

Designing for Change: Design solutions for anthropogenic and climate change impacts on riparian ecosystems and hydrology in Northeast Kansas.

By

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A REPORT

Submitted in partial fulfillment of the requirements for the degree

MASTER OF LANDSCAPE ARCHITECTURE

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KANSAS STATE UNIVERSITY

Manhattan, Kansas

2021

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Abstract

Anthropogenic climate change has been recognized as a threat to rivers and their riparian corridor. Climactic conditions influenced by anthropogenic activity such as temperature increase, extended drought periods, large precipitation events, and water shortages are projected to rapidly increase within the next century. This project addresses some of the negative effects of anthropogenic climate change on the Kansas River. These effects include channel function, floodplain disconnection from the river, and riparian ecosystem fragmentation (fragmentation of native riparian habitats, both freshwater and terrestrial species).

This project approaches riparian vegetation and floodplain restoration through the use of the existing physical integrity of the river channel and floodplain as a template to reconnect the Kansas and Wakarusa Rivers to their geomorphic floodplain, in conjunction with expansion of the native riparian vegetation buffers. Native riparian vegetation and floodplain restoration implementation and management strategies were assessed in case studies and projected onto four study sites in this project: three on the Kansas River, and one on the Wakarusa River (a tributary of the Kansas River). The purpose of this project is to provide examples of native riparian vegetation and floodplain restoration application within the context of landscape architecture in Kansas at sites with varying existing site conditions and needs.

A detailed botanical line drawing of a plant. The base of the plant features a dense rosette of long, narrow, blade-like leaves that radiate from a central point. Several upright, slender stems emerge from the center of the rosette. These stems are branched, with each branch bearing a cluster of small, numerous flowers or fruits. The overall appearance is that of a herbaceous plant, possibly a species of grass or a small flowering plant in the same family.



(Figure by author 2021)

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Acknowledgments

I have been extremely lucky to receive as much support and encouragement as I did during my five years at Kansas State in the landscape architecture program. Many friends and mentors have been gained during the program.

I want to first thank my husband, Noah. Thank you for all your unconditional support of me and my work. Within the 2020-2021 school year we got married, survived a global pandemic, and graduated college. You and Sydney (our dog) have been on many adventures during our time at K-State and will have many more in the future.

To my family, thank you for your constant support and encouragement during my time at K-State and in life. Mom, Dad, Megan, and Ian, thank you for your full support of me transferring colleges after my first year to pursue the 5-year landscape architecture master's degree at K-State, driving up to Manhattan to attend all my events, and your unconditional love. Sharon and Royce, thank you for your love and support.

Next, I would like to thank my Grandma Sara for instilling a love for nature at an early age [e.g., traveling all over Kansas for 4-H geology trips, the importance of not killing insects, and love for gardening (both flowers and vegetables)]. I cherished our phone calls and the relevant sources you sent me in the mail relating to whatever topic I was studying each semester.

Additionally, I would like to thank all the professors who taught me in the landscape architecture department during my academic career. I have never had teachers who cared as much about their student's success as you did. Additionally, I would like to thank my major professor, Dr. Timothy Keane for your guidance during this report. Finally, I want to thank my committee members Dr. Kimberly With and Dr. Walter Dodds; I learned so much about the importance of the field of ecology during the research for this report thanks to you.

Abstract

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This project approaches riparian vegetation and floodplain restoration through the use of the existing physical integrity of the river channel and floodplain as a template to reconnect the Kansas and Wakarusa Rivers to their geomorphic floodplain, in conjunction with expansion of the native riparian vegetation buffers. Native riparian vegetation and floodplain restoration implementation and management strategies were assessed in case studies and projected onto four study sites in this project: three on the Kansas River, and one on the Wakarusa River (a tributary of the Kansas River). The purpose of this project is to provide examples of native riparian vegetation and floodplain restoration application within the context of landscape architecture in Kansas at sites with varying existing site conditions and needs.

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Glossary

Anthropogenic -

Human-caused impact on the environment (European Environmental Agency 2020).

Biodiversity -

The count of species in an area. This term can be used interchangeably with species richness (Pimm 2020).

Bankfull Stage -

"The state at which water starts to flow over the floodplain" (Leopold, Emmett, Silvey, Rosgen 2013).

Bankfull Width –

"Lateral extent of the water surface elevation perpendicular to the channel at bankfull depth" (Washington State Department of Natural Resources 2004).

Ecological Services (Riparian Areas)–

When the term ecological services are used in this proposal it refers to the following services. The services listed do not cover the entire range of ecological services provided by riparian areas, but includes some key services:

Mitigation of nonpoint source pollution, removing excess nutrients and sediment from surface runoff and groundwater.

Vegetation modifies the temperature conditions for aquatic plants and animals, stabilizes stream banks, mitigates flooding, and contributes to the health of adjacent freshwater habitats (Pusey, Arthington 2003 cited in Anderson, Barnett, Clark, Olivero Sheldon, Prince, Vickery 2016).

Floodplain –

"The relatively flat depositional surface adjacent to the river that is formed by the river under current climatic and hydrologic conditions" (Leopold, Emmett, Silvey, Rosgen 2013). Floodplains experience occasional or periodic flooding (Boyd 2015).

Geomorphology –

"Study of surface forms on the earth" (Dunne and Leopold 1978).

Incised Stream/Rivers –

"Channels that are vertically contained or, in a general sense, have abandoned their floodplains, thus, they are flooded less frequently" (Rosgen 1997).

Climate Mitigation –

Actions designed to reduce the vulnerability of natural and societal systems to the effects of climate change (IPPC 2007).

Range–

"Area where particular species can be found during its lifetime. Species ranges include areas where individuals or communities may migrate or hibernate" (Rutledge, Ramroop, Boudreau, McDaniel, Tang, Sprout, Costa, Hall, Hunt 2011). Climate can impact a species' range (Rutledge et al. 2011).

Reference Reach –

A specified study length of the river, this project uses the Stream Visual Assessment Protocol's recommendation of a length 12 times the bankfull width (USDA and NRCS 2009).

Resilience (Ecological) –

"The ability of an ecosystem to maintain its normal patterns of nutrient cycling and biomass production after being subjected to damage caused by an ecological disturbance." (Levin 2015).

River Restoration –

Restoring the natural function, stability, and biological condition (Rosgen 1997).

Riparian Corridor –

“A strip of vegetation adjacent to an aquatic system that connects two or more larger patches of vegetation (i.e., habitat) and through which an organism will likely move over time. These landscape features are often referred to as conservation corridors, wildlife corridors, and dispersal corridors. Some scientists have suggested that corridors are a critical tool for reconnecting fragmented habitat “islands.” (Stewart, Wang, Lyons, Horwatich, Bannerman 2007).

Riparian Buffer Strip –

“Riparian Buffer Strip. A linear band of permanent vegetation adjacent to an aquatic system primarily intended to maintain or improve water quality by trapping and removing various non-point source pollutants (e.g., contaminants from herbicides and pesticides; nutrients from fertilizers; and sediment from upland soils) from both overland and shallow subsurface flow. Buffer strips occur in a variety of forms, including herbaceous or grassy buffers, grassed waterways, or forested riparian buffer strips. A buffer strip may provide a variety of other functions, including habitat for plants and animals if enough land-area is retained to meet the life-history needs of a particular species, and movement corridors if they provide suitable connections between larger blocks of habitat.” (Stewart, Wang, Lyons, Horwatich, Bannerman 2007).

Rosgen’s Stream Classification System –

Quantitatively describes a combination of river features that integrate mutually adjusting variables of channel form and classify them into Aa+, A, B, C,

D, DA, E, F, G streams; a visual aid is found in Figure 1. Stream types are grouped by morphological similarities i.e. entrenchment, channel form, width/depth ratio, sinuosity, slope, and channel materials (Rosgen 1996).

Watershed –

“A watershed is an area of land that drains all the streams and rainfall to a common outlet such as the outflow of a reservoir, mouth of a bay, or any point along a stream channel. Watersheds can be as small as a footprint or large enough to encompass all the land that drains water into rivers.” (USGS 2019).

“The word “watershed” is sometimes used interchangeably with drainage basin or catchment. Ridges and hills that separate two watersheds are called the drainage divide. The watershed consists of surface water--lakes, streams, reservoirs, and wetlands--and all the underlying groundwater. Larger watersheds contain many smaller watersheds. It all depends on the outflow point; all of the land that drains water to the outflow point is the watershed for that outflow location. Watersheds are important because the streamflow and the water quality of a river are affected by things, human-induced or not, happening in the land area “above” the river-outflow point.” (USGS 2019).



Black Capped Chickadee *Poecile atricapillus*

Non-Migratory Cavity Nesting Birds found in Kansas. Black Capped Chickadee make nests in dead trees or branches with rotting wood (Kansas Native Plants 2018).
(Figure 1.1 by author 2021)

Chapter 01

Introduction

Dilemma

Human development and flood control efforts within a river's floodplain may have been initially well-intended but have led to unforeseen ecological consequences and complications. Some of the unintended consequences include straightening, channelization, encroachment, lateral containment, of the river; change in sediment regime, pattern, and profile of a river (Rosgen 1997); increased damage from large flooding events, fragmentation of populations of aquatic and wildlife species, and fragmentation and conversion of native riparian vegetation. The consequences previously described currently exist along the Kansas River and its tributaries. Development within the Kansas River's floodplain is not projected to halt anytime soon. The economic revenue the Kansas river provides for its users is too great to abandon human activity on it completely, even at the detriment of other ecosystem communities relying on the Kansas River Corridor. A concert of human activity within the Kansas River floodplain and rapid anthropogenic climate change (e.g., longer periods of drought) continue to significantly alter the ecological, economical, and hydrologic services the Kansas River provides.

Thesis Statement

Increasing structural diversity and biodiversity in a river's floodplain and riparian corridor and improving natural stream function can increase ecological resilience. Dense urban development and human activity along the Kansas River continue to threaten the ecological services (e.g., flood abatement) the Kansas River corridor provides. Restoration of riparian vegetation, floodplain land, and river function requires the implementation of targeted design and management strategies explored in this project.

Purpose

Humans have relied heavily on Kansas streams and rivers, dating as far back as the Paleoindian period (Roper 2009) and have done their best to control those waterways to suit their needs. Wildlife and vegetation too have historically relied on the riparian vegetation and the natural flooding disturbances surrounding the waterways in Kansas. Anthropogenic flood control efforts have allowed humans to develop closer to the river, providing a false sense of security. Simultaneously, flood control efforts have diminished and fragmented native riparian vegetation, wildlife, and aquatic species habitats (Theobald, Merritt, Norman 2010; Rohweder 2015; The Kansas State Conservation Commission 2014; Stewart, Wang, Lyons, Horwath, Bannerman 2007; Fernandes, Aguiar, Ferreira 2011; Fischer, Martin, Fischenich 2000). Furthermore, changing the dimension, pattern, and profile of the Kansas streams (Rosgen 1997). The report, Designing for Change aims to show the relationship between designing and implementing riparian and floodplain restoration techniques on the Kansas and Wakarusa Rivers and resilience of the studied riparian ecosystems against the adverse impacts of anthropogenic climate change (Seavy et al. 2009).

From my literature review, numerous articles were reviewed stating the importance of riparian restoration to prepare riparian ecosystems for climate change (Theobald et al. 2010; Anderson, Barnett, Clark, Olivero, 2016; Seavy et al. 2009). I wanted to apply this widely accepted theory of the correlation between river function and climate change resiliency to three reaches on the Kansas River and one reach on the Wakarusa River. The Wakarusa River was added to my study area to provide a perspective from two different scales of targeted riparian restoration. The Kansas and Wakarusa Rivers were selected from a previous pilot study of the Kansas River corridor in the LAR 705 Regional Super Studio that involved applying the three principles of the Green New Deal: decarbonization, justice, and jobs to the Kansas River Corridor region leading into Kansas City, Kansas called for by the Landscape Architecture Foundation (LAF 2020).

The LAR 705 Regional Superstudio section C (sections A and B focused on the city and site scales in Kansas City) collectively set boundaries for the superstudio site. The studio's site is located within the Kansas River corridor and starts where the Wakarusa River flows into the Kansas River and ends where the Kansas River flows into the Missouri River, shown in Figure 1.2. The LAR 705 studio section C's project boundaries include the Kansas River and its adjoining floodplain and riparian area. The following master's project report: Designing for Change does not strictly adhere to these boundaries, but the studio boundary influenced the choice to focus on the Kansas and Wakarusa Rivers. Designing for Change focuses on river stability, vegetation and wildlife resilience, species abundance, and the physical measures it will take for river and riparian restoration.

I am conducting the study of floodplain reconnection on the Kansas and Wakarusa Rivers to determine if it is possible to use the existing physical integrity of river channel and floodplain as a template to reconnect the Kansas and Wakarusa Rivers to their geomorphic floodplain (Poff, Allan, Bain, Karr, Prestegard, Richter, Sparks, Stromberg 1997; Theobald et. al 2010; Fischer et al. 2000, Rosgen 1996; Rohde, Hostmann, Peter, Ewald 2006). There are existing studies on floodplain reconnection and riparian vegetation restoration; however those tend to be better suited for rivers with cropland surrounding them (King County 2019) or floodplains that have been abandoned by anthropogenic activity (Gonzalez, Masip, Tabacchi, Poulin 2016) as opposed to densely populated urban areas. Since the Kansas River continues to be a source of economic profit and a desirable feature to live near, the rapid progression of anthropogenic climate change (EPA 1998; National Conference of State Legislatures 2008) will continue to degrade the floodplain and native riparian vegetation at a faster rate than it can naturally repair itself.

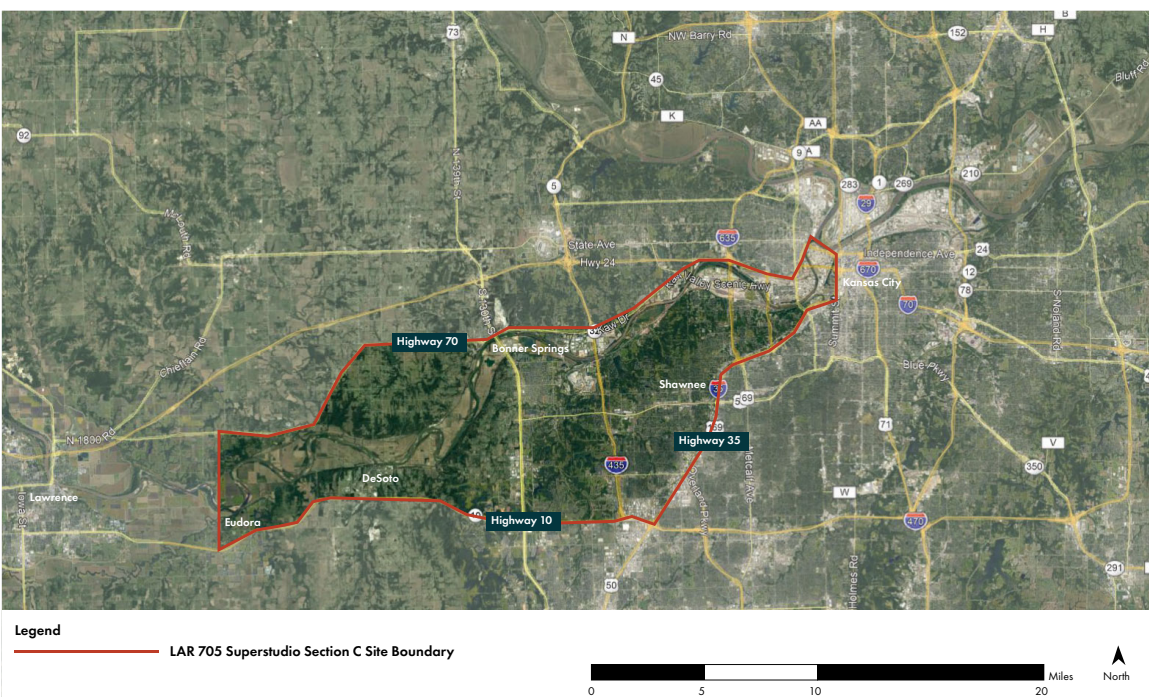


Figure 1.2 LAR 705 Regional Superstudio -
Figure 1.2 shows the rough boundaries of the LAR 705 Regional Superstudio site. The site follows along the highways surrounding the Kansas River starting in Eudora, KS and ending in Kansas City (Figure by author, adapted from ArcGIS Earth 2020).

Project Goals

The overall design approach for Designing for Change focuses on the mitigation of negative impacts caused by human activity adjacent to the river in addition to proposed design elements that will prepare the site for resilience against climate change. Initial site analysis is done through the Stream Visual Assessment Protocol Version Two (USDA and NRCS 2009) to assess the existing conditions of the three sites on the Kansas River and one site on the Wakarusa River. The goal of this project is to discover what creative design solutions landscape architects can provide to assist the existing rivers, classified as F Stream types (Rosgen's classification of rivers, shown in Figure 1.3, and the stream type classification breakdown in Figure 1.4 below), to C5 Kansas River and C4 Wakarusa River to reach a more stable functioning state. Additionally, rivers will be reconnected in sections to their floodplain to provide floodwater storage and access to the water table at the four study sites.

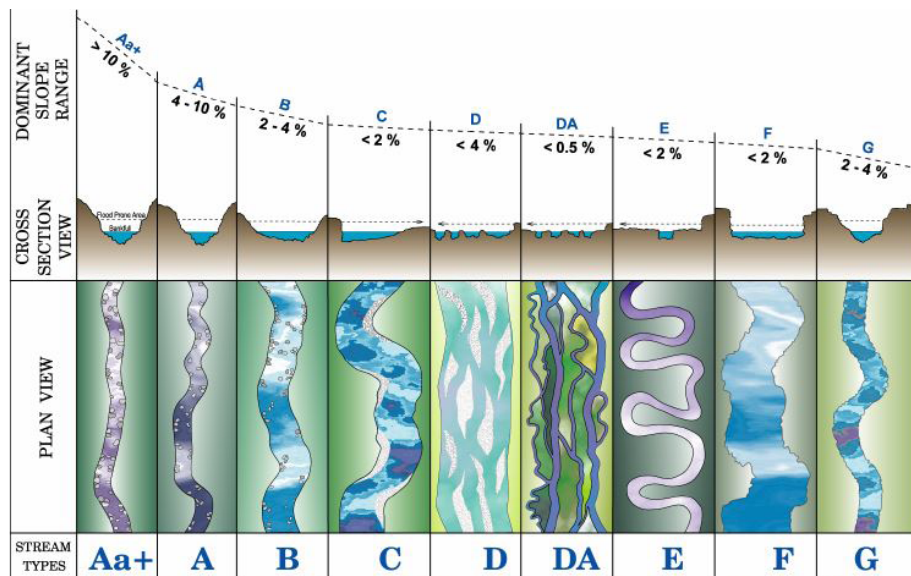
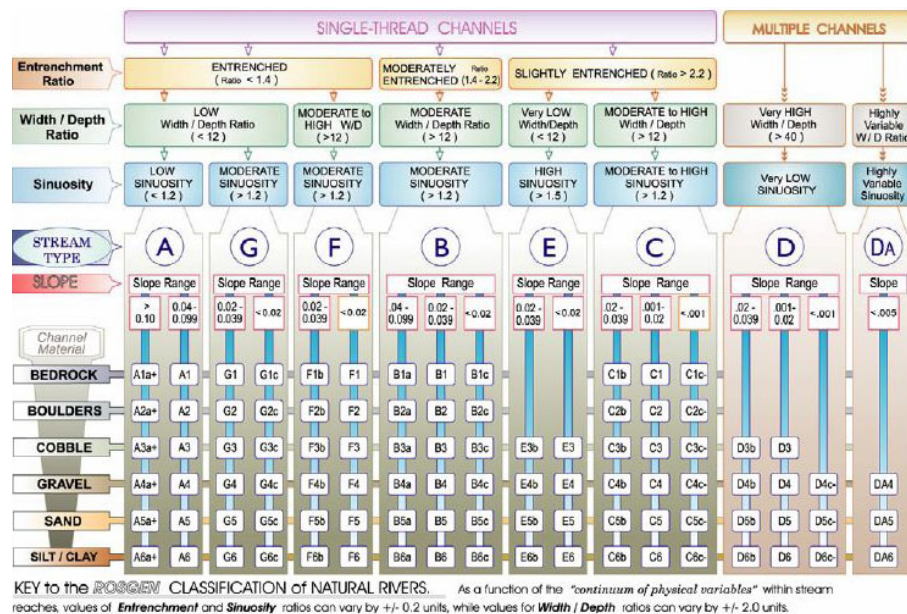


Figure 1.3 Visual Example of Rosgen's Major Stream Types –

Figure 1.3 provides a visual aid for the major stream types. These stream types are further classified based on the bed material; the Kansas River is classified as a C5 stream (Rosgen 1996).



KEY to the ROSGEN CLASSIFICATION OF NATURAL RIVERS. As a function of the "continuum of physical variables" within stream reaches, values of **Entrenchment** and **Sinuosity** ratios can vary by +/- 0.2 units, while values for **Width/Depth** ratios can vary by +/- 2.0 units.

Figure 1.4 Rosgen Classification of Natural Rivers –

Figure 1.4 diagrams the classification system created by Rosgen used to determine the type of stream one is working with (Rosgen 1996).

The goal of this study is to establish restoration design practices that can be applied to the entire Kansas River corridor and its tributaries. Riparian ecological resilience is needed to protect and increase water quality, stabilize streambanks, enhance or improve biodiversity, provide erosion control, and regulate sediment storage, transport, and distribution (Steward et al. 2007; Fischer et. al 2000; Seavy et al. 2009, Rosgen 1997). The initial site assessment focuses on visually assessing native riparian vegetation abundance and quality, existing and potential aquatic species habitat, and existing stream bank stability to address what physical changes are needed to convert the study sites to a more stable functioning condition. A functioning river is defined as one that maintains the ability to transfer the water and sediment of its watershed in a way that maintains its dimension, pattern, and profile without aggrading or degrading (Rosgen 1997). This project seeks to achieve a functioning river by using a geomorphological approach, meaning, documenting the dimensions, pattern and profile of natural, stable channels in Kansas and recreating those conditions on the unstable form (Rosgen 1997).

Natural stream channel restoration uses the relationships associated with bankfull width flow, geomorphic valley type, and geomorphic stream type (NRCS 2007). This project uses the Rosgen Classification System (Rosgen 1996) when analyzing the study sites; however it should be noted there are varying types of classification in existence, such as the River Styles Framework, Natural Channel Classification, and the channel form-based statistical classification. The Rosgen Classification System (Rosgen 1996) was chosen because it provides a broad classification using common characteristics for a rapid assessment of existing streams (USDA & NRCS 2007). The methodology diagram used in this project is shown in Figure 1.5.

Visual assessment tools are important for reaching a broader audience in restoration practices. It is easy for ecologists to communicate findings with one another just as it is from one landscape architect to another regarding technical site assessment. However, translating the more "technical findings" and assessments to the general public for them to repeat can be

more difficult. Visual assessment tools allow landowners and the general public to easily assess a site to determine the existing conditions in order to form a foundation for riparian vegetation and floodplain restoration. The Stream Visual Assessment Protocol Version II produced by the National Resources Conservation Service and United States Department of Agriculture provides a visual assessment tool for landowners to easily assess their property using key visual elements (USDA & NRCS 2009). In addition to restoring river channel function, a score of 5 or higher (scored out of 10) from the modified SVAP Version II (USDA & NRCS 2009), addressed further in Chapter 03 Process, is the ideal goal for the studied sites outcome. The broad technical elements needed to achieve a successful riparian and floodplain restoration include:

- Increase in structural complexity
- Reduction in chemical pollution from runoff
- Reconnect the river to its historic floodplain
- Increase in ecosystem complexity

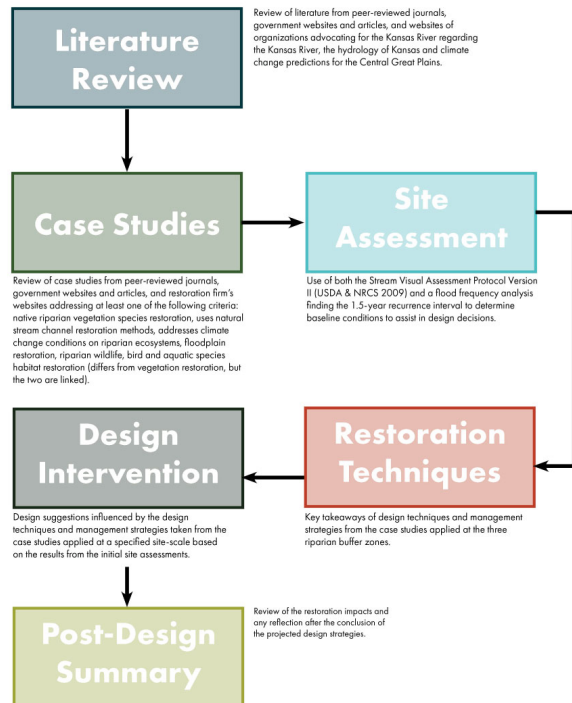


Figure 1.5 Methodology Diagram –
Figure 1.5 graphically shows the outline of the methods used by the author to create the report Designing for Change (Figure by author 2020).





Big Bluestem *Andropogon gerardii*
Native Grass; provides shelter for nesting birds and insects. Songbirds and prairie chickens consume the seed and white-tailed deer graze the vegetative parts (USDA & NRCS Plant Guide 2006), and is best suited in upland areas within the riparian corridor. (Figure 2.1 by author 2021).

Chapter 02

Background

Background

This chapter is intended to provide background information in regard to the root of the dilemma being studied in this report. First, this chapter will give a brief background on the overall hydrologic system in Kansas, and then focuses on the Kansas River. Within the Kansas River basin, the history of anthropogenic activity on the Kansas River including past and present land-use is explained. Next, the report looks at the history of flooding on the Kansas River and addresses the importance of floodplain restoration, providing some general examples of past floodplain restoration projects and techniques. Finally, this chapter concludes with an overview of the Kansas River Riparian corridor, covering riparian ecosystem services, issues/threats the riparian corridor faces, and impacts climate change is predicted to have on the Kansas River Riparian Corridor.

Overview of Hydrology

In Kansas, there are more than 10,000 miles of streams systems and more than 12,000 lakes, reservoirs, and ponds (Weiser-Alexander 2020). The hydrology system and wetlands in Kansas provide habitat for a large variety of species of birds, fish, mammals, reptiles, and invertebrates (Kenny 2010). Kansas waterways are especially important to migratory waterfowl and shorebirds (Kenny 2010). The Kansas River system is shown in Figure 2.2. There are twelve major river basins in Kansas; the Upper Republican, Smoky Hill-Saline, Solomon, Upper Arkansas, Cimarron, Lower Arkansas, Neosho, Walnut, Kansas-Lower Republican, Missouri, Marais Des Cygnes, and Verdigris, shown in Figure 2.3 (The Kansas State Conservation Commission 2014, The University of Kansas 2020). The major river basins boundaries shown in Figure 2.3 were delineated for management purposes and not necessarily exact topographic boundaries. Each watershed contains a sub-watershed system or is a piece of a larger watershed network.



Figure 2.2 The Kansas River System

The figure shows the entire Kansas River and its tributaries from its beginning at the confluence of the Smoky Hill and Republican Rivers then flowing east and emptying into the Missouri River (figure by author, adapted from ArcGIS 2020).

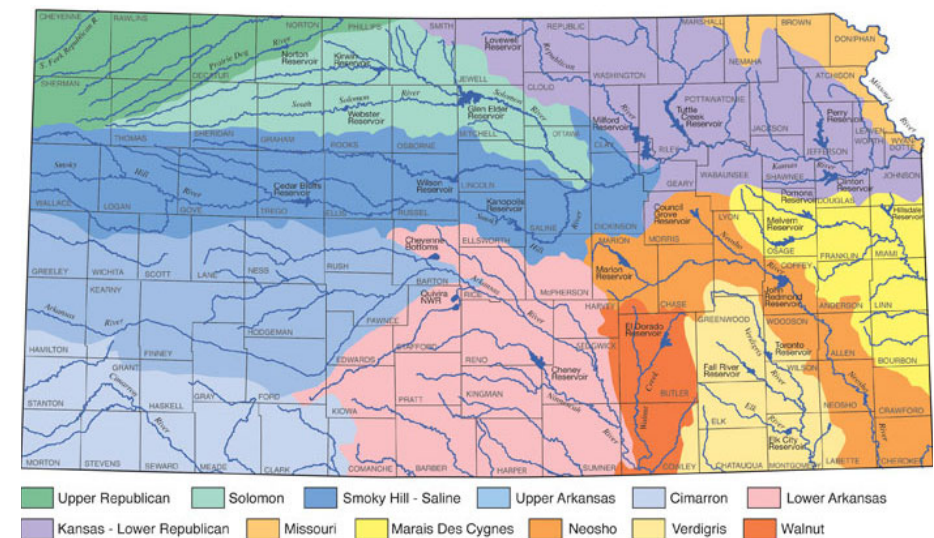


Figure 2.3 Major River Basins in Kansas -

The twelve major river basins in Kansas and their relationship with the waterways that flow within them (Figure by author, adapted from The University of Kansas 2020)

Kansas River History

The Kansas River has sustained life for aquatic, wildlife, vegetative species since its creation from glacial deposits during the Pleistocene Epoch (Friends of the Kaw 2020). Early settlers, but not the first settlers, of the Kansas River were the Kanza Tribe, who lived on the shore of the Kansas River and gave it the name the Kaw (Weiser, Legends of Kansas 2020). Since the early settlers, humans have gravitated towards the Kansas River to settle down, develop cities, and utilize the river's economic and ecological services. The Kansas River hosts a large portion of Kansas' population. In 1998, nearly 40% of the state's population lived in the ten counties bordering the river (Grisafe 1998). The 2010 census showed that 45% of the state's population resides in the same sample area (World Population Review 2021).

The Kansas River is located within the Kansas River Watershed, shown in Figure 2.4. The Kansas River Basin collects runoff from an area of approximately 61,440 square miles of predominantly agricultural land (US. Army Corps of Engineers 2010, Dort Jr. 2009). The Kansas River Basin spans three states, collecting runoff from parts of Colorado and Nebraska. The floodplain boundary and land-cover for the Kansas River Basin is shown below in Figure 2.4. Rainfall varies in the Kansas River Basin from east to west. For example, the western-most side of the Kansas River Basin located around the Goodland, KS area averages approximately 18" annually (U.S. Army Corps of Engineers 2010). 400 miles east in the eastern-most portion of the Kansas River Basin, located in Kansas City, KS averages around 38" annually (U.S. Army Corps of Engineers 2010).

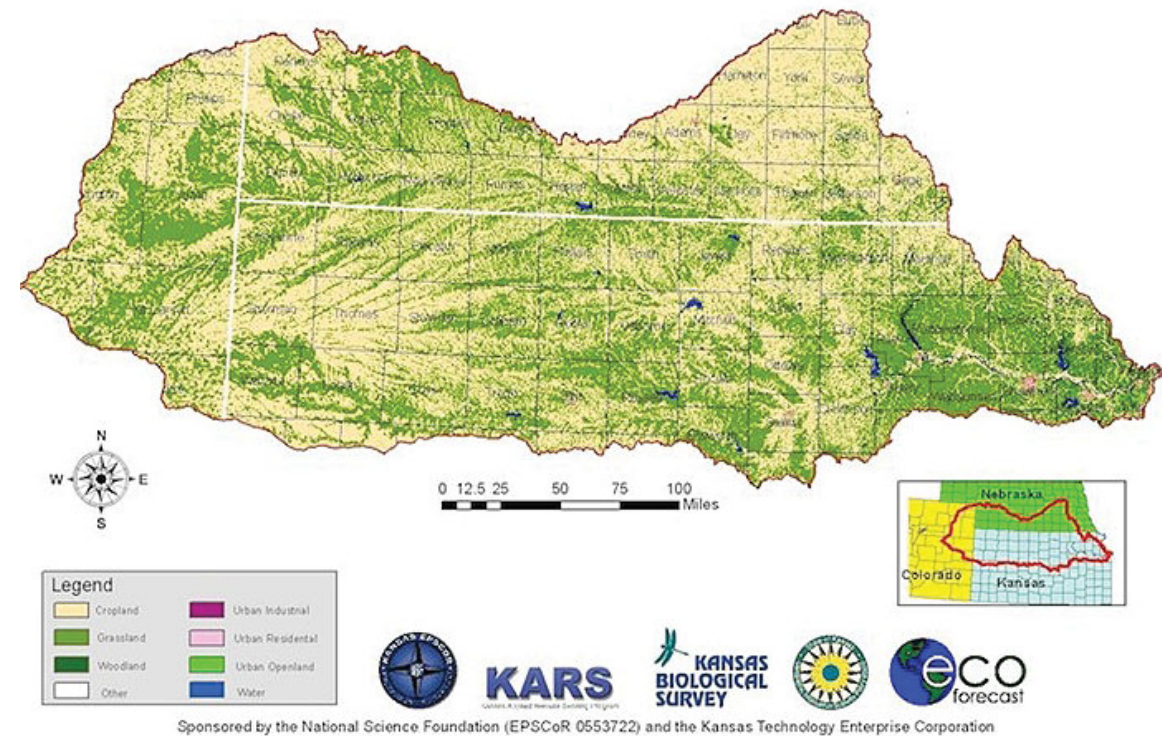


Figure 2.4 Kansas River Watershed Floodplain Land Cover -
Figure 2.4 shows the Kansas River Watershed and the land-cover within the large watershed (Woltemade 2010 cited by Friends of the Kaw 2020).

The Kansas River is located in a watershed within the Kansas River Basin called the Kansas-Republican River Watershed. Eight sub-watersheds feed into the Kansas-Republican River Watershed, four of which encompass the Kansas River shown in Figure 2.5 (adapted from Friends of the Kaw 2020). The Kansas River begins at the confluence of the Republican and Smoky Hill rivers, runs for approximately 170 river miles east (U.S. Corps of Engineers 2010), and ends when it flows into the Missouri River in Kansas City (Weiser et al. 2020, Weiser-Alexander 2020).

The sediment carrying capacity and water transportation of the Kansas River is affected by precipitation, sediment supply, channel characteristics, and velocity of the water (Brady, Grisafe, McCauley, Ohlmacher, Quinodoz, Nelson 1998). All of the factors that affect the Kansas River's sediment carrying capacity and water transportation are highly variable and can be influenced by human activity and climactic patterns. Past studies have shown the sediment carrying capacity of the Kansas River to be in the range of one to two million tons of sand per year (Brady et al. 1998); however this number is subject to change depending on the outside influences.

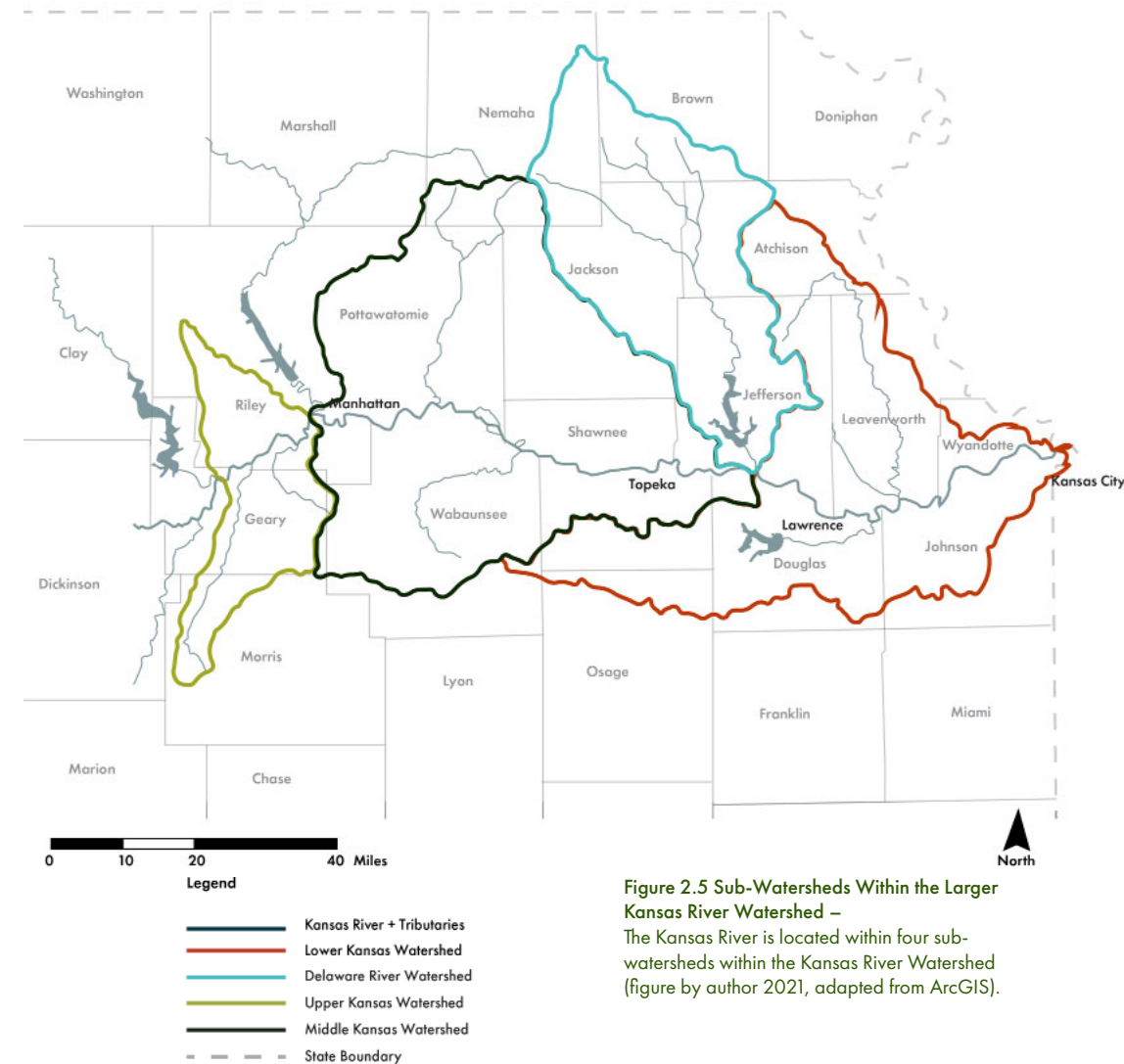


Figure 2.5 Sub-Watersheds Within the Larger Kansas River Watershed –
The Kansas River is located within four sub-watersheds within the Kansas River Watershed (figure by author 2021, adapted from ArcGIS).

Land-Use on the Kansas River

Land-use within floodplains of the Kansas River plays a vital role in the function of many ecological services provided within that floodplain. It is important to catalog and understand the different existing or potential land-uses within a floodplain and riparian area before creating a restoration plan. Human activities within the floodplain are often overlooked in riparian and floodplain restoration projects although those activities play a vital role in shaping the ecological recovery and future land-use (Hulse & Gregory 2004). Development in the floodplain can disrupt, displace, or completely remove the existing flora and fauna; however, economic values and productivity of the land tends to take priority in past development trends (Hulse & Gregory 2004). This section explains the existing land-uses along the Kansas River to form a better understanding of the current and future patterns of human development on the Kansas River.

Land-use along the Kansas River can be classified into industrial, residential and commercial development, transportation, and agriculture. Stream water quality can be directly related to land-use. The type of land-use influences the runoff, sediments, nutrients, flow, water temperature, and channel morphology of the surrounding water system shown in Figures 2.6 and 2.7 (Stewart et al. 2007). The land-use pattern around and on the Kansas River from 2015 is shown in Figure 2.8; the percentage of each use is shown in Table 2.1. The key areas to note are those with urban woodland and agriculture adjacent to the river as they pose the highest potential for restoration rather than the dense urban development (Hulse & Gregory 2004).

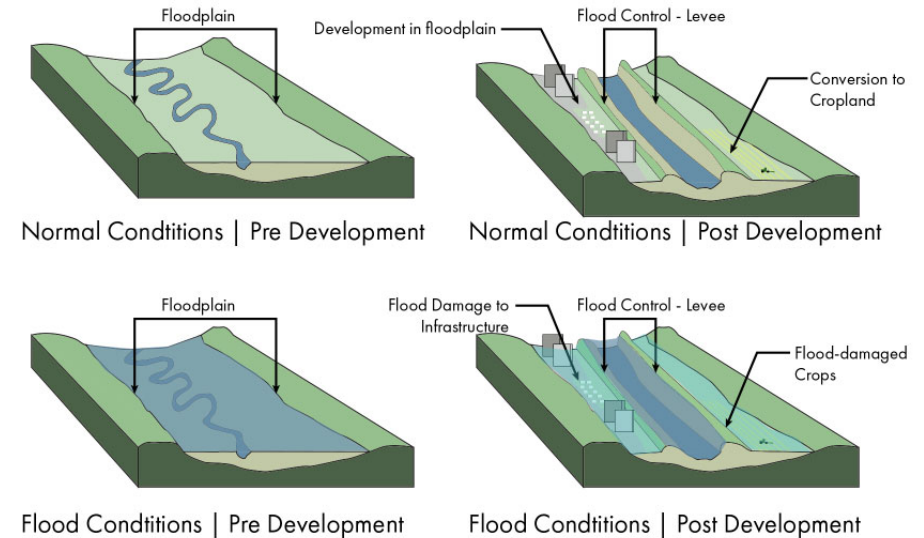


Figure 2.6 Development Within Floodplain in Flood Conditions -
A river carves its own floodplain over time, providing itself with the amount of space it needs to hold water during flood conditions. Humans have put in flood control structures along the Kansas River in order to “safely” develop within the river’s historic floodplain, causing expensive and sometimes fatal damage during flood events larger than the flood control structures can handle (Figure by author 2021).

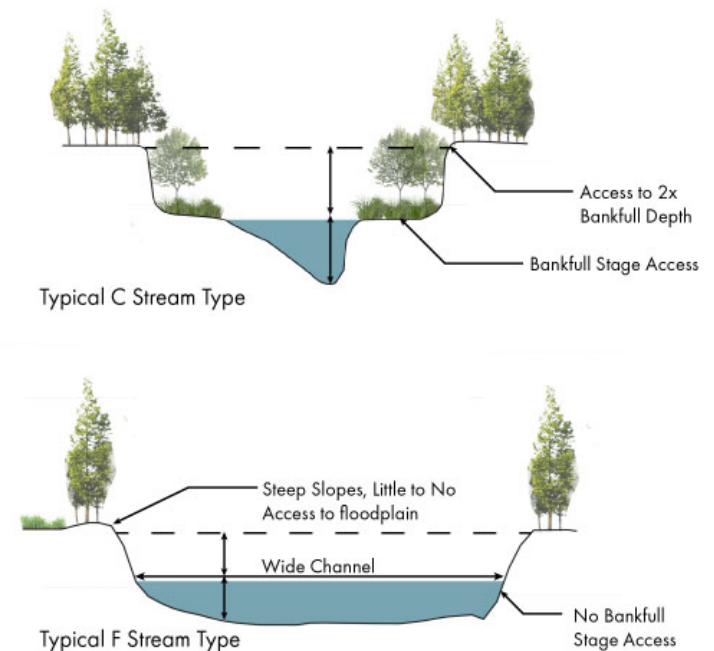
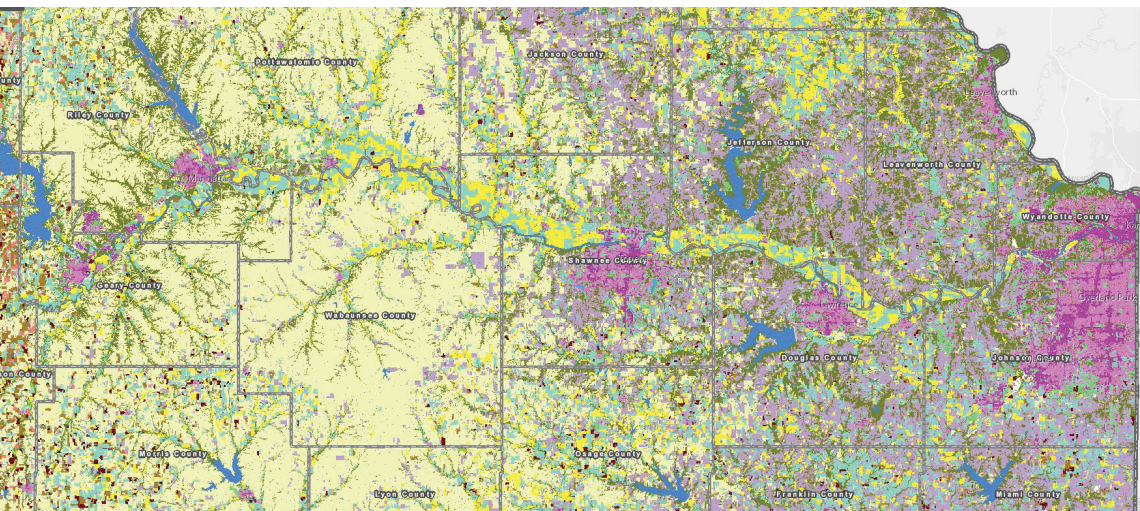


Figure 2.7 Typical C and F Streams -
Typical C stream types are slightly entrenched while the typical F stream types are entrenched and deeply incised (adapted from Rosgen 1997).



