

On either side of the levee:
exploring social and ecological benefits of adaptive flood resilience strategies

by

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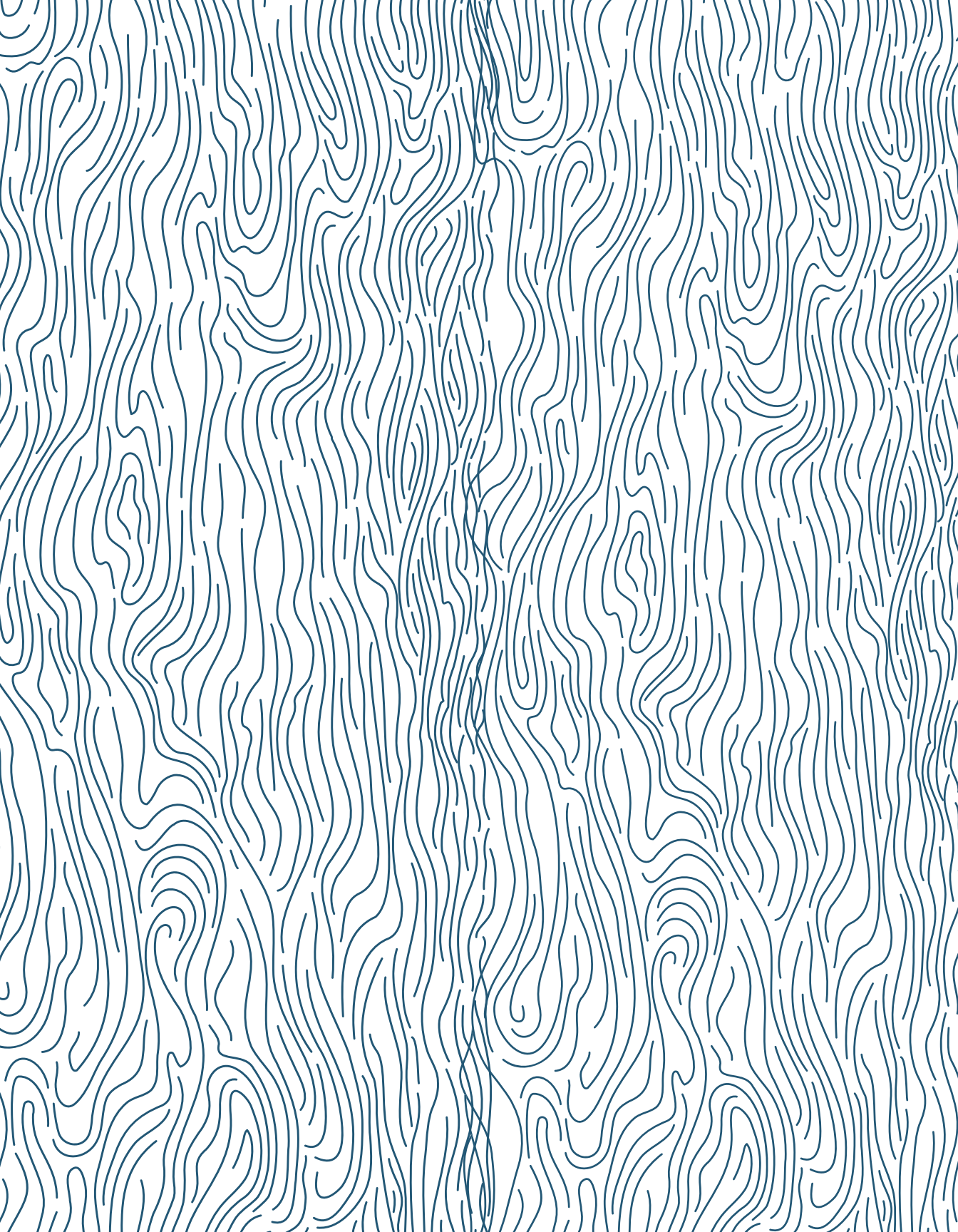
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Hyung Jin Kim, Ph. D.

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Abstract

With increasing urbanization and threats from climate change, urban flooding has become a prevalent issue, leading to a growing reliance on levees along many river cities. While urban levees are an essential measure of protection in many of these communities, they often disconnect people from access to the river and can have detrimental effects on natural floodplain ecosystems. The city of Manhattan, Kansas has experienced several major flood events in recent decades and is pursuing a project which includes several upgrades to the levee, including raised walls, improved relief wells, and structural reinforcements. Even with the coming levee improvements, alternative methods should be explored to mitigate further flood damage, improve human connection with the waterfront, and restore natural floodplain ecosystems. Thus, this study examines both the social and ecological aspects of levee design by asking the following question: “How can levees be reimagined to enhance flood resilience, ecological function, and community access to the riverfront?”. This, along with several related sub-questions, is answered by (1) developing a framework for levee design analysis through a comprehensive synthesis of literature; (2) using survey methods to assess community members’ perception of river access before and after design interventions; and (3) proposing an adaptive levee design strategy for the city of Manhattan, Kansas that provides ecological and social benefits in addition to mitigating the risk of urban flooding. The study contributes to the body of work in landscape architecture through the exploration of innovative strategies to produce an improved levee design that combines traditional typologies with more creative, nature-based adaptations and enhances human experience.



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Hyung Jin Kim Ph. D.*

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With increasing **urbanization** and threats from **climate change**, urban flooding has become a prevalent issue, leading to a growing reliance on levees along many river cities. While urban levees are an essential measure of protection in many of these communities, they often **disconnect** people from access to the river and can have detrimental effects on natural **floodplain ecosystems**. The city of Manhattan, Kansas has experienced several major flood events in recent decades and is pursuing a project which includes several upgrades to the levee, including raised walls, improved relief wells, and structural reinforcements. Even with the coming levee improvements, alternative methods should be explored to **mitigate further flood damage**, improve **human connection with the waterfront**, and **restore natural floodplain ecosystems**. Thus, this study examines both the social and ecological aspects of levee design by asking the following question: “How can levees be reimaged to enhance flood **resilience**, **ecological function**, and **community access to the riverfront**?”. This, along with several related sub-questions, is answered by (1) developing a framework for levee design analysis through a comprehensive synthesis of literature; (2) using survey methods to assess community members’ perception of river access before and after design interventions; and (3) proposing an adaptive levee design strategy for the city of Manhattan, Kansas that provides **ecological** and **social benefits** in addition to **mitigating the risk of urban flooding**. The study contributes to the body of work in landscape architecture through the exploration of innovative strategies to produce an improved levee design that combines traditional typologies with more creative, **nature-based** adaptations and enhances **human experience**.

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Preface

This project began as an idea with little direction, a passion for rivers and people, with inspiration from my lived experiences. I grew up along the Missouri River, learning to love the dynamics of the natural world and growing to understand the relationship between people and place. As a result, I have always been passionate about seeing how communities engage with the natural ecosystems that surround them. I hope with this project to enhance that connection, bridging the gap between social and ecological, built and natural, designed and spontaneous.

01

Introduction

Problem & Significance

As climate change and urbanization increase, floods will become more frequent, especially in rapidly developing areas. Urban levees are essential to protect communities against the risk of flooding in many US cities. In the case of storm surges, levees protect these cities from flooding and minimize structural damage, reducing costs to homeowners (CIRIA et al. 2013; Montz & Tobin 2008; USACE n.d.). The construction of these features also creates more space for land use near the river, such as development or agriculture. However, these structures can be costly compared to nature-based flood solutions and require more work to maintain. When floods do occur, there is always a risk that the levee may fail or be overtopped, meaning that these structures alone do not reduce insurance premiums, nor do they eliminate the need to evacuate during these events (Ding et al. 2023; FEMA n.d.; KDA 2018; Zhu et al. 2007). In terms of ecological systems, levee construction often leads to a loss of native habitat and inhibits natural floodplain functions.

Opposite the waterside, the height of the levee structure creates both a visual and physical barrier between residents and the river, limiting access to and interaction with water amenities and its natural features (CIRIA et al. 2013; FEMA n.d.; Kondolf & Pinto 2017; May 2006; Vercruysse et al. 2022). Though levees play an essential role in the flood protection of many urban areas, they often disconnect people from access to the river and can have detrimental effects on natural floodplain ecosystems. Over several centuries, rivers have transformed in their use - from a

highway to transport goods, to a location for waste disposal, to more recent perception as a beneficial amenity to the public. The consideration of rivers as social-ecological systems is important to understand the complex factors of issues like these and address topics such as ecology, connectivity, and disaster resilience of communities (Chakraborty & Chakraborty 2017; CIRIA et al. 2013; Kondolf & Pinto 2017; Groffman et al. 2003; Parsons 2019; Zhang et al. 2021).

The City of Manhattan, Kansas has experienced several major flood events in recent decades and is pursuing a project which includes several upgrades to the levee, including raised walls, improved relief wells, and structural reinforcements. Even with the coming levee improvements, alternative methods should be explored to mitigate further flood damage, improve human connection with the waterfront, and restore natural floodplain ecosystems. An improved levee strategy that combines traditional typologies with nature-based adaptations could work to enhance the transition between urban and natural areas, mimic traditional floodplain ecology, increase infiltration, and mitigate disasters (Beagle et al. 2019; Plane & Iknayan 2021; Zhang et al. 2021). Understanding how people interact with the Manhattan riverfront will be important to assess public perception of the levee, desire for access, and work toward solutions that may be applied to other cities interested in reintegrating their waterfronts with the public.

“How can levees be reimagined to enhance flood resilience, ecological function, and community access to the riverfront?”

Research Questions

The goal of this study is to explore both the **social** and **ecological** aspects of levee design by asking the primary research question, “How can levees be reimagined to enhance flood resilience, ecological function, and community access to the riverfront?”. This question will be answered through research-informed design, focused on synthesizing riparian ecology and social connectivity as seen in the subsequent sub-questions:

Q1. What are the ecological and flood resilience benefits of an adaptive levee design in Manhattan, KS?

Q 1-1: What are benefits of combining man-made and natural flood mitigation strategies?

Q 1-2: How will vegetation impact the structural integrity and function of a traditional levee?

Q 1-3: How can existing precedent studies inform an adaptive river levee design? Which elements of the examined precedents will be most relevant and beneficial to this design proposal?

Q2: How can this design enhance river access and user experience of the levee for residents of Manhattan, KS?

Q 2-1: What barriers does a traditional levee present to human-river interaction?

Q 2-2: What design interventions can enhance people’s experience of the river?

Q 2-3: What is the community’s perception on natural floodplain function vs. man-made levee design interventions?

02

Literature Review

Chapter Overview

The literature review synthesizes information gathered from reputable articles about riparian ecology, flood resilience, levee construction, social connectivity, and other relevant topics to draw conclusions that ultimately inform the design proposal. The literature map (Figure 2.1) exemplifies topic relationships and how subtopics interact to form research-based decisions.

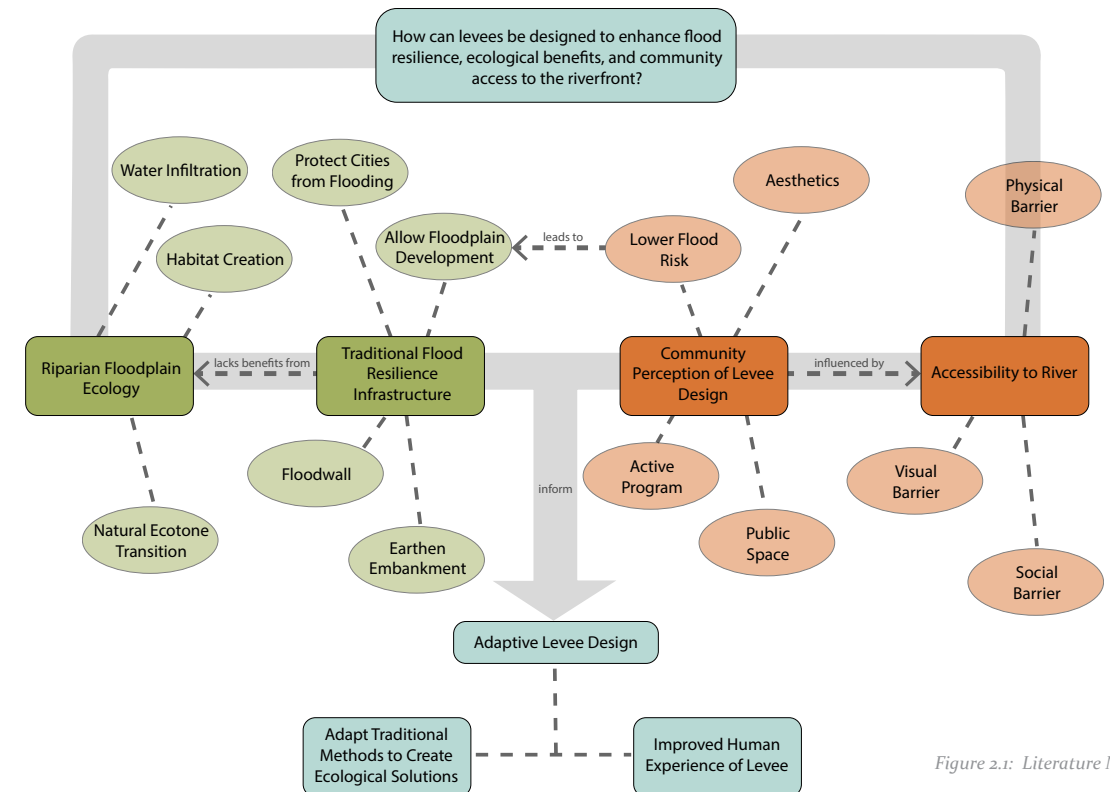


Figure 2.1: Literature Map

Literature Review

Many cities depend on levees for protection from floods, but as a result are disconnected from their natural river ecosystems, lose floodplain function, and face a reduction of native riparian habitat. Often, these man-made structures provide a false sense of security to those who wish to build in floodplain areas, leading to an increase in development and, as a result, more damage when flood events do occur. With increasing urbanization and threats from climate change, urban flooding has become a prevalent issue, leading to a growing reliance on levees along many river cities. Existing literature speaks to the issues of floodplain urbanization, ecological impacts, and the sociology of urban riparian systems (Chakraborty & Chakraborty 2017; Groffman et al. 2003; Islam 2020; Montz & Tobin 2008). While many studies acknowledge the barriers and increased risks created by levees, there are few realistic, cost-effective, and sustainable solutions to this growing dilemma. With an understanding of ecology, social dynamics, design, and interdisciplinary collaboration, landscape architects are uniquely poised to address this issue on both sides of the levee and propose innovative solutions.

History & Function of Levees

Levees are typically built along a waterway, intended to reduce the risk of flooding, either by excluding or diverting water from developed areas to prevent inundation (CIRIA et al. 2013; USACE n.d.). The most common types of flood protection systems are earthen embankments or floodwalls. Embankments can be the only physical feature of a levee, but often work in combination with other structures for erosion protection, stability, and

seepage control. They can be made up of homogenous, compacted soil or be ‘zoned’ – having less permeable soil in the center – to mitigate seepage issues (CIRIA et al. 2013; USACE n.d.). Some levees are considered “composite levees”, constructed using soil as well as structural components for reinforcement, such as concrete walls, steel sheet piles, or geotextiles. Floodwalls can also be a separate structure which acts as a barrier to prevent flood waters from entering the protected area, typically made of reinforced concrete. These structures are built when an earthen embankment is not a viable option, typically due to spatial constraints (CIRIA et al. 2013; USACE n.d.).

Throughout history, humans have settled along rivers and other waterways because they provide an abundance of resources, transportation, and excellent land for agriculture (Groffman et al. 2003; Islam 2020; Vercruyssen et al. 2022). As settlement grew however, people needed to find solutions to keep their cities safe from the risk of flooding by the very rivers that gave them life. Construction of levees can be traced back for around 150 years, with a major increase during the 1940s -1960s (Ding et al. 2023). This increase may also be somewhat credited to a rise in technology becoming available to alter river corridors at a greater scale (Islam 2020). As urbanization has increased, so has the need for flood resilience structures. New construction of levees, however, has been uncommon in recent years. Many of these systems began as agricultural levees built to protect farmland at times of high water, and have since been modified (raised, widened, reinforced) as land use has changed (CIRIA et al. 2013, Ding et al. 2023, Knox 2022).

Even as they have become more prevalent in society, levees are one of the least studied or mapped features of river-floodplain systems worldwide, and the full extent of artificial levees in the contiguous United States is not entirely known (Ding et al. 2023; Knox 2022). Sources note that about 30,000 miles of levees exist along major rivers in the U.S., with 43% of citizens living in a county with at least one levee (McCully 2007; Montz & Tobin 2008). Despite this extensive investment and protection, flood-related losses in the U.S. increased by more than double (\$3 billion annual flood losses) in the second half of the century even after billions of dollars spent on flood protection projects (Knox 2022). Often the false sense of security created by the construction of levees leads to this type of destruction, denoted the “levee effect” by many scholars (Ding et al. 2023; Islam 2020; Montz & Tobin 2008). With rising waters due to urbanization and climate change, levees are more susceptible to breach. A breach occurs when a gap forms in the levee, allowing water to flow uncontrolled into surrounding areas. This catastrophic failure may be created over a longer period of time due to issues such as erosion, heavy loads, seepage, and settlement, or may be caused by one sudden traumatic event (CIRIA et al. 2013; Ding et al. 2023; McCully 2007; USACE n.d.).

Many levees were built several decades ago, and their floodplains have since been developed, limiting options for designers and engineers to create more social and ecologically focused spaces. This subsequent urbanization and the necessary levee upgrades, along with a changing climate, have led to serious degradation of fluvial systems. In fact, very few rivers, if any, can be considered

“natural” or have the potential to be restored to their once pristine state (Chakraborty & Chakraborty 2017; Dahl et al. 2017; Islam 2020; Knox 2022; May 2006; McCool 2012; Nunnally et al. 1987; Parsons 2019). Some of these impacts are detailed in the following sections.

River Ecology Interaction

Traditional levee typologies often ignore natural ecosystem patterns, reducing the land used to a rocky barrier or mown lawn edge. This, along with compacted soils from construction and use of the levee greatly limit infiltration of stormwater and other benefits that contribute to the diversity and function of floodplains (see Figure 2.2). Floodplains are a critical part of river ecosystems, alleviating pressure from both natural and anthropogenic risks. These ecosystems infiltrate and store water in flood events, sequester contaminants, and can provide refuge for organisms displaced by the disturbance (Knox 2022; Parsons 2019; Plane & Iknayan 2021; Shafroth et al. 2023). By creating artificial edges and disconnecting natural floodplain gradients, levees and similar structures decrease habitat diversity and limit the ability of floodplains to recover from disturbance (Knox 2022; Parsons 2019). Disturbance is a key component of many river ecosystems, defined as a process that creates stress for an ecosystem as compared to its natural state (Knox 2022). Resilience, or the capacity of systems to self-regulate, adapt, and recover from such stresses, is also a key factor in the long-term stability of a riparian corridor (Chakraborty & Chakraborty 2017; Knox 2022; Parsons 2019; Vercruyssen et al. 2022). Leaning into these natural systems is essential for

creating a successful social-ecological system such as an urban river. By building more structures to withstand and repel these systems' natural function instead of allowing them to occur naturally, we only increase the risk and damage to our built environment.

Current levees have strict vegetation management guidelines in place to ensure structural integrity of the system. Ordinances such as vegetation-free zones are enforced to ensure stability and reduce the possibility of seepage. Vegetation management primarily focuses on three performance objectives: 1) protect the levee from external erosion, 2) maintain adequate access and visibility, and 3) prevent development of vegetation induced damage or defects (CIRIA et al. 2013). The United States Army Corps of Engineers (USACE) and several other sources identify common concerns of vegetation on levees, with the main issues being root damage, animal burrowing, and visibility of the surface of the structure for inspection (CIRIA et al. 2013; Nunnally et al. 1987; USACE 2019). Vegetation provides habitat for many small animal species which often create burrows, resulting in openings with the potential for seepage. Large roots of woody plants and trees in natural floodplain ecosystems strengthen the stability of banks but create risk of large gaps in the embankment if toppled over. Many guidelines suggest that grass be mowed close to the ground as clear visibility is essential in identifying these potential risks during inspections in order to repair them and prevent further damage.

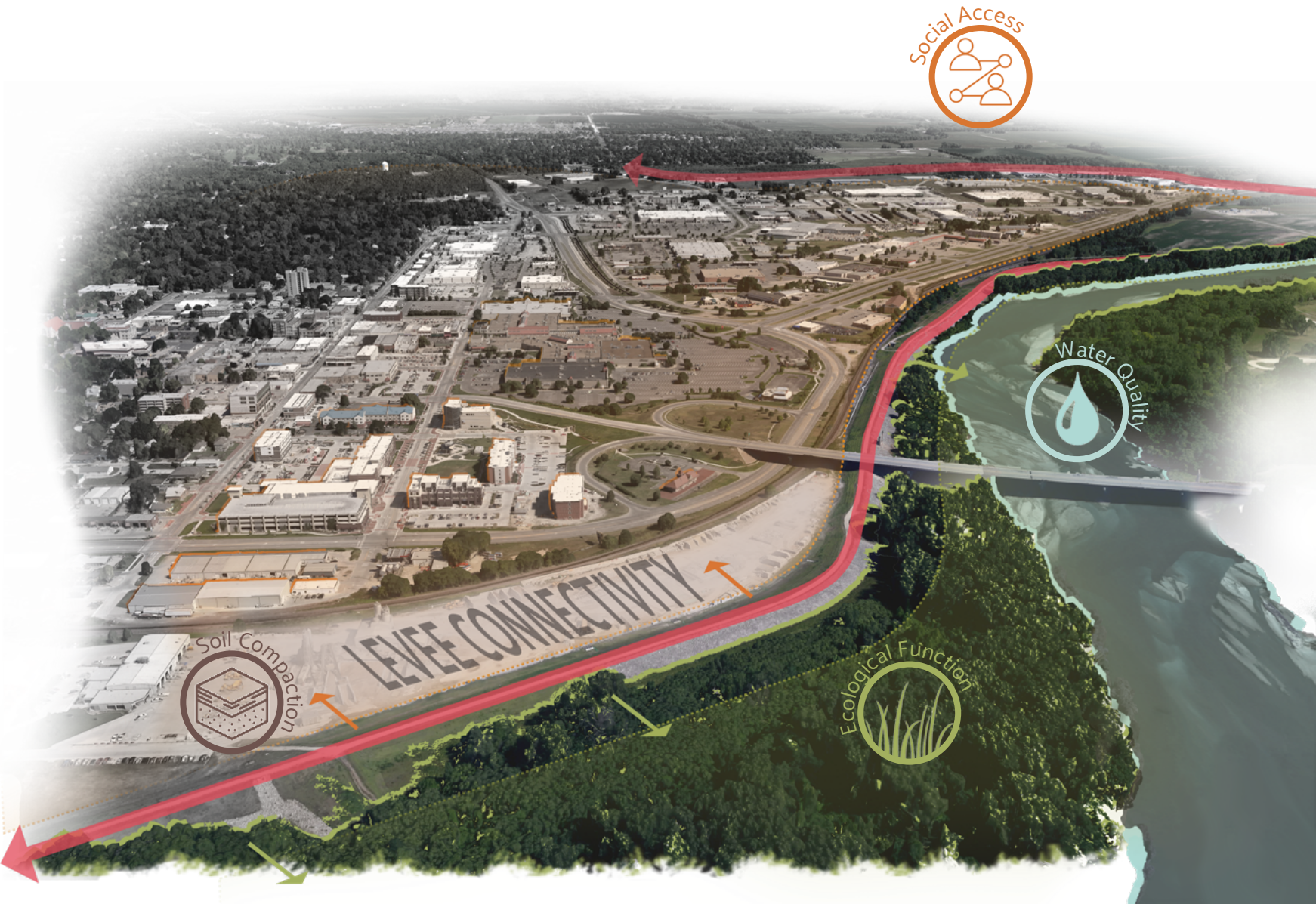


Figure 2.2: Common Issues with Levee Design

Despite these concerns, vegetation can provide several benefits to levees and the larger river ecosystem. Grass surfacing can provide ecological value and enhance the quality of the ecosystem if native species are used. In addition, these types of riparian vegetation act as a transition zone between upland and lowland ecosystems (grassland, woodland, wetland, etc). While levees are often seen as barriers to lateral connectivity, if used correctly they could benefit the larger corridor by connecting linear habitats and providing a path for species migration (CIRIA et al. 2013). Natural floodplain ecosystems provide benefits such as vegetative buffers to trap sediment & runoff of agriculture chemicals, improve water quality downstream, maintain stable water temperatures, stabilize banks, slow flow speeds, and prevent erosion (CIRIA et al. 2013; Groffman et al. 2003; Islam 2020; Knox 2022).

Floodplain Urbanization

Urbanization has played a significant role in the development of levees over the past several decades. Land along the river has been historically sought after for industry, and more recently, downtown revitalization. As these lots continue to be built, there is an increased need for protection. This leads to levee improvements, only pushing the issue of flooding downstream and creating a false sense of security for these newly developed areas. The aforementioned “levee effect” is a common result of the construction of flood protection systems, leading to an increase in urban development. Ding et al. (2023) note that the development of levees in the United States corresponds with a 62% increase in urban growth. This rate is double that of the

rest of the country, showing the radical change in perception of risk in areas “protected” by levees. The total urban area in floodplains has nearly doubled since 1985, most of which has been constructed in areas with 1/20 annual probability of flooding, also known as the 500-year floodplain (Andreadis et al. 2022). Where levees are built, development follows, increasing the vulnerability of infrastructure and inhabitants to damage from flooding (Ding et al. 2023; Knox 2022; Montz and Tobin 2008; Zhu et al. 2007).

Levee as Barrier & Potential Solutions

With the construction of levees, floodwalls, and other man-made flood prevention infrastructure, communities lose access the rivers upon which they were built. These corridors were once essential aspects of city life, providing commerce, transportation, and other amenities. Over time, however, the impacts of human action on rivers have diminished water quality, biodiversity, and geomorphology of these channels, which in turn has negative impacts on society’s perception and overall quality of life (Groffmann et al. 2003; McCool 2012). In many cases, linking rivers to their cities by visual access is just as important as providing physical connection to raise awareness of the river and promote human interaction with the waterfront (Kondolf & Pinto 2017; May 2006).

Some levees are beginning to be constructed or modified with not only flood protection, but human experience such as recreation and other social uses in mind (Beagle et al. 2019; Cecchetti et al. 2020; CIRIA et al. 2013; Nunnally et al. 1987;

Plane & Iknayan 2021; Zhang et al. 2021). Many of these designs occur in places where there are constructed setbacks, or naturally wider space between the embankment and the river's edge. A setback levee occurs when the levee is built farther away from the riverbank. These systems restore space for natural river meandering, promote flood resilience, and create ideal accommodation for animal habitat, as well as providing opportunity for low impact uses like recreation or restoration areas (CIRIA et al. 2013; Dahl et al. 2017; KDA 2018) This is becoming more common in other countries as well, with the UK promoting "making space for water" and the Netherlands adopting the idea of "room for the river" (Islam 2020; Vercruysse et al. 2022; Zhu et al. 2007).

Another potential solution to some of these issues is the "ecotone" or "horizontal" levee, being tested on the west coast of the United States. These ideas aim to use nature-based measures to either replace conventional flood prevention infrastructure such as levees, or work with these existing features to create an adaptive solution. (Beagle et al. 2019; Cecchetti et al. 2020; Plane & Iknayan 2021). This hybrid approach works to alleviate some of the negative impacts caused by levee construction while providing environmental benefits and taking community input into consideration. An ecotone levee is a gently sloping construction on the waterside of a levee, mimicking ecotones of the native riparian system, creating wetland habitat, and protecting the coast from erosion by absorbing impact of storm waves before they reach the shoreline.

The horizontal levee takes this approach a step further by introducing underground irrigation to support wetlands and remove contaminants. (Beagle et al. 2019; Cecchetti et al. 2020; Plane & Iknayan 2021). This approach, though largely untested and yet to receive a certification from FEMA, has promise regarding the future of levee construction for ecological restoration and climate change mitigation.

The literature notes that even though levees are essential to protect many riverfront cities, there is a general lack of data on these structures, their functions, and limitations. Some studies on the success of a "horizontal" or "ecotone" levee have been conducted in the San Francisco Bay area, as mentioned previously. These designs combine man-made structures and nature-based adaptation to eliminate the harsh transition between the natural floodplain and developed areas, imitate natural processes, increase infiltration, reduce flood risk, and provide essential species habitat (Beagle et al. 2019, Plane & Iknayan 2021). While there seems to be success in these coastal studies, there is a lack of research when it comes to levee adaptation along inland rivers. This study aims to address this gap by proposing innovative levee design typologies to understand both social and ecological aspects of urban flood resilience strategies and gather information that may be relevant to other riverfront projects. By exploring this topic in detail, cities can gain insight into how adaptive levee design can be used to improve connection between the water and the city and restore ecological floodplain function while still protecting developed areas from flood risk.

03

Methodology

Chapter Overview

This study uses an applied research approach through a community survey, precedent studies, and research-informed design methods to explore adaptive levee design strategies and their applications to urban rivers (see Figure 3.1 for the methodology approach and outcomes). The ecological focus of the research consisted of a comprehensive review and synthesis of existing literature and precedent studies. A framework informed by significant themes drawn from the literature, combined with design features of individual precedent studies enables comparison between typologies and their applicability in various contexts to enhance design development.

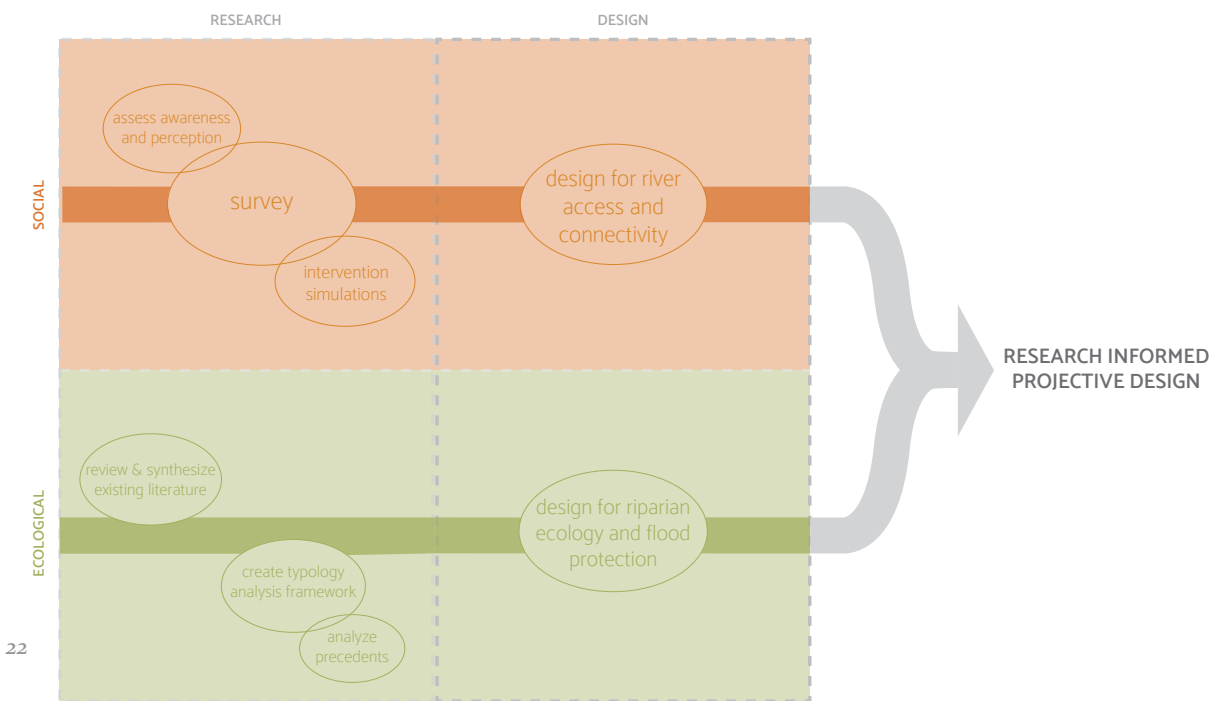


Figure 3.1: Methodology Process

The social focus of the research consisted of a community survey to assess awareness and perception of the existing levee and receive feedback on design interventions that would guide potential solutions. The survey gathered data on how often visitors interact with the riverfront, what activities draw them to visit, their perceived value of existing features, and perceived barriers to access. In addition, participants ranked their likelihood to visit the riverfront in five proposed scenarios: a fully ecological approach to the site, a fully developed approach, a hybrid approach, visual access and awareness of the river, and physical access to the river.

Informed by this process, the projective design produced a conceptual masterplan at the city scale and several context-based design strategies at an individual site scale. These adaptations to the existing levee structure are intended to provide both social and ecological benefits to each selected transect. These solutions should be widely applicable to river levees throughout the United States. Manhattan, Kansas, was chosen as a study site due to its history of flooding, recent levee development, and accessibility for research. Since a large amount of funding, time, and effort has already been committed to levee improvements, the research focuses on working with the current levee to adapt and improve its ecological function, flood protection, and access to the riverfront.

Study Area & Population

This study focuses on the southeastern portion of the city of Manhattan, KS, along the shoreline of the Kansas and Big Blue Rivers. The current levee (and proposed upgrade) extends along the Big Blue River from the intersection of Casement Road and Hayes Drive, south to the confluence with the Kansas River and wrapping around upstream, west of the Wastewater Treatment Plant (WWTP) facility, continuing south of Fort Riley Boulevard and the railroad tracks until South Manhattan Avenue. Figure 3.2 shows the City of Manhattan in relation to the larger watersheds in Kansas and Riley County, as well as the location of the levee in relation to the rest of the city.

The target population for the survey portion of this study includes residents of Manhattan, Kansas. Manhattan’s population is 54,100 (United States Census Bureau, 2020), which would require a sample size of 382 subjects to achieve sufficient data at the 95% confidence level with a confidence interval of 5 (Creative Research Systems 2012; O’Leary 2007). Other studies conclude that a sample size anywhere between 30-500 participants is appropriate for convenience sampling methods (Memon et al. 2020; O’Leary 2007; Roscoe 1975). Due to time and budget constraints, this research must rely on convenience sampling. Surveys were shared with community groups through various avenues such as email newsletters, Facebook, and NextDoor. As this study involves human subjects, Institutional Review Board (IRB) approval was required prior to final data collection. The research presented no more than minimal risk of harm to subjects involved in this study.

