

Campus ecology: assessing the performance and management of green infrastructure at Kansas
State University

by

Lukas Freelove

A REPORT

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Approved by:

Major Professor
Lee R. Skabelund

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Abstract

Green infrastructure is essential for creating healthy, sustainable spaces by integrating natural systems into urban environments. It enhances human well-being and ecological resilience while providing key ecosystem services like stormwater management. As green infrastructure projects become more popular and, in some cases, mandatory, these systems must be well-designed, properly implemented, and adequately maintained. Unfortunately, many projects suffer from issues stemming from poor design, faulty implementation, or inadequate maintenance.

At Kansas State University, for instance, several green infrastructure projects require more attention. This issue is not unique to KSU; numerous other projects across various locations also need improvements in design and management.

This research focuses on how increasing biodiversity and effective management strategies of green infrastructure can benefit its performance and the crews responsible for its upkeep. The study explores these systems' planting strategies, design, performance, and current management practices. The research culminates in a proposed design for green infrastructure and strategies for improved management.

CAMPUS ECOLOGY



LUKAS FREELOVE

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*Assessing the Performance and
Management of Green Infrastructure
at Kansas State University*

Campus Ecology: Assessing the Performance and Management of Green Infrastructure at Kansas State University

A report submitted in partial fulfillment of the requirements for the degree: Master of Landscape Architecture

Department of Landscape Architecture and Regional & Community Planning: College of Architecture, Planning & Design, Kansas State University

Master's Project Committee:

Lee Skabelund, Associate Professor, Department of LARCP

Howard Hahn, Associate Professor, Department of LARCP

Cody Domenghini, Ph. D., Assistant Professor, Department of Horticulture and Natural Resources

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At Kansas State University, for instance, several green infrastructure projects require more attention. This issue is not unique to KSU; numerous other projects across various locations also need improvements in design and management.

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Glossary

Biodiversity- Biological diversity in an environment as indicated by numbers of different species of plants and animals (“Definition of BIODIVERSITY” 2024) **Monoculture** - Growth consisting of a single crop, plant, or organism (“Definition of MONOCULTURE” 2024)

Bioswale - Bioswales are vegetated, mulched, or xeriscaped channels that treat and retain stormwater as they move it from one place to another (EPA).

Designed Plant Community - Intentional layering of multiple plants to create a bio-diverse design (Rainer and West 2015a)

Green Infrastructure - Infrastructure that uses vegetation, soils, and other elements and practices to restore some of the natural processes required to manage and often infiltrate water and create healthier urban environments. At the city or county scale, green infrastructure is a patchwork of natural areas that provides habitat, flood protection, cleaner air, and cleaner water (US EPA, OW 2015).

Green Roofs - Green roofs are covered with growing media and vegetation that enable rainfall infiltration and evapotranspiration of stored water (US EPA, OW 2015).

Infiltration Basins - A basin that is a shallow impoundment created to infiltrate stormwater into the soil. This feature effectively increases groundwater recharge (thus increasing baseflow to nearby streams) and can also help remove pollutants from stormwater (US EPA, OW 2015).

Inlet - An opening to allow surface and stormwater into a green infrastructure system (“Green Infrastructure-DEP” n.d.)

Outlet - A pipe or opening in a green infrastructure system that allows water to leave the system. It can be above or below ground (“Green Infrastructure-DEP” n.d.)

Permeable Pavement - Alternatives to traditional pavement on our paved surfaces can help reduce runoff by infiltrating rainwater and melting snow. These alternative materials, including pervious asphalt, pervious concrete, interlocking pavers, and plastic grid pavers, allow rain and snowmelt to seep through the surface down to underlying layers of soil and gravel (US EPA, REG 01 2015).

Rain Garden - Also known as bioretention or biofiltration, cells are shallow, vegetated basins that collect and absorb runoff from rooftops, sidewalks, and streets. This practice mimics natural hydrology by infiltrating, evaporating, and transpiring stormwater runoff (EPA)

Service Levels - "Service Levels refer to both the amount and frequency of maintenance activities required for any given area of campus. Currently there are three levels of maintenance; Service Levels A, B and C. Certainly different parts of campus require different Service Levels. In general, higher Service Levels are assigned to higher profile portions of the campus (Service Level A) with the intent of presenting the best possible image to welcome visitors to the University and providing high quality environments for students and staff" (Kansas State University 2023).

CHAPTER 1

Introduction



Fig 1.1 Permeable pavement guides stormwater to rain gardens (Boucher 2009).

Introduction

Green infrastructure plays a crucial role in developing healthy, sustainable environments by weaving natural systems into urban areas. It boosts human well-being and ecological strength while offering essential ecosystem services such as stormwater management. As green infrastructure projects gain traction and become mandatory in some cases, it's vital to ensure these systems are thoughtfully designed, effectively executed, and properly maintained. Regrettably, many projects encounter challenges due to poor design, improper implementation, or insufficient maintenance. For instance, several Kansas State University green infrastructure initiatives need more attention. However, this is not just a Kansas State issue; numerous other projects across various regions also require enhancements in design and management.

This research examines how increasing biodiversity and adopting effective management strategies for green infrastructure can enhance its performance and support the teams responsible for its maintenance. The study will investigate these systems' planting strategies, design, performance, and current management practices, ultimately proposing a design for green infrastructure along with strategies for better management.

Dilemma

Climate change is rapidly creating more challenging precipitation issues, including fewer, inconsistent, and extreme storm events. With more sporadic and intense storm events, green infrastructure (GI) has been added to more projects worldwide as a way to help increase biodiversity, ecosystem services, and many other benefits for people and the environment. Many stakeholders are adding green infrastructure because it is said to be more “cost-effective” and these landscapes have the potential to provide more benefits while reducing the environmental harms and high costs often associated with gray infrastructure. However, the design and management of GI systems can make these statements untrue. Some green infrastructure systems lack biodiversity, are improperly designed, and fail to adequately provide stormwater services. Or, these landscapes are mismanaged, leading to an inefficient system. This research examined how specific green infrastructure systems' planting design and management lead to improved or failed performance. The research will help others think about creating a sustainable green infrastructure system and how these projects can be managed in the long term to enhance performance.

Importance

Green infrastructure design aims to create healthy, sustainable spaces by integrating natural systems into urban environments. Good GI design enhances human well-being and ecological resilience while providing key ecosystem services like stormwater management. As green infrastructure projects become more popular and, in some cases, mandatory, these systems must be well-designed, properly implemented, and adequately maintained.

Research Questions

How can college campuses effectively manage bio-diverse green infrastructure? How do management strategies affect the performance of green infrastructure on college campuses over time?

Goals

1. Understand the link between effective management and green infrastructure performance.
2. Discover the importance of biodiversity in green infrastructure for both performance and management
3. Highlight the importance of green infrastructure for college campuses.



Fig 1.2 Rain garden fills due to large storm event, allowing for stormwater to infiltrate ("Bioswale" 2008).



Fig 1.3 West Memorial Stadium Green Roof in early spring (Freelove 2025).

Methodology

The methods of this study include green infrastructure inventory, comparative analysis, and interviews. A literature review was conducted first to understand the existing research on the role of design, implementation, and management in green infrastructure systems. Along with understanding maintenance strategies for certain green infrastructure systems. From there, site inventory was done. The inventory classifies green infrastructure projects that are already existing at Kansas State University. Next, a comparative analysis was conducted, analyzing five projects on campus. With this study, I was able to compare and find similarities between the projects to understand how design and management strategies influenced the efficiency of the green infrastructure system. Finally, interviews were done. From these interviews, I was able to understand how projects on campus are managed, the time spent, and the process of how the maintenance teams work.

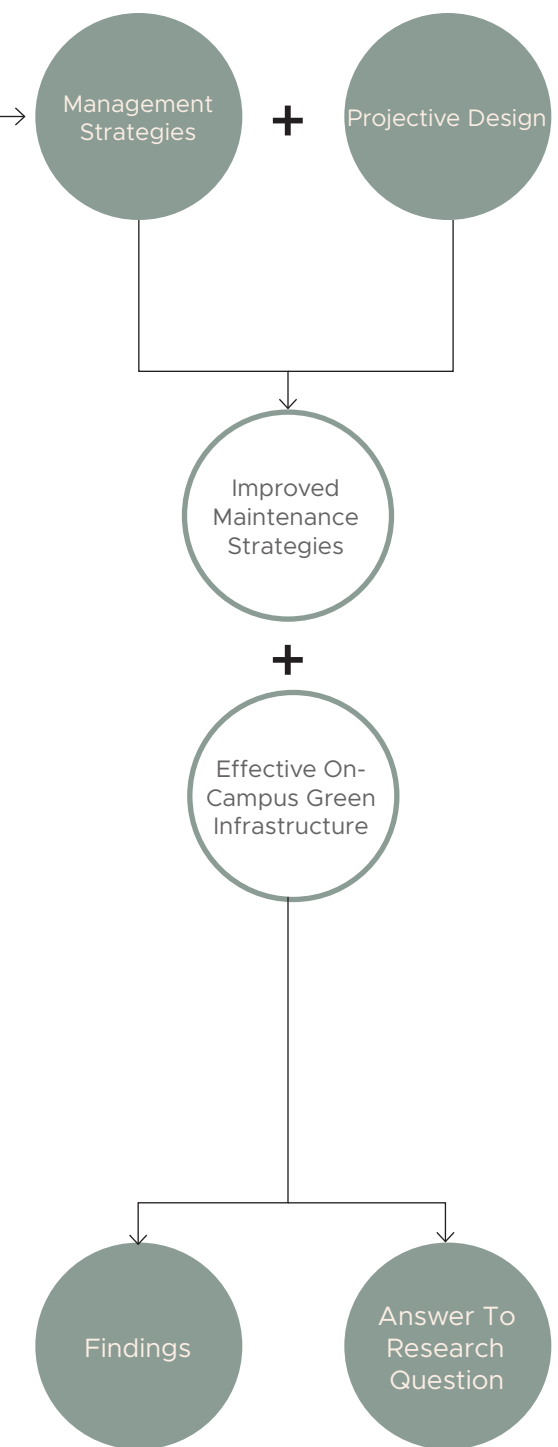
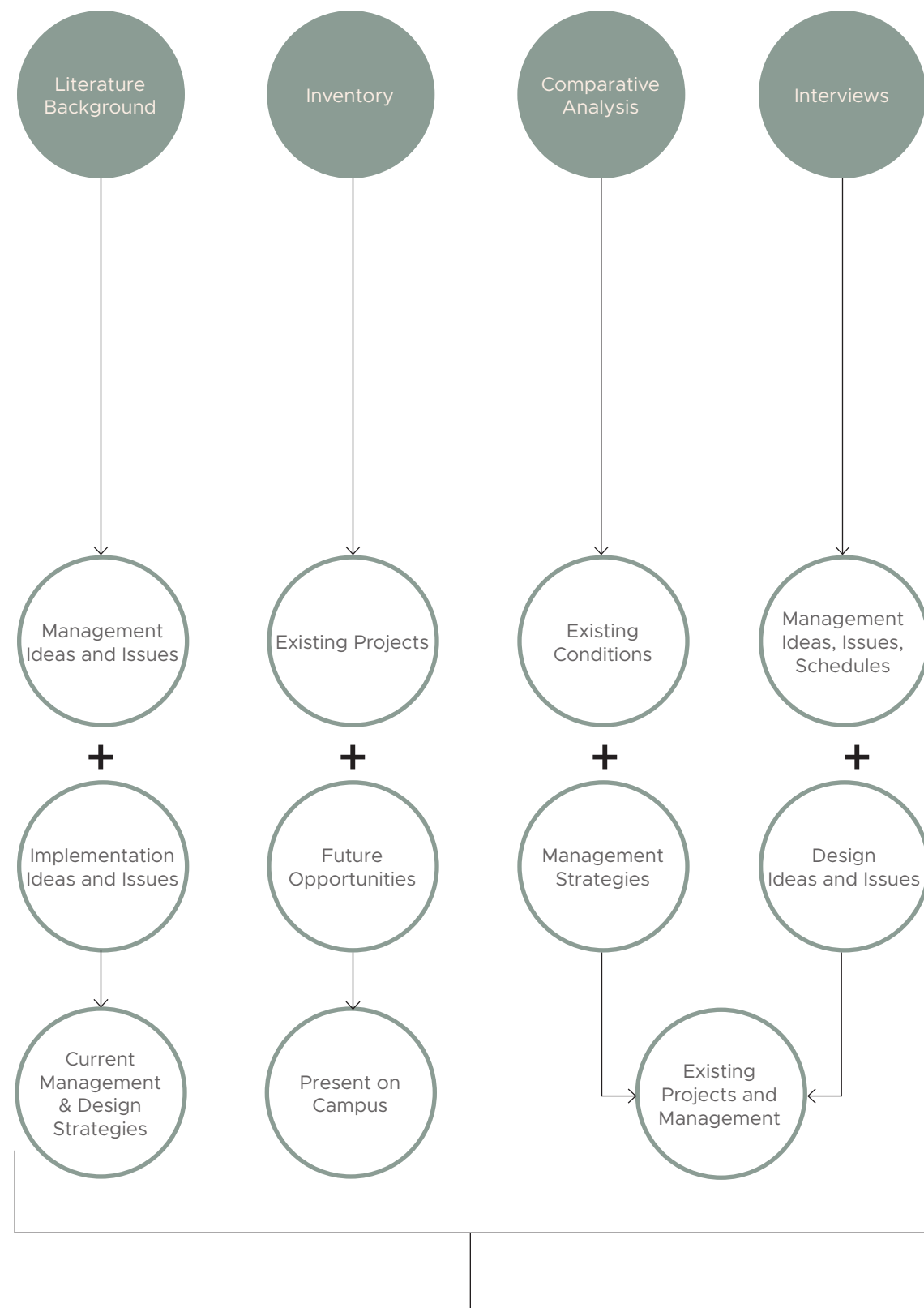


Fig 1.4 Methods diagram (Freelove 2024).

CHAPTER 2

Background



Fig 2.1 Peters Recreation Center's retention basin fills with stormwater runoff from the surrounding context (Freelove 2024).

Context

Kansas State University Master Planning Process

Previously, Kansas State saw a master plan completed for the campus in 2013. For the 2025 master plan, the team is looking to potentially serve shortages that could complement Vet Med, The Peters Recreation Center, Housing, etc. Along with that, there are five principles that have been highlighted: Student Experiences, Heritage Buildings, Expand Research, Resilient Campus, and Mobility/Parking/Transportation. Through many scenarios shown by the master planning team, the Rec, and former Edwards Hall do not see much change in the preliminary 2025 master plan ("Campus Master Plan").

Projective Design Site

Currently, our site represents the headwaters of Campus Creek, the primary creek that flows through the campus. However, these headwaters are experiencing significant challenges due to heavy runoff from the surrounding athletic facilities, parking areas, and the Peters Recreation Center. To the west and south of the Peters Recreation Center, there are the only “green infrastructure” projects near the headwaters. Unfortunately, this channel is suffering from severe degradation and erosion, primarily due to the substantial volumes of stormwater rapidly flowing through the area. The grass detention basin is not aesthetically appealing and creates a large mowing issue for maintenance.

The erosion and degradation issues are exacerbated by the high-speed runoff, which undermines the channel’s stability and reduces its effectiveness in managing stormwater. Addressing these problems requires a comprehensive approach that includes improving runoff management strategies, enhancing the green infrastructure project, and implementing additional measures to protect and restore the natural integrity of the headwaters.



Fig 2.2 Peters Recreation Swales (Freelove 2024).

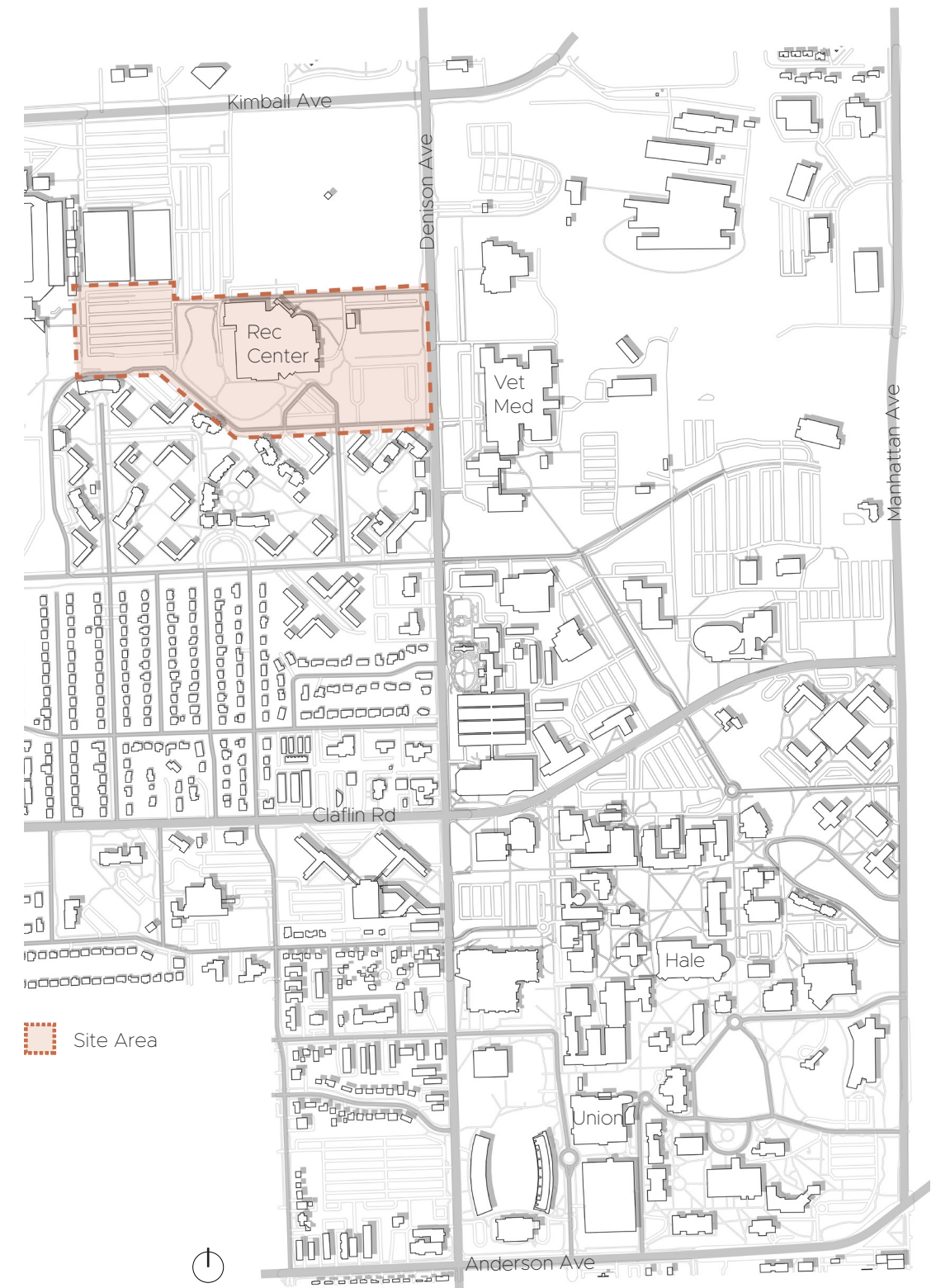


Fig 2.3 Site location diagram

Literature Review

Introduction

Urban areas worldwide are grappling with shifting rainfall patterns and diminishing biodiversity. The increasing frequency and intensity of rainfall, rapid urbanization, and climate change are straining existing infrastructure. In response, many regions are turning to green infrastructure as a critical strategy for promoting sustainability and biodiversity (Lepczyk et al. 2017). This shift is not limited to urban areas; college campuses worldwide also embrace these innovative ideas.

Many college campuses have initiated green infrastructure projects, such as green roofs, rain gardens, green stormwater infrastructure, native landscaping, and more (Anis et al 2018, Bouma et al. 2013, Shirmathi et al. 2023). While these projects aim to support native ecology and ecosystem services, it's important to note that not all succeed. Poor design and incorrect planting methods can lead to monocultures, damaging biodiversity (Herzog 2016, Rainer and West 2015a). Inadequate Financial or personnel resources can also result in a lack of maintenance, further undermining the success of a project (Van Valkenburgh and Saunders 2013).

While the adoption of green infrastructure for stormwater management is rising, there is an urgent need for better implementation and management methods (Bassi et al. 2019). Current mismanagement often leads to neglected systems and dissatisfaction among stakeholders. Addressing this issue is crucial for the successful and sustainable development of green infrastructure (Cook and Vanderzanden 2011a, Keesstra et al. 2018, Van Valkenburgh and Saunders 2013).

History of Recent Practices and Issues

Background of College Campuses and Green Infrastructure Development:

Many college campuses in the United States suffer from highly manicured and intensely managed landscapes. Campus spaces can be too much for maintenance teams to maintain at a high standard, leading to overworked staff and neglected landscapes. Today, most college landscapes only consist of pavement, lawn, some trees, and planting around buildings, allowing stormwater to rush freely into streams, pipes, and other infrastructure (Reed et al. 2024, Shrimathi et al. 2023).

