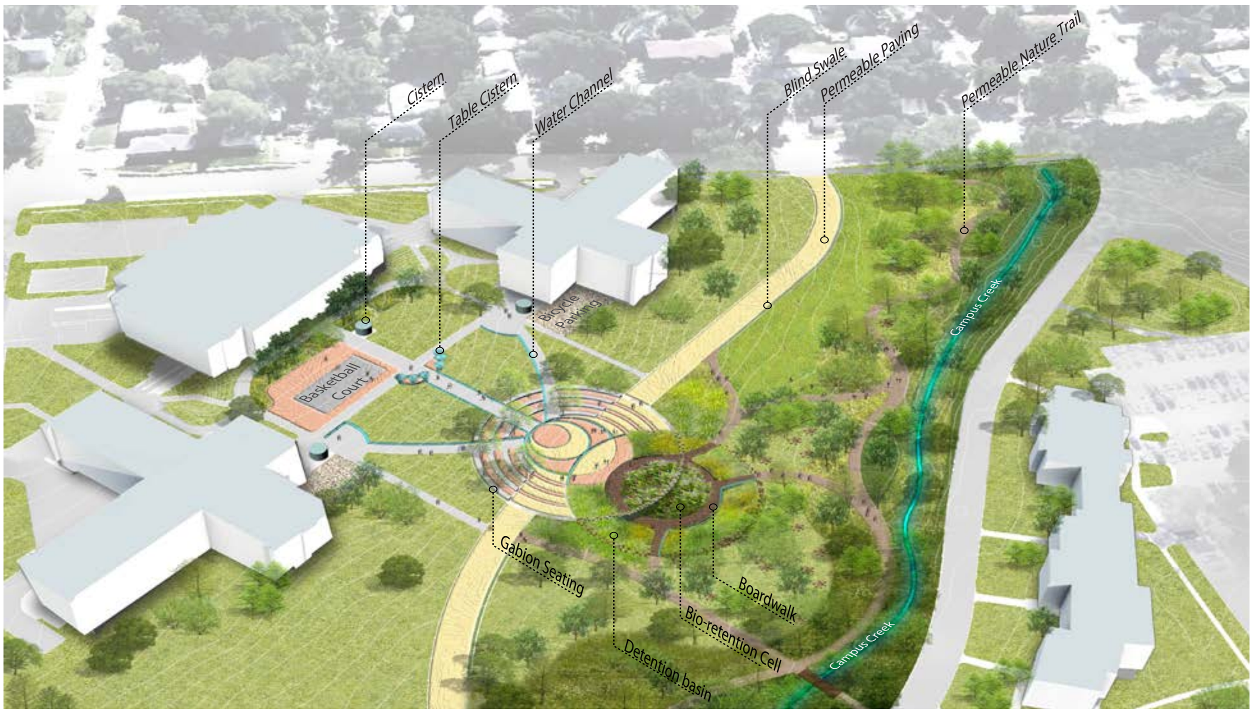
Stronger Quinlan

Connecting the Strong Complex and the Quinlan Natural Area through Innovative Green Infrastructure Practices



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Abstract

Situated at the downstream end of the Campus Creek Corridor, the Quinlan Natural Area has greeted Kansas State University students and faculty walking to class for more than five decades. Decorated with natural seating areas and native tree species, this tribute to the University's first landscape architect is falling into a state of disrepair. Development upstream to the north in the Strong Complex has created a vast impermeable watershed that generates large volumes of stormwater runoff during precipitation events that quickly exceed Campus Creek's effective capacity. The result has been poor stream water quality and frequent flash flooding in the Quinlan Natural Area as well as the eastern residential portion of the City of Manhattan, Kansas. The "Stronger Quinlan" project is designed to disconnect the Strong Complex watershed from Campus Creek by capturing and infiltrating stormwater runoff at the source as a first step in alleviating the flooding issue. Since a significant portion of the impervious area is comprised of building roofs, the proposed design utilizes three cisterns to rapidly collect stormwater as it falls and then slowly release the stored water over a 48-hour span to a bioretention cell/detention basin system, which promotes onsite infiltration for groundwater recharge. Before reaching the bioretention cell, water will flow through an eco-revelatory plaza bisecting a main pedestrian thoroughfare to engage users in the hydrologic process. Currently, more than 24,000 people interact with the site on an annual basis making the site location particularly attractive to demonstrate the value of green infrastructure.

Table of Contents

Site Selection 1-2

Site Selection 1

Site Problem 1

Site History: Honoring the Legacy of Dr. Quinlan 2

Site Value to KSU Campus Community 2

The KSU 2025 Master Plan 2

The Design Solution 3-10

Comprehensive Site Design 3

Green Infrastructure Components 4

Planting Plan 6

Maintenance 6

Modeling and Quantitative Analysis 7

Stormwater Education and Community Engagement 8

Climate Resiliency 9

Project Phasing 10

Budget 10

References A-1

Appendix A-2

Site Selection

Site Description

The site selected for this project (Figure 1) is located on the campus of Kansas State University in Manhattan, Kansas. This site includes the Quinlan Natural Area, a woody riparian zone, and the Strong Complex, a living community surrounded by the residential buildings of Boyd, Van Zile, and Putnam. Campus Creek, a small stream that runs through the center of campus, is found in Quinlan Natural Area adjacent to Campus Creek Road. Petticoat Lane and Campus Creek Road, which encircle the Quinlan Natural Area, are currently used by vehicular traffic for campus access. The Campus Creek Complex houses several community outreach businesses that attract numerous visitors from the City of Manhattan and the surrounding area.

