THE POTENTIAL FOR RECONNECTION ON THE LOWER ILLINOIS RIVER

by

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Abstract

The purpose of this study is to evaluate leveed floodplains along the La Grange segment (Peoria to La Grange, IL) of the Lower Illinois River (LIR) for their potential in creating both specific and diverse array of floodplain habitats if they were to be hydrologically reconnected. To better understand the potential habitat availability within the levee protect floodplain of the La Grange segment, the Land Capability Potential Index (LCPI) was used. The LCPI uses hydrological, hydrologic, land-surface elevation, and soil data to create an index of potential physical habitat patches which can be applied to assess the suitability of a particular floodplain area for a particular species of interest, such as the threatened Decurrent False Aster, *Boltonia decurrens*. In addition, we used spatial statistics software (FRAGSTATs) to assess reconnected floodplain areas physical-habitat (LPCI patch) heterogeneity and screened floodplain- areas which may provide moist-soil habitats. Most of the *B.decurrens* habitat occurs (>50%) along the southern portion of the La Grange segment within Clear Lake and Beardstown levee districts. Clear Lake and Beardstown levee districts also contain the largest diversity in physical habitat patches. Moist-soil habitat is mostly located in the northern portion of the LaGrange segment with the majority of this habitat type found within the Spring Levee district (31.7 km^2). The levee district with the most potential to enhance important habitat types and physical habitat diversity is the Clear Lake Levee District.

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CHAPTER 1

INTRODUCTION

The Illinois River is considered to be one of North America's most significant river systems. In the late 1800's through the early 1930's privately constructed levees were built to increase farming on the Illinois River floodplain (Lian et al., 2012). Upon the completion of the Chicago Sanitary and Ship Canal in 1900, the Illinois River was connected to Lake Michigan and became the primary means to transport effluent out of Chicago. The water from Lake Michigan and effluent from Chicago substantially increased the river's annual discharge. Then starting in 1930 eight lock and dams (LD) were constructed to maintain a minimum 2.7m navigation channel on the Illinois River between the confluence of the Mississippi River to the Chicago Sanitary and Ship Canal (Collins, 2000). The majority (six) of these LDs have gated concrete gravity dams. The two most downstream LDs on the Illinois River (the La Grange and Peoria LD) possess "wicket dams", which are raised during periods of low flow to increase water height and lowered during high flow to allow the water to pass through relatively unobstructed.

The engineering and management of the Illinois River for the services of flood mitigation, commercial navigation, and effluent disposal have substantially altered the river's natural flood pulse. The flood pulse on the Illinois River used to consist of one large pulse that began in the fall, crested in the spring, and fell in early summer. Summer flows were relatively stable, with only an occasional flood every few years (Sparks et al., 1998). Now floods are larger and occur sporadically throughout the year, nearly eliminating the low stable summer flows which are beneficial to many wetland plants (Sparks et al., 1998; Mettle et al., 2001).

Throughout the early 1900's into the 1950's, factories (point sources) disposed of toxic effluent into the river (Theiling, 1999). These actions not only polluted the river but caused harmful accumulations of toxic substances on the un-leveed portion of the floodplain. The alteration of the flood pulse, discharge regime, and water levels coupled with the toxic substance in effluent from the City of Chicago and elsewhere, resulted in deterioration of the ecological health of Illinois River and its floodplain.

Due to the deterioration of the Illinois River's water quality and ecological health, the US Research Council advised in the late 1980s that the restoration of the Illinois and its floodplain become a national priority (The Nature Conservancy). Recently a push for the conservation and rehabilitation of ecosystem services has caused investments from the public and private sectoes towards the conversion of levee districts into functional floodplains (Sparks et al. 2000). A significant amount of time and money has gone into naturalizing portions of the Illinois River ecosystem (Ahn et al., 2006). One of the many challenges of restoration planning is determining where to rehabilitate and what that area might look like when rehabilitation is completed.

The Illinois River has undergone human induced modification that has isolated the river from large portions of its floodplain. This has resulted in a reduction of the functioning floodplain habitat (Sparks, 2000; Ahn et al., 2004). If large scale floodplain reconnection is to be implemented along the Illinois River as a mechanism to improve its ecological health, levee protected floodplain areas need to be screened to determine where there is the greatest potential for river-floodplain reconnection to meet river management objectives. The Land Capability Potential Index (LCPI) is a regional scale methodology which can help inform managers and decision makers about where a floodplain reconnection may be best suited to meet restoration goals. The LPCI uses hydraulically-modeled water-surface elevations, hi-resolution DEMs for floodplain topography, and soils data to index the relative wetness of floodplain patches which can be used to screen floodplain areas usable for a particular species of interests (e.g., physical floodplain habitats; Jacobson et al., 2011).

Habitat simplification is also an important consideration when determining management actions. Leveeing off large portions of floodplain reduces the diversity of floodplain habitats because once floodwaters come in contact with the levee they increase in depth, eliminating shallow-water habitats critical for the life cycles for many riverine biota (Tockner et al., 2010). Coupling the LCPI base soil and wetness patches with spatial statistics such as the Simpson Diversity Index, the habitat heterogeneity or diversity of physical-floodplain habitats can be assessed. Understanding the potential for habitat diversity can help create a more sustainable riverine ecosystem.

Moist-soil plants grow when mud flats below the tree line are uncovered after the spring floods. They are an important food source for many water fowl, resident beaver (*Castor Canadensis*) and muskrat (*Ondatra zibeticus*). They also help stabilize the shorelines,- decrease turbidity, and can indicate a naturalized flood pulse (Ahn et al., 2006). Changes to the hydrologic regime of the Lower Illinois River (LIR) has reduced the productivity of moist-soil plants (Ahn et al., 2004). Using the LCPI wetness patches and delineated tree line, the location of moist-soil habitat can be assessed.

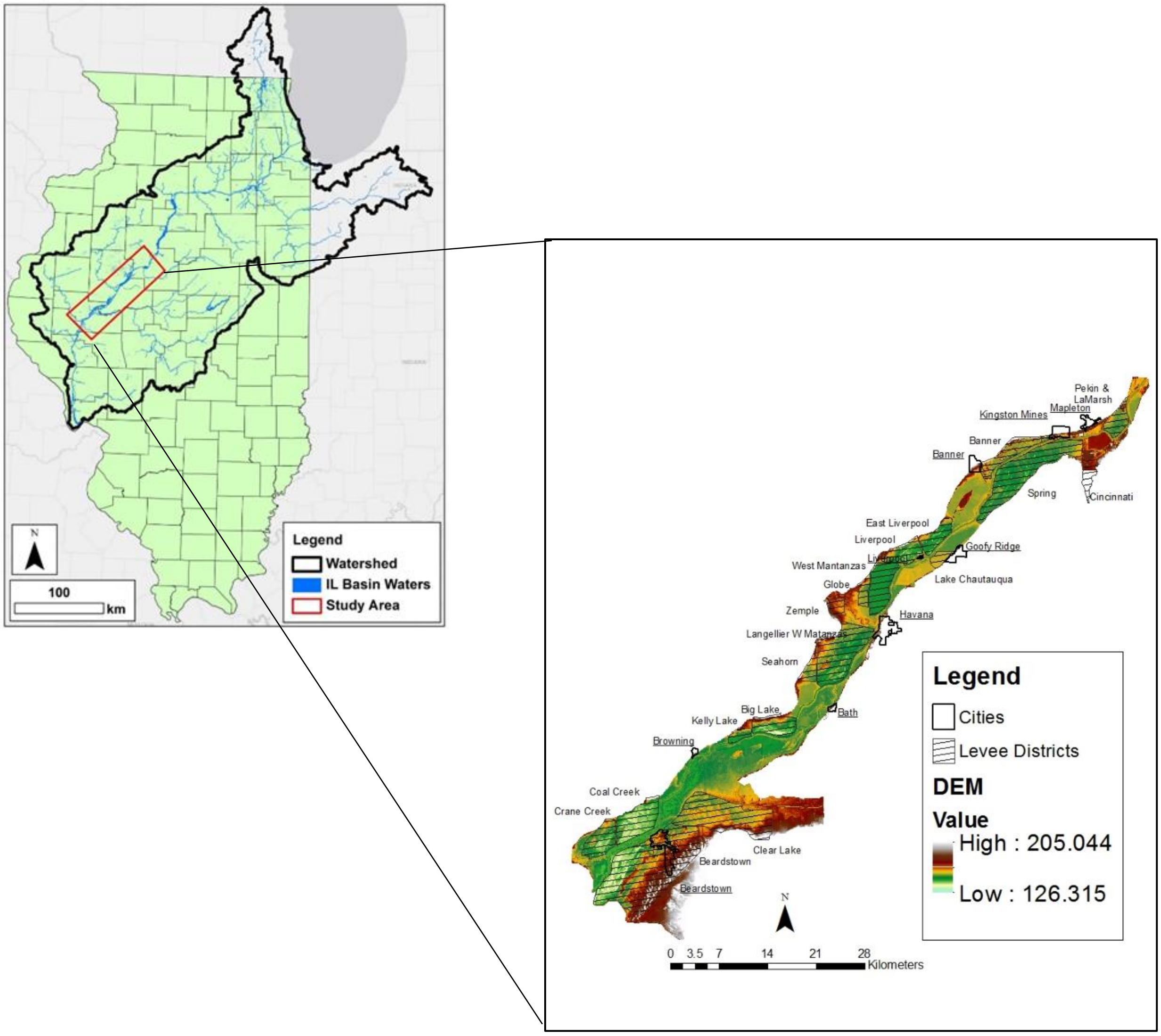


Figure 1.The study area within the Illinois River basin and a detailed map of the La Grange segment.

This thesis focuses on the application of LCPI, the spatial distribution of physical-habitat patches (LCPI patches), and the identification of moist soil habitats to identify, quantify, and assess the diversity of potential floodplain habitats located within currently levee protected floodplain areas along the La Grange segment of the LIR (Figure 1). The purpose of this research is to assess- the aforementioned methodologies for the identification of floodplain areas which have the greatest potential for creating habitat if they were to be hydrologically reconnected to LIR.

CHAPTER 2

LITIERATURE REVIEW

This literature review is broken into five sections: (1) definition and description of floodplains (2) floodplain restoration, (3) moist-soil plants and their associated habitats, (4) *Boltonia decurrens* and its associated habitats, and (5) the Land Capability Potential Index. The floodplain section focuses on the role floodplains play in the river system. Restoration explores the theory of habitat heterogeneity. The moist-soil plants section centers on the potential benefits of this important plant assemblage. The *Boltonia decurrens* discussion highlights the effects of a deteriorated floodplain has on threatened native species.

2.1 Floodplain

Floodplains are areas adjacent to the river channel subject to inundation. They provide services such as flood reduction, minimizing non-point source pollution, and wildlife habitat (De Jager et al., 2012). Floodplains are considered one of the most altered ecosystems due to human activity, despite their importance to not only to numerous species but to people as well (Lake et al. 2007). One of the more serious threats is the simplification of habitats and landscapes (Tockner et al., 2010). By reducing the diversity of the floodplain, the continued existence and sustainability of the ecosystem, including its services is threatened (Tockner et al., 2010).

2.2 Connectivity

Connectivity is the interaction between the river and the floodplain and a key factor for life in these habitats (Poff et al. 2010). The connection between a river and its floodplain is driven by its flood pulse (Junk et al. 1989). The regular inundation of the floodplain influences the nutrient cycle, sediment deposition, and biota (Freeman et al., 2013). Depending on the size of the river, the duration and timing of flood pulses differ. Small rivers and streams have more sporadic and flashier floods, while larger rivers have longer more predictable flooding (Junk et al,. 1989). When the river floods, the velocity of the water decreases allowing for nutrients and sediments to settle out of the water (De Jager et al., 2012). The distribution of the nutrients due to the flood pulse is thought to be like a mosaic, creating different habitats along the entire river (Ward et al., 1998). Due to humans modifying the flows in many rivers, the flood pulses of many hydrologic systems have been altered. These alterations generally include changes to the magnitude, frequency, and duration of floodplain (Galat and Lipkin. 2000).

There are three ways a river connects to the floodplain: longitudinal, lateral, and vertical (Lake et al. 2007). A river and floodplain connection allows the migration of not only nutrients, sediments, and woody debris, but animal and plants as well (Junk et al. 1989; Collins, 2000). Migration is especially important when it comes to wildlife (Junk et al. 1989). Understanding the connectivity between the floodplain and the main channel is helpful when assessing biodiversity and food production (Throp et al., 2010). Many aquatic species are not adapted to living their entire lives within the main channel. The life histories of many riverine organisms require floodplain habitats for spawning, juvenile phase or feeding. Floodplains also provide refugia for a wide variety of organisms during floods (Junk et al., 1989).