With intense storms happening more frequently, campuses worldwide have tried to resolve problems like stormwater management, infrastructure inefficiencies, and erosion by using green infrastructure practices. However, many green infrastructure systems are poorly implemented or maintained and lose integrity (Rainer and West 2015c, Van Valkenburgh and Saunders 2013). Maintenance crews lack knowledge and direction, leading to mismanagement and poor performance (Cook and Vanderzanden 2011c, Rainer and West 2015c, Van Valkenburgh and Saunders 2013). As the system declines, weeds and invasive species encroach upon green infrastructure. This creates an unaesthetic look, the system fails, and many green infrastructure installations are removed. Many of these issues stem from the implementation of standard landscape management practices and a lack of communication (Cook and Vanderzanden 2011c, Rainer and West 2015c). Lack of adequate landscape staff or expertise (particularly related managing native plants and more complex plantings or ecosystems) is another significant hurdle that is a challenge, especially when university budgets are tight.

Current Practices and Issues for Green Infrastructure Design, Implementation and Management

Planting and Design:

In green infrastructure, two crucial components are the plant material and soil (Berland 2017, Brodsky et al. 2019). In the early twentieth century, people believed that plant communities were super-organisms, and that species cooperated to benefit the group (Rainer and West 2015a). This created thoughts that plant communities had distinct boundaries and transitions between them. However, this is incorrect. Species react to the site. Biological interactions, such as soil relationships and competition, are crucial. Creating a group of overlapping plant populations that coexist and interact makes a strong bio-diverse community (Brodsky et al. 2019, Cook and Vanderzanden 2011a). Even though research supports these ideas, planting still is not always done this way (Dowdell et al. 2024, Rainer and West 2015a). Designers have plant lists that they know and frequently use despite differing micro-conditions. However, not all plants perform the same in different areas.

Along with incorrectly selected plants, the design of specific spaces does not always yield the best outcome. Many sites suffer from heavy annual plantings, sparse plantings, the creation of a monoculture, and many more issues (Cook and Vanderzanden 2011a, Cook and Vanderzanden 2011b, Rainer and West 2015b). These designs adhere to the normalcy of grouping plants to show form and order. When it comes to green infrastructure, one of the most significant issues is too much bare ground. Open soil allows weeds, invasive species, and erosion to diminish the system's function (Rainer and West 2015b).

Implementation and Management:

Before projects are implemented, the site must be prepared for design interventions. One of the most significant changes green infrastructure requires is soil amendments (Cook and Vanderzanden 2011b, Rainer and West 2015c). Engineered soil is often created for

optimal water drainage, but these conditions may be less suitable for vigorous plant health. Plants need moisture to stay present in the soil to help with transpiration and evapotranspiration. As water moves out quickly, less is available for plant life to use (Brodsky et al. 2019, Rainer and West 2015c). If engineered soil is not used, current site soils are chemically and physically amended to meet what some think is optimal. Once again, this can hurt plant establishment and growth in green infrastructure systems. Plants cannot adapt to the present soil, and the soil can be depleted of nutrients that plants need to survive (Brodsky et al. 2019, Rainer and West 2015c). Also, while projects are being built, soil suffers from extreme compaction due to heavy machinery preparing the site. With the soil being too compact, plants cannot establish (Cook and Vanderzanden 2011b, Rainer and West 2015c).

The soil and plants are essential in green infrastructure systems (Bruner et al. 2023, Cook and Vanderzanden 2011a, Rainer and West 2015b). Some plants suffer from how they are grown in the nursery, causing issues for the establishment, and others suffer from poor implementation. Plants are improperly planted, the root balls are cut, or many other problems can arise (Cook and Vanderzanden 2011c). Even with proper implementation, the project can still fail. This is due to management issues.

Green infrastructure is a complex system with many parts, including planting, drains, pipes, soil, and other components that can be confusing to care for (Bruner et al. 2023, KC Water 2022). Once a design is done and implemented, stakeholders, designers, and maintenance crews need clear and frequent communication about expectations. Different plants may intrude, and if there is minimal guidance on whether plants are invasive, this may lead to the removal of desired species. Drains and inlets clog with plant debris, often leading to removing all plant debris. Plant debris is integral to the natural decomposition process and helpful in green infrastructure. Sometimes, the water flow causes erosion, allowing water to channelize within a system (Cook and Vanderzanden 2011a, Cook and Vanderzanden 2011b, Person et al. 2024). Designers and stakeholders may get frustrated, especially if a maintenance guide has yet to be created.

These same issues are seen on college campuses. Planting design can sometimes not be of high quality or lacks biodiversity. Some campuses need more staff for the campus size or green infrastructure project. Campuses often lack the guides to maintain such projects, leaving maintenance crews to do what they see best. With these issues, many have sought to change this, leading to new ideas for design, implementation, and maintenance practices.

Improving Green Infrastructure Performance with Design and Management In Mind

As more green infrastructure projects are built, awareness of what plant species are being used, and plant community design is moving to the forefront. First, designed plant communities follow more native plant palettes, contributing to native biodiversity (Hudekova 2022, Rainer and West 2015b). Native plants and trees which are adapted to the region, allow for more tolerance of local site conditions. However, not all native plants are available, so understanding what specific ecosystem services a plant provides can better lead to selecting a suitable replacement (Rainer and West 2015b).

Along with plant selection, the design of the plant community is becoming more immersive and successful. The book *Planting in a Post-Wild World* by Thomas Rainer and Claudia West displays an important way of looking at planting design. Designing plant communities creates a bio-diverse and effective natural system (Rainer and West 2015b). Instead of placing plants individually by group, they use vertical layering to create visually striking landscapes. Their process consists of four layers: structural, seasonal theme, filler, and ground cover plant layers. These layers intertwine to create a dynamic and somewhat wild planting (Rainer and West 2015b). The most critical layer of the four is the ground cover layer. This layer of low ground cover plants spread underneath the more significant plantings, covering bare soil. With the ground covered, there is less chance for weeds to migrate into the system and heavy erosion (Cook and Vanderzanden 2011a, Cook and Vanderzanden 2011d, Rainer and West 2015b).

These ideas can help a green infrastructure system function very well. With higher plant and root mass, erosion will decline (Berland et al. 2017, Brodsky et al. 2019, Person et al. 2024, Rainer and West 2015c). Along with less erosion, a higher plant and root system population improves rainwater percolation, absorption, and filtration (Brodsky et al. 2019, Person et al. 2024, Rainer and West 2015b). Once these systems are created and installed, the long-term management shapes the success of green infrastructure.

On college campuses, once a green infrastructure project is installed, the system must be managed correctly. Many of these systems fail in different ways: plants die, water moves through the system too rapidly, pipes and drains become clogged, etc. (Anis et al. 2018, Rainer and West 2015c, Reed et al. 2024). Some campuses lack the knowledge to care for these systems or are not given a sufficient management guide. However, designers and other stakeholders can collaborate with grounds crews to create a management plan and guide that is easily understood and translatable to others (Cook and Vanderzanden 2011a, KC Water 2022, Rainer and West 2015c).

Once plants are installed, management begins. Grounds crews handle establishing and getting the plants rooted in time. However, not all plants make it through this stage. If plants are stressed or die, grounds crews must know precisely what to do. When plants die, it is good to pay attention to how they die (Rainer and West 2015c). Some might have been from poor placement, or other out compete them. Replacement plants can be installed, or a different plant that has been identified can be installed in the place of another. Mulch can be added to cover the ground so that weeds do not intrude and cover displacement paths due to water movement (Cook and Vanderzanden 2011a, Cook and Vanderzanden 2011d). Along with small-scale management of plant life come larger management practices. Some ecosystems require different needs; some may need to be burned or mowed; others may require large-scale hand removal of weeds or unwanted species. With these management ideas in mind, it is important to remember that plant systems are dynamic. Plants can move from year to year, and if the system functions well, it can be dynamic (Bruner 2023 et al., Keesstra et al. 2019, Rainer and West 2015c).

Along with plant care, the green infrastructure system itself contributes many pieces to the puzzle. To ensure the system is functioning, continued monitoring and maintenance are needed. For example, inlets should be cleared when clogged with leaf litter, trash, and sediment. Pipes and outlets will also get clogged with the same type of debris and need to be removed. Along with blockages, water movement can lead to erosion and displaced material such as rock, soil, mulch, and many more components (KC Water 2022). Replacement material should be added, and the erosion should be monitored for other solutions. Green infrastructure is not invincible; sometimes, it needs physical repairs (KC Water 2022, Van Valkenburgh and Saunders 2013, Vijayaraghavan et al. 2021).

Opportunities

College campuses provide a unique opportunity for green infrastructure projects to be implemented and tested. Institutions have many opportunities for students and faculty to participate in these projects (Ahn 2016, Bouma et al. 2023, Reed et al. 2024). Working with multiple disciplines and documentation of new ideas, technologies, and research can greatly benefit others. Grounds crews can learn from this research and better manage these green infrastructure systems (Ahn 2016, Anis et al. 2018). This would lead to a more robust and dynamic system requiring less maintenance over time. Implementing green infrastructure in a campus setting allows grounds crews, faculty, students, and others to learn from these systems while creating a more bio-diverse campus setting.

People rely on biodiversity and ecosystems (Cardinale et al. 2012). Without ecosystem services, people start to suffer from losing goods and services provided by bio-diverse landscapes. Not only do people need biodiversity, but so do landscapes themselves. Ecosystems are very susceptible to degradation from invasive species, development, climate change, and many other factors (Cardinale et al. 2012, Herzog 2016, Lepczyk et al. 2017). On college campuses, this is no different. Institutions start to expand and renovate to accommodate the student body. However, the monotonous landscape of lawns and trees found on university landscapes is harmful to regional biodiversity and too much for maintenance crews to manage (Anis et al. 2018, Reed et

al. 2024). However, with green infrastructure, this can change. Green infrastructure needs more upfront management but will require less intense care over time.

As green infrastructure is implemented more often, using biodiversity within these systems will help address the biodiversity issue and improve the system's function. Better planting design strategies and a long-term management plan increase biodiversity and enhance system functions. Need for ongoing high-quality staff training is very important, especially since part-time student staff may be frequently used on campuses. This will ensure the continued success of green infrastructure, creating spaces where people and the environment can work together.

CHAPTER 3

Comparative Analysis



Fig 3.1 Bio-diverse green infrastructure helps stormwater effectively and naturally infiltrate soil into the soil, slowing runoff (MSU 2012).

Inventory

Kansas State University (K-State) has many green infrastructure projects across the campus. The inventory map shows where these projects are located on campus. Each type of green infrastructure was classified and, five green infrastructure projects were studied: **The Meadow, Carl Ice Engineering Hall Bio-Retention System**, the **Bioswales North of Seaton Hall, Seaton Hall Rain Garden**, and the **Memorial Stadium Green Roofs**.

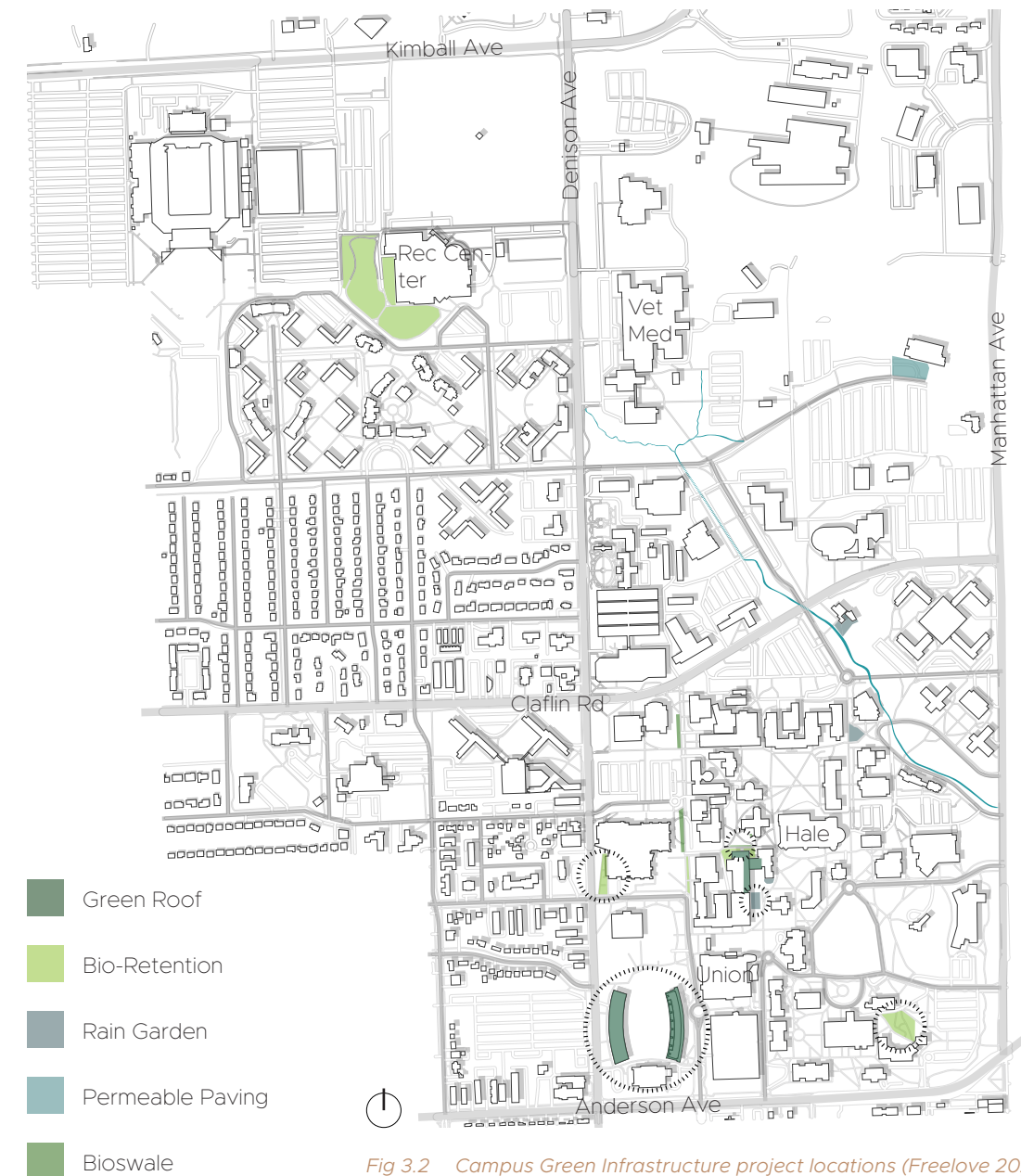


Fig 3.2 Campus Green Infrastructure project locations (Freelove 2024).

Comparative Analysis

The five projects are described and imagery helps to reveal what they look like and what issues and successes are apparent. Along with the photo analysis, each design was evaluated using biodiversity, design, management strategies, and performance criteria. After investigating these five areas, I compare the projects, identifying where each works correctly and is appropriately managed and whether the design created a bio-diverse green infrastructure project. To do this, the Rapid Ecological Assessment Rubric was used to evaluate soil and plant health during the fall of 2024 (Moore et al. 2012). I then, assessed each project using criteria about management and how the green infrastructure project is cared for.

1 BIODIVERSITY

PLANT ABUNDANCE

- 1. Are there a sufficient amount of plants present?
- 2. Is the ground covered?

PLANT DIVERSITY

- 1. Rainer and West's Four Layers: Structural, Seasonal Theme, Filler, Groundcover

2 MANAGEMENT

TIME

- 1. Is enough time being spent on these systems?
- 2. What time issues are they facing? Is the system too time intensive?
- 3. Schedule

STRATEGIES

- 1. Invasive Removal?
- 2. Cost?
- 3. Landscape Care?

LONGTERM PLAN

- 1. Is there a longterm plan present?
- 2. Replacement Plan?

3 PERFORMANCE

COST BENEFIT

- 1. How does this project compare to what used to be in its place?
- 2. What costs have lessened due to added green infrastructure?

SYSTEM FUNCTION

- 1. Are the components functioning properly?
- 2. Is the management allowing for the functions to work effectively?

SOIL HEALTH

- 1. Is there a healthy soil community? Apparent erosion?

Fig 3.3 Comparative analysis diagram (Freelove 2024).

Memorial Stadium

The Kansas State University Memorial Stadium, built in the 1920s, was the first campus memorial. It honors alumni and students who gave their lives in World War One. Plaques on the stadium's East and West sides commemorate these veterans. From 1922 to 1967, all Kansas State football games were hosted at Memorial Stadium, which are now played at the Bill Snyder Family Stadium. Today, Memorial Stadium is primarily used for marching band practice, club soccer, rugby, high school events, exercise, and leisure.

The \$2.5 million green roof project was completed in 2015 (west side) 2016 (east side). Excess seating was turned into prairie green roofs to recreate plant communities that mimic the Flint Hills Ecoregion. This green roof system serves as a protective layer, protecting the waterproof membrane for the buildings below. The green roofs also help cool the buildings below. These systems also provide many opportunities for research and education. The green roofs have received performance-based research, with ongoing data collection by students and faculty relating to pollinators, soils, soil moisture, and vegetation (changes related to species richness and dominant species).

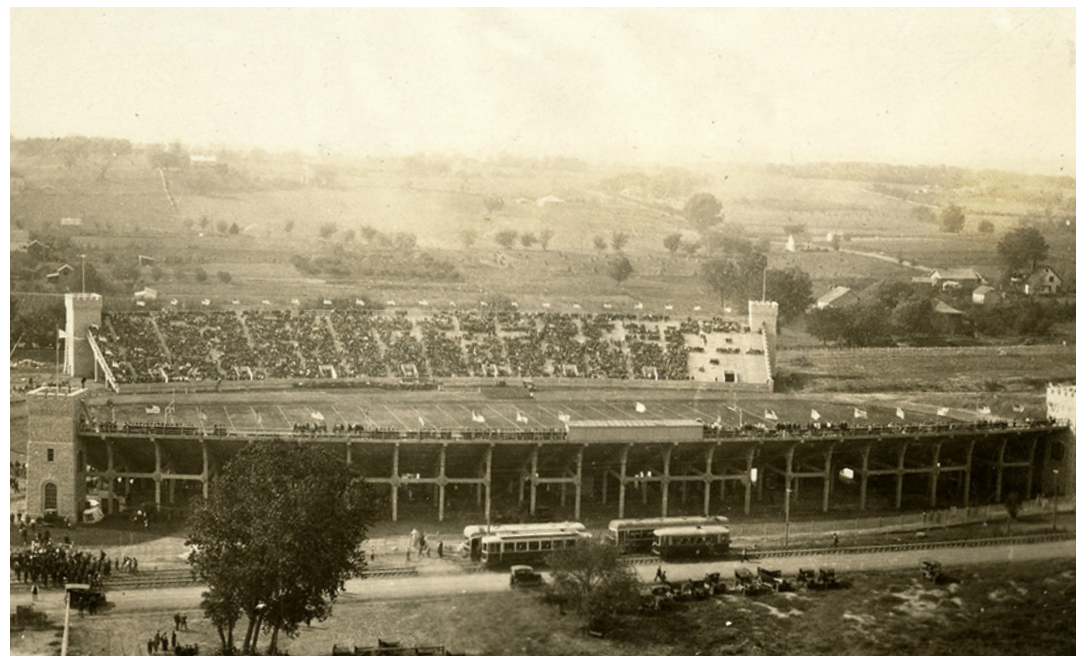


Fig 3.4 Aerial image of a Kansas State University football game in 1924 (Kansas State University).

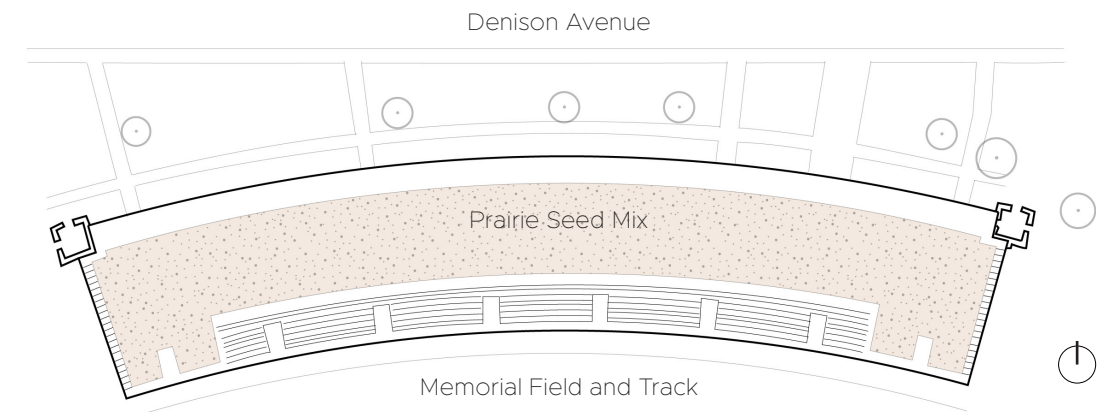


Fig 3.5 West Memorial Stadium Green Roof 2015 (Freelove 2025).

