planting density and species diversity in these beds are opportunities to improve the performance and environmental function of the landscape.

Plant Density

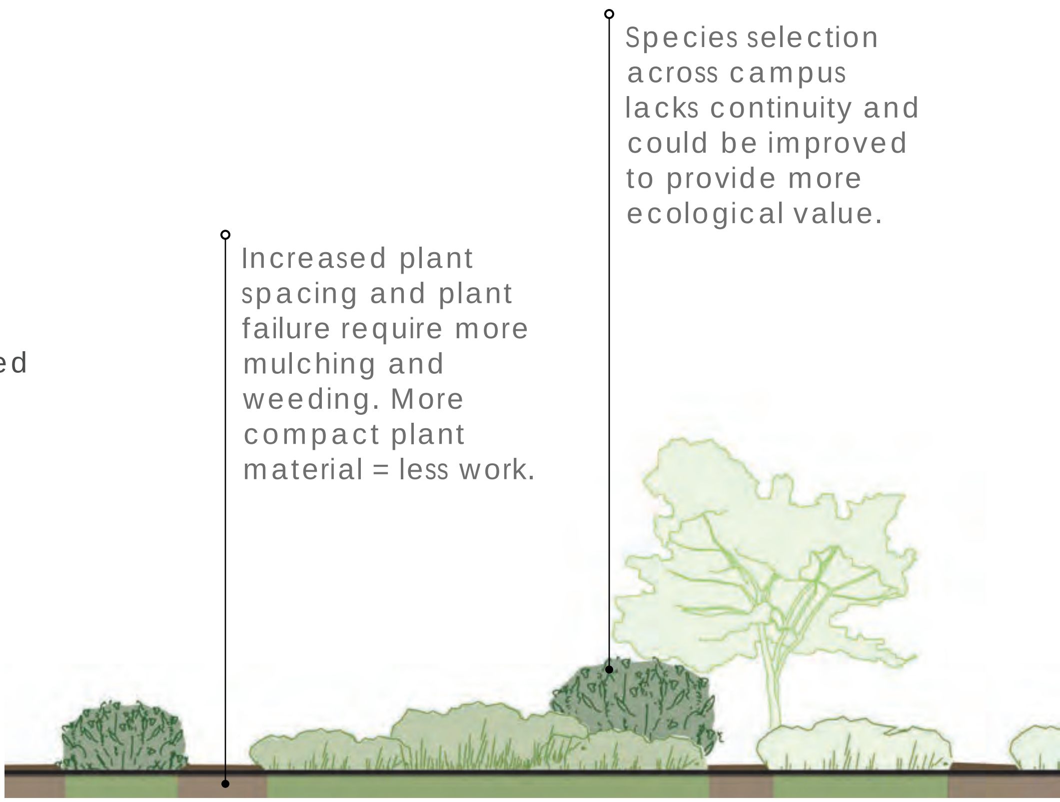
There are many examples of existing planting beds that lack the density necessary to reduce weed pressures. These beds encourage the continued use of mulch and chemical weed control.

Species Diversity

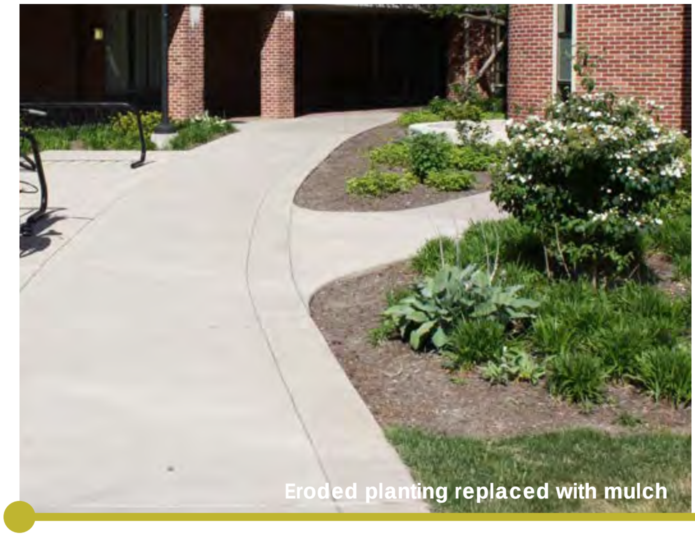
There are examples on campus of plant beds that have good species diversity, but these beds often lack continuity providing maintenance obstacles for those who have less herbaceous plant knowledge.

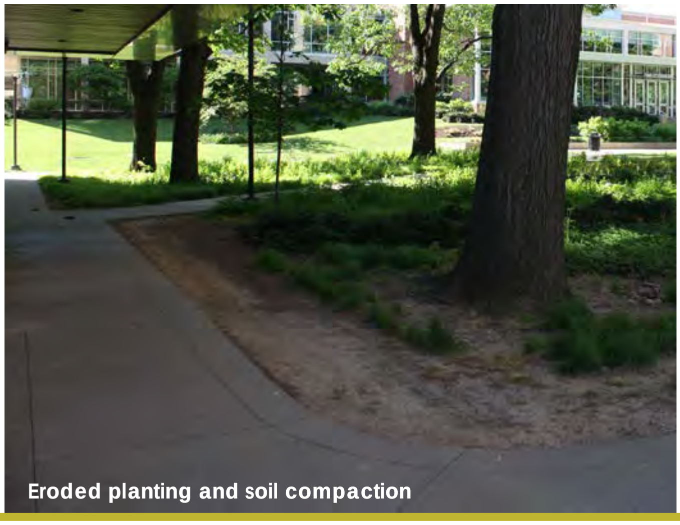
Coverage

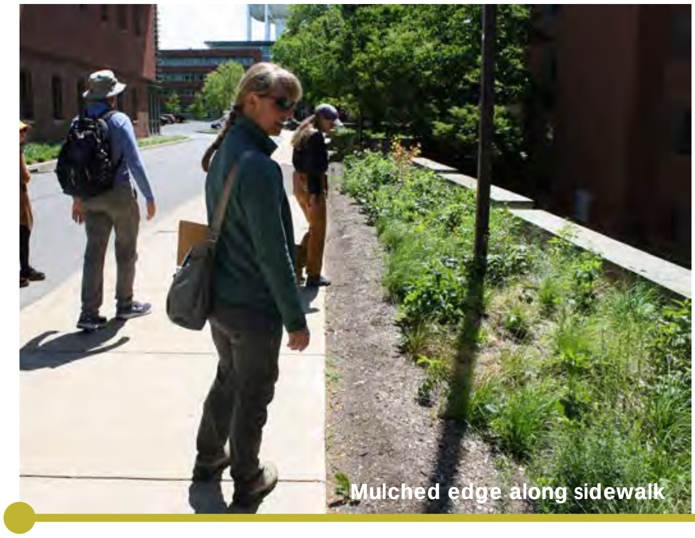
Plant spacing could be adjusted to reduce the need for mulch and increase biomass (carbon sequestration potential) in existing plant beds.

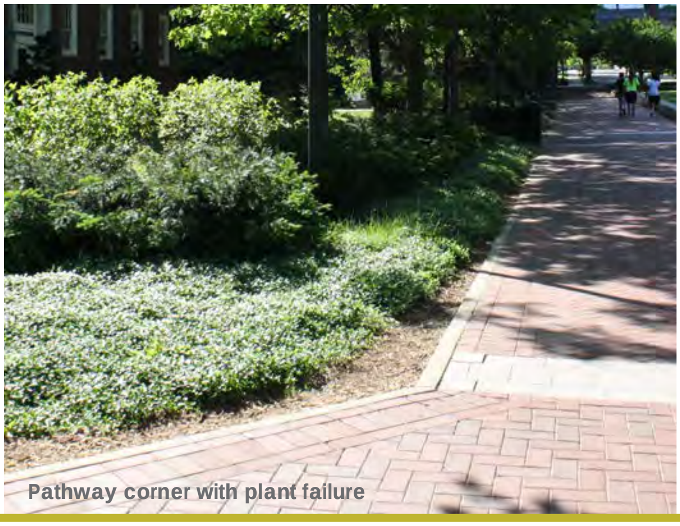


APPENDIX B: EXISTING CONDITIONS ASSESSMENT


Eroded planting replaced with mulch


Eroded planting and soil compaction


Mulched edge along sidewalk


Pathway corner with plant failure


Barren edge of pathway, near a steam line


Suffering lawn above a steam line

Traffic

"Shortcuts" and "goat paths" created by students wear on lawn or plant material grown adjacent to paths. Corner conditions are especially challenging for plant success.

OBSERVED PATTERN 4

PATHWAY EDGES

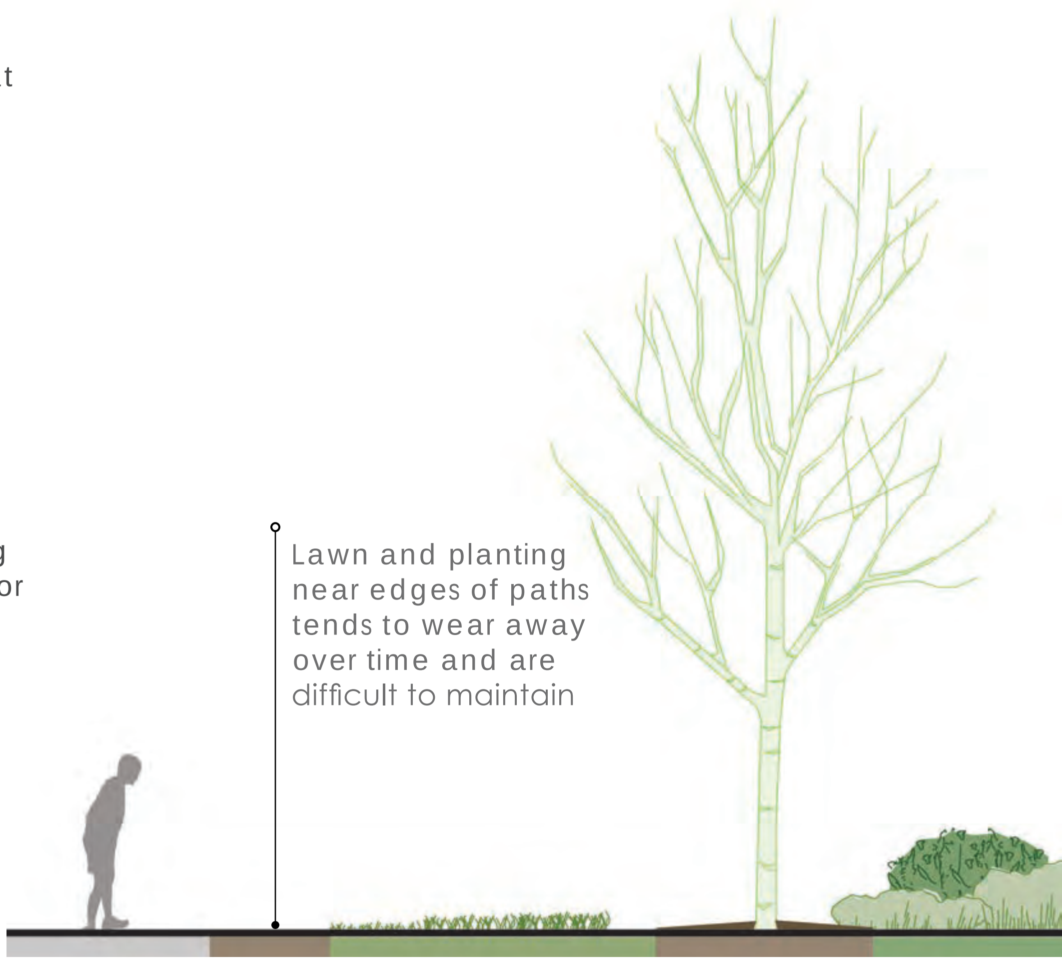
Eroded pathway edges can be found throughout the campus especially along highly trafficked pathways.

Snow Removal

Snow removal methods such as salting and plowing pathways are harsh on the adjacent landscapes, often wearing away any lawn or planting that once existed.

STEAM LINES

Steam lines are a constant challenge on campus, causing many surface plantings to fail or at least preventing them from thriving.



C

APPENDIX BASELINE METRICS METHODOLOGY

ARTS & SCIENCES QUAD, NEAR THE ARTS COTTAGE | 2023

APPENDIX C: BASELINE METRICS METHODOLOGY

BASELINE DEVELOPMENT (EXISTING CONDITIONS)

The process for developing the Penn State Campus baseline greenhouse gas (GHG) emissions and sequestration included:

1. Collection of data and quantities from Penn State staff in collaboration with the consultant team
2. Inputting the unit quantities into the Pathfinder app for general materials and methods
3. Adding customized elements into the Pathfinder app as needed for items specific to Penn State
4. Populating the overall scorecard summarizing campus net GHG outcomes

CALCULATIONS FOR OPERATIONAL EMISSIONS

Maintenance Equipment

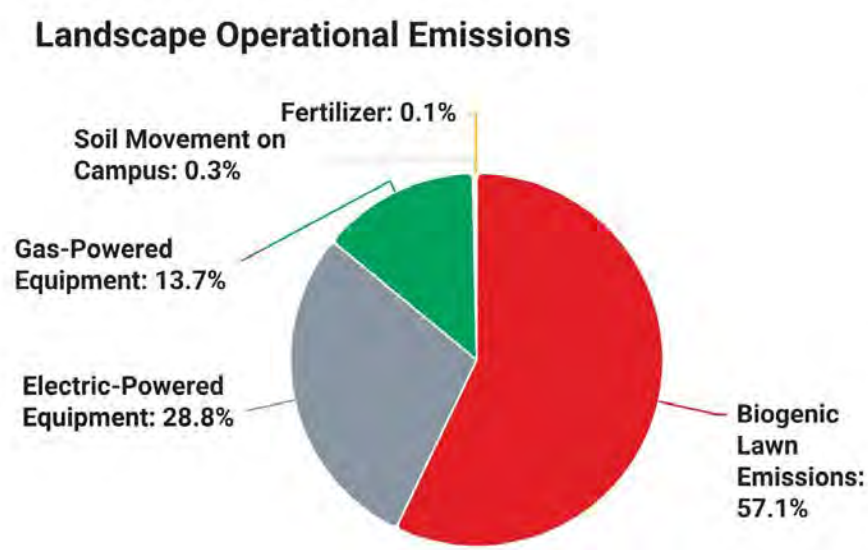
When using Pathfinder, the cumulative hours of usage annually for these types of equipment are entered.

For gas-powered equipment, emissions are calculated as follows:

Emissions = HP * EF * Runtime * LF

Where:

HP: Rated horsepower of the equipment [in hp] – user input or default present in calculator




climatepositive design

Climate Positive Design **Scorecard**

Plants

Element	Total impact
Minimal management lawn	2,078,063.2 kg
Subtotal	2,078,063 kg

Operations

Element	Total impact
Soil Movement Off and Back onto Campus in 2022	9,188 kg
Lawn-mowers (electric)	978,334.2 kg
Trimmers/Edgers (electric)	70,256 kg
Leaf blowers (gas)	339,877.8 kg
Lawn-mowers (gas)	158,474.3 kg
Applied NPK to shrubs	3,277.3 kg
Subtotal	1,559,408 kg
Net Impact over 50 Years	3,637,471 kg CO2-eq
Annual Impact	72,750 kg CO2-eq

Project Baseline (Current 2023 Emissions)

EF: Emissions factor for the pollutant, from the equipment [in g/hp-hr] – obtained from an EPA publication[5] Runtime: Number of hours that the equipment was functioning [in hr] – user input

LF: Load factor - fraction of time equipment is used at rated HP [unitless] – obtained from an EPA publication[6]

For electric-powered equipment, emissions are calculated as follows:

Emissions = Power * EF * Runtime * LF

Where:

Power: Rated power of the equipment [in W] – user input for voltage/current rating or default present in calculator

EF: Emissions factor for US average electricity [in kgCO2eq] – obtained from an EPA publication7

Runtime: Number of hours that the equipment was functioning [in hr] – user input

LF: Load factor - fraction of time equipment is used at rated HP [unitless] – same as gas-powered

Electric Mowers (Mean Green Electric Zero Turn Lawn Mower and Greenworks Zero Turn): 7,200 watts, 11,648 hours annually

Penn State mows 6.5 months out of the year, mowing every 5 business days. 6.5 months = 26 weeks. 26 weeks = 182 days. Within those 182 days are 52 weekend (non-business) days. Therefore, 182-52=130 days of potential mowing. 130 / 5 business days = 26 mows / yr. = 11,648 hours annually)

Electric Trimmers: 1,500 watts, 1,456 hours annually

Electric Equipment Types: Greenworks and Dewalt. Mostly electric Mean green Zero Turn and Greenworks Zero Turn. Backpack (Solo) Sprayers. ZSprayers.

Gas Powered Blowers: 4.5 horsepower, 1,456 hours annually (Practice is to: Mulch, vacuum, blow into piles and collect. Bring to Penn State Compost Center.)

Gas Powered Push Mowers: 5 horsepower, 1,456 hours annually

Maintenance Hours Estimates (provided by Stimson):

- 28 grounds maintenance employees, working 6.5 months (26 weeks) annually
- Assuming an average of 23 mowing cycles annually
- Typical lawn maintenance tasks during the work week per employee during this 6.5 month period includes:
    - 16 hours of ride mowing (16 hrs/wk x 28 staff x 26 weeks = 11,648 hours annually)
    - 2 hours of push mowing (2 hrs/wk x 28 staff x 26 weeks = 1,456 hours annually)

  - 2 hours of string trimming (2 hrs/wk x 28 staff x 26 weeks = 1,456 hours annually)
  - 2 hours of blowing/cleaning (2 hrs/wk x 28 staff x 26 weeks = 1,456 hours annually)
  - 22 hrs/wk total lawn maintenance (22 hrs/wk x 28 staff x 26 weeks = 16,016 hours annually)
- The remainder of their typical work week during the 6.5 month lawn maintenance period includes:
  - 10 hours of trash/picking (10 hrs/wk x 28 staff x 26 weeks = 7,280 hours annually)
  - 4 hours of weeding, pruning, spraying (4 hrs/wk x 28 staff x 26 weeks = 2,912 hours annually)
  - 2 hours of off time (vacation, sick, etc) (2 hrs/wk x 28 staff x 26 weeks = 1,456 hours annually)
  - 2 hours mulching (2 hrs/wk x 28 staff x 26 weeks = 1,456 hours annually)
  - 18 hrs/wk total non-lawn maintenance tasks (18 hrs/wk x 28 staff x 26 weeks = 13,104 hours annually during lawn mowing period)

Soil Movement

Emissions associated with the transportation of soil – both import and off-haul – are based on the volume of soil being moved. Data is used from Athena IE4B[8], from which transportation impacts were averaged for a variety of aggregate products with similar characteristics to soil.

Soil Movement (soil was removed from campus and brought back in 2022): 13,880 cu.ft.

Fertilizer

Emission factors associated with fertilizer production are obtained from Dr Gu's study[9] (reference 3[10]).

For NPK, these are 4.76 kg CO2/kg N; 0.73 kg CO2/kg P; 0.55 kg CO2/kg K.

The emission factor associated with fertilizer application is obtained from Table 11.1 of the IPCC report referenced[11]. It is 0.01 kg N20/kg N applied.

Users can either input amounts of N, P and K applied every year (can be varied in each year) to obtain fertilizer emissions or input number of Agriform tablets applied per tree/shrub, which has an emission factor of 0.0385 kgCO2eq/tablet calculated using the numbers above.

Penn State Hort Bed Fertilizers: 6 applications for first year, 4 applications after year 1.

Product: OMNI rated Triforce (only used on hort beds).

22.7kg for 12,500 sf

N 16%, P 2%, K 2%.

Nitrogen kg/sf = 0.000288, Phosphorus kg/sf = 0.000036, Calcium kg/sf = 0.000036

Application rate per manufacturer (4 lbs/1,000sf / 1.8 kg/1,000sf)

Lawn Emissions

Summary

Grass absorbs carbon dioxide the same way trees do, but on a smaller scale. Through photosynthesis, each plant takes carbon from the atmosphere and uses it to build more plant matter. When grass dies or trees are cut down, that carbon is released back into the atmosphere. - *Scientific American, Ashley Ahearn on December 1, 2008*[12]

Lawns can be either net sources or sinks depending on the interplay of the soil N2O flux and carbon sequestration9.

N2O is a greenhouse gas with about 298 times the GWP of CO2 (GWP of CO2 is 1) and is released when microbes act on excess nitrate available after mowing or the application of fertilizer. Intensively managed lawns (those that are regularly irrigated, mowed and fertilized) have higher carbon sequestration but also a higher N2O flux, which can overpower the former.

Despite the Penn State campus only uses organic fertilizers on its lawns and does not irrigate, greenhouse gas emissions still originate from lawn clipping decomposition and denitrification alone. Depending on the age of the lawn and its ability to sequester carbon and process nitrogen, a percentage of the carbon and nitrogen found within decomposing lawn clippings is released back into the atmosphere.