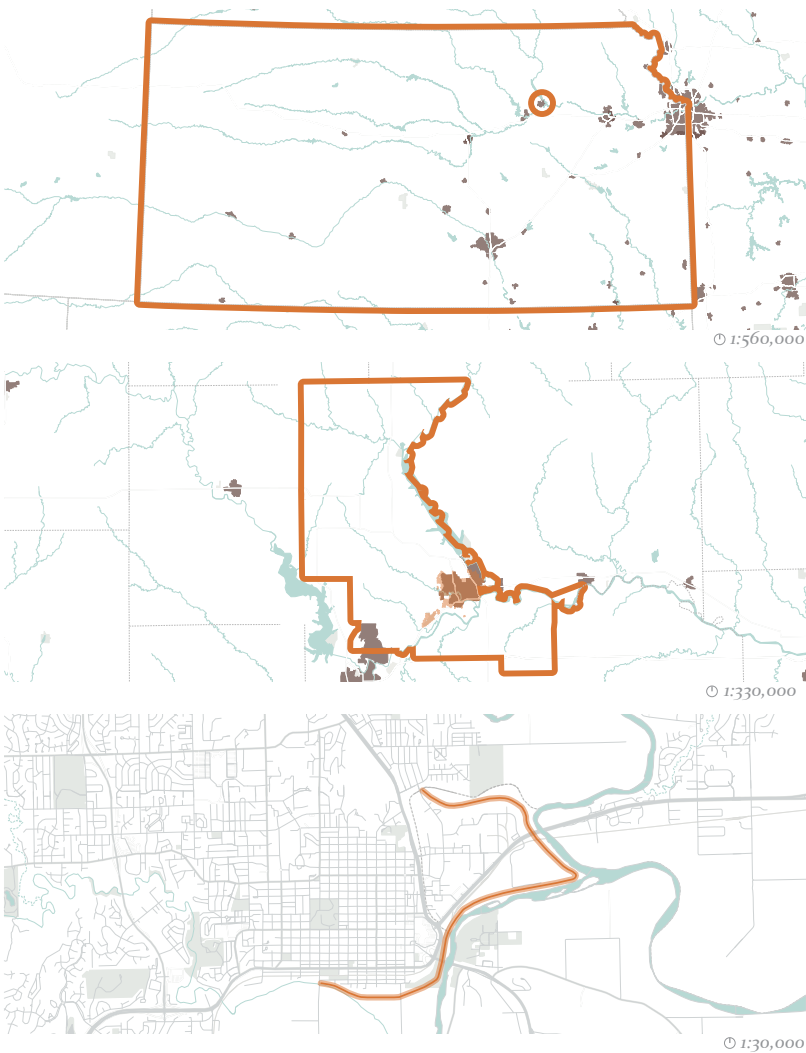
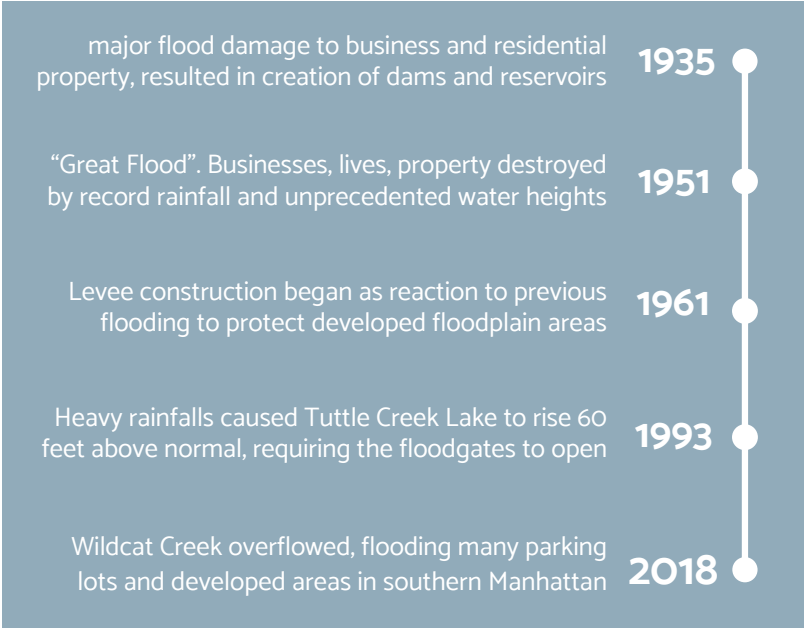


Figure 3.2: Context Map: State, County & City - Site Scales

Manhattan, KS Flood History & Resilience Plan



Due to its position at the confluence of the Kansas and Big Blue rivers and many other factors, the city of Manhattan has experienced several major flood events throughout its history, and as a result, gradually increased its flood protection infrastructure over time. Most recently, the city has worked to update the Wildcat Creek Floodplain Management plan and reliability of the existing levee system - "designed to be an innovated, comprehensive planning process to better understand the flooding problem and develop sound solutions" (City of Manhattan 2021; City of Manhattan 2022).

Site Selection for Design

To place the study within a relevant context, a thorough city-scale analysis and multiple site visits were conducted. The research used GIS and thematic mapping to represent factors such as land cover, land use, flood risk, population density, and other relevant information that could be used to identify specific transects and/or study areas of interest. Important mapping data was obtained through FEMA flood maps and the Riley County GIS Database, among other sources. Next, sites were selected based on the surrounding context by identifying criteria and relevant locations along the existing levee to choose representative cases for each proposed typology.

The research proposes that five sites of urban-to-river transects along the existing levee be analyzed: one near the southern entrance of the Linear Trail, one through the existing Midwest Concrete Materials (MCM) site, one across the Manhattan Town Center, one at the Wastewater Treatment Plant, and one along the northern portion of the levee near Northeast Community Park (see Figure 3.7 for a location map of the selected transects). These transects exemplify a variety of typologies including residential, commercial, and agricultural areas, while also highlighting their connectivity, ecology, and flood resilience. Once study transects were selected, a detailed analysis of each was conducted – synthesizing elements from site inventory to assess the benefits and constraints of both social and ecological conditions.

What are the **ecological** and **flood resilience** benefits of an adaptive levee design in Manhattan, KS?

Research Question #1: Methods

The following research questions were developed to guide the direction of study related to **ecological opportunities and challenges** of an adaptive levee design.

“Q 1-1: What are the benefits of combining man-made and natural flood mitigation strategies?” is answered by a comprehensive review of the literature and the development of a framework to assess the benefits and constraints of traditional levees with nature-based solutions. The precedents analyzed exemplify a range of traditional and innovative strategies which are compared and used to guide the projective design process.

“Q 1-2: How will vegetation impact the structural integrity and function of a traditional levee?” is answered by a detailed review of levee guidelines (from the Construction Industry Research and Information Association (CIRIA), United States Army Corps of Engineers (USACE), and other reputable organizations). This review of current documents, in addition to early conversations with city officials, established a baseline understanding of typical approaches and potential risks associated with levee vegetation.

“Q 1-3: How can existing precedent studies inform an adaptive river levee design? Which elements of the examined precedents will be most relevant and beneficial to this design proposal?” is answered by conducting precedent studies to better understand potential typologies and applications to the Manhattan levee. The research inventories the pros and cons of different approaches, synthesizes existing literature, uses discussions with relevant stakeholders, and proposes reasonable adaptations that can be applied to the river levee in Manhattan, KS.

Manhattan Levee: Ecological Opportunities and Constraints

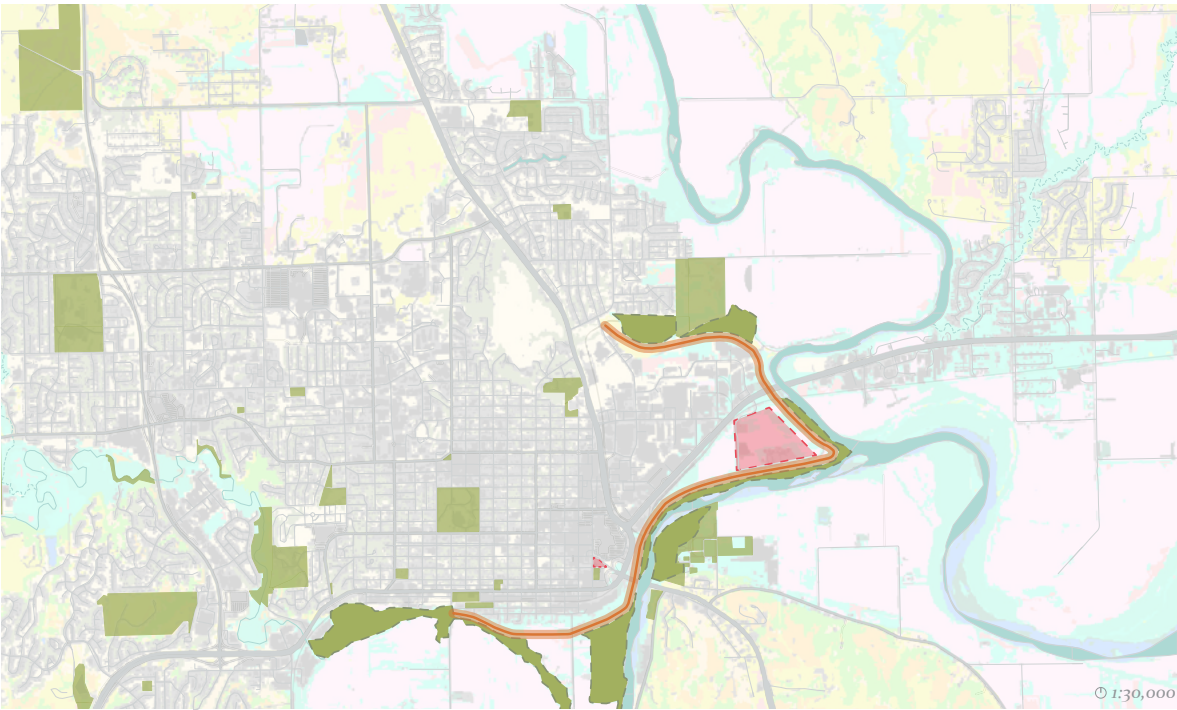


Figure 3.3: Ecological Opportunities Map

Ecological Opportunities

The native ecosystem that is intact along the riparian corridor serves as a baseline state for the success of ecological function. Several types of land cover, from floodplain forest to ruderal shrubland to tallgrass prairie, are found nearby. The water treatment center provides an opportunity to improve water quality, while the Flint Hills Discovery Center could work to inform the public on relevant topics and even host cleanups, trail walks, or other community engagement events. The existing parks system can also be expanded to improve access to green space in the city, especially with plans to restore the northernmost portion of the levee to a forested floodplain area.

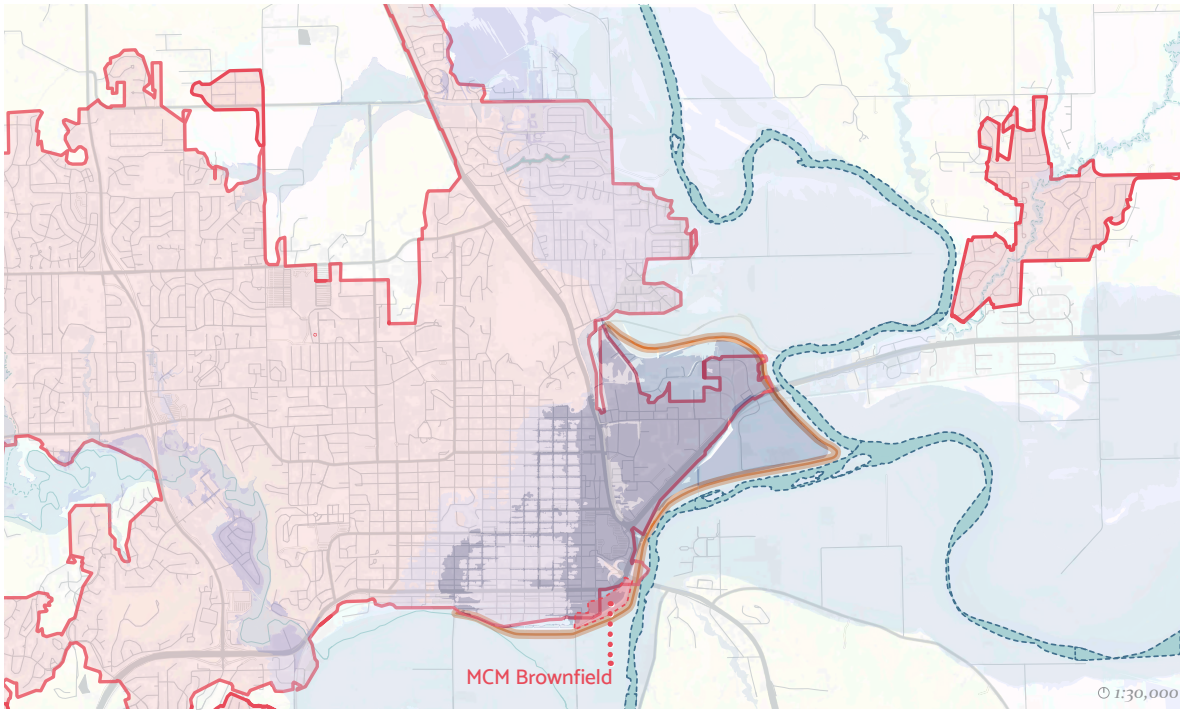
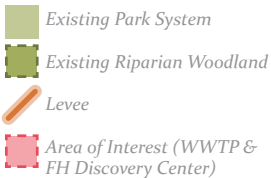


Figure 3.4: Ecological Constraints Map

Ecological Constraints

One major issue directly adjacent to the river is the Midwest Concrete Materials (MCM) site, in addition to many other contaminated industrial sites nearby. The city is currently assessing the area as a brownfield before any new developments may be undertaken. Urban development, in general, has proven to be a threat to the floodplain and river health. This has contributed to the poor water quality of the corridor. With the way the city and the levee have developed, flooding is always a concern, especially in areas unprotected by the levee.

How can this design
enhance **river access**
and **user experience** of
the levee for residents
of Manhattan, KS?

Research Question #2: Methods

The following research questions were developed to guide the direction of study related to **social opportunities and challenges** of an adaptive levee design.

“Q 2-1: What barriers does a traditional levee present to human-river interaction?” is answered through a survey method to assess surrounding neighborhoods’ awareness of, access to, and perception of the existing levee system compared to an adaptive hybrid approach (see Appendix B for survey questions). Based on the literature review and site analysis results, projective design interventions were developed and shared with stakeholders to gather feedback and further inform the final design proposal.

“Q 2-2: What design interventions can enhance people’s experience of the river?” is answered using previous studies and stakeholder feedback to adapt design interventions that improve residents’ visual and physical access to the riverfront. Interventions included varying levels of development to gauge interest, with some focused more on creating economic opportunity downtown and others directed toward a strictly ecological approach. The final design proposals are situated on various transects throughout the river corridor, corresponding to sections identified during the site analysis process.

“Q 2-3: What is the community’s perception of natural floodplain function vs. man-made levee design interventions?” Finally, these designs were assessed via the same community survey to compare existing conditions and proposed interventions using the design simulations to understand the community’s perception of man-made vs. natural levee design interventions and support claims found in existing research. Results of the surveys were adapted and synthesized as part of the projective design.

Manhattan Levee: Social Opportunities and Constraints

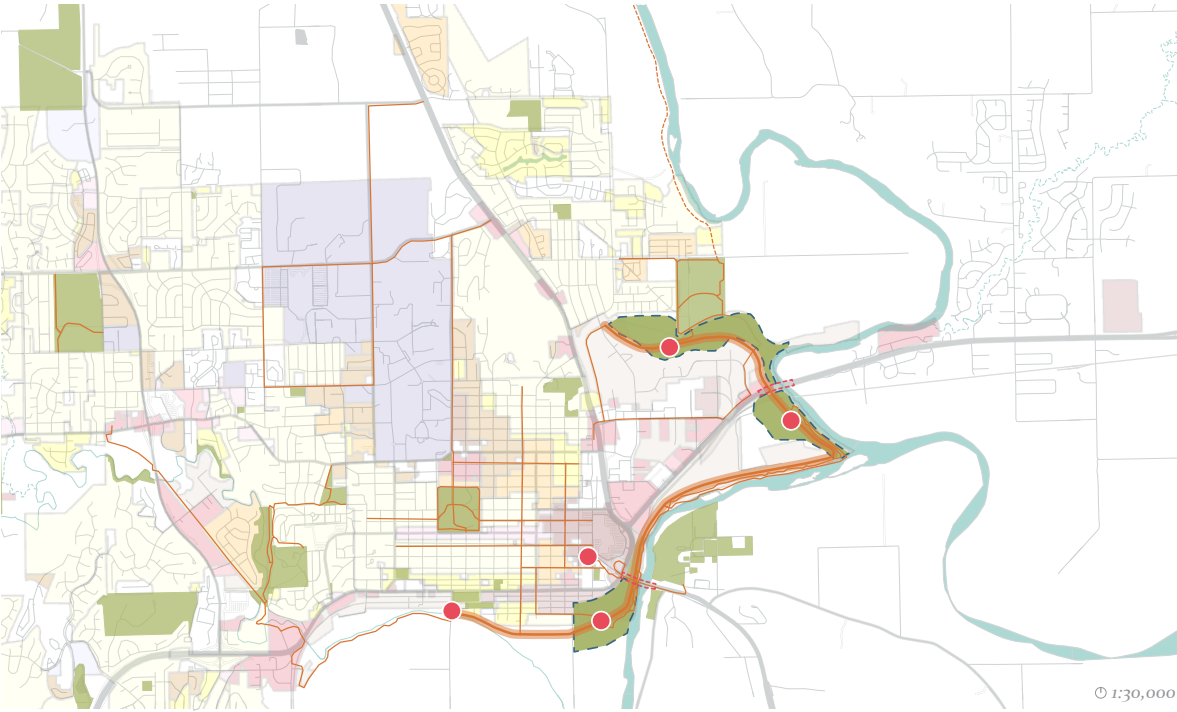


Figure 3.5: Social Opportunities Map

Social Opportunities

The existing features found in the City of Manhattan provide many opportunities to capitalize on social connectivity and expand access to the riverfront. For example, the park system is well maintained and connected through city-wide networks such as the Linear Trail. The existing bridge structure could provide support for a pedestrian river crossing. Local business activity in the downtown area is suited for attracting visitors and economic development, which could create partnerships that would benefit the community’s awareness of and engagement with the riverfront, such as the Flint Hills Discovery Center.

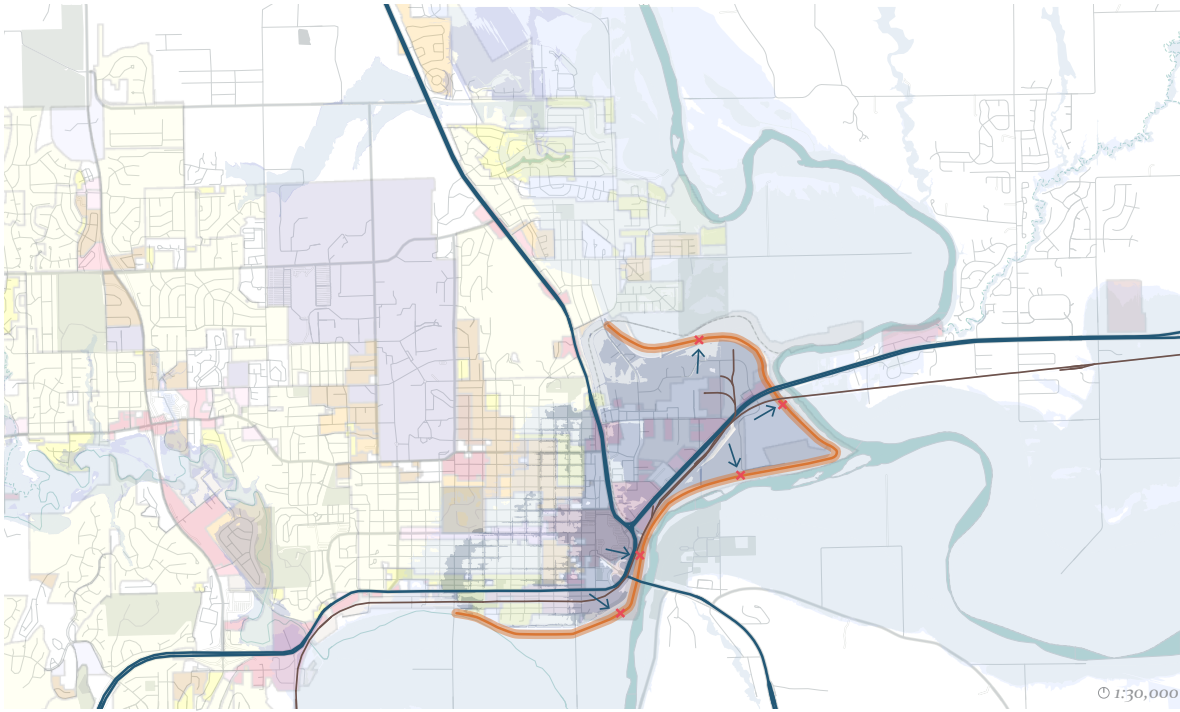


Figure 3.6: Social Constraints Map

Social Constraints

While existing features may create positive opportunities for some aspects of community, many constraints are also associated with the current infrastructure. The most notable in this project is the levee itself. The embankment creates a visual and physical barrier to the riverfront, leaving many residents completely unaware of this valuable asset. Zoning and land ownership can also pose difficulties for design proposals with many stakeholders involved. For example, the levee, railroad, and highway are all current obstacles hindering riverfront interaction, and all are owned by separate entities.

The site selection process consisted of existing conditions analysis, site visits, and suitability determination. The determining factors for site selection included surrounding land use, existing vegetation, waterfront context, and existing access to the riverfront. The sites selected are representative of the various contexts found along typical riverfronts and levees. Important connections in these cases include residential, commercial, industrial, water treatment facilities, and public park space. Each of these typologies provide unique social and ecological benefits by overcoming existing obstacles.

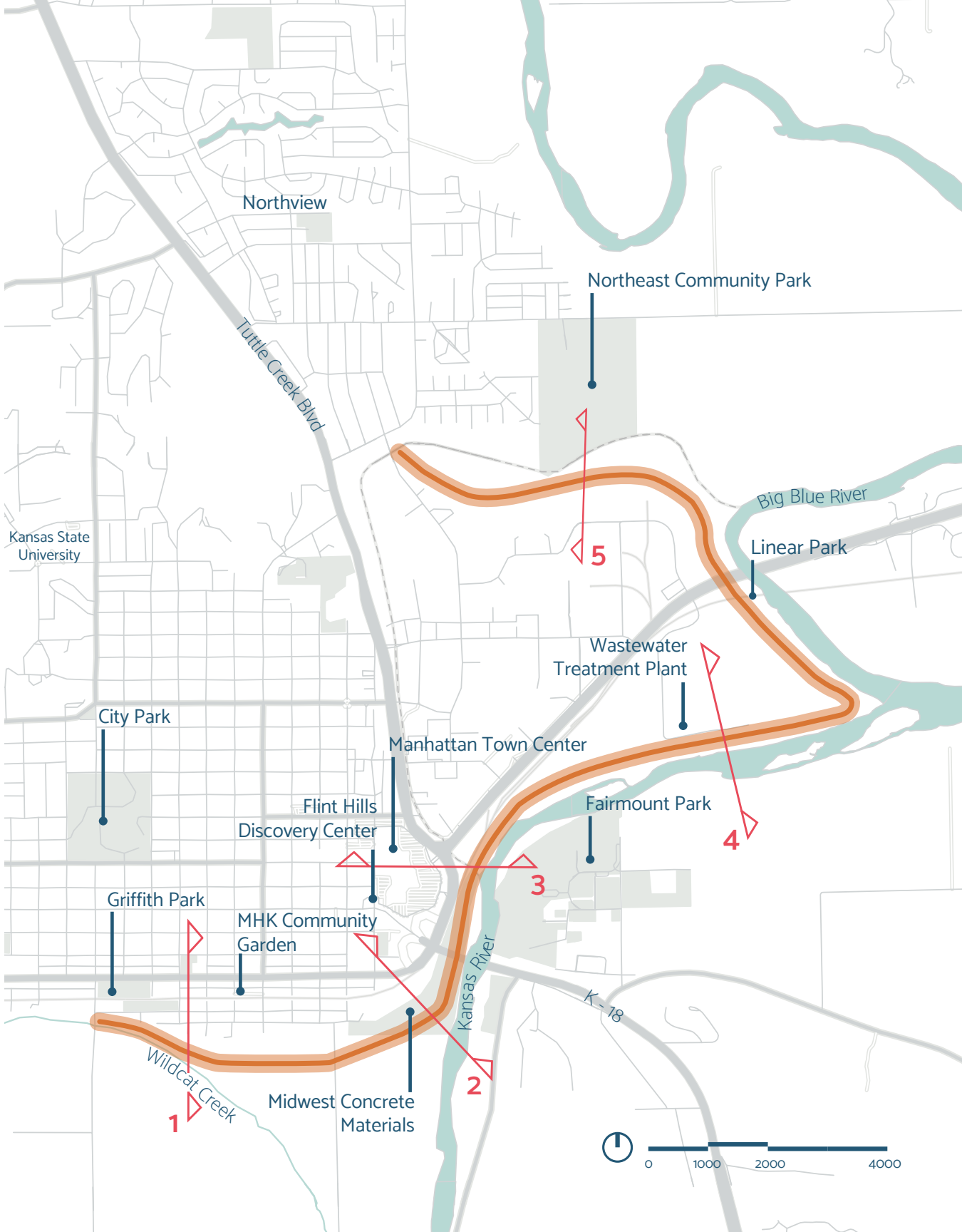


Figure 3.7: Transect Selection Map

Transect #1: Residential Levee Trail



Figure 3.8: Transect 1 Social Analysis

Social Analysis

This area of the levee is located near the southern entry point of the linear trail, drawing attention from visitors who often use it for recreation. Many residences sit in close proximity to the levee at its lowest point, meaning they rely on the structure for safety.

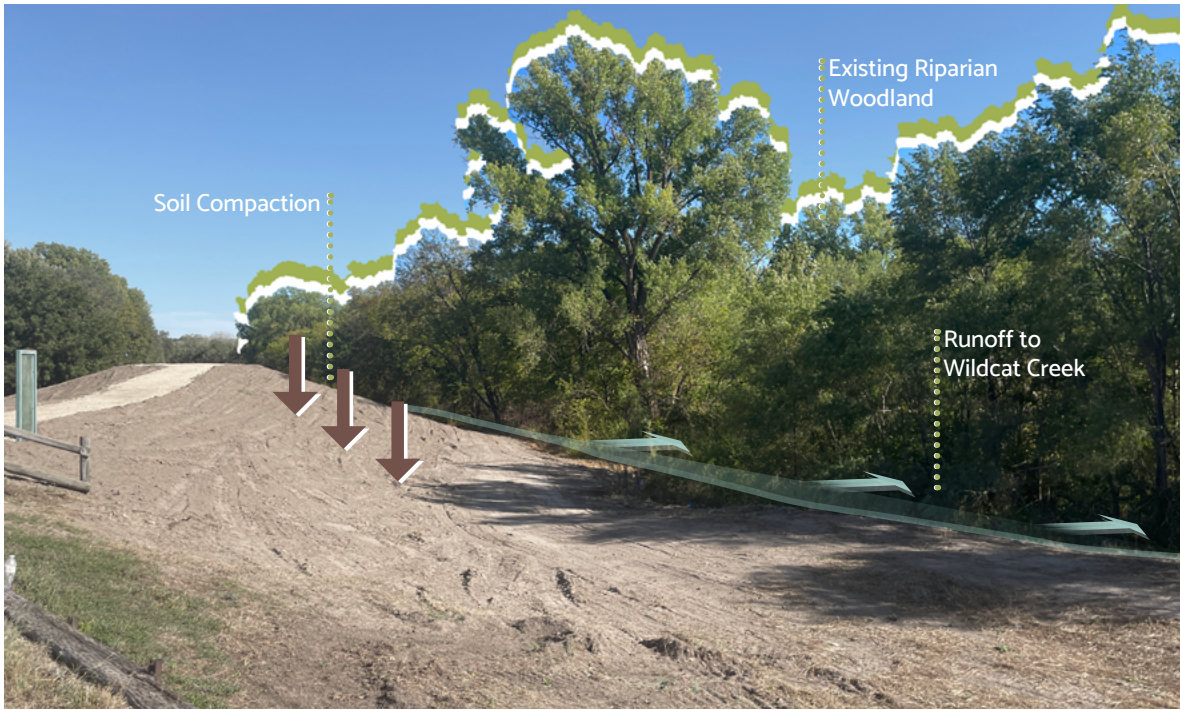
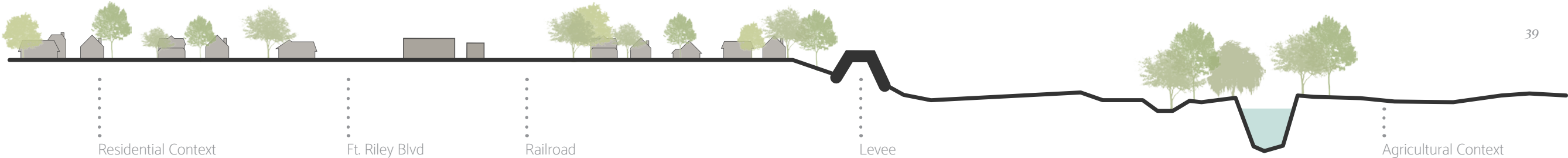


Figure 3.9: Transect 1 Ecological Analysis

Ecological Analysis

The distance between the levee structure and Wildcat Creek in this location is minimal. The existing riparian woodland sits directly at the base of the levee, leaving little room for adaptation. With the current construction on the levee, the soil is compacted for flood protection, damaging any native ecosystems that may have existed previously.



Land Use

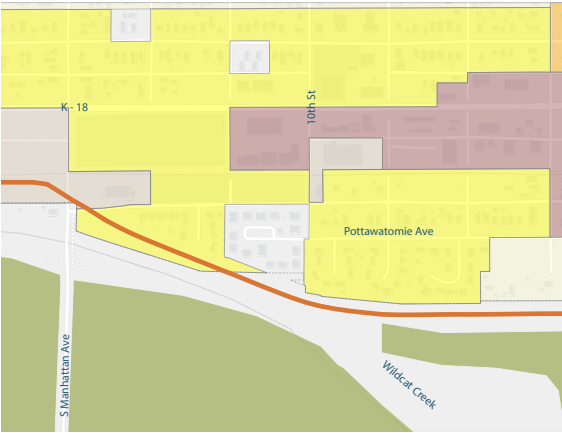


Figure 3.10: Transect 1 Land Use Map

- Medium Density Residential
- Low Density Residential
- Industrial / Commercial Services
- Light Industrial
- Agricultural

Existing Access

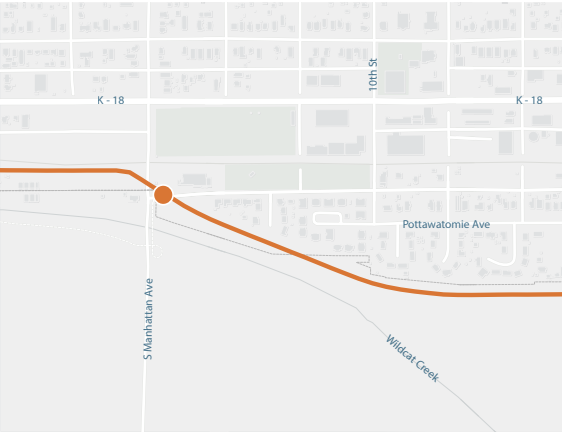


Figure 3.11: Transect 1 Access Points Map

- Levee
- Access Point

Native Ecology



Figure 3.12: Transect 1 Ecology Map

- Eastern Floodplain Forest
- Eastern Floodplain Ruderal Grassland
- Cropland
- Levee

Flood Inundation Areas



Figure 3.13: Transect 1 Flood Risk Map

1:2,500

- 100 Year Floodplain
- 500 Year Floodplain
- Area of Reduced Flood Risk
- Levee

Transect #2: Downtown Industrial Site



Figure 3.14: Transect 2 Social Analysis

Social Analysis

The MCM site is a major barrier to any interaction with the levee or the river beyond. In addition to being separated by the railroad tracks and Ft. Riley Boulevard, current land use makes the area very private and unappealing to visitors, with no connection to the greater downtown area.



Figure 3.15: Transect 2 Ecological Analysis

Ecological Analysis

Due to the concrete facility, the site is currently a brownfield, requiring a detailed assessment and mitigation plan prior to any new proposed land use. Some areas of the embankment are covered in riprap to prevent erosion, which also limits the growth of native habitat. However, the space between the levee and the river in this area is wide, with a large swath of existing woodland and potential for an expansive horizontal design.



