Spatial and Temporal Analysis of Island Morphology in Lower Pool 18 of the Mississippi River

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SPATIAL AND TEMPORAL ANALYSIS
OF ISLAND MORPHOLOGY IN
LOWER POOL 18 OF THE MISSISSIPPI RIVER

By

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ABSTRACT

The Upper Mississippi River System has a significant trend in island loss due to river engineering structures. However, Lower Pool 18 is observed as a counterexample to the island loss pattern with its island development near Lock and Dam 18 during the past 80 years. This research is modeled after a study done in Lower Pool 6 of the Upper Mississippi River where an island development was found to contradict the island loss prevalence. The Lower Pool 18 research's goal is to map, describe, and explain spatial patterns of islands growth, persistence and loss. Historical maps and aerial photographs of the islands, throughout the time period of before the lock and dams were implemented up until today, will be used as the main source of data. Visual analysis, descriptive analysis, and a preliminary explanation was completed to explain the spatial patterns of the islands' morphology. Results have shown the spatial growth of the Lower Pool 18 islands to be significant as well as the pattern in which it occurs. Historic flooding levels and human engineering sources are possible contributors to this particular instance of island growth. These findings will aid river managers in future decision making on engineering and restoration plans. The results will also serve as another counterexample to the island loss pattern, and will result in a better understanding of the Mississippi River.

INTRODUCTION

Humans have a history of controlling the natural world around them. This includes controlling the flow of water along rivers and through creating monoculture crops to feed ourselves. The Mississippi River, like many other large rivers, is heavily managed and altered by engineering structures and practices such as dams, levees, bank clearing, dredging, and more (Gupta, 2007; Pinter et. al, 2000). These structures have led to significant impacts on river function and composition. The structures in place within the Mississippi River system have increased the flood stage over time due to the restricted water flow from levees and lock and dams (Pinter et. al, 2000). This increase in flood stage has altered river development by means of sedimentation rates. Because of the levees, the river is at a fixed width and allows only a finite amount of suspended bedload transportation. This alteration created the river bed to aggregate with the restriction of further floodplains to develop (Gilvear, 1999). Another impact of river engineering is significant loss of islands and erosion of shorelines (Gurnell and Petts, 2002). For the Upper Mississippi River, documented island loss (Collins and Knox, 2003; Palmer et al., 2007) is extensive in the pooled river reaches just upstream of the 29 lock and dams (USACE 2016; see Figure 1).

Figure 1. A total of 29 lock and dams exist on the Upper Mississippi River and are managed by the U.S. Army Corps of Engineers in three districts (St Paul, Rock Island and St Louis). Much of the previous work on island loss and island restoration has taken place in the St Paul District (Lock and Dams 1 - 10). The Rock Island District (Lock and Dams 11-22) has received less attention and much work is needed in this district to document island loss and the impact of island restoration efforts (USACE, 2016).

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The lock and dams diminish island areas by two processes: (1) increasing the water level and drowning the islands and (2) increasing the water surface-area which increases wind-wave size and erosion potential (Maynord and Martin 1996). The net result is a general decrease or elimination of islands in vast areas upstream of each dam (see Figure 2 for example).

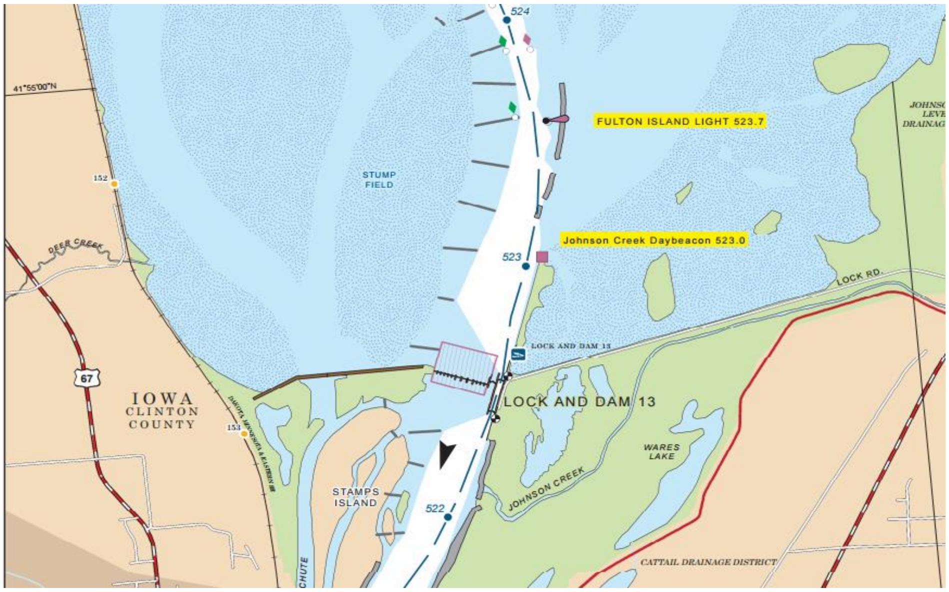


Figure 2. A map of the river near Lock and Dam 13 illustrates the impact of dam construction on islands (USACE, 2012). Upstream of the dam, the areas shown as "stump fields" mark the locations of former islands that have been drowned or eroded following the dam construction. By contrast, islands persist in the river reaches immediately below each dam (see Stamp's Island for example).

While barge-based navigation remains a top priority for river managers, restoration efforts within these engineered rivers have attempted to create a variety of habitats and stabilize and rebuild islands. Between 1985 and 2010, restoration efforts on the Mississippi River have cost at least $241 million (USACE, 2010) and have provided river managers and scientists with many opportunities to learn how the river responds to management interventions. Managers now recognize the need to understand the river as a set of interrelated systems driven by the hydrology and the sediment regime (Meade and Moody 2010). Changes to the hydrology (floods) and sediment regime (sources and sinks of sediment) result in periods of sediment erosion or deposition for the banks and islands both upstream and downstream. With this in mind, past restoration efforts have led to island growth, persistence, or loss (Piégay et al., 2009).