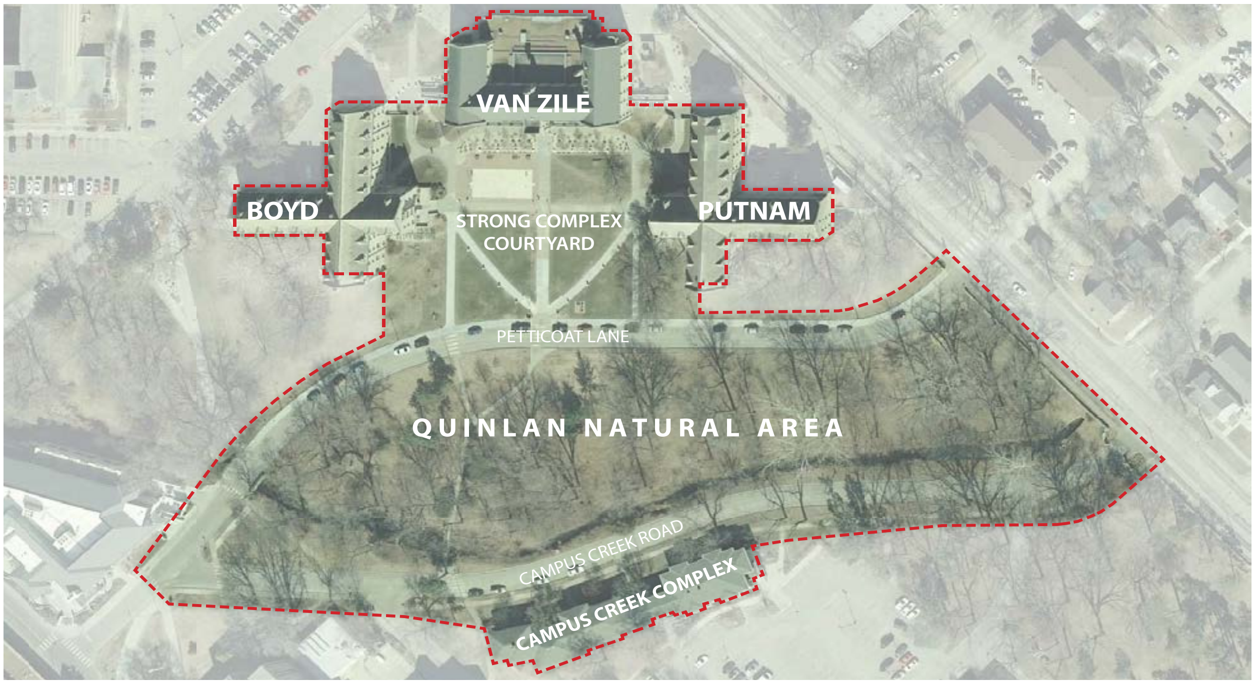


Figure 1. Current layout of the proposed site.

Site Problems

Campus Creek, whose headwaters originate from the North end of the Kansas State University campus, is characteristically flashy and exhibits poor water quality. The Creek is buried underground and daylighted at several different locations along its length. The banks of Campus Creek are not maintained and have been overgrown by weedy, invasive species that do not promote a healthy riparian ecosystem. Campus Creek flows through Quinlan Natural Area before being buried underground and entering the stormwater network for the City of Manhattan. Impervious cover throughout the creek's watershed contributes to frequent flash flooding, accelerated channel erosion, and poor habitat conditions. These conditions render this ecological amenity less attractive to KSU students and the surrounding community while limiting its use.

Figure 2. Surface flooding in Quinlan Natural Area, adjacent to Campus Creek, following a 1.1" storm event.

Figure 3. Surface flooding in Quinlan Natural Area, leaves the site unusable due to excess ponded water.

Site History: Honoring the Legacy of Dr. Quinlan

The Quinlan Natural Area is named after Dr. Leon Reed Quinlan, a Harvard graduate who came to Kansas State University as the first campus landscape architect. From 1927 to 1952, Quinlan served as Supervisor of Campus Landscaping and his career spanning contributions to the quality and character of the campus' green open spaces are a hallmark of his career. After his retirement in 1964, there was a movement to honor his enduring legacy with the dedication of a site on campus in his name. The site was meant to serve as demonstration project which reflected Dr. Quinlan's aesthetic and ecological convictions and thus, the Quinlan Natural Area was created. The original design of Quinlan Natural Area called for a "lush gardens area" which would serve as an "outdoor classroom for Horticulture and Landscape Architecture students and an oasis of beauty for visitors"[1]. The original vision was replaced by a plan that incorporated native plant species to keep maintenance costs to a minimum and work with the ecology of northeastern Kansas.

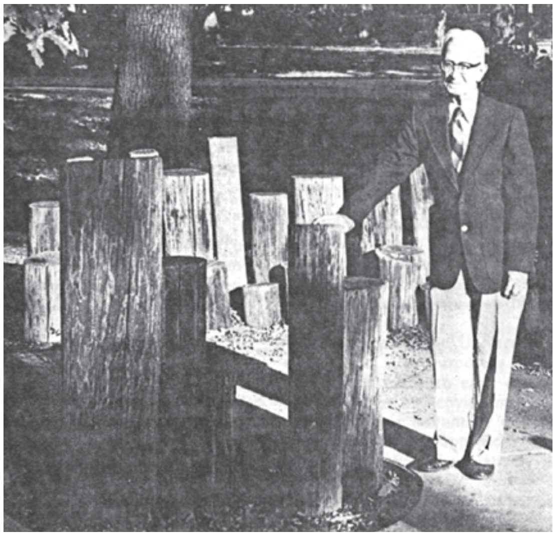


Figure 4. Dr. Leon Quinlan with some of the original tree stump seating areas in Quinlan Natural Area[1].

In the late 1920s, Dr. Quinlan was instrumental in planting and nurturing hundreds of tree and shrub species throughout campus. Education was a core tenant of the site vision with nameplates, complete with the common and botanical names, placed on trees and shrubs throughout the site. Dr. Quinlan also utilized wooden stump seating features in the shaded woodland area adjacent to Campus Creek. The original design intention is all but lost, as the wooden stumps have begun to rot, much of the vegetation has been overgrown by invasive species, and flooding issues have made it challenging for a safe and healthy riparian ecosystem to persist.