Legend

Urban Commercial/Industrial	Alfalfa
Urban Residential	Fallow
Urban Openland	Double-Crop
Urban Woodland	Warm-Season Grassland
Urban Water	Cool-Season Grassland
Corn	Woodland
Soybean	Water
Sorghum	Other
Winter Wheat	

Figure 2.8 2015 Kansas Land Cover Level II -

Figure 2.8 shows the land-cover that makes up the Kansas River corridor as defined by the Kansas Geological Survey (Kansas Applied Remote Sensing 2017).

General Class	Floodplain Area		12-Mile Corridor	
	%	Sq. Miles	%	Sq. Miles
Commercial/Indus.	4	14.1	3	47.9
Cropland	60	201.4	28	472.8
Grassland	14	48.6	45	774.3
Other	4	15	2	30.4
Residential	3	10.4	6	103.1
Urban-Grassland	1	4.8	2	39.4
Urban-Water	0	0.2	0	1.7
Urban-Woodland	0	0.5	1	11.2
Water	6	19.1	2	37.6
Woodland	7	24.1	11	185.6

Table 2.1 2015 Kansas Land Cover Level II Percentages-

Table 2.1 shows the percentage of land-use types that make up the Kansas River corridor as defined by the Kansas Geological Survey (Kansas Applied Remote Sensing 2017).

The listed land-uses are largely for human activities. The commercial/industrial, cropland, residential, and urban land-uses can be linked to the increase in impervious surface area along the floodplain, acceleration of erosion, removal of vital vegetation, pollution runoff, and incision of the streambank (human – pipes and conduits, and natural – eroded banks) that have been documented on the Kansas River (Kansas Water Science Center 2018). The existing land-uses contribute to unstable streambanks and a lack of biodiversity along the Kansas River (Stewart et al. 2007).

Finding patterns in economic land productivity along the Kansas River will assist in determining the willingness of landowners to cooperate in river floodplain and riparian vegetation restoration efforts (Hulse & Gregory 2004). Historic and current economic resources extracted from the Kansas River and its floodplain include limestone, aggregate, and sand and gravel (Grisafe 1998). Heavy dredging and extraction from the Kansas River have led to a lowering of the bed elevation in the Kansas River, prompting the U.S. Army Corps of Engineers to place restrictions on the amount of sand and gravel that can be extracted from certain river reaches and an annual limit on total amount of sand and gravel extracted starting in 1991 (Brady et al. 1998).

If the riparian and floodplain areas chosen for restoration are currently profitable to the landowner, the landowner may be less willing to give up that piece of land for restoration purposes. The regulations and cost involved in riparian and floodplain restoration are factors that should be considered when seeking out restoration areas and long-term planning of ecological recovery. If the goals of the restoration project are in direct conflict with the economic profits of the proposed site, the economic profit factors may nullify the restoration efforts (Hulse & Gregory 2004). The current societal view of holding economic profit above ecological benefit will require a shift in attitude towards making ecological services priority over economic services in order to see tangible change.

Flooding

Flooding is often a feared natural disaster. Humans have done their best to protect their development from flooding through dams, levees, and stabilizing streambanks that are by nature dynamic and changing (Hulse & Gregory 2004). In some cases, the flood control effort by humans has led to even more severe flooding events by preventing the natural dissipation of excess water on to the floodplains (Pahl-Wostl 2006). Many species of riparian vegetation and fish species rely on the natural flooding process to germinate and spread their seed (González et al. 2017). For example, the eastern cottonwood tree (*Populus deltoides*) relies on disturbances caused by flood events to germinate (González, Masip, Tabacchi, Poulin 2017; Hulse & Gregory 2004). Examples of fish species that require respawning in floodplain areas are given in Chapter 04 Case Studies.

Floodplains are meant to be inundated with water during flood events. Nevertheless, due to levees and dams, humans have been able to develop within floodplains. An example of significant flood control efforts in Kansas includes the construction of a large number of small lakes with a jump from 12 in 1920 to 5,240 in 1995 (USACE 2010). Development within the floodplain can lead to damaged infrastructure and even death during a flood event. This section briefly covers the flooding history along the Kansas River.

Flooding along the Kansas River has occurred repeatedly over the years, but the damage to settlements increases as more development occurs along the river. There have been four documented “notable” floods along the Kansas River: 1844, 1903, 1951, and 1993 (Friends of the Kaw 2020). Although the risk of flood damage increases if the development lies within the floodplain of a river, that has not stopped humans from continuing to develop within the Kansas River floodplain. The false security of human-made levees and dams play a role in human development within the floodplain of the Kansas River. Most levees along the Kansas River are only built to withstand 25-year or 50-year floods (Friends of the Kaw 2020). This means, when a

flood larger than a 25- or 50-year flood, a 4% or 2% chance in any year, comes along, it has the potential to cause major flood damage to the development within the floodplain.

The largest recorded flood along the Kansas River was in 1844 with water reaching 40-feet above normal stream levels (Friends of the Kaw 2020). At the time, there was not dense developed infrastructure along the Kansas River like there is today so the damage to infrastructure is considered low. However, flood damage did cause hardships to the indigenous tribes along the Kansas River in addition to extensive ecological disturbances to the wildlife and aquatic species (Friends of the Kaw 2020).

One of the more recent impactful floods on the Kansas River occurred in 1951 (Kansas Historical Society 2011). The Nature Conservancy reports this flood as being the spark for increased flood control on the Kansas River through a network of levees, dams and reservoirs (Mehl 2020). A report from the Kansas Historical Society stated that some areas received 18.5 inches of rain during a single rain event with the eastern half of Kansas averaging 8 inches (Kansas Historical Society 2011). The flooding spanned from Manhattan, KS to Kansas City, Kansas. At least 19 people were killed, 1,100 people were injured, 45,000 homes were damaged, 17 major bridges were washed away, and an estimate of \$2.5 billion in damages occurred (Friends of the Kaw 2020).

The most recent notable flood on one of the Kansas River’s tributaries occurred in September 2018. Manhattan, KS was affected the most by this flood due to several factors including levee failures and the backing up the Kansas River causing its tributary, Wildcat Creek, to flood. The governor of Kansas had to declare a state of emergency for five Kansas counties following the 2018 Kansas River flood (Davies 2018). Due to the 2018 flood, approximately 300 people were displaced, and the Manhattan Fire Department had to rescue or evacuate over 150 people (Davies 2018).

Flooding patterns can be loosely tracked and predicted through annual peak streamflow frequency in addition to mapping

out historic patterns of the river channel behavior. This project calculates the flood frequency using data from the USGS water data website, located under the USGS Water Resources tab, subheading USGS Current Water Data for Kansas (USGS 2020). A flood recurrence interval is the average interval of time in which a specific magnitude of flooding event will occur, for example, the term 100-year flood on the Kansas River refers to a certain streamflow measured in cubic feet per second that is predicted to occur every 100-years on the Kansas River (USGS 2020). Each stream has its own flood recurrence interval and can be affected by the land-use within the river's floodplain. Peak streamflow is recorded through a series of gauges located along a river. When the flood recurrence interval or any other water data such as cross-sectional area and water depth for a specific site needs to be found, one would review the data from the closest stream gauge on that river. The 1.5-year recurrence interval is used for the assessment of the Kansas and Wakarusa Rivers because the streamflow at the 1.5-year recurrence interval provides data for the most common conditions on the river at any given time. It is to be noted that the flow of the Kansas River when this report is published can be considered drought-like flows. Meaning, if this report were to be replicated for real-life application, it may be beneficial to find the 1.1-year or 1-year recurrence interval flows to mimic flows strained by climate change conditions.

The 1.5-year recurrence interval was determined after charting the peak annual streamflow for each site in Excel in descending order (largest to smallest) with an assigned ascending number next to it (1, 2, 3, 4, 5.....). The recurrence interval was found using the recurrence interval equation, discussed more in Chapter 03 Process. Once the recurrence interval was determined for each of the documented peak annual streamflow, the numbers were plotted into a chart with streamflow on the y-axis and the recurrence interval on the x-axis using a logarithmic trendline. The equation for the logarithmic trendline was used to calculate the 1.5-year recurrence interval for each site; each chart is shown

in the appendix. The bankfull width shown in Figure 2.9, mean depth, and cross-sectional area was found using the 1.5-year recurrence streamflow for each studied site. The book "Historical Channel Changes of the Kansas River and Its Major Tributaries" by Wakefield Dort Jr. is consulted to determine historic channel behavior of the Kansas and Wakarusa Rivers (Dort Jr. 2009).

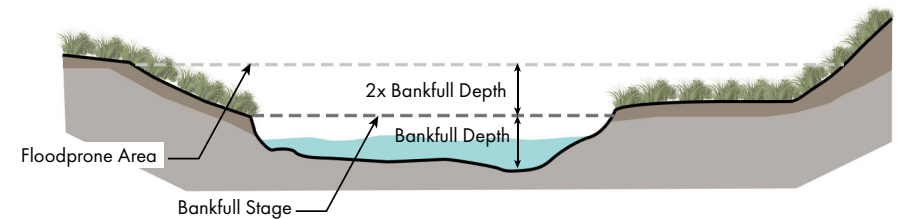


Figure 2.9 Relationship Between Bankfull Depth and Floodprone Area -
A river's floodprone elevation can be found at two times the bankfull depth. The floodprone area is typically 2.2 times the width of the bankfull width (adapted from Rosgen 1996).

Floodplain Restoration

Floodplains are an essential component to both a functioning riparian ecosystem and river system. Floodplains are built by the river and are part of the channel at high flow (Rosgen 1996). Historic channel movement and floodplain extent of the Kansas River are shown in Figure 2.10. The ecological services floodplains provide include storing and slowing floodwaters, improving water quality, safeguarding people and property, creating fertile soils for crops, nurture life, protection and restoration of native biodiversity (vegetation, wildlife, and aquatic habitats), provide recreation, and recharge groundwater (American Rivers 2019; The Kansas Conservation Commission 2014; Theobald et al. 2010). A river that is disconnected from its floodplain can become incised or channelized, the consequences of which include accelerated streambank erosion, land loss, aquatic habitat loss, lowering of water tables, land productivity reduction, excess lateral migration, and downstream sedimentation (Theobald et al. 2010, Rosgen 1997, The Kansas Conservation Commission 2014). The relationship between the bankfull width and floodplain is shown in Figure 2.11.

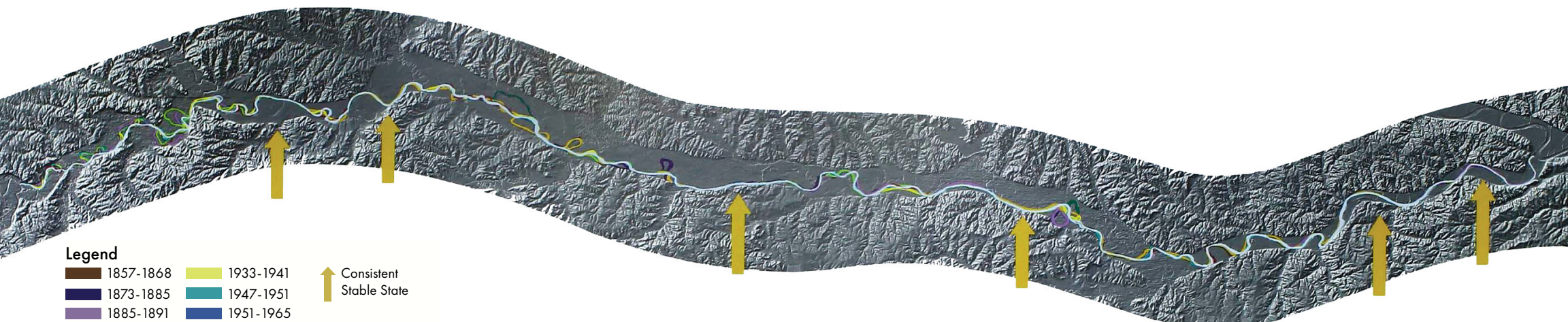


Figure 2.10 Historic Channel Changes of the Kansas River -
The Kansas River has changed its meander pattern over time, the figure above shows the Kansas River's movement throughout its historic floodplain from years 1857-2004 (Dort Jr. 2009).

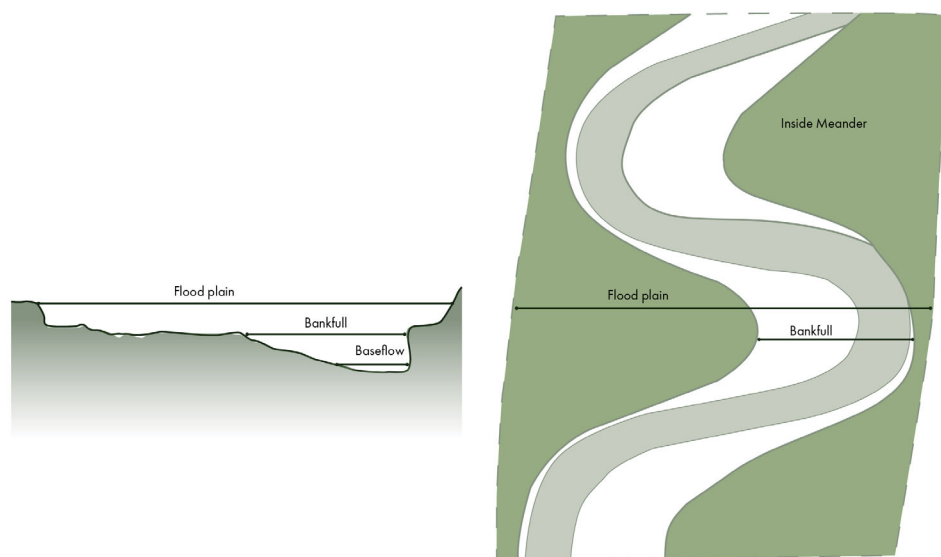


Figure 2.11 A River's Baseflow, Bankfull Width, and Floodplain -
A river's baseflow, bankfull width, and floodplain have an interdependent relationship. The average baseflow, or the 1.5-year recurrence flow determines the river's elevation and width at bankfull. The river carves out its floodplain as it moves over time (adapted from Rosgen 1996).

Fully restoring the Kansas River's floodplain is unrealistic due to permanent development within its boundaries. Nevertheless, measures can be taken to restore sections of the Kansas River's floodplain back to a higher functioning state. Most riparian vegetation requires the physical disturbance floods provide to regenerate, making it difficult to provide those conditions on a heavily regulated waterway (González et al. 2017; Hulse & Gregory 2004; Hughes 2003). Currently, there is no standard set of guidelines or regulations for floodplain restoration in urban areas, as each restoration project has specific conditions that are unique to the area. As of now, the Kansas River is predominantly surrounded by cropland, but population projections suggest that by 2025, nearly half of the Kansas population will live in the ten counties surrounding the Kansas River (Brady, Grisafe, McCauley, Ohlmacher, Quinodoz, Nelson 1998); as of 2010 45% of the population lives within the ten counties surrounding the Kansas River (World Population Review 2021). Nevertheless, there are case studies for floodplain and riparian restoration in more rural areas. Chapter 04 will present existing case studies that align with this project's set of guidelines that are detailed in Chapter 03.

One of the foundational principles upon which landscape architecture stands is to, "design and plan the restoration of natural places disturbed by humans such as wetlands, stream corridors, mined areas and forested land." (ASLA 2015). It will take a full multidisciplinary team to work together with the public's support to overhaul the damages to Kansas riparian

corridors and the ecosystems they support, caused by human activities (Rohweder 2015, Norman et. al 2015). It is not solely the landscape architect's duty to repair, reconnect, and heal the broken riparian corridors caused by human activity but will require full cooperation from a multidisciplinary group. Many landscape architects' project sites are located in floodplains or contain a stream running through them. It is vital that landscape architects have a basic understanding of floodplain and river restoration best management practices to design sites that are beneficial to the riparian vegetation, wildlife and aquatic habitat, and water quality within the designed site and surrounding ecosystems.

Kansas River Riparian Corridor

Riparian Ecosystem Services

Riparian zones provide a higher percentage of ecosystem services and natural resources compared to their size in the surrounding landscape (Theobald et. al 2010; Fischer et al. 2000; The Kansas State Conservation Commission 2014; Anderson et al. 2016). This report focuses on riparian vegetation restoration as an important component of riparian ecosystem protection because, "the streamside plant communities are major determinants of the abundance and quality of nutritional resources for stream ecosystems." (Gregory, Swanson, McKee, Cummins 1991). The Kansas River is located in eastern Kansas and is predominantly made up of riparian forest, consisting of cottonwood (*Populus deltoides*), sycamore (*Platanus occidentalis*), green ash (*Fraxinus pennsylvanica*), with an understory of smaller trees, shrubs, and vines (Monda, Wedel, Schenck 1993, The Kansas Conservation Commission 2014). The riparian forests in Kansas make up the majority of the 1.5 million acres of Kansas forests with 83 percent occurring in the eastern one third of the state (The Kansas Conservation Commission 2014). The riparian woodlands of the Central Great Plains contain the greatest species richness of birds out of the types of vegetation groups. For example 164 bird species are found in riparian woodland, 72 species in wetlands, 36 species in grasslands, and 15 species in xeric shrubland (Guertin, Easterling, Brandle 1997).

Examples of the ecosystem services provided by riparian corridors and buffers include improved habitat quality and biodiversity, wildlife movement and gene flow, stabilization of stream channels, erosion control through sediment storage, providing organic matter, water temperature control, reduction of flood peaks, and recharge points for renewing groundwater supplies (Fischer et. al 2000, Dallimer, Rouquette, Skinner, Armsworth, Maltby, Warren, Gaston 2012, Theobald et. al 2010). Human development has altered and converted the native riparian vegetation that makes up the riparian corridors, the Kansas State Conservation released a river and stream corridor management guide in 2014 stating, "wetlands were once an integral part of most Kansas stream corridors. Since (human) settlement, a great number of stream corridor wetlands have been converted to other uses, primarily agriculture, residential, and industrial." (The Kansas Conservation Commission 2014).

Issues & Threats

"At no other time in the history of modern man [human] have the cumulative impacts associated with development along the river had a greater impact on water resource values," (Rosgen 1996). According to David Rosgen, rivers are sensitive indicators of environmental stress and we must have a better understanding of the consequences of our impacts on the river systems and their ecological services we [humans] rely on (Rosgen 1996).

Humans have adapted to the issues caused by human development and climate change by changing their immediate environment, heating or cooling their homes, and preparing their communities (Anderson, Barnett, Clark, Olivero Sheldon, Prince, Vickery 2016). However, plants and animals cannot change their direct environment and have to move in order to survive (Anderson et al. 2016).

Human development impacts the stream's ability to naturally regulate itself, offsetting the balance of sediment transportation (Theobald et al. 2010; Rosgen 1997). The rivers become incised due to human interference on a river system that includes channelization, straightening, encroachment, confinement, urban development and suburban development, major floods, alteration of sediment regime and riparian vegetation (Rosgen 1997).

Climate Change

The negative impacts caused by human activity on riparian corridors are being accelerated by climate change. Climate change induced issues currently threatening the Kansas River corridor include increases in air and surface water temperatures, alterations in the magnitude and seasonality of precipitation and run-off, shifts in phenological changes of wildlife and vegetation groups, and distribution of plants and animals (Meyer, Sale, Mulholland, Poff 2007; Seavy et al. 2009). For example, in a warmer and drier climate, grasslands and savannas could eventually replace many of the forests and woodlands in eastern Kansas (U.S. EPA 1998). In 1998, the U.S. EPA listed the oak savannas transition zone of the eastern part of Kansas as a globally threatened ecosystem (U.S. EPA 1998). Climate change predictions used for the determined sites on the Kansas River are taken from climate predictions for the entirety of the Central Great Plains.

The Kansas River could face Dust Bowl-like conditions due to an increase in average daily temperature, a decrease in rainfall periods, and an increase in drought periods (Kahn 2015; Frankson, Kunkel, Stevens, Easterling, Lin, Shulski 2017). Kansas has been susceptible to severe droughts in the past. The last recorded drought occurred in the 2000-2006 water year (October 1, 1999, through September 30, 2006), making it the sixth hydrologic drought during the past eight decades (Putnam, Perry, Wolock, 2008). However, Kansas is still currently in a drought period, as shown in Figure 2.12. This drought produced record streamflow lows on many different rivers in Kansas, including the Republican River, Smoky Hill River, and upper Kansas (Putnam et al. 2008). A water year, or a hydrological year, discharge year, or flow year, is the twelve-month period between October 1st (start of a water cycle) and September 30th of the following year used by the United States Geological Service and hydrologists to measure precipitation totals (Penn State Extension 2020).

The impacts of the drought that occurred during water years 2000-2006 included record-low water levels at Milford Lake,

Perry Lake, and Kanopolis Lake; a water emergency in Salina, KS because their municipal water supply is from alluvial wells connected to the Smoky Hill River; and a record number of minimum desirable streamflow violations – this reflects the degradation of stream habitat in addition to limitations and restrictions put on many water users, such as irrigation for agriculture (Putnam et al. 2008). Future droughts have the potential to be just as detrimental if not more severe than the one occurring in water years 2000-2006 in Kansas if precautionary measures are not taken on the water systems.

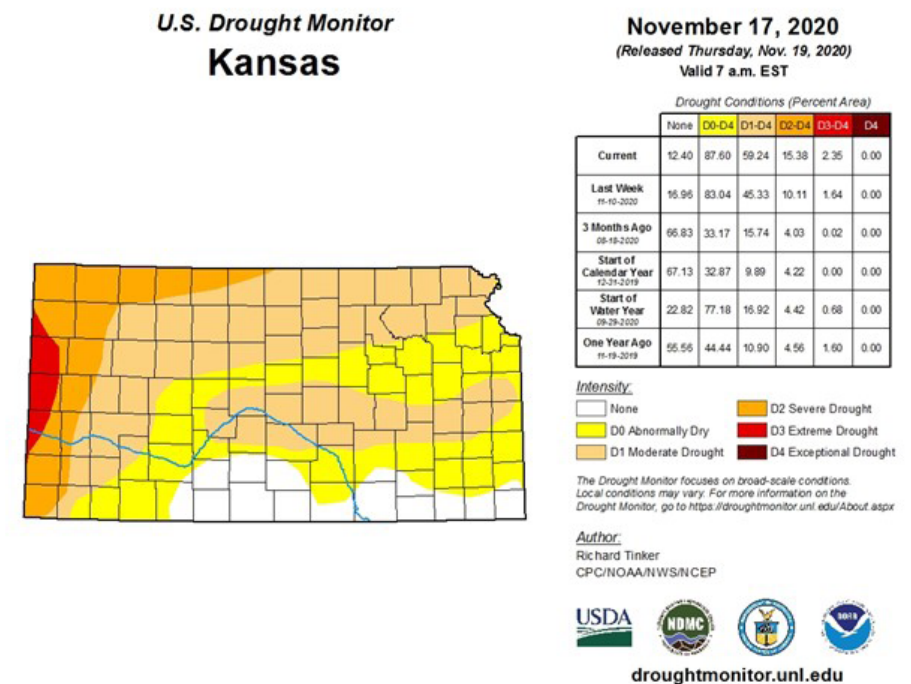


Figure 2.12 Kansas Drought Monitor Map -
This map shows the drought state of Kansas in November 2020 (The National Drought Mitigation Center 2020).

Water resources in Kansas are negatively impacted by climate change in Kansas. The water resources in Kansas are unevenly distributed (EPA 1998), and with the additional pressures of climate change, water shortages and extended periods of drought will disproportionately affect people depending on where they are located in Kansas. In western Kansas, water is scarce and heavily used for agriculture practices, causing there to be an uneven balance between how much water is being taken from groundwater compared to how quickly the groundwater can replenish itself. In eastern and south-central Kansas, where more urban areas are located, surface water is the main resource (EPA 1998). Less rain in summer and earlier snowmelt in spring, increased evaporation, and warmer temperatures will lead to higher stream flows in winter and spring and lower stream flows, groundwater levels, and lake levels in the summer months (EPA 1998). Lower stream flows will influence the number of fish, game, and wildlife populations found in the streams, lakes, and reservoirs in Kansas (EPA 1998; National Conference of State Legislatures 2008). A lower number of fish, game, and wildlife populations have both ecological and economic consequences due to the disruption in the local ecosystems and a decrease in recreational revenue for state parks in Kansas.

Floods and large precipitation events are projected to increase in Kansas, while drought days and temperatures are projected to increase (Kansas City Water Service 2016; National Conference of State Legislatures 2008; EPA 1998). The average number of days per year exceeding 1.5" is projected to increase by 12% by mid-century and nearly double by the end of the century (Kansas City Water Service 2016). Within the past 50 years, the amount of rainfall in the four wettest days of the year has increased by nearly 15% in the Great Plains and is projected to increase further (EPA 2016). Flooding can be costly and deadly. On average floods can cost \$33 million worth of damage in Kansas annually (National Conference of State Legislatures 2008). Increases in flooding can lead to increased levels of pollution and fertilizer levels in surface and groundwater near urban areas and farms; such is the case surrounding the Kansas River (National Conference of State Legislatures 2008; Anderson et al. 2016). Noticeable changes in climate typically take hundreds of years

but have been accelerated by anthropogenic greenhouse gases (IPPC 2007). A quote from an article in the Kansas Geological Society identifies how climate change can go unnoticed to the untrained eye; "The negative effects of one extremely dry year can be overcome relatively quickly when it is preceded or followed by a wetter year, but several years of nearly uninterrupted drought can lead to serious long-lasting socioeconomic and environmental problems." (Layzell and Evans 2013). Documented global warming effects include the warming of lakes and rivers, altering the thermal structure and water quality of those water bodies (IPPC 2007). Warming of water systems also affect the terrestrial biological systems; examples include the earlier occurrence of spring events such as leaf-unfolding, bird migration, and egg-laying, and northward shifts in ranges in plant and animal species (IPPC 2007).

Shifts in vegetation have been documented in the Central Great Plains ecoregion. Upland from the riparian woodland, there has been documentation of an increase in abundance of woody species in grasslands and savannas worldwide, including the Central Great Plains (Briggs, Knapp, Blair, Heisler, Hoch, Lett, McCarron 2005). The noted driving forces behind the increase in woody species according to the Briggs et al. 2005 report include changes in climate, atmospheric carbon dioxide concentration, nitrogen deposition, grazing pressure, and anthropogenic disturbances (Briggs et al. 2005; Archer, Andersen, Predick, Schwinning, Steidl, Woods 2017). An example of a woody invasive species invading the Kansas River vegetation is Honeysuckle (Lonicera family). Honeysuckle is a woody species that was introduced to the Central Great Plains as a decorative lawn shrub but has since taken over the understory along river and stream corridors. Archer et al. (2017) gives a detailed description of how woody species invade grasslands;

"The proliferating trees and shrubs can be non-native species that were introduced purposely or accidentally or native species that have either increased in abundance within their historic ranges or expanded their geographic range. Woody plants have been displacing grasses across bioclimatic zones. Trees proliferate in humid regions while unpalatable shrubs replace grasses in more

arid regions, which is regarded as a type of desertification. In both cases, the proliferation of trees and shrubs threatens the maintenance of grassland and savanna ecosystems and the plants and animals that are endemic to these systems.” (Archer et al. 2017).

The invasion of non-native woody species can pose a threat to the diversity of the existing grassland and riparian vegetation found along the Kansas River and the overall Central Great Plains. During the first two practice Stream Visual Assessment Protocol analysis that I have performed, one reach of the Kansas River, and one reach along Wildcat Creek, non-native invasive woody species, primarily honeysuckle, were the dominant vegetation cover along the banks and floodplains. The Central Great Plains grasslands, the vegetation patterns predominantly surrounding the riparian woodland of the Kansas River, are projected to look different in the future due to the effects of accelerated climate change. Grasslands fall between desert shrublands and woodlands/forests (Archer et al. 2017; Briggs et al. 2005). The projected increase in drought and arid conditions for the Central Great Plains (Meyer, Sale, Mulholland, Poff 2007; Seavy et al. 2009) and decrease in cooler days may cause the vegetation to shift into either desert shrubland or woodland/forest in the Central Great Plains.

Riparian woodlands of the Central Great Plains will be impacted by water availability during drought periods and high fluctuations in the water table (Guertin, Easterling, Brandle 1997). The riparian species relying on flooding disturbances to regenerate will be the most impacted by period of drought within riparian forests (González et al. 2017; Hulse & Gregory 2004; Hughes 2003). Management strategies for beaver populations will need to be in-place during and after physical installation of riparian restoration plans. Beavers are both extremely beneficial to riparian woodlands, but can also be extremely detrimental if not managed properly (Clements 1991). Humans have driven beavers out of riparian areas through over-trapping and habitat destruction. Each site will need to be individually assessed and managed for the best results for both the beaver population

and the riparian area. Most beavers can be found within the tributaries of major rivers in Kansas, as large river flows will blow out a dam opposed to the more gentle flows of the tributaries.

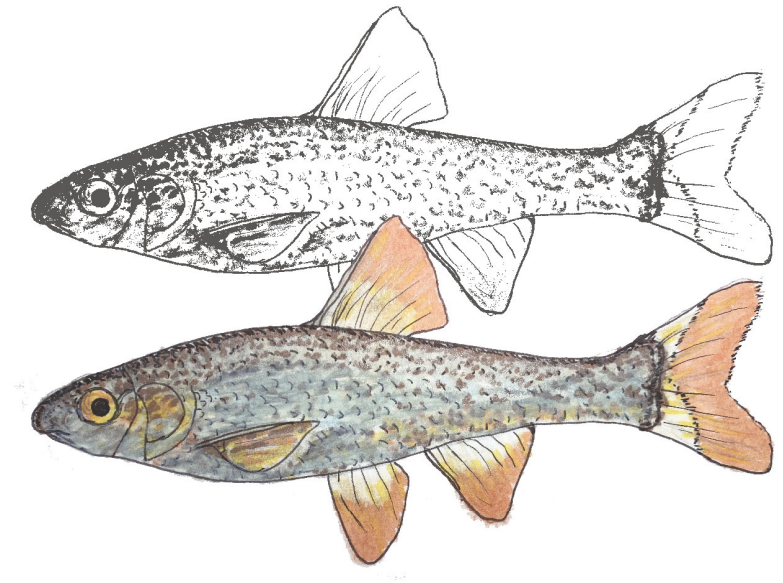
Models for vegetation species migration show changes in forest species composition in response to climate change through a replacement of northeastern species with more southern species (Guertin, Easterling, Brandle 1997). The land-use and management practices surrounding riparian woodlands that are focused predominantly on protecting cropland and infrastructure development can lead to an increase in heterogeneous species assemblages and an increase in invasive species within the riparian woodlands (Theobald et al. 2010 and IPPC 2007). Shifts in temperature and precipitation will lead to less open water and a higher vegetation cover, causing a decrease in waterfowl habitat (EPA 1998).

Current and predicted climate trends in Kansas for the next century suggest water shortages caused by increased drought days and a continued high demand for water. Policies and management strategies for water conservation and protection are required to protect the shrinking water resources. The economic impact of climate change causing a loss of wildlife, game, and aquatic species habitat will put a strain on government-funded parks and wildlife protection areas. “In 2006, nearly 1.5 million people spent more than \$643 million on wildlife viewing, hunting, and fishing in Kansas. The industry in turn supported 15,364 jobs in the state”. (National Wildlife Federation & Kansas Wildlife Federation 2009). It will take participation from both policy makers and landowners to make progress to reduce the amount of greenhouse gases being produced in Kansas.

Restoration and protection of riparian corridors and water resources is one step in the larger solution for mitigating anthropogenic climate change in Kansas. Increasing access points to the Kansas River’s floodplain and expanding the floodplain in areas provide more water storage, increased native riparian cover, and provides habitat for native terrestrial wildlife and aquatic species. An increase in native riparian vegetation

cover will increase carbon storage and runoff filtration, in addition to providing habitat cover. Although there is no one perfect solution to reducing the amount of greenhouse gases humans are producing, floodplain and riparian vegetation restoration along the Kansas River will reduce the concentration of those greenhouse gases and help to remove pollutants from chemical runoff in the Kansas River system. Floodplain and riparian vegetation restoration will need to be supplemented with other efforts, management practices, and policies to reduce the predicted effects of anthropogenic climate change.





Topeka Shiner *Notropis topeka*

Threatened species of fish first found in the Topeka, Kansas area. The Topeka Shiner has been reduced to less than 10 percent of its historical geographic range due to anthropogenic activity (Center for Biological Diversity) (Figure 3.1 by author 2021).

Chapter 03

Process

Process

A thorough literature review was completed by the author comprising the history of the Kansas River, natural stream channel restoration, riparian corridor restoration, and predicted climate change conditions of the Central Great Plains. The information from the literature review was used to inform the case study selection process. The methods in this study include case studies of existing floodplain and riparian vegetation restoration projects. The case studies were placed in two categories; site analysis of river restoration projects in Kansas that mimic conditions of the proposed sites along the Kansas and Wakarusa Rivers, and case studies that were outside of the Kansas border. Both categories of case studies needed to meet the criteria listed in the section below. The design applications found in the case studies will influence the design suggestions for the three riparian forest buffer zones influenced by the “ideal riparian buffers” published by the Kansas Forest Service in 2006: streambank stability zone, main filtration zone, and initial filtration zone (Kansas Forest Service 2006) that are adapted to fit this project: bankfull floodplain zone, floodprone area zone, and the upland vegetation zone. Finally, before any projected designs can occur, a site assessment of the four focus study sites will be conducted using a combination of the Stream Visual Assessment Protocol Version II (USDA & NRCS 2009) and a flood frequency analysis, using the 1.5-year flood frequency flow to find cross-sectional area, width, mean depth, and bankfull width. The initial assessments of each site are critical in establishing an understanding of existing site conditions, streamflow rates, channel condition, and assessment of any threats that need to be addressed.

Case Studies

Information from the literature review was used to create criteria for the case studies used in this report. The criteria used to select the case studies are listed below. Each case study needed to address one or more of the following criteria listed below. Each case study will be assessed at the end of Chapter 04 on how the studies handled or addressed the listed criteria.

- Riparian vegetation restoration
- Uses natural stream channel restoration methods
- Addresses climate change conditions on riparian ecosystems
- Floodplain restoration
- Habitat restoration (differs from vegetation restoration, but the two are linked)

The methods used for riparian vegetation and floodplain restoration in each case study were analyzed in addition to how each study assessed the success of the restoration. Case studies play a vital role in this project because they provide examples of riparian and stream channel restoration projects with similar goals and site conditions to the goals and objectives of this project. The first case study section covers case studies of river restoration projects in Kansas. The “in Kansas” case study section provides a foundation for techniques used in similar conditions as the proposed sites on the Kansas and Wakarusa Rivers. The second case study section is not limited by the boundary of Kansas and therefore allows projects of multiple design and scale to be reviewed. The case studies were used to provide a holistic view into what techniques work and do not work regarding riparian and stream restoration projects. The case studies and their relationship to the overall project are listed below and will be further discussed in Chapter 04 Case Studies.

Case Studies in Kansas

The study of local river restoration projects allowed for a better understanding of how others have stabilized river reaches in similar conditions to those the proposed sites will face. While some of these local case studies are not identical stream types (Rosgen 1996) as the Kansas and Wakarusa Rivers, they still face similar climatic and spatial conditions as the proposed study sites.

Case Studies Outside of Kansas

The case studies outside of Kansas are meant to provide a different perspective on river floodplain and riparian restoration. Although the broader scale case studies might have different climatic conditions than the Kansas and Wakarusa River sites, they still provide a baseline guide and techniques that can be applied to the proposed sites. The analysis of these case studies is meant to provide a broad synthesis of design, policy, and restoration techniques and best management practices that can be applied to any future restoration projects.

Riparian Buffer Zones

The “ideal forest buffer” proposed by the Kansas Forest Service consists of three horizontal buffer zones along any given river (Kansas Forest Service 2006). The “ideal forest buffer” will be used to influence a modified version of the three buffer zones that better fits this project. The three buffer zones used in this project are: 1) the bankfull floodplain zone, 2) the floodprone area zone, and 3) the upland vegetation zone. This riparian forest guideline will be used as an outline for the hierarchy of restoration guidelines applied at four study sites. The original version three horizontal buffer zones making up the “ideal forest buffer” proposed by the Kansas Forest Service are listed in the Table 3.1.

The version of the “ideal forest buffer” (Kansas Forest Service 2006) adapted to suit the needs of this project is listed in Table 3.2. The projected design proposals for the Kansas and Wakarusa River sites will use this table. The adapted version of the “ideal forest buffer” (Kansas Forest Service 2006) used in this project will not include suggested widths due to every site having different conditions.

	Purpose	Recommended Width	Management Suggestion Within Zone
Streambank Stability Zone	Create a stable bank adjacent to the water's edge. Provides streambank stability and contributes organic matter and large woody debris to the stream channel. (Kansas Forest Service 2006)	15 feet from the water's edge. (Kansas Forest Service 2006)	Limited to stabilizing the banks and removing potential problem vegetation. (Kansas Forest Service 2006)
Main Filtration Zone	Allow necessary contact time between runoff and the forest floor. Provides wildlife habitat and wood production. (Kansas Forest Service 2006)	50 feet from the edge of zone one. (Kansas Forest Service 2006)	Periodic harvesting and thinning of vegetation. (Kansas Forest Service 2006)
Initial Filtration Zone	Converts concentrated flow to sheet flow. Compromising dense grasses and forbs that are mowed or grazed to recycle trapped nutrients and maintain various growth. (Kansas Forest Service 2006)	15 feet from the edge of zone two. (Kansas Forest Service 2006)	Occasional mowing, burning or grazing to maintain vegetation height and health. (Kansas Forest Service 2006)

Table 3.1 The “Ideal Forest Buffer”

The table shows the “ideal forest buffer” proposed by the Kansas Forest Service. The three zone concept is used to influence the modified version used in design suggestions for the Kansas and Wakarusa River sites (Kansas Forest Service 2006).

	Purpose	Vegetation Requirements
Bankfull Floodplain Zone	Natural streambank stability methods will be applied and include creating more bankfull floodplain area through fill or excavating the streambank down to meet the bankfull floodplain elevation through heavy machinery. Slopes will need to be at or under 3:1, with a 2:1 slope being preferable for revegetation purposes. This area may be inundated with water every 2-3 years. The deep rooted native vegetation will provide bank stability for the newly excavated slopes.	Invasive species will need to be removed or controlled before new revegetation occurs. The vegetation required for this zone needs to be deep rooted native, slow growing trees and shrubs in combination with quick establishing native cover vegetation tolerant of wet conditions. The vegetation tolerant of wetter conditions implemented directly alongside the water's edge can be used as habitat for aquatic, amphibian, and waterfowl species.
Floodprone Area Zone	Excavation down to the floodplain elevation may be required in this area as well, following the no-greater than 3:1 slope rule. This area may be inundated with water every 10-15 years. The large trees and shrubs provide habitat for wildlife and bird species.	Invasive species will need to be removed or controlled before new revegetation occurs. The vegetation required for this zone needs to be deep rooted native trees, shrubs, and vegetation tolerant of wet, medium, and dry conditions. Fruit-bearing species provides a food source for bird and wildlife species, woody trees, shrubs, and tall vegetation cover provides habitat for bird and wildlife species. Native pollinator species are suggested for this area to sustain the pollinator species of Kansas.
Upland Vegetation Zone	This site will serve as habitat for native wildlife species in addition to a preliminary filtration system for the water runoff. The deep roots of the tallgrasses will help to prevent soil erosion and store carbon, preventing it from being released into the atmosphere.	Invasive species will need to be removed or controlled before new revegetation occurs. The vegetation required for this zone needs to be deep rooted native grasses, shrubs, and vegetation that can tolerate dry and drought conditions. The tallgrasses in combination with other native herbaceous and woody species will provide habitat for native wildlife species. Native flowering species are suggested for this area to sustain the pollinator species of Kansas.

Table 3.2 Riparian Buffer Zone

The riparian buffer zones listed in this table will be used to help guide the projected design suggestions after the initial site assessment has been conducted (Table by author, adapted from Kansas Forest Service 2006).

Site Assessment

The purpose of the initial site assessment was to document existing conditions in order to lay a foundation for the next steps of the design. Each site was visually assessed by me using the Stream Visual Assessment Protocol Version II (SVAP Version II) (USDA & NRCS 2009). The results from the SVAP Version II are coupled with a flood frequency analysis to determine baseline conditions of the site. The SVAP Version II (USDA & NRCS 2009) was chosen for its user-friendly layout, easily understood by nearly any discipline or landowner; in addition to being a widely recognized form of assessment.

Stream Visual Assessment Protocol Version II (USDA & NRCS 2009)

The SVAP Version II assessment sheet contains two sections, each containing sub-categories:

- 1) Preliminary Assessment
 - Watershed Description
 - Stream/Reach Description
- 2) Field Assessment
 - Preliminary Field Data
 - Element Scores

The data extrapolated from the SVAP Version II and used in this project are the categories "Watershed Description", "Preliminary Field Data", and "Element Scores". The contents used for this project under the three categories are displayed below (SVAP Version II full documents in appendix):

Preliminary Field Data:

- Date of assessment
- Riparian cover types (%): tree, shrub, herbaceous, bare
- Bankfull channel width (ft)
- Reach length (ft)
- Floodplain width (ft)

The visual assessment is conducted using a copy of the element score sheet and the listed criteria for rating the elements. To conduct the on-site assessments, the author printed out copies

of the scoring sheets available for anyone to download off the Internet from the Natural Resources Conservation Service (NRCS) website. The author printed out the supplemental assessment criteria along with the scoring sheets contained in the SVAP Version II assessment document from the NRCS website. The supplemental assessment criteria was bound in a binder to assist in organization during the on-site assessment. Table 3.3 shows the rating table used in the SVAP Version II (USDA & NRCS 2009).