Biodiversity and Design

The Memorial Stadium green roofs are a combined 43,050 sf. However, the slope of the green roofs was seen as a potential issue. Geofoam was used to fill the existing seats on a 20-degree slope. Then a lightweight engineered sandy soil with a 5–6-inch depth was added. A nylon erosion mat was installed to hold the soil in place. Then, the roof was seeded for plant establishment. A total of 28 species were planted and seeded within the system. Many species that are present resemble surrounding prairies. Some of those species include: multiple coneflower species, Sideoats and Hairy Grama, Prairie Dropseed, Indian Grass, Big and Little Bluestem, multiple species of aster, Wild Blue Indigo, Blue False Indigo, Blazing Star, Purple Prairie Clover, Showy and Foxglove Beardtongue, Bee Balm, yarrow species, etc. Only one of the species is not native to the nearby Konza Prairie (Skabelund & Alam 2021). It has been reported that the plant species have grown well on the steep slope and provide the tallgrass prairie look. For the soil, the slope mattered greatly. With the higher slope, water sheds more quickly, so more irrigation is needed to help the plant life during extended drought periods. Also, since the soil is lightweight and sandy (with some shale added on the east side) it can dry out quickly, leading to a broader range of soil moisture levels depending on precipitation timing and irrigation coverage (Skabelund & Alam 2021).



Fig 3.6 The planting of the Memorial Stadium Green Roofs emulates the Flint Hills Ecoregion (Freelove 2024).

Management

To keep seeded and planted vegetation alive, spray irrigation was added which helped with plant establishment, and it is used two or three times each week throughout the growing season (typically late April to early October). The Kansas State University Grounds staff oversee the monitoring of irrigation and the management of vegetation itself. This project is in an urban environment, so volunteer species can easily migrate into the system (Skabelund 2020). Some of the plant species are seen as nuisance species. However, not all. If species are deemed nuisance species, they should be pulled or cut and removed before viable seeds develop. There is currently no system to identify what can and cannot stay other than woody plants and those that cause allergies, are prickly, or are deemed too large and unsightly for the green roofs (especially ragweed, pigweed, prickly lettuce, wild sweet clover, and maretail). Woody plants are removed because the root systems of woody plants can destroy the shallow green roof system (Skabelund 2020). Plants that cause allergic reactions are also removed to protect users of the site. This project has already seen some issues with weeds and invasives due to a lack of early weed removal and incomplete irrigation coverages during hot, dry periods. This leads to some issues with species composition and vegetation cover. With bare areas, more weeds can move into the system. Other issues that continue to persist are litter, damage to irrigation pipes, and ground-dwelling wildlife that burrow in the substrate and eat some of the vegetation (“Kansas State” 2021). Prairie-like vegetation is typically kept until March to allow cover for wildlife, including pollinators. The vegetation is weed-whacked once a year in the spring by K-State Grounds staff, who leave the clippings on the roof to compost after cutting plant material back to an approximately 4-6 inch height.

Kansas State Meadow

In 2013, an existing patch of lawn outside the Marianna Kistler Beach Museum was transformed into a native meadow. Planted by seed, the meadow was designed to be a learning laboratory for faculty and staff and to heighten awareness of grassland ecosystems. This project has stormwater collection benefits. Collecting and filtering stormwater before it reaches on-site inlets (“The Meadow”).

Faculty and students have continually monitored this project for its many benefits. Many pollinators and insects have been caught and found in this ecosystem, providing more opportunities for ecosystem learning. Along with research and observation components, it is a place of experience. In this place, site users can understand what is happening around them and immerse themselves in a native landscape (“The Meadow”).



Fig 3.7 The Meadow transformed a lawn into a natural landscape (Skabelund 2015).

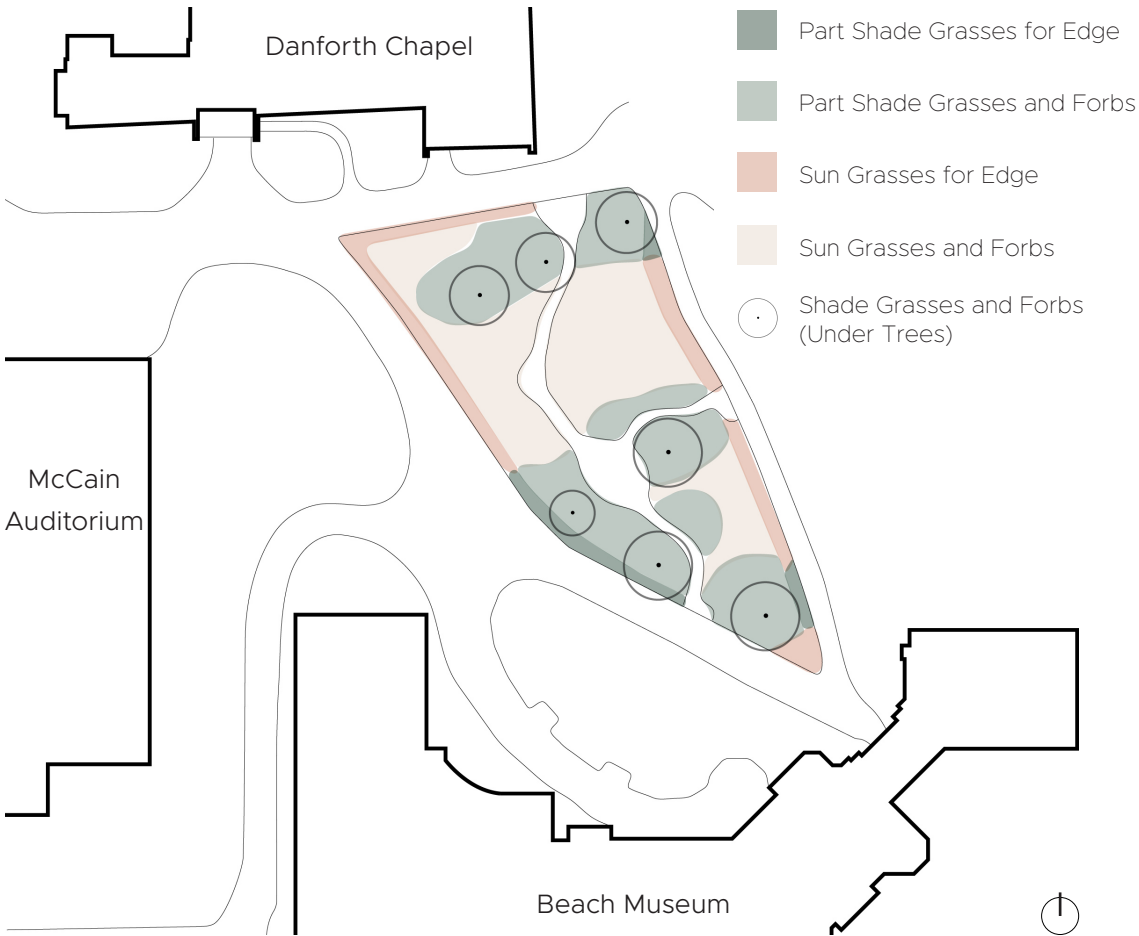


Fig 3.8 The Meadow planting layout (Freelove 2025).

Design and Biodiversity

The K-State meadow is approximately 14,300 sf. The project was designed to emulate the native prairies that are seen around the Flint Hills Ecoregion. The nearby Konza Prairie served as the area where species were selected from (“The Meadow”). The species were put into five different mixes in response to the site and edge conditions to create successful plant and animal habitats. The five different mixes were: part shade grasses and forbs, shade grasses and forbs, part shade grasses for edge, sun grasses for edge, and sun grasses and forbs (“The Meadow”). The site also retained two existing trees and has multiple paths through the site with a large gathering space in the center.



Fig 3.9 This prairie-like area is maintained by student workers and volunteers (Freelove 2024).

Management

This project saw much maintenance before and after construction in 2013. Most of the intense upkeep occurred in the first three years after construction. University grounds and volunteers from the museum and LARCP department monitored and weeded extensively (“The Meadow”). Now, most of the maintenance is done by volunteers and student workers. Continuous monitoring of plant species, weed removal, litter disposal, and other management needs are done (“The Meadow”). Also, this project does not require as much irrigation as a lawn of an equal size due to the abundant native plant life. Finally, this landscape is chemical-free with no chemical fertilizers, pesticides, or herbicides (“The Meadow”). By not using any chemicals on the landscape and low mowing frequency, the cost of upkeep for this project is minimal compared to other areas around campus.

Carl Ice Engineering Hall Bio-Retention

In 2016, Engineering Hall was built at Kansas State University. This building encompasses Rathbone, Durland, and Fielder Halls. The building created many new spaces for research, classrooms, laboratories, offices, student gathering areas, and an auditorium. This building is a great recruiting tool for prospective students (“Engineering Addition”). Outside the main entry to Durland Hall is the Engineering Bio-Retention System built for the building. Six cells were planted along the walk to the entry to capture and hold stormwater runoff from the building and the surrounding impervious surfaces. It also collects water from the permeable paving that surrounds it. This space was meant for study and research by engineering students and faculty (Samford n.d.).



Fig 3.10 The Engineering Bio-Retention originally was successful and had vigorous plant life (Skabelund 2020).

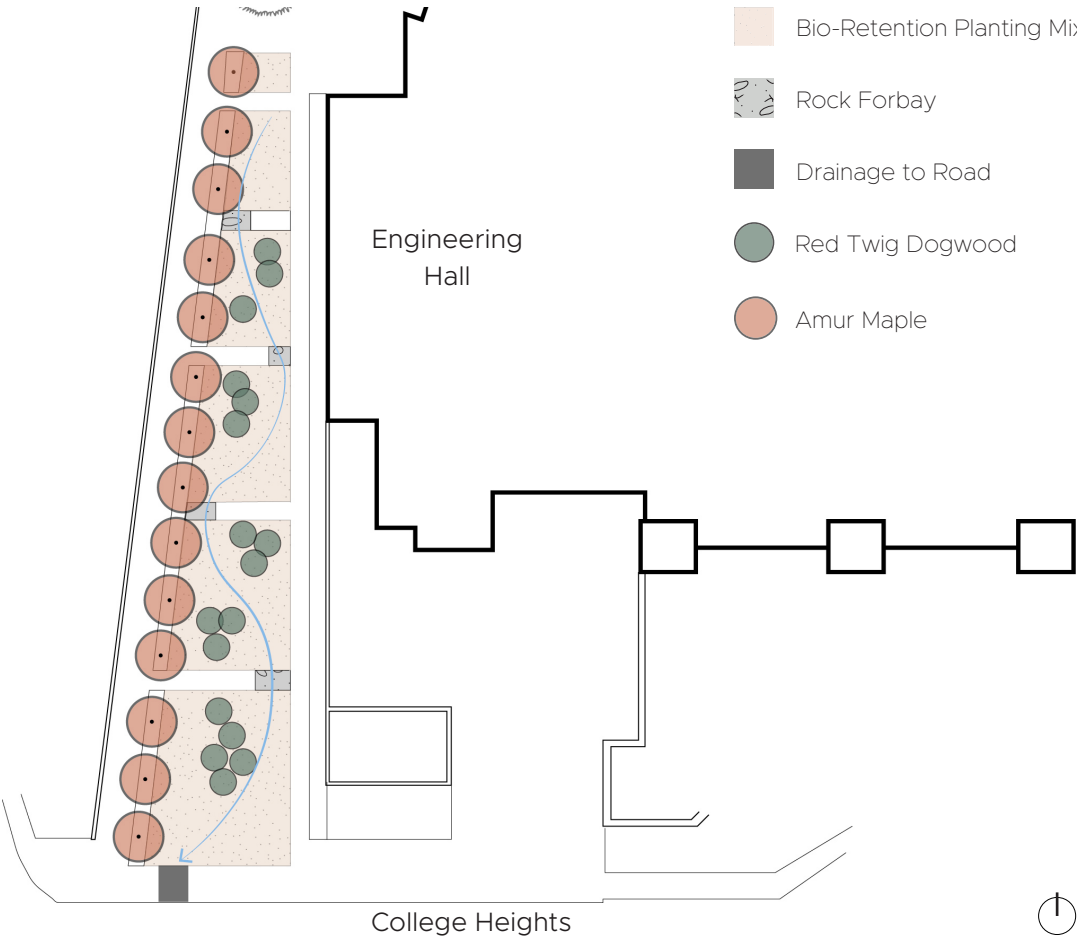


Fig 3.11 Engineering Bio-Retention Diagram (Freelove 2025).

Design and Biodiversity

The design of this bio-retention system was fairly simple. Only three species of plants were used throughout. The species include Red Twig Dogwood, Blue Flag Iris, and Common Rush. These are the only species that were planted within each of the cells. Through each cell, water is collected from the surrounding building, impervious surfaces, and permeable pavement. The water is supposed to be slowed and infiltrated by the vegetation into the sandy-engineered soil as stormwater makes its way toward the road and the southwest corner of the bio-retention cells. The system has started to decline due to its overly simplistic design, low biodiversity, and inadequate soil moisture levels during dry spells. Currently, there is a considerable loss of plant life, large bare spots, and many indicators of erosion. Very tall sunflowers, a few little bluestem, wild sweet clover, prickly lettuce, and various other ruderal or pioneering species have started to grow.



Fig 3.12 Engineering Bio-Retention Area (Freelove 2024).

Management

The Engineering Bio-Retention System under the landscape services draft plan is classified as service level A (Kansas State 2023). This area is part of the main campus and is regularly maintained by Grounds staff at Kansas State University. However, the system experiences issues with sand and sediment accumulation and significant water flow, leading to the erosion of the engineered soil. These problems are exacerbated by the loss of plant life due to poor planting choices. Once the irrigation was turned off, the selected plants lacked adequate moisture and many plants began to die, especially in the sunnier areas in the three southern cells. The grounds staff is working with what has survived, as no formal management plan has been developed and implemented since construction. Another challenge the grounds staff faces is leaf removal. The long, narrow walkways collect large amounts of leaf litter in the fall from the maples, making it a long process to air-blow the fallen leaves away.

Seaton Hall Rain Garden

In 2017, Kansas State's Architecture, Planning, and Design building was added. The new addition created more studio space for the expanding college. Along with more studio space was an improved library, fabrication laboratory, auditorium, offices, and open design areas (Confluence). The new addition is also a LEED Silver Certified facility ("Seaton Hall"). This is due in part to the exterior relationship. Seaton/Regnier Hall has multiple green roof systems, multiple rain gardens, bioswales, cisterns, and native plantings. This helps the building achieve a 50% reduction in irrigation and a 38.3% reduction in potable water use ("Seaton Hall"). The rain garden to the south of Regnier Hall (and east of Seaton Hall's West Wing) is the largest and has the most abundant plant life. On the north side of the building is the longest bioswale, which captures water from the sidewalk and surrounding context.



Fig 3.13 Pollinators enjoy plantings within the rain garden south of Regnier Hall (Skabelund 2018).

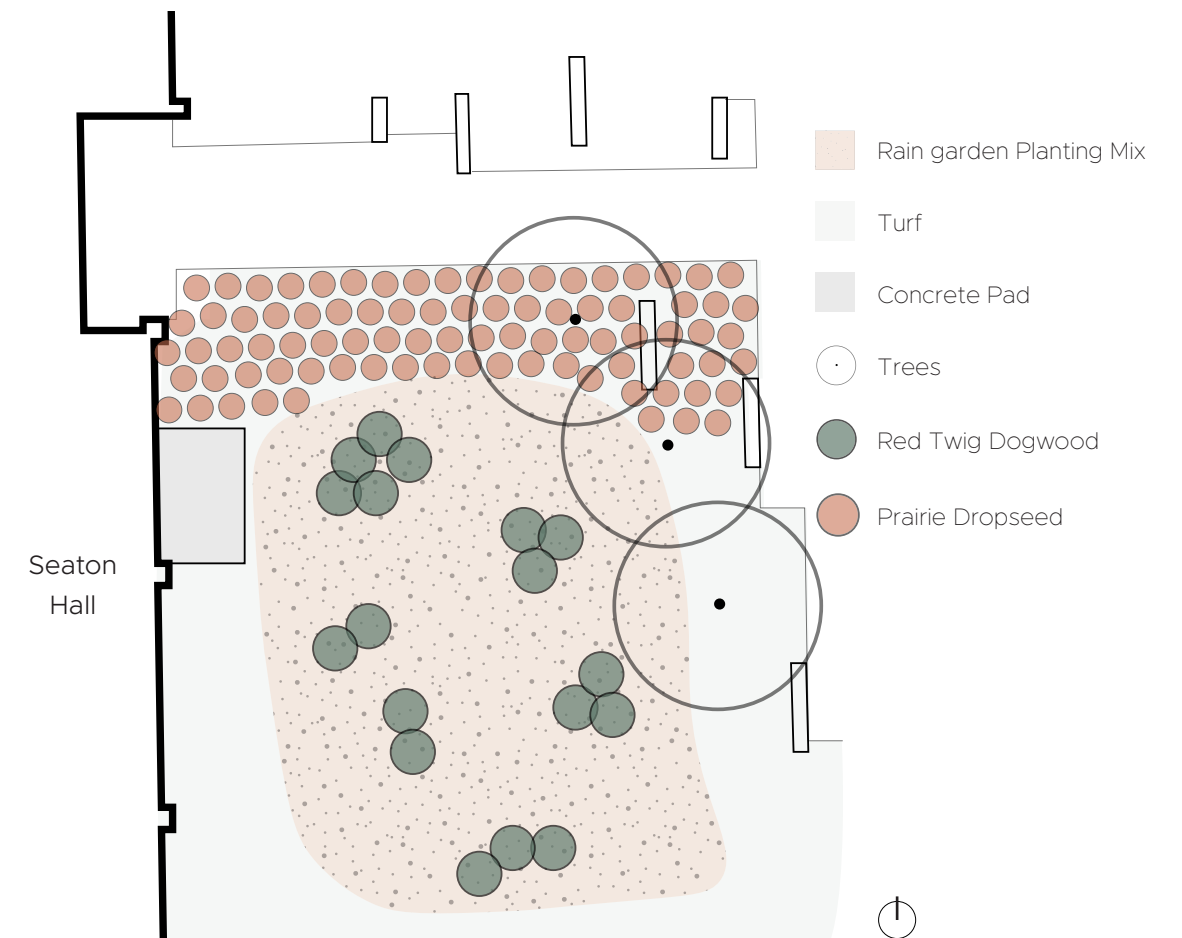


Fig 3.14 Seaton Hall Rain Garden diagram (Freelove 2025).

Design and Biodiversity

The studied rain garden that is situated on the east side of Seaton Hall is approximately 3,700 sf. With its relatively small size, the rain garden is filled with many native plant species that help with stormwater retention and infiltration. Notable species include Prairie Dropseed, Little Bluestem, Joe Pye Weed, Swamp Milkweed, Rattlesnake Master, Blue Sedge, and Soft Rush. All these species are somewhat evenly spaced within the area with other species of grasses and sedges. Red Twig Dogwood is sporadically placed along with those species, and three Thornless Honey Locusts fill out the system. The rain garden has a concrete pad directly to the west of the main infiltration area that feeds water directly to the rain garden. Under the ground, the system has a sandy-silt mixed, engineered soil to help water move through this system faster. Along with the engineered soil, a large stormwater cisterns lie within a bed of gravel underneath the rain garden.



Fig 3.15 Seaton Hall rain garden (Skabelund 2023).

Management

The Seaton Hall Rain Garden is designated as service level A in the landscape services plan, which prioritizes efforts in this area (Kansas State 2023). The system is mowed in early spring to support plant life, hinder weed growth, and promote the intended plants. Leaf litter is removed through raking, and hand-weeding is employed to eliminate weeds instead of utilizing chemical applications. This approach protects the desired species from exposure to pesticides that could harm them (Kansas State 2023). In addition to these standard planting services, trash and debris are cleared regularly to maintain a tidy appearance. Volunteer support with weeding has been frequently provided by landscape architecture faculty member, Lee Skabelund. One spring, K-State Grounds staff used a large machine to cut vegetation and damaged many of the dogwood stems in the rain garden. Since that time (due to stress caused by this damage and also by dry spells) the dogwood have been in decline.

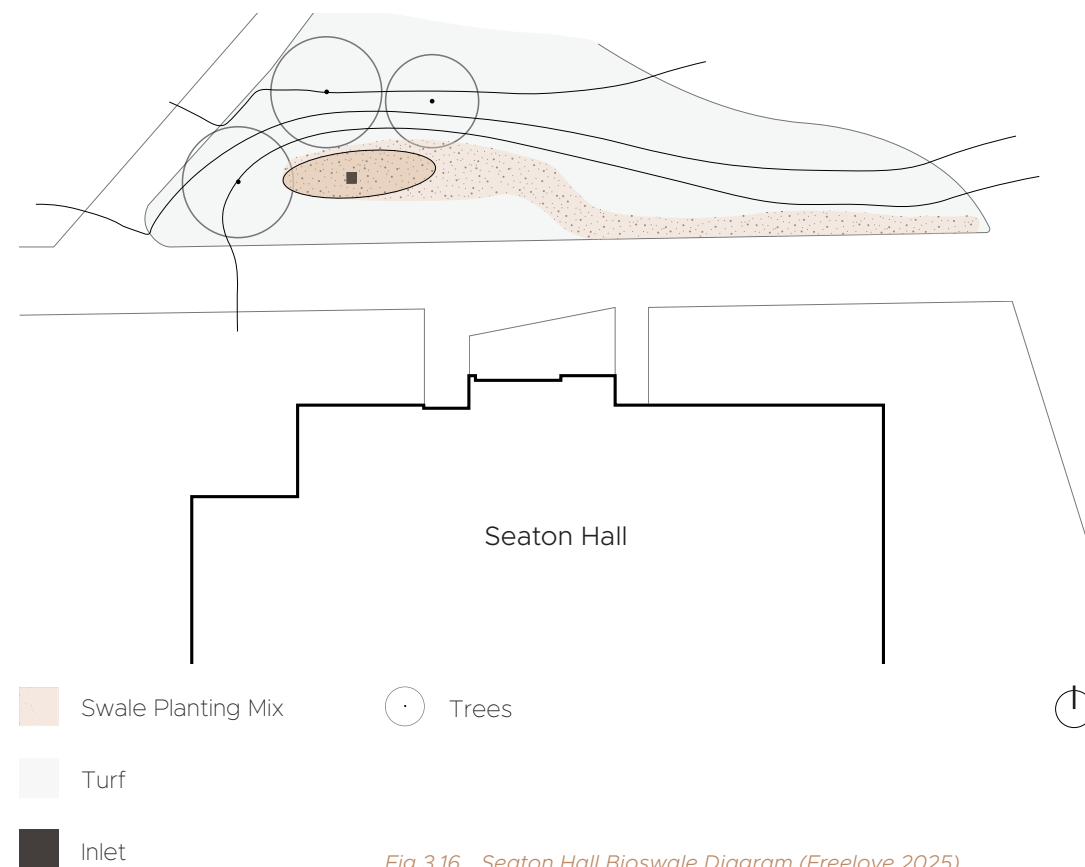


Fig 3.16 Seaton Hall Bioswale Diagram (Freelove 2025).