Nitrogen is naturally occurring within soil. Regardless of supplemental nitrogen fertilizer application, lawns require nitrogen to grow so will extract it from the soil through the root system and distribute it throughout the lawn blades. Therefore, lawn clippings contain nitrogen and once cut these clippings succumb to decomposition (which is when microbes digest clippings and release the carbon dioxide back into the atmosphere through respiration). Denitrification is a similar process where the nitrogen found within lawn clippings is broken down by microorganisms which then ingest, convert and release nitrous oxide back into the atmosphere.

The primary data source used in the Penn State Sustainable Landscape Implementation Plan analysis (also used in the Pathfinder Application) to calculate lawn or turf grass greenhouse gas (GHG) emissions was extracted from[9]: Gu, C., Crane, J., Hornberger, G., & Carrico, A. (2015). The effects of household management practices on the global warming potential of urban lawns. Journal of Environmental Management. After obtaining the lawn areas on Penn State's campus, they are then multiplied by the emissions/sequestration factors in kg-CO2eq for lawn planting obtained from Dr Gu's study which studied urban turfgrass systems in Nashville, TN. While this publication is considered the seminal study on the topic (and was recommended by a third party consultant, Atelier Ten, in 2019 as the foremost reputable data on the subject) note that it suggests additional further study and analysis are needed to advance this topic area as limited information is currently available to date.

APPENDIX C: BASELINE METRICS METHODOLOGY

Based on the above, Penn State's estimated current lawn emissions are as follows:

Penn State Baseline (current) Lawn Emissions of 346.5 kg CO2ha/yr (0.003kg CO2-eq/ sf-year) represent:

- Penn State mows 6.5 months out of the year, mowing every 5 business days. 6.5 months = 26 weeks. 26 weeks = 182 days. Within those 182 days are 52 weekend (non-business) days. Therefore, 182-52=130 days of potential mowing. 130 / 5 business days = 26 mows / year = 11,648 hours annually)
- No irrigation
- Mowing at 3" height with electric equipment only (note maintenance equipment emissions are captured separately and include electric mowing, electric trimming, and gas powered blowers.)
- Organic fertilizer application only (no synthetics)
  - The emissions value (from the MIN strategy of the referenced report[9]) includes no fertilizer carbon cost which means that only on-site Penn State-made natural fertilizer has been applied (i.e., compost or manure).
- Estimate of 85% clipping recycle (remain in place) - per MIN strategy study calculation of the Gu study[9]
- Lawn area: 6,455,379 sf (148 acres)

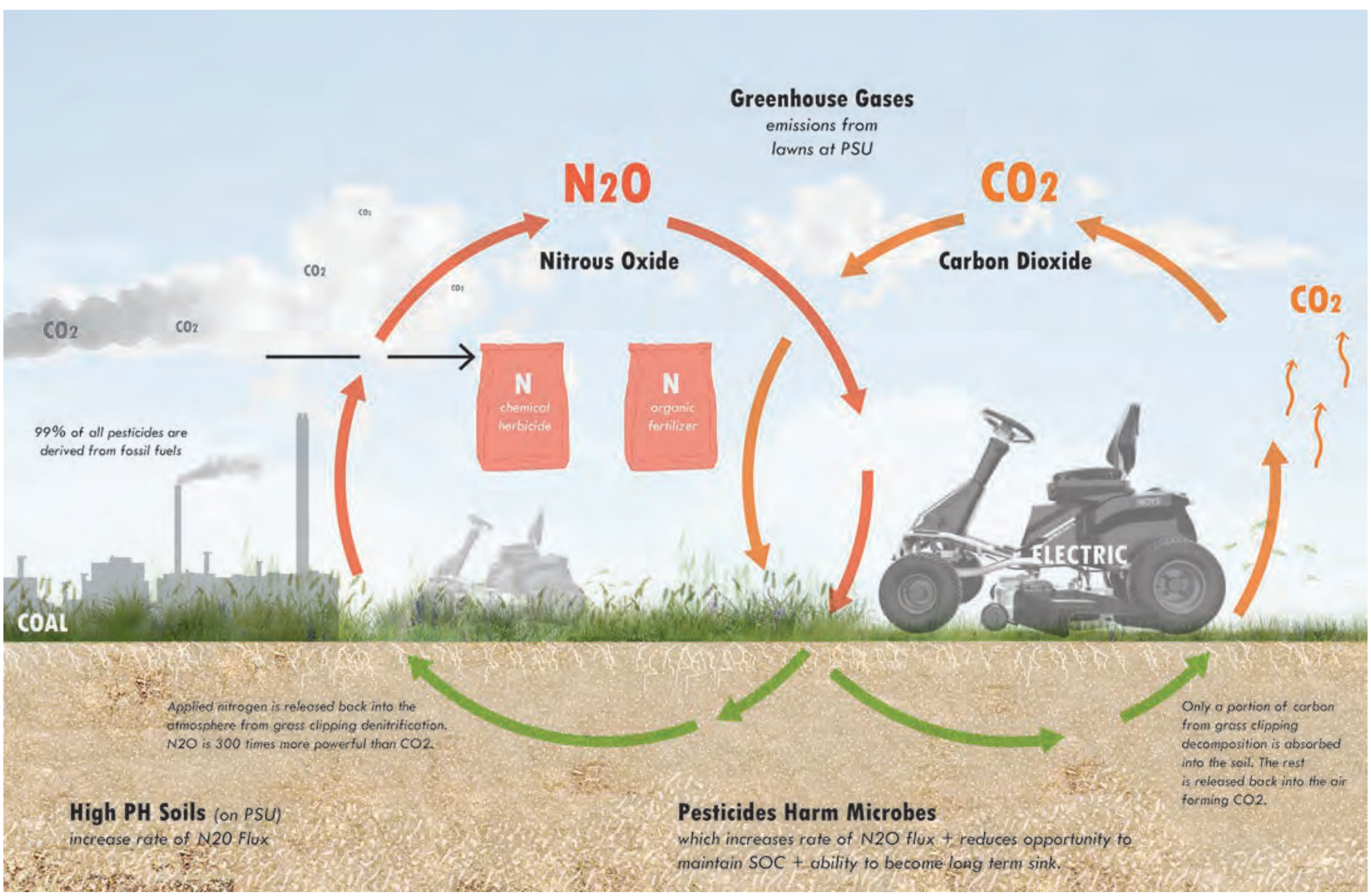
Disclaimers, Exclusions and Assumptions: The analysis is considered to be conservative in approach, as its lawn emissions have the potential to be much higher.

1. The MIN and MOD lawn management strategies used in the study[9] include 16 mowing events per year each while INT assumes 22 per year. Based on Penn State's estimated 26 mowing events per year using the MIN values yields conservative results. This approach was taken to allow for contingencies of assumptions and estimations. If the INT lawn management strategy was used to account for the higher mowing event frequency, Penn State's overall environmental impact from lawn management would have been about 4.5 times greater than documented in the Baseline as it would include incorrect assumptions in other areas such as fertilizer use.
2. Herbicide emissions are significant and have been excluded from this study. Products used on Penn State campus include Battleship III and Dimension. They are applied through spray or fertilizer, at the application rate of 2 times per year at .0000kg/sf. average. For future study and/or reference, Roundup emits 31.29 kilograms of CO2e per kilogram of product applied while other pesticides produce greater than 40 kilograms CO2e per kilogram on average.
3. Fertilizer application rates were not provided or estimated. However, the study notes that fertilizer, even organic, can include high levels of nitrogen. Therefore, the fertilizer application included on

campus may add nitrogen to the lawn which can then be partially released into the atmosphere in the form of nitrous oxide (referred to as N20 flux), which is a greenhouse gas approximately 298 times more potent than CO2 by volume.

4. High pH soils increase the rate of N20 flux. Considering the soils on Penn State's campus are highly alkaline (basic), the chances that there is a high rate of N20 flux is likely, but can only be confirmed through monitoring and testing, which was not currently available at the time of this report.

5. As the calculations are not exact in nature, the data impact findings should be considered an estimate, based on the best data available to date.



APPENDIX C: BASELINE METRICS METHODOLOGY

Lawn Emissions Methodology and Calculations

Lawn Management Article Summary for Pathfinder Data

The data used in the Pathfinder Application to calculate lawn or turf grass greenhouse gas (GHG) emissions was extracted from:

Table 6 within the article[9] lists the final study data for the Intensive (INT), moderate (MOD), and minimal (MIN) lawn management scenarios. Data shown includes nitrous oxide (N20) flux, soil organic carbon sequestration rate (dSOC), carbon cost (CC) and net Global Warming Potential (GWP) estimates for the three different lawn management scenarios.

Table 6
The 75-year mean N_2O flux, SOC sequestration rate (dSOC), carbon cost (CC) and net Global Warming Potentials (GWPs) for the INT, MOD, and MIN scenarios.

	INT	MOD	MIN
Soil N_2O fluxes (kg N ha^{-1} yr^{-1})	3.57	1.11	0.75
dSOC (kg C ha^{-1} yr^{-1})	18.47	4.99	−28.8
CC_N (kg CO_2-eq ha^{-1} y^{-1})	424.23	104.87	0
CC_k (kg CO_2-eq ha^{-1} y^{-1})	55	21	0
$CC_{fertilizer}$ (kg CO_2-eq ha^{-1} y^{-1})	424.23	104.87	0
CC_{mowing} (kg CO_2-eq ha^{-1} y^{-1})	482.2	350.7	350.7
$CC_{irrigation}$ (kg CO_2-eq ha^{-1} y^{-1})	59.77	14.94	0
CC_t (kg CO_2-eq ha^{-1} y^{-1})	966.2	470.5	350.7
Net GWP(kg CO_2 ha^{-1} y^{-1})	2442.5	845.4	697.2

As shown in Table 6, the carbon costs for fertilizer, irrigation, and mowing are listed separately and then included in the Net GWP estimate totals at the bottom. The calculation used to determine the net GWPs can be found in section 2.9 Net GWPs estimates.

2.9. Net GWPs estimates

To achieve a complete accounting of the climatic impact of lawn management, we adopted the following equation to calculate the combined GWPs for 100 years (Li et al., 2005):

$$Net\ GWP = 25 \times 16 \times CH_4/12 + 298 \times 44 \times N_2O/28 - 44 \times dSOC/12 + CC_t \left(kg\ CO_2\ ha^{-1} yr^{-1}\right) \quad (2)$$

where net GWP (kg CO_2 equivalent ha^{-1} y^{-1}) is the net global warming potential; CH_4 is CH_4 flux (kg C ha^{-1} y^{-1}); N_2O is N_2O flux (kg N ha^{-1} y^{-1}). dSOC is the change in soil organic carbon (SOC) or SOC sequestration rate (kg C ha^{-1} y^{-1}), and CC_t is the total carbon cost of lawn maintenance including mowing, fertilizer application, and irrigation (kg CO_2 ha^{-1} yr^{-1}).

Therefore, the remaining equation used to calculate lawn emissions on Penn State's campus are:

Net Global Warming Potential (kg CO2 eq) = lawn clipping biogenic decomposition (CO2) and denitrification (N2O) = methane (CH4) emissions (sink) + lawn nitrous oxide (N2O) emissions - sequestration rate of soil organic carbon (dSOC)

(Net GWP for Penn State Lawn = 25 x 16 x CH4/122 + 298 x 44 x NO/28 - 44 x dSOC/12)

To fully extrapolate the equation above, the conversion for other greenhouse gases (dSOC, N20, and CH4) to CO2 equivalent can be found as shown below[13].

TABLE IV

Simulated annual average soil C-sequestration (ΔSOC), N_2O, and CH_4 emissions for standard (STD) and alternative (ALT) management (see Table III for details), and change in CO_2-equivalent emissions (ALT minus STD) for a 100-yr time horizon

	ΔSOC[a] (kg C ha^{-1} y^{-1})		N_2O flux[b] (kg N ha^{-1} y^{-1})		CH_4 flux[b] (kg C ha^{-1} y^{-1})		ALT minus STD (kg CO_2-equiv. ha^{-1} y^{-1})			
Site	STD	ALT	STD	ALT	STD	ALT	ΔSOC[c]	N_2O[d]	CH_4[e]	Total
Iowa	−420	−1200	+7.4	+12	−2.6	−2.7	−2800	+2100	−3.1	−670
Hebei	+150	−680	+13	+20	−1.7	−2.0	−3100	+3200	−9.2	+140
Bavaria	−97	−440	+8.8	+17	−0.96	−1.2	−1300	+4000	−7.4	+2700

All values reported to two significant figures.
[a]Negative values imply net annual sequestration of carbon in soil; positive values imply net annual loss of carbon from soil.
[b]Flux sign convention is positive for net emissions from soil, negative for net uptake by soil.
[c]kg CO_2-equivalents ha^{-1} y^{-1} = $(\Delta SOC_{ALT} - \Delta SOC_{STD}) \times$ (44 kg CO_2/12 kg C).
[d]kg CO_2-equivalents ha^{-1} y^{-1} = $(N_2O_{ALT} - N_2O_{STD}) \times$ (44 kg N_2O/28 kg N) × 296.
[e]kg CO_2-equivalents ha^{-1} y^{-1} = $(CH_{4\,ALT} - CH_{4\,STD}) \times$ (16 kg CH_4/12 kg C) × 23.

The lawn data in Pathfinder includes the net GWP for each management scenario minus the irrigation and mowing carbon costs to allow for a more customized lawn management approach. An explanation of the calculation for and inclusions within each carbon cost can be found in section 2.8 Carbon costs of lawn management.

2.8. Carbon costs of lawn management

The carbon costs (CC) are the amount of energy consumed by different turfgrass maintenance practices from manufacturing to the amount used in lawn management. Energy use can then be converted to units of CO_2 equivalent (CE) to represent equivalent amount of CO_2 emitted from these energy uses. CCs are summed for each turfgrass management practice to estimate the total CC (CC_t) (Zirkle et al., 2011).

$$CC_t = CC_{fertilizer} + CC_{mowing} + CC_{irrigation} \quad (1)$$

where CC_t is the total carbon costs from lawn care practices [kg CO_2 ha^{-1} y^{-1}]; $CC_{fertilizer}$ is the carbon costs of manufacturing, transporting and commercializing the fertilizer [kg CO_2 ha^{-1} y^{-1}]; CC_{mowing} is the carbon costs of mowing [kg CO_2 ha^{-1} y^{-1}]; and $CC_{irrigation}$ is the carbon costs of irrigation [kg CO_2 ha^{-1} y^{-1}].

The CE conversion of fertilizer was 4.76 kg CO_2/kg N, 0.73 kg CO_2/kg P, and 0.55 kg CO_2/kg K respectively (Lal, 2004a). $CC_{fertilizer}$ was the sum of the products of annual amount of N, P, and K in kg applied and their corresponding conversions.

To estimate CC_{mowing}, we assume that 2.47 gallon gasoline is consumed to mow one hectare lawn using a walk-behind mower (Sahu 2008). The CE conversion of gasoline is 8.87 kg CO_2 per gallon of gasoline (Lal, 2004b). To determine the total kg of CO_2 emitted each year by gasoline, we multiply 2.47 gal $ha^{-1}$by 8.87 kg CO_2 gal^{-1} and the mowing times a year.

To calculate $CC_{irrigation}$, a hand-moved sprinkler conversion of 1.9 kgCO_2 ha^{-1} per irrigation event from farm operation was adopted to represent the carbon cost of each irrigation event (Lal,

APPENDIX C: BASELINE METRICS METHODOLOGY

The irrigation carbon cost applies only to lawn watering frequency and since Penn State does not irrigate lawns this cost does not apply to the study. Similarly, the mowing carbon cost in the study data is calculated based on emissions from gas-powered equipment. This cost was also deemed irrelevant as users can specify lawn equipment type in the carbon cost section of Pathfinder. Mowing frequency impact on lawn growth and emissions are included within the net GWP estimates.

Based on the Table 6 data, below is the formula used in Pathfinder:

Original net GWP estimates - CCmowing - CCirrigation = Pathfinder net GWP estimates.

- MIN: 697.2 kg CO_2/ha/yr - 350.7 kg CO_2/ha/yr - 0 = 346.5 kg CO_2/ha/yr* (fertilizer excluded)
- MOD: 845.4 kg CO_2/ha/yr - 350.7 kg CO_2/ha/yr - 14.94 kg CO_2/ha/yr = 479.76 kg CO_2/ha/yr (for reference only, not included in the Penn State analysis)
- INT: 2442.5 kg CO_2/ha/yr - 482.2 kg CO_2/ha/yr - 59.77 kg CO_2/ha/yr = 1900.53 kg CO_2/ha/yr (for reference only, not included in the Penn State analysis)

* Indicates the emissions value used for Penn State lawn.

Therefore, the understanding based on the information provided in the study is that the remaining emissions data used for the Penn State lawn emissions analysis are primarily from lawn clipping decomposition (carbon release) and denitrification (nitrous oxide release).

Based on the data collected through survey results in the article, all lawns contribute to greenhouse gas (GHG) emissions either through releasing carbon or nitrous oxide back into the environment. As shown in Figure 4 (below), all lawns experience an eventual decline of the soil organic carbon (SOC) meaning that as mowing continues, not all of the discarded carbon in the clippings is being reabsorbed back into the lawn.

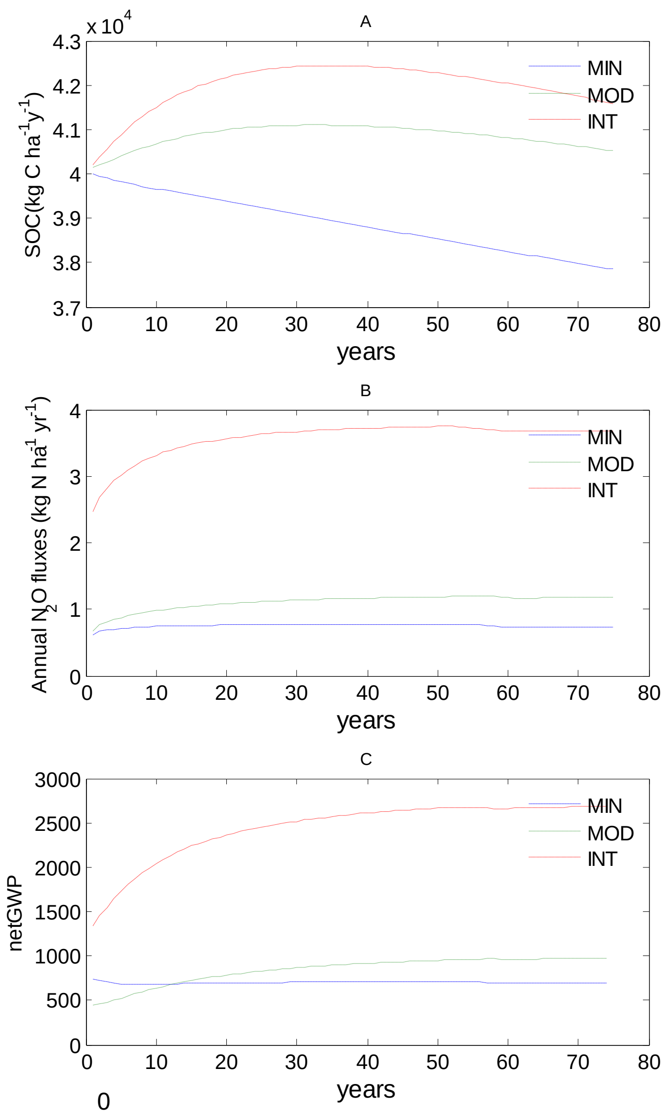


Figure 4. DNDC modeled impacts of lawn management scenarios (i.e. MIN, MOD, and INT) on long-term SOC accumulation (A), annual N2O flux (B), and ned GWP (C) over 75 years.

This is similar to the N_2O emissions as aesthetically pleasing lawns require nitrogen fertilizer on a regular basis with more needed initially at seeding or sodding. When this practice is combined with clipping recycle (leaving the clippings in place) and is not carefully monitored, it can create an over-saturated nitrogen environment which then releases N_2O into the environment consistently over the lifetime of the lawn. That said, according to the study results, clipping recycle combined with reducing or, better yet, stopping nitrogen fertilizer application is a best management practice (BMP) for creating a lawn that minimizes environmental impact. An additional bonus to clipping recycle is that it negates the carbon costs associated with the removal, transportation, and decomposition of the clippings in a landfill or similar location.

APPENDIX C: BASELINE METRICS METHODOLOGY

Embodied Emissions

A variety of LCA databases exist that can quantify environmental impacts associated with construction materials. Often this information comes directly from manufacturers in the form of 'Environmental Product Declarations' (EPDs) – a standard way of communicating an industrial product's environmental impacts. Data from manufacturer supplied EPDs and the Athena database8 have been built into the Pathfinder for the user to quantify the Global Warming Potential (GWP) of their product selections.

Based on the existing materials used on the site, the team quantified the elements and calculated their embodied carbon emissions using the Pathfinder.