Elements Scored:

Element	Score
Channel Condition	
Bank Condition	
Riparian Area Quantity	
Riparian Area Quality	
Canopy Cover	
Water Appearance	
Nutrient Enrichment	
Manure or Human Waste	
Pools	
Barriers to Movement	
Fish Habitat Complexity	
Aquatic Invertebrate Habitat	
Aquatic Invertebrate Community	
Riffle Embeddedness	
Salinity	
A. Sum of all elements scores	
B. Number of elements scored	
Overall score A/B:	
1 to 2.9 Severely Degraded	
3 to 4.9 Poor	
5 to 6.9 Fair	
7 to 8.9 Good	
9 to 10 Excellent	

Table 3.3 Stream Visual Assessment Protocol Version II Assessment Chart

Existing site elements are categorized and rated based on a standard visual criteria to aid in qualitatively evaluating the condition of aquatic ecosystems (USDA & NRCS 2009).

Each element listed in the table represents a set of assessment criteria rated on a scale of 0-10 for each category. The full descriptions of the scoring used on each element are listed in the appendix. The elements used to score each site were channel condition, bank condition, riparian area quantity, riparian area quality, canopy cover, water appearance, nutrient enrichment, pools, barriers to movement, fish habitat complexity, and aquatic invertebrate habitat because they were the most relevant to this project. Human waste or manure aquatic invertebrate community, riffle embeddedness, and salinity were left out because those elements are not as relevant to this project. If this project is reproduced, the assessor must use the same elements assessed in this project to obtain comparable results.

The full evaluation criteria used for the elements are detailed in the beginning of Chapter 05 Design Application. The SVAP Version II will be used in concert with flood frequency analyses studies for each site to establish a foundation of existing conditions that the proposed designs will be developed from.

Flood Frequency Analysis

The flood frequency analysis is used to find the streamflow of the 1.5- year flood frequency flow. Peak streamflow data taken from the USGS water data for Kansas (<https://waterdata.usgs.gov/ks/nwis/rt>) (USGS 2020) at the nearest stream gage for each site. The peak streamflow for each gage is plotted in Excel filtered from highest to lowest, the DeSoto assessment is used as the example shown in table 3.4; the four flood frequency analysis will be shown in more depth in the appendix. The Excel graph was broken up into four different categories: Rank, Streamflow, Recurrence Interval, and Probability; an example shown in Table 3.4.

Once all of the peak streamflow numbers were plotted, the recurrence interval was calculated, example shown in Table 3.5, using the formula:

$$R.I. = (n+1)/m$$

R.I. = Recurrence Interval

n = total number of years considered

m = rank of flow (largest to smallest)

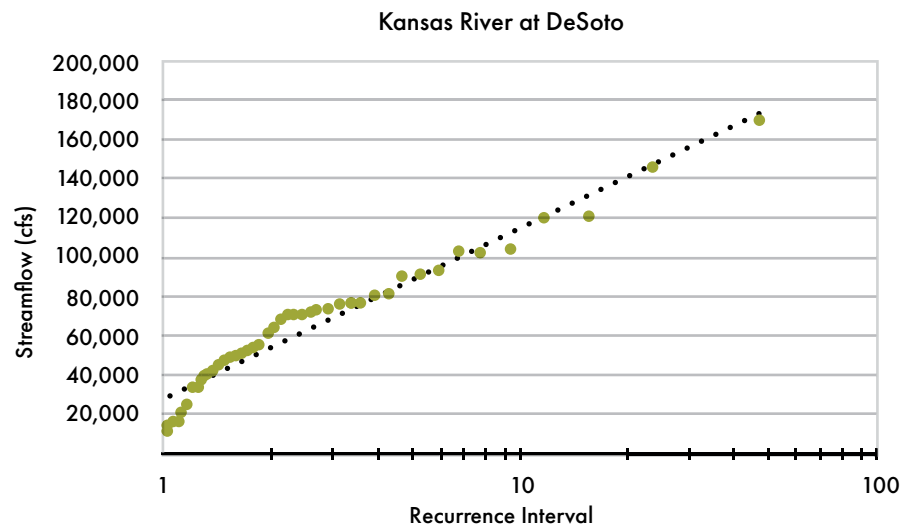
The probability was calculated using the formula:

$$\text{Probability} = (1/R.I.) * 100$$

R.I. = Recurrence Interval

Rank	Stream Flow	Recurrence Interval	Probability
1	170,000.00	47	2.127659574
2	146,000.00	23.5	4.255319149
3	121,000.00	15.66666667	6.382978723
4	120,000.00	11.75	8.510638298
5	104,000.00	9.4	10.63829787
6	103,000.00	7.833333333	12.76595745
7	103,000.00	6.714285714	14.89361702
8	92,900.00	5.875	17.0212766
9	91,800.00	5.222222222	19.14893617
10	90,900.00	4.7	21.27659574
11	80,800.00	4.272727273	23.40425532
12	80,200.00	3.916666667	25.53191489
13	76,800.00	3.615384615	27.65957447
14	76,300.00	3.357142857	29.78723404
15	76,200.00	3.133333333	31.91489362
16	74,100.00	2.9375	34.04255319
17	73,400.00	2.764705882	36.17021277
18	72,400.00	2.611111111	38.29787234
19	71,200.00	2.473684211	40.42553191
20	70,700.00	2.35	42.55319149
21	70,400.00	2.238095238	44.68085106
22	68,700.00	2.136363636	46.80851064
23	64,000.00	2.043478261	48.93617021
24	61,500.00	1.958333333	51.06382979
25	55,500.00	1.88	53.19148936
26	54,900.00	1.807692308	55.31914894
27	52,700.00	1.740740741	57.44680851
28	51,500.00	1.678571429	59.57446809
29	50,700.00	1.620689655	61.70212766
30	49,300.00	1.566666667	63.82978723
31	48,700.00	1.516129032	65.95744681
32	46,800.00	1.46875	68.08510638
33	45,600.00	1.424242424	70.21276596
34	43,300.00	1.382352941	72.34042553
35	39,800.00	1.342857143	74.46808511
36	39,100.00	1.305555556	76.59574468
37	38,600.00	1.27027027	78.72340426
38	33,500.00	1.236842105	80.85106383
39	33,500.00	1.205128205	82.9787234
40	25,900.00	1.175	85.10638298
41	24,800.00	1.146341463	87.23404255
42	21,800.00	1.119047619	89.36170213
43	16,200.00	1.093023256	91.4893617
44	15,800.00	1.068181818	93.61702128
45	15,600.00	1.044444444	95.74468085
46	12,200.00	1.02173913	97.87234043

Table 3.4 Stream Flood Frequency Analysis
Finding the 1.5-year recurrence interval involves plotting the peak streamflow data found on the USGS water data website for Kansas (USDA & NRCS 2009).



Logarithmic trendline equation generated by Excel: $y = 37948 \ln(x) + 28251$
 y = streamflow (cfs)
 x = any given recurrence interval
 $y = 37948 \ln(1.5) + 28251$
 $y = 43,637.60$ cfs for the 1.5-year recurrence flow

Table 3.5 Finding 1.5-year Recurrence Flow

The recurrence interval was plotted against the streamflow using a logarithmic trendline. Excel generates the trendline equation that is used to solve for 1.5-year recurrence flow (USDA & NRCS 2009).

The probability is not as critical information as the recurrence interval, but it was calculated for a better understanding of the probability of each streamflow. After all of the recurrence intervals were calculated, the 1.5-year flood frequency flow was calculated by creating a new scatter-plot in Excel. The recurrence interval was plotted on the x-axis and the streamflow was the y-axis. The trendline was then set to logarithmic, and the equation for the logarithmic trendline was automatically calculated by Excel. The data for each site is shown below. An additional neighboring gage for each site was calculated in order to compare the flowrates for the surrounding reach. The calculations are included in Chapter 05 Design Application. Once all of the 1.5-year flood frequency flows were calculated

for each site, the cross-sectional area, width, and mean depth were found by going to the USGS water data for each Kansas site and comparing the 1.5-year flood frequency flow to the chart under the "Surface Water: Field Measurements" drop-down menu for each gage. After getting to the "Surface Water: Field Measurements" the "HTML Table with Channel Data" was selected. The cross-sectional area and width were found by finding the streamflow on the field measurements chart that aligned with the 1.5-year flood frequency flow. If the streamflow on the field measurements chart did not align with the 1.5-year flood frequency flow, then the data for two entries above the closest number to the 1.5-year flood frequency flow, and two entries below were averaged to determine the cross-sectional area and width. The cross-sectional area and width were used to calculate mean depth. The formula for mean depth used is:

$$\text{Mean depth} = \text{cross sectional area (ft}^2\text{)} / \text{width (ft)}$$

The entrenchment ratio and width/depth ratio equations used in the cross-sectional areas taken at each study site are:

$$\text{Entrenchment ratio} = \text{flood prone width (ft)} / \text{bankfull width (ft)}$$

$$\text{Width/Depth ratio} = \text{bankfull width (ft)} / \text{mean depth (ft)}$$

The goal for a C4 and C5 river is to have a width/depth ratio less than 50 and an entrenchment ratio no less than 1.4 (Rosgen 1997).



Eastern Chipmunk *Tamias striatus griseus*

Eastern chipmunks are likely to be found along wooded bluffs bordering waterways in eastern Kansas and prefer fallen logs on the floor of deciduous forests (Kansas Mammal Atlas 2017) (Figure 4.1 by author 2021).

Chapter 04

Case Studies

Case Studies

Nine case studies were identified for further study on how they handled floodplain and riparian vegetation restoration in a variety of settings (from rural to urban). There were a multitude of sources including peer-reviewed journal articles that conducted long-term studies, restoration firms' websites with fully installed projects and projects that are still in their early implementation stages, and government articles and journals. The case studies were selected for how they addressed one or more of the following criteria: riparian vegetation restoration, use of natural stream channel restoration methods, addresses climate change conditions on riparian ecosystems, floodplain restoration, and habitat restoration. The selected cases studies were categorized into two sections: case studies in Kansas and case studies outside of Kansas. Information and data for the case studies were collected through journal articles, restoration firms' project descriptions, and state websites and published reports. The case studies in Kansas tended to focus primarily on streambank stabilization and the case studies outside of Kansas focused more on floodplain and riparian restoration.

An overview of each project's background and project description is given to provide context on the techniques, management methods, and analysis strategies used. The key takeaways from the case studies will be categorized into direct design implementation strategies or management strategies for long-term site observation. Summary and reflection are noted after each project stating why the case study was chosen and how the study or project could relate to or be applied at the Kansas and Wakarusa River sites. This chapter concludes with a synthesis chart comparing how each case addressed the criteria noted above and the key takeaways from each case study that will be used to influence the projected site designs on the Kansas and Wakarusa Rivers.

Case Studies in Kansas

Delaware River Watershed Restoration & Protection Strategy (WRAPS) Application on the Delaware River

Location -

Delaware River, Delaware Watershed in Northeast Kansas

Scale -

The project was located on the Delaware River and consisted of 23 project sites spanning four counties.

Date -

Official WRAPS watershed plan adopted in May 2007; restoration efforts on the Delaware River began in June 2010 and finished in March 2017.

Participants -

Delaware River Watershed Restoration and Protection Strategy (WRAPS), Glacial Hills Resource Conservation and Development Region, Inc., a stakeholder leadership team composed of eleven people, Wildhorse Riverworks, and the Kansas Department of Health & Environment.

Project Goals or Expected Outcomes -

WRAPS goals: Water resource decisions, framework for advancement of watershed objectives, and establish a structure using best management practices and load reduction goals that will be used to assemble the resources necessary to advance watershed restoration work (WRAPS 2020). Project goals for application: Reduce the high streambank erosion rates, loss of valuable farmland, achieve a reduction in sediment volumes entering Perry Federal Reservoir, improve stream function, and improve aquatic and terrestrial habitats (Wildhorse Riverworks 2017).

Project Information -

This project was started after stakeholders in the watershed convened and identified water resource protection needs and goals for a watershed restoration and protection plan. The stakeholders identified seven key water pollutants, a list of best management practices to reduce non-point source pollution, and identification of various educational and outreach strategies to promote water restoration and protection objectives (WRAPS 2011). The best management practices

most suited for the Delaware River are categorized by the varying land-uses including cropland, livestock, gully, and streambank. The four best management practice categories and their proposed best management practice techniques are listed below in Table 4.1:

Land-Use	Best Management Practices
Cropland	• Riparian vegetation buffers • Permanent vegetation • Grassed waterways • Retention structures • No-till systems • Sub-surface fertilizer application
Livestock	• Vegetative filter strip • Relocate livestock feedlots and feeding pens • Relocate pasture feeding sites • Alternative (off-stream) watering system • Rotational grazing system
Gully	• Sediment basins • Diversions • Constructed wetlands • Riparian buffers
Streambank	• Willow cuttings / native vegetation • Bank re-shaping • Stone toe protection • Rock vanes and weirs

Table 4.1 Best Management Strategies for Land-Use Type on Delaware River

During the planning phase the Watershed Restoration & Protection Strategy involves using best management strategies assigned to certain land-uses (WRAPS 2020).

The best management practices were implemented on the Delaware River in Atchison, Brown, Jackson, and Jefferson Counties in Kansas. The collective restoration includes 23 project sites, spans collectively over 3.8 miles of the river, and established over 28 acres of riparian habitat (Wildhorse Riverworks 2017). Wildhorse Riverworks determined Longitudinal Peaked Stone toe protection and either rock vanes or bendway weirs were the best options to reduce streambank erosion after reviewing detailed survey and geomorphic information data was collected for each site. Bendway weirs and rock veins were used to redirect the flow away from the bank in order to reduce the water velocity (Wildhorse Riverworks 2017). These structures were used to reduce the width/depth ratio and to work with the stream's natural movement in order to bring the stream to a more natural state. After streambank stabilization construction was completed, native grass

mixture was seeded into the slopes in addition to native tree and shrub species. According to Wildhorse Riverwork's project description, a total of 18,675 bare-root seedlings and 3,368 live cuttings were planted on the streambanks (Wildhorse Riverworks 2017).

Summary & Reflection -

The Delaware River Watershed Restoration and Protection Strategy application on the Delaware River was chosen as a case study because it addressed best management practices for streambank restoration. The case study used stream restoration techniques to mitigate erosion and sediment transportation through stone-toe protections (thick layer of rocks at the base of the streambank), rock vanes, and weirs. These techniques have the potential to be applied on the Kansas and Wakarusa River study sites. The restoration on the Delaware River provided the Delaware River access to its floodplain in the designed areas and implemented native vegetation along the banks that dually served as natural erosion control and habitat for riparian vegetation.

South Fork Republican River Restoration Phase I

Location -

South Fork River, Kansas

Scale -

Project spans across the South Fork of the Republican River in Kansas.

Date -

Project submitted NAWCA grant in October 2015, and grant awarded in May 2016.

Participants -

North American Wetlands Conservation Act, Kansas Department of Wildlife, Parks, and Tourism, National Wild Turkey Federation, Cheyenne County Noxious Weed Department, Natural Resource Conservation Service, Republican River Restoration Partners, Pheasants Forever, and Cheyenne County Wildlife, Inc.

Project Goals or Expected Outcomes -

Improve wildlife habitat, open canopy to provide waterfowl roosting habitat and hunting opportunities, control encroachment of invasive saltcedars and Russian olive trees and shrubs, improve the health of the river system, and restore surface and groundwater flows to the Republican River.

Project Information -

The main technique used for restoring areas along the Republican River is invasive species removal and monitoring/maintenance for at least three years after removal is done on the restored areas. The process used for removal was to cut and mulch the invasive species and spot treat the stumps with a chemical that is approved for use around aquatic environments. The chemical used to halt the growth of the stumps is called Garlon 3A, a salt solution that is water soluble and degrades with sunlight (Bain 2019). Invasive species removal was key to this river restoration project because the invasive species threatened to out-compete with the native species, taking away habitat cover for the wildlife that use the Republican River. The Republican River is considered a stopover point for migrating waterfowl who use the open riparian canopy it provides. The project removed an estimate of 4,000 trees along the Republican River. The second phase of this project was halted due to contractor issues and the small NAWCA award not being granted. Before and after photos of restoration areas are shown in Figures 4.2-4.5.



Figures 4.2-4.5 South Fork Republican River Restoration Phase I

The four figures show sections of the south fork Republican River before and after restoration intervention (Bain 2019). It is to be noted that the before pictures are taken in the winter and the after photos are during the growing season.

Summary & Reflection -

The South Fork Republican River Restoration Phase I was chosen for its use of a simple restoration technique to improve the riparian vegetation, wildlife, and aquatic species habitat along the stretch of the entire South Fork Republican River Reach within the boundaries of Kansas. The project sites at the Kansas and Wakarusa Rivers may require solutions in some places that do not involve earthwork. By simply identifying and controlling the invasive species within the floodplain allows native vegetation that aquatic and wildlife species rely on for habitat to flourish.

Case Studies Outside of Kansas

Middle Ebro River Floodplain Vegetation Restoration

Location -

Middle Ebro River, Iberian Peninsula, NE Spain

Scale -

The study occurred over a 346 km stretch of the Middle Ebro River in between Logrono and La Zaida through the region Ebro Depression. Riparian vegetation at 33 sites where different restoration approaches were applied within the Middle Ebro River floodplain were assessed over the span of 20 years.

Date -

The study of the 33 sites lasted from 1980-2006, the peer-reviewed paper was published a journal article in 2016.

Participants -

Eduardo González, Adriá Masip, Eric Tabacchi, Monique Poulin

Project Goals or Expected Outcomes -

Assess vegetation establishment on floodplain lands abandoned completely by human activity and restored by a gradient of different approaches including active channel widening and floodplain excavation and simple abandonment of human activities (e.g., agriculture, gravel extraction, and forestry) with and without the plantation of native shrubs and trees (González, Masip, Tabacchi, Poulin 2016).

Project Information -

This project prefaced their study stating that fully restoring natural riparian floodplain is unrealistic, but local-scale recovery of riparian plant communities in areas that have a low economic value and landowners are willing to allot their land for restoration purposes. The researchers took two floodplain restoration approaches to this study, a geomorphic approach, and a simple cessation of human activity with no earthwork (referred to as conversion approach). The geomorphic approach included channel widening through dismantling and setting back flood defenses, and floodplain lowering by excavation. The conversion approach involved different interventions: 1) existing hybrid poplars were left alone, 2) existing poplars were clear-cut with allowance of resprouting, and 3) poplars were clear-cut and chemical stump removal was applied. The results of the study were compared to 13 reference reaches located in areas designated as nature reserves.

The Middle Ebro River floodplain vegetation restoration plan addressed the social stigma of removing flood defense in populated areas because stabilizing channels are commonly thought to be the only effective solution to reduce flood risk. As a result of this stigma, the researchers stated that there is a need for a more socially acceptable restoration actions that improve ecological value of lands and riparian vegetation restoration. The solution to the stigma of flood defense removal implemented in this project included lowering the floodplain by using heavy machinery to excavate without altering the flood defenses to allow groundwater access for the recovering plant community that would be otherwise inaccessible. This strategy allows for the groundwater access without increasing the flood risk in the vicinity. The purpose of excavation was to mimic the natural cycles of succession. However, in more elevated floodplains without access to groundwater, disturbance may lead to invasive pioneer species. The potential for invasive species was taken into consideration in this study and stated that the new growth was not strictly riparian. The sites that used the geomorphic strategy were found to share the most similarities with riparian vegetation found at the reference reaches. In addition to revegetation of riparian species, the geomorphic sites allowed for channel migration and increased floodwater storage.

Riparian and wetland vegetation were not predominantly found in converted sites apart from the occasional species that had a high capacity for vegetative regeneration through root suckering (González, Masip, Tabacchi, Poulin 2016). It was noted that conditions immediately following human abandonment of the floodplain was the biggest factor in vegetation regeneration rates than its geomorphic approach counterpart. The researchers concluded that, “as long as the conditions immediately following abandonment can be partially modulated by humans, management can greatly influence trajectories of vegetation recovery.” (González, Masip, Tabacchi, Poulin 2016). The study sites with the three variations of poplar species showed that if forest-like communities were the goal, leaving them untouched or allowing for re-sprouting after cutting was the most effective solution. However, these two strategies left the area with non-structurally complex vegetative communities. The converted sites overall were more heterogeneous and diverse than the geomorphic sites; however that did not mean that diversity contained a majority of riparian species. The researchers concluded that there needs to be further research on active restoration methods for floodplain vegetation regrowth.

Summary & Reflection -

The Middle Ebro River Floodplain Vegetation Restoration study was chosen because of its well-documented assessment. The study compares the ability of excavation of the floodplain and removal of human activity/development on the site to determine which approach yields the highest riparian vegetation community. This study showed that both options work and would require management practices after installment. The sites at the Kansas and Wakarusa Rivers all have different land-uses that would either allow for excavation to reconnect the river to the floodplain or would need the converted site approach that does not need earthwork.

Lones Levee Setback and Floodplain Restoration Project

Location -

Middle Green River, King County, Washington

Scale -

This project involves removing three levees totaling 4,112 feet and recover up to 45 acres of connected forest floodplain within an 81.4-acre site.

Date -

Project waiting on funding as of this published date.

Participants -

The King County Department of Natural Resources and Parks

Project Goals or Expected Outcomes -

Restoration of natural river processes, increase quantity and diversity of salmon habitat, and maintain existing level of off-site flood and erosion protection for agricultural land, private farms and residences and Green Valley Road.

Project Information -

This project is still currently a proposal as of written date; however, it was selected to provide an example of present day (most current date to this project) floodplain restoration techniques being used in the United State. The proposal includes plans of removing three existing levees at the Lones – Turley levee site. This proposal is the result of the Chinook salmon being listed as endangered in 1999, and their population continuing to dwindle on the Green River due to flood control measures such as levees and dams. In 2005, the WRIA 9 Salmon Habitat Plan identified the need for salmon habitat restoration and repopulation in the Green/Duwamish and Central Puget Sound Watershed (Green/Duwamish and Central Puget Sound Watershed Water Resource Inventory Area 9 (WRIA9) Steering Committee 2005).

To create new fish and wildlife habitat the plan proposes to remove 1,600 linear feet of Lones Levee and construct a new setback facility. The removal of the 1,600 linear feet includes the removal of over 25,000 cubic yards of rock and native substrate material and the removal of 600-800 trees that will be redistributed within the adjacent river and floodplain area. The new erosion protection facility that will replace the decaying Lones levee involves the construction of 400 linear feet of buried rock revetment and up to twelve engineered

log jams that spans over 1,500 linear feet. A 600-foot berm will be constructed to maintain or reduce flooding on adjacent private property.

The construction of the new revetment will expose the native cobble that will be used for gravel bar creation and used by salmon for spawning, the rest will be recycled for planting trees and shrubs on other government property. Once the levees are gone, the new setback facility is expected to reconnect the natural channel migration flow, forming an island-braided pattern in the channel in addition to logjams, spring brooks, floodplain ponds, and flood channels. The project is proposed to create 20-25 acres of wider and shallower active river channel, 30-45 acres of connected forested floodplain, and 10 acres of immediate off-channel habitat. The previously listed project outcomes are meant to provide a diverse habitat for the respawning of Green River Chinook salmon and steelhead stocks, and the wildlife that rely on the Green River.

Summary & Reflection -

This project proposal was well documented and laid out in GIS format, showing current conditions and proposed future conditions. It was selected because it provided some insight to how government municipalities are currently handling floodplain restoration and aquatic/wildlife habitat creation while being cognizant of surrounding private property. This project addressed natural channel restoration, habitat creation, levee removal, mitigation of high runoff flows from adjacent agriculture land, and protection from flooding of adjacent agriculture land through underground levees. Costs in this project are lowered through recycling natural materials extracted from the levee that are reused as fish and wildlife habitat within the adjacent floodplain area. Overall, this project is similar in scale to the more rural Kansas and Wakarusa River proposed sites.

South Fork Republican Restoration Coalition: Stream Management and Restoration Planning Project

Location -

South Fork of the Republican River, South Platte Basin, Colorado

Scale -

60 river miles of the South Fork Republican River in Colorado.

Date -

Started January 2018, monitoring still continues as of this publish date.

Participants -

South Fork Restoration Coalition, Republican River Water Conservation District, Colorado Parks and Wildlife, Three River Alliance, The Nature Conservancy, and the Republican River Water Conservation District.

Project Goals or Expected Outcomes -

– The listed project goals include improvement of in-stream surface flows in the project area; restoration of riparian and riverine habitat in order to address wildlife and native fish habitat needs; reduce invasive vegetation; and create future economic-based opportunities in the project planning area (Daniel 2019).

Project Information -

Stakeholders in the South Fork Republican River Restoration involved in the planning process include agricultural producers, riparian landowners, aquatic and riparian science, environmental advocacy, utilities or other water management, recreation and tourism, local government and land use planners, and state and federal agencies. The stakeholders are engaged in the entire process of the project, shown in Figure 4.6. The South Fork Republican River Restoration project consists of five strategies plans for achieving the project goals.

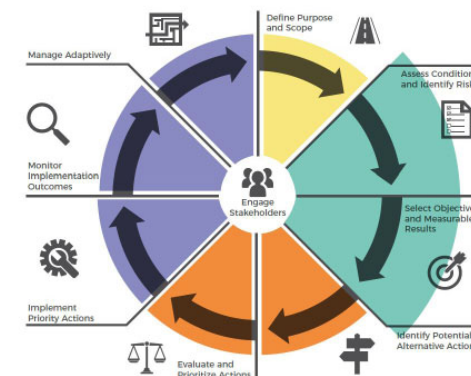


Figure 4.6 Stakeholder Engagement Phase of Restoration Plan

The diagrammatic figure shows how the stakeholder engagement phase entails for the overall restoration plan (Daniel 2019).

The five strategy plans are 1) River Channel and Floodplain Restoration Assessment, 2) Riparian Corridor and Riverine Habitat Restoration Plan, 3) Hydrology Assessment to Determine Surface Flow Needs, 4) Native Fish Population and Habitat Research, and 5) Recreation Economic Opportunities Assessment. Data collection and analysis consisted of vegetation mapping, shallow soil sampling, documenting historical flooding, documenting historical riparian forest dynamics, assessing surface and groundwater hydrology, and identifying species and habitats of concern on the South Fork Republican river (Clarke 2019). The initial assessment plan assessed the following variables shown in Table 4.2 to evaluate watershed health and delivery of ecosystem services:

Variable		Assessment Level
Ecological Integrity:		
X	Existing Flow Regime	Less Precise
X	Future Flow Regime	Less Precise
X	Sediment Regime	Moderate
	Water Quality	
X	Network Connectivity	Moderate
X	Floodplain Hydrology	Less Precise
X	Riparian Vegetation	More Precise
X	Stream Complexity	Moderate
X	Structural Complexity	Moderate
Regulating and Maintenance:		
X	Flood Regulation	Less Precise
X	Groundwater Recharge	Less Precise
X	Erosion Control	Moderate
X	Pest Regulation	Moderate
X	Regulatory Compliance	Moderate
Provisioning:		
X	Agricultural Production	Less Precise
	Drinking Water Supply	
	Industrial Processing	
	Hydropower Production	
Cultural:		
X	Aesthetics and Intrinsic Values	Less Precise
X	Symbolic/Emblematic Species	Less Precise
X	Boating Recreation	Less Precise
X	Angling Recreation	Less Precise

Table 4.2 Assessment Variables to Determine Watershed Health

The South Fork Republican Restoration Coalition used the variables in the table above to determine the existing conditions of the watershed (Daniel 2019).

The River and Channel Floodplain Assessment focuses on restoration of water and sediment load conveyance regimes disrupted by Bonny Dam without impacting the dam's storage capacity and flood control intent. Sedimentation distribution control strategies enlisted in this project include a series of offset bioengineered sediment traps and cattail management. Cattails contribute to sediment entrapment and cause issues with the channel flow (Clarke 2019).

The Riparian Corridor and Riverine Habitat Restoration Plan will assess and evaluate management alternatives and construct a River Corridor Restoration Plan to improve riparian habitat (Daniel 2019). The identified techniques for native riparian forest habitat include targeting invasive species, creative opportunities for passive recruitment of cottonwoods, targeting riparian plantings for streambank stabilization, and restoring vulnerable and threatened plant communities (Clarke 2019). Other identified invasive plants marked for removal in this project include Russian olive, Tamarisk, and Kochia. The removal of the invasive species allows room for native plants to grow.

The Hydrology Assessment to Determine Surface Flow Needs assess hydrologic regimes in the watershed to elevate stream function and support fish populations using existing data models (Daniel 2019). This section developed from the Republican River Basin Study Executive Summary (2016) that showed an overall decrease in flows and altered flow regimes throughout the Republican River Basin. The low flow rates and altered flow regime would favor some fish spawning habitat over others (USDIBRTSC 2016).

The Native Fish Population and Habitat Research will identify potential fish habitat using habitat evaluation surveys. Identified fish species that would benefit from this restoration include the brassy minnow, orangethroat darter, and stonecat, all of which are threatened or a species of concern (Clarke 2019). Finally, the Recreation Economic Opportunities Assessment will explore alternatives for recreation at the former reservoir site (Daniel 2019).

Summary & Reflection -

The South Fork Republican River stream management project was selected because of its categorization of five strategy plans for restoration that addressed aquatic and wildlife habitat protection, economic growth through recreation, floodplain and river function, and riparian vegetation installation. This project also mapped and documented historic flooding on the river and historic riparian forest dynamics. Historic stream channel patterns and floodplain area data is available and will be referred to on the Kansas and Wakarusa Rivers to better understand the river's behavior. This project had a very organized assessment plan that was easy to understand, and most assessments could potentially be replicated at the Kansas and Wakarusa River sites.

Random Probability Distribution and Priority Effects in Floodplain Restoration on the Cosumnes River

Location -

The Nature Conservancy's Cosumnes River Preserve, California's Central Valley

Scale -

The study site is made up of two restored floodplains, at 300 permanent vegetation plots.

Date -

The study took place over the course of six years, beginning in 2000 and concluded in 2006.

Participants -

Wendy Trowbridge, University of Nevada Reno

Project Goals or Expected Outcomes -

The goal of this study was to 1) test the success of process-based restoration regarding establishment and persistence of native wetland species and 2) to test if community plant assembly on the two restored floodplains proceed in a deterministic fashion (Trowbridge 2007).

Project Information -

This project began at the beginning of a wet cycle on the Cosumnes River. Levee breaches along the study areas allowed water and sediment to flow onto the two connected floodplains (Trowbridge 2007). This study wanted to test the common belief that 1) if physical processes are restored, plant communities will naturally reassemble themselves, and 2) restored communities will resemble reference sites (Trowbridge 2007). If the hypothesis was correct, then the two floodplains would have similar plant communities.

During the winter and spring water flowed onto the floodplain areas. Then slowly drained during the late spring and summer seasons; flowing from the northern floodplain into the southern floodplain. Both floodplains were inundated (full of water) for the same range of time and both contain ephemeral ponds at their lowest points.

In order to track plant community change, a total of 260 permanent plot markers were installed over 16 transects (140 plots on the northern and 120 plots on the southern) (Trowbridge 2007). Plant communities were analyzed through community groups based on their species cover using TWINSAN and inundation was hypothesized to be the main gradient controlling plant distribution. There were four different patterns of change identified for the plant communities over the course of the study: consistently increasing, consistently decreasing, wet increasing, and dry increasing (Trowbridge 2007).

At the end of the study, native perennial plants were the dominant species and the plant communities have sorted themselves out in relation to elevation (higher plots, middle plots, and lower plots). The study found that plants on the northern floodplain followed the pattern predicted for deterministic community assembly and inundation frequency was a larger determining factor in determining species distribution. The southern floodplain did not follow the pattern predicted for deterministic community assembly. After the 10-year study, the southern floodplain still showed signs of dispersal limitation (Trowbridge 2007). This discrepancy in the southern floodplain was attributed to the short peak of an invasion of a nitrogen fixer species that may have altered the soil chemistry. Another factor attributed to the southern floodplain's high level of dispersal limitation is the two years extra years of wetter conditions at the beginning of the study

causing poor seed establishment conditions. The norther floodplain consisted of more sedges and rushes while the southern floodplain consisted more of perennial forbs at the conclusion of the study (Trowbridge 2007).

The concluding takeaway from this study is that it may be more effective to set goals based on desired characteristics of the system instead of goals based on historic site behaviors. Trowbridge also stated that inundation duration and frequency are not adequate predictors of short-term trajectories (Trowbridge 2007). This study concludes that restoration of the floodplains did lead to the establishment of riparian plant communities primarily composed of native species; and regular prolonged flooding is necessary to maintain the newly established native riparian plant communities (Trowbridge 2007).

Summary & Reflection -

This study was selected due to its study and challenge of a commonly held assumption about riparian plant species ability to establish during every riparian restoration. The findings showed that while riparian and floodplain restoration does produce native plant community creation, varying factors can alter the speed and stability of the species establishment. This finding will help in assessing the existing plant communities and the future plant community formation at the Kansas and Wakarusa River sites. This study shows that one cannot assume that riparian restoration will produce stable cohesive plant communities within a short amount of time following the restoration process.

Estimating Site Resilience

Location -

The Northeastern landscapes of the United States.

Scale -

The study focused on north eastern area of the United States.

Date -

Study published in 2016.

Participants -

The Nature Conservancy: Mark Anderson, Analie Barnett, Melissa Clark, Charles Ferree, Arlene Olivero Sheldon, and John Prince; sponsored by Doris Duke Charitable Foundation and the U.S. Department of the Interior, Fish and Wildlife Service

Project Goals or Expected Outcomes -

To quantify landscape diversity at a 30-m scale and estimate the number of species-relevant microclimate to assess the site's resilience.

Project Information -

This study and metric creation were developed from past studies that proved sites with high landscape diversity and local connectiveness create "microclimate buffers" that shield resident species from the direct effects of climate change (Anderson, Barnett, Clark, Ferree, Olivero Sheldon, Prince 2016). The study quantifies landform variety, elevation range, and a wetland score to create a landscape diversity metric.

Landform variety was quantified using a model that classifies a surface into one of 17 elementary landforms using a 30-m digital elevation model in GIS that analyzed slope, aspect, land position, and moisture accumulation. Landform variety was deemed an important metric because landforms determine local vegetation patterns due to their combination of temperature, moisture, exposure, nutrient availability, soil depth, and its influence on species distribution (Anderson et al. 2016). The study states that position, moisture, slope, and aspect combine to create small-scale environments. An example from the study showed that south-facing steep slopes created the best conditions for the timber rattlesnake because the snake likes to sun itself, however if conditions get hotter, it will likely move to a cooler environment (Anderson et al. 2016).

Elevation range affects species distribution when species are seeking the desired climate habitat. The study states that past studies show an upward migration of species to escape the increasing warming southern temperatures (Anderson et al. 2016). Elevation was measured using a 30-m digital elevation map (DEM) with the null areas (development and ocean area) removed.

The wetland score discussed in this paragraph is important because wetlands create microhabitats. Wetlands are especially important in relationship to the rapidly changing climate because they retain soil moisture longer, dry out unevenly, and preserve a mixture of organic and wetland soils (Anderson et al. 2016). The study states, "Protecting wetlands and riparian corridors has been suggested as one of the single best actions in promoting resilience and in sustaining biodiversity" (Naiman 1993, Fremier 2015; cited in Anderson et al. 2016). To calculate the wetland score the researchers compiled data from the National Wetlands Inventory data that was gridded into 30 m and the non-wetland classes were removed. Soil diversity was also mapped to identify areas with high soil diversity using the gSSURGO. The final results were mapped by giving each variable "Z-scores" with a mean of 0 and standard deviation of 1 and combined them into a single index (Anderson et al. 2016). The final combined map shows the areas with the most microclimates based on landform variety, uncorrelated elevation range, wetland density, and soil diversity as having the highest landscape diversity.

Summary & Reflection -

This study was chosen for its quantification of a site's ability to be resilient in the rapidly changing climatic conditions. The metrics used in this study can be altered and applied at the Kansas and Wakarusa River sites to aid in assessing what changes need to be made to create the ideal "microclimate buffer" for that area. Topographic and elevation maps can be made for the Kansas and Wakarusa sites in addition to gathering information from the National Wetlands Inventory to create an overview of the site's existing conditions.

Succession of Fish Diversity After Reconnecting A Large Floodplain to the Upper Danube River

Location -

The upper Danube River, 68 km north of Munich.

Scale -

15 river sections of the upper Danube River; 15 oxbow sections, and 7 floodplain ponds, each on a stretch of 30 m.

Date -

Study published in 2015, assessment from 2010-2013.

Participants -

Joachim Pander, Melanie Mueller, and Juergen Geist; Aquatic Systems Biology Unit, Department of Ecology and Ecosystem Management, Technische Universität München, Mühlenweg

Project Goals or Expected Outcomes -

Analyze the colonization and succession of the fish community in the new floodplain river and the changes in existing adjacent habitats over a period of four years (Pander, Mueller, Geist 2015).

Project Information -

The study's principal theory is that the colonization of newly built or restored floodplain habitats with fish is a strong indicator to measure the success of floodplain restoration (Pander, Mueller, Geist 2015). The study took place on the newly permanent floodplain river was created to improve the connectivity of the Danube to its floodplain, restore groundwater level fluctuations of the adjacent alluvial forest, provide additional fish habitat, and reconnected oxbow habitats (Pander, Mueller, Geist 2015). There were three hypotheses tested during the study, "1) The artificial floodplain channel serves as substitute habitat for critical life stages of fishes and consequently mitigates the loss of habitat space and quality in the main river. 2) Colonization and succession patterns of fishes in the restored floodplain habitats depend on distinct habitat type properties, degree of connectivity and the fish community of the source habitat. And 3) Colonization time and population development can be predicted based on data of life history strategies and degree of specialization." (Pander, Mueller, Geist 2015). The conditions prior to the installation showed a shift in fish population from an abundance of potamal species and a decrease in rheophilic species (Pander, Mueller, Geist 2015).

From 2010 to 2013 fish communities were studied in the three present fish communities: river sections, oxbow sections, and floodplain ponds. The study sites were represented in fifteen river sections, fifteen oxbow sections and seven floodplain ponds, all using a sampling stretch of 30m for the initial phase after implementation (Pander, Mueller, Geist 2015). Long-term sampling was done on six 30 m stretches per habitat type. Sampling was always conducted in spring and summer. Software was used to track the changes in abiotic habitat characteristics, number of individuals, species density and diversity.

Results showed an increase in water depth in all of the study sites. Aquatic vegetation species structure richness and cover changed seasonally with lower quantity in spring and higher quantity in the summer (Pander, Mueller, Geist 2015). Before the floodplain river was opened, 21 fish species were documented. The highest level of fish species colonization occurred within the initial period (first two months) after the floodplain river was opened. A total of 37 fish species and one lamprey species from 11 families were sampled, a total of 57,166 individuals (Pander, Mueller, Geist 2015). It was concluded that the amount of time for fish species to colonize a new floodplain river depended on the functional traits of the respective species (Pander, Mueller, Geist 2015). The river sections were less affected by seasonal fluctuation compared to the oxbow sections that were highly influenced by seasonal fluctuation (higher numbers in summer than spring). The overall successfulness of fish species colonization on a newly reconnected floodplain river and oxbows were strongly influenced by habitat properties such as current speed, substratum composition of the stream bed, and water depth (Pander, Mueller, Geist 2015).

Summary & Reflection -

This case study was used to show the importance of monitoring fish species colonization post-floodplain restoration in order to determine the restoration project's success at providing adequate aquatic habitat. The study sites on the Kansas and Wakarusa Rivers design and restoration goals include the creation of aquatic habitat. The methods used in this case study provide a foundation for potential initial indicators of the site's successfulness in providing adequate aquatic habitat post-design implementation.

Floodplain Ecology Restoration Scenarios Given Changes to River Flows Under Climate Change on the San Joaquin River, California

Location -

San Joaquin River in California.

Scale -

Covers part of the Lower San Joaquin River in the South Delta.

Date -

Study published in 2014.

Participants -

M. K. Matella, A. M. Merenlender, Environmental Science, Policy, and Management, UC Berkeley.

Project Goals or Expected Outcomes -

Integrate streamflow dynamics with floodplain area to quantify species-specific habitat availability using hydraulic modeling, spatial analysis, and statistical measures of flow regime to prove that restoration of fish habitat will require a more natural flow regime to make use of restored floodplain and achieve the desired hydrological habitat connectivity (Matella & Merenlender 2014).

Project Information -

The study measures the benefits of increasing floodplain connectivity for a group of species (Sacramento splittail and Chinook salmon) on the San Joaquin Delta using an integrated hydro-ecological model and compares the resulted quantified benefits to past, present, and future flow regimes under several restoration options (Matella & Merenlender 2014). The Sacramento splittail and the Chinook salmon were chosen because they are key indicators of floodplain ecosystem health because they use the Central Valley floodplains for spawning and rearing and the populations have declined in the recent years in conjunction to the lack of floodplain access. The study area included part of the Lower San Joaquin River in the South Delta and includes several opportunities to adjust the river's flow path for floodplain reconnection. The historic flows were divided into two different categories, pre- and post-installation of the dams and models for what the flows would currently look like if the dams were not installed were additionally projected. The relationship between hydrologic and ecological parameters were measured using the Hydrologic Engineering Center Ecosystems Function Model (HEC-

EFM). "HEC-EFM uses a time series of daily mean flow and stage as well as parameters of variables such as season, duration, rate of change and frequency of occurrence to characterize an ecological response." (Matella & Merenlender 2014). Flow frequency, duration, seasonality, inundation, and habitat characteristics were essential indicators in determining a floodplain's sustainability and used in this study to create the conceptual framework for the study sites (Matella & Merenlender 2014).

The proposed restoration treatment using channel alteration included: the current levee configuration, the addition of a backwater slough, and setting back the eastern levee and removing cross levees (Matella & Merenlender 2014). ArcMap was used to create the surface study models and the water data was taken from the USGS water data website. According to the models, 33 years out of the 81-year period of record met the flow threshold for splittail spawning. Using the current conditions, approximately 696 ha is the maximum recoverable floodplain habitat area within the 20km study reach. The levee setbacks add an estimated 1781 ha of habitat for potential inundation, and the slough bypass option provides 603ha corridor on the San Joaquin River (Matella & Merenlender 2014). The study determined that both hydrologic and species habitat modeling is needed to successfully quantify habitat recovery from channel restoration projects (Matella & Merenlender 2014). Understanding the required flow for specific species that require inundated floodplain area to respawn and rear is important information to review before starting restoration projects.

Summary & Reflection -

This study was chosen for its utilization of historic, current, and predicted annual stream flows in conjunction with species habitat modeling to quantify habitat recovery from channel restoration projects. Although the project studying the Kansas and Wakarusa Rivers does not physically quantify habitat recovery, it does calculate the annual peak streamflow at each site in order to determine the existing flows. The methods used in this case study could potentially be used to quantify the habitat recovery rates in the future at the Kansas and Wakarusa study sites.

Synthesis

The selected case studies provide examples of different techniques used for riparian vegetation and floodplain restoration at varying scales. Nearly all of the case studies stated that there needed to be more investigation into floodplain restoration because there is a lack of existing studies of floodplain and riparian restoration at an urban scale. The objective of this chapter was to compare the similarities, differences, and results of the varying techniques of restoration used throughout the case studies.

There were several key recurring themes in the case studies: 1) it is possible, and essential to keep human activity (past, present, and future trends in development) in mind during the entire restoration process, 2) it is impossible to restore a stream, floodplain, and its riparian vegetation back to a 100% natural state, 3) flooding is necessary to maintain riparian habitat within a floodplain, 4) reconnecting parts of the river back to the floodplain is a critical part of floodplain restoration and successfulness of some aquatic species repopulation, and 5) maintaining diversity of species within a floodplain plays a crucial role in the site's ability to withstand future climate change impacts. The case studies proved that it is possible to conduct riparian and floodplain restoration at multiple scales of scale, settings, and intervention practices. Each case study had a set of restoration goals and objectives that the study or project wanted to reach and kept those at the forefront of the initial decision-making process and assessment: mitigation, rehabilitation, or restoration.