Land Use



Figure 3.16: Transect 2 Land Use Map

- Community Commercial
- Medium Density Residential
- Low Density Residential
- Industrial / Commercial Services
- Downtown

Existing Access



Figure 3.17: Transect 2 Access Points Map

- Levee
- Access Point

Native Ecology

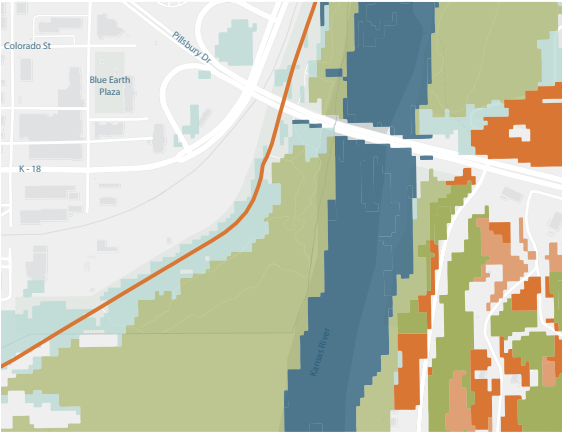


Figure 3.18: Transect 2 Ecology Map

- Eastern Floodplain Forest
- Eastern Floodplain Ruderal Grassland
- Redcedar Woodland/Shrubland
- Tallgrass Prairie
- Mixed Chinquapin Oak-Bur Oak Ravine Woodland
- River
- Levee

Flood Inundation Areas



Figure 3.19: Transect 2 Flood Risk Map

- 100 Year Floodplain
- 500 Year Floodplain
- Area of Reduced Flood Risk
- Levee

Transect #3: Commercial Center

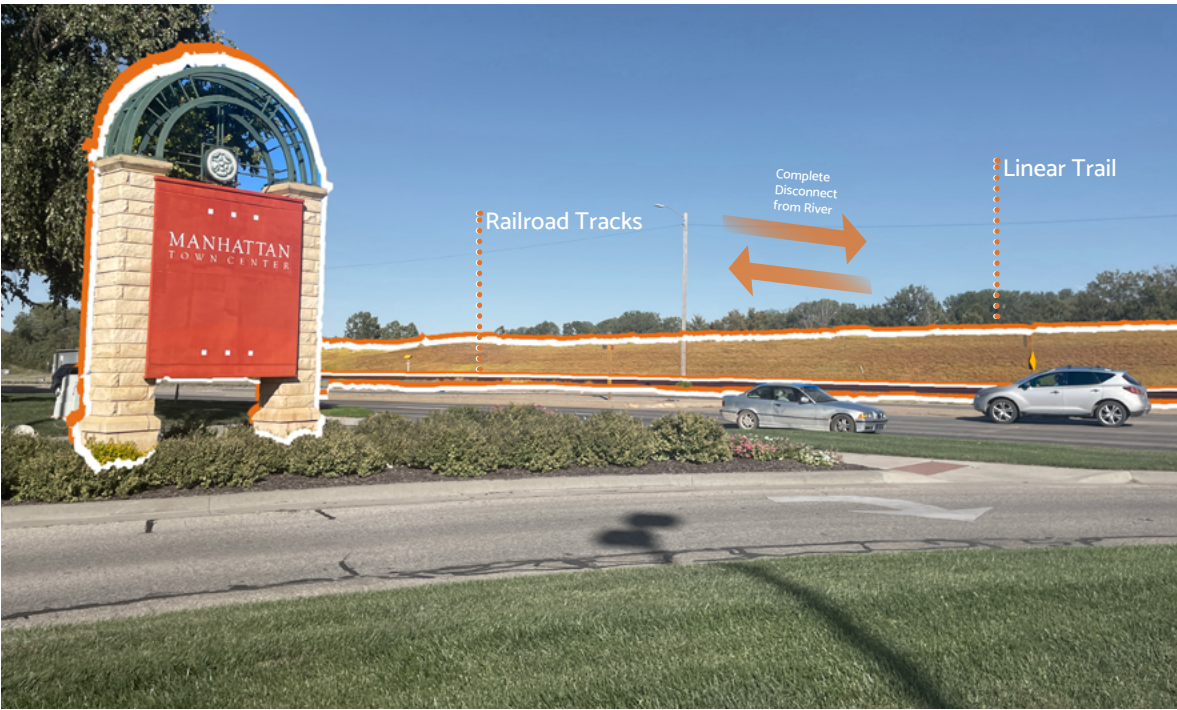


Figure 3.20: Transect 3 Social Analysis

Social Analysis

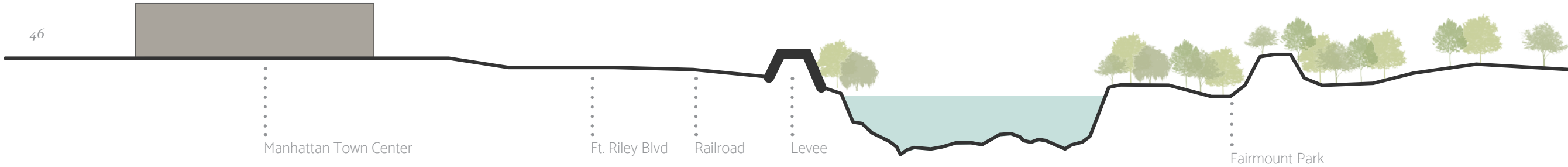
This area is potentially the most problematic in terms of accessibility, with the highway, railroad, and levee creating a complete disconnect between the city and the river. Accompanied by commercial development, there is no space for pedestrian use, recreation, or natural space.



Figure 3.21: Transect 3 Ecological Analysis

Ecological Analysis

The opposite side of the levee, however, shows a fairly successful native landscape and distribution of transitional species. There are still some areas of riprap edges, and the proximity of the levee to the river should be considered with its steep slope.



Land Use

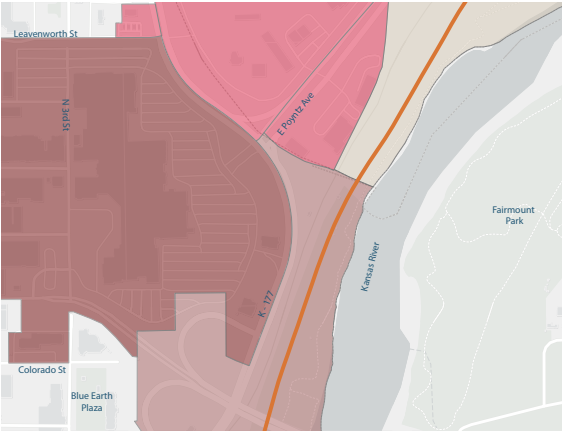


Figure 3.22: Transect 3 Land Use Map

- Community Commercial
- Industrial / Commercial Services
- Light Industrial
- Downtown

Existing Access



Figure 3.23: Transect 3 Access Points Map

- Levee

Native Ecology

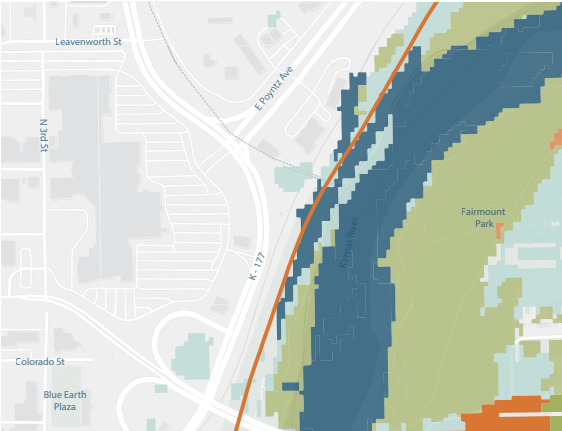


Figure 3.24: Transect 3 Ecology Map

- Eastern Floodplain Forest
- Eastern Floodplain Ruderal Grassland
- Redcedar Woodland/Shrubland
- Tallgrass Prairie
- Mixed Chinquapin Oak-Bur Oak Ravine Woodland
- River
- Levee

Flood Inundation Areas

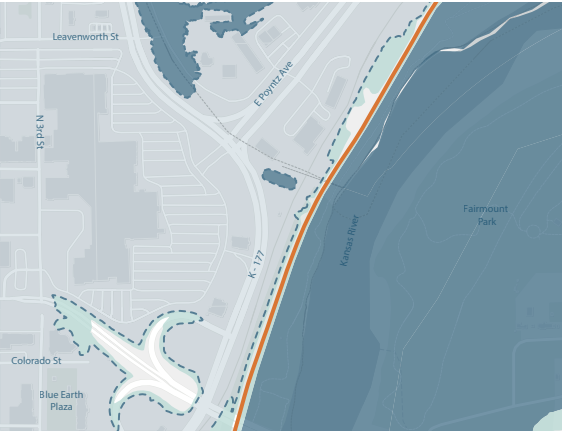


Figure 3.25: Transect 3 Flood Risk Map

- 100 Year Floodplain
- 500 Year Floodplain
- Area of Reduced Flood Risk
- Levee

1:2,500

Transect #4: Water Treatment Facility



Figure 3.26: Transect 4 Social Analysis

Social Analysis

This area, similar to the MCM site, has limited access to the public. It is secluded from any major entry points and the WWTP does not provide any visual appeal. Some sections have potential for trail access, but the current features would not support community interaction.

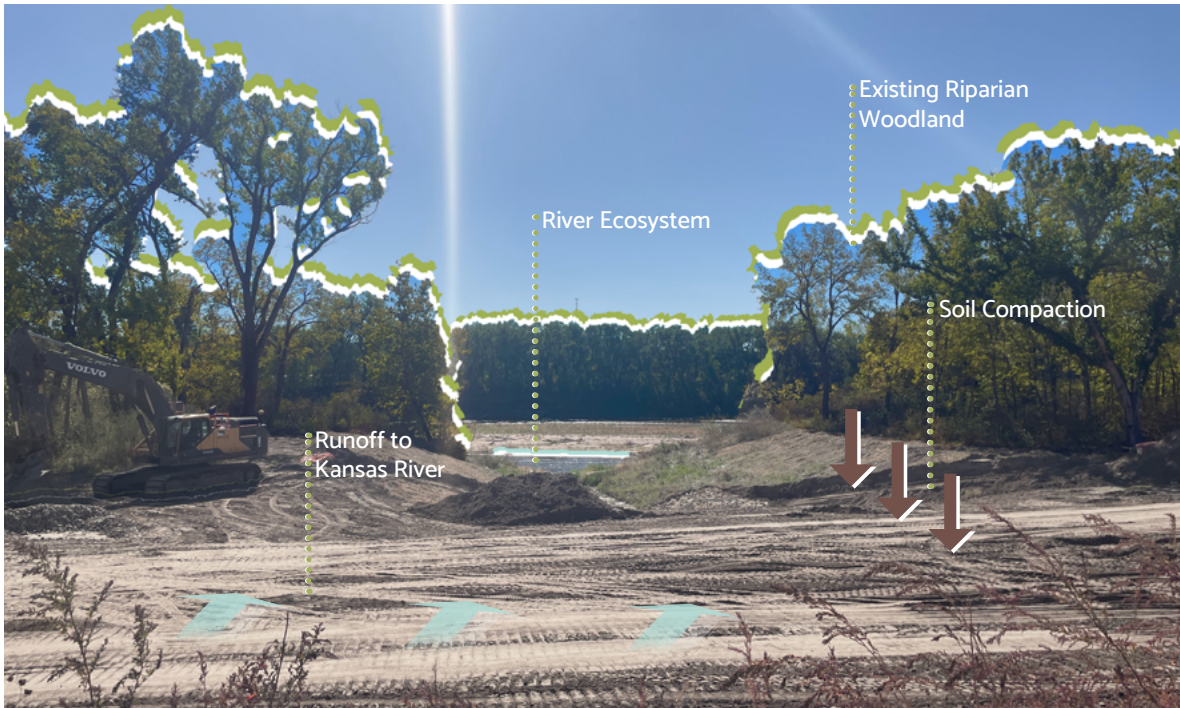
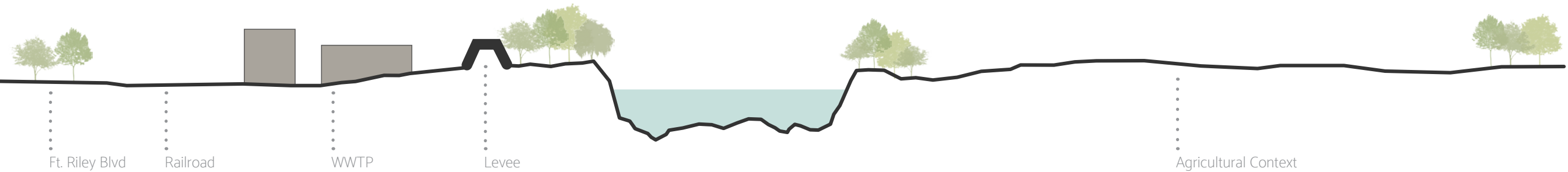


Figure 3.27: Transect 4 Ecological Analysis

Ecological Analysis

Construction has been heavy in this location as well, leaving behind damaged habitats, potential pollution, and compacted soils. The distance between the levee and the river along with the proximity to the WWTP make this a suitable option for stormwater management and water quality improvements.



Land Use



Figure 3.28: Transect 4 Land Use Map

Light Industrial

Existing Access



Figure 3.29: Transect 4 Access Points Map

- Levee
- Access Point

Native Ecology

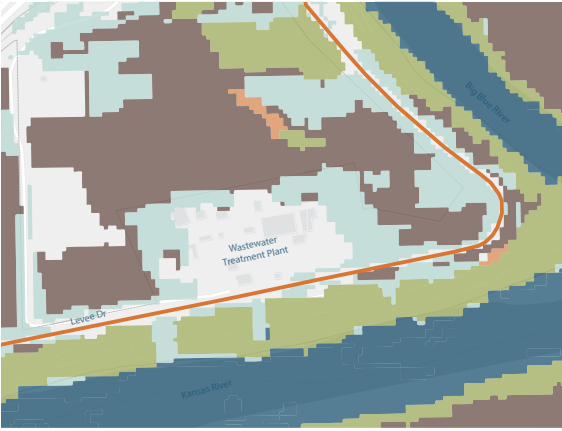


Figure 3.30: Transect 4 Ecology Map

- Eastern Floodplain Forest
- Eastern Floodplain Ruderal Grassland
- Redcedar Woodland/Shrubland
- Cropland
- River
- Levee

Flood Inundation Areas



Figure 3.31: Transect 4 Flood Risk Map

1:2,500

- 100 Year Floodplain
- 500 Year Floodplain
- Area of Reduced Flood Risk
- Levee

Transect #5: Industrial Community Park



Figure 3.32: Transect 5 Social Analysis

Social Analysis

Located behind the industrial park, this part of the levee is not currently accessible to the public. However, part of the levee improvement plan includes a new trail entry point behind the T. Russell Reitz animal shelter, which may provide access north of the levee and improve connectivity of the Linear Trail.

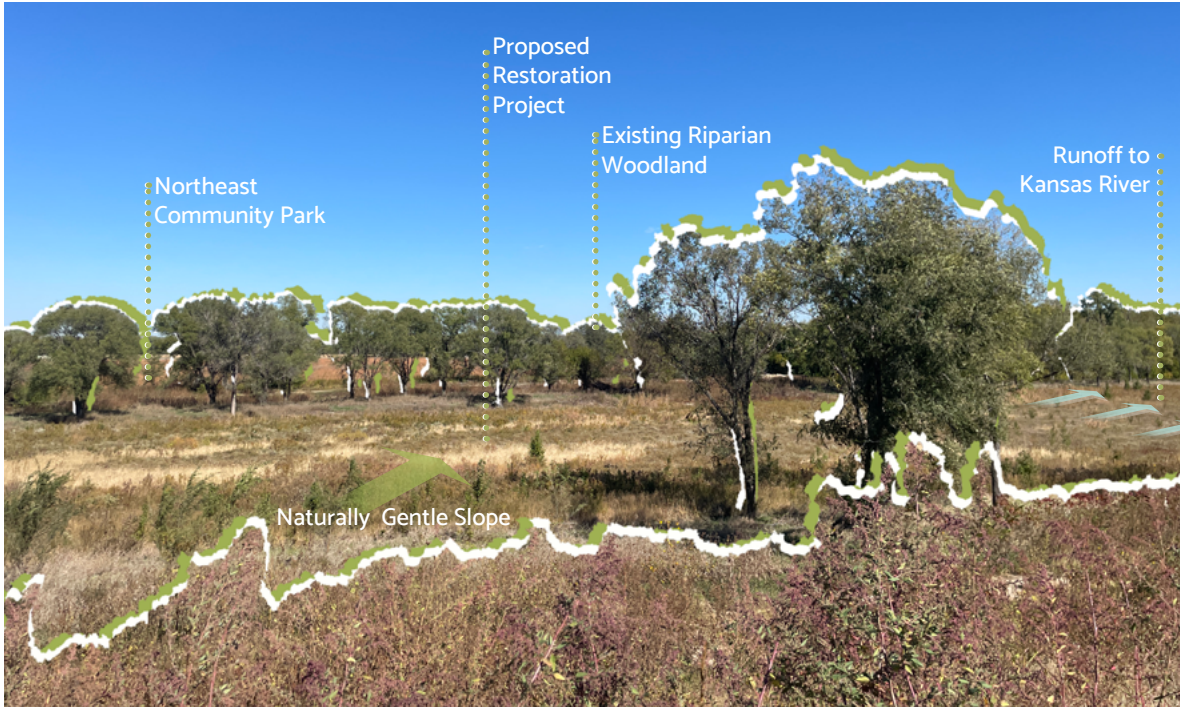
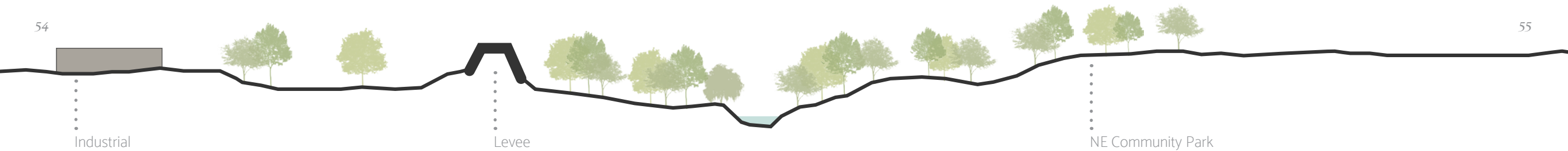


Figure 3.33: Transect 5 Ecological Analysis

Ecological Analysis

Another part of the levee improvement plan is to use this area north of the levee to account for any trees that might be displaced during the project, restoring the native riparian woodland that would occur in this low-lying area.



Land Use



Figure 3.34: Transect 5 Land Use Map

- Low Density Residential
- Industrial / Commercial Services
- Park Space

Existing Access

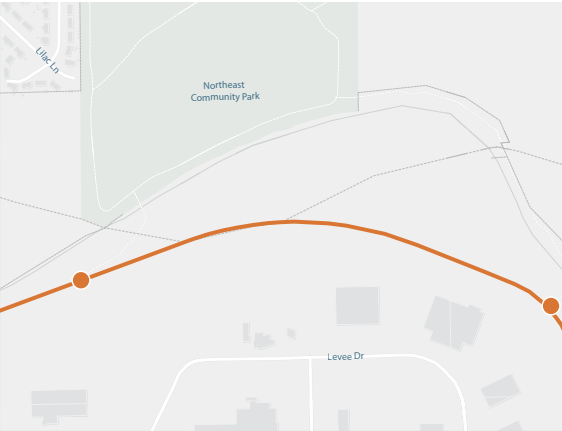


Figure 3.35: Transect 5 Access Points Map

- Levee
- Access Point

Native Ecology



Figure 3.36: Transect 5 Ecology Map

- Eastern Floodplain Forest
- Eastern Floodplain Ruderal Grassland
- Redcedar Woodland/Shrubland
- Tallgrass Prairie
- Urban Grasses / Park Space
- Agricultural
- Levee

Flood Inundation Areas



Figure 3.37: Transect 5 Flood Risk Map

© 1:2,500

- 100 Year Floodplain
- 500 Year Floodplain
- Area of Reduced Flood Risk
- Levee

Community Survey Analysis

After completing this thorough site analysis, a survey was distributed to local residents to understand their awareness of, access to, and perception of the existing waterfront and levee system. Questions regarding perception of existing obstacles, frequency of interaction, access points used, and contributing factors to visitation were asked in order to answer the research question 2-1: *“What barriers does a traditional levee present to human-river interaction?”*. A series of design intervention types were presented to the survey respondents, prompting them to consider what level of development and accessibility to the waterfront they would like to see. This section was related to research question 2-2: *“What design interventions can enhance people’s experience of the river?”*. Similarly, respondents ranked a set of statements about the value and perception of the levee, nature, and riverfront areas in Manhattan based on their level of agreement or disagreement, answering the final research question 2-3: *“What is the community’s perception of natural floodplain function vs. man-made levee design interventions?”*

After receiving IRB approval, the survey distribution process began (see Appendix A for IRB exemption letter). A six-week window, from January 2nd to February 12th, 2024, was allotted to receive adequate responses. Surveys were distributed to the general population of the city of Manhattan, relying on convenience sampling to achieve as many responses from community members as possible. Each group was targeted based on availability and community outreach, with the goal of reaching a wider audience of relevant stakeholders.

An initial post on NextDoor was created on January 2nd, with a follow-up posted three weeks later on January 27th. The survey was also shared in several Facebook groups, through which the posting date depended on approval from each individual group’s administrators. *The Manhattan Kansas Community Discussion Board* survey was posted on January 7th, the *Manhattan KS Regional Forum* survey was posted on January 15th, and the *“MANHAPPINESS” Happenings and Events in and around Manhattan, KS* survey was posted on January 15th. The post was also submitted to the *Manhattan, KS Outdoors* page, but never shared with the public. In addition to these online resources, an invested community member shared a list of emails for individuals who had previously shown interest in a riverfront project. This list was input to Qualtrics, which published the survey on January 3rd using its email distribution feature. The list comprised 63 people and received 26 responses – a response rate of 44%. After contacting the Executive Director of Downtown Manhattan, Inc., a link to the survey was also shared in the January edition of the monthly Downtown Manhattan newsletter to reach local residents and business owners in the area. The reach of this distribution and amount of participants from this email list is unknown. (See Appendix C for all survey distribution methods).

Precedent Study Analysis

The survey saw a successful amount of engagement, receiving 139 views. However, not all viewers completed the survey in full – questions ranged from 86 to 96 responses throughout the survey. Results were calculated using completed responses for each question. Data were grouped by type of responses (river access/awareness, type of activity, flood protection, intervention preferences, etc.) to achieve a more comprehensive understanding of common themes among the results. Statistical analysis was used to discover any relevant correlations that may not have been obvious from the initial analysis. Graphs and charts were created to clearly represent findings and compare results, such as demographic information, frequency of interaction with the river, and perceptions of levee design. A more in-depth analysis of survey questions, responses, and relevant correlation data is found in the following chapter.

In addition to survey responses, precedent study analysis was an important portion of the research for this project. This part of the study worked to answer both research question 1-1: “*What are the benefits of combining man-made and natural flood mitigation strategies?*,” and question 1-3: “*How can existing precedent studies inform an adaptive river levee design?*” Many flood resilience and ecological adaptation precedents were identified through initial searches, and the final six cases presented in this report were chosen through a list of inclusion and exclusion criteria for relevance. Criteria for inclusion were as follows: the project was located adjacent to a waterfront (preferably a river or an inland body of water), included a flood resilience structure or design component, provided ecological benefits, provided social benefits, was completed or at least partially completed, and located in a semi-urban area. Most projects found included several of these elements, so the criteria for exclusion were: the project was incomplete, located along an ocean coast, or in an area of high urban density that would not be relevant to a project in Manhattan, KS. Most excluded projects were either incomplete, too urbanized, or both. (See appendix D for a full list of inclusion and exclusion criteria).

To analyze the selected case studies, a matrix was created based on significant themes drawn from the literature review. These themes were **1) Resilience**, **2) Ecology**, and **3) Connectivity** (see figure 3.38). The resilience category was broken down into elements of flood mitigation, adaptability, and disturbance resistance/recovery. *Flood mitigation* is an essential element of this design approach, working to prevent the issue before it can cause any damage to the city. *Adaptability* can be defined as the capability to adjust to varying conditions, or to modify the use

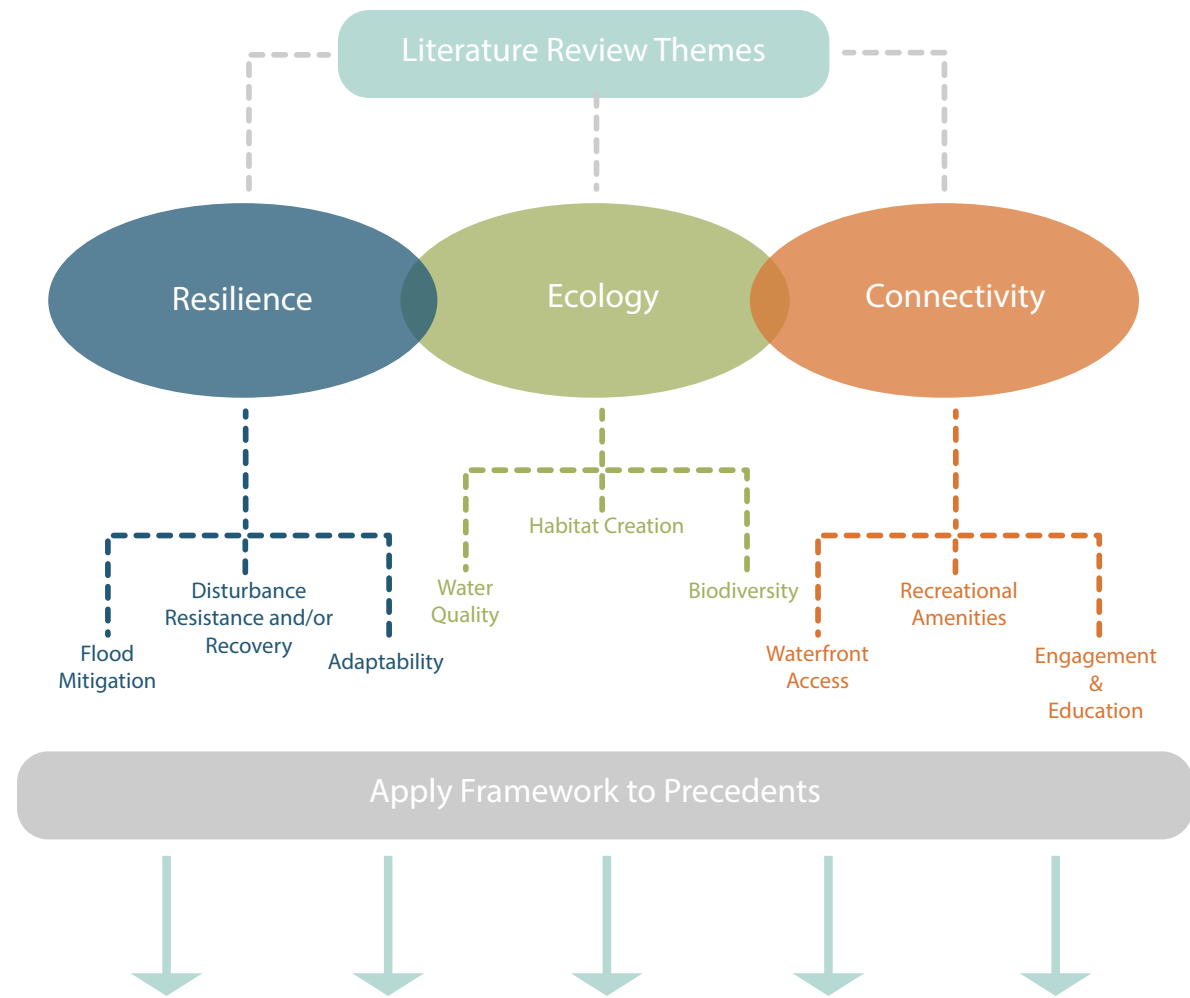


Figure 3.38: Precedent Study Analysis Criteria

of a certain design component. *Disturbance* is a valuable part of riparian ecosystems, replenishing resources and establishing resiliency, often measured by the capacity to recover from external pressures. The ecology category was divided into water quality, biodiversity, and habitat creation. *Water quality*, in many examples, was identified by stormwater management and pollutant remediation. *Biodiversity* and *habitat creation* were often associated with native ecosystem restoration or wildlife population. The connectivity category had a more social focus, with design elements of waterfront access, recreational amenities, and engagement & education. *Waterfront access* was measured by the physical connection of the public to the water. *Recreational amenities* could consist of active and passive uses such as of trails, playgrounds, sports fields, etc. *Engagement and education* were measured by community awareness of the waterfront – often through wayfinding and signage, or sometimes through actual educational tours or other sessions. The analysis also identified which type of flood protection strategy was employed: a traditional levee or earthen embankment, floodwalls, setbacks, ecosystem restoration, or some combination of typologies.

Each case study was compared against the previously listed criteria, with each analysis individualized by design components exhibited in the case study itself (seen in the following chapter). After analyzing each individual case study, the results were synthesized into a summary matrix that compared the success of each project based on their level of resilience, ecology, and connectivity, as well as using an understanding of the project features to determine suitability for a project on the riverfront in Manhattan, KS.

O4

Research Results

Chapter Overview

This section provides a summary of the research findings for this project. In order to gather information on the interactions with and perceptions of the existing levee and proposed intervention strategies, surveys were distributed to Manhattan, KS residents. Precedent studies were analyzed to determine their relevance to the proposed project and to measure their success in resilience, ecology, and connectivity, using a framework informed by literature. The conclusions drawn from this research were then used to make informed design decisions.

“It’s a functional element that is needed for **storm control**, but needs to be looked at in terms of not cutting off **access** to this natural resource. I favor an improvement plan that celebrates this **beautiful natural amenity**.”

Community Survey Results

The first research method of this project consisted of a survey shared with residents of Manhattan, KS, to assess community awareness and interaction with the riverfront. Questions addressed river access, awareness, types of activities, frequency of use, and how the community values various elements of the riverfront. In addition, five potential interventions were shared, gathering feedback on the type of development and access that would draw more visitors. Survey results are grouped into themes, identifying common responses and key takeaways to inform design solutions.

Participant Demographics

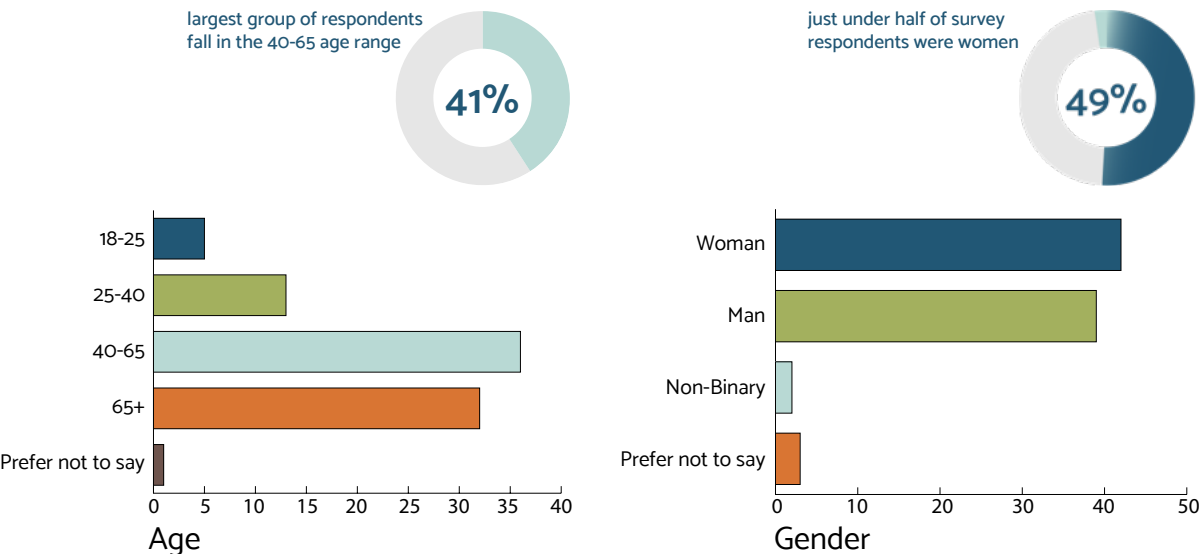


Figure 4.1: Demographics Data - Age

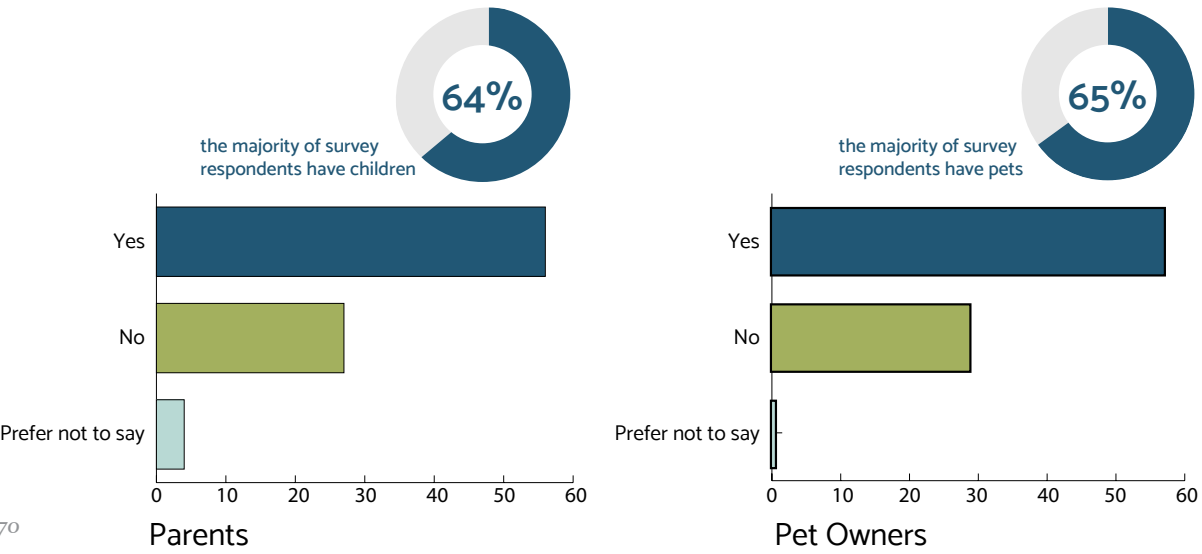


Figure 4.2: Demographics Data - Gender

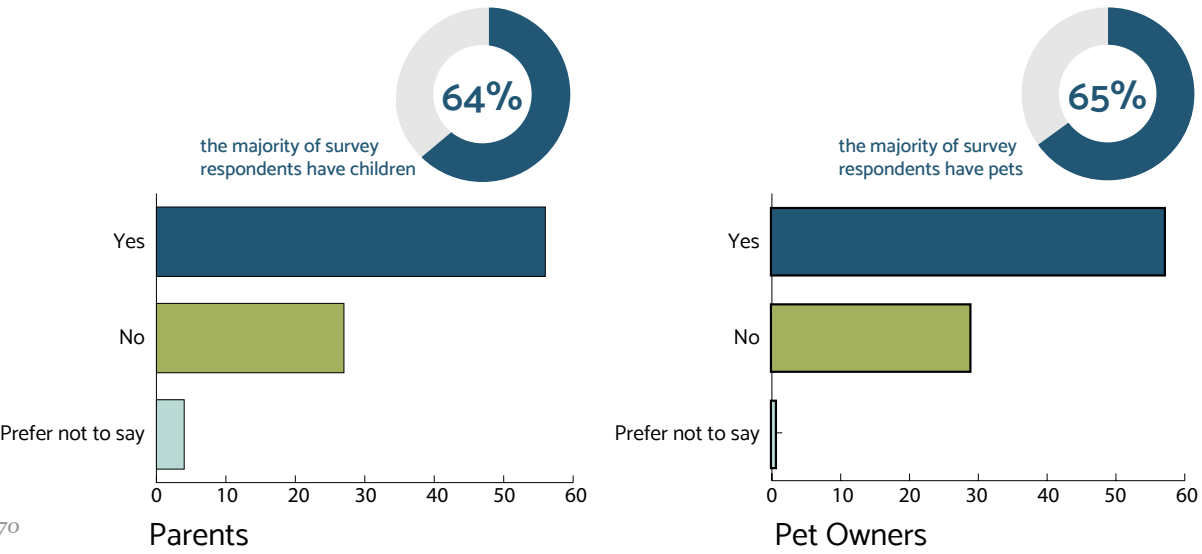


Figure 4.3: Demographics Data - Parents

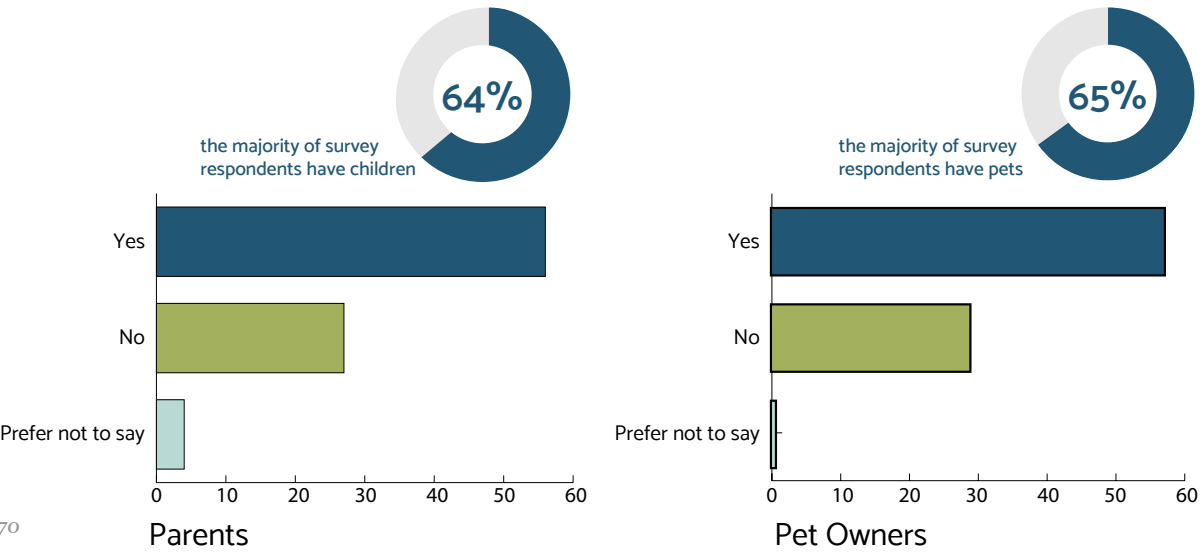


Figure 4.4: Demographics Data - Pet Owners

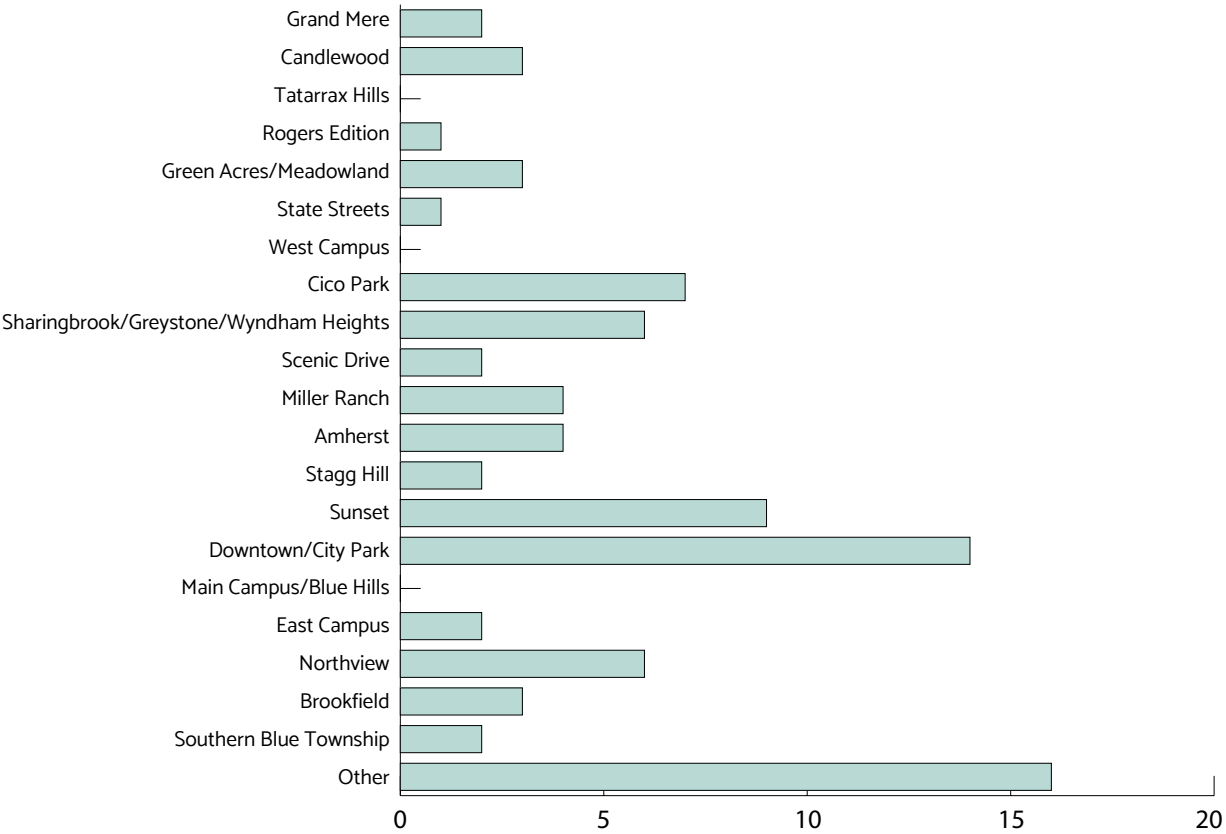


Figure 4.5: Demographics Data - Neighborhood

The survey attracted a wide mix of respondents - about half women and half men, a large group of those over 40 years old, and many people who have children and own pets (see Figures 4.1-4.4). Responses came from almost every neighborhood around the city (Figure 4.5), which provides a wide range for opinions and data.