Understanding how the Upper Mississippi River responds to engineering is partially addressed by Freyer and Jefferson (2013) in their island research in Pool 6[1]. In their

[1] Pool 6 is the water area upstream of Lock and Dam 6. It is bounded by the river banks and the next dam upstream (Lock and Dam 5A). The Upper Mississippi River is divided into reaches (called pools) based on the lock and dam that creates the pool.

work, they contrast the island gain in Pool 6 to the general loss of islands in Pools 5-13. Their primary goal was to identify factors that make sites geomorphically favorable for island restoration in the UMRS or other large, engineered rivers with shallow pooled areas, and they point to the need to study the history island-loss and -growth in other pools.

Based on preliminary observations of island growth in Pool 18 (near Burlington, IA) the goal of this research is to map, describe, and explain spatial patterns of islands growth, persistence and loss in Lower Pool 18 and to see if the island growth similar to what Freyer and Jefferson (2013) found in Lower Pool 6. Specifically, this proposed research addresses the following two questions: (1) what geomorphic factors have contributed to island gain in Lower Pool 18? And (2) using identical methods to Freyer and Jefferson (2013), does Lower Pool 18 serve as another counterexample to the island loss prevalence like Lower Pool 6? This research has the potential to aid managers in understanding the most important factors for island restoration. It will also produce the most detailed set of island maps for the study area.

STUDY AREA

Pool 18 of the Mississippi River was formed when Lock and Dam 18 (Figure 1) was completed May 1937 (USACE, 2015). The pool extends 26.6 miles from Lock and Dam 18 in Gladstone, IL to Lock and Dam 17 in New Boston, IL. The Iowa River, a large source of sediment (USACE, 2000), enters the Mississippi in Upper Pool 18. The pool contains 11,746 acres of aquatic habitat (Iowa DNR, 2016) including secondary channels, sloughs, floodplains and wetlands. Lock and Dam 18 has a maximum lift of 9.8 feet and an average lift of 6.9 feet, and is located 410.5 miles above the Mississippi River and Ohio River confluence (USACE, 2015). The lock lift of 9.8 feet means water levels were increased by this magnitude. This increase in water-surface elevation would have drowned many island as the pool filled behind the dam.

A quick examination of aerial photographs (Figure 3) reveals a distinct pattern of island loss (between the early 1930s and 1950s) and a growth of island area between the 1950s and today. The massive loss in island area coincides with dam construction but the island growth is unexpected (Freyer and Jefferson 2013).

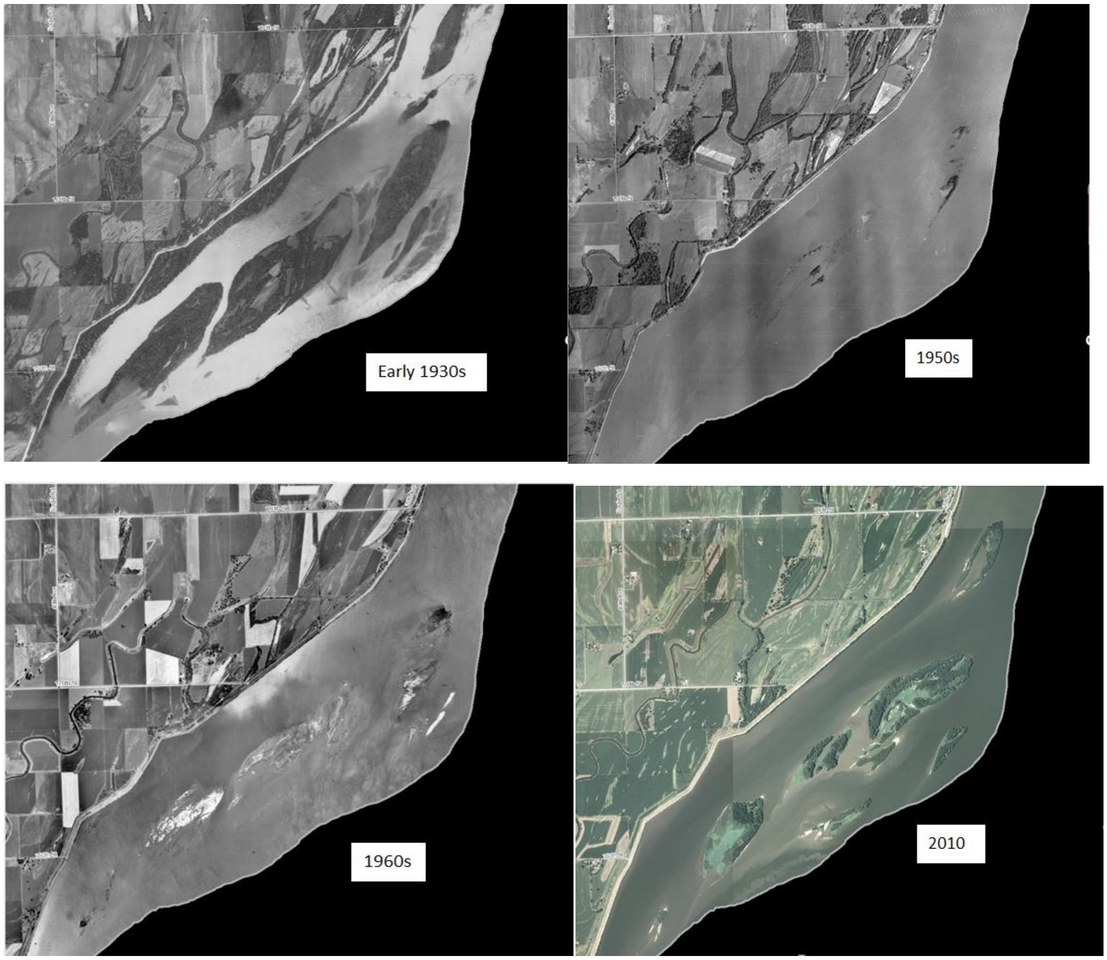


Figure 3. Island loss and growth in lower Pool 18 as shown in historic aerial photographs. No previous study has specifically examined the island patterns of Pool 18 and these islands could provide another useful counterexample of island growth on the Mississippi River (Iowa State University, 2017). In additional to the aerial photographs, photos exist for late 1930s and for each year between 2000 and 2015.