The case study applications can be applied within the three riparian forest buffer zones discussed in Chapter 03 Process or as management strategies for long-term site analysis. Table 4.3 on the following page provides a visual synthesis and summary of the case studies.

Case Study Key

Case Study 1	Delaware River WRAPS Application on the Delaware River
Case Study 2	South Fork Republican River Restoration Phase I
Case Study 3	Middle Ebro River Floodplain Vegetation Restoration
Case Study 4	Lones Levee Setback and Floodplain Restoration Project
Case Study 5	South Fork Republican Restoration Coalition: Stream Management and Restoration Planning Project
Case Study 6	Random Probability Distribution and Priority Effects in Floodplain Restoration on the Cosumnes River
Case Study 7	Estimating Site Resilience
Case Study 8	Succession of Fish Diversity After Reconnecting A Large Floodplain to the Upper Danube River
Case Study 9	Floodplain Ecology Restoration Scenarios Given Changes to River Flows Under Climate Change on the San Joaquin River, California

Table 4.3 Case Study Synthesis Chart

This table visually lays out all of the case studies and shows how what criteria they address and the key takeaways from each (Table by author 2021).

	Case Study 1	Case Study 2	Case Study 3	Case Study 4	Case Study 5	Case Study 6	Case Study 7	Case Study 8	Case Study 9
Riparian Vegetation Restoration	X	X	X		X	X		X	
Floodplain Restoration			X	X	X			X	X
Use of Natural Stream Channel Stability Methods	X			X					
Addresses Climate Change Conditions							X		
Habitat Restoration	X	X		X	X				X
Case Study Key Takeaways	A total of 18,675 bare-root seedlings and 3,368 live cuttings were planted on the streambanks of the Delaware River. Longitudinal peaked stone protection, rock vanes, and bendway weirs were implemented to reduce the width/depth ratio and work with the stream's natural movements. A collective of 28 acres of riparian habitat was created, spanning across 28 different sites on the Delaware River by reconnecting the river to its floodplain, channel meandering, and planting of native vegetation.	Invasive species were identified and removed using a three-year maintenance plan. The invasive species were removed to allow native riparian vegetation species to compete, and continue to perform their ecosystem services such as habitat for waterfowl, wildlife, and aquatic species. This case study was chosen as a low-impact solution for areas where a lot of earthwork is not feasible.	The project used two riparian vegetation restoration approaches: geomorphic (excavation) & conversion (no earthwork). The geomorphic resulted in more native riparian species. The conversion was more heterogeneous and diverse, but did not necessarily contain predominantly native riparian species. The conversion sites heavily relied on management practice for a successful riparian species revegetation. The geomorphic sites provided more floodwater and water table storage. Channel widening allowed for better channel migration.	Removal of existing levees allowed for natural spring brooks, floodplain ponds, and reconnected the Green River to its floodplain in the restored area. Removal of existing levee and setback of the new flood facility allowed the channel to return to its natural island-braided pattern. The project utilized log jams, spring brooks, floodplain ponds, and natural channel migration patterns. Habitat for aquatic and wildlife species was created through the addition of wood structures and removal of existing levees.	The <i>Riparian Corridor and Riverine Habitat Restoration Plan</i> identified invasive and removed invasive vegetation species to allow for passive recruitment of Cottonwood; used riparian vegetation to stabilize streambanks, and restored vulnerable plant communities. Water and sediment load conveyances regimes were studied and a series of offset bioengineered sediment traps and cattail management were implemented. Fish and wildlife habitats in the area were evaluated and the needs for each were addressed. Some techniques included channel restoration and an increase in riparian vegetation.	This case study tested a restored floodplain's ability to regenerate riparian vegetation after human abandonment. It proved that regular prolonged flooding is necessary to maintain the newly established riparian plant communities.	This case study quantified and created metrics for a site's ability to be resilient against rapidly changing climate conditions. The study concluded that the more diverse landscapes (e.g. species, structure, topography) would be the most resilient against climate change conditions. Diverse topography and species composition (wildlife and vegetation) can create "microclimate buffers" for small ecosystems by keeping a cooler, shadier climate than its surroundings.	This case study tracked rates and quantities of fish colonization within a newly constructed floodplain. The study arose from a large change in the fish species composition of the Danube River. The study indicated that once the river was reconnected to its floodplain, there was a surge in fish colonization. By reconnecting the river to the floodplain, the fish species saw an increase in the diversity and population size of fish. The newly constructed floodplain became a habitat and spawning area for the fish.	The case study on the Lower San Joaquin River demonstrated that it is possible to quantify habitat recovery using past, current, and future flow rates in conjunction with habitat modeling.

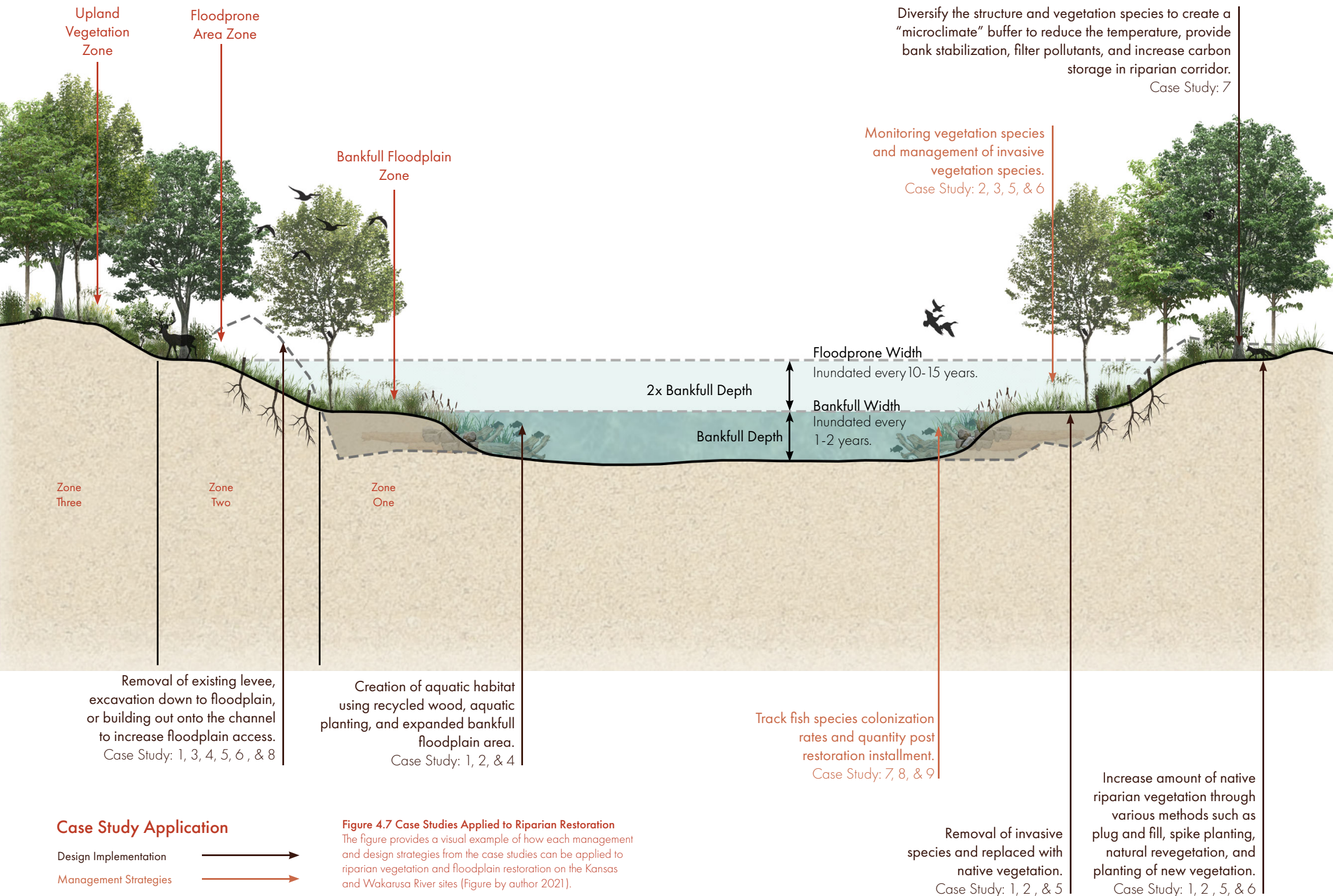


Figure 4.7 Case Studies Applied to Riparian Restoration
The figure provides a visual example of how each management and design strategies from the case studies can be applied to riparian vegetation and floodplain restoration on the Kansas and Wakarusa River sites (Figure by author 2021).



Eastern Red Bat *Lasiurus borealis*
Eastern red bats forage for insects over fields and water in early evening and prefer to live in hollow trees (Great Plains Nature Center 2013) (Figure 5.1 by author 2021).

Chapter 05

Design Application

Design Application

This chapter explores the application of design guidelines and techniques for riparian and floodplain restoration influenced by results found in the previous chapter, Case Studies, and the literature review. The proposed restoration procedure applied on three sites on the Kansas River and one site on the Wakarusa River will address the primary concerns: riparian vegetation species restoration; wildlife and aquatic species habitat creation; streambank stabilization; and reconnection of the river to its floodplain. The previously listed site concerns will be addressed to better prepare the sites for the current and predicted rapid impacts of anthropogenic climate change that will affect the streamflow, vegetation composition; and wildlife and aquatic species ranges along the Kansas River corridor within the next century.

An initial site assessment and analysis must take place before any design suggestions can be applied. The initial site assessment for each study site includes the SVAP version II (USDA & NRCS 2009) and a flood frequency analysis using information found on the USGS Kansas Water Data website (USGS 2020). This chapter will first review the full chart of the SVAP version II elements used for scoring each site, then review the overarching design restoration targets that can be applied to all of the sites and is not particular to one area. Next, each study site will show the initial assessments and analysis followed by the design suggestions based upon the initial assessments using the broader guideline of the three riparian buffer zones determined in Chapter 04 Case Study. The four sites will be presented in the following order: The Kansas River sites will be displayed by how they occur geographically from east to west along the Kansas River: 1) The Kansas River at Ogden, Kansas, 2) The Kansas River at DeSoto, Kansas, 3) The Kansas River at Shawnee, Kansas. The Wakarusa River at Eudora, Kansas, a tributary of the Kansas River, will be the final study site of this chapter.

Stream Visual Assessment Protocol Version II Table				
Channel Condition	No incision, active channel connected to floodplain.	Some recovery from past incision, floodplain connected in some areas.	Active incision, stressed plants, disconnected floodplain, steep banks.	Headcuts, active incision, no floodplain connection, steep streambanks.
	10 9	8 7 6	5 4 3	2 1 0
Incised Channel	No incision, active channel connected to floodplain.	Less than 3 bars, minimal lateral migration, few shallow areas.	3-4 bars in channel, sediment deposition causing shallow channel.	Braided channel (5+ bars), severe sediment deposition, bank erosion.
	10 9	8 7 6	5 4 3	2 1 0
Aggrading Channel	No incision, active channel connected to floodplain.	Less than 3 bars, minimal lateral migration, few shallow areas.	3-4 bars in channel, sediment deposition causing shallow channel.	Braided channel (5+ bars), severe sediment deposition, bank erosion.
	10 9	8 7 6	5 4 3	2 1 0
Hydrologic Alteration	Bankfull flows occur, no flood control in floodplain, natural flow regime.	Bankfull flow only occurs every 3-5 years, development in floodplain.	Bankfull flow only 6-10 years, development in the floodplain.	Bankfull flows rarely occur, development runoff directly into stream.
	10 9	8 7 6	5 4 3	2 1 0
Bank Condition	Banks are stable and protected, no artificial structures, no excessive erosion, little to no livestock or recreation near banks.	Moderately stable banks, limited number of structures present, recreation + livestock use does not effect streambank.	Moderately unstable banks, artificial structures cover more than 1/2 of reach, excessive bank erosion, recreation + livestock use contribute to erosion.	Banks are unstable, artificial structures are dominant use in reach, active bank failure, recreation + livestock use contribute to bank instability.
	10 9	8 7 6	5 4 3	2 1 0
Separately Assess Left & Right Bank	10 9	8 7 6	5 4 3	2 1 0
Riparian Area Quantity	Natural plant community extends 2+ bankfull widths more than the entire active floodplain	Natural plant community extends at least 1/2 of bankfull width, less than 30% vegetation gaps.	Natural plant community extends at least 1/3 of the bankfull width, vegetation gaps exceed 30% of reach.	Natural plant community extends less than 1/3 of bankfull width, vegetation gaps exceed 30% of reach.
	10 9	8 7 6	5 4 3	2 1 0
Riparian Area Quality	Natural and diverse riparian vegetation with composition, density and age structure, no invasive species or concentrated flows.	Natural and diverse riparian vegetation with composition density, little or no concentrated flows, invasive species present in small numbers.	Natural vegetation compromised, evidence of concentrated flows, invasive species common.	Little or no natural vegetation, evidence of concentrated flows running through entire riparian area, invasive species widespread.
	10 9	8 7 6	5 4 3	2 1 0
Canopy Cover	50-75% of water surface shaded within the length of the stream in reach.	>75% of water surface shaded within the length of the stream in reach.	49-20% of water surface shaded within the length of the stream in reach.	<20% of water surface shaded within the length of the reach.
	10 9	8 7 6	5 4 3	2 1 0

Water Appearance	Water is very clear, submerged features in stream visible at depths of 3 to 6 feet. No motor oil or sheen on surface.	Water is slightly turbid, especially after storm event, submerged features in stream visible at depths of 1.5 to 3 feet. No motor oil sheen on surface.	Water is turbid most of the time, submerged features in stream visible .5 to 1.5 feet, and/or motor oil is present on water surface or areas of slackwater, and/or evidence of metal precipitates in stream.	Extremely turbid water most of the time, submerged features in stream are visible only within .5 feet below surface, and/or motor oil sheen is present on the water surface or areas of slackwater.
	10 9	8 7 6	5 4 3	2 1 0
Nutrient Enrichment	Clear water along entire reach. Little algal growth present.	Fairly clear or slightly greenish water, moderate algal growth on substrates.	Greenish water particularly in slow sections, abundant algal growth, especially during warmer months, and/or slight odor of ammonia, and/or sporadic growth of aquatic plants within slackwater areas.	Pea green present, thick algal mats dominating stream, and/or strong odor of ammonia, and/or dense stands of aquatic plants widely dispersed.
	10 9	8 7 6	5 4 3	2 1 0
Pools	More than 2 deep pools separated by riffles, each with 30%+ of the pool bottom covered by depth, wood, or other cover, shallow pools also present.	1 or 2 deep pools separated by riffles, each with 30% of the pool bottom covered by depth, wood, or other cover, at least one shallow pool present.	Pools present but shallow, only 10-30% of pool bottoms are obscured due to depth or wood cover.	Pools are absent, but some slow water habitat is available, no cover discernible, or reach is dominated by shallow or continuous pools or slow water.
	10 9	8 7 6	5 4 3	2 1 0
Barriers to Aquatic Species Movement	No artificial barriers that prohibit movement of aquatic organisms during any time of the year.	Physical structures, water withdrawals and/or water quality seasonally restrict movement of aquatic species.	Physical structures, water withdrawals and/or water quality restrict movement of aquatic species throughout the year.	Physical structures, water withdrawals and/or water quality prohibit movement of aquatic species.
	10 9	8 7 6	5 4 3	2 1 0
Fish Habitat Complexity (See appendix for listed types of habitat features used in assessment).	10+ habitat features available, at least one of which is considered optimal in reference sites.	Eight to nine habitat features available.	Six to seven habitat features available.	Less than four habitat features available.
	10 9	8 7 6	5 4 3	2 1 0
Aquatic Invertebrate Habitat (See appendix for listed types of habitat type characteristics used in assessment).	At least nine types of habitat present. A combination of wood with riffles should be present and suitable in addition to other types of habitat.	Eight to six types of habitat. Sites may be in need of more wood or reference habitat features and stable wood-riffle sections.	Three to two types of habitat present.	None to one type of habitat present.
	10 9	8 7 6	5 4 3	2 1 0

Table 5.1 SVAP Version II

The table shows the evaluation criteria used to score the individual elements used for this project (USDA & NRCS 2009),

Restoration Goals Applicable to All Sites

- Restore native riparian vegetation woodlands and grasslands in the riparian areas and some of the uplands with mature native trees, shrubs, and native grass mixes. Each site will have its own vegetation selection based on site conditions, however an overarching list of recommended native vegetation species is listed in the tables on the following page.
- Restore or protect habitat for the 48 + fish species (KDWPES 2006) that use the Kansas River and provide open canopy and a diverse understory for the over 136 bird species utilizing the riparian communities in the Great Plains (Tubbs 2013).
- Provide a “microclimate buffer” (area of cooler temperatures that provide protection from the warmer surrounding climatic conditions) for the aquatic and wildlife species by diversifying the riparian vegetation species, providing habitat, and carbon sequestration.

Table 5.2 Trees for Riparian Buffer in Kansas
List of recommended tree species for riparian buffers in Kansas.

Recommended Tree Species for Riparian Buffers in Kansas	
Common Name	Scientific Name
Black Walnut	Juglans nigra
Black Willow	Salix nigra
Bur Oak	Quercus macrocarpa
Eastern Cottonwood	Populus deltoides
Hackberry	Celtis occidentalis
Honeylocust	Gleditsia triacanthos
Red Oak	Quercus rubra
Pecan	Carya illinoensis
Silver Maple	Acer saccharinum
Sycamore	Platanus occidentalis
Peach-Leaved Willow	Salix amygdaloides
Pawpaw	Asimina triloba
Bitternut Hickory	Carya cordiformis
Kentucky Coffeetree	Gymnocladus dioica
American Basswood	Tilia americana

Restoration Objectives Applicable to All Sites

- Create aquatic and wildlife habitats by using the root wads and logs of the removed invasive trees to create wooden habitat structures. Aquatic habitats comprised of wood will need to be consistently submerged under water. The deadwood removed or collected during the removal phase can be used for wildlife habitat structures.
- Increase in flood storage by excavating the streambank down to meet the elevation at bankfull width.
- Removal of invasive vegetation species using clear-cut and treatment methods. A broad list of invasive species found in Kansas riparian woodland is listed in the table on the following page. Large groups of specific invasive species found at each site will be listed in the site’s assessment section.

Table 5.3 Shrub Species for Riparian Buffer in Kansas
List of recommended native shrub species to used in riparian buffers in Kansas.

Recommended Shrub Species for Riparian Buffers in Kansas	
Common Name	Scientific Name
American Plum	Prunus americana
Fragrant Sumac	Rhus aromatica
Sandbar Willow	Salix exigua
Sandhill Plum	Prunus angustifolia
Golden Currant	Ribes aureum
Choke Cherry	Prunus virginiana
Buttonbush	Cephalanthus occidentalis
Burningbush	Euonymus atropurpureus
Missouri Gooseberry	Ribes missouriense

Mesic Native Grass Seed Mix	
Common Name	Scientific Name
Indian Grass	Sorghastrum nutans
Nodding Wild Rye	Elymus canadensis
Big Bluestem	Andropogon gerardii
Virginia Wild Rye	Elymus virginicus
Switch Grass	Panicum virgatum

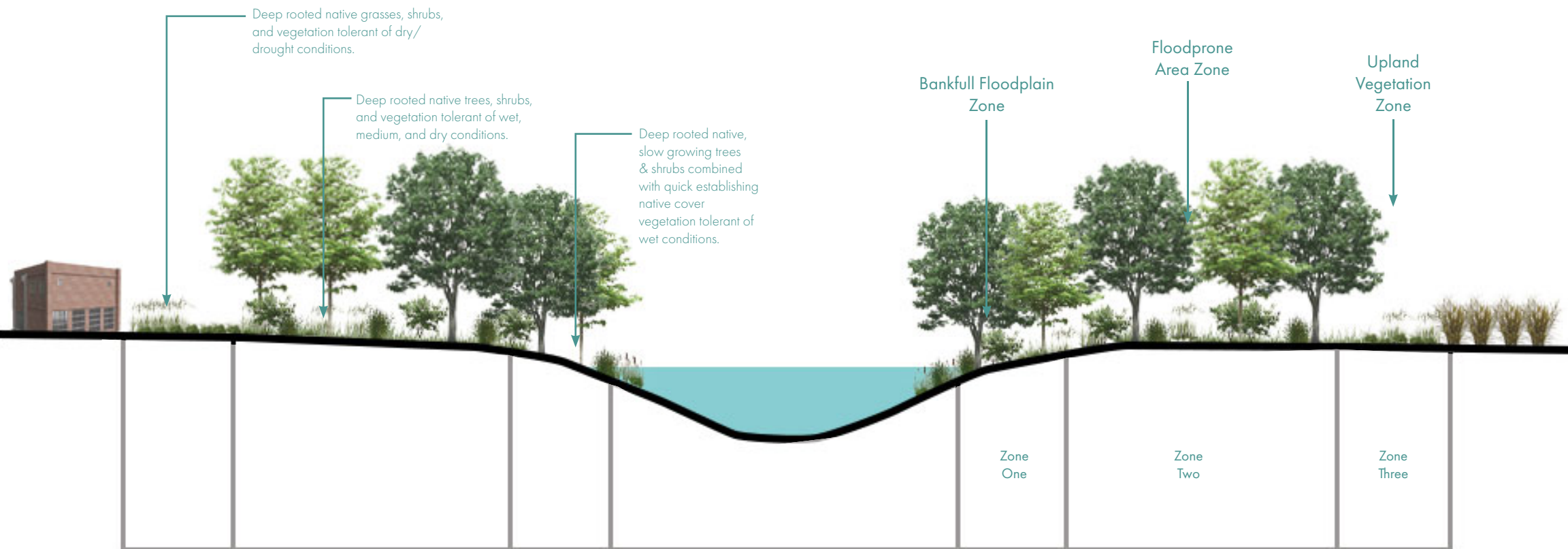
Table 5.4 Dry Native Grass Seed Mix
Listed are native grass species to Kansas that are suited for dry and drought tolerant conditions.

Wet/Mesic Seed Mix - Native Wildflowers + Native Grasses	
Common Name	Scientific Name
New England Aster	Aster novae-angliae
Purple Prairie Clover	Dalea purpurea
Spotted Joe-Pye	Eupatorium maculatum
Dogtooth Daisy	Helenium autumnale
Torrey's Rush	Juncus torreyi
Prairie Blazing Star	Liatris pycnostachya
Cardinal Flower	Lobelia cardinalis
Great Blue Lobelia	Lobelia siphilitica
Wild Bergamot	Monarda fistulosa
Mountain Mint	Pycnanthemum virginianum
Green Bulrush	Scirpus atrovirens
Stiff Goldenrod	Solidago rigida
Culver's Root	Beronicastrum virginicum
Golden Alexander	Zizi aurea
Sweet Flag	Acorus calamus
Swamp Milkweed	Asclepias incarnata
Water Plantain	Alisma subcordatum
Bottle Brush Sedge	Carex hystricina
Fox Sedge	Carex vulpinoidea
Wild Blue Flag Iris	Iris birginica shrevei
False Dragon's Head	Physostegia virginiana
Arrowhead	Sagittaria latifolia
River Bulrush	Scripus fluviatilis
Soft-Stemmed Bulrush	Scripus validus
Indian Grass	Sorghastrum nutans
Prairie Cord Grass	Spartina Pectinata
Creek Sedge	Carex amphibola

Table 5.5 Native Plants for Wet/Dry Conditions
Listed are a mix of native vegetation and grasses that are best suited for both wet and dry conditions, some are beneficial to pollinators and provide habitat for wildlife and aquatic species.

Common Kansas Forest Invasive Species	
Common Name	Scientific Name
Callery or Bradford Pear	Pyrus calleryana
Garlic Mustard	Alliaria petiolata
Japanese Honeysuckle	Lonicera japonica
Amur Honeysuckle	Lonicera maackii
Tartarian Honeysuckle	Lonicera tatarica
Morrow's Honeysuckle	Lonicera morrowii
Autumn Olive	Elaeagnus umbellata
Common Buckthorn	Rhamnus cathartica
Japanese Barberry	Berberis thunbergii
Multiflora Rose	Rosa multiflora
Saltcedar	Tamarix ramosissima
Tree of Heaven	Ailanthus altissima
Russian Olive	Elaeagnus angustifolia
Princess Tree	Paulownia tomentosa
Black Locust	Robinia pseudoacacia
Euonymus Wintercreeper	Euonymus fortunei
Old World Bluestem	Bothriochloa ischaemum
Chinese bushclover	Sericea lespedeza

Table 5.6 Invasive Species List
Listed are the invasive species commonly found in forest areas in Kansas.



Principal Guidelines for Riparian Buffer Design

Figure 5.2 Suggested Riparian Buffer Zones

The section-cut provides a general outline for the three buffer zones and their location used in this project (Figure by author 2021, adapted from Kansas Forest Service 2006).



Bankfull Floodplain Zone

General Planting Plan

Deep rooted native, slow growing trees & shrubs combined with quick establishing native cover vegetation tolerant of wet conditions.

Woody Species:

Eastern Cottonwood	<i>Populus deltoides</i>
Black Walnut	<i>Juglans nigra</i>
Sycamore	<i>Platanus occidentalis</i>
Silver Maple	<i>Acer saccharinum</i>
Kentucky Coffeetree	<i>Gymnocladus dioica</i>
Black Willow	<i>Salix nigra</i>
Sandbar willow	<i>Salix exigua</i>

Herbaceous Species:

Spotted Joe-Pye	<i>Eupatorium maculatum</i>
Cardinal flower	<i>Lobelia cardinalis</i>
Prairie blazing star	<i>Liatris pycnostachya</i>
Swamp milkweed	<i>Asclepias incarnata</i>
Water plantain	<i>Alisma subordatum</i>
New England aster	<i>Aster novae-angliae</i>
Fox Sedge	<i>Carex vulpinoidea</i>
Bottle brush sedge	<i>Carex hystricina</i>
Creek sedge	<i>Carex amphibola</i>
Sweet flag	<i>Acorus calamus</i>
Arrowhead	<i>Sagittaria latifolia</i>
River bulrush	<i>Scripus fluviatilis</i>
Soft-stemmed bulrush	<i>Scripus validus</i>

Upland Vegetation Zone

General Planting Plan

Deep rooted native grasses, shrubs, and vegetation tolerant of mesic and occasional dry/drought conditions.

Herbaceous Species:

Dogtooth daisy	<i>Helenium autumnale</i>
Purple prairie clover	<i>Dalea purpurea</i>
Stiff goldenrod	<i>Solidago rigida</i>
Mountain mint	<i>Pycnanthemum virginianum</i>
Golden Alexander	<i>Zizi aurea</i>

Grass Species:

Indian Grass	<i>Sorghastrum nutans</i>
Nodding Wild Rye	<i>Elymus canadensis</i>
Big Bluestem	<i>Andropogon gerardii</i>
Virginia Wild Rye	<i>Elymus virginicus</i>
Switch Grass	<i>Panicum virgatum</i>

Woody Species:

Sandhill plum	<i>Prunus angustifolia</i>
Fragrant sumac	<i>Rhus aromatica</i>
American plum	<i>Prunus americana</i>



Floodprone Area Zone

General Planting Plan

Deep rooted native trees, shrubs, and vegetation tolerant of wet, wet-mesic, and mesic conditions.

Woody Species:

Bur oak	<i>Quercus macrocarpa</i>
Honeylocust	<i>Gleditsia tricanthos</i>
Chinkapin oak	<i>Quercus muehlenbergii</i>
Shagbark Hickory	<i>Carya ovata</i>
Bitternut Hickory	<i>Carya cordiformis</i>
Red oak	<i>Quercus rubra</i>
American basswood	<i>Tilia americana</i>
Pawpaw	<i>Asimina triloba</i>
Pecan	<i>Carya illinoensis</i>
Sandhill plum	<i>Prunus angustifolia</i>
Burningbush	<i>Euonymus atropurpureus</i>
Fragrant sumac	<i>Rhus aromatica</i>
Choke Cherry	<i>Prunus virginiana</i>
American plum	<i>Prunus americana</i>
Golden currant	<i>Ribes aureum</i>
Buttonbush	<i>Cephalanthus occidentalis</i>
Missouri gooseberry	<i>Ribes missouriense</i>

Herbaceous Species:

Stiff goldenrod	<i>Solidago rigida</i>
Great blue lobelia	<i>Lobelia siphilitica</i>
Golden Alexander	<i>Zizi aurea</i>
Prairie blazing star	<i>Liatris pycnostachya</i>
Purple prairie clover	<i>Dalea purpurea</i>
New England aster	<i>Aster novae-angliae</i>
Spotted Joe-Pye	<i>eupatorium maculatum</i>
Torrey's rush	<i>Juncus torreyi</i>
Wild bergamot	<i>Monarda fistulosa</i>
Green bulrush	<i>Scirpus atrovirens</i>
Culver's root	<i>Beronicastrum virginicum</i>
Swamp milkweed	<i>Asclepias incarnata</i>
False Dragon's head	<i>Physostegia virginiana</i>



Figures 5.3-5.5 Riparian Buffer Zones Vegetation Pallets

The section-cut provides a general outline for the three buffer zones and their location used in this project (Figures by author 2021).

Kansas River at Ogden, Kansas

Location



Figure 5.6 Rough Boundaries of Ogden

This map gives an idea of the rough boundaries of the Kansas River at Ogden site chosen by the author, boundary lines may be subject to change (Figure by author 2020, adapted from ArcGIS 2020).

Site Description

The site is located at the edge of Ogden, Kansas behind the River Trail Apartment Homes. The site is accessible by taking Cimarron Trail to the Kansas River Trail Boat Launch. The site is part of a large meander in the Kansas River surrounded by agriculture fields and residential apartments.

Ogden | Site Assessment

Stream Visual Assessment Protocol Version II Score										
Element	Score									
	0	1	2	3	4	5	6	7	8	9 10
Channel Condition										
Hydrologic Alteration										
Bank Condition										
Riparian Area Quantity										
Riparian Area Quality										
Canopy Cover										
Water Appearance										
Nutrient Enrichment										
Pools										
Barriers to Movement										
Fish Habitat Complexity										
Aquatic Invertebrate Habitat										

Overall Score: 5 Fair

Table 5.7 SVAP Version II at Ogden

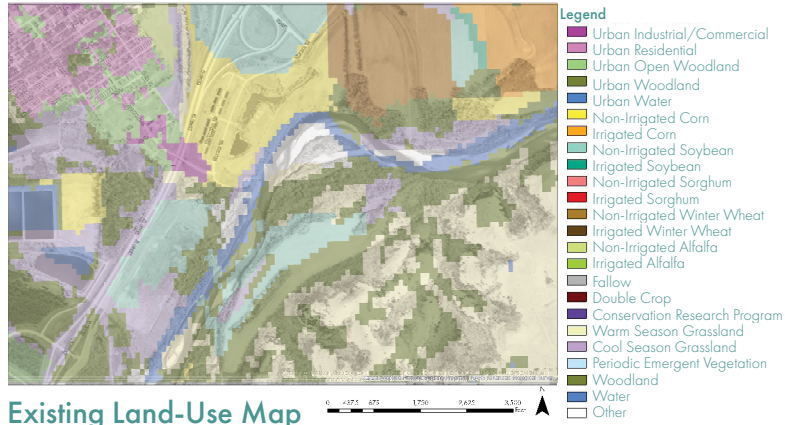
The results from the SVAP Version II conducted at Ogden by author (Table by author 2021, adapted from USDA & NRCS 2009).

Flood Frequency Analysis	
1.5-Year Flood Frequency Flow (cfs)	12,149.80
Bankfull Width (ft)	626.67
Bankfull Elevation (ft)	1026
Mean Depth (ft)	3
Cross-Sectional Area (ft)	4332.86
Velocity (ft/s)	2.8

Table 5.8 Flood Frequency Analysis for Ogden

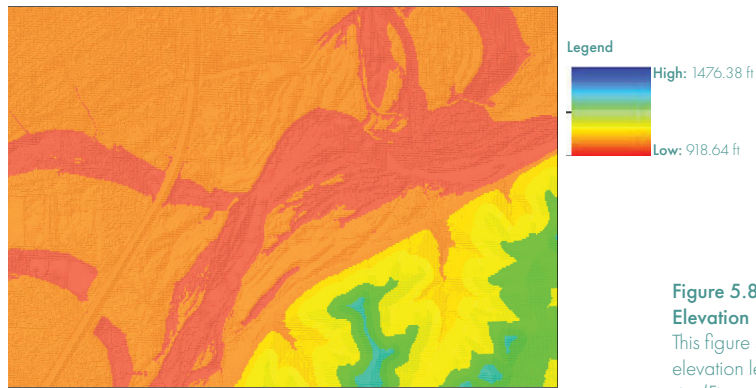
The results from the flood frequency analysis for Ogden conducted by author (Table by author 2021).

Ogden | Site Assessment



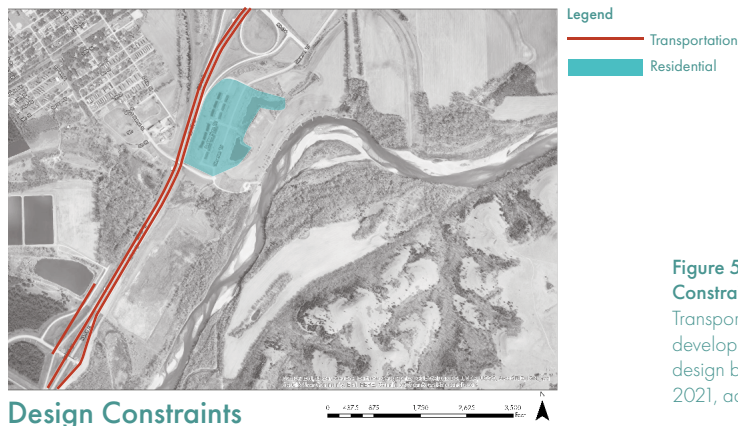
Existing Land-Use Map

Figure 5.7 Ogden Existing Land-Use
This figure shows the existing land-use on and surrounding the Ogden site (Figure by author 2021, adapted from ArcGIS).



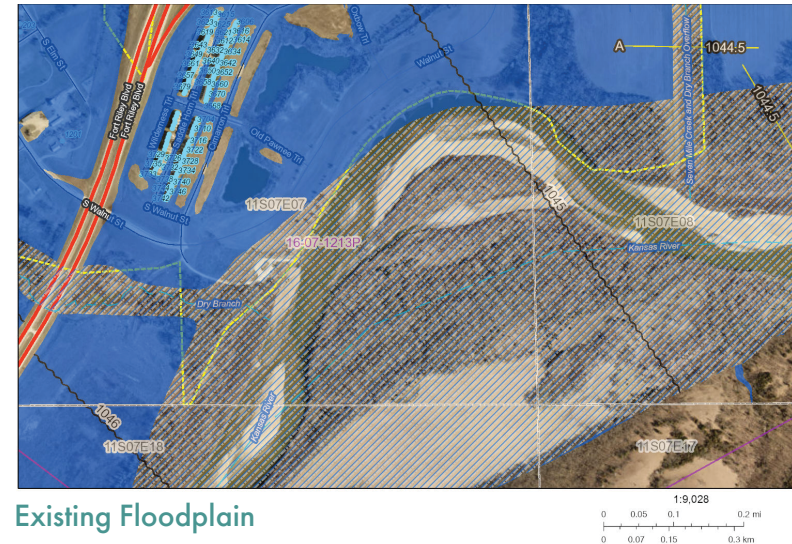
Existing Elevation Map

Figure 5.8 Ogden Existing Elevation
This figure shows the existing elevation levels around the Ogden site (Figure by author 2021, adapted from ArcGIS).



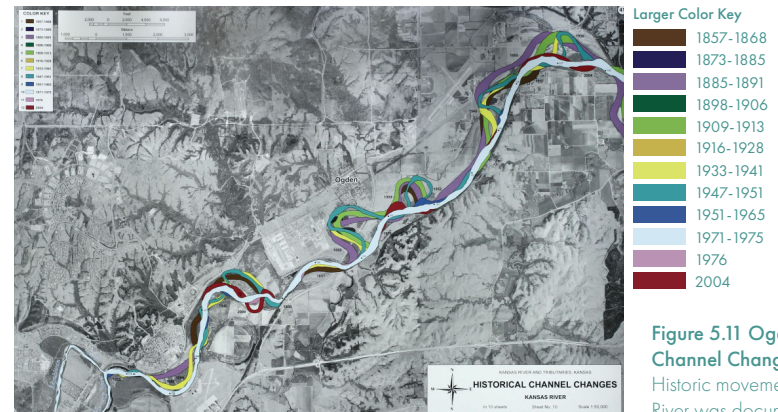
Design Constraints

Figure 5.9 Ogden Design Constraints
Transportation and residential development constrict some of the design boundaries (Figure by author 2021, adapted from ArcGIS).



Existing Floodplain

Figure 5.10 Ogden FEMA Floodplain Boundaries
The figure shows the current (as of this publication) floodplain boundaries determined by FEMA and Kansas Department of Agriculture (FEMA & KDA 2021).



Historic Channel Changes

Figure 5.11 Ogden Site Historic Channel Changes
Historic movement of the Kansas River was documented from 1857-2004 (Dort Jr. 2009).



Existing Conditions

Figure 5.12 Existing Conditions at Ogden Site

This map shows the spatial relationship of the existing land-use and site conditions of the site and its surroundings (Figure by author 2021, adapted from ArcGIS 2020).

Site Assessment Summary

The site is surrounded by agriculture fields and a residential apartment complex that has caused fragmentation, a decline/disruption in riparian vegetation cover, and increases the non-point source pollution from runoff. Past efforts to control bank erosion on the northern side of the meander are noted. The river looks to have access to its floodplain to the south, however the north looks as though it lacks regular access to the floodplain. The southern portion of the meander shows a sizeable vegetative riparian buffer separating a mix of agriculture fields and cool season grasslands. The existing wildlife and aquatic habitat are minimal and the existing riparian vegetation coverage can be outwardly expanded (shown in site plan) and linked to the larger surrounding riparian buffer.

Restoration Design Objectives:

- Improve river function by converting the river from an F stream type to a functioning C5 stream type (Rosgen 1997).
- Reconnect the northern portion of the bend to its floodplain without removing the existing rock weirs on the outside bend to prevent further streambank erosion. Reconnect the southern side of the upstream, middle, and downstream banks to the floodplain through mechanical excavation.
- Build a bankfull bench on the southern side of the river where needed to reconnect the river to its floodplain and achieve the bankfull width.
- Revegetate the northern and southern streambanks post-excavation to prevent further erosion. Expand the native riparian vegetation buffer on the northern and southern sides of the river. Remove the invasive species within the existing wooded areas and fill in with native riparian vegetation.
- Addition of walking trails in the area to the north of the bend to provide an area for people to interact with the riparian vegetation and Kansas River in a non-invasive way and to increase outdoor recreational tourist visits to Ogden.

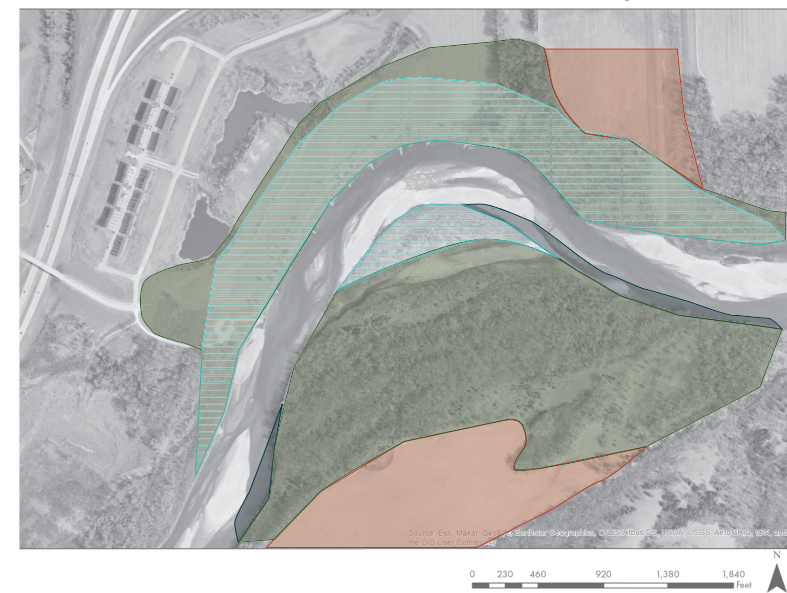
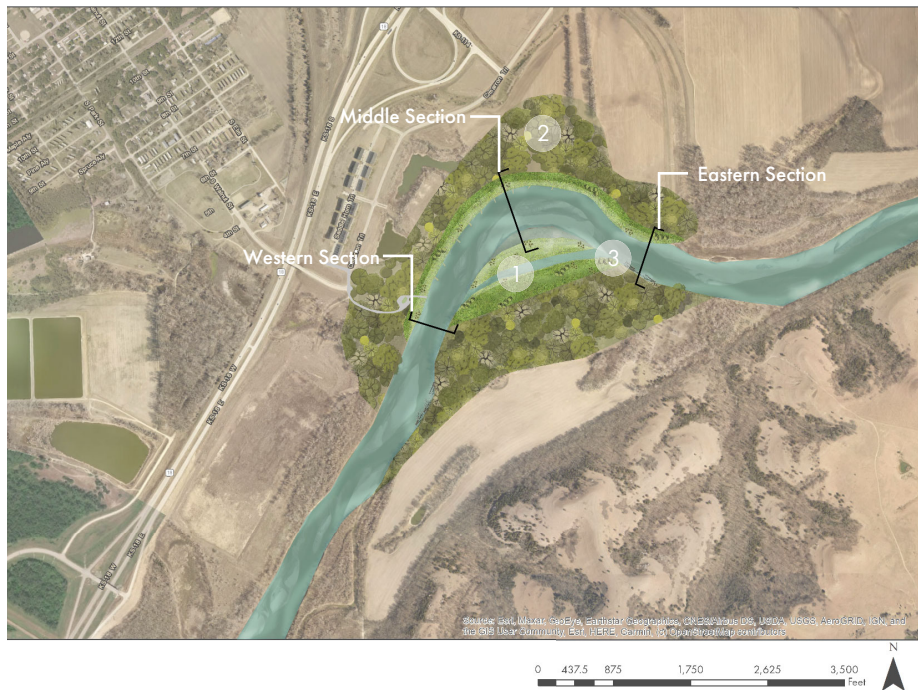


Figure 5.13 Projected Site Design

The map outlines the projected design suggestions for the Kansas River at Ogden site (Figure by author 2021, adapted from ArcGIS 2021).

Overview of Design Application from Site Analysis

- Floodplain Agriculture Methods
- Aquatic Habitat Implementation
- Invasive Species Removal + Implementation of Native Riparian Vegetation
- Floodplain Earthwork



Ogden - Overall Site Design

Figure 5.14 Master Plan of Projected Design at Ogden Site

The plan provides a visual representation of the proposed design implementations for the Kansas River at Ogden, Kansas site (Figure by author 2021, adapted from ArcGIS 2021).