For the floodplain habitat to effectively connect to the main channel, floodplain morphologies must allow that inundation (Jacobson et al. 2011). One of these morphologies is the tie channel (Rowland et al., 2009). Tie channels are single thread, bi-directional channels that connect the river to floodplain lakes (Rowland et al., 2005). Many species use these channels to gain access to backwater lakes (Rowland et al., 2005). Side channels are another common feature found within the floodplains which help connect backwater habitats to the main channel. These secondary channels provide feeding and spawning habitat for many riverine fishes. Large-scale flood events help create side channels, and keep the entrances clear to allow passage to aquatic organisms (Barko and Herzog, 2011). Human alterations like river training structures (i.e., wing dikes) and levees have closed off or resulted in the infilling many side channels with sediment resulting in a simplification of the river channel's form (Barko and Herzong, 2011). Sedimentation and subsequent vegetating of side channels can restrict access to these important geomorphic features eliminating habitat for many aquatic organisms (Godaire. 2010; Barko and Herzog, 2011).

The river-floodplain connectivity is not only is beneficial to wildlife, but to people as well. One of the many services rivers and their floodplains provide is nutrient cycling. Excess nitrogen is a concern within the Mississippi River System. The export of nitrogen from the Mississippi River Basin is attributed as the primary driver of the large hypoxic zone located in the northern Gulf of Mexico (National Resource Council [NRC] 2008). Within large rivers, side channels, and floodplain wetlands, substantial denitrification has been documented (Thorp et al. 2010; Strauss et al. 2011). Denitrification is the primary mechanisms for in-stream N loss. When soil becomes anaerobic, microorganisms use N ions (e.g., NO_3- and NO_2-) as microbial electron acceptors producing N_2 which can diffuse into the atmosphere. Soil is the primary ecosystem component in nitrogen removal. As nitrogen-rich water inundates the floodplain, nitrogen is quickly loss within less than six hours after initial inundation of soil (Schramm et al., 2009; Strauss et al., 2011). Some of the flood water is retained by backwater lakes and impoundments. These lentic systems often have low sediment and water column nitrogen concentrations. The anaerobic and organic-rich sediment provides an ideal environment which is ideal for denitrification (Strauss et al., 2011). Epiphytes and macrophytes uptake and assimilation contributes to the reduction of nitrogen (De Jager and Houser, 2012). Backwater habitats in which these plants are found also have longer retention times which allow more nitrogen to be removed from the system. The benefits of the floodplain as nitrogen sinks only occur if there is a river-floodplain connection. If water is confined to the main channel the majority of the denitrification river systems are lost.

2.2.1Biological Importance of Floodplain Connectivity

Floodplains are some of the most diverse ecosystems in the world because flood pulse constantly alters the aquatic and terrestrial habitats (Tockner et al., 2000). The flood pulse is the concept that rivers and floodplains are part of a single dynamic system connected by hydrological and ecological processes (Junk et al., 1989). It is considered to be a major influence on biota and is shown in the dynamic floodplain plant communities. Much like a gradient, the most flood tolerant communities are closest to the river and least flood tolerant are farther away (Junk et al., 1989). The flood tolerant species have special adaptations that allow them to not only survive, but take advantage of the annual floods. One of these adaptations is the aerenehyma, which allows the diffusion of oxygen from areal shoots to maintain growth (Collin, 2000). Another adaptation is the design of seeds and the timing of their dispersal (Junk et al., 1989). Plants take advantage of floods by producing floating seeds during flood events. The seeds are then dispersed to new habitats where competition has been eliminated (Poff et al., 1997). As floods become more infrequent other woody species begin to out-compete the more flood tolerant species (Ahn et al., 2006). This transition zone is called a tree line. A tree line is where the flood pulse is frequent enough to produce the necessary moist-soil for germination, but not so frequent that trees don’t have time to mature before they are drowned. Floodplain trees can survive short periods of inundation as long as the upper branches are not overtopped (Sparks et al., 1998). Smaller annual floods help to maintain the gradient, but floodplain trees can live for decades and overtime begin to encroach upon the flood tolerant plant community during periods of drought (Ahn et al., 2006). It is not until a large disturbance, like a large flood, resets succession that the tree line is pushd back (Sparks et al., 1998).

2.3 Restoration

With a growing world there is a need to balance our desires as people with the requirements of the environment. This is especially true with streams and rivers. There is an increase in the demand for water from streams and rivers for agriculture, industrial, and personal use (Freeman et al. 2012). Humans also altered rivers, not just to divert flow, but to retain water using dams and levees to mitigate inundation from floods. Dams interrupt the longitudinal and lateral connectivity changing the flow of nutrients, sediments and organic matter (Lake et al. 2007). The result of these flow alterations are substantial changes in flood duration, flood magnitude and consequently plant community composition (De Jager et al., 2012). In 1973, the Clean Water Act was passed. Since then our waterways have improved, however, in 2004 the Environmental Protection Agency declared that the waterways are continuing to deteriorate (Palmer et al., 2006). With the increasing awareness of the negative effects human have on river systems, there is a push to restore rivers (Palmer et al., 2004). In general, river restoration aims to restore ecosystem functions to a level that meets ecological and socio-economic goals (Jacobson et al., 2011). Restoration is often not possible and rehabilitation is often difficult. For this reason, the land with the most benefits needs to be identified to insure greatest benefits from the economic and social disruption cost (Sparks and Branden, 2007).

2.3.1 Biological Assessment

One of the key components of restoration is the biological assessment. A biological assessment evaluates the biota of an area including environmental factors that have direct and indirect effects on the temporal and spatial variation of the biota (Stoddard et al., 2006). To understand how humans have affected the environment, there has to be a comparison between current conditions and natural conditions without human interference (Steedman, 1994). The natural conditions used for comparison are called reference conditions (Karr and Chu, 1999). Biological assessments help to understand what aspects of the human environment is causing a negative response in a species. This is to insure that actions undertaken to rehabilitate the environment will address the cause of the decline.

2.3.2 Restoration Theory

There are a variety of ecological theories that can be used to help guide restoration or rehabilitation efforts. One of the most well-known theories is habitat heterogeneity. Habitat heterogeneity posits that the more physically diverse a given area is, the greater the species diversity it will contain (MacArther and MacArther, 1961).

While many studies have shown a correlation between habitat heterogeneity and species diversity, no specific cause(s) or mechanism(s) have been shown to be the cause for this relationship (Freemark et al., 1986; Danielson, 1991; Benton et al., 2003; Báldi, András, 2008). However, several theories have proposed mechanisms for the correlation between habitat heterogeneity and species diversity. For riverine organisms, it has been proposed that a species may live in more than one habitat over its life cycle, and each habitat needs to be restored before the species is able to recover (Lake et al. 2007). By reconnecting the river to its floodplain, riverine habitat diversity can be created or enhanced. These habitats are then used by biota for food supply, spawning, and shelter. The disturbance and refugia theory looks at the relationship between habitat heterogeneity and the requirement for shelter against disturbances. It deals with the requirement for shelter habitat against disturbances (Lake et al. 2007). Disturbances can be from droughts to floods and substantial changes in temperature. When the shelter habitat is eliminated, the species faces an increase in mortality. When there is a reduction in flow, from drought or dams, fish or other aquatic animals are cut off from refugia and are more exposed to predators or extremes temperature (Freeman et al. 2012).

There are studies, however, that question the importance of habitat heterogeneity in restoration projects (Goetz et al., 2007). Increasing habitat heterogeneity may not result in biodiversity because other factors could have a greater influence. Water quality and regional species pool are both factors that can influence biodiversity (Palmer et al, 2010). Water quality is well known for eliminating sensitive species and leaving only the hardiest. On the other hand, if the species pool is limited then not matter how diverse a habitat, biodiversity will be limited.

2.4 Moist-soil Plants

Moist-soil plants are a typically a collection of annual grasses and forbs that grow on mudflats exposed during the summer (Ahn et al. 2006). They are an important part of management for many refuges and private-land projects because they are important food sources for migrating waterfowl, beavers, and muskrats (Strader et al. 2005). Japanese millet (*Echnocloa frumantacea*), Water hemp (Acnida tubercolata), and Nutgrass (Cyperus Strigosus) help to feed over 17 species of waterfowl along the Illinois River System (Ahn et al. 2004). Moist-soil plants also help to keep sediment stable, reducing the turbidity of the water and provide detritus, a major food source for many aquatic animals (Ahn et al. 2006; Hamilton et al., 1992).

In addition to being food for wildlife, it is hypothesized that moist-soil plants could possibly be used as indicators of a naturalized flood pulse (Ahn et al. 2004). This is due to their reliance upon the flood pulse to both expose the mudflats and exclude competition. If a mudflat is inundated during the growing season there is a high chance of the plants drowning. On the other hand, if the mudflats are not flooded enough, then more competitive woody plants species will replace the moist-soil species (Toner and Keddy, 1997; Ahn et al. 2004). To determine where moist-soil habitat is located knowledge of the local hydrologic system and vegetation is critical. Tree line often marks the upper boundary flow reoccurrence of the moist-soil plants, while low flow is considered the lower boundary (Ahn et al. 2004). By determining where those boundaries are, the location of moist-soil habitat can be delineated.

2.5 Boltonis decurrens

A moist-soil plant that is of particular interest is the nationally threatened Decurrent False Aster, *Boltonia decurrens*. The *B.decurrens* was first put on the nationally threatened species list in 1988 (Collin, 2000). Annual surveys of *B.decurrens* population show the substantial fluctuations in population sizes. Years with similar number of survey sites saw populations range from two hundred thousand to 1.6 million individuals (USFWS, 2012). These large changes in *B.decurrens* populations make determining the stability of the population difficult.

B.decurrens is found along the ILR and along a small portion of the Mississippi River near St. Louis (Schwegman and Nyboer, 1985). It is an early successional, moist-soil plant that lives in open areas with abundant sunlight (Collins, 2000). It is found in wet prairies, shallow marshes, and shores of open rivers, creeks, and lakes (Schwegman and Nyboer, 1985). In order to survive it requires regular, natural or man-made, disturbances to expose the seeds to sunlight. The *B.decurrens* is known to grow in a variety of soils; however, it prefers sandy loam soil. *B.decurrens* grown in sandy loam soil had significantly more biomass and inflorescences than *B.decurrens* grown in other soil under the same conditions (Smith et a. 1995; Mettler et al., 2001). Historically, the annual flooding of the Illinois River provided a natural disturbance which helped to maintain populations by creating open areas with substantially less competition (Dewoody et al., 1998; Collins, 2000). Without this disturbance *B.decurrens* would be pushed out in three to five years (Smith et al., 1995). Floods also replenish the soil with nutrients that help *B.decurrens* to compete with other species, assuming other requirements like light and moisture are met (Mettler et al. 2001). The importance of flooding was shown in the aftermath of the 1993 Mississippi flood when Smith et al. (1998) found larger populations in areas that experienced a greater degree of flooding.

The *B.decurrens* can reproduce vegetatively or sexually. A plant produces one or more basal rosettes during the fall that spring those rosettes bolt and bloom (Collins, 2000). Then the next fall the flowers produce copious amounts of achenes. Schwegman and Nyboer (1989) found a single plant can on average produce 50,000 achenes. From the original 50,000 about 40,000 of them will grow into seedlings (Smith and Keevin, 1998). Due to the structure of the achenes, the *B.decurrens* has the ability to travel a long distance, as it is able to float on water for weeks; even though this greatly reduces the vitality of the achenes, the plant can still colonize new places (Smith et al. 1995). In a single population, seeds from 3-5 source populations can be found (Dewoody et al., 1998). A limitation of the achenes is the light requirement. They can only sprout when there is less than 0.2 inches of soil covering the seed.

2.5.1 The Decline of the B.decurrens

The primary reason why the *B.decurrens* is threatened is that levees reduce the frequency of inundation in protected floodplain areas allowing the land to be put into agricultural production and/or reducing the frequency of disturbance that *B.decurrens* needs to survive. The lack of floodplain connectivity also prevents the achenes of the *B.decurrens* from being moved to new places to colonize. Siltation caused by farming buries the achenes so they are unable to grow into new plants (Smith et al., 1995). Building recreation spots also reduces population. Recreation areas also contribute to *B.decurrens* decline by replacing habitat with ramps, docks, and lawns (Collins, 2000).

Another factor in the decline of *B.decurrens* is the timing of floods. While it is considered a flood-tolerant species, it cannot handle being overtopped during the growing period (Collins, 2000). This can occur when Peoria Dam releases water during the summer growing period drowning the *B.decurrens* (Sparks et al., 1998).