In addition to the dam, Pool 18 contains many other engineering structures such as wing dams and closing dikes that divert the flow to the main channel. This in turn makes the water flow faster and erode the bed and the banks, while trapping sediment around them to extend out the land (Alexander et al., 2012). It may be that the island growth is related to these structures. The pattern of island loss followed by island growth makes this a potentially interesting part of the river for understanding island dynamics in the Mississippi River.

The specific islands in Pool 18 that are focused on within this project are north of Lock and Dam 18. As seen in Figure 3, these islands have undergone a vast amount of spatial change within the past 80 years. The islands Big Dasher, Oquawka Island, and Long Island (Figure 4) have a unique history unlike a majority of other islands within the Mississippi River.

Figure 4. The Islands within Lower Pool 18. This map was created by the author and depicts a closer look at the specific islands on the Mississippi River researched within this project.

LITERATURE REVIEW

Although there is a vast amount of research done on the Mississippi River, there is still more to learn. Islands are one aspect of the ecosystem that is being studied and understood, especially with respect to their disappearance or high plant and animal diversity. However, in certain cases along the river's body, islands have been observed to be growing back. This island development is occurring where dams have previously flooded the river, and islands along with it. Now in that location, islands are observed to be growing. The goal of this research is to map, describe, and explain spatial patterns of islands growth, persistence and loss in Lower Pool 18. The results will then be compared to a similar study done in Lower Pool 6 where island growth was present (Freyer and Jefferson, 2013). In order to better understand the project's purpose and results, a discussion of sedimentation, island formation and importance, and human engineering structures will be explained.

Within a river's system, flooding, sediment trapping, and vegetation are factors that are crucial for island development. Islands and expanded shorelines are produced by trapping the suspended load within the flow (Zanoni et al., 2008). This sediment trapping happens during a flooding, or high-water, event. The discharge from flooding can allow the settling out of sediments because the flow will be slowed down. Once vegetation begins to grow and their roots infiltrate the soil, the island's sediments will become stabilized and less susceptible to erosion (Osterkamp, 1998). Since low flow is needed to deposit sediments, an island is often found in a meandering river, which commonly has a low gradient, low flow, and a large proportion of suspended sediment relative to the amount of bed load (Gao et al., 2013). A river island is characteristically a long and narrow formation within the river channel, and may become a permanent island. They may also be eroded by runoff, and the eroded sediment deposited further downstream to form another river island, thus creating an almost continuous dynamic (Gao et al., 2013).

Islands can play a significant role in riverine processes. If islands become too large within the river system, it can cause embankment erosion, and damage to ports, forming serious threats to various cities located along the river (Gao et al., 2013). Islands are also important because they hold a place for high biological diversity (Zanoni et al., 2008). Islands are important because they create physical habitats that are in close proximity to one another which is superior to a homogenous land or aquatic area. (Walters and Williams, 1999; Johnson, et al. 1995). This terrestrial and aquatic habitat supports special types of vegetation that are not common within other types of ecosystems. Without a place for a diverse vegetation to grow, there is a decrease in protection against wind. The wind will thus increase wave energy to the windward side and therefore increase erosion of shorelines of the islands or bank shorelines (Johnson, et al. 1995). Islands also create backwaters that allow for fish habitats and reproduction areas and nesting grounds for birds, especially the Bald Eagle in Pool 18. Not only are islands important for ecological purposes, but also for understanding the geomorphic history of the river, but also the pool itself. Islands are created from high-energy processes such as glaciation, flooding, and avulsion. This redistribution of sediments has created records of these large events in layer after layer (Osterkamp, 1997).

When looking from the geological time period, fluvial islands are unstable due to the natural processes of erosion and sediment movement downstream (Osterkamp, 1997). There is a limited amount of studies conducted on the growth of islands within the Mississippi River due to the prevalence of islands disappearing due to the raise in the flood stage (Pinter et al., 2010) and the wind-energy erosion (Maynord and Martin, 1996).

In order for rivers to function, they need to have flooding, sediment erosion and deposition, and shifting habitat patches as a way to keep it rejuvenated and diverse (Gurnell and Petts, 2002). However, most rivers are heavily engineered by humans. The structures that humans have created including dams, levees, dikes, and revetments are designed for a multitude of reasons including deepening the water levels, flood control, sediment control, and more. There also comes a number of impacts and issues on river aspects such as its sediment transport, hydrology, geomorphology, water quality, and habitats, especially along the Mississippi River (Alexander, et al. 2012). According to Alexander et al. (2012), finding the direct causes and effects are very limited due to the small number of datasets from before the structures were put in, from the vast number of engineering structures built, and from the prolonged response times. However, many researchers have spent time looking into the effects. Researchers Meade and Moody (2010), have studied how and why the suspended-sediment discharge is declining within the Mississippi River. They find the correlation with dams and the restricting of sediment transport due to a coincided time of the use of the dams and the drop in suspended-sediment discharges because the sediment gathers behind it. Structures such as dikes and revetments were used along the river's shorelines. These structures, according to the researchers, also played a role in decreasing the sediment discharge. This happened as a result of trapping the sediment and protecting the shoreline from further erosion, which is a contributor to the sediment discharge within the flow (Meade and Moody, 2002). Wing dams and closing dikes are used to provide protection against the main channel from filling up with sediment by directing the main flow of the river through the middle. Thus scouring out the river bed and eliminating the need to dredge (Huthoff, et al. 2013).