1

Streambank Stabilization

- Western Cross-Section
- Middle Cross-Section
- Eastern Cross-Section

2

Riparian Vegetation Restoration

- Riparian vegetation buffer zone
- Invasive species removal
- Revegetate slopes with native riparian vegetation

3

Aquatic Habitat Creation

- Added deadwood
- Expanded floodplain area

1 Streambank Stabilization + Floodplain Reconnection

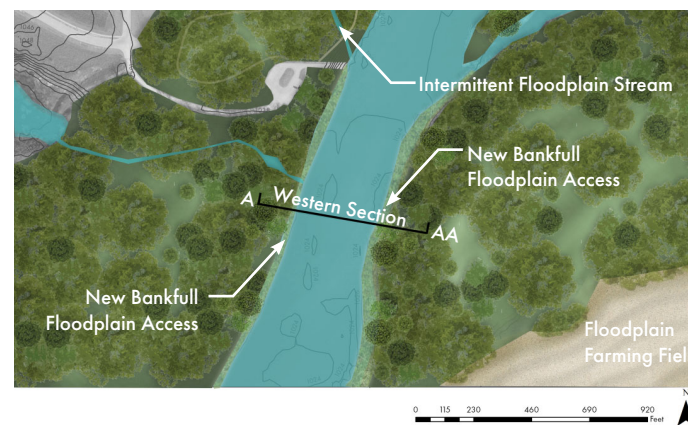


Figure 5.15 Western Section Cut at Ogden

The map shows the location of the first section cut shown on the following page (Figure by author 2021, adapted from ArcGIS 2021).

West Cross-Section Location

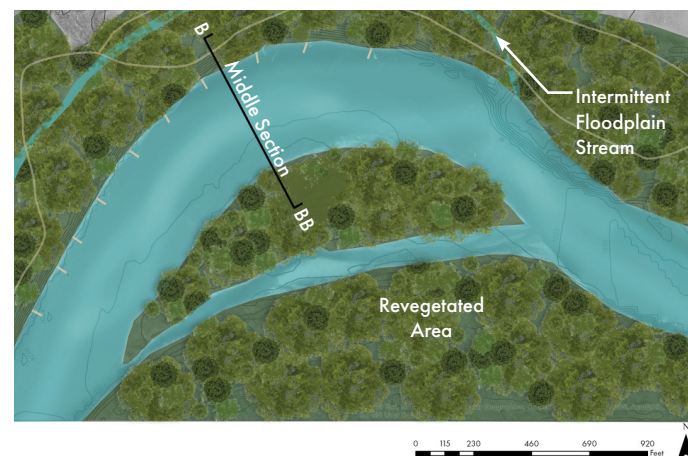


Figure 5.16 Middle Section Cut at Ogden

The map shows the location of the second section cut shown on the following page (Figure by author 2021, adapted from ArcGIS 2021).

Middle Cross-Section Location

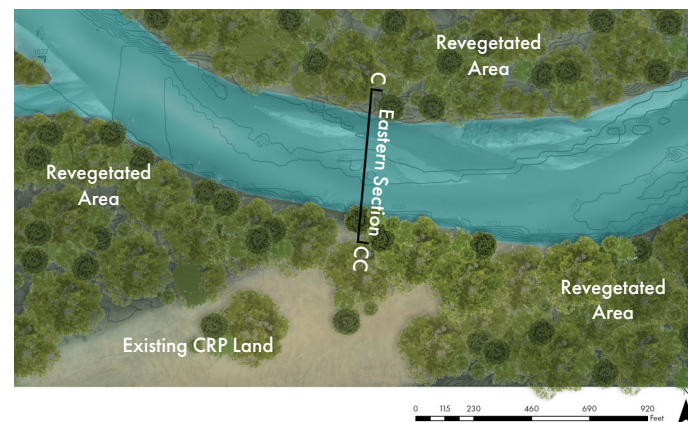
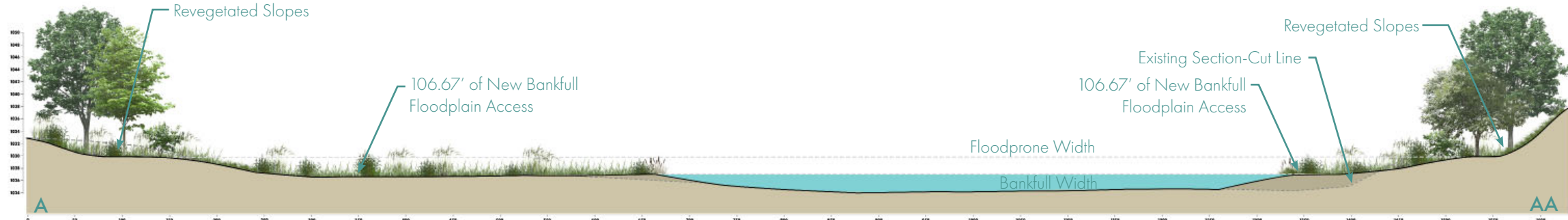


Figure 5.17 Eastern Section Cut at Ogden

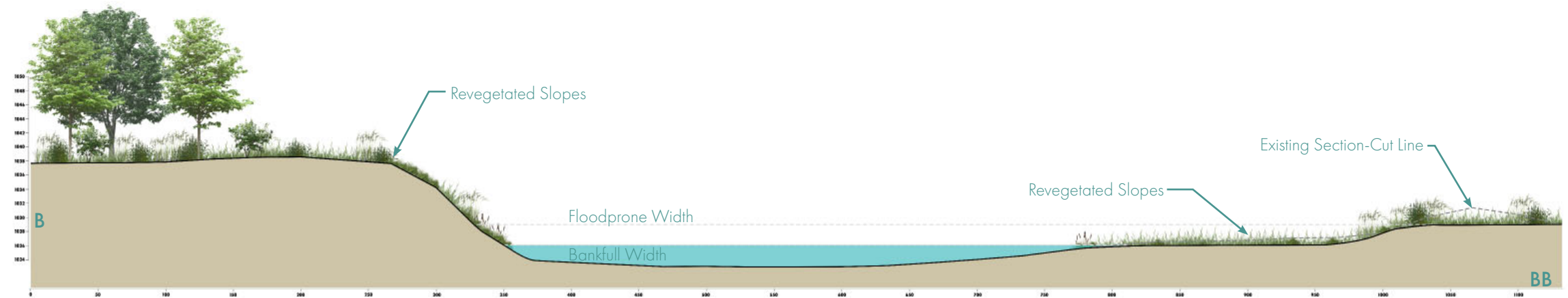
The map shows the location of the third section cut shown on the following page (Figure by author 2021, adapted from ArcGIS 2021).

East Cross-Section Location

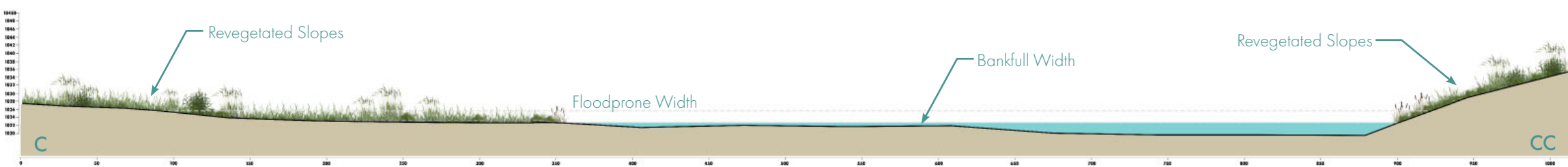
Figures 5.18-5.20 Streambank Stabilization and Floodplain Reconnection Application at the Ogden Site
 The three section cuts provide a visual of the projected streambank and earthwork changes (Figure by author 2021, adapted from ArcGIS 2021).



Ogden Northern Cross-Section



Ogden Middle Cross-Section



Ogden Southern Cross-Section

1 Streambank Stabilization + Floodplain Reconnection

Streambank Stabilization - Proposed Steps

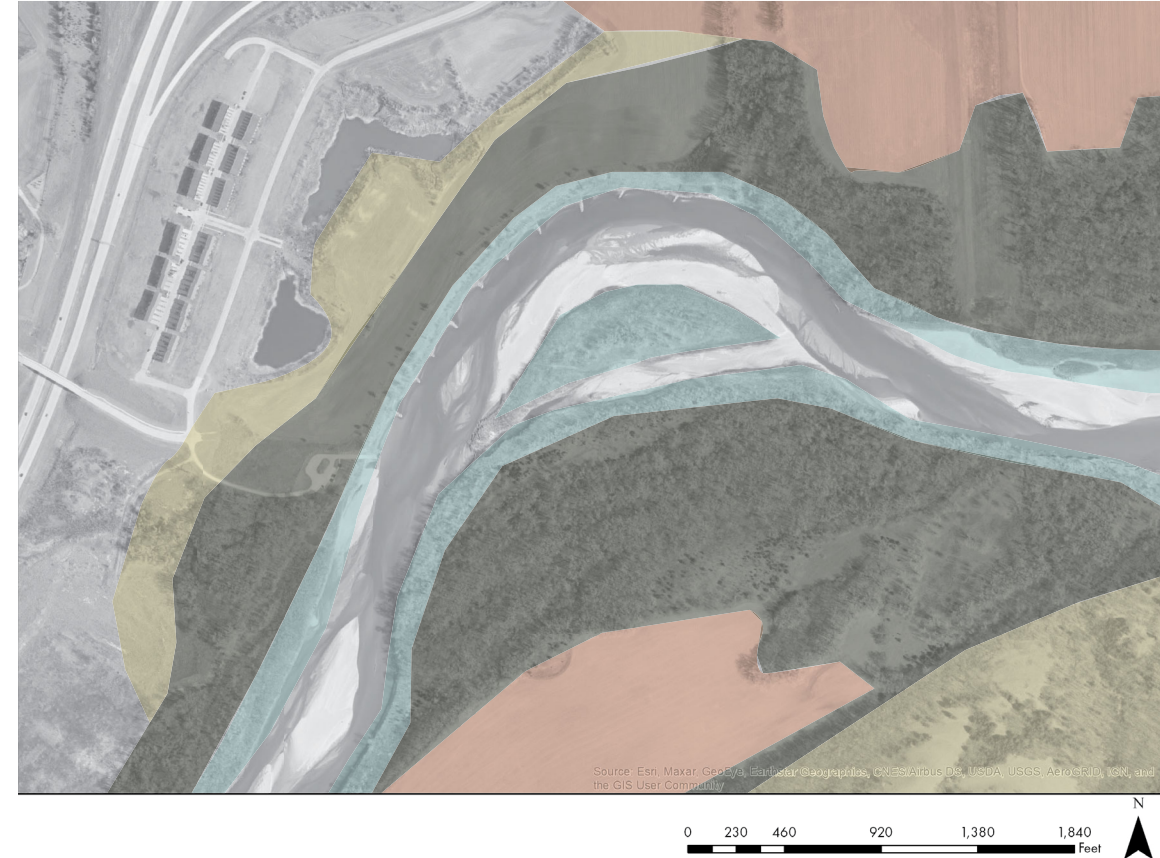
- Before planting native vegetation along the streambanks, the cutting and removal of invasive species is required. Invasive species found on site include, but are not limited to: honeysuckle (*Lonicera* family: *maackii*, *japonica*, *tatarica*) and Saltcedar (*Tamarix ramosissima*)
- All excavated slopes must maintain a 3:1 slope ratio or less for successful revegetation, a 2:1 slope is preferred.

Rough Total of Proposed Added Bankfull Floodplain Access

This number is found by adding up the area of bankfull width floodplain added in between the cross-sections sampled divided by the number of cross-sections taken (three) for an average estimate of total bankfull floodplain area added. It is to be noted that these numbers are an estimate of the approximative area, exact numbers would require on-site measurements.

Estimated Total of Bankfull Floodplain Area Added: 6.76 Acres.

2 Riparian Vegetation Restoration



Ogden Overall Planting Areas

Figures 5.21 Proposed Planting Master Plan for Ogden Site

The figure shows the proposed planting areas for the Ogden Site (Figure by author 2021, adapted from ArcGIS 2021).

Streambank Stability Area

Species in this area need to tolerate wetter conditions for several days in addition to periods of dry conditions.

Woody species: Eastern cottonwood (*Populus deltoides*), sycamore (*Platanus occidentalis*), silver maple (*Acer saccharinum*), Kentucky coffeetree (*Gymnocladus dioica*), sandhill plum (*Prunus agustifolia*), sandbar willow (*Salix exigua*)

Herbaceous species: Spotted Joe-Pye (*Eupatorium maculatum*), cardinal flower (*Lobelia cardinalis*), prairie blazing star (*Liatri pycnostachya*), swamp milkweed (*Asclepias incarnata*), water plantain (*Alisma subcordatum*), New England aster (*Aster novae-angliae*), fox sedge (*Carex vulpinoidea*), bottle brush sedge (*Carex hystricina*)



Floodprone Area

Species in this area need to tolerate occasional standing water and periods of dry drought conditions.

Woody species: American basswood (*Tilia americana*), red oak (*Quercus rubra*), shagbark hickory (*Carya ovata*)

Herbaceous species: Stiff goldenrod (*Solidago rigida*), great blue lobelia (*Lobelia siphilitica*), golden Alexander (*Zizi aurea*), prairie blazing star (*Liatris pycnostachya*), purple prairie clover (*Dalea purpurea*)



Upland Area

Species in this area need to tolerate dry conditions including periods of drought.

Grass species: Mesic native grass seed mix

Herbaceous species: dogtooth daisy (*Helenium autumnale*), purple prairie clover (*Dalea purpurea*), stiff goldenrod (*Solidago rigida*), mountain mint (*Pycnanthemum virginianum*)



Floodplain Agriculture

Floodplain agriculture fields plan for flooding and are generally harvested 3 out of every 5 years. Farmers have the potential to get support from the government for participating in floodplain farming management strategies.

Ogden Native Riparian Restoration Overview:

Little to no native riparian vegetation on site based on initial SVAP Version II (USDA & NRCS 2009). The existing vegetation was predominantly invasive species including, but not limited to: amur honeysuckle (*Lonicera maackii*), garlic mustard (*Alliaria petiolata*), and black locust (*Robinia pseudoacacia*). The existing riparian buffer was thin and lacked species diversity. Approximately 90% of the northern side of the Kansas River is bare and cropland comes up to the edge of the river. The southern side of the river bend is predominantly covered in woody vegetation species.

Suggestions for native riparian vegetation restoration for the Kansas River at Ogden, Kansas includes revegetating the northern and southern areas adjacent to the river. The area to the south of the river bend will require invasive species removal and treatment. The both sides of the river's vegetation composition will include all four types of the planting groups listed in this project. This site will have the most upland vegetation compared to the other three sites. The Conservation Reserve Program (CRP) land on the southern side of the site shall be managed to the standards of the Farm Service Agency.



Figures 5.22 Expanded Trail System and Native Riparian Vegetation

Trails expanded from the existing boat ramp allows users to interact with the restored native riparian vegetation (Figure by author 2021, adapted from ArcGIS 2021).

Kansas River at DeSoto, Kansas

Location

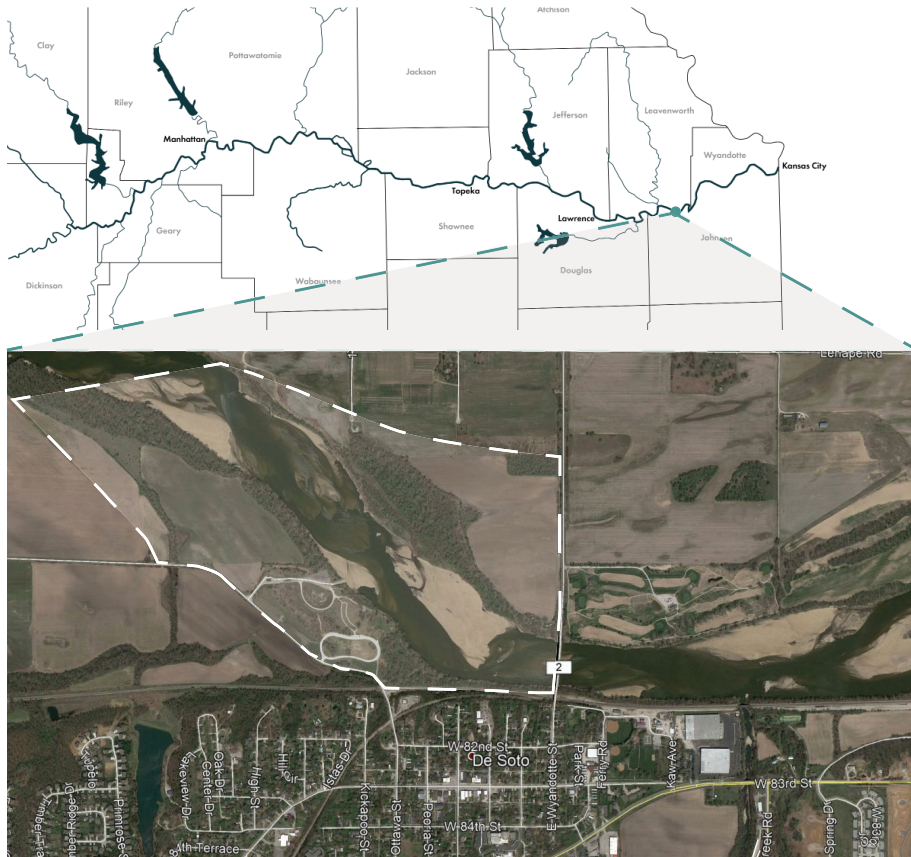


Figure 5.23 Rough Boundaries of DeSoto Site

This map gives an idea of the rough boundaries of the Kansas River at DeSoto site chosen by the author, boundary lines may be subject to change (Figure by author 2020, adapted from ArcGIS 2020).

Site Description

The site is located along the Kansas River directly north of the town of DeSoto, Kansas. The recreational area Riverfest Park falls within the determined site boundaries and it used as a starting point for integrating riparian and floodplain educational elements into the restoration project.

DeSoto | Site Assessment

Stream Visual Assessment Protocol Version II Score										
Element	Score									
	0	1	2	3	4	5	6	7	8	9 10
Channel Condition										
Hydrologic Alteration										
Bank Condition										
Riparian Area Quantity										
Riparian Area Quality										
Canopy Cover										
Water Appearance										
Nutrient Enrichment										
Pools										
Barriers to Movement										
Fish Habitat Complexity										
Aquatic Invertebrate Habitat										

Overall Score: 5.8 Fair

Table 5.9 SVAP Version II at DeSoto

The results from the SVAP Version II conducted at DeSoto by author (Table by author 2021, adapted from USDA & NRCS 2009).

Flood Frequency Analysis	
1.5-Year Flood Frequency Flow (cfs)	43,637.60
Bankfull Width (ft)	628
Bankfull Elevation (ft)	771-773
Mean Depth (ft)	10
Cross-Sectional Area	9,200
Velocity (ft/s)	4.74

Table 5.10 Flood Frequency Analysis for DeSoto

The results from the flood frequency analysis for DeSoto conducted by author (Table by author 2021).

DeSoto | Site Assessment

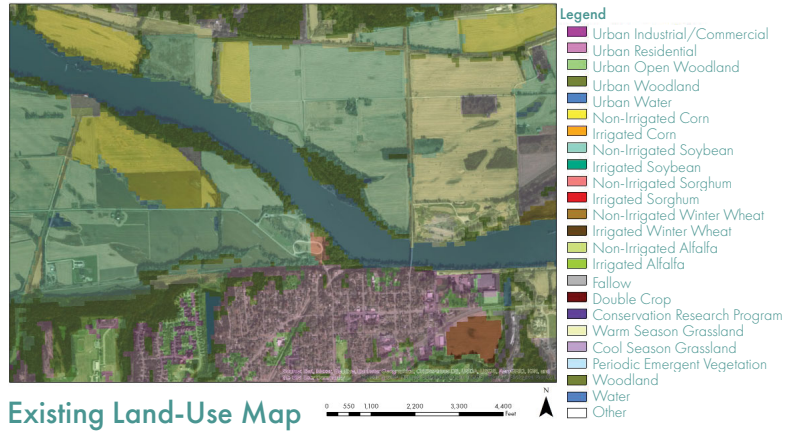


Figure 5.24 DeSoto Existing Land-Use
This figure shows the existing land-use on and surrounding the DeSoto site (Figure by author 2021, adapted from ArcGIS).

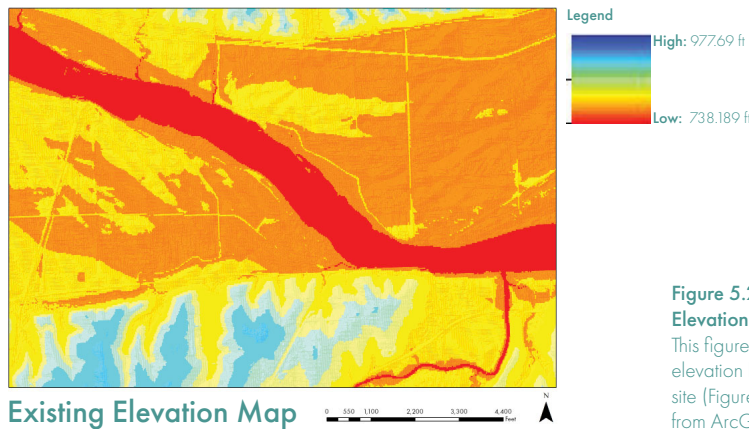


Figure 5.25 DeSoto Existing Elevation
This figure shows the existing elevation levels around the DeSoto site (Figure by author 2021, adapted from ArcGIS).

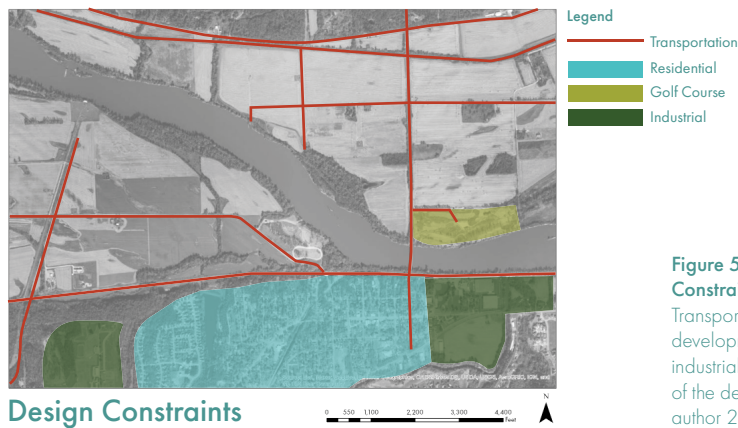


Figure 5.26 DeSoto Design Constraints
Transportation, residential development, a golf course, and industrial development constrict some of the design boundaries (Figure by author 2021, adapted from ArcGIS).

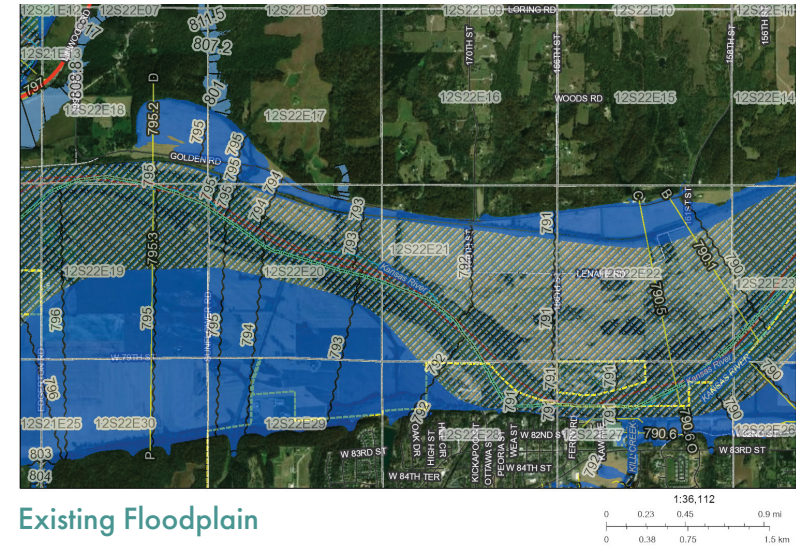


Figure 5.27 DeSoto FEMA Floodplain Boundaries
The figure shows the current (as of this publication) floodplain boundaries determined by FEMA and Kansas Department of Agriculture (FEMA & KDA 2021).

Legend + FEMA Flood Definitions

- A** Areas with a 1% annual chance of flooding and a 26% chance of flooding over the life of a 30-year mortgage. Because detailed analyses are not performed for such areas; no depths or base flood elevations are shown within these zones (FEMA 2010).
- AE** The base floodplain where base flood elevations are provided. AE Zones are now used on new format FIRMs instead of A1-A30 Zones (FEMA 2010).
- AH** Areas with a 1% annual chance of shallow flooding, usually in the form of a pond, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Base flood elevations derived from detailed analyses are shown at selected intervals within these zones (FEMA 2010).
- AO** River or stream flood hazard areas, and areas with a 1% or greater chance of shallow flooding each year, usually in the form of sheet flow, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Average flood depths derived from detailed analyses are shown within these zones (FEMA 2010).

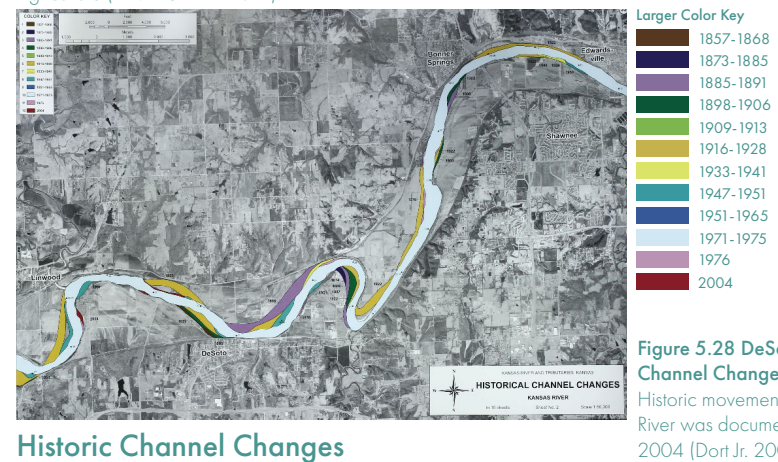
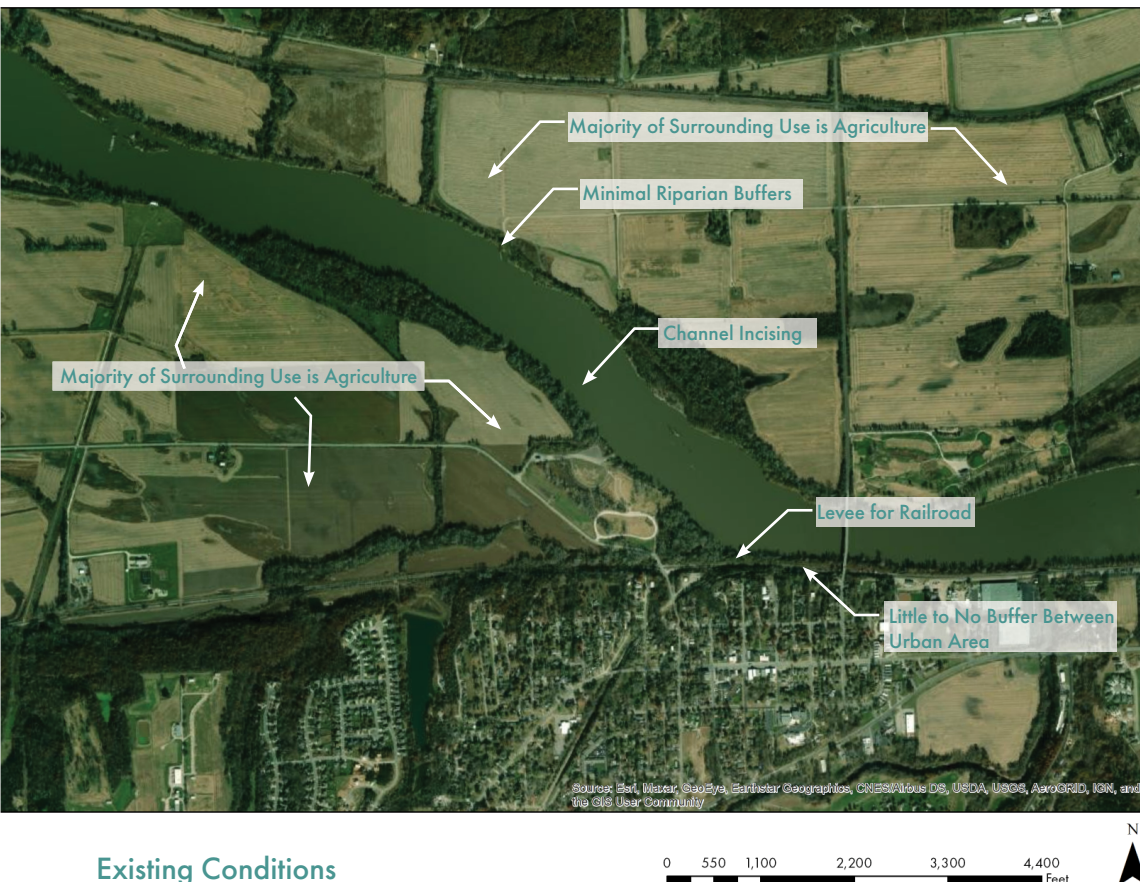


Figure 5.28 DeSoto Site Historic Channel Changes
Historic movement of the Kansas River was documented from 1857-2004 (Dort Jr. 2009).



Existing Conditions

Figure 5.29 Existing Conditions at DeSoto Site

This map shows the spatial relationship of the existing land-use and site conditions of the site and its surroundings (Figure by author 2020, adapted from ArcGIS 2020).

Site Assessment Summary

The site has existing riparian buffers along the Kansas River, but will need to be expanded. Agriculture fields, urban, and residential make up the majority of the land-use surrounding the Kansas River at this site. The agriculture fields, urban, and residential areas cause fragmentation in the riparian vegetation in addition to contributing to non-point source runoff pollutants into the Kansas River. While Riverfest Park aids in habitat protection for animals, the current protection is minimal. There are little to no designated areas for wildlife and aquatic vegetation habitats apart from the Riverfest Park area.

Restoration Design Objectives:

- Improve river function by converting the river from an F stream type to a functioning C5 stream type (Rosgen 1997).
- Reconnect the river to its floodplain on the southern and northern bank through bankfull benches and mechanical excavation down to the bankfull elevation. Excavated slopes should be planted with native riparian vegetation immediately to prevent further erosion.
- Expand the riparian vegetation buffer on both the northern and southern slopes after initial removal and treatment of invasive species.
- Extend walking trails from Riverfest Park to the west to provide an area for people to interact with the riparian vegetation, wildlife species, and aquatic species, and the Kansas River in a non-invasive way.
- Retain some of the existing cropland and convert it to floodplain agriculture.

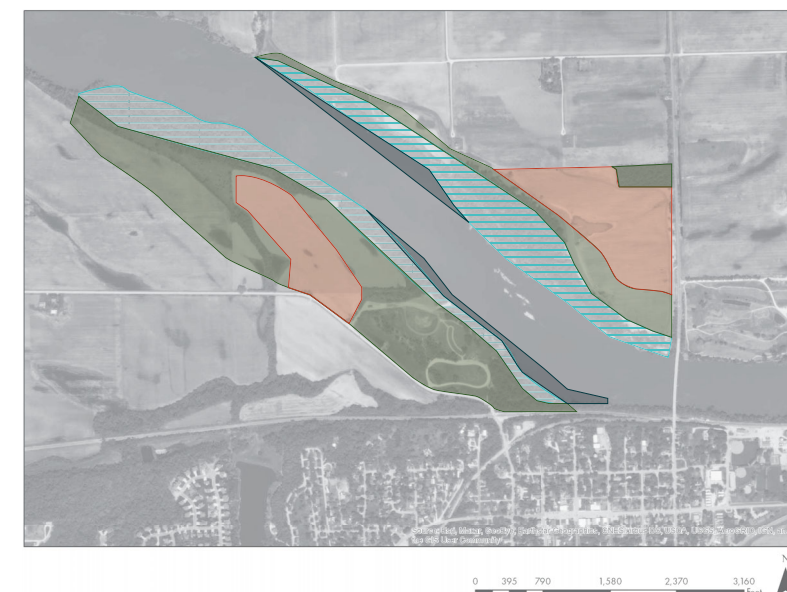


Figure 5.30 Projected Site Design

The map outlines the projected design suggestions for the Kansas River at DeSoto site (Figure by author 2021, adapted from ArcGIS 2021).

Overview of Design Application from Site Analysis

- Floodplain Agriculture Methods
- Aquatic Habitat Implementation
- Invasive Species Removal + Implementation of Native Riparian Vegetation
- Floodplain Earthwork



DeSoto - Overall Site Design

Figure 5.31 Master Plan of Projected Design at DeSoto Site

The plan provides a visual representation of the proposed design implementations for the Kansas River at DeSoto, Kansas site (Figure by author 2021, adapted from ArcGIS 2021).

1

Streambank Stabilization

- Northern Cross-Section
- Middle Cross-Section
- Southern Cross-Section

2

Riparian Vegetation Restoration

- Riparian vegetation buffer zone
- Invasive species removal
- Revegetate slopes with native riparian vegetation

3

Aquatic Habitat Creation

- Added deadwood
- Expanded floodplain area

1 Streambank Stabilization + Floodplain Reconnection

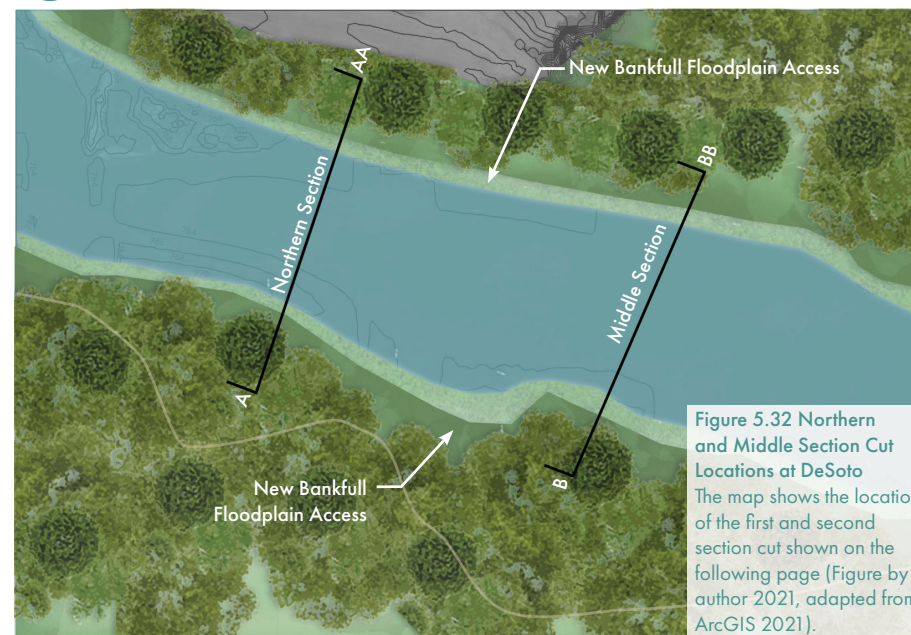


Figure 5.32 Northern and Middle Section Cut Locations at DeSoto
The map shows the location of the first and second section cut shown on the following page (Figure by author 2021, adapted from ArcGIS 2021).

Northern + Middle Cross-Section Locations

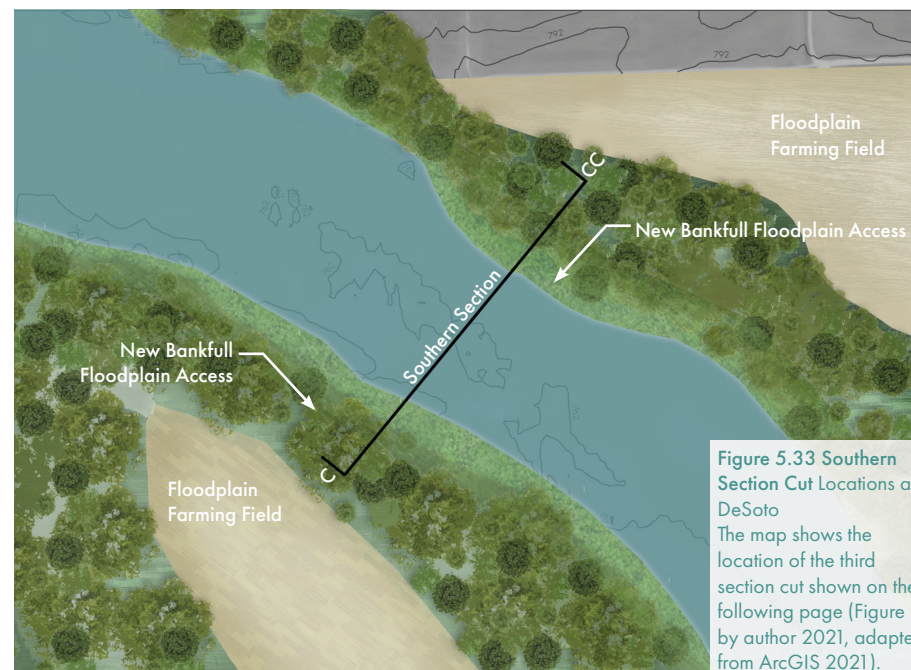


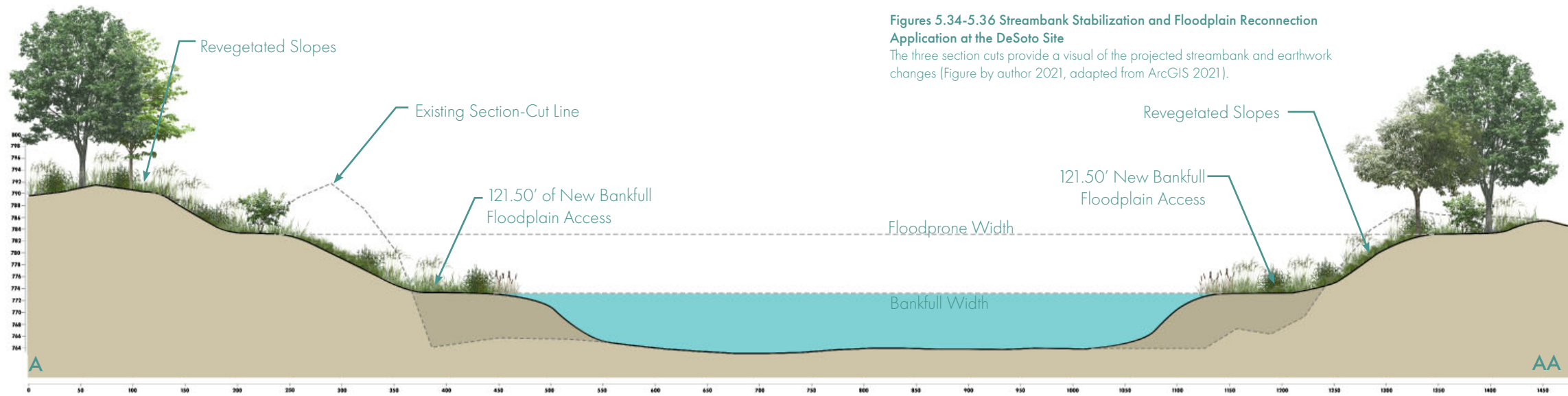
Figure 5.33 Southern Section Cut Locations at DeSoto
The map shows the location of the third section cut shown on the following page (Figure by author 2021, adapted from ArcGIS 2021).

Southern Cross-Section Location

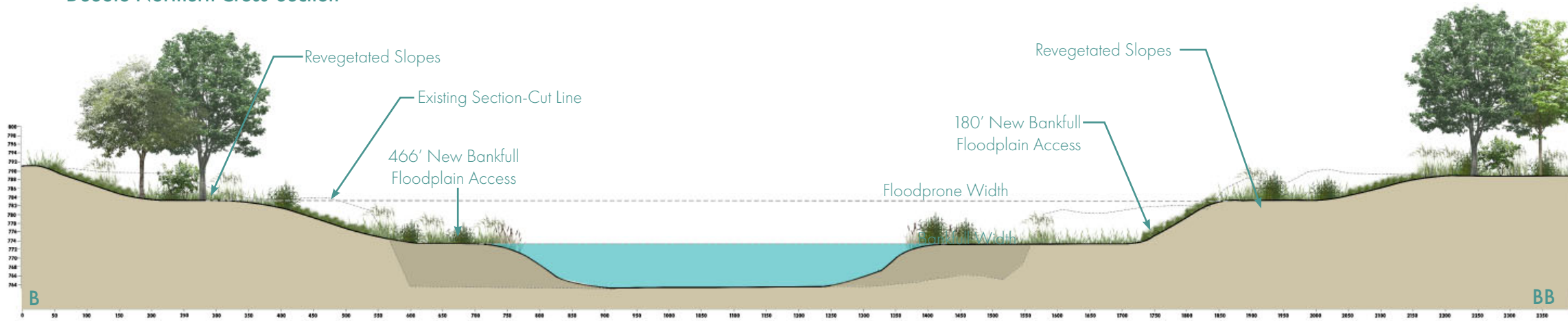


Figures 5.34-5.36 Streambank Stabilization and Floodplain Reconnection Application at the DeSoto Site

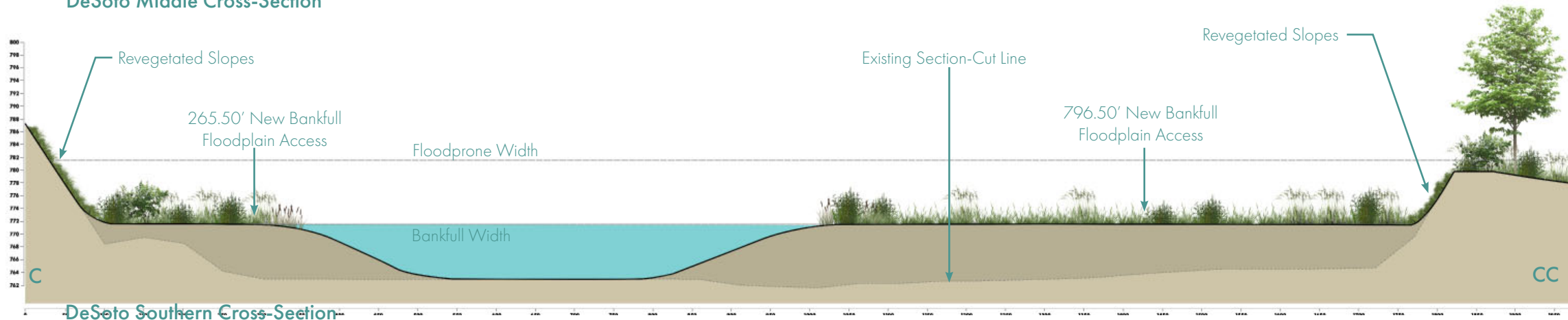
The three section cuts provide a visual of the projected streambank and earthwork changes (Figure by author 2021, adapted from ArcGIS 2021).



DeSoto Northern Cross-Section



DeSoto Middle Cross-Section



DeSoto Southern Cross-Section

1 Streambank Stabilization + Floodplain Reconnection

Streambank Stabilization - Proposed Steps

- Before planting native vegetation along the streambanks, the cutting and removal of invasive species is required. Invasive species found on site include, but are not limited to: honeysuckle (*Lonicera* family: *maackii*, *japonica*, *tatarica*) and Saltcedar (*Tamarix ramosissima*)
- All excavated slopes must maintain a 3:1 slope ratio or less for successful revegetation, a 2:1 slope is preferred.