HARDSCAPE - PRODUCT STAGE EMISSIONS

The calculation works as follows:

1. The user ascertains hardscaping materials being installed in the project under the following categories – paving, wall, curbs and headers, fences and gates, site elements, drainage/irrigation, subsurface elements, and planting/soil.
2. The user enters quantities of each material expected to be installed, performing unit conversions if necessary, to get data in the units accepted by the calculator.
3. The calculator has in-built values for GWP-per-unit of different materials, which are multiplied by the quantity of materials to get that product's GWP impact in kg CO2-eq.

The primary data source for embodied carbon of materials comes from the Athena Impact Estimator[8].

HARDSCAPE - TRANSPORTATION, CONSTRUCTION, USE AND END-OF-LIFE STAGE EMISSIONS

GWP impact data associated with the transportation, construction (including site work) and end-of-life stages is beyond the scope boundary of EPDs, and is dependent on project characteristics. The consultant team conducted test studies using Athena to estimate these impacts as a percentage of product-stage emissions. Based on these results, the impacts of transportation, construction and end-of-life processes are assumed to be 30% of product-stage emissions – (25%) transportation and (5%) installation.

For computing use-stage emissions, the consultant team made assumptions about the number of times each material would be replaced during the life of the project. These assumptions are based on the 2011 Architectural Manual published by the DCA Office of Affordable Housing[14] and modified by the team based on project experience and extent of replacement.

Materials

Element	Total impact
Steel Reinforcement	41,733.6 kg
Pipe - PVC Schedule 40	230,817.9 kg
Pipe - 8" (20.3cm) HDPE	3,368.2 kg
Organic Mulch	0 kg
Loose Aggregate Paving	13,157.1 kg
Sand	160.8 kg
Aggregate Base - Compacted	712,967.4 kg
Asphalt - Pedestrian	920,842.5 kg
Concrete - Pervious	2,501.6 kg
Asphalt - Vehicular	71,321,929.6 kg
Stone Paving	284,284 kg
Concrete Unit Pavers	157,536.3 kg
Concrete - Pedestrian	17,154,925.5 kg
Rubberized Play Surfacing	42,110.1 kg
Steel Reinforcement - Welded Wire Mesh	638,983.2 kg
Steel Reinforcement - #4 rebar @ 16" OC	663,474.1 kg
Concrete - Pedestrian	542,056.1 kg
Brick	9,271.3 kg
Concrete Site Wall	1,529,891.9 kg
Subtotal	**94,270,011 kg CO2e**

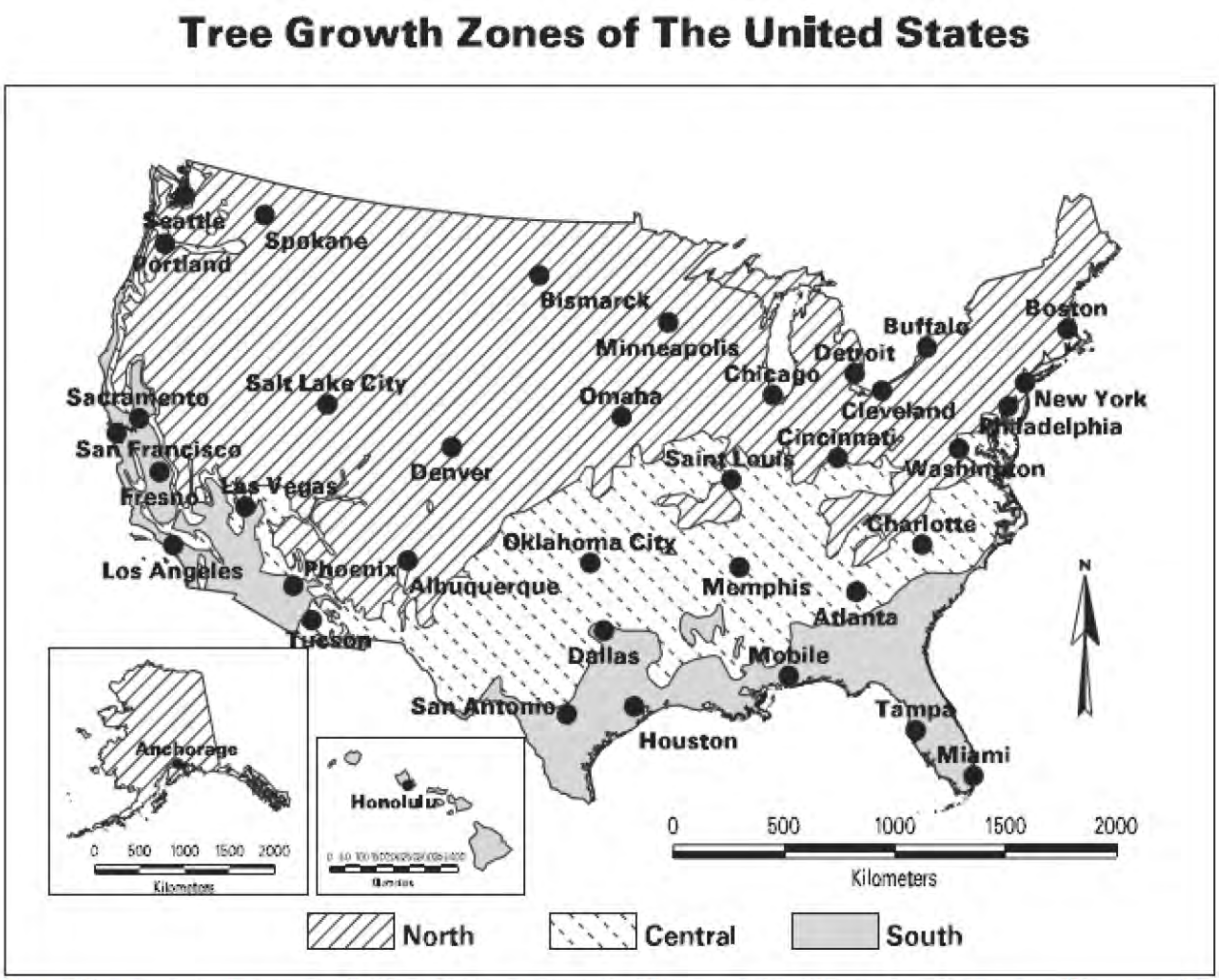
Biogenic Carbon Sequestration

TREES AND SHRUBS

All data used for calculating sequestration and decomposition for trees and shrubs is obtained (and modified as noted) from EG McPherson's seminal publication[1] listed in the footnotes, produced by the USDA Forest Service.

The calculation works in the following manner:

1. The user selects the geographical region in which the project is located as North, South or Central based on the Growth Zones Map
2. The user enters the number of each of the six type of trees being planted:



Ctg+ e 18—Tree growth zones for the United States correspond with mean number of freeze-free days per year (North = < 180, Central = 180-240, South = > 240) (Repeated as figure 25 in Appendix D).

2. The user enters the number of each of the six type of trees being planted:

Dec-Large	19	Definitions:
Dec-Med	14	• Deciduous—foliation period generally matches the duration of the cooling season
Dec-Small	1	• Evergreen—year-round foliation (includes conifers and broad leaf evergreens)
Evr-Large	28	• Large—mature height greater than 15 m (50+ ft)
Evr-Med	21	• Medium—mature height 10-15 m (35-50 ft)
Evr-Small	2	• Small—mature height <10 m (<35 ft)

3. Gross sequestration is calculated for each tree group (Dec-Large, Dec-Med, etc.) for 5-year age periods by multiplying the following:

    a. Number of trees in that tree group

    b. Mature sequestration rate (annual) for that tree group and region, obtained from Appendix A15. These were determined empirically during the USDA study

    c. Tree Age/Survival Factors (annual) for that age period and region, obtained from Appendix H,15. This is the product of a tree age factor (what % of Mature sequestration/decomposition rate is the tree going to experience in the given age period) and survival factor (what % of originally planted trees are expected to be alive in the given age period) – both determined empirically

    d. 5 (since above factors are annual, and we are calculating for a 5-year period)

4. Gross decomposition is calculated the same way as described above, by replacing the mature sequestration rate (b) by the mature decomposition rate.

5. Gross sequestration and gross decomposition numbers for each tree group and each age period are summed together, and the latter is subtracted from the former to obtain net sequestration for the project over 80 years.

MODIFICATIONS FOR SHRUBS

To account for the smaller size of shrubs, the mature sequestration and decomposition rates are obtained by doing the following:

- **Large shrubs:** Dividing rates for 'Dec-small' and 'Evr-small' tree groups for all regions by 3
- **Medium shrubs:** Dividing Large shrub rates by 2
- **Small shrubs:** Dividing Medium shrub rates by 2

Shrubs also have shorter lifespans – assumed to be 10 years, and the tree age/survival factors have been modified as follows:

- For Age Period 1-5, factors from the 11-15 age period for equivalent tree groups have been used to reflect a fast-growth period
- For Age Period 6-10, factors from the 31-35 age period for equivalent tree groups have been used to reflect a growth period closer to maturity

REPLANTING

The following assumptions have been made about replacement of dead trees and shrubs:

- 15% of the number of original planted trees are replanted every 20 years
- 100% of the number of originally planted shrubs are replaced every 10 years

An estimated quantity of the existing plant material on Penn State's core campus was calculated by the team and added to the Pathfinder to quantify biogenic carbon sequestration over a 50 year lifespan.

Climate Positive Design **Scorecard**

Plants

Element	Total impact
Perennials / Multi-Layer Shrub Mix	1,277,433.3 kg
Deciduous Small Shrubs	984,154 kg
Deciduous Large Shrubs	984,154 kg
Evergreen Medium Shrubs	159,932 kg
Deciduous Medium Shrubs	1,107,198 kg
Evergreen Large Shrubs	142,159 kg
Evergreen Small Shrubs	142,159 kg
Forest Preservation	1,137,110.9 kg
Evergreen Large Trees	4,282 kg
Evergreen Medium trees	13,263 kg
Evergreen Small Trees	11,026 kg
Deciduous Large Trees	97,962 kg
Deciduous Medium trees	302,085 kg
Deciduous Small Trees	347,305 kg
Stormwater Planting	2,884,806.9 kg

Net Impact over 50 Years **9,595,030 kg CO2**

APPENDIX C: BASELINE METRICS METHODOLOGY

PROPOSED PLAN

The process for developing the Penn State Campus baseline greenhouse gas (GHG) emissions and sequestration included:

1. Collection of data and quantities from Penn State staff in collaboration with the consultant team
2. Inputting the unit quantities into the Pathfinder app for general materials and methods
3. Adding customized elements into the Pathfinder app as needed for items specific to Penn State
4. Populating the overall scorecard summarizing campus net GHG outcomes

Plants

Element	Total impact
Minimal management lawn	2,078,063.2 kg
Subtotal	**2,078,063 kg**

Operations

Element	Total impact
Soil Movement Off and Back onto Campus in 2022	9,188 kg
Lawn-mowers (electric)	978,334.2 kg
Trimmers/Edgers (electric)	70,256 kg
Leaf blowers (gas)	339,877.8 kg
Lawn-mowers (gas)	158,474.3 kg
Applied NPK to shrubs	3,277.3 kg
Subtotal	**1,559,408 kg**
Net Impact over 50 Years	3,637,471 kg CO2-eq
Annual Impact	72,750 kg CO2-eq

Operational Emissions

Please refer to the Landscape Transformation Strategy table on page 171 to see the calculated performance % improvements

From the project baseline operational emissions to the proposed condition, a ~60% emissions reduction is accomplished.

Baseline: 3,637,471 kg CO2e/50 yrs (3,638 tonnes)

Proposed Option 1

Reduce Mowing from every 5 days to every 6 days =1,666,785.40 kgCO2e/50yrs. 54.2% emissions reductions

Proposed Option 2**

Reduce Mowing from every 5 days to every 7 days = 1,440,626.37kgCO2e/50yrs. 60.4% emissions reductions (selected option)

Operational Emissions from Proposed Option 2: Reduced Mowing from every 5 to 7 days	Emissions (kg CO2e)
Turf Biogenic Emissions	(891,489.46)
Electric Lawn Mowers	(419,705.37)
Electric Trimming	(70,256.00)
Electric Blowers	(51,888.98)
Electric Lawn (Push) Mowers	(7,286.57)
Eliminate Soil Movement	0.00
Eliminate Chemical Fertilizers	0.00
Net Impact over 50 Years	(1,440,626.37)

Potential Options:

Option 1: Relax mowing frequency from every 5 business days to every 6 business days:

Penn State mows 6.5 months out of the year, mowing every 6 business days. 6.5 months = 26 weeks. 26 weeks = 182 days. Within those 182 days are 52 weekend (non-business) days. So 182-52=130 days of potential mowing. 130 / 6 business days = 22 mows / yr.

Option 2(selected option): Relax mowing frequency from every 5 business days to every 7 business days:**

Penn State mows 6.5 months out of the year, mowing every 7 business days. 6.5 months = 26 weeks. 26 weeks = 182 days. Within those 182 days are 52 weekend (non-business) days. So 182-52=130 days of potential mowing. 130 / 7 business days = 19 mows / yr.

Embodied Emissions

The overall SLIP goal is to reduce 70% net by 2030, net zero emissions by 2035, and ideally zero out by 2040.

The following is a non-exhaustive list of strategies that Penn State can consider to reduce the campus's embodied carbon emissions. It can also be used to inform recommended revisions to the OPP Design and Construction Standards (refer to the "Application" section of the report for more details on specific recommendations):

- Reduce quantity of paving and structures
- Reduce concrete, stone, steel and foam (carbon-intensive materials) and consider using sustainably harvested wood as a substitute for concrete or metals
- Consider gravel, terrazzo, asphalt or other aggregate-based paving (trade-off with heat island reduction)
- Mandate specifications for low carbon materials
- Substitute cement with cementitious substitutions (SCMs) in concrete mixes (such as fly-ash, slag, glass pozzolan or others) and increase strength test duration
- Minimize over-design of site elements
- Maximize recycled content (especially in steel, etc.) and utilize re-purposed materials
- Specify and use locally sourced materials
- For more detailed considerations, refer to the Climate Positive Design Toolkit at https://climatepositivedesign.com/wp-content/uploads/2023/09/Climate-Positive-Design_Design-Toolkit.pdf

Biogenic Carbon Sequestration

The chart below outlines the typology transition and increase in potential carbon sequestration.

The performance improvement from baseline of sequestering 9,595,030.1 kgCO2e/50 yrs (9,595.03 tonnes/50yrs) to the proposed condition of sequestering 16,025,592.10 kg/CO2e/50yrs (16,025.59 tonnes CO2e/50yrs) is approximately a 40% sequestration increase.

Landscape transformation strategy	Carbon sequestration increase potential	Higher-performing landscape area
Replace lawn areas in dense shade:	+ 06.9%	+ 06.85 acres
Replace lawn areas on steep slopes:	+ 04.0%	+ 04.02 acres
Expand existing plant beds	+ 18.5%	+ 34.45 acres
Transform self-contained lawn panels	+ 07.2%	+ 22.89 acres
Transform lawn verges & parking islands	+ 02.7%	+ 09.54 acres
Replace mulched areas	+ 00.7%	+ 05.05 acres
	+ 40.0%	**+82.80 acres**

Maximize tree canopy cover:	*	+/- 425 new trees
Maximize Open Woodland Footprint:	+ __._%	+/-
Increase density in existing plant beds:	+ __._%	+/- 95% coverage

* Increasing by 425 deciduous medium size trees would increase sequestration by 161,902 kgCO2e over 50 years (and a ~1.0% overall sequestration increase)

Note: Implementation of all the ground flora transformation strategies listed above in green will meet the SLIP's stated goals for carbon sequestration increase. The "maximize tree canopy cover", "maximize open woodland footprint", and "increase density in planting beds" strategies have been excluded from the overall carbon sequestration increase potential calculations because their extents have not been quantified at this time. That said, implementation of these strategies would be in addition to meeting the SLIP's goals for carbon sequestration increase. These strategies should be pursued throughout core campus as an impactful step towards improved sustainability.

Exclusions / Assumptions / Data Sources

The following items have been identified as areas for further refinement and knowledge base expansion:

- Biogenic lawn emissions from decomposition and denitrification
- Capture sequestration rates at the species level
- Research more comprehensive sources for plant ecosystems (forests, wetlands, perennials, grasslands, mangroves etc.)
- Research and metrics on nursery practices to inform planting related emissions
- Regionally-specific electricity emissions factors for electric-powered equipment
- Expansion of Environmental Product Declarations (EPDs) of hardscaping construction materials with GWP-per-unit data
- Emissions related to lighting and related energy usage
- Carbon impacts of water usage from different sources (potable, reclaimed etc.) and benefits of minimizing use

References (in order of citation)

1. McPherson, EG.; Simpson, JR. (1999). Carbon dioxide reduction through urban forestry: Guidelines for professional and volunteer tree planters. Gen. Tech. Rep. PSWGTR-171. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture.
2. Carbon Cycle in Trees. Obtained from https://serc.carleton.edu/eslabs/carbon/1a.html. Last accessed 04/17/2019.
3. Greenhouse Gas Protocol. Obtained from https://ghgprotocol.org/. Last accessed 11/08/2023.
4. Climate Positive Design Toolkit. Obtained from https://climatepositivedesign.com/wp-content/uploads/2023/09/Climate-Positive-Design_Design-Toolkit.pdf. Last accessed 11/08/2023.
5. US Environmental Protection Agency (2010). Exhaust Emission Factors for Nonroad Engine-Modeling – Spark-Ignition.
6. Banks, J. L., & McConnell, R. (2015, April). National Emissions from Lawn and Garden Equipment. In the International Emissions Inventory Conference, San Diego.
7. US Environmental Protection Agency - Greenhouse gas equivalencies calculator: https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator. Last accessed on 04/18/2019.
8. “ATHENA® Impact Estimator for Buildings V5.2 Software and Database Overview.” (2017). Athena Sustainable Materials Institute, Ontario, Canada.
9. Gu, C., Crane, J., Hornberger, G., & Carrico, A. (2015). The effects of household management practices on the global warming potential of urban lawns. Journal of environmental management, 151, 233-242.
10. Interpretation of a 2004 Study (Lal, R. (2004). Carbon emissions from farm operations. Environ. Int. 30 (7), 981-990.
11. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Last accessed 04/17/2019.
12. Ahearn, Ashley. (2008) Carbon-Offset Cowboys. Scientific American. https://www.scientificamerican.com/article/carbon-cowboys/#:~:text=Soil%20Sequestration,released%20back%20into%20the%20atmosphere. Last accessed 11/08/2023.
13. Li, C.S., Frolking, S., Butterbach-Bahl, K., 2005. Carbon sequestration in arable soils is likely to increase nitrous oxide emissions, offsetting reductions in climate radiative forcing. Clim.Change72(3),321e338. 331.
14. 2011 Architectural Manual published by the DCA Office of Affordable Housing. https://www.scirp.org/(S(351jmbntvnsjt1aadkposzje))/reference/ReferencesPapers.aspx?ReferenceID=1131778.

D

APPENDIX OPPORTUNITY AREA MAPPING & DIAGRAMS

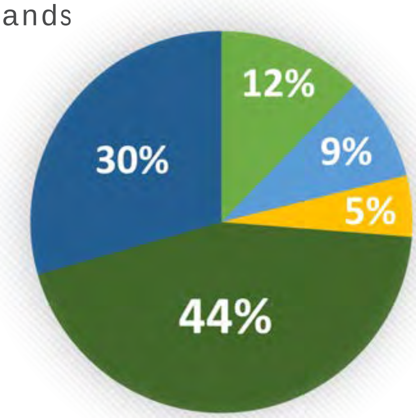
ARTS & SCIENCES QUAD, NEAR THE ARTS COTTAGE | 2023

APPENDIX D: OPPORTUNITY AREA MAPPING & DIAGRAMS

AREAS OF OPPORTUNITY

Improved landscape performance will be achieved by replacing higher-emitting landscapes with lower-emitting ones, while concurrently increasing the carbon sequestration potential of those areas. To meet the SLIP sustainability goals, input reductions & increased sequestration must occur on all +/-85 acres of the identified areas. The focus areas for maximizing sustainable ground flora shall include the following:

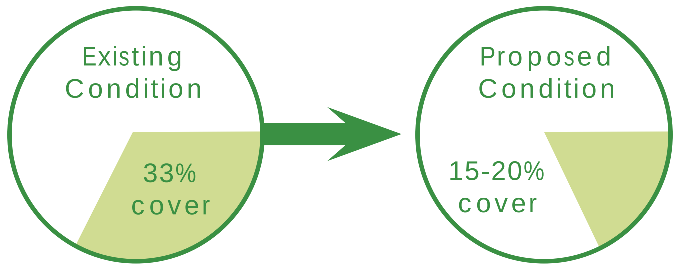
- Lawn verges and parking islands
- Lawns in dense shade
- Steep lawn slopes
- Fragmented lawns
- Isolated lawn islands



- 9.54 ac - Lawn verges & parking islands
- 6.85 ac - Lawns in dense shade
- 4.02 ac - Steep lawn slopes
- 35.45 ac - Fragmented lawns
- 22.89 ac - Isolated lawn islands

REDUCING THE LAWN FOOTPRINT

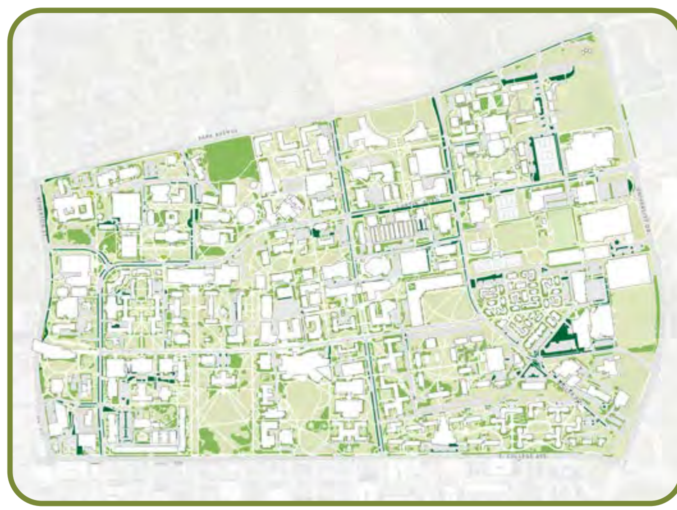
Lawns are the predominant landscape type on campus and make up 33% of the core campus groundcover. In order to shift the campus to a more sustainable landscape and achieve Penn State's emission reduction goals, the SLIP aims to reduce the lawn area from 33% cover to 15-20% cover. This would achieve a 50-60% reduction in the overall square footage of lawn and significantly reduce maintenance operation inputs.



