Urban climate resilience in disinvested neighborhoods: the role of green infrastructure in addressing climate change threats

by

Jenna Goldsmith

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College of Architecture Planning and Design

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Approved by:

Major Professor
Sara Hadavi

Abstract:

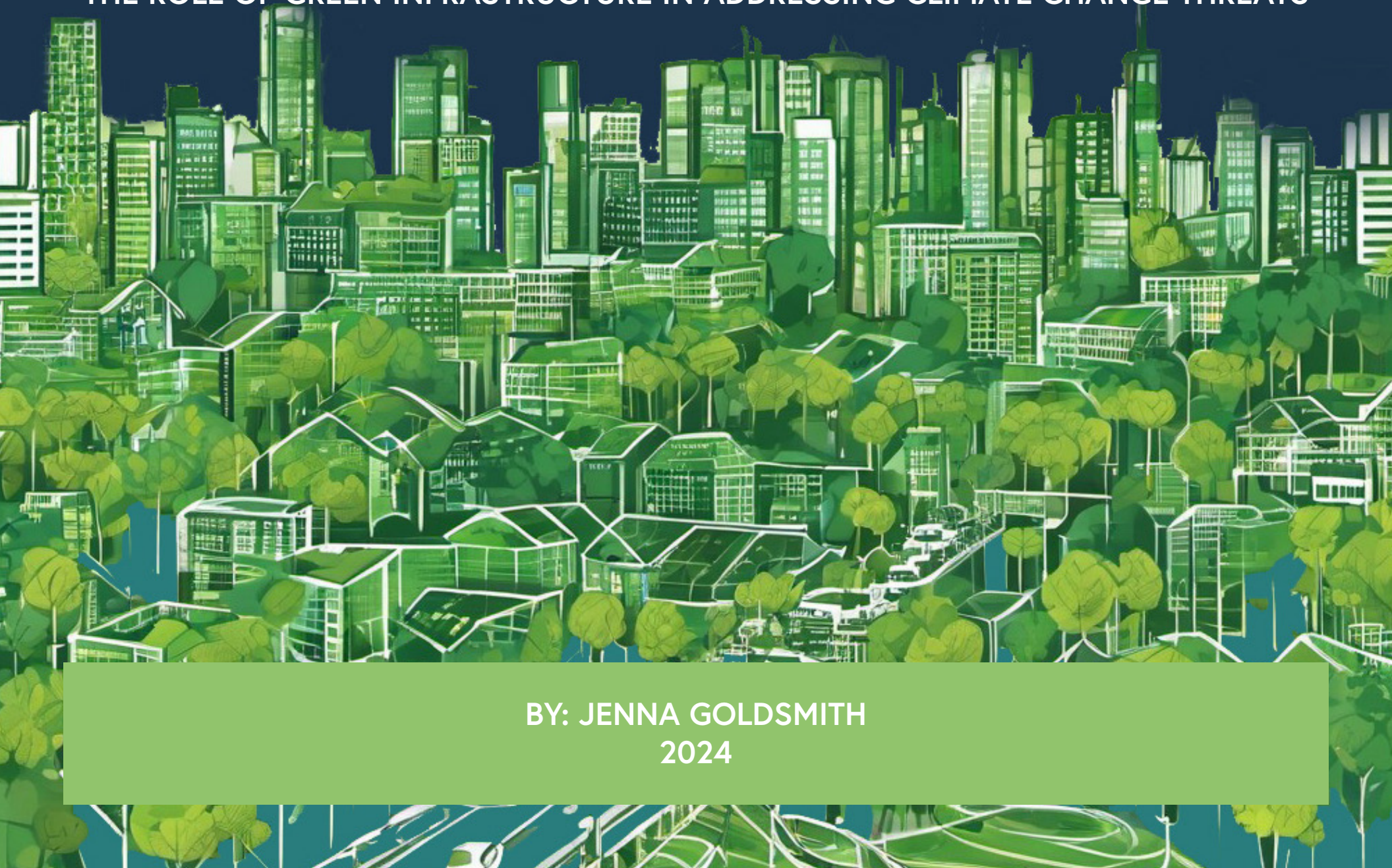
Climate change poses a unique threat in urban areas as they are typically home to diverse people from vastly different socio-economic backgrounds. Knowing that the consequences of climate change disproportionately impact communities of lower socio-economic status compared to others (Santamouris, 2023; Block et al., 2012), it is important to examine ways to boost the environmental resilience of these areas. Many of these communities have less access to necessary ecological resources and services, caused by a long history of disinvestment and discriminatory zoning laws that have increased segregation and decreased investment. One long-term impact of these trends is the higher vacancy levels within these neighborhoods. The culmination of these factors has made these neighborhoods vulnerable to the increasing threats and impacts of climate change. It is becoming increasingly crucial that cities focus on boosting the resilience of these historically disinvested neighborhoods to prevent future catastrophes. While high rates of urban vacancies can have vast negative impacts, these abandoned lots can provide a unique opportunity for cities to create positive change through revitalization projects in the face of the climate crisis. Climate resilience is understood as the ability of a community to cope and manage the impacts of climate change without a detrimental outcome (Pamukcu-Albers et al., 2021; Ramyar et al., 2021; Schleussner, Pfleidrer et al., 2021; Tauhid, 2018). This project has investigated how different types of green infrastructure can improve the environmental resilience of historically disinvested areas and how the site selection process for these greening projects could be reimagined to be more equitable and need-based. More specifically, this study explores how certain types of green infrastructure can mitigate the impacts of climate change-induced drought, flooding, and urban heat island effects. This study focuses on nine high-vacancy neighborhoods in Kansas City, Missouri, which have historically been impacted by

redlining practices, to examine how site-specific implementations of green infrastructure can increase the community's ability to withstand potential climate adversities.

Environmental data was collected through public city resources related to the area's existing ecological conditions and hazards. This data was used for two rounds of GIS analytical mapping to gain knowledge of current conditions in the study area and locate suitable sites for potential revitalization efforts. A suitability model was created and used to produce suitability maps to discover potential sites. Furthermore, three different climate change models were analyzed to gain a baseline understanding of possible future climatic conditions and were used as a baseline for decision-making for green infrastructure typology design. With this information, a framework of green infrastructure typologies matched with suitable sites in the study area was created to improve the community's resilience to drought, flooding, and urban heat island effects. The anticipated increase in resilience was exhibited through an overall theoretical network of green infrastructure that could be implemented in the study area. These findings offer more insights into the study and approach to improving urban climate resilience and contribute to the existing body of literature by identifying critical urban greening implementations for boosting climate resilience at various scales. The broader outcome of this study would be related to its potential implications in improving urban climate resilience in historically disinvested communities.

URBAN CLIMATE RESILIENCE IN DISINVESTED NEIGHBORHOODS:

THE ROLE OF GREEN INFRASTRUCTURE IN ADDRESSING CLIMATE CHANGE THREATS



BY: JENNA GOLDSMITH

2024

URBAN CLIMATE RESILIENCE IN DISINVESTED NEIGHBORHOODS: THE ROLE OF GREEN INFRASTRUCTURE IN ADDRESSING CLIMATE CHANGE THREATS

Jenna Goldsmith | 2024
Major Professor: Sara Hadavi
Supervisory Committee: Howard Hahn & Shakil Kashem

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

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Kansas State University, Manhattan, Kansas

Dedicated to my mentors, colleagues, and loved ones whose unwavering support and encouragement have fueled my academic pursuit. Your belief in me has been the cornerstone of this endeavor. Thank you for your endless support and guidance.

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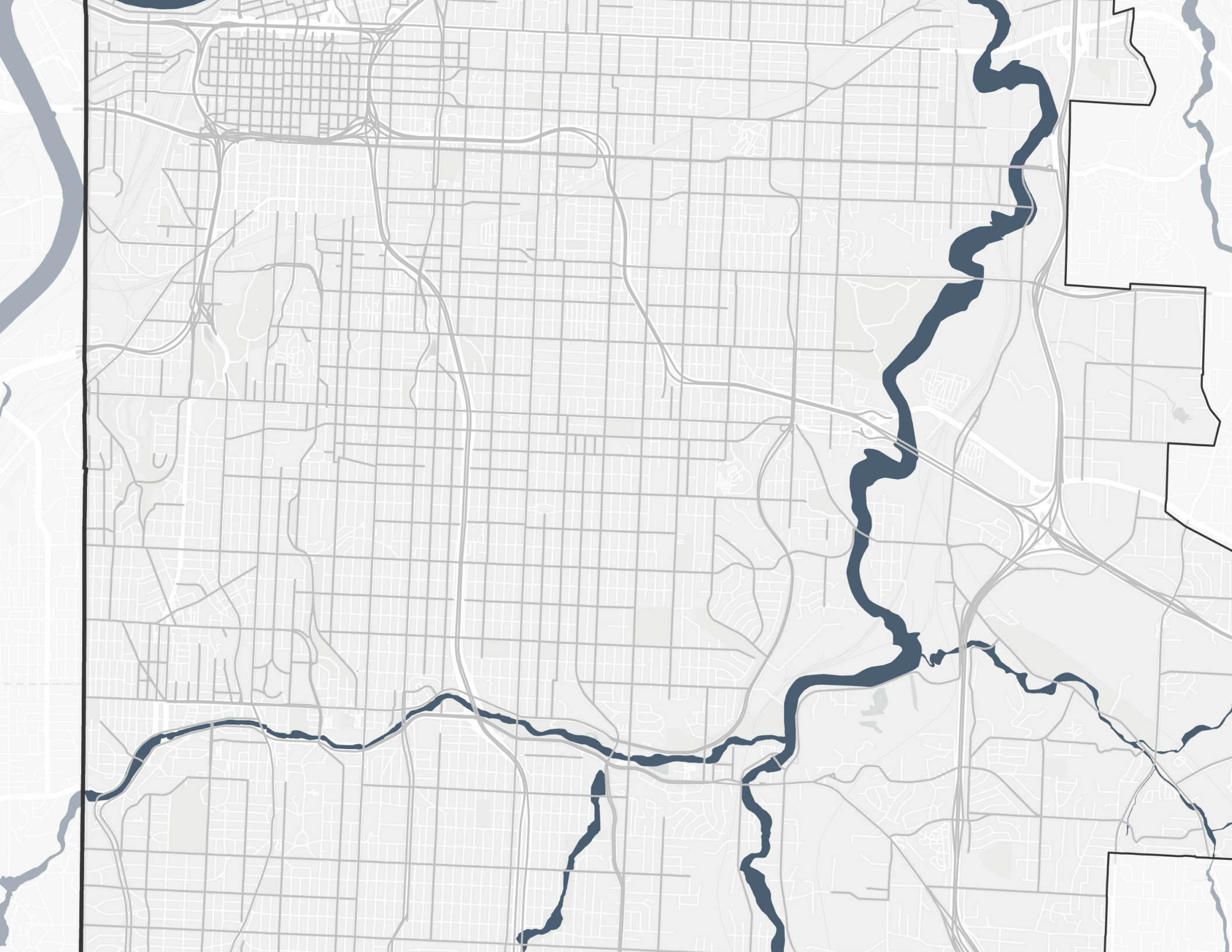
ABSTRACT:

Climate change poses a unique threat in urban areas as they are typically home to diverse people from vastly different socio-economic backgrounds. Knowing that the consequences of climate change disproportionately impact communities of lower socio-economic status compared to others (Santamouris, 2023; Block et al., 2012), it is important to examine ways to boost the environmental resilience of these areas. Many of these communities have less access to necessary ecological resources and services, caused by a long history of disinvestment and discriminatory zoning laws that have increased segregation and decreased investment. One long-term impact of these trends is the higher vacancy levels within these neighborhoods. The culmination of these factors has made these neighborhoods vulnerable to the increasing threats and impacts of climate change. It is becoming increasingly crucial that cities focus on boosting the resilience of these historically disinvested neighborhoods to prevent future catastrophes. While high rates of urban vacancies can have vast negative impacts, these abandoned lots can provide a unique opportunity for cities to create positive change through revitalization projects in the face of the climate crisis. Climate resilience is understood as the ability of a community to cope and manage the impacts of climate change without a detrimental outcome (Pamukcu-Albers et al., 2021; Ramyar et al., 2021; Schleussner, Pfleidrer et al., 2021; Tauhid, 2018). This project has investigated how different types of green infrastructure can improve the environmental resilience of historically disinvested areas and how the site selection process for these greening projects could be reimagined to be more equitable and need-based. More specifically, this study explores how certain types of green infrastructure can mitigate the impacts of climate change-induced drought, flooding, and urban heat island effects. This study focuses on nine high-vacancy neighborhoods in Kansas City, Missouri, which have historically been impacted by redlining practices, to examine how site-specific implementations of green infrastructure can increase the community's ability to withstand potential climate adversities.

Environmental data was collected through public city resources related to the area's existing ecological conditions and hazards. This data was used for two rounds of GIS analytical mapping to gain knowledge of current conditions in the study area and locate suitable sites for potential revitalization efforts. A suitability model was created and used to produce suitability maps to discover potential sites. Furthermore, three different climate change models were analyzed to gain a baseline understanding of possible future climatic conditions and were used as a baseline for decision-making for green infrastructure typology design. With this information, a framework of green infrastructure typologies matched with suitable sites in the study area was created to improve the community's resilience to drought, flooding, and urban heat island effects. The anticipated increase in resilience was exhibited through an overall theoretical network of green infrastructure that could be implemented in the study area. These findings offer more insights into the study and approach to improving urban climate resilience and contribute to the existing body of literature by identifying critical urban greening implementations for boosting climate resilience at various scales. The broader outcome of this study would be related to its potential implications in improving urban climate resilience in historically disinvested communities.



1 Introduction

As the global population continues to grow exponentially, more and more of the human population is choosing to reside in urban areas. The natural systems, such as forests and rivers, located within urbanized areas have been drastically altered and degraded due to human development in these regions. Additionally, due to the dense growth of cities, most of these areas have been developed using predominantly impervious materials such as concrete. Grey infrastructure has been the traditional approach to mitigating environmental hazards, such as flooding in urbanized areas. However, due to rapid urbanization and climate change impacts, grey infrastructure solutions are no longer viable for addressing future climate hazards (Zuniga-Teran et al., 2020). In the 2016 Ramyars study, climate change can be defined as a notable shift in the typical climate conditions of a region, which may trigger subsequent consequences such as drought, flood, and urban heat island impacts, among many others due to human development (Kloesel, 2018; MARC & Climate Action KC, 2021; Meerow and Stults, 2016; Ramyar et al., 2021; Sturiale and Scuderi, 2019; Tauhid, 2018). Specifically, this project is focused on the climate change impacts of flooding, drought, and urban heat islands in cities.

Due to the inherent multidimensionality of climate change-related impacts, resilience has become a key topic and concern for cities as they have begun to prepare for future climatic conditions. The term resilience has become increasingly popular due to its applicability to all the facets and dimensions of climate change. Because of the popularity of this topic, the term resilience has become hard to define, as it depends on one's long-term goals. In the context of this report, climate resilience is defined as the capacity of an environmental system to bounce back and withstand potential ecological hazards or disasters and its ability to continually evolve to changing climate conditions (MARC & Climate Action KC, 2021; Pamukcu-Albers et al., 2021; Ramyar et al., 2021; Schleussner, Pfleidrer, et al., 2021; Sturiale and Scuderi, 2019; Tauhid, 2018; Zuniga-Teran et al., 2020).

One approach cities have begun to explore regarding how to address the multidimensional issue of climate change is implementing green infrastructure networks. Green infrastructure can be delineated as public green spaces,

environmental practices, and naturally occurring systems that increase the ecological functioning, value, or quality of an area (Pamukcu-Albers et al., 2021; Ramyar et al., 2021; Zuniga-Teran et al., 2020). Green infrastructure systems provide various ecosystem services and can offer benefits that address many interconnected issues. This project explores explicitly types of green infrastructure that have the potential to address flooding, drought, and urban heat island hazards. This study is focused on the climate change hazards of drought, flooding, and urban heat island impacts because of their relevance in future climate change models related to the Midwestern region of the United States. Inspiration for this project was directly taken from the "KC Regional Climate Action Plan" by the Mid-America Regional Council and the "KC Green Climate Protection and Resilience Plan" by the City of Kansas City, Missouri. Both plans discussed the importance of building environmental resilience by implementing green infrastructure systems, especially in areas that house potentially vulnerable populations. Figure 1.1 visualizes the thought process behind how this project was developed and the steps taken to complete it.

Research Question:

How can different types of green infrastructure enhance a community's resilience to climate change-induced drought, flooding, and urban heat island effects?

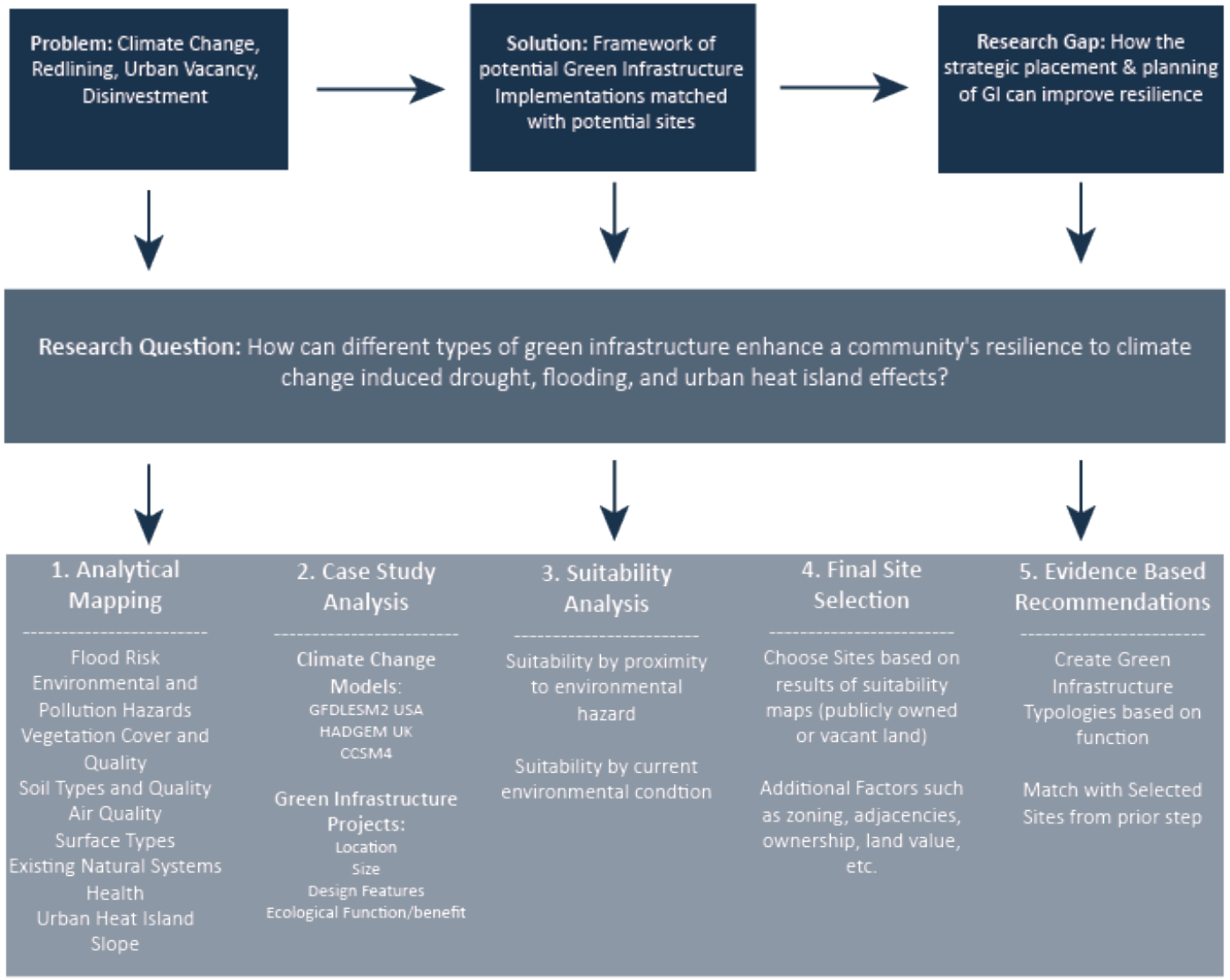
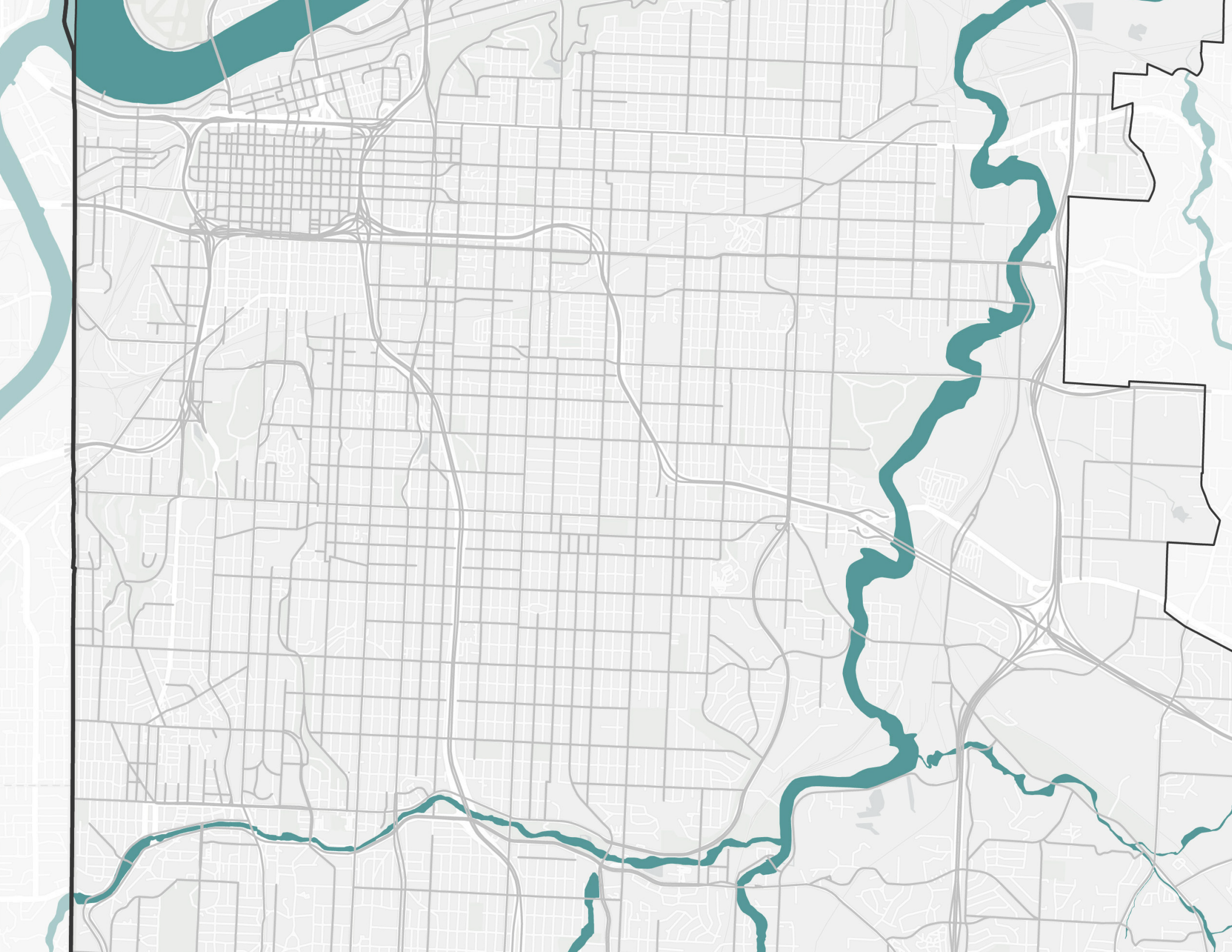


Figure 1.1: Study Process



2 Background Information:

Literature Review

This literature review aims to provide a deeper understanding of the significant factors that need to be considered when planning for future climate conditions in an urban setting. Figure 2.2 visualizes the topics explored in the following sections and their subsequent relationships to one another.

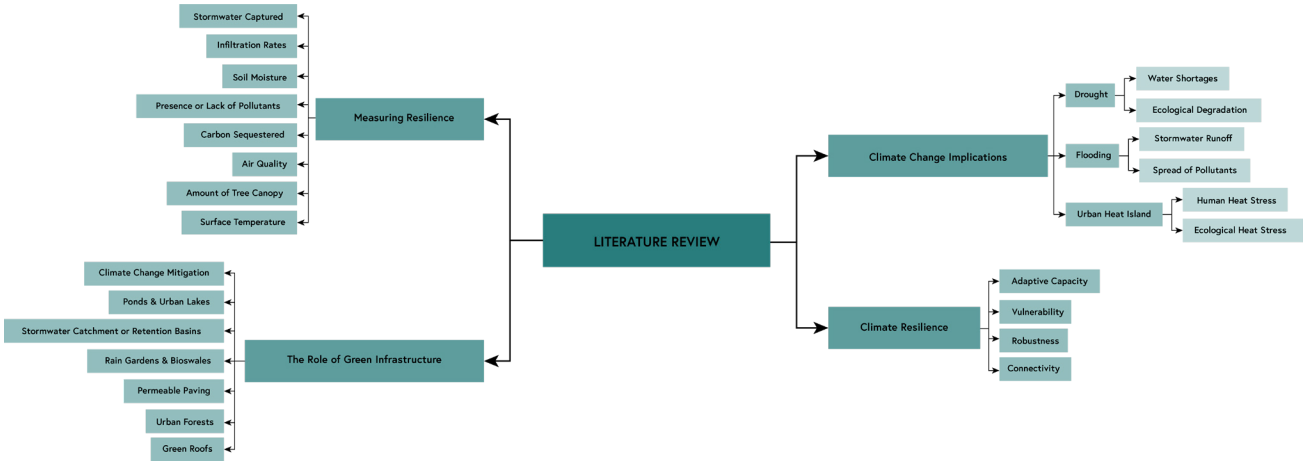


Figure 2.2: Literature Review Diagram

Climate Change Implications

Climate change has been a significant topic of discussion recently, as the impacts have begun to be felt across the globe. Climate change's long-term impacts on people depend on one's geographic location and socio-economic status. While most of the phenomena discussed in the following sections are naturally occurring cycles, their impacts will be far more extreme and long-lasting due to the influence of climate change.

Drought

Droughts are a deficit or lack of precipitation in an area over a notable period (AWWA, 2019; City of Kansas City, Missouri, 2022; Grant, 2012; Kloesel, 2018). Droughts are a natural part of the hydrologic cycle but can be challenging to predict and prepare for as they are a part of the same cycle as flooding. For example, a city may experience several years of drought conditions, followed by significant precipitation the following year. Due to the years of drought, higher amounts of precipitation or a flooding event could cause more damage and take longer for the area to bounce back from the event (Cook et al. 2007).

In urbanized areas, droughts pose several distinct threats, such as water scarcity and ecological degradation. Droughts can have catastrophic and vast impacts, especially in regions highly dependent on groundwater resources, such as cities in the Midwest. While it is essential to acknowledge the innate impacts drought will have on human health, this study primarily focuses on climate change's ecological impacts. Furthermore, a significant problem the natural environment faces due to droughts is the inability to recharge or replenish groundwater resources. Without adequate precipitation, groundwater resources will be used faster than they are replenished, causing water shortages (Grant, 2012). This is of great concern in urbanized areas, which, as previously discussed, house

many vulnerable communities that are more susceptible to experiencing water shortages or degraded water quality as a direct result of the disinvestment in their communities. Ecological degradation is another significant impact of increased drought conditions due to climate change. When natural water systems begin to dry out due to drought, the quality of the soils and vegetation of these systems often become degraded and more vulnerable to the inverse hydrologic impact of flooding. Additionally, the traditional method of dealing with flooding threats has inversely made urban areas more susceptible to negative drought impacts. The grey infrastructure located within cities has inversely contributed to the effects of drought in urban areas, as these engineered systems push water away from city centers during significant precipitation events, which then cannot be collected or used by the inhabitants later during periods of drought (Tauhid, 2018).

Flooding

Flooding is typically characterized by increased precipitation within a region, which causes an existing waterway to inundate surrounding dry land (Grant, 2012; Tauhid, 2018; Webber and Samaras, 2022). Flooding poses a significant threat to urban areas due to the high population in these centers, in addition to the presence of industrial or human-caused pollution. This is of great concern, as climate change projections anticipate that rainfall events will occur more frequently and for far more extended periods of time (City of Kansas City, Missouri, 2022; Tauhid, 2018).

Because of this anticipated trend in precipitation, cities will be more vulnerable to the flooding of natural water systems in the region, such as rivers, streams, or creeks, because of the historical approach and treatment of these natural systems (Grant, 2012). Most modern-day cities have highly degraded floodplains due to development encroaching on or entirely covering what was once a natural floodplain (Grant, 2012). A flood plain is the space surrounding a waterway that often floods when the water system overflows (National Geographic, 2023). These modern conditions make cities more vulnerable to the negative impacts of flooding. While flooding is a natural phenomenon, human activity and development in these areas have altered how these natural systems function, and as a result, the water can no longer be absorbed by the floodplain.

Additionally, human development within floodplains has introduced pollution into the water and soil systems in the area, which can quickly spread when flooding events occur and can have vast impacts on the area's water quality and ecosystem health (Angel, 2018; Tauhid, 2018). Due to the traditional grey infrastructure approach to mitigating flood impacts, flooding in urban areas can often have 'domino effects' on surrounding communities. Grey infrastructure is designed to capture water from an area and channel it downstream most efficiently to limit the damage done to an area using highly engineered systems (Grant, 2012). Because the predominant infrastructure cities have in place to manage or cope with flooding events is often impervious, high rates of stormwater runoff and lower rates of infiltration back into the ground are typical in these areas. This approach to mitigating the impacts of flooding is no longer practical on its own, as it does not slow the water down enough to infiltrate into the ground, resulting in a mass amount of water being lost and pollution spreading across large areas of land.

Flooding poses an additional threat, as drought and flooding cycles are highly dependent on one another, and climate change poses the extra risk of these natural processes having catastrophic and long-term impacts. As previously discussed, flooding can become more catastrophic after a long period of drought due to the ecological degradation that often occurs during periods of lower precipitation. When these natural systems are not healthy and no longer function properly, the surrounding area's vulnerability increases due to the system's inability to cope with the inundation of precipitation.

Urban Heat Island

Urban Heat Island is a newer phenomenon that has been studied more recently due to the rapid urbanization of cities across the globe over the last century or so. The urban heat island effect can be explained as the much warmer temperature trends in urbanized areas compared to surrounding rural areas due to the abundant use of impervious paving materials and building mass (Grant, 2012; MARC & Climate Action KC, 2021). While urban heat islands have been observed for a long time, climate change is expected to intensify its impacts through an overall increase in average temperatures in conjunction with an increase in the amount, intensity, and duration of severe heat waves (Kloessel, 2018). This trend is of great concern in the summer months due to the projected increase in consecutive hot days and the impact this will have on evaporation rates. According to the Fourth National Climate Assessment, hot days are characterized by the maximum temperature of an area reaching 100 degrees Fahrenheit or higher (Kloessel, 2018).

The primary threats related to urban heat islands that are of most significant concern in this study include anticipated heat stress on humans and the environment and ecological degradation caused by heat stress on the natural environment. Urban heat island impacts will disproportionately impact communities within cities depending on where they live and how they travel daily. For example, people who are more reliant on active transportation, such as walking or biking, will be more vulnerable to these impacts as they will be far more exposed to these conditions daily (MARC & Climate Action KC, 2021). Additionally, communities of lower economic status tend to live in areas with less access to quality tree canopy and regions with higher percentages of impervious surface cover (MARC & Climate Action KC, 2021). Concerning urban heat island trends, this poses a significant disadvantage to these communities because people who rely on active transportation have less access to shade produced by trees, resulting in an increased vulnerability to heat-related stress or hazards.

Another major threat related to urban heat islands is the subsequent stress on ecological systems due to extreme heat events. Typically, prolonged periods of extreme heat are accompanied by an overall lack of precipitation. This results in the moisture, typically stored in soils and plants, being evaporated into the air much faster than usual (Grant, 2012). Because of this higher rate of evaporation and lower amounts of water entering these systems to replenish the evaporated water, they can quickly become dried out and degraded, affecting how these systems function daily.

Climate Resilience

Urban settings pose a unique challenge when planning for climate change impacts, as they are home to a highly diverse population. Climate change in the urban setting poses an additional threat, as these issues will disproportionately negatively impact vulnerable communities. Vulnerable communities are groups of people who may be more susceptible to the adverse impacts of climate change due to their socioeconomic status, geographic location, illness, or disability (MARC & Climate Action KC, 2021). Different populations in an urban setting will be more vulnerable to unavoidable climate change impacts depending on their physical abilities and socio-economic standing.

Because of this issue's complexity and the uncertainty associated with future climate hazards, it is pivotal that cities plan to boost their resilience to these future disasters. Climate resilience is vital as climate change impacts increase in frequency and severity. Due to the multidimensional threats these climate hazards pose, it will be critical to begin planning ways to address these related issues (Meerow & Stults, 2016).

There are many ways to define resilience, but this study focuses on three specific parameters that contribute to a system's resilience: adaptive capacity, robustness, and connectivity. While an extensive number of parameters could be

evaluated, adaptive capacity, robustness, and connectivity were chosen due to their relevance to the greater threat of climate change and their ability to theoretically measure them.

Adaptive capacity is the ability of a system to change or evolve due to a climate disaster or hazard (MARC & Climate Action KC, 2021; Meerow and Stults, 2016; Pamukcu-Albers et al., 2021). The ability of a natural system to adapt to future climate trends and conditions will be critical as future climate projections show significant pendulum swings in long-term climate conditions. This means that natural systems will need to be designed and implemented to encourage them to evolve with the surrounding conditions. This can be addressed by using diverse and native plantings in these systems (City of Kansas City, Missouri, 2022).

The term robustness refers to a system's ability to mitigate the impacts of a climate disaster on other systems (Meerow and Stults, 2016; Zuniga-Teran et al., 2020). The concept of robustness is fundamental, as it relates to addressing an issue at the source and trying to stop a potential domino effect. In urban settings, robustness is often looked at in association with the existing grey infrastructure of an area and how implementing an additional nature-based system may increase the robustness of the systems (Zuniga-Teran et al., 2020).

Connectivity is a crucial aspect of resilience as it relates to the relationship between one system and other existing or future systems in an area (Tauhid, 2018; Zuniga-Teran et al., 2020). A significant benefit of connected green infrastructure systems is how their functions can address various threats in one area (Ramyar et al., 2021). For example, suppose there are green infrastructure systems located in relation to one another. In that case, their ability to address a variety of potential climatic hazards will boost the whole area's climate resilience. Connectivity can also relate to wildlife migration in these areas through reconstructing wildlife corridors in the urban environment (Tauhid, 2018; Zuniga-Teran et al., 2020).

The Role of Green Infrastructure

Lately, cities have been investigating how implementing green infrastructure can help mitigate a variety of climate change impacts. Green infrastructure, or nature-based solutions, work with natural systems and ecosystem services to address climatic hazards such as drought, flooding, and urban heat island effects. These systems are often used in conjunction with or instead of traditional grey infrastructure networks to address drought, flooding, and urban heat island risks.

Green Infrastructure to Address Droughts

The focus and function of green infrastructure systems, designed to address drought issues, are centered around the storage, recycling, and reuse of two types of water: greywater and stormwater. Greywater is wastewater produced within buildings from appliances or things such as showers or laundry machines (National Academies of Science, 2016). Greywater reuse and recycling is a process that typically occurs on private properties, either through people's homes or workplaces, and is far less commonly applied in public spaces. Hence, this study centers more on stormwater catchment systems in public spaces. Stormwater is best defined as the water generated from rain or snowfall, which can be measured or obtained after a precipitation event (National Academies of Science, 2016). Standard green infrastructure systems that are used to capture, store, and reuse stormwater are ponds, urban lakes, and stormwater catchment systems.

Ponds and Urban Lakes

Ponds and urban lakes are naturally occurring systems that can be designed or mimicked to achieve the same functions. These systems are functioning ecosystems that provide habitat and various ecosystem services, including the storage and subsequent infiltration of stormwater in urban settings (Pamukcu-Albers et al., 2021). Of course, like all-natural systems, their health determines the quality of services provided. Ponds and urban lakes offer the opportunity to capture stormwater and slowly filter it back into the ground, actively cleaning the pollutants out of the stormwater through the vegetation and soil systems (Grant, 2012). See Figure 2.3 for a visual example of an Urban Lake.

Figure 2.3: Urban Lake Precedent (Living Architecture Monitor, 2022)

Stormwater Catchment or Retention Basins:

Another approach to harvesting and reusing stormwater in urban areas is through stormwater catchment systems. These systems tend to be more engineered and designed to catch water at one location and store it for use and treatment in another. For example, a vegetated catchment basin may be designed to retain stormwater and filter some of it through the vegetation and soil, while the rest gets channeled into a pipe and sent to the existing grey infrastructure system (Gordon et al., 2018; Tauhid, 2018). Additionally, using native plantings within these basins is beneficial during periods of drought, as these plants tend to be more able to withstand minimal amounts of precipitation and support necessary pollinator species (Angel, 2018; City of Kansas City, Missouri, 2022; MARC & Climate Action KC, 2021). See Figure 2.4 for a visual example.

Figure 2.4: Stormwater Retention Basin (Lenexa Kansas, 2024)

Green Infrastructure to Address Flooding

The main functions of green infrastructure systems, designed to address flood hazards, are improving stormwater runoff and infiltration rates. These two areas are of particular concern in urban areas due to the high percentages of impervious surfaces, as discussed in prior sections. Paired with existing grey infrastructure in an area, green infrastructure systems can create a more holistic approach to mitigating flood hazards in urbanized areas (Grant, 2012; Tauhid, 2018; Zuniga-Teran et al., 2020). The following sections focus on evaluating several types of green infrastructure that have been widely used to address and mitigate flooding impacts. These systems have many ecosystem benefits besides their primary functions, which are mentioned but not the focus of this literature review.

Rain Gardens and Bioswales

Rain Gardens are a commonly used green infrastructure system that aims to mitigate flood impacts at or near the source. These systems are typically designed as a shallow basin or trench, which houses a wide range of drought and flood-tolerant native vegetation, see Figure 2.5 (Grant, 2012; Webber and Samaras, 2022). The process of selecting species for rain gardens is critical to the system's success and must withstand a wide range of conditions. In addition to filtering out pollutants from stormwater, native plants used in rain gardens can be a source of habitat for various species and support key pollinator species (Grant, 2012). In addition to species selection, soil type and quality are also crucial to rain gardens' health and success. Rain gardens require permeable and quickly draining soils to increase infiltration capacity (Grant, 2012).

Bioswales are designed with similar functions and intent to rain gardens, see Figure 2.6. Still, they are slightly different as they are typically accompanied by some underground pipe or engineered system that connects to the area's grey infrastructure network. Bioswales are usually used near buildings or significant developments to encourage the water to flow away from these spaces or to be harvested underground (Webber and Samaras, 2022). While these systems do have a connected pipe that aims to channel water away from the system, the design of these vegetated systems still can filter out contaminants and infiltrate water into the ground as rain gardens do (Tauhid, 2018).

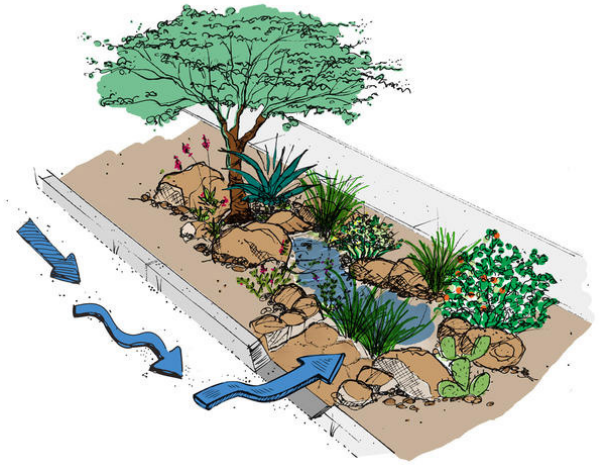


Figure 2.5 Rain Garden Precedent (Watershed Management Group, 2014)

Figure 2.6 Bioswale Precedent (Lenexa Kansas, 2024)

Permeable Paving

Permeable paving is a simple solution to improving an area's ability to cope with flooding. Permeable or pervious surfaces allow or encourage water to infiltrate into the ground below them, see Figure 2.7. Using permeable surfaces such as vegetation, gravel, permeable pavers, etc., reduces runoff rates in cities and lessens the amount of moisture lost from the ground daily (Block et al., 2012).

Due to how cities have been developed over time, most urbanized areas have large percentages of their surface area covered in impervious materials. Impervious surfaces, or surfaces that prohibit water from passing through them have extensively affected the quality and health of urban soils. Typically, urban soils in areas with high amounts of impervious paving face issues of low soil moisture, high levels of compaction and pollution, nutrient deficiencies, and a lower volume of space for plant roots to grow in (Block et al., 2012). Because of the impact impervious paving has on the health of soil and flooding, many cities are looking into ways to increase permeability across urbanized regions. While this is an ideal proposition, one hindrance to this solution is the often high financial cost of tearing out concrete or other surface types and replacing them with a permeable option.

Figure 2.7 Permeable Paving Precedent (Lenexa Kansas, 2024)

Green Infrastructure to Address Urban Heat Island

Green infrastructure systems, commonly used to address the urban heat island effect, are primarily focused on providing shade and reducing evapotranspiration rates, see figure 2.8. These two functions are vital to reducing the urban heat island effect due to their ability to change the area's microclimate (Balany et al., 2020; Grant, 2012; Pamukcu-Albers et al., 2021). Shade is a crucial factor in addressing urban heat islands as it blocks the solar radiation from the sun and cools the surrounding area (Belany et al., 2020). Furthermore, evapotranspiration is the release of water through plants or soil, which evaporates into the air. Urban forests and green and white roofs are widely used to mitigate the impacts of the urban heat island effect. They are successful due to their ability to regulate and cool the microclimate of urban areas. While these two systems can provide many benefits and can also be used to address issues of flooding and drought, they were analyzed in the following section through their ability to mitigate the impacts of urban heat islands.