This project will help fill in the research gap about reappearing islands. Most of the research about islands discusses the erosion and disappearance of islands, especially of those who have a high amount of human engineering interference. A detailed look into the islands of Lower Pool 18 will give a visual description of how the islands are spatial growing. The research will also give a more descriptive look at what is happening in Pool 18, as little research has. This will allow for a new perspective on island morphology to shatter the misconception that islands are largely eroding along a vast majority of the Upper Mississippi River.

METHODOLOGY

The methods used in this research will closely follow the methods established by Freyer and Jefferson (2013) and Zanoni et al. (2008). Like Freyer and Jefferson (2013), this research utilized historic aerial photographs, hydrologic data, and engineering records as data sources. The analysis was completed in three general parts including: (1) map-overlay analysis of island maps over time (similar to maps shown in Figure 1); (2) descriptive statistics of island characteristics over time; and (3) preliminary explanation between island changes and hydrologic and engineering activities.

The first phase of this research involved the downloading and georeferencing of historic aerial photographs and tracing island/shoreline features. All island and shorelines were saved to an ArcMap 10.4 geodatabase as polygon feature classes. These aerial photographs, provided by Iowa State University (2017), were also determined by the water levels at the time the photograph was taken in order to minimize error (Table 1). The river gages that are located at Keithsburg, IL and Lock and Dam 18 gave those levels at a certain date (NOAA, 2016). Accounting for differences in water levels during the time the photos were taken account for the different availabilities to use the photographs to outline the perimeter of the island. If the water levels were too high, an analysis could give the wrong impression that the island had eroded away. A GIS-based overlay analysis was used to map and quantify island changes by use of the union tool. This spatial analysis then created an attribute table to allow me to classify which sections of land changed from water to land, land to water, stayed land, and stayed water. This produced a set of maps for Lower Pool 18 that is similar to Freyer's maps (shown in Figure 5; Freyer and Jefferson, 2013).

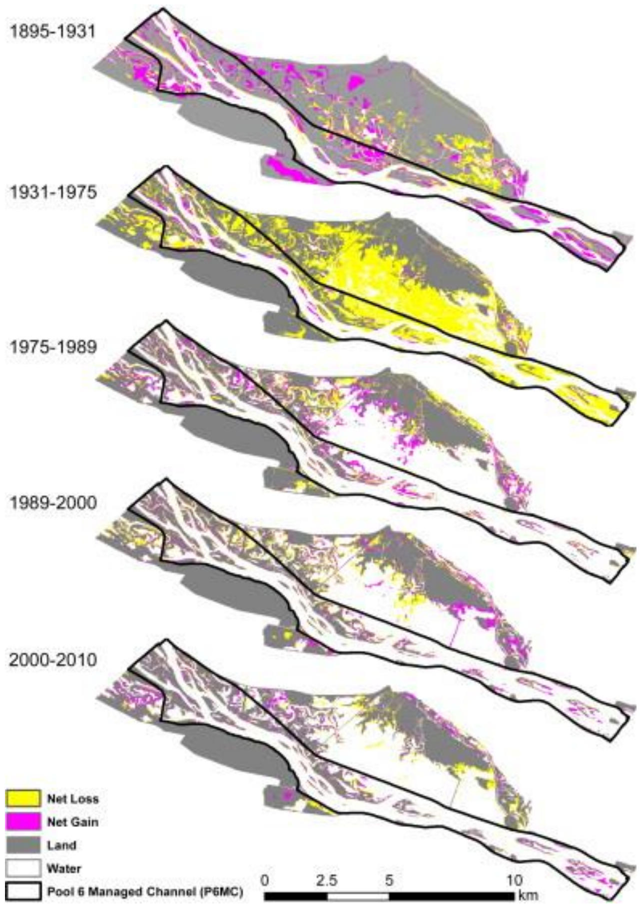


Figure 5. This figure depicts the area of land growth (pink) and loss (yellow) of the islands in Pool 6 of the Mississippi River (Freyer and Jefferson, 2013). Analysis was done by overlaying each photograph in GIS (Geographic Information System) and outlining the islands to observe the changes in land through time.

The time series of historic island maps and photographs, from the time period of 1927 to today, provided the basis for trend analysis and descriptive statistics. This phase of the research produced tables and graphics of the land/water areas over time in Lower Pool 18. The map that was created was also altered in Adobe Illustrator to show the net loss, net gain, and what has spatially stayed consistent within the islands in different colors. An analysis was completed to visually show the percent change of the islands over time graphically. A set extent of approximately 16,730,920 m² was placed over the islands to determine the total area once combined with the area of the land. The area of land was then divided by the total area to define what the percent of land was during that time period.

Table 1. The Aerial Photographs' source and information.

Year	Source	Date Photo Taken	River Stage (Ft)	Notes
1927	Iowa State Geographic Map Server	Sept 4 1927	1.8	
1940s	Iowa State Geographic Map Server	July 21 1941	5.1	
1950s	Iowa State Geographic Map Server	Sept 13 1951	7	Sediment left from River Dredging
1960s	Iowa State Geographic Map Server	July 11 1963	5	
1970s	Iowa State Geographic Map Server	May 28 1969	9.7	
1980s	Iowa State Geographic Map Server	April 28 1984	12	
1990s	Iowa State Geographic Map Server	April 14 1998	18.6	
2000s	Iowa State Geographic Map Server	April 5th 2002	9.7	
2013	Iowa State Geographic Map Server	N/A	N/A	

The third phase of this analysis involves a preliminary explanation. In an attempt to explain why these islands are growing, persisting, and eroding in a certain way, engineering history and timing and magnitude of floods were taken into account. A partial analysis was done by lining up previous knowledge about how wing dams, lock and dams, and flooding are documented to alter landscapes with the factual knowledge of how the particular islands in Lower Pool 18 have developed over time.