Rough Total of Proposed Added Bankfull Floodplain Access

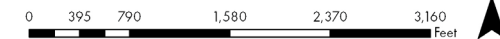
This number is found by adding up the area of bankfull width floodplain added in between the cross-sections sampled divided by the number of cross-sections taken (three) for an average estimate of total bankfull floodplain area added. It is to be noted that these numbers are an estimate of the approximative area, exact numbers would require on-site measurements.

Estimated Total of Bankfull Floodplain Area Added: 63.31 Acres.

2 Riparian Vegetation Restoration



DeSoto Overall Planting Areas



Figures 5.37 Proposed Planting Master Plan for DeSoto Site

The figure shows the proposed planting areas for the DeSoto Site (Figure by author 2021, adapted from ArcGIS 2021).

Streambank Stability Area

Species in this area need to tolerate wetter conditions for several days in addition to periods of dry conditions.

Woody species: Black walnut (*Juglans nigra*), eastern cottonwood (*Populus deltoides*), sycamore (*Platanus occidentalis*), silver maple (*Acer saccharinum*), Kentucky coffeetree (*Gymnocladus dioica*), sandhill plum (*Prunus agustifolia*), sandbar willow (*Salix exigua*)

Herbaceous species: Spotted Joe-Pye (*Eupatorium maculatum*), cardinal flower (*Lobelia cardinalis*), prairie blazing star (*Liatris pycnostachya*), swamp milkweed (*Asclepias incarnata*), water plantain (*Alisma subcordatum*), New England aster (*Aster novae-angliae*), fox sedge (*Carex vulpinoidea*), bottle brush sedge (*Carex hystricina*)



Floodprone Area

Species in this area need to tolerate occasional standing water and periods of dry drought conditions.

Woody species: American basswood (*Tilia americana*), red oak (*Quercus rubra*), shagbark hickory (*Carya ovata*), fragrant sumac (*Rhus aromatica*), choke cherry (*Prunus virginiana*)

Herbaceous species: Stiff goldenrod (*Solidago rigida*), great blue lobelia (*Lobelia siphilitica*), golden Alexander (*Zizia aurea*), prairie blazing star (*Liatris pycnostachya*), purple prairie clover (*Dalea purpurea*)



Upland Area

Species in this area need to tolerate dry conditions including periods of drought. This site will not have as many grass species compared to the floodplain area species.

Grass species: Mesic native grass seed mix

Herbaceous species: dogtooth daisy (*Helenium autumnale*), purple prairie clover (*Dalea purpurea*), stiff goldenrod (*Solidago rigida*), mountain mint (*Pycnanthemum virginianum*)



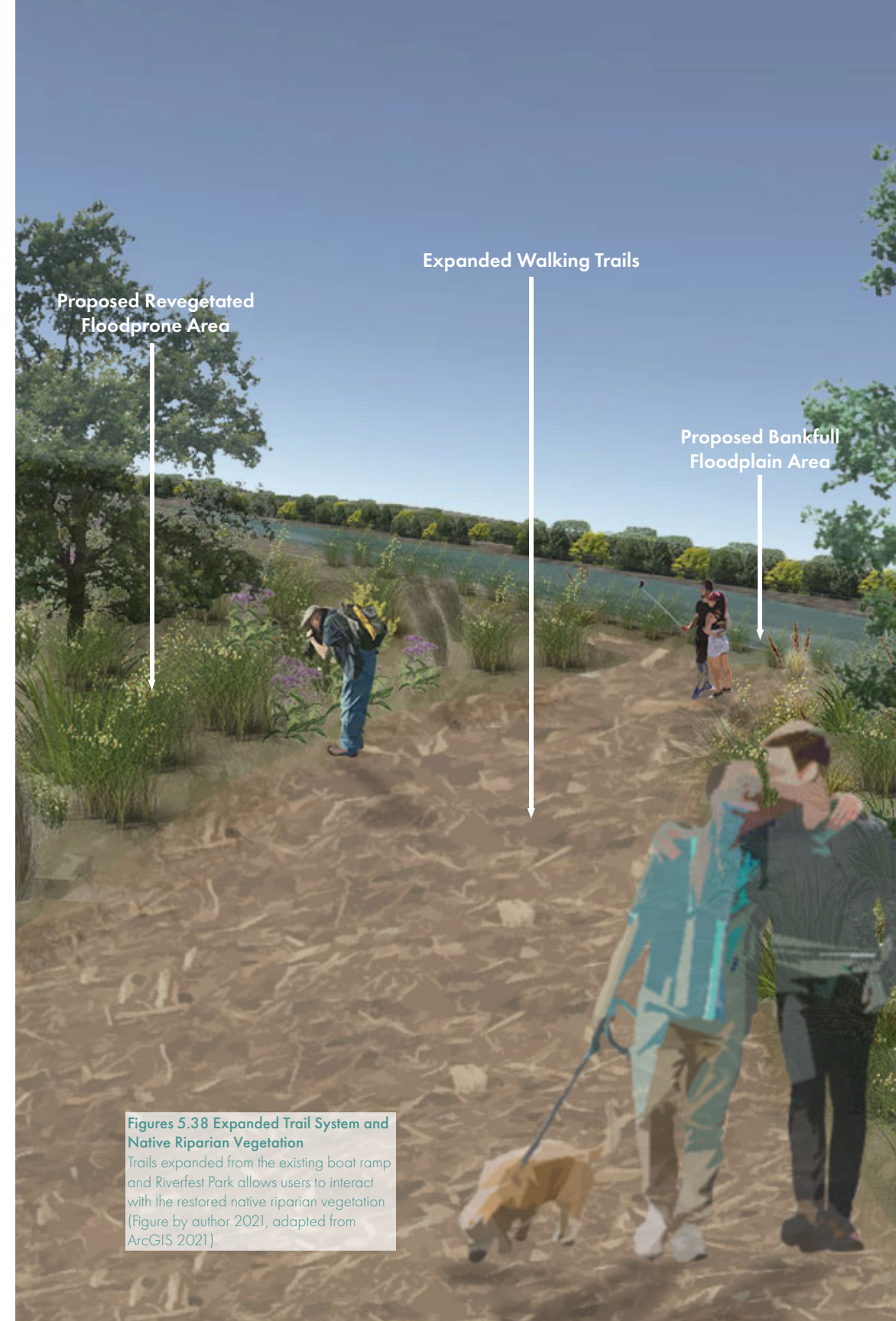
Floodplain Agriculture

Floodplain agriculture fields plan for flooding and are generally harvested 3 out of every 5 years. Farmers have the potential to get support from the government for participating in floodplain farming management strategies.

DeSoto Native Riparian Restoration Overview:

Little to no native riparian vegetation on site based on initial SVAP Version II (USDA & NRCS 2009). The existing vegetation was predominantly invasive species including, but not limited to amur honeysuckle (*Lonicera maackii*), garlic mustard (*Alliaria petiolata*), and black locust (*Robinia pseudoacacia*). The DeSoto and Shawnee site will have a higher number of the invasive species Callery pear trees (*Pyrus calleryana*) due to the more populated urban areas surrounding the area. The existing riparian buffer was thin and lacked species diversity. 70% of the streambank slopes were bare.

Suggestions for native riparian vegetation restoration for the Kansas River at DeSoto, Kansas includes expanding bankfull floodplain access and revegetating the newly excavated areas from the bankfull floodplain expansion. Eastern cottonwood (*Populus deltoides*) is the predominant tree species in the existing riparian vegetation buffer and some oak species. Implementation of a wet mesic/dry vegetation species mix in the newly expanded floodprone area will require initial invasive species removal and management. The area in between the floodplain agriculture field and the floodprone area buffer will be vegetated with upland vegetation that can handle drought conditions better than the first two zones. The native plant selection includes pollinators, berry and fruit producing species to feed wildlife species, and taller vegetation used for wildlife and aquatic species habitat.



Figures 5.38 Expanded Trail System and Native Riparian Vegetation

Trails expanded from the existing boat ramp and Riverfest Park allows users to interact with the restored native riparian vegetation (Figure by author 2021, adapted from ArcGIS 2021).

Kansas River at Shawnee, Kansas

Location

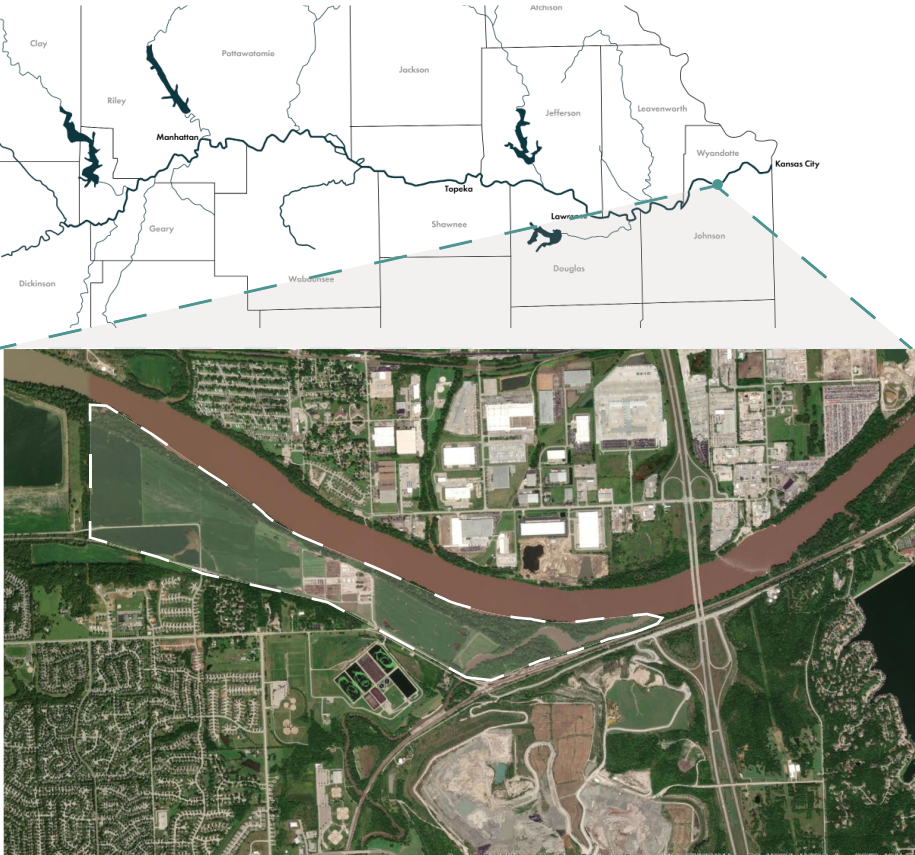


Figure 5.39 Rough Boundaries of Shawnee
This map gives an idea of the rough boundaries of the Kansas River at Shawnee site chosen by the author, boundary lines may be subject to change (Figure by author 2020, adapted from ArcGIS 2020).

Site Description

The Kansas River at Shawnee, Kansas is located about two miles to the west of Lake Quivira. Mill Creek Streamway Park is located at the eastern tip of the site, Mill Creek empties into the Kansas River at this location.

Shawnee | Site Assessment

Stream Visual Assessment Protocol Version II Score										
Element	Score									
	0	1	2	3	4	5	6	7	8	9 10
Channel Condition										
Hydrologic Alteration										
Bank Condition										
Riparian Area Quantity										
Riparian Area Quality										
Canopy Cover										
Water Appearance										
Nutrient Enrichment										
Pools										
Barriers to Movement										
Fish Habitat Complexity										
Aquatic Invertebrate Habitat										

Overall Score: 3.8 Poor

Table 5.11 SVAP Version II at Shawnee
The results from the SVAP Version II conducted at Shawnee by author (Table by author 2021, adapted from USDA & NRCS 2009).

Flood Frequency Analysis	
1.5-Year Flood Frequency Flow (cfs)	46,495.70
Bankfull Width (ft)	804.67
Bankfull Elevation (ft)	747
Mean Depth (ft)	11
Cross-Sectional Area (ft)	12,933.33
Velocity (ft/s)	3.60

Table 5.12 Flood Frequency Analysis for Shawnee
The results from the flood frequency analysis for Shawnee conducted by author (Table by author 2021).

Shawnee | Site Assessment

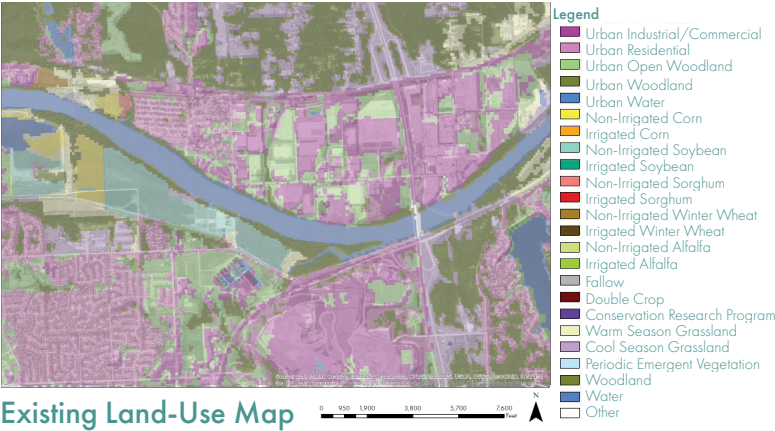


Figure 5.40 Shawnee Existing Land-Use
This figure shows the existing land-use on and surrounding the Shawnee site (Figure by author 2021, adapted from ArcGIS).

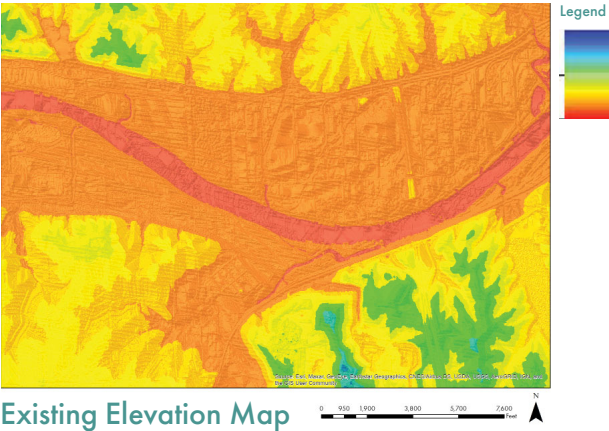


Figure 5.41 Shawnee Existing Elevation
This figure shows the existing elevation levels around the Shawnee site (Figure by author 2021, adapted from ArcGIS).

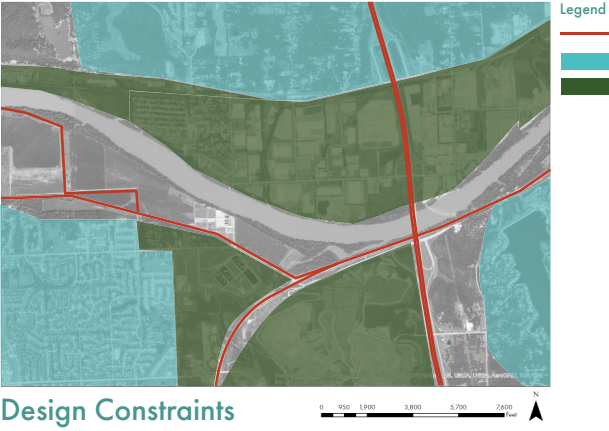


Figure 5.42 Shawnee Design Constraints
Transportation, residential and industrial development constrict most of the design boundaries (Figure by author 2021, adapted from ArcGIS).

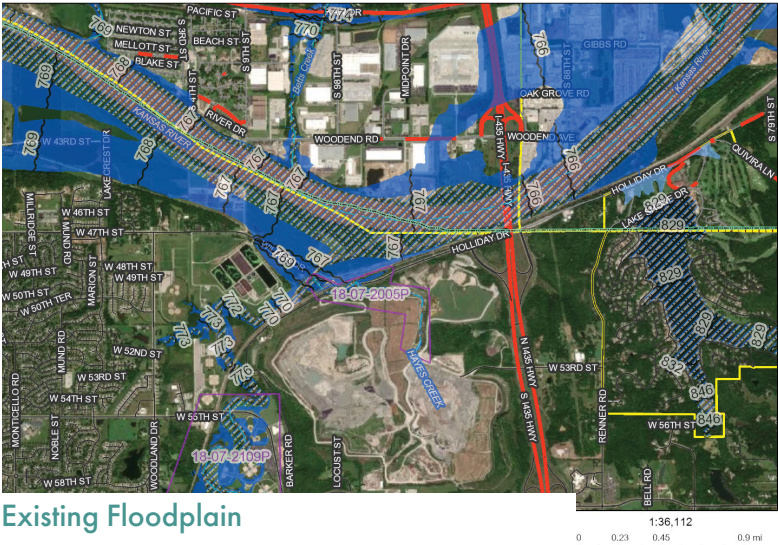


Figure 5.43 Shawnee FEMA Floodplain Boundaries
The figure shows the current (as of this publication) floodplain boundaries determined by FEMA and Kansas Department of Agriculture (FEMA & KDA 2021).

Legend + FEMA Flood Definitions

- AE, Floodway
- LOMR Areas
- Lettered Cross Sections
- Base Flood Elevations
- Base Flood Approximate Elevations
- Unlettered, Mapped Cross Sections

Legend

- A Areas with a 1% annual chance of flooding and a 26% chance of flooding over the life of a 30-year mortgage. Because detailed analyses are not performed for such areas, no depths or base flood elevations are shown within these zones (FEMA 2010).
- AE The base floodplain where base flood elevations are provided. AE Zones are now used on new format FIRMs instead of A1-A30 Zones (FEMA 2010).
- AH Areas with a 1% annual chance of shallow flooding, usually in the form of a pond, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Base flood elevations derived from detailed analyses are shown at selected intervals within these zones (FEMA 2010).
- AO River or stream flood hazard areas, and areas with a 1% or greater chance of shallow flooding each year, usually in the form of sheet flow, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Average flood depths derived from detailed analyses are shown within these zones (FEMA 2010).

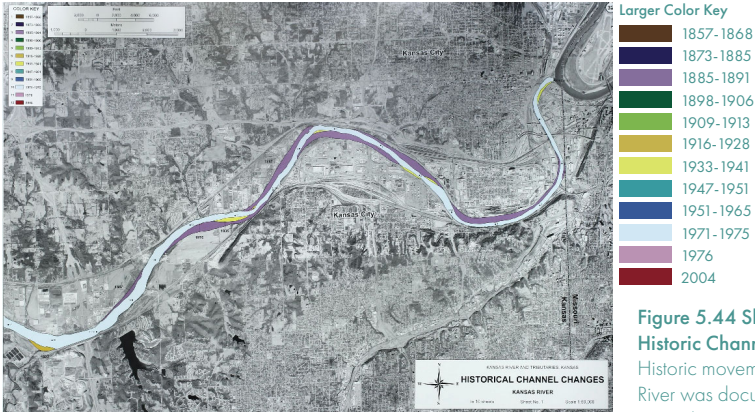


Figure 5.44 Shawnee Site Historic Channel Changes
Historic movement of the Kansas River was documented from 1857-2004 (Dort Jr. 2009).



Existing Conditions

Figure 5.45 Existing Conditions at Shawnee Site

This map shows the spatial relationship of the existing land-use and site conditions of the site and its surroundings (Figure by author 2020, adapted from ArcGIS 2020).

Site Assessment Summary

The site is surrounded with dense urban and industrial development. A sand and gravel dredging company is located directly across from the site on the Kansas River to the north east. The Johnson County Landfill is directly adjacent to the site to the east. Agriculture is the primary land-use in the proposed restoration area. There is a small dam less than 2 miles downstream from the site. The dense development has caused fragmentation to the surrounding riparian corridor. The river is extremely incised and completely disconnected from its floodplain on both the north and the south side. Mill Creek Streamway park contains a small Conservation Research Program (CRP) area intended to provide habitat for wildlife species in addition to a large walking trail loop. The desired floodplain cannot be fully utilized due to the compact development surrounding the site.

Restoration Design Objectives:

- Improve river function by converting the river from an F stream type to a functioning C stream type (Rosgen 1997).
- Reduce non-point source runoff pollution from the adjacent landfill and dense industrial development.
- Mitigate erosion caused by the sand and gravel dredging company directly across from the restoration site.
- Provide access to the floodplain on the southern side of the Kansas River and the addition of a floodplain stream on the southern side of the river.
- In this project the existing warehouse lot is being absorbed and turned into a riparian buffer, however, if that is not an option, the design can still be applied around the existing warehouse, minus the addition of the floodplain stream.
- Streambanks on southern side of river to be excavated and stabilized with native vegetation. The northern streambanks cannot be excavated, but will be stabilized using bankfull benches made out of wood and other natural materials.

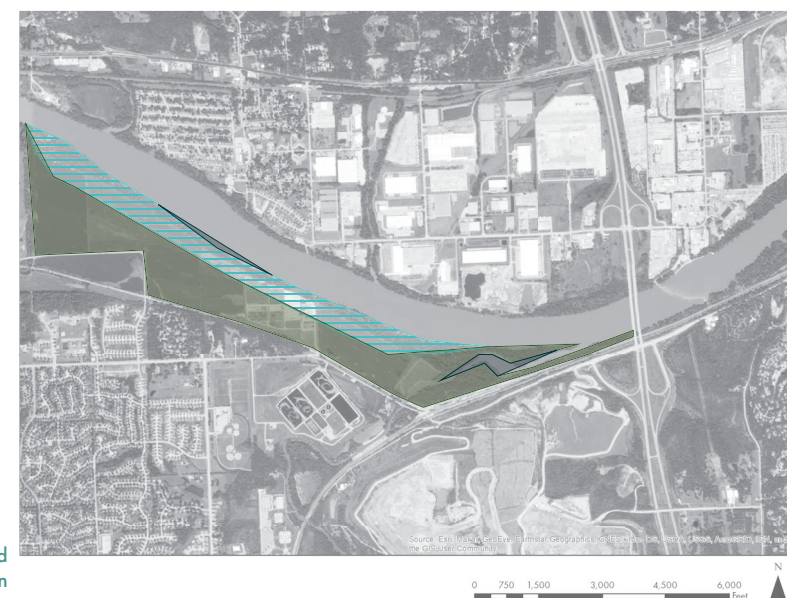
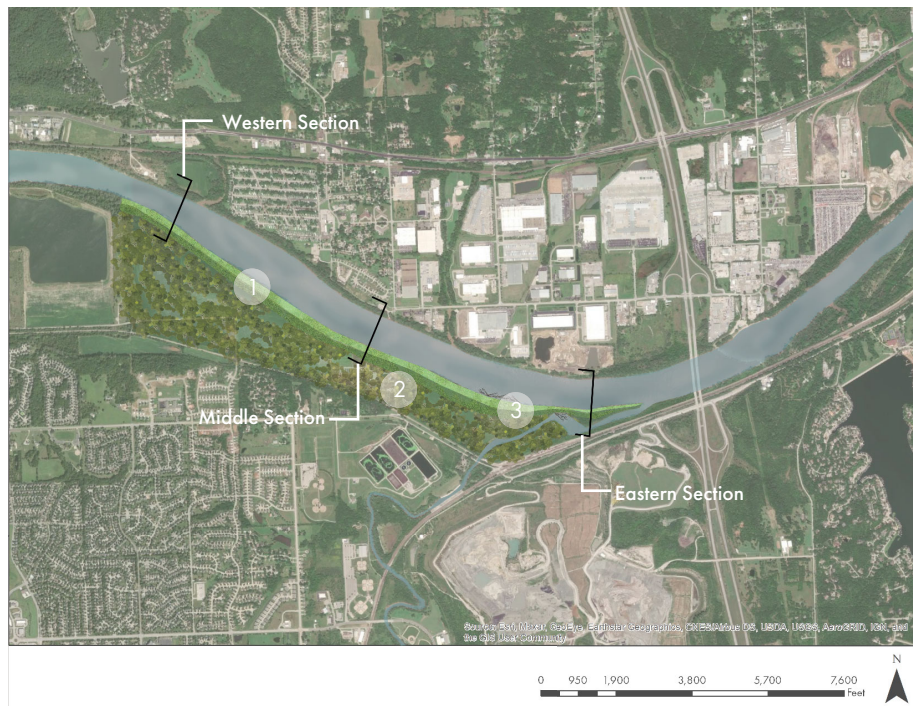


Figure 5.46 Projected Site Design

The map outlines the projected design suggestions for the Kansas River at Shawnee site (Figure by author 2021, adapted from ArcGIS 2021).

Overview of Design Application from Site Analysis

- Aquatic Habitat Implementation
- Invasive Species Removal + Implementation of Native Riparian Vegetation
- Floodplain Earthwork



Shawnee - Overall Site Design

Figure 5.47 Master Plan of Projected Design at Shawnee Site

The plan provides a visual representation of the proposed design implementations for the Kansas River at Shawnee, Kansas site (Figure by author 2021, adapted from ArcGIS 2021).

1

Streambank Stabilization

- Western Cross-Section
- Middle Cross-Section
- Eastern Cross-Section

2

Riparian Vegetation Restoration

- Riparian vegetation buffer zone
- Invasive species removal
- Revegetate slopes with native riparian vegetation

3

Aquatic Habitat Creation

- Added deadwood
- Expanded floodplain area

1

Streambank Stabilization + Floodplain Reconnection



Figure 5.48 Western Section Cut Location at Shawnee

The map shows the location of the first and second section cut shown on the following page (Figure by author 2021, adapted from ArcGIS 2021).

Western Cross-Section Location

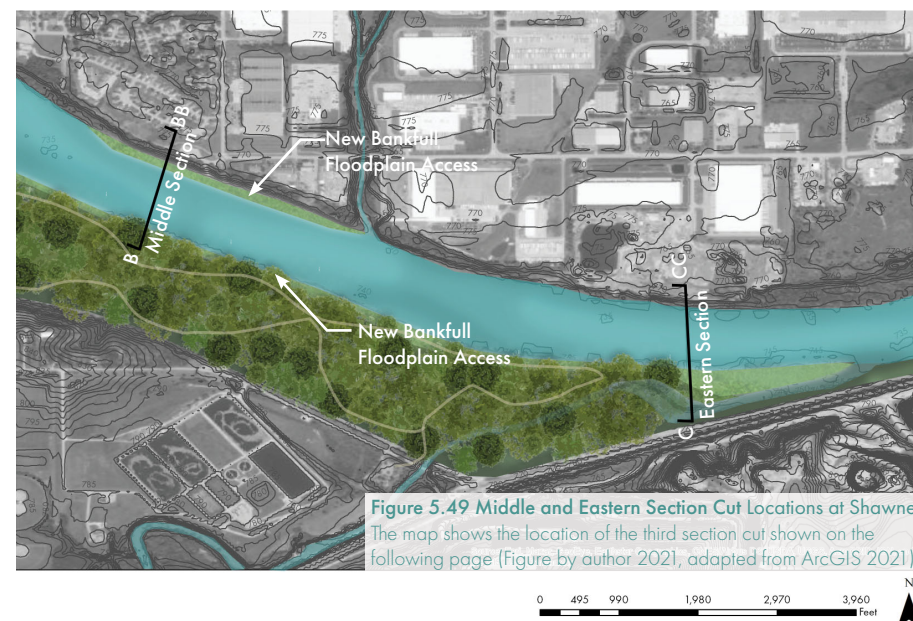


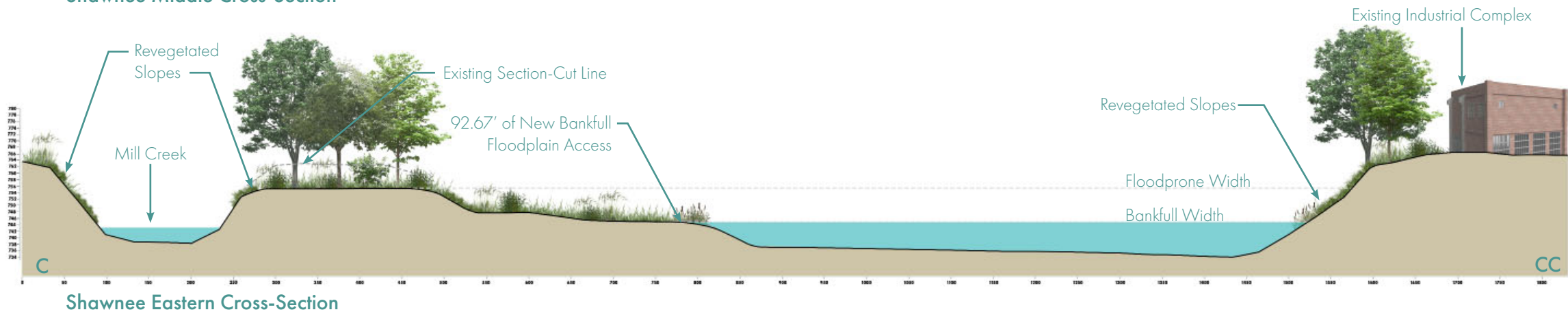
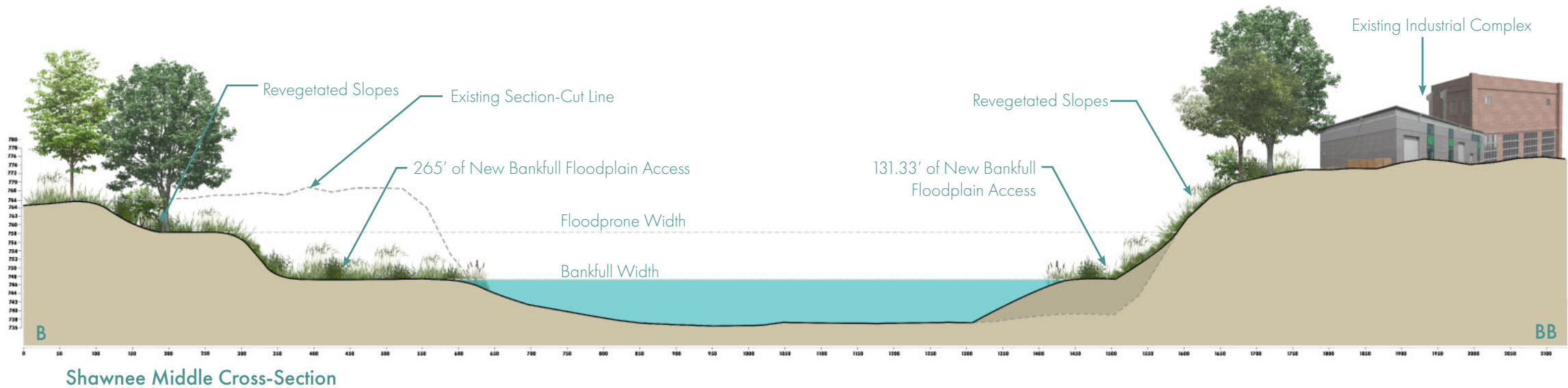
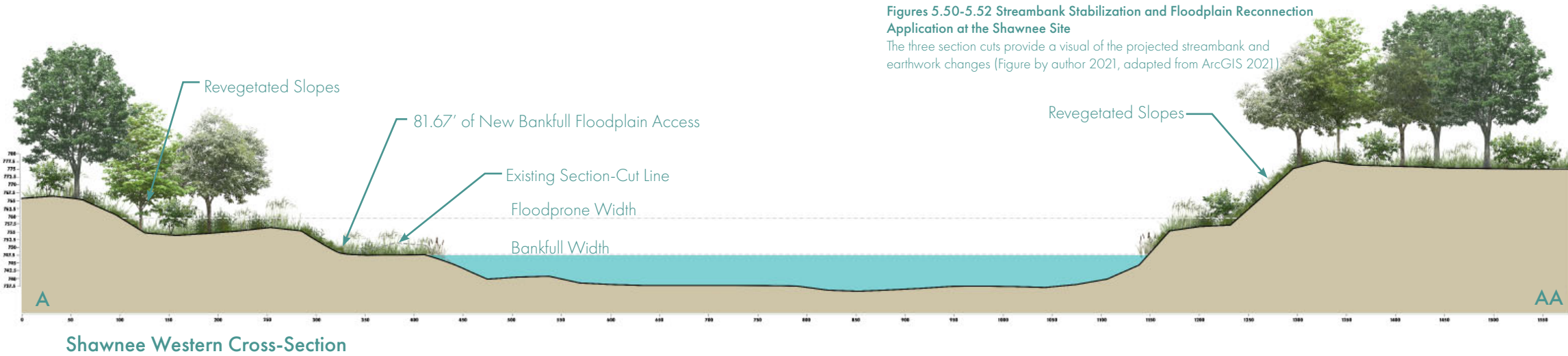
Figure 5.49 Middle and Eastern Section Cut Locations at Shawnee

The map shows the location of the third section cut shown on the following page (Figure by author 2021, adapted from ArcGIS 2021).

Middle + Eastern Cross-Section Locations

Figures 5.50-5.52 Streambank Stabilization and Floodplain Reconnection Application at the Shawnee Site

The three section cuts provide a visual of the projected streambank and earthwork changes (Figure by author 2021, adapted from ArcGIS 2021).



1 Streambank Stabilization + Floodplain Reconnection

Streambank Stabilization - Proposed Steps

- Before planting native vegetation along the streambanks, the cutting and removal of invasive species is required. Invasive species found on site include, but are not limited to: honeysuckle (*Lonicera* family: *maackii*, *japonica*, *tatarica*), euonymus wintercreeper (*Euonymus fortunei*), and Saltcedar (*Tamarix ramosissima*)
- All excavated slopes must maintain a 3:1 slope ratio or less for successful revegetation, a 2:1 slope is preferred.

Rough Total of Proposed Added Bankfull Floodplain Access

This number is found by adding up the area of bankfull width floodplain added in between the cross-sections sampled divided by the number of cross-sections taken (three) for an average estimate of total bankfull floodplain area added. It is to be noted that these numbers are an estimate of the approximative area, exact numbers would require on-site measurements.

Estimated Total of Bankfull Floodplain Area Added: 68.25 Acres.

2 Riparian Vegetation Restoration



Shawnee Overall Planting Areas

Streambank Stability Area

Species in this area need to tolerate wetter conditions for several days in addition to periods of dry conditions.

Woody species: Black walnut (*Juglans nigra*), eastern cottonwood (*Populus deltoides*), sycamore (*Platanus occidentalis*), silver maple (*Acer saccharinum*), Kentucky coffeetree (*Gymnocladus dioica*), sandhill plum (*Prunus agustifolia*), sandbar willow (*Salix exigua*)

Herbaceous species: Spotted Joe-Pye (*Eupatorium maculatum*), cardinal flower (*Lobelia cardinalis*), prairie blazing star (*Liatris pycnostachya*), swamp milkweed (*Asclepias incarnata*), water plantain (*Alisma subcordatum*), New England aster (*Aster novae-angliae*), fox sedge (*Carex vulpinoidea*), bottle brush sedge (*Carex hystericina*)

Floodprone Area

Species in this area need to tolerate occasional standing water and periods of dry drought conditions.

Woody species: American basswood (*Tilia americana*), red oak (*Quercus rubra*), shagbark hickory (*Carya ovata*), fragrant sumac (*Rhus aromatica*), choke cherry (*Prunus virginiana*)

Herbaceous species: Stiff goldenrod (*Solidago rigida*), great blue lobelia (*Lobelia siphilitica*), golden Alexander (*Zizia aurea*), prairie blazing star (*Liatris pycnostachya*), purple prairie clover (*Dalea purpurea*)

Upland Area

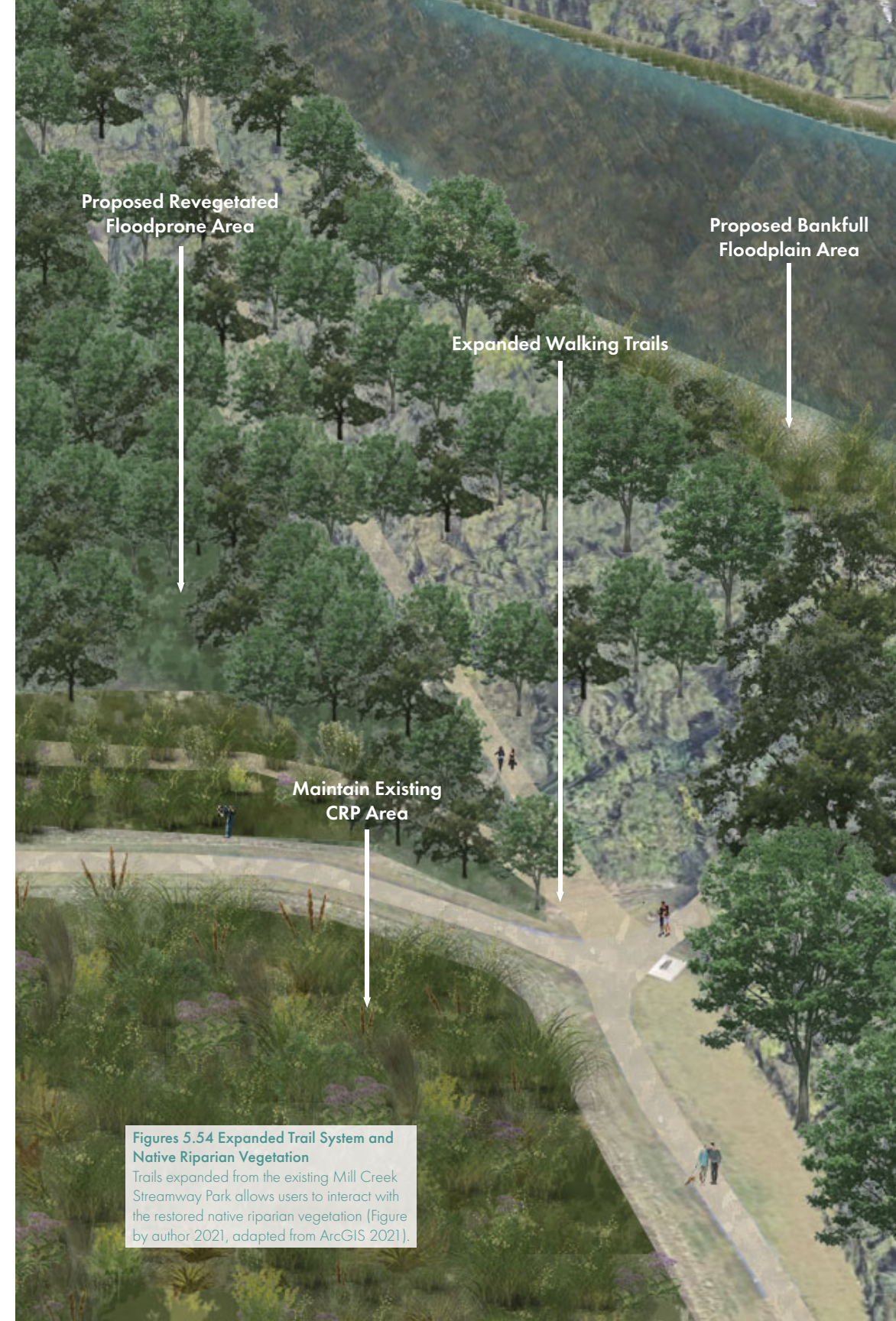
Species in this area need to tolerate dry conditions including periods of drought. This site will not have as many grass species compared to the floodplain area species.

Herbaceous species: dogtooth daisy (*Helenium autumnale*), purple prairie clover (*Dalea purpurea*), stiff goldenrod (*Solidago rigida*), mountain mint (*Pycnanthemum virginianum*)

Shawnee Native Riparian Restoration Overview:

Little to no native riparian vegetation on site based on initial SVAP Version II (USDA & NRCS 2009). The existing vegetation was predominantly invasive species including, but not limited to amur honeysuckle (*Lonicera maackii*), garlic mustard (*Alliaria petiolata*), and black locust (*Robinia pseudoacacia*). The DeSoto and Shawnee site will have a higher number of the invasive species Callery pear trees (*Pyrus calleryana*) due to the more populated urban areas surrounding the area. The existing riparian buffer was thin and lacked species diversity. 70% of the streambank slopes were bare.

Suggestions for native riparian vegetation restoration for the Kansas River at Shawnee, Kansas includes expanding bankfull floodplain access and revegetating the newly excavated areas from the bankfull floodplain expansion. Eastern cottonwood (*Populus deltoides*) is the predominant tree species in the existing riparian vegetation buffer. Implementation of a wet mesic/dry vegetation species mix in the newly expanded floodprone area will require initial invasive species removal and management. The native plant selection includes pollinators, berry and fruit producing species to feed wildlife species, and taller vegetation used for wildlife and aquatic species habitat.



Figures 5.54 Expanded Trail System and Native Riparian Vegetation

Trails expanded from the existing Mill Creek Streamway Park allows users to interact with the restored native riparian vegetation (Figure by author 2021, adapted from ArcGIS 2021).

Wakarusa River at Eudora, Kansas

Location

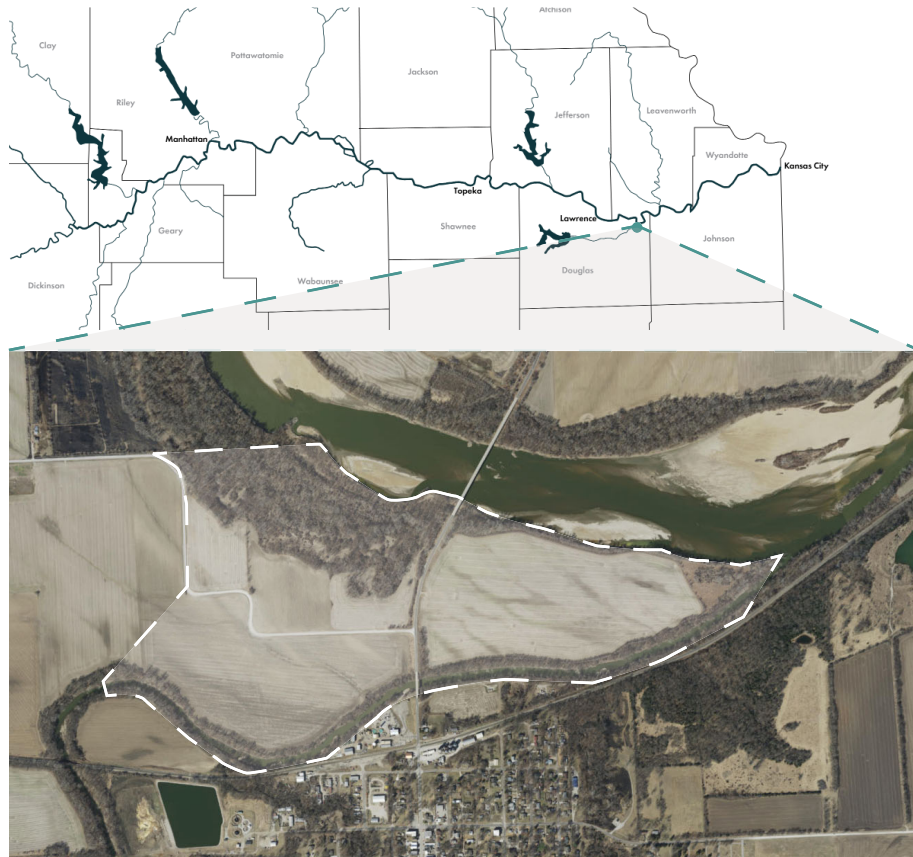


Figure 5.55 Rough Boundaries of Wakarusa Site

This map gives an idea of the rough boundaries of the Wakarusa River at Eudora site chosen by the author, boundary lines may be subject to change (Figure by author 2020, adapted from ArcGIS 2020).

Site Description

The Wakarusa River site is located to the north of Eudora, Kansas where the Wakarusa River flows into the Kansas River. The site is predominantly surrounded by agriculture cropland. A municipal warehouse and rail line flank the southern edge of the Wakarusa within a majority of the site.