* all x axis units represent number of responses

Frequency of Use

How often do you interact with waterfronts in Manhattan?

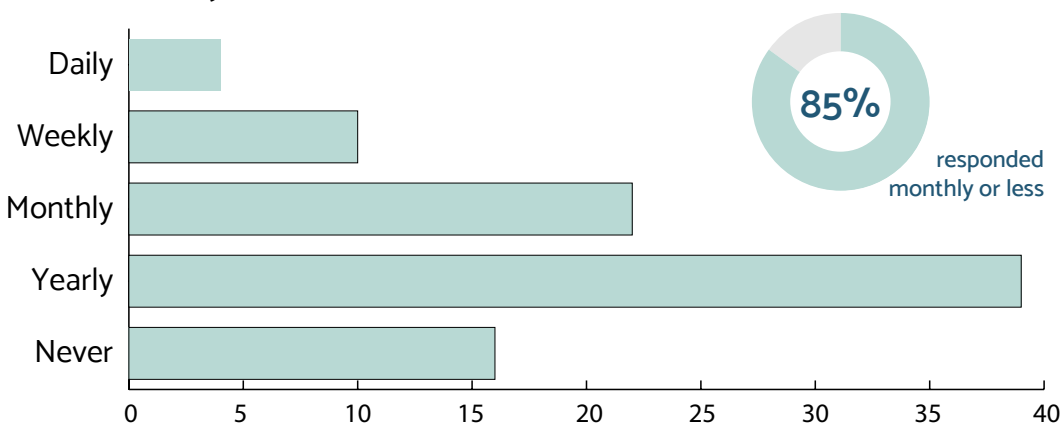


Figure 4.6: Waterfront Interaction Frequency

How often do you use the Linear Trail (when open to the public)?

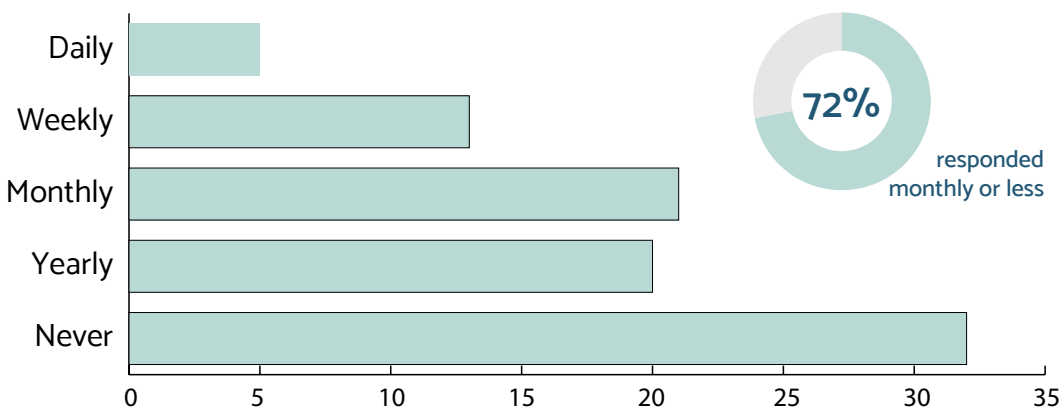


Figure 4.7: Linear Trail Use Frequency

What draws you to the waterfront? What activities do you partake in?

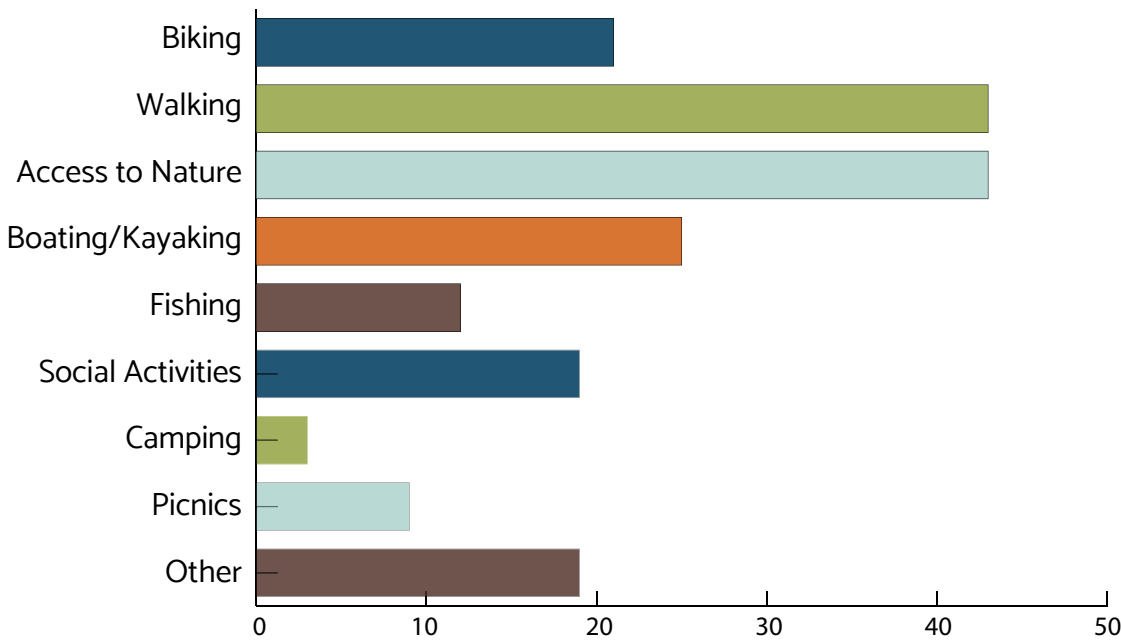


Figure 4.8: Waterfront Activities

Based on the responses, most people do not interact with waterfronts or the Linear Trail very often (Figures 4.6 & 4.7). When they do, the activities are focused on passive recreation such as biking, walking, or simply viewing nature (Figure 4.8). This could be because people prefer these activities, or there may not be available programming for other options. The “other” category included a variety of activities, such as swimming, fossil hunting, geocaching, birdwatching, running, and others.

* all x axis units represent number of responses

Accessibility & Awareness

What would you consider the biggest obstacle to river access currently?

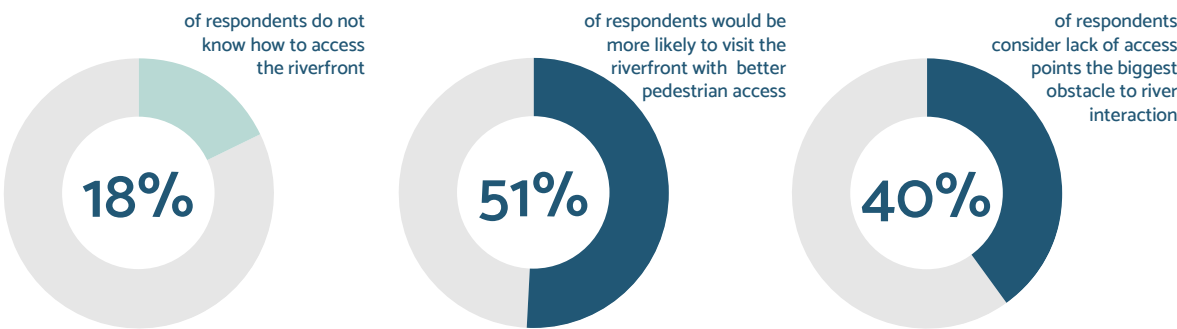
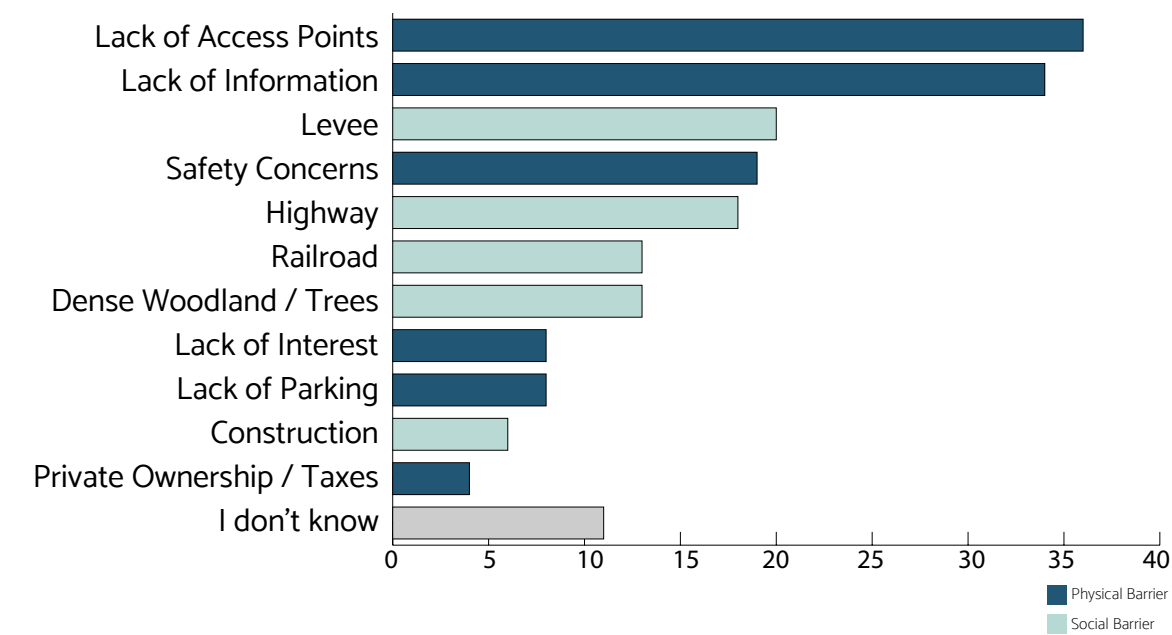


Figure 4.9: Accessibility Barriers

What would make you more likely to visit the riverfront?

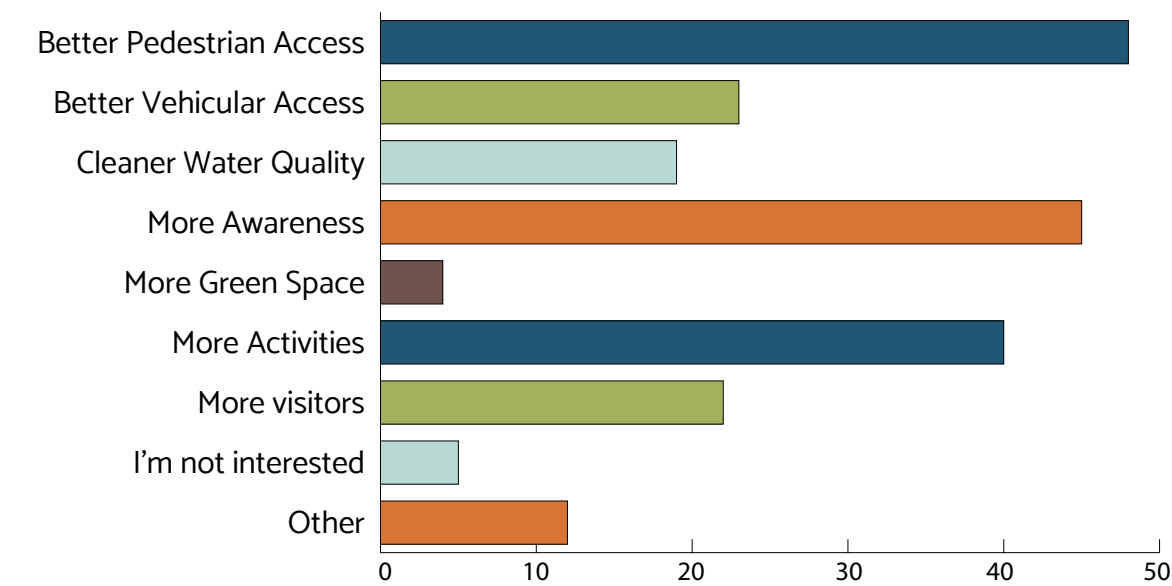
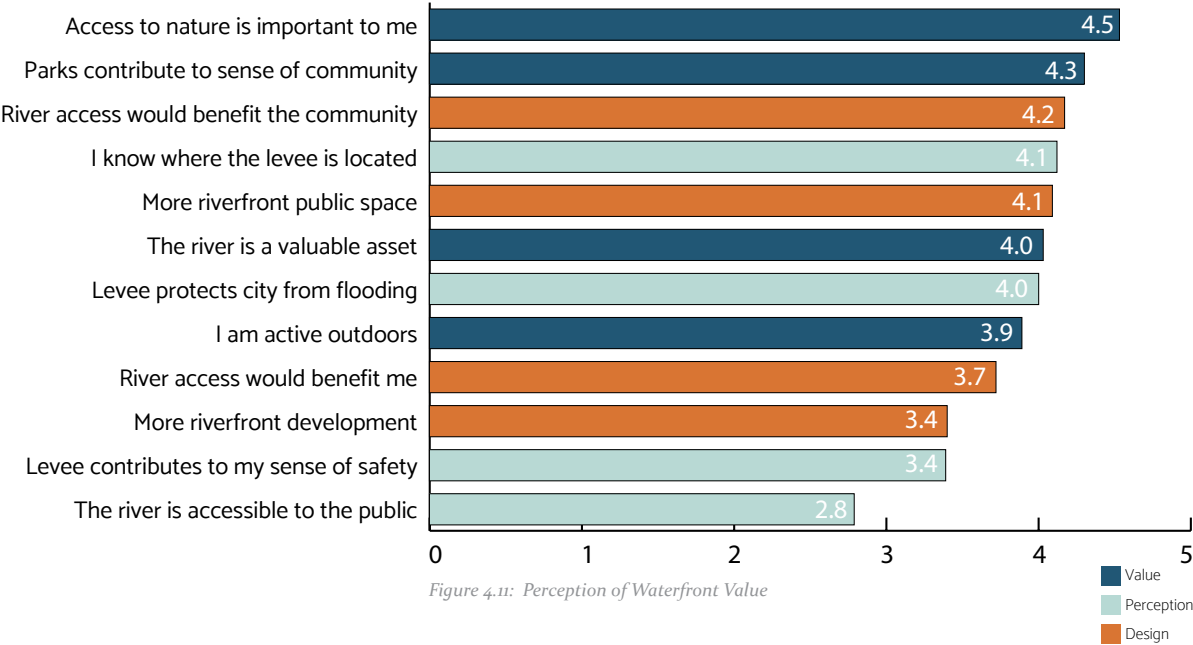


Figure 4.10: Desired Waterfront Function

Part of the significance of this project was the issue of accessibility and awareness relating the city of Manhattan to the river, which is proven by the responses gathered here (Figure 4.9). Many respondents agreed that the river is not accessible in its current state, citing lack of information and accessible entry points as major obstacles. Some respondents did not know where the levee was located at all, and those that did may not know how to access the riverfront, much less consider it an active destination.

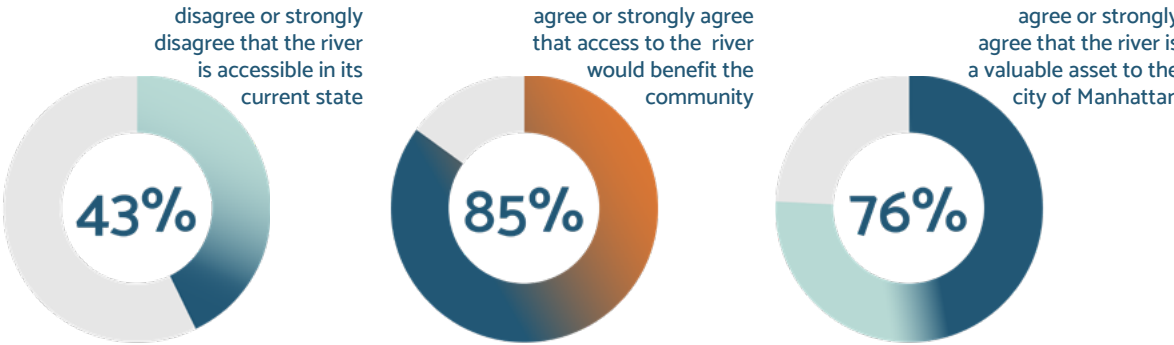
Levee, Nature and Riverfront Areas: Perception Value Statements



Information in this graph was drawn from the value statements portion of the survey. Respondents were presented with twelve statements about the levee, riverfront, and their perceptions of nature and asked to state the degree to which they agreed or disagreed on a five-point scale (Figure 4.11).

The most valuable or agreed with statements were: “It is important to me to have access to nature”, “Parks contribute to the sense of community I feel in my neighborhood”, and “Improved access to the river would be beneficial to the larger Manhattan community”. This shows desire for public space and access to natural features in creating a strong community presence.

The least valuable or agreed with statements were: “In its current state, the river is accessible to the public”, “The levee contributes to the sense of safety I feel where I live”, and “I would like to see more development along the riverfront”. This indicates a strong disconnect between residents and river interaction, as well as opinions on the levee and commercial urban space development.



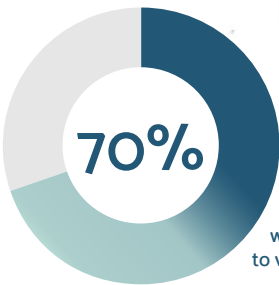
* x axis units represent level of agreement (0 = strongly disagree to 5 = strongly agree)

Intervention 1: Fully Ecological Approach

"I think it is important to **compliment nature** and have a subdued appearance."

"Pay attention to **what is already there.**"

"The river needs **protected from development** at all costs."



would be somewhat or very likely to visit the riverfront in this scenario

"Kansas waterways are variable and flood-prone, so I'd love to see improvements that acknowledge and, dare I say, **celebrate their nature!**"

"Access to a riverfront in a community helps to build a sense of responsibility and **appreciation for the river and waterways.** It gets the community interested in keeping the river clean and **riparian habitat in good condition.**"

Figure 4.12: Ecological Intervention Sketch

This approach would fully restore the area around the levee to its natural state, working to preserve native ecological function. The majority of responses to this interventions were positive, with 70% of respondents stating that they would be somewhat or very likely to visit the levee/riverfront if this type of design were implemented.

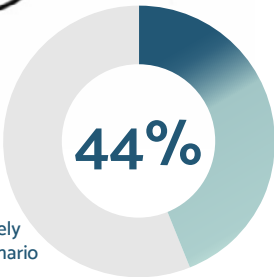
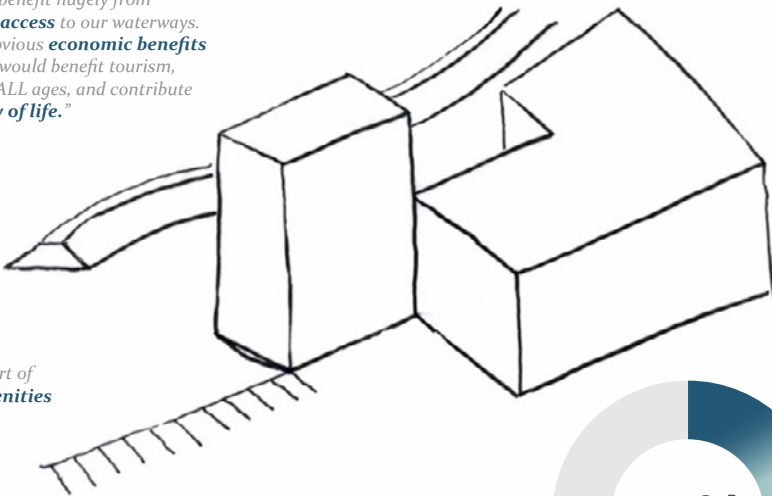
Intervention 2: Fully Developed Approach

"Walking trails with paddle boats & kayaks to rent, **restaurants, shops & a bar area overlooking the river.**"

"Creating strong places on the riverfront will require **active programming** and opportunities for passive use and programs. Maintaining flood control requirements with **public use** is the challenge."

"This area would benefit hugely from **development of access** to our waterways. Other than the obvious **economic benefits** and boon, access would benefit tourism, public health for ALL ages, and contribute greatly to **quality of life.**"

"this area should look at strengthening the **connection of the hotel district** and Blue Earth plaza to encourage tourism to this part of Manhattan and provide other and **new amenities** for visitors and residents to enjoy."



would be somewhat or very likely to visit the riverfront in this scenario

Figure 4.13: Development Intervention Sketch

The fully developed approach would focus mainly on economic growth and activating the riverfront, building structures to provide views to the river and improving vehicular access. This intervention was much more polarizing, with the largest response group being 'somewhat likely' (29%) followed closely by 'very unlikely' (21%).

Intervention 3: Hybrid Approach

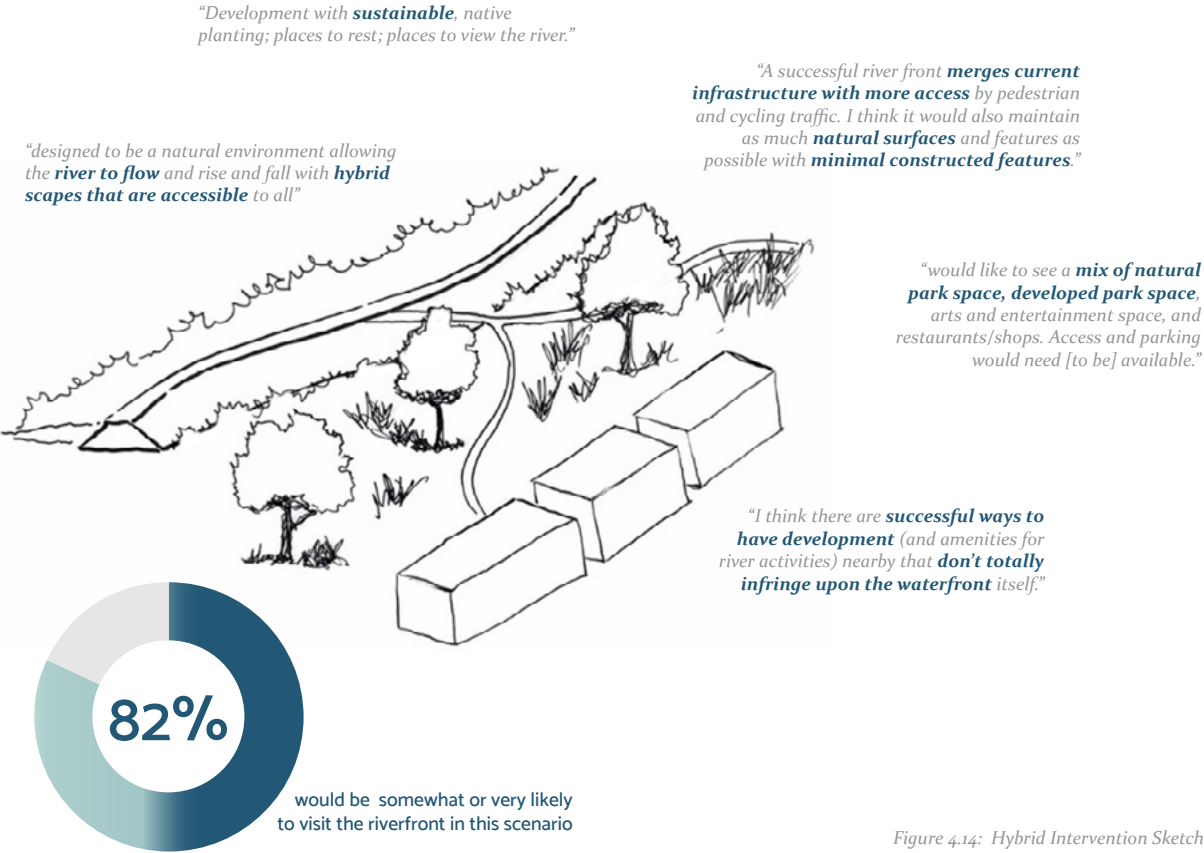


Figure 4.14: Hybrid Intervention Sketch

This option was by far the most popular, combining the previous two approaches with a mix of native restoration, flood protection, active programming, and access to the linear trail and riverfront. Almost half of the respondents answered ‘very likely’.

Intervention 4: Physical Access

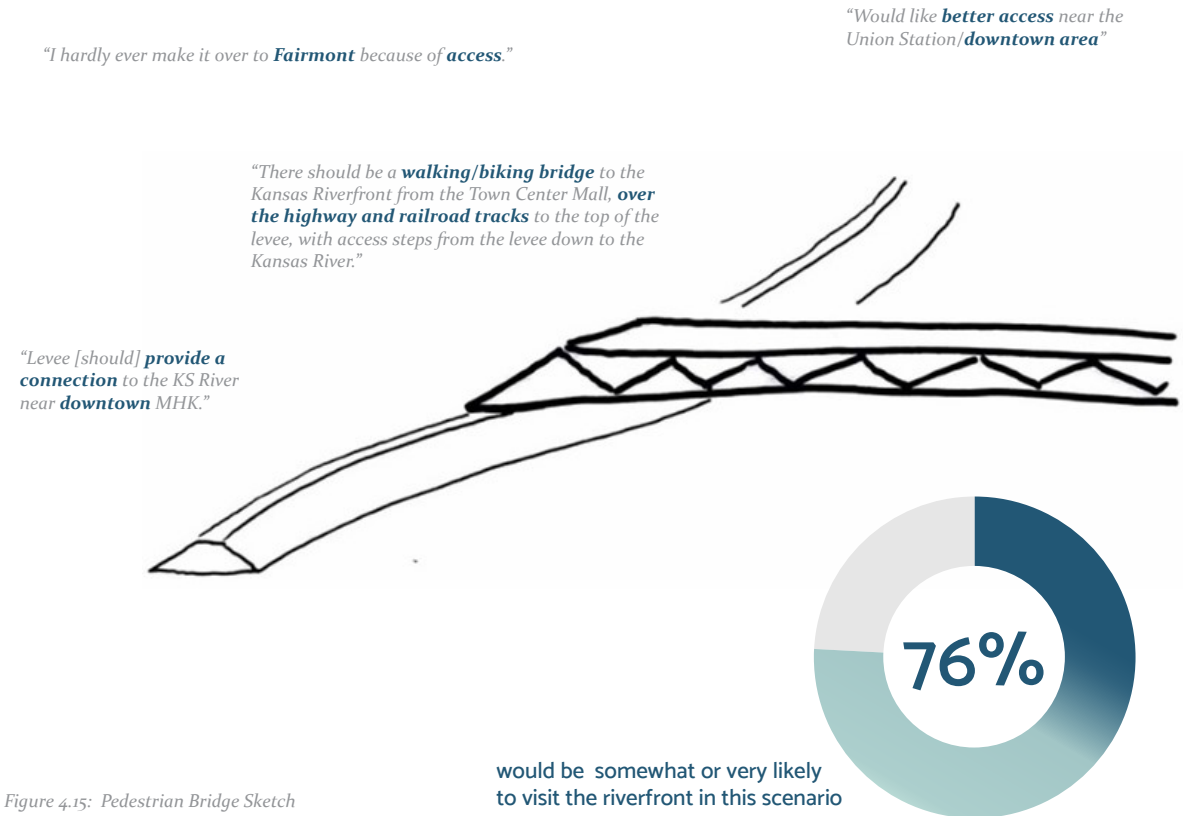


Figure 4.15: Pedestrian Bridge Sketch

The physical access intervention is focused on getting visitors to interact directly with the river, whether that be through a pedestrian bridge to cross the highway, boardwalks at river level, or some other option. Responses to this scenario were overwhelmingly positive, with only four negative responses.

Intervention 5: Visual Access & Awareness

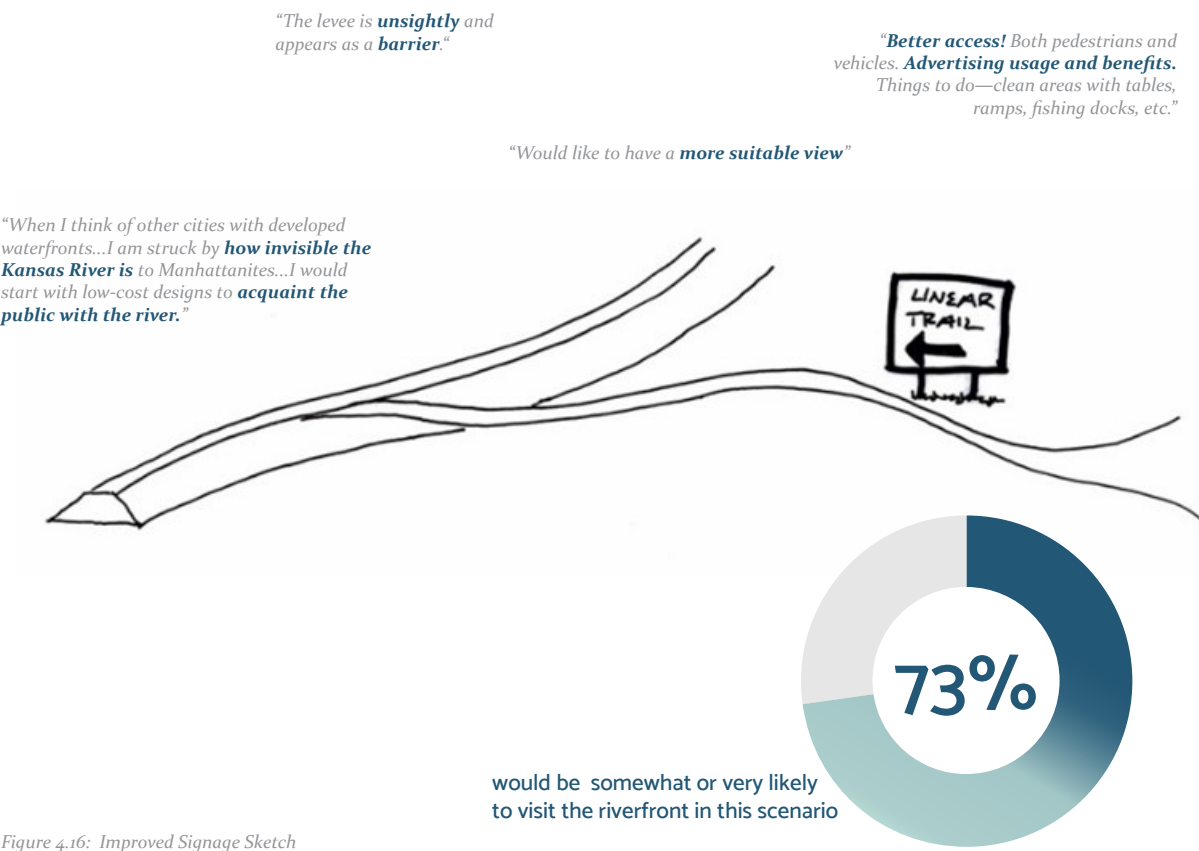


Figure 4.16: Improved Signage Sketch

Visual access emphasizes informing residents about the asset that the river provides, helping them know where to access it, and improving views that are currently inhibited by the levee. This scenario also received very positive responses that informed the design proposal.