RESULTS

Since the time period of 1927, Pool 18 of the Mississippi River has undergone substantial changes in human engineering alterations and geomorphology. The islands within the year 1927 represent the pre-lock and dam river. Within a selected area, the islands made up over 16 percent, the largest area out of any other years (Figure 6). Lock and Dam 18 was then put into effect just a decade later in May of 1937. This created an over 95 percent decrease in land to

1938 since the water levels were increased over 7-10 ft total. Only slivers of land have been left behind, those that originally had a high enough elevation to survive the water increase (Appendix A). The majority of this land was on the shorelines of the islands where sediment is known to aggregate first in many cases. From the 1940s to the 1950s, an approximate 14 percent land increase happened. Some of this land came from the US Army Corps of Engineers when they deposited a large amount of sediment that came from the river bed after it had been dredged. The largest land increase occurred in the years 1950s to 1960s. This an 80 percent increase is mostly observed on the southernmost island extending into the middle of the river channel. Other islands seem to begin to fill with sediment from the inside within this time period. From the 1960s to the 1970s, there was a substantial 45 percent decrease in spatial area. This time span is longer than the others due to the 1970s aerial photograph having too high of water levels to be accurate. A majority of the land eroded away in the southern islands, where it was recently the area to have increased the most. The northern islands had areas that aggregated the most. After this time span, the spatial growth of the islands seems to be more consistent. There was a 27 percent increase after this large loss of land in the next time period of 1980 to 1990. New island have spatially appeared in this time period. There is one located the furthest north and one located near the middle of the river channel, more south. In the next time span from the 1990s to the 2000s, there is a 40 percent increase in land. The land has mostly grown and not been lost. In the southernmost island, a ‘V’ shape has formed from the original deposition from the US Army Corps. The land is seen to have filled in the gaps for other islands as they look to be becoming more mature. From the 2000s to 2013, there is a 32 percent increase in land. This increase has completely filled in two of the islands where they are no longer ‘V’ shaped. Other islands have been extended upon to add width or length.

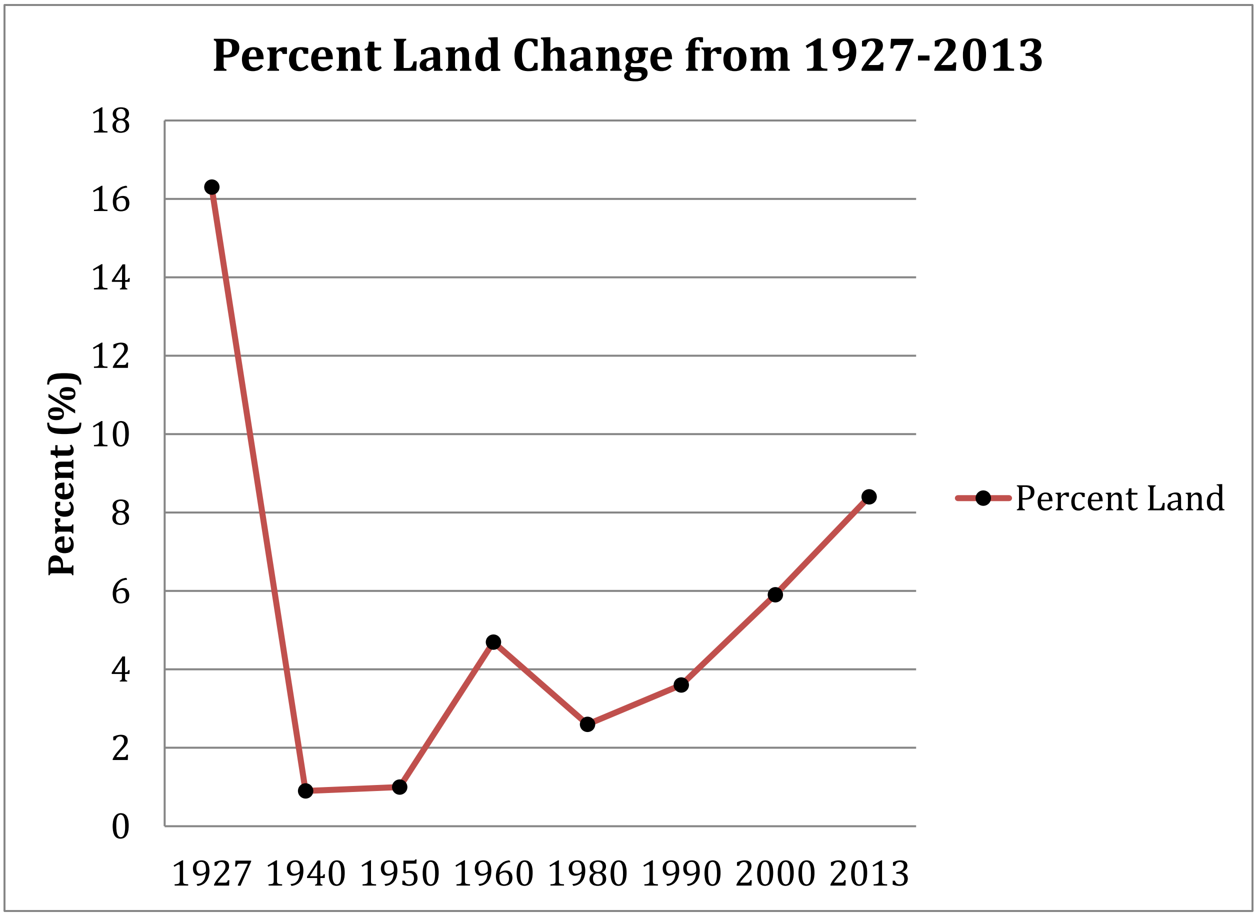


Figure 6. The percent of land change of the islands in Lower Pool 18 of the Mississippi River from 1927 to 2013. Spatial area of the land and given surrounding extent was used to calculate results.