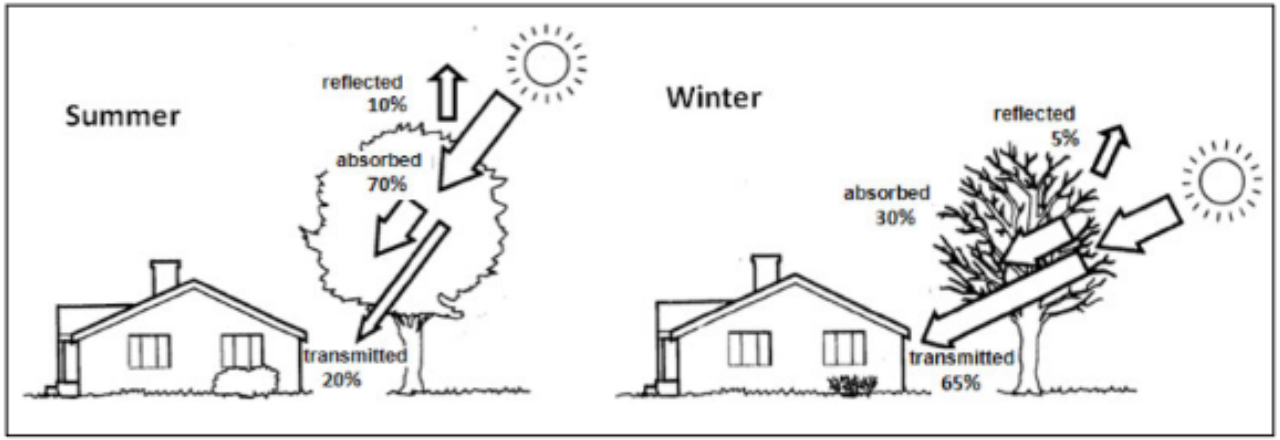


Figure 2.8: Urban Heat Island Diagram (Block et al., 2012)

Urban Forests

Trees are a precious resource when it comes to the regulation of our environment. They provide a multitude of benefits including increased shade, lower rates of evapotranspiration, soil stabilization, carbon sequestration, flood risk mitigation, and a variety of other ecosystem services (City of Kansas City, Missouri, 2022; Grant, 2012; MARC & Climate Action KC, 2021; Pamukcu-Albers et al., 2021; Sturiale and Scuderi, 2019; Zuniga-Teran et al., 2020).

The term 'urban forests' refers to the naturally forested areas and systems that are protected and conserved in the urban environment; these systems often surround riparian or stream corridors in the urban environment (City of Kansas City, Missouri, 2022). These natural systems provide many benefits, but due to rapid urbanization in many cities worldwide, these systems are in poor health and are not always protected and prioritized, see Figure 2.9.

Street trees also play an essential role in addressing urban heat island impacts. The selection and location of street trees are crucial, as the urban environment is generally unsuitable for many trees to thrive. Additionally, street trees' attributes, such as their leaf type and growing patterns, highly impact their ability to mitigate urban heat island impacts. For example, broad-leaf deciduous trees are commonly used to provide shade and regulate the microclimate of their immediate surroundings (Pamukcu-Albers et al., 2021).

Using urban tree canopy as green infrastructure to address urban heat islands is most successful when approached through a forestry or ecosystem perspective. This means that each tree in the area is part of a more extensive interconnected system of trees, in which biodiversity should be prioritized, and the health of each tree has the potential to impact another (Grant, 2012; Zuniga-Teran et al., 2020).

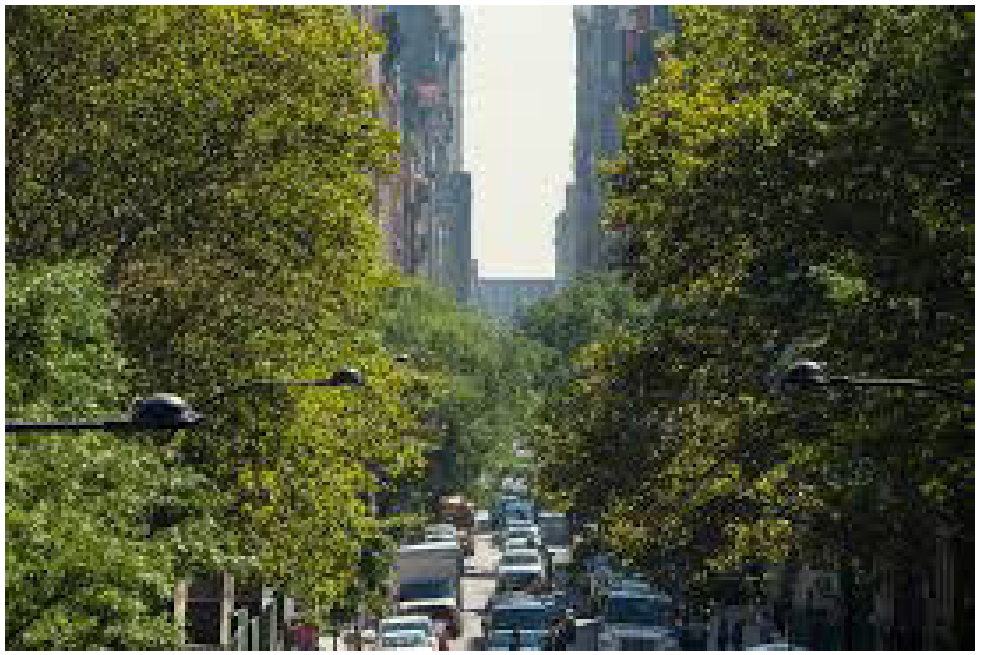


Figure 2.9: Urban Forest Graphic (USDA, 2015)

Green Roofs

Green roofs provide a unique opportunity in urban areas, allowing more minor scale interventions in areas with limited open and available green space (Balany et al., 2020). Green roofs can be a valuable piece of green infrastructure in densely developed settings, primarily used to mitigate the urban heat island effect, but can also be beneficial in collecting and infiltrating stormwater (Grant, 2012; Tauhid, 2018; Webber and Samaras, 2022; Zuniga-Teran et al.).

There are two main types of green roofs: intensive and extensive, see Figure 2.10. The primary difference between these two systems is the depth of the soil layer implemented on the roof (Balany et al., 2020). Intensive green roofs are designed to plant larger plants or trees and use a deeper base layer of soil to support these plants' more extensive root mass. While intensive green roofs can support more robust plantings, they are also far more costly and require more regular maintenance and watering (Belany et al., 2020). Extensive green roofs use a shallower layer of soil, which requires far less initial cost and maintenance and can support a lesser variety of vegetation (Belany et al., 2020). In addition to plantings, green roofs can incorporate water retention systems, such as rain barrels, to catch stormwater, and they can either store it on-site and reuse it for any potential irrigation needs or channel it into surrounding systems.

Figure 2.10: Green Roof Precedent (Shigley, 2010)

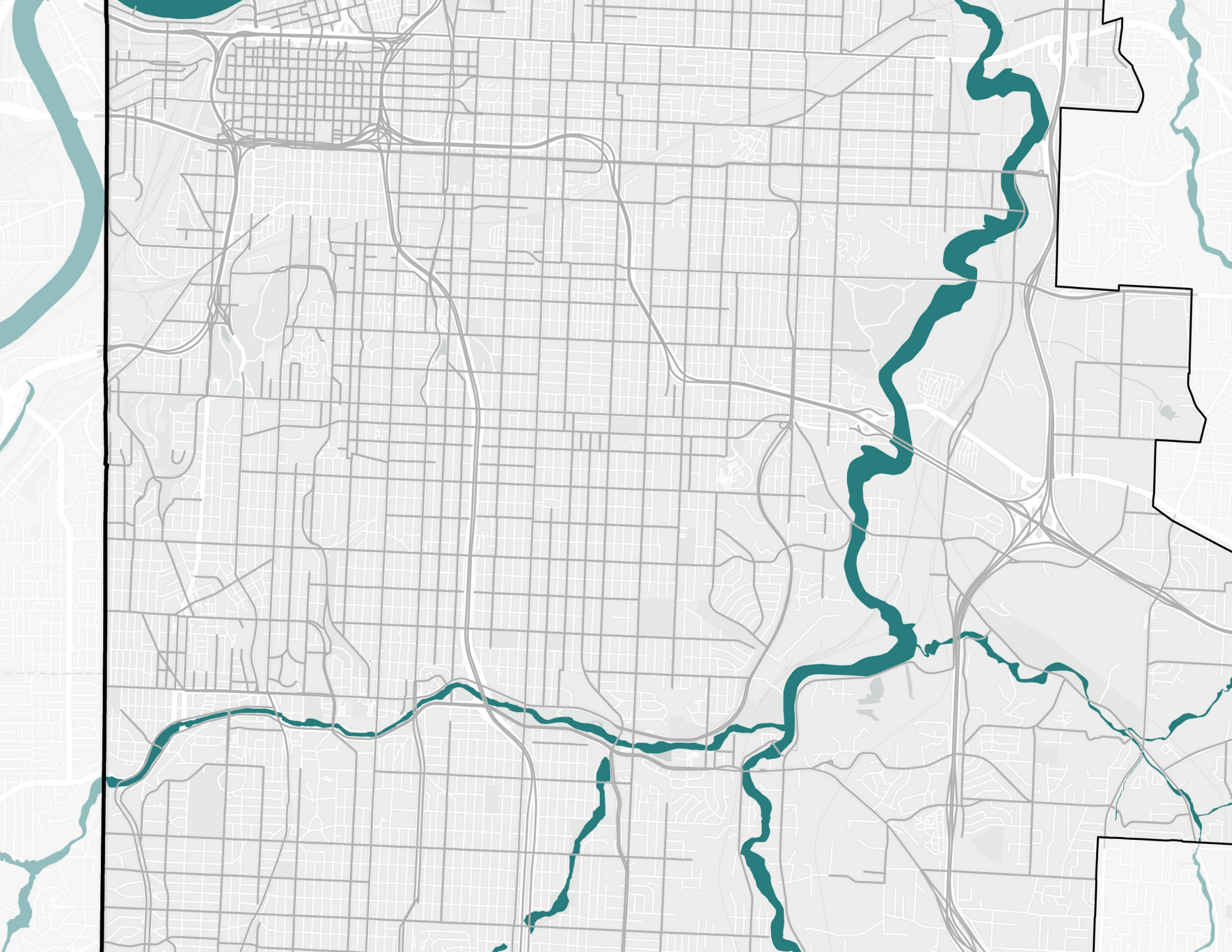
Measuring Resilience

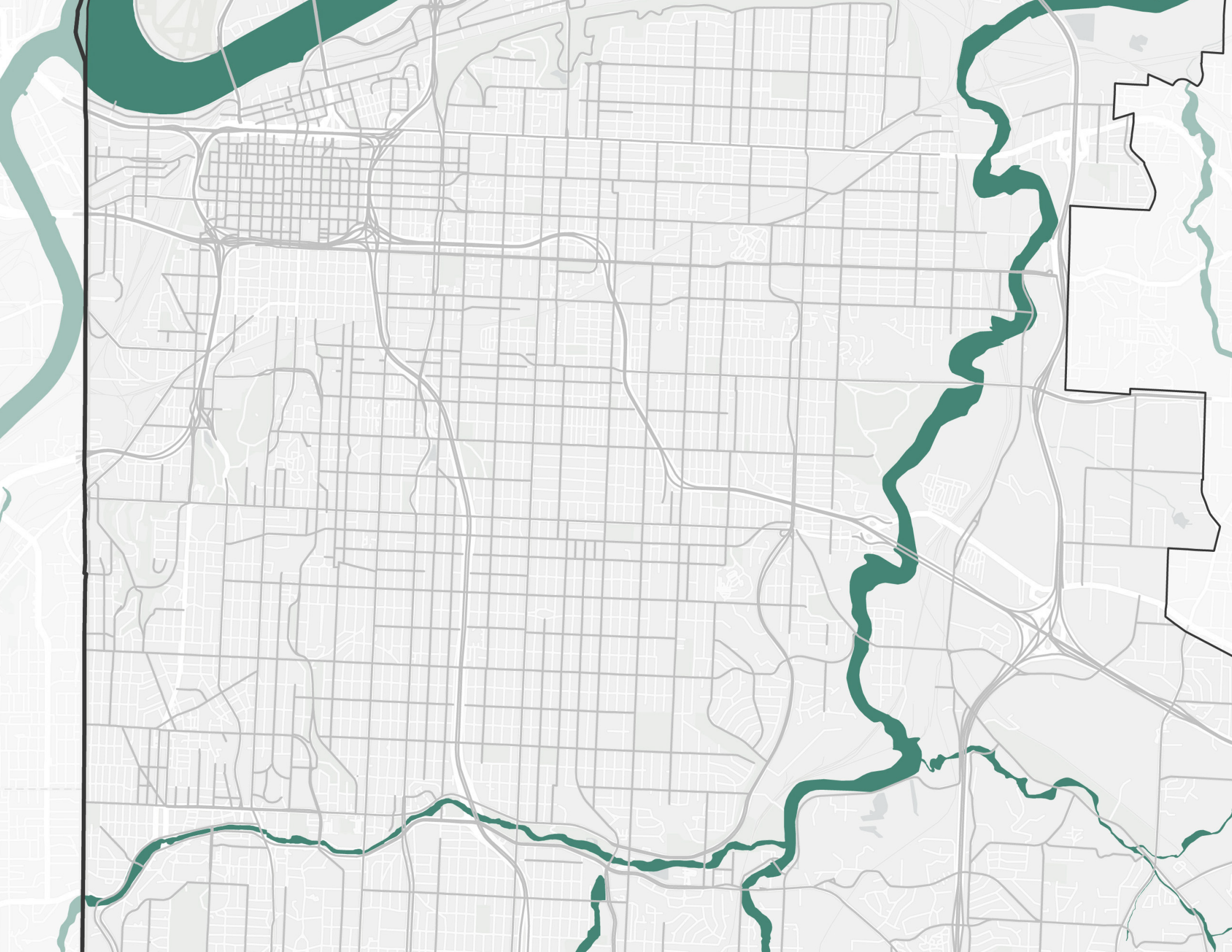
When measuring or quantifying resilience, researchers are typically focused on measuring the functions and goals of a system (Webber and Samaras, 2022). Because of this, green infrastructure systems must be designed to meet a specific set of functions or goals. Typically, measurements will be taken to understand the area's existing conditions before implementation. Then, these same metrics will be measured after the system has been established to gain an understanding of an increase or decrease in resilience. Metrics that typically relate to measuring the resilience of systems designed to address drought, flooding, or urban heat islands might include but are not limited to the amount of water captured, infiltration rates, soil moisture, evapotranspiration rates, average surface temperature, presence/amounts of pollutants, and biodiversity levels (Gordon et al., 2018; Webber and Samaras, 2022). Table 2.1 organizes the potential metrics related to green infrastructure based on the ecological function or goal of the system.

A couple of other aspects of measuring the resilience of green infrastructure systems relate to these systems' adaptive capacity, robustness, connectivity, and vulnerability. These four concepts shape our understanding of how these systems were designed and their ability to evolve with the changing environment. Addressing these aspects when designing potential green infrastructure systems is a way to ensure that green infrastructure is designed to withstand potential climate hazards or disasters.

Table 2.1: Measuring Resilience

Green Infrastructure Function	Measurable Outcome
Mitigate Drought	-Water Captured -Infiltration Rates -Soil Moisture
Mitigate Flooding	-Water Captured -Infiltration Rates -Presence or Lack of Pollutants
Mitigate Urban Heat Island	-Carbon Sequestered -Air Quality -Amount of Tree Canopy -Surface Temperature





3 Methods:

The study area chosen for the research proposal is located within nine neighborhoods in eastern Kansas City, Missouri. The nine selected neighborhoods are South Hyde Park, Manheim Park, Ivanhoe Southwest, Ivanhoe Southeast, Oak Park Southeast, Vineyard Northwest, Vineyard, and Vineyard Estates. The neighborhoods were selected for the focus of this project due to their history with redlining and discriminatory zoning laws (see Figure 3.11). These laws have had long-term consequences for the area, resulting in decades of disinvestment. As a result, this area is far more vulnerable to the negative impacts of climate change.

This study intends to investigate the existing environmental conditions in the study area to develop a deep understanding of its current health and hazards. Then, through spatial analysis of climate change models, a baseline understanding of potential climactic conditions in the near and distant future has been explored across the nine neighborhoods. This information was used as a 'benchmark' for future design interventions to ensure that the resulting product will have the capacity to withstand future climate conditions and hazards. In conjunction with climate change model case studies, green infrastructure case studies were analyzed for their size and effectiveness in addressing significant climate hazards and events. An additional round of analytical mapping was conducted to discover which sites within the study area are most suitable for potential revitalization. The following sections explain the steps taken to conduct this research project.

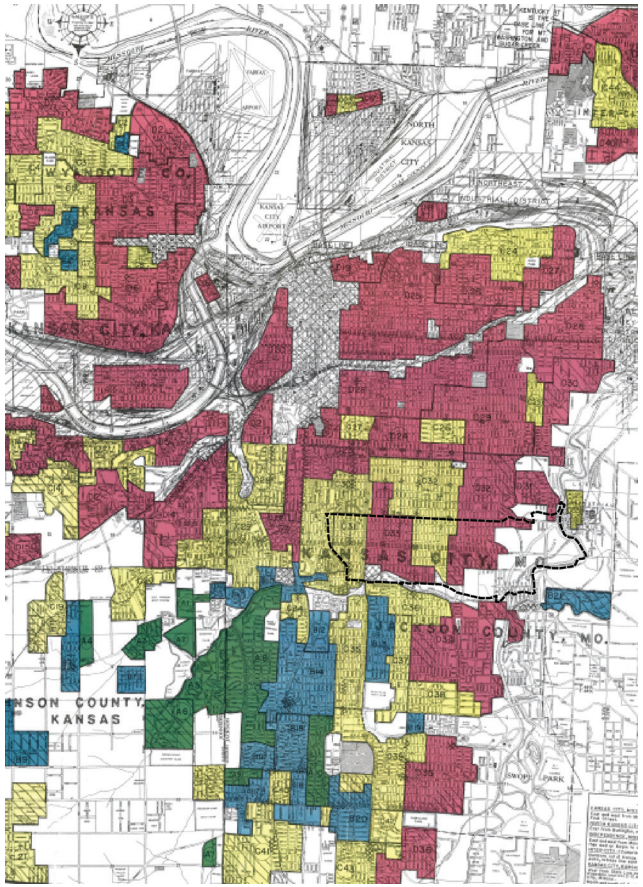


Figure 3.11: Study Area Within the Broader Historical Redlining Context (Mapping Inequality, n.d.)

Analytical Mapping

Analytical mapping of current environmental conditions within these nine neighborhoods in Kansas City, Missouri, was key to understanding the study area's current state. Several environmental factors were explored in depth through a variety of different analytical maps, as presented in Figure 3.12.

The information obtained through these analytical maps was organized and layered to conclude specific vulnerabilities the study area currently has and the environment's overall health in this area. Through the analysis of the listed environmental factors, the following thematic maps were created to explore the existing environmental trends and hazards of the study area, including vegetation cover, watersheds and stream health, flood risk, soil types and quality, soil, and water pollution hazards, urban heat island trends, and slope.

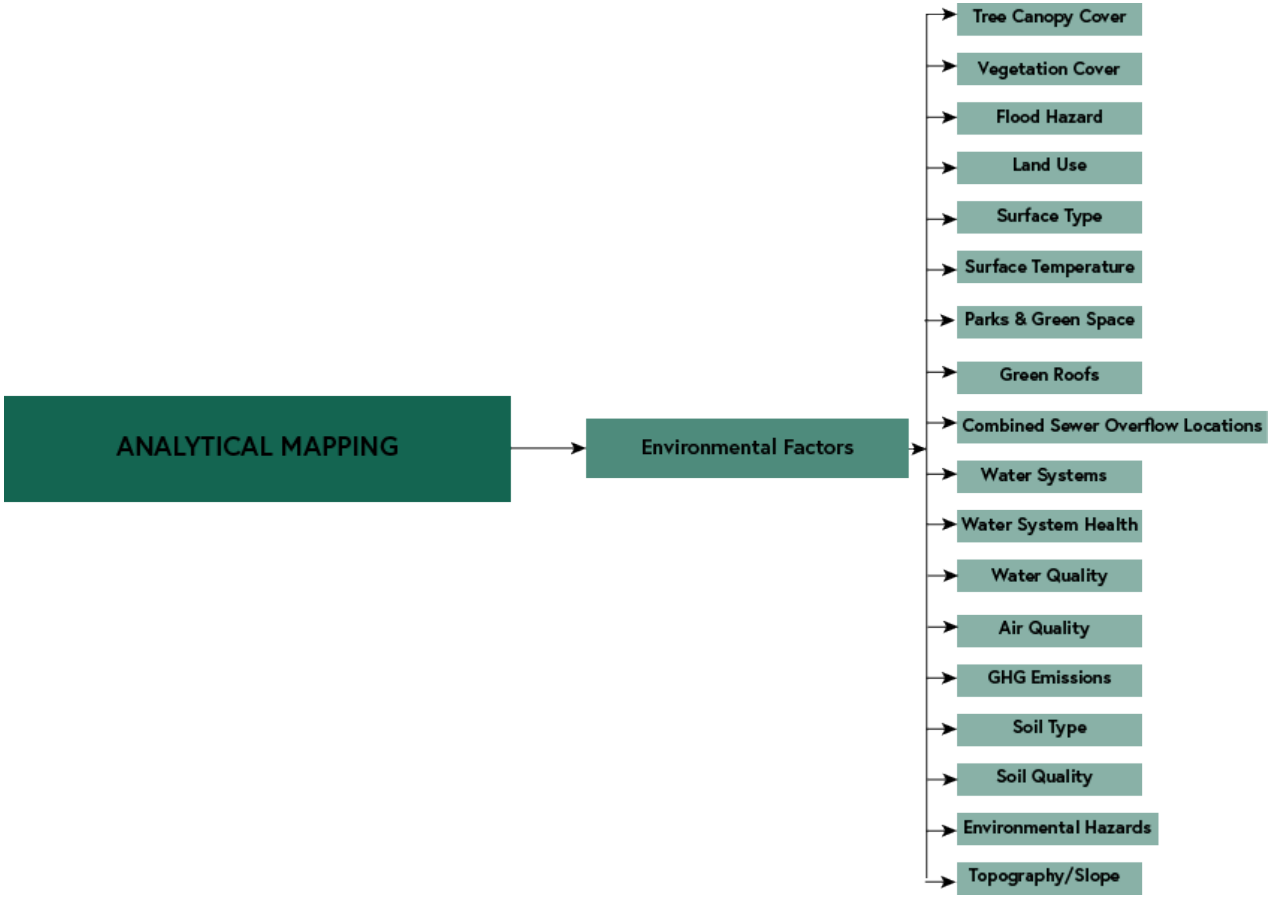


Figure 3.12: Environmental Factors to be Mapped and Analyzed

Vegetation Cover

Figure 3.13 visualizes the distribution of tree canopy and green space throughout the study area. From this map, we can see that there are significant gaps in tree canopy distribution in the Ivanhoe Southeast and Ivanhoe Southwest neighborhoods. Additionally, neighborhoods with existing parks and green spaces or naturally wooded areas appear to have more access to vegetation, but this does not indicate the quality or health of these existing systems.

Figure 3.13: Neighborhood Vegetation Cover

Watersheds and Stream Health

The entirety of this research project's study area falls within the more significant Blue River watershed. Additionally, Figure 3.15 visualizes the stream corridors within the study area and their current state of health. This information helped to inform where major drainage areas exist and potential areas that may need revitalization to address flooding and pollution threats.

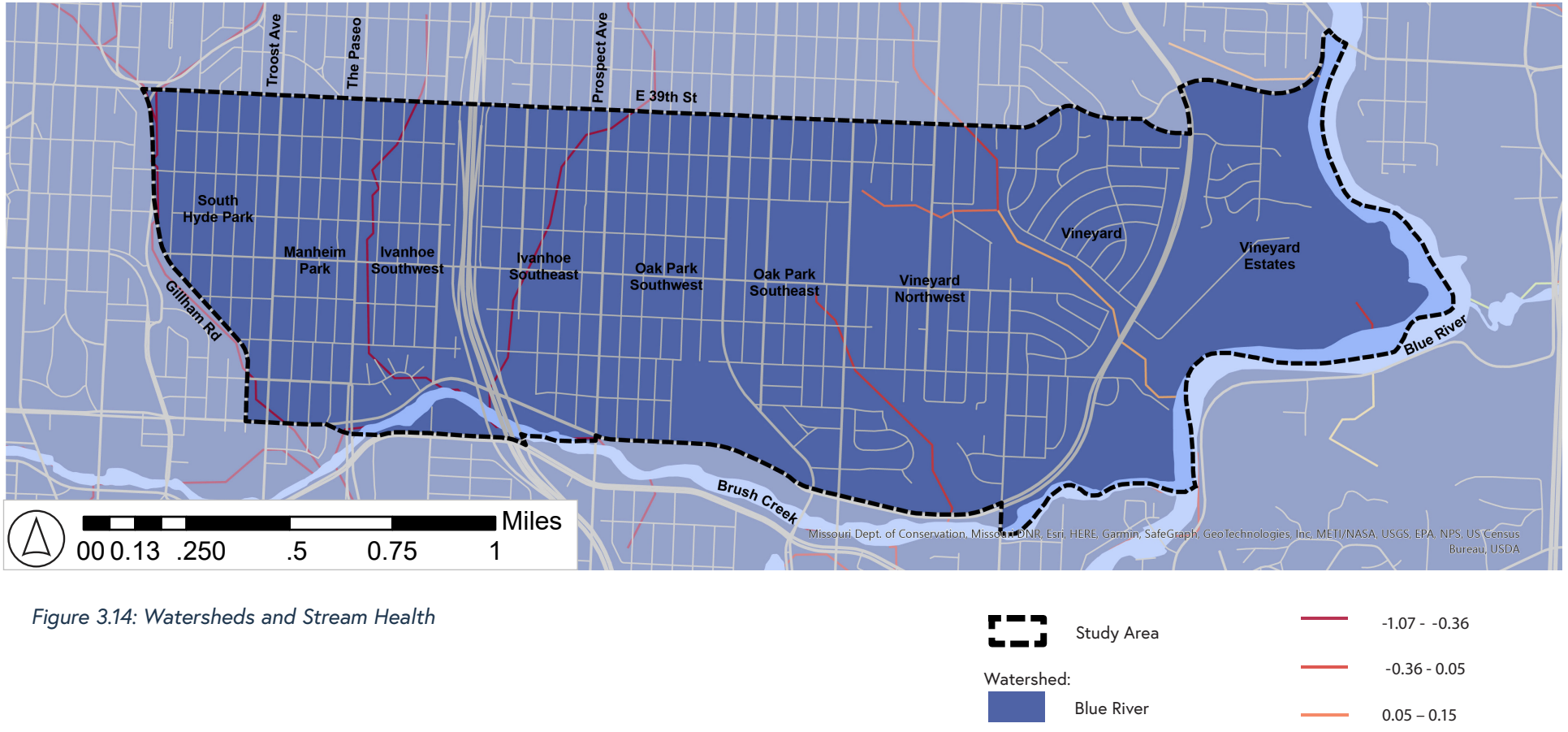


Figure 3.14: Watersheds and Stream Health

Flood Risk

According to Figure 3.16, the neighborhoods within the study area that are most vulnerable to flooding are Vineyard Estates, Vineyard, South Hyde Park, Ivanhoe Southwest, and Ivanhoe Southwest. There are additional concerns in these areas as there are high amounts of impervious surfaces and lower distributions of vegetation cover. These two factors add additional concern as they indicate that less water will be able to infiltrate the ground in this area, and runoff rates could be detrimental to the spread of flooding.

Figure 3.15: Neighborhood Flood Risk

Soil Types and Quality

The study area features three main types of soil: alfisols, entisols, and mollisols. Alfisols are typically clay-based soil with high natural fertility and, as a result, are often an ideal soil for agricultural use. Entisols are sand-based soils that are low in organic matter content. Lastly, mollisols are darkly colored soils high in organic matter and very fertile. Figure 3.17 visualizes the dispersal of these soil types within the study area. Due to the study area's urban setting, the soil type information was also layered with potential pollution sources, such as combined sewer outfall areas and hazardous waste sites, to determine possible sources of soil pollution or degradation.

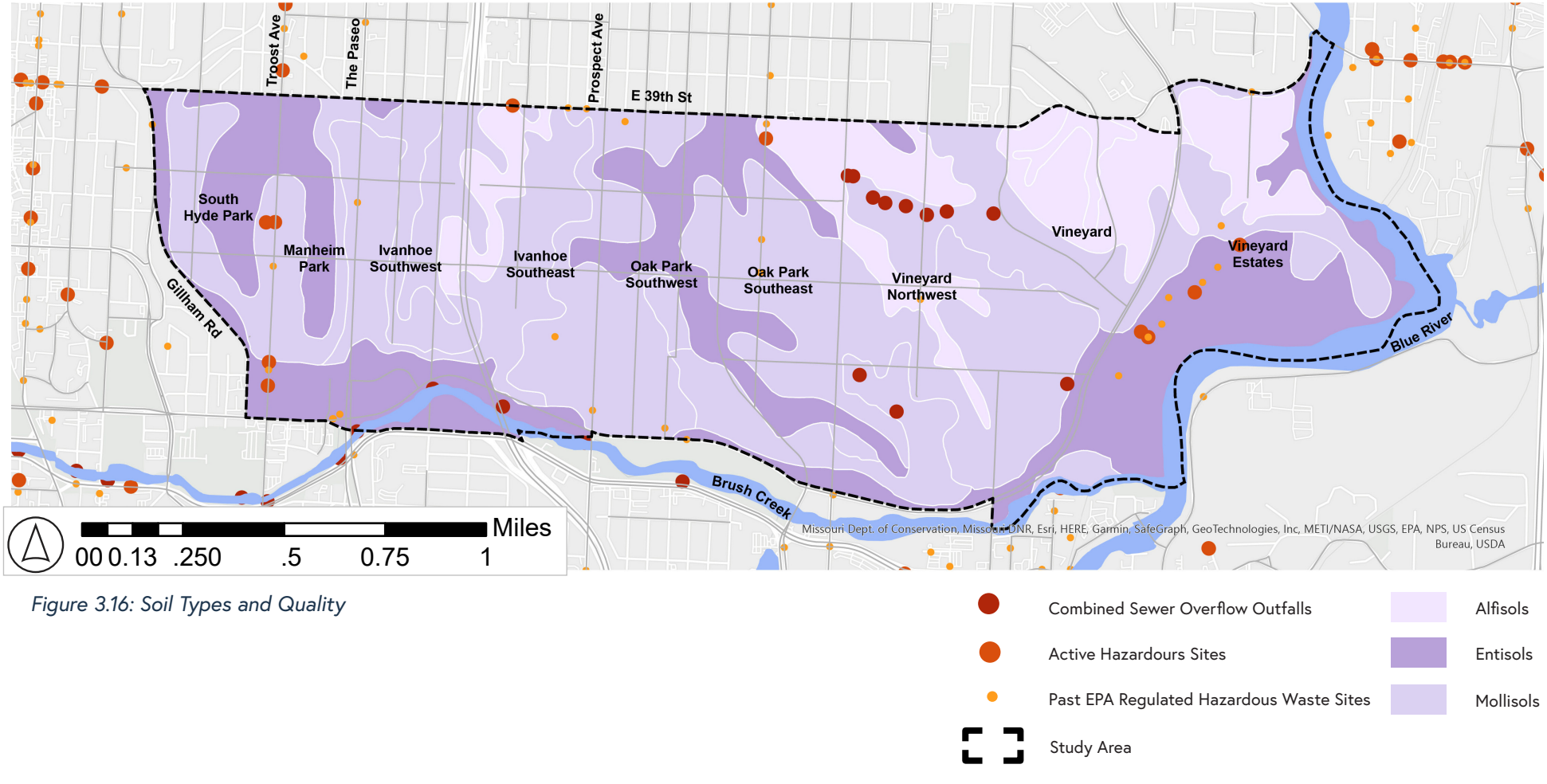


Figure 3.16: Soil Types and Quality

Soil and Water Pollution Hazards

Figure 3.18 demonstrates the relationship between existing and prior hazardous waste sites and the streams in the study area. In addition to known pollution sources, this map looks at reports of illegal dumping as a potential source of pollution. The location of these hazards is of great concern, as they align right along streams and drainage zones in the area, which are connected to the Blue River watershed and Brush Creek to the south. With the potential of increased flood frequency and longevity due to climate change, it will be essential to address these pollution sources to decrease the spread of hazardous materials to the surrounding environment.

Figure 3.17: Soil and Pollution Hazards (Hemsath, 2023)

- Combined Sewer Overflow Outfall
- EPA RCRA Hazardous Waste Sites
- Past EPA RCRA Hazardous Waste Sites
- Study Area
- Illegal Dumping
  - Sparse
  - Dense
- FEMA Flood Hazard Zone
  - 0.2% Annual Chance Flood Hazard
  - 1% Annual Chance Flood Hazard
  - Regulatory Floodway
- Stream Health Score:
  - < -0.36
  - -0.36 – 0.05
  - 0.05 – 0.15
  - 0.15 – 0.35
  - -0.35 – 0.43

Urban Heat Island Trends

The urban heat island trends currently taking place in the study area were spatially analyzed by examining the relationship between the presence of tree canopy and surface temperature. Figure 3.19 shows the need for increased tree canopy in many of the neighborhoods within the study area to decrease the severity of the urban heat island trends in this area.

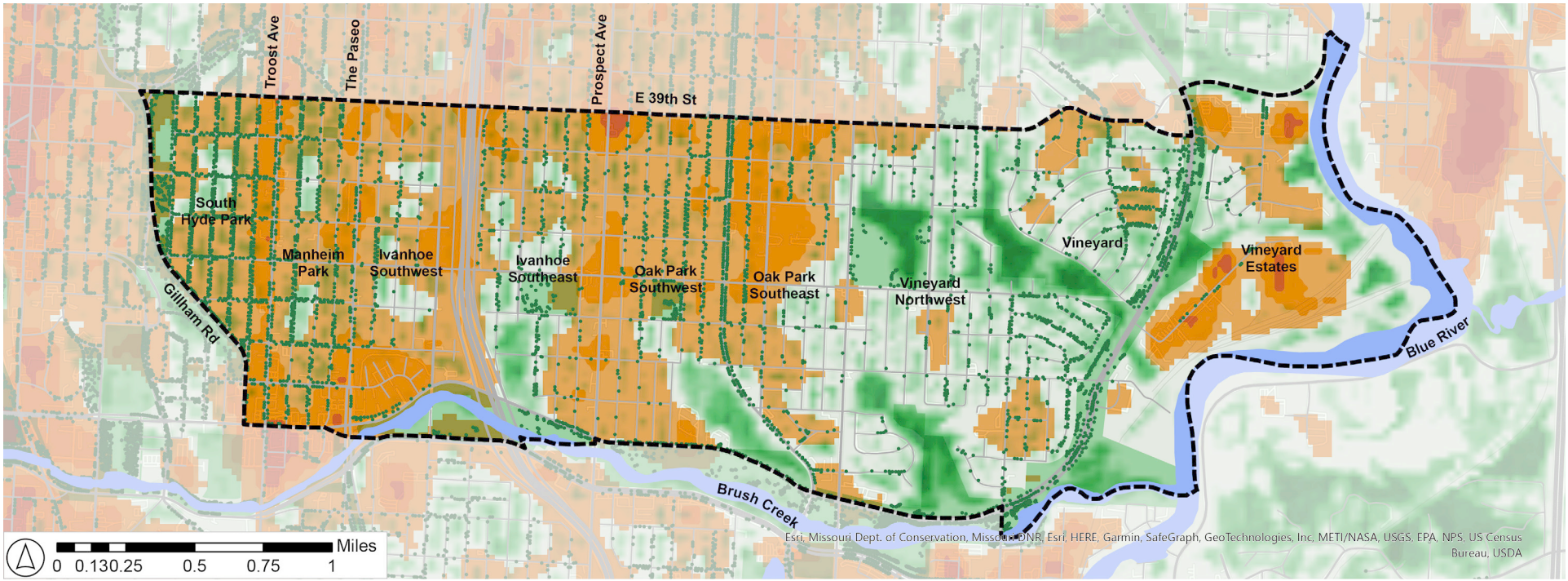


Figure 3.18: Urban Heat Island Trends (Hemsath, 2023)

Slope

As Figure 3.20 shows, the study area features widely varying slope levels across the entire space, ranging from 0-32% slope. The area's terrain can impact a variety of things, especially when it comes to understanding how water will drain/travel. Many of the highly sloped regions of the study area are understood to be streams or existing natural greenspaces, but a few areas are of concern as they are near or along major roadways. Steeply sloped roadways pose additional flooding threats, as the impervious material does not allow water to infiltrate the ground, resulting in mass amounts of stormwater runoff in the area. Looking to the future, implementing systems in these areas that would help to slow and infiltrate the stormwater would be of great benefit.

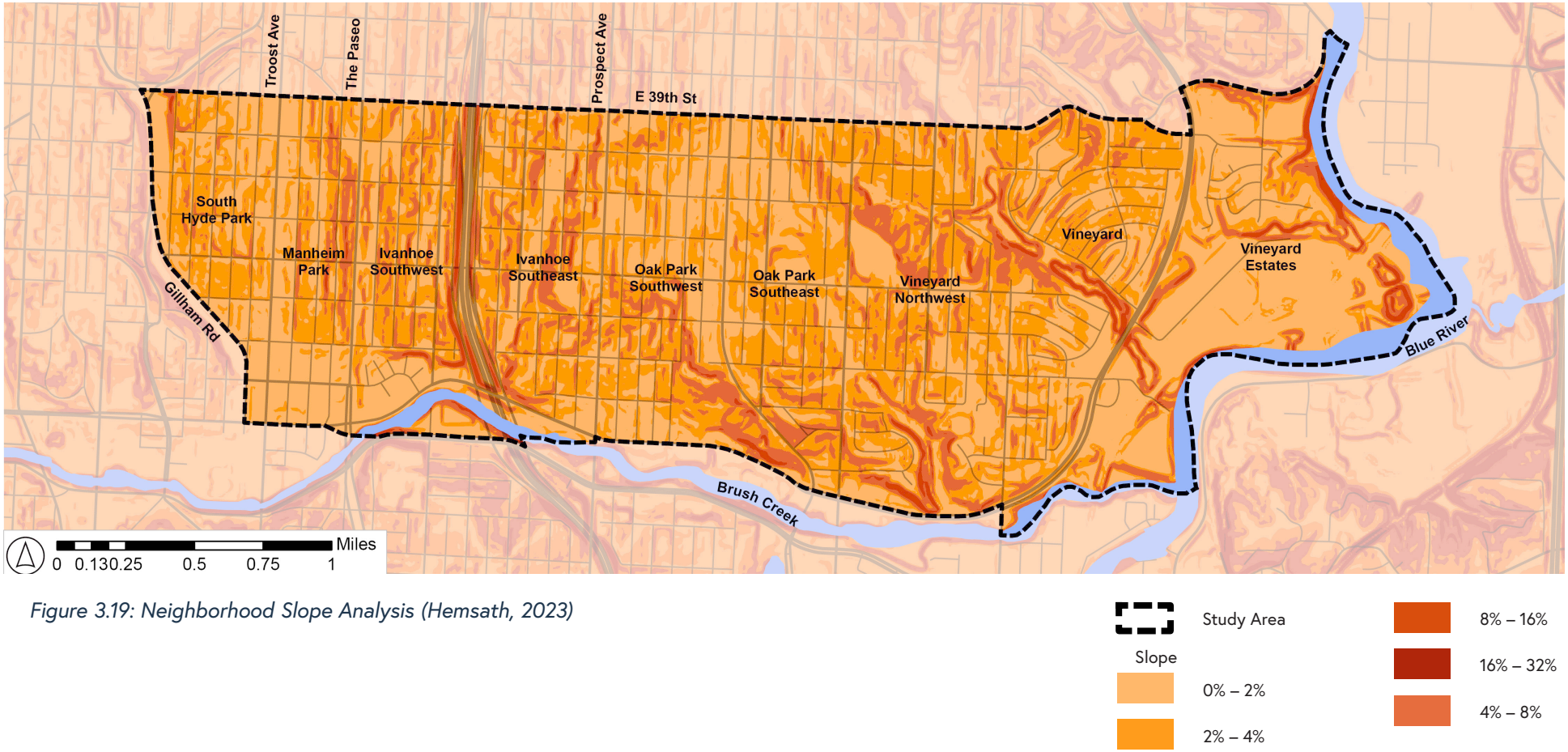


Figure 3.19: Neighborhood Slope Analysis (Hemsath, 2023)

Case Study Analysis

This project involved several different case studies to gain a deeper understanding of future climate projections and types of green infrastructure. By analyzing a series of climate projection models, I gained vital knowledge related to the future climatic and environmental conditions of the study area. Additionally, understanding what scale and types of green infrastructure work best through case study analysis informed decision-making around developing potential green infrastructure system typologies in later steps.

Climate Change Case Studies

Three different climate change models have been analyzed to better understand potential future climactic and environmental conditions. These climate models were also examined through two scenarios, RCP 4.5 and RCP 8.5. RCP or Representative Concentration Pathways are "consistent sets of projections of only the components of radiative forcing that are meant to serve as input for climate modeling, pattern scaling, and atmospheric chemistry modeling" (Science on a Sphere, 2023). RCP 4.5 uses projections based on the assumption that high amounts of carbon reductions will be made soon, while RCP 8.5 uses projections exhibiting high carbon emission rates. The climate models used for this process are the GFDL-ESM2M USA, HADGEM UK, and the CCSM4.

The Geophysical Fluid Dynamics Laboratory developed the GFDL-ESM2M climate model in the United States. This model is based on the interactions between five major components: the atmosphere, hydrosphere, cryosphere, land surface, and biosphere (GFDL, 2023). This information was compiled based on geographic location over time and can be used to understand potential future climatic conditions.

The HADGEM UK climate model, or the Hadley Centre Global Environment Model, was created in the United Kingdom. This climate model primarily uses combined atmospheric and oceanic data and living components such as vegetation and oceanic biology to indicate potential future climate trends and data (Collins et al., 2008).

Lastly, the CCSM4, or Community Climate System Model 4, comprises four different climate models that simulate the earth's atmosphere, sea-ice, land, ocean, land ice, and a 'coupler'. A coupler is a component of this model that "coordinates the models and passes information between them" (National Center for Atmospheric Research, 2020). This model explores how these components' interaction over time spatially impacts climate trends.

In addition to future climate data, historical climate data from the region was also gathered to understand the changes occurring in the area entirely. See Figure 3.21 for a breakdown of the types of climate data that were collected and analyzed.