Site Value to KSU Campus Community

The Quinlan Natural Area is well situated to serve the social needs of the Kansas State University campus community. Approximately 580 students are housed directly adjacent to the Quinlan Natural Area in the Strong Complex, which encompasses Boyd, Putnam, and Van Zile residence halls. Over 24,000 students visit the KSU campus each day, many of whom pass through the Quinlan Natural Area[2]. Facilities staff referred to the site as one of the "treasures of the KSU campus", and indicated that there are many programmatic uses of the site throughout the year. Black Student Union hosts an annual welcome back barbeque, summer cheerleading camps use the space to practice routines, and the Union Program Council hosts a number of social events. In addition to being located in a heavily populated area, the site is only a quarter of a mile away from Aggieville, which is a popular restaurant and shopping district in Manhattan. The site is situated in a perfect location to reconnect students and campus visitors to the Quinlan Natural Area and Campus Creek. Through an eco-revelatory approach, this project aims to demonstrate that green infrastructure can help solve pragmatic issues such as recurrent flooding while having a positive impact on the community.

The KSU 2025 Master Plan

Kansas State University's 2025 Master Plan outlines strategies to provide opportunity for sustainable growth. In addition to the construction of new buildings and infrastructure changes around campus, the 2025 Master Plan describes a restored riparian corridor to Campus Creek that is aimed at improving water quality and quantity control throughout the creek[2]. Both Petticoat Lane and Campus Creek Road, surrounding the Quinlan Natural Area, will be closed to traffic and utilized as new pedestrian corridors[2]. *Stronger Quinlan* align its design goals with those outlined in the 2025 Master Plan while deepening connections between people and place via integrated green infrastructure systems.

The Design Solution

Comprehensive Site Design

The Stronger Quinlan project is designed to repair urban ecosystem health and provide flood mitigation services along the Campus Creek Corridor. Currently, the vast majority of runoff from the Strong Complex is piped directly into the creek which overloads the capacity of the riparian corridor during periods of intense rainfall. This project provides a solution by disconnecting the upper watershed from the creek and retaining the majority of stormwater runoff on-site. The Stronger Quinlan project utilizes three 10,000 gallon cisterns that collect roof runoff from Boyd, Van Zile and Putnam residence halls to alleviate the water load directly piped to the creek system. Stormwater collected in the Van Zile cistern is allocated for campus irrigation reuse which reduces the irrigation water demand from the City of Manhattan. The Boyd and Putnam cisterns are slated to slowly release their total volumetric capacity through a runnel network to create an interactive water plaza that empties into a central bioretention cell. The slow release of cistern water allows maximum infiltration of roof runoff in the bioretention cell. The woody riparian area along Campus Creek in the Quinlan Natural Area was restored to create an additional creek buffer that provides shaded pathways and stump seating areas for visitors. Pervious paving was strategically utilized in existing impervious areas, creating pedestrian walkways in accordance with the Kansas State University 2025 Master Plan. Native vegetation was applied throughout the site due to its drought and flood resilient qualities as well as its ability to provide habitat and aesthetic appeal. This design creates a vibrant, healthy ecosystem nestled in the center of Kansas State University's campus while providing a unique opportunity for students and visitors alike to interact with a comprehensive and effective green infrastructure system.

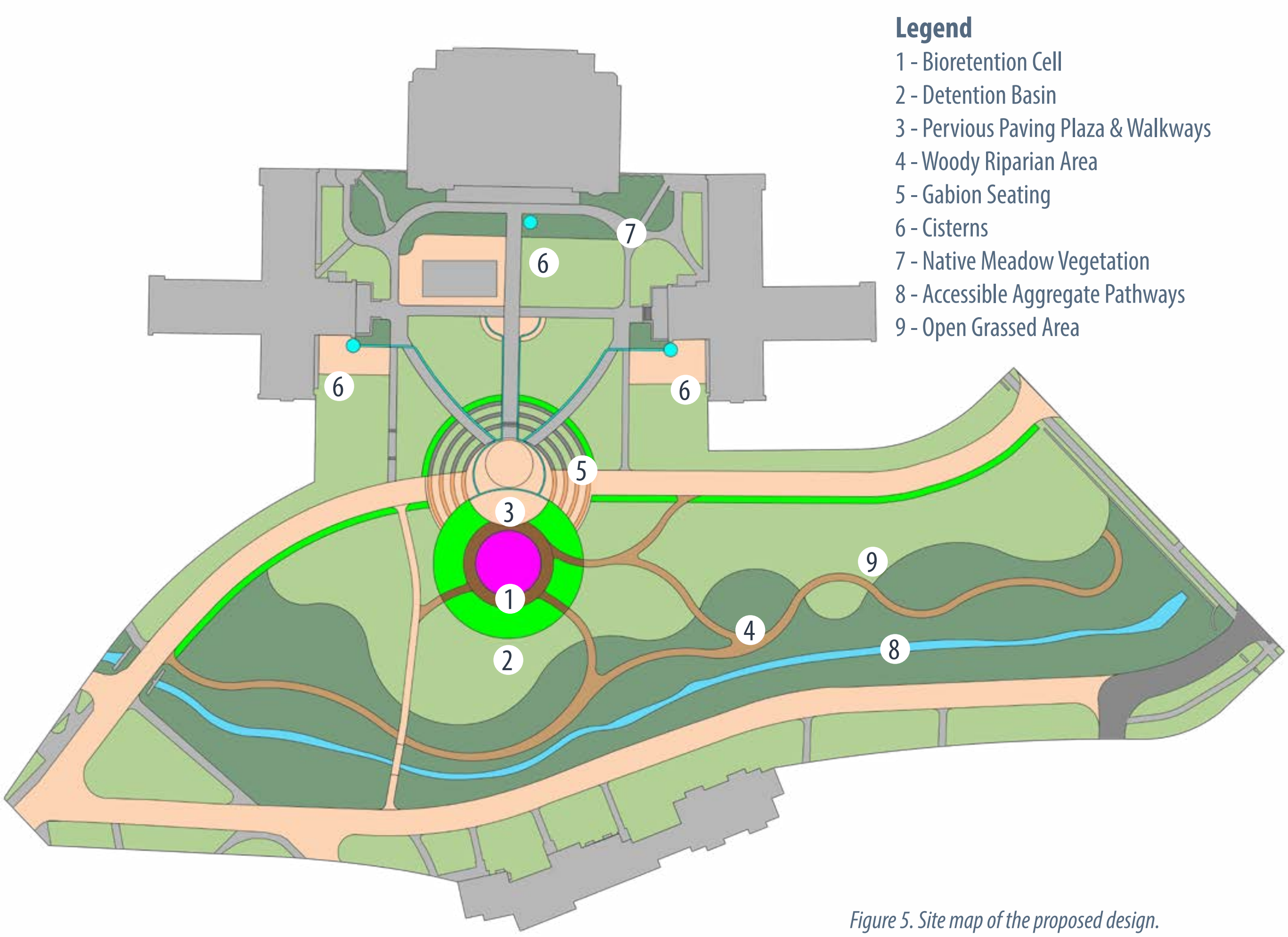


Figure 5. Site map of the proposed design.