Correlation Analysis

Many of the most significant correlation results were produced from similarly themed questions. For example, positive perceptions of the levee’s effectiveness and its contribution to a sense of safety, desire for connection with nature and frequency of visits to the Linear Trail, as well as desire for more riverfront development and agreement with the ‘fully developed’ approach all showed moderate, positive correlations. Another moderate correlation included question 9.7 (Improved access to the river would be beneficial to the larger Manhattan community), with both questions 9.8 (I would like to see more development along the riverfront) and 9.9 (I would like to see more public space along the riverfront), exemplifying an overall desire for increased connection and activity along the waterfront. Question 9.5 (In its current state, the river is accessible to the public) produced a moderate negative correlation with question 9.7 (Improved access to the river would be beneficial to the larger Manhattan community). This is consistent with other results and contributes to the observation that many residents perceive the river as currently inaccessible, but would like to see that change.

Summary of Survey Results

The results from the survey provided many responses consistent with previous research, noting the inaccessibility of the river, lack of current use, and desire for access to nature with actively programmed spaces. One interesting takeaway was that a majority of respondents believed that the lack of access points and awareness of the river and linear trail were often a larger obstacle than the physical barriers of the levee, railroad, and highway. Many people are not aware of the asset that exists, or have no desire to interact with it as is - not maintained, programmed, or used by the community.

Based on these results and combined with takeaways from the case studies, design solutions were developed for each of the five previously identified transects. The hybrid approach was the most popular, with a combination of natural and developed features, physical and visual access. Creating a space that is resilient to flooding, ecologically sensitive, and well connected should be priorities for the success of the design.

Precedent Study Analysis

As part of the research methods, precedent studies were systematically selected and analyzed using a matrix informed by the literature to determine their relevance to this project. After identifying several potential projects during the research process, a set of inclusion and exclusion criteria was used to determine the final six precedents that were ultimately studied (See Appendix D for criteria). Each example examines how the design elements used in the precedent align with the goals of the proposed project – fulfilling criteria in the **Resilience**, **Ecology**, and **Connectivity** categories. Main takeaways are summarized and grouped into these themes, and benefits are analyzed for their suitability to the proposed project in Manhattan, KS.

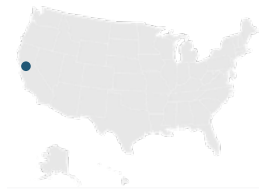
Precedent Studies Analyzed:

- *Oro Loma Sanitary District Horizontal Levee – Oro Loma, CA*
- *Super Levees – Tokyo, Japan*
- *Dominguez Gap Wetlands – Long Beach, CA*
- *“Room for the River” – Nijmegen, Netherlands*
- *Levee Park – Winona, MN*
- *Atlantic Park La Vaguada de las Llamas – Santander, Spain*



Precedent Study #1: Oro Loma Sanitary District Horizontal Levee

Oro Loma, CA



The Oro Loma Sanitary District Horizontal Levee Project was an experimental idea constructed in the San Francisco Bay area between 2015 and 2017. The project was led by the Oro Loma Sanitary District and the San Francisco Estuary Institute, with collaboration from several other entities, such as Save the Bay, UC Berkeley, the San Francisco Regional Water Quality Control Board, the Hayward Area Shoreline Planning Association, governmental entities, and volunteers. The implementation of this project emerged as a way to test the viability of the “horizontal” or “ecotone” levee approach as a nature-based solution to sea level rise, coastal flooding, and water quality (Beagle et al. 2019; Juvera 2021; Kershner & Braddock 2021).

The goal of an ecotone levee is to combat several issues created by traditional flood resilience structures with one design. The implementation of ecotone or horizontal levees typically occurs between the edge of a tidal marsh area and the crest of a typical earthen embankment, sloping down away from the inland and toward the bay (Figure 4.17). By designing a slope more shallow than traditional earthen embankments, the ecotone levee does not create a barrier between the wetland and upland habitats, providing opportunities to restore some natural transition

Figure 4.17: Oro Loma Brackish Marsh Restoration (Bezalel 2021)

zones. This slope is typically 20:1 or gentler (as compared to a typical 3:1 or 4:1 steep embankment), allowing plenty of space for native grasses and sedges to establish and migrate with the changing water levels and climate (Beagle et al.; Okamoto 2015). These species also contribute to the native ecosystem by offering refuge for small animals such as birds and rodents – in this case, the endangered Ridgway’s rail and salt marsh harvest mouse (Plane & Iknayan 2021). In addition to providing essential species habitat, vegetation planted along the slope also works to break waves that may approach the shore. The wide, gentle slope helps to reduce the height and velocity of waves, minimizing the risk of overtopping and flooding. A horizontal levee, as seen in this example (Figure 4.18), takes this multi-benefit idea one step further with the addition of subsurface irrigation with treated wastewater to remove nutrients and support brackish wetlands (Beagle et al. 2019; Plane & Iknayan 2021). Significant flood risk management benefits, water quality improvements, native habitat restoration, and cost benefits have been successfully measured in this particular study (Eaton 2013; Juvera 2021).

Other projects plan to follow the example set by the Oro Loma project, including the Palo Alto Horizontal Levee Pilot Project and the larger Hayward Regional Shoreline Masterplan, both also in collaboration with the San Francisco Estuary Partnership. Though there has been much success with these early experimental projects, FEMA has yet to state its opinion on the certification of the horizontal levee, and the strategy does not seem to have been tested in environments outside of the Bay Area (Beagle et al. 2019; Plane & Iknayan 2021).



Figure 4.18: Horizontal Levee Ecosystem
(SFEP 2018)

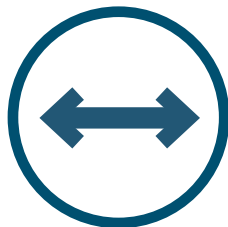
Main Takeaways



Wastewater Treatment
The subsurface irrigation in this pilot project has proven effective at removing nutrients and contaminants of concern from treated effluent before it flows into the bay.



Rehabilitation of Function
By integrating flood control and habitat restoration, the approach can bring back a “lost” ecosystem and rehabilitate the traditional role of ecotone transitions.



Horizontal Approach
This unique design utilizes ideas from the native ecosystem, restoring transitional features, providing a soft edge rather than a harsh vertical barrier, and improving habitat connectivity.



Native Habitat
The formerly degraded embankment has been transformed into a “living laboratory” of native vegetation, using a mix of native wet meadow, riparian scrub, and freshwater wetland species.

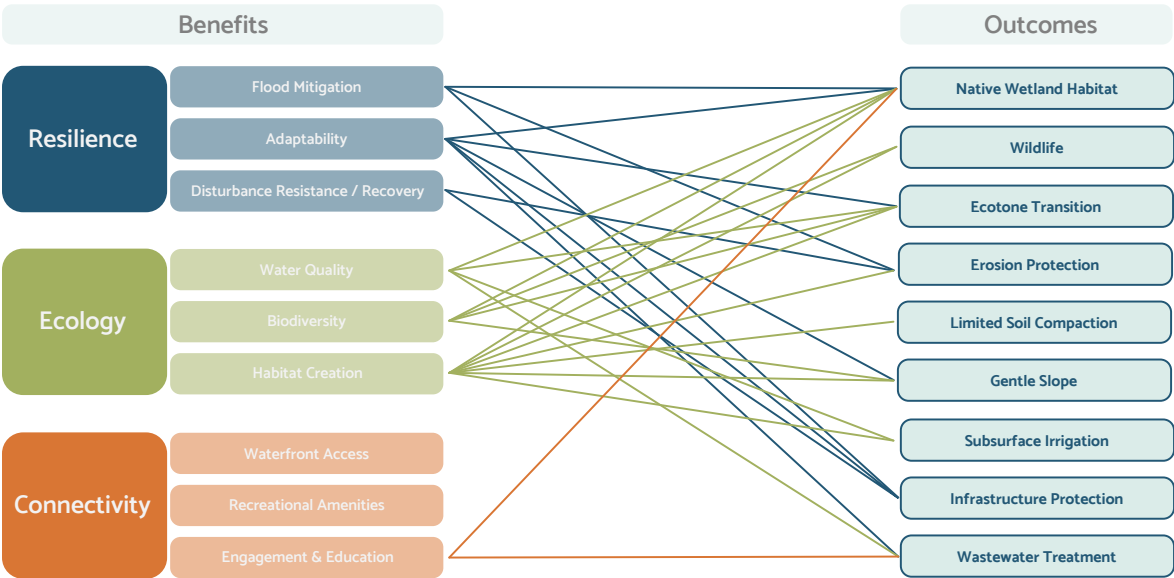


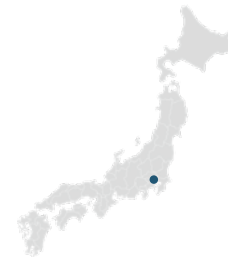
Figure 4.19: Oro Loma Horizontal Levee Analysis Map

Benefit Analysis
The majority of benefits from this precedent study are ecology-related, with a few strong resilience features (Figure 4.19). One major takeaway for design application might be the implementation of biodiversity and habitat restoration for a multi-benefit effect, with wastewater treatment as an additional function. Though many areas along the study corridor would be too narrow for a design like this, it would be interesting to see how certain elements might be integrated.



Precedent Study #2: Japanese Super Levees

Tokyo, Japan



Super Levees, sometimes categorized as “high-standard embankments” are a unique design approach implemented in Japan to combine disaster-protection infrastructure with urban development, allowing the public to regain access to their rivers while mitigating the threat of flooding (Figure 4.20). Since the 1980s, Japan has built super levees along many rivers in Tokyo and Osaka. Typically thirty times wider than their height, these structures provide opportunities for multifunctional development, including residential, commercial, and public spaces. In recent years, they have typically only been built in highly dense, built-up areas in large cities to prevent serious consequences (TDLC 2017; McKean 2013; MLIT n.d.). Because of its size, the super levee is resistant to overtopping, seepage, and earthquakes and is able to withstand larger-scale floods than ordinary levees. This river embankment is extremely wide with a very shallow slope and is often implemented with urban redevelopment and land rezoning. This combination of flood resilience and redevelopment opportunity offers multiple benefits to the communities in which they are built.

Several super levees have been constructed along the Arakawa, Edogawa, and Tamagawa, and other rivers. Many of these structures incorporate dense urbanization, with areas closer to the riverbank reserved for open green space or sports fields. Paths for walkers, runners, or bikers are a popular feature of the super levee, along with other recreational functions that help to maximize land use efficiency (Figure 4.21). For example, the Komatsugawa High-Standard Embankment offers a golf course, dog park, soccer fields, a trail, natural areas, and improved views of the river. Miyagawa Tsutsumi Park holds an annual Sakura Festival for visitors to view the blossoms along a promenade, another common feature of these super levee parks. Futako Tamagawa Rise and Park is a highly developed example that integrates a shopping center, restaurants, and offices with family-friendly parks and nature-based stormwater solutions (World Bank 2019).

Even with the multiple benefits created by this solution, there are several limitations. Since the implementation of super levees requires major construction, rezoning, and development, the costs and timeline of this process are unrealistic for an already established city. In addition, many of the rivers where these designs are constructed are highly channelized, urban areas that do not provide many ecosystem services.



Figure 4.21: Recreation at Arakawa Super Levee (Vellut 2014)

Main Takeaways



Multifunctional Resilience
With its broad base and large structure, a super levee can resist the effects of both floods and earthquakes while providing several social benefits.



Recreation
The multifunctionality of super levees extends to public use and visitor engagement. With ample space and gentle slopes, the open space becomes an area to gather, socialize, and recreate.



Development Opportunity
Super levees are often accompanied by the rezoning and development of nearby urban districts. With substantial protection, developers capitalize on the benefits that river access provides.

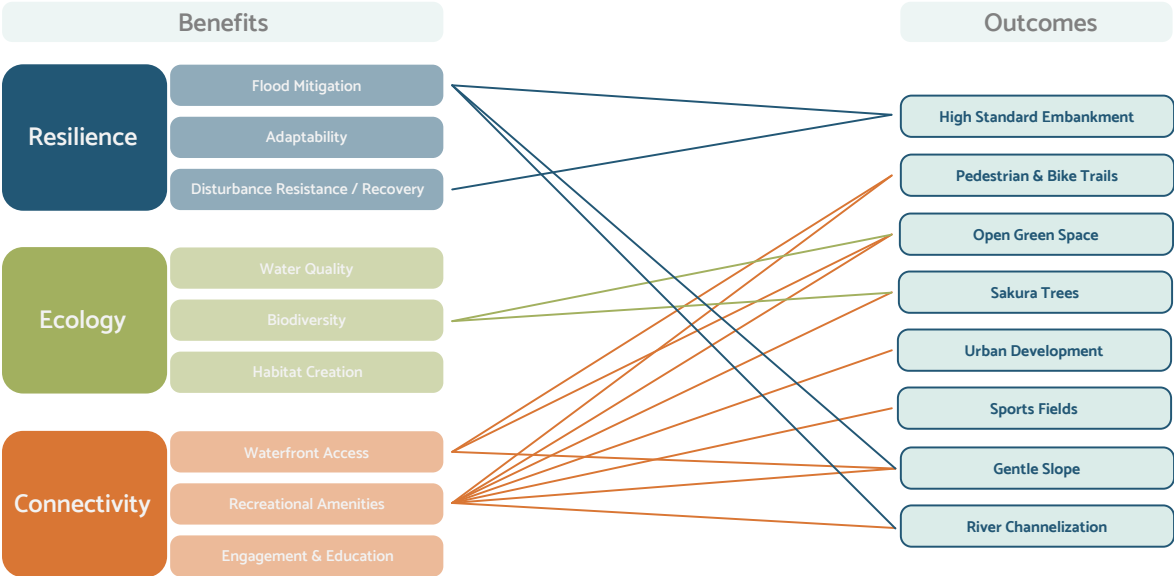


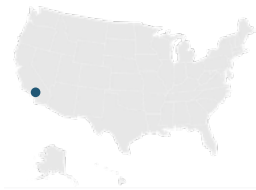
Figure 4.22: Super Levee Analysis Map

Benefit Analysis
This precedent study relies heavily on the social aspect of the design, even with its strong disaster resilience component. Few, if any, ecological benefits are noted, and the amount of redevelopment required makes the idea of a super levee unfeasible for many existing river cities. However, the idea of creating a multi-functional space that people are excited to interact with is an important takeaway (Figure 4.22).



Precedent Study #3: Dominguez Gap Wetlands

Long Beach, CA



The Dominguez Gap Wetlands is an example of a successful multi-benefit project that improves the social, ecological, and resilience aspects of a community. Implemented in 1996 as part of the LA River Master Plan, the wetlands were one of the top five demonstration projects in the trial. LA County Public Works describes the project as the first of its kind in the region, “maintain[ing] the integrity of flood protection along the urban lower reaches of the river, while introducing new water quality elements, groundwater recharge, restoration of native habitat, pedestrian and equestrian trails, environmental education, and river bike trail enhancements” (LACPW 2008).

In the 1950s, the basin was initially built to provide flood control for Long Beach and later used to replenish groundwater during storms. With the new project in 2008, constructed wetlands and amenities expanded the use of the site in addition to continued flood protection and water conservation efforts (Figure 4.23). Construction on the 37-acre site cost \$7.1 million, and it continues to benefit the community, using flows from the LA River and local urban runoff to sustain habitat for plants and wildlife (LACPW n.d.).

Figure 4.23: Wetland Ecosystem Restoration (Mazor 2008)

Historically, the LA River has been polluted by stormwater runoff contaminated by human impacts such as littering, dumping illegal contaminants, and over-watering lawns. The Dominguez Gap Wetlands works to mitigate these impacts, treating 1.3 to 3.2 million gallons of stormwater and urban runoff a day. In addition to filtering and storing runoff, the project is currently used as a source of fresh groundwater for the drought-stricken region (Cabrera 2017; LACPW 2008).

Hidden beside the channelized LA River, the Dominguez Gap Wetlands provide a lush native landscape that draws interaction from local residents – humans and wildlife alike (Figure 4.24). When the project opened, scientist Jim Bays described the unique challenge and opportunity it presented, saying, “the Dominguez Gap Wetlands will return important ecological functions of water quality improvement, wildlife habitat, and aquifer recharge to the urban lower Los Angeles River ... By encompassing the restoration within an attractive community park, the project will be certain to become an exciting destination for birdwatchers, hikers, bicyclists, and the interested public.” (LACPW 2008).



Figure 4.24: Wetlands in relation to LA River Channel (LACPW 2018)

Main Takeaways



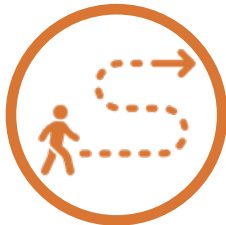
Rehabilitation of Function
A combination of native ecosystem restoration and new water quality elements works to rehabilitate the wetlands as a source of groundwater recharge and runoff filtration.



Stormwater Treatment
Contaminated stormwater runoff in LA County has historically been an issue. The constructed wetland system filters millions of gallons of runoff each day, greatly improving water quality.



Public Education
Friends of the LA River regularly offers guided tours of the wetlands to inform visitors of their existence and benefits to the ecosystem and community.



Public Access
The wetlands are highly accessible to the public, with pedestrian and horseback trails, two bird observation decks, and a bike trail rest station.

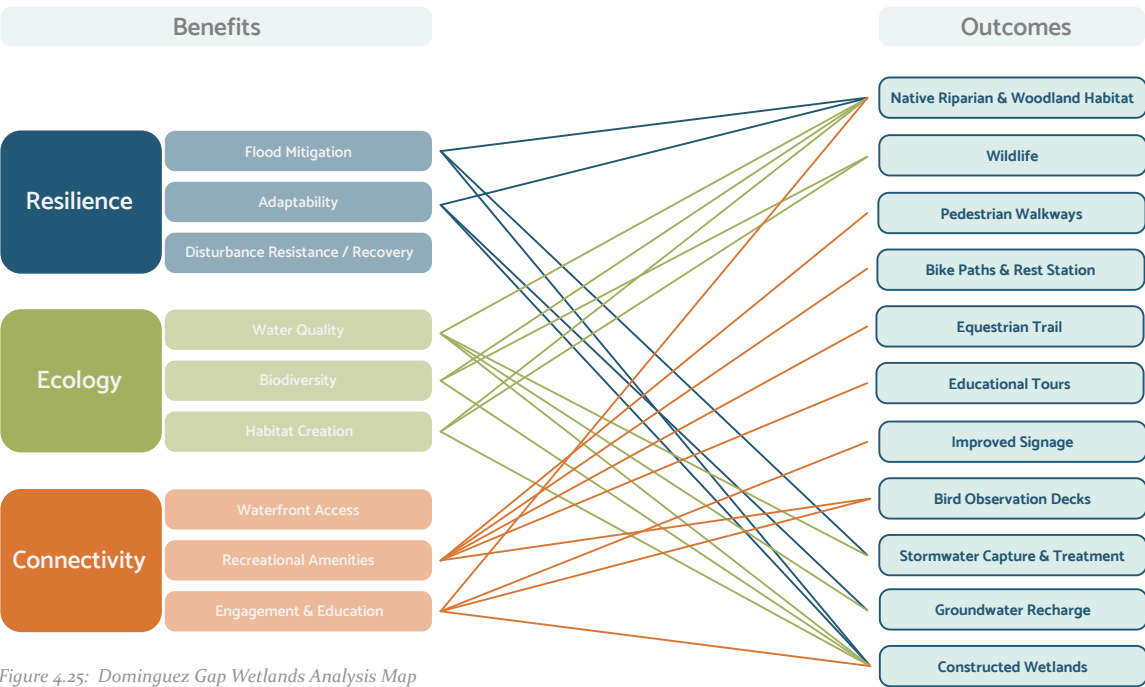


Figure 4.25: Dominguez Gap Wetlands Analysis Map

Benefit Analysis

This precedent study is one of the most applicable to the design challenges faced in this project. Though not situated directly on the riverbank, the strategies and benefits provided in the Dominguez Gap Wetlands align closely with the goals of resilience, ecology, and connectivity, laid out in the methods (Figure 4.25). The success of the native ecosystem and the level of interaction achieved with the community are highlighted and would be appropriate for the proposed conceptual design.



Precedent Study #4: “Room for the River”

Nijmegen, Netherlands



The Netherlands has always been flood-prone and, as a result, mastered the use of levees (or dikes) to protect their cities. For centuries, this was a successful approach until major floods in the 1990s caused the Dutch government to rethink its flood resilience strategy. By 2007, the “Room for the River” program was developed. This strategy implements several solutions to urban flooding issues, including lowering the levels of flood plains, creating water buffers, relocating levees, increasing the depth of side channels, and constructing flood bypasses. The “Room for the River” approach has been implemented nationwide, with most projects already completed (Netherlands Water Partnership 2019).

The approach aimed to restore the river’s natural floodplain in optimal locations in order to protect vulnerable areas. Three main objectives of this plan were:

- “By 2015 the branches of the Rhine will cope with a discharge capacity of 16,000 cubic metres of water per second without flooding;

Figure 4.26: Aerial Project Overview (H+N+S 2018)

- The measures implemented to increase safety will also improve the overall environmental quality of the river region;
- The extra room the rivers will need in the coming decades to cope with higher discharges due to the forecast climate changes, will remain permanently available” (Netherlands Water Partnership 2019).

Nijmegen is one complex example of this strategy in action (Figure 4.26). The city sits along the river Waal, near where it makes a sharp change in direction, causing higher water levels as the flow is constricted. To reduce flood risk, the levee was moved 350 meters inland to create space for a bypass channel, which will help drain water when it reaches high levels. In addition, the design of a river island park, based on river water dynamics and the sedimentation process, provides community access to the water in a unique way (Figure 4.27). Together, the channel and the park integrate water, nature, recreation, and urban activities (H+N+S n.d.). This dynamic approach accommodates fluctuating water levels, providing protection from flood risk in addition to an immersive experience.



Figure 4.27: Flood Adaptation in action
(H+N+S 2018)

Main Takeaways



Innovation

The strategies employed in this design required a new approach to thinking about flood resilience, a multidisciplinary team, and adaptive, nature-based solutions.



Dynamic Adaptation

Every element of this project is designed to work with, rather than against, natural ecosystem functions, allowing the city to become more resilient to changing water levels.



Native Habitat

By incorporating river water dynamics and sedimentation conditions into the design, various ecotones will develop over time to reflect native processes.



Social Impact

The design has made the river more accessible and interactive for the public, with the new island park providing a space for events and other recreational attractions.

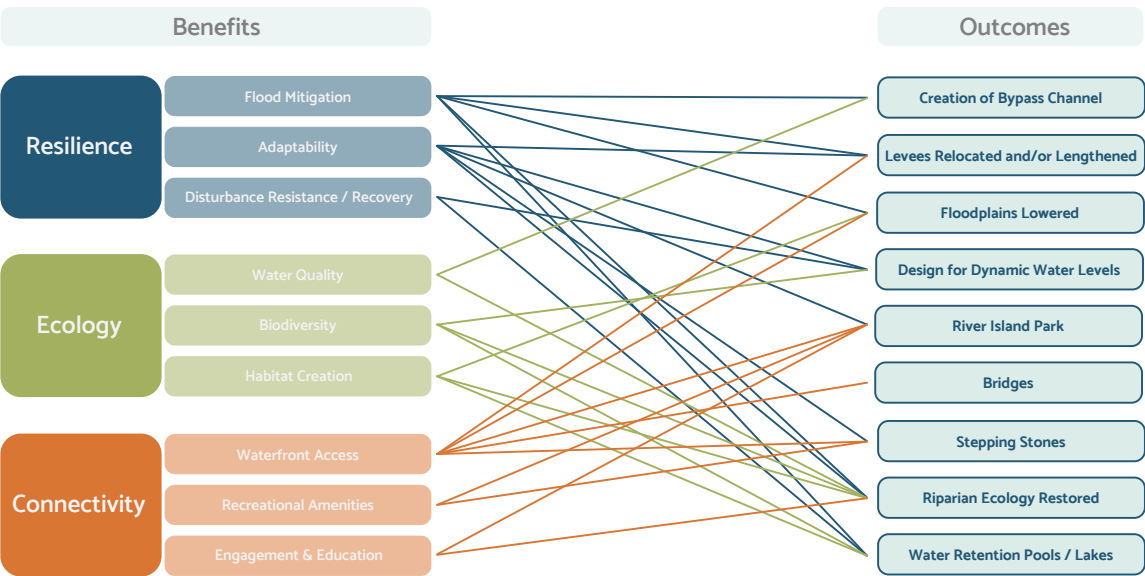


Figure 4.28: Room for the River Analysis Map

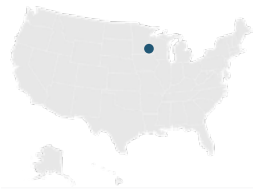
Benefit Analysis

Though the intensive construction in this precedent study and the relocation of levees are outside the scope of this proposed design project, the innovative ideas proposed, dynamic adaptation, and social aspects are valuable principles that may be applicable. (Figure 4.28)



Precedent Study #5: Levee Park

Winona, MN



Like many cities, Winona, Minnesota was disconnected from its riverfront by flood protection infrastructure. In 2007, the City of Winona began planning for potential solutions to revitalize the riverfront, with four main goals in mind:

1. **Mix of Uses** - Encourage a wide range and integrated mix of industrial, retail, restaurant, park, entertainment, and residential uses along the riverfront
2. **Improve Access** - Improve visual and physical access to the River and the riverfront's relationship with adjacent areas of the City
3. **Provide Recreation Options** - Provide river recreation options along the Mississippi River shoreline to enhance community livability and attractiveness to tourists... Redesign and improve Levee Park as a gateway to Downtown Winona
4. **Maintain Current Assets** - Maintain and improve upon Winona's existing industrial, business, and goods-transportation assets on the river while improving the river ecologically (City of Winona 2007).

Figure 4.29: Levee Park Public Center (City of Winona n.d.)

The multidisciplinary firm ISG was ultimately selected to complete the design for an updated Levee Park. The design took place in two phases to improve both the park itself and the surrounding industrial corridor, transforming the area into a year-round destination for events and entertainment with the community in mind (ISG, Inc n.d.). An elevated plaza built into the levee structure is a main feature of the park, integrating indoor and outdoor uses while providing views to the natural beauty of the Mississippi River (Figure 4.29). Community access was a major driver of this project, which was achieved through improved branding, wayfinding, lighting, pedestrian accessibility, active green spaces, and plans for economic development (Figure 4.30). The city also made an effort to contribute to the ecological function of the space by restoring some native areas along the trail, improving stormwater infrastructure, and educating the public on water quality (ISG, Inc n.d.).



Figure 4.30: Levee Park Boulevard & Overlook (City of Winona n.d.)

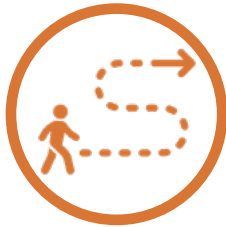
Main Takeaways



Multifunctional Resilience
The main feature of the park is a large plaza built into the existing levee. This direct approach to connectivity is a unique idea that provides some insight into the feasibility of these structures.



Social Engagement
Community feedback was considered throughout the design process to gauge their interests and values, ultimately creating a vibrant district thriving with activity year-round.



Public Access
Accessibility was a main priority, connecting Levee Park to downtown through pedestrian-first streets and riverfront corridors, ramps, wayfinding, and other intentional design features.

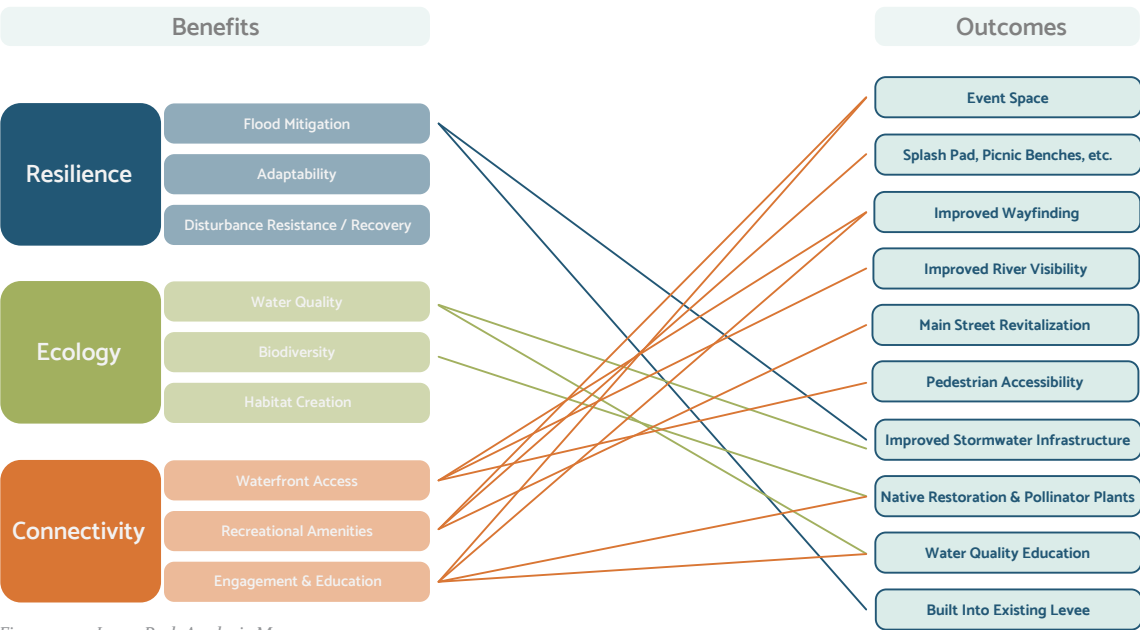


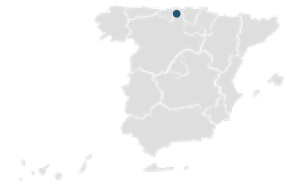
Figure 4.31: Levee Park Analysis Map

Benefit Analysis
The social connectivity aspect of this precedent study is a valuable lesson when approaching the design proposal (Figure 4.31). Integrating the surrounding industrial corridor with the park itself and emphasizing both visual and physical access led to the success of the Levee Park project, even if the ecological goals were lacking in some areas.



Precedent Study #6: Atlantic Park La Vaguada de las Llamas

Santander, Spain



The Vaguada de las Llamas was once a river that flowed into the Atlantic Ocean but was disconnected from the coast due to the development of the surrounding areas. These human impacts left a low-lying, marshy riverbed area, which created an interesting ecosystem with unique species of reeds growing to inhabit the wetland. Over time, the landscape became degraded and increasingly separated from the city as highways made the area invisible and inaccessible to the public, and a common ground for dumping pollutants (Land8 2015; Landezine 2023).

Atlantic Park in Santander, Spain, seamlessly combines ecological restoration with urban park design to expand an existing wetland as the central element of a public space. Constructed between 2005 and 2008, the design team from Batlle I Roig Arquitectura worked to address the immediate environmental issues on the 30-hectare site and create a space that would become accessible to the public. The park is divided into three zones, the low-lying areas, the “Atlantic zone”, and the higher level – “each characterized by their use, character, and planting scheme and divided by the park’s topography” (Land8 2015).

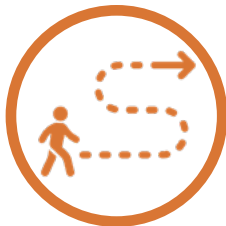
The lowest section consists of the existing riverbed and an artificial lake inhabited by wetland plant species. This area is not directly accessible for visitors; rather, they can view the ecosystem from a series of raised boardwalks, allowing an immersive experience without disturbing the vegetation. The “Atlantic zone” is a sloped transition area that creates a buffer between the passive and active zones, allowing space for native species to establish. This area also provides opportunities for passive recreation, with pathways for pedestrians and cyclists to pass through and connect to the nearby university campus (Figure 4.32). The highest level is community-focused, with playgrounds, an outdoor amphitheater, botanical gardens, and open green space for active recreation (Figure 4.33) (Batlleiroig n.d.; Land8 2015; Landezine 2023).

This approach was influenced by the morphology of the Atlantic Ocean, created to mimic the structure and ecology of the region while adapting to site-specific conditions. Overall, the design aims to create a vibrant public space integrated with the community, providing the access that they were previously denied while still preserving the unique biodiversity of the local climate.



Figure 4.33: Upper Level Recreation Access
(Surroca 2008)

Main Takeaways



Relationship with Context
Contextual relationship was an important concept of this design, connecting to the adjacent university and other major pathways to fully integrate the park into the urban fabric.



Streambed Ecology
As part of an existing riverbed, ecological restoration was important to the design concept. By constructing an artificial lake, wetland species have space to expand and thrive.



Boardwalk Immersion
Visitors to the park can immerse themselves in the ecosystem by traveling on the boardwalk system that spans the marsh without disturbing the vegetation.



Pollutant Remediation
The site was previously used for illegal dumping purposes, severely degrading over time and losing valuable biodiversity. The project addressed this need immediately and established a strong native ecosystem to restore traditional function.

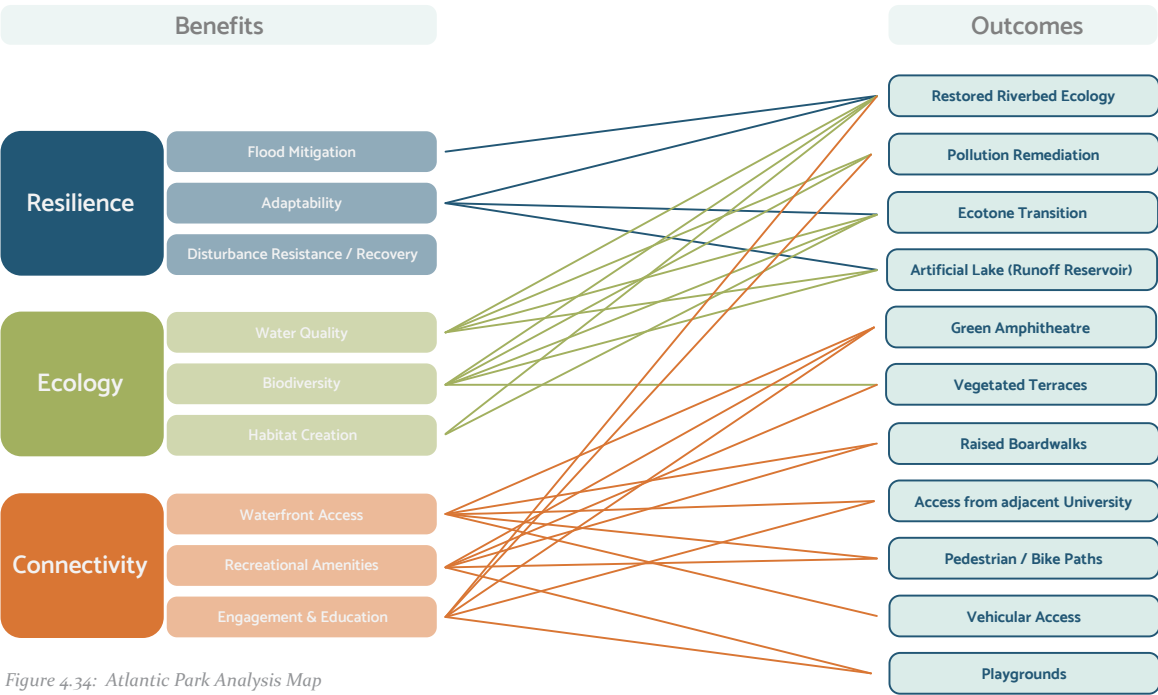


Figure 4.34: Atlantic Park Analysis Map

Benefit Analysis

This precedent study offers successful examples of both social and ecological benefits that may be applied to the design proposal (Figure 4.34). Of course, an active riparian system will differ from the self-contained example here, but the relationship with context, ecological restoration, and immersive boardwalk experience are relevant design strategies for the project.