Seaton Hall Bioswale Design and Biodiversity

North of Seaton Hall lies a bioswale designed to catch and retain water from the northern area. The bioswale spans approximately 1,150 square feet of planted space that holds water. The plant species in this bioswale are similar to those in the rain garden to maintain a consistent aesthetic appeal. This area also features engineered sandy-silt soil underneath. Although there is no cistern below, water is directed to a low point and inlet in the bioswale during heavy rain events. At that point, the water begins to percolate down into the soil.



Fig 3.17 Seaton Hall Bioswale (Goold 2024).

Management

The landscape services plan categorizes the Seaton Hall bioswale as service level A (Kansas State 2023). Therefore, this area receives careful attention to maintain a tidy appearance. Weeds are hand-removed to minimize chemical use, and the edges are trimmed to ensure a well-maintained look (Kansas State 2023). Volunteer support with weeding has been frequently provided by landscape architecture faculty member, Lee Skabelund. The system also undergoes raking and annual cuttings to eliminate leaf litter and encourage the growth of desired species. Trash and debris are removed timely by grounds to keep a good appearance.

Analysis

The Rapid Ecological Assessment Rubric (Moore et al. 2012) was used for each project to evaluate soil and plant health. This rubric examines the relationships between plants and soil; for plant health, factors considered include density, diversity, composition, and vigor. Soil health and structure are assessed through indicators such as organic matter color, roots and residue, subsurface compaction, soil tilth, and erosion signs. Next, faunal health is evaluated, which looks for earthworms, soil macrofauna, and other species, including undesirable ones (Moore et al. 2012). In addition to this rubric, I also discuss other management criteria. This involves understanding how current management practices are applied to each project and whether they support vegetation and soil health. This evaluation also considers the time required, personnel, litter, damage, and unresolved issues.

Management

	Time and Trained Personnel	Damage or Unattended Issues, Litter	Management Guide or Plan
4 Excellent	Enough time is spent on taking care of the project, and checked on multiple times a month. Enough trained personnel take care of the project, 2 at the minimum	No damage to plant life, soil, and infrastructure. No unattended issues. No litter present.	Is a detailed management guide, plan or schedule. Issues have a plan for fixes.
3 Good	Project is taken care of 1 time every month. At least 1 trained employee is present	Minimal damage to plant life, soil, and infrastructure. Minimal unattended issues. Minimal litter present.	Somewhat detailed management guide, plan or schedule. Issues have a plan for fixes, and some have been addressed.
2 Fair	Project is taken care of 1 time every 2-3 months. Maybe 1 trained employee is present	Some damage to plant life, soil, and infrastructure. Some unattended issues. Some litter present.	Somewhat of management guide, plan or schedule. Issues have a plan for fixes, and no have been addressed.
1 Poor	Project is taken care of 1 time every 4-6 months. No trained employee is present	Large amount of unattended issues and damage to all aspects of the project. Large amount of litter present.	No management guide, plan or schedule. Issues have persisted for extended time with no plan for fixes.

Fig 3.18 Campus GI management criteria (Freelove 2025).

Plant Health				Faunal Health			
	Density	Diversity and Composition	Vigor		Earthworms	Soil Macrofauna	Undesired Species
4 Excellent	Plants closely spaced with even distribution pattern. Less than 20% soil surface exposed.	Diverse plant community with no invasive species.	Plants are vigorous with balanced mix of young and mature growth.	4 Excellent	10 or more earthworms in excavated area with many casts and holes	Several other species of soil macrofauna (i.e., beetle and cicadae larvae, millipedes, etc.) present	No mosquitoes or mosquito larvae present
3 Good	Plants closely spaced with somewhat even distribution pattern. 20-40% soil surface exposed.	Diverse plant community with a few less desirable species.	Plants are vigorous with no deformed growth patterns	3 Good	5–9 earthworms in excavated area with some casts and holes	A few other species of soil macrofauna present	No mosquito larvae, though a few mosquitoes
2 Fair	Patchy plant spacing and distribution pattern. 40-60% soil surface exposed.	Reduced diversity with some less desirable and invasive species.	Plants pale green or yellowing, deformed growth patterns or are developing close to the ground.	2 Fair	1–4 earthworms in excavated area with few casts and holes	1 other species of soil macrofauna present	Mosquito larvae present in standing water
1 Poor	Fragmented/clumped plant spacing and distribution pattern. Over 60% soil surface exposed	Restricted diversity with many undesirable or invasive species.	Plants appear stressed, are developing close to the ground. Most are dead or dying	1 Poor	Neither earthworms or their casts and holes in excavated area	No other species of soil macrofauna present	Both mosquitoes and mosquito larvae prevalent

Fig 3.19 Plant and Faunal Health criteria (Freelove 2025, adapted from Moore et al. 2012).

Soil Health				Soil Erosion Indicators			
	OM Color	Roots/Residue	Subsurface Compaction		Soil Tilth	Sheet/Rills and Gullies	Deposition and Pedestaling
4 Excellent	Topsoil clearly defined, darker than subsoil	Roots penetrate over 15 cm deep; surface residue	Wire flag easily inserted 20 cm or more	4 Excellent	Soil crumbles well and is easy to slice through	Soil removal by wind or water is not evident. No bare soil deposits. Plants have colonized soil deposits.	Recent gully formation is not evident. If gullies are present, they are small and vegetated. Plant pedestaling is not evident.
3 Good	Topsoil somewhat darker than subsoil	Roots 10 cm to 15 cm deep; surface residue abundant	Wire flag inserted 20 cm deep or more, but with some effort	3 Good	Soil crumbles fairly well but some clods persist	Small rills developing. Transported soil remains on site. A few bare soil deposits. Plants are stabilizing recent deposits.	Very little recent gully formation. If some gullies present, they are small and vegetated. Very little plant pedestaling.
2 Fair	Topsoil only slightly darker than subsoil	Roots 5 cm to 10 cm deep; some surface residue	Considerable effort required to insert flag up to 20 cm	2 Fair	Soil is cloddy	Sheet and/or rill erosion occurring in small areas. Most soil remains on site. Several small soil deposits due to deposition. Plants have not stabilized.	Some recent gully formation but still small and unbranched. Plant pedestaling is evident but not so severe that roots are exposed.
1 Poor	No difference between color of topsoil and subsoil	Roots less than 5 cm deep; no or little surface residue	Wire cannot be inserted to 20 cm depth without bending or breaking	1 Poor	Soil very cloddy; clods hard like brick	Sheet and rill erosion occurring in large areas. Much of the soil transported off site. Deposited soil inhibiting plant growth or present as large, bare deposits.	Well-developed, active gullies present. Plant pedestaling has exposed plant roots.

Fig 3.20 Soil health and Erosion Indicators criteria (Freelove 2025, adapted from Moore et al. 2012).

Memorial Stadium Analysis

The green roofs of Memorial Stadium demonstrate good plant health and spacing. The plants encompass a wide variety of species, with very few areas of exposed soil. These bare soil sections are primarily located near the top and bottom of the green roof, where some structural components supporting the soil can be seen. The soil remains in good condition, and the layers are largely well-defined. The soil shows no signs of compaction, which aids in water infiltration and movement through the system. A few areas of deposition and eroded soil were observed along the edges of the green roof where open soil is present. Although not many species were found in the soil, a diverse array of species was noted throughout the system. Different species of pollinators were present among the vegetation, with no mosquitoes detected. The Memorial Stadium green roofs received scores of 3.8/4 in plant health, 3.1/4 in faunal health, 3.5/4 in soil health, and 3.25/4 regarding soil erosion indicators.

Minor damage was observed on the green roof itself. The exposed netting and soil structure showed minimal damage, with some eroded soil around them. The above-ground meters and drains were all in good condition with no visible damage. However, trash and litter were scattered throughout both green roofs. With many people using the athletic fields and sitting in the stands, trash can easily be thrown into the system. The green roof exhibited no signs of excessive leaf litter, which minimizes the chance of leaves clogging the drainage system. The Memorial Stadium green roofs are classified under landscape service level A (Kansas State University 2023), meaning they receive regular management (sometimes by volunteers). This area follows a schedule, and employees track their completed tasks. Overall, the Memorial Stadium green roofs received a score of: 3.5/4 for time and personnel, 2.5/4 for damage or unattended issues, and a 3/4 for having a sufficient management plan and schedule.

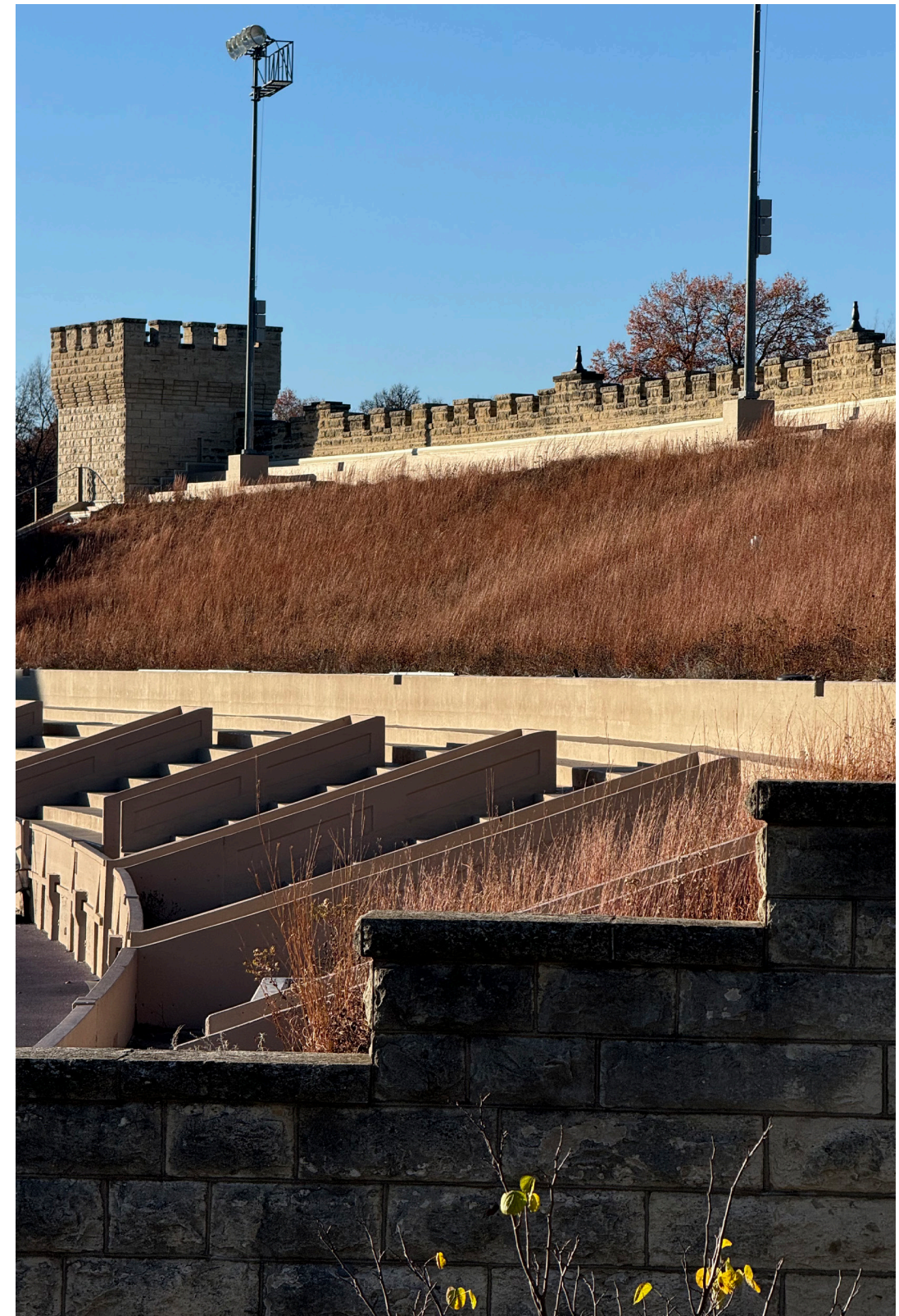


Fig 3.21 West Memorial Stadium Green Roof in the fall (Freelove 2024).



Fig 3.22 East Memorial Stadium Green Roof in the spring (Freelove 2025).

Lee Skabelund weeded out foxtail, fescue, bluegrass, prickly lettuce, ragweed, marestail, wild sweet clover, and sought to keep other weedy species in check between 2016-2024, sometimes working with other volunteers. Hundreds of thousands of weeds have been removed from the two large green roofs by Lee and other volunteers, while woody plants (including bush honeysuckle, elms, hackberry, Prunus, and other species) have been pulled or clipped by Lee, volunteers, and K-State Grounds staff. Professor Skabelund, two botanists, graduate students, and other researchers have worked to identify plants growing on the green roofs and document changes since implementation K-State Grounds staff have sometimes used herbicide to try to kill woody plants on the Memorial Stadium green roofs.

Leaks on the two green roofs and challenges in maintaining consistent irrigation coverage due to irrigation line breaks and rotor head malfunctions have created dry spots in a number of locations, but most especially in large parts of the East Memorial Stadium Green Roof. In these areas, foxtail, spurge, prickly lettuce, and other pioneering species are quite abundant and desirable native species scarce (Lee Skabelund, pers. comm., March 2025).

Carl Ice Engineering Hall Bio-Retention Analysis

The Engineering Bio-Retention System is presently facing several issues. Most of the plants within the cells have deteriorated. The system's lack of biodiversity and persistent moisture has led to the demise of many plants. Initially, this project received irrigation during its first few years to aid its establishment. However, once irrigation ceased, the plants began to decline due to their moisture needs. Over 60% of the soil surface is exposed across all cells combined. With the loss of plant species, numerous problems are emerging within the soil itself. Much of the soil is being displaced by water, resulting in many gullies and some stone materials being relocated by water. In addition to erosion concerns, the remaining plant life shows visible roots and limited residue in certain areas. The lowest cell is currently facing the most subsoil issues, with little distinction between the topsoil and subsoil. The second lowest cell displays the best soil structure and the healthiest-looking plant life. The soil crumbles quite well in all cells except for the lowest. The cells show decent faunal health, but no signs of the undesired species exist. In this project's plant and soil assessments, the bioretention was rated: 1.3/4 in plant health, 2.1/4 in soil erosion indicators, 2.3/4 in soil health and structure, and 3/4 in faunal health.

To maintain the system, significant damage has occurred to the soil, plant life, and infrastructure. Some control valves are missing or have damaged lids. Pipes have caused erosion spots in the system. High water levels damage some metal trim holding the stones in place. In addition to the infrastructure issues, planting shows evidence of weeds, and no replacement plants have been added to specific cells. K-State grounds regularly manage this project and adheres to service level A standards (Kansas State University 2023). However, there are traces of litter, and the damage has not yet been repaired. Large amounts of leaf litter have accumulated in the system, clogging the drain at the southernmost point of the cells. This can lead to backups within the system, causing further erosion issues. The engineering bio-retention received scores of 3.5/4 in time and personnel, 1.5/4 in damage and issues, and 2/4 in terms of a sufficient management plan.



Fig 3.23 Eroded rock transitions between Engineering Bio-Retention Cells (Freelove 2024).

Kansas State Meadow Analysis

The Kansas State Meadow currently appears to be performing well. All the plantings are in good condition, and the spacing between them leaves little bare soil. However, some undesirable species are present, specifically ragweed and foxtail. Ragweed poses challenges for those with seasonal allergies, while foxtail can dominate the ecosystem, out-competing other species. In terms of soil conditions, there are few to no evident signs of soil erosion. The close planting and variety of species help hold the soil together and facilitate stormwater infiltration from the surrounding area. Overall, the health and structure of the soil are good. The soil layers are mostly distinct, and most roots from the plantings reach a suitable depth. However, certain areas in the meadow experience slightly compacted soil, particularly in the lower sections where more water accumulates. The soil crumbles fairly well, although some clods are present. Overall, faunal health is quite good. There are no mosquitoes, and several organisms inhabit the system. The soil has few earthworms, and a few millipedes were observed. In the plant and soil assessments, the meadow received scores of: 3.75/4 for plant health, 4/4 for the absence of soil erosion, 3.3/4 for soil health and structure, and 3/4 for faunal health.

The management of the Kansas State Meadow is quite intriguing compared to other projects. Volunteers from across the campus and student workers assist in maintaining the meadow. University grounds staff did not have the time to provide regular help with the system. However, the meadow benefited from a comprehensive early management and installation guide. The work plan details tasks to be completed from pre-installation through the management of the system three years into the future. With this guide, the project had a strong starting direction for installation and management, which can result in less maintenance over time. A task list also indicates how much time the student workers should spend on each task per week. The student workers undergo training in which they learn to identify invasive plant species and understand when to remove them. Within the system itself, no trash was found; however, there was a considerable amount of leaf litter. The meadow exhibits strong management qualities that keep it functioning effectively. The project received a 4/4 in time and personnel, 3.75/4 in damage and litter, and 4/4 in management guide and plan.



Fig 3.24 The K-State Meadow provides a strong sense of place while providing ecosystem services that benefit people and the environment (Skabelund 2022).

Seaton Hall Rain Garden Analysis

The Seaton Hall Rain Garden appears to be functioning well. Most of the ground is covered by planting, with little bare soil at the low point. The edges around the Prairie Dropseed do not fully cover the soil, allowing water to flow quickly off the sidewalk into the system. The plants are healthy, and there is significant diversity within the system. The rain garden shows no signs of erosion, and the soil crumbles easily. The subsurface of the rain garden exhibits good color and is mostly well-defined, with deep-rooted plants. The soil is not compacted, allowing for effective infiltration. No traces of undesirable species or mosquitoes were found. However, there was a lack of macrofauna in the soil, with few earthworms or other species present. In the assessments of plants and soil, the Seaton Hall Rain Garden received scores of: 3.8/4 for plant health, 3/4 for faunal health, 3.6/4 for soil health, and 3.8/4 for the absence of soil erosion indicators.

The Seaton Hall Rain Garden shows no visible damage within the system. All control valve areas are in good condition, and nothing above ground appears to be damaged. Since none of the plants seem harmed, there is no need to replace any species. In addition to not needing replacement plants, there were few traces of weeds and unwanted species in the system. The rain garden also shows no signs of trash or litter. Some leaf litter was present but not excessive enough to cause blockages. Kansas State Grounds classifies this site as service level A, and it receives regular maintenance (Kansas State University 2023). Volunteer weeding from LARCP staff, Lee Skabelund, weeding prickly lettuce, ragweed, marestail, wild sweet clover, and removing Canada goldenrod due to its weedy nature. Kansas State Grounds has met several times with professor Skabelund to talk about weedy plant concerns. The Seaton Hall Rain Garden received scores of: 3.5/4 in time and personnel, 4/4 in trash and unattended issues, and 3/4 in a sufficient management guide.



Fig 3.25 Good soil coverage and diverse species allow the rain garden to thrive (Skabelund 2018).

Seaton Hall Bioswale Analysis

The Seaton Hall Bioswale features excellent plant coverage, with very few bare soil spots at its low and high points. However, some open areas are visible on the southern edges and center of the swale, revealing the plastic webbing used to stabilize the soil. The diversity of plant species is good for the limited space, with few undesirable species present. Ragweed was discovered in a small area, which may pose allergenic issues for some individuals. Desirable native plants appear healthy, and the soil is relatively in good condition. The only signs of erosion are near the center of the swale, where there is a steep slope, and along the southern edge, where water enters. The soil structure remains sound, with somewhat darker subsoil, and the plants demonstrate good root depth along with some surface residue. Some areas of the soil around the bioswale were compacted. Earthworms and a few other species were identified within the system. Wasps, bees, and a butterfly were observed, although there wasn't much insect activity within the soil. Overall, the Seaton Hall Bioswale received scores of: 3/4 for plant health, 2.8/4 for faunal health, 2.75/4 for soil erosion indicators, and 3/4 for soil health.