Recommended reduction of lawn area within Penn State's core campus, by 2035

Replace Lawn Verges & Parking Islands

Lawn verges and parking islands are impacted by annual snow & salt loads, and severe soil compaction. These areas are time-consuming to maintain and require annual repair from winter damage.



Approximate area of existing lawn verges & parking islands

Expand existing Planting Beds

There are innumerable examples of lawn fragments as a result of multiple tree saucers, utilities, furnishings, and encroachment from plantings. These areas are difficult to mow and are unusable for recreational purposes. In many instances, an expansion of existing planting beds out to existing paving will eliminate these fragments and will reduce the tedious tasks of lawn trimming and push-mowing around a variety of obstacles.

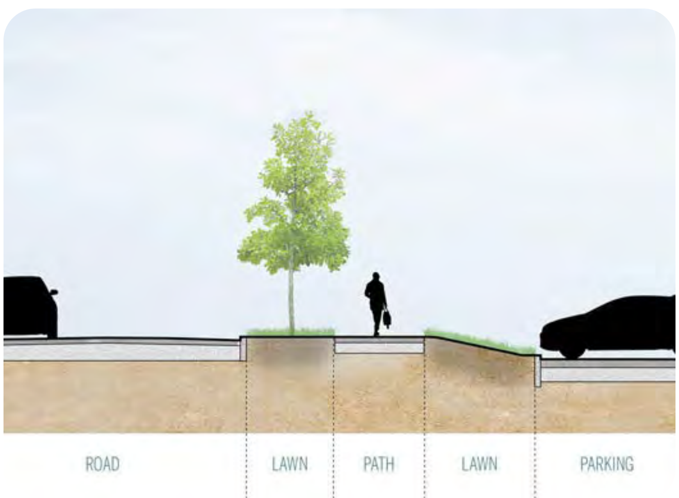
Approximate area of existing planting beds that can expand

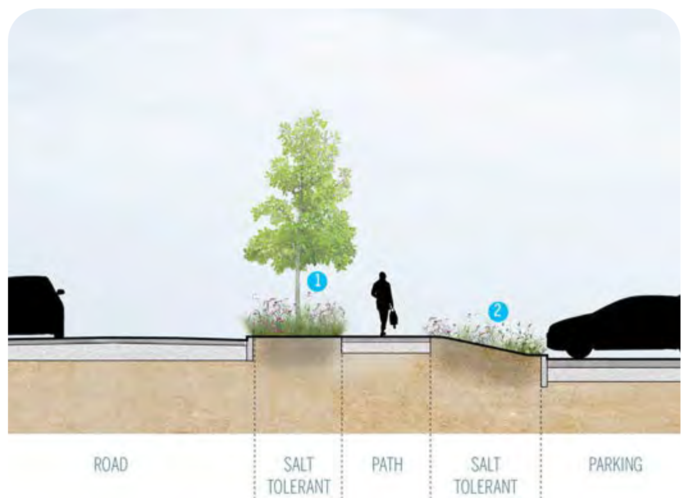
A typical condition of an existing lawn verge between the sidewalk and Burrowes Road.

A typical condition of a small fragmented lawn strip that can easily be absorbed by the planting bed.

Existing condition

Proposed condition





Replace Lawns in Dense Shade

There are examples across campus of struggling lawn areas in moderate to dense shade conditions that make it difficult for lawns to flourish. These areas are typically not sought out for recreational use and should be considered for change.

Approximate area of existing lawns in dense shade

Replace Lawns on Steep Slopes

Steep lawn slopes are difficult to maintain and are essentially unusable. Changing these challenging sites to a more sustainable landscape typology can lower maintenance inputs and provide environmental benefits.

Approximate area of existing lawns on steep slopes

Replace Self-Contained Lawn Panels

There are many examples across core campus of lawn panels framed by circulation routes on all sides. These self-contained islands of lawn have no relationship to any particular building or planting, and therefore have no context in many cases. These may present opportunities to experiment with new and unique landscape types.

Approximate area of self-contained existing lawn panels

Existing condition

Proposed condition

INCREASING PLANTING DENSITY

The SLIP aims to create and nurture healthier and more abundant ecosystems on campus. Increasing planting density shall aim to increase plant diversity, promote a range of food and habitat, and increase stability by reducing weed competition, and therefore the reliance on chemical use and annual mulching.

Replace Expansive Mulched Areas

Large mulch beds are pervasive across the campus, adding little ecological value to the campus landscape.

Densify Existing Planting Beds

Many existing planting beds on campus could be converted into more sustainable, lower maintenance ground flora typologies. Elements that work can remain and be enhanced by more elements of target vegetation typologies. Campus landscape architects and Hort Techs should begin by evaluating current planting beds and determine if a conversion makes sense, or if total makeover and replacement with new ground flora typologies is a better decision.

Increase Tree Canopy Cover

Site investigation and conversations with Penn State staff revealed that there are opportunities to significantly increase canopy cover by strategically adding trees of varying sizes. Priority should be given to large canopy trees or smaller understory tree species when there is not enough room for large trees.

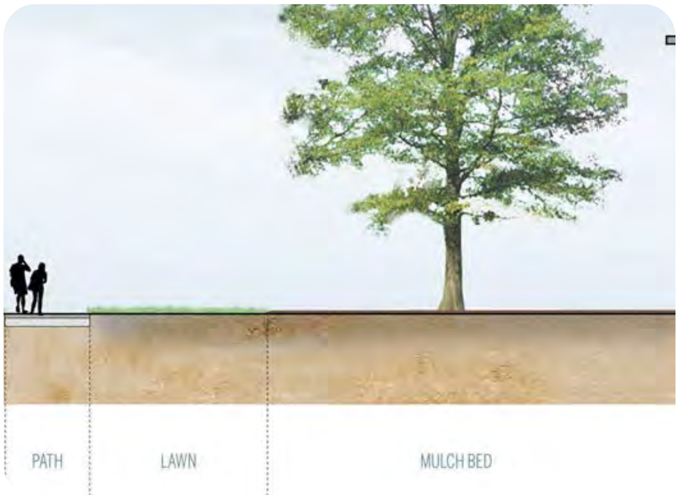
Approximate area of existing lawns in dense shade

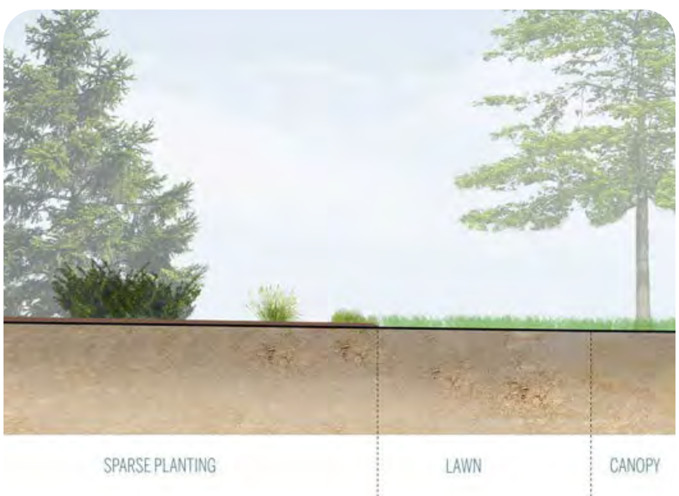
Approximate area of existing lawns on steep slopes

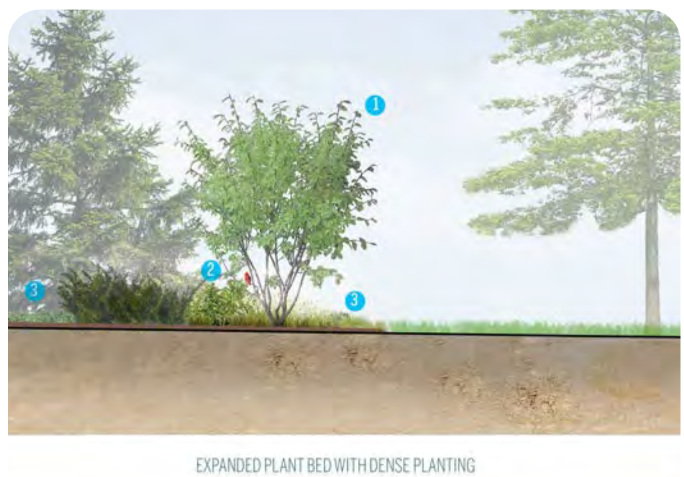
Approximate area of self-contained existing lawn panels

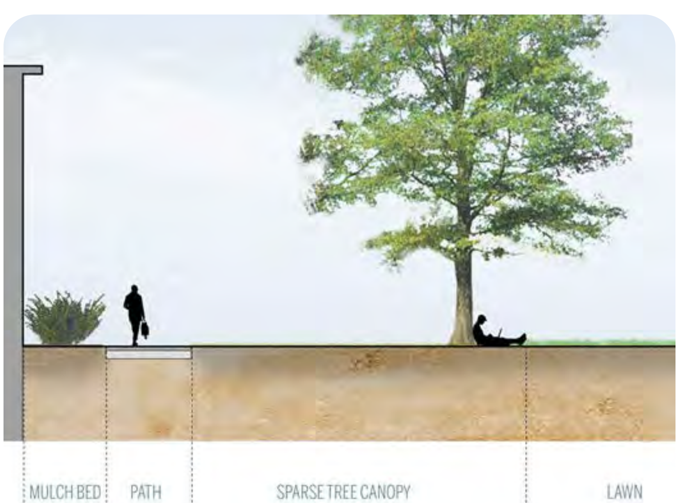
Existing condition

Proposed condition









E

APPENDIX PLANTING TYPOLOGY DETAILS

ARTS & SCIENCES QUAD, NEAR THE ARTS COTTAGE | 2023

APPENDIX E: TREE AND GROUND FLORA TYPOLOGY DETAILS

Tree and shrub recommendations to maximize canopy cover

The SLIP recommends maximizing campus tree cover, diversity, and resilience. The lists below suggest appropriate species and cultivar choices. However, additions should not be limited to this list. If additional species, subspecies, and cultivars with potential are discovered, they should be planted and evaluated. Transplant sizes should be carefully evaluated. Most trees transplant well at a size of 1 to 2.5 inches caliper while minimizing transplant shock.

CANOPY TREES

Abies concolor
Acer rubrum (and cultivars), *A. saccharum*
Carya glabra, C. ovata
Catalpa speciosa
Celtis occidentalis
Cladrastis kentukea
Diospyros virginiana
Gleditsia triacanthos
Gymnocladus dioicus (and seedless cultivars)
Liquidambar styraciflua
Liriodendron tulipifera
Maclura pomifera (and seedless cultivars)
Magnolia acuminata
Nyssa sylvatica (and cultivars)
Pinus strobus, P. virginiana
Prunus serotina
Quercus alba, Q. bicolor, Q. coccinea, Q. ellipsoidalis, Q. montana, Q. muehlenbergii, Q. rubra
Salix amygdaloides
Tilia americana
Ulmus ‘Jefferson’, *U.* ‘New Harmony’, *U.* ‘Princeton’, *U.* ‘Valley Forge’ (and other cultivars)

UNDERSTORY AND EDGE TREES

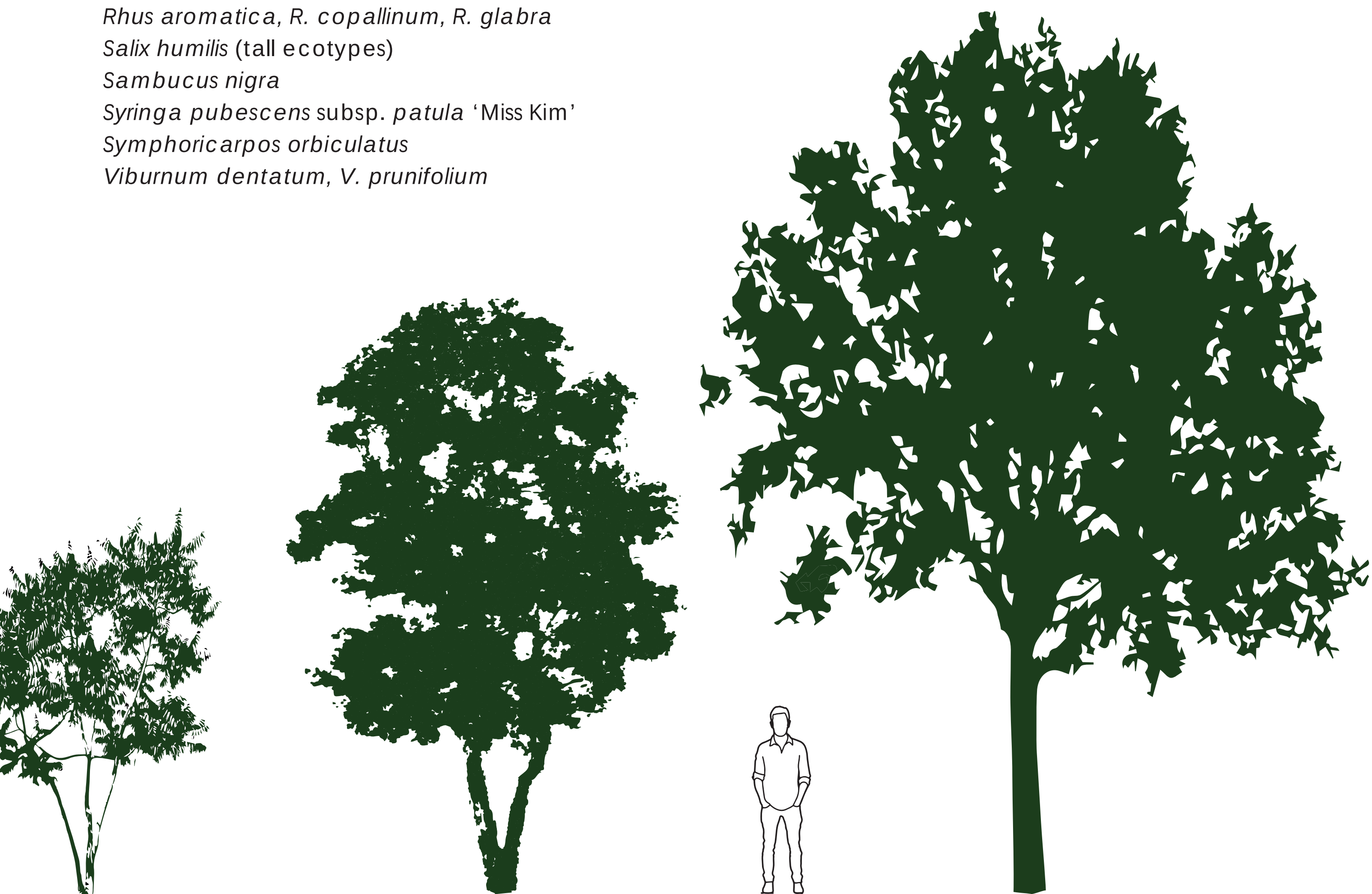
Acer pensylvanicum
Amelanchier canadensis, A. laevis
Asimina triloba
Carpinus caroliniana
Cercis canadensis
Chionanthus virginicus
Cornus alternifolia, C. mas, C. officinalis
Crataegus chrysocarpa, C. crus-galli, C. laevigata, C. phaenopyrum
Halesia carolina
Ilex opaca
Juniperus virginiana var. silicicola
Malus coronaria
Magnolia virginiana
Ostrya virginiana
Prunus virginiana
Rhus typhina
Sassafras albidum
Sorbus americana
Syringa reticulata
Zanthoxylum americanum

LARGE SHRUBS

Aesculus parviflora
Calycanthus floridus
Cephalanthus occidentalis
Cornus amomum, C. racemosa
Hamamelis virginiana
Hydrangea arborescens 'Haas Halo'
Lindera benzoin
Morella pensylvanica
Prunus americana
Ptelea trifoliata
Rhus aromatica, R. copallinum, R. glabra
Salix humilis (tall ecotypes)
Sambucus nigra
Syringa pubescens subsp. *patula* 'Miss Kim'
Symphoricarpos orbiculatus
Viburnum dentatum, V. prunifolium

MEDIUM TO SMALL SHRUBS

See shrub massing typology for further information.



APPENDIX E: TREE AND GROUND FLORA TYPOLOGY DETAILS

Tree and shrub recommendations

Challenges

Constant disturbance.
Trees and shrubs are in constant danger of being negatively impacted by construction and event activities, mowing, and recreational site use. It is essential that Penn State improves and enforces its tree protection requirements. Soil protection should be integrated into these guidelines to protect tree root zones.

Limited nursery availability.
Nurseries grow limited genetic diversity and rarely offer the most appropriate ecotypes for central Pennsylvania. Tree and shrub procurement should be diversified and planned well ahead of installation. Strengthen connections with local growers and/or improve Penn State's ability to strategically grow trees and shrubs with appropriate genetics at campus nursery.

Perceived root competition from herbaceous and shrub under-plantings.
Properly designed and installed tree under-plantings can benefit tree and soil health, and protect tree trunks and roots from herbicide residues and physical damage. Select ground covers with compatible root systems to minimize competition with tree roots. Minimize root zone disturbance and compaction during installation of under-plantings. Priority should be given to seeding and careful planting of smaller landscape plugs, quarts, and bare root material. Under-planted herbaceous species MUST be installed into the soil, not just a thin layer of compost or mulch.

Damage from past construction activities.
Campus has a history of massive building and soil movement. Compaction and low-productivity subsoils caused by past construction equipment and grading are abundant on campus. It is of utmost importance to improve impacted soils and enforce de-compaction requirements for building and planting projects, especially around new and existing trees. Follow best soil de-compaction and management practices.

Climate uncertainty and new pests and diseases.
Due to uncertainty around climate change and arrival of new pests and diseases, it is difficult to predict which species will be most adapted to what lies ahead. Diversify tree collection by increasing species and genetic diversity. Prioritize species from climates that similar to what is predicted for the Penn State area in the future but ensure species also thrive under current conditions.

An example of tree and soil protection adjacent to an existing construction project.

The nursery holding yard near the greenhouse facilities illustrates a limited palette of common tree and shrub species.

An example of herbaceous under-plantings protecting the base of a mature tree, forming a dense groundcover that limits weed competition.

A recent herbaceous perennial planting shows some plugs planted into a layer of compost or mulch, rather than into the soil below.

Stylized sun meadow

Design intent

This stylized meadow typology is designed to replace larger turf areas on core campus. The plant palette is intentionally kept short and legible. Several strong flower events, the strong presence of persistent grasses in winter, and carpets of spring bulbs ensure year round visual appeal.

Site selection

- Limit use to sites with low to medium productivity soils. Locations with nutrient rich, moist soils must be avoided! Limited topsoil depth and moderate to high soil compaction levels are acceptable.
- Best in locations with consistent site conditions over a larger area.
- Best for large to medium scale turf conversions in areas where a more visually complex aesthetic is appropriate.
- Requires full to part sun.