	Oro Loma Horizontal Levee	Super Levee	Dominguez Gap Wetlands	“Room for the River”	Levee Park	Atlantic Park
Resilience						
Ecology						
Connectivity						
Design Strategy	Horizontal / Ecotone Levee	High Standard Embankment	Ecosystem Restoration	Setbacks, Levees, Ecosystem Restoration	Levee, Floodwall	Ecosystem Restoration
Suitability						

Figure 4.35: Precedent study Synthesis x Goals Matrix

Design Application

Ideas from all case studies will be beneficial to the design process, but it is essential to analyze suitability before applying any strategies to the proposal. As seen in the synthesis matrix, resilience and ecology elements from the Oro Loma Horizontal Levee and “Room for the River” projects were the most applicable to the goals defined in the research methods, while social elements of the Levee Park and Atlantic Park were the most relevant to the ‘connectivity’ goal. “Room for the River” meets all the design criteria, but may be less feasible when applied to the Manhattan, KS levee site. These goals and strategies were further synthesized and applied where appropriate among the identified transects.

Filled Circle: Criteria Fulfilled

Not Suitable for MHK Project

Somewhat Suitable for MHK Project

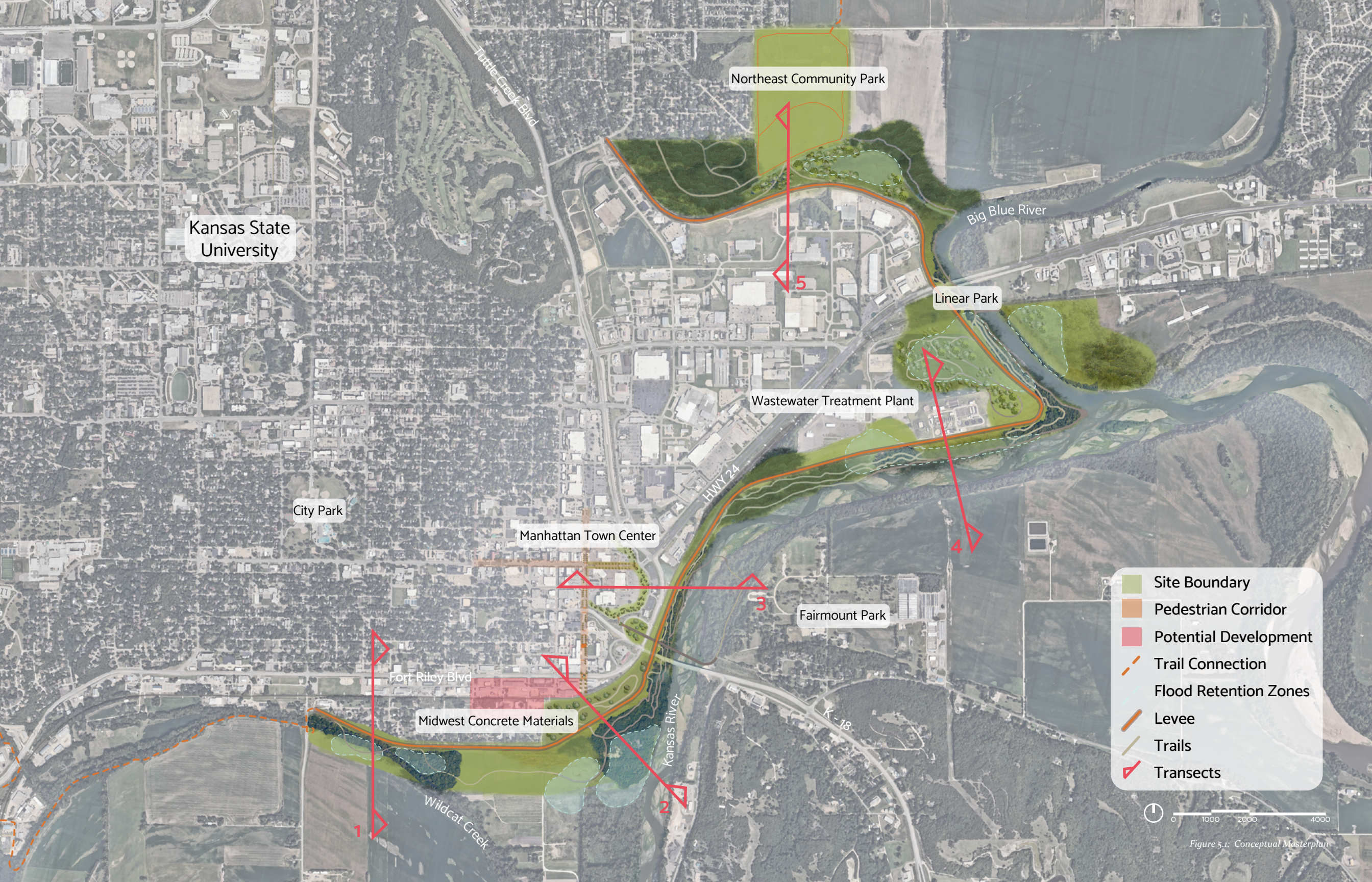
Suitable for MHK Project

05

Design Proposal

Chapter Overview

Using information gathered from surveys and precedent studies, the following section details design proposals for each of the five identified transects along the river corridor. The conceptual masterplan shows a long-term proposal for flood resilience, connectivity, and ecological health. Each transect proposal defines social and ecological outcomes, highlighted by three main goals, images of the transect in typical dry and flood conditions, and an experiential image to showcase the opportunities and benefits presented by the design.



- Site Boundary
- Pedestrian Corridor
- Potential Development
- Trail Connection
- Flood Retention Zones
- Levee
- Trails
- Transects



Figure 5.1: Conceptual Masterplan

Conceptual Masterplan

The vision for the levee masterplan integrates ideas gathered from the literature, survey, and precedent study analysis and applies them to a large-scale, long-term plan to create an accessible, resilient greenbelt along the Kansas and Big Blue rivers. Major interventions are concentrated around the selected transects (Figure 5.2), applying various techniques from the research as they are suitable to each individual context and identified goals. Some main ideas of this design proposal include expanded park space and improved trail connectivity to create a continuous greenbelt around the city, creating an axis from Poyntz Ave through Manhattan Town Center and across the river, implementing pedestrian bridges and boardwalks for increased interaction with the waterfront, and otherwise adjusting the slope of the levee or providing alternative paths to create an accessible riverfront. By capitalizing on existing conditions and overcoming the barriers presented by the levee and other constraints, the design works to improve the ecological and social conditions of the Manhattan riverfront.

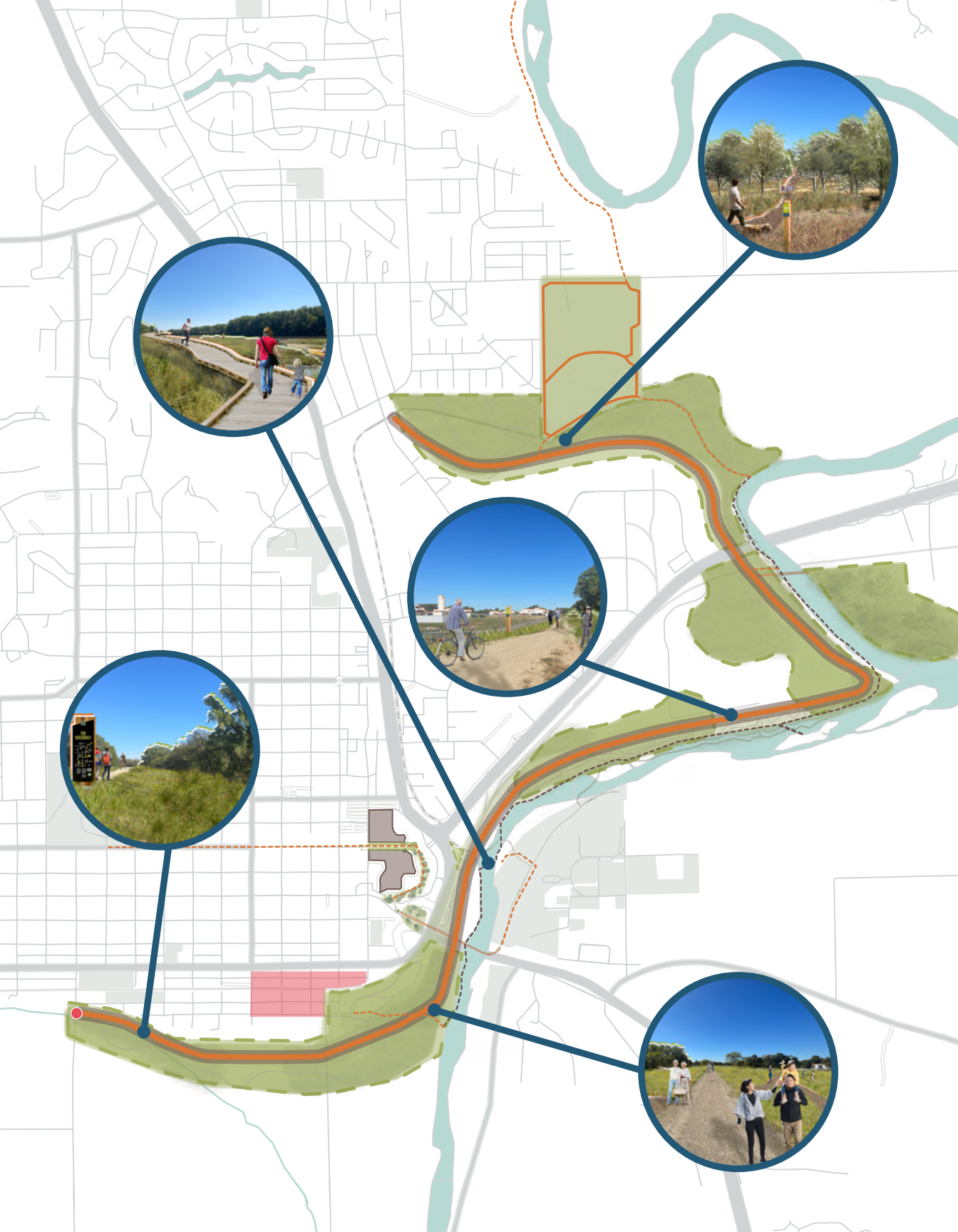


Figure 5.2: Transect Design Location Map

Levee Structure Adaptation

At the transect scale, this horizontal approach is proposed to adapt the existing levee structure - widening the base, providing structural stability and protection from water seepage, and creating space for native habitat to thrive. As seen in the diagram (Figure 5.3), layers of insulation, waterproofing, and a root barrier (mimicking those found in a green roof) would work to preserve the existing infrastructure and prevent structural issues potentially caused by the integration of plants, a common concern of the USACE and other entities. This adaptation would build upon the existing structure and be applied only where there is adequate space and/or previous disturbance so as not to damage existing ecosystems and old-growth trees. For example, the area near the Wastewater Treatment Plant has been identified for the implementation of a horizontal levee, similar to those seen in the precedents to promote ecotone transition and water quality improvements. Several ecosystem types can be found along this transitional slope, moving from the freshwater marsh/emergent wetland along the river's edge to the upland prairie near the crest of the existing levee structure (see Figure 5.4 for plant selection).

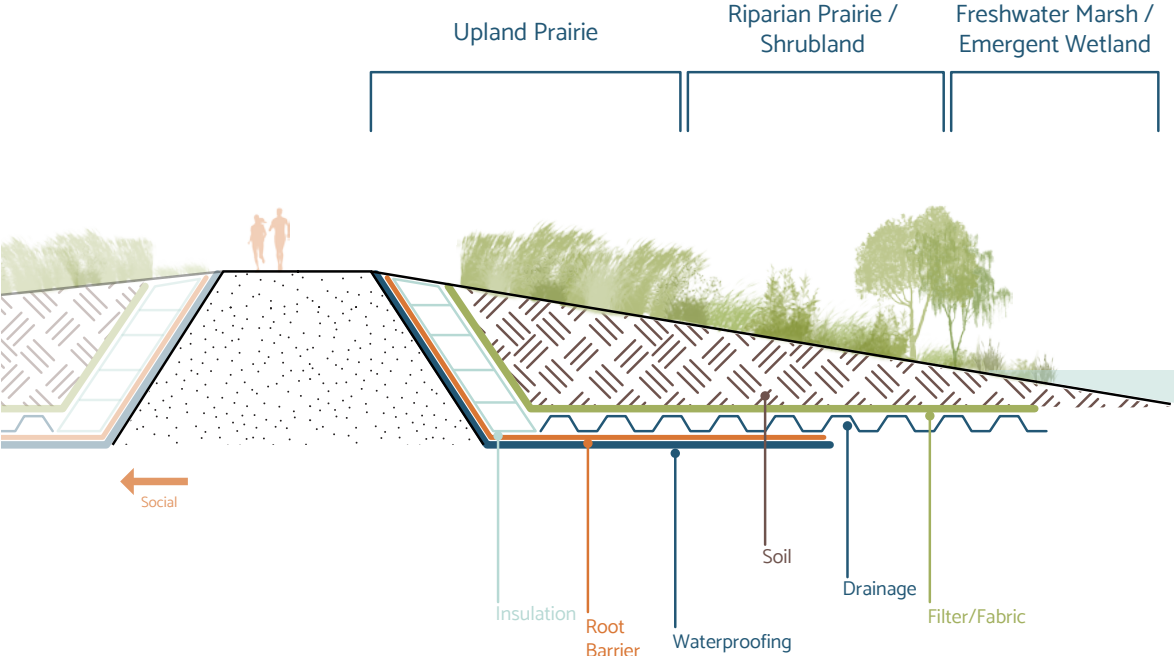


Figure 5.3: Structural Adaptation Diagram - Ecological

Riparian Species Selection		
Upland Prairie Little Bluestem Indian grass Side-oats grama Switchgrass Blue grama	Riparian Prairie/Shrubland Sandbar Willow Prairie cordgrass Joe pye weed Tall meadow rue Great blue lobelia	Freshwater marsh/wetland Hammock sedge Bulrush Swamp milkweed Common water-willow River birch

Figure 5.4: Example Plant Palette

Similarly, on the land side, this approach can be used to create a more shallow slope for recreational use. The protective layers remain the same to prevent root damage, water seepage, and other erosion and compaction issues. Likewise, this design would only be beneficial where adequate space is available to expand upon the existing structure without damaging the ecosystem – for example, the Midwest Concrete Materials site is identified for this type of approach in the proposal. As with the ecological recommendations, the social design implements layers of use, creating a multifunctional, resilient, and active space on the waterfront (see Figure 5.5). Active use takes place on the edges, with the continuation of the Linear Trail atop the existing levee structure and recreation areas near the bottom of the slope. In between, a restoration of the native riparian prairie ecosystem is proposed to provide visual and educational interest, create species habitat, and infiltrate water if a flood overtopping the levee were to occur. The shallow slope creates accessible pathways to connect both sides of the levee, bridging the gap between social and ecological functions of the riparian corridor.

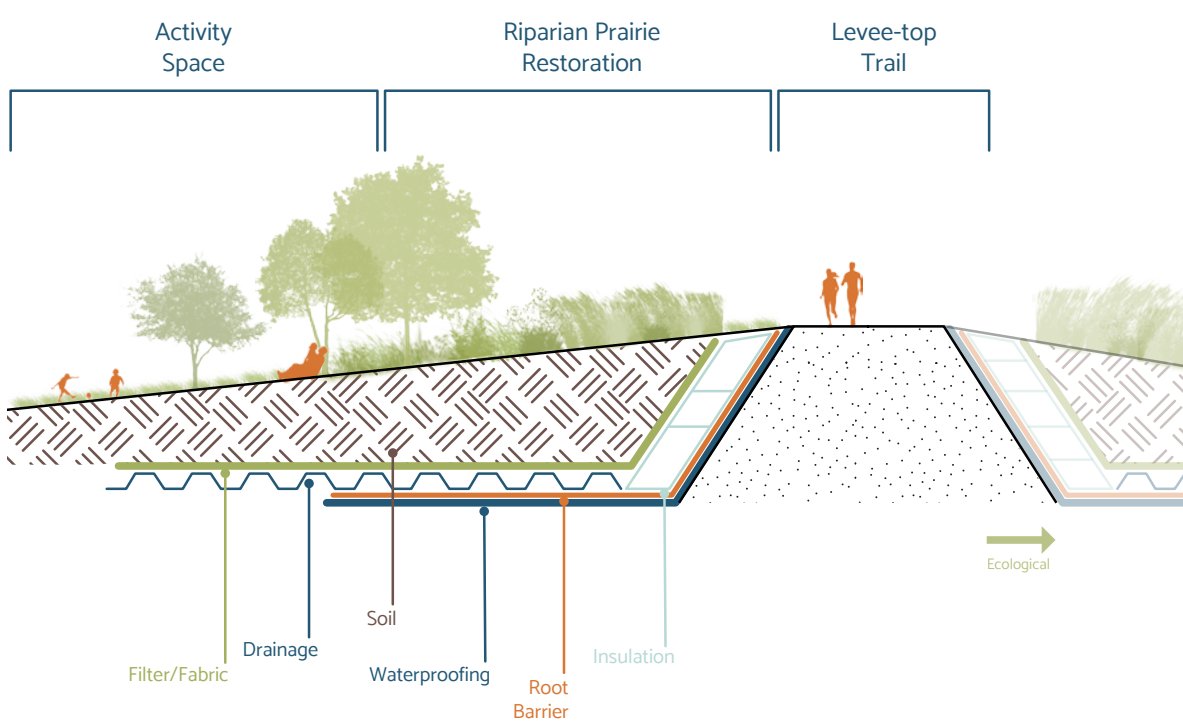


Figure 5.5: Structural Adaptation Diagram - Social

Linear Trail Entry Transect

Social Outcomes

Situated at the southern entrance to the Linear Trail and near a residential neighborhood, this first transect has the opportunity to create a large social impact. A focus on improved signage and branding works to enhance awareness of, accessibility to, and engagement with the trail and the larger network.

Protection of homes north of the levee is a main priority, combining existing infrastructure with additional ecological approaches to reduce flood risk. In addition to the Linear Trail entrance, this transect serves as a gateway to the larger park system that will stretch along the banks of the river and connect the city of Manhattan with its surrounding context.



Ecological Outcomes

Though this section of the levee is not located directly adjacent to the river, Wildcat Creek is often prone to flooding. In order to improve the flood resilience of the existing levee structure, a few different strategies are proposed. First, the floodplain forest ecosystem that is native to riparian areas should be restored, which will facilitate improved infiltration of any excess water, provide native species habitat, and prevent erosion along the creek bank. In addition, the slope of the levee will be altered to create a more natural ecotone transition. With these improvements, retention basins will be implemented to gather runoff and redirect the flow away from nearby residences.



Goal #1 - Flood Mitigation & Resident Safety

As the closest transect to a residential area, safety is a top priority. The design integrates existing and improved flood resilience strategies for protection.



Goal #2 - Access & Engagement

By educating the public about the trail and waterfront, improved awareness and use of this entrance can provide access to the larger park network.



Goal #3 - Habitat Creation

Restoration of native ecosystems not only improves resilience, but can also contribute to the larger connectivity and health of many species.

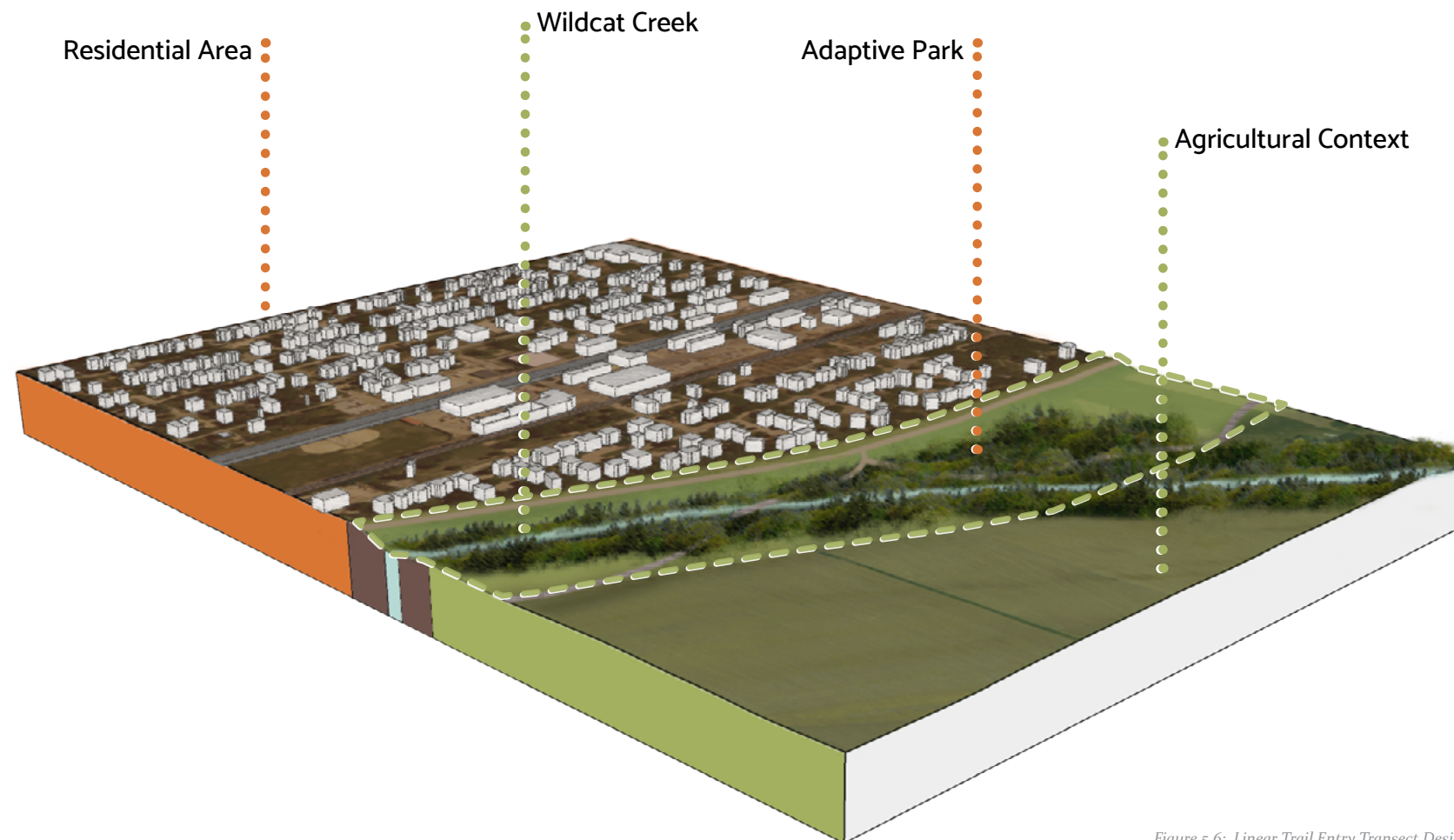


Figure 5.6: Linear Trail Entry Transect Design



In both dry and flood conditions, the site provides opportunities for local residents and visitors to engage with the community, learn about existing natural ecosystems, or simply use the trail to access destinations downtown or elsewhere on the connected greenway. This space is programmed with a more passive use in mind, provoking interest through additional trails and native species.

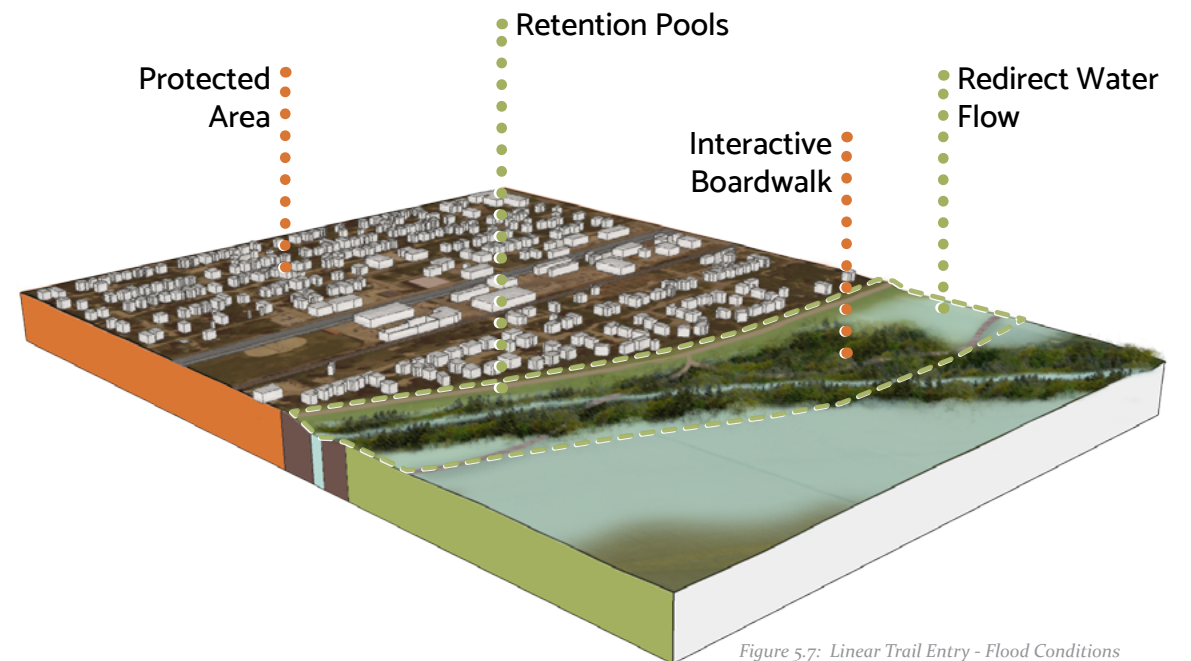
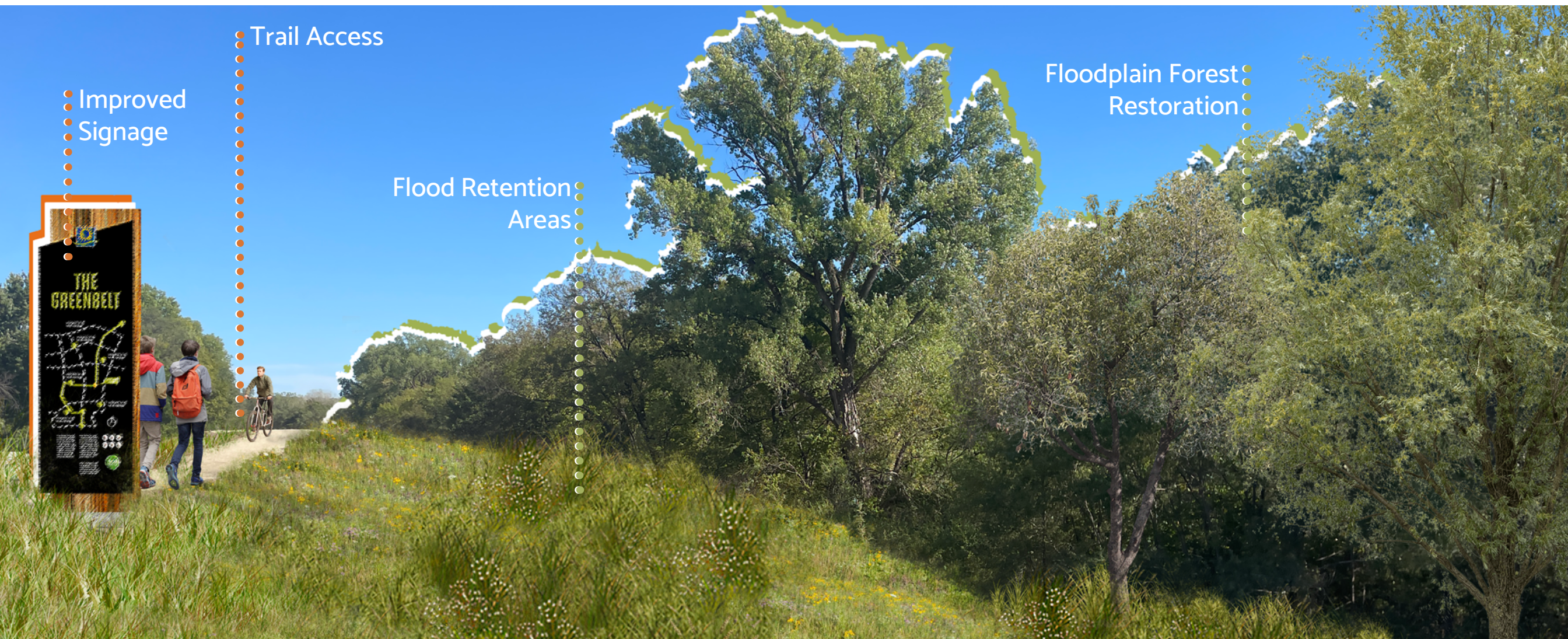


Figure 5.7: Linear Trail Entry - Flood Conditions

Figure 5.8: Linear Trail Transect Site Plan



Industrial - Park Transect

Social Outcomes

Transformed from an old concrete fabrication site, this area provides ample space to widen the levee and create a gradually sloping park. It expands on the existing mountain biking trail system, offering a variety of uses with active and passive programming. Building on the larger network, this site marks the beginning of the riverside boardwalk, which invites visitors to interact directly with the waterfront. Continuation of improved signage provides awareness, direction, and creates a cohesive organization throughout the greenbelt.

This area has a direct connection to the downtown hospitality district and the potential to draw many visitors. Existing industrial sites not included in the park boundary may serve as sites for additional commercial development, implementing a more hybrid social-ecological approach.



Ecological Outcomes

Similar to the social objectives, the riverside of the levee works with a gradual slope to reduce such a harsh transition between the riparian system and urban flood infrastructure. Retention pools are created to encourage native plant colonization and provide areas for water to collect in times of flood, while simultaneously creating a more accessible path and interesting terrain for visitors to explore.

The existing concrete site has contaminated and compacted the soils on site, which should be mitigated by remediation efforts and ecosystem restoration. The design will capitalize on the existing floodplain forest near the river, full of thriving species and providing a baseline for ecosystem health potential.



Goal #1 - Park Amenity & Recreation

The wide area landside of the levee provides ample space and opportunity to use a horizontal approach and create an active public space.



Goal #2 - Biodiversity

Restoration of native ecotones helps to provide flood resilience, native habitat, and education opportunities for the community of Manhattan.



Goal #3 - Adaptive Resilience

Retention pools offer space for water storage when flooded and provide opportunities for the public to engage with the river and understand its dynamic nature.

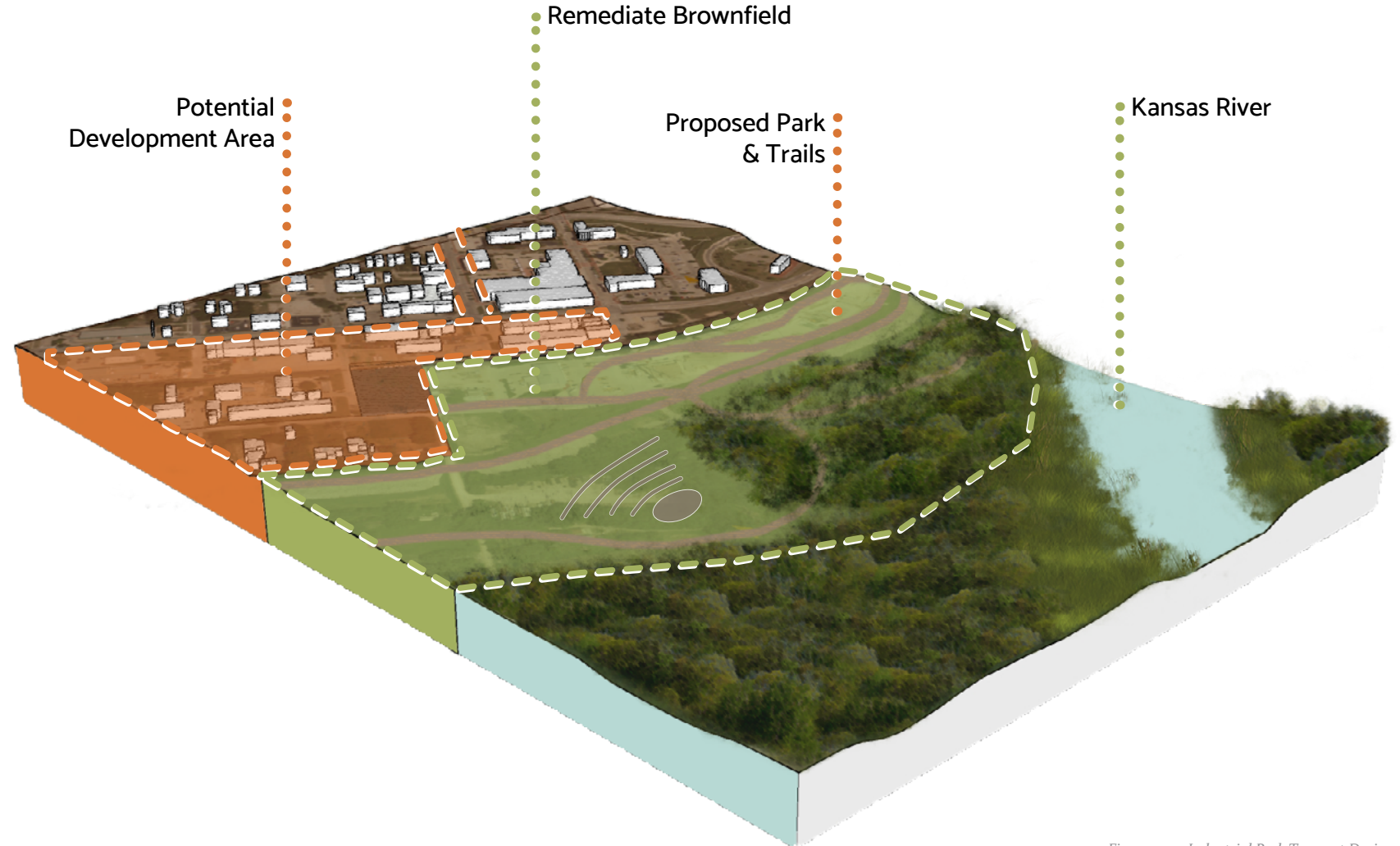


Figure 5.10: Industrial Park Transect Design



This area was of notable interest to survey respondents, many of whom advocated for its use as a park and to capitalize on its proximity to both the downtown area and the river. It will provide one of the most truly adaptive spaces along the greenbelt, serving as a catalyst site for many of the social and environmental benefits to be achieved by this project.