Green Infrastructure Components

Detention Basin with Nested Bioretention Cell

This innovative design of a bioretention cell nested within a detention basin will effectively detain and infiltrate stormwater runoff leaving the Strong Complex, thereby reducing the hydrologic load on Campus Creek and improving overall water quality. Bioretention cells are known to restore predevelopment hydrology by mimicing the natural hydrologic regime, which can reduce average peak flows from 45 to 99%[3]. Detention basins are similarly effective at controlling and detaining runoff volume, especially during larger storm events. The bioretention cell in this system has been designed to effectively capture and store a 1.1" water quality event, while the detention basin is sized to detain the 25-year (24-hour) recurring storm event (5.98"). The detention basin sizing for the larger storm event is purposefully intended to create a system that has the capacity to handle more frequent and intense storms anticipated with climate change.

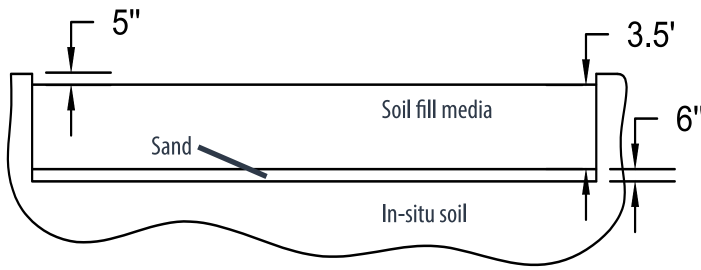


Figure 6. A cross-section of the bioretention cell. The ponded surface water will infiltrate within 9.5 hours and the fill media has a drawdown time of 26 hours following the 1.1" water quality event. An overflow structure ensures a drawdown time of 15 hours, which prevents standing water for long periods of time following a larger precipitation event.

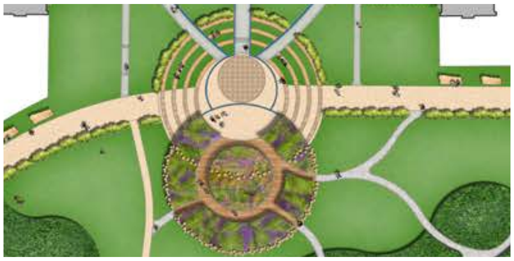


Figure 7. The detention basin/bioretention cell engages the community with aggregate pathways, encouraging visitors to slow down and interact with system and examine vegetation and wildlife. Both pervious walkways, utilized by students, and gabion seating overlooks the system, providing a comfortable viewpoint and gathering space.

Downspout Disconnection & Rainwater Harvesting

Figure 8. Proposed rainwater harvesting cistern, located next to Boyd Residence Hall.

Rainwater harvesting is used in this design as a ecorevelatory component and stormwater harvesting tool. Rising population, rapid urbanization, and changing climatic conditions all have major impacts on water demand and supply. The International Food Policy Research Institute predicts that by 2050 approximately 52 percent of the global population will be exposed to severe water shortages[4]. Three large cisterns proposed for this site will address some of these issues by harvesting and storing roof runoff for reuse to supplement municipal irrigation. Downspouts from the dormitory roofs are currently piping water directly to Campus Creek, will be disconnected and fed directly to the large cisterns. Water will be slowly, passively released from these cisterns at a rate of 1.7 GPM through a runnel system to create an engaging water feature that delivers and deliver water to the bioretention system and Quinlan Natural Area, as needed.

Permeable Pavement

Pervious pavement was selected for this site because of its dual function as a stormwater management practice and as a pavement system. Pervious pavement enhances the natural hydrologic components of infiltration and storage when compared to traditional impermeable pavement. Research has shown that pervious pavement can reduce the average runoff volume between 50% and 93%[3]. In clay soils, pervious pavement can control smaller storms (less than 2 cm) and retain the "first flush" runoff of larger storm events[3]. The walkway dividing Quinlan Natural Area and the Strong Complex is currently open to vehicular traffic, but has been identified by the KSU 2025 Vision as future pedestrian corridor, which is replaced with pervious paving in the proposed design. Additional pervious concrete systems will be placed throughout the site, such as surrounding the basketball court in the Strong Complex and for the path leading to Campus Creek. The addition of pervious concrete in this design will infiltrate stormwater that would otherwise become runoff and flow to Campus Creek.

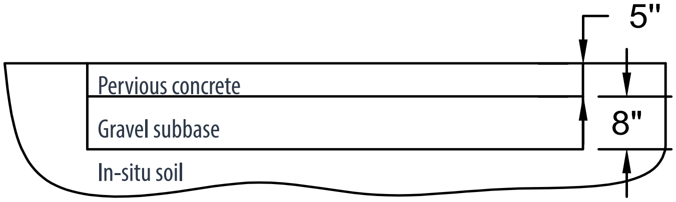


Figure 8. A cross-section view of the pervious concrete paving system. The proposed design recommends a 5-inch pervious concrete layer, supported by 8-inches of gravel subbase. The pervious concrete profile has the capacity to store stormwater from the 10-year, 24-hour storm while providing adequate structural support for pedestrian traffic and emergency vehicles.

Non-Structural Elements

Urban Tree Canopy

The riparian corridor within Quinlan Natural Area that runs along Campus Creek is a woody riparian ecosystem. This corridor, which has been overrun by weedy, invasive species due to neglect, will be restored to a healthy and functioning woody ecosystem with trees and native vegetation. Urban tree canopies have been found to intercept precipitation and provide a multitude of ecosystem services in urban areas, such as provision of wildlife habitat and mitigation of the urban heat island effect[5]. A number of cities throughout the US, such as Chicago and Philadelphia, have developed initatives to restore the urban tree canopy and its associated benefits[5]. The urban tree canopy in the Quinlan Natural Area will assist in mitigation of the water quantity load to Campus Creek, and also provide a number of services for KSU students, who may utilize the space to hang hammocks between the trees or study in the shade.