2.6 Land Capability Potential Index (LPCI)

The LCPI was developed for the classification of the Lower Missouri River bottom lands to assess floodplain land for habitat conservation potential (Jacobson et al. 2007). The purpose of the LCPI is to provide a coarse index on the different habitats over a large area. This can then be used to dtermine, on a physical level, the capability of the land to support management goals.

LCPI uses land-surface elevation, hydrology, hydrologic, and soil datasets to assess the study area for potential habitat. To estimate wetness, water-surface elevations are intersected with land surface. The water-surface elevations are calculated using a hydraulic model then interpolated across the landscape using GIS. Soil drainage classes are added along with any other relevant data like soil type. The results provide an assessment of a patch of floodplain wetness (i.e. well-drained and frequently flooded) which can be linked to the habitat needs of floodplain plants or other biota Jacobson et al., 2011).

Along the Lower Missouri River Floodplain Jacobson et al., (2011) used LCPI at a regional scale (10s to 1000 km^2) to identify suitable locations for cottonwood (*Populus deltoids*) regeneration. Cottonwood regeneration sites were classified using LPCI as locations with well-drained entisols that flooded every two years. Once located, these sites can be assessed at a finer scale to determine their suitability for cottonwood regeneration.

This study looks to find *B.decurrens* habitat by applying many of the same techniques as Jacobson et al. (2011). Soil and wetness are two important factors in the growth and success of *B.decurrens*. It is hoped this methodology will be helpful in locating areas that have potential to be *B.decurrens* habitat if reconnection is undertaken.

CHAPTER 3

METHODS

The applications of LCPI will be the focus of this thesis, with physical habitat diversity and moist-soil habitat assessment as supplementary tools to assist in rating of floodplain areas for their potential in creating desired habitats. Three methodologies will be used to analsis the floodplain along the La Grange reach of the Illinois River for its reconnection potential. These methodologies are: LCPI based habitat suitability analysis, physical habitat heterogeneity assessment, and moist-soil habitat mapping.

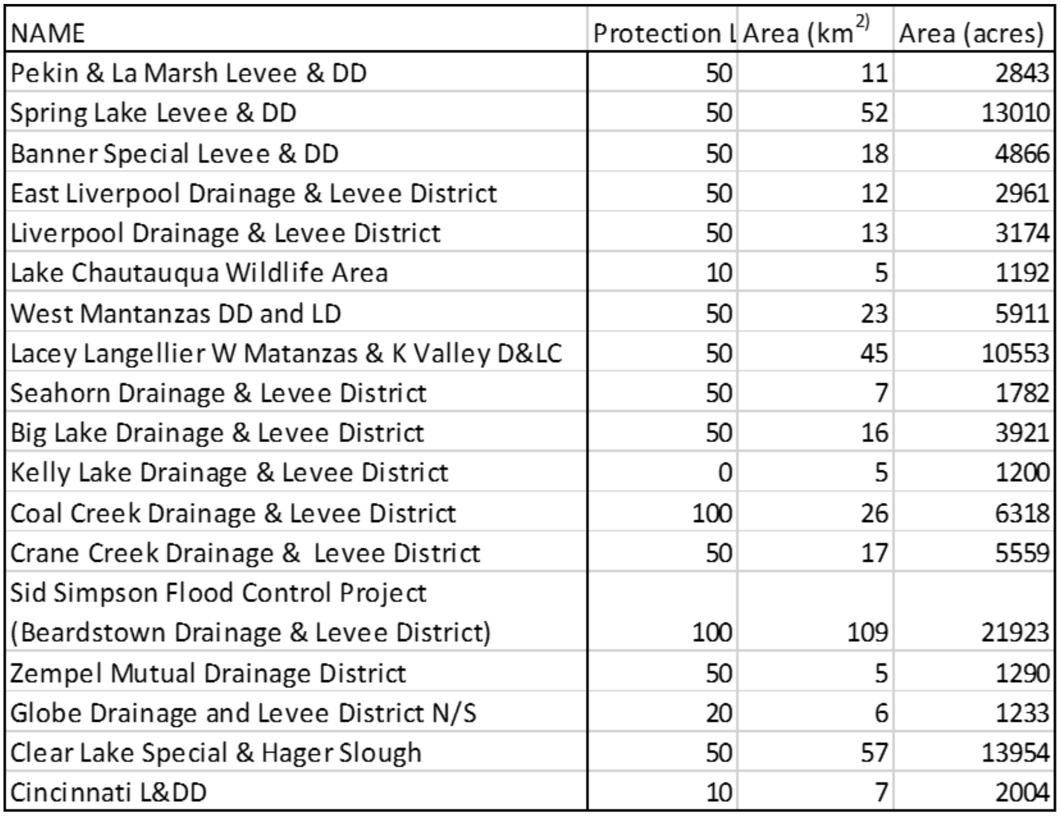
3.1 Study Segment

For this study, I chose to assess the potential for floodplain reconnection along the La Grange segment of the Illinois River. The La Grange segment extends 129 km from the Peoria Lock & Dam located near Peoria, Illinois, to La Grange Lock & Dam located south of Beardstown, Illinois (Figure 1). The La Grange segment was selected because it contains the largest population of *B.decurrens* (USFWS, 2012) and there were high-resolution geospatial data sets and an existing hydraulic model from which to perform the LPCI and related analyses.

The La Grange segment of the Illinois River has been substantially influenced by the Quaternary glaciations. The Mississippi River flowed through this segment of the Lower Illinois River (LIR) valley until about 20,000 years ago when it was redirected by the Shelbyville advance of the Wisconsin ice sheet into its current valley along the Illinois-Missouri border (Knox 2007).

The current Illinois River has a large floodplain with a low gradient which is the remnant of previous glaciation when both the Mississippi and Illinois rivers had larger flows (Talkington, 1991). Due to the low slope and aggradation in the LIR valley during and after the last glacial retreat, many backwater lakes and wetlands were created (Belrose 1979).

Table 1.The levee districts found along the La Grange segment of the Lower Illinois River and the area of floodplain protected by each.



NAME	Protection L	Area (km$^{2)}$	Area (acres)
Pekin & La Marsh Levee & DD	50	11	2843
Spring Lake Levee & DD	50	52	13010
Banner Special Levee & DD	50	18	4866
East Liverpool Drainage & Levee District	50	12	2961
Liverpool Drainage & Levee District	50	13	3174
Lake Chautauqua Wildlife Area	10	5	1192
West Mantanzas DD and LD	50	23	5911
Lacey Langellier W Matanzas & K Valley D&LC	50	45	10553
Seahorn Drainage & Levee District	50	7	1782
Big Lake Drainage & Levee District	50	16	3921
Kelly Lake Drainage & Levee District	0	5	1200
Coal Creek Drainage & Levee District	100	26	6318
Crane Creek Drainage & Levee District	50	17	5559
Sid Simpson Flood Control Project (Beardstown Drainage & Levee District)	100	109	21923
Zempel Mutual Drainage District	50	5	1290
Globe Drainage and Levee District N/S	20	6	1233
Clear Lake Special & Hager Slough	50	57	13954
Cincinnati L&DD	10	7	2004

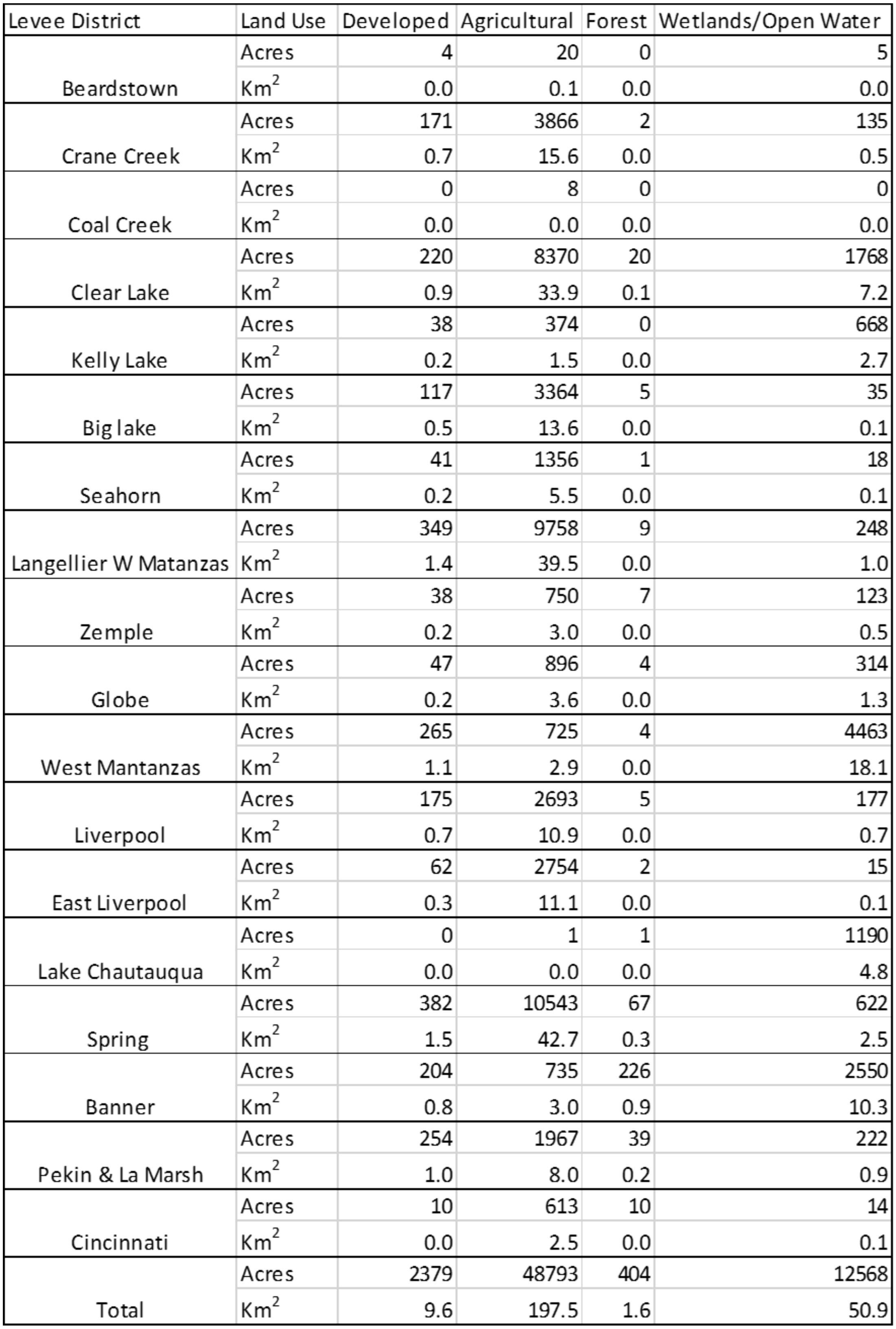
There are 18 levee districts along the La Grange study segment (Table 1). The majority of the lands (76 percent; 197 km^2 out of 259 km^2) along the study segment are levee protected areas that are currently in agriculture production. Outside the levee districts there are 97 km^2 of wetlands, 94 km^2 of floodplain waterbodies and 80 km^2 floodplain forests. The large area of floodplain wetlands and water bodies along this river segment is due to three floodplain preserves: The Chautauqua National Wildlife Refuge, the Nature Conservancy's Emiquon, and Spunky Bottoms Preserves. These preserves and refuges were largely established as environmental preservation sites. However, the majority of these preserves are "protected" by relatively smaller levee systems to shelter the wetland and floodplain waterbodies from unnaturally high flows, high sediment loads, and invasive species (Havena et al. 2003).

3.2 Data and Model Sources

The exceedance probabilities used in this study were calculated by employing historic flow and stage data from three hydrologic monitoring stations: Peoria, Kingston Mine, and La Grange Pool. The hydrologic data from the Peoria and La Grange gages are collected by USACE. At the Kingston Mine gage, discharge measurements are collected by the USGS and water surface elevations (WSELs) are collected by the USACE. The USACE's hydrologic data was compiled from Rivergages.com and the Kingston Mine discharges were compiled from the USGS's National Water Information System (USGS 2015). Topographical data was obtained from a 1 m^2 resolution LiDAR based Digital Elevation Model (DEM) compiled by the Upper Midwest Environmental Science Center (UMESC) of the USGS (http://www.umesc.usgs.gov/rivers/illinois/la_grange/lag_gis_data.html#dem). Soil data was compiled from the Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) (http://websoilsurvey.nrcs.usda.gov/).