Site preparation

- Verify utilities in the field.
- Perform composite soil test in proposed areas to ensure soils are depauperate enough for this ground flora typology.
- Install tree protection if needed.
- Tilling soils should be avoided. If decompaction is required prior to seeding, use deep plow to loosen up soil. Avoid damaging tree roots.
- Undesirable plant populations (such as *Cirsium arvense*) should be properly removed prior to seeding. This may take one or more growing seasons.
- Remove existing turf, excess mulch, or other undesirable ground flora. Turf removal shall be done by mechanical equipment or by other sustainable means where tree roots are not an issue. Minimize use of chemical turf removal

Installation

- Install bulbs (optional) in specified clusters following best bulb planting practices.
- Order specified custom seed mix for total area to be seeded. Order species ecotypes closest to Pennsylvania. Order individually packaged seed or seed mix depending on installation method (drill seeding versus broadcast seeding).
- Seeding should be performed by experienced meadow installers with appropriate equipment.
- Install temporary erosion matting if needed to increase seed germination. Use ECS-2B™ Double Net Straw Biodegradable Rolled Erosion Control Matting or similar product.

Stylized sun meadow seed mix

Species	oz per acre
Achillea millefolium	1.10
Allium cernuum	34.00
Andropogon virginicus	13.07
Asclepias tuberosa	89.61
Baptisia australis	95.04
Blephilia ciliata	0.33
Bouteloua curtipendula	13.15
Carex molesta	3.92
Coreopsis lanceolata	4.75
Coreopsis tinctoria	0.32
Dalea purpurea	10.45
Daucus carota	4.61
Echinacea pallida	40.84
Eragrostis spectabilis	0.47
Gaillardia pulchella	5.03
Liatris aspera	7.78
Monarda bradburiana	0.70
Penstemon digitalis	11.11
Prunella vulgaris	3.13
Pycnanthemum tenuifolium	0.59
Pycnanthemum virginianum	0.98
Rudbeckia hirta	0.66
Schizachyrium scoparium	86.76
Sisyrinchium angustifolium	5.52
Solidago odora	1.84
Symphyotrichum ericoides	10.45
Symphyotrichum pilosum	1.49
Tridens flavus	6.74
Verbena stricta	5.95
Viola sororia	2.18

Area in acres: 1

Area in sq ft: 43,560

Total seeds per sq ft: 150

28.91 lb seed per acre (excluding nurse crop)

Total species: 30 (excluding nurse crop)

Total grasses: 38.50%

Total forbs: 61.50%

Supplement seed mix with appropriate nurse crop at supplier recommended rates:

Regreen™ (sterile cover crop) at 45 lb/ acre or similar.

Inter-planted bulbs and bare root ephemerals (optional)

Species	Minimum QTY per acre	Bulbs per cluster	Bulb spacing within cluster (inches o.c.)
Chionodoxa forbesii	13,068	100 to 150	6
Crocus tommasinianus	16,335	100 to 150	6
Claytonia virginica	653	15 to 25	12
Muscari armeniacum	22,869	50 to 75	8
Narcissus 'Jetfire'	13,068	25 to 50	10

Stylized sun meadow

Installation and management schedule

	Time of year	Action
Site preparation	May to September	Remove existing turf and undesirable plants from future meadow areas.
	October to November	Install bulbs and bare root material (optional).
	November to December.	Seed meadow areas.
Year 1	May to September	Approximately every six weeks, cut meadow to a height of 6 inches above ground. Monitor meadow monthly. Remove problematic weeds (such as *Cirsium arvense* and *Artemisia vulgaris*) as needed.
Year 2	May to September	Monitor meadow monthly. Remove problematic weeds (such as *Cirsium arvense* and *Artemisia vulgaris*) as needed.
	June	Strategically cut to a height of 6 to 8 inches above ground to control weeds if needed. Ideal timing for this is prior to seadhead development of undesirable or invasive plants.
Year 3	February or before bulbs emerge	Annual meadow cut back. Remove organic debris and compost if possible.
	May to September	Monitor meadow monthly. Evaluate strength of seasonal flower themes, weed pressure, and overall species diversity. Remove problematic weeds (such as *Cirsium arvense* and *Artemisia vulgaris*) as needed. Develop enhancement seeding strategy if improvements are required.
	December	Cut meadow to 6 inches above ground and spread enhancement seed mix.
Year 4		Repeat annual and strategic cutbacks, monitoring, removal of undesirable species, and enhancement seeding as needed.

Challenges

Initial weed pressure.
Weed pressure during the first 1-3 years can be very high due to large areas of open soil. It is essential that the meadow is cut as specified to reduce weed pressure and allow seeds to germinate. Follow specified cut heights to avoid damaging seedlings. Do not irrigate meadow as additional water may increase weed pressure.

Meadow too tall and floppy,
Cut meadow in June if too tall and species are starting to lean over. Remove cut debris to lower nutrient and organic matter levels. Do NOT apply fertilizer or any other nitrogen inputs. Do not irrigate. If underlying soils are too productive, this strategic cut may be necessary annually.

Not enough flowers or winter structure.
Monitor and evaluate seasonal flower themes and winter structure. Determine enhancement seed list and order seed for winter overseeding. Do not alter seed mix with tall or overly aggressive species to preserve the original design intent of a low, showy meadow. Do NOT order generic seed mixes. Consult with meadow specialist if needed. Also consider installing forb plugs as resources allow in strategic, high-visibility areas as clusters and drifts.

Relatively long establishment period.
Put up attractive signage educating the public about prolonged meadow establishment, especially in the first year when plants are still small. Cold-season grass dominant meadows can take 3 years to establish, while warm-season grass dominant meadows may take 4-5 years, or more. Hold a series of workshops and educational events to explain meadow making process.

Misconception that meadow can be left alone after establishment.
NO meadow can be seeded and then left alone. This meadow requires regular monitoring, weed management, overseeding, and annual cutback. If it is left alone, spontaneous herbaceous and woody plants will take a hold and shift meadow aesthetics and ecology into an undesirable direction. Once a meadow has been neglected for a while, it may be impossible to repair it. In such cases, a complete reseeding may be needed.

Disturbance from foot traffic, events, and construction activity.
Use fencing, signage, or planted buffer strips to discourage the public from stepping into meadow. Protect meadow from all construction and event activity. If damage to vegetation occurred, evaluate and repair. Gaps in vegetative cover must be repaired immediately, for example by spreading enhancement seed mix over gaps to stop undesirable plants from taking over.

Stylized shade meadow

Design intent

This ground flora typology is a dense tapestry of low grasses sprinkled with short and colorful forbs and bulbs. The selected species thrive in part shade near buildings or under trees. The majority of species naturalize and form a dense, winter-green carpet over time.

Site selection

- Designed to replace bare areas, mulched beds, or struggling turf in part to full shade.
- Suitable for medium to large areas in locations where a simple, naturalistic carpet of low ground covers is appropriate.
- Not suitable for very deep shade under structures or immediately under large, mature trees with dense crowns and shallow surface roots (such as beeches). See Chapter 3. Application for plant recommendations for very deep shade.

Site preparation

- Verify utilities in the field.
- Install tree protection if needed.
- Undesirable plant populations (such as *Cirsium arvense*) should be properly removed prior to seeding. This may take one or more growing seasons.
- If soils are highly compacted, core aerate or spot auger to loosen soil while minimizing impact on tree roots. Tilling soils should be avoided, especially if area is near trees.
- If soils are low in nutrient and organic matter content, add 2 to 3 inches of high quality, weed-free compost. Work compost into top soil horizon during decompaction process.
- Remove existing turf, excess mulch, or other undesirable ground flora.
- Spread 2 inches of leaf mulch or double shredded hardwood mulch. Do NOT over-mulch.

Installation

- Install bulbs (optional) in specified clusters following best bulb planting practices.
- Order specified custom seed mix for total area to be seeded. Order species ecotypes closest to Pennsylvania. Order individually packaged seed or seed mix depending on installation method (drill seeding versus broadcast seeding).
- Seeding should be performed by experienced meadow installers with appropriate equipment.
- Install temporary erosion matting if needed to increase seed germination. Use ECS-2B™ Double Net Straw Biodegradable Rolled Erosion Control Matting or similar product.

Stylized shade meadow seed mix

Species	oz per acre
Ageratina altissima	2.18
Agrostis perennans	0.39
Anemone virginiana	11.67
Aquilegia canadensis	8.30
Blephilia ciliata	2.45
Carex blanda	29.04
Carex divulsa	23.05
Carex grisea	43.56
Carex molesta	15.68
Carex muskingumensis	9.80
Diarrhena americana	272.25
Festuca rubra	4.61
Festuca subverticillata	5.68
Monarda bradburiana	21.78
Zizia aurea	30.39

Area in acres: 1

Area in sq ft: 43,560

Total seeds per sq ft: 150

30.05 lb seed per acre (excluding nurse crop)

Total species: 15 (excluding nurse crop)

Total grasses: 52.00%

Total forbs: 48.00%

Supplement seed mix with appropriate nurse crop at supplier recommended rates:

Regreen™ (sterile cover crop) at 45 lb/ acre or similar.

Inter-planted bulbs and bare root spring ephemerals (optional)

Species	Minimum QTY per acre	Bulbs per cluster	Bulb spacing (inches o.c.)
Claytonia virginica	653	15 to 25	12
Eranthis hyemalis	12,415	50 to 100	6
Galanthus nivalis	13,068	50 to 100	6
Hyacinthoides non-scripta	3,267	25 to 50	12
Narcissus ‘Jetfire’	9,801	25 to 50	12
Narcissus ‘Rijnveld’s Early Sensation’	9,801	25 to 50	12
Narcissus ‘Tete A Tete’	9,801	25 to 50	12
Scilla siberica	6,534	50 to 75	8

Stylized shade meadow

Installation and management schedule

	Time of year	Action
Site preparation	April to September	Remove undesirable plants, such as turf, ornamental plants, and tree seedlings.
	September to October	Spread 1 inch of shredded leaves or mulch. Do NOT over-mulch. Carefully rake out excess leaf fall from nearby trees.
	October to November	Install bulbs and bare root material (optional).
	November to December	Spread custom seed mix.
Year 1	May to October	Monitor regularly for seeding success and weed pressure. Remove undesirable plants using low-disturbance mechanical removal or spot treatment with species-specific herbicides. Develop enhancement seeding strategy if aesthetic improvements are required or if there are gaps in planting.
	June	Lightly trim grass seed heads and brown stems if needed. Do not cut any lower than 12 inches above ground.
	October to November	Carefully rake out excess leaf fall from nearby trees.
	November to December	Spread enhancement seed mix if needed.
Year 2		Repeat monitoring, removal of undesirable species, light June and end of winter trim, and enhancement seeding as needed.

Challenges

Low seed germination rates of shade-loving ground covers.

Most ground cover species for shade have extremely low germination rates. Seed germination should be monitored and evaluated. Spread more shade meadow seed mix if germination was low to ensure proper vegetative cover.

Tree roots.

Most shade meadow areas are under or near trees. Protect trees and their roots from damage during site preparation, installation, and longterm meadow management. Install live plants from small container sizes, such as plugs and quarts. Use hand tools and augers with narrow bids. Live plants MUST be planted into the soil below, not just the thin mulch layer. Avoid large equipment and any unnecessary soil compaction. Install temporary tree protection if needed.

Initial weed pressure.

Monitor seeded areas regularly for weed pressure. Carefully remove undesirable plants before they go to seed or spread via rhizomes or stolons. Avoid soil disturbance during weed removal. Compatible pre-emergent herbicides can be used to suppress weeds during establishment.

Not enough flowers.

This typology is intented to be greener and quieter than other ground flora typologies. Compatible flowering forbs and bulbs can be added over time to strengthen flower themes and increase visual and ecological appeal. Avoid tall species to preserve overall design intent and legibility.

Dense shade limits growth.

Most of the recommended species require part shade for optimal growth and may grow less vigorously in very deep shade under trees or structures. See recommendations for challenging areas (Pages XX) for species recommendations for very deep shade.

Fall foliage smothers meadow species.

Excess leaf fall from nearby deciduous trees should be carefully raked out of meadow areas and composted to prevent bare spots in ground flora. Leave some debris to function as mulch and to enrich the soil.

Tree seedlings coming up between meadow species.

Meadow areas should be monitored frequently for undesirable tree seedlings and vines. It is recommended to remove seedlings before they get too large or start to spread. However, their removal should be scheduled for later in the season to minimize damage to delicate forbs within the mix.

Dormancy during drought.

The shade meadow may go dormant during serious drought. Emergency irrigation may be needed during extreme drought to ensure acceptable aesthetics. If gaps appear after drought ends, spread enhancement seed mix to repair full vegetative cover.

Turf conversion to meadow

Design intent

This ground flora typology preserves existing turf grasses, allows them to grow up, and enhances them with colorful forbs and bulbs for maximum visual appeal and ecological function. Turf to meadow conversions have a more naturalistic and visually complex aesthetic. Their relatively low implementation cost, however, make them an attractive solution for larger areas.

Site selection

- Areas with dry to mesic, low-productivity soils in full sun to light shade.
- Suitable for medium to large areas in locations where a more naturalistic but short meadow of low is appropriate.
- Strong structural frames balance the more naturalistic look of this meadow. Areas surrounded by pathways, buildings, or mowed buffer strips are especially appropriate for this typology.

Site preparation

- Verify utilities in the field.
- Undesirable plant populations (such as *Cirsium arvense*) should be properly removed prior to installation. This may take one or more growing seasons.

Installation

- Cut existing turf 2 to 3 inches above ground to ensure enhancement seed mix has sufficient contact with soil.
- Install bulbs (optional) in specified clusters following best bulb planting practices.
- Order specified custom seed mix for total area to be seeded. Order species ecotypes closest to Pennsylvania. Order individually packaged seed or seed mix depending on installation method (drill seeding versus broadcast seeding).
- Broadcast seed over entire area. Drill seeding may not be possible due to existing meadow vegetation to remain.

Recommended turf enhancement species

Species	oz per acre
Achillea millefolium	1.83
Allium cernuum	25.50
Andropogon virginicus	15.68
Asclepias syriaca	44.80
Asclepias tuberosa	149.35
Chrysanthemum leucanthemum	15.68
Cichorium intybus	4.90
Conoclinium coelestinum	0.60
Daucus carota	6.91
Echinacea purpurea	59.18
Eupatorium hyssopifolium	2.84
Monarda fistulosa	3.29
Penstemon digitalis	26.14
Pycnanthemum tenuifolium	0.78
Pycnanthemum virginianum	1.08
Rudbeckia fulgida var. fulgida	10.45
Rudbeckia hirta	1.33
Ruellia humilis	37.70
Solidago odora	2.30
Symphyotrichum ericoides	10.45
Symphyotrichum pilosum	2.99
Tridens flavus	11.24

Area in acres: 1

Area in sq ft: 43,560

Total seeds per sq ft: 150

27.19 lb seed per acre (no nurse crop)

Total species: 22

Total grasses: 17.00%

Total forbs: 83.00%

Inter-planted bulbs and spring ephemerals (optional)

Species	Minimum QTY per acre	Bulbs per cluster	Bulb spacing (inches o.c.)
Galanthus nivalis	6,534	50 to 100	6
Narcissus 'Rijnveld's Early Sensation'	26,136	25 to 50	12
Narcissus 'Tete A Tete'	26,136	25 to 50	12
Scilla siberica	6,534	50 to 75	8

Turf conversion to stylized meadow

Installation and management schedule

	Time of year	Action
Site preparation	April to October	Do not mow meadow. Let vegetation/turf grow to 12 inches above ground, then spot treat undesirable plants Cut to 4 inches above ground 2 weeks after herbicide application. Repeat herbicide/mow cycle as often as possible to exhaust populations of undesirable plants.
	December	Cut to 4 inches above ground. Install bulbs (optional). Spread enhancement seed mix.
Year 1	January to March	Cut to 4 inches above ground before bulbs emerge. Remove and compost organic debris.
	Early to late May	Cut meadow to 6 to 8 inches above ground whenever it reaches 12 to 18 inches height. If possible, carefully remove excess debris after each cut to remove nutrients from site.
	May to October	Monitor regularly for seeding success, weed pressure, and strength of seasonal flower events. Mechanically remove or spot treat undesirable species, such as *Artemisia vulgaris* and *Cirsium arvense*. Use species-specific herbicides to minimize impact on desirable plants. Remove tree seedling and vines regularly and while they are still small. Spread more enhancement seed mix over any bare areas that appear after weed removal.
	December	If needed, cut meadow to 6 to 8 inches above ground, remove debris, and spread enhancement seed mix.
Year 2		Repeat monitoring, removal of undesirable species, May, June, and end of winter cut, and enhancement seeding as needed.

Challenges

Dominance of cool season turf grasses.

Cool season grasses are highly competitive in our climate and, if unmanaged or strengthened by fertilizer or irrigation, can outcompete weaker species. Strategic spring to mid summer cuts can reduce cool season grass dominance and open up space for more desirable forbs and warm season grasses. It is essential that meadow is on the same cutting schedules every year so desirable species can find their spatial and temporal niches and flourish.

Tree and vine seedlings.

Remove tree seedlings and vines manually or by spot treating with species-specific herbicides to minimize impact on desirable plants. Do not let undesirable tree seedlings get too large. Remove as soon as they are detected. Mark and protect tree seedlings that are to remain.

More naturalistic look.

This meadow typology is more visually complex. Regularly mowed buffer strips around meadows can create a neater appearance and convey intent. Winter interest can be improved over time by enhancing meadow with attractive warm season grasses, such as *Andropogon virginicus*. Mowable, cosmopolitan species composition includes attractive meadow species from Europe to maximize aesthetic appeal.

Weed identification.

It is not necessary for maintenance staff to know all species in the meadow. Staff should, however, be familiar with undesirable plants that require immediate removal. Perform regular field learning sessions to teach proper weed identification and removal techniques.

Removal of organic debris.

If possible, remove organic debris after winter cutback to lower soil productivity for a shorter and more diverse meadow. Develop efficient debris removal strategy using hay bailer or machine-operated rakes to reduce labor cost.

Low shrub massings

Design intent

Single species shrub massings form attractive yet resilient carpets where herbaceous ground flora typologies are hard to sustain. Sturdy branches, persistent presence on the land, and the ability resprout after disturbance make shrub massings a solution for tough spots, such as steep slopes. The neat and tidy appearance of low shrub massings is highly compatible with Penn State's campus-wide aesthetic. Shrubs should be under-planted with tidy, shade-tolerant ground covers to reduce weed pressure and maximize ecological function. Limited seasonal change and pollinator value can be balanced by planting ground cover species under shrubs.

Site selection

- Best in sun to part shade.
- Steep slopes and other hard to access areas.
- Beds where increased vegetation height and winter presence can reduce undesirable foot traffic through planting.
- Suitable for high to low visibility areas of medium size.

Site preparation

- Verify utilities in the field.
- Undesirable plant populations (such as *Cirsium arvense*) should be properly removed prior to installation. This may take one or more growing seasons.
- Remove existing turf, excess mulch, or other undesirable ground flora.
- Decompacted planting beds ahead of planting if needed. Avoid tilling the soil. Use spot auger or deep plow to loosen up compaction.

Installation

- Install shrubs from small to medium size containers, such as one to five gallon size containers.
- Spread 2 inches of leaf mulch or double shredded hardwood mulch. Do NOT over-mulch.
- Install ground covers between shrubs to suppress weeds. Use small to medium size containers, such as landscape plugs or quarts.

Recommended species

Low ground cover shrubs
Ceanothus americanus
Comptonia peregrina
Diervilla lonicera
Juniperus chinensis and J. horizontalis cultivars
Rhus aromatica 'Gro-Low'
Rosa rugosa (cultivars)
Salix humilis (short ecotypes only!)
Sorbaria sorbifolia
Taxus canadensis

Herbaceous ground covers under shrubs
Antennaria plantaginifolia
Carex pensylvanica, C. woodii
Chrysogonum virginianum var. *australe*
Geum fragarioides
Packera obovata
Prunella vulgaris
Viola sororia, V. striata

Diervilla lonicera shrub massing under-planted with *Carex pensylvanica.*

Low shrub massings

Installation and management schedule

	Time of year	Action
Site preparation	April to September	Mechanically remove or spot treat undesirable species, such as *Artemisia vulgaris* and *Cirsium arvense*. Use species-specific herbicides to minimize impact on desirable plants.
	September to October	Install shrubs. Mulch area between shrubs. Install herbaceous under-plantings.
Year 1	April to October	Monitor for shrub survival and weed pressure. Irrigate if needed. Replace dead or weak shrubs to ensure dense vegetative cover. Remove tree seedling and vines regularly and while they are still small.
Year 2		Repeat monitoring, removal of undesirable species, and enhancement with more shrubs to fill gaps as needed.

Challenges

Initial weed pressure.

Planting area should be mulched with 2 inches of shredded hardwood mulch or shredded leaves prior to planting. It is ESSENTIAL that live plants are planted into the soil below the mulch, and not just into the mulch layer. Compatible pre-emergent herbicides can be used to suppress weeds if the planting does not receive an initial seed mix.

Tree and invasive vine seedlings.