Information obtained from these climate models was used as a "benchmark" for the projective design process to ensure all designs will meet the needs of future climate conditions. It is essential to look at several different climate models and scenarios, as future climactic conditions will be highly variable and hard to predict, and no model can 100% accurately predict these conditions.

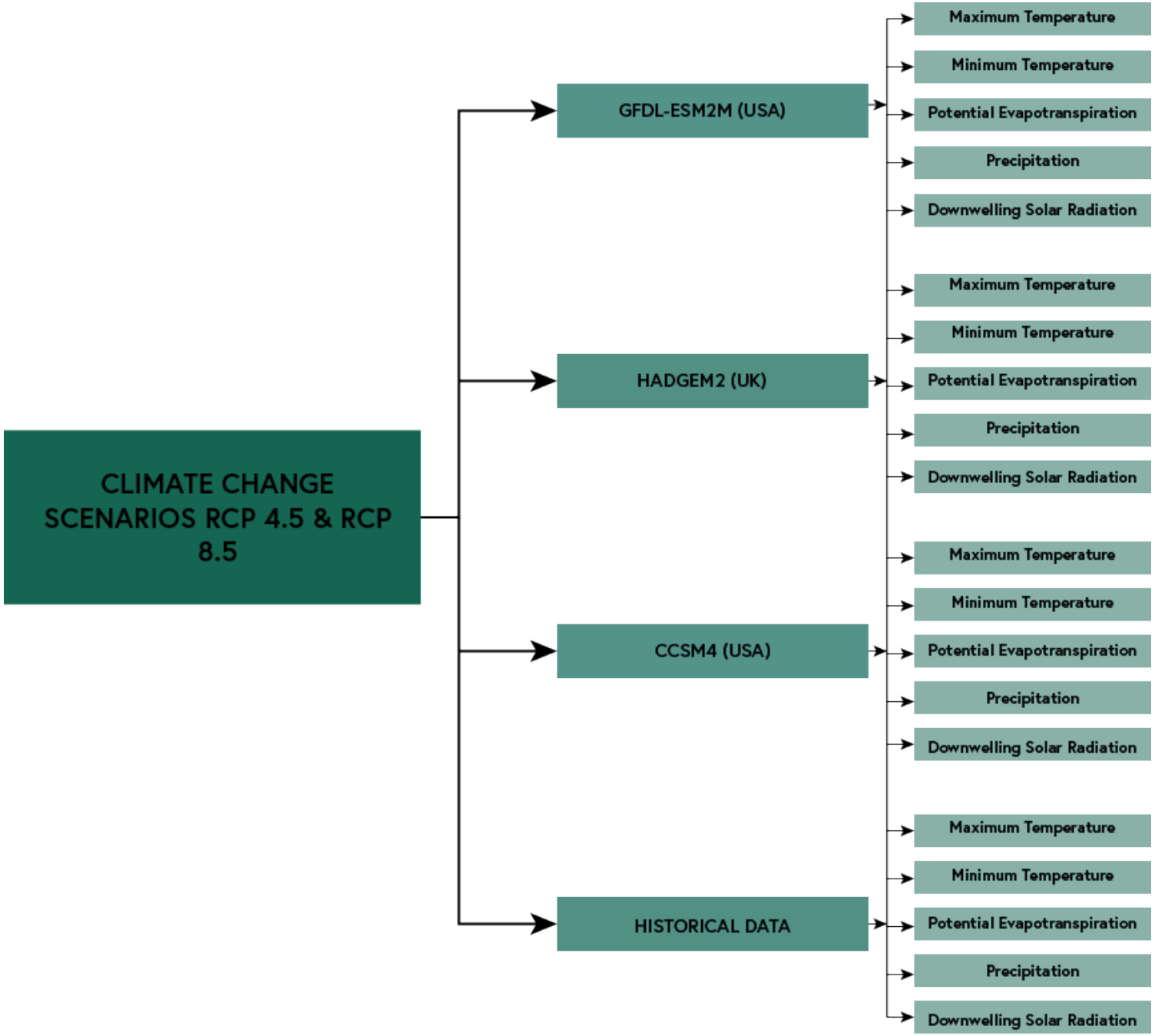


Figure 3.20: Climate Change Scenarios and Models to be Analyzed

Green Infrastructure Project Case Studies

The next set of case studies related to specific green infrastructure systems and networks that address drought, flooding, and urban heat island effects. Case studies were chosen to better understand how the systems work, how they are designed, and how their ecological benefits are measured. The information gathered through these case studies has been systematically organized to fully understand each green infrastructure project and in what instances it may be applicable.

Tables 3.2 - 3.4 document the exploration and analysis of various green infrastructure projects located within the Midwest that have successfully addressed or mitigated the impacts of drought, flooding, or urban heat islands. Another critical aspect of choosing these case studies is their scale and location. All the case studies selected are located within an urban or residential area. They are within a specific size that applies to the constraints of the study area of this project.

Table 3.2 Drought Mitigation Case Studies

DROUGHT MITIGATION CASE STUDIES

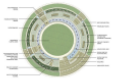
PROJECT	LOCATION	SIZE	DESIGN FEATURES	ECOLOGICAL FUNCTIONS & BENEFITS	IMAGE	REFERENCE
EPA Region 7 Headquarters	11201 Renner Boulevard Lenexa, Kansas 66219	31 acres	bio swales, rain gardens, infiltration basin, sediment forebays, constructed wetland, native plantings	Reduction in Stormwater Runoff Pollution Removal Carbon Sequestration		Hahn, Howard, and Timothy R. Kelliams. "EPA Region 7 Headquarters." Landscape Performance Series. Landscape Architecture Foundation, 2016. https://doi.org/10.31353/cs1050
Tyner Interpretive Center and Kent Fuller Air Station Prairie	2400 Compass Rd Glenview, Illinois 60026	32 acres	Green roof, prairie preservation, permeable paving, water retention basin	Water Storage Reduction in Stormwater Runoff Generates Solar Power		Deming, M. Elen, and Scott Douglas. "Tyner Interpretive Center and Kent Fuller Air Station." Landscape Performance Series. Landscape Architecture Foundation, 2015. https://doi.org/10.31353/cs0900
The Morton Arboretum: Meadow Lake and Permeable Main Parking Lot	4100 Illinois Route 53 Lisle, Illinois 60532	27 acres	permeable paving, bioswales, constructed wetlands, native plantings, habitat creation	Water Storage Improved Water Quality Increased Biomass Density Pollution Removal		Mattson, Mary Pat, and Sarah Hanson. "The Morton Arboretum: Meadow Lake & Permeable Main Parking Lot." Landscape Performance Series. Landscape Architecture Foundation, 2014. https://doi.org/10.31353/cs0760
One Drop At A Time	168 Elm Avenue Elmhurst, Illinois 60126	7,500 sf	Green roof, underground water storage, permeable paving, rain gardens, bio swales, native plantings	Water Infiltration Carbon Sequestration		Kim, Kinki, and John Whalen. "One Drop at a Time." Landscape Performance Series. Landscape Architecture Foundation, 2013. https://doi.org/10.31353/cs0510
Advocate Lutheran General Hospital Patient Tower	1775 Dempster Street Park Ridge, Illinois 60068	1.5 acres plus 0.5-acre extensive green roof	stormwater retention basin, rain gardens, permeable paving, native plantings, green roof	Reduction in Stormwater Runoff Pollution Removal		Mattson, Mary Pat, and Rachel Guinn. "Advocate Lutheran General Hospital Patient Tower." Landscape Performance Series. Landscape Architecture Foundation, 2013. https://doi.org/10.31353/cs0560
Chicago Museum of Science and Industry Smart Home	5700 S Lake Shore Drive Chicago, Illinois 60637	33,200 sf	native plantings, bioswale, rain garden, green roofs, permeable paving	Water Storage Stormwater Infiltration		Mattson, Mary Pat, and Rachel Guinn. "Chicago Museum of Science and Industry Smart Home." Landscape Performance Series. Landscape Architecture Foundation, 2013. https://doi.org/10.31353/cs0570
Uptown Normal Circle and Streetscape	W. Beaufort Street & Constitution Trail Normal, Illinois 61761	4.87 acres	underground water storage, infiltration planters, native plantings, street trees	Water Storage Stormwater Infiltration Pollution Removal Carbon Sequestration		Ellis, Christopher D, Byoung-Suk Kweon, Sarah Alward, and Robin Burke. "Uptown Normal Circle and Streetscape." Landscape Performance Series. Landscape Architecture Foundation, 2011. https://doi.org/10.31353/cs0050

Table 3.3 Flood Mitigation Case Studies

FLOOD MITIGATION CASE STUDIES

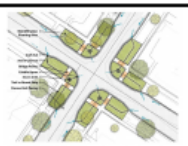
PROJECT	LOCATION	SIZE	DESIGN FEATURES	ECOLOGICAL FUNCTIONS & BENEFITS	IMAGE	REFERENCE
Argyle Shared Street	W Argyle St. & N Sheridan Rd Chicago, Illinois 60640	2.3 acres/3 city blocks	permeable pavers, infiltration planters, Native Plantings	Water Storage		Hanson, Sarah, and Matthew Callone. "Argyle Shared Street." Landscape Performance Series. Landscape Architecture Foundation, 2019. https://doi.org/10.31353/cs1490
Swope Campus Parking Lot and Entry Plaza	Kansas City Water Services, 4800 East 63rd Street Kansas City, Missouri 64130	6.20 acres	permeable paving, underground water storage, native plantings	Reduction in Stormwater Runoff Carbon Sequestration Temperature Reduction		Hahn, Howard, and Timothy R. Kellams. "Swope Campus Parking Lot and Entry Plaza." Landscape Performance Series. Landscape Architecture Foundation, 2016. https://doi.org/10.31353/cs1070
Middle Blue River Basin Green Solutions Pilot Project	Marlborough Kansas City, Missouri 64131	100 acres	Rain gardens, underground water storage, permeable paving, native plantings, bioswales	Reduction in Stormwater Runoff Water Storage and Infiltration Carbon Sequestration		Hahn, Howard, and Timothy R. Kellams. "Middle Blue River Basin Green Solutions Pilot Project." Landscape Performance Series. Landscape Architecture Foundation, 2016. https://doi.org/10.31353/cs1060
Boneyard Creek Restoration: Scott Park and the Second Street Detention Basin	Second Street Basin Champaign, Illinois 61820	10 acres	Retention basins, rain garden, bioswale, creek bank stabilization, native plantings	Water Storage Improved Habitat Quality Improved Water Quality		Kim, Kinki, and John Whalen. "Boneyard Creek Restoration: Scott Park and the Second Street Detention Basin." Landscape Performance Series. Landscape Architecture Foundation, 2013. https://doi.org/10.31353/cs0490
Charles City Permeable Streetscape Phase 1	Hulin Street and N. Joslin Street Charles City, Iowa 50616	5 acres (16 blocks of street ROW)	permeable paving, infiltration areas	Reduction in Stormwater Runoff		Yang, Bo, Pamela Blackmore, and Yue Zhang. "Charles City Permeable Streetscape Phase 1." Landscape Performance Series. Landscape Architecture Foundation, 2012. https://doi.org/10.31353/cs0390
Ravinia Festival South Parking Lot	418 Sheridan Road Highland Park, Illinois 60035	1.3 acres	permeable paving, underground water storage	Eliminated Surface Flooding Carbon Sequestration		Ellis, Christopher D., Byoung-Suk Kweon, Sarah Alward, and Robin Burke. "Ravinia Festival South Parking Lot." Landscape Performance Series. Landscape Architecture Foundation, 2011. https://doi.org/10.31353/cs0040

Table 3.4 Urban Heat Island Mitigation Case Studies

URBAN HEAT ISLAND MITIGATION CASE STUDIES

PROJECT	LOCATION	SIZE	DESIGN FEATURES	ECOLOGICAL FUNCTIONS & BENEFITS	IMAGE	REFERENCE
P Street Corridor, Phase 1	P Street Lincoln, Nebraska 68508	6 city blocks	Street trees, permeable paving, native plantings, stormwater retention,	Carbon Sequestration Stormwater Runoff Infiltration		De Almeida, Catherine, Hannah LoPresto, and Brandon Zambrano. "P Street Corridor, Phase 1." Landscape Performance Series. Landscape Architecture Foundation, 2018. https://doi.org/10.31353/cs1340
Mary Bartelme Park	115 S Sangamon St Chicago, Illinois 60607	2.3 acres	underground water infiltration basin, permeable paving, native plantings	Reduction in Stormwater Runoff Surface Temperature Reduction		Deming, M. Elen, and Scott Douglas. "Mary Bartelme Park." Landscape Performance Series. Landscape Architecture Foundation, 2015. https://doi.org/10.31353/cs0890
South Grand Boulevard Great Streets Initiative	South Grand Boulevard and Arsenal Street St. Louis, Missouri 63118	6-block corridor	permeable paving, rain gardens, street trees, native plantings	Surface Temperature Reduction		Yang, Bo, Pamela Blackmore, and Yue Zhang. "South Grand Boulevard Great Streets Initiative." Landscape Performance Series. Landscape Architecture Foundation, 2012. https://doi.org/10.31353/cs0420
Kansas State University Memorial Stadium Green Roofs	705 N MLK Jr. Drive Manhattan, Kansas 66502	38,000 sf (total of two roofs)	green roofs, native plantings	Increased Soil Biomass Increased Habitat Space Energy Savings		Skabelund, Lee R., and M. M. Lakhon Alam. "Kansas State University Memorial Stadium Green Roofs." Landscape Performance Series. Landscape Architecture Foundation, 2020. https://doi.org/10.31353/cs1690
Sarah E. Goode STEM Academy	7651 South Homan Avenue Chicago, Illinois 60652	17.2 acres	rain gardens, green roofs, stormwater retention, permeable paving	Reduction in Stormwater Runoff Stormwater Treatment & Storage Surface Temperature Reduction Pollution Removal		Mattson, Mary Pat, and Sarah Hanson. "Sarah E. Goode STEM Academy." Landscape Performance Series. Landscape Architecture Foundation, 2014. https://doi.org/10.31353/cs0780
Gary Comer Youth Center	7200 South Ingleside Chicago, Illinois 60619-1322	8,160 sf	green roof, native plantings	Surface Temperature Reduction		Yocom, Ken and Della Lacson. "Gary Comer Youth Center." Landscape Performance Series. Landscape Architecture Foundation, 2011. https://doi.org/10.31353/cs0210

Suitability Analysis

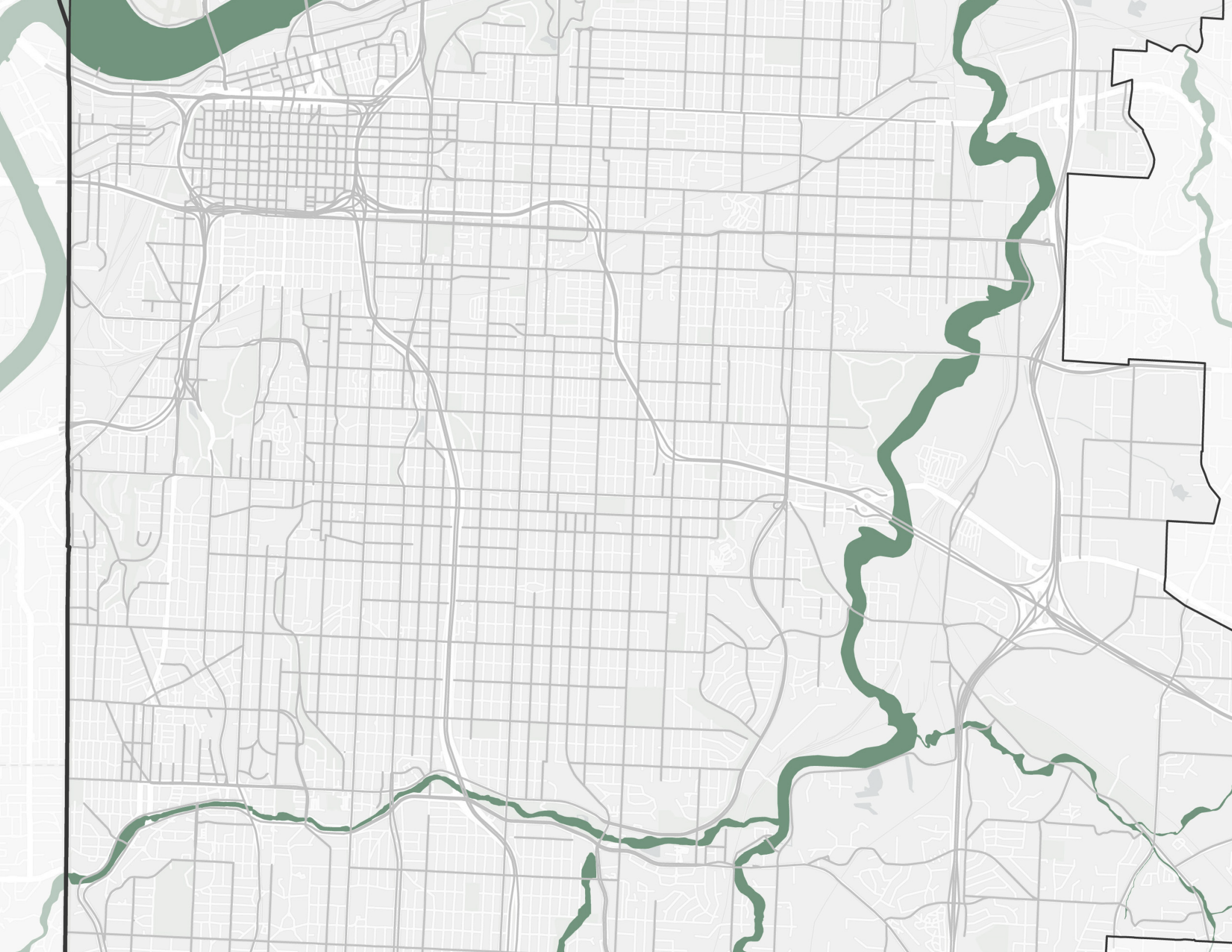
Suitability mapping was used to establish which sites within the study area need additional green infrastructure implementations to boost the areas' resilience to potential climate disasters. The following suitability maps were created: street tree, small scale combined drought flood, large scale combined drought flood, and water retention. This process began with establishing a set of parameters to be analyzed and compiled into one map based on the needs of each system. These maps took the information acquired in the previous sections and applied them spatially and visually within the project area to determine suitable locations for potential interventions. These maps explored the existing environmental conditions of the study area in relation to the needs or spatial requirements of potential green infrastructure typologies. Suitability was scored on a low, moderate, and high suitability scale in the mapping process.

Final Site Selection

Final site selection took place once all suitability analysis mapping was completed. Using the insights gained from both rounds of analytical mapping and the climate change models helped select potential sites and match the site with the necessary ecological function. Since drought and flood events are closely related, sites that were discovered to be vulnerable to drought or flooding were designated to address both events on-site. In addition to the results of the previous steps, site selection was also based on additional spatial characteristics and criteria of current vacant parcels within the area. The extra set of criteria considered for the final sites selected for this study included factors such as ownership, zoning, land value, and adjacencies to surrounding parcels. From here, many sites were selected as in need and suitable for potential revitalization and were tiered based on their suitability and matched with a potential intervention.

Evidence-Based Recommendations:

Using the information gained from the prior aspects of this study, I then created a framework of green infrastructure typologies matched with potentially suitable sites selected in the previous sections. These typologies were designed and decided upon using the information gained through case studies on green infrastructure projects, aiming to boost the area's resilience to possible drought, flood, or urban heat island risks. Looking at the overall functional capacity of each green infrastructure typology and comparing this information to future climate change projections helped to see if these sites will be better suited to withstand and bounce back from potential climate disasters. This process sought to investigate how different types of green infrastructure can boost a community's climate resilience. The information gained from this investigation will inform future decisions regarding green infrastructure implementations. In addition to the tiered framework of suitable sites matched with potential green infrastructure interventions, this framework includes evidence-based recommendations and guidelines to ensure the success and sustainability of these systems. All the recommendations and guidelines created in this section are based upon information gathered and analyzed in prior steps of this study and the standards and policies of Kansas City, Missouri. Ideally, if this project were to be implemented, this framework would allow these systems to connect back to the greater green infrastructure network within Kansas City today.



4 Analysis and Findings:

In this section, I will discuss the results and findings of several of the components from the methods section, including the climate data analysis, green infrastructure case study analysis, suitability mapping, and the final sites selected based on the understanding of the following sections. Through this analysis, many insights were gained relating to the anticipated future climactic conditions in the study area, in addition to what types of green infrastructure might be best suited to address these conditions.

Climate Data Analysis Findings:

As discussed in previous sections, historical climate data and future climate projections were obtained to better understand future conditions. The climate data was obtained from monthly records and projections, so each category analyzed has vast ranges as it spans each month of the whole year in a region that fully experiences all the seasons. The following sections present the results obtained through this analysis.

Historical Climate Data Analysis:

To fully understand the future, we must first understand past climate trends. Climate data was collected from 1950-2005 directly from the Kansas City area around the parameters of maximum temperature, minimum temperature, precipitation, evapotranspiration, and radial downwelling solar radiation trends. To keep this analysis simple and tangible, I have broken down each data set into four analysis categories: minimum, maximum, mean, and median. Table 4.1 shows the brief takeaways discussed in this section.

Table 4.1 Historical Climate Takeaways

Climatic Factors	HISTORICAL DATA		
	Minimum	Maximum	Average
Max Temp(F)	21.1	99	65.5
Min Temp(F)	0.95	74.1	45
Precip(mm)	0.354	482.1	85.5
PotEvap(mm)	21	227	102
RSDS(Wm-2)	68.2	295.7	179.9

When looking at the historical trends of maximum temperatures in this area, the average maximum temperature through the years was around 65.5 degrees Fahrenheit, and the highest maximum temperature reached 99 degrees Fahrenheit. Minimum temperatures averaged around 45 degrees Fahrenheit and reached an all-time low of 0.95 degrees. Compared to the conditions we are experiencing currently, one can already begin to see the temperature changes, which look drastically different just 20 or so years after this data was collected. Figures 4.21 and 4.22 visually present these historical temperature trends.

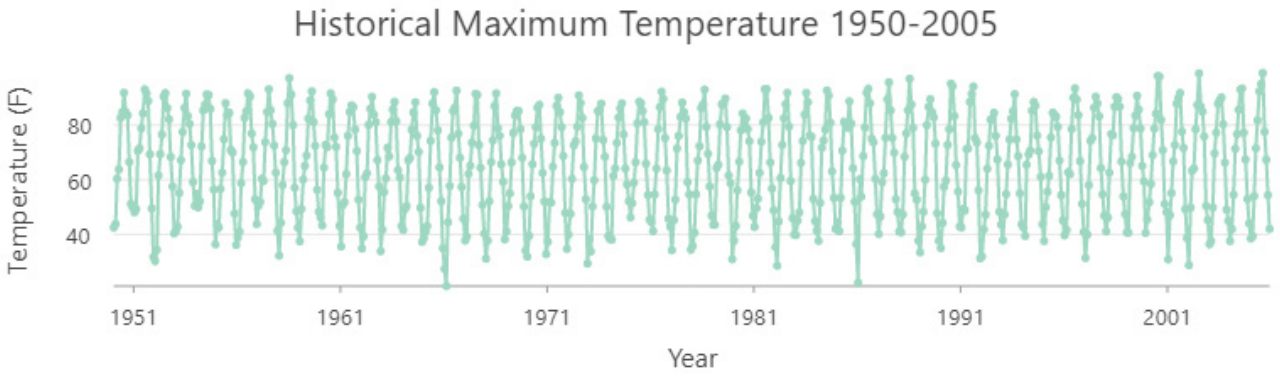


Figure 4.21: Historical Maximum Temperature

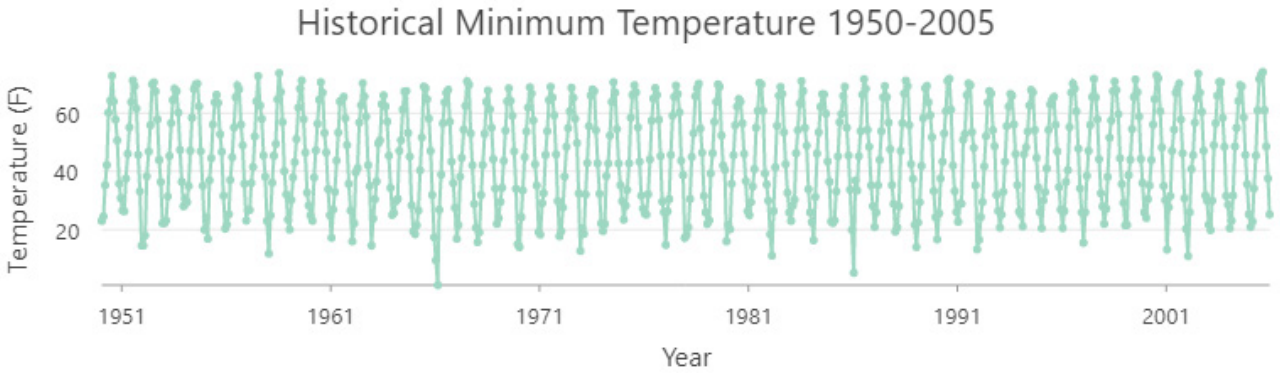


Figure 4.22: Historical Minimum Temperature

Historically, this region averaged about 85.5 mm of precipitation each month but had major ranges depending on the year and time of year. In some months, Kansas City reached a maximum of 482.1 mm of precipitation, whereas in other months, the area received a minimum of 0.354 mm of precipitation. These trends can be seen in Figure 4.23

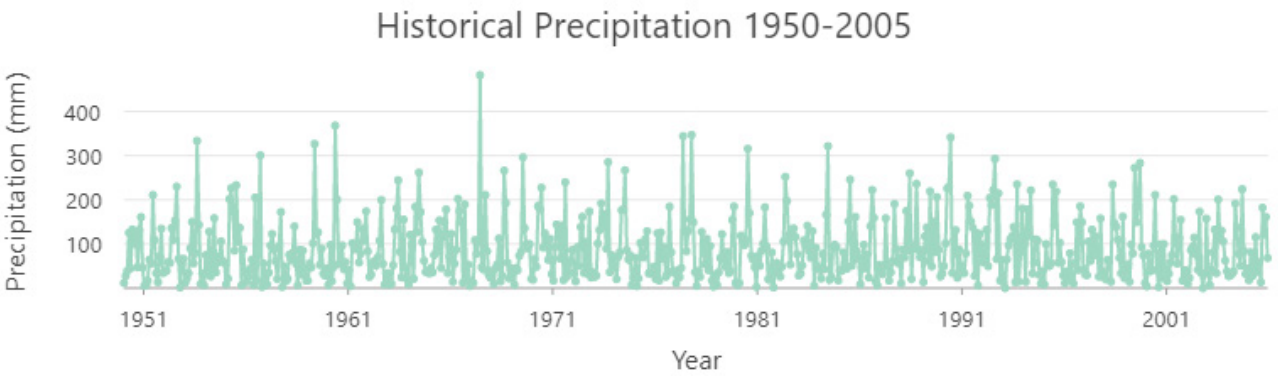


Figure 4.23: Historical Precipitation

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Figure 4.24 visualizes the historical evapotranspiration rates in this area. The average level of evapotranspiration during this period was 102 mm and had a much closer range throughout the year compared to some of the other factors analyzed. The maximum amount of evapotranspiration occurred during this period was 227 mm, and the minimum amount was around 21 mm.

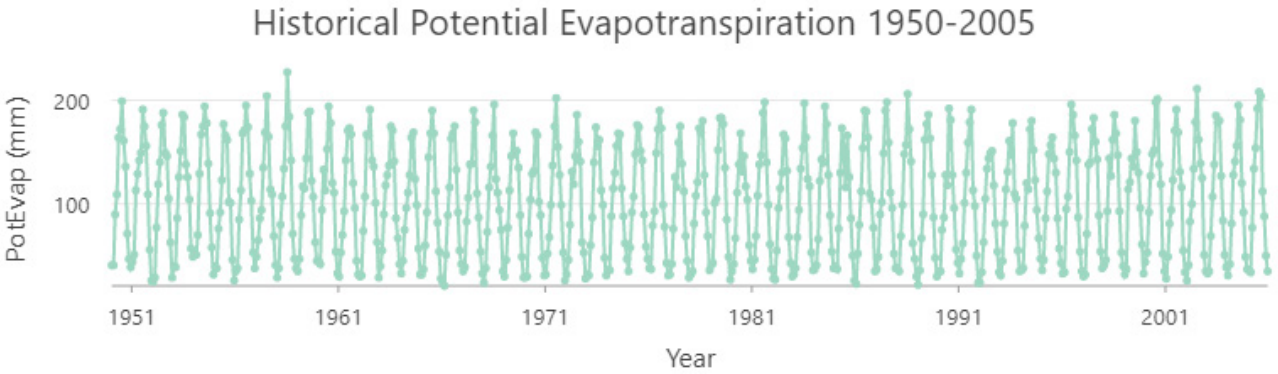


Figure 4.24: Historical Potential Evapotranspiration

Lastly, figure 4.25 shows this area's historical solar radiation levels and trends. On average, this area experienced 179.9 Wm-2 of solar radiation and experienced a slightly more extensive range throughout the year compared to the evapotranspiration rates during this time. Radial downwelling solar radiation levels reached a maximum of 295.7 Wm-2 and a minimum of 68.2 Wm-2.

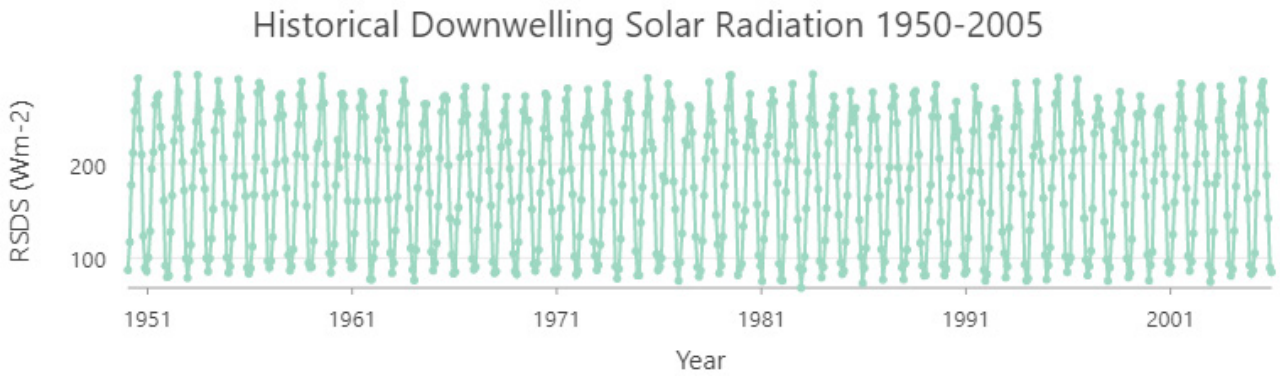


Figure 4.25: Historical Downwelling Solar Radiation

RCP 4.5 Climate Projection Analysis:

Now, we will look at the first scenario of climate projection data, RCP 4.5. In this scenario, we anticipate making substantial carbon reductions in time for the reductions to impact the data. This is the ideal scenario, and as a society, we should aim to reduce carbon emissions as soon as possible.

Figure 4.26 visualizes the maximum temperature trends across the three models examined in this study (the CCSM4, GFDL-ESM2M, and HadGEM2). According to the climate projections, the GFDL-ESM2M model is projecting a fair amount above the other two models, with a maximum of 115.7 degrees Fahrenheit. The other two models report maximum temperatures of 105.6 degrees Fahrenheit and 107.6 degrees Fahrenheit. If you take the average of these three models, the maximum temperature projection would be around 109.6 degrees Fahrenheit. On average, the three models are projecting around the same for an average maximum monthly temperature, with results of 69.9, 67.9, and 71 degrees Fahrenheit.

Table 4.2 RCP 4.5 Climate Projection Takeaways

	RCP 4.5		
	CCSM 4	GFDL-ESM2M	HadGEM2
Average			
Max Temp (F)	69.9	67.9	71
Min Temp (F)	49.8	48	47.1
PotEvap (mm)	116.9	115.1	103.9
Precip (mm)	86.8	84.5	92.1
RSDS (Wm-2)	185.1	182.9	179.7
Maximum			
Max Temp (F)	105.6	115.7	107.6
Min Temp (F)	81.4	79.6	86.5
PotEvap (mm)	273	272	354
Precip (mm)	706.3	421.1	503.6
RSDS (Wm-2)	317.1	310.2	304.2
Minimum			
Max Temp (F)	23.8	26.1	26.1
Min Temp (F)	7.8	7.9	8.6
PotEvap (mm)	19	17	15
Precip (mm)	0	0	0
RSDS (Wm-2)	66.6	66.9	63.1

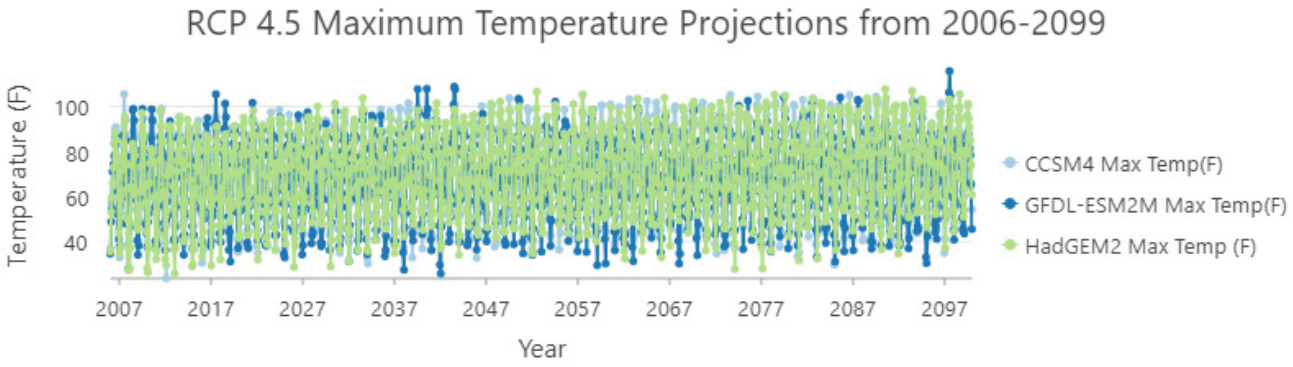


Figure 4.26: RCP 4.5 Max Temp

When examining the minimum temperature climate projections for RCP 4.5, we can anticipate a slightly higher minimum temperature than historically experienced. All three climate models' forecasts for this category are close, with projected minimum temperatures of 7.8, 7.9, and 8.6 degrees Fahrenheit. On average, the models project an average monthly minimum temperature of 48.3 degrees Fahrenheit amongst the three models. Figure 4.27 depicts the results of the RCP 4.5 minimum temperature analysis.

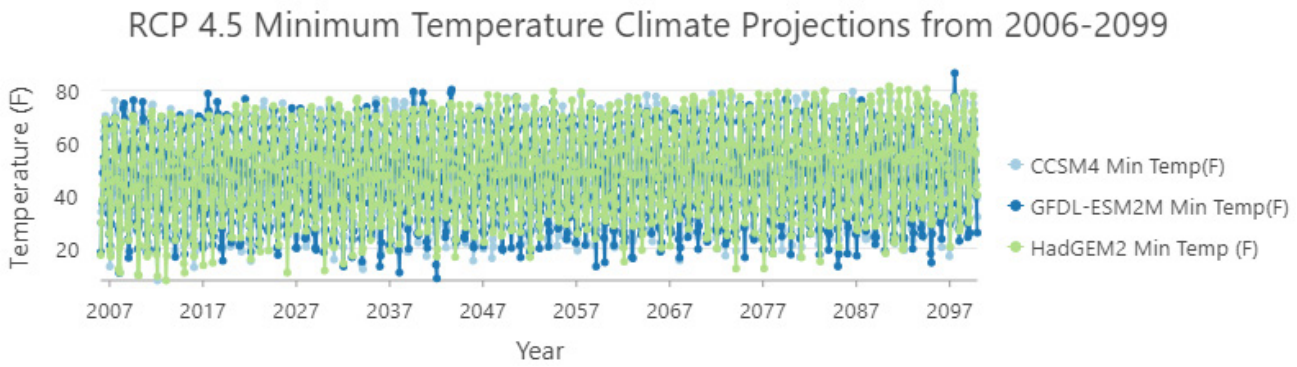


Figure 4.27: RCP 4.5 Minimum Temperature

The RCP 4.5 potential evapotranspiration climate projections vary slightly, with the HadGEM2 and CCSM4 models projecting fairly in unison and the GFDL-ESM2M model as the slight outlier. Figure 4.28 visualizes the following results. The average of all three models' maximum potential evapotranspiration projections is 299 mm per month, with the most significant outlier being the GFDL-ESM2M model's projection of 354 mm per month. Additionally, the average minimum amount of potential evapotranspiration projected amongst the three models is 17 mm per month. The average potential evapotranspiration projected monthly amongst the three models is 111.9 mm.

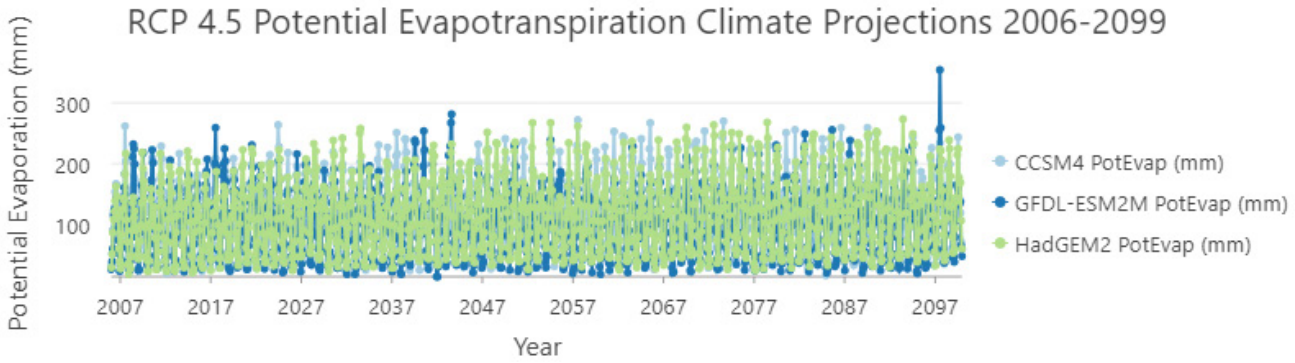


Figure 4.28: RCP 4.5 Potential Evapotranspiration

Diving into the RCP 4.5 precipitation projections for the next hundred years or so, Figure 4.29 visualizes these findings. All three models project that there will be a minimum of 0 mm of precipitation per month, with a much more considerable maximum amount of precipitation anticipated. The HadGEM2 model projects the highest maximum amount of precipitation, with 706.3 mm per month, while the CCSM4 projects 421.1 mm, and the GFDL-ESM2M projects 503.6 mm in one month. The average anticipated maximum amount of precipitation between the three models in one month is 543.6 mm. The average precipitation projected between the models every month sits at 87.8 mm.

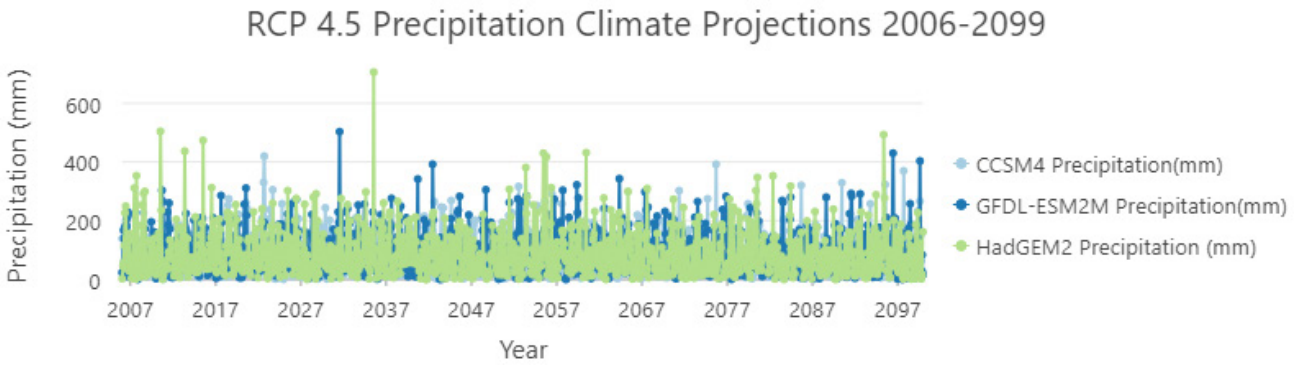


Figure 4.29: RCP 4.5 Precipitation

For the final factor analyzed in the RCP 4.5 scenario, figure 4.30 shows the projected radial downwelling solar radiation trends between the three models. These results show that little variation is anticipated in solar radiation between the three models. The average maximum amount of radial downwelling solar radiation is projected to be 310.5 Wm-2 between the models, and the average minimum is 65.5 Wm-2. Additionally, the average amount of solar radiation anticipated each month between the models is projected to be 182.5 Wm-2.

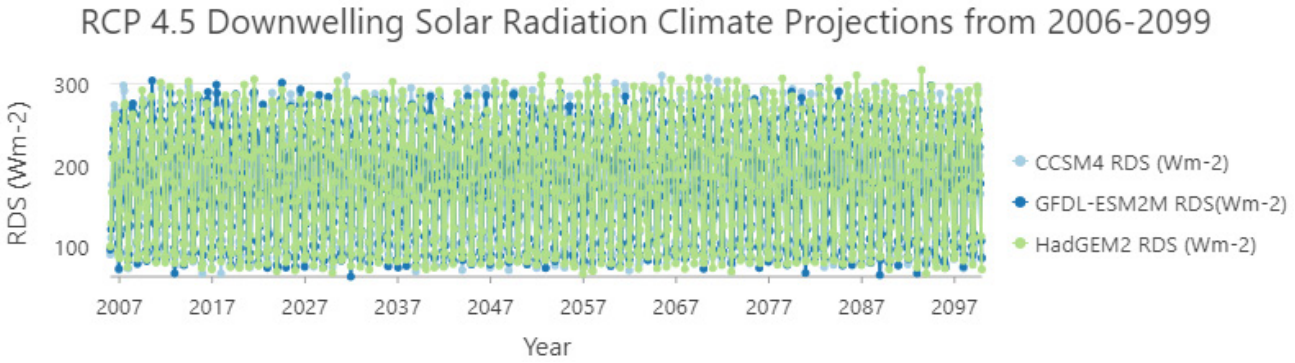


Figure 4.30: RCP 4.5 Downwelling Solar Radiation

RCP 8.5 Climate Projection Analysis:

The final set of climate projections analyzed through this study was through the lens of the RCP 8.5 climate scenario. The RCP 8.5 scenario is based on the possibility that we continue to emit high rates of carbon emissions and do not make reductions in time, resulting in a more significant strain on our climate and, subsequently, our environment. Table 4.3 provides quick data projection takeaways for the following section.