An existing 1-D hydraulic model, constructed for the Illinois River Floodway Computation (ILRFC) by USACE Rock Island District, was used to model water-surface elevations. This hydraulic modeling was constructed by the USACEs in HEC-RAS. The cross-sections,

Table 2.Land use within the 18 La Grange levee districts. Agricultural include crops, pasture, and grasslands.



Levee District	Land Use	Developed	Agricultural	Forest	Wetlands/Open Water
Beardstown	Acres	4	20	0	5
	Km^2	0.0	0.1	0.0	0.0
Crane Creek	Acres	171	3866	2	135
	Km^2	0.7	15.6	0.0	0.5
Coal Creek	Acres	0	8	0	0
	Km^2	0.0	0.0	0.0	0.0
Clear Lake	Acres	220	8370	20	1768
	Km^2	0.9	33.9	0.1	7.2
Kelly Lake	Acres	38	374	0	668
	Km^2	0.2	1.5	0.0	2.7
Big lake	Acres	117	3364	5	35
	Km^2	0.5	13.6	0.0	0.1
Seahorn	Acres	41	1356	1	18
	Km^2	0.2	5.5	0.0	0.1
Langellier W Matanzas	Acres	349	9758	9	248
	Km^2	1.4	39.5	0.0	1.0
Zemple	Acres	38	750	7	123
	Km^2	0.2	3.0	0.0	0.5
Globe	Acres	47	896	4	314
	Km^2	0.2	3.6	0.0	1.3
West Mantanzas	Acres	265	725	4	4463
	Km^2	1.1	2.9	0.0	18.1
Liverpool	Acres	175	2693	5	177
	Km^2	0.7	10.9	0.0	0.7
East Liverpool	Acres	62	2754	2	15
	Km^2	0.3	11.1	0.0	0.1
Lake Chautauqua	Acres	0	1	1	1190
	Km^2	0.0	0.0	0.0	4.8
Spring	Acres	382	10543	67	622
	Km^2	1.5	42.7	0.3	2.5
Banner	Acres	204	735	226	2550
	Km^2	0.8	3.0	0.9	10.3
Pekin & La Marsh	Acres	254	1967	39	222
	Km^2	1.0	8.0	0.2	0.9
Cincinnati	Acres	10	613	10	14
	Km^2	0.0	2.5	0.0	0.1
Total	Acres	2379	48793	404	12568
	Km^2	9.6	197.5	1.6	50.9

manning's *n* values, expansion–contraction coefficients, bridges, lateral and in-stream structures, and levee elevations for the hydraulic modeling here were adopted from the ILRFC (USACE 2004b). The discharge and water surface elevation (stage) data required to calibrate and validate the hydraulic model was gathered from three hydrologic monitoring stations identified above.

3.3 Hydraulic Modeling

HEC-RAS is a one-dimensional hydraulic model (i.e. velocity is width and depth averaged) designed to predict the water-surface elevations (WSEL) along a river reach for a given discharge condition. HEC-RAS solves the mass and momentum conservation equations using implicit finite difference approximations and Preissman's second-order scheme (USACE, 2010). The Illinois River Flood Computation Study HEC-RAS model was calibrated to measure WSELs at three hydrologic monitoring stations along the study segment for 2013 (Table 3; Figure 2). This was done by adjusting flow roughness factors (Manning's *n*), until the modeled WSEL closely matched the observed WSELs. Upon completion of the calibration the hydraulic model was validated to observed WSELs at the same hydrologic monitoring stations for 2008. 2013 and 2008 were chosen because they are the top two flood years in the past 20 years.

Table 3. The river mile, agency that operates the hydrologic monitoring station, the type of data available for each river gauge station and the description of how these data were used in this study.

Name	River Mile	Agency	Type	Purpose
Peoria	157.7	USACE	Flow	Flow Exceedance Values
Kingston Mine	145.4	USGS and USACE	Stage and Flow	Flow Exceedance Values and Calibration and Validation
Havana	119.6	USACE	Stage	Calibration and Validation
Beardstown	88.6	USACE	Stage	Calibration and Validation
La Grange Pool	80.2	USGS	Flow	Flow Exceedance Values

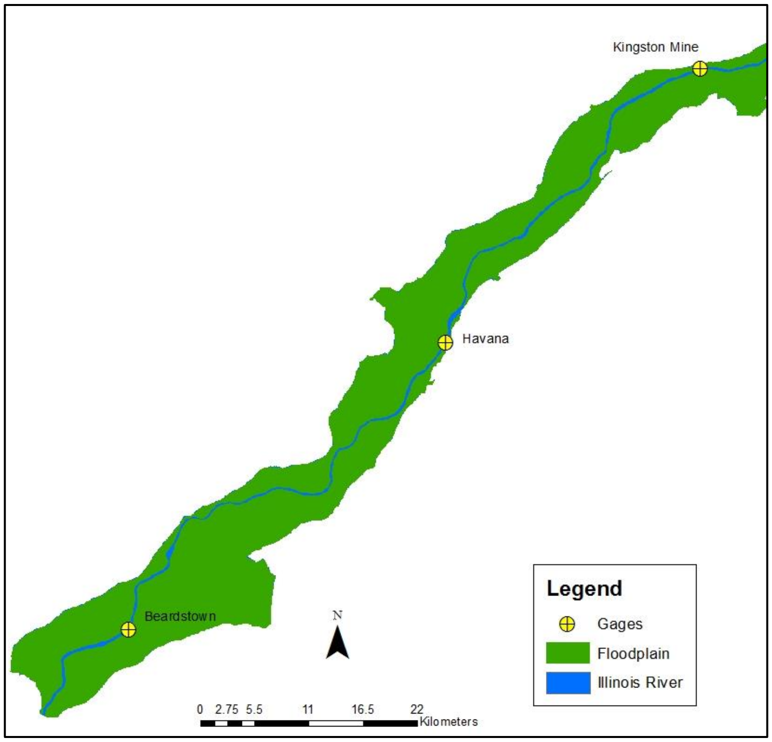


Figure 2 Locations of the three hydrologic monitoring stations, Breadstown, Havana, and Kingstron Mine, used to calibrate and validate the hydraulic model in HEC_RAS.

3.3.1 Flow Exceedance Probability Estimations

This study looked at the WSEL for the 95, 75, 50, 25, 10, 1, 0.5, 0.2, 0.1, 0.02, and 0.01 percent exceedance probabilities. For HEC-RAS to accurately model the correct WSELs, the discharge for each of these exceedance probabilities needed to be calculated. To achieve this discharge data from years 1987 to 2014 was gathered from Peoria, Kingston Mine, and La

Grange Pool. For each station, the discharges were ranked by magnitude with 1 being the largest discharge. Next an exceedance probability was calculated using the following equation:

$$P = 100 \times \frac{M}{n = 1}$$

Where P is the probability that a given discharge will be equaled or exceeded for a given percentage of time, M is the ranked of the discharge and n is the number of events for the period of record.

3.3.2 Scenarios

Two scenarios were modeled. Scenario 1 uses the current configuration of levees along the study segment to predict WSELs. In scenario 2, all levees were removed for full reconnection. These scenarios were chosen to show the current condition and the potential change if all levee floodplain areas where reconnected. The no levees scenario provides insights into which floodplain areas might be best suited for the establishment of habitat of interest or which areas provide the most physical-habitat diversity.

3.4 Hydraulic Modeling and Flood-depth Grid Generation

For the exceedance probabilities of interest, flood depth grids were constructed using the WSEL calculated using the hydraulic model. The vertical datum of the elevation data used in the ILRFC study was the National Geodetic Datum (NGVD) of 1929. Prior to developing the flood-depth grids these water surface elevations were converted to the modern North America Vertical Datum (NAVD) of 1988 to be consistent with the Lidar based DEM. This was accomplished by multiplying the known WSEL used in the model by 0.12 m. All resulting WSEL were then based upon the NAVD of 1988.

Flood-depth grids were created for the LCPI to determine the extent of inundation for different exceedance probabilities. WSELs for each exceedance probability of interest were interpolated between each of the hydraulic model's cross-sections using the Topo-to-Raster Tool in ArcMap. This procedure creates raster map of WSELs for the entire study segment. A WSEL map was constructed for each exceedance probability of interest. Next these WSEL maps were subtracted in ArcMap from the LiDAR based DEM to generate a flood-depth grid (raster map of flood depths).

3.5 Habitat Assessment

Habitat was assessed for the two-connection scenarios (current conditions and without levees) using three approaches: LPCI based habitat suitability analysis, heterogeneity of LCPI wetness classes, and moist-soils. The habitat suitability analysis looked at which levee districts have the appropriate soil-wetness class for *B.decurrens* regeneration. Heterogeneity of wetness classes used to investigate the physical-habitat diversity in each levee district for the full range of exceedance probabilities. Moist-soil assessment evaluated floodplain areas within levee districts with the potential to support moist-soil plants.

3.5.1 Habitat Suitability Assessment

This study looked to find areas suitable for the restoration of *B.decurrens* using the LPCI suitability Areas with sandy loamy or loamy sand soil and with inundation exceedance probabilities of 25% to 0.2% for the no levee scenario were chosen as the soil-wetness class with the greatest potential for *B.decurrens* regeneration. Such areas where identified using rasterized version of the SURRGO soils data layer and an inundation extent maps. Each soil texture type in this raster layer was reclassified to a two digit number that ended in zero starting with 10 for course soils textures grading to 90 for fine grained soils. The value of 100 was reserved for water or urban areas. The reclassified soils layer was then added to a raster layer of the inundation extent for a given flow exceedance which was classified as 0 for no water and 1 for inundated areas. The addition of these two raster layer create a third, new, raster layers in which the values ranged from 10-99. Next, this third raster layer could then be reclassified to indicate areas which were suitable for *B.decurrens* for the exceedance probability assessed. This process was then repeated for each of the exceedance probabilities between 25% and 0.2%. Each of these suitability layers were finally combined to create a suitability map for *B.decurrens.*

3.5.2 Assessment of Physical Habitat Diversity

To measure habitat heterogeneity, Simpson’s diversity index was used. Simpson’s index measures the probability that any two physical-habitats patches selected at random will be different (Simpson, 1949). Physical habitat heterogeneity was calculated for the 95%-0.1% exceedance probabilities. The 0.02% and 0.01% probabilities were excluded from this analysis because the entire floodplain was inundated resulting in not very little change in habitat heterogeneity. To find the heterogeneity of floodplain areas within the levee districts for the exceedance probabilities, the soil raster was added to each individual FDG. A mask was created for each district to separate the LCPI for each district into different files. This was done to understand how heterogeneity changes at each exceedance probability within each levee district. Each file was converted to ASCII format and uploaded into FRAGSTATS, which calculated the Simpson’s diversity index value for each district at all the exceedance probabilities evaluated in this study. FRAGSTATS computes a wide range of landscape metrics like diversity, evenness, and patch richness. Simpson' diversity index was chosen because it less sensitive to changes in rarer physical habitats (Nagendra, 2002). The score was recorded in excel where the average score for each district was calculated from all exceedance probabilities. The Simpson's diversity index was used.

$$\mathrm{SIDI} = 1 - \sum_{i=1}^{m} P_i^2 \tag{2}$$

P-Proportion of individuals for one particular species divided by total number of species and

m-Number of species

3.5.3 Moist-Soil Habitat Assessment

Moist-soil habitat is the area between the tree line and excessive inundation. Excessive inundation was determined to be land that had an exceedance probability >70% (Ahn et al., 2004). Three points of tree-line elevation along the La Grange Segment of the Illinois River were gathered from Ahn et al., (2006). First, these elevations were interpolated across the entire study segment reach to map out the approximate elevation (surface) of the tree line extent. The tree line along the La Grange follows the valley slope and increases in elevation as you follow the river upstream. Starting out at 131.0 m NAVD (1988) at RM 80.35, the tree line increased to 134.50 m (NAVD 1988) at 157.7 RM (Peoria LD). This raster elevation surface was subtracted from the DEM to a layer to estimate floodplain areas below the tree line. Next the FDG for the 75%-flow exceedance probability was used to delineate the absolute lowest elevation for the most soil units. The 50% and 25% exceedance probabilities are included to show the difference in inundation potential for moist-soil habitats. The tree line raster was reclassified into 0 for above tree line and 1for below tree line. This was then added to the 75%, 50%, and 25%

exceedance probabilities which was reclassified into 0 is (no water) and 1 is (water) to create a map of potential moist soil habitats.