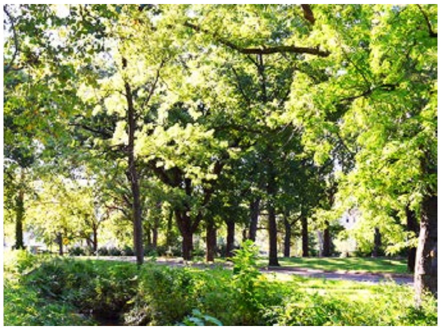


Figure 9. Some of the existing tree canopy, which will be preserved, in Quinlan Natural Area.

Area of restored native plant communities
5.11 acres

Native Vegetation Restoration

The Kansas climate traditionally exhibits extreme weather swings, with long periods of drought followed by periods of intense rainfall. Temperatures range from very hot and dry during the summer to cold, snowy, and windy during the winter months. Native vegetation has proven to be extremely resilient to these weather fluctuations, and thus was implemented throughout the design. Grasses native to the tallgrass prairie of Kansas (e.g. Little Bluestem, Switchgrass) have been found to promote infiltration and prevent erosion due to their fibrous root structure. Native shrubs and forbs provide habitat for a wide range of pollinators, monarchs, and wildlife. The riparian area along Campus Creek will be restored using vegetation native to Kansas, and there will be a native grasses planting area located next to Van Zile hall. Both the bioretention cell and detention basin will be planted with a mixture of native grasses and forbes designed to promote natural hydrologic mechanisms. The utilization of native vegetation throughout the design will create a resilient and healthy ecosystem that reduces stormwater runoff by promoting infiltration, evapotranspiration, and groundwater recharge. All vegetation selected for use across this site is resilient to periods of temporary inundation and drought, and is utilized in specific areas of the site based upon sunlight preferences of the individual plant.

Planting Plan

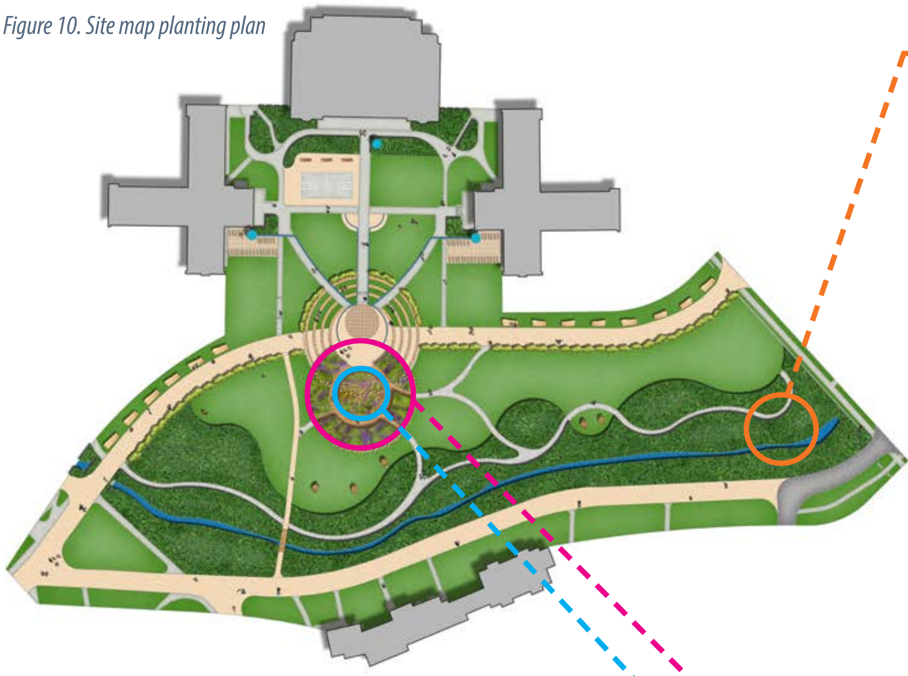


Figure 10. Site map planting plan

Wooded Riparian Area

Wingstem[6]
Provides pollinator habitat, resilient to poor water quality

Emory's Sedge[7]
Resilient to poor water quality, provides habitat

Buttonbush[8]
Provides pollinator habitat, erosion control

Fox Sedge[9]
Bioremediation, erosion control, provides habitat

Bioretention Cell

Indian Grass[10]
Provides habitat, prevents erosion, promotes infiltration

Swamp Milkweed[12]
Provides nectar and habitat for pollinators (especially monarchs)

Tall Thistle[11]
Provides nectar and habitat for pollinators

Switchgrass[13]
Bioremediation, prevents erosion, promotes infiltration

Detention Basin

Big Bluestem[14]
Promotes infiltration, prevents erosion

Little Bluestem[15]
Bioremediation, prevents erosion, promotes infiltration

Sweet Coneflower[16]
Provides nectar and habitat for native bees

Maintenance

The proposed site maintenance recommendations are consistent with current Kansas State University Department of Facilities maintanance activities and equipment, and are supported by Facilities staff (See attached letter of support).

Permeable Pavement

The infiltration rate of the pervious pavement system should be tested on an annual basis and should be swept with a street sweeper at least twice a year to prevent clogging of the void spaces. KSU Facilities currently uses a street sweeper to maintain university roads and will be able to utilize this equipment to maintain the permeable pavement on site.

Rainwater Cisterns

The cisterns should be inspected after any rainfall events exceeding the 1.1-inch water quality storm event to ensure that the overflow structure is functioning properly. The cisterns will also need to be winterized in the fall, before the first freeze, by draining and disconnecting the cisterns from the roof downspouts. The cisterns will need to be disinfected in the spring before they are reconnected to the roof downspout system.

Native Vegetation

The native prairie vegetation should be mowed annually in the fall to hinder the growth of woody and invasive species. Invasive species should also be weeded and removed 2-3 times per year during the growing season, or as needed. Invasive species should likewise be weeded out of the native prairie and riparian vegetation 2-3 times per year.