Table 4.3 RCP 8.5 Climate Projection Takeaways

	RCP 8.5		
	CCSM 4	GFDL-ESM2M	HadGEM2
Average			
Max Temp (F)	71.9	69.5	73.7
Min Temp (F)	49.7	48.5	52.5
PotEvap (mm)	120	110	126
Precip (mm)	83.9	89.9	85.3
RSDS (Wm-2)	182.5	181.5	186.3
Maximum			
Max Temp (F)	115.6	116.9	113.3
Min Temp (F)	85.1	85.7	89.5
PotEvap (mm)	343	331	330
Precip (mm)	489.3	415.2	694.4
RSDS (Wm-2)	308.9	301.3	318
Minimum			
Max Temp (F)	32.8	26.5	19.5
Min Temp (F)	16.5	9.9	2.15
PotEvap (mm)	26	14	21
Precip (mm)	0	0	0
RSDS (Wm-2)	68	69.8	67.2

Figure 4.31 explores the maximum temperatures projected through the same three models but through the RCP 8.5 climate scenario. All three models project closely related results for maximum temperature, with CCSM4 coming in at 115.6, GFDL-ESM2M at 116.9, and HadGEM2 at 113.3 degrees Fahrenheit. The three models in the RCP 8.5 scenario generally project significantly higher maximum temperatures. The average maximum temperature projected between the three models is 71.7 degrees Fahrenheit.

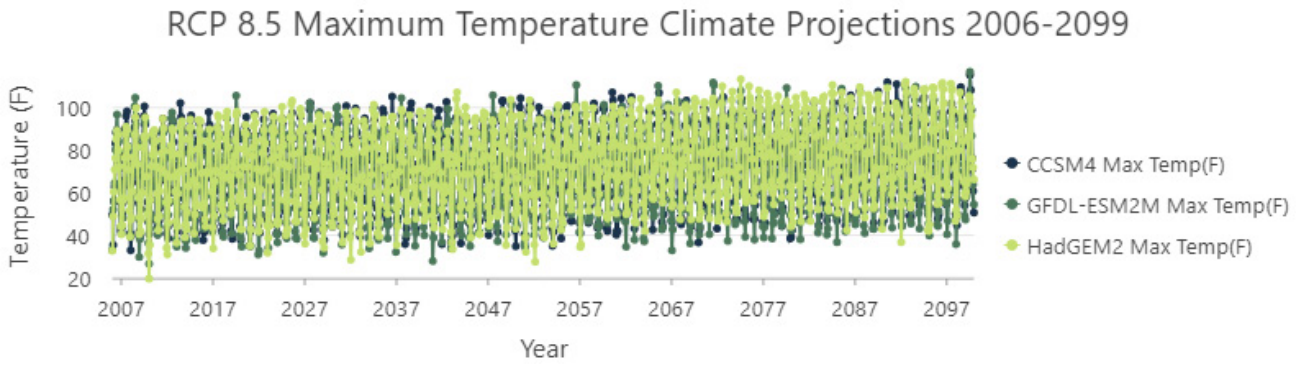


Figure 4.31: RCP 8.5 Maximum Temperature

Figure 4.32 explores the minimum temperature trends projected for RCP 8.5 across the three models. This scenario projects much higher minimum temperatures, with CCSM4 projecting 16.5 degrees Fahrenheit, GFDL-ESM2M projecting 9.9, and HadGEM2 projecting 2.15 degrees Fahrenheit. The average minimum temperature projected per month between the three models is 50.2 degrees Fahrenheit.

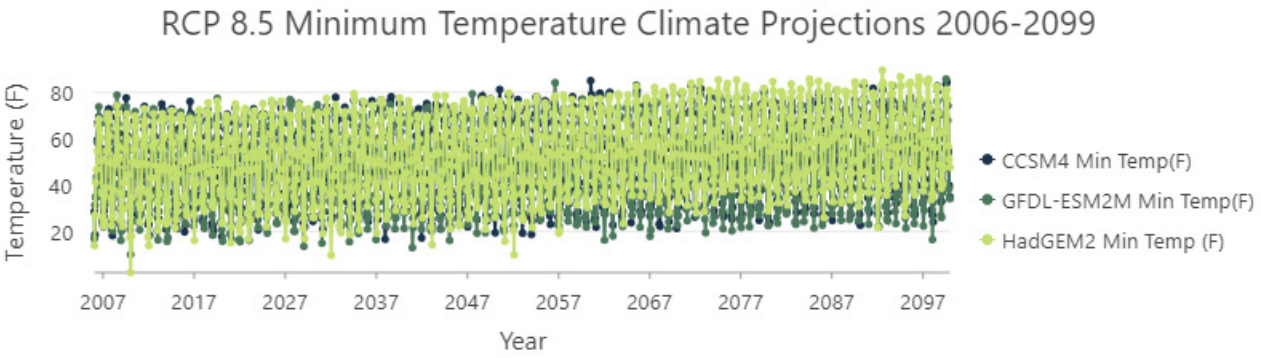


Figure 4.32: RCP 8.5 Minimum Temperature

The average maximum amount of potential evapotranspiration projected through the RCP 8.5 scenario is 86.7 mm, with the HadGEM2 model projecting the highest monthly amount at 89.5 mm. There is quite a bit of variance between the three models' projections for minimum amounts of potential evapotranspiration, with CCSM4 forecasting 16.5, GFDL-ESM2M projecting 9.9, and HadGEM2 projecting 2.15 mm. The average minimum amount of potential evapotranspiration between the three models is 9.5 mm monthly. The average projected amount of potential evapotranspiration between the three models is 50.2 mm. Figure 4.33 visualizes these results.

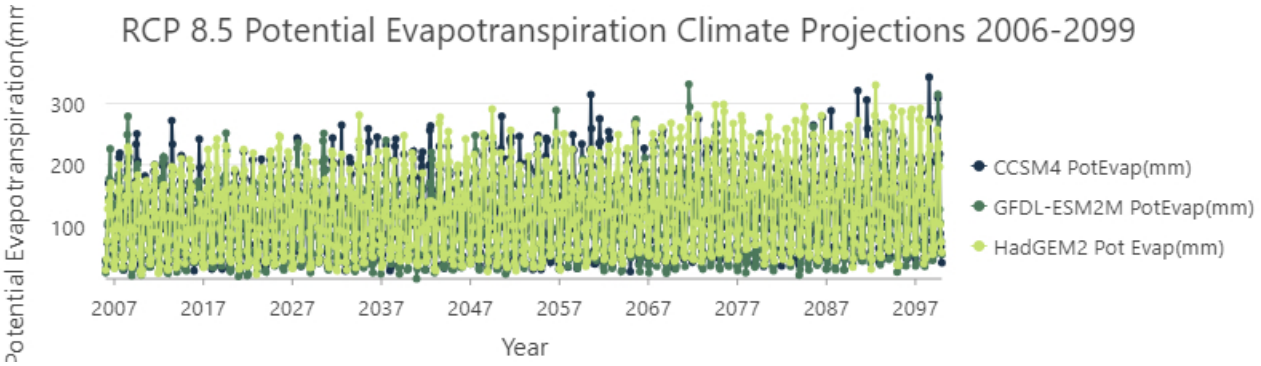


Figure 4.33: RCP 8.5 Potential Evapotranspiration

Like RCP 4.5, RCP 8.5 anticipates that the minimum amount of precipitation this area will experience in a month will be 0 mm, which is consistent across all three models. Regarding the maximum amounts of precipitation projected, there is once again a decent amount of variation between the three models' projections. CCSM4 anticipates a maximum of 489.3 mm, GFDL-ESM2M projects 415.2 mm, and HadGEM2 shows a maximum of 694.4 mm in one month. The average of the three models' projected maximum precipitation level is 532.9 mm. The average amount of precipitation projected monthly between the three models comes in at 86.3 mm. Figure 4.34 visualizes these trends.

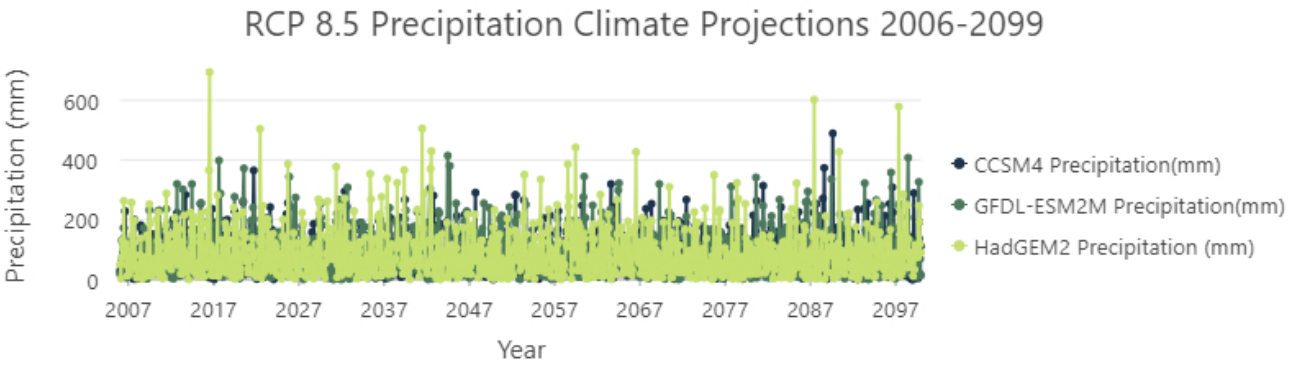


Figure 4.34: RCP 8.5 Precipitation Projections

Figure 4.35 highlights the findings discussed in this section, which are related to the trends in solar radiation projected through the RCP 8.5 climate scenario. On average, the three models combined project a monthly rate of 183.4 Wm-2 of downwelling solar radiation. There is the most variance in these projections for the maximum amounts of solar radiation projected amongst the three models, with CCSM4 projecting 308.9 Wm-2, GFDL-ESM2M projecting 301.3, and HadGEM2 projecting 318 Wm-2. Finally, the average minimum rate of solar radiation anticipated through this scenario monthly sits at 68.3 Wm-2.

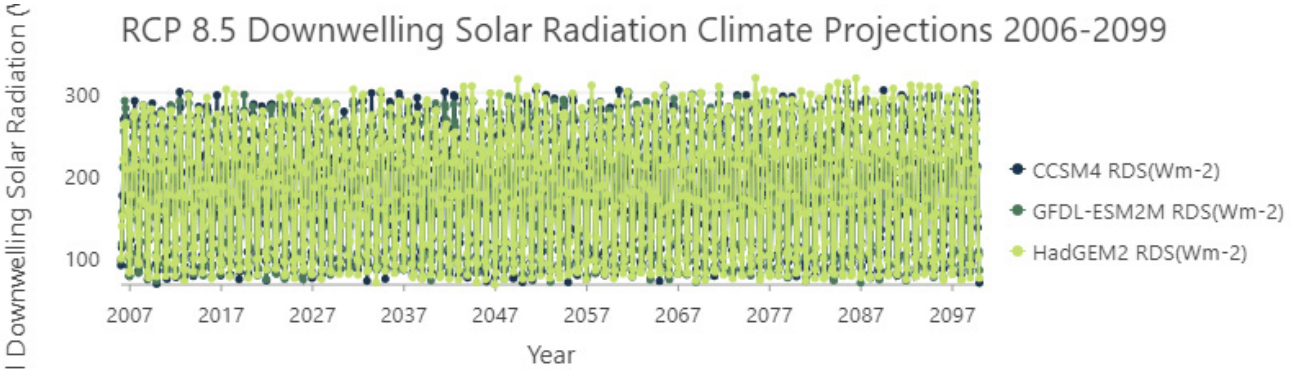


Figure 4.35: RCP 8.5 Downwelling Solar Radiation

Collective Climate Data Analysis Takeaways:

Now that we have analyzed each scenario individually, it is time to gain a baseline understanding of what these projections mean and the potential benchmarks the recommended green infrastructure systems will need to meet to prevent climate disasters based on these projections. See Table 4.4.

Compared to historical temperature trends, we can anticipate the maximum temperature to increase between 6 and 17 degrees Fahrenheit and the average maximum monthly temperature to increase by 2 to 8 degrees Fahrenheit. The minimum temperature is also expected to increase by 2 to 16.5 degrees Fahrenheit. On average, the minimum monthly temperature is expected to grow from 2 to 7.5 degrees Fahrenheit. These results tell us that conditions throughout the year are generally likely to be warmer overall, and efforts to promote cooling will be essential, especially during summer when the maximum temperatures are expected to be significantly higher.

Now, we will evaluate the projected trends in evapotranspiration compared to historical evapotranspiration trends. The results for this section are pretty interesting, as the average amount of evapotranspiration is projected to be lower for RCP 8.5 compared to RCP 4.5. Historically, the average level of

Table 4.4 Collective Climate Data Takeaways

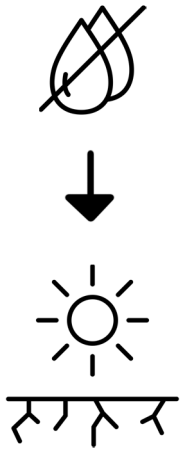
	HISTORICAL	RCP 4.5			RCP 8.5		
	CanESM2M	CCSM 4	GFDL-ESM2M	HadGEM2	CCSM 4	GFDL-ESM2M	HadGEM2
Average							
Max Temp (F)	65.5	69.9	67.9	71	71.9	69.5	73.7
Min Temp (F)	45	49.8	48	47.1	49.7	48.5	52.5
PotEvap (mm)	102	116.9	115.1	103.9	120	110	126
Precip (mm)	85.5	86.8	84.5	92.1	83.9	89.9	85.3
RSDS (Wm-2)	179.9	185.1	182.9	179.7	182.5	181.5	186.3
Maximum							
Max Temp (F)	99	105.6	115.7	107.6	115.6	116.9	113.3
Min Temp (F)	74.1	81.4	79.6	86.5	85.1	85.7	89.5
PotEvap (mm)	227	273	272	354	343	331	330
Precip (mm)	482.1	706.3	421.1	503.6	489.3	415.2	694.4
RSDS (Wm-2)	295.7	317.1	310.2	304.2	308.9	301.3	318
Minimum							
Max Temp (F)	21.1	23.8	26.1	26.1	32.8	26.5	19.5
Min Temp (F)	0.95	7.8	7.9	8.6	16.5	9.9	2.15
PotEvap (mm)	21	19	17	15	26	14	21
Precip (mm)	0.354	0	0	0	0	0	0
RSDS (Wm-2)	68.2	66.6	66.9	63.1	68	69.8	67.2

evapotranspiration experienced was 85.5 mm per month, but looking towards the future, it could be anywhere from 35 mm less (RCP 8.5) to 27 mm more (RCP 4.5). The maximum level of evapotranspiration is anticipated to be much lower for both scenarios compared to the historical levels, with an estimated decrease of anywhere between 183 mm and 395 mm. Additionally, projections show a slight increase in the projected minimum levels of evapotranspiration, with an anticipated rise anywhere from 9 to 16 mm more.

Overall, projected monthly precipitation amounts are anticipated to be highly variable. We can estimate a decrease of anywhere from 10 to 16 mm of precipitation per month compared to historical averages. Maximum precipitation levels are projected to drastically increase compared to historical levels, with an increase of 305 – 316 mm per month. Historically, the minimum amount of precipitation was around 21 mm. Still, RCP 4.5 and RCP 8.5 agree across all models that there will indeed be months where zero precipitation occurs in the future.

Lastly, I will discuss the overall analysis of the trends in projected amounts of radial downwelling solar radiation. Compared to the other categories, the solar radiation levels are only anticipated to change a little, no matter the scenario or climate model, compared to historical levels in the area. The average amount of solar radiation is estimated to increase slightly, ranging from 3 to 4 Wm-2 higher than the historical average. The maximum amount of solar radiation is estimated to grow a bit more, with an anticipated increase of anywhere from 10 to 15 Wm-2 higher. Compared to the historical trend, the minimum level of solar radiation is supposed to stay the same, with a possible decrease of 3 Wm-2 or a minimal increase of up to 0.1 Wm-2 projected between the two scenarios.

Using this collective data analysis as a benchmark for future climate conditions, we can better understand the capacity increase necessary to prevent system failure or climate disaster in the study area.



Drought:

-Can expect a general increase in evapotranspiration levels

-RCP 8.5 projected lower levels than RCP 4.5

-All scenarios project months with 0 precipitation

Flooding:

-Highly variable precipitation month – month

Urban Heat Island:

-Significantly higher temperatures in the summer months

-Cooling efforts year-round will be needed

-Solar Radiation not anticipated to change greatly for either scenario

Green Infrastructure Case Study Analysis Findings:

The green infrastructure case studies were used to gather information on successfully implemented green infrastructure projects and what made these projects so successful. Additionally, data was gathered around the sizes of these projects and what combination of design features resulted in the most optimal ecological functions and ultimately boosted resilience for the area. While case studies were analyzed based on what climate threat the projects seemed to address the most, most of the projects addressed many issues on one site. Ultimately, this analysis led to the decision-making process behind potential green infrastructure typology designs and the kind of sites to be located for each typology.

Project Size

On average, projects focused on flood mitigation were about 4.9 acres in size, with one project being a significant outlier in the data at 100 acres in size total. Granted, this project was considered due to the many smaller design interventions featured on site. Projects that were analyzed and related most to drought mitigation tended to be much more prominent on average than the flooding projects, with an average size of 13.97 acres. Similar to the flood mitigation case study projects, there were a couple of outliers in this data set, with two projects being less than an acre in size. The projects that focused primarily on mitigating urban heat island effects ranged in size vastly, with an average size of 6.6 acres, but spanned from .187 to 17 acres.

Design Features and Resulting Function

Many of the projects evaluated for this study comprised various design features that addressed several issues on one site. Design features noted several times to address flooding were permeable paving, retention basins, underground water storage, rain gardens, and native plantings. Drought mitigation projects had many design features in common with flood mitigation projects, with bioswales, rain gardens, permeable paving, water retention basins, native plantings, and green roofs noted most frequently. Urban heat island mitigation projects commonly featured street tree planting, green roofs, native plantings, and permeable paving.

Because of the vast overlap between the design features of all the projects evaluated, four major site selection typologies were developed to address the climate-related issues of drought, flooding, and urban heat island effects. The street tree site selection typology was created to encourage additional street tree plantings and additional plantings in vacant lots or open green spaces. This typology aims to address the gaps in the study area's existing urban forest and increase its capacity to mitigate heat stress, erosion, and stormwater runoff. For this study, two site selection typologies were created to address drought and flooding issues on the same site. Because of the combination of these systems, it would be assumed that multiple design features would be implemented on each site depending on the existing conditions and needs of the site. The combined system sites come in two different size ranges based on the existing sizes of vacant parcels in the study area, with the large-scale combined drought flood system ideally being a site or multiple sites with a total area of 3-4 acres and the small-scale combined drought flood system being a site which is an acre or less in total space. Additionally, the site selection typology for water retention was created in hopes of locating already naturally occurring collection points within the study area that may be larger in size and have the capacity to hold and store water, subsequently addressing drought and flood issues on one site.

Suitability Mapping Analysis Findings:

The process of suitability mapping began with the creation of matrices that delineated the parameters to be considered and analyzed for each suitability map. From here, the same method was used for each suitability analysis in the ArcGIS Pro software. For each suitability map, specific data layers were compiled and clipped to the extent of the study area to ensure that all information and relevant data within the study area were considered. Using the parameters set in the matrices, each data set was categorized from 0-3, 0 being an exclusionary factor, 1 being low suitability, two being moderate, and 3 being high suitability. Some data sets, such as existing trees, were categorized using buffers to establish what areas were already densely planted versus which were sparser or lacking. From here, all data sets were turned into raster data and then calculated using the same weight to eliminate any chance of bias in decision-making. This process resulted in creating four suitability maps with various data layers compiled into one raster layer, delineating low, moderate, and high suitability for potential interventions throughout the study area.

The factors analyzed for the suitability mapping process were inspired by several precedent projects, which are refereced in Appendix F.

Suitability Model Process and Framework

A suitability model was created to conduct the suitability analysis process using a systematic approach. While each suitability analysis map was created using slightly different data sets and varying parameters depending on the type of suitable sites sought, each map was created following the same model. This framework or workflow is visually explained in Figure 4.36, which shows how each data type was analyzed and then subsequently calculated together to create one cohesive analytical map. Point data was analyzed using a series of geoprocessing tools in ArcGIS and was eventually turned into raster data. For the context of this project, the point data being analyzed was typically either a hazard or an existing feature, which needed a visual buffer placed around it for analysis. After the multiple-ring buffer tool was applied to the data set, it was turned into raster data and reclassified per the parameters of the suitability matrix created for the map. A similar process was conducted for polygon and raster data sets, in which all data was inevitably turned into raster data and reclassified per the suitability parameters. Once all the data types were turned into raster data, they were calculated and combined into one raster layer. They were reclassified one final time to align with the simplified suitability scale of one to three, or low, moderate, or high suitability. Since this process can become lengthy and redundant depending on how many data layers are being analyzed, a model was implemented using ArcGIS to generate maps more efficiently. Figure 4.37 shows the workflow followed by the model created for street tree suitability for this study. For reference, the navy-blue ovals are the data sets being analyzed and used in the map, the yellow rectangles are the geoprocessing tools applied to the data sets, and the green ovals are the resulting outcome from the analyzed data. The arrows in this diagram indicate the inputs and outputs of this model and the sequential process used to produce one final map graphic. For this project, all data sets were analyzed on an equal field. Still, if weighting were to be applied to this process, using a model would help quickly show the differences between generated outcomes depending on the applied weighting.

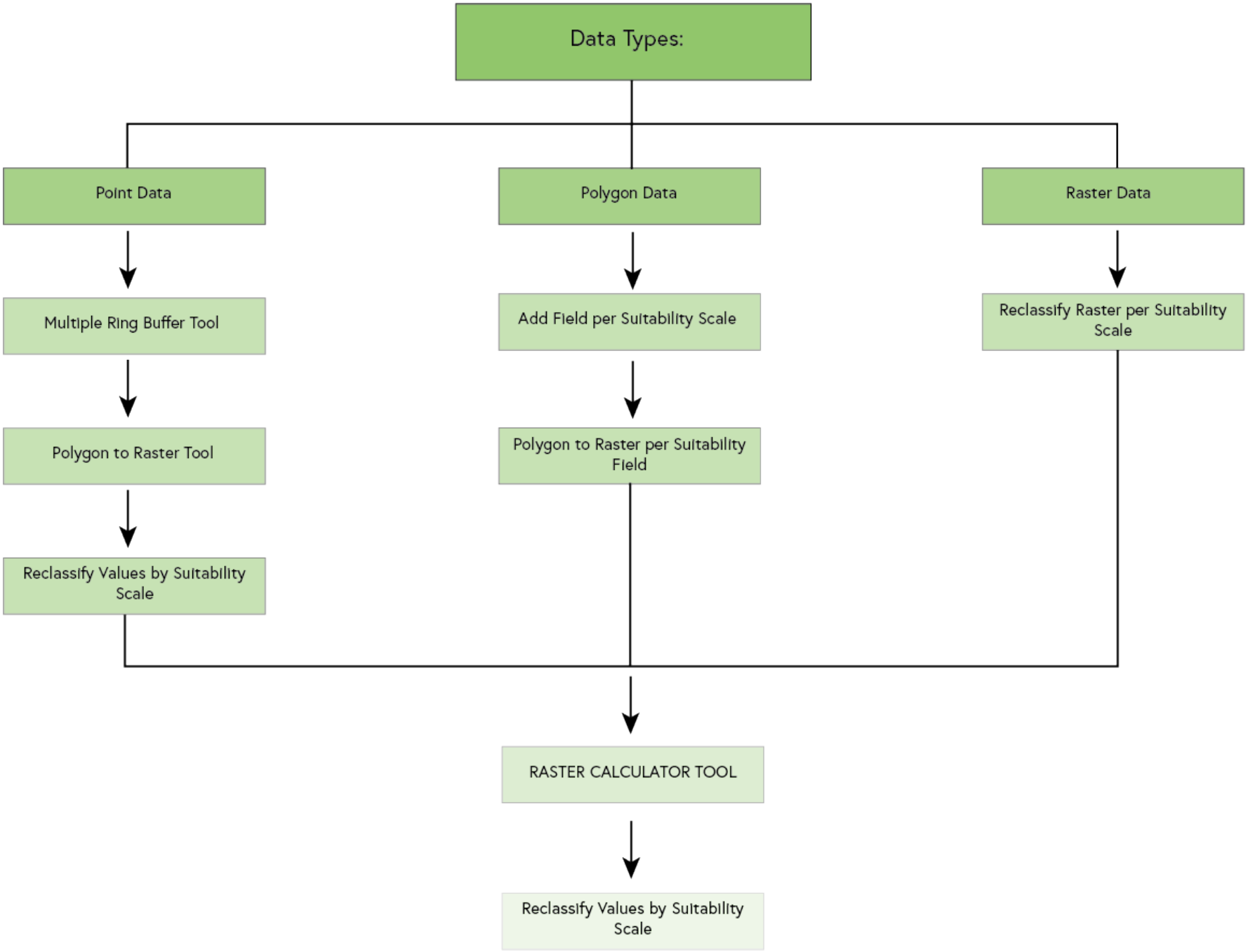


Figure 4.36 Suitability Model Process

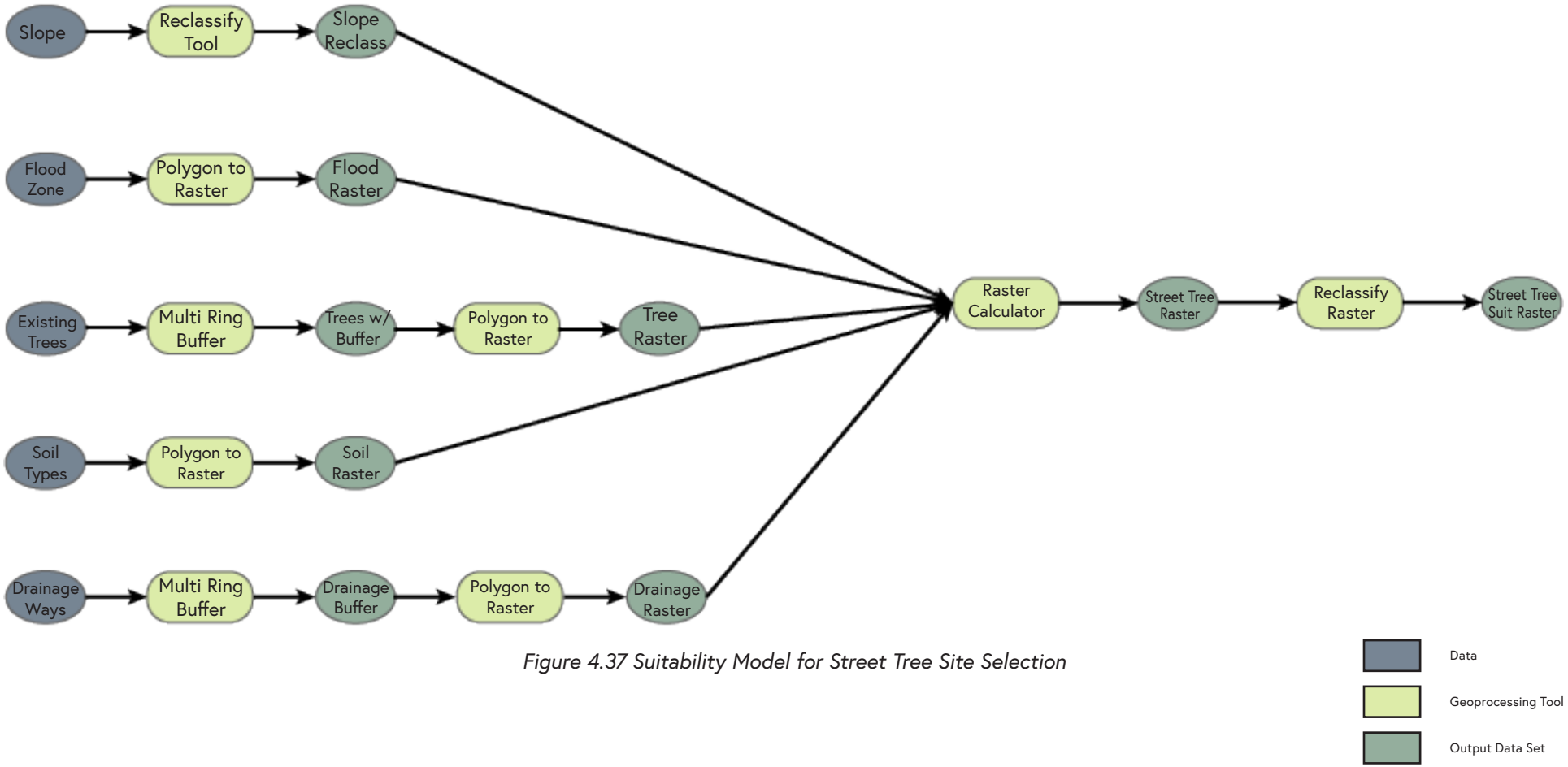


Figure 4.37 Suitability Model for Street Tree Site Selection

Street Tree Suitability

The criteria for street tree suitability were created based on five factors, which were chosen due to their impact on tree growth success. In addition, they prioritized areas in which increased tree canopy would provide the most ecosystem services and, as a result, boost the surrounding areas' resilience to potential climate disasters. See Table 4.5 for a visual breakdown of the parameters discussed next.

No exclusionary factor was selected for the slope analysis layer, as trees can grow on any slope. Areas with higher slopes were prioritized over those with lower percentages of slope, as these areas are known to have issues with erosion and runoff, and trees can help address both of those issues.

The following analysis layer chosen was the FEMA flood hazard zone, in which parameters were selected based on the need to stabilize the ground and prevent flooding. Because of this reasoning, the 1% flood zone was given a suitability score of 3 as it is most likely to be flooded annually. From there, the 0.2% flood zone was scored with moderate suitability, and all areas outside these two flood zones and the drainage way scored a 1.

The presence of existing trees was considered, as the goal of this study is to target areas that currently lack tree canopy cover. Buffers were set around each existing tree at distances of 30, 50, 75, and 100 feet. Everything outside the 100-foot distance was considered highly suitable for additional tree planting; between 75 and 100 feet was considered moderate, and low suitability was set between 50 and 75 feet. Thirty feet or less was viewed as the exclusionary parameter for this dataset. Soil parameters were decided upon based on the general soil types ideal for growing trees. Soils with high percentages of sand or rock were set as the exclusionary value. Subsequently, soils containing high percentages of clay were scored as low, and silt-loam and loam-dominated soils were prioritized for tree planting.

The final layer considered for this suitability map was the existing drainage ways on site, consisting of the smaller streams or creeks that flow into the primary water source, Brush Creek, which is the main water source in this study. Like the flood hazard layer, the actual stream beds were set as the exclusionary factor. Like the existing trees layer, buffers were set around the drainage ways in the study area at 50 and 100 feet to target the areas most likely to flood or need further soil stability due to erosion issues. All areas outside these buffers were considered lower suitability for this analysis layer. See Figures 4.38 and 4.39 for the resultant map created

Table 4.5 Street Tree Suitability Matrix

	Suitability Rating			
Suitability Scale for Street Trees	**0 Exculsionary Factors**	**1 Low**	**2 Moderate**	**3 High**
Analysis Layer	**Exclusionary**	**Least favorable <--------- (or protect)**	**----------**	**----------> Most favorable (or free to alter)**
Slope		1-5%	5-10%	10+%
FEMA Flood Hazard Zone	within the drainage way	*Everything Else*	Within the 0.2% Floodplain	Within the 1% floodplain
Existing Trees	w/in 30 ft	50 ft	75 ft	100+ ft
Soils	high % sand or rock	high % clay	silt loam	loam
Drainage ways	Within the Stream Bed	everything else	w/in 100 ft of the Stream Bed	w/in 50 ft of the Stream Bed

Street Tree Suitability Map:

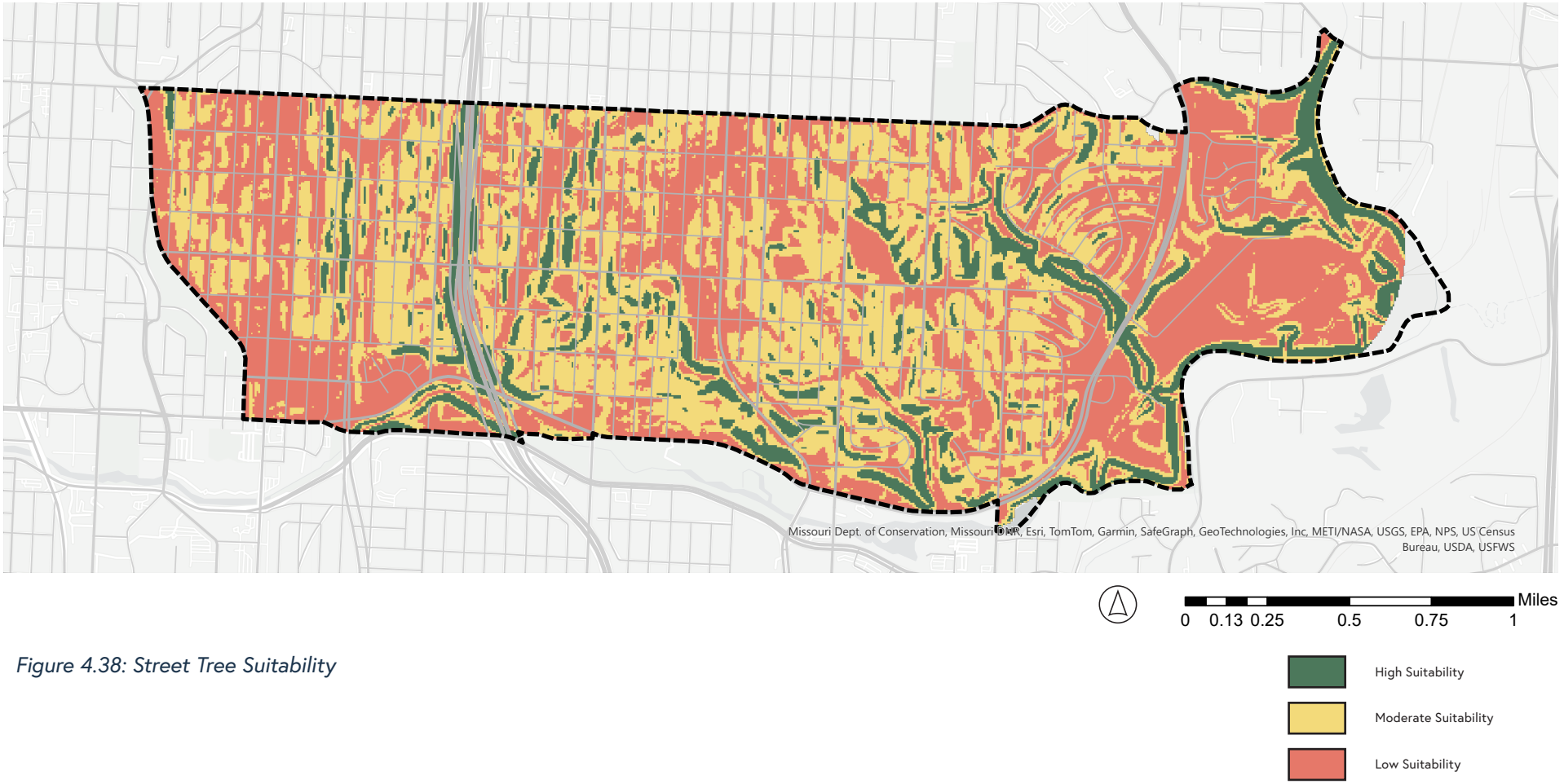


Figure 4.38: Street Tree Suitability

Street Tree Suitability Axononmetric:

Figure 4.39: Street Tree Suitability Axon View

Large Scale Combined Drought Flood Suitability

Before defining the parameters that made up the suitability scale for the large-scale combined drought flood suitability map, it is essential to note the difference between this map and the small-scale combined drought flood suitability map. There is no difference between the parameters evaluated for each map as they aim to address the same issue: areas to slow down the runoff rate and capture stormwater. The difference between these two systems would be the size of the parcel or parcels ultimately being selected for revitalization. In the large-scale combined drought flood system, the analysis is targeted to sites between one and 4 acres in total size. This will be discussed further in the final site selection section, which was based on the findings of the green infrastructure case studies and the availability of sites within this study area. If this study were to be repeated, this size could vary depending on the size of possible sites in other regions. See Table 4.6 for a visual breakdown of the parameters chosen for this suitability analysis.

Like street trees, no exclusionary factor was set for slope for this suitability analysis, as plantings will help address issues of erosion and runoff in any degree of slope. Because of this, areas most susceptible to high rates of runoff and erosion (areas with higher percentages of slope) were prioritized, and areas with 5% or less were scored as low suitability.

The analysis layer of the FEMA flood hazard zones was also used to target areas that are frequently and most severely impacted by floods. Because of this, all areas that land within the 1% floodplain were ranked highly suitable, and all areas within the 0.2% floodplain were ranked moderate suitability. Anything outside these floodplains was considered low suitability, and the drainage way was excluded from the scale.

Because this analysis looks explicitly at areas to implement systems to slow down runoff and retain water, the presence of existing structures was considered an exclusionary factor. Buffers were also set around these existing structures at distances of 100 and 150 feet to prevent liability of the potential of these systems failing and subsequently flooding an existing structure. Anything within 100 feet of the structure was considered low suitability, and anywhere between 100 and 150 feet from the structure was regarded as moderate suitability. Outside of these buffers, all other areas were considered highly suitable.

For this suitability map, soils that are the most fertile and optimal for plant life to thrive in were targeted, as these systems are typically densely vegetated. Similar to the last suitability map, soils with high amounts of sand and rock were excluded from consideration. Soils with high percentages of loam were considered the highest suitability, and high percentages of slit loam were regarded as moderate suitability, with high percentages of clay in the soil being ranked as low suitability.

The final parameter for this suitability scale was the drainage ways on site. Any space within the stream bed itself was excluded from consideration. Still, within 100 feet of the stream bed, the highest suitability was scored, as these are typically areas with high rates of erosion and runoff. Additionally, between 100 and 150 feet from the stream bed was considered moderate suitability, and anywhere outside these distances was considered low suitability for this analysis layer. See Figures 4.40 and 4.41 to view the map created using these paramters.

Table 4.6 Large Scale Combined System Suitability Matrix

	Suitability Rating			
Suitability Scale - Large Scale Combined System	**0 Exculsionary Factors**	**1 Low**	**2 Moderate**	**3 High**
Analysis Layer	**Exclusionary**	**Least favorable <--------- (or protect)**	**----------**	**----------> Most favorable (or free to alter)**
Slope		1-5%	5-10%	10+%
FEMA Flood Hazard Zone	within the drainage way	Everything Else	Within the 0.2% Floodplain	Within the 1% floodplain
Structures	Existing Structure	Within 100 ft	150 + ft	Everything Else
Soils	high % sand or rock	high % clay	silt loam	loam
Drainage ways	W/in the Stream Bed	Everything Else	w/in 150 ft of the Stream Bed	w/in 100 ft of Stream Bed

Large Scale Combined Drought Flood Suitability Map:

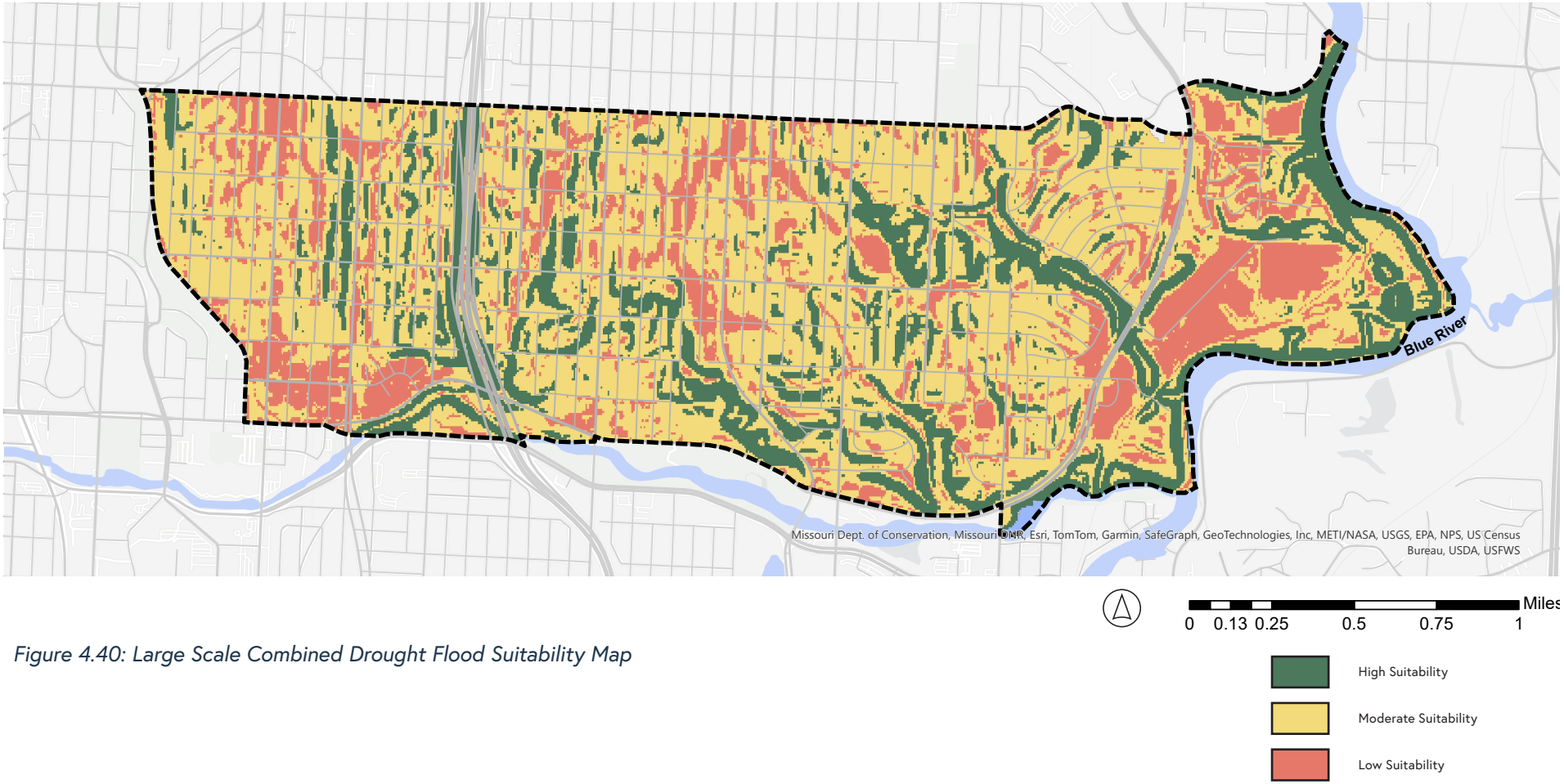


Figure 4.40: Large Scale Combined Drought Flood Suitability Map

Large Scale Combined Drought Flood Suitability Axonometric:

Figure 4.41: Large Scale Combined Drought Flood Suitability Axonometric

Small Scale Combined Drought Flood Suitability

As discussed in the large-scale combined drought flood suitability section, the parameters for this section are identical to the prior. For this suitability scale, sites less than an acre in total size will be targeted for revitalization. Once again, this decision was based on the information gathered through the green infrastructure case study analysis process. To avoid redundancy, the detailed breakdown of each parameter will not be repeated in this section, but Table 4.7 does break these layers down again for reference, and Figures 4.42 and 4.43 visualize the mapped data.