Carefully remove mechanically or baste on target specific herbicide without damaging shrubs. Remove as soon as they are observed. Do not let them get large. On slopes, cut at base and baste with herbicide to minimize disturbance and erosion.

Potential to damage tree roots if installed directly under existing trees.

Use smallest possible container sizes to under-plant existing trees with shrub massings. Take shrubs out of pots, shake of excess potting media and partially bare root shrubs prior to planting. Carefully dig holes by hand or with auger to avoid tree roots. Do not over-dig holes to minimize damage. Irrigate well after planting.

Avoid tall shrub species and/or cultivars.

IF shrubs grow too thick and tall and are obstructing views, replace with smaller shrub species or cultivars. Push denser, taller shrubs to back of planting bed allowing areas near paths to be open for optimal visibility. Limb shrubs up if needed to improve visibility. Replace all shrub massings that require regular pruning with more appropriate species and cultivars of lower height. Let shrubs fill in and form a dense vegetative carpet.

Damage caused by disturbance.

Replant damaged areas immediately after disturbance occurred to ensure dense ground cover. Gaps in shrub massings may lead to weed outbreaks and higher maintenance costs. Enhance with more shade tolerant under-plantings if needed to suppress weeds.

APPENDIX E: TREE AND GROUND FLORA TYPOLOGY DETAILS

Block planting beds

Design intent

This highly attractive typology is formed by a mosaic of single-species blocks locking together in attractive, weed-suppressing carpets. Repetition of blocks increases legibility and seasonal flower events. Larger blocks of more aggressive species are ideal for filling difficult areas with attractive, low-maintenance planting.

Site selection

- Suitable for highly visible beds on campus.
- Best for small to medium size beds.
- Suitable for full sun to shade.
- Soil condition is not a limiting factor as block plantings work on a wide range of soil types.

Site preparation

- Verify utilities in the field.
- Undesirable plant populations (such as *Cirsium arvense*) should be properly removed prior to installation. This may take one or more growing seasons.
- Remove existing turf, excess mulch, or other undesirable ground flora.
- Decompacted planting beds ahead of planting if needed. Avoid tilling the soil. Spot auger or deep plow to loosen up compaction.

Installation

- Install mulch for weed suppression. Do not over-mulch.
- Mark single species blocks on the ground and make adjustments prior to plant layout.
- Layout plants immediately prior to planting.
- Install block species from live plants. Use smaller container sizes (landscape plugs, quarts, and one gallon size containers) where possible to reduce transplant shop and save cost.
- Under-plant larger block species with compatible ground covers for additional weed suppression and ecological function. Most ground covers listed for Shrub Massings are appropriate for underplanting taller perennial blocks.
- Smooth out mulch and add a little mulch where needed to restore clean mulch cover.
- Install bulbs.

Species for medium-size mixed block planting

For sun

Allium 'Millennium' (and similar cultivars)
Amsonia 'Blue Ice'
Amsonia hubrichtii
Asclepias tuberosa
Calamintha 'Montrose White' and 'Triumphator'
Coreopsis pubescens 'Sunshine Superman, *C. verticillata* 'Zagreb'
Helianthus salicifolius 'Autumn Gold'
Kalimeris incisa 'Blue Star', *K. integrifolia* 'Daisy Mae'
Monarda bradburiana, M. fistulosa 'Claire Grace'
Nepeta 'Walker's Low' (and other cultivars'
Panicum virgatum 'Shenandoah'
Physostegia virginiana 'Pink Manners'
Pycnanthemum flexuosum, P. incanum 'Stowe Away', *P. tenuifolium, P. virginianum*
Rudbeckia fulgida var. *fulgida*
Scutellaria incana
Sesleria autumnalis
Solidago odora, S. rugosa 'Fireworks'
Sporobolus heterolepis
Stachys officinalis 'Hummelo' (and other cultivars)
Symphyotrichum novae-angliae 'Purple Dome', *S. oblongifolium* 'October Skies' and 'Raydon's Favorite'
Vernonia lettermannii 'Iron Butterfly'

For shade

Anemone hybrida 'Honorine Jobert'
Blephilia ciliata
Carex cherokeensis, C. divulsa, C. muskingumensis (and cultivars)
Chelone lyonii 'Hot Lips' (requires moisture)
Deschampsia cespitosa 'Goldtau'
Eurybia divaricata (and cultivars), *E.* x *herveyi* 'Twilight'
Hakonechloa macra
Heuchera 'Autumn Bride'
Lysimachia lanceolata 'Burgundy Mist'
Sesleria autumnalis
Symphyotrichum cordifolium (and cultivars)

Dependable species for large single-species massings

For sun

Boltonia asteroides
Calamagrostis brachytricha
Eupatorium hyssopifolium
Euthamia graminifolia
Oenothera fruticosa 'Fireworks'
Physostegia virginiana 'Vivid' (requires moisture)
Pycnanthemum muticum
Rudbeckia fulgida var. *deamii, R. triloba*
Ruellia humilis
Zizia aurea (requires moisture)

For part shade

Anemone canadensis, A. virginiana
Carex emoryi, C. flacca 'Blue Zinger'
Chasmanthium latifolium
Conoclinium coelestinum (requires moisture)
Diarrhena americana
Geranium macrorrhizum and cultivars
Packera aurea, P. obovata
Sesleria autumnalis
Solidago sphacelata 'Golden Fleece'
Teucrium canadense (requires moisture)

Block planting beds

Installation and management schedule

	Time of year	Action
Site preparation	April to September	Mechanically remove or spot treat undesirable species, such as *Artemisia vulgaris* and *Cirsium arvense*. Use species-specific herbicides to minimize impact on desirable plants.
	September	Mulch planting areas. Install block plantings from live plants. Irrigate well after planting.
	October to November	Install bulbs (optional).
Year 1	February	Annual cutback. Remove excess organic debris and compost on campus.
	April to June	Monitor regularly for undesirable plants. Intensive weed removal from spring to early summer is essential. Remove weeds while they are still small. Early removal allows planting to fill in and reduces weed pressure throughout the later growing season.
	June to October	Regular monthly planting monitoring. Determine enhancement planting strategy if areas need to be refreshed or increased in density. Careful weed removal as needed. Evaluate if spring mulching is necessary. Avoid unnecessary re-mulching!
	September	Enhance with more live plants where needed to ensure dense vegetative cover.
Year 2		Repeat monitoring, removal of undesirable species, and enhancement with more shrubs to fill gaps as needed.

Challenges

Traditional planting maintenance can be damaging.

Maintenance actions should be thought through and in line with what a planting actually needs. Avoid annual re-mulching and allow plants to become the ‘green mulch’. Enhance planting with more plants to ensure dense vegetative carpet. Only fertilize and irrigate if absolutely necessary. Do not deadhead flowers—if plants fall over, replace with more compact species or cultivars.

Weed pressure between plants.

Carefully remove weeds in spring and early summer. After weed removal, planting should fill in densely and shade the ground for optimal weed suppression during the remaining growing season. If mulch is added, do not over-mulch and take care NOT to bury sensitive plant crowns under mulch.

Planting stability.

Use recommended plant palette of species with similar competitiveness and growth behavior to avoid imbalance or one species taking over. Only use long-lived species with appropriate growth behavior to ensure stability and lower maintenance needs. Aggressively spreading species should only be used in single-species blocks or paired with species of similar behavior.

Summer drought.

Recommended species are adapted to site soils and highly drought tolerant. No supplemental irrigation should be needed. If extreme drought occurs, some species may require occasional emergency irrigation to prevent irreversible plant damage.

Tree seedlings and invasive vines.

Monitor regularly and remove as soon as they are detected. Do not let seedlings get large!

Matrix planting beds

Design intent

Individual plants are layered together in an attractive, yet resilient carpet. Repetition of flowering forbs creates powerful seasonal bloom events. Bulbs provide spring color and integrated ornamental grasses ensure strong winter interest. Matrix plant palettes are carefully selected to ensure stability and long-lasting flower themes.

Site selection

- Best for smaller size planting beds in high to medium visibility areas.
- Full sun to part shade.
- Species selection can be adjusted to meet a broad spectrum of site conditions.

Site preparation

- Verify utilities in the field.
- Undesirable plant populations (such as *Cirsium arvense*) should be properly removed prior to installation. This may take one or more growing seasons.
- Remove existing turf, excess mulch, or other undesirable ground flora.
- Decompacted planting beds ahead of planting if needed. Avoid tilling the soil. Spot auger or deep plow to loosen up compaction.

Installation

- Install mulch for weed suppression. Do not over-mulch.
- Layout plants immediately prior to planting. Start by placing inter-planted emergents. Then place matrix species one species at a time. Start with flowering matrix species and fill in with ground covering matrix species at the end.
- Install matrix species from live plants. Use smaller container sizes (landscape plugs, quarts, and one gallon size containers) where possible to reduce transplant shop and save cost.
- Smooth out mulch and add a little mulch where needed to restore clean mulch cover.
- Install bulbs.

Species for full sun matrix planting

Matrix species

Allium 'Millenium' (and similar cultivars)
Amsonia 'Blue Ice'
Anaphalis margaritacea
Asclepias tuberosa
Bouteloua curtipendula
Calamintha 'Montrose White' and 'Triumphator'
Eragrostis spectabilis
Eriogonum allenii 'Little Rascal'
Eurybia spectabilis
Kalimeris incisa 'Blue Star', *K. integrifolia* 'Daisy Mae'
Monarda bradburiana
Muhlenbergia reverchonii UNDAUNTED
*Nepeta (*cultivars)
Origanum laevigatum 'Herrenhausen'
Rudbeckia fulgida 'Little Goldstar'
Salvia nemorosa cultivars (short lived)
Scutellaria 'Appalachian Blues'
Sesleria autumnalis
Sporobolus heterolepis
Stachys officinalis 'Hummelo' (and other cultivars)

Inter-planted emergents

Allium 'Purple Sensation'
Allium sphaerocephalon
Echinacea pallida (short lived)
Eremurus (hardy spp. and cultivars)
Eryngium planum 'Blaukappe'
Kniphofia cultivars
Liatris scariosa, L. spicata
Lycoris squamigera
Schizachyrium scoparium 'Standing Ovation'
Sorghastrum nutans GOLDEN SUNSET
Verbena stricta (short lived)
Veronicastrum virginicum 'Queen of Diamonds'

Species for part shade matrix planting

Matrix species

Blephilia ciliata
Carex amphibola, C. cherokeensis, C. divulsa, C. leavenworthii, C. pensylvanica, C. woodii
Deschampsia cespitosa 'Goldtau'
Erigeron pulchellus var. *pulchellus* 'Lynnhaven Carpet'
Euphorbia amygdaloides var. *robbiae*
Eurybia divaricata, E. x *herveyi* 'Twilight'
Festuca rubra
Geranium spp.
Hakonechloa macra
Helleborus foetidus and hybrid cultivars
Heuchera 'Autumn Bride'
Lysimachia lanceolata 'Burgundy Mist'
Monarda bradburiana
Phlox carolina 'Kim', *P. pilosa*
Polystichum acrostichoides, P. polyblepharum
Sesleria autumnalis

Inter-planted emergents

Anemone hybrida 'Honorine Jobert'
Cimicifuga racemosa (and cultivars)
Osmunda cinnamomea, O. claytoniana (require moisture)

Matrix planting beds

Installation and management schedule

	Time of year	Action
Site preparation	April to September	Mechanically remove or spot treat undesirable species, such as *Artemisia vulgaris* and *Cirsium arvense*. Use species-specific herbicides to minimize impact on desirable plants.
	September	Mulch planting areas. Install matrix plantings from live plants. Irrigate well after planting.
	October to November	Install bulbs (optional).
Year 1	February	Annual cutback. Remove excess organic debris and compost on campus.
	April to June	Monitor regularly for undesirable plants. Intensive weed removal from spring to early summer is essential. Remove weeds while they are still small. Early removal allows planting to fill in and reduces weed pressure throughout the later growing season.
	June to October	Regular monthly planting monitoring. Determine enhancement planting strategy if areas need to be refreshed or increased in density. Careful weed removal as needed. Evaluate if spring mulching is necessary. Avoid unnecessary re-mulching!
	September	Enhance with more live plants where needed to ensure dense vegetative cover.
Year 2		Repeat monitoring, removal of undesirable species, and enhancement with more shrubs to fill gaps as needed.

Challenges

Species composition shifts over time, diluting seasonal flower themes.

Monitor planting composition and flower themes regularly. Take original planting design or sketch into the field to fully understand how planting has shifted over time. Enhance planting as needed to ensure seasonal flower themes are strong.

Tree seedlings and invasive vines.

Monitor regularly and remove as soon as they are detected. Do not let seedlings get large!

Higher visual complexity.

Plants are mixed with one another and it can be harder to identify undesirable species. Planting staff does not need to know every plant in the mix. However, it is key that staff knows all undesirable species. Perform regular in the field weed identification training.

For optimal public appeal, ensure planting height is low and orderly frames around planting are properly maintained.

When designing matrix plantings, keep species to a minimum to avoid too much visual complexity. Make sure there are enough species in the mix to create strong seasonal flower themes and good winter ground cover. Emergents are not always needed, especially if planting under trees and shrubs.

F

APPENDIX PILOT PROJECT DETAILS AND CONSIDERATIONS


FISHER PLAZA SHADE MEADOW | 2023

Westgate Existing Conditions: 31269 SF

(National Averages)

Description	Measurement	Unit	Unit Cost	Cost per instance	Instances / yr	Total / yr
Bed Maintenance						
Cultivate bed, no mulching		MSF (1,000 SF)	$26.00	$0.00	0	$0.00
Fall clean-up of flower bed, including pick-up mulch for re-use		MSF	$365.00	$0.00	0	$0.00
Fertilize flower bed, dry granular 3lb. / MSF		MSF	$5.37	$0.00	0	$0.00
Police, hand pick-up	5.87	MSF	$12.15	$71.26	4	$285.04
Spring prepare	5.87	MSF	$182.00	$1,067.43	1	$1,067.43
Weed mulched bed	5.87	MSF	$18.25	$107.04	4	$428.15
Weed un-mulched bed		MSF	$45.50	$0.00	0	$0.00
Lawn Maintenance						
Aerate lawn, 18" cultivating width, walk behind		MSF	$4.79	$0.00	0	$0.00
Aerate lawn, 48" cultivating width	21.28	MSF	$0.97	$20.64	1	$20.64
Aerate lawn, 72" cultivating width		MSF	$0.65	$0.00	0	$0.00
Edge lawn, using powered edger at walks		CLF (100 LF)	$4.15	$0.00	0	$0.00
Edge lawn, using powered edger at planting beds	339.00	CLF (100 LF)	$15.20	$5,152.80	1	$5,152.80
Power rake	21.28	MSF	$8.10	$172.38	1	$172.38
Shrub maintenance						
Shrub bed fertilize dry granular 3lb./MSF		MSF	$5.37	$0.00	0	$0.00
Weed, by handhoe		MSF	$45.50	$0.00	0	$0.00
Weed, by spray out		MSF	$11.40	$0.00	0	$0.00
Spray after mulching		MSF	$7.60	$0.00	0	$0.00
Fertilizing						
Dry granular, 4 lb./MSF, hand spread		MSF	$18.07	$0.00	0	$0.00
Tractor towed spreader 8'		MSF	$4.32	$0.00	0	$0.00
Tractor towed spreader 12'		MSF	$3.78	$0.00	0	$0.00
Truck whirlwind spreader		MSF	$3.47	$0.00	0	$0.00
Water soluble, hydro spread, 1.5 lb./MSF	21.28	MSF	$5.18	$110.24	1	$110.24
Weed control	21.28	MSF	$2.62	$55.76	4	$223.02
Mowing						
Mowing brush, tractor with rotary mower, light density		MSF	$32.15	$0.00	0	$0.00
Mowing brush, tractor with rotary mower, medium density		MSF	$54.15	$0.00	0	$0.00
Mowing brush, tractor with rotary mower, heavy density		MSF	$78.50	$0.00	0	$0.00
Lawn mowing, power push mower, 30"-32"	2.13	MSF	$2.61	$5.55	26	$144.41
Lawn mowing, riding mower, 48"-58"	19.15	MSF	$1.51	$28.92	26	$751.95
Mowing with tractor & attachments - cutter or sickle-bar, 5', smooth terrain		MSF	$2.13	$0.00	0	$0.00
Edge trimming with weed whacker	21726.00	LF	$0.06	$1,303.56	13.00	$16,946.28
Shrub Pruning						
Prune shrub bed, general		MSF	$52.00	$0.00	0	$0.00
Mulching						
Aged bark, 3" deep, hand spread	651.67	SY	$8.03	$5,232.88	1	$5,232.88

Existing annual landscape maintenance costs exclude shrub and tree care.

ANNUAL MAINTENANCE COSTS	$30,535.21
ANNUAL COSTS PER SQUARE FOOT	$0.98

Westgate Proposed Conditions: 31269 SF

(National Averages)

Description	Measurement	Unit	Unit Cost	Cost per instance	Instances / yr	Total / yr
Bed Maintenance						
Cultivate bed, no mulching		MSF (1,000 SF)	$26.00	$0.00	0	$0.00
Fall clean-up of flower bed, including pick-up mulch for re-use	0.00	MSF	$365.00	$0.00	0	$0.00
Fertilize flower bed, dry granular 3lb. / MSF		MSF	$5.37	$0.00	0	$0.00
Police, hand pick-up	31.27	MSF	$12.15	$379.92	18	$6,838.53
Spring prepare	31.27	MSF	$182.00	$5,690.96	1	$5,690.96
Weed mulched bed	31.27	MSF	$18.25	$570.66	12	$6,847.91
Weed un-mulched bed		MSF	$45.50	$0.00	0	$0.00
Lawn Maintenance						
Aerate lawn, 18" cultivating width, walk behind		MSF	$4.79	$0.00	0	$0.00
Aerate lawn, 48" cultivating width	2.01	MSF	$0.97	$1.95	1	$1.95
Aerate lawn, 72" cultivating width		MSF	$0.65	$0.00	0	$0.00
Edge lawn, using powered edger at walks		CLF (100 LF)	$4.15	$0.00	0	$0.00
Edge lawn, using powered edger at planting beds		CLF (100 LF)	$15.20	$0.00	1	$0.00
Power rake	31.27	MSF	$8.10	$253.28	2	$506.56
Shrub maintenance						
Shrub bed fertilize dry granular 3lb./MSF		MSF	$5.37	$0.00	0	$0.00
Weed, by handhoe	31.27	MSF	$45.50	$1,422.74	3	$4,268.22
Weed, by spray out		MSF	$11.40	$0.00	0	$0.00
Spray after mulching		MSF	$7.60	$0.00	0	$0.00
Fertilizing						
Dry granular, 4 lb./MSF, hand spread		MSF	$18.07	$0.00	0	$0.00
Tractor towed spreader 8'		MSF	$4.32	$0.00	0	$0.00
Tractor towed spreader 12'		MSF	$3.78	$0.00	0	$0.00
Truck whirlwind spreader		MSF	$3.47	$0.00	0	$0.00
Water soluble, hydro spread, 1.5 lb./MSF	2.01	MSF	$5.18	$10.41	1	$10.41
Weed control	2.01	MSF	$2.62	$5.26	4	$21.06
Mowing						
Mowing brush, tractor with rotary mower, light density		MSF	$32.15	$0.00	0	$0.00
Mowing brush, tractor with rotary mower, medium density		MSF	$54.15	$0.00	0	$0.00
Mowing brush, tractor with rotary mower, heavy density		MSF	$78.50	$0.00	0	$0.00
Lawn mowing, power push mower, 30"-32"		MSF	$2.61	$0.00	0	$0.00
Lawn mowing, riding mower, 48"-58"	2.01	MSF	$1.51	$3.03	26	$78.89
Mowing with tractor & attachments - cutter or sickle-bar, 5', smooth terrain	31.27	MSF	$2.13	$66.60	4	$266.41
Edge trimming with weed whacker	535.50	LF	$0.06	$32.13	5	$160.65
Shrub Pruning						
Prune shrub bed, general		MSF	$52.00	$0.00	0	$0.00
Mulching						
Aged bark, 3" deep, hand spread		SY	$8.03	$0.00	1	$0.00

ANNUAL MAINTENANCE COSTS	$24,691.55
ANNUAL COSTS PER SQUARE FOOT	$0.79

**Projected annual landscape maintenance costs exclude shrub and tree care.*

Refer to APPENDIX F for more pilot project details and other considered sites

Chapel Woods Existing Conditions: 39769 SF

(National Averages)

Description	Measurement	Unit	Unit Cost	Cost per instance	Instances / yr	Total / yr
Bed Maintenance						
Cultivate bed, no mulching	0.55	MSF (1,000 SF)	$26.00	$14.30	4	$57.20
Fall clean-up of flower bed, including pick-up mulch for re-use	0.55	MSF	$365.00	$200.75	1	$200.75
Fertilize flower bed, dry granular 3lb. / MSF	0.55	MSF	$5.37	$2.95	4	$11.81
Police, hand pick-up	13.82	MSF	$12.15	$167.96	4	$671.85
Spring prepare	13.82	MSF	$182.00	$2,515.97	1	$2,515.97
Weed mulched bed	13.82	MSF	$18.25	$252.29	4	$1,009.15
Weed un-mulched bed		MSF	$45.50	$0.00	0	$0.00
Lawn Maintenance						
Aerate lawn, 18" cultivating width, walk behind		MSF	$4.79	$0.00	0	$0.00
Aerate lawn, 48" cultivating width	28.37	MSF	$0.97	$27.52	1	$27.52
Aerate lawn, 72" cultivating width		MSF	$0.65	$0.00	0	$0.00
Edge lawn, using powered edger at walks		CLF (100 LF)	$4.15	$0.00	0	$0.00
Edge lawn, using powered edger at planting beds	11.96	CLF (100 LF)	$15.20	$181.79	1	$181.79
Power rake	28.37	MSF	$8.10	$229.82	1	$229.82
Shrub maintenance						
Shrub bed fertilize dry granular 3lb./MSF		MSF	$5.37	$0.00	0	$0.00
Weed, by handhoe		MSF	$45.50	$0.00	0	$0.00
Weed, by spray out		MSF	$11.40	$0.00	0	$0.00
Spray after mulching		MSF	$7.60	$0.00	0	$0.00
Fertilizing						
Dry granular, 4 lb./MSF, hand spread		MSF	$18.07	$0.00	0	$0.00
Tractor towed spreader 8'		MSF	$4.32	$0.00	0	$0.00
Tractor towed spreader 12'		MSF	$3.78	$0.00	0	$0.00
Truck whirlwind spreader		MSF	$3.47	$0.00	0	$0.00
Water soluble, hydro spread, 1.5 lb./MSF	28.37	MSF	$5.18	$146.97	1	$146.97
Weed control	28.37	MSF	$2.62	$74.34	4	$297.35
Mowing						
Mowing brush, tractor with rotary mower, light density		MSF	$32.15	$0.00	0	$0.00
Mowing brush, tractor with rotary mower, medium density		MSF	$54.15	$0.00	0	$0.00
Mowing brush, tractor with rotary mower, heavy density		MSF	$78.50	$0.00	0	$0.00
Lawn mowing, power push mower, 30"-32"	2.84	MSF	$2.61	$7.40	26	$192.52
Lawn mowing, riding mower, 48"-58"	25.54	MSF	$1.51	$38.56	26	$1,002.54
Mowing with tractor & attachments - cutter or sickle-bar, 5', smooth terrain		MSF	$2.13	$0.00	0	$0.00
Edge trimming with weed whacker	1987.00	LF	$0.06	$119.22	13.00	$1,549.86
Shrub Pruning						
Prune shrub bed, general		MSF	$52.00	$0.00	0	$0.00
Mulching						
Aged bark, 3" deep, hand spread	1536.00	SY	$8.03	$12,334.08	1	$12,334.08

ANNUAL MAINTENANCE COSTS	$20,429.19
ANNUAL COSTS PER SQUARE FOOT	$0.51

Existing annual landscape maintenance costs exclude shrub and tree care.