The overall spatial change of the islands in Lower Pool 18 from 1927 to 2013 is significant (Figure 7). A 53 percent decrease is the total spatial loss during this timeframe. The islands appear to be within the same vicinity of the islands there before the Lock and Dam was opened. They also appear to be significantly smaller in proportion, thus the 53 percent decrease. However, these islands have had approximately 80 years to develop while the 1927 islands have had a longer geologic timespan.

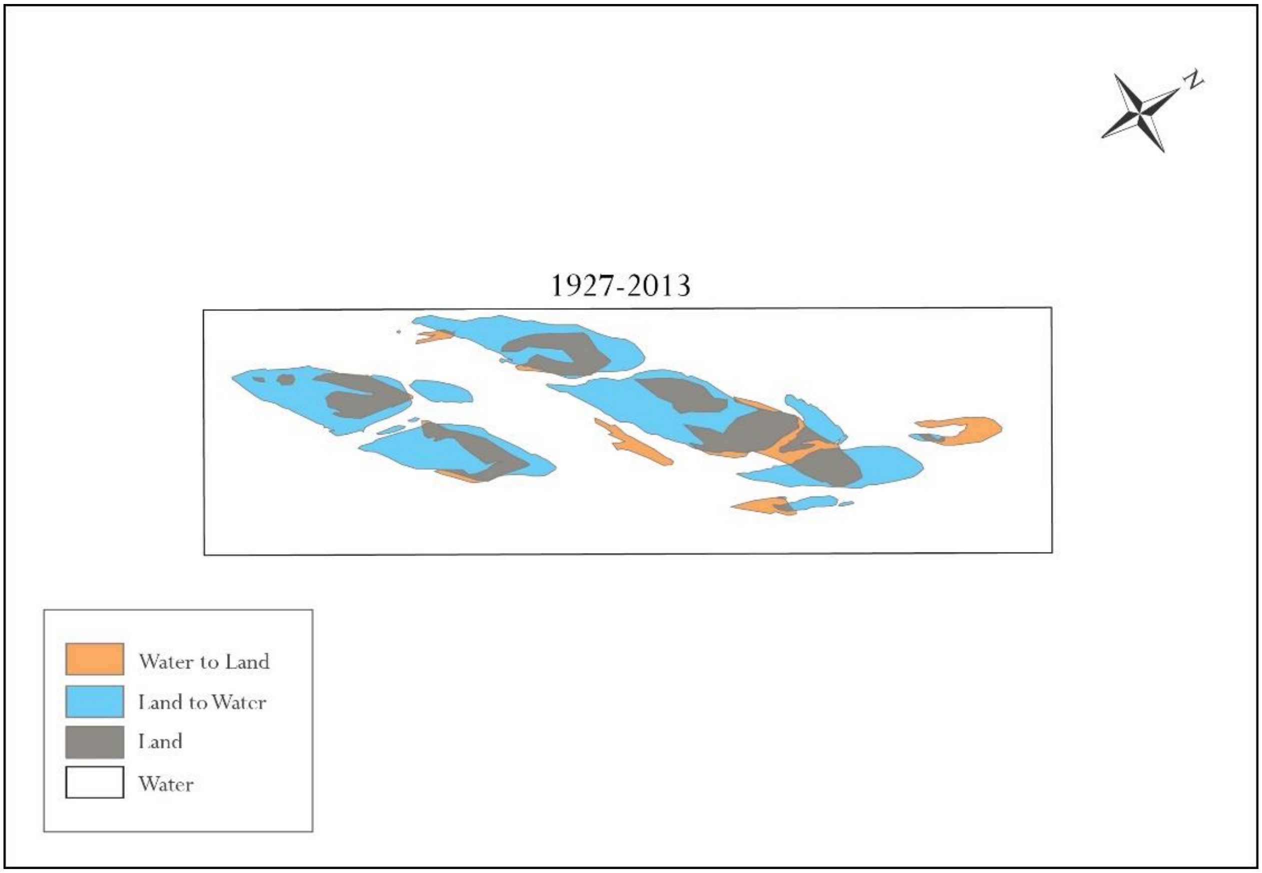


Figure 7. Overall land change from 1927 to 2013 indicating land growth (orange), persistence (gray), or loss (blue) in Lower Pool 18.

There are 18 wing dams and closing dikes present within the study area of this research project. All were built within the years 1900, 1915, and 1927, but only 5 have been altered post-lock and dam. Two wing dams were partially removed in 1938. One had 150 feet removed while the other had 300 feet removed. The other three dams were repaired in 1983 to their original parameters.

As flooding will be a factor analyzed for a possible explanation for the spatial growth of islands, the historic crests are an important result (Table 2). Within the timespan from the 1960s to the 1980s, there were two historic crests. In 1965 the sixth ranked historic flood happened with the levels coming up to 20.46 feet. In 1973 the eighth historic flood occurred with a height of 19.35 feet. Between the time periods 1990 and 2000, three historic crests took place. The tenth and second historic crests at 19.10 feet and 24.15 feet happened in the year 1993. Then in 1998, the eleventh historic crest happened at a level of 18.71 feet. Finally, within the timespan between the 2000s and 2013, four historic crests were recorded. In 2001, the fourth historic crest was documented to have had a flood level of 20.72 feet. There were two historic crests in 2008, the seventh and the first. The seventh ranked crest had a level of 20.35 feet while the first had a level of 24.49 feet. There was also a historic crest in 2011 at a level of 19.19 feet, making it rank ninth.

Table 2. Historic Flood Crests given by National Oceanic and Atmospheric Administration (NOAA) at the Keithsburg, IL river gage.