3.6 Habitat Model Sensitivity Assessment

Assessing the sensitivity of the habitat models was accomplished by increasing or decreasing the WSEL by 0.2 m and then evaluating the changes in the habitat model predictions. A change of ±0.2 m was chosen because it represents the average error in the hydraulic model's WSEL. Differences in the habitat model predictions were evaluated for low, medium, and high exceedance probability. The flood-depth grid is the exception, because flood-depth grid is the foundation for the habitat models all flood-depth grids created were included in the evaluation on top of the low, medium, and high exceedance probability. The precise exceedance probabilities varied relative to the specific analyses (Table 4).

Table 4. The exceedance values used to assess the sensitive of the flood-depth grids and the high, low, and medium exceedance probabilities used for the habitat suitability and physical habitat heterogeneity.

Habitat Assessment	Exceedance probabilty (%)
Flood-depth Grid	95,25,1,0.1,0.01
Habitat Suitablility	25,1,0.1
Physical Habitat Heterogeneity	95,1,0.1

CHAPTER 4

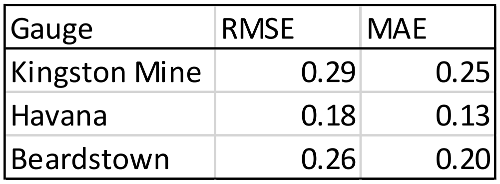
RESULTS

4.1 Hydraulic Modeling Results

4.1.1 Calibration and Validation Results

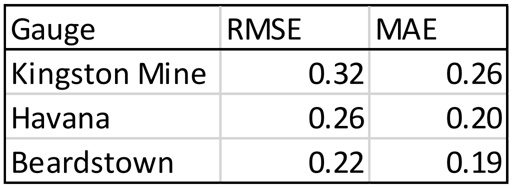
The model was calibrated to the 2013 and validated to the 2008 hydrographs. The flood of 2013 was chosen because it was a record setting flood (~200 year flood at Peoria, IL) for the majority of the La Grange Segment of the LIR. The second largest flood during the last 20 years was in 2008 which had the estimated return period of a 50 year event. The Root Mean Square Error (RMSE) ranged from 0.18 to 0.29 m for the calibration and 0.22 to 0.32 m for the validation (Tables 5, 6).

Table 5. Root-mean square error and the mean absolute error (m) for calibration to observed water-surface elevations from 2013.



Gauge	RMSE	MAE
Kingston Mine	0.29	0.25
Havana	0.18	0.13
Beardstown	0.26	0.20

Table 6. Root-mean square error and the mean absolute error (m) for validation to observed water-surface e from 2008.



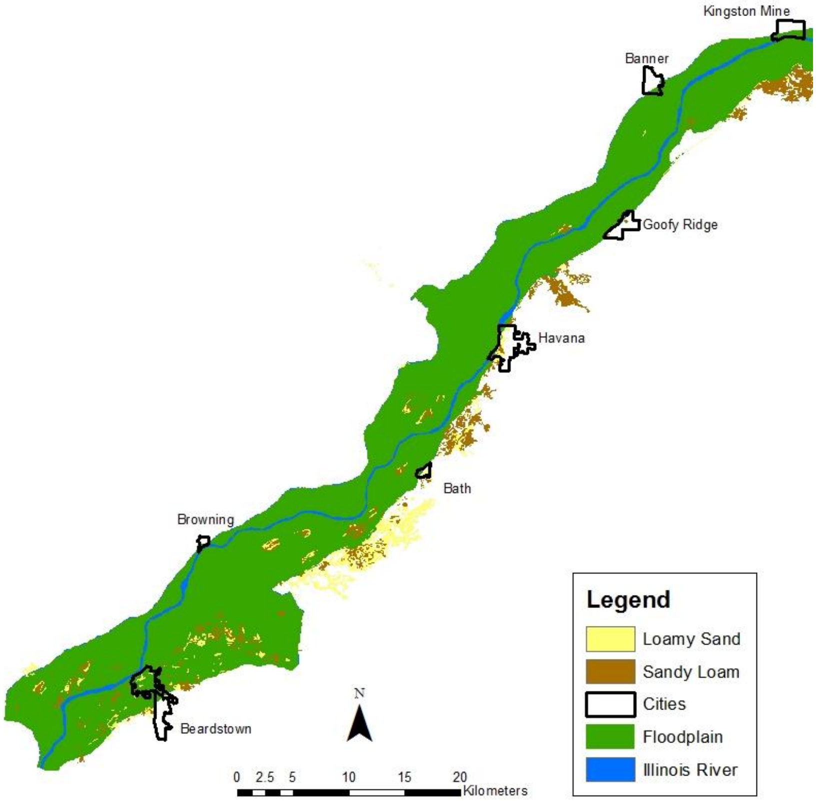
Gauge	RMSE	MAE
Kingston Mine	0.32	0.26
Havana	0.26	0.20
Beardstown	0.22	0.19

4.1.2 Differences in WSELS between the Current and No Levees Scenarios

Flooding along the La Grange segment can be extensive, even at higher exceedance probabilities (Figure 4 and 5). For example at the 25% exceedance probability (a flow that statistically occurs at least 91 days out of the year), over half of the floodplain would be inundated if levees were not present. However, levee removal can lower flood levels. The WSELs for the no levee scenario were 0.21 m lower on average than those for the scenarios with levees (Table 7). The majority of the flood reduction benefit occurs at the smaller exceedance probabilities (i.e., larger floods). For example, flows with the 95% and 75% exceedance probabilities only saw a decrease of approximately 0.1 m while flow with an exceedance probability of 0.01% and 0.02% (50 and 100 year floods) saw average decreases in the water-surface elevation of approximately 0.25 m. RM 157 through RM 154.1 experienced the most reduction in WSEL.

Table 7. The average change in water depth between the levee and no levee scenarios for a given exceedance probability.

Exceedance Proability (%)	Average Change (m)
95	0.00
75	0.01
50	0.04
25	0.18
10	0.36
1	0.25
0.5	0.27
0.2	0.29
0.1	0.29
0.02	0.32
0.01	0.31



4.2 LCPI

Figure 3.The distribution of loamy sand and sandy loam soil along the La Grange segment of the Lower Illinois River.

Since the purpose of this study was to investigate floodplain reconnection potential along this segment of the LIR, the results will focus on the no levees scenario unless otherwise stated. The LCPI divided the study area by soil type and the probability of inundation. This resulted in

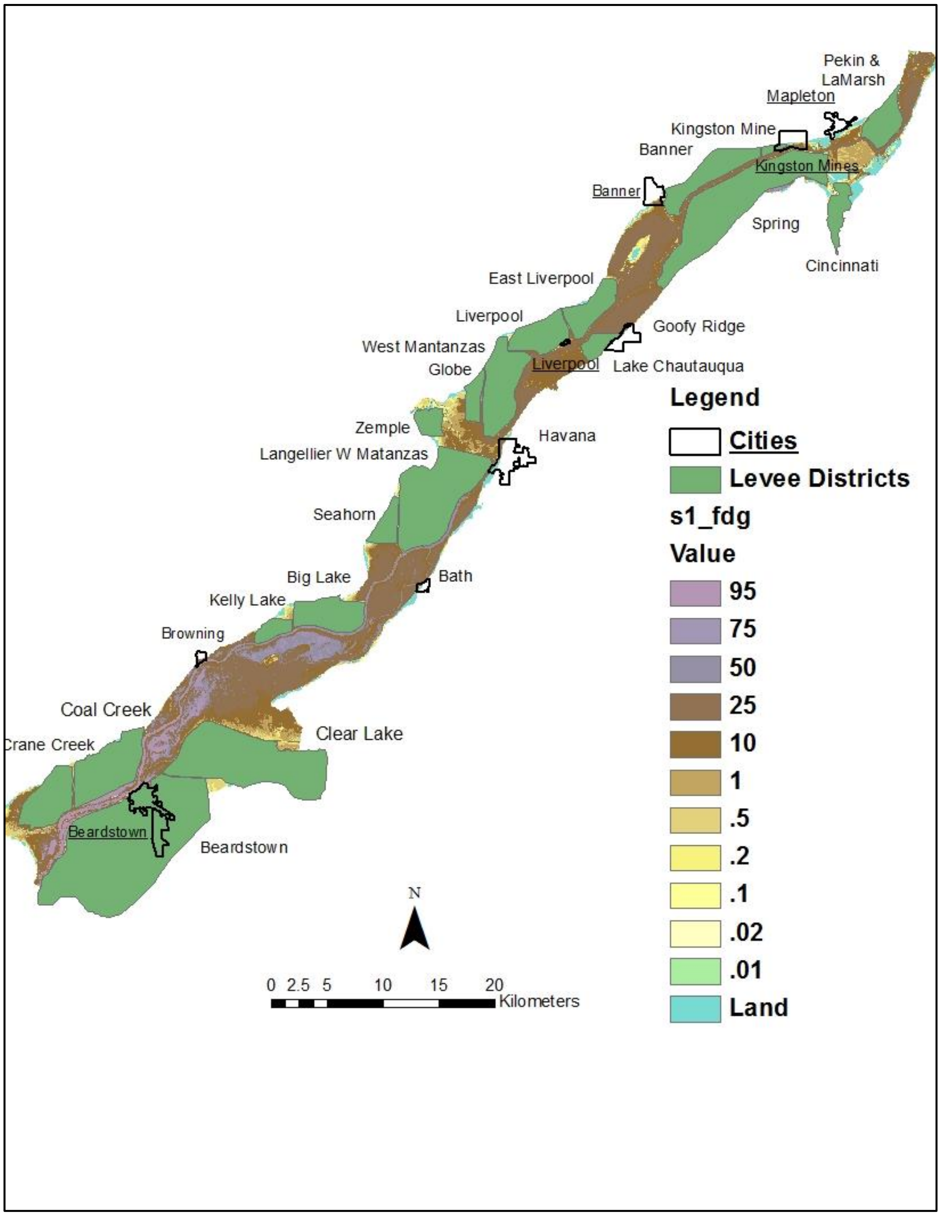


Figure 4. Flood-depth grid for with levees scenario. The flood-depth grids show the extent of flooding for each exceedance probability

99 potential physical-habitat patches.

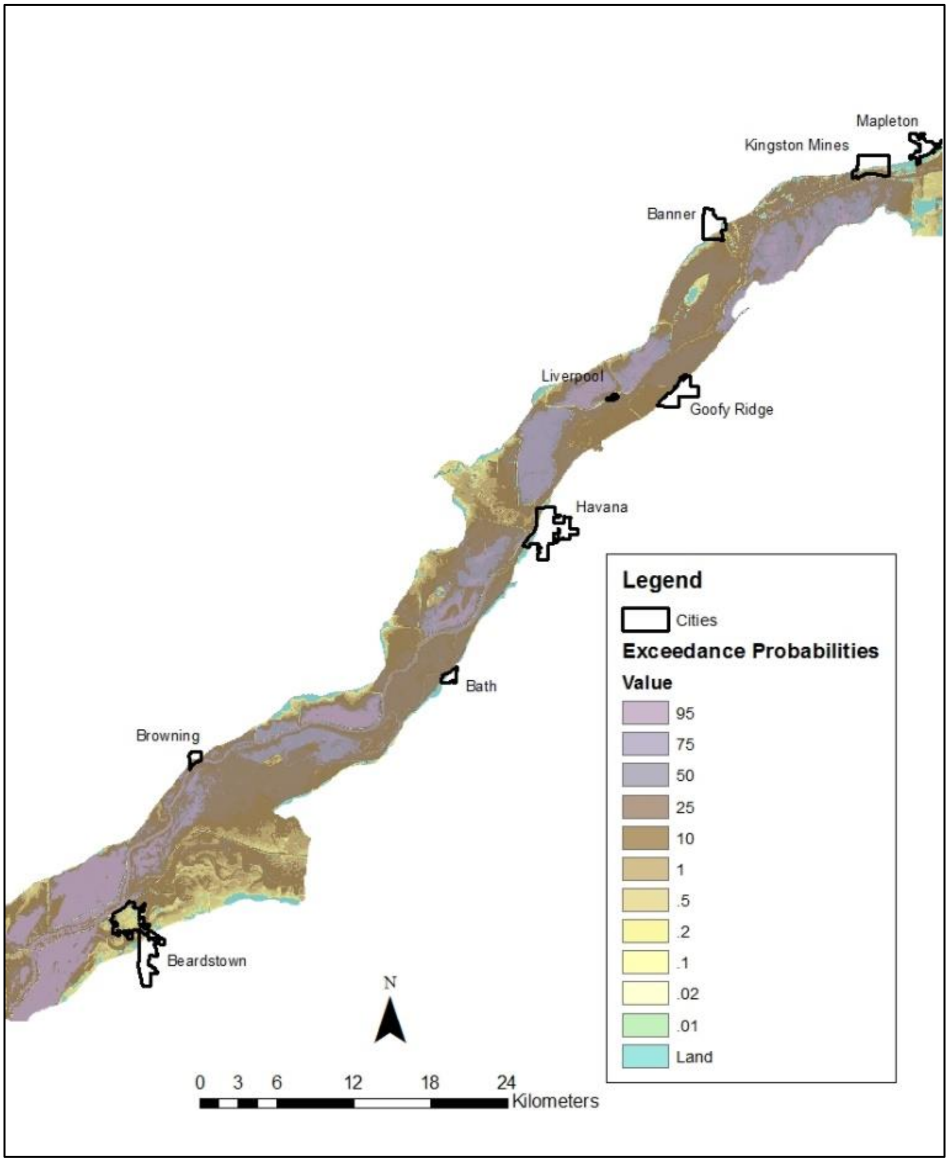


Figure 5. Flood-depth grid for no levees scenario.