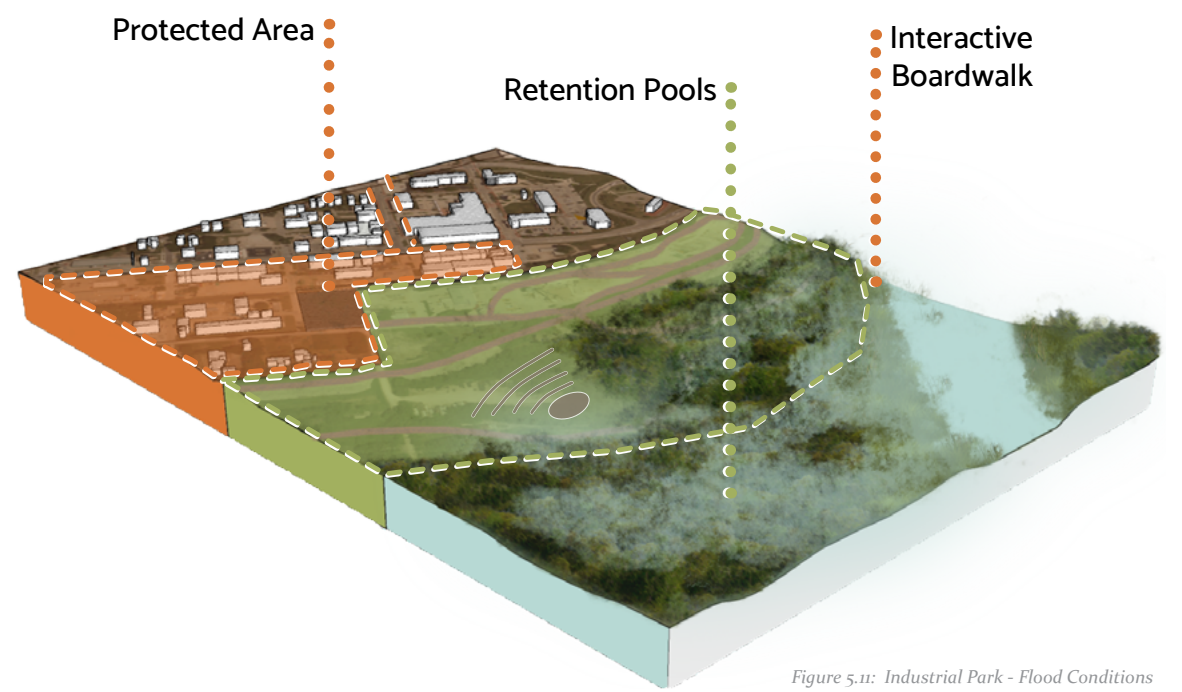


Figure 5.11: Industrial Park - Flood Conditions

Figure 5.12: Industrial - Park Transect Site Plan



Town Center Crossing Transect

Social

Connectivity and access are a priority for this section, as it is currently disconnected from the river by three major barriers – the levee, highway, and railroad. The main solution to this issue is the implementation of an elevated pedestrian bridge to provide an accessible path to the river and maintain the extension of the Manhattan Town Center. A strong pedestrian axis is proposed along Poyntz Ave through the mall – transforming the existing atrium into an outdoor pedestrian mall and connecting to a smaller greenbelt around the parking lot. In addition, the continued boardwalk encourages direct interaction with the water and connects across to Fairmount Park.



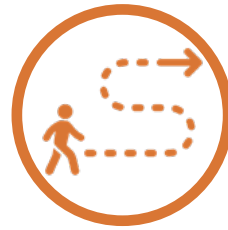
Ecological

While this area is more socially focused, ecology is still an important factor for every section of the design. As part of the greenbelt, it contributes to the connectivity of linear habitat and improves ecosystem quality. Implementation of native plantings and a reduced waterside slope work together with retention basins opposite the levee to infiltrate water before it can reach the urban center. Dedicated overflow zones on either side of the river reduce flood risk and direct water to more beneficial areas.



Goal #1 - Accessibility

To overcome the existing barriers, pedestrian access and trail connectivity are important elements for this portion of the design.



Goal #2 - Flood Resilience

Manhattan Town Center is covered by impervious surfaces, so creating adaptive, nature-based solutions is important to reduce flood risk.



Goal #3 - Engagement

Implementation of the pedestrian bridge and active programming work to improve awareness of the waterfront and engage visitors.

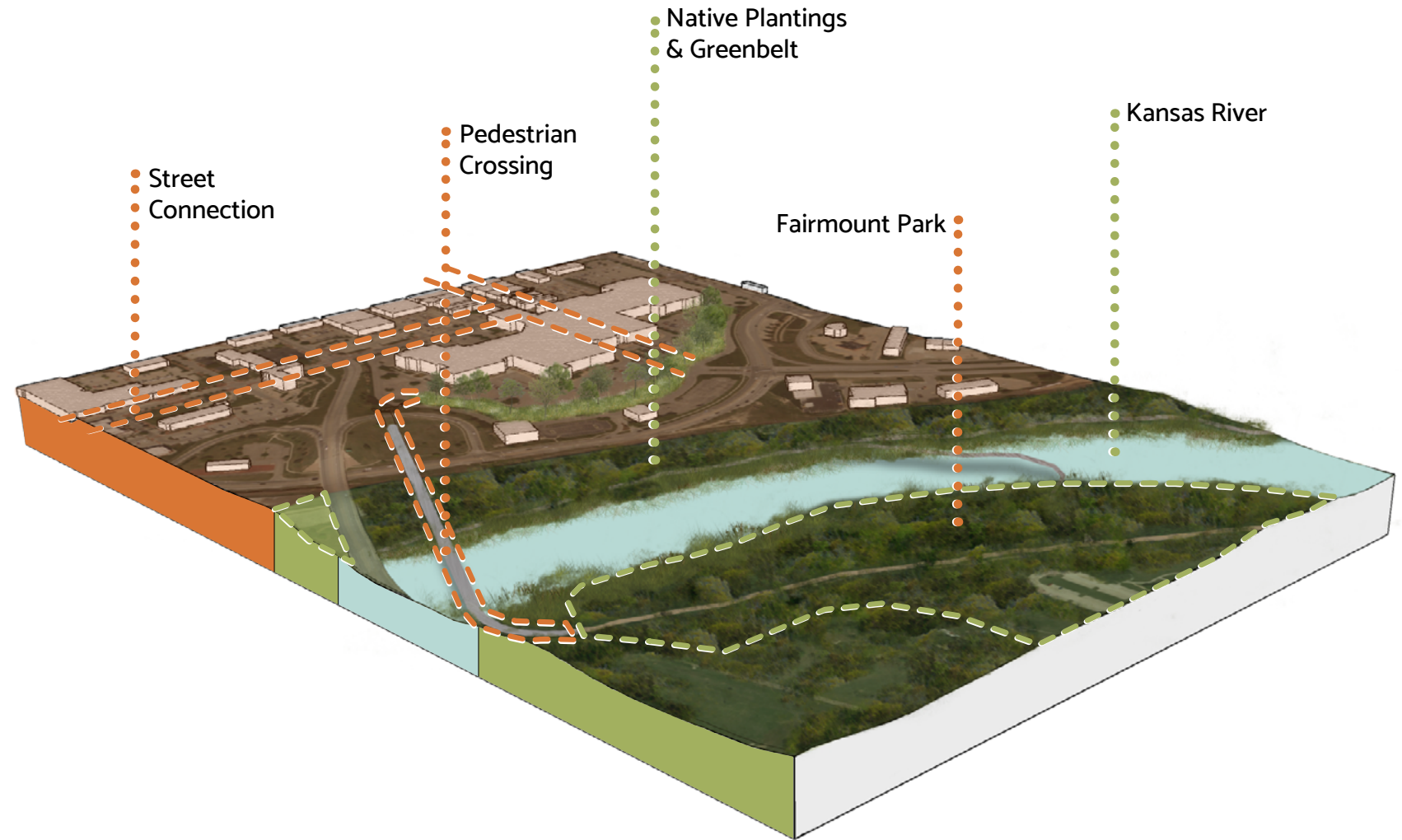


Figure 5.14: Town Center Crossing Transect Design



As a main hub for social activity connected to downtown, Manhattan Town Center could provide a major asset for the city. Many community members noted this in their survey responses, citing a desire for a more pedestrian-friendly area and the lack of connection to the river and adjacent parks such as Fairmount. This area is already fairly well protected from flood events, so improving the ecology and community engagement would be a significant benefit.

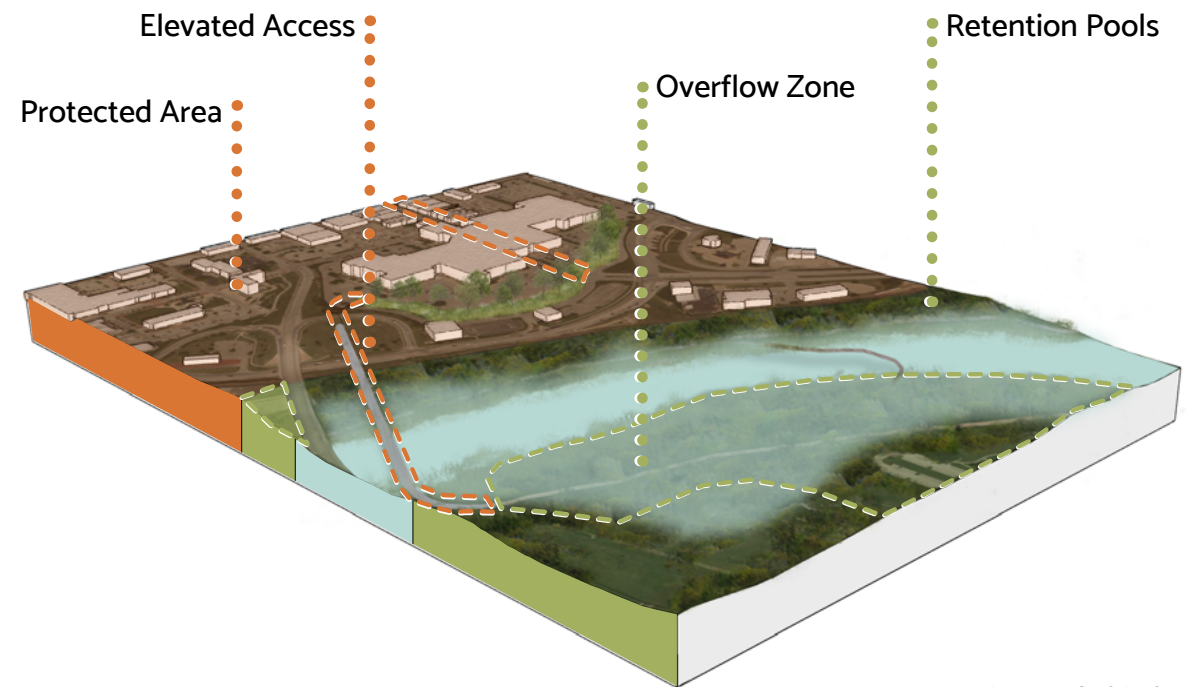


Figure 5.15: Town Center Crossing - Flood Conditions

Figure 5.16: Town Center Crossing Transect Site Plan



● Floodplain
● Forest

● River Access
● Boardwalk

● Native Wetland

● Water
● Recreation

Water Treatment Transect

Social

Despite presenting opportunities to improve trail access and views to the river, the area surrounding the wastewater treatment facility owned by the city is currently not accessible to the public. The design works to adapt this space by implementing new park space around the facility that will draw visitors.

Access points to the existing trail system and connection with the boardwalk encourage activity that will pass by the space. To take advantage of this opportunity, educational signage may be implemented to inform users of the purpose of the horizontal levee, and importance of riparian ecosystems and water quality.



Ecological

This transect draws design aspects from the horizontal levee precedent, experimenting with various native species to reduce flood risk and erosion, provide ecosystem habitat, and improve water quality. Below the surface, wastewater treatment and irrigation support this ecotone slope and riparian wetlands.

Using the horizontal approach should provide a multi-benefit solution to many issues created by the existing levee system, removing barriers and restoring natural transitions while still working to prevent flooding. There may be some limitations to this approach as it has not yet been implemented along river corridors, but adequate space and maintenance should provide opportunity for success.



Goal #1 - Water Quality

Utilizing features of the existing wastewater treatment facility will benefit the goals of this project, combined with nature-based solutions to restore water quality.



Goal #2 - Habitat Creation

By restoring the natural slope and ecotone transition of the levee's riparian edge, the ecosystem supports native species habitat.



Goal #3 - Adaptability

Creating a space that can have both private and public, social and ecological uses is an essential part of this design, uniquely adapting to human interaction and river dynamics.

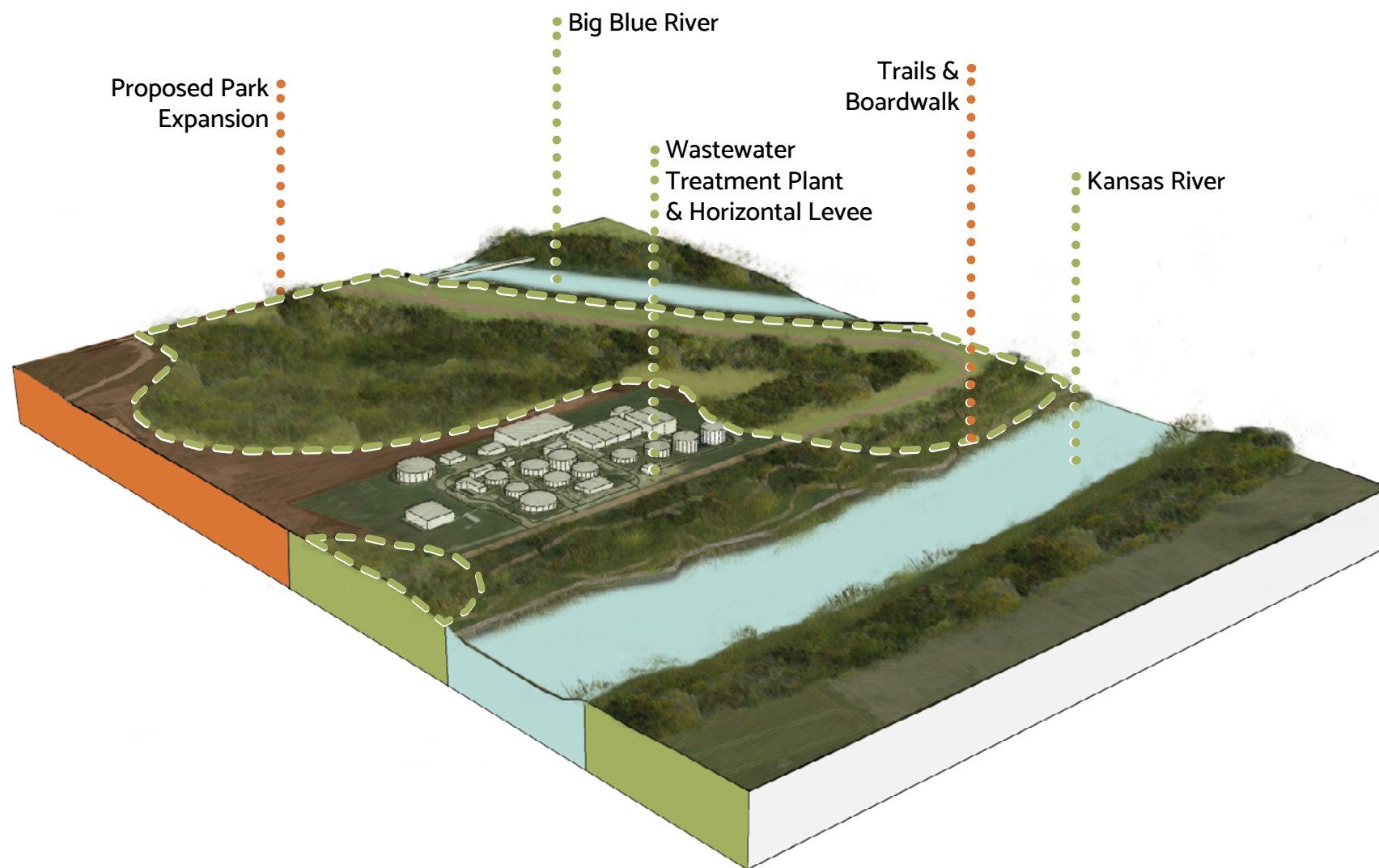


Figure 5.18: Water Treatment Transect Design



Currently underutilized, transforming this area into an interactive public space will be essential to create a continuous connection along the levee throughout the entire greenbelt. The existing trail system and river lookout found in this section are elements that can be enhanced to improve community interaction, in addition to ecology and water quality improvements provided by the water treatment facility.

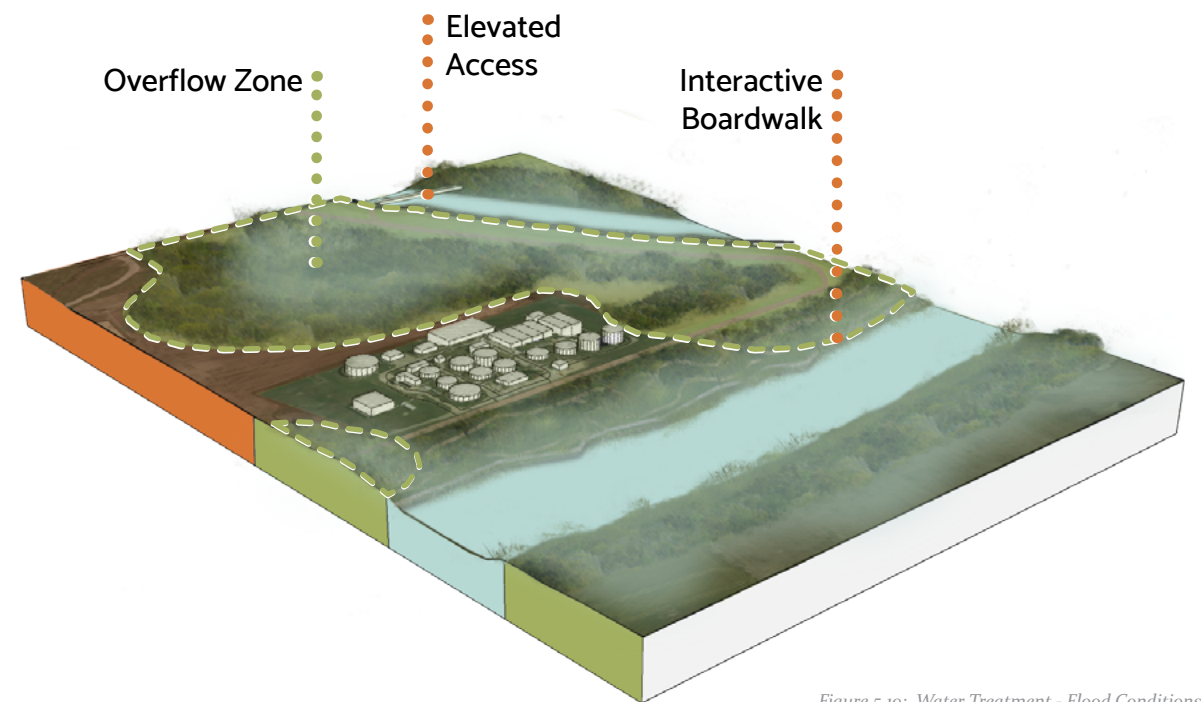


Figure 5.19: Water Treatment - Flood Conditions

Figure 5.20: Water Treatment Transect Site Plan



NE Community Park Transect

Social

Currently hidden north of the industrial park, the design works to improve awareness and access to this portion of the linear trail and expand upon existing park space. Northeast Community Park and the Northview neighborhood sit opposite the levee, creating an opportunity for community engagement.

The city has plans to create an additional entrance to the linear trail in this section, expanding on the existing network. Improved signage and active programming to draw attention and visitors to the area would benefit the larger community and promote interaction with the waterfront.



Ecological

Due to the levee construction project, several patches of floodplain forest ecosystem have been impacted. The city has plans to use this area north of the levee for the restoration of these native species. The design expands upon this, proposing more restoration areas as well as education information for the public who interact with the space.

Since this transect is set back from the river, there are fewer direct impacts, but flood mitigation is still a main priority for the design. A retention pool is proposed in the open area southeast of the park between the river and the levee for storage and redistribution of excess water flow.



Goal #1 - Restoration

By reintroducing native floodplain forest and riparian wetland ecosystems, the greenbelt becomes more resilient to flood events.



Goal #2 - Trail Connection

The existing trails in Northeast Community Park provide the opportunity to expand the trail network and further improve connectivity.



Goal #3 - Engagement & Education

Connecting trails and restoring ecosystems improves access and education opportunities for local residents, inviting community interaction.

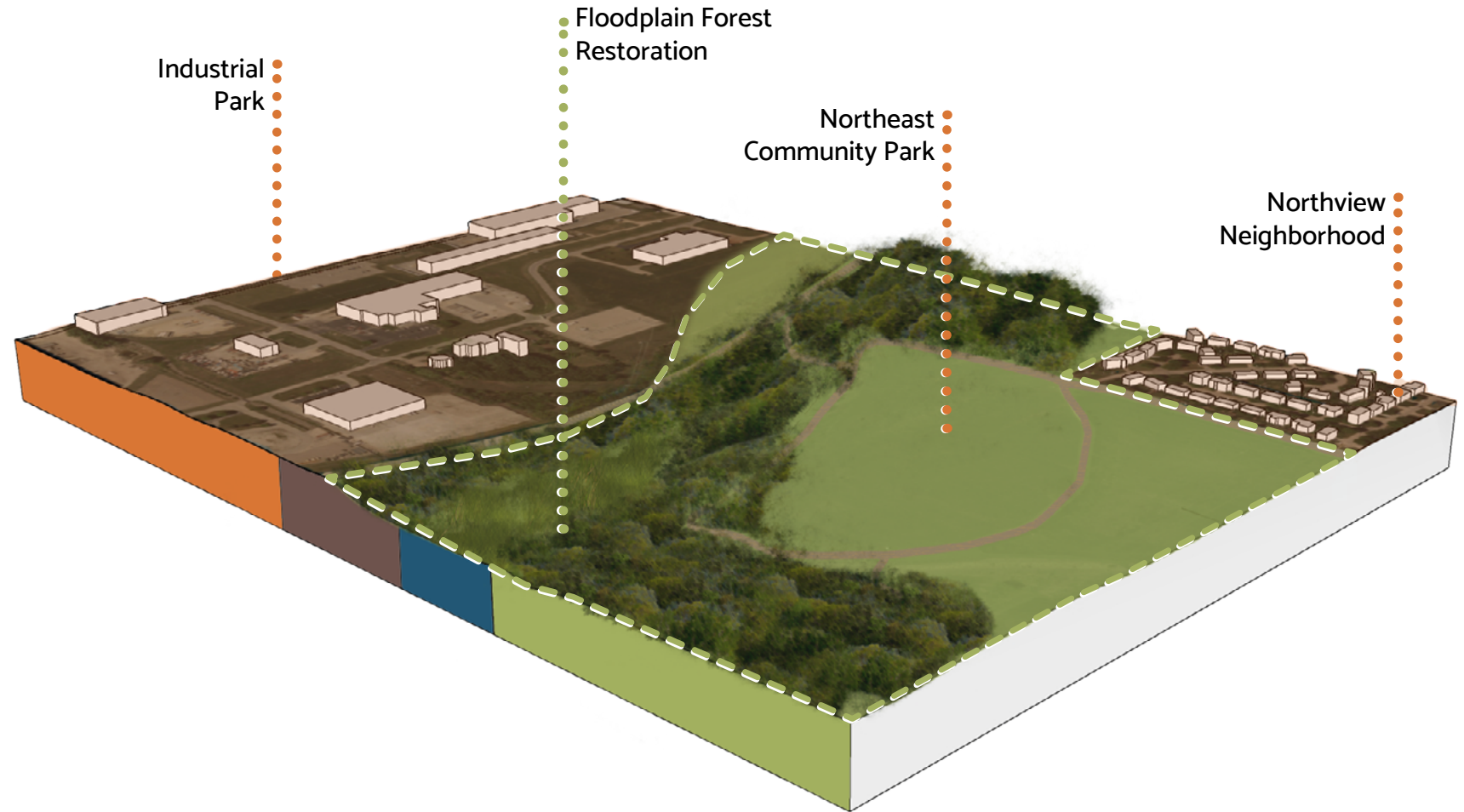


Figure 5.22: NE Community Park Transect Design



By expanding upon existing park infrastructure, this space will be more approachable to the public. Many survey respondents expressed concern about flooding in Northview since it is not protected by the levee. This approach adapts existing infrastructure by adding nature-based solutions that can be applied in multiple situations to mitigate flood risk and damage.

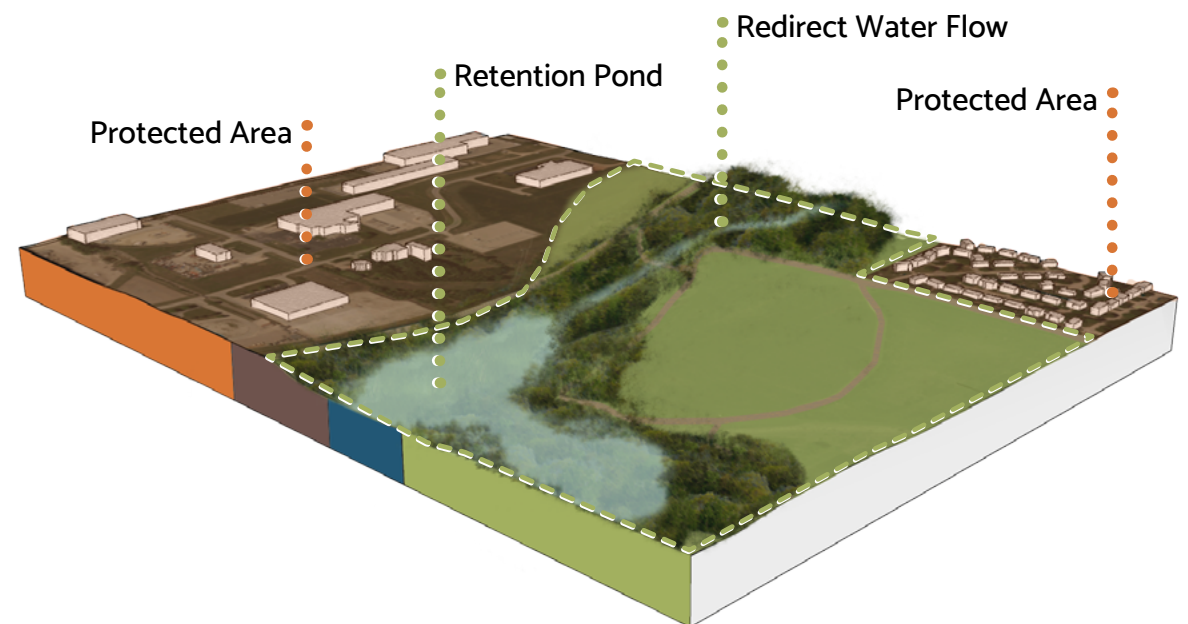


Figure 5.23: NE Community Park - Flood Conditions

Figure 5.24: NE Community Park Transect Site Plan



Floodplain Forest
Restoration

Retention
Pond

Trail
Connection

06

Conclusion

Key Findings

This report, culminating several months of research, design, and production, has developed an understanding of urban levees - mapping historical issues and proposing potential solutions for adaptive design of flood resilience structures. Ecological opportunities were addressed mostly through riverside solutions, focusing on floodplain restoration, water infiltration, and resilience. Social opportunities were fulfilled by synthesizing results from community surveys, working to create a visible, accessible, and interactive space near the levee and river, minimizing the barriers presented currently. Through this research-informed design process, the report examines and proposes solutions to the main research question, “How can levees be reimagined to enhance flood resilience, ecological function, and community access to the riverfront?”.

Various research methods were applied to address each of the research questions and meet identified objectives. A thorough review of the literature and levee guidelines provided insight into the benefits of combining man-made and natural flood mitigation strategies (Q 1-1), barriers to human-river interaction (Q 2-1), as well as how vegetation might impact the structural integrity of a traditional levee design (Q 1-2). Using major themes drawn from this literature review, a framework was created to assess existing projects as precedents for design solutions. These precedent studies showcased existing approaches to adaptive levee structures and identified successful design elements (Q 1-3). A community survey to assess existing perception, awareness, and interaction with the river further informed residents’ view of the current barriers (Q 2-1) and desire for specific interventions (Q 2-2). By assessing the

reaction to various design interventions in the survey (Q 2-3), the results were synthesized with ideas from previous research and precedent studies and used to inform projective design solutions.

Each research method presented unique results that contributed to the final project development. Some main takeaways from the survey included community desire for accessibility, increased use, and active programming. Many respondents noted that the lack of awareness is a larger obstacle than the physical barrier – people do not know that the riverfront is available for public recreation, or they have no desire to visit in its current state. However, most wanted to see better access, believe it is an asset to the city, and would be more likely to visit with better pedestrian access and awareness. Precedent studies offered unique perspectives on similar issues and provided guidance for the design proposal. The most successful examples implemented a multi-functional resilience approach, producing ecological and social benefits. Each project contained useful ideas with varying contexts, so it was important to assess the relevance and suitability to the proposed project when considering each strategy.

The research-informed design synthesizes these main ideas into specific solutions for the levee in Manhattan, Kansas, consisting of an overall strategic plan and five individual transect proposals. These adaptive strategies provide a unique approach to addressing both social and ecological issues of levee design in river cities.

Discussion & Limitations

Due to the nature of the research question and the scope of the project, this study has some limitations. Since the research was a part of the author’s master’s report, there were strict time constraints that must be met, and the expertise of the researcher was limited to their course of study. More in-depth research over the course of several seasons and a more involved design process would be beneficial to the final outcomes. However, this concise version is a well-developed base that may serve as a precedent for future research or be applied to other similar cities. Due to these time and budget constraints, convenience sampling was the method chosen to collect survey data. This may lead to certain types of bias (non-response, etc.) and cannot be considered representative of the entire Manhattan, Kansas population.

Manhattan, Kansas was chosen due to its history of flooding, current levee projects, and accessibility for research. This city is an appropriate case study for many cities in the Midwest, but typological solutions may not apply to all urban levee situations.

Also, the levee in Manhattan is currently under construction, which posed some limits to access for substantial site analysis but also provided an opportunity to discuss the existing project with stakeholders. Physical constraints on the project (i.e., distance between the levee and the river) are part of the research problem and considered in the design process but should also be noted as potential limitations of this study. Limitations in research are mainly related to existing available literature. The study only uses articles written in or translated into English, though many other projects have been conducted throughout Asia and Europe. In addition, many of the case studies found in the United States have been performed on the coast, meaning that strategies for these projects may or may not translate successfully to inland river systems. While this may limit the relevance of these examples to the study, it also provides an opportunity for this project to fill a gap in research and propose innovative application of these ideas in developed river corridors.

Contribution & Future Study

This research project contributes to the larger body of work in landscape architecture through the exploration of an existing gap in research and innovative strategies to produce an improved levee design that combines traditional typologies with more creative, nature-based adaptations and enhances human experience. Addressing the gap in research of river levees and the application of adaptive design methods allows this study to provide an example for the city of Manhattan, Kansas, and other midwestern river cities to expand upon. By considering the river a social-ecological system and understanding how people interact with the Manhattan riverfront, the designed solutions will work to improve public perception of the levee, desire for access, and value of the riparian corridor, and provide a case study to be applied to other cities interested in reintegrating their waterfronts with the public.



Figure 6.1: View from Manhattan Levee

References

- Andreadis, Konstantinos M, Oliver E J Wing, Emma Colven, Colin J Gleason, Paul D Bates, and Casey M Brown. 2022. "Urbanizing the Floodplain: Global Changes of Imperviousness in Flood-Prone Areas." *Environmental Research Letters* 17 (10): 104024. <https://doi.org/10.1088/1748-9326/ac9197>.
- Batlleiroig. n.d. "Parque Atlántico En Santander." Batlleiroig. <https://www.batlleiroig.com/projectes/parc-atlantic/>.
- Beagle, J., Lowe, J., McKnight, K., Safran, S., Tam, L., & Szambelan, S. J. 2019. Adaptation Measures. In San Francisco Bay Shoreline Adaptation Atlas. San Francisco Estuary Institute (SFEI) & San Francisco Bay Area Planning and Urban Research Association (SPUR). Publication #915, San Francisco Estuary Institute, Richmond, CA. https://www.spur.org/sites/default/files/2019-05/SPUR_SFEI_SF_Bay%20Shoreline_Adaptation_Atlas.pdf.
- Cabrera, Agustin. 2017. "Dominguez Gap Wetlands: Connecting Community to the Environment." *OurWaterLA*. December 21, 2017. <https://ourwaterla.org/dominguez-gap-wetlands-connecting-community-to-the-environment/>.
- Cecchetti, A. R., Stiegler, A. N., Graham, K. E., & Sedlak, D. L. 2020. The horizontal levee: a multi-benefit nature-based treatment system that improves water quality and protects coastal levees from the effects of sea level rise. *Water Research X*, 7. <https://doi.org/10.1016/j.wroa.2020.100052>.
- Chakraborty, Abhik, and Shamik Chakraborty. 2017. "Rivers as Socioecological Landscapes." In *Rivers and Society: Landscapes, Governance and Livelihoods*, edited by Malcolm Cooper, Abhik Chakraborty, and Shamik Chakraborty, 1st ed. London: Routledge. <https://doi.org/10.9774/gleaf.9781315680088>.
- City of Manhattan. 2021. "Resilient Wildcat Creek." <https://engagemhk.org/resilient-wildcat-creek>.
- City of Manhattan. 2022. "Construction of Manhattan levee upgrades set to begin." <https://cityofmhk.com/CivicAlerts.aspx?AID=2152>.
- City of Winona. 2007. "City of Winona Riverfront Revitalization Plan." <https://www.cityofwinona.com/DocumentCenter/View/2313/Riverfront-Plan-Final?bidId=>.
- Construction Industry Research and Information Association (CIRIA), United States Army. Corps of Engineers (USACE), & France. Ministère de l'écologie, du développement durable et de l'énergie. 2013. *The International Levee Handbook*. CIRIA.
- Creative Research Systems. 2012. "Sample Size Calculator". <https://www.surveysystem.com/sscalc.htm>.
- Dahl, Travis, Charles Theiling, and Waleska Echevarria. 2017. "Overview of Levee Setback Projects and Benefits." Coastal and Hydraulics Laboratory (U.S.). <https://doi.org/10.21079/11681/22767>.
- Ding, Meng, Peirong Lin, Shang Gao, Jida Wang, Zhenzhong Zeng, Kaihao Zheng, Xudong Zhou, Dai Yamazaki, Yige Gao, and Yu Liu. 2023. "Reversal of the Levee Effect towards Sustainable Floodplain Management." *Nature Sustainability*, August. <https://doi.org/10.1038/s41893-023-01202-9>.
- Eaton, Joe. 2013. "The Laid Back Levee – Estuary News Magazine." *Estuary News*, April 2013. <https://archive.estuarynews.org/estuary-news/the-laid-back-levee/>.