The bioswale located north of Seaton Hall currently needs some maintenance. The central area lacks vegetation and requires replacement plants to cover the bare soil, which will help prevent unwanted species and control erosion. LARCP staff Lee Skabelund has assisted with the removal of prickly lettuce, ragweed, maretail, bindweed, and wild sweet clover, and also attempted to keep crown vetch in check the past few years since these species are considered weedy. Kansas State Grounds staff have spot sprayed a herbicide on the crown vetch in this area, but it is still present. The various types of plastic webbing used to keep mulch in place make weeding difficult. There was minimal plant litter causing blockages, and the infrastructure components showed no physical damage. Kansas State Grounds classifies this site as service level A, ensuring it receives regular maintenance and trash removal (Kansas State University 2023). The bioswale has received scores of 3/4 for time and personnel, 2.75/4 for damage and unattended issues, and 3/4 for a sufficient management plan.



Fig 3.26 The Seaton Hall Bioswale is an example of GI that can take less time to manage than mowing due to its biodiversity and plant spacing (Goold 2024).

Comparative Analysis Findings

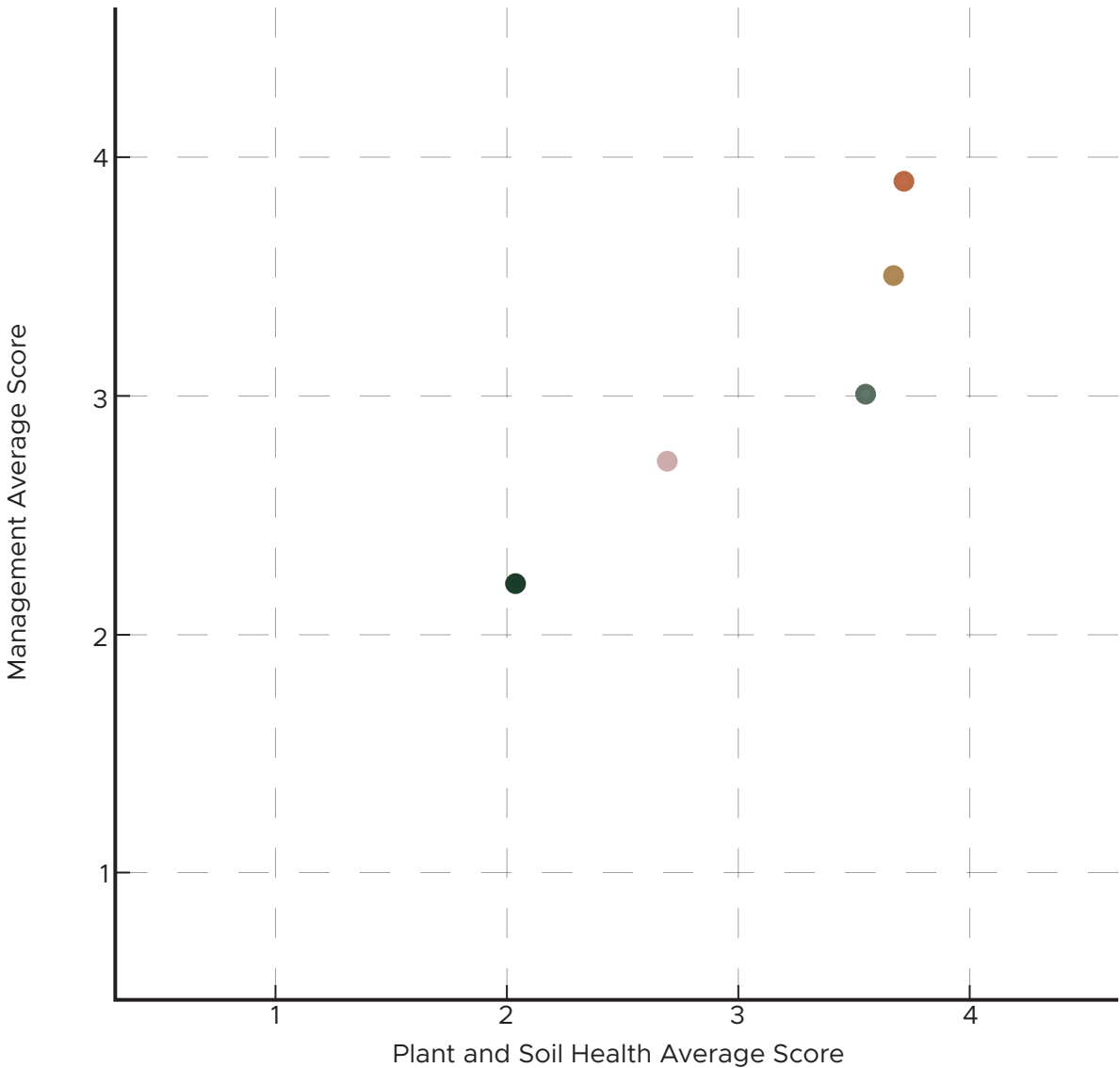
Kansas State University has a diverse array of green infrastructure projects throughout the campus, each requiring distinct maintenance strategies. The five projects studied displayed various conditions due to their design, implementation, and management.

Overall, the green infrastructure systems on campus are in good condition, except for the bio-retention area in front of Engineering Hall. This issue arises from several factors. The design did not incorporate a sufficient variety of plant species and proper species selections related to engineered and existing soils.. Without the right species, the plants did not receive enough water to survive once the irrigation was turned off. Consequently, the plantings declined, resulting in large bare spots and subsequent soil degradation, which created a difficult-to-manage system.

The other systems show good species diversity and ground coverage. With a varied and resilient selection of plants, a system has a strong foundation for success. Effective ground coverage prevents weedy or invasive species from quickly rooting in bare soil, allowing the intended species to thrive. A diverse planting leads to a varied root system, which facilitates effective stormwater management and supports a robust soil community. Soil macrofauna finds a suitable habitat, promoting a strong system that benefits plants and soil. The systems that performed well in plant and faunal health assessments were healthy and managed effectively.

The Kansas State Meadow was the only project equipped with an installation and a three-year post-installation management guide. This provision enabled careful system monitoring, resulting in an ecologically diverse space that requires less maintenance over time. Kansas State Grounds prioritizes the other systems. They receive more than regular attention and are a central focus of landscape bed maintenance. Being on the high-priority service list ensures these projects are well maintained. However, having a comprehensive management guide would be beneficial in helping them ensure tasks are completed and the proper frequency is maintained. This would allow the Grounds team to manage these systems effectively while providing adequate time for other areas of the campus landscape, contributing to a sustainable campus that students and faculty can both learn from and enjoy.

Results



- K-State Meadow**
Plant/Soil Avg : 3.7
Management Avg : 3.9
- Seaton Hall Bioswale**
Plant/Soil Avg : 2.8
Management Avg : 2.9
- Seaton Hall Rain garden**
Plant/Soil Avg : 3.5
Management Avg : 3.5
- Engineering Bio-Retention**
Plant/Soil Avg : 2.1
Management Avg : 2.3
- Memorial Stadium Green Roofs**
Plant/Soil Avg : 3.4
Management Avg : 3.0

Fig 3.27 Test results average graph (Freelove 2025).

CHAPTER 4

Interviews



Fig 4.1 Engineering Bio-Retention Area after a storm (Freelove 2024).

Interviews

In-depth, semi-structured interviews provided an opportunity to learn more about the maintenance and management of green infrastructure at Kansas State University. The aim was to gain insights from professionals responsible for these systems at the Kansas State. This deepened the author's understanding of the operations within a maintenance team by offering information on time spent, management practices, and the current challenges faced in overseeing green infrastructure management goals and maintenance practices within the campus landscape. Participants were identified by contacting Kansas State faculty and staff managing GI projects across the campus.

Interview Findings

Two interviews were conducted with faculty and staff (2025) at Kansas State University to better understand the management of the campus and the K-State meadow. Each interviewee either worked in the maintenance and management division at Kansas State, or maintained another GI project on campus. Both interviews added diversity and depth to the findings. Each interview provided detailed management and maintenance information for GI projects around Kansas State University. Interviewees remain anonymous for privacy

The K-State Meadow is primarily managed by volunteers and some student workers. With this ongoing work, the system has adequate management, a detailed schedule of tasks, and a clear outline of the hours to be worked each week. Most of the maintenance for the plant life is carried out by hand, with occasional mowing occurring within the system. The Meadow remains completely chemical-free, which is not so for all of Kansas State. This space is an excellent example of a chemical-free landscape and demonstrates its effectiveness on a college campus. In addition to its care, the meadow functions as a living laboratory. Many students and faculty utilize this space to study issues. Green infrastructure on a college campus provides these opportunities, creating spaces for students to learn and research, which can lead to a deeper understanding of these systems' performance and importance.

Kansas State University has a relatively small landscape services crew to maintain the campus landscape. A total of 20 employees manage approximately 239 acres of campus land (Kansas State University 2023). The campus is divided into three different service levels: service level A, service level B, and service level C. These levels indicate the order of importance within university management, with level A deemed most important. Service level A is the main core of the campus, service level B is centered around the Peter's Recreation Center, and service level C encompasses areas that are further from the campus core. Using these service levels helps guide maintenance crews on priorities and tasks to complete. Along with these service levels, the crews can efficiently track time spent on tasks and equipment usage. Through computer software, they log time, which

allows for effective task tracking and identifies areas that might need more attention (K-State Staff 2025).

Despite this efficient system, some challenges remain. Time and manpower represent the first issue. With only 20 full-time employees, managing such a large area is demanding. This situation arises from budgetary restrictions, contributing to low staff numbers and older equipment. However, these challenges motivate grounds staff to explore alternative options for landscape care and maintain focus on the campus's critical areas (K-State Staff 2025).



Fig 4.2 Student volunteers helping plant a rain garden (Center for Neighborhood Technology 2008).

CHAPTER 5

Projective Design

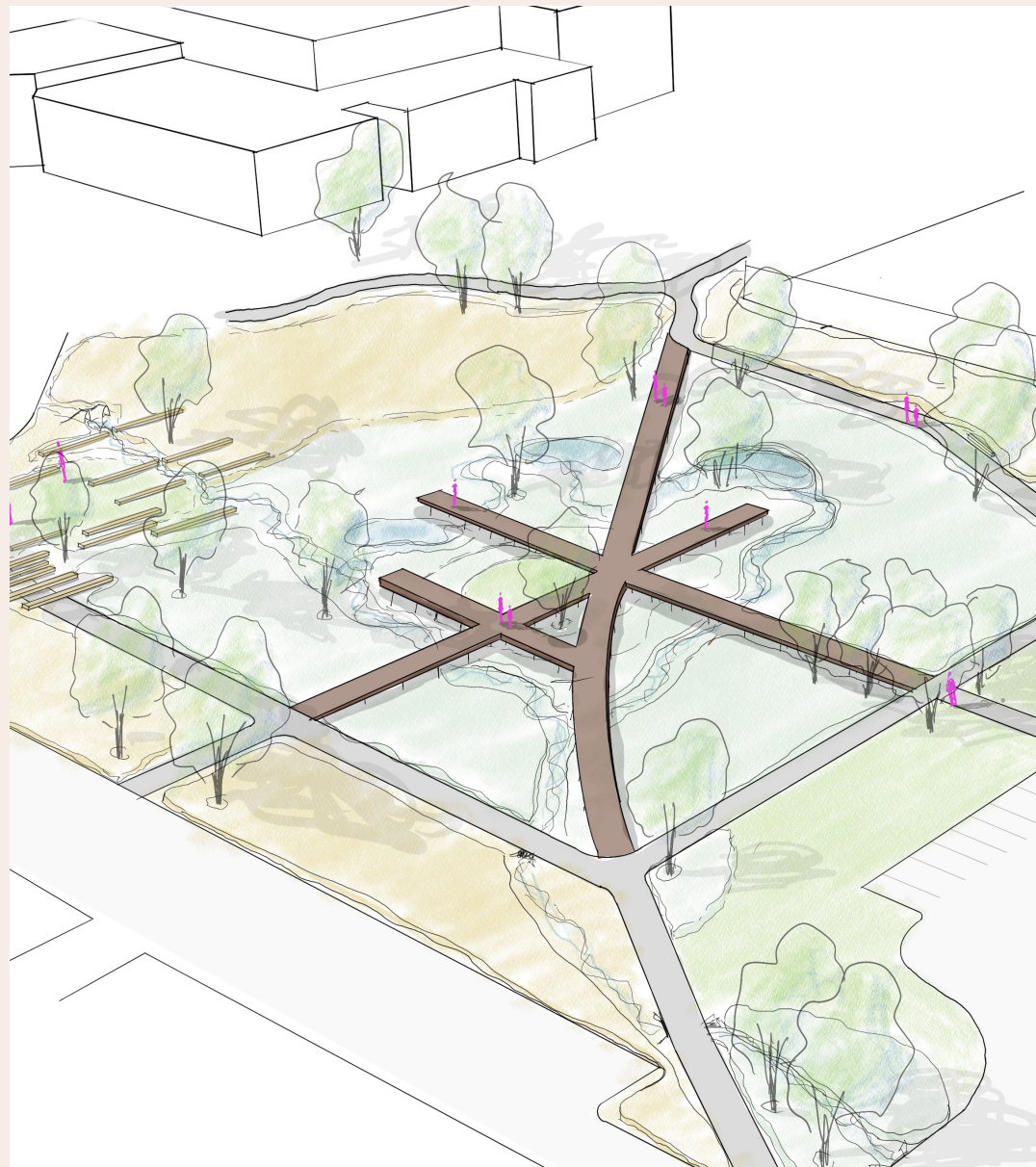


Fig 5.1 Process design for former Edward's Hall (Freelove 2025).

Site Analysis

There is a large amount of parking at Peter's Recreation Center, surrounded by the Bill Snyder Family Stadium, and former Edwards Hall. The site currently has two swales from the parking lot, entering from the parking areas west and south of Bill Snyder Family Stadium. With large storm events, high volumes of water have eroded the bank of the grass swale, leading to more limestone rip rap being added. However, the banks continue eroding, and invasive species find a place within the rip rap. Along with that, a large turfgrass basin lies south of Peter's Recreation Center. This basin stores some stormwater during a large storm. However, it is hardly ever filled by water, even for significant rain events. This basin provides low visual and ecological quality. In the site's southeast corner, Edward's Hall was previously surrounded by parking. Now, the parking remains, and a pipe from the Recreation Center sends water onto the west part of the old Edwards Hall parking. This stormwater flows to the low point of the site and eventually sends stormwater across Denison Avenue to Campus Creek. Site analysis and imagery were done to understand the current issues with stormwater and the watershed, hardscape, softscape, soils, and existing drainage ways. With this information, a projective design was completed to provide natural stormwater solutions while providing the Recreation Center Complex with more opportunities to engage in outdoor recreation.



Fig 5.2 The swales around Peter's Recreation Center suffer from fast moving stormwater, leading to erosion and the addition of rip rap (Freelove 2024).



Fig 5.3 Around the Peters Recreation Complex is a series of paths that can be expanded (Freelove 2024.)



Fig 5.4 The Bill Snyder Family Stadium parking lot currently sheets runoff to the surrounding landscape (Freelove 2024).



Fig 5.5 The Peters Recreation Complex has the opportunity for indoor/outdoor relationships but does not fully capitalize on the opportunity (Freelove 2024).



Fig 5.6 Edwards Hall originally was home to campus police within a building. Now the site sits without a building and an opportunity to help with stormwater issues (Freelove 2024).



Fig 5.7 Edwards Hall currently has some areas where stormwater expels onto the parking lot, then flows into storm drains without any stoppage (Freelove 2024).



Fig 5.8 The Peters Recreation Complex has a drainage basin in front of the building and could start seeing more runoff with more intense storms (Freelove 2024).



Fig 5.9 Current drainage pipes are filled by off-site sediment, leaves, and debris causing clogging during large rain events (Freelove 2024).



Fig 5.10 The swales on the west side of the Peter's Recreation site see large volumes of water moving through them (Freelove 2024).

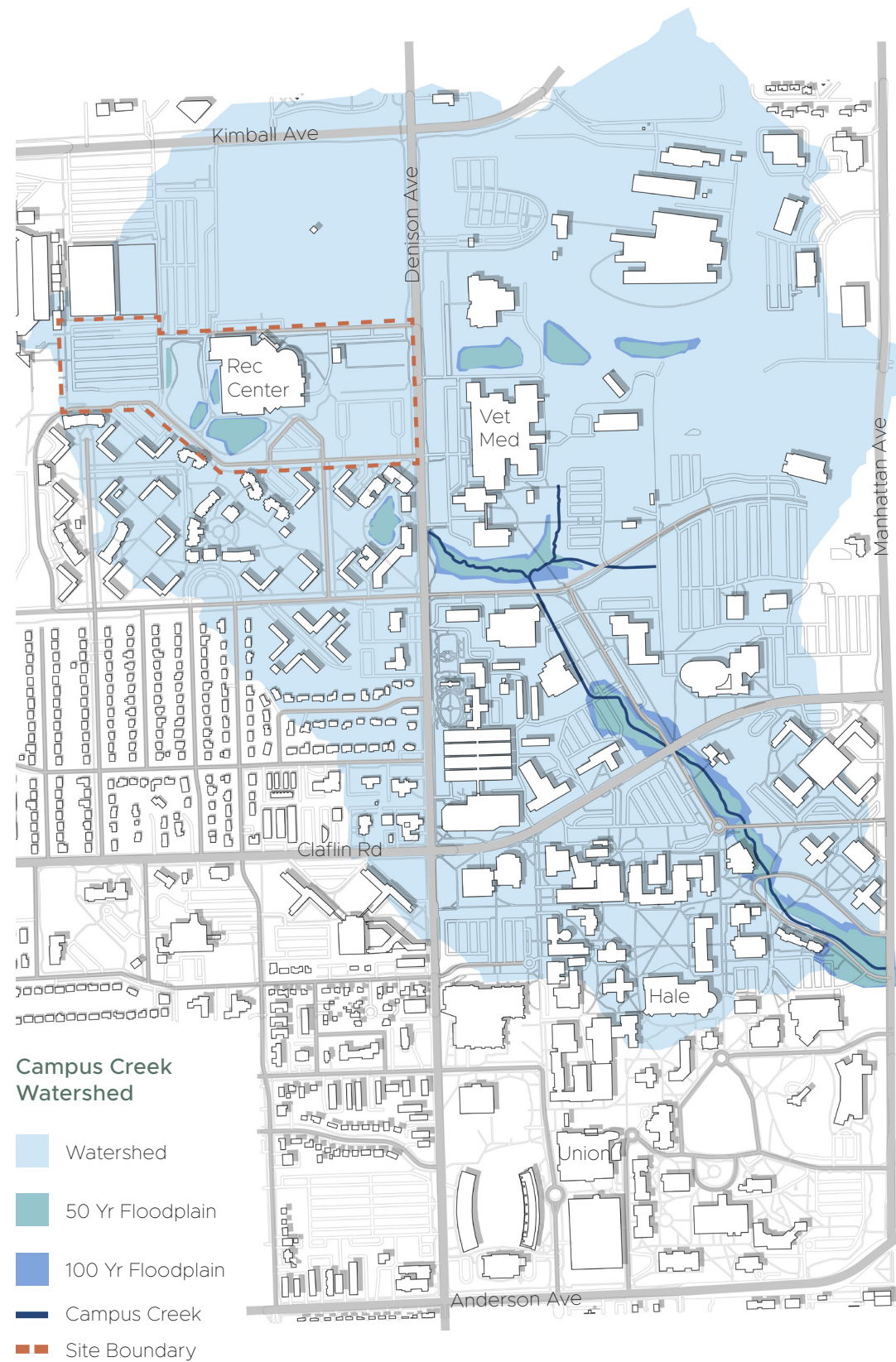


Fig 5.11 Campus Creek watershed boundary diagram (Freelove 2025).

Watershed Analysis

The site sits in the watershed that feeds into Campus Creek. This tributary of the Kansas River runs through Kansas State campus, and suffers from bank erosion due to high amounts of runoff and channelized water movement. The selected site is within the headwaters of this creek and will allow the design to help slow runoff from the stadium parking lot, artificial turf rec fields, and buildings. By slowing down the runoff, and infiltrating and holding water in a large storm event, the creek will see less flooding issues. Within the site, most of the high-volume water movement is coming from the east stadium parking lot, the Peter's Recreation Center, intramural fields, and the sport courts.