The top two physical-habitat patches that encompass the majority of the floodplain within the study segment are silty-clay loam with an inundation exceedance probability of >10% (180.1 km^2) and silty-clay loam with an exceedance probability of > 1% (76.2 km^2). Together these two physical-habitat patches encompass 46% of the total floodplain area.

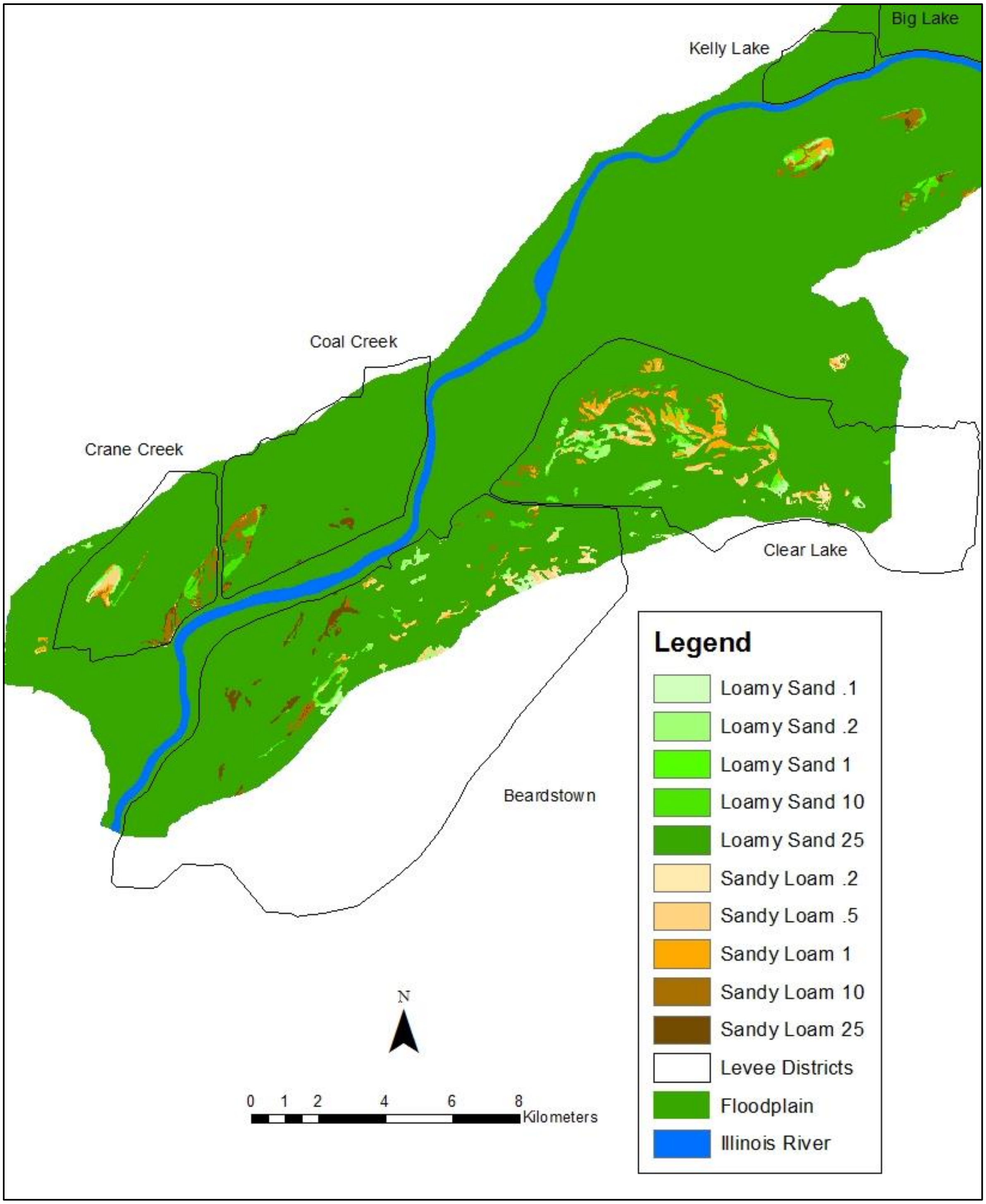


Figure 6. The location of loamy sand and sandy loam with an exceedance probability of 25-.1%, along the lower portion of the La Grange segment.

Table 8. The area of potential *B.decurrens* habitat located in each of the 18 levee districts in the La Grange segment.

Levee District	Area (km^2)
Beardstown	3.90
Crane Creek	1.70
Coal Creek	1.10
Clear Lake	6.40
Kelly Lake	0.00
Big lake	0.00
Seahorn	0.00
Langellier W Matanzas	1.60
Zemple	0.00
Globe	0.00
West Mantanzas	0.00
Liverpool	0.33
East Liverpool	0.00
Lake Chautauqua	0.00
Spring	0.63
Banner	0.00
Pekin & La Marsh	0.05
Cincinnati	0.03
Outside levees	7.90
Total	23.64

The physical-habitat patches which are conducive to *B.decurrens* are sandy loam or loamy sand soils with inundated exceedance probability ranging between 25% and 0.2%. They encompassed approximately 4% (23.6 km^2) of the floodplain within the study area. The two levee districts which have the most suitable areas for the recruitment of *B.decurrens* are Clear Lake and Beardstown Levee Districts with 6.4 km^2 and 3.9 km^2, respectively (Table 8 and Figure. 6). These levee districts contain more than double amount of the sandy loam soil then any of the other 16 levee districts within the study segment. The areas within the Clear Lake Levee District in which the sandy loam soils are found have an inundation exceedance probability of 0.5% or ~every 2 years. In the Beardstown Levee District, sandy loam soils are mostly inundated at 10% exceedance probability and cover 22% (0.86 km^2) of suitable area.

When looking at both scenarios only habitat found outside of the levee districts can be compared. The levee scenario has 6.9 km^2 of the appropriate soil-wetness classes and the no levee scenario has 7.9 km^2 outside of the levee districts. These soil-wetness classes are scattered throughout the reach in small fragments with the exception of a large area located within the Sanganois State Fish and Wildlife Area (Figure 6).

4.3 Physical Habitat Diversity

The levee district with the highest average Simpson's index is Beardstown with an average index value of 0.85. The Clear Lake Levee District has the second highest average Simpson Index with a value of 0.75. The levee district with the lowest average Simpsons Index is Lake Chautauqua with a value of 0.047. Zemple district is second lowest at 0.21. The average Simpson Index value for all the levee districts is 0.5 with a standard deviation of 0.21 (Figure 7; Table 9). When looking at the Simpson Index scores by a particular flow exceedance probability, the values range from a maximum of 0.54 at the 25% exceedance probability to a minimum of 0.04 at the 0.1 exceedance probability. Overall, the Simpson Indexes values generally decrease when flow exceeds or falls below 25% exceedance probability (Figure. 7). There are a few districts that do not follow this pattern. Clear Lake, Zemple, and Liverpool are just a few districts that experience their greatest diversity during other exceedance probabilities. The 0.2 and 0.1 (5 and 10 year floods) are the only probabilities that do not produce maximum diversity in any district.

Table 9. The mean Simpson's diversity index value for each of the 18 levee districts in the La Grange segment.

Levee District	Simpson Score
Beardstown	0.85
Crane Creek	0.71
Coal Creek	0.48
Clear Lake	0.75
Kelly Lake	0.66
Big lake	0.70
Seahorn	0.27
Langellier W Matanzas	0.37
Zemple	0.21
Globe	0.43
West Mantanzas	0.43
Liverpool	0.61
East Liverpool	0.32
Lake Chautauqua	0.05
Spring	0.62
Banner	0.71
Pekin & La Marsh	0.38
Cincinnati	0.42
Average	0.50

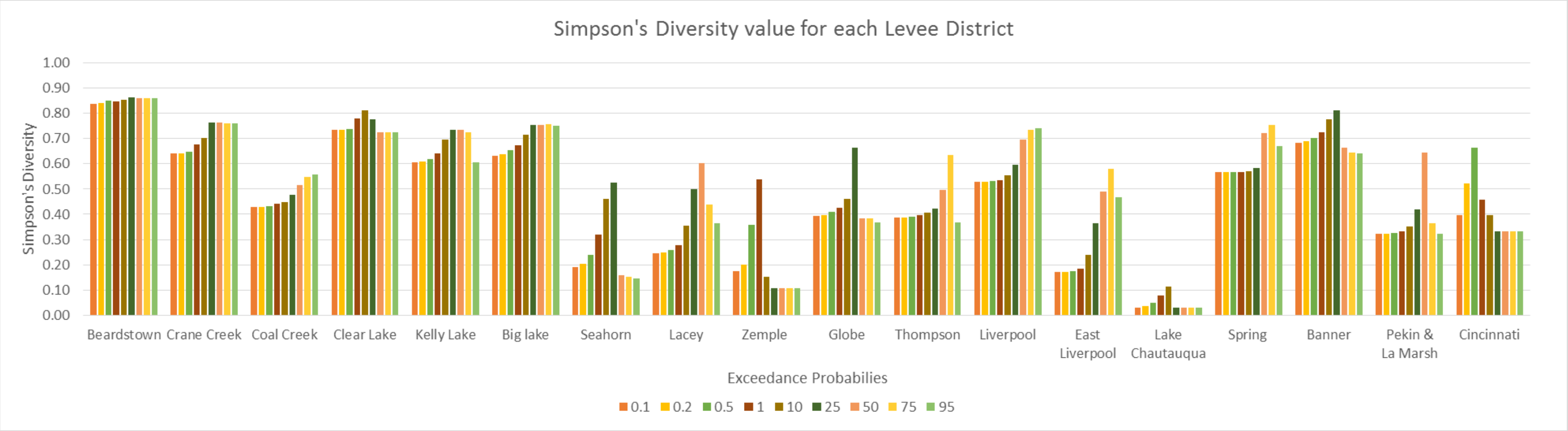


Figure 7. The Simpson's diversity for each levee district at each probability.

4.4 Moist-Soil Assessment

Most of the potential moist-soil habitat occurs in districts north of the Sanganois State Fish and Wildlife Area (Figure 8). Spring Lake Levee District has the largest area (31.7 km^2) with potential moist-soil habitat. The Cincinnati, Lake Chautauqua, and Zemple levee districts have no floodplain areas suitable for moist-soils habitat. On average each district has 4.7 km^2 of floodplain area suitable for moist-soil habitat. Levee districts along the lower stretch of the study segment have very little potential habitat with water reaching the tree-line most of the year (Figure 9).