Rank	Year	Flood Levels (ft)
1	2008	24.49
2	1993	24.15
3	2014	22.63
4	2001	20.72
5	2013	20.57
6	1965	20.46
7	2008	20.35
8	1973	19.35
9	2011	19.19
10	1993	19.10
11	1998	18.71

DISCUSSION AND CONCLUSION

The spatial change of island growth, persistence, and loss within this study is shown to be significant findings to provide a basis for future research. The historic flooding within the time frame this study focuses on, along with the human engineering developments, is observed to have a preliminary strong correlation with the pattern of growth.

A possible contributor to the spatial gain of land would be the major flooding events. Flooding is known to aid in the sedimentation of shorelines and islands when the waters move too slowly to hold the suspended sediments, thus depositing them onto pre-developed land (Zanoni et al., 2008). Starting from the 1980s, the islands had a much more consistent spatial increase in land compared to the other time periods. Within this time frame, seven of the eleven historic floods happened. However, two historic floods happened within the time span between the 1960s and 1980s. During this time, there was a significant spatial decrease in land.

Wing dams and closing dikes capture sediment by creating a slowed river flow within their reaches. These man-made barriers allow for a base structure that the sediment can stick behind, away from the erosive powers of strong currents. With the observation that the new islands have developed within the same vicinity as the pre-lock and dam islands, the wing dams may have been a contributor to the spatial growth over time. There is reason to believe that after the islands were flooded in 1937, some of the sediment was kept underneath the surface as a result of the wing dams. Along with these human engineering structures, being within such a close proximity to a lock and dam could also result to be a contributor to sediment build-up for these specific patch of islands. This would be caused by the lock and dam's ability to inhibit the continuous movement of sediment downstream (Alexander, et al. 2012).

This study provided similar results to Freyer and Jefferson's 2013 research. The islands in Lower Pool 18 seem to be growing at a similar rate in a similar situation as those islands in Pool 6, however their study was on the entirety of one pool while this study focused on the lower section of a pool. It is believed that the wing dams and Lock and Dam 6 are large contributors to island growth due to sediment trapping, which is seen within this study as well. The Pool 6 research also had substantial land loss after the flooding between the years of 1960 and 1980 and growth after the more recent floods to have come through. This is similar to what this research observed.

What is shown in Freyer and Jefferson's study (2013) as well as this research, is that islands are being observed to be regenerating without extensive efforts being done by any management practices. As stated early, the United States has spent approximately $241 million on restorations efforts on the Mississippi River alone within the past 25 years (Freyer and Jefferson, 2013). With more extensive research into what is causing this land growth, mock situations can be applied to other areas on the river to reduce labor and monetary costs. A correlational analysis can be done in future research based off of the preliminary explanation given from this study to determine the factors contributing to spatial growth and change of island morphology.

REFERENCES

Alexander, J.S., Wilson, R.C., Green, W.R., 2012. A brief history and summary of the effects of river engineering and dams on the Mississippi River system and delta. 9781411334243, USGS.

Collins, M.J. and Knox, J.C., 2003. Historical changes in Upper Mississippi River water areas and islands. *JAWRA Journal of the American Water Resources Associatio*n, 39(2), pp.487-500.

Freyer, J.B., Jefferson, A.J., 2013. An exception to island loss in the engineered Upper Mississippi River: History of land growth in Pool 6 and implications for restoration. Anthropocene 2 (2013) 65-75.

Gao, Chao, Chen, S., Yu, J., 2013. River islands' change and impacting factors in the lower reaches of the Yangtze River based on remote sensing. *Quaternary International* 304, pp. 13-21.

Gilvear, D.J., 1999. Fluvial geomorphology and river engineering: future roles utilizing a fluvial hydrosystems framework. *Geomorphology*, 31(1-4) 229-245.

Gupta, A. (Ed.), 2007. Large Rivers: Geomorphology and Management. John Wiley & Sons, Ltd, Chichester, 689 pp.

Gurnell, A.M., Petts, G.E., 2002. Island-dominated landscapes of large floodplain rivers: a European perspective. Freshwater Biology 47, 581-600.

Hutoff, F., Pinter, N., and Remo, J. W. F. (2013). Theoretical analysis of wing dike impact on river flood stages. *Journal of Hydraulic Engineering* 139, pp. 550-556.

Iowa DNR, 2016. Mississippi River Pool 18. Iowa Department of Natural Resources.

Iowa State University, 2017. Iowa Geographic Map Server. Iowa State University Geographic Information Systems Support & Research Facility.

Johnson, B.L., Richardson, W.B., Naimo, T.J., 1995. Past, present, and future concepts in large river ecology. Bioscience 45 (3) 134-141.

Meade, R. H., and Moody, J.A. 2010. "Causes for the decline of suspended-sediment discharge in the Mississippi River system, 1940–2007." *Hydrological Processes* 24, no. 1, 35-49.

Maynord, S.T., Martin, S.K., 1996. Upper Mississippi River System Navigation/ Sedimentation Study. USACE, , pp. 1–72.

NOAA, 2016. Advanced Hydrologic Prediction Service. National Oceanic and Atmospheric Administration.

Osterkamp, W.R., 1998. Processes of fluvial island formation, with examples from Plum Creek, Colorado and Snake River, Idaho. *Wetlands*, 18(4), pp. 530-545.

Palmer, M., Allan, J.D., Meyer, J. and Bernhardt, E.S., 2007. River restoration in the twenty-first century: data and experiential knowledge to inform future efforts. *Restoration Ecology*, 15(3), pp.472-481.

Piégay, H., Grant, G., Nakamura, F., Trustrum, N., 2009. Braided river management: from assessment of river behavior to improved sustainable development. In: Sambrook Smith, G.H., Best, J.L., Bristow, C.S., Petts, G.E., (Eds.), Braided Rivers: Process, Deposits, Ecology and Management. Blackwell Publishing Ltd, Oxford, UK, pp. 257-275.