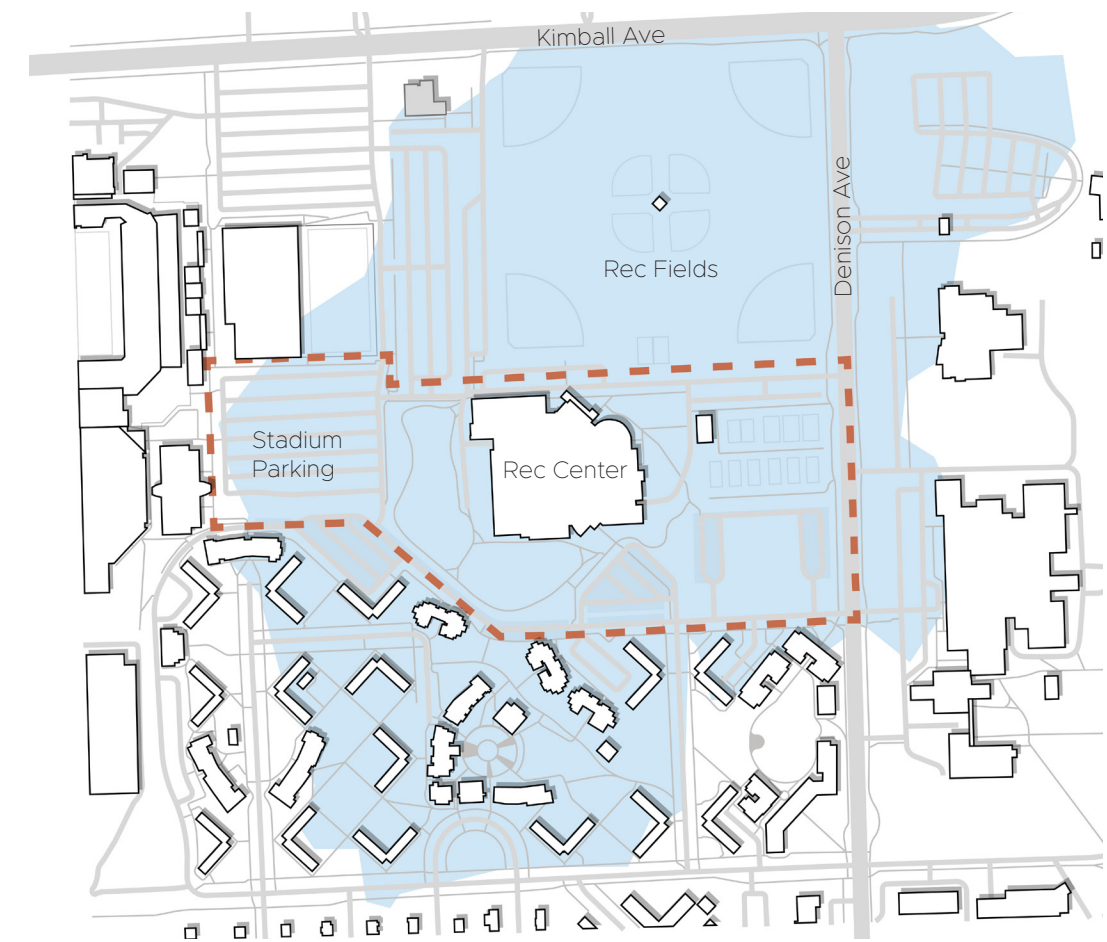


Fig 5.12 Site watershed boundary diagram (Freelove 2025).



Softscape vs. Hardscape

- Softscape
- Hardscape
- Artificial Turf
- Site Boundary
- Existing Trees
-

Fig 5.13 Hardscape and softscape diagram (Kerner 2025).

Much of the site features hardscape, with large buildings like Peter's Recreation Center, Bill Snyder Family Stadium, and the new practice facility to the northwest. Parking takes up a significant portion of the hardscape, leaving little space for natural plantings that could help slow down fast-moving runoff. Some of the existing trees are in good condition and are included in our design.



Soils

- 7682 Wymore Silty Clay Loam
- 7861 Wymore Silty Clay Loam
- 3919 Smolan Silt Loam
- Site Boundary
-

Fig 5.14 Soils diagram (Freelove 2025).

In GI systems, soil is one of the most crucial elements. Creating a healthy soil environment enables water, plants, and other organisms to contribute to natural processes. Understanding the existing soil conditions was beneficial for recognizing what was already there and how GI systems could be applied to improve stormwater retention and infiltration.

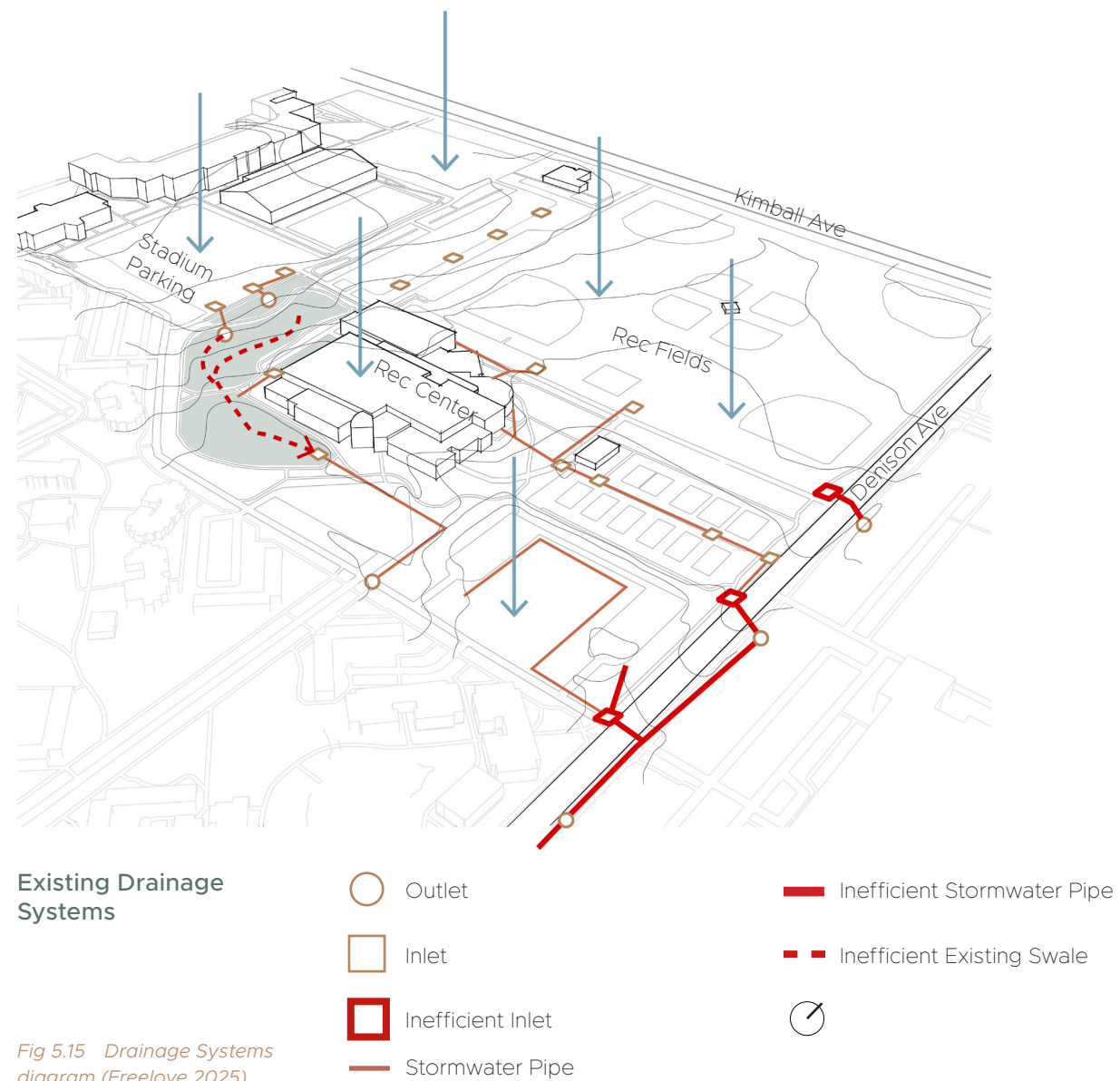


Fig 5.15 Drainage Systems diagram (Freelove 2025).

According to a 2013 report, "Stormwater System" Master Plan (BG Consultants 2013), not all stormwater pipes were functioning efficiently. The pipes located at the southeast of the site and those crossing Denison are often overwhelmed and do not operate as they should. These pipes feed directly into the upper part of the northwest branch of Campus Creek.



Fig 5.16 The swales provided great maintenance issues with many invasive species, and difficulty in maintaining the swale edges (Tilley 2024).



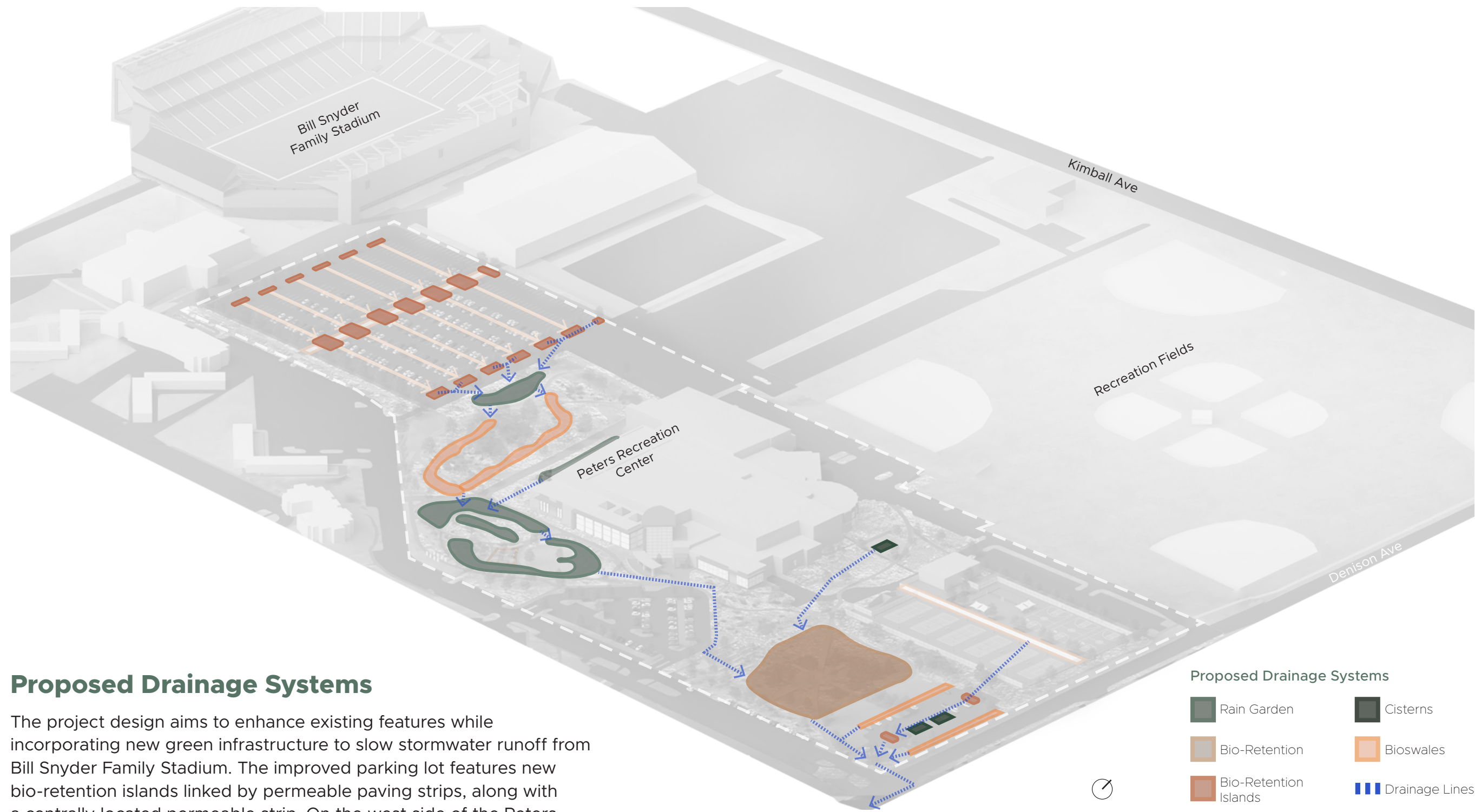
Fig 5.17 Proposed Site Aerial of Edwards Hall (Freelove 2025).

Projective Design

The project design for the Peters Recreation Center and East Bill Snyder Family Stadium parking seeks to reduce large flows of stormwater and filter pollutants from the stadium parking lot through the Peters Recreation Complex site to the former Edwards Hall, leading to Campus Creek. In the stadium parking lot, a spacious walkway was added to guide visitors to the stadium. This walkway features bio-retention cells planted on both sides. At each end of the aisles, islands were converted into bio-retention cells, and permeable paving strips were installed through the parking lot to enhance stormwater infiltration. With trees planted in some of the cells, additional shade is provided over the parking lot, lowering temperatures in certain areas for visitors during gameday tailgates.

The Peters Recreation Complex has transitioned from turfgrass to a more vegetated landscape. This change reduces the frequency of mowing required for maintenance crews. In addition to enhancing naturalization, the eroded swales were widened and made shallower to facilitate easier mowing if needed. This modification enabled the installation of check dams and step pools to slow down the runoff flow. At the south end of the Peters Recreation Center, the large turfgrass basin was converted into a natural green infrastructure system. These systems include rain gardens, natural areas, and bioswales. Within this natural green infrastructure, outdoor classrooms, a frisbee golf course, and improved running and walking trails were integrated to enhance the outdoor recreation experience at Peters Recreation Center. The east side of the complex received new pickleball courts with a cistern underneath to help reuse stormwater.

Former Edwards Hall underwent a significant transformation. Only one parking area remains, featuring bio-retention cells in the islands and a cistern below. An extensive planted bio-retention system spans throughout the center of the area. This design allows large volumes of stormwater to collect and infiltrate during intense storm events. Site users can interact with the system via boardwalks and paths throughout the area.



Proposed Drainage Systems

The project design aims to enhance existing features while incorporating new green infrastructure to slow stormwater runoff from Bill Snyder Family Stadium. The improved parking lot features new bio-retention islands linked by permeable paving strips, along with a centrally located permeable strip. On the west side of the Peters Complex, the swale system has been upgraded with step pools and check dams. New rain gardens have been added south of the complex. Lastly, Edwards Hall has been transformed into a large bio-retention area, reducing the runoff rate before it reaches Campus Creek.

Proposed Drainage Systems

- | | |
|---|--|
|  Rain Garden |  Cisterns |
|  Bio-Retention |  Bioswales |
|  Bio-Retention Islands |  Drainage Lines |

Fig 5.18 Stormwater Systems Diagram (Freelove 2025).



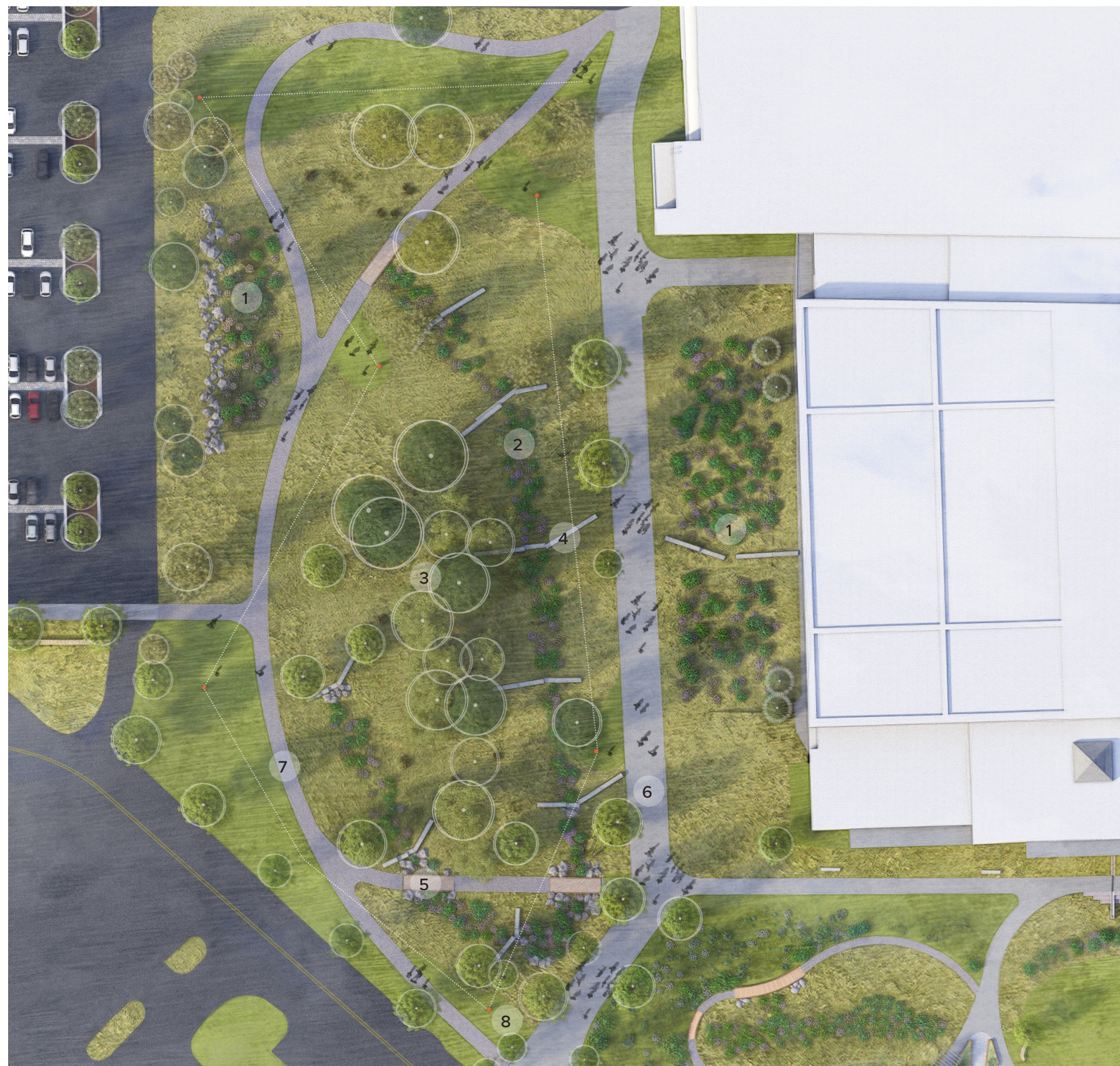
Fig 5.19 Existing conditions of swales west of the Peters Recreation Complex (Freelove 2024).

Currently, the west side of the Peters Recreation Complex has swales that are difficult to maintain. Erosion from fast-moving stormwater has degraded the banks, leading to the addition of rocks that do not stabilize the bank line. This results in further erosion and the proliferation of invasive species due to the challenges in managing the swales.



Fig 5.20 Proposed design of swales west of the Peters Recreation Complex (Freelove 2025).

The projective design aims to widen the swales and soften the banks. This is achieved by reusing limestone from the swales for gabions as weirs and adding step pools to slow water movement. This creates areas that can be mowed when necessary, and over time, less frequent mowing and maintenance would be required compared to the current turf system.



West Peters Recreation Center Site Plan

1. Rain garden
2. Bioswale and Step-Pools
3. Existing Tree Grove
4. Limestone Gabions
5. Boardwalk
6. Extended Road and Walkway
7. Improved Gravel Trail
8. Frisbee Golf Course



Fig 5.21 Proposed West Peters Recreation Complex Site Plan (Freelove 2025).



Fig 5.22 The enhanced swale allows for slower water movement, and a more aesthetic and functional landscape. (Freelove 2025).



Fig 5.23 Existing Edwards Hall site conditions (Freelove 2024).

The former site was once home to Edwards Hall. Now, an empty turf area is bordered by two impermeable parking lots. Steep slopes from the surrounding area direct fast-moving stormwater along with runoff from the Peters Rec Complex roof. This situation results in unchecked runoff that leads to Campus Creek. This area also undergoes unnecessary and frequent mowing due to the turf area located in the middle of the former Edwards Hall and its surrounding context.

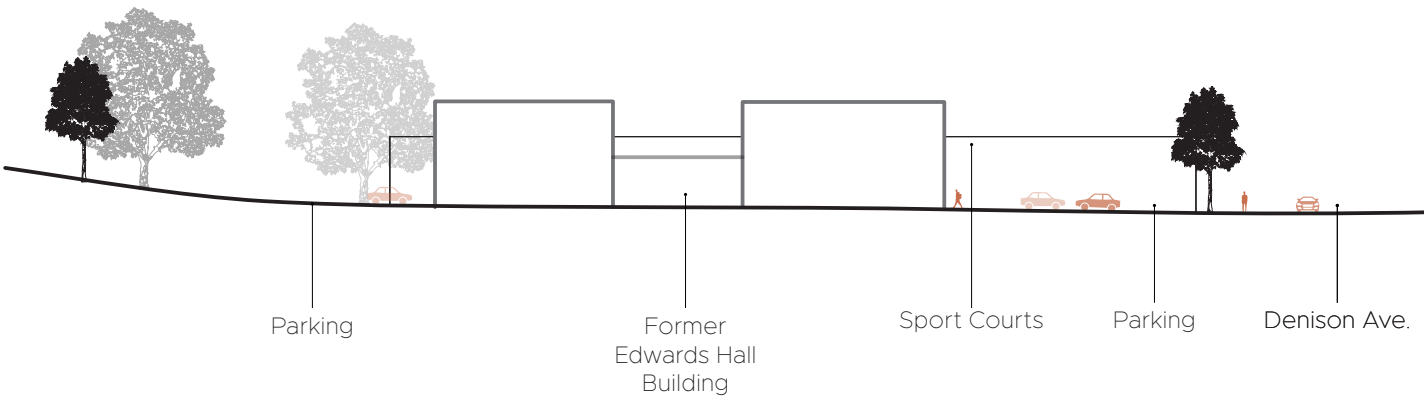


Fig 5.24 Existing Edwards Hall Site Section (Freelove 2025).



Fig 5.25 Proposed Design of Edwards Hall Site (Freelove 2025).