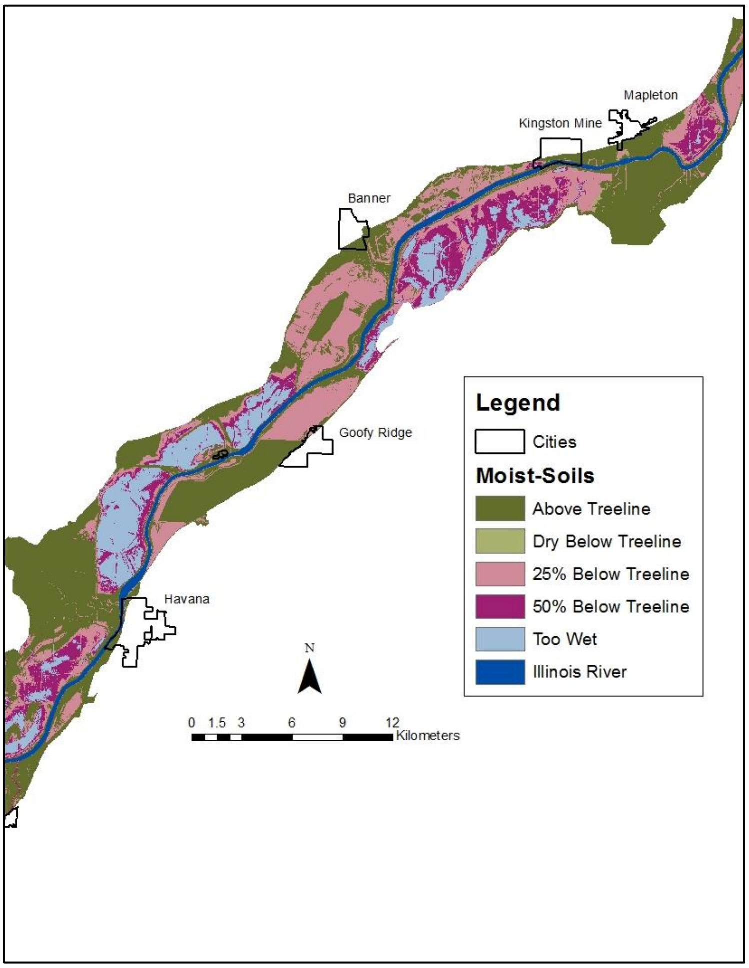


Figure 8. The distribution of potential moist-soil habitat for the no levees scenario.

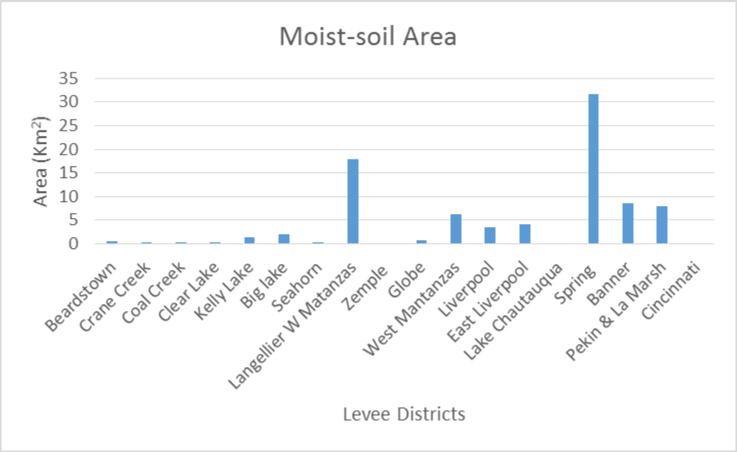
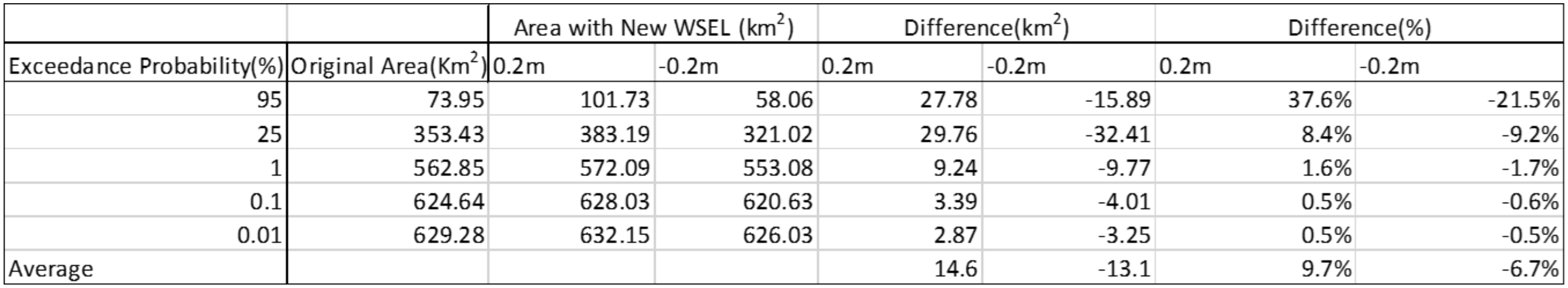


Figure 9. The potential moist-soil habitat broken down by levee districts.

4.5 Sensitivity Assessment Results

The sensitivity of the flood-depth grids changes with flow. Low flows (i.e., 95% exceedance probability) are highly sensitive to changes in WSEL (Table 9). For this exceedance probability, the area of inundation increased by over 30% with an addition of 0.2 m of WSEL. Conversely, larger flows (i.e., flow exceedance probability of 0.01) are less sensitive to 0.2 m change in water surface elevation with only a ~0.5% change in area of inundation. In habitat diversity, many levee districts did not have much sensitivity to WSEL change. Most levee districts that experienced a substantial change in Simpson Value saw on average an increase; only Big Lake District did not (Table 11). West Mantanzas Levee District showed the greatest sensitivity with an average absolute change of 0.05 (Table 12). Lake Chautauqua was the least sensitive only varying an average of 0.001. The overall average change in in the Simpson Diversity Index values was 0.01.



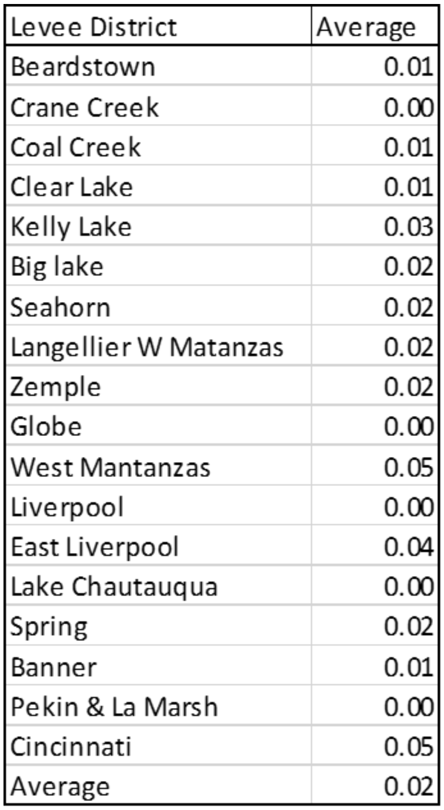
		Area with New WSEL (km^2)		Difference(km^2)		Difference(%)	
Exceedance Probability(%)	Original Area(Km^2)	0.2m	-0.2m	0.2m	-0.2m	0.2m	-0.2m
95	73.95	101.73	58.06	27.78	-15.89	37.6%	-21.5%
25	353.43	383.19	321.02	29.76	-32.41	8.4%	-9.2%
1	562.85	572.09	553.08	9.24	-9.77	1.6%	-1.7%
0.1	624.64	628.03	620.63	3.39	-4.01	0.5%	-0.6%
0.01	629.28	632.15	626.03	2.87	-3.25	0.5%	-0.5%
Average				14.6	-13.1	9.7%	-6.7%

Table10. The difference in area with a change of ± 0.2 m water-surface elevation.

Table 11.The difference and average difference in Simpson value for each levee district at a given exceedance probability when the WSEL has been changed by ± 0.2 m.

Simpson's Diversity Index Sensitivity Analysis							
	Exceedance Probability (%)						
	0.1		1		95		Average
Levee District	0.2m	-0.2m	0.2m	-0.2m	0.2m	-0.2m	
Beardstown	0.00	0.01	0.00	0.00	0.00	0.00	0.010
Crane Creek	0.00	0.00	-0.01	0.01	0.00	0.00	0.00
Coal Creek	0.00	0.00	0.00	0.00	-0.03	0.04	0.00
Clear Lake	0.00	0.00	-0.02	0.02	0.00	0.00	0.00
Kelly Lake	0.00	0.01	-0.01	0.01	0.12	-0.02	0.02
Big lake	-0.05	-0.04	-0.01	0.01	0.00	-0.01	-0.02
Seahorn	0.00	0.02	-0.03	0.03	0.00	0.00	0.00
Langellier W Matanzas	0.00	0.00	-0.01	0.01	0.06	-0.04	0.00
Zemple	0.00	0.04	-0.05	0.01	0.00	0.00	0.00
Globe	0.00	0.01	-0.01	0.01	0.00	0.00	0.00
West Mantanzas	0.00	0.00	0.00	0.00	0.28	-0.01	0.04
Liverpool	0.00	0.00	0.00	0.00	0.00	-0.01	0.00
East Liverpool	0.00	0.00	0.00	0.00	0.10	-0.11	0.00
Lake Chautauqua	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spring	0.00	0.00	0.00	0.00	0.05	-0.04	0.00
Banner	0.00	0.01	-0.01	0.01	0.00	0.00	0.00
Pekin & La Marsh	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Cincinnati	0.01	0.11	0.10	-0.06	0.00	0.00	0.03
Average	0.00	0.01	0.00	0.00	0.04	-0.02	0.01

Table 12. The average absolute change in Simpson value for each levee district under the no levee scenario when the WSEL was changed ± 0.2 m.



Levee District	Average
Beardstown	0.01
Crane Creek	0.00
Coal Creek	0.01
Clear Lake	0.01
Kelly Lake	0.03
Big lake	0.02
Seahorn	0.02
Langellier W Matanzas	0.02
Zemple	0.02
Globe	0.00
West Mantanzas	0.05
Liverpool	0.00
East Liverpool	0.04
Lake Chautauqua	0.00
Spring	0.02
Banner	0.01
Pekin & La Marsh	0.00
Cincinnati	0.05
Average	0.02

CHAPTER 5
DISCUSSION

5.1 LCPI and *B.decurrens* Suitable Habitat Analysis

Using the LCPI approach, this study was able to quantify particular habitat patches along the La Grange segment of the LIR. Two factors that can influence a plant's survival are inundation and soil characteristics. The LCPI methodology divides up the landscape into different habitats based upon these two important factors. Using these pieces of information, a species' preferred habitat could be located. In the case of *B.decurrens*, the preferred habitat is sandy-loam and loamy-sand soils that are inundated 25% to 0.1% of the time (Smith et al., 1995; Mettler et al., 2001). This type of habitat was mostly found south of the Sanganois State Fish and Wildlife Area (20.9 km^2). Two levee districts, Clear Lake and Beardstown, were determined to have the most potential habitat for the *B.decurrens*. Clear Lake District has the greatest amount of potential habitat with 6.4 km^2. Beardstown District is second with 3.9 km^2 of potential habitat. Where these districts differ is the size and distribution of these habitats. The high exceedance probabilities are relatively spread out in Clear Lake District, but they mostly occur in the lower portion of Beardstown District. This clustering in the Beardstown District is attributed to elevated WSELs created by the La Grange Lock and Dam. This is clearly seen in Crane Creek District, which is directly across the river. There is a clear distinction between the locations of the habitats with a high or low exceedance probability. Clear Lake District and Crane Creek both have large continuous patches of suitable habitat. The largest continuous patch is approximately 1.4 km^2 compared to Beardstown District's largest patch which is approximately

0.7 km^2. Larger patches are generally preferred in restoration efforts because larger habitat areas can support a greater number individuals to help sustain the population (Robinson et al., 1992).

5.1.1Limitations of LCPI

One of the biggest limitations of using the LCPI to estimate the rehabilitation potential of floodplain lands is its focus on one species. Rehabilitations that only seeks to restore a single species generally fail. There are complicated inter-species relationships between a given organisms and its surrounding community that are ignored and prompt failure as a result. A healthy community often supports a species by fulfilling needs that are less apparent (Kauffman et al., 1997). Another limitation is the requirement for a certain amount of knowledge. Accurate soil and inundation preferences for the target species are necessary for the application of this approach.

5.1.2 Potential in Assessing Floodplain Habitat

Significant amounts of time and energy go into protecting and rehabilitating endangered and threatened species. Finding a location that would give a plant the best chance at survival is important. The LCPI is useful in taking a large area and reducing it to a smaller area that is suited to the *B.decurrens*. By identifying Clear Lake and Beardstown as the districts with the most habitats, research can be focused on those area instead of the entire segment. This includes understanding how habitat will change under different scenarios. The hydraulic modeling method can be used to predict flood height under a variety of conditions. Using the WSELs allows for the assessment of certain actions, such as levee removal or setback. This would affect the availability of habitat, which is significant when attempting to protect or enhance habitats for threatened and endangered floodplain species.

5.2 LCPI and Physical Habitat Heterogeneity

Floodplain soils and inundation frequency can play a role in species composition. Areas with a large variation in soil characteristics and inundation could potentially support a greater diversity of plant species. Having a variety of habitat could allow for more animals to benefit from reconnection by providing not just food or refuge, but spawning habitat as well. To assess the spatial diversity in these physical floodplain characteristics, FRAGSTATS was employed, which is a software program programed for spatial statistics such as ecologically relevant metrics like the Simpson Diversity Index. In this study, the Simpson Diversity Index estimation tool in FRAGSTATS was used to assess physical-habitat-heterogeneity between LPCI based on wetness patches within the La Grange reach's levee districts.