Modeling and Quantitative Analysis

Hydrologic Modeling

The hydrologic modeling software, PCSWMM, was chosen to simulate hydrologic function of the project site and compare current environmental conditions to the proposed site design. A 3-meter digital elevation model was delineated to determine the watershed topography and hydrologic soil group C was used for the site area. Precipitation information was obtained from the City of Manhattan and the NOAA Precipitation Frequency Data Server. The SCS Curve Number method was utilized to estimate the runoff volume in each scenario. The model applied dynamic wave routing for event-based simulation of site conditions.

Quantitative Analysis

The proposed design effectively reduces stormwater runoff leaving the Strong Complex and Quinlan Natural Area and alleviates the water load on Campus Creek. Additionally, the design changes delay the hydrograph (Figure 10) and extend baseflow over a longer period of time. Captured roof runoff is released through the runnel system, which flows downstream into the combined detention basin/bioretention cell for infiltration (Figure 7). The restored riparian corridor along Campus Creek acts as a buffer to infiltrate excess stormwater which bypasses the detention basin system. This design effectively mitigates current flooding issues along the Campus Creek Corridor and will be invaluable as climate change related precipitation patterns become more intense.

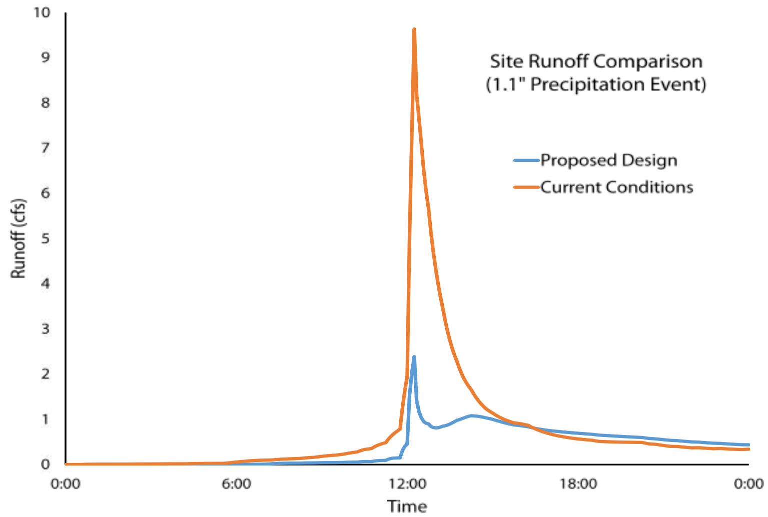
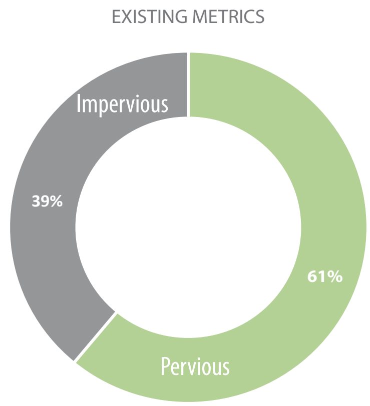


Figure 10. Comparison between the proposed design (blue) and current conditions (orange) demonstrates that the proposed design substantially reduces runoff and delays the hydrograph.



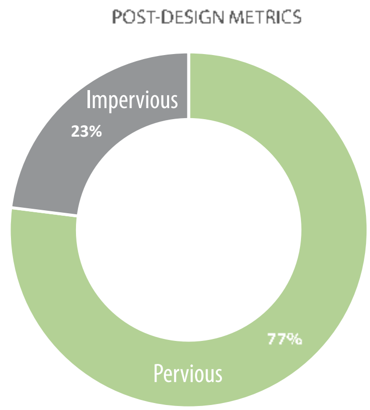


Figure 11. The proposed design reduced impermeable surfaces by 16% when compared to current land cover conditions.

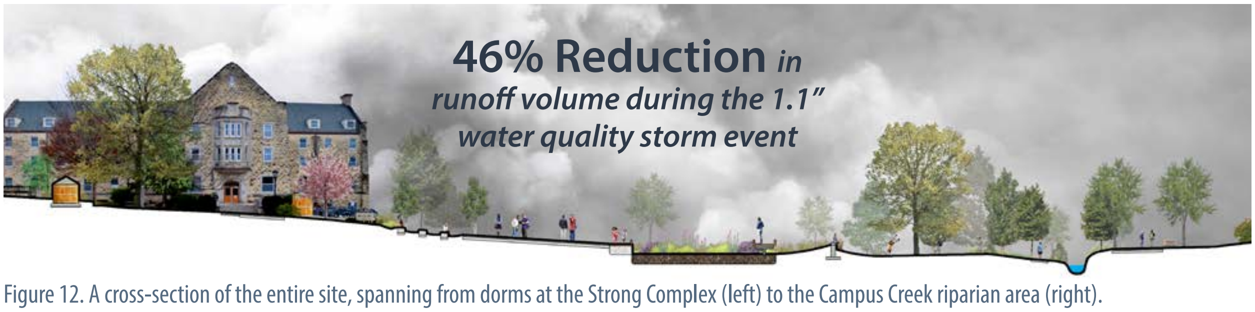


Figure 12. A cross-section of the entire site, spanning from dorms at the Strong Complex (left) to the Campus Creek riparian area (right).

Stormwater Education and Community Engagement

A Living Lab for Campus Research

There are a number of efforts underway on the Kansas State University campus to enhance sustainability while promoting nature education and research. The rain garden at the International Student Center (ISC) and the Meadow, a native prairie grass restoration adjacent to the Beach Museum of Art, are highlights of campus sustainability projects that are utilized for research and education in engineering and landscape architecture departments at KSU. The EPA recently awarded a grant to KSU that will extend research at the Meadow through a teaching-based monitoring effort aimed at better understanding the ecosystem services of the site. The Stronger Quinlan project emulates the research and education efforts demonstrated by the ISC rain garden and the Meadow, providing an opportunity to increase awareness about the importance of green infrastructure and sustainable landscape practices through a cohesive aesthetic and functional design appropriate to the Great Plains Ecoregion.

Figure 13 (above). Aerial view of the Meadow, a native priarie restoration on KSU campus[17].