Pinter, N., Jemberie, A.A., Remo, J.W.F., Heine, R.A., Ickes, B.S., 2010. Cumulative impacts of river engineering, Mississippi and Lower Missouri rivers. River Research and Applications 26 (5) 546-571.

Pinter, N., Thomas, R., and Wlosinski, J.H., 2000. Regional impacts of levee construction and channelization, Middle Mississippi River, USA. *Flood Issues in Contemporary Water Management*, 71(2) 351-361.

USACE, 2000. Upper Mississippi River and Illinois waterway cumulative effects study. Volume 1: geomorphic assessment. U.S. Army Corps of Engineers, Rock Island Districts 218 pp.

USACE, 2010. Upper Mississippi River Restoration Environmental Management Program Report to Congress. U.S. Army Corps of Engineers, Rock Island, St. Paul, St. Louis Districts 61 pp.

USACE, 2012. Upper Mississippi River Navigation Charts. U.S. Army Corps of Engineers, Rock Island, St. Paul, St. Louis Districts.

USACE, 2015. Lock & Dam 18. U.S. Army Corps of Engineers, Rock Island District.

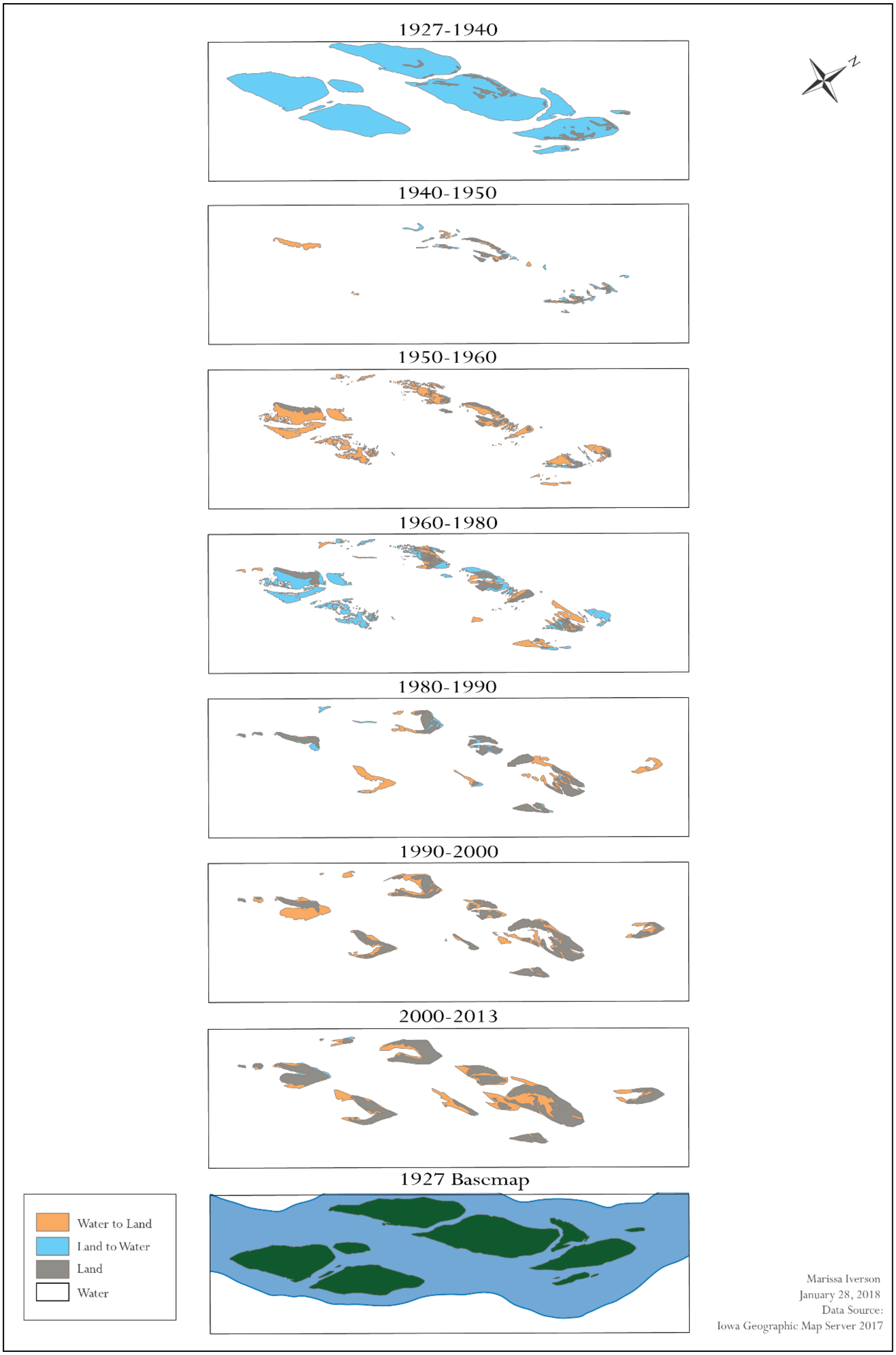
USAC, 2016. The 9-Foot Channel Navigation Project on the Upper Mississippi River. Publication available: www.mvp.usace.army.mil/2016_9_Foot_Channel_Brochure.pdf

Walters, G., and Williams, C. 1999. Riparian forest overstory and herbaceous layer of two upper allegheny river islands in Northwestern Pennsylvania. *Castanea*, *64*(1), 81-89.

Zanoni, L., Gurnell, A., Drake, N., Surian, N., 2008. Island dynamics in a braided river from analysis of historical maps and air photographs. River Research and Applications 24 (8) 1141-1159.

APPENDICIES

APPENDIX A


1927-1940
1940-1950
1950-1960
1960-1980
1980-1990
1990-2000
2000-2013
1927 Basemap
N
Water to Land
Land to Water
Land
Water
Marissa Iverson
January 28, 2018
Data Source:
Iowa Geographic Map Server 2017