Physical habitat heterogeneity along the LIR floodplain is greatest when there is a mix of dry and inundated habitat. Throughout the study segment this occurs most often at the 25% exceedance probability. In general, physical habitat diversity is relatively low in many levee districts: Lake Chautauqua, Seahorn, and East Liverpool districts. This can be attributed to the low-slope of the floodplain and the elevated discharges related to the redirection of flow from the city of Chicago and elsewhere, which have augmented Illinois River discharges. Greater areas of habitat diversity along the study segments tend to be in areas with relatively more topographic relief. These areas are generally found toward the southern end of the La Grange segment and contain fluvial landforms such as terraces and tributary fans. Other areas contain relict Pleistocene aeolian, and glacio-fluvial landforms which increase the topographic relief in areas like Banner and Clear Lake Districts. Most districts experience a clear peak in physical habitat diversity at a certain exceedance probability. The few districts that do not are located near the La Grange Lock and Dam like Beardstown and Crane Creek Levee Districts. At what exceedance probability this peak occurs can depend on a variety of factors like diversity in soil, elevation, and distance from river. Districts that are set farther back from the river tend to experience their greatest diversity at higher exceedance probabilities. Cincinnati and Zemple are both setback from the river and have the greatest diversity at 0.5% and 1% respectively.

5.2.1 Limitations of Physical Habitat Diversity

A limitation in using physical habitat heterogeneity to determine habitat potential is that it does not consider other limitations that limit the establishment or recovery of floodplain biota. One of the factors that may limit the recovery of floodplain biota is the alteration to the time of the natural flood pulse. Hydrologic alternations have changed the predictable flooding and drying cycle along the LIR and replaced it with a more erratic flooding throughout the year (Sparks, 1998). Some floodplain biota may be particularly sensitive to the temporal alteration in the flood pulse and creating floodplain diversity may not help floodplain organisms to recover (Ahn et al., 2006)

5.3 Moist-Soil Assessment

Moist-soils are an important assemblage of plants that help stabilize banks and provide food for many aquatic fowl (Strader, 2005). Plants rely heavily upon the annual flood pulse to moist soils in order to reduce competition from woody species. Moist-soil habitats occur where there is enough inundation to exclude trees, but not so much that survival of the moist soil plant is not possible. Spring and Langellier Districts have the most potential moist-soil habitat. Both of the districts are located north of the Sanganois State Fish and Wildlife Area. This is due to higher variability in WSELs for the 25% to 50% percent exceedance probabilities. With more area between the tree line and the river, there is a greater opportunity for moist-soil habitat to occur. A lower WSEL helps to increase habitat by reducing the probability that the river will inundate the moist-soil habitat at inopportune time. The southern most districts have little to almost no most-soil habitats because the navigation dam keeps WSELs elevated to near the tree line which limits the potential for moist soils plants to establish and thrive to create a suitable environment.

5.3.1 Limitation Moist-Soil.

Long-term changes in the carrying capacity of the LIR can impact the position of the tree line. Tree lines are not static, but fluctuate with changes in river hydraulics and decadal changes in flow frequencies. The data used from Ahn et al. (2006) was gathered from aerial photographs and topographic maps. Depending on when the pictures were taken or maps created, the LIR could have experienced changes in its flow carrying capacity. This could potentially allow a new tree line to form, changing the amount of moist-soil habitat a district would create (Ahn et al., 2006). Hydraulic alterations not only affect the tree line, but also whether or not moist-soils can grow. Just like timing of floods may play an important role in floodplain diversity, it can also play a large role in whether or not moist-soils plants will grow (Strader, 2005). Moist-soils need a period with no flooding to allow plants the time to grow tall enough to survive future flooding (Ahn et al., 2004). If the river were to flood during this period it could potentially kill all the moist-soil plants.

5.4 Levee District’s Potential for Habitat Rehabilitation

Many districts have potential for habitat rehabilitation. Districts to the south of the Sanganois State Fish and Wildlife Area have more potential for rehabilitation. Overall the analysis performed suggests a few of the districts (6) only have substantial potential in two of the three assessed rehabilitation categories. Five districts have potential in all three rehabilitation categories. Five districts only have potential in one rehabilitation category and two districts appear to have very little rehabilitation potential (Table 13). Clear Lake has the most rehabilitation potential overall. Not only does it have the largest amount of potential *B.decurrens* habitat, it also has the second highest physical-habitat diversity. While it does not have a lot of natural moist-soil potential, this can be changed by artificially moving the tree line back by disking or disturbing the soil in a way that sets back succession (Strader, 2005). Clear Lake is dominated by farmland. Corn is the primary agricultural product with a few patches of soybeans and alfalfa in the region. The district also contains a few buildings and a system of roadways. Clear Lake District is south of the Sangamon River and the Sanganois State Fish and Wildlife Area. The Sanganois State Fish and Wildlife Area is a state owned refuge that has been reconnected to the IR. If Clear Lake District were to be reconnected to the LIR, it could potentially be assimilated into the Sanganois State Fish and Wildlife Area. Revenue could be generated through hunting and fishing licenses. The Sangamon River is just outside the Clear Lake district along its northern border. If the levee were to be removed, a section of the IR's floodplain would be reconnected to not only the IR but to the Sangamon River as well. Reconnection of the Clear Lake district to the LIR benefits locals by flood height reduction. By allowing flood water greater access to the floodplain, the town of Beardstown can see a reduction in flooding by reducing the stress on the levees that protect the city. This makes Clear Lake district one of the better candidates for reconnection.

Other likely candidatses for reconnection are the West Mantanzas Levee District which encompasses the TNC's Emiquon Preserve, the Banner Levee District, which contains the Banner Marsh State Fish and Wildlife Area, and the Lake Chautauqua Levee District, which surrounds the Chautauqua national Wildlife Area. These areas may be politically the easiest to reconnect to the LIR because they have already been taken out of agricultural production, which would reduce the cost of land acquisition. However, these areas generally do not contain large areas of habitat potential for the *B.decurrens*, moist soils habitats, or relatively high physical-habitat diversity. This is due to the fact that these are low areas, which are already covered by surface water bodies such as Mud Lake (Figure 10). Due to the relatively low elevation of these areas, they would be frequently to permanently inundated which would limit the areas suitable for terrestrial or transitional floodplain species.

5.5 Future Research

Future research needs to determine the quality of LCPI as a predictor of where species will grow. For example, future studies can undertake the confirmation that *B.decurrens* is present in areas identified by LCPI analysis that are currently connected to the LIR. If *B.decurrens* are

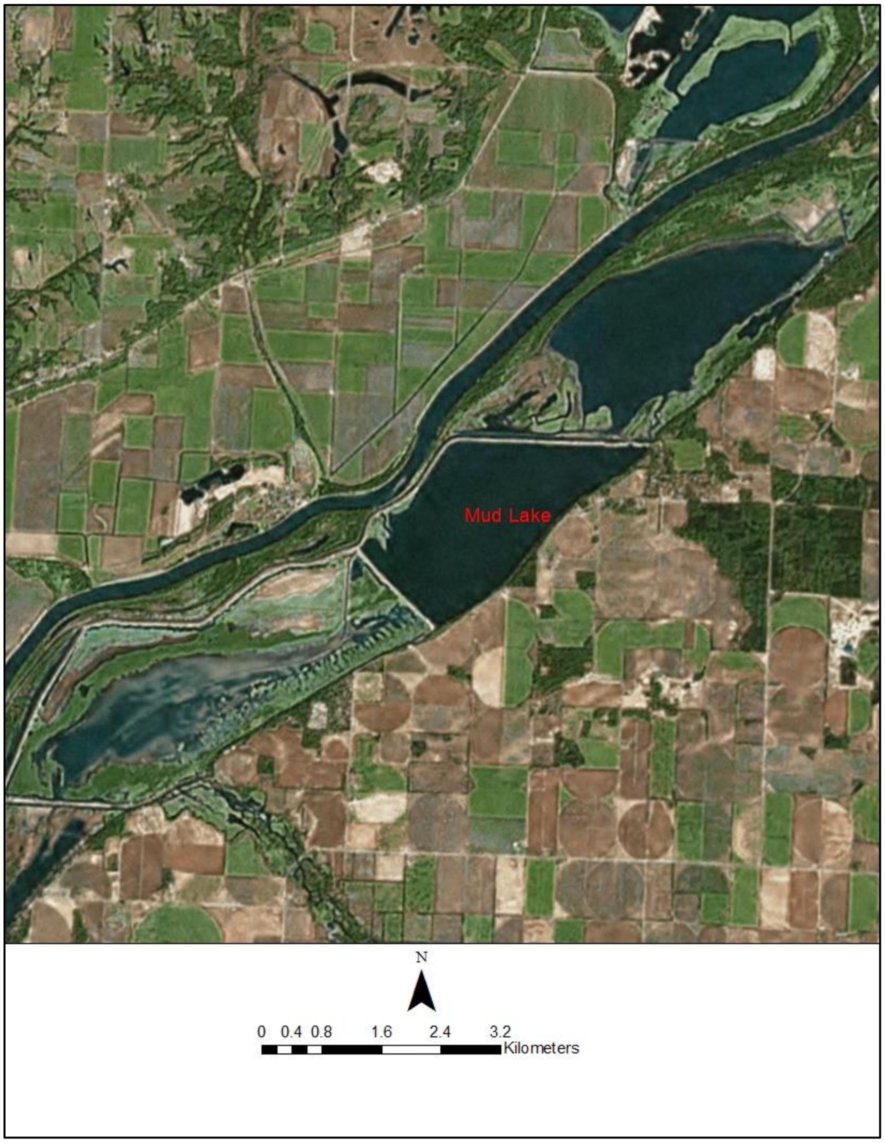


Figure 10. An aerial photograph of Mud Lake.

not in the areas predicted by the LCPI analysis, another study may be able to determine what other factor or factors are influencing this plant's recruitment and growth. These factor then may then be incorporated into the LCPI or other modeling approaches for more precise analysis on where the *B. decurrens* are prospering. LCPI may also benefit from a 2-D hydraulic model. 2-D models generally provide more realistic filling of the floodplain and add another parameter, such as depth averaged flow velocity, to evaluate habitat patches. A more detailed model of the floodplain inundation could help to refine the location of LCPI's physical habitats and increase the habitat patch resolution. Other physical habitat parameters and spatial metrics should also be tested for the realistic assessment of floodplain habitat potential.

CHAPTER 6

CONCLUSION

The LCPI suitability analysis, physical-habitat heterogeneity assessment, and moist-soil assessment are methods by which to screen floodplain areas for their habitat potential or suitability. The two habitat LPCI wetness classes (physical habitat patches) which encompass a substantial portion of the study segment investigated here are silt clay loam with an exceedance probability of 10% and silty clay loam with on exceedance probability of 1%. Together these two habitats make up 46% of the total area. *B.decurrens* requires sandy loam and loam sand soils with an inundation frequency of between 0.1% and 25%. Approximately, 4.0% (23.6 km^2) of the floodplain area study here possessed these physical characteristics. The Clear Lake and Beardstown Levee Districts contain the majority of these areas ~43% (10.3 km^2 out of 23.6 km^2) relative to the other levee districts. The total area for moist-soils habitat (84.7km^2) is more than triple the total for *B.decurrens* habitat. A third of this type of habitat is located in Spring Lake Levee District (31.7 km^2) which is twice the amount of any other levee district (17.8km^2). The Beardstown Levee District also ranked first in physical habitat heterogeneity, with Clear Lake Levee district ranked as a close second. Overall the analyses performed here suggest that Clear Lake Levee District has the most potential for the generation of creating *B.decurres* habitat and physical habitat diversity. Though it only has a small amount of moist-soil habitat this could be changed with certain management actions. In addition, this levee district has only small amounts of infrastructure and buildings making it potentially a more politically palatable choice for reconnection than levee districts which contain substantial amounts of infrastructure and development such as the Beardstown Levee District. Other levee districts such as West

Mantanzas, Banner, and Lake Chautauqua levee districts which are largely wildlife refuges might also be more politically viable candidates for reconnection. However, these floodplain areas do not contain substantial areas of *B.decurrens* or moist soils habitats, nor do they have relatively high physical-habitat diversity. This suggests these districts may have relatively lower habitat benefits then other levee districts which contain substantially more floodplain agriculture, infrastructure and development. This indicates that achieving a more equitable balance between human demands and ecological needs maybe politically difficult along this segment of the LIR.

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