Wakarusa | Site Assessment

Stream Visual Assessment Protocol Version II Score										
Element	Score									
	0	1	2	3	4	5	6	7	8	9 10
Channel Condition										
Hydrologic Alteration										
Bank Condition										
Riparian Area Quantity										
Riparian Area Quality										
Canopy Cover										
Water Appearance										
Nutrient Enrichment										
Pools										
Barriers to Movement										
Fish Habitat Complexity										
Aquatic Invertebrate Habitat										

Overall Score: 4.8 Poor

Table 5.13 SVAP Version II at Eudora

The results from the SVAP Version II conducted at Eudora by author (Table by author 2021, adapted from USDA & NRCS 2009).

Flood Frequency Analysis	
1.5-Year Flood Frequency Flow (cfs)	2,359.05
Bankfull Width (ft)	112.47
Bankfull Elevation (ft)	795
Mean Depth (ft)	9.12
Cross-Sectional Area (ft)	1,025.33
Velocity (ft/s)	2.30

Table 5.14 Flood Frequency Analysis for Eudora

The results from the flood frequency analysis for Eudora conducted by author (Table by author 2021).

Wakarusa | Site Assessment

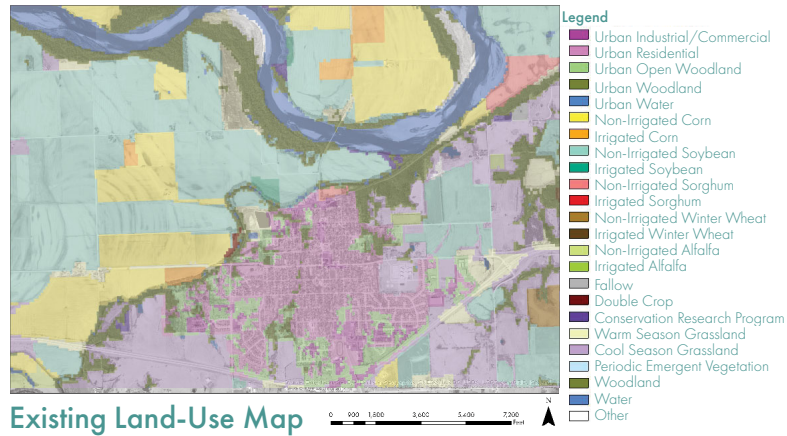


Figure 5.56 Wakarusa Existing Land-Use
This figure shows the existing land-use on and surrounding the Wakarusa site (Figure by author 2021, adapted from ArcGIS).

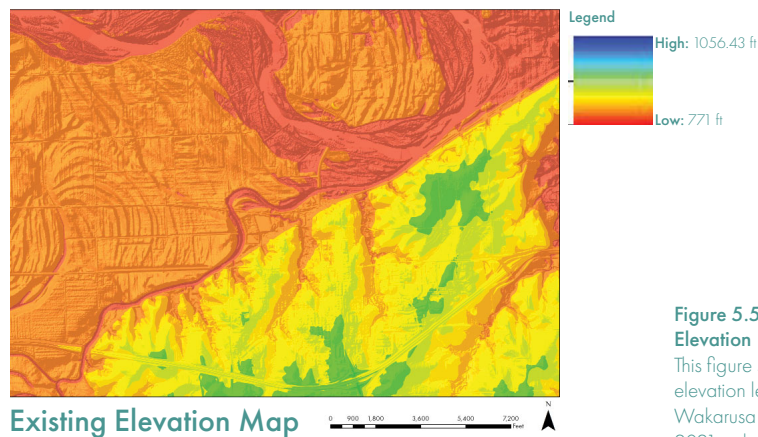


Figure 5.57 Wakarusa Existing Elevation
This figure shows the existing elevation levels around the Wakarusa site (Figure by author 2021, adapted from ArcGIS).

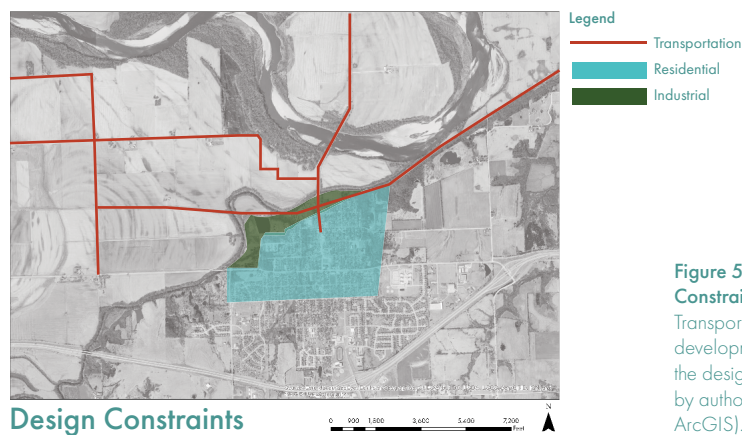


Figure 5.58 Wakarusa Design Constraints
Transportation and residential development constrict some of the design boundaries (Figure by author 2021, adapted from ArcGIS).

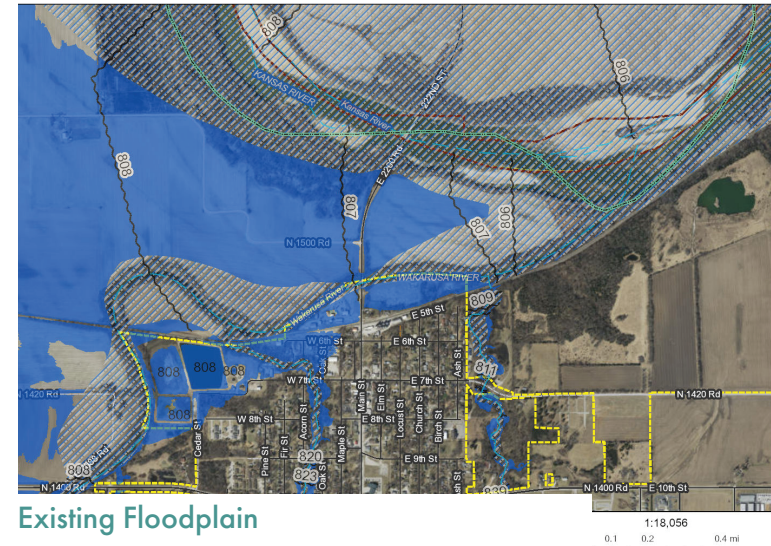


Figure 5.59 Eudora FEMA Floodplain Boundaries
The figure shows the current (as of this publication) floodplain boundaries determined by FEMA and Kansas Department of Agriculture (FEMA & KDA 2021).

Legend + FEMA Flood Definitions

- AE, Floodway
- LOMR Areas
- Lettered Cross Sections
- Base Flood Elevations
- Base Flood Approximate Elevations
- Unlettered, Mapped Cross Sections

Figure 5.57 Wakarusa Existing Elevation
This figure shows the existing elevation levels around the Wakarusa site (Figure by author 2021, adapted from ArcGIS).

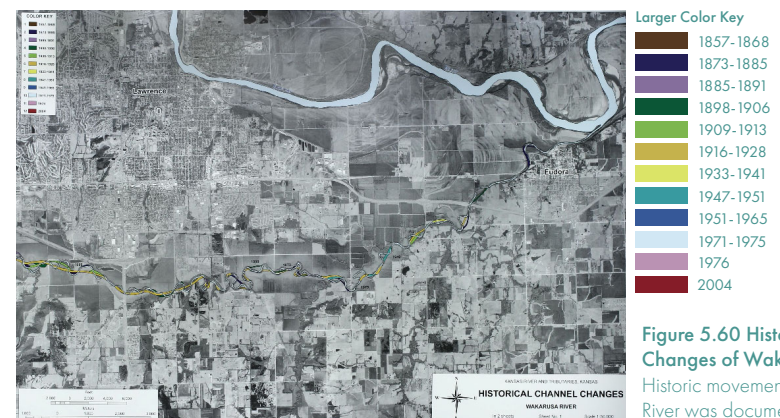


Figure 5.60 Historic Channel Changes of Wakarusa River
Historic movement of the Kansas River was documented from 1857-2004 (Dort Jr. 2009).



Existing Conditions

Figure 5.61 Existing Conditions at Wakarusa Site

This map shows the spatial relationship of the existing land-use and site conditions of the site and its surroundings (Figure by author 2020, adapted from ArcGIS 2020).

Site Assessment Summary

The site is primarily surrounded by agriculture fields and a small portion of residential. Agriculture fields contribute to non-point source runoff pollution into both the Kansas and Wakarusa Rivers on this site. The streambanks are incised, and the river is disconnected from its floodplain. There is some riparian buffer vegetation made up predominately invasive species.

Design Implementation

- Improve river function by converting the river from an F stream type to a functioning C4 stream type (Rosgen 1997).
- Excavation of the northern side of the Wakarusa River to reconnect it to its floodplain.
- Streambanks that are excavated will be stabilized with native vegetation. The streambank adjacent to the railroad track and Eudora Municipal storage area cannot be excavated and will be stabilized and revegetated.
- Removal of invasive species along the streambanks and revegetate with native riparian vegetation. Expand the riparian vegetation buffer on the northern slope of the Wakarusa and southern slope of the Kansas River.
- Conversion of the adjacent agriculture fields into floodplain agriculture where noted.

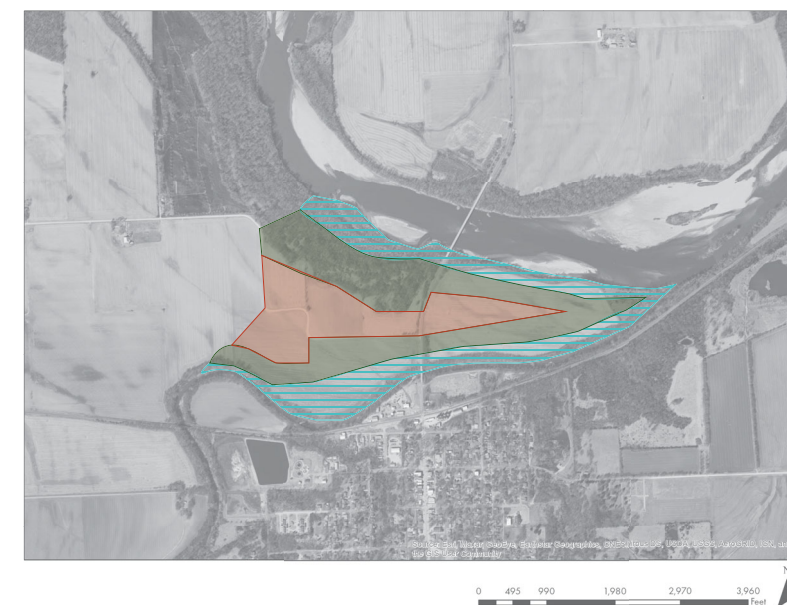
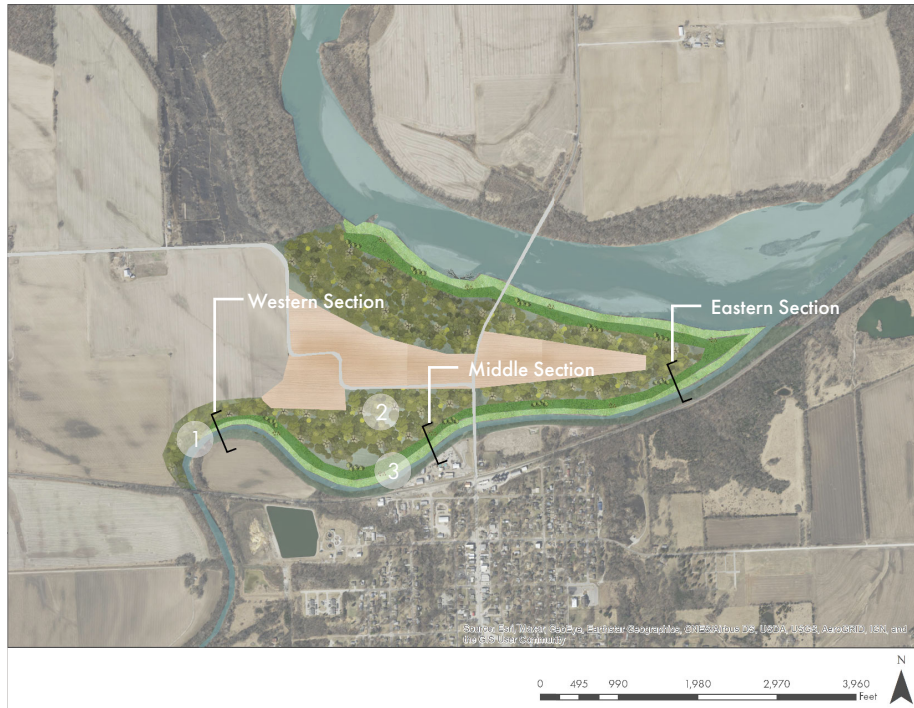


Figure 5.62 Projected Site Design

The map outlines the projected design suggestions for the Wakarusa river at Eudora site (Figure by author 2021, adapted from ArcGIS 2021).

Overview of Design Application from Site Analysis

- Floodplain Agriculture Methods
- Aquatic Habitat Implementation
- Invasive Species Removal + Implementation of Native Riparian Vegetation
- Floodplain Earthwork



Wakarusa - Overall Site Design

Figure 5.63 Master Plan of Projected Design at Wakarusa Site

The plan provides a visual representation of the proposed design implementations for the Wakarusa River at Eudora, Kansas site (Figure by author 2021, adapted from ArcGIS 2021).

1

Streambank Stabilization

- Western Cross-Section
- Middle Cross-Section
- Eastern Cross-Section

2

Riparian Vegetation Restoration

- Riparian vegetation buffer zone
- Invasive species removal
- Revegetate slopes with native riparian vegetation

3

Aquatic Habitat Creation

- Added deadwood
- Expanded floodplain area

1

Streambank Stabilization + Floodplain Reconnection

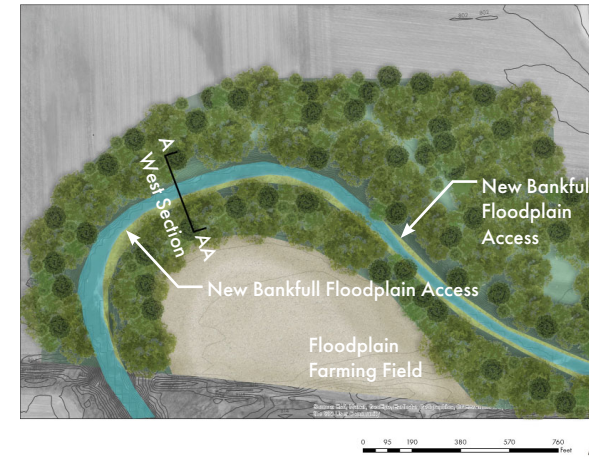


Figure 5.64 Western Section Cut at Eudora

The map shows the location of the first section cut shown on the following page (Figure by author 2021, adapted from ArcGIS 2021).

Western Cross-Section Location



Figure 5.65 Middle Section Cut at Eudora

The map shows the location of the second section cut shown on the following page (Figure by author 2021, adapted from ArcGIS 2021).

Middle Cross-Section Location

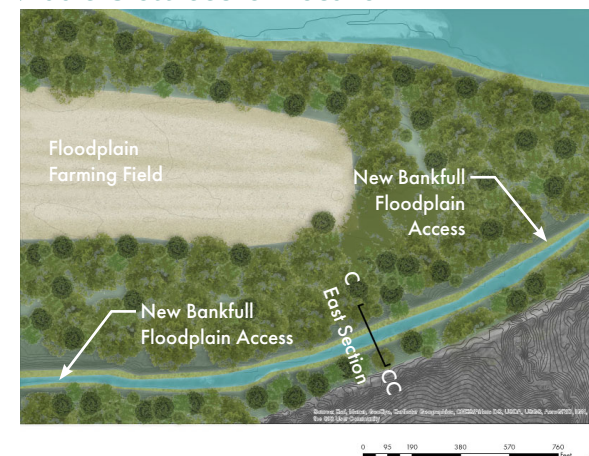
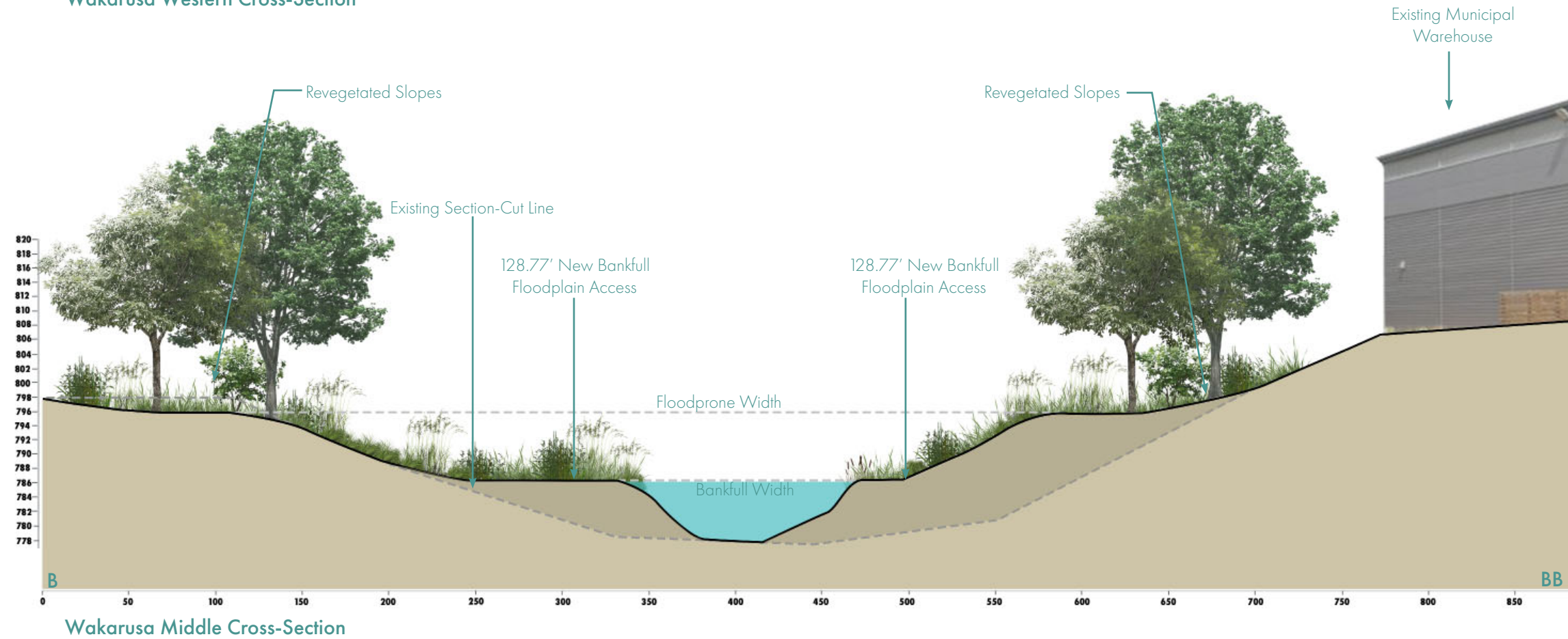
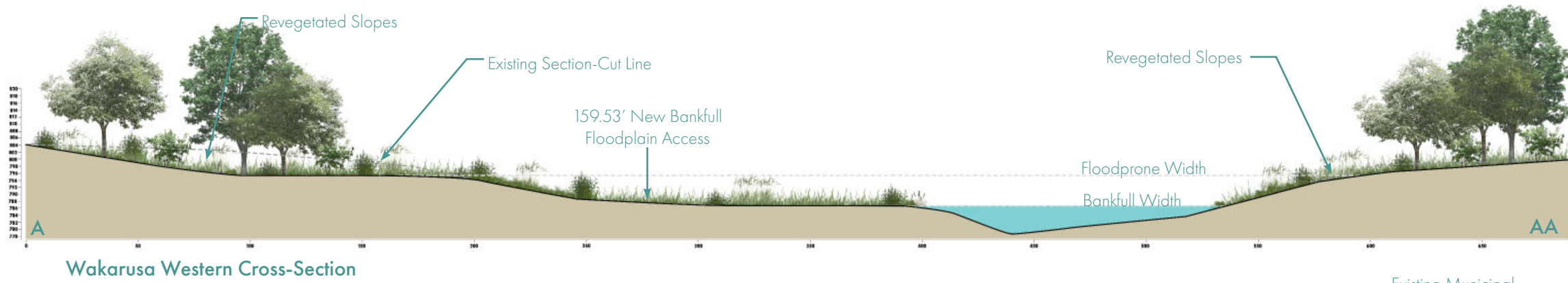


Figure 5.66 Eastern Section Cut at Eudora

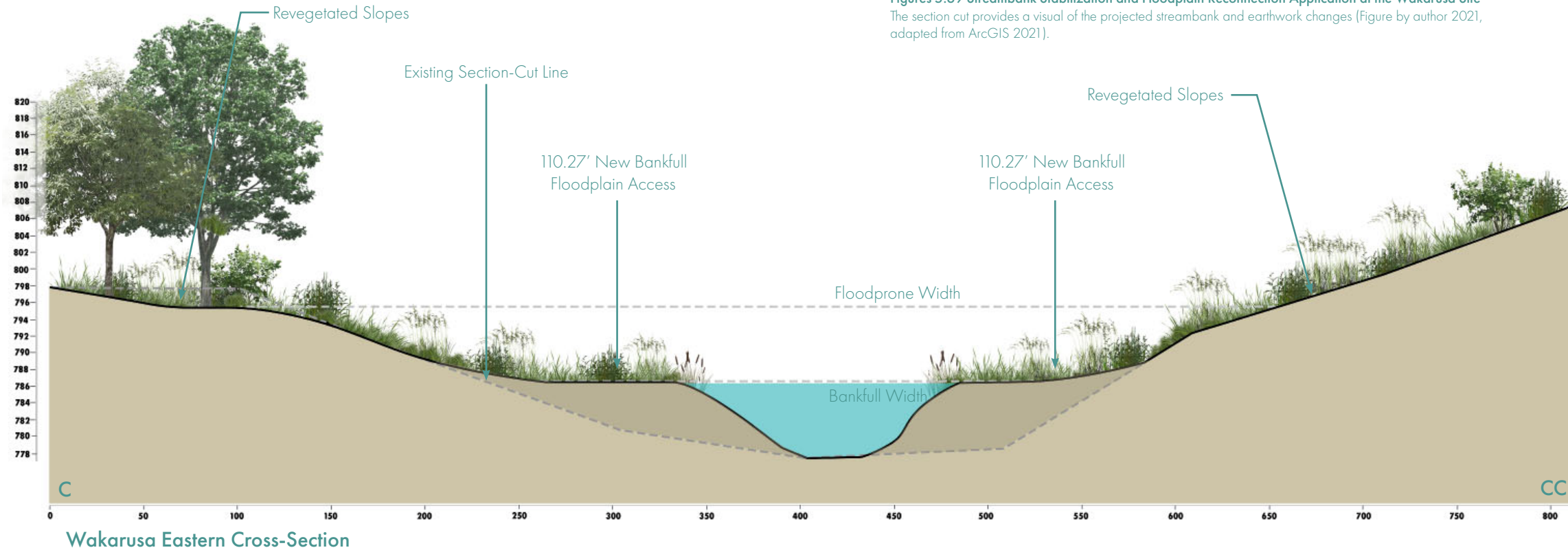
The map shows the location of the third section cut shown on the following page (Figure by author 2021, adapted from ArcGIS 2021).

Eastern Cross-Section Location

Figures 5.67-5.68 Streambank Stabilization and Floodplain Reconnection Application at the Wakarusa Site
 The two section cuts provide a visual of the projected streambank and earthwork changes (Figure by author 2021, adapted from ArcGIS 2021).



Figures 5.69 Streambank Stabilization and Floodplain Reconnection Application at the Wakarusa Site
The section cut provides a visual of the projected streambank and earthwork changes (Figure by author 2021, adapted from ArcGIS 2021).



1 Streambank Stabilization + Floodplain Reconnection

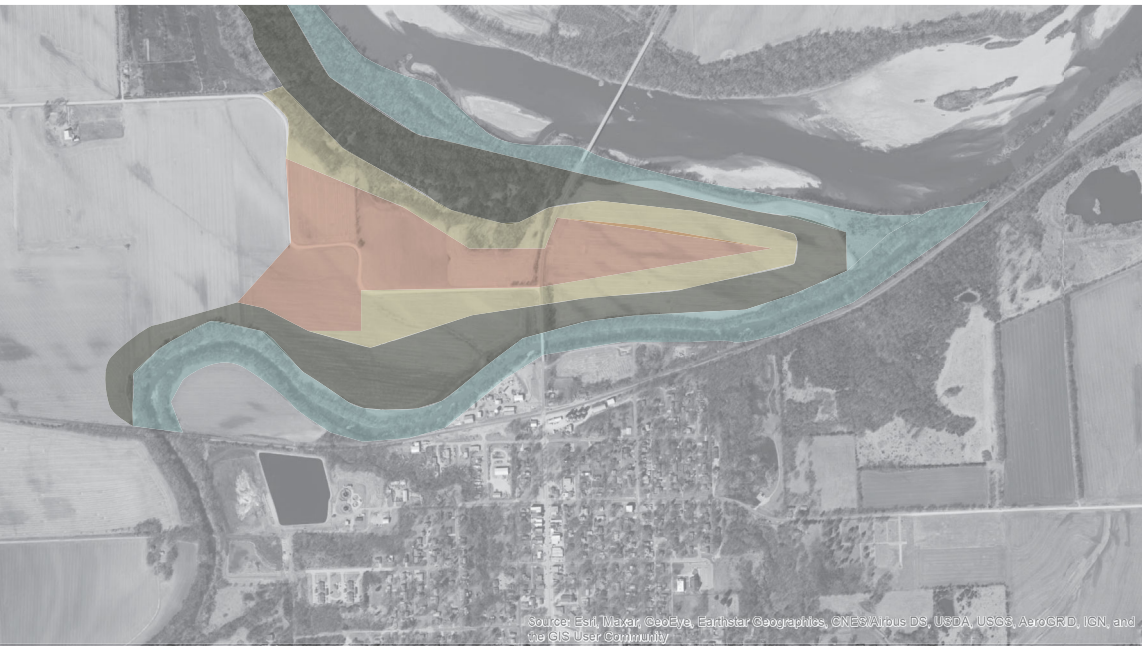
Streambank Stabilization - Proposed Steps

- Before planting native vegetation along the streambanks, the cutting and removal of invasive species is required. Invasive species found on site include, but are not limited to: honeysuckle (*Lonicera* family: *maackii*, *japonica*, *tatarica*) and Saltcedar (*Tamarix ramosissima*)
- All excavated slopes must maintain a 3:1 slop ratio or less for successful revegetation, a 2:1 slope is preferred.

Rough Total of Proposed Added Bankfull Floodplain Access

This number is found by adding up the area of bankfull width floodplain added in between the cross-sections sampled divided by the number of cross-sections taken (three) for an average estimate of total bankfull floodplain area added. It is to be noted that these numbers are an estimate of the approximative area, exact numbers would require on-site measurements.

Estimated Total of Bankfull Floodplain Area Added: 40.70 Acres.



Wakarusa Overall Planting Areas

Figures 5.70 Proposed Planting Master Plan for Wakarusa Site

The figure shows the proposed planting areas for the Wakarusa Site (Figure by author 2021, adapted from ArcGIS 2021).

Streambank Stability Area

Species in this area need to tolerate wetter conditions for several days in addition to periods of dry conditions.

Woody species: Black walnut (*Juglans nigra*), eastern cottonwood (*Populus deltoides*), sycamore (*Platanus occidentalis*), silver maple (*Acer saccharinum*), Kentucky coffeetree (*Gymnocladus dioica*), sandhill plum (*Prunus agustifolia*), sandbar willow (*Salix exigua*)

Herbaceous species: Spotted Joe-Pye (*Eupatorium maculatum*), cardinal flower (*Lobelia cardinalis*), prairie blazing star (*Liatris pycnostachya*), swamp milkweed (*Asclepias incarnata*), water plantain (*Alisma subcordatum*), New England aster (*Aster novae-angliae*), fox sedge (*Carex vulpinoidea*), bottle brush sedge (*Carex hystricina*)

Floodprone Area

Species in this area need to tolerate occasional standing water and periods of dry drought conditions.

Woody species: American basswood (*Tilia americana*), red oak (*Quercus rubra*), shagbark hickory (*Carya ovata*), fragrant sumac (*Rhus aromatica*), choke cherry (*Prunus virginiana*)

Herbaceous species: Stiff goldenrod (*Solidago rigida*), great blue lobelia (*Lobelia siphilitica*), golden Alexander (*Zizia aurea*), prairie blazing star (*Liatris pycnostachya*), purple prairie clover (*Dalea purpurea*)

Upland Area

Species in this area need to tolerate dry conditions including periods of drought.

Grass species: Mesic native grass seed mix

Herbaceous species: dogtooth daisy (*Helenium autumnale*), purple prairie clover (*Dalea purpurea*), stiff goldenrod (*Solidago rigida*), mountain mint (*Pycnanthemum virginianum*)

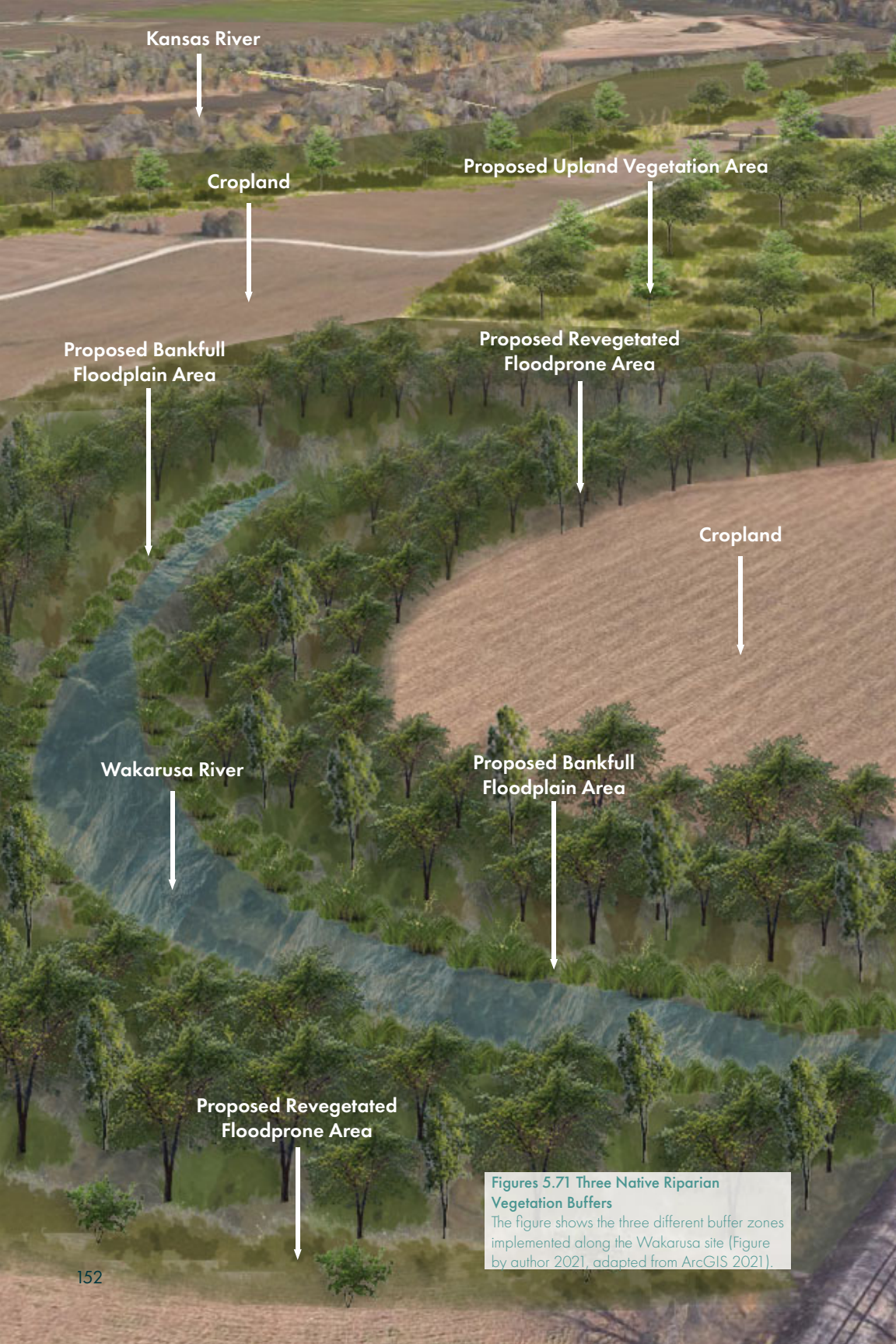
Floodplain Agriculture

Floodplain agriculture fields plan for flooding and are generally harvested 3 out of every 5 years. Farmers have the potential to get support from the government for participating in floodplain farming management strategies.

Wakarusa River Native Riparian Restoration Overview:

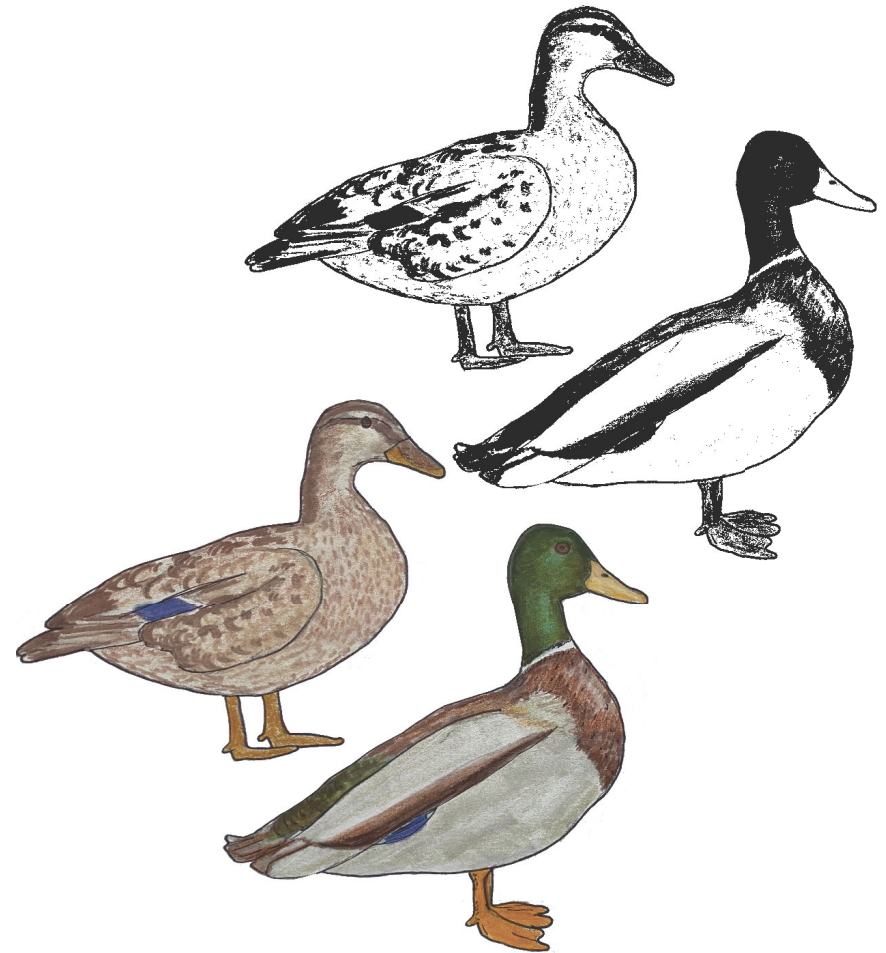
Little to no native riparian vegetation on site based on initial SVAP Version II (USDA & NRCS 2009). The existing vegetation was predominantly invasive species including, but not limited to amur honeysuckle (*Lonicera maackii*), garlic mustard (*Alliaria petiolata*), and black locust (*Robinia pseudoacacia*). The existing riparian buffer was thin and lacked species diversity. 70% of the streambank slopes were bare.

Suggestions for native riparian vegetation restoration for the Wakarusa River at Eudora, Kansas includes expanding bankfull floodplain access and revegetating the newly excavated areas from the bankfull floodplain expansion. Eastern cottonwood (*Populus deltoides*) is the predominant tree species in the existing riparian vegetation buffer and some maple species. Implementation of a wet mesic/dry vegetation species mix in the newly expanded floodprone area will require initial invasive species removal and management. The area in between the floodplain agriculture field and the floodprone area buffer will be vegetated with upland vegetation that can handle drought conditions better than the first two zones. The native plant selection includes pollinators, berry and fruit producing species to feed wildlife species, and taller native vegetation used for wildlife and aquatic species habitat.



Figures 5.71 Three Native Riparian Vegetation Buffers
The figure shows the three different buffer zones implemented along the Wakarusa site (Figure by author 2021, adapted from ArcGIS 2021).





Mallard *Anas platyrhynchos* (male & female)

The ancestor of nearly all domestic duck breeds. Mallards can be found at local city or suburban parks and near streams, rivers, or lakes in Kansas and all of North America (Cornell University 2019). (Figure 6.1 by author 2021).

Chapter 06

Conclusion

Conclusion

Human development has a large influence on the greenhouse gasses being pumped into the atmosphere and our waterways and it is only projected to increase in the next century. The Kansas River is too valuable of an economic resource for human activity to halt on it completely, however mitigation strategies for future development can aid in protecting and restoring the river channel and surrounding riparian corridor from predicted negative climate change consequences. The purpose of this project is to convey the ecological benefits of including riparian corridor and floodplain restoration into design and development plans that fall within a river's floodplain, applied on the Kansas River and its tributary the Wakarusa River. Each site has its own set of criteria and conditions that need to be addressed, that is why a "cookie cutter" approach to riparian vegetation and floodplain restoration will not work. Each restoration project is unique and requires an initial site assessment to determine the individual restoration needs of the site in order to increase species diversity and repair or mitigate stream channel dysfunction. Once the design intervention occurs, the restoration process will not necessarily provide an immediate result. Instead, the site needs to be monitored over time and require appropriate management practices to have the best chance at recovering and being resilient against future anthropogenic climate change.

Designing for Change is a hypothetical design projection on the Kansas River. To get the most accurate results field measurements would need to be surveyed on site and the implemented designs would need to be monitored and managed over time. The goal of this report was to determine if it was possible to use the existing physical integrity of the river channel and floodplain as a template to reconnect the Kansas and Wakarusa Rivers to their geomorphic floodplain while increasing the native riparian vegetation and creation of habitat for wildlife and aquatic species. It should also be noted that the channel sections delineated with areas of fill out onto the channel will need to be reinforced with stronger materials than just soil as it will be difficult to keep intact during high flood events while waiting for vegetation to stabilize it.

The four study sites showed that there is potential to reconnect the Kansas and Wakarusa Rivers to their floodplain and expand the riparian vegetation in the study areas to mitigate the adverse effects of the surrounding anthropogenic land-uses. Restoration design projections were possible through initial site assessments (SVAP Version II), understanding the 1.5-year recurrence flow and bankfull information (flood frequency analysis), and a combination of streambank and riparian area restoration techniques (understanding the different zones and what vegetation type goes in the zone; streambank stabilization using native riparian vegetation; best management practices from past studies).

Restoration Impacts

Expansion of floodplain area and creation of floodplain access points for the Kansas and Wakarusa Rivers was the primary goal of this project. At every site it was possible to reconnect the river to its floodplain, some sites had more access than others. It was also possible to expand the bankfull floodplain and floodprone areas at every site, even in the dense urban conditions at the Shawnee site. Expansion and increase of native riparian vegetation at all four sites was deemed possible. Expanding and increasing the native riparian vegetation at the four sites reduces the temperatures within the riparian corridor by providing more shade cover and increased carbon sequestration (Anderson et al. 2016).

As the study sites moved eastward down stream and closer to the Kansas City area the channel narrowing, and floodplain encroachment (by human development) increased while floodplain access decreased. Although it is impossible to fully restore the Kansas River's floodplain due to permanent development, this project provides examples of potential areas of reconnection to help mitigate the increased erosion and provide water storage areas. Providing more groundwater storage will increase site resilience against predicted climate change impacts such as: water shortages, decreased in soil infiltration, and increased pollutants going into the waterways; by storing more quantities of water and filtering out pollutants through the native

riparian vegetation. Increased groundwater storage also aids in replenishing the aquifer storage of the surrounding land-uses such as agriculture, residential, and urban areas. The amount of floodplain restoration is shown in Table 6.1.

Estimated Amount of Floodplain Area Created at the Four Study Sites:	
Site	Floodplain Area
Kansas River at Ogden, Kansas:	6.76 Acres
Kansas River at DeSoto, Kansas:	63.31 Acres
Kansas River at Shawnee, Kansas:	68.25 Acres
Wakarusa River at Eudora, Kansas:	40.70 Acres
Total amount of floodplain created on Kansas River (Ogden, DeSoto, and Shawnee):	140 Acres of floodplain storage at bankfull width & 4.27% of the length of the Kansas River.
Estimated Amount of Floodplain Area Created for the Entire Kansas River:	
3244 Acres of floodplain added if the entire river floodplain was restored & 141,787,800 cubic feet of flood storage.	

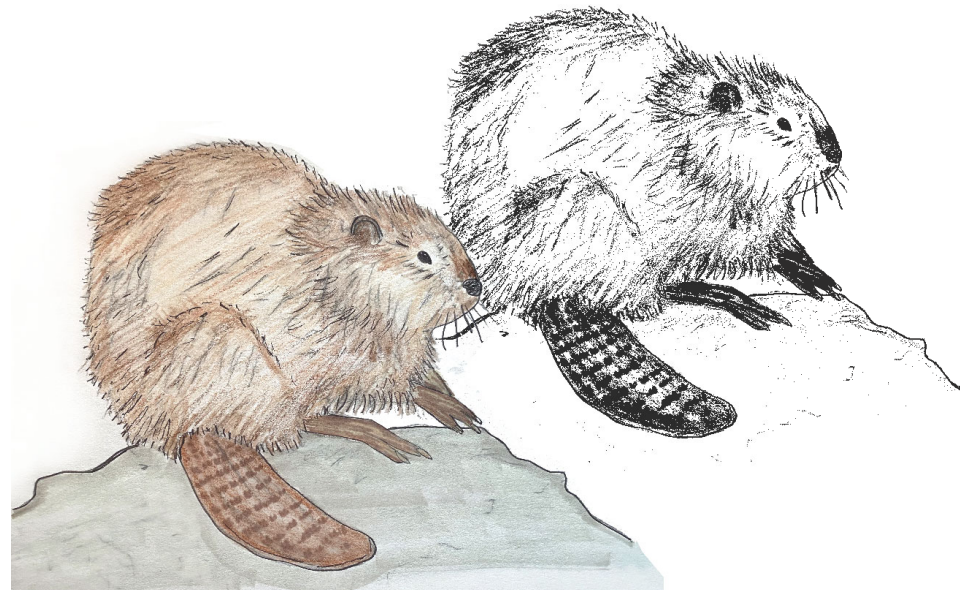
Table 6.1 Estimated Amount of Floodplain Created
This table provides approximate numbers for the total amount of floodplain created at the four sites and the entire Kansas River (Table by author 2021).

Project Limitations

One of the biggest limitations to this report is the lack of time available to conduct the research. The research for this project involves a lot of ecological terminology and need for a basic understanding of natural river function. Going into this project I had little to no knowledge of river function or how to conduct a flood frequency analysis. Another limitation is the ability to combine and synthesize three different and sometimes broad concepts: landscape architecture design, ecological functions of riparian corridors, and stream restoration. This project successfully combines the three disciplines; however, I believe it is important to further the study and integrating of the three fields in addition to any other profession that deals with riparian ecosystems because anthropogenic climate change is rapidly increasing and threatening to further fragment and degrade the ecological services provided by the riparian corridors.