Chapel Woods Proposed Conditions: 39769 SF

(National Averages)

Description	Measurement	Unit	Unit Cost	Cost per instance	Instances / yr	Total / yr
Bed Maintenance						
Cultivate bed, no mulching		MSF (1,000 SF)	$26.00	$0.00	0	$0.00
Fall clean-up of flower bed, including pick-up mulch for re-use		MSF	$365.00	$0.00	0	$0.00
Fertilize flower bed, dry granular 3lb. / MSF		MSF	$5.37	$0.00	0	$0.00
Police, hand pick-up	39.77	MSF	$12.15	$483.19	12	$5,798.32
Spring prepare		MSF	$182.00	$0.00	0	$0.00
Weed mulched bed	39.77	MSF	$18.25	$725.78	5	$3,628.92
Weed un-mulched bed		MSF	$45.50	$0.00	0	$0.00
Lawn Maintenance						
Aerate lawn, 18" cultivating width, walk behind		MSF	$4.79	$0.00	0	$0.00
Aerate lawn, 48" cultivating width		MSF	$0.97	$0.00	0	$0.00
Aerate lawn, 72" cultivating width		MSF	$0.65	$0.00	0	$0.00
Edge lawn, using powered edger at walks		CLF (100 LF)	$4.15	$0.00	0	$0.00
Edge lawn, using powered edger at planting beds		CLF (100 LF)	$15.20	$0.00	0	$0.00
Power rake	39.77	MSF	$8.10	$322.13	4	$1,288.52
Shrub maintenance						
Shrub bed fertilize dry granular 3lb./MSF		MSF	$5.37	$0.00	0	$0.00
Weed, by handhoe	22.06	MSF	$45.50	$1,003.55	5	$5,017.74
Weed, by spray out		MSF	$11.40	$0.00	0	$0.00
Spray after mulching		MSF	$7.60	$0.00	0	$0.00
Fertilizing						
Dry granular, 4 lb./MSF, hand spread		MSF	$18.07	$0.00	0	$0.00
Tractor towed spreader 8'		MSF	$4.32	$0.00	0	$0.00
Tractor towed spreader 12'		MSF	$3.78	$0.00	0	$0.00
Truck whirlwind spreader		MSF	$3.47	$0.00	0	$0.00
Water soluble, hydro spread, 1.5 lb./MSF		MSF	$5.18	$0.00	0	$0.00
Weed control		MSF	$2.62	$0.00	0	$0.00
Mowing						
Mowing brush, tractor with rotary mower, light density		MSF	$32.15	$0.00	0	$0.00
Mowing brush, tractor with rotary mower, medium density		MSF	$54.15	$0.00	0	$0.00
Mowing brush, tractor with rotary mower, heavy density		MSF	$78.50	$0.00	0	$0.00
Lawn mowing, power push mower, 30"-32"		MSF	$2.61	$0.00	0	$0.00
Lawn mowing, riding mower, 48"-58"		MSF	$1.51	$0.00	0	$0.00
Mowing with tractor & attachments - cutter or sickle-bar, 5', smooth terrain	22.06	MSF	$2.13	$46.98	4	$187.92
Edge trimming with weed whacker	2322.00	LF	$0.06	$139.32	5	$696.60
Shrub Pruning						
Prune shrub bed, general		MSF	$52.00	$0.00	0	$0.00
Mulching						
Aged bark, 3" deep, hand spread		SY	$8.03	$0.00	1	$0.00

ANNUAL MAINTENANCE COSTS	**$16,618.01**
ANNUAL COSTS PER SQUARE FOOT	**$0.42**

**Projected annual landscape maintenance costs exclude shrub and tree care.*

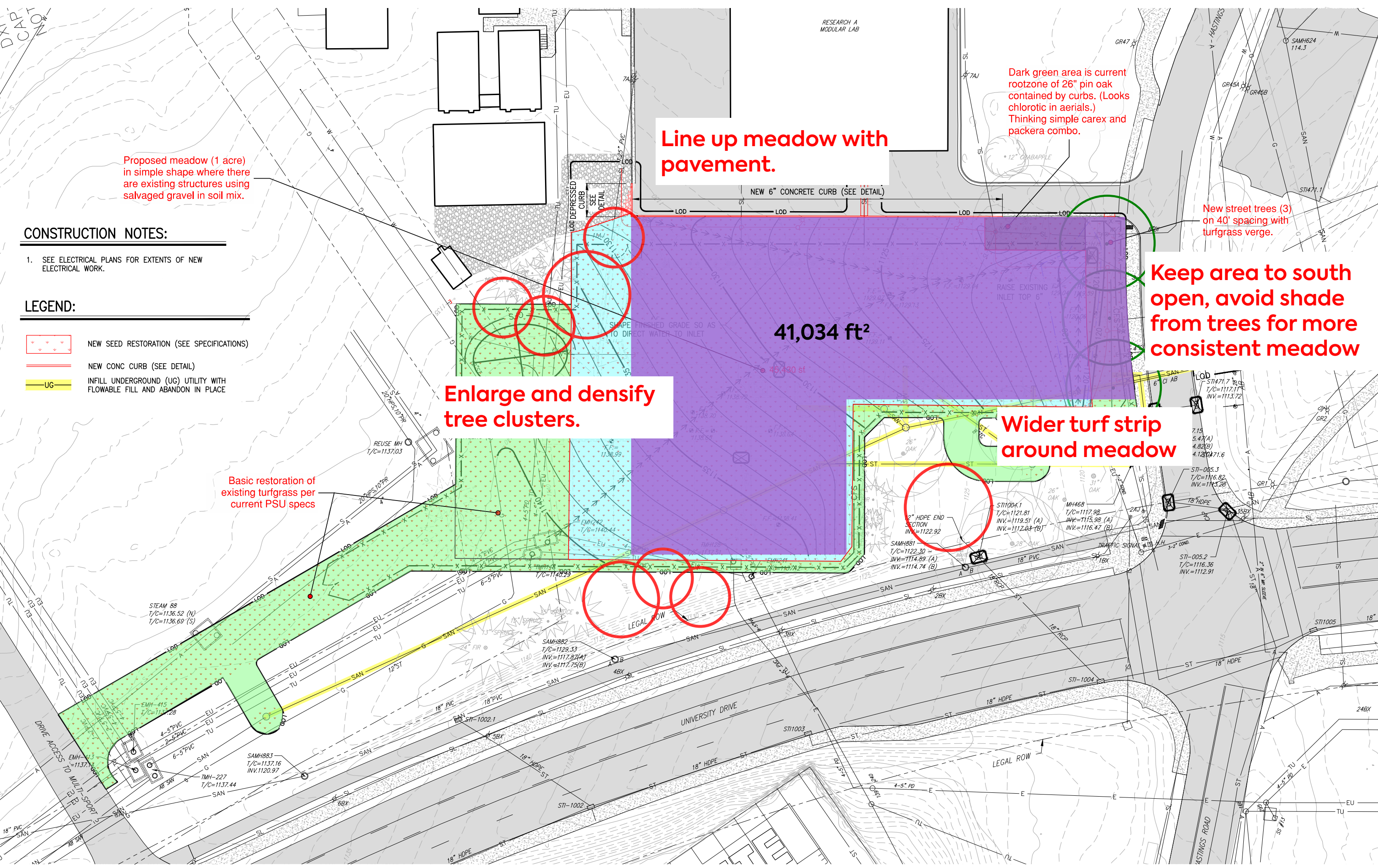
Refer to APPENDIX F for more pilot project details and other considered sites

APPENDIX F: CONSIDERED PILOT PROJECT AREAS

FOREST RESOURCES LAB

The Forest Resources Lab Building is slated for demolition, which has presented a potential opportunity to test a new “Pictoral Sun Meadow” typology. This typology was specifically designed for poor quality soils that are anticipated after a building demolition, so it will naturally not be a candidate for broad implementation across campus.

The meadow mix identified here will perform well in low-fertility, dry, and gravelly sub-soils amended with a thin layer of lean local topsoil. This is an example of how the SLIP recommendations may provide helpful tools for unique or even temporary solutions to common campus development decisions.



PICTORIAL SUN MEADOW

Pictorial meadow seed mix

Area in acres:	0.94
Area in sq ft:	41,034
Total seeds per sq ft:	150
Total seed mix (lb):	32.13
Seed mix per acre (lb):	34.11

Quantity (oz)	Species	Size
1.04	*Achillea millefolium*	Seed
16.01	*Allium cernuum*	Seed
0.28	*Anaphalis margaritacea*	Seed
4.92	*Andropogon virginicus*	Seed
140.69	*Asclepias tuberosa*	Seed
36.21	*Baptisia alba*	Seed
18.58	*Bouteloua curtipendula*	Seed
13.68	*Callirhoe involucrata*	Seed
21.22	*Callirhoe triangulata*	Seed
1.15	*Cichorium intybus*	Seed
4.92	*Coreopsis grandiflora*	Seed
4.48	*Coreopsis lanceolata*	Seed
7.69	*Coreopsis major*	Seed
0.46	*Coreopsis tinctoria*	Seed
16.41	*Dalea purpurea*	Seed
1.08	*Daucus carota*	Seed
13.57	*Dianthus carthusianorum*	Seed
64.12	*Echinacea pallida*	Seed
0.66	*Eragrostis spectabilis*	Seed
3.15	*Eryngium planum* 'Blaukappe'	Seed
7.89	*Eschscholzia californica*	Seed
3.28	*Eurybia spectabilis*	Seed
27.98	*Gaura lindheimeri*	Seed
4.14	*Gaillardia pulchella*	Seed
18.94	*Liatris aspera*	Seed
0.05	*Linaria canadensis*	Seed
12.31	*Linum perenne*	Seed
5.86	*Monarda bradburiana*	Seed
0.82	*Monarda citriodora*	Seed
0.58	*Monarda fistulosa*	Seed
1.46	*Oenothera speciosa*	Seed
14.20	*Penstemon grandiflorus*	Seed
0.62	*Penstemon pallidus*	Seed
0.06	*Pseudognaphalium obtusifolium*	Seed
0.18	*Pycnanthemum tenuifolium*	Seed
0.31	*Pycnanthemum virginianum*	Seed
3.04	*Rudbeckia fulgida* var. *deamii*	Seed
11.84	*Ruellia humilis*	Seed
12.26	*Schizachyrium scoparium*	Seed
2.12	*Silene virginica*	Seed
2.60	*Sisyrinchium angustifolium*	Seed
0.31	*Symphyotrichum ericoides*	Seed
5.64	*Verbena stricta*	Seed
7.33	*Zizia aptera*	Seed

Adjacent no-mow area near University Drive

Cover crop

Quantity (lb)	Species	Size	Seed rate (lb/ac)
42.39	Regreen (sterile cover crop)	Seed	45

Pictorial meadow bulb mix (optional)

Total bulbs per sq ft:	1.50
Total bulb quantity:	33,853

Quantity	Species	Size	Spacing within clusters	Bulbs per cluster
12,310	*Chionodoxa forbesii*	Bulb	6" o.c.	100 to 150
15,388	*Crocus tommasinianus*	Bulb	6" o.c.	100 to 150
21,543	*Muscari armeniacum*	Bulb	8" o.c.	50 to 75
12,310	*Narcissus* 'Jetfire'	Bulb	10" o.c.	25 to 50

FISHER PLAZA

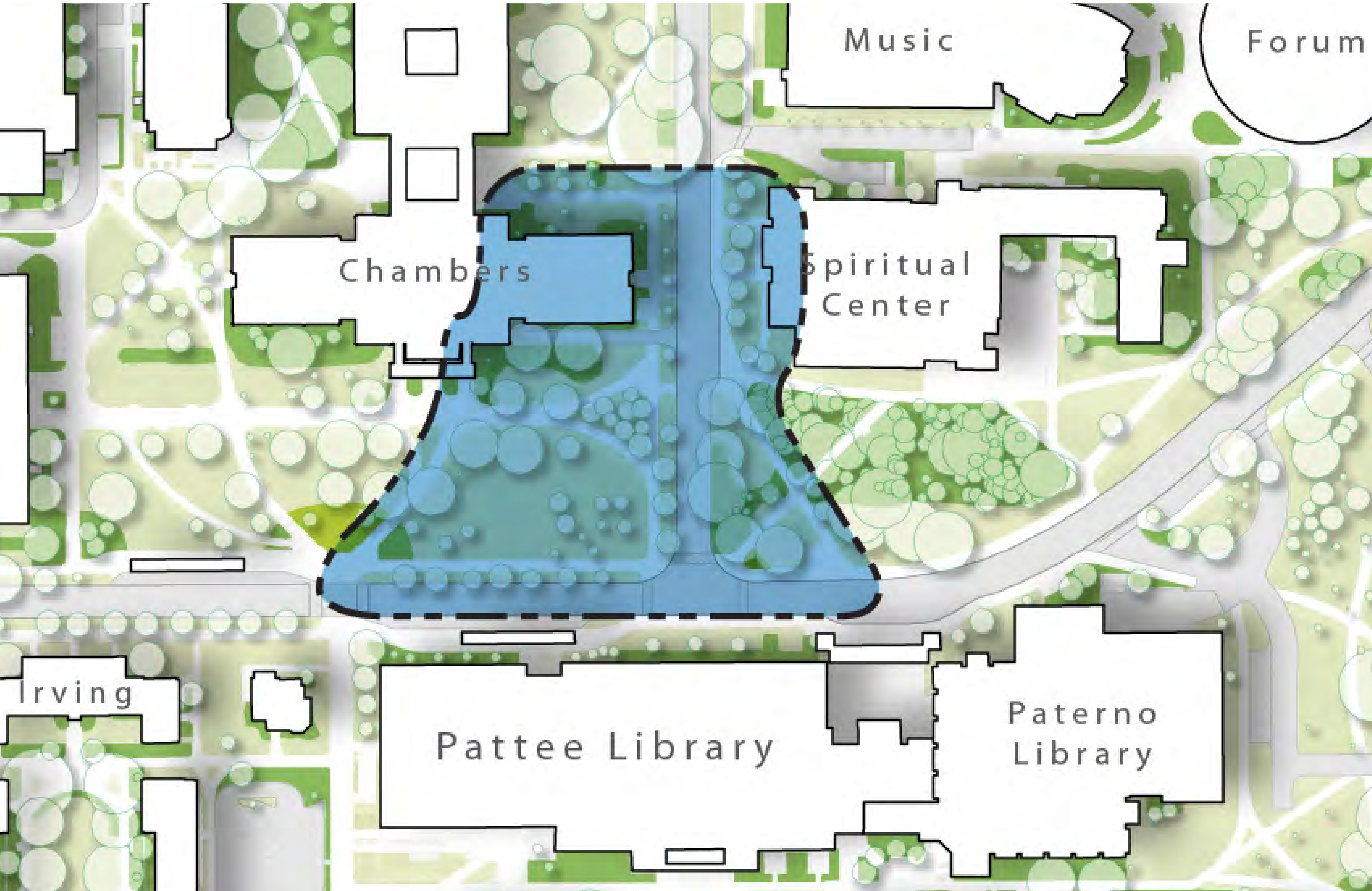
The landscape of the eastern edge of Fisher Plaza is comprised of predominantly lawns that slope gently toward Curtin Road. Chambers Building has some varied foundation plantings and expansive mulched areas. The honeylocust grove from the original design is beginning to fail. There is a good recent example of a stylized shade meadow under a grove of river birch trees. This eastern end of Fisher Plaza does not appear to get much recreational use. On the east side of Allen Road, Chapel Woods dissolves into a broad lawn verge.