Table 4.7 Small Scale Combined System Suitability Matrix:

	Suitability Rating			
Suitability Scale - Small Scale Combined System	**0 Exculsionary Factors**	**1 Low**	**2 Moderate**	**3 High**
Analysis Layer	**Exclusionary**	**Least favorable <--------- (or protect)**	**----------**	**----------> Most favorable (or free to alter)**
Slope		1-5%	5-10%	10+%
FEMA Flood Hazard Zone	within the drainage way	Everything Else	Within the 0.2% Floodplain	Within the 1% floodplain
Structures	Existing Structure	Within 100 ft	150 + ft	Everything Else
Soils	high % sand or rock	high % clay	silt loam	loam
Drainage ways	W/in the Stream Bed	Everything Else	w/in 150 ft of the Stream Bed	w/in 100 ft of Stream Bed

Small Scale Combined Drought Flood Suitability Map:

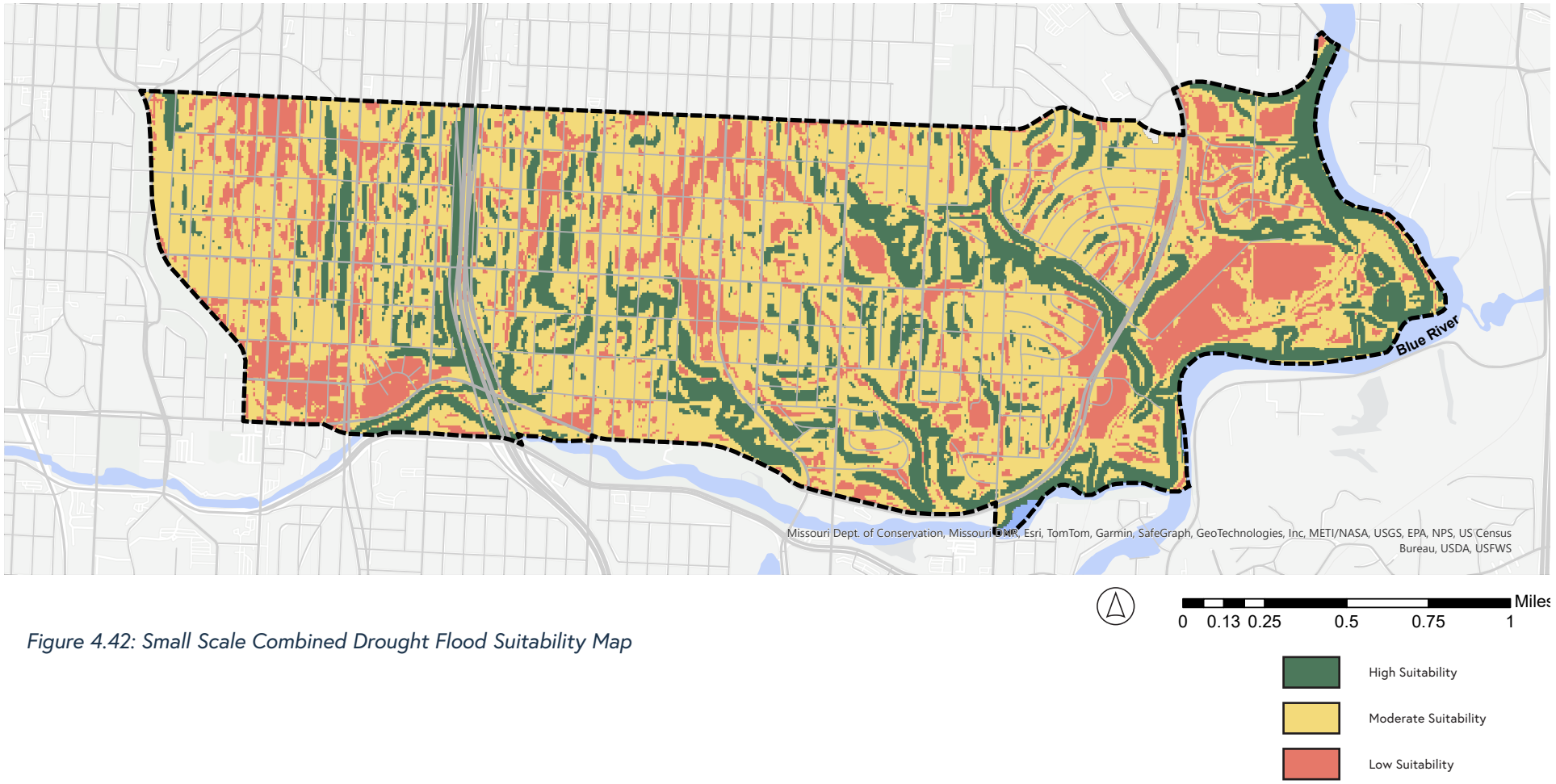


Figure 4.42: Small Scale Combined Drought Flood Suitability Map

Small Scale Combined Drought Flood Suitability Axonometric:

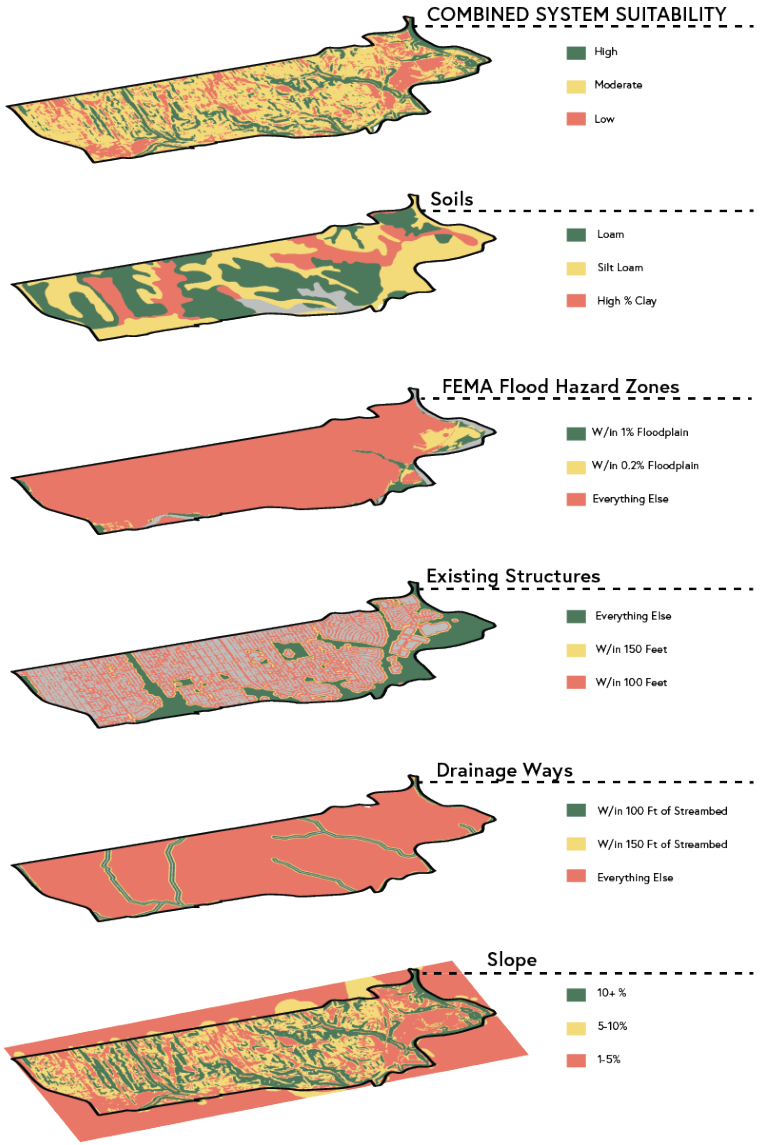


Figure 4.43: Small Scale Combined Drought Flood Suitability Axonometric

Water Retention Suitability

For this suitability scale, areas were targeted with the goal of capturing and storing large amounts of water in spaces that are down slope and naturally collect water as is. Because of this, the parameters for these systems look slightly different and are slightly more complex than those discussed in previous sections. Please refer to Table 4.8 for a visual breakdown of these parameters and Figures 4.44 and 4.45 for the resulting map.

When considering percentages of slope to target for these systems, areas with a slight natural slope are ideal, which is why a 2-4% slope is considered highly suitable for this scale. Additionally, a 5-8% slope was considered moderate, and an 8-10% slope was considered low suitability. Completely flat areas or spaces with high slopes above 10% were excluded from this analysis.

Because these systems would involve extensive soil excavation in most cases, the parameters around the FEMA flood hazard zones also look quite different for this scale. Once again, anywhere within the drainage way has been excluded from the analysis. For this scale, anywhere within the 1% floodplain was considered low suitability, as these areas tend to be somewhat fragile, and excavating large amounts of soil in them is not advisable. Anything within the 0.2% floodplain was considered highly suitable, as this is farther outside the most fragile area and still has significant flood threats that must be addressed. All areas outside these flood zones were considered moderately suitable for this scale.

Once again, buffers were put around existing structures to avoid potential flooding and destruction of property and utilities related to these buildings. Anywhere within the existing structure was excluded from consideration, and within 100 feet of the structure was once again scored as low suitability. The buffer was expanded for this suitability scale, and anything within 200 feet was considered moderately suitable, but anything outside of this 200-foot distance was considered highly suitable.

Once more, soils with high sand or rock content were excluded from the analysis. Since these systems are looking to target areas that can retain water, soils with higher percentages of clay were ranked as highly suitable, and soils with high percentages of loam were ranked as moderately suitable. Consequently, soils with high silt loam content were considered low suitability for water retention.

Drainage ways were approached slightly differently, as similar to the floodplain, the areas directly surrounding them tend to be somewhat fragile, and extensive soil excavations in these areas are not advisable. Because of this, areas within 50 feet of an existing stream bed were excluded from consideration, and areas within 100 feet of the stream bed were ranked as low suitability. Additionally, areas within a 200-foot distance of the stream bed were considered moderate suitability, and anything outside these boundaries was ranked as highly suitable.

The existing tree cover was the final analysis layer for this suitability scale. This is slightly different from existing trees as previously analyzed for the street tree suitability scale. It is okay if there are some trees on site where these systems are located as long as they do not dominate the site. Because of this, areas with more than 15% tree canopy cover were excluded from the analysis as it would call for removing too many trees to implement a system of this caliber successfully. Furthermore, areas with 10-15% tree canopy cover were ranked low suitability, and 5-10% tree canopy cover was moderately suitable. Sites most ideal for water retention systems would ideally only 2-4% existing tree canopy cover on site.

Table 4.8 Water Retention Suitability Matrix

	Suitability Rating			
Suitability Scale Water Retention System	**0 Exculsionary Factors**	**1 Low**	**2 Moderate**	**3 High**
Analysis Layer	**Exclusionary**	**Least favorable <--------- (or protect)**	**----------**	**----------> Most favorable (or free to alter)**
Slope	0% or higher than 10%	8 - 10%	5 - 8%	2 - 4%
FEMA Flood Hazard Zone	within the drainage way	Within the 1% floodplain	*Everything Else*	Within the 0.2% Floodplain
Structures	Existing Structure	Within 100 ft	Within 200 ft	Everything Else
Soils	high % sand or rock	silt loam	loam	high % clay
Drainage ways	w/in 50 ft of stream bed	w/in 100 ft of Stream Bed	w/in 200 ft of the Stream Bed	Everything Else
Existing Tree Cover	<15% Coverage	10 -15%	5 - 10%	2 - 4%

Water Retention Suitability Map:

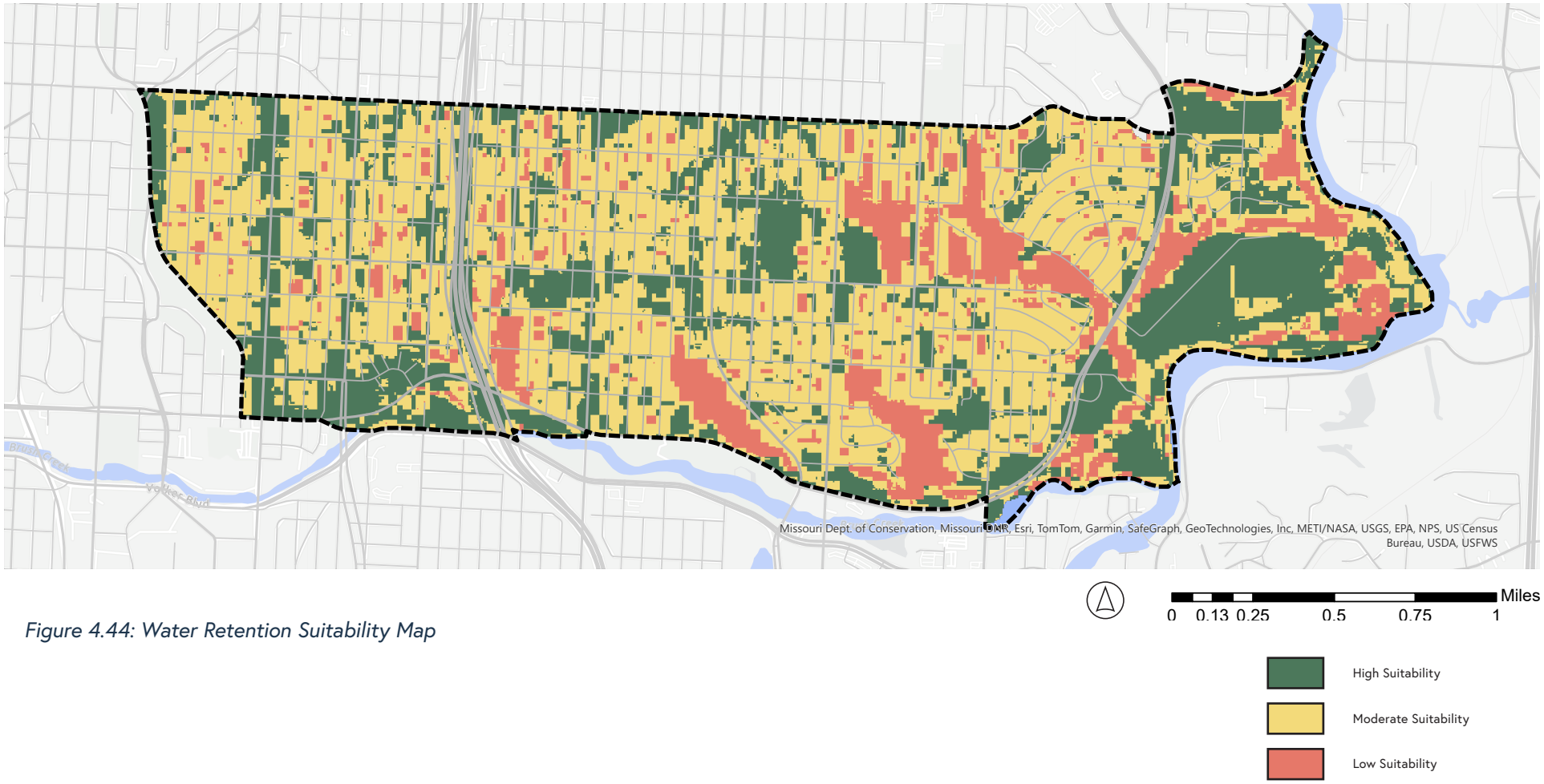


Figure 4.44: Water Retention Suitability Map

Water Retention Suitability Axonometric:

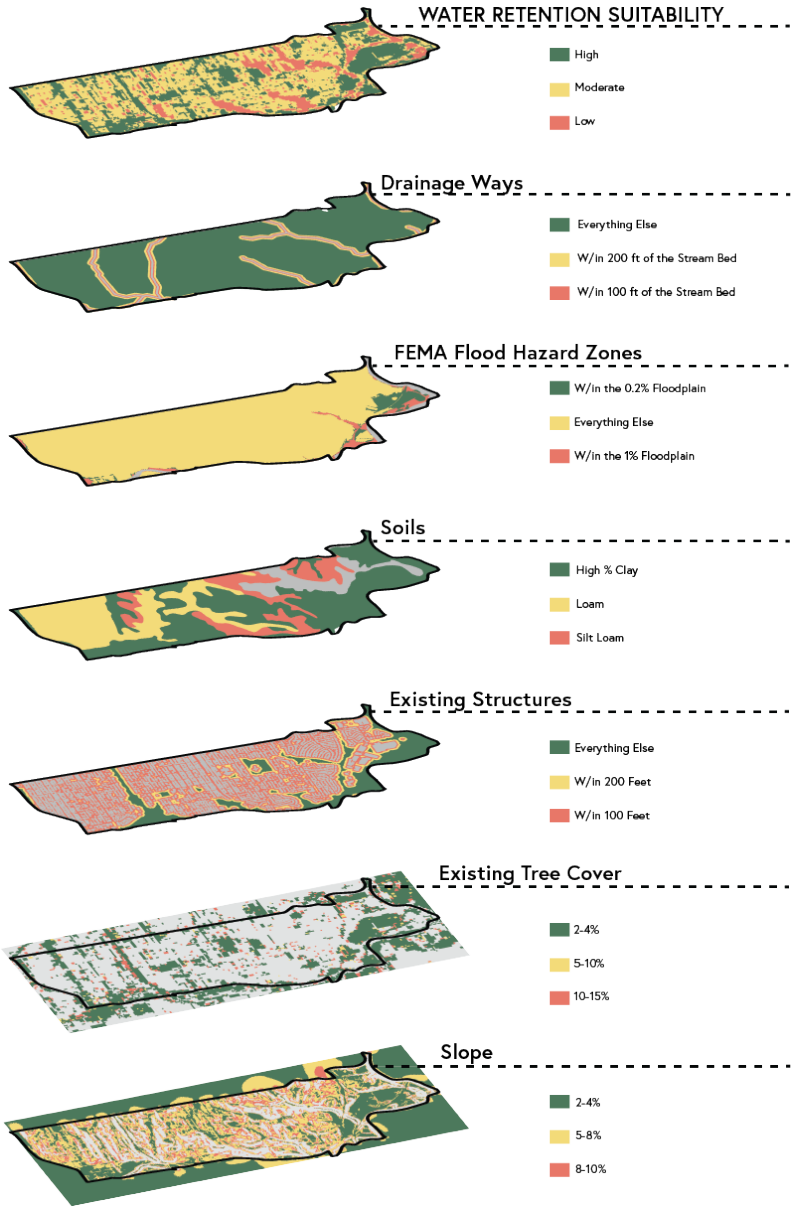


Figure 4.45: Water Retention Suitability Axonometric

Preliminary Site Selection:

Preliminary sites were selected based on the results of the suitability analysis process. The information gathered through the suitability mapping process was overlayed with all the potential parcels and streets within the study area that correlated to the sizing requirements decided upon in prior steps. Sites were selected for the four project typology categories: street tree implementation, large-scale drought flood systems, small-scale drought flood systems, and water retention systems. Additional factors were considered in addition to the suitability analysis in later sections once typologies were designed. Sites were ultimately chosen based on their relationship to their surroundings, zoning, ownership, and land value. For further clarity around the entire site selection decision making process, please refer to the diagram in Appendix E, which visually describes all steps taken to choose the final recommended sites for potential implementations.

Street Tree Implementation

The site selection process for street tree suitability looked different from the other site typologies, as this typology is solely focused on implementing additional trees in the study area, whether on the street, vacant lots, or natural green spaces. Additionally, because trees have so many vast environmental benefits and can help address the three major climatic threats this study is focused on, it is recommended that areas with high and moderate suitability be targeted for additional planting. See Figure 4.46 for the potential sites selected for additional tree planting.

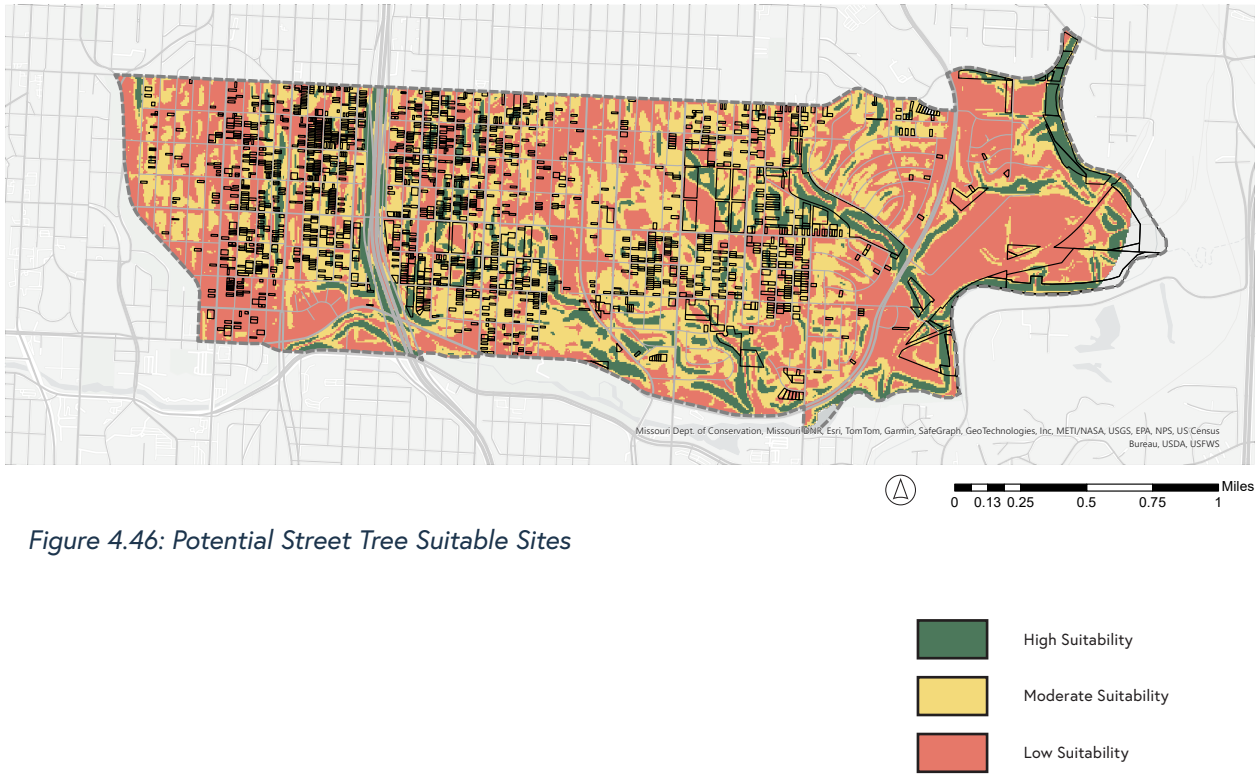


Figure 4.46: Potential Street Tree Suitable Sites

Large Scale Combined Drought Flood Systems

There were about 30 vacant lots in the study area, which correlated with the size requirements decided upon for the potential implementation of a large-scale combined drought and flood green infrastructure system. After additional analysis of factors, this amount was paired down to 12 potential sites that would be most suitable for implementing this type of large-scale system. Figure 4.47 visualizes these potential sites in relation to the overall suitability map that was created.

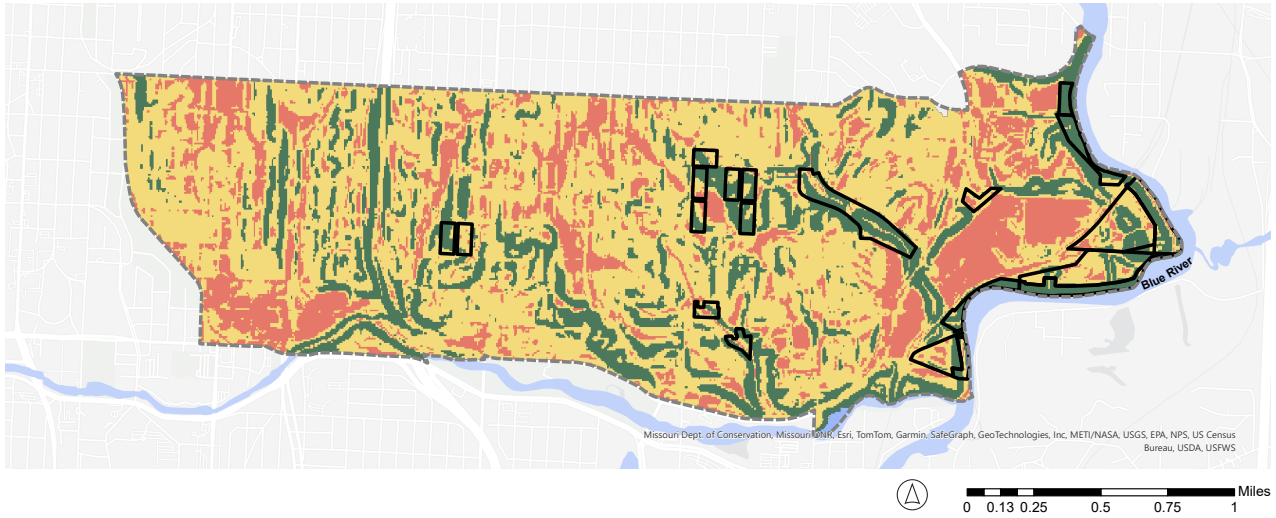


Figure 4.47: Large Scale Combined System Potential Suitable Sites

Small Scale Combined Drought Flood Systems

Because the size of the small-scale combined drought flood green infrastructure typology is one acre or less and the study area is predominantly made up of dense urban residential lots, there were far more potential sites that could be used for projects of this kind. Granted, while there were far more sites that met the size requirements of this site selection typology, only some of these sites are entirely suitable for a project of this kind. In total, around 100 potential sites were identified as ideal for the implementation of a small-scale combined drought flood green infrastructure system. It is also important to note that implementing systems of this kind may be more successful if several were implemented within close range to one another, such as along the same street, as the connectivity of these systems is a critical factor in increasing resilience. Figure 4.48 visualizes all the potential sites currently vacant and under one acre in size in the study area in relation to the suitability map.

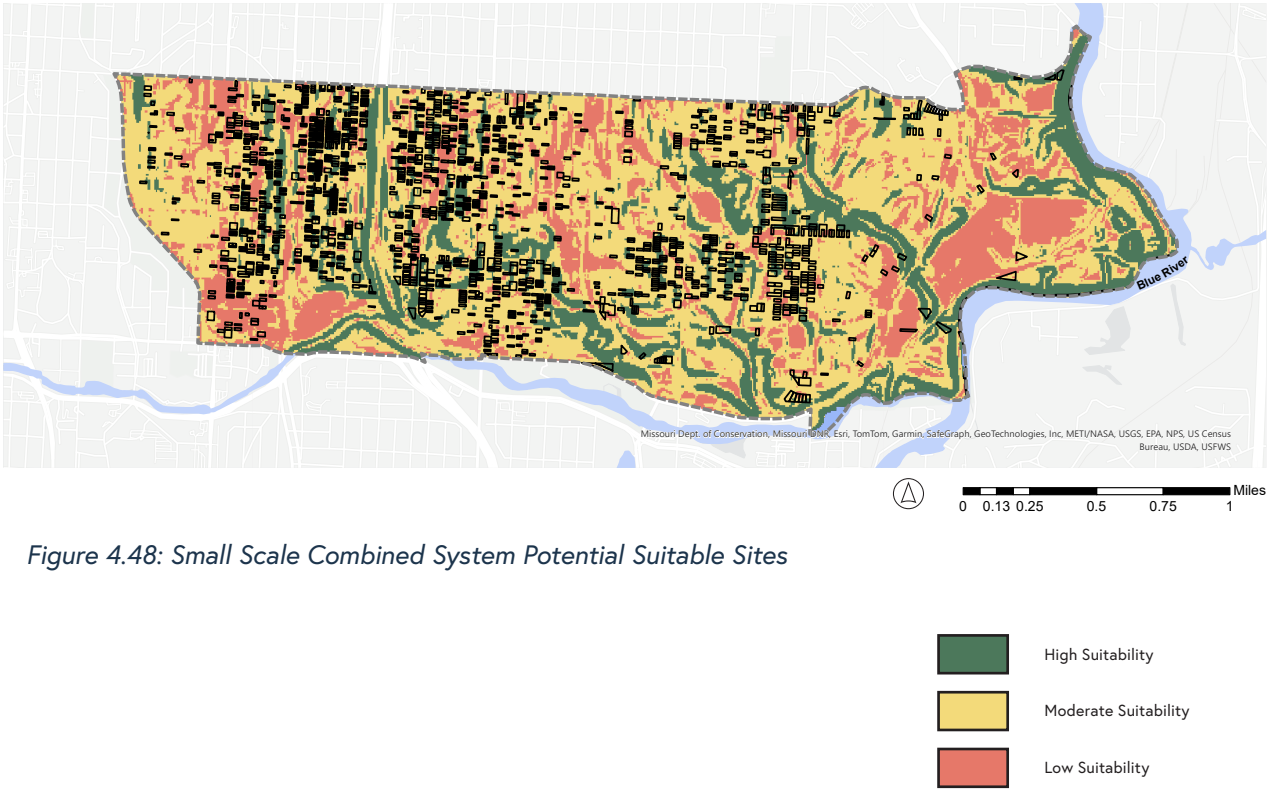


Figure 4.48: Small Scale Combined System Potential Suitable Sites

Water Retention Systems

Compared to the other site selection typologies evaluated in this study, the water retention system resulted in the lowest number of potential sites being a good fit within the study area. Of the 28 vacant lots in the study area that match the size requirements of a system like this, only seven sites in this selection are genuinely suitable for implementing this kind. These results are not entirely surprising, as this site selection typology had the most factors to be considered and targeted the most significant sites in relation to these factors in an area with predominantly smaller residential lots. See Figure 4.49 for a visual of these potential sites concerning the water retention suitability map.

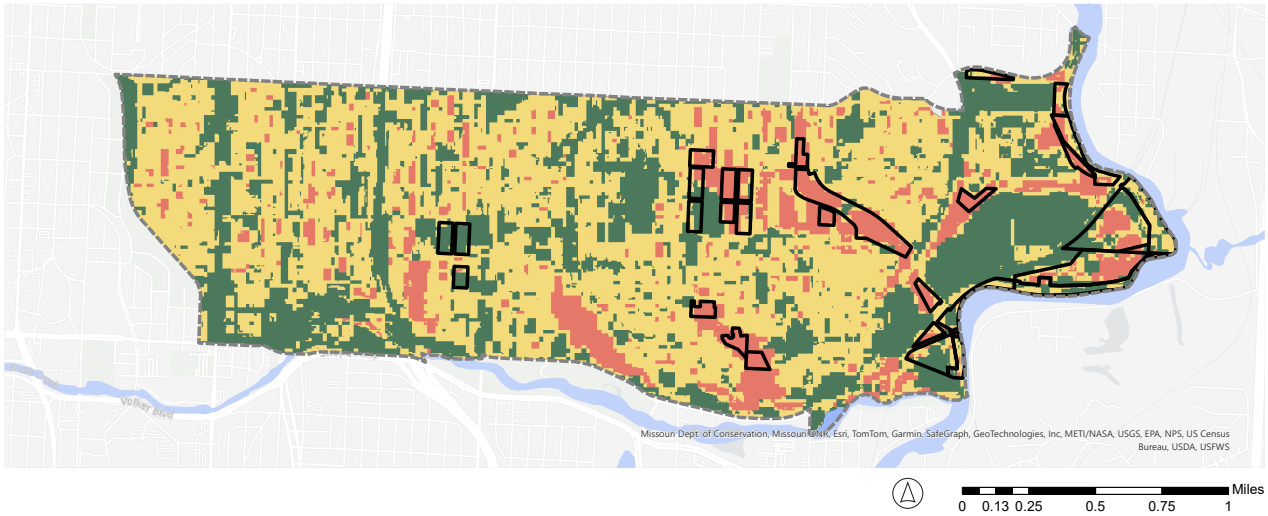
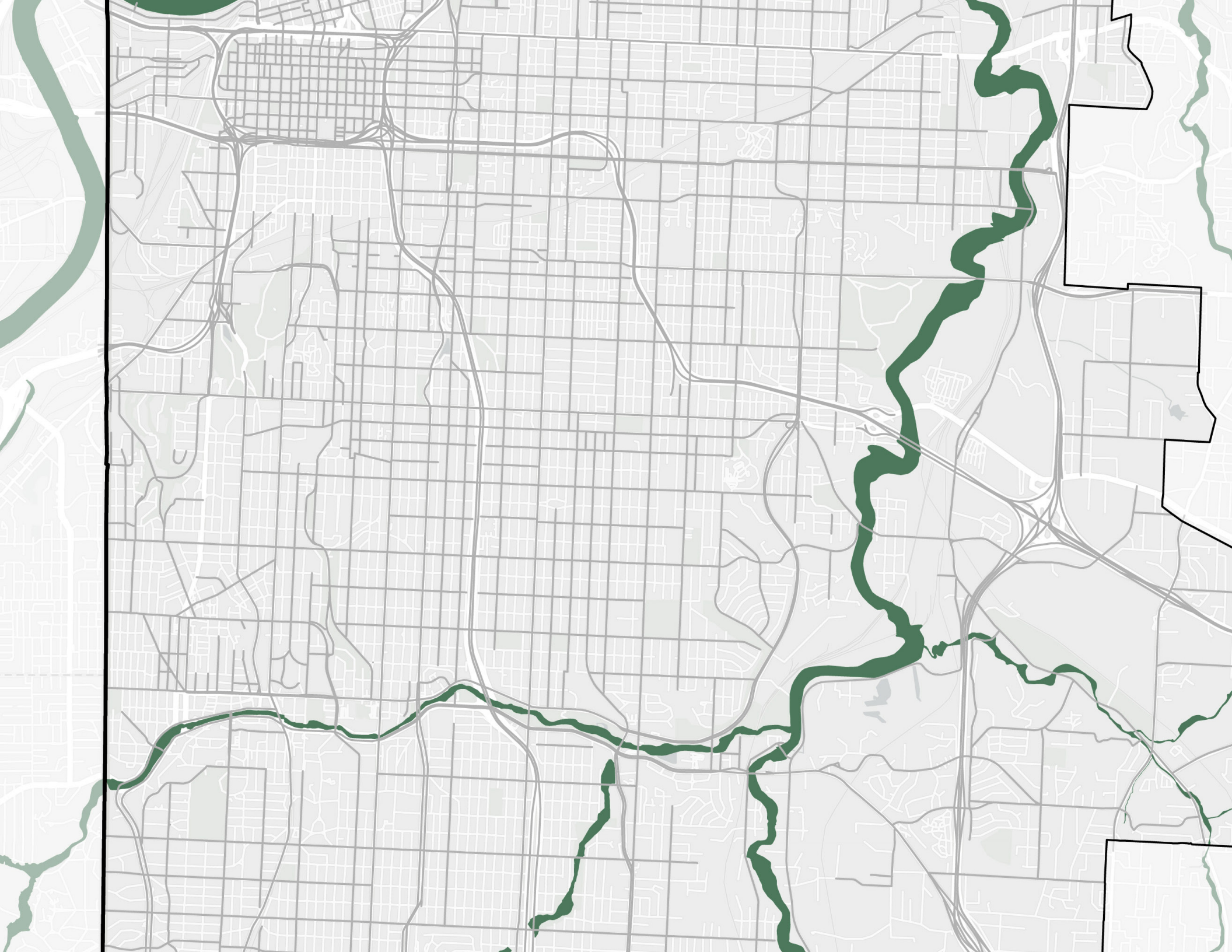
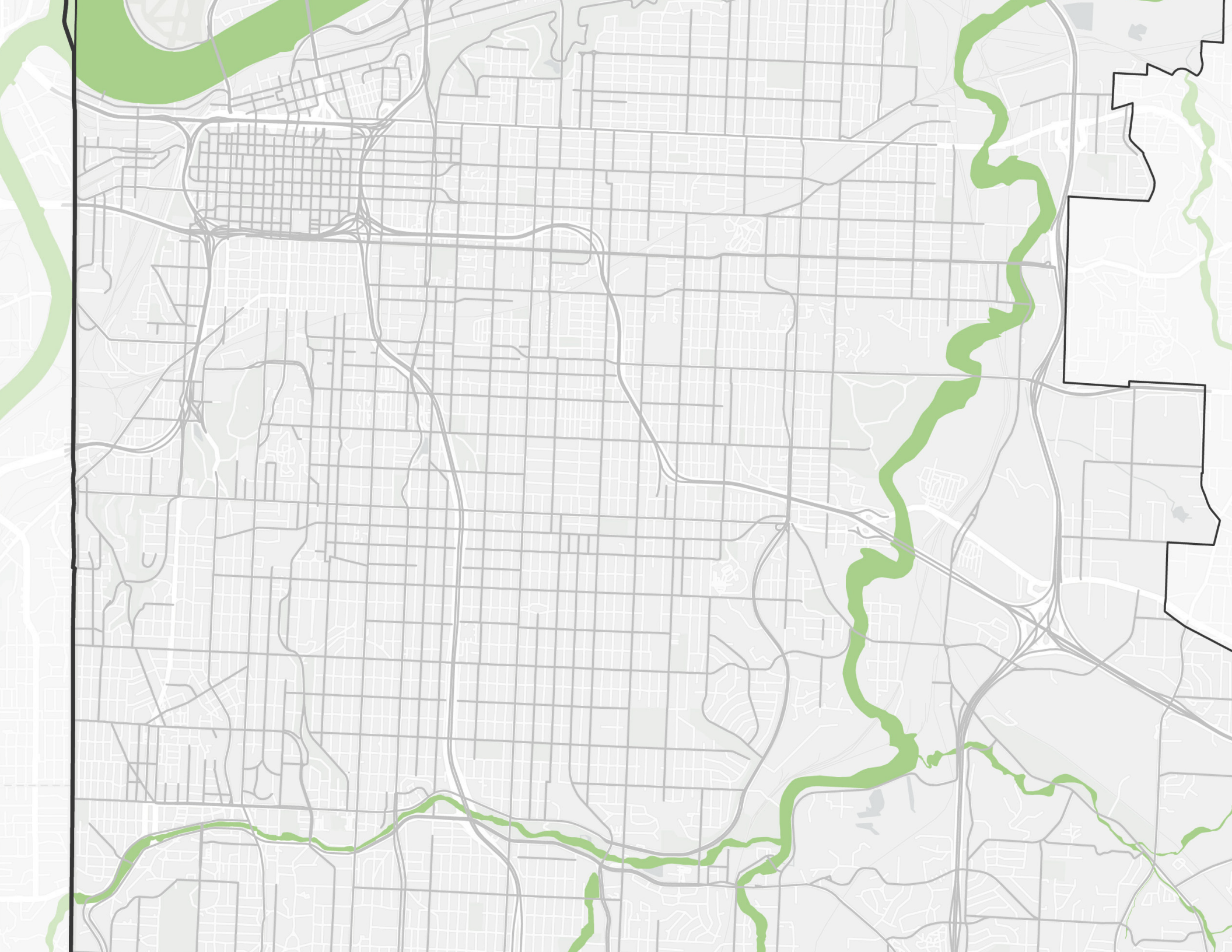


Figure 4.49: Water Retention Potential Suitable Sites





5 Evidence Based Recommendations:

The following sections are a culmination of all the information gathered and analyzed throughout all prior sections of this study, which led to the creation of potential design prototypes and subsequent proposed guidelines of how to implement and maintain these prototypes in the long term. The created prototypes are a baseline design, including specific design features or elements matched with existing site conditions, which aim to boost resilience to one or more climate threats. Figure 5.50 visualizes the decision-making process used to navigate decision-making relating to green infrastructure implementations for this study. The two primary components of this decision-making framework included site selection and implementation considerations. Since the previous section has explained the site selection and suitability process in detail, this section primarily concerns the implementation considerations of potential greening projects to be recommended. The significant factors considered and discussed for each suggested implementation include maintenance, funding, community engagement, and planting recommendations and considerations.