Broader Impacts

This report was meant to provide an example of how landscape architects can aid in the connection between the ecologists, developers, landowners, engineers, and landscape architects. Although there was no community engagement conducted in this project, the community is a valuable resource for riparian corridor and floodplain restoration projects. Restoration projects will rely heavily on the support of advocates and community support to help break down the preconceived notion that the best river is a heavily controlled river. Reconnecting the river to its floodplain can also mean reconnecting people to nature and their rivers. In recent history rivers have been heavily controlled and looked at with disdain, it is my hope that through this project people can see that it is possible to redevelop a relationship with the river and give the river back some control of itself.



American Beaver *Castor canadensis*

The American Beaver is primarily an aquatic animal with a waterproof coat found in rivers and streams. The colonization of beavers within a riparian area can be beneficial to restoration efforts if managed properly; as they can have a negative impact on newly growing woody vegetation (Anderson 2002). (Figure R.1 by author 2021).

Resources

Resources

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Figure 5.1 - Figure by author. 2021.

Figure 5.2-5.71 - Figure by author. 2021. Map base from ArcGIS. 2021.

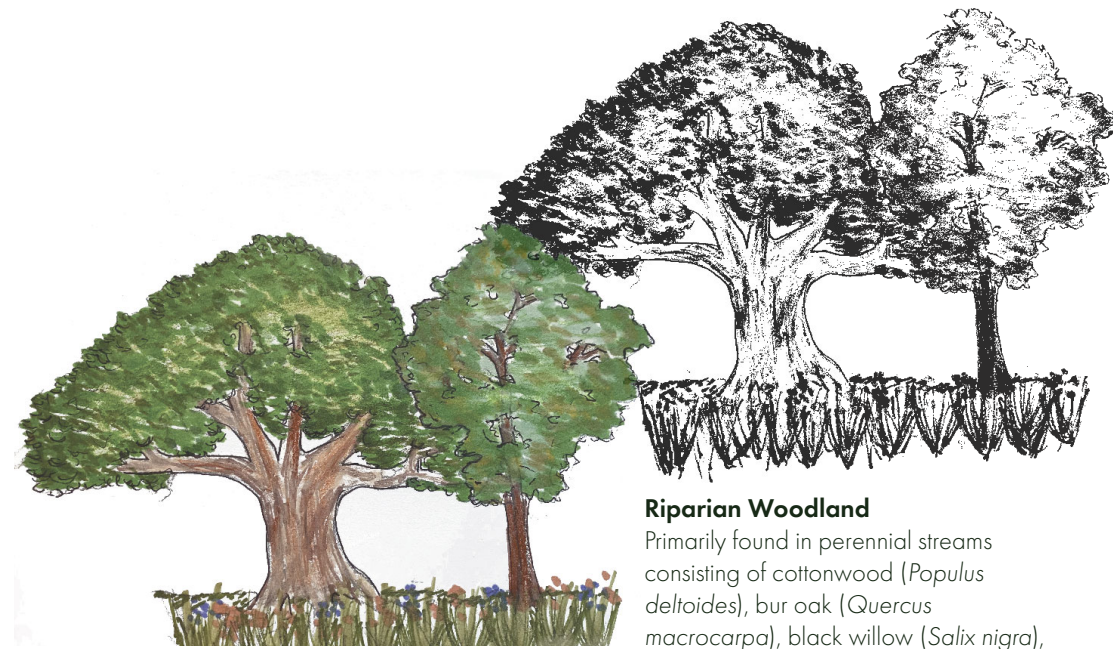
Figure 6.1 - Figure by author. 2021.

Figure R.1 - Figure by author. 2021.

Figure A.1 - Figure by author. 2021.

Figure AA.1-AA.3 - Figure by author. 2021. Map base from ArcGIS. 2021.

Figures AB.1-AB.12 - Figure by author. 2021. Map base from ArcGIS. 2021.



Riparian Woodland

Primarily found in perennial streams consisting of cottonwood (*Populus deltoides*), bur oak (*Quercus macrocarpa*), black willow (*Salix nigra*), or sycamore (*Platanus occidentalis*) trees. (Figure A.1 by author 2021).

Appendices

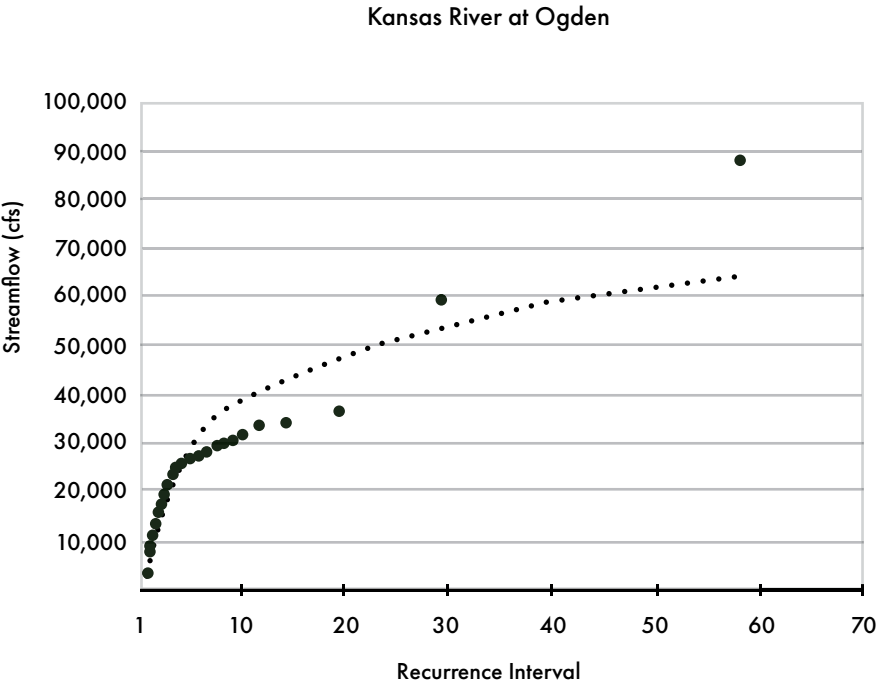
Appendix A

SVAP Version II Results

Kansas River at Ogden, Kansas

Rank	Stream Flow	Recurrence Interval	Probability
1	87,600	58	1.724137931
2	59,400	29	3.448275862
3	36,800	19.33333333	5.172413793
4	34,300	14.5	6.896551724
5	33,100	11.6	8.620689655
6	31,300	9.666666667	10.34482759
7	29,900	8.285714286	12.06896552
8	29,200	7.25	13.79310345
9	28,200	6.444444444	15.51724138
10	27,500	5.8	17.24137931
11	26,800	5.272727273	18.96551724
12	26,500	4.833333333	20.68965517
13	26,400	4.461538462	22.4137931
14	25,900	4.142857143	24.13793103
15	25,700	3.866666667	25.86206897
16	25,700	3.625	27.5862069
17	24,500	3.411764706	29.31034483
18	23,900	3.222222222	31.03448276
19	22,900	3.052631579	32.75862069
20	22,900	2.9	34.48275862
21	22,300	2.761904762	36.20689655
22	22,100	2.636363636	37.93103448
23	22,000	2.52173913	39.65517241
24	21,500	2.416666667	41.37931034
25	19,600	2.32	43.10344828
26	19,300	2.230769231	44.82758621
27	19,300	2.148148148	46.55172414
28	18,000	2.071428571	48.27586207
29	17,700	2	50
30	17,000	1.933333333	51.72413793
31	16,200	1.870967742	53.44827586
32	16,200	1.8125	55.17241379
33	16,000	1.757575758	56.89655172
34	15,800	1.705882353	58.62068966
35	15,100	1.657142857	60.34482759
36	15,000	1.611111111	62.06896552
37	14,700	1.567567568	63.79310345
38	14,400	1.526315789	65.51724138
39	14,300	1.487179487	67.24137931
40	13,200	1.45	68.96551724
41	12,500	1.414634146	70.68965517
42	12,200	1.380952381	72.4137931
43	11,700	1.348837209	74.13793103
44	10,800	1.318181818	75.86206897
45	10,100	1.288888889	77.5862069
46	9,910	1.260869565	79.31034483
47	9,890	1.234042553	81.03448276
48	9,640	1.208333333	82.75862069
49	9,070	1.183673469	84.48275862
50	8,950	1.16	86.20689655
51	8,610	1.137254902	87.93103448
52	7,710	1.115384615	89.65517241
53	7,430	1.094339623	91.37931034
54	7,400	1.074074074	93.10344828
55	3,420	1.054545455	94.82758621
56	2,910	1.035714286	96.55172414
57	2,790	1.01754386	98.27586207

Table AA.1 Stream Flood Frequency Analysis
Finding the 1.5-year recurrence interval involves plotting the peak streamflow data found on the USGS water data website for Kansas (USDA & NRCS 2009).



Logarithmic trendline equation generated by Excel: $y = 14111 \ln(x) + 6428.30$
 y = streamflow (cfs)
 x = any given recurrence interval

$y = 14111 \ln(1.5) + 6428.30$
 $y = 12,149$ cfs for the 1.5-year recurrence flow

Figure AA.1 Finding 1.5-year Recurrence Flow
The recurrence interval was plotted against the streamflow using a logarithmic trendline. Excel generates the trendline equation that is used to solve for 1.5-year recurrence flow (USDA & NRCS 2009).

Kansas River at DeSoto, Kansas

Rank	Stream Flow	Recurrence Interval	Probability
1	170,000.00	47	2.127659574
2	146,000.00	23.5	4.255319149
3	121,000.00	15.66666667	6.382978723
4	120,000.00	11.75	8.510638298
5	104,000.00	9.4	10.63829787
6	103,000.00	7.833333333	12.76595745
7	103,000.00	6.714285714	14.89361702
8	92,900.00	5.875	17.0212766
9	91,800.00	5.222222222	19.14893617
10	90,900.00	4.7	21.27659574
11	80,800.00	4.272727273	23.40425532
12	80,200.00	3.916666667	25.53191489
13	76,800.00	3.615384615	27.65957447
14	76,300.00	3.357142857	29.78723404
15	76,200.00	3.133333333	31.91489362
16	74,100.00	2.9375	34.04255319
17	73,400.00	2.764705882	36.17021277
18	72,400.00	2.611111111	38.29787234
19	71,200.00	2.473684211	40.42553191
20	70,700.00	2.35	42.55319149
21	70,400.00	2.238095238	44.68085106
22	68,700.00	2.136363636	46.80851064
23	64,000.00	2.043478261	48.93617021
24	61,500.00	1.958333333	51.06382979
25	55,500.00	1.88	53.19148936
26	54,900.00	1.807692308	55.31914894
27	52,700.00	1.740740741	57.44680851
28	51,500.00	1.678571429	59.57446809
29	50,700.00	1.620689655	61.70212766
30	49,300.00	1.566666667	63.82978723
31	48,700.00	1.516129032	65.95744681
32	46,800.00	1.46875	68.08510638
33	45,600.00	1.424242424	70.21276596
34	43,300.00	1.382352941	72.34042553
35	39,800.00	1.342857143	74.46808511
36	39,100.00	1.305555556	76.59574468
37	38,600.00	1.27027027	78.72340426
38	33,500.00	1.236842105	80.85106383
39	33,500.00	1.205128205	82.9787234
40	25,900.00	1.175	85.10638298
41	24,800.00	1.146341463	87.23404255
42	21,800.00	1.119047619	89.36170213
43	16,200.00	1.093023256	91.4893617
44	15,800.00	1.068181818	93.61702128
45	15,600.00	1.044444444	95.74468085
46	12,200.00	1.02173913	97.87234043

Table AA.2 Stream Flood Frequency Analysis
Finding the 1.5-year recurrence interval involves plotting the peak streamflow data found on the USGS water data website for Kansas (USDA & NRCS 2009).

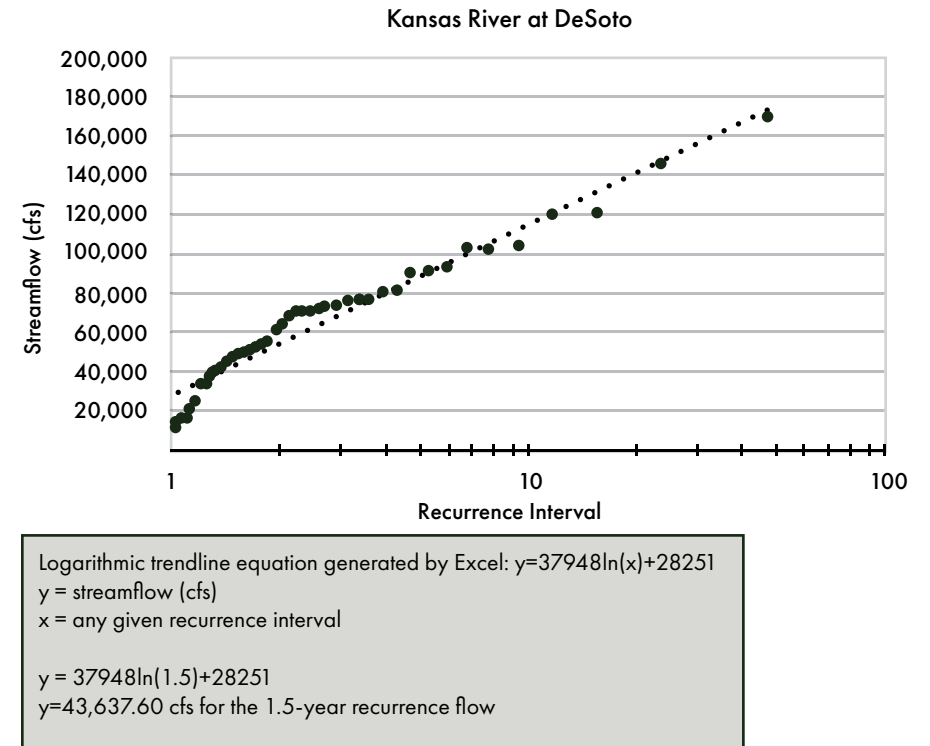


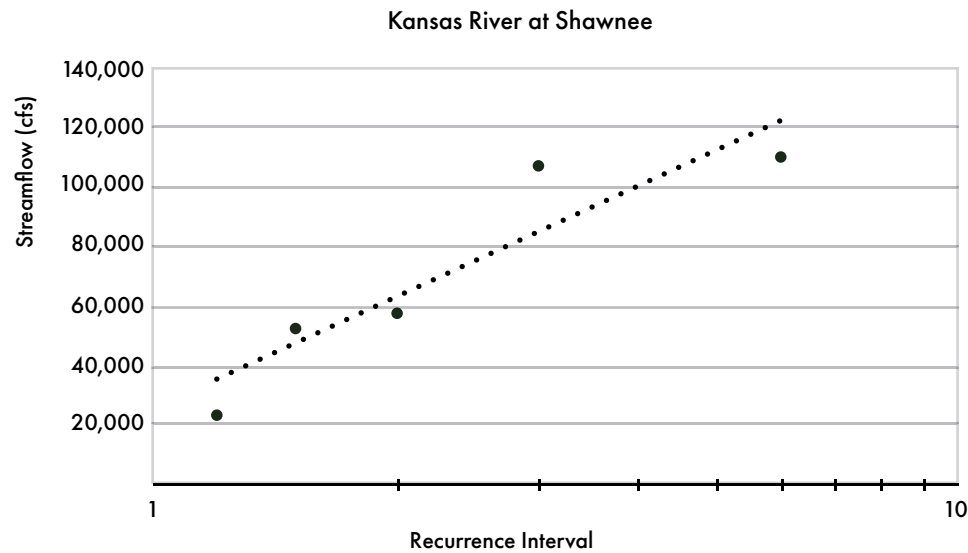
Figure AA.2 Finding 1.5-year Recurrence Flow

The recurrence interval was plotted against the streamflow using a logarithmic trendline. Excel generates the trendline equation that is used to solve for 1.5-year recurrence flow (USDA & NRCS 2009).

Kansas River at Shawnee, Kansas

Rank	Stream Flow	Recurrence Interval	Probability
1	109000	6	16.66666667
2	107000	3	33.33333333
3	57800	2	50
4	52100	1.5	66.66666667
5	22600	1.2	83.33333333

Table AA.3 Stream Flood Frequency Analysis
Finding the 1.5-year recurrence interval involves plotting the peak streamflow data found on the USGS water data website for Kansas (USDA & NRCS 2009).



Logarithmic trendline equation generated by Excel: $y = 54115 \ln(x) + 24554$

y = streamflow (cfs)

x = any given recurrence interval

$y = 54115 \ln(1.5) + 24554$

$y = 46,495.70$ cfs for the 1.5-year recurrence flow

Figure AA.3 Finding 1.5-year Recurrence Flow

The recurrence interval was plotted against the streamflow using a logarithmic trendline. Excel generates the trendline equation that is used to solve for 1.5-year recurrence flow (USDA & NRCS 2009).

Kansas River at Lecompton, Kansas (For Shawnee Comparison)

Rank	Stream Flow	Recurrence Interval	Probability
1	483,000	71.00	1.41
2	190,000	35.50	2.82
3	140,000	23.67	4.23
4	125,000	17.75	5.63
5	123,000	14.20	7.04
6	116,000	11.83	8.45
7	109,000	10.14	9.86
8	96,400	8.88	11.27
9	95,500	7.89	12.68
10	92,900	7.10	14.08
11	90,300	6.45	15.49
12	87,100	5.92	16.90
13	85,800	5.46	18.31
14	84,400	5.07	19.72
15	80,900	4.73	21.13
16	78,300	4.44	22.54
17	78,200	4.18	23.94
18	77,800	3.94	25.35
19	74,500	3.74	26.76
20	73,200	3.55	28.17
21	72,100	3.38	29.58
22	71,800	3.23	30.99
23	71,500	3.09	32.39
24	67,200	2.96	33.80
25	67,200	2.84	35.21
26	66,800	2.73	36.62
27	64,500	2.63	38.03
28	63,600	2.54	39.44
29	63,300	2.45	40.85
30	60,200	2.37	42.25
31	60,100	2.29	43.66
32	59,200	2.22	45.07
33	57,000	2.15	46.48
34	56,300	2.09	47.89
35	56,000	2.03	49.30
36	54,200	1.97	50.70
37	54,200	1.92	52.11
38	48,900	1.87	53.52
39	48,400	1.82	54.93
40	47,200	1.78	56.34
41	46,800	1.73	57.75
42	46,100	1.69	59.15
43	44,900	1.65	60.56
44	44,100	1.61	61.97
45	43,700	1.58	63.38
46	43,400	1.54	64.79
47	42,200	1.51	66.20
48	41,100	1.48	67.61
49	40,700	1.45	69.01
50	40,100	1.42	70.42
51	39,000	1.39	71.83
52	38,600	1.37	73.24
53	37,900	1.34	74.65
54	37,100	1.31	76.06
55	35,200	1.29	77.46
56	35,000	1.27	78.87
57	32,900	1.25	80.28
58	31,900	1.22	81.69
59	27,900	1.20	83.10
60	26,600	1.18	84.51
61	24,700	1.16	85.92
62	19,500	1.15	87.32
63	17,700	1.13	88.73
64	16,800	1.11	90.14
65	16,800	1.09	91.55
66	15,200	1.08	92.96
67	14,800	1.06	94.37
68	14,200	1.04	95.77
69	13,600	1.03	97.18
70	12,600	1.01	98.59

Table AA.4 Stream Flood Frequency Analysis

Finding the 1.5-year recurrence interval involves plotting the peak streamflow data found on the USGS water data website for Kansas (USDA & NRCS 2009).

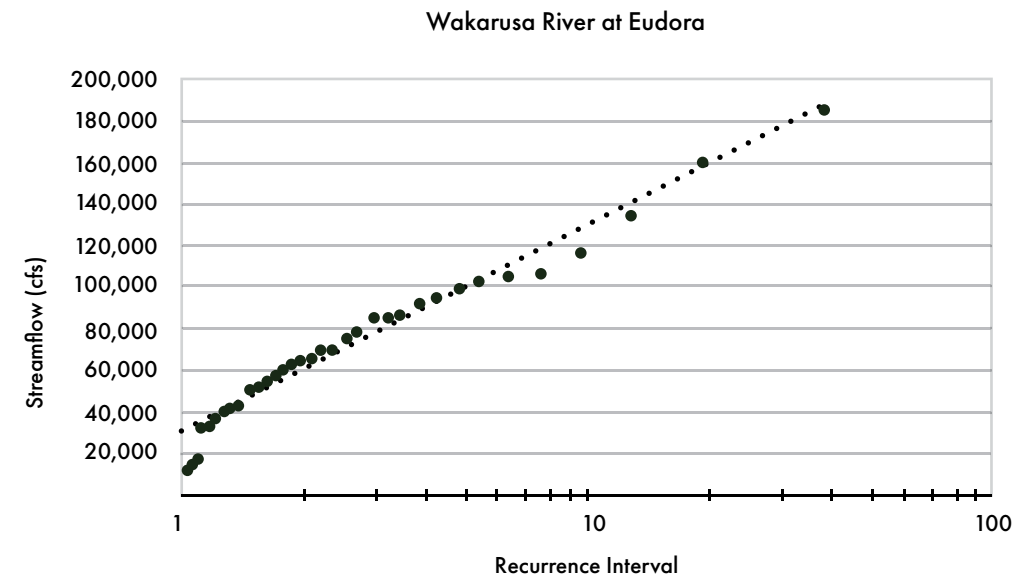
Logarithmic trendline equation generated by Excel:
 $y = 56435 \ln(x) + 9963.50$
 y = streamflow (cfs)
 x = any given recurrence interval

$y = 56435 \ln(1.5) + 9963.50$
 $y = 32,845.90$ cfs for the 1.5-year recurrence flow

Wakarusa River at Eudora, Kansas

Rank	Stream Flow	Recurrence Interval	Probability
1	9230	38	2.631578947
2	8060	19	5.263157895
3	6770	12.66666667	7.894736842
4	5770	9.5	10.52631579
5	5320	7.6	13.15789474
6	5320	6.333333333	15.78947368
7	5170	5.428571429	18.42105263
8	4980	4.75	21.05263158
9	4790	4.222222222	23.68421053
10	4590	3.8	26.31578947
11	4330	3.454545455	28.94736842
12	4250	3.166666667	31.57894737
13	4220	2.923076923	34.21052632
14	3950	2.714285714	36.84210526
15	3750	2.533333333	39.47368421
16	3530	2.375	42.10526316
17	3500	2.235294118	44.73684211
18	3330	2.111111111	47.36842105
19	3240	2	50
20	3190	1.9	52.63157895
21	3110	1.80952381	55.26315789
22	2950	1.727272727	57.89473684
23	2790	1.652173913	60.52631579
24	2700	1.583333333	63.15789474
25	2540	1.52	65.78947368
26	2530	1.461538462	68.42105263
27	2170	1.407407407	71.05263158
28	2140	1.357142857	73.68421053
29	2060	1.310344828	76.31578947
30	2030	1.266666667	78.94736842
31	1900	1.225806452	81.57894737
32	1740	1.1875	84.21052632
33	1650	1.151515152	86.84210526
34	1620	1.117647059	89.47368421
35	845	1.085714286	92.10526316
36	761	1.055555556	94.73684211
37	603	1.027027027	97.36842105

Table AA.5 Stream Flood Frequency Analysis
Finding the 1.5-year recurrence interval involves plotting the peak streamflow data found on the USGS water data website for Kansas (USDA & NRCS 2009).



Logarithmic trendline equation generated by Excel: $y=2179.10\ln(x)+1475.50$
 y = streamflow (cfs)
 x = any given recurrence interval
 $y = 2179.10\ln(1.5)+1475.50$
 $y=2,359.05$ cfs for the 1.5-year recurrence flow

Table AA.4 Finding 1.5-year Recurrence Flow

The recurrence interval was plotted against the streamflow using a logarithmic trendline. Excel generates the trendline equation that is used to solve for 1.5-year recurrence flow (USDA & NRCS 2009).

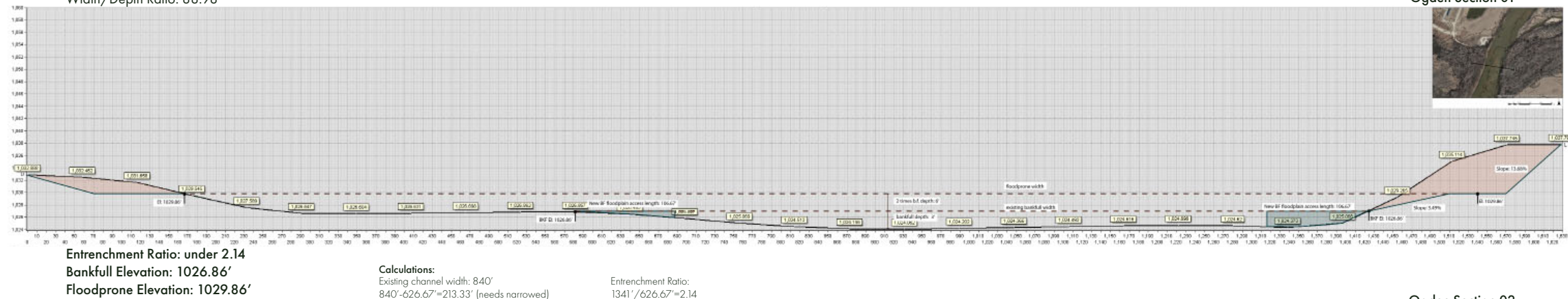
Appendix B

Cross-Sectional Areas Altered Based on Flood
Frequency Analysis

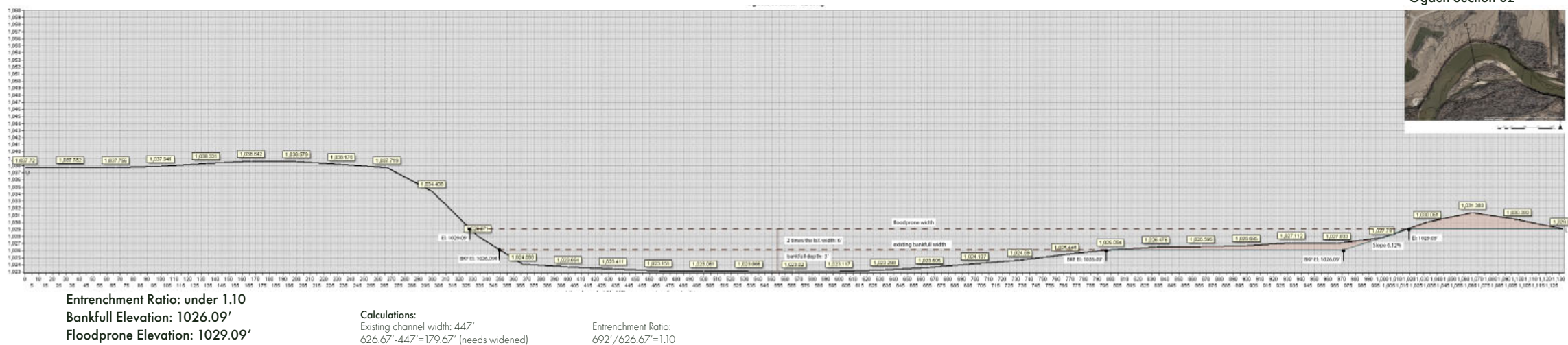
Kansas River at Ogden, Kansas

Numbers for all Ogden sites:
Cross-Sectional Area: 4,413.33'
Bankfull Width: 626.67'
Mean Depth (original): 7.04'
Mean Depth: 3'
Width/Depth Ratio: 88.98

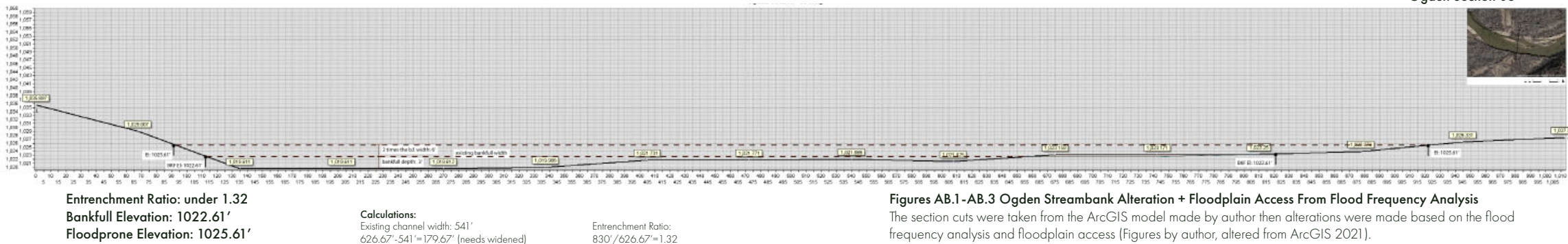
Ogden Section 01



Ogden Section 02



Ogden Section 03

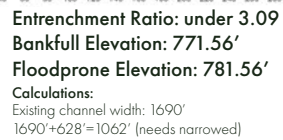


Figures AB.1-AB.3 Ogden Streambank Alteration + Floodplain Access From Flood Frequency Analysis
The section cuts were taken from the ArcGIS model made by author then alterations were made based on the flood frequency analysis and floodplain access (Figures by author, altered from ArcGIS 2021).

Numbers for all DeSoto sites:
 Cross-Sectional Area: 9,200'
 Bankfull Width: 628'
 Mean Depth (original): 14.65'
 Mean Depth: 10'
 Width/Depth Ratio: 42.87

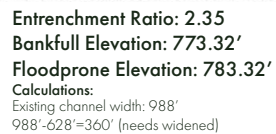
Numbers for all DeSoto sites:
 Cross-Sectional Area: 9,200'
 Bankfull Width: 628'
 Mean Depth (original): 14.65'
 Mean Depth: 10'
 Width/Depth Ratio: 42.87

Figure 1. Aerial photograph of a river bend. A line connects two points on opposite banks, labeled 'U' and 'A'.



Entrenchment Ratio:
1939'/628'=3.09

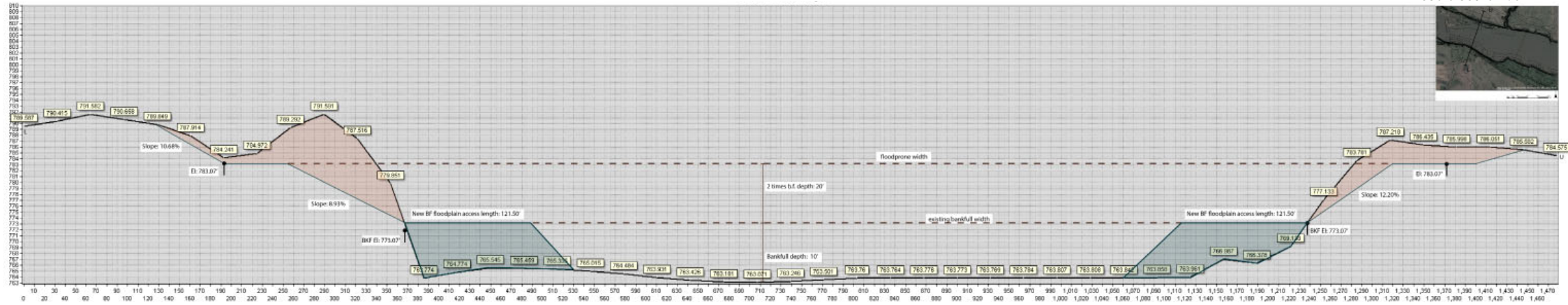
Aerial photograph showing a river bend. A line is drawn across the river bend, labeled 'A' at the right end, indicating the location of the cross-section shown in Figure 1.



Entrenchment Ratio:
 $1478' / 628' = 2.35$

The section cuts were taken from the ArcGIS model made by author then alterations were made based on the flood frequency analysis and floodplain access (Figures by author, altered from ArcGIS 2021).

DeSoto Section 03



Entrenchment Ratio: under 1.32

Bankfull Elevation: 773.07'

Floodprone Elevation: 783.07'

Calculations:
Existing channel width: 988'
626.67'-541'=179.67' (needs widened)

Entrenchment Ratio:
830' / 626.67'=1.32

Figure AB.6 DeSoto Streambank Alteration + Floodplain Access From Flood Frequency Analysis

The section cuts were taken from the ArcGIS model made by author then alterations were made based on the flood frequency analysis and floodplain access (Figures by author, altered from ArcGIS 2021).

Kansas River at Shawnee, Kansas

Numbers for all Shawnee sites:

Cross-Sectional Area: 12,933.33'

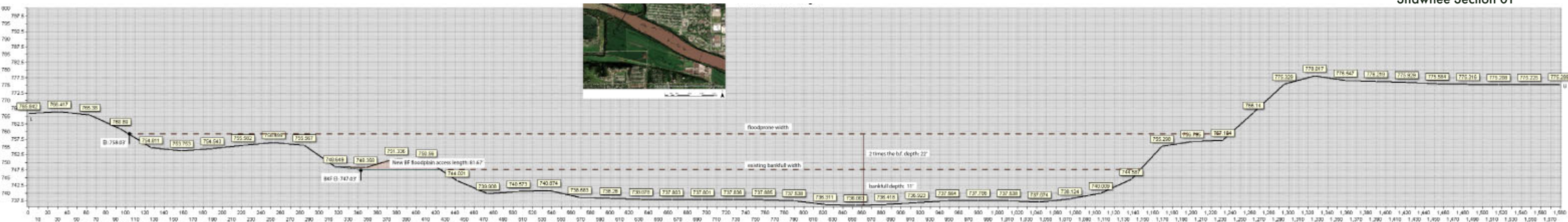
Bankfull Width: 804.67'

Mean Depth (original): 16.07'

Mean Depth: 11'

Width/Depth Ratio: 50.06

Shawnee Section 01



Entrenchment Ratio: 1.41

Bankfull Elevation: 747.03'

Floodprone Elevation: 758.03'

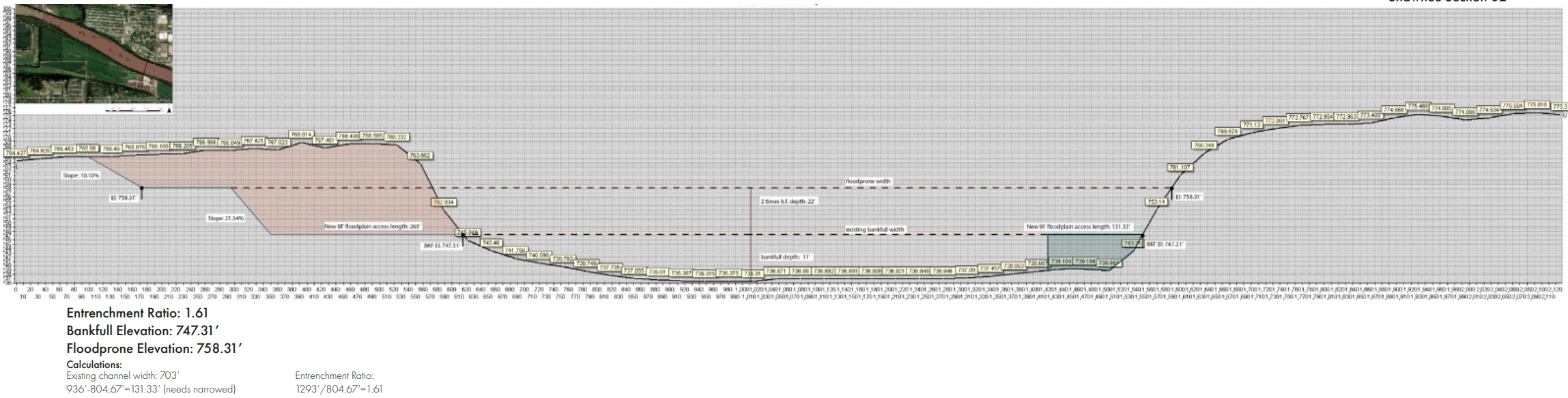
Calculations:
Existing channel width: 703'
804.67'-723'=81.67' (needs widened)

Entrenchment Ratio:
1134' / 804.67'=1.41

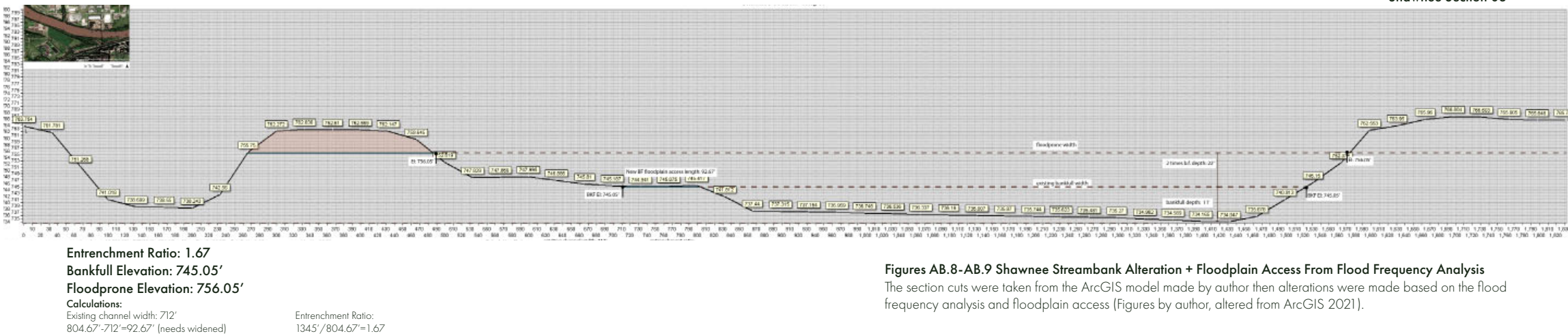
Figure AB.7 Shawnee Streambank Alteration + Floodplain Access From Flood Frequency Analysis

The section cuts were taken from the ArcGIS model made by author then alterations were made based on the flood frequency analysis and floodplain access (Figures by author, altered from ArcGIS 2021).

Shawnee Section 02



Shawnee Section 03

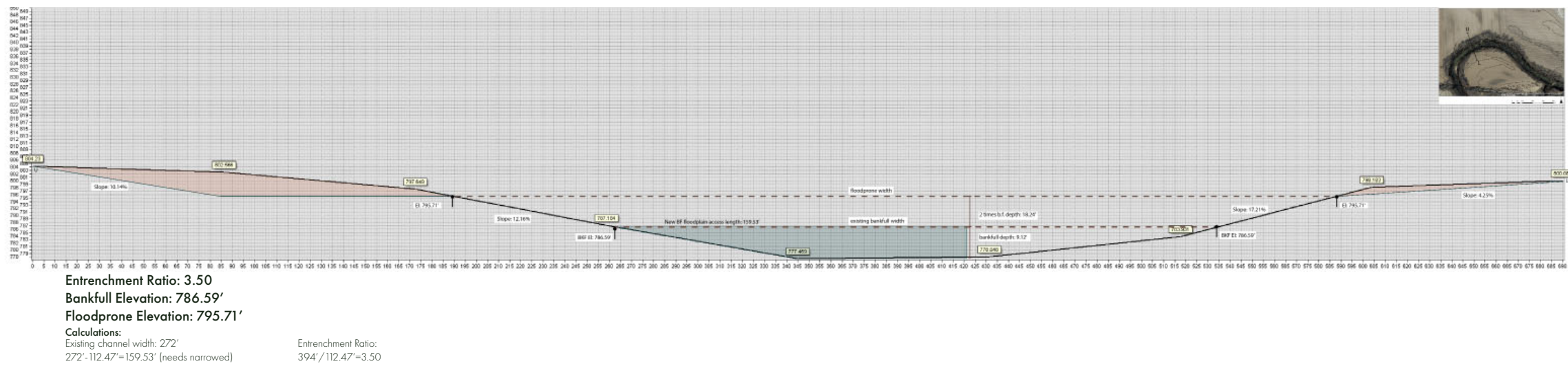


Figures AB.8-AB.9 Shawnee Streambank Alteration + Floodplain Access From Flood Frequency Analysis
 The section cuts were taken from the ArcGIS model made by author then alterations were made based on the flood frequency analysis and floodplain access (Figures by author, altered from ArcGIS 2021).

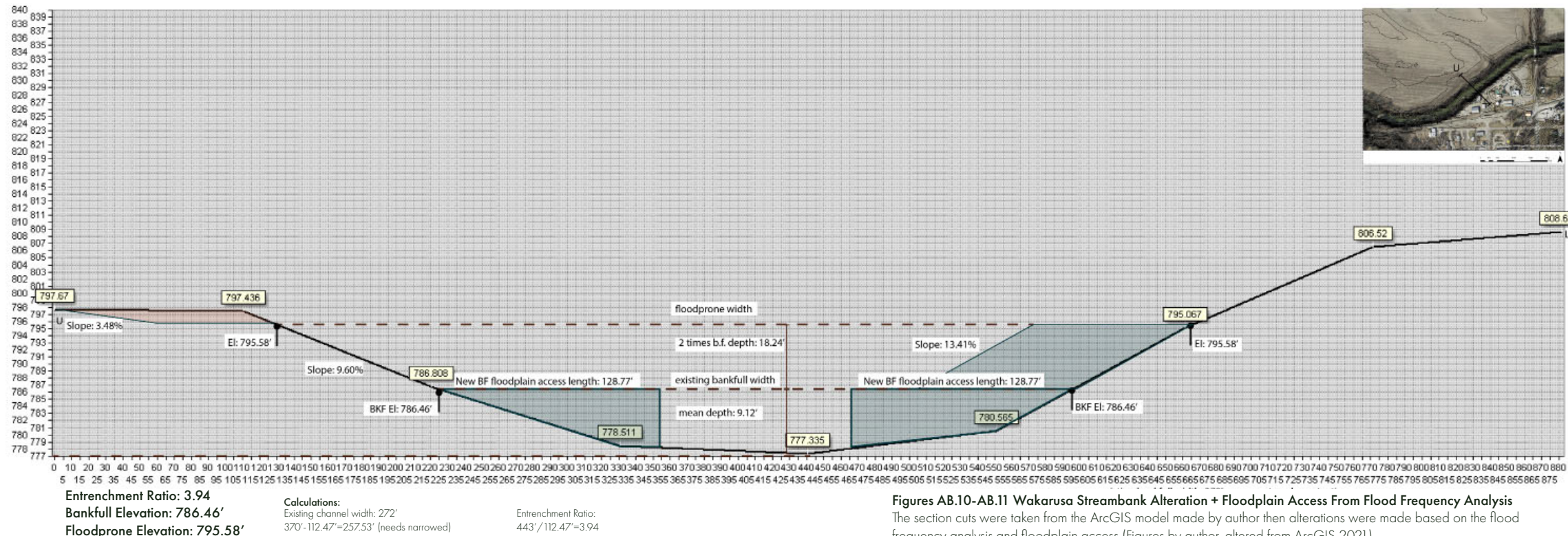
Wakarusa River at Eudora, Kansas

Numbers for all Wakarusa sites:
 Cross-Sectional Area: 1,025.33'
 Bankfull Width: 112.47'
 Mean Depth: 9.12'
 Width/Depth Ratio: 12.34

Wakarusa Section 01



Wakarusa Section 02



Figures AB.10-AB.11 Wakarusa Streambank Alteration + Floodplain Access From Flood Frequency Analysis
 The section cuts were taken from the ArcGIS model made by author then alterations were made based on the flood frequency analysis and floodplain access (Figures by author, altered from ArcGIS 2021).