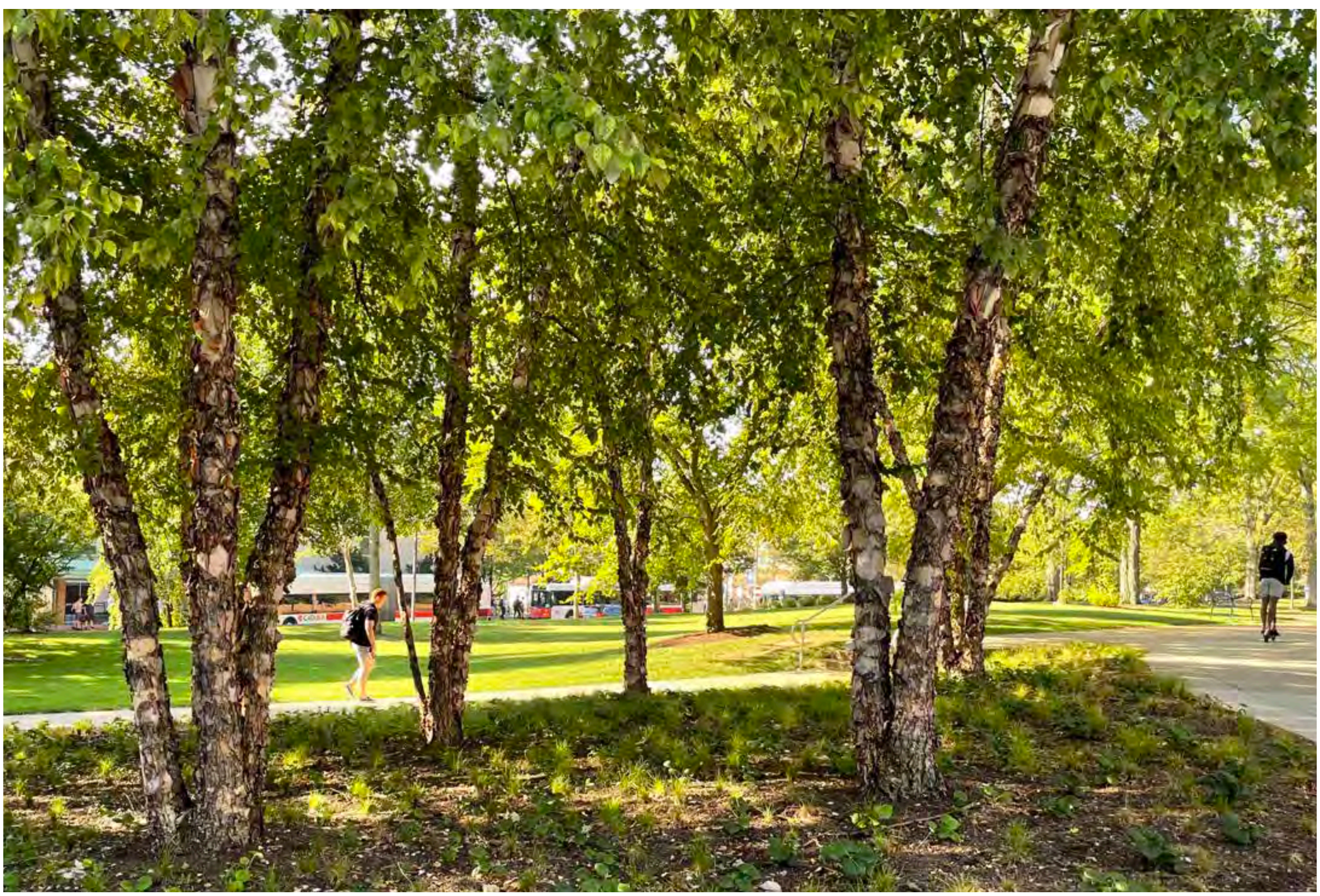
Pros

- High visibility, limited use&utilities, protected
- Maximize planting bed density or convert existing to more sustainable ground flora
- Opportunity to maximize tree canopy cover
- Beginnings of stylized shade meadow
- Conditions right for all other proposed ground flora typologies

Cons

- Likely should be grounded in the planning context of the entire Fisher Plaza
- Failing honeylocusts over time will change environmental conditions & character





OBELISK GARDEN

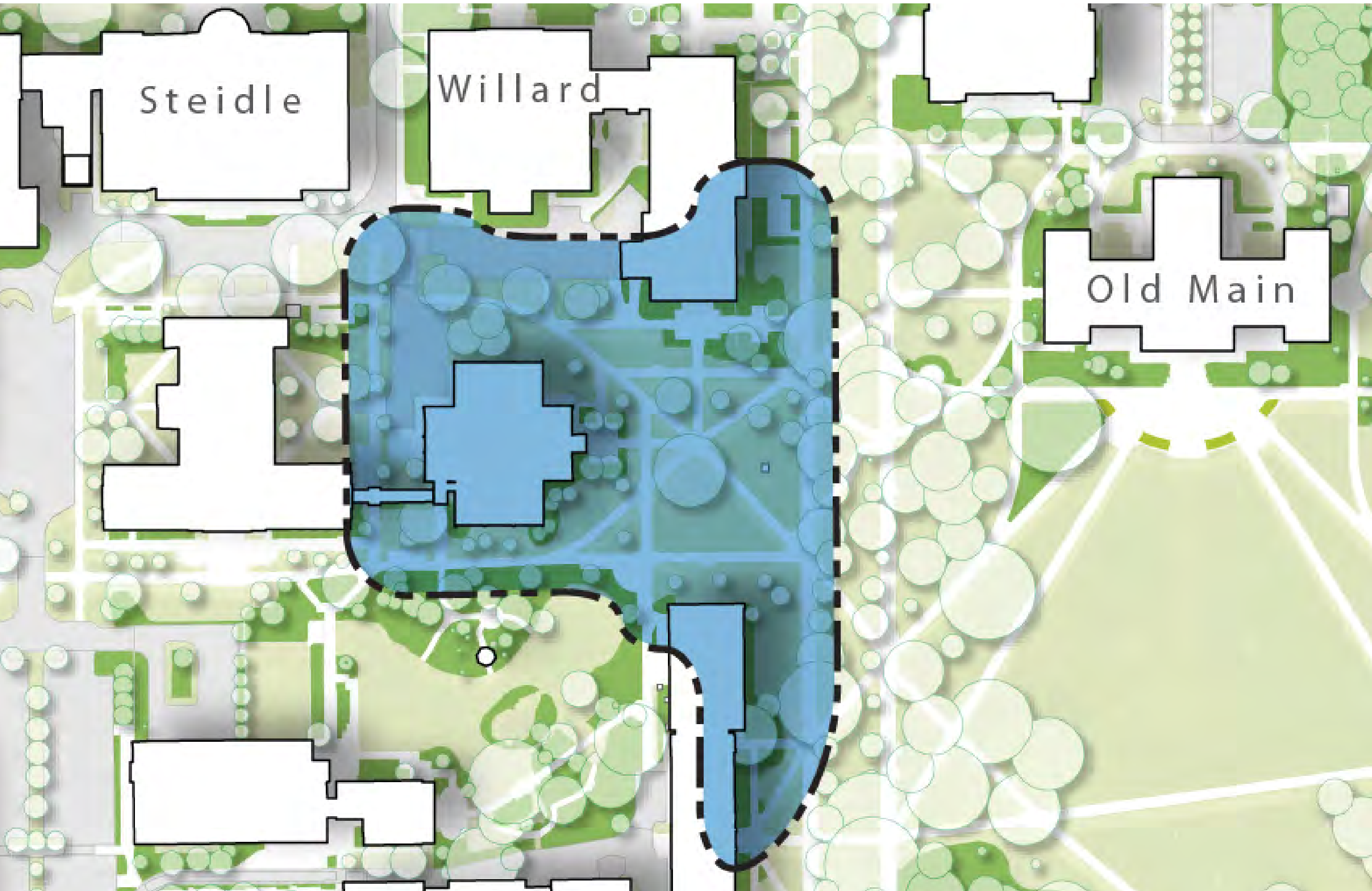
The Obelisk Garden is a high visibility landscape that physically and visually connects Pattee mall and the Alumni Gardens. The plantings around Electrical Engineering East building are overgrown and nondescript. There are parking lots and service areas between EE East and Willard Buildings. The lawn panels are gently sloping toward College Ave, and are occasionally used for tented events, such as ArtsFest. A large plane tree defines the center of the lawn.

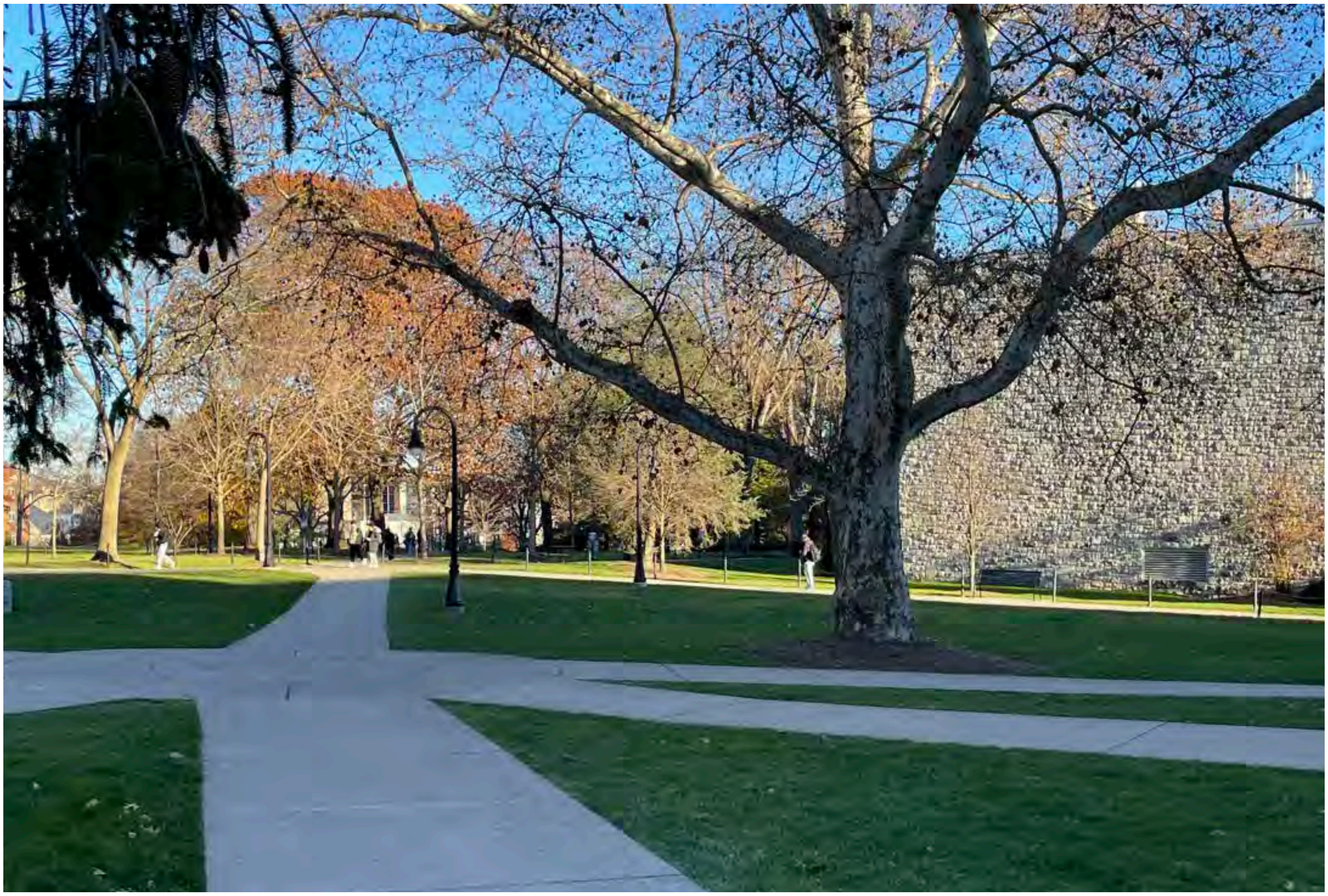
Pros

- High visibility - prominent, limited use
- Maximize planting bed density or convert existing to more sustainable ground flora
- Opportunity to increase tree canopy cover
- Conditions right for many proposed ground flora typologies

Cons

- Heavy foot traffic, generally unprotected
- Substantial utilities, including steam
- Some may perceive as an important ceremonial / sacred space?
- May be impacted by Sackett Building demo?





APPENDIX F: CONSIDERED PILOT PROJECT AREAS

MILLENNIUM SCIENCE COMPLEX CROSSROADS

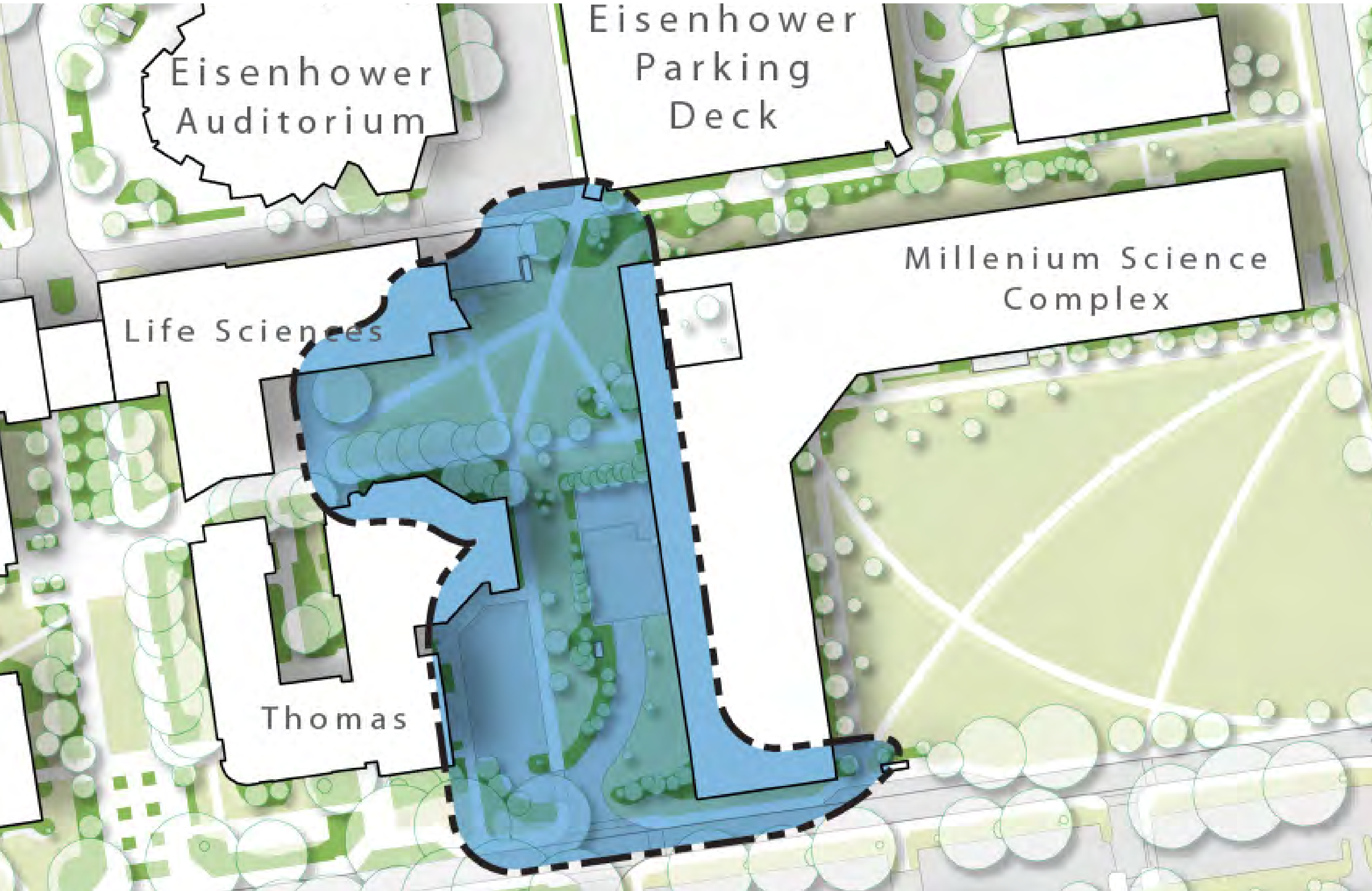
The landscape panels at these circulation crossroads are mostly lawn, with some minimal tree, shrub, and groundcover plantings along the edges of buildings. The site is generally flat, but does not appear to receive much recreational activity. There is a parking lot behind Thomas Building and service yard for Millennium Science Complex.

Pros

- Good site for full-sun typologies
- Maximize planting bed density or convert existing to more sustainable ground flora
- Potential turf conversion to stylized meadows (sun & shade)?
- Perhaps millennium science lawn as site for more sustainable turf care pilot?

Cons

- Lower visibility (back-of-house) feel
- Major utility crossroads, including steam
- Potential drainage issues?



APPENDIX F: CONSIDERED PILOT PROJECT AREAS

SOUTH HALLS & EASTVIEW TERRACE

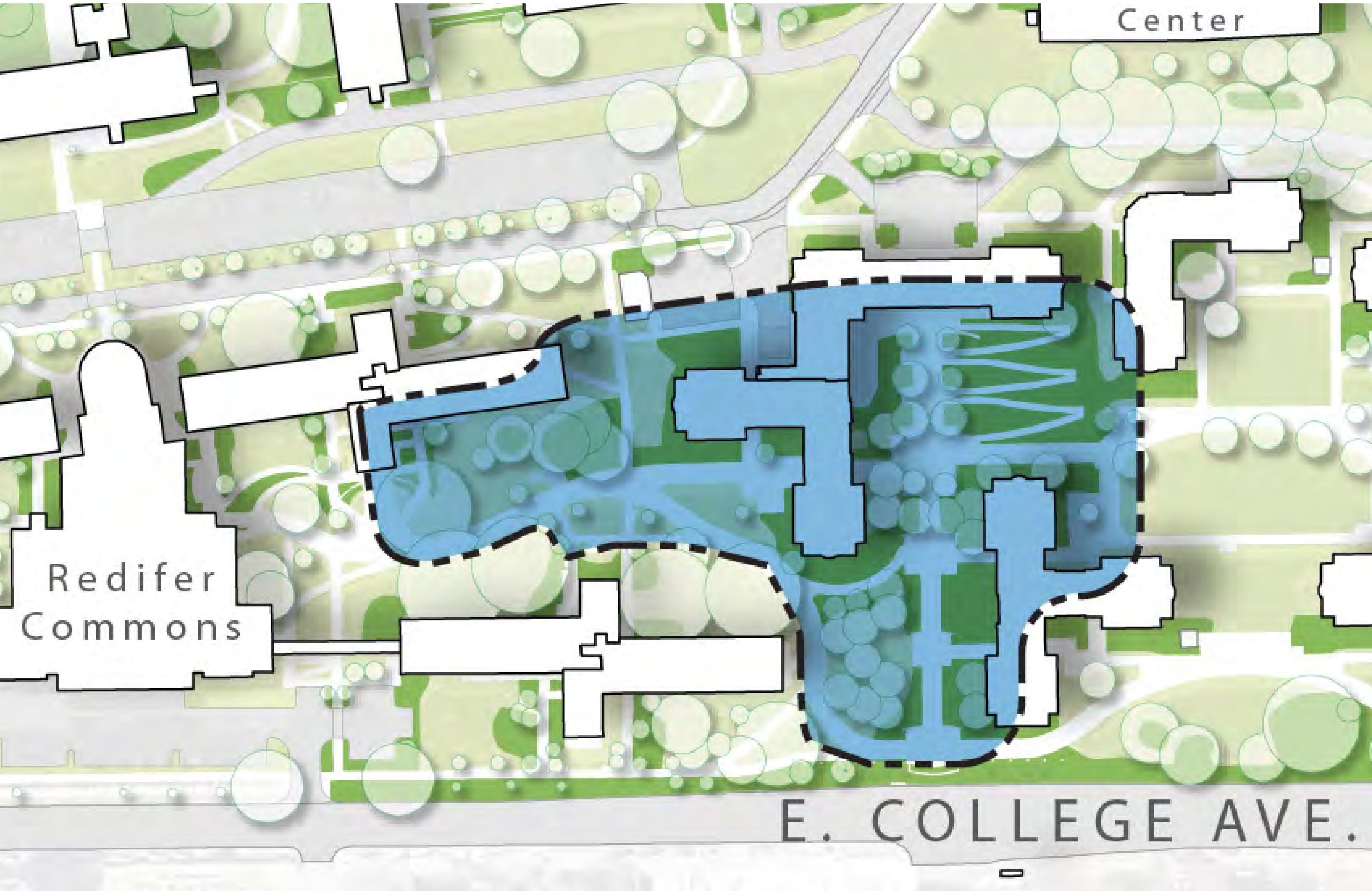
The sloping lawns and planting beds within this area are generally steeper than most other areas of campus. The steep planting beds have been a challenge for OPP to keep densely planted. Conversely, the lawn slopes are in good condition, but are very challenging and time-consuming to maintain. This landscape gets very little use from students.

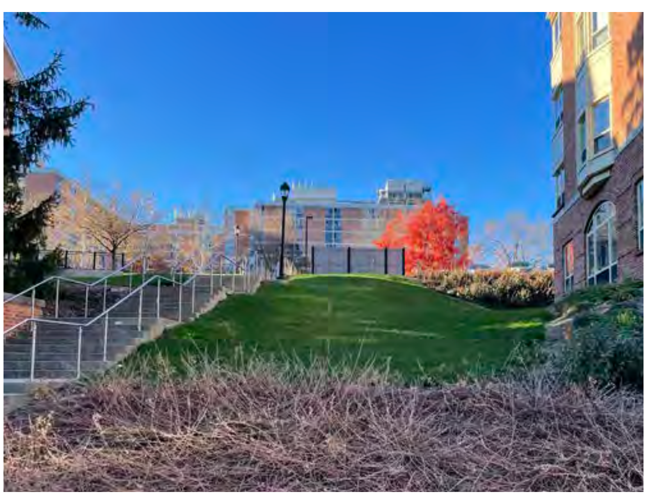
Pros

- Residential area - communication/ engagement potential
- Conditions right for many proposed ground flora typologies
- Maximize planting bed density or convert existing to more sustainable ground flora
- Opportunity to maximize tree canopy cover
- Opportunity to test typologies on slopes and in expansive mulched areas

Cons

- Slopes are steeper than typical on campus
- Drill seeding opportunities less likely here





HASTINGS ROAD & UNIVERSITY DRIVE

This area is largely a sloping lawn with fairly dense groves of canopy and understory trees. In some spots, the lawn is being shaded out by the dense tree canopy. Along University Drive, there is a stormwater swale that appears to be sparsely vegetated by volunteer species, with bare soil visible in other areas. The Nuclear Reactor and Research East Buildings have little to no shrub and groundcover foundation plantings. The groundplane is generally a blank slate here.

Pros

- High visibility area from University Drive
- Conditions right for many proposed ground flora typologies
- Limited shrub & groundcover layers
- Opportunity to continue character of no-mow plantings east of Univ. Drive
- Opportunity to test stormwater planting typologies - some stormwater funding?

Cons

- Major utility crossroads, including steam
- Drill seeding opportunities less likely here