Eco-Revelatory Design

The Stronger Quinlan project incorporates the ethos of eco-revelatory design, which attempts to create a heightened sense of awareness of ecological processes by making them visible and tangible. Eco-revelatory design is based upon the concept that "the physical revelation of ecological processes in the landscape encourages human users of that landscape to value those ecological processes differently than they otherwise would."[18] The eco-revelatory components of the Stronger Quinlan project include downspout disconnections, rainwater harvesting systems with decorative wildlife murals, runnels transporting stormwater, and the central bioretention area. The design deliberately spotlights these ecological components to maximize the revelatory nature and peak community interest.

Figure 14 (below). Community visitors at the Meadow enjoy native vegetation and wildlife[17].

Community Engagement

The proposed design promotes interactive education and community engagement by connecting site visitors to native vegetation of the Kansas Flint Hills grasslands and its resident pollinators, wildlife, and waterways. Cistern murals in the Strong Complex displaying herons in tall reeds, dragonflies in flight, and pollinating butterflies will highlight the natural wildlife of Kansas. Students traveling through the site on their way to class will have the option to take a permeable paving pedestrian pathway or meander along the "path less traveled" adjacent to the creek. The gabion structures provide seating for studying or social gatherings, the open meadow will facilitate leisure sports like frisbee, and quiet woodland areas along the creek will create a comfortable, shaded resting place. Extracurricular KSU organizations like the Wildlife Society, Popenoe Entomology Club, and the Horticulture Club will have a unique place on campus to host outdoor events and field trips.

Interaction with the site is not limited to students as local organizations from Manhattan and the surrounding area can also find great educational benefit and utilize the outdoor space. Community involvement from interest and volunteer groups such as the Friends of the KAW Riverkeepers, Kansas Master Gardeners, Kansas Master Naturalists, and the Kansas Native Plant Society would have the opportunity to learn from our restoration efforts while helping with site management in return.

Climate Resiliency

Northeastern Kansas is expected to experience more volatile weather patterns in coming years due to climate change. Climate predictions anticipate shorter and more intense precipitation events, while droughts will be hotter and of greater duration. These shifts in temperature and precipitation will place extreme stress on existing water supplies[19], and therefore effective management will be needed to mitigate the impacts of the changing climate. Mitigation of flooding and severe erosion amongst deluge conditions will prevent disruption of natural ecosystems and minimize the extent of damage. The creation of additional water storage and promotion of natural hydrologic functions will create systems that are resilient to the changing climate. The proposed site design will effectively manage natural water resources by increasing water storage, decreasing water demand, and promoting infiltration and recharge of groundwater. The three cisterns adjacent to the residential buildings will store 30,000 gallons of water, which may be reused for irrigation purposes throughout the area. The conversion of turf grass lawn to native vegetation decreases irrigation water demand and increases resiliency to drought. Native vegetation improves infiltration and groundwater recharge, which helps to restore the natural hydrologic regime in Campus Creek by maintaining steady baseflow, even in times of drought.

One effect of climate change that is often overlooked is the increase in the number of frost free days or lengthened growing season that a region will experience. While a longer growing season could benefit farmers by resulting in higher yields, the longer growing season also provides weeds and invasive species a longer time period to spread and aggravate allergies. The US-EPA estimates that the ragweed pollen season in Kansas increased by 25 days from 1995-2015[20]. Opportunistic weeds, such as ragweed, establish quickly in disturbed soils (e.g. flood/erosion afflicted areas). The proposed site design establishes a healthy, natural ecosystem which regulates Campus Creek water levels and combats the spread of invasive weed species while reducing the allergen concentration in the air[21].

Climate change has been slow to gain widespread acceptance in Kansas. As a result, the implementation of environmental management schemes that mitigate climate change on local scales are extremely valuable in making incremental progress towards an overall solution. Those involved in climate change efforts must find creative ways to educate the public and implement solutions. The proposed site design serves as a demonstration project which educates the public on the extensive benefits of green infrastructure, including climate change mitigation. The presence of an established site that improves environmental quality and provides a natural oasis for visitors may help to convince those resistant to climate change intervention to accept progressive solutions for the additional plethora of benefits provided.

Biological Control of Mosquitoes

Mosquitoes are a persistent nuisance on the Kansas State University campus, and climate change will only exacerbate this issue. The shorter winters caused by a warming Kansas climate will lengthen the mosquito breeding season, thus increasing the potential for carrying and spreading these diseases[22]. Urbanization and land development have also been shown to facilitate the life cycle of resident Zika- and West Nile-vectoring mosquitoes, including *Aedes albopictus* and *Culex spp.*, respectively[23,24]. Currently, the project site contains suitable breeding sites along the creek and in adjacent areas of standing water. Mosquitoes that successfully develop here, in addition to immigrant mosquitoes from the surrounding campus landscape, are chronically deterring students from using the site. The proposed design intends to combat these adverse impacts by creating a design capable of controlling mosquito population in the face of climate change by means of (1) proper native plant selection and (2) biological control by natural enemies.

Many developed areas face chronically high mosquito populations due to both the availability of breeding sites and the loss of predators that act as biological control agents[25]. The native plant palette integrated throughout the design promotes improved stream conditions and subsequently, natural predators of mosquito eggs and larvae such as naiadic odonates, crayfish, and mosquito fish (*Gambusia affinis*). Adult mosquitoes will be controlled by aerial predators such as songbirds, bats, dragonflies, damselflies, and a score of other insectivores.

Project Phasing

The proposed project phasing is designed to be implemented on a 6-year schedule and comply with the University's 2025 Master Plan. Phasing ideas are supported by KSU's Associate Director of Campus Planning and Facilities Management.

Phase I: Years 1-2

Phase I of the Stronger Quinlan project will implement the installation of the three above-ground cisterns, the detention basin and nested bioretention cell, the gabion structure seating area, and the runnels that connect these features. This phase requires the majority of landscape disturbance, which is why is has been selected for the initial project phasing. Landscaping within the Strong Complex/Quinlan Natural Area will occur at the end of Phase I. Native plant seeding efforts along the nature trail will occur at the end of Phase II. Once completed, the green infrastructure features in this phase will be fully functional and will begin treating stormwater quantity and quality.