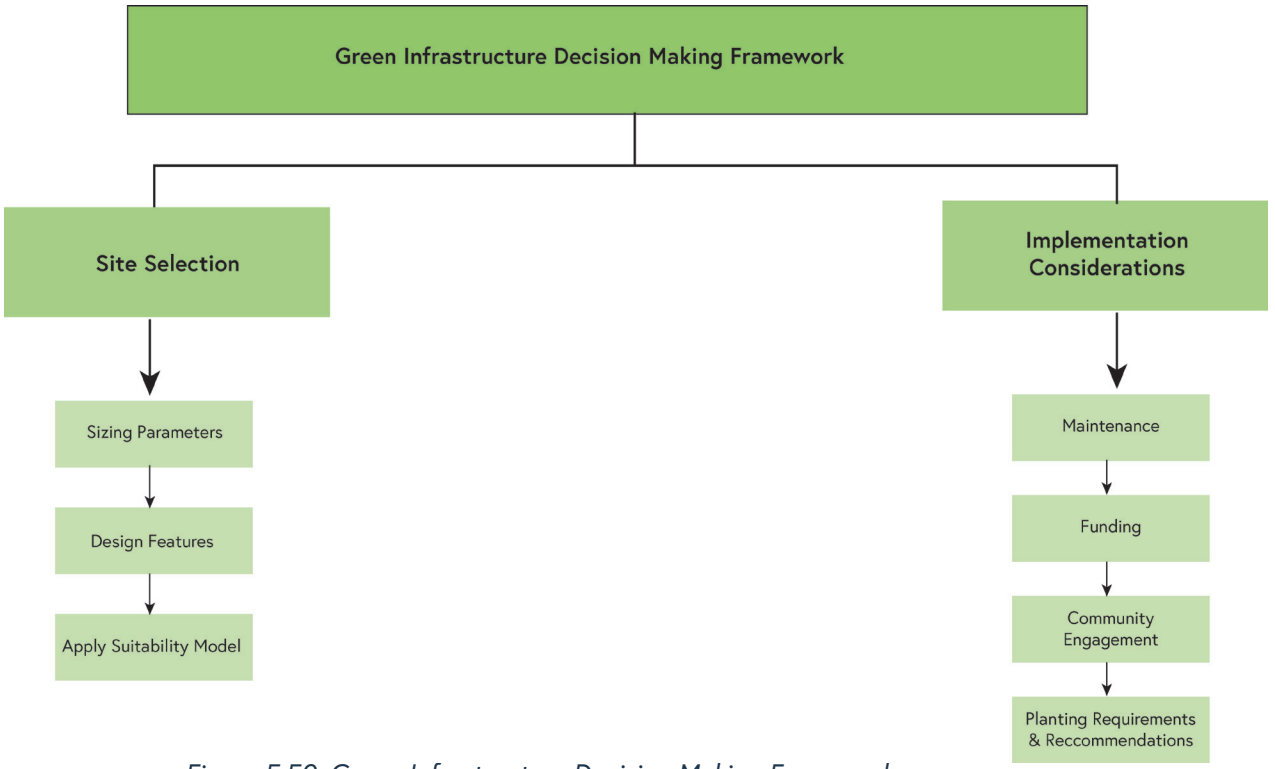


Figure 5.50: Green Infrastructure Decision Making Framework

Green Infrastructure Typologies & Guidelines:

Five different green infrastructure system typologies or prototypes were created to visualize the potential implementations discussed throughout this study. These baseline prototypes seek to emulate current site conditions in the study area and address the subsequent effects of flooding, drought, and urban heat islands on the area. Through the green infrastructure case studies, specific design features were identified and combined to create these green infrastructure typologies. It is important to note that while green roofs were a common element and project type analyzed through the green infrastructure case studies, they will not be considered a potential solution for this study as they take vast amounts of funding. This study area lacks the facilities to implement such a project efficiently. With this being said, all the following recommended typologies are focused on increasing tree and plant matter in the area, with the addition of some simple technologies that could be implemented and maintained easily. These typologies aim to provide realistic and achievable baseline designs, which could be elaborated upon when designed for a specific site but could be applied to sites with the same general attributes. It is also important to note that if any of these typologies were to be used as the basis of a design project implemented in this area, community engagement would need to be conducted to ensure that the community understood the project and had a role in the shaping of these now public spaces in their community. In addition to community engagement, adequate funding would need to be sourced, and a comprehensive maintenance plan would need to be created to ensure these systems thrive and adapt to the changing environmental conditions for years to come.

Street Tree Planting Design

The first design typology created for this study was a street tree planting design typology. Because trees have such vast ecological benefits and the potential to mitigate all three climate factors this study is focused on, additional tree planting in this area is of high priority. While this design typology was developed to offer a baseline approach to planting trees in a highly urban condition, additional tree planting is encouraged in natural areas and public green spaces, see Figure 5.51.

Potential design features for the street tree planting design include street trees from the approved planting list (see Appendix A for the official list of all approved trees per the City of Kansas City, Missouri) and mulch over the planting area. In addition to these two key elements, it is recommended that in areas with existing runoff issues, paving around the planting area should be made pervious, and a planting cell technology should also be implemented to maximize the amount of water that could be infiltrated into the ground. An example of a street tree planting cell is the product Silva Cells (https://www.deeproot.com/products/silva-cell/), which can boost stormwater management on-site and provide more volume for root growth in highly urban conditions. While these design features are a bit more costly, additional investment is recommended in areas that need additional stormwater management. Using a planting cell and pervious paving is not necessary for all instances. Appendix C features the official planting guide per the City of Kansas City, Missouri, with a planting diagram.

It is recommended that street trees be planted between the curb along the street and the sidewalk or adjacent space. Trees should be adequately spaced for growth and proper maintenance; according to the Kansas City Missouri Parks and Rec Department, leaving 30 to 60 feet of space between street trees is recommended. Additionally, the planting space should be wide enough to allow for the proper growing conditions of the selected type of tree. Appendix B features a modified list of approved street trees that would best address issues relating to runoff and stormwater, as well as required planting space. Other essential factors to consider

before planting street trees include the proximity to overhead powerlines and other overhead or underground utilities within the planting area. In terms of the long-term care and maintenance of the newly planted trees, it is essential to address any issue the tree is having immediately and ensure the tree is adequately fertilized and watered until fully established.

Additionally, the City of Kansas City, Missouri, created a tree program in 2023 to encourage additional tree planting within the city where residents can apply to receive a free tree to grow on their property (https://www.kcmo.gov/city-hall/departments/neighborhood-services/free-trees). This program is specifically geared towards the planting of trees on private property. Still, additional funding for tree planting can be obtained through grants from sources such as the USDA Forestry Service. One specific funding source is the USDA National Urban and Community Forestry Program, which seeks to help fund urban tree canopy projects and initiatives.

Based on the findings from the suitability analysis conducted in the previous section, several streets were selected as a top priority for additional street tree planting, as visualized in Figure 5.52. While these streets aren't the only areas within the study area that need more street trees, they could be a good starting point for this area to begin enhancing the local tree canopy cover.

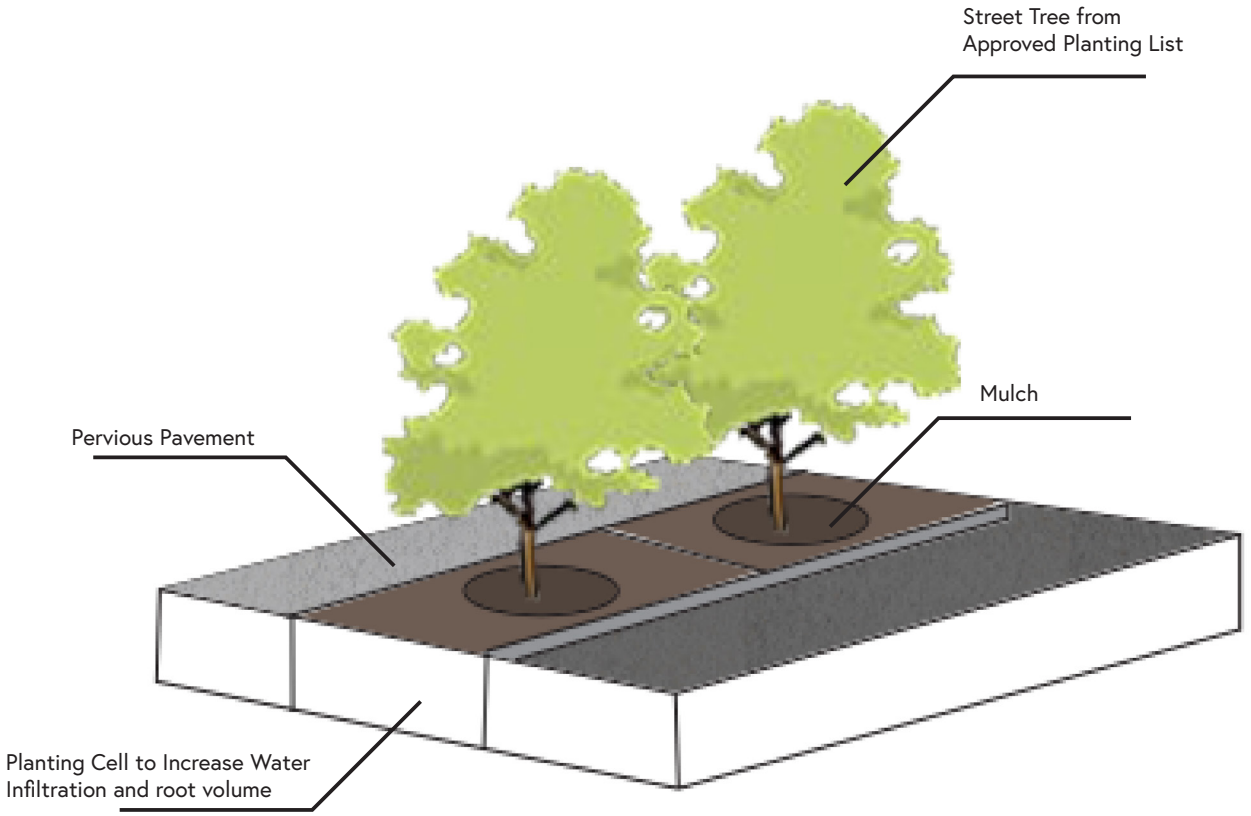


Figure 5.51: Street Tree Planting Design Typology

Figure 5.52 Recommended Streets for Additional Street Trees

Water Retention Basin Design

The water retention basin design aims to retain and infiltrate stormwater draining within the study area. This design can be flooded and hold water, but since climate predictions indicate potential drought conditions, this basin could also be dry and full of vegetation, see Figure 5.53. Additionally, this typology could be designed to function as an urban pond and support fauna and flora, becoming a usable space for recreation within the study area. Implementation design features include flood-tolerant trees and native plants, large rocks or boulders, and potential underground water storage. It is important to note that when choosing plants for a project of this type, consider species tolerant to extreme conditions that could survive in flooded and drought conditions. While this project implementation is mainly suggested for use in areas with flooding and standing water issues, underground water storage allows harvesting and reusing this water for other purposes, especially during times of water scarcity. See Appendix D for planting recommendations for native plants which are tolerant to these conditions.

Since these projects would be larger in scale than most of the other typologies, funding, maintenance, and community engagement will be essential. Projects of this size and scope will likely need a long-term maintenance plan and regimen, which should be conducted by the local parks and rec or public works department, depending on the project's location. Additionally, community engagement efforts will be essential, especially if this design were to be made into an urban pond and, subsequently, a source of recreation and pride for surrounding communities. Decision-making around what kind of retention system should be discussed at community engagement events is critical to ensure that the system created meets the ecological and social needs of the surrounding communities. Potential funding sources for this project include grants from the EPA and FEMA, which provide grant opportunities for green infrastructure projects explicitly relating to flooding issues.

Because water retention can only take place on far more specific sites compared to other typologies, there are far fewer recommended sites within this area for this type of project. Figure 5.54 visualizes these selected sites.

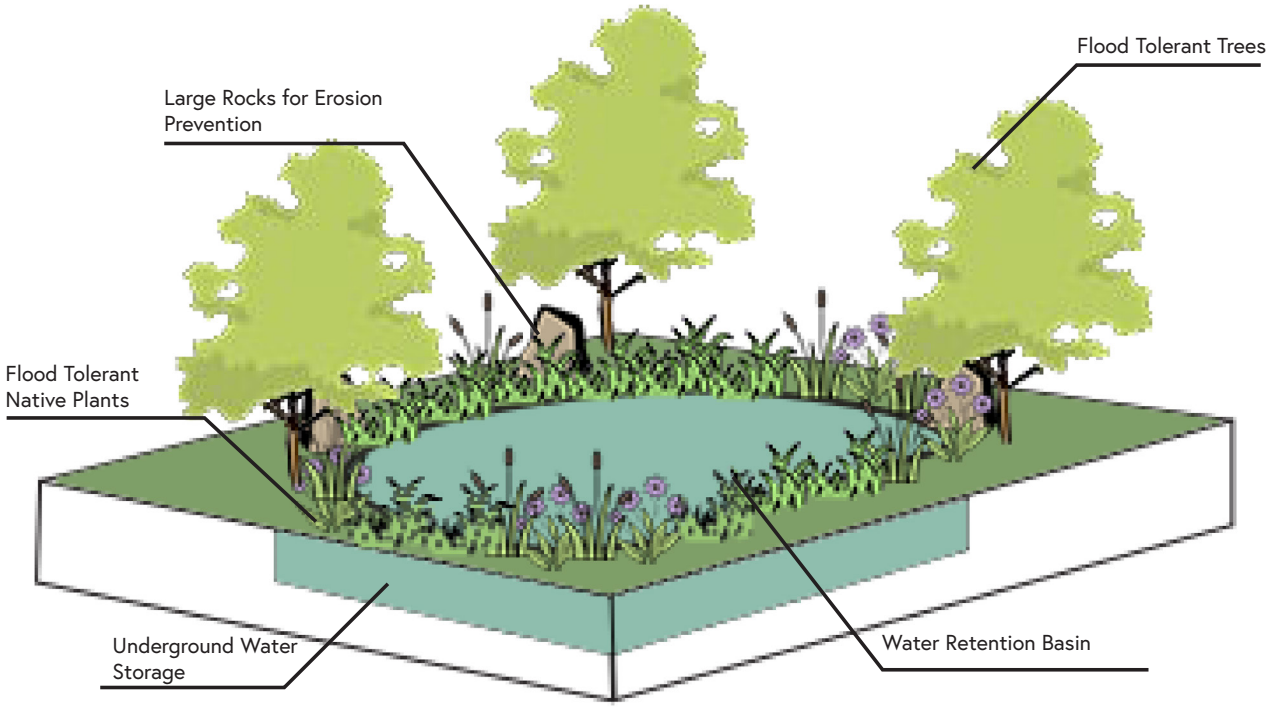


Figure 5.53 Water Retention Design Typology

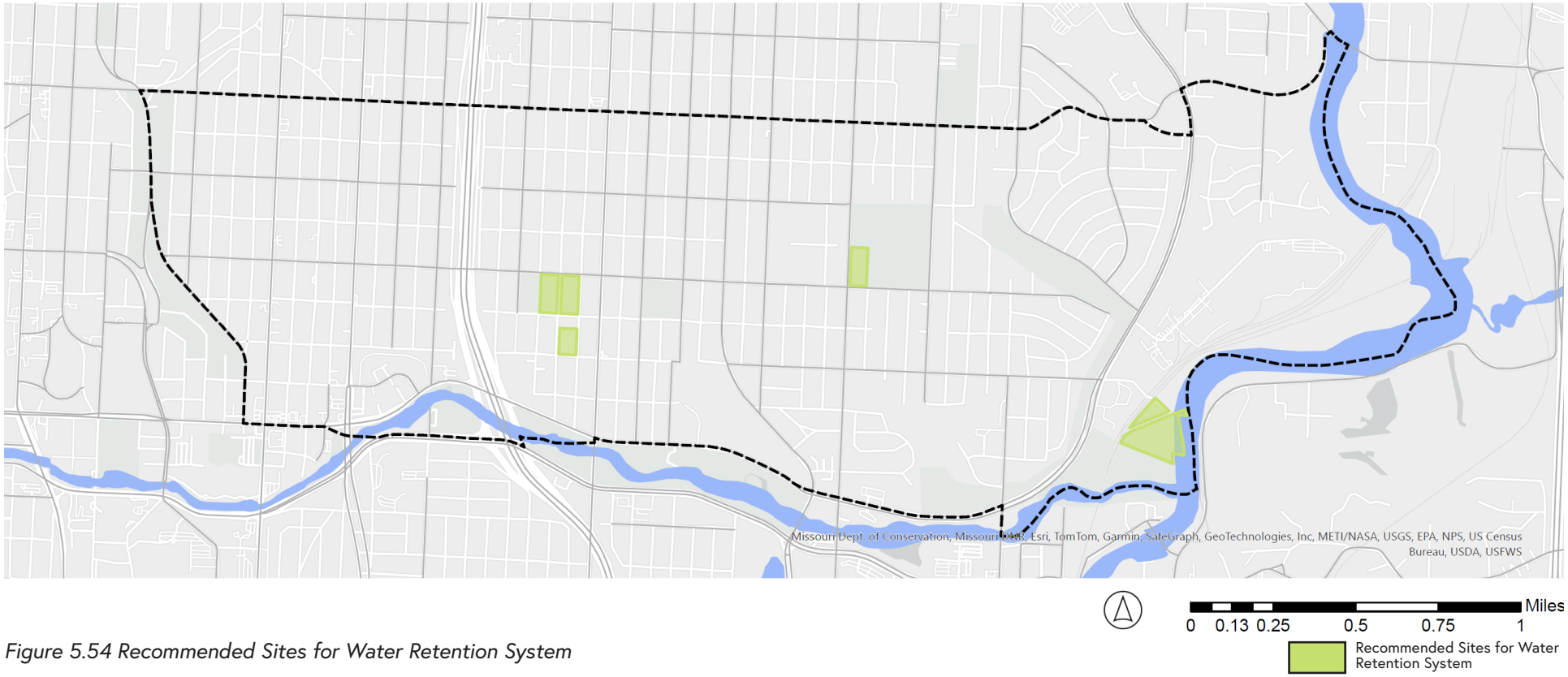


Figure 5.54 Recommended Sites for Water Retention System

Residential Vacant Lot Infiltration System Design

Due to the high percentage of vacant lots within the study area, a design typology was created to repurpose these lots into ecologically productive spaces rather than just remaining vacant. This typology could be implemented on steeply sloping and flatter lots, with the primary goal of additional water infiltration being the same regardless of the existing conditions, see Figure 5.55. Recommended design features include native plantings and trees on the vacant lot itself, pervious sidewalks, street trees, and flood-tolerant plantings within a roadside bioswale or rain garden.

Native plantings and trees within the vacant lot itself can have many ecological functions, including stormwater management and pollination efforts. Additionally, a bioswale or rain garden next to the street can help address water runoff during storm events, provide additional infiltration, and eliminate potential pollutants through natural processes. Pervious paving around the planted areas would provide a surface for walking while encouraging additional water infiltration.

Projects of this type would require community engagement, as this would occur near or adjacent to residents' homes. Engaging communities through their neighborhood affiliations or programs may be the best approach to building awareness of these project types, educating the public on their importance, and receiving community feedback on the aesthetic design of these spaces. These systems would also require long-term maintenance plans, which should be led by the group implementing the project. Many potential funding sources could be applied for and acquired through federal government agencies and programs such as the Environmental Protection Agency and the Department of Housing and Urban Development, which offers many different grants for implementing green infrastructure projects that address climate or environmental threats.

Due to the vast number of small residential vacant lots within this study area, many potential sites were selected as high priority for possible intervention.

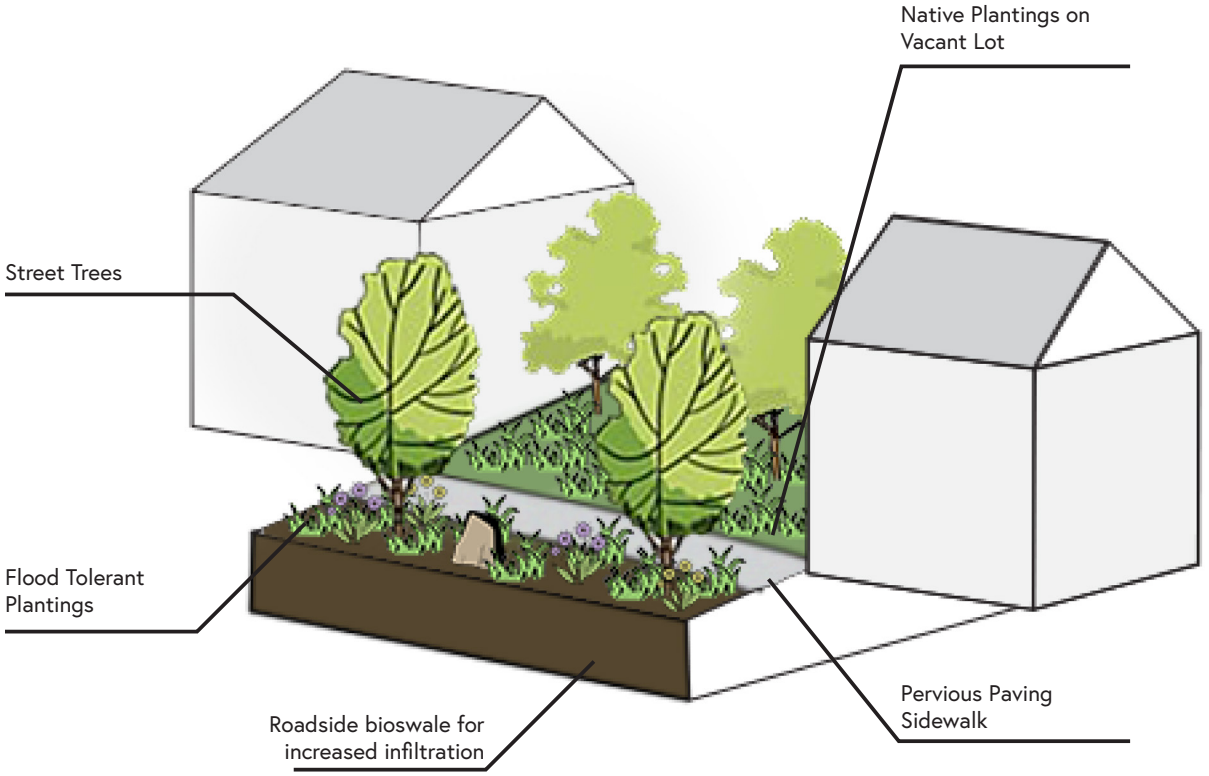


Figure 5.55 Residentail Vacant Lot Infiltration System Design

Because some of them are close to one another, this poses an opportunity to implement these types of projects across multiple sites, which could create a far more resilient system than just one or two throughout the study area. Figure 5.56 visualizes the recommended sites for implementing the residential vacant lot infiltration system.

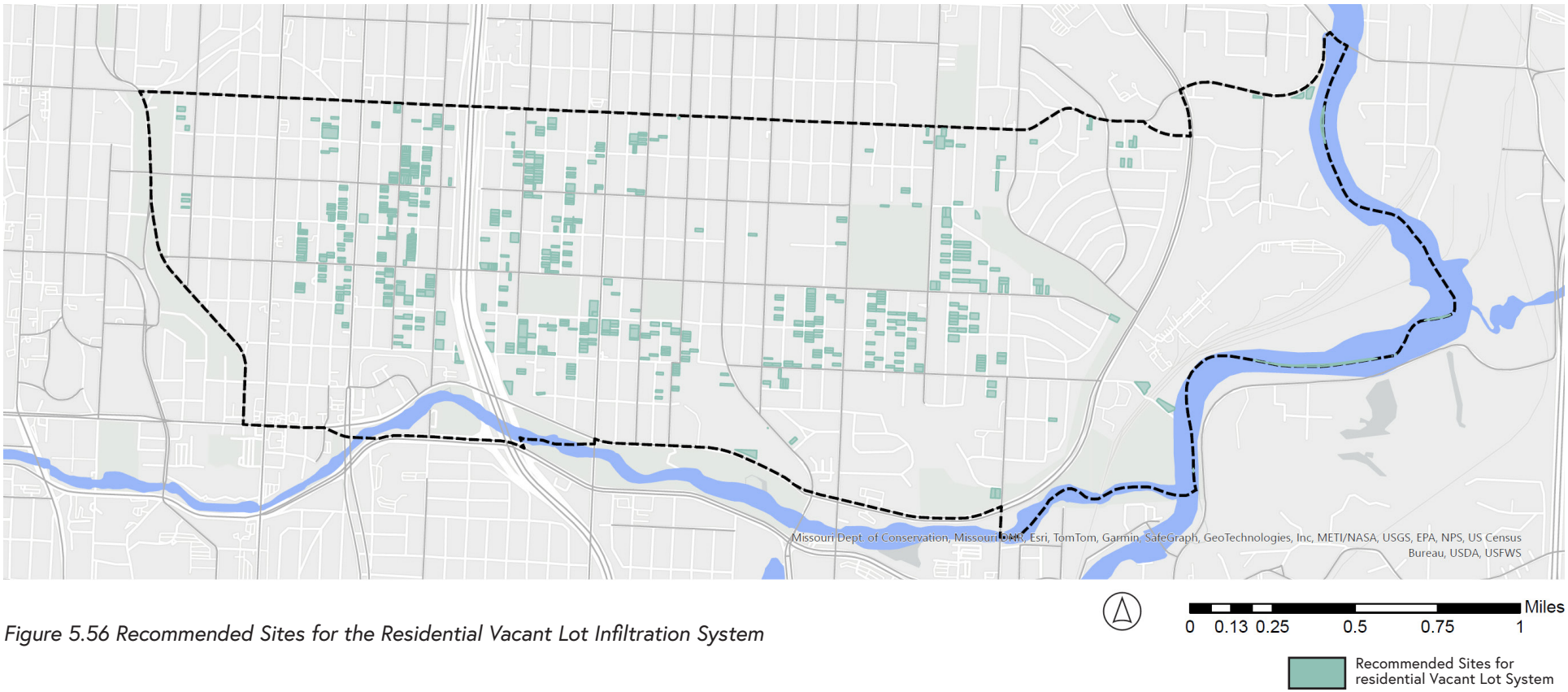


Figure 5.56 Recommended Sites for the Residential Vacant Lot Infiltration System

Urban Streetscape Infiltration System Design

The urban streetscape infiltration design aims to address stormwater runoff issues in areas with high amounts of impervious surface and steep slopes, such as several of the main roadways in the study area. This design includes curb cuts, flood-tolerant native trees, permeable pavement, and a bioswale with native plantings, see Figure 5.57. While this typology is recommended to be applied in areas of high slope due to the existing runoff issues, it could also be located in less steeply sloped regions that are also experiencing problems with flooding or standing water. This design aims to slow down the rate of runoff, provide additional stormwater infiltration opportunities, increase the urban tree canopy, and address issues of potential pollutants. In an area that relies heavily on active and public transportation, including systems on the main heavily trafficked streets could significantly impact pedestrian comfort and safety levels.

These systems should be equipped with diverse plant life that is tolerant to extremes in climate trends and can handle extreme flooding and drought periods. It will also be essential to gain community support through community engagement efforts if this design typology were to be implemented throughout the study area, as it will dramatically change the visual appearance of the main streets in the area. Gaining a sense of pride and understanding of the importance of systems like these will be necessary for the communities that live near potential project sites for these systems. These systems should be implemented with a long-term maintenance plan to ensure the system functions sustainably and the plant life has longevity. This type of project could be implemented at various scales, and therefore, the budget for a project of this type could vary profoundly. Potential funding sources include the EPA, FEMA, HUD, and Forestry Service grants. Additionally, if this design typology were to be implemented expansively, green bonds could be another way to fund this type of project.

Since this typology would ideally be implemented in areas of heavy vehicular

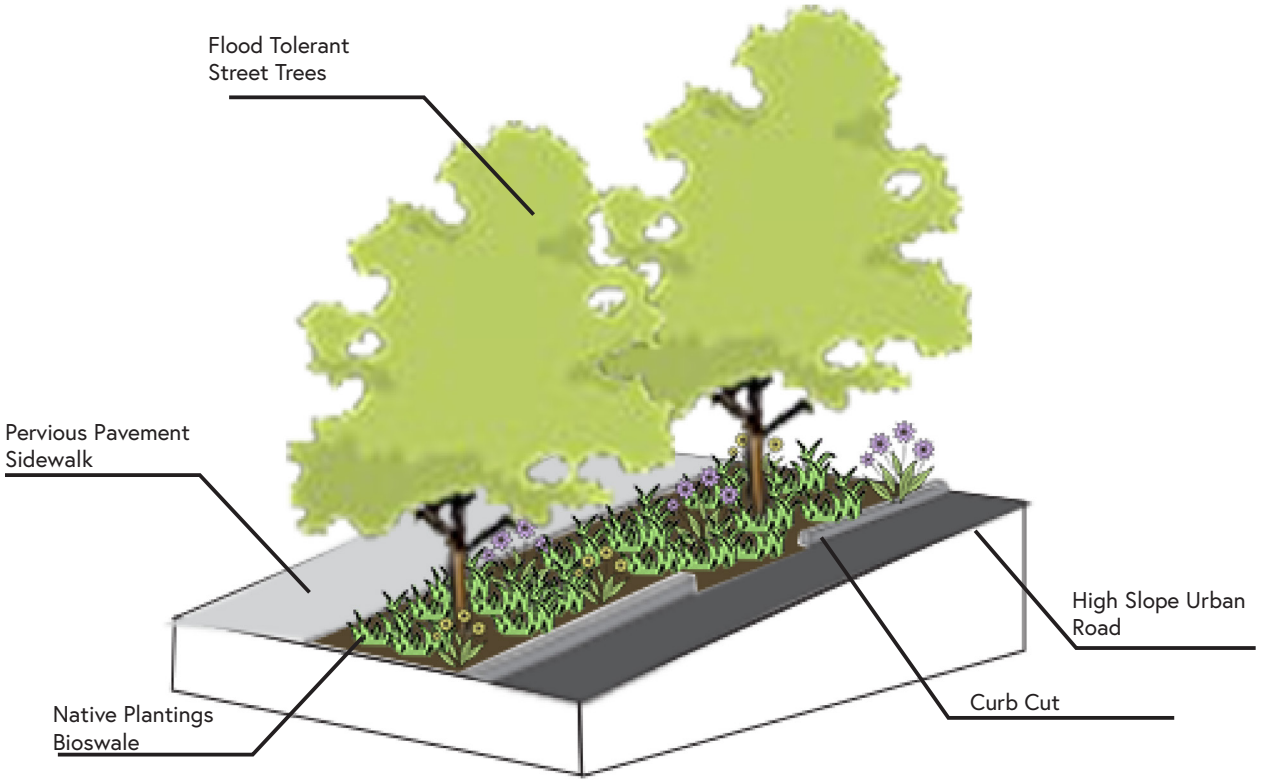


Figure 5.57 Urban Streetscape Infiltration System Design Typology

and pedestrian traffic, several of the region's main streets, which are less residential than some of the other streets, have been selected. Figure 5.58 shows the recommended streets for this system to be implemented.

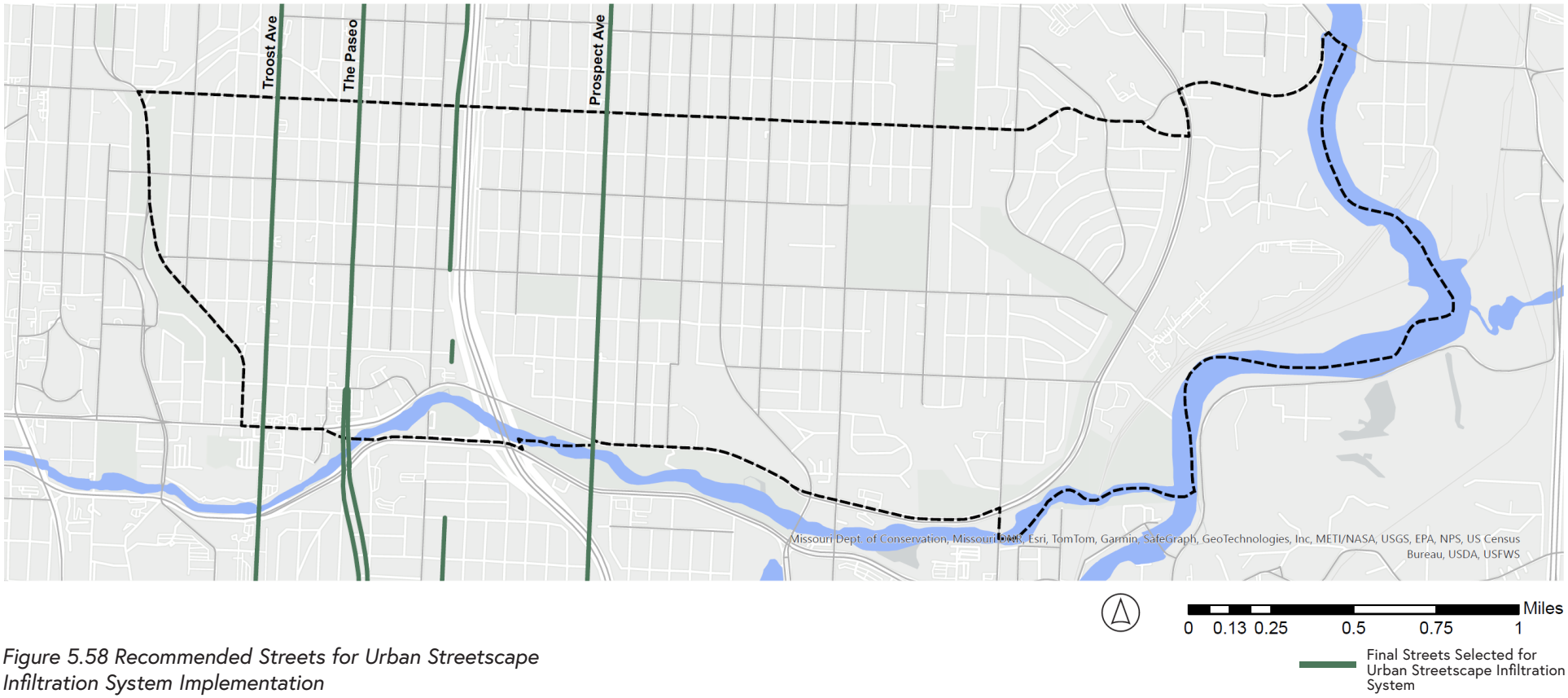


Figure 5.58 Recommended Streets for Urban Streetscape Infiltration System Implementation

Existing Natural System Remediation Design

Several existing streams or drainage ways within the study area and portions of Brush Creek are currently in relatively poor condition. It is essential that these systems are remediated and brought back to a thriving and healthy condition to ensure they will be able to handle potential future climate events without failure, see Figure 5.59. To accomplish this, it will be necessary first to remove all trash, debris, and pollutants currently occupying the area. Addressing erosion issues will likely be of great concern, as most of these natural drainage ways are in steeply sloped areas. Design elements for this design typology include flood-tolerant native trees, flood-tolerant native plants, and large rocks or boulders for additional erosion control. It will be essential to choose highly adaptable plantings, as these drainage ways may not constantly be flooded, especially during drought or water scarcity. Trees and boulders will also stabilize the banks of these drainage ways and stream beds. Projects of this scope are to be used to boost the resilience of these natural systems and their ability to bounce back to major flood or drought events without detrimental impacts on the surrounding environment and communities.

Community engagement for these projects might look slightly different than others, as educating the public about why these efforts are important and getting them involved in the remediation process is essential. There are a multitude of potential funding sources. Still, some options include the EPA Urban Waters Small Grants Program, DOI Rivers, Trails, and Conservation Assistance (RTCA) Program, and Building Resilient Infrastructure and Communities (BRIC) program, all of which seek to help fund projects that address issues relating to flooding and urban water systems.

The site selection process for this typology was based upon the large-scale combined drought flood systems suitability analysis and specifically related to the natural systems within the study

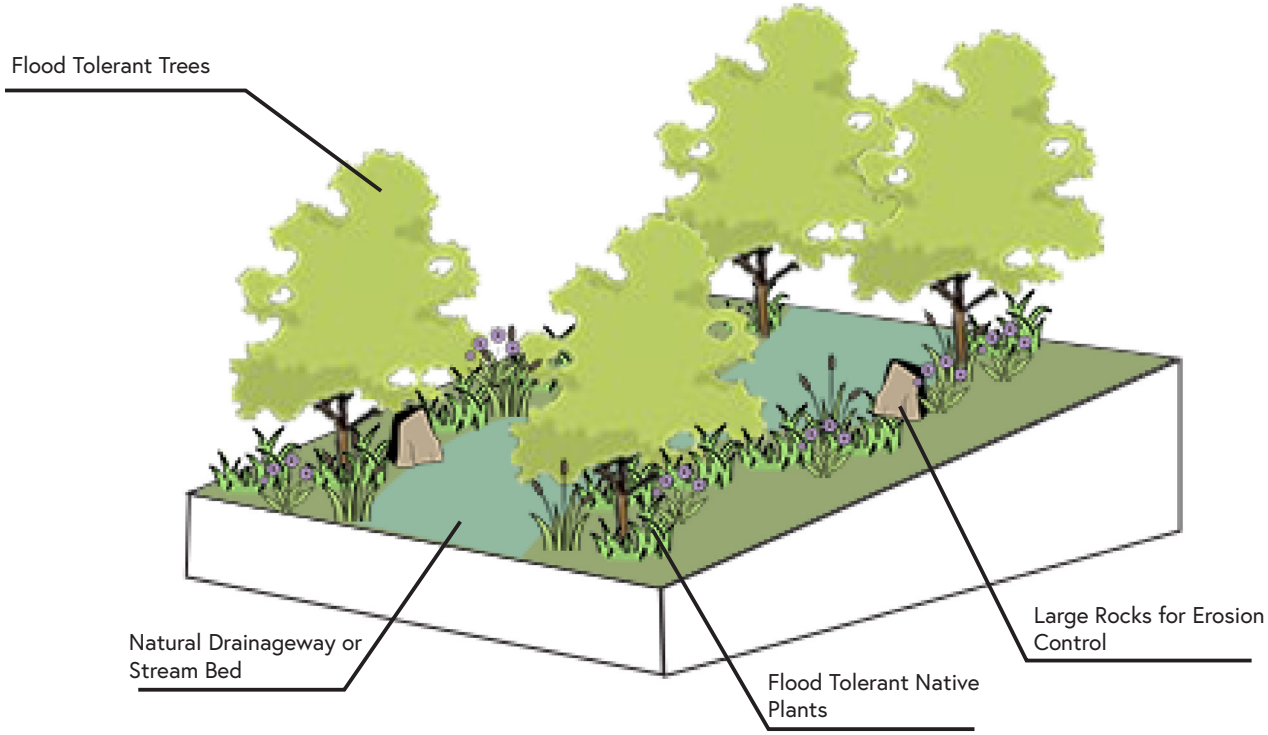


Figure 5.59 Existing Natural System Remediation Design Typology

area. A handful of sites were selected and recommended for the implementation of this typology and are shown in Figure 5.60.

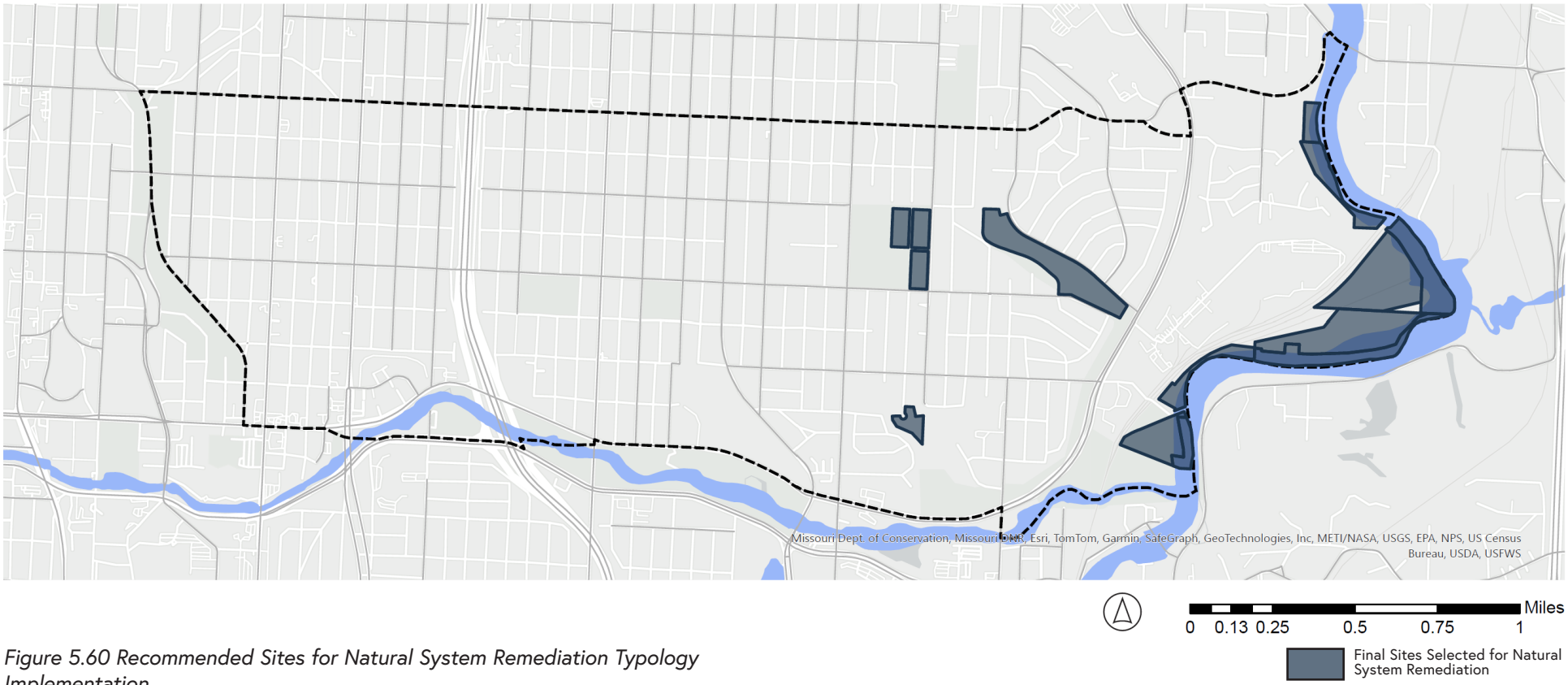


Figure 5.60 Recommended Sites for Natural System Remediation Typology Implementation

Theoretical Green Infrastructure Network:

When it comes to increasing the resilience to climate change-induced drought, flooding, and urban heat island threats, multiple projects and different scales and functions must be implemented to boost the ecological health and resilience of the area. With this in mind, a theoretical green infrastructure network was created based on whether projects would be implemented at all the recommended sites. Figure 5.61 and 5.62 visualize the project locations throughout the study area. It is important to note that some sites or streets were selected as suitable for multiple projects. For Further clarification on the site selection process taken for this study, please refer to Appendix E.