The projective design transforms the former Edwards Hall into a large, natural bio-retention area. Only one parking area remains, and the surrounding landscape mimics the Flint Hills Ecoregion. Over time, this space will lead to reduced mowing in the area, creating a visually interesting landscape that slows stormwater runoff to Campus Creek. The surrounding slopes have been made less dramatic to ease mowing and have been converted from turf to native grasslands.

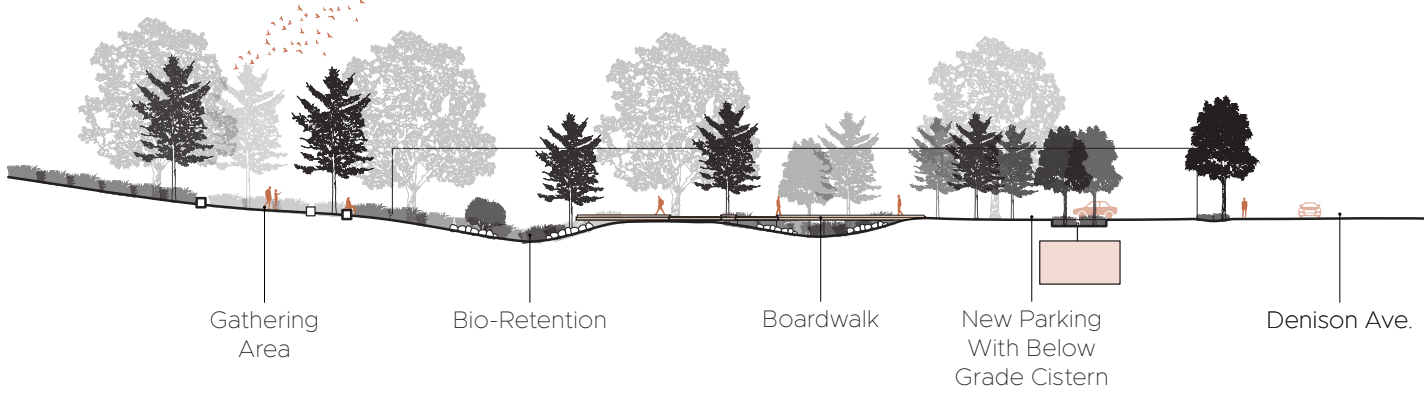


Fig 5.26 Proposed Section of Edwards Hall Site (Freelove 2025).



Former Edwards Hall Site Plan

1. New Parking Lot
2. Planted Islands
3. Lawn
4. Gathering Space
5. Boardwalk
6. Bio-Retention Area
7. Native Plantings
8. Bioswale



Fig 5.27 Proposed Edwards Hall Site Plan (Freelove 2025).

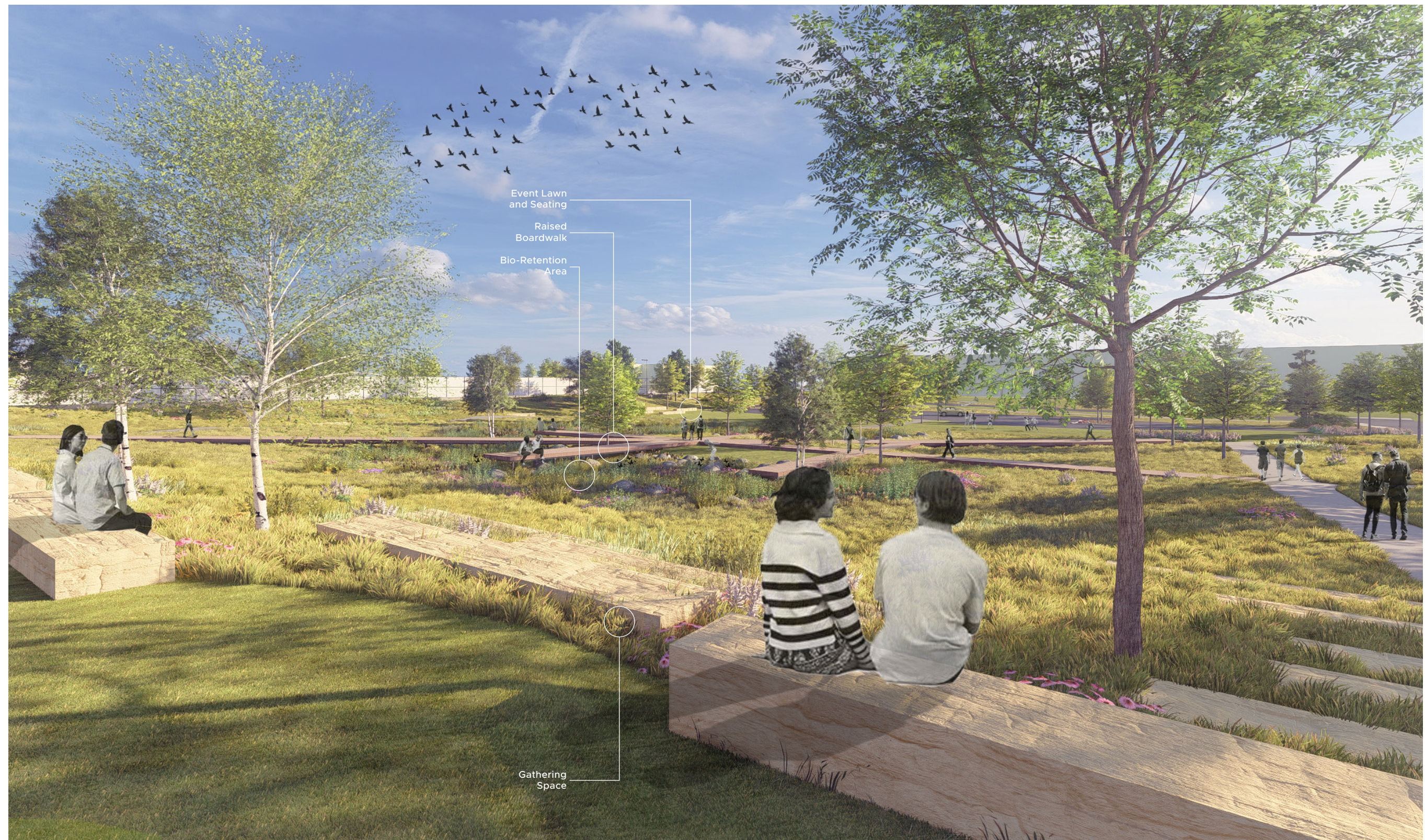


Fig 5.28 Site users can interact with the bio-retention systems in multiple ways, while the GI System provides crucial ecosystem services (Freelove 2025).

Maintenance Practices

For projective design, the maintenance and management goals were to reduce the amount of upkeep needed for the area around the rec while addressing stormwater issues. Kansas State Grounds mows these areas frequently to maintain a manicured appearance, especially during football season. Stormwater concerns are tackled by transitioning to a more naturalized landscape, and eventually, management and maintenance can be less frequent. Transforming this landscape from a manicured turfgrass system does not equate to “no maintenance.” Instead, it creates a more ecologically and visually robust landscape, which can lead to less intensive and frequent management. The first three years following project implementation are critical. Intensive weed control should be conducted during this period to ensure that green infrastructure systems perform as intended. For weed control, mowing and hand removal must be employed to encourage desired species to root and grow within the system. Once the system is established, burning is recommended every two to four years if permitted. This practice will enhance species diversity and help control unwanted species. Additionally, burning should be paired with mowing to protect trees and infrastructure from fire damage, while incomplete burning preserves patches for wildlife cover as other areas recover. However, if burning is not feasible, mowing is advised at least once a year to aid in weed control

In conjunction with plant management, examining each type of green infrastructure within the design is essential. Testing their performance and identifying issues such as erosion, blockages, damage, and drainage time is crucial; neglecting these checks can lead to various problems. A more detailed guide was created for the site, allowing grounds crews to review it and schedule timing for specific management practices. With this guide template, Kansas State University Grounds can use this for more projects across the campus to ensure there is an efficient system in place for care.

Project Title: Bill Snyder Family Stadium Southeast Parking Lot

Project Number:

Contractor:

Date:

Filter Applicable Components

See All Components

Sample Frequency

Filter Required Tasks Only

See All Tasks

Reset Tasks

GSI Component	Required Tasks	Frequency	Time of Year	Responsible Party	GSI Sites Included	Required
GSI-1 Inlets	Inspect for standing water, sediment, debris, trash, blockages, and structural integrity	Bi-Weekly		Tech 1		Yes
	Remove sediment, debris, trash, blockages	Bi-Weekly		Tech 1		Yes
	Repair damage	As Needed		Tech 1		Yes
GSI-2 Energy Dissipation & Pollutant Removal	Inspect integrity and record debris depth	Bi-Weekly		Tech 2		Yes
	Remove sediment, debris, and trash	Bi-weekly		Tech 2		Yes
	Repair erosion or other damage	As Needed		Tech 2		Yes
GSI-3 Above Grade Barriers						
GSI-4 Permeable Pavements	Inspect for sediment, trash, debris, blockages, clogging, and check condition	Quarterly		Tech 2		Yes
	Remove surface sediment, debris and trash	Monthly		Tech 2		Yes
	Remove weeds	Quarterly		Tech 2		Yes
	Remove stains and other markings	Quarterly		Outside Party		Yes
	Vacuum with walk-behind unit	Semi-annually		Outside Party		Yes
	Deep clean with vacuum and pressure wash combination	As Needed		Outside Party		Yes
	Repair damage	As Needed		Outside Party		Yes
	Dress paver joints with aggregate	As Needed		Outside Party		Yes
GSI-5 Soil & Aggregate Media	Inspect 48-hours after 3-inches of rainfall in 24 hour period and record standing water depth	Annually		Tech 2		Yes
	Inspect during or immediately following rain event for trash, debris, flow blockages, erosion paths, and	Seasonally		Tech 2		Yes
	Remove sediment, debris, and trash	Bi-weekly		Tech 2		Yes
	Replace settled or excavated materials, repair erosion/damage	Quarterly		Tech 2		Yes
GSI-7 Landscaping	Inspect for vegetation health, bare spots, weeds, overgrowth, unkempt edges, and mulch coverage	Weekly		Tech 2		Yes
	Maintain clean landscape edges, prune plants	Weekly		Tech 2		Yes
	Manage disease and pests	Weekly		Tech 2		Yes
	Remove weeds	Monthly		Tech 2		Yes
	Remove dead plants	Semi-Annually		Tech 2		Yes
	Refresh mulch	Semi-Annually		Tech 2		Yes
	Water vegetated areas	As Needed		Tech 2		Yes
	Install new plants	As Needed		Tech 2		Yes
GSI-8 Piping	Inspect for standing water, structural integrity, secure access points, record debris depth	Bi-Weekly		Tech 1		Yes
	Remove sediment, debris, trash, blockages	Monthly		Tech 1		Yes
	Repair damage	As Needed		Tech 1		Yes
GSI-9 Outlets	Inspect for sediment, trash, debris, blockages, structural integrity, and outlet control mechanism	Bi-Weekly		Tech 1		Yes
	Clear flow paths and remove sediment, trash, debris, and blockages	Monthly		Tech 1		Yes
	Repair damage	As Needed		Tech 1		Yes
GSI-10 Storage Chambers						
Insert Additional Component on Tab 1						

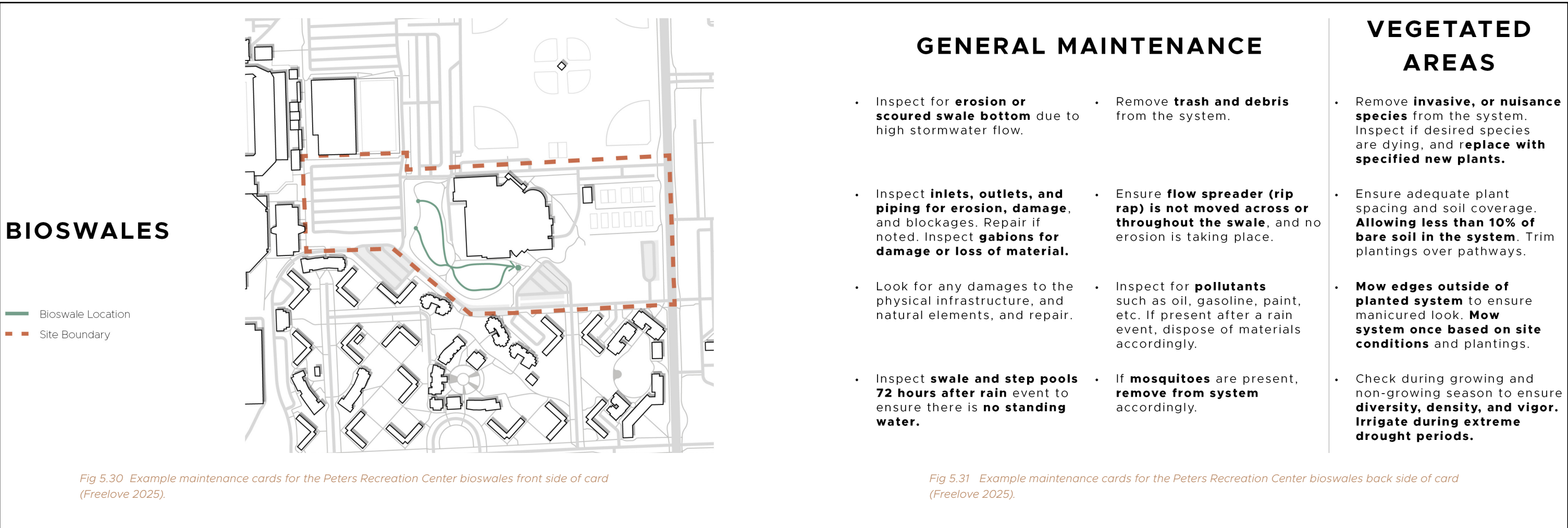
Fig 5.29 Example maintenance sheet for the improved Bill Snyder Family Stadium Parking (Freelove 2025, Adapted from KC Water 2022).

Maintenance Cards

To aid Kansas State Grounds during on-site assessments, flashcards have been created to present the most pertinent information needed for inspections, along with additional important considerations throughout the year. This tool ensures that grounds personnel monitor specific issues and note their observations. Additionally, invasive species cards have been developed to help grounds crews identify plants that may dominate natural systems. With this knowledge, maintenance teams can utilize these cards for similar projects across campus, continually adding to the collection as new green infrastructure projects are established, facilitating efficient checks.

Further Opportunities

This also creates opportunities for other departments at Kansas State to engage in research and systems management. Continued volunteer support from students in Biology, Horticulture, and Landscape Architecture, as well as various other majors across campus, can contribute to the maintenance, monitoring, and research of GI systems.



CHAPTER 6

Conclusion



Fig 6.1 Planted green infrastructure system (MSU 2011).

Implications

This research project at the Peters Recreation Center creates various green infrastructure spaces that provide numerous ecosystem benefits and offer opportunities for interaction and learning. Along with the design, the maintenance cards and schedules developed allow crews to understand what tasks need to be performed and their frequency. These cards can be continually updated to accommodate all types of green infrastructure on campus, and the schedules can be used by Kansas State Grounds to fulfill their specific needs. The literature review, inventory, comparative analysis, and interviews informed the design and development of the maintenance cards and schedules. Through this process, I gained insight into the GI initiatives at Kansas State University, the current management strategies, and the efficiency of GI systems. I have addressed the questions, “How can college campuses effectively manage biodiverse green infrastructure? How do management strategies address the performance of green infrastructure on college campuses over time?” The proposed design and maintenance cards and schedules facilitate the implementation of biodiverse GI systems and guidance on their care over time. With maintenance having these tools, other programs around campus can contribute to the monitoring and testing of the GI systems.

Limitations

There are several significant limitations to consider when evaluating this study's findings. First, some issues that these projects encountered were not due to mismanagement. Instead, they stemmed from poor design and implementation, which caused the projects to fail and function improperly. This study is also multidisciplinary and the development of management plans should involve landscape architects, engineers and landscape management/horticulture professionals who manage green infrastructure and other landscapes. Their input would enhance the understanding of how to create and manage green infrastructure holistically. Additionally, other stakeholders should be involved, such as researchers, who can test and continuously monitor the effectiveness of these projects and management practices. Some projects examined as precedents had associated performance data and have been continuously tested. However, not all projects had pre-existing performance data. Nonetheless, the use of the Rapid Ecological Health Assessment across all projects aids in understanding ecological functions. Despite these limitations, the report still effectively addresses the original question and provides guidance for the projective design and management of the projective design and future projects.



Fig 6.2 The Peters Recreation Center sees a deluge of stormwater runoff from the surrounding context (Freelove 2024).

Recommendations

Kansas State University can leverage this research and projective design as part of the evolving campus master plan and the K-State Next Gen Plan. The projective design could connect to the current master plan to improve the student and visitor experience at Peter's Recreation Center and other athletic facilities. Additionally, Kansas State's divisions can utilize the created checklists. These checklists guide maintenance crews on what to look for and help document any issues they observe, allowing for effective fixing or maintenance of projects. This could promote more green infrastructure initiatives across Kansas State as it aims to become a more sustainable campus within the City of Manhattan. As these management practices are routinely implemented, researchers can monitor the performance of these projects to assist maintenance crews in determining whether different management strategies lead to longer project lifespans. This research can also benefit many other college campuses throughout the United States. Other campuses looking to enhance green infrastructure can adopt these maintenance and management guides for their own projects. As projects progress, new ideas and standards may emerge, fostering a more sustainable learning environment for numerous campuses.



Fig 6.3 Exposed piping in lowest Engineering Bio-Retention Cell at Kansas State (Freelove 2024).



Fig 6.4 Sunset on the Seaton Hall rain garden (Ramirez 2024).

Significance

From this research and design, Kansas State can begin implementing these maintenance standards across campus for both existing and potential new green infrastructure projects. With the 2013 and 2025 Kansas State University campus master plans each highlighting sustainability, these strategies for maintaining sustainable components can enhance the university's success. Not only can Kansas State benefit from this research, but other universities pursuing green infrastructure projects might also adopt and adapt these maintenance strategies to their specific contexts. Additionally, the Manhattan community has an opportunity to integrate some of these concepts. Manhattan has faced flooding issues in the past and has dealt with numerous stormwater challenges. With a solid understanding and schedule for maintaining these systems, the Manhattan community can proactively explore opportunities to expand green infrastructure. As urbanization accelerates and significant storm events occur more frequently, runoff problems will persist. In a rapidly urbanizing world, outdoor spaces become increasingly vital for the well-being of urban residents as well as for ecological health. Green infrastructure provides numerous advantages for managing stormwater and addressing the ecological needs of both plant and animal species. Besides the environmental benefits, green infrastructure also supports human well-being. However, these systems may fail quickly if green infrastructure projects are improperly implemented, designed, or managed. By better understanding how to manage green infrastructure, these projects can be more effectively utilized and enjoy increased longevity.

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Fig 5.3. Freelove, Lukas. 2025. Peter’s Rec Gravel Trail. Photo.

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Fig 5.5. Freelove, Lukas. 2025. Entrance to Peter’s Rec Center. Photo.

Fig 5.6. Freelove, Lukas. 2025. Current Edward’s Hall. Photo.

Fig 5.7. Freelove, Lukas. 2025. Edward’s Hall Pipe. Photo.

Fig 5.8. Freelove, Lukas. 2025. Peter’s Rec Center Basin. Photo.

Fig 5.9. Freelove, Lukas. 2025. Rec Clogged Pipes. Photo.

Fig 5.10. Freelove, Lukas. 2025. Rock Swales Overflowing. Photo.

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Fig 5.30. Freelove, Lukas. 2025. Example Maintenance Card Front for on-Site Bioswales. Image created in Adobe Illustrator.

Fig 5.31. Freelove, Lukas. 2025. Example Maintenance Card Back for On-Site Bioswales. Image created in Adobe Illustrator.

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Fig 6.3. Freelove, Lukas. 2024. Exposed Pipe. Photo.

Fig 6.4. Ramirez, Ady. 2024. Seaton Sunset. Photo.