Federal Emergency Management Agency (FEMA). "Floodwalls and Levees Advantages and Disadvantages." n.d. https://emilms.fema.gov/is_0280/groups/22.html.

Groffman, Peter M., Daniel J. Bain, Lawrence E. Band, Kenneth T. Belt, Grace S. Brush, J Morgan Grove, Richard V. Pouyat, Ian C. Yesilonis, and Wayne C. Zipperer. 2003. "Down by the Riverside: Urban Riparian Ecology." *Frontiers in Ecology and the Environment* 1 (6): 315–21. [https://doi.org/10.1890/1540-9295\(2003\)001\[0315:DBTRUR\]2.0.CO;2](https://doi.org/10.1890/1540-9295(2003)001[0315:DBTRUR]2.0.CO;2).

H+N+S. n.d. "Room for the River Nijmegen." <http://www.hnsland.nl/en/projects/room-river-nijmegen/>.

ISG, Inc. n.d. "LEVEE PARK + MAIN STREET REVITALIZATION." <https://www.isginc.com/portfolio/levee-park-main-street-revitalization>.

Islam, Nazrul. 2020. *Rivers and Sustainable Development: Alternative Approaches and Their Implications*. New York, NY: Oxford University Press.

Juvera, Liz. 2021. "Oro Loma Living Laboratory." San Francisco Estuary Partnership (blog). August 30, 2021. <https://www.sfestuary.org/oro-loma-living-laboratory/>.

Kansas Department of Agriculture (KDA). 2018. "Floodplain Management in Kansas: Quick Guide." <https://agriculture.ks.gov/docs/default-source/dwr-floodplains/kansas-floodplain-quick-guide.pdf?sfvrsn=4>.

Kershner, Jessi, and Kathryn Braddock. 2021. "Using Horizontal Levees to Buffer the Effects of Sea Level Rise in San Francisco Bay." *Climate Adaptation Knowledge Exchange (CAKE)*. 2021. <https://www.cakex.org/case-studies/using-horizontal-levees-buffer-effects-sea-level-rise-san-francisco-bay>.

Knox, R. L. 2022. *The Geography of Artificial Levees in the United States* [Colorado State University]. In ProQuest Dissertations and Theses. <https://er.lib.k-state.edu/login?url=https://www.proquest.com/dissertations-theses/geography-artificial-levees-united-states/docview/2673353382/se-2?accountid=11789>.

Kondolf, G. Mathias, and Pedro J. Pinto. 2017. "The Social Connectivity of Urban Rivers." *Geomorphology* (Amsterdam, Netherlands) 277: 182–96. <https://doi.org/10.1016/j.geomorph.2016.09.028>.

Land8: Landscape Architects Network (Land8). 2015. "Atlantic Park Combines Ecology and Community to Create a Spectacular Urban Space." *Land8* (blog). March 31, 2015. <https://land8.com/atlantic-park-combines-ecology-and-community-to-create-a-spectacular-urban-space/>.

Landezine. 2023. "Atlantic Park in Santander by Batlleiroig." *Landezine* (blog). 2023. <https://landezine.com/atlantic-park-in-santander-by-batlleiroig/>.

Los Angeles County Public Works (LACPW). 2008. "Los Angeles County Flood Control District Opens Historic LA River Wetlands Project." 2008. https://pw.lacounty.gov/wmd/documents/DominguezGap_article.cfm.

Los Angeles County Public Works (LACPW). n.d. "Dominguez Gap Wetlands." Accessed January 27, 2024. <https://pw.lacounty.gov/swp/dominguezgapwetlands/>.

May, Rachel. 2006. "'Connectivity' in Urban Rivers: Conflict and Convergence between Ecology and Design." *Technology in Society* 28 (4): 477–88. <https://doi.org/10.1016/j.techsoc.2006.09.004>.

McCool, Daniel. 2012. “River City: Urban Riverscapes”. In *River Republic: The Fall and Rise of America’s Rivers*. Edited by Daniel McCool, 219– 23. New York: Columbia University Press.

McCully, Patrick. 2007. “Before the Deluge: Coping with Floods in a Changing Climate,” *IRN Dams, Rivers and People Report 2007*, International Rivers Network, Berkeley, CA.

McKean, Cameron Allan. 2013. “Tokyo Building Enormous ‘Super-Levees’ to Hold Back Its River.” *Next City News*. 2013. <https://nextcity.org/urbanist-news/tokyo-is-building-enormous-super-levees-to-hold-back-its-river>.

Ministry of Land, Infrastructure and Transport (MLIT). n.d. “Flood Management in Japan.” *River Bureau*. https://www.narbo.jp/data/o4_materials/ma_fmij.pdf.

Memon, Mumtaz Ali, Hiram Ting, Jun-Hwa Cheah, Ramayah Thurasamy, Francis Chuah, and Tat Huei Cham. 2020. “Sample Size for Survey Research: Review and Recommendations.” *Journal of Applied Structural Equation Modeling* 4 (2): i–xx. [https://doi.org/10.47263/JASEM.4\(2\)01](https://doi.org/10.47263/JASEM.4(2)01).

Monda, Matthew J., Kerry L. Wedel, and Eric Schenck. 1993. “Classification of Wetland and Riparian Areas in Kansas.” *State of Kansas*. https://kwo.ks.gov/docs/default-source/project-pages/wetland-program/classification-of-wetland-and-riparian-areas-in-kansas.pdf?sfvrsn=a5e98414_2.

Montz, Burrell E., and Graham A. Tobin. 2008. “Livin’ Large with Levees: Lessons Learned and Lost.” *Natural Hazards Review* 9 (3): 150–57. [https://doi.org/10.1061/\(ASCE\)1527-6988\(2008\)9:3\(150\)](https://doi.org/10.1061/(ASCE)1527-6988(2008)9:3(150)).

Netherlands Water Partnership. 2019. “Room for the River Programme | Dutch Water Sector.” 2019. <https://www.dutchwatersector.com/news/room-for-the-river-programme>.

Nunnally, Nelson R., F. Douglas Shields, and James Hynson. 1987. “Environmental Considerations for Levees and Floodwalls.” *Environmental Management* 11 (2): 183–91. <https://doi.org/10.1007/BF01867197>.

Okamoto, Ariel Rubissow. 2015. “Oro Loma and Castro Valley Sanitary Districts to Test Experimental Levee.” *Oro Loma Sanitary District*. <https://oroloma.org/wp-content/uploads/horizontal-levee-overview.pdf>.

O’Leary, Zina. 2007. *The Essential Guide to Doing Research*. Repr., (Twice). London: SAGE.

Parsons, Melissa. 2019. “Extreme Floods and River Values: A Social–Ecological Perspective.” *River Research and Applications* 35 (10): 1677–87. <https://doi.org/10.1002/rra.3355>.

Pierce County Public Works Surface Water Management. 2016. “Levee Vegetation Management.” <https://www.piercecountywa.gov/ArchiveCenter/ViewFile/Item/4622>.

Plane, Ellen, and Kelly Iknayan. 2021. “Ecotone Levees and Wildlife Connectivity: A Technical Update to the Adaptation Atlas.” Publication #1037, San Francisco Estuary Institute, Richmond, CA. https://www.sfei.org/sites/default/files/biblio_files/AdaptationAtlas_TechnicalUpdate_September%202021_medres.pdf.

Roscoe, J. T. 1975. “Fundamental research statistics for the behavioral sciences” (Second ed.). New York: Holt Rinehart and Winston.

Shafroth, P. B., Stromberg, J. C., & Patten, D. T. 2002. Riparian Vegetation Response to Altered Disturbance and Stress Regimes 12 (1). [https://doi.org/10.1890/1051-0761\(2002\)012\[0107:RVRTAD\]2.0.CO;2](https://doi.org/10.1890/1051-0761(2002)012[0107:RVRTAD]2.0.CO;2).

Tokyo Development Learning Center (TDLC). 2017. “Protecting from Catastrophic Floods While Boosting Shared Prosperity with Super Levees.” https://programme.worldwaterweek.org/Content/ProposalResources/PDF/2017/pdf-2017-7137-1-Japan%20Project%20Brief_ArakawaShinden.pdf.

United States Army Corps of Engineers (USACE). n.d.. National Levee Safety Guidelines - Chapter 2 - Understanding Levee Fundamentals.

United States Army Corps of Engineers (USACE). 2019. “Guidelines for Landscape Planting and Vegetation Management at Levees, Floodwalls, Embankment Dams, and Appurtenant Structures”. https://www.publications.usace.army.mil/Portals/76/Users/182/86/2486/EP_1110-2-18.pdf?ver=bVt-L-DvQrASeFS6szPNaw%3D%3D.

United States Census Bureau. 2020. “QuickFacts: Manhattan, KS”. <https://www.census.gov/quickfacts/fact/table/manhattancitykansas/POP010220#POP010220>.

Vercruysse, Kim, Robert C. Grabowski, Ian Holman, Adani Azhoni, Brij Bala, Jeroen Meersmans, Jian Peng, et al. 2022.

“Place based Interpretation of the Sustainable Development Goals for the Land river Interface.” Sustainability Science 17: 1695–1714. <https://doi.org/10.1007/s11625-022-01176-1>.

World Bank. 2019. “Learning from Japan’s Experience in Integrated Urban Flood Risk Management: A Series of Knowledge Notes—Appendix: Case Studies in Integrated Urban Flood Risk Management in Japan.” World Bank, Washington, D.C.

Zhang, Fuping, Guoqiang Liu, Zhenyang Peng, Jun Chen, and Zijie He. 2021. “Research on Urban Ecological Levees under the Background of the Great Protection of the Yangtze River.” IOP Conference Series: Earth and Environmental Science 781 (3): 032018. <https://doi.org/10.1088/1755-1315/781/3/032018>.

Zhu, Tingju, Jay R. Lund, Marion W. Jenkins, Guilherme F. Marques, and Randall S. Ritzema. 2007. “Climate Change, Urbanization, and Optimal Long-Term Floodplain Protection.” Water Resources Research 43 (6): W06421-n/a. <https://doi.org/10.1029/2004WR003516>.

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Data retrieved from ArcGIS:

- University of Kansas. Kansas Ecological Systems Map. ArcGIS Map Service. https://tiles.arcgis.com/tiles/ZOdjAzAQ2Bof85zi/arcgis/rest/services/morap_webmerc/MapServer/o.

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Data retrieved from ArcGIS:

- City of Manhattan, KS - Community Development and GIS. comBoundary_CoreData_Current. Feature Service Feature Class. https://services.arcgis.com/rFQQFFw3jz8ox3VY/arcgis/rest/services/M_CityLimit/FeatureServer
- FEMA. Flood Zones. Feature Service Feature Class. https://services.arcgis.com/rFQQFFw3jz8ox3VY/arcgis/rest/services/Flood_Zones/FeatureServer.
- University of Kansas. Kansas Ecological Systems Map. ArcGIS Map Service. https://tiles.arcgis.com/tiles/ZOdjAzAQ2Bof85zi/arcgis/rest/services/morap_webmerc/MapServer/o.

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Data retrieved from ArcGIS –

- City of Manhattan, KS - Community Development and GIS. Manhattan Zoning Districts. Feature Service Feature Class. https://services.arcgis.com/6WmEmDp2YlKJhJt/arcgis/rest/services/MHK_Zoning__Manhattan_Development_Code_Updates_/FeatureServer.

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Data retrieved from ArcGIS –

- City of Manhattan, KS - Community Development and GIS. Manhattan Zoning Districts. Feature Service Feature Class. https://services.arcgis.com/6WmEmDp2YlKJhJt/arcgis/rest/services/MHK_Zoning__Manhattan_Development_Code_Updates_/FeatureServer
- FEMA. Flood Zones. Feature Service Feature Class. https://services.arcgis.com/rFQQFFw3jz8ox3VY/arcgis/rest/services/Flood_Zones/FeatureServer.

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- City of Manhattan, KS - Community Development and GIS. Manhattan Zoning Districts. Feature Service Feature Class. https://services.arcgis.com/6WmEmDp2YlKJjhJt/arcgis/rest/services/MHK_Zoning__Manhattan_Development_Code_Updates_/FeatureServer.

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- University of Kansas. Kansas Ecological Systems Map. ArcGIS Map Service. https://tiles.arcgis.com/tiles/ZOdjAzAQ2Bof85zi/arcgis/rest/services/morap_webmerc/MapServer/o.

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- Data retrieved from ArcGIS –
- FEMA. Flood Zones. Feature Service Feature Class. https://services.arcgis.com/rFQQFFw3jz8ox3VY/arcgis/rest/services/Flood_Zones/FeatureServer.

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- Data retrieved from ArcGIS –
- City of Manhattan, KS - Community Development and GIS. Manhattan Zoning Districts. Feature Service Feature Class. https://services.arcgis.com/6WmEmDp2YlKJjhJt/arcgis/rest/services/MHK_Zoning__Manhattan_Development_Code_Updates_/FeatureServer.

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- University of Kansas. Kansas Ecological Systems Map. ArcGIS Map Service. https://tiles.arcgis.com/tiles/ZOdjAzAQ2Bof85zi/arcgis/rest/services/morap_webmerc/MapServer/o.

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- Data retrieved from ArcGIS –
- FEMA. Flood Zones. Feature Service Feature Class. https://services.arcgis.com/rFQQFFw3jz8ox3VY/arcgis/rest/services/Flood_Zones/FeatureServer.

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- Data retrieved from ArcGIS –
- City of Manhattan, KS - Community Development and GIS. Manhattan Zoning Districts. Feature Service Feature Class. https://services.arcgis.com/6WmEmDp2YlKJhJt/arcgis/rest/services/MHK_Zoning__Manhattan_Development_Code_Updates_/FeatureServer.

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- Data retrieved from ArcGIS –
- University of Kansas. Kansas Ecological Systems Map. ArcGIS Map Service. https://tiles.arcgis.com/tiles/ZOdjAzAQ2Bof85zi/arcgis/rest/services/morap_webmerc/MapServer/o.

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- Data retrieved from ArcGIS –
- FEMA. Flood Zones. Feature Service Feature Class. https://services.arcgis.com/rFQQFFw3jz8ox3VY/arcgis/rest/services/Flood_Zones/FeatureServer.

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- Data retrieved from ArcGIS –
- City of Manhattan, KS - Community Development and GIS. Manhattan Zoning Districts. Feature Service Feature Class. https://services.arcgis.com/6WmEmDp2YlKJhJt/arcgis/rest/services/MHK_Zoning__Manhattan_Development_Code_Updates_/FeatureServer.

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- University of Kansas. Kansas Ecological Systems Map. ArcGIS Map Service. https://tiles.arcgis.com/tiles/ZOdjAzAQ2Bof85zi/arcgis/rest/services/morap_webmerc/MapServer/o.

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- Data retrieved from ArcGIS –
- FEMA. Flood Zones. Feature Service Feature Class. https://services.arcgis.com/rFQQFFw3jz8ox3VY/arcgis/rest/services/Flood_Zones/FeatureServer.

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- Data retrieved from ArcGIS –
- City of Manhattan, KS - Community Development and GIS. Manhattan Zoning Districts. Feature Service Feature Class. https://services.arcgis.com/6WmEmDp2YlKJjhJt/arcgis/rest/services/MHK_Zoning__Manhattan_Development_Code_Updates_/FeatureServer.

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- Data retrieved from ArcGIS –
- FEMA. Flood Zones. Feature Service Feature Class. https://services.arcgis.com/rFQQFFw3jz8ox3VY/arcgis/rest/services/Flood_Zones/FeatureServer.

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Base Image from Google Earth:

- Google Earth. 2023. Aerial View of Manhattan, KS. Google Satellite Imagery. Accessed March 6, 2024. <https://earth.google.com/web/@39.18448022,-96.56183917,8843.1674953a,od,35y,359.9968h,ot,or/data=OgMKATA>.

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Figure 5.8: Mueller, Abigail. 2024. *Linear Trail Transect Site Plan*. Digital Image.

Base Image from Google Earth:

- Google Earth. 2023. Aerial View of Linear Trail Entrance, Manhattan, KS. Google Satellite Imagery. Accessed April 4, 2024. <https://earth.google.com/web/@39.17285911,-96.5682576,310.80022667a,3011.71728625d,35y,359.99439789h,ot,or/data=OgMKATA>.

Figure 5.9: Mueller, Abigail. 2024. *Residents use trail for recreation and access*. Digital Image.

Figure 5.10: Mueller, Abigail. 2024. *Industrial Park Transect Design*. Digital Image.

Figure 5.11: Mueller, Abigail. 2024. *Industrial Park - Flood Conditions*. Digital Image.

Figure 5.12: Mueller, Abigail. 2024. *Industrial - Park Transect Site Plan*. Digital Image.

Base Image from Google Earth:

- Google Earth. 2023. Aerial View of Midwest Concrete Materials Site, Manhattan, KS. Google Satellite Imagery. Accessed April 4, 2024. <https://earth.google.com/web/@39.17264601,-96.55654147,-27021.08335454a,29235.99984409d,35y,0.0041h,ot,or/data=OgMKATA>.

Figure 5.13: Mueller, Abigail. 2024. *Expanded park space at industrial site*. Digital Image.

Figure 5.14: Mueller, Abigail. 2024. *Town Center Crossing Transect Design*. Digital Image.

Figure 5.15: Mueller, Abigail. 2024. *Town Center Crossing - Flood Conditions*. Digital Image.

Figure 5.16: Mueller, Abigail. 2024. *Town Center Crossing Transect Site Plan*. Digital Image.

Base Image from Google Earth:

- Google Earth. 2023. Aerial View of Manhattan Town Center, Manhattan, KS. Google Satellite Imagery. Accessed April 7, 2024. <https://earth.google.com/web/@39.17865864,-96.55541605,-26969.87089794a,28891.59480959d,35y,0.0008h,ot,or/data=OgMKATA>.

Figure 5.17: Mueller, Abigail. 2024. *Visitors walk along wetland boardwalk*. Digital Image.

Figure 5.18: Mueller, Abigail. 2024. *Water Treatment Transect Design*. Digital Image.

Figure 5.19: Mueller, Abigail. 2024. *Water Treatment - Flood Conditions*. Digital Image.

Figure 5.20: Mueller, Abigail. 2024. *Water Treatment Transect Site Plan*. Digital Image.

Base Image from Google Earth:

- Google Earth. 2023. Aerial View of Wastewater Treatment Plant, Manhattan, KS. Google Satellite Imagery. Accessed April 9, 2024. <https://earth.google.com/web/@39.187876,-96.53831765,-26855.89495938a,29916.38439219d,35y,o.0117h,ot,or/data=OgMKATA>.

Figure 5.21: Mueller, Abigail. 2024. *Ecotone habitat improves water quality*. Digital Image.

Figure 5.22: Mueller, Abigail. 2024. *NE Community Park Transect Design*. Digital Image.

Figure 5.23: Mueller, Abigail. 2024. *NE Community Park - Flood Conditions*. Digital Image.

Figure 5.24: Mueller, Abigail. 2024. *NE Community Park Transect Site Plan*. Digital Image.

Base Image from Google Earth:

- Google Earth. 2023. Aerial View of Northeast Community Park, Manhattan, KS. Google Satellite Imagery. Accessed April 9, 2024. <https://earth.google.com/web/@39.19954389,-96.54469419,-26773.73829652a,29833.77868638d,35y,o.0077h,ot,or/data=OgMKATA>.

Figure 5.25: Mueller, Abigail. 2024. *Trail connection at NE Community Park*. Digital Image.

Chapter 6

Figure 6.1: Mueller, Abigail. 2023. *View from Manhattan Levee*. Photograph.

Appendix

Appendix A: IRB Exemption Letter



TO: Hyung Kim
Landscape Archit & Comm Plan
Manhattan, KS 66506

Proposal Number: IRB-11958

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

DATE: 12/08/2023

RE: Proposal Entitled, “On Either Side of the Levee: Exploring Social and Ecological Benefits of Adaptive Flood Resilience Strategies.”

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

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

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

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

Electronically signed by Lisa Rubin on 12/08/2023 5:22 PM ET

Appendix B: Survey Questions

SURVEY: Re-imagining Manhattan, KS Levee and Riverfront

Hello, my name is Abigail Mueller, and I am a graduate student studying Landscape Architecture at Kansas State University. This survey aims to assess surrounding neighborhoods’ awareness of, access to, and perception of the existing levee system in Manhattan and potential levee design solutions to inform my master’s report research. It should take no longer than 15 minutes to complete this survey.

There are no known risks associated with participating in this study. You may not receive any direct benefits from your participation, but we hope your answers will have the opportunity to inform design interventions for the levee in Manhattan, KS, and potential application to other urban rivers in the Midwest. Participation is voluntary. Refusal to participate will involve no penalty or loss of benefits to which the subject is otherwise entitled, and the subject may discontinue participation at any time without penalty or loss of benefits. Any relevant results will be published in the researcher’s master’s report, which will be publicly available via K-State K-Rex.

All collected information will be kept confidential and accessed only by the research team. Results will be anonymous, and the identities of the participants will not be identified in the report. Your information will not be used or distributed for future research studies. The data will be stored securely for three years and destroyed when no longer needed to conduct the study.

If you have any questions or concerns, contact the researchers:
Abigail Mueller
Master’s Student, Department of Landscape Architecture and Regional & Community Planning
abigail18@ksu.edu; or

Hyung Jin Kim, Ph.D.
Associate Professor, Department of Landscape Architecture and Regional & Community Planning
hyungjin@ksu.edu, (785) 532-2439.

If you have any questions about your rights as a research subject, you may speak with:
Lisa Rubin
Chair, Committee on Research Involving Human Subjects
203 Fairchild Hall, Kansas State University
Manhattan, KS 66506
(785)532-3224

By completing this survey, you are giving your consent to participate.

Thank you for taking the time to participate in this survey. Your answers are greatly appreciated!

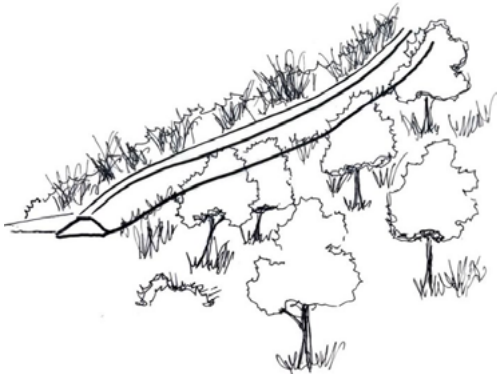
- How often do you interact with waterfronts in Manhattan?
 - Daily
 - Weekly
 - Monthly
 - Yearly
 - Never
- Which waterfront in Manhattan do you interact with the most?
 - Kansas River
 - Big Blue River
 - Wildcat Creek
 - Other (specify): _____
- What draws you to interact with these waterfronts? What activities do you take part in?
 - Biking
 - Walking
 - Access to nature
 - Boating/kayaking
 - Fishing
 - Social Activities
 - Camping
 - Picnic
 - Other (specify): _____
- How often do you use Linear Trail on the levee (when open to the public)?
 - Daily
 - Weekly
 - Monthly
 - Yearly
 - Never
- If you go to the river, which access point do you use?
 - Fairmount Boat Launch
 - Fairmount Park & Trails
 - Linear Park
 - River Trails & Outlook
 - I don’t know how to access the riverfront.
 - Other (specify): _____
- What would you consider the biggest obstacle to river access currently?
 - Highway
 - Railroad
 - Levee
 - Dense woodland
 - Lack of information
 - Lack of interest/desire
 - Lack of access points, trails/sidewalks, or pedestrian connection
 - Lack of parking space
 - Safety concerns
 - I don’t know
 - Other (specify): _____

- What would make you more likely to visit the river?
 - Better access for pedestrians and bikers
 - Better access for drivers
 - Cleaner water quality
 - More awareness of the river and trails (signage, information, etc.)
 - More greenery
 - More river activities
 - More people visiting the river
 - None of the above / I am not interested in visiting the river
 - Other (specify): _____
- What are your thoughts on the current levee? The improvement plan?

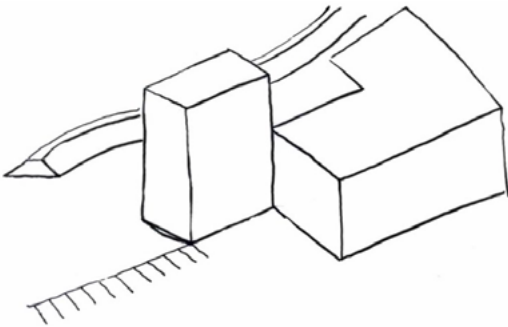
The following questions are about your **thoughts on the levee, nature, and riverfront areas within the City of Manhattan**. Please select how much you agree with each of the following statements, on a five-point scale (1: strongly disagree - 5: strongly agree).

Statement	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
The river is a valuable asset to the City of Manhattan.					
I know where the levee is located.					
The levee is successful in protecting the city from flooding.					
The levee contributes to the sense of safety I feel where I live.					
In its current state, the river is accessible to the public.					
Improved access to the river will be beneficial to me personally.					
Improved access to the river will be beneficial to the larger Manhattan community.					
I would like to see more development along the riverfront (businesses, restaurants, shops, housing).					
I would like to see more public space along the riverfront (parks, playgrounds, other amenities).					
It is important to me to have access to nature.					
I would consider myself an active outdoors person.					
Parks contribute to the sense of community I feel in my neighborhood.					

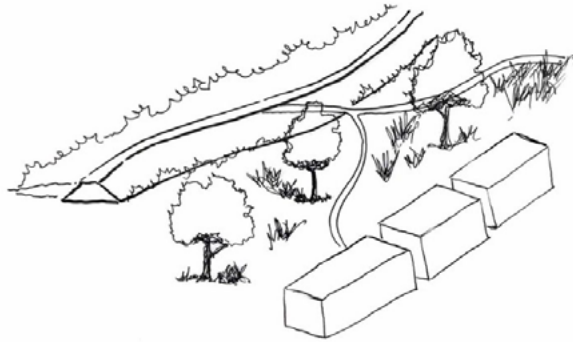
The following questions ask about your preference on various levee design ideas to enhance access to the river in Manhattan. The function, stability and capacity of the Manhattan levee will be the same for each scenario. Please answer how likely you would be to interact with the levee/riverfront in each design idea, on a five-point scale (1: very unlikely - 5: very likely).



- 1) Fully Ecological Approach
- If a design like this were implemented, how likely would you be to visit?
 - 1 (Very unlikely)
 - 2 (Unlikely)
 - 3 (Neutral)
 - 4 (Likely)
 - 5 (Very likely)

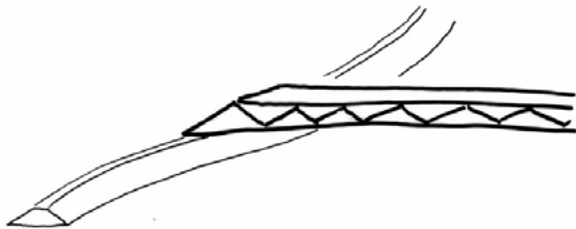


- 2) Fully Developed Approach
- If a design like this were implemented, how likely would you be to visit?
 - 1 (Very unlikely)
 - 2 (Unlikely)
 - 3 (Neutral)
 - 4 (Likely)
 - 5 (Very likely)



3) Hybrid Ecological / Developed Approach

- If a design like this were implemented, how likely would you be to visit?
 - 1 (Very unlikely)
 - 2 (Unlikely)
 - 3 (Neutral)
 - 4 (Likely)
 - 5 (Very likely)



4) Physical Accessibility (Pedestrian Bridge)

- If a design like this were implemented, how likely would you be to visit?
 - 1 (Very unlikely)
 - 2 (Unlikely)
 - 3 (Neutral)
 - 4 (Likely)
 - 5 (Very likely)

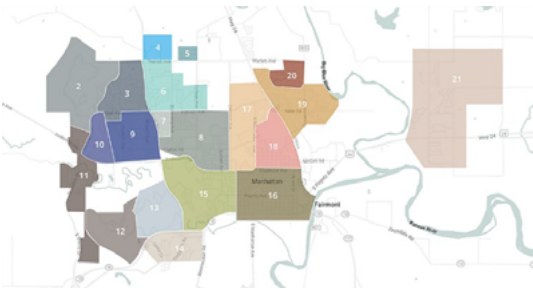


- Do you have any other suggestions for improvements to the levee and/or access to the river in Manhattan? Share your vision of a successful riverfront.

Please tell us about yourself and your household

- What is your age?
 - 18-25
 - 25-40
 - 40-65
 - 65+
 - Prefer not to answer
- What is your gender?
 - Woman
 - Man
 - Nonbinary
 - Other
 - Prefer not to answer
- Do you have children?
 - Yes
 - No
 - Prefer not to answer
- Do you have pets?
 - Yes
 - No
 - Prefer not to answer

Select the neighborhood in which you reside:



Appendix C: Survey Distribution

Downtown MHK Newsletter

GS

Gina Snyder <historicdowntown@gmail.com>

DMI Annual Calendar 2024.docx

23 KB

This email originated from outside of K-State.

Hello Neighbors! Happy New Year!

The 2024 downtown event calendar is attached to this email. Also, please look for the Annual Downtown Stakeholders Survey in your email next week. It is an important tool in framing our goals for the future and we cannot do that, without you.

Riverfront and Levee Survey

You have the opportunity to partake in a riverfront and levee survey from a Master's student at K-State. If you are interested in giving your feedback, Follow this link to the Survey:

[Take the Survey.](#)

Qualtrics Email List

Hello everyone!

I am a graduate student at K-State researching riverfront access and people's views on the levee in Manhattan, KS. I am currently using a survey to gather responses from people around town to help guide the next steps of my master's project and report. I received this list of emails from Phil Anderson, who shared them with me because you all have expressed interest in a riverfront project in the past. Responses will be anonymous. If you have a few minutes to spend participating in my survey I would greatly appreciate it! (See link below)

Feel free to reach out to me if you have any questions. Thank you so much, and happy new year!

Abby Mueller (she/her)

Kansas State University | College of Architecture, Planning & Design

Landscape Architecture | 5th Year M.L.A.

abymu@ksu.edu | 620-289-3523

Follow this link to the Survey:

[Take the Survey](#)

Or copy and paste the URL below into your internet browser:

https://kstate.qualtrics.com/jfe/form/SV_cOob7Yu2MKWcPNI?Q_DL=Y8IMFZ5ph1Obssz3_cOob7Yu2MKWcPNI_CGC_HNHYSXS5FNv0Jeqb&Q_CHI=email

Follow the link to opt out of future emails:

[Click here to unsubscribe](#)

Facebook & NextDoor Posts

Abby Mueller

Manhattan KS Regional Forum

January 15 • 🌐

Hello everyone!

I'm a graduate student at K-State researching riverfront access and people's views on the levee in Manhattan. I will be using a survey to gather responses from people around Manhattan to help guide my project. If you have a few minutes to spend participating in my survey I would really appreciate it!

Thank you so much!

KSTATE.QUALTRICS.COM

Qualtrics Survey | Qualtrics Experience Management

View in group

Abby Mueller

Manhattan Kansas Community Discussion Board

January 7 • 🌐

Hello everyone! I'm a graduate student at K-State researching riverfront access and people's views on the levee in Manhattan. I will be using a survey to gather responses from people around town to help guide my project. If you have a few minutes to spend participating in my survey I would really appreciate it! Thank you so much, and happy new year!

KSTATE.QUALTRICS.COM

Qualtrics Survey | Qualtrics Experience Management

View in group

Abby Mueller

"MANHAPPINESS" Happenings and Events in and around Manhattan, KS

January 15 • 🌐

Hello everyone!

I'm a graduate student at K-State researching riverfront access and people's views on the levee in Manhattan. I will be using a survey to gather responses from people around Manhattan to help guide my project. If you have a few minutes to spend participating in my survey I would really appreciate it!

Thank you so much!

KSTATE.QUALTRICS.COM

Qualtrics Survey | Qualtrics Experience Management

View in group

Abby Mueller

Aggieville • 2 Jan • 🌐

Hello everyone!

I'm a graduate student at K-State researching riverfront access and people's views on the levee in Manhattan. I will be using a survey to gather responses from people around town to help guide my project. If you have a few minutes to spend participating in my survey I would really appreciate it!

Thank you so much, and happy new year!

https://kstate.qualtrics.com/jfe/form/SV_cOob7Yu2MKWcPNI

Qualtrics Survey | Qualtrics Experience Management

kstate.qualtrics.com

4

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220

221

Appendix D: Precedent Study

Inclusion - Exclusion Criteria

	Inclusion							Exclusion		
	Waterfront adjacent (inland body of water)	Flood resilience structure or component	Completed or partially completed	Social benefits provided	Ecological benefits provided	Semi-urban area		Coastal	Incomplete	High urban density
Oro Loma: Horizontal Levee Project	x	x	x		x	x		x		
Dominguez Gap Wetlands	x	x	x	x	x	x				
Japan Super Levees	x	x	x	x		x				x
Greater New Orleans Urban Water Plan	x	x		x	x				x	x
Room for the River – urbanNext	x	x	x	x	x	x				
Palo Alto Horizontal Levee Pilot Project	x	x			x			x	x	
Sears Point Wetland Restoration	x	?	x		x			x		
Chicago Riverwalk	x	x	x	x	x					x
Atlantic Park in Santander (Spain)	x	x	x	x	x					x
Waterloo Greenway Conservancy (ATX) https://thefield.asla.org/2023/06/15/restoring-a-neglected-landscape/	x			x	x				x	x
Projects - The Greenway Foundation (DEN) https://westernslopeconservation.org/paonia-river-park/ https://www.uncovercolorado.com/activities/paonia-river-park/	x		x	x	x				x	x
Levee Park + Main Street Revitalization Case Study	x	x	x	x	?	x				
Prague - https://worldlandscapearchitect.com/omgeving/	x	x		x	x				x	x
Cedar Rapids Riverfront – Sasaki https://landscapearchitecturemagazine.org/2016/10/19/cedar-rapids-riverfront/ https://www.thegazette.com/local-government/cedar-rapids-riverfront/	x			x	x	x			x	
*1 - E = Total of 4										