Phase II: Years 3-4

Designated permeable pavement and crushed aggregate trails will be installed during Phase II. Interference of features implemented in Phase I will be avoided to allow them to operate during the installation of Phase II. Crushed aggregate trails along the creek will be installed before Phase III because soil disturbance by human activity often facilitates the colonization of invasive plants; therefore Phase III will include invasive plant removal. Native plant seeding efforts along the crushed aggregate trail will occur between Phase II and Phase III.

Phase III: Years 5-6

Phase III includes native vegetation restoration and seeding, invasive plant removal, and implementation of stump seating areas in the wooded riparian area. As implied in the discussion of Phase II, earlier construction may have provided proper habitat for invasive plants, so removal and management after Phase II and Phase III is critical. Any additional landscaping of native vegetation throughout the site will be completed in this stage.

Budget and Funding Sources

The Stronger Quinlan project costs comparably to other green infrastructure projects of this scale. It is estimated that all three phases of the design would be implemented at a cost of approximately $526,000. Phase I, estimated to cost $116,000, will have the most substantial positive impact on alleviating water load to Campus Creek. As part of Phase I, the cistern installation ($48,000)[26,27] and bioretention/detention establishment ($55,000)[28,29] are the two main features that will have the largest impact on runoff characteristics. Phase II, estimated at $390,000, will provide aesthetic appeal along with new campus pathways such as the aggregate trail ($6,000)[30] and permeable pedestrian walkway ($375,870)[31,32]. The Phase III native grass renovation will be the least expensive phase, estimated at $17,000[33].

Funding for this project can be procured partially through cooperation with the Kansas State University Master Plan projects as this design satisfies a number of construction and design goals already slated for coming years. Contributions from the City of Manhattan are also likely as a mitigated flood risk could save the City in reduced flood damage and lessen the strain on municipal sewer facilities. Grants such as the EPA's Source Reduction Assistance Grant Program and FEMA's Pre-Disaster Mitigation Program are available as potential funding sources as well[34].

Conclusion

Stronger Quinlan has the potential to leave a lasting impact on the Manhattan community. As a land grant university, the proposed design honors the core value of sustainability and the legacy of Dr. Leon Reed Quinlan. The rainwater harvesting cisterns and bioretention cell serve as a cohesive and eco-revelatory green infrastructure installation, and will help solve the current issues of flooding while reducing irrigation needs of the landscape.

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Calculations

Rainwater Harvester Inputs:

Parameter	Value
Rainfall Input File[35]	Manhattan Daily
Capture Factor[36]	0.9
Water Cost[37]	$0.001593
Sewer Cost[37]	$0.004013
WQv Storm Depth	1.1 in
Cistern Volume	3000 gal
Cistern Cost	$10800
Irrigated Area	129726 ft^2
Irrigation System	Impact Sprinkler
Irrigation Efficiency[36]	75%
Soil Texture	Silty Clay Loam
Plant Available Water[36]	0.13 in/in
Irrigated Crop	Turf Grass
Effective Root Depth[36]	6 in
Allowable Water Depletion[36]	50%
Evapotranspiration[38]	Manhattan Monthly

Proposed Design Area:

Category	Area (ft^2)
Buildings	55884
Boyd Hall	*13267*
Van Zile Hall	*19450*
Putnam Hall	*13179*
Campus Creek Complex	*9988*
Other Impervious	27357
Restored Nature Trail	7855
Permeable Paving	50166
Lawn	123438
Shrub	80034
Swales	4082
Detention Basin	9951
Bioretention Area	*2206*
Boardwalk	*2229*
Gabion Walls	1252
Daylighted Creek Area	5248
Other	978
Total Site Area	**366245**

Existing Area:

Category	Area (ft^2)
Buildings	55884
Boyd Hall	*13267*
Van Zile Hall	*19450*
Putnam Hall	*13179*
Campus Creek Complex	*9988*
Other Impervious	87538
Gravel Aggregate	3911
Lawn	210544
Shrub	3257
Other	5111
Total Site Area	**366245**

Permeable Pavement - Generic Sizing		
**Designed for emergency vehicle access		
Ambulance	2	vehicles/day
Load	18	kips per axle
EAL =	1	
Design life =	20	years
ESAL =	14600	equiv. single axle lo
CRB =	15	
Soil support va	5.75	
SN =	1.7	
SN required =	2.1	
a1 =	0.32	per in
d1 =	5	in
a2 =	0.14	
d2 =	8	in
SNc =	2.72	
SNc > SN req?	YES	

Flowing into Bioretention Cell:		
Weighted CN =	78.16	
S =	2.79	
I_a =	0.56	
P =	1.10	in
Q_{runoff} =	0.09	in
Q_{runoff} =	0.01	ft
V_{runoff} =	985.61	ft^3
V_{runoff} =	27909.37	L
BRC Area =	2206	ft^2
Ponding depth =	0.45	ft
Ponding depth =	5.36	in
K =	0.50	in/hour
K =	0.00	in/sec
A =	2206.00	ft^2
ΔH	3.95	ft
L	3.50	ft
Q =	0.03	cfs
Q =	103.65	ft^3/hr
Tpond =	9.51	hr
Tmedia =	26.07	hr

Overflow structure:		
Ia/P =	0.14302	
L hyd. Pa	300	ft
H (elev) =	16	ft
tc =	1.94798	min
qu =	1000	cfs/mi2*in
A =	2.67215	acre
qp =	9.23026	cfs
qp guess	0.5	cfs
N	1	
Cd	0.6	
g	32.2	ft/s2
H	0.33	ft
A (orifice)	0.18077	ft2
d (orifice)	0.47975	ft
d (orifice)	5.75699	in
Drawdown time =	15.0768	hrs
L=	0.55	ft
	6.62	

Flowing into Detention Basin		
Weighted CN =	74.13	
S =	3.49	
I_a =	0.70	
P =	4.88	in
Q_{runoff} =	2.28	in
Q_{runoff} =	0.19	ft
V_{runoff} =	27138.17	ft^3
V_{runoff} =	768466.03	L
Detention Basin Area =	9951	ft^2
Ponding depth =	3.17	ft
Ponding depth =	38.09	in