APPENDIX

Appendix A - Maintenance Cards

PROBLEM
SPECIES



Sericea Lespedeza



Common Buckthorn



Eastern Red Cedar



Smooth Brome



Teasel



Amur Honeysuckle



Common Reed



Garlic Mustard



Salt Cedar



Autumn Olive

PROBLEM SPECIES



Bur Ragweed



Canada Thistle



Kudzu Vine



Musk Thistle



Quackgrass



Field Bindweed



Johnson Grass



Hoary Cress



Pignut



Russian Knapweed

RAIN GARDENS

- Rain Garden Location
- - - Site Boundary



GENERAL MAINTENANCE

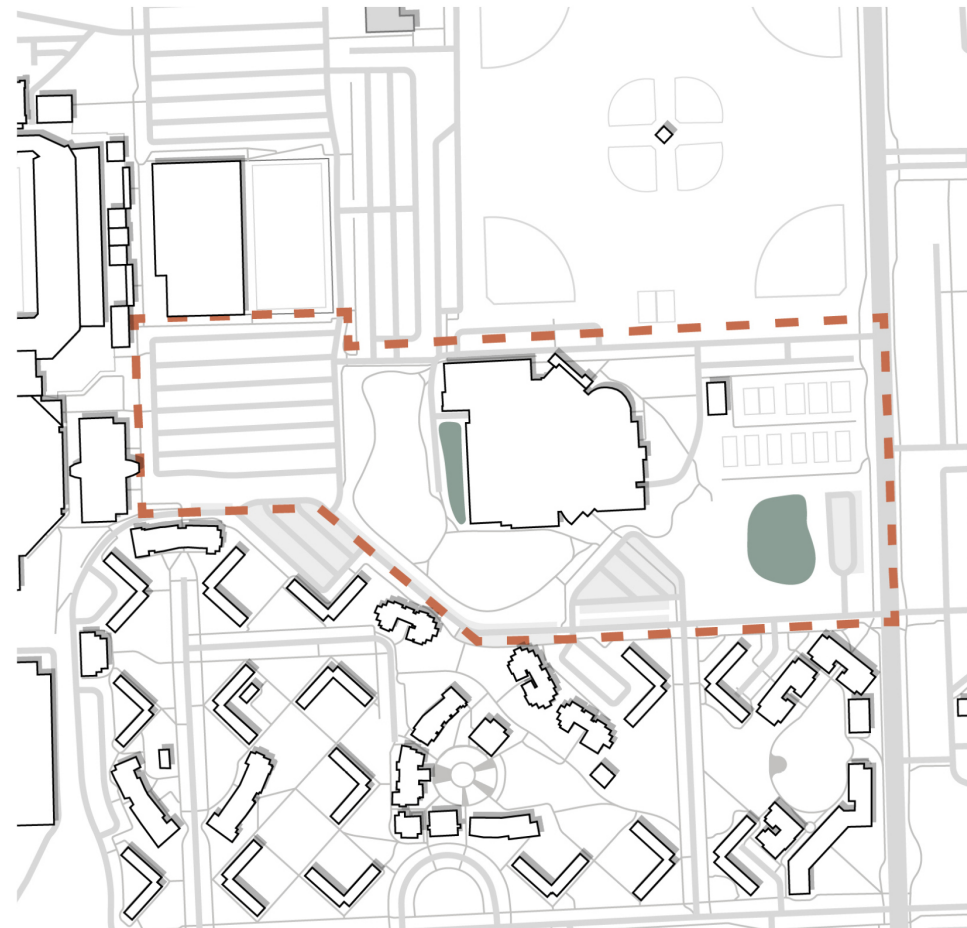
- Inspect for **erosion, scoured soil, or high levels of deposition** at the bottom of the basin due to high stormwater flow.
- Inspect **inlets, outlets, and piping for erosion, damage, and blockages**. Repair damages and remove blockages. Ensure **easy access**. Remove trash/debris.
- Ensure **water is entering the basin**. There is no deposition of rockery, or within the splash box.
- Remove trash and debris. Inspect for **mosquitoes and remove** from the system accordingly. Ensure **water is drained 48-72 hours after a significant rain event**.

VEGETATED AREAS

- Remove **invasive, or nuisance species** from the system. Inspect if desired species are dying, and **replace with specified new plants**.
- Ensure adequate plant spacing and soil coverage. **Allowing less than 10% of bare soil in the system**. Trim plantings over pathways.
- Mow edges of planted system to ensure manicured look. Mow system once a year **based on site conditions and plantings**.
- Check during growing and non-growing season to ensure **diversity, density, and vigor**.
- Remove **leaf litter** causing blockages, or excess amounts. Ensure planting is **not crowing inlets and outlets**.
- During establishment, watering is required to ensure successful implementation (2-3 years). **Irrigation post-establishment should be done during extended drought**.
- If mulch is used, a proper mulch layer is intact, with no bare spots. **Fill bare spots** to ensure weeds stay out of the system.

BIO-RETENTION BASINS

- Bio-Retention Basin Location
- - Site Boundary



GENERAL MAINTENANCE

- Inspect for **erosion, scoured soil, or high levels of deposition** at the bottom of the basin due to high stormwater flow.
- Inspect **inlets, outlets, and piping for erosion, damage, and blockages**. Repair damages and remove blockages. Ensure **easy access**. Remove trash/debris.
- Ensure **water is entering the basin**. There is no deposition of rockery, or within the splash box.
- Remove trash and debris. Inspect for **mosquitoes and remove** from the system accordingly. Ensure **water is drained 48-72 hours after a significant rain** event.

VEGETATED AREAS

- Remove **invasive, or nuisance species** from the system. Inspect if desired species are dying, and **replace with specified new plants**.
- Ensure adequate plant spacing and soil coverage. **Allowing less than 10% of bare soil in the system**. Trim plantings over pathways.
- Mow edges of planted system to ensure manicured look. Mow system once a year **based on site conditions and plantings**.
- Check during growing and non-growing season to ensure **diversity, density, and vigor**.
- Remove **leaf litter** causing blockages, or excess amounts. Ensure planting is **not crowing inlets and outlets**.
- During establishment, watering is required to ensure successful implementation (2-3 years). **Irrigation post-establishment should be done during extended drought**.
- If mulch is used, a proper mulch layer is intact, with no bare spots. **Fill bare spots** to ensure weeds stay out of the system.

BIOSWALES

- Bioswale Location
- Site Boundary



GENERAL MAINTENANCE

- Inspect for **erosion or scoured swale bottom** due to high stormwater flow.
- Remove **trash and debris** from the system.
- Inspect **inlets, outlets, and piping for erosion, damage, and blockages**. Repair if noted. Inspect **gabions for damage or loss of material**.
- Ensure **flow spreader (rip rap) is not moved across or throughout the swale**, and no erosion is taking place.
- Look for any damages to the physical infrastructure, and natural elements, and repair.
- Inspect for **pollutants** such as oil, gasoline, paint, etc. If present after a rain event, dispose of materials accordingly.
- Inspect **swale and step pools 72 hours after rain** event to ensure there is **no standing water**.
- If **mosquitoes** are present, **remove from system** accordingly.

VEGETATED AREAS

- Remove **invasive, or nuisance species** from the system. Inspect if desired species are dying, and **replace with specified new plants**.
- Ensure adequate plant spacing and soil coverage. **Allowing less than 10% of bare soil in the system**. Trim plantings over pathways.
- Mow edges outside of planted system** to ensure manicured look. **Mow system once based on site conditions** and plantings.
- Check during growing and non-growing season to ensure **diversity, density, and vigor**. **Irrigate during extreme drought periods**.

PERMEABLE PAVING

- Permeable Paving Location
- - Site Boundary



GENERAL MAINTENANCE

- Inspect surface course after every **storm exceeding 1 in of rainfall. Remove unwanted sediment** after surface is fully drained.
- Surface must be inspected once annually **for cracking, spalling, erosion, and unwanted plants. Herbicides cannot be used.**
- Check for **debris, damage, and blockages. Repair** damage and marks.
- Care should be used when removing snow. **Sand, grit or cinders may not be used for snow or ice control**
- De-icing **chemicals cannot be used** on pervious material **less than one year old**
- Surface **must be vacuum swept 4 times a year**, followed by air blowing or power washing.

DRAIN TIME

- Drain time **must be tested each spring after the last snow or ice event.** This should be based on what infiltration rate is specified for a certain amount of water poured on the surface.
- If actual drain time and design drain time are drastically different, its **components must be evaluated**
- If the system **fails to drain in 72 hours, corrective action must take place.**

BELOW GRADE CISTERNS

- Cistern Location
- - - Site Boundary



GENERAL MAINTENANCE

- Check for **debris, damage, and blockages**. Repair damage if any.
- Check **pumps and controls** for **warnings or failures**.
- **Remove excess debris and sediment** that causes blockages
- Access points must be **clearly defined and visible**.
- Check insect screen for damage. **Replace if damaged or if mosquitoes are present** in the cistern. Remove mosquitoes if present.
- Check **reuse systems and filters for damage and blockages**.

DRAIN TIME

- Inspect **regularly within 72 hours of a rainfall event to ensure the cistern is empty**. If not empty, repair damage, check controls, or remove sediment from the system.

Appendix B - Maintenance Schedules

All maintenance guides are based on (KC Water 2022) template for GSI maintenance.

Project Title: Bill Snyder Family Stadium Southeast Parking Lot

Project Number:

Contractor:

Date:

Filter Applicable Components

See All Components

Sample Frequency

Filter Required Tasks Only

See All Tasks

Reset Tasks

GSI Component	Required Tasks	Frequency	Time of Year	Responsible Party	GSI Sites Included	Required
GSI-1 Inlets	Inspect for standing water, sediment, debris, trash, blockages, and structural integrity	Bi-Weekly		Tech 1		Yes
	Remove sediment, debris, trash, blockages	Bi-Weekly		Tech 1		Yes
	Repair damage	As Needed		Tech 1		Yes
GSI-2 Energy Dissipation & Pollutant Removal	Inspect integrity and record debris depth	Bi-Weekly		Tech 2		Yes
	Remove sediment, debris, and trash	Bi-weekly		Tech 2		Yes
	Repair erosion or other damage	As Needed		Tech 2		Yes
GSI-3 Above Grade Barriers						
GSI-4 Permeable Pavements	Inspect for sediment, trash, debris, blockages, clogging, and check condition	Quarterly		Tech 2		Yes
	Remove surface sediment, debris and trash	Monthly		Tech 2		Yes
	Remove weeds	Quarterly		Tech 2		Yes
	Remove stains and other markings	Quarterly		Outside Party		Yes
	Vacuum with walk-behind unit	Semi-annually		Outside Party		Yes
	Deep clean with vacuum and pressure wash combination	As Needed		Outside Party		Yes
	Repair damage	As Needed		Outside Party		Yes
	Dress paver joints with aggregate	As Needed		Outside Party		Yes
GSI-5 Soil & Aggregate Media	Inspect 48-hours after 3-inches of rainfall in 24 hour period and record standing water depth	Annually		Tech 2		Yes
	Inspect during or immediately following rain event for trash, debris, flow blockages, erosion paths, and	Seasonally		Tech 2		Yes
	Remove sediment, debris, and trash	Bi-weekly		Tech 2		Yes
	Replace settled or excavated materials, repair erosion/damage	Quarterly		Tech 2		Yes
GSI-7 Landscaping	Inspect for vegetation health, bare spots, weeds, overgrowth, unkept edges, and mulch coverage	Weekly		Tech 2		Yes
	Maintain clean landscape edges, prune plants	Weekly		Tech 2		Yes
	Manage disease and pests	Weekly		Tech 2		Yes
	Remove weeds	Monthly		Tech 2		Yes
	Remove dead plants	Semi-Annually		Tech 2		Yes
	Refresh mulch	Semi-Annually		Tech 2		Yes
	Water vegetated areas	As Needed		Tech 2		Yes
	Install new plants	As Needed		Tech 2		Yes
GSI-8 Piping	Inspect for standing water, structural integrity, secure access points, record debris depth	Bi-Weekly		Tech 1		Yes
	Remove sediment, debris, trash, blockages	Monthly		Tech 1		Yes
	Repair damage	As Needed		Tech 1		Yes
GSI-9 Outlets	Inspect for sediment, trash, debris, blockages, structural integrity, and outlet control mechanism	Bi-Weekly		Tech 1		Yes
	Clear flow paths and remove sediment, trash, debris, and blockages	Monthly		Tech 1		Yes
	Repair damage	As Needed		Tech 1		Yes
GSI-10 Storage Chambers						
Insert Additional Component on Tab 1						

GREEN STORMWATER INFRASTRUCURE
MAINTENANCE SCHEDULE

Project Title:

Peters Recreation Green Infrastructure

Project Number:

Contractor:

Date:

Filter Applicable Components

See All Components

Sample Frequency

Filter Required Tasks Only

See All Tasks

Reset Tasks

GSI Component	Requi r ed Tasks	Frequency	TI me of Year	Responsible Party	GSI Sites Included	Required
GSI-1 Inlets	Inspect for standing water, sediment, debris, trash, blockages, and structural integrity	Bi - Weekl y		Tech 1		Yes
	Remove sediment, debris, trash, blockages	Bi - Weekl y		Tech 1		Yes
	Repair damage	As Needed		Tech 1		Yes
GSI-2 Energy Dissipation & Pollutant Removal	Inspect integrity and record debris depth	Bi - Weekl y		Tech 1		Yes
	Remove sediment, debris, and trash	Bi - weekl y		Tech 1		Yes
	Repair erosion or other damage	As Needed		Tech 1		Yes
GSI-3 Above Grade Barriers	Inspect structural integrity	Annual l y		Tech 1		
	Repair structural, erosion or other damage	As Needed		Tech 1		
GSI-4 Permeable Pavements	Inspect for sediment, trash, debris, blockages, clogging, and check condition	Quarterly		Tech 2		Yes
	Remove stains and other markings	Quarterly		Outside Party		Yes
	Remove weeds	Quarterly		Tech 2		Yes
	Remove surface sediment, debris and trash	Monthly		Tech 2		Yes
	Vacuum with walk-behind unit	Semi-annually		Outside Party		Yes
	Deep clean with vacuum and pressure wash combination	As Needed		Outside Party		Yes
	Repair damage	As Needed		Outside Party		Yes
	Dress paver joints with aggregate	As Needed		Outside Party		Yes
GSI-5 Soil & Aggregate Media	Remove sediment, debris, and trash	Bi-Weekly		Tech 2		Yes
	Inspect 48-hours after 3-inches of rainfall in 24 hour period and record standing water depth	Annually		Tech 2		Yes
	Inspect during or immediately following rain event for trash, debris, flow blockages, erosion paths, and	Seasonally		Tech 2		Yes
	Replace settled or excavated materials, repair erosion/damage	Quarterly		Tech 2		
GSI-7 Landscaping	Inspect for vegetation health, bare spots, weeds, overgrowth, unkempt edges, and mulch coverage	Weekly		Tech 2		Yes
	Maintain clean landscape edges, prune plants	Weekly		Tech 2		Yes
	Mow perimeter	Weekly		Tech 2		Yes
	Mow turf grass areas	Weekly		Tech 2		
	Apply pre-emergent herbicide	Quarterly		Tech 2		Yes
	Remove weeds	Monthly		Tech 2		Yes
	Manage disease and pests	Monthly		Tech 2		Yes
	Manage disease and pests	Monthly		Tech 2		Yes
	Remove algae and other aquatic weeds	Annually		Tech 2		Yes
	Refresh mulch	Semi-Annually		Tech 2		Yes
	Remove dead plants	Semi-annually		Tech 2		Yes
	Install new plants	As Needed		Tech 2		Yes
	Water vegetated areas	As Needed		Tech 2		Yes
GSI-8 Piping	Inspect for standing water, structural integrity, secure access points, record debris depth	Bi-Weekly		Tech 2		Yes
	Remove sediment, debris, trash, blockages	Monthly		Tech 2		Yes
	Repair damage	As Needed		Tech 2		Yes
GSI-9 Outlets	Inspect for sediment, trash, debris, blockages, structural integrity, and outlet control mechanism	Bi-Weekly		Tech 2		Yes
	Clear flow paths and remove sediment, trash, debris, and blockages	Monthly		Tech 2		Yes
	Repair damage	As Needed		Tech 2		Yes
GSI-10 Storage Chambers	Inspect for standing water, sediment, debris, trash, blockages, secure access points, structural	Monthly		Tech 2		Yes
	Remove sediment, debris, trash and blockages	Monthly		Tech 2		Yes
	Deep clean with jet wash and vacuum combination	Annually		Tech 2		Yes
	Repair damage	As Needed		Tech 2		Yes

GREEN STORMWATER INFRASTRUCURE
MAINTENANCE SCHEDULE

Project Title:

Former Edwards Hall Green Infrastructure

Project Number:

Contractor:

Date:

Filter Applicable Components

See All Components

Sample Frequency

Filter Required Tasks Only

See All Tasks

Reset Tasks

GSI Component	Requi r ed Tasks	Frequency	TI me of Year	Responsible Party	GSI Sites Included	Required
GSI-1 Inlets	Inspect for standing water, sediment, debris, trash, blockages, and structural integrity	Bi - Weekl y		Tech 1		Yes
	Remove sediment, debris, trash, blockages	Bi - Weekl y		Tech 1		Yes
	Repair damage	As Needed		Tech 1		Yes
GSI-2 Energy Dissipation & Pollutant Removal	Inspect integrity and record debris depth	Bi - Weekl y		Tech 1		Yes
	Remove sediment, debris, and trash	Bi - weekl y		Tech 1		Yes
	Repair erosion or other damage	As Needed		Tech 1		Yes
GSI-3 Above Grade Barriers	Inspect structural integrity	Annual l y		Tech 1		Yes
	Repair structural, erosion or other damage	As Needed		Tech 1		Yes
GSI-4 Permeable Pavements	Inspect for sediment, trash, debris, blockages, clogging, and check condition	Quarterly		Tech 2		Yes
	Remove weeds	Quarterly		Tech 2		Yes
	Remove stains and other markings	Quarterly		Outside Party		Yes
	Vacuum with walk-behind unit	Semi-annually		Outside Party		Yes
	Deep clean with vacuum and pressure wash combination	As Needed		Outside Party		Yes
	Repair damage	As Needed		Outside Party		Yes
	Dress paver joints with aggregate	As Needed		Outside Party		Yes
	Inspect 48-hours after 3-inches of rainfall in 24 hour period and record standing water depth	Annual l y		Tech 2		Yes
GSI-5 Soil & Aggregate Media	Inspect during or immediately following rain event for trash, debris, flow blockages, erosion paths, and	Seas onal l y		Tech 2		Yes
	Remove sediment, debris, and trash	Bi - weekl y		Tech 2		Yes
	Replace settled or excavated materials, repair erosion/damage	Quarterl y		Tech 2		Yes
	Inspect for vegetation health, bare spots, weeds, overgrowth, unkempt edges, and mulch coverage	Weekl y		Tech 2		Yes
GSI-7 Landscaping	Mow perimeter	Weekl y		Tech 2		Yes
	Mow turf grass areas	Weekl y		Tech 2		Yes
	Maintain clean landscape edges, prune plants	Weekl y		Tech 2		Yes
	Remove weeds	Mont hl y		Tech 2		Yes
	Manage disease and pests	Mont hl y		Tech 2		Yes
	Remove dead plants	Semi - Annual l y		Tech 2		Yes
	Refresh mulch	Semi - Annual l y		Tech 2		Yes
	Water vegetated areas	As Needed		Tech 2		Yes
	Install new plants	As Needed		Tech 2		Yes
GSI-8 Piping	Inspect for standing water, structural integrity, secure access points, record debris depth	Bi - Weekl y		Tech 2		Yes
	Remove sediment, debris, trash, blockages	Mont hl y		Tech 2		Yes
	Repair damage	As Needed		Tech 2		Yes
GSI-9 Outlets	Inspect for sediment, trash, debris, blockages, structural integrity, and outlet control mechanism	Bi - Weekl y		Tech 2		Yes
	Clear flow paths and remove sediment, trash, debris, and blockages	Mont hl y		Tech 2		Yes
	Repair damage	As Needed		Tech 2		Yes
GSI-10 Storage Chambers	Inspect for standing water, sediment, debris, trash, blockages, secure access points, structural	Monthly		Tech 2		Yes
	Remove sediment, debris, trash and blockages	Monthly		Tech 2		Yes
	Deep clean with jet wash and vacuum combination	Annually		Tech 2		Yes
	Repair damage	As Needed		Tech 2		Yes

Appendix C - IRB Approval and Interview Questions



TO: Lee Skabelund
Landscape Archit & Comm Plan
Manhattan, KS 66506

FROM: Lisa Rubin, Chair
Committee on Research Involving Human Subjects

DATE: 02/07/2025

RE: Proposal Entitled, "Campus Ecology: Assessing the Performance and Management of Green Infrastructure."

Proposal Number: IRB-12627

The Committee on Research Involving Human Subjects / Institutional Review Board (IRB) for Kansas State University has reviewed the proposal identified above and has determined that it is EXEMPT from further IRB review. This exemption applies only to the proposal - as written – and currently on file with the IRB. Any change potentially affecting human subjects must be approved by the IRB prior to implementation and may disqualify the proposal from exemption.

Based upon information provided to the IRB, this activity is exempt under the criteria set forth in the Federal Policy for the Protection of Human Subjects, **45 CFR §104(d), category:Exempt Category 2 Subsection ii.**

Certain research is exempt from the requirements of HHS/OHRP regulations. A determination that research is exempt does not imply that investigators have no ethical responsibilities to subjects in such research; it means only that the regulatory requirements related to IRB review, informed consent, and assurance of compliance do not apply to the research.

Any unanticipated problems involving risk to subjects or to others must be reported immediately to the Chair of the Committee on Research Involving Human Subjects, the University Research Compliance Office, and if the subjects are KSU students, to the Director of the Student Health Center.

Electronically signed by Lisa Rubin on 02/07/2025 5:50 PM ET

- How often do you check to see if the project performs efficiently?
- Do you have any other thoughts on green infrastructure maintenance?
- How much time do you dedicate to caring for campus green infrastructure?
- What are your most significant issues with managing these projects?
- What management strategies have been the most effective and the least effective?
- How do you track what tasks have been and have not been completed?
- How do you set the schedule for the crew members taking care of these projects?
- Do maintenance crew members undergo a green infrastructure care training process?
- What green infrastructure projects on campus provide the most maintenance issues?
- What other types of green infrastructure projects would you like to see Kansas State implement?