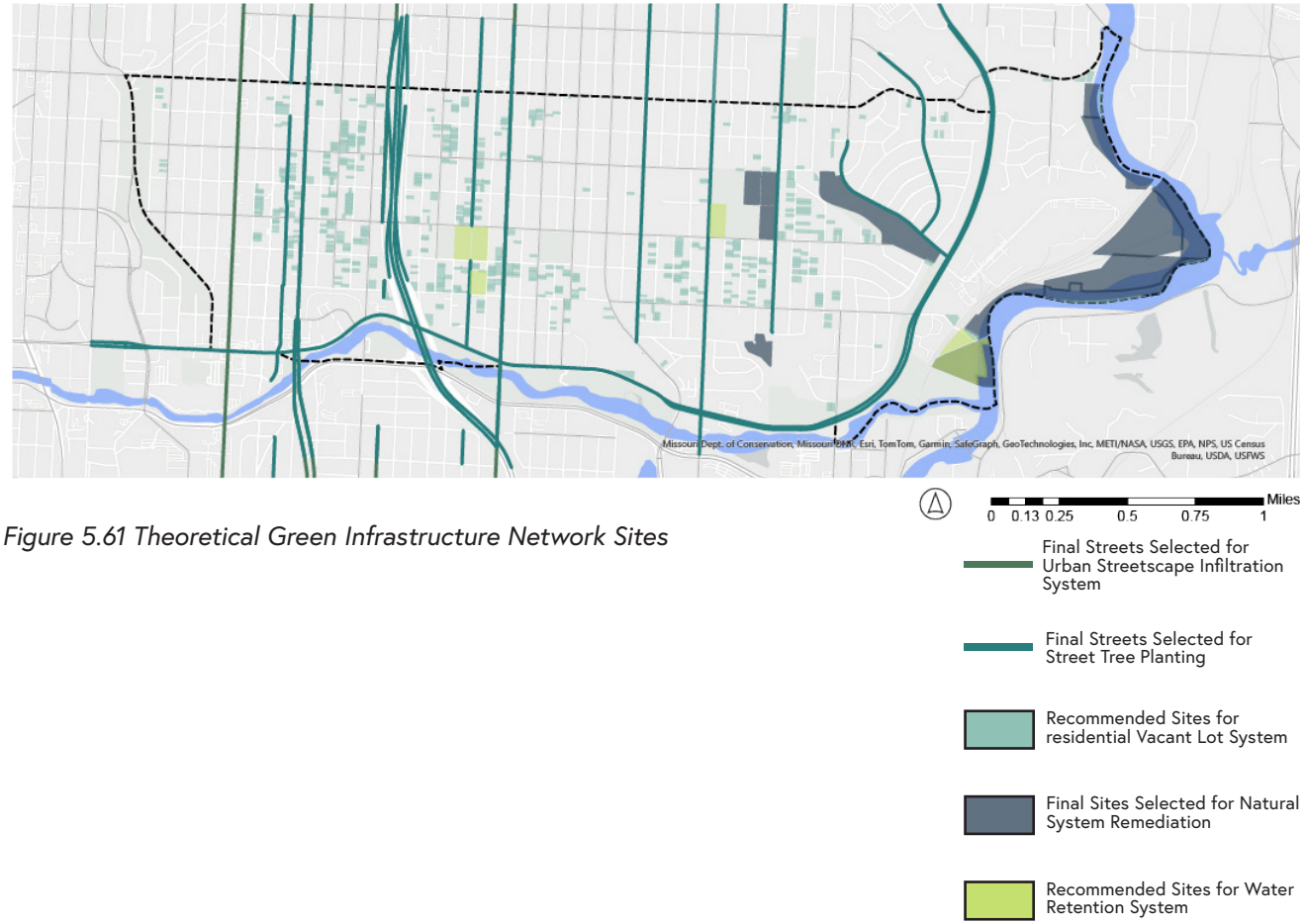


Figure 5.61 Theoretical Green Infrastructure Network Sites

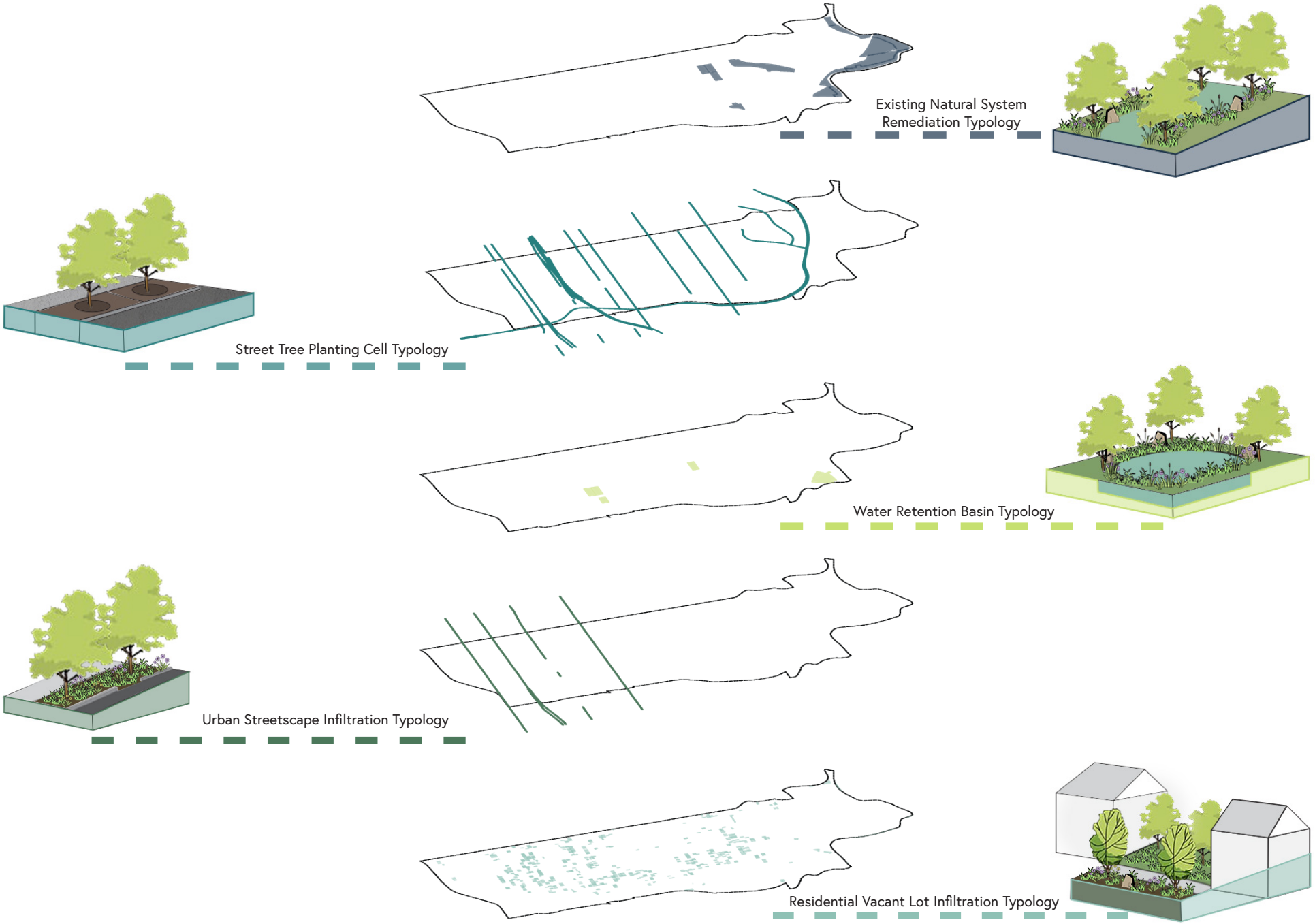
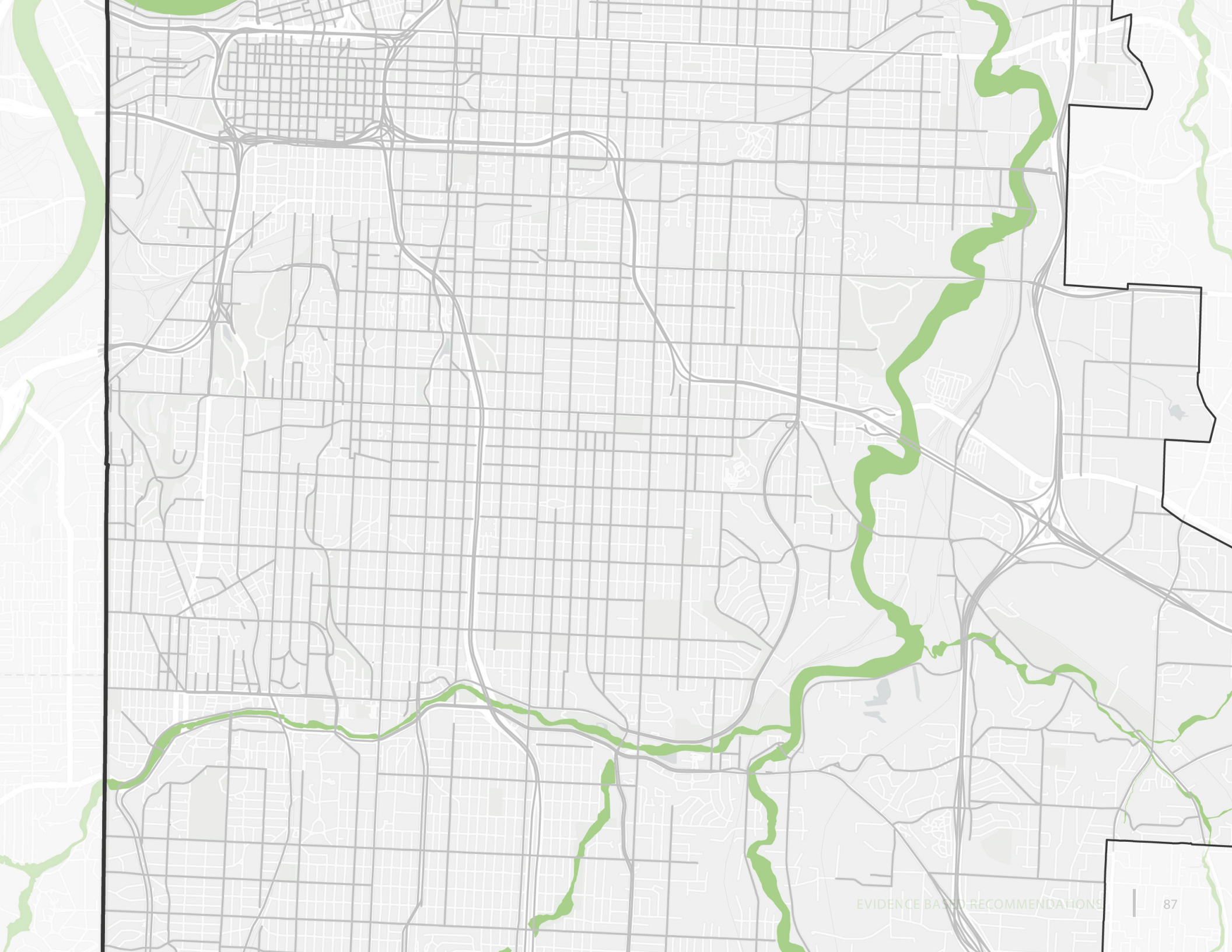
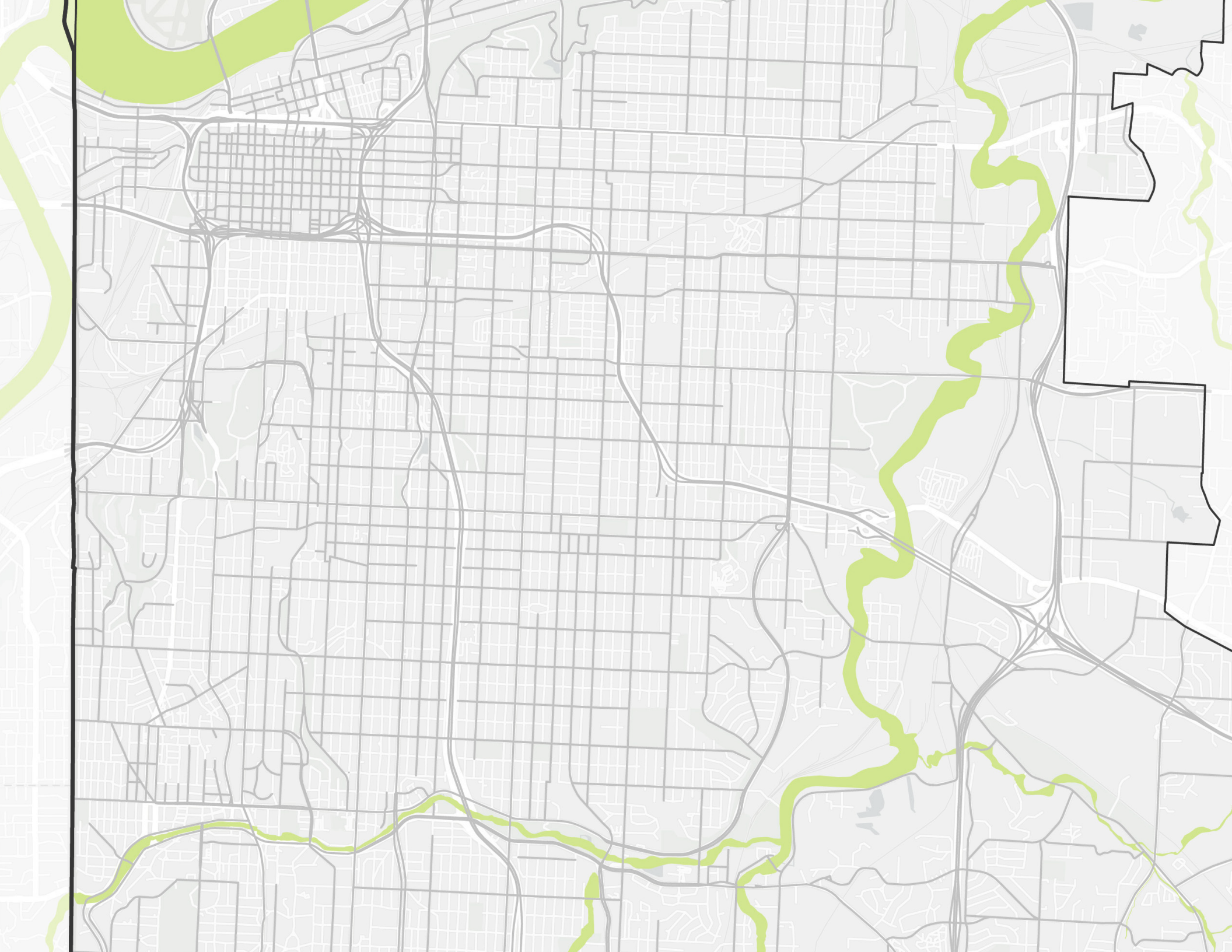


Figure 5.62 Theoretical Green Infrastructure Network Sites with Typology Reference





6 Discussion and Conclusions:

The information obtained through this project aims to give insight into the decision-making process around boosting resilience to climate change impacts at a community level in historically disinvested neighborhoods. Environmental data relating to the current conditions and hazards of the study area, nine neighborhoods located within the east side of Kansas City, Missouri, has been collected and used for both types of analytical mapping carried out through this study. Additionally, a baseline understanding of future climate conditions was developed through case study analysis and used as a benchmark for subsequent design processes. Case studies of green infrastructure projects implemented within the Midwest region also helped inform decision-making regarding what design features work best together to address or mitigate drought, flooding, and urban heat island impacts. The expected outcome of this project is the creation of a theoretically proposed green infrastructure network in the study area that would increase resiliency against drought, flooding, and urban heat island effects, in addition to an in-depth process that could be repeated for making decision-making about suitable sites Figures 6.63 through 6.65 demonstrate the framework created for considering all potential factors which may impact this area's need for green infrastructure projects, and the potential solutions developed through this study.

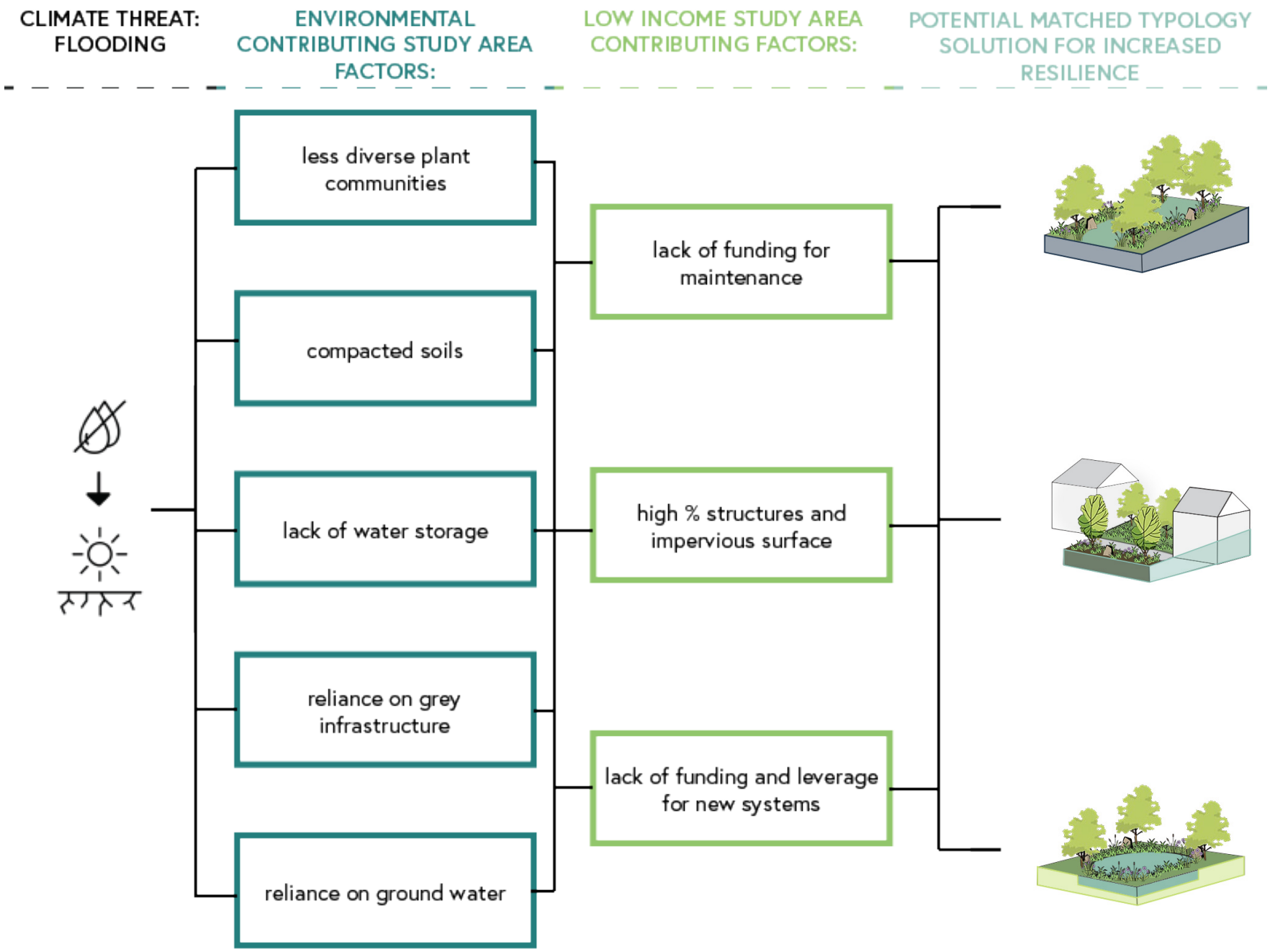


Figure 6.63 Drought Threat to Solution Framework

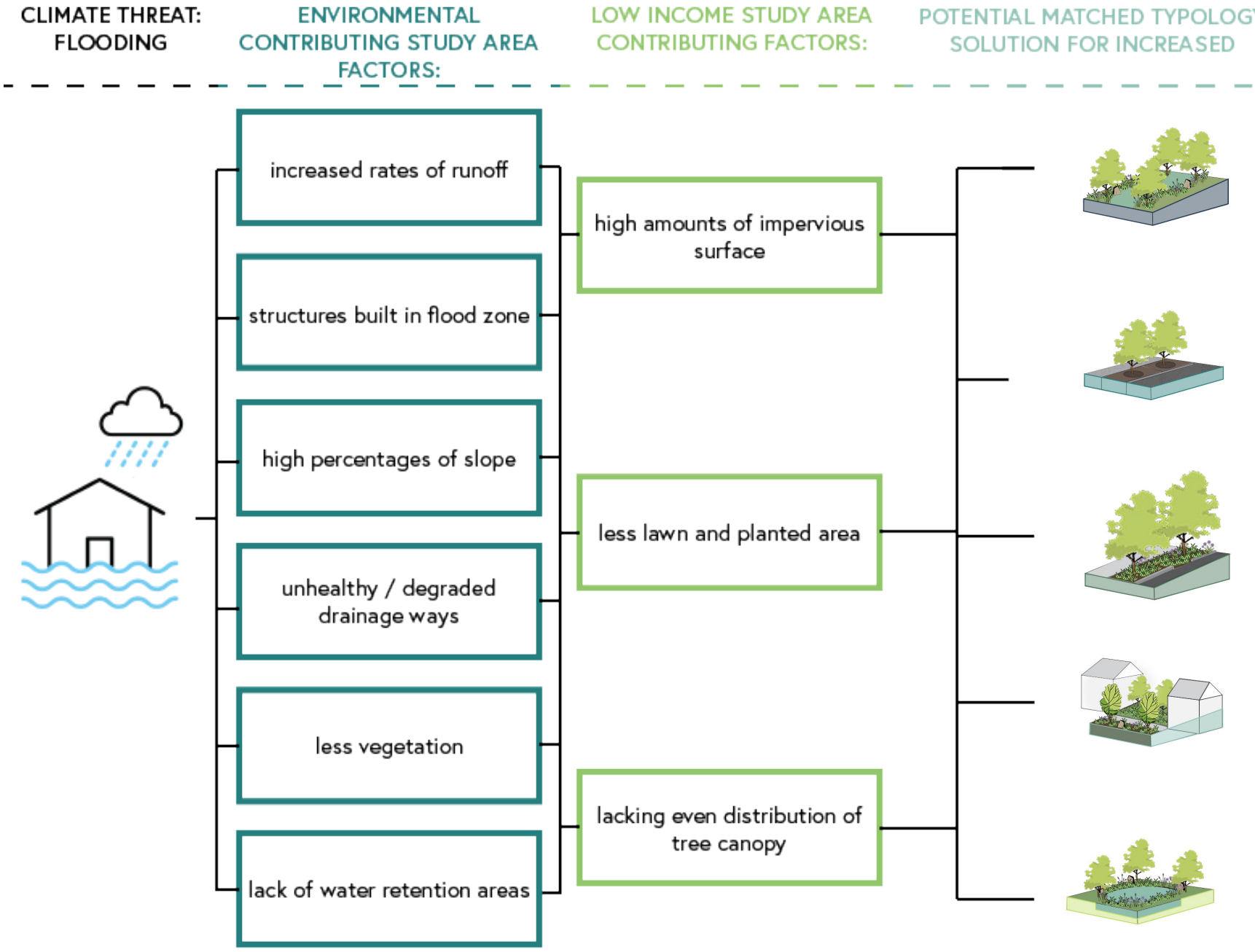


Figure 6.64 Flooding Threat to Solution Framework

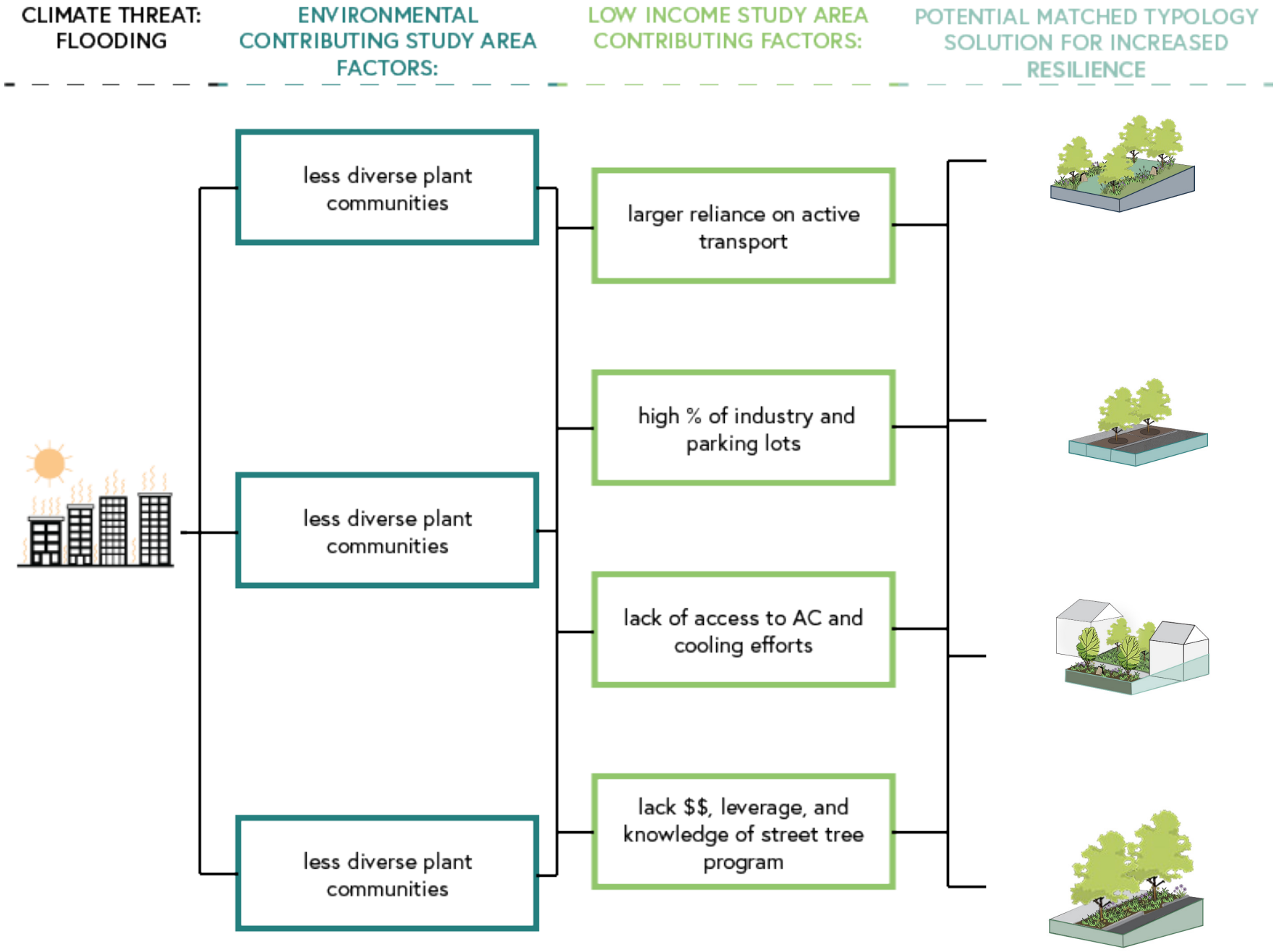
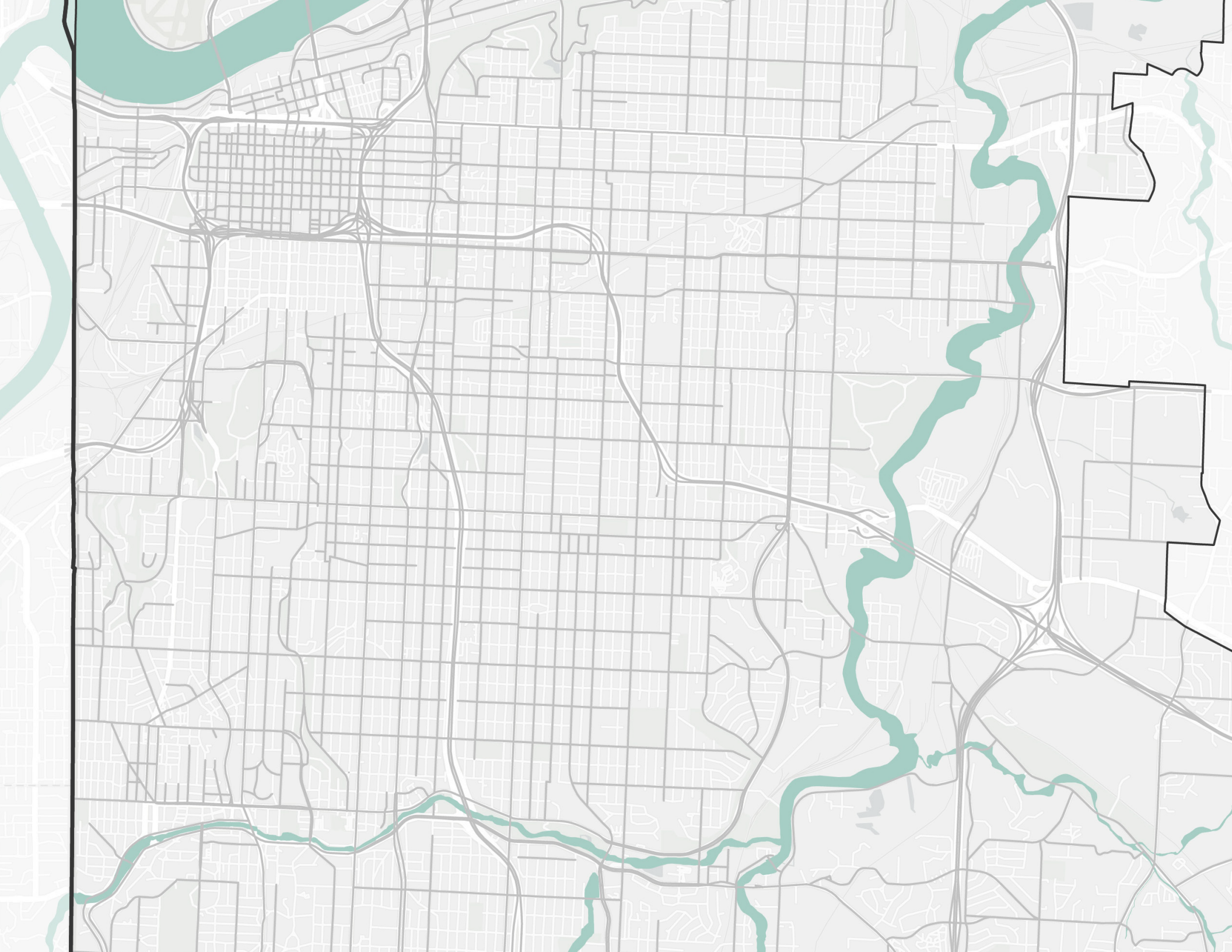


Figure 6.65 Urban Heat Island Threat to Solution Framework

While the overarching goal of this study is to boost resilience to climate change impacts, due to the time constraints of this project, this study was only focused on addressing issues related to climate change-induced drought, flooding, and urban heat island impacts. Additionally, while climate change models can give us a good idea of future climate conditions, there is still uncertainty around this data since it is impossible to 100% accurately predict future conditions. In addition to these two limitations, it is essential to note that this project touches on various issues that would significantly impact the people living in these neighborhoods. Because of this, if this project were to be implemented in real life, it would require extensive community engagement to ensure that the community was involved and supportive of the decisions about their community. Additionally, knowing that this study is focused on a disinvested area, it is crucial to take all possible measures to prevent gentrification and displacement of the members of this community while also ensuring that all designs and implementations are created at a high standard of care. Knowing gentrification can become a major issue, prior to implementing a project of this type it is crucial to conduct ample community engagement, ensure that adequate funding has been secured for all parts of the project including long term maintenance of the system, and to make sure local community members and organizations are actively involved in all phases of the project. One final limitation of this project is the weighting of parameters mapped for the suitability analysis process. Since it was decided that all parameters would receive equal weight for this study due to time constraints, all parameters were analyzed on an even playing field. If this process were to be repeated, weighting should be applied to the parameters to explore how this might impact the outcome and ensure that all scenarios are thoroughly investigated before making a final decision about site selection. This study aims to shift our view of urban vacancies and to see them as potential opportunities rather than disadvantages to communities. Through the exploration and findings gathered in this project, this study aims to contribute to the existing discussion around climate resilience in historically disinvested areas by proposing revitalizing publicly owned land and vacant properties by implementing green infrastructure systems. Additionally, this project could be used as a decision-making tool or strategy for cities to use when planning future climate resilience projects.



References, Figures, & Tables:

References

Angel, J., C. Swanston, B.M. Boustead, K.C. Conlon, K.R. Hall, J.L. Jorns, K.E. Kunkel, M.C. Lemos, B. Lofgren, T.A. Ontl, J. Posey, K. Stone, G. Takle, and D. Todey, 2018: Midwest. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 872–940. doi: 10.7930/NCA4.2018.CH21

Balany, F., Ng, A. W., Muttil, N., Muthukumaran, S., & Wong, M. S. (2020). Green Infrastructure as an Urban Heat Island Mitigation Strategy—A Review. Water, 12(12), 3577. https://doi.org/10.3390/w12123577

Block, A. H., Livesley, S., & Williams, N. S. G. (2012). Responding to the urban heat island: A review of the potential of green infrastructure [Report]. Victorian Centre for Climate Change Adaptation Research. https://apo.org.au/node/237206

City of Kansas City, Missouri. (2022) KC GREEN Climate Protection & Resilience Plan. https://www.kcmo.gov/home/showpublisheddocument/9912/638112897582470000

Collins, W.J., N. Bellouin, M. Doutriaux-Boucher, N. Gedney, T. Hinton, C. D. Jones, S. Liddicoat, G. Martin, F. O'Connor, J. Rae, C. Senior, I. Totterdell, S. Woodward, T. Reichler, J. Kim, 2008: Evaluation of the HadGEM2 model. Met Office Hadley Centre Technical Note no. HCTN 74, available from Met Office, FitzRoy Road, Exeter EX1 3PB http://www.metoffice.gov.uk/publications/HCTN/index.html

Feng, J., Haddad, S., Gao, K., Garshasbi, S., Ulpiani, G., Santamouris, M., Ranzi, G., & Bartesaghi-Koc, C. (2023). Chapter 6—Fighting urban climate change—State of the art of mitigation technologies. In R. Paolini & M. Santamouris (Eds.), Urban Climate Change and Heat Islands (pp. 227–296). Elsevier. https://doi.org/10.1016/B978-0-12-818977-1.00006-5

GFDL. (2023). Earth System Models. https://www.gfdl.noaa.gov/earth-system-model/

Gordon, B. L., Quesnel, K. J., Abs, R., & Ajami, N. K. (2018). A case-study based framework for assessing the multi-sector performance of green infrastructure. Journal of Environmental Management, 223, 371–384. https://doi.org/10.1016/j.jenvman.2018.06.029

Grant, G. (2012). Ecosystem services come to town: Greening cities by working with nature. John Wiley & Sons, Incorporated. https://ebookcentral.proquest.com/lib/ksu/detail.action?pq-origsite=primo&docID=977924#

Khan, H. S., Paolini, R., & Santamouris, M. (2023). Chapter 3—Synergies and exacerbations—Effects of warmer weather and climate change. In R. Paolini & M. Santamouris (Eds.), Urban Climate Change and Heat Islands (pp. 73–121). Elsevier. https://doi.org/10.1016/B978-0-12-818977-1.00005-3

Kloesel, K., B. Bartush, J. Banner, D. Brown, J. Lemery, X. Lin, C. Loeffler, G. McManus, E. Mullens, J. Nielsen-Gammon, M. Shafer, C. Sorensen, S. Sperry, D. Wildcat, and J. Ziolkowska, 2018: Southern Great Plains. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 987–1035. doi: 10.7930/NCA4.2018.CH23

MARC & Climate Action KC. (2021). Regional Climate Action Plan. https://www.marc.org/environment/environment-plans/climate-action-plan#:~:text=The%20Kansas%20City%20Regional%20Climate,the%20entire%20Kansas%20City%20region

Meerow, S., & Stults, M. (2016). Comparing Conceptualizations of Urban Climate Resilience in Theory and Practice. Sustainability, 8(7), Article 7. https://doi.org/10.3390/su8070701

National Academies of Sciences, E., and Medicine, Division on Earth and Life Studies, Water Science and Technology Board, & Committee on the Beneficial Use of Graywater and Stormwater: An Assessment of Risks, C., and Benefits. (2016). Using Graywater and Stormwater to Enhance Local Water Supplies: An Assessment of Risks, Costs, and Benefits. National Academies Press. http://ebookcentral.proquest.com/lib/ksu/detail.action?docID=4591889

National Center for Atmospheric Research (2020). CCSM4 (Community Climate System Model version 4), Model Item, OpenGMS, https://geomodeling.njnu.edu.cn/modelItem/2b7c21d0-1f27-42aa-a4d7-f6ca2220d02e

National Geographic. (2023). Floodplain. https://education.nationalgeographic.org/resource/flood-plain/

Pamukcu-Albers, P., Ugolini, F., La Rosa, D., Grădinaru, S. R., Azevedo, J. C., & Wu, J. (2021). Building green infrastructure to enhance urban resilience to climate change and pandemics. Landscape Ecology, 36(3), 665–673. https://doi.org/10.1007/s10980-021-01212-y

Pitman, S. D., Daniels, C. B., & Ely, M. E. (2015). Green infrastructure as life support: Urban nature and climate change. Transactions of the Royal Society of South Australia, 139(1), 97–112. https://doi.org/10.1080/03721426.2015.1035219

Ramyar, R., Ackerman, A., & Johnston, D. M. (2021). Adapting cities for climate change through urban green infrastructure planning. Cities, 117, 103316. https://doi.org/10.1016/j.cities.2021.103316

Santamouris, M. (2023). Chapter 1 - Urban climate change: Reasons, magnitude, impact, and mitigation. In R. Paolini & M. Santamouris (Eds.), Urban Climate Change and Heat Islands (pp. 1–27). Elsevier. https://doi.org/10.1016/B978-0-12-818977-1.00002-8

Schleussner, C.-F., Pfleiderer, P., Andrijevic, M., Vogel, M. M., Otto, F. E. L., & Seneviratne, S. I. (2021). Pathways of climate resilience over the 21st century. Environmental Research Letters, 16(5), 054058. https://doi.org/10.1088/1748-9326/abed79

Science on a Sphere. (2023). Climate Model: Temperature Change (RCP 4.5) - 2006 – 2100. https://sos.noaa.gov/catalog/datasets/climate-model-temperature-change-rcp-45-2006-2100/#description-data-source

Sturiale, L., & Scuderi, A. (2019). The Role of Green Infrastructures in Urban Planning for Climate Change Adaptation. Climate, 7(10), Article 10. https://doi.org/10.3390/cli7100119

Tauhid, F. A. (2018). URBAN GREEN INFRASTRUCTURE FOR CLIMATE RESILIENCE: A REVIEW. Nature: National Academic Journal of Architecture, 5(1), Article 1. https://doi.org/10.24252/nature.v5i1a7

Webber, M. K., & Samaras, C. (2022). A Review of Decision Making Under Deep Uncertainty Applications Using Green Infrastructure for Flood Management. Earth's Future, 10(7), e2021EF002322. https://doi.org/10.1029/2021EF002322

Zuniga-Teran, A. A., Gerlak, A. K., Mayer, B., Evans, T. P., & Lansey, K. E. (2020). Urban resilience and green infrastructure systems: Towards a multidimensional evaluation. Current Opinion in Environmental Sustainability, 44, 42–47. https://doi.org/10.1016/j.cosust.2020.05.001

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Living Architecture Monitor. (2022). Community-Scale Green Infrastructure Generates Optimal Performance. https://livingarchitecturemonitor.com/articles/community-scale-green-infrastructure-su22

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Lenexa Kansas. (2024). Green Infrastructure. https://www.lenexa.com/government/departments___divisions/rain_to_recreation/stormwater_operations/green_infrastructure

Figure 2.5: Rain Garden Precedent
Watershed Management Group. (2014, September 3). Green Stormwater Infrastructure Overview & Resources. https://watershedmg.org/learn/resources/GSI

Figure 2.6: Bioswale Precedent
Lenexa Kansas. (2024). Green Infrastructure. https://www.lenexa.com/government/departments___divisions/rain_to_recreation/stormwater_operations/green_infrastructure

Figure 2.7: Permeable Paving Precedent
Lenexa Kansas. (2024). Green Infrastructure. https://www.lenexa.com/government/departments___divisions/rain_to_recreation/stormwater_operations/green_infrastructure

Figure 2.8: Urban Heat Island Diagram
Block, A. H., Livesley, S., & Williams, N. S. G. (2012). Responding to the urban heat island: A review of the potential of green infrastructure [Report]. Victorian Centre for Climate Change Adaptation Research. https://apo.org.au/node/237206

Figure 2.9: Urban Forest Graphic
USDA. (2015). Flickr. Retrieved April 5, 2024, from https://www.flickr.com/photos/usdagov/21579665486/

Figure 2.10: Green Roof Precedent
Shigley, S. (2010). Green Infrastructure: Green Roofs and Walls. Retrieved February 8, 2024, from https://www.asla.org/contentdetail.aspx?id=43536

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Mapping Inequality. (n.d.). Retrieved September 29, 2023, from https://dsl.richmond.edu/panorama/redlining/

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Bender, K. (2020). Kansas City Missouri Parks and Boulevards [Shape File]. City of Kansas City, Missouri. https://data.kcmo.org/dataset/Kansas-City-Missouri-Parks-and-Boulevards-Map/h5fe-gwsc
Esri. (2023). USA NLCD Tree Canopy Cover [Imagery Layer]. ArcGIS Living Atlas of the World. Retrieved Sept. 21, 2023 from https://www.arcgis.com/home/item.html?id=f2d114f071904e1fa11b4bb215dc08f3
Bender, Kate. (2020). Kansas City Neighborhood Boundaries. [Data Set]. City of Kansas City, Missouri. Retrieved Sept. 21, 2023 from https://data.kcmo.org/Neighborhoods/Kansas-City-Neighborhood-Boundaries/q45j-ejyk
Esri. (2023). Light Gray Canvas Base. [Vector Tile Layer]. ArcGIS Living Atlas of the World. Retrieved Sept. 21, 2023 from https://www.arcgis.com/home/item.html?id=291da5eab3a0412593b66d384379f89f
Esparza,T. (2021) KCMO Trees [Feature Layer]. City of Kansas City, Missouri. https://kcmo.maps.arcgis.com/home/item.html?id=11c623840e974766b39fe77e759f5c51&sublayer=0 Retrieved Sept. 21, 2023

Figure 3.14: Watersheds and Stream Health
Sanders, Greg. (2022). Watersheds. [Polygon Layer]. Mid-America Regional Council National Resource Inventory. Retrieved Sept. 21, 2023. https://kstate.maps.arcgis.com/home/item.html?id=ef67514f00384181ac5071f283fd6219
MARC. (2022). Stream and Riparian Health in Greater Kansas City. [Feature Layer]. Mid-America Regional Council National Resource Inventory. Retrieved Sept. 21, 2023 https://kstate.maps.arcgis.com/home/item.html?id=46dd9a9d533045eb84ed62ec958ae142
Bender, Kate. (2020). Kansas City Neighborhood Boundaries. [Data Set]. City of Kansas City, Missouri. Retrieved Sept. 21, 2023 from https://data.kcmo.org/Neighborhoods/Kansas-City-Neighborhood-Boundaries/q45j-ejyk
Esri. (2023). Light Gray Canvas Base. [Vector Tile Layer]. ArcGIS Living Atlas of the World. Retrieved Sept. 21, 2023 from https://www.arcgis.com/home/item.html?id=291da5eab3a0412593b66d384379f89f

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Bender, Kate. (2020). Kansas City Neighborhood Boundaries. [Data Set]. City of Kansas City, Missouri. Retrieved Sept. 21, 2023 from https://data.kcmo.org/Neighborhoods/Kansas-City-Neighborhood-Boundaries/q45j-ejyk

Esri. (2023). Light Gray Canvas Base. [Vector Tile Layer]. ArcGIS Living Atlas of the World. Retrieved Sept. 21, 2023 from https://www.arcgis.com/home/item.html?id=291da5eab3a0412593b66d384379f89f

Esri Landscape. (2023). USA Flood Hazard Areas. [Feature Layer Map]. ArcGIS Living Atlas of the World. Retrieved Sept. 21, 2023 from https://livingatlas-dcdev.opendata.arcgis.com/datasets/esri::usa-flood-hazard-areas-2/about

Esri. (2023). USA NLCD Tree Canopy Cover [Imagery Layer]. ArcGIS Living Atlas of the World. Retrieved Sept. 21, 2023 from https://www.arcgis.com/home/item.html?id=f2d114f071904e1fa11b4bb215dc08f3

Esparza,T. (2021) KCMO Trees [Feature Layer]. City of Kansas City, Missouri. https://kcmo.maps.arcgis.com/home/item.html?id=11c623840e974766b39fe77e759f5c51&sublayer=0 Retrieved Sept. 21, 2023

Bender, K. (2020). Kansas City Missouri Parks and Boulevards [Shape File]. City of Kansas City, Missouri. https://data.kcmo.org/dataset/Kansas-City-Missouri-Parks-and-Boulevards-Map/h5fe-gwsc

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Esri. (2023). USA Soils Map. [Feature Layer]. ArcGIS Living Atlas of the World. Retrieved Sept. 21, 2023 https://www.arcgis.com/home/item.html?id=06e5fd61bdb6453fb16534c676e1c9b9

Esri Landscape. (2023). USA Flood Hazard Areas. [Feature Layer Map]. ArcGIS Living Atlas of the World. Retrieved Sept. 21, 2023 from https://livingatlas-dcdev.opendata.arcgis.com/datasets/esri::usa-flood-hazard-areas-2/about

EPA. (2023). National Combined Sewer Overflow Inventory. [Data Set]. Environmental Protection Agency. Retrieved Sept. 21, 2023. https://echo.epa.gov/tools/data-downloads#downloads

EPA. (2023). Past EPA Regulated Hazardous Waste Sites. [Data Set]. EnviroAtlas. Retrieved Sept. 21, 2023. https://enviroatlas.epa.gov/enviroatlas/interactivemap/

EPA.(2023) Active Hazardous Waste Sites. [Data Set]. EnviroAtlas. Retrieved Sept. 21, 2023. https://enviroatlas.epa.gov/enviroatlas/interactivemap/

Bender, Kate. (2020). Kansas City Neighborhood Boundaries. [Data Set]. City of Kansas City, Missouri. Retrieved Sept. 21, 2023 from https://data.kcmo.org/Neighborhoods/Kansas-City-Neighborhood-Boundaries/q45j-ejyk

Esri. (2023). Light Gray Canvas Base. [Vector Tile Layer]. ArcGIS Living Atlas of the World. Retrieved Sept. 21, 2023 from https://www.arcgis.com/home/item.html?id=291da5eab3a0412593b66d384379f89f

Figure 3.17: Soil and Pollution Hazards

Hemsath, E. (2023). Soil and Water Pollution Hazards. [Map]

311 Call Center. (2023). 311 Call Center Reported Issues. [Data Set]. City of Kansas City, Missouri. Retrieved Sept. 21, 2023 from https://data.kcmo.org/311/311-Call-Center-Reported-Issues/d4px-6rwg

Bender, Kate. (2020). Kansas City Neighborhood Boundaries. [Data Set]. City of Kansas City, Missouri. Retrieved Sept. 21, 2023 from https://data.kcmo.org/Neighborhoods/Kansas-City-Neighborhood-Boundaries/q45j-ejyk

Enforcement and Compliance History Online. (2023). ICIS-NPDES Discharge Points Summary. [Data Set]. United States Environmental Protection Agency. Retrieved Sept. 21, 2023 from https://echo.epa.gov/tools/data-downloads/icis-npdes-discharge-points-download-summary

EPA Facility Registry Service. (2023). EPA Facility Registry Service (FRS): RCRA_INACTIVE. [File Geodatabase]. United States Environmental Protection Agency. Retrieved Sept. 21, 2023 from https://catalog.data.gov/dataset/epa-facility-registry-service-frs-rcra_inactive

EPA Facility Registry Service. (2023). EPA Facility Registry Service (FRS): RCRA_ACTIVE. [File Geodatabase]. United States Environmental Protection Agency. Retrieved Sept. 21, 2023 from https://catalog.data.gov/dataset/epa-facility-registry-service-frs-rcra_active

Esri Landscape. (2023). USA Flood Hazard Areas. [Feature Layer Map]. ArcGIS Living Atlas of the World. Retrieved Sept. 21, 2023 from https://livingatlas-dcdev.opendata.arcgis.com/datasets/esri::usa-flood-hazard-areas-2/about

Esri. (2023). Light Gray Canvas Base. [Vector Tile Layer]. ArcGIS Living Atlas of the World. Retrieved Sept. 21, 2023 from https://www.arcgis.com/home/item.html?id=291da5eab3a0412593b66d384379f89f

MARC. (2022). Stream and Riparian Health in Greater Kansas City. [Feature Layer]. Mid-America Regional Council National Resource Inventory. Retrieved Sept. 21, 2023 https://kstate.maps.arcgis.com/home/item.html?id=46dd9a9d533045eb84ed62ec958ae142

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Hemsath, E. (2023). Urban Heat Island and Tree Canopy [Map]

Bender, Kate. (2020). Kansas City Neighborhood Boundaries. [Data Set]. City of Kansas City, Missouri. Retrieved Sept. 21, 2023 from https://data.kcmo.org/Neighborhoods/Kansas-City-Neighborhood-Boundaries/q45j-ejyk

Esri Landscape. (2023). USA Flood Hazard Areas. [Feature Layer Map]. ArcGIS Living Atlas of the World. Retrieved Sept. 21, 2023 from https://livingatlas-dcdev.opendata.arcgis.com/datasets/esri::usa-flood-hazard-areas-2/about

Esri. (2021). USA NLCD Tree Canopy Cover. [Raster Image]. ArcGIS Living Atlas of the World. Retrieved Sept. 21, 2023 from https://landscape10.arcgis.com/arcgis/rest/services/USA_NLCD_Tree_Canopy/ImageServer

Esri. (2023). Light Gray Canvas Base. [Vector Tile Layer]. ArcGIS Living Atlas of the World. Retrieved Sept. 21, 2023 from https://www.arcgis.com/home/item.html?id=291da5eab3a0412593b66d384379f89f

The Trust for Public Land. (2023). Urban Heat Island Severity for U.S. cities – 2019. [Raster Image]. ArcGIS Living Atlas of the World. Retrieved Sept. 21, 2023 from https://server6.tplgis.org/arcgis6/rest/services/heat_severity_2019/ImageServer

Figure 3.19: Neighborhood Slope Analysis
Hemsath, E. (2023). Percent Slope. [Map].
3D Elevation Program. (2023). USGS 1/3 Arc Second n40w095 20230613. [GeoTIFF]. US Geological Survey. Retrieved Sept. 21, 2023, from https://apps.nationalmap.gov/downloader/
Bender, Kate. (2020). Kansas City Neighborhood Boundaries. [Data Set]. City of Kansas City, Missouri. Retrieved Sept. 21, 2023, from https://data.kcmo.org/Neighborhoods/Kansas-City-Neighborhood-Boundaries/q45j-ejyk
Esri Landscape. (2023). USA Flood Hazard Areas. [Feature Layer Map]. ArcGIS Living Atlas of the World. Retrieved Sept. 21, 2023, from https://livingatlas-dcdev.opendata.arcgis.com/datasets/esri::usa-flood-hazard-areas-2/about

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Data Retrieved from: University of California MERCED. (n.d.). MACA Home. https://climate.northwestknowledge.net/MACA/data_csv.php

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3D Elevation Program. (2023). USGS 1/3 Arc Second n40w095 20230613. [GeoTIFF]. US Geological Survey. Retrieved Sept. 21, 2023, from https://apps.nationalmap.gov/downloader/
Esri Landscape. (2023). USA Flood Hazard Areas. [Feature Layer Map]. ArcGIS Living Atlas of the World. Retrieved Sept. 21, 2023 from https://livingatlas-dcdev.opendata.arcgis.com/datasets/esri::usa-flood-hazard-areas-2/about
Esri. (2023). USA NLCD Tree Canopy Cover [Imagery Layer]. ArcGIS Living Atlas of the World. Retrieved Sept. 21, 2023 from https://www.arcgis.com/home/item.html?id=f2d114f071904e1fa11b4bb215dc08f3
Esparza,T. (2021) KCMO Trees [Feature Layer]. City of Kansas City, Missouri. https://kcmo.maps.arcgis.com/home/item.html?id=11c623840e974766b39fe77e759f5c51&sublayer=0 Retrieved Sept. 21, 2023
Esri. (2023). USA Soils Map. [Feature Layer]. ArcGIS Living Atlas of the World. Retrieved Sept. 21, 2023 https://www.arcgis.com/home/item.html?id=06e5fd61bdb6453fb16534c676e1c9b9
MARC. (2022). Stream and Riparian Health in Greater Kansas City. [Feature Layer]. Mid-America Regional Council National Resource Inventory. Retrieved Sept. 21, 2023 https://kstate.maps.arcgis.com/home/item.html?id=46dd9a9d533045eb84ed62ec958ae142

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Esri. (2023). USA Soils Map. [Feature Layer]. ArcGIS Living Atlas of the World. Retrieved Sept. 21, 2023 https://www.arcgis.com/home/item.html?id=06e5fd61bdb6453fb16534c676e1c9b9
MARC. (2022). Stream and Riparian Health in Greater Kansas City. [Feature Layer]. Mid-America Regional Council National Resource Inventory. Retrieved Sept. 21, 2023 https://kstate.maps.arcgis.com/home/item.html?id=46dd9a9d533045eb84ed62ec958ae142
3D Elevation Program. (2023). USGS 1/3 Arc Second n40w095 20230613. [GeoTIFF]. US Geological Survey. Retrieved Sept. 21, 2023, from https://apps.nationalmap.gov/downloader/
Esri Landscape. (2023). USA Flood Hazard Areas. [Feature Layer Map]. ArcGIS Living Atlas of the World. Retrieved Sept. 21, 2023 from https://livingatlas-dcdev.opendata.arcgis.com/datasets/esri::usa-flood-hazard-areas-2/about
Parcel Viewer—City of Kansas City, MO. (n.d.). Impervious Surfaces. Retrieved Sept. 21, 2023, from https://maps.kcmo.org/apps/parcelviewer/

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Esri. (2023). USA Soils Map. [Feature Layer]. ArcGIS Living Atlas of the World. Retrieved Sept. 21, 2023 https://www.arcgis.com/home/item.html?id=06e5fd61bdb6453fb16534c676e1c9b9

MARC. (2022). Stream and Riparian Health in Greater Kansas City. [Feature Layer]. Mid-America Regional Council National Resource Inventory. Retrieved Sept. 21, 2023 https://kstate.maps.arcgis.com/home/item.html?id=46dd9a9d533045eb84ed62ec958ae142

3D Elevation Program. (2023). USGS 1/3 Arc Second n40w095 20230613. [GeoTIFF]. US Geological Survey. Retrieved Sept. 21, 2023, from https://apps.nationalmap.gov/downloader/

Esri Landscape. (2023). USA Flood Hazard Areas. [Feature Layer Map]. ArcGIS Living Atlas of the World. Retrieved Sept. 21, 2023 from https://livingatlas-dcdev.opendata.arcgis.com/datasets/esri::usa-flood-hazard-areas-2/about

Parcel Viewer—City of Kansas City, MO. (n.d.). Impervious Surfaces. Retrieved Sept. 21, 2023, from https://maps.kcmo.org/apps/parcelviewer/

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Esri. (2023). USA Soils Map. [Feature Layer]. ArcGIS Living Atlas of the World. Retrieved Sept. 21, 2023 https://www.arcgis.com/home/item.html?id=06e5fd61bdb6453fb16534c676e1c9b9

MARC. (2022). Stream and Riparian Health in Greater Kansas City. [Feature Layer]. Mid-America Regional Council National Resource Inventory. Retrieved Sept. 21, 2023 https://kstate.maps.arcgis.com/home/item.html?id=46dd9a9d533045eb84ed62ec958ae142

3D Elevation Program. (2023). USGS 1/3 Arc Second n40w095 20230613. [GeoTIFF]. US Geological Survey. Retrieved Sept. 21, 2023, from https://apps.nationalmap.gov/downloader/

Esri Landscape. (2023). USA Flood Hazard Areas. [Feature Layer Map]. ArcGIS Living Atlas of the World. Retrieved Sept. 21, 2023 from https://livingatlas-dcdev.opendata.arcgis.com/datasets/esri::usa-flood-hazard-areas-2/about

Parcel Viewer—City of Kansas City, MO. (n.d.). Impervious Surfaces. Retrieved Sept. 21, 2023, from https://maps.kcmo.org/apps/parcelviewer/

Esri. (2023). USA NLCD Tree Canopy Cover [Imagery Layer]. ArcGIS Living Atlas of the World. Retrieved Sept. 21, 2023 from https://www.arcgis.com/home/item.html?id=f2d114f071904e1fa11b4bb215dc08f3

Esparza,T. (2021) KCMO Trees [Feature Layer]. City of Kansas City, Missouri. https://kcmo.maps.arcgis.com/home/item.html?id=11c623840e974766b39fe77e759f5c51&sublayer=0 Retrieved Sept. 21, 2023

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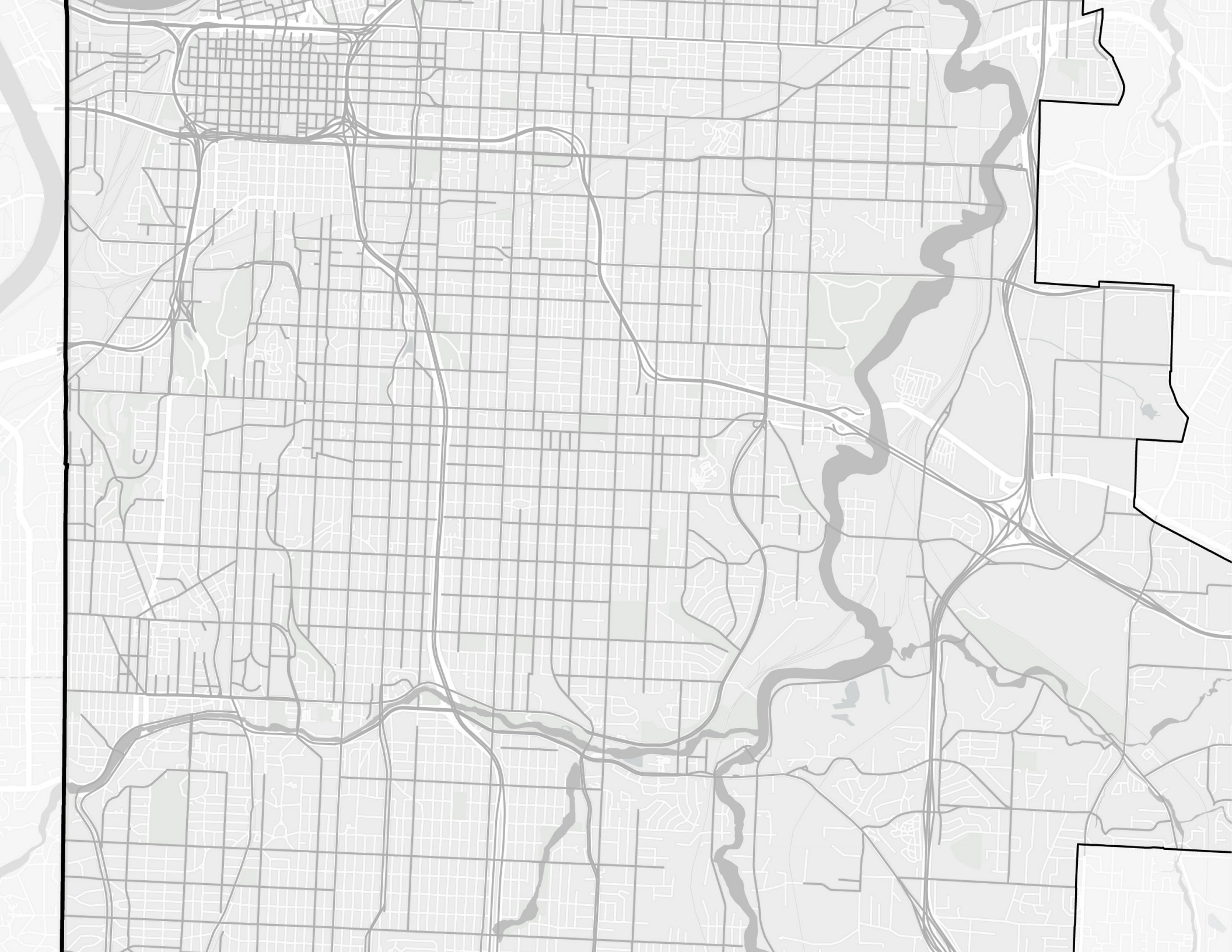


Appendices:

Appendix A: KCMO Approved Street Tree List

KC Parks and Rec. (2018). Street Tree Planting Requirements. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://kcparks.org/wp-content/uploads/2021/03/KCMO-TREE-PLANTING-SPECIFICATIONS-Nov-2018.pdf

KCMO Parks and Recreation Department --Forestry Operations

Figure 1: Approved Street, Parkway, and Boulevard Trees

COLUMNAR OR NARROW CROWNS
(trees with a crown spread less than 15'-20')

Small/Short (trees with a mature height of less than 30')

Common Name	Scientific Name and Cultivar(s)	Max DBH for KCMO (inches)	Minimum Planting Area (feet)
American Hornbeam	Carpinus caroliniana 'Native Flame®' JFS_KW6, 'Palisade® CCSQU PP 11280'	22	6x6
Eastern Redbud	Cercis canadensis 'Rising Sun™' JN2 PP 21451' , 'Merlot' PP 22297	20	5x5
Japanese Tree Lilac	Syringa reticulate 'Ivory Silk®'	12	5x5
Serviceberry (single stem)	Amelanchier grandiflora 'Robin Hill', Autumn Brillance'	16	5x5
Sugar Maple	Acer saccharrum 'Sugar Cone'	12	5x5
Zelkova	Zelkova serrata 'City Sprite' JFS-KW1 PP 20996	24	5x5

Medium (trees with a mature height less than 40')

Common Name	Scientific Name and Cultivar(s)	Max DBH for KCMO (inches)	Minimum Planting Area (feet)
European Hornbeam	Carpinus betulus, 'Fastigiata'	36	7x7
Ginkgo	Ginkgo biloba, 'Princeton Sentry'	27	6x6

Large/Tall (trees with a mature height greater than 40')

Common Name	Scientific Name and Cultivar(s)	Max DBH for KCMO (inches)	Minimum Planting Area (feet)
Crimson Spire	Quercus robur x Q. alba	38	7x7
Hackberry	Celtis occidentalis 'Prairie Sentinel'	30	6x6
Honeylocust	Gleditsia triacanthos 'Draves 'PP 21698' 'Street Keeper®	30	7x7
Red Maple, Armstrong	Acer rubrum 'Armstrong'	30	6x6
Regal Prince	Quercus robur x Q. bicolor, 'Long'	48	8x8
Sugar Maple	Acer saccharum, 'Endowment'	36	7x7
Tulip tree	Liriodendron tulipfera, "Fastigiatum'	33	7x7
Zelkova	Zelkova serrata, 'Musahino'	24	6x6

KC Parks and Rec. (2018). Street Tree Planting Requirements. https://kcparks.org/wp-content/uploads/2021/03/KC-MO-TREE-PLANTING-SPECIFICATIONS-Nov-2018.pdf

NORMAL CROWN SPREADS

Small/Short (trees with a mature height of less than 30')

Common Name	Scientific Name and Cultivar(s)	Max DBH for KCMO (inches)	Minimum Planting Area (feet)
American Hophornbeam	Ostrya virginiana	12	5x5
American Hornbeam	Carpinus caroliniana 'Native Flame®' JFS_KW6	30	6x6
Eastern (Red) Whitebud	Cercis canadensis f. alba 'Royal White'	24	5x5
Eastern Redbud	Cerces canadensis, 'Forest Pansy', 'Appalachian Red', 'Rising Sun'	24	5x5
Lilac	Syringa reticulate, "Japanese Lilac Tree'	12	5x5
Pacific Sunset Maple	Acer truncatum x A. plantanoides 'Warrenred'	24	6x6
Paperback Maple	Acer griseum	12	5x5
Serviceberry (single stem)	Amelanchier laevis 'JFS-Arb' PP 15304 Spring Flurry®	16	5x5
Serviceberry (single stem)	Amelanchier grandiflora 'Robin Hill', Autumn Brillance'	16	5x5
Serviceberry (single stem)	Amelanchier arborea 'Downy', ' Shadbow', 'Juneberry', 'shadbush'	16	5x5
Sugar Cone Maple	Acer saccharum 'Sugar Cone'	16	5x5
Tatarian Maple	Acer tataricum, 'Summer Splendor'	18	5x5
White Flowering Dogwood	Cornus florida	20	5x5
Zelkova	Zelkova serrata 'City Sprite' JFS-KW1 PP 20996	24	5x5

KC Parks and Rec. (2018). Street Tree Planting Requirements. https://kcparks.org/wp-content/uploads/2021/03/KC-MO-TREE-PLANTING-SPECIFICATIONS-Nov-2018.pdf

Medium (trees with a mature height of less than 40')

Common Name	Scientific Name and Cultivar(s)	Max DBH for KCMO (inches)	Minimum Planting Area (feet)
Black Tupelo	Nyssa sylvatica 'Hayman Red' 'Afterburner Tupelo', 'David', Firestarter 'JFS-red'	36	7x7
Emerald Sunshine Elm	Ulmus propinqua, 'JFS-Beirberich'	46	7x7
Frontier Elm	Ulmus carpinifolia x parvifolia	46	7x7
Linden	Tilia americana 'Lincoln'	36	7x7
Honey Locust	Gleditsia triacanthos var. inermis, 'Imperial'	36	7x7
Overcup Oak	Quercus lyrata	40	7x7

Large/Tall (trees with a mature height of more than 40')

Common Name	Scientific Name and Cultivar(s)	Max DBH for KCMO (inches)	Minimum Planting Area (feet)
Bald Cypress	Taxodium distichum 'Shawnee Brave'	44	8x8
Bur Oak	Quercus macrocarpa	50	8x8
Caddo Maple	Acer saccharum, "Autumn Splendor'	42	8x8
Chinkapin Oak	Quercus muehlenbergii	40	7x7
American Elm	Ulmus americana 'Valley Forge', 'Jefferson', 'Princeton', 'New Harmony'	48	8x8
Ginkgo	Ginkgo biloba, 'Autumn Gold'	30	7x7
Hackberry	Celtis occidentalis 'Chicagoland'	30	7x7
Kentucky Coffee Tree	Gymnocladus dioicus 'Espresso'	36	7x7
Linden	Tilia Americana 'Boulevard', 'Continental Appeal'	42	7x7
Honey Locust	Gleditsia triacanthos var. inermis, 'Shademaster', 'Imperial', 'Skyline'	46	8x8
Northern Red Oak	Quercus rubra	60	8x8
Post Oak	Quercus stellata	24	6x6
Red Maple, Autumn Blaze	Acer x freemanii, "Jeffsred'	36	7x7
Red Maple, Red Sunset	Acer rubrum, "Red Sunset'	36	7x7
Shumard Oak	Quercus shumardii	48	8x8
Silver Leaf Linden	Tilia tomentosa	42	8x8
Sugar Maple	Acer saccharum 'Fall Fiesta', 'Legacy'	36	7x7
Swamp White Oak	Quercus bicolor	60	8x8
Tuliptree	Liriodendron Tulipifera	36	7x7
White Oak	Quercus alba	48	8x8

COMMON NAME	SCIENTIFIC NAME	MINIMUM PLANTING AREA	FLOOD TOLERANT	IMAGE	ADDITIONAL CONSIDERATIONS
American Hornbeam	Carpinus caroliniana 'Native Flame®' JFS_KW6, 'Palisade® CCSQU PP 11280'	6 X 6	X		
Serviceberry (single stem)	Amelanchier grandiflora 'Robin Hill', Autumn Brillance'	5 X 5	X		
Hackberry	Celtis occidentalis 'Prairie Sentinel'	6 X 6	X		
Red Maple, Armstrong	Acer rubrum 'Armstrong	6 X 6	X		
White Flowering Dogwood	Cornus florida	5 X 5	X		
Swamp White Oak	Quercus bicolor	8 X 8	X		
Silver Maple	Acer saccarinum	12 X 12	X		Needs at least 20' between plant and walkways

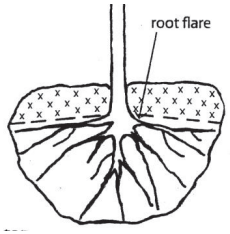
COMMON NAME	SCIENTIFIC NAME	MINIMUM PLANTING AREA	FLOOD TOLERANT	IMAGE	ADDITIONAL CONSIDERATIONS
Sweetgum	Liquidambar styraciflua	8 X 8	X		Needs at least 20' between plant and walkways
Black Tupelo	Nyssa sylvatica 'Hayman Red' 'Afterburner Tupelo', 'David', Firestarter 'JFS-red'	7 X 7	X		
Bur Oak	Quercus macrocarpa	8 X 8	X		
Bald Cypress	Taxodium distichum 'Shawnee Brave'	8 X 8	X		
Emerald Sunshine Elm	Ulmus propinqua, 'JFS-Beirberich'	7 X 7	X		
Frontier Elm	Ulmus carpinifolia x parvifolia	7 X 7	X		
American Elm	Ulmus americana 'Valley Forge', 'Jefferson', 'Princeton', 'New Harmony'	8 X 8	X		

KC Parks and Rec. (2018). Street Tree Planting Requirements. https://kcparks.org/wp-content/uploads/2021/03/KC-MO-TREE-PLANTING-SPECIFICATIONS-Nov-2018.pdf

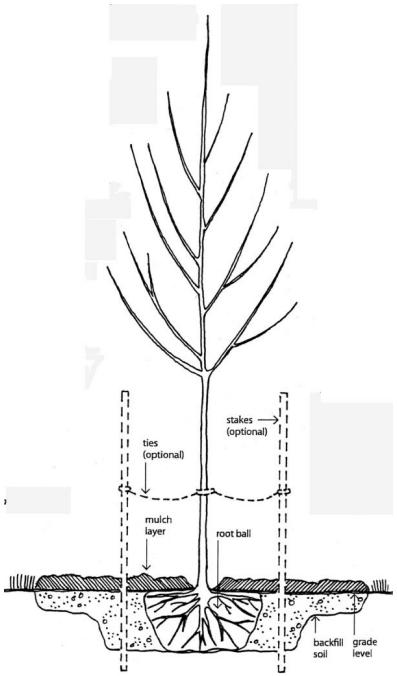
FIGURE 2— TREE PLANTING STANDARD DETAIL

Finding the Root Flare:

For balled-and-burlapped trees, probe the top of the soil ball chose to the trunk to find the first roots. You can do this with a stout wire. Check in two or more locations to make sure you've located the top major roots. Leave the burlap in place to make moving the tree easier. Measure the distance from the top of the soil ball to the root flare. Next, subtract that distance from the total depth of the burlapped soil ball.



The distance from the top-most buried root to the bottom of the ball is the correct depth to dig the pit.



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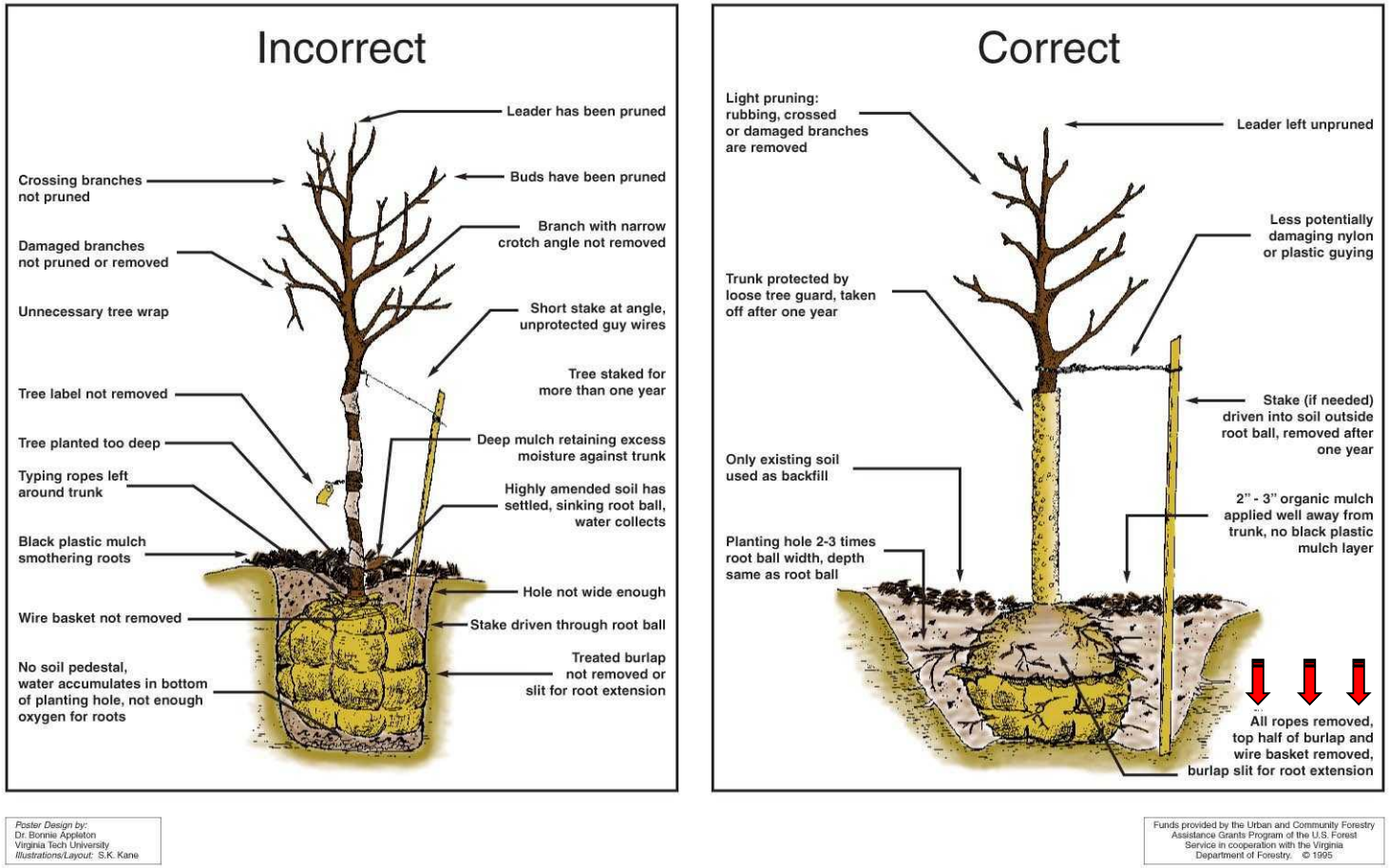
KC Parks and Rec. (2018). Street Tree Planting Requirements. https://kcparks.org/wp-content/uploads/2021/03/KC-MO-TREE-PLANTING-SPECIFICATIONS-Nov-2018.pdf

FIGURE 4—PLANTING QUALITY

PRUNING AT PLANTING NOT REQUIRED!
PRUNING SHOULD ONLY BE DONE BY A QUALIFIED ARBORIST OR FORESTER



Appendix D: KCMO Drought and Flood Tolerant Planting List

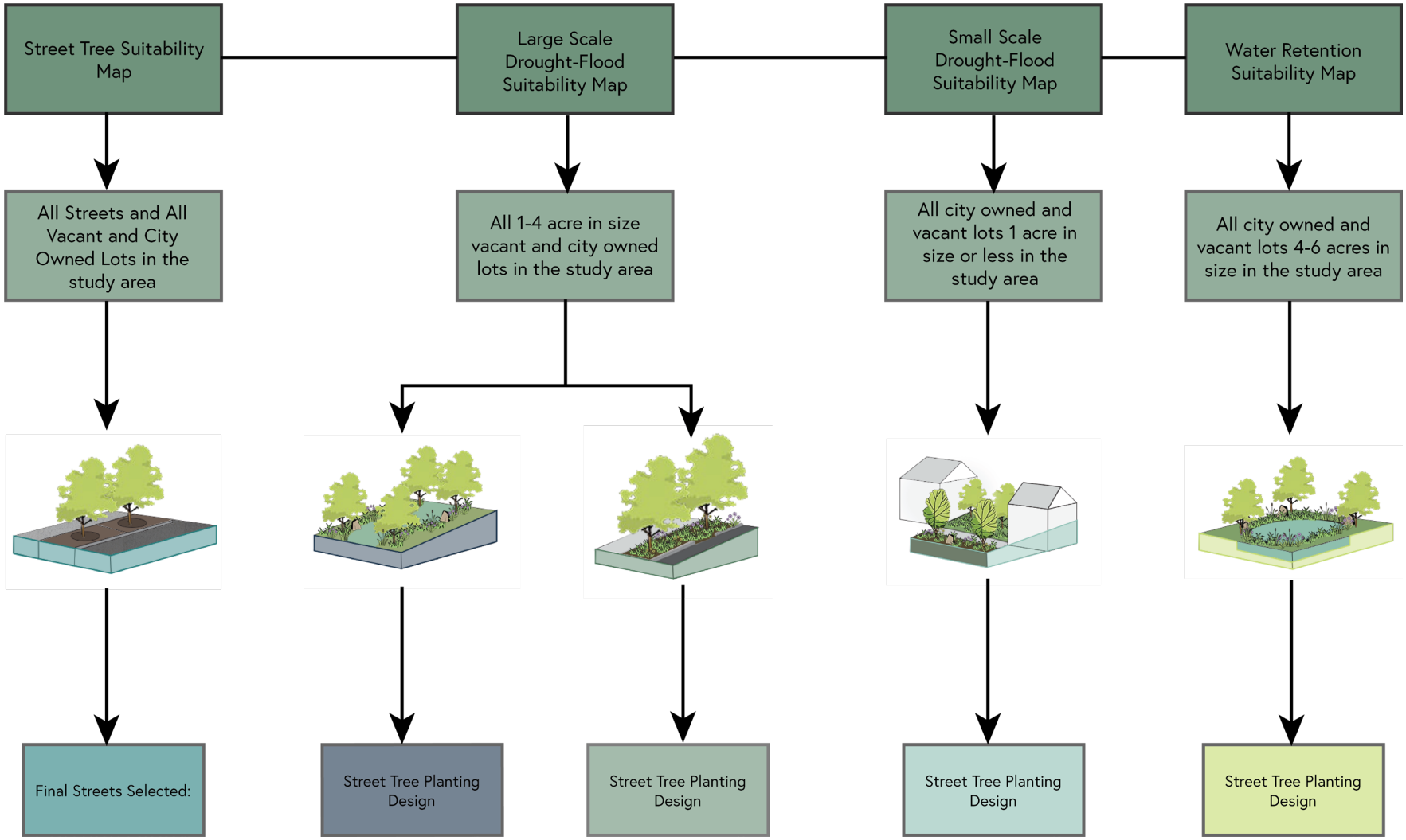
The following plant lists were all derived from the Missouri Conservationist (Richter, 2017), and is a baseline starting point for plant selection for potential greening projects in this area. Prior to implementation, final plant selections would need to be made and could include other plants than the ones listed in the following sections.

Drought Tolerant Plant Recommendations:
- Indian Paintbrush
- Missouri evening primrose
- Rose verbena
- Orange puccoon
- Black eyed susans
- Yellow coneflowers
- Butterfly weed
- Blazing star
- Fall asters
- Yellow goldenrods

Flood Tolerant Plant Recommendations
- Red cardinal flowers
- Blue lobelias
- Rattlebox loosestrife
- Lizards tail
- Swamp milkweed
- Southern blue flag
- False dragonhead
- Purple coneflowers
- Common milkweed
- Coreopsis
- Purple prairie clover
- Indian grass
- Bluestem
- Buffalo grass

Native Prairie Plants which are tolerant to changing conditions:
- Little bluestem
- Big bluestem
- Sideoats gramma
- Indian grass
- Blazing stars
- Milkweeds
- Coneflowers
- Rattlesnake master
- Compass plants

Appendix E: Site Selection Process Diagram



The Site Selection Process Diagram demonstrates the steps in the decision making process taken to select final sites for the design typologies to be theoretically implemented upon. Starting with the suitability maps created, then overlaying the potential sites based upon the sizing requirements, and matching these with a design typology. From here sites were selected based on other factors such as adjacencies, zoning, land cover, and location within the study area.

Factors Selected Based Upon the Following Projects:

Gelan, E. (2021). GIS-based multi- criteria analysis for sustainable urban green spaces planning in emerging towns of Ethiopia: The case of Sululta town. Environmental Systems Research, 10(1), 13. https://doi.org/10.1186/s40068-021-00220-w

Evans, K. (2021). GREEN INFRASTRUCTURE SITE SUITABILITY ANALYSIS For Wyandotte County and Kansas City, Kansas. https://cdr.lib.unc.edu/downloads/9k41zp264

Apud, A., Faggian, R., Sposito, V., & Martino, D. (2020). Suitability Analysis and Planning of Green Infrastructure in Montevideo, Uruguay. Sustainability, 12(22), Article 22. https://doi.org/10.3390/su12229683

Additionally, available GIS data to the public also dictated what factors could and could not be analyzed for suitability analysis in this project.

Variable	Data Details	Data Source
CSO Area	Boundary area of the combined sewer system	UGWC GIS database
History of Overflows	Points indicating locations where instances of overflow flooding have been recorded by the UGWC public works department	Lucity database
Discharge Points	Points indicating locations of discharge points, where stormwater runoff re-enters the natural environment	UGWC GIS database
Flood Hazard Area	Boundaries of the 100-year and 500-year flood hazard zones	UGWC GIS database
Water Bodies	Boundaries of lakes, rivers, and streams within Wyandotte County	UGWC GIS database
Slope	Boundaries delineating the degree of slope on land within Wyandotte County	Summer 2020 AmeriCorps project
Soils	Boundaries delineating the different types of soil found within Wyandotte County	UGWC GIS database
Impervious Area	Boundaries delineating the different types of ground cover (sidewalks, trails, roads, pervious) within Wyandotte County	UGWC GIS database
Public Parks	Boundaries of public parks within Wyandotte County	UGWC GIS database
Public Trails	Paths of public trails in Wyandotte County	UGWC GIS database
Schools	Points indicating locations of elementary and secondary schools	UGWC GIS database
Environmental Justice	Census tract boundaries exported from the American Community Survey with race and income data	2019 American Community Survey
Land Bank Parcel	Parcels owned by the Wyandotte County Land Bank	UGWC GIS database
Public Ownership	Parcels where UGWC buildings or UGWC properties are located	UGWC GIS database
Vacant Parcel	Parcels identified as vacant having no improvement value (no features such as houses, garages, barns, athletic facilities, and parking lots)	UGWC GIS database
Zoning	Boundaries of zoning designations in Wyandotte County (including Kansas City, Edwardsville, and Bonner Springs)	UGWC GIS database; KC Mapping, a consultant to Bonner Springs

(Evans, 2021)

Task	Oct 1-7	Oct 8-14	Oct 15-21	Oct 22-28	Column1
Lit Review Draft 1					
COMMITTEE MEMBERS DETERMINED		10/13!			
Proposal Development					
Lit Review Editing					
Case Study Analysis Framework					
Case Study Analysis					
START INTIAL BOOK DEISGN				10/26!	
Task	**Nov 1-4**	**Nov 5-11**	**Nov 12-18**	**Nov 19-25**	**Nov 26-30**
Final Proposal Editing					
FULL PROPOSAL DUE 5 pm		11/6!			
Proposal Revisions					
Site selection phase 1					
REVISED PROPOSAL TO COMMITTEE 5 PM			11/17!		
THANKSGIVING BREAK				BREAK	
PRELIMINARY MASTERS REPORT REVIEWS					
Task	**Dec 3-9**	**Dec 10-16**	**Dec 17-23**	**Dec 24-30**	**Column1**
Proposal Revisions					
FINAL PROPOSAL DUE		12/12 !!			
Suitability Mapping					
Winter Break - Revisions and Continue Working		BREAK	BREAK	BREAK	
Revisions due if need be					1/12!!
Task	**Jan 1-6**	**Jan 7-13**	**Jan 14-20**	**Jan 21-27**	**Jan 28-31**
Projective Design Phase					
Initial Document Design					
DOCUMENT OUTLINE AND DESIGN DUE					1/29!
Report Writing					
Task	**Feb 1-3**	**Feb 4-10**	**Feb 11-17**	**Feb 18-24**	**Feb 25-29**
Finalize Projective Design Phase					
SUBSTANTIAL COMPLETION TO COMMITTEE			2/12!!		
Report Writing editing					
SUBSTANTIAL COMPLETION REVIEWS					
Task	**Mar 3-9**	**Mar 10-16**	**Mar 17-23**	**Mar 24-31**	**Column1**
Final Report and book editing					
FINAL REPORT DRAFT DUE TO MAJOR PROFESSOR			3/18!		
Prep For Final Defense					
Task	**Apr 1-6**	**Apr 7-13**	**Apr 14-20**	**Apr 21-30**	**Column1**
FINAL DEFENSE PRESENTATIONS					
FINAL EXAM BALLOTS DUE 5 PM TO GRAD SCHOOL		4/12!			
Task	**May 1-4**	**May 5-11**	**May 12-18**		
EDTR SUBMISSION DUE	5/3!				
GRADUATION			5/12 !!!!		