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Remote Sensing Evaluation of Human Impacts on the Lower Muskegon River, MI

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Introduction

The Muskegon River has a long history of human impact. The largest impact to the river morphology has been the introduction and removal of dams to the hydrological system. Three dams lie within the lower Muskegon River that contribute to local hydroelectric power: Croton Dam, Hardy Dam, and Rogers Dam. One such dam was installed in the Big Rapids area, but later removed in 2001 (Michalek 2015). The impact of installing dams into rivers is detrimental, but removing them is also just as influential.

A previous study from Michigan State University described the post-glacial history of fluvial landform changes in the upper Muskegon River (Evart to Houghton Lake). They found paleochannels and used carbon dating to describe the change through geologic history (Arbogast 2008). Another similar study by Michigan State University utilizes both land survey maps and recent aerial images to look at channel characteristics and influences on the river (Michalek 2015). Michalek concludes that the upper section contains multiple river cutoff points and change in sinuosity (high sinuosity to low sinuosity) over time. This study will look at assessing the impacts of humans on the lower Muskegon River system using remote sensing techniques.

Methodology

Study Area

The study area covers the expanse of the Muskegon River through four counties: Muskegon, Newaygo, Mecosta, and Osceola. In Muskegon county the Muskegon River discharges into Muskegon Lake, and flows into Lake Michigan. Muskegon county is more urbanized than the other three counties which likely plays a factor in river migration movement. Newaygo and Osceola counties are the least urbanized counties and contain cropland and large forested areas. Mecosta county has a mixture of urbanization and natural state land. The largest urbanized area in the county is the Big Rapids area, mainly due to the existence of Ferris State University.

Field Observations

Field observations were conducted between early June and mid-August of 2018. The objective of the field observations was to observe features seen from aerial photos and collect localized information on the spatial dynamics of the river system. GPS points were recorded with a Spectra Precision SP80 GNSS GPS unit for precise accuracy. Locations of the observation sites are shown in **Figure 1**. The findings from the field observations are described in **Table 1**.

Figure 1: Location map of the study area with Observation Sites points.

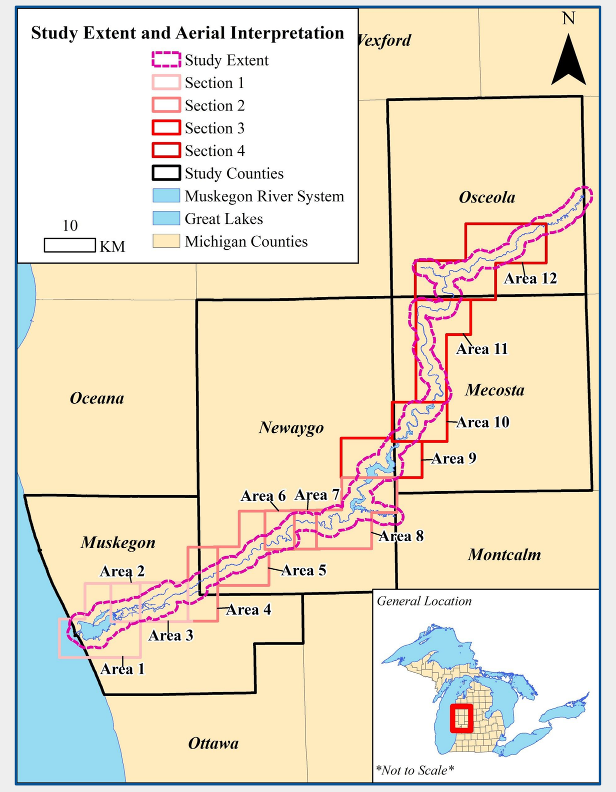

Figure 2: Location map of the designated areas within the study area along with a 1.5 km buffer around the river.

Methodology (cont.)

Remote Sensing Techniques

Three different aerial images were utilized to characterize the change observed in the river. The aerial images used are Digital Orthometric Quadrangle (DOQ's), National Agriculture Imagery Program (NAIP) images, and High Resolution Orthoimagery. The years included in the analysis were from 1993, 1994, 1997 thru 2000, 2008, and 2016. These years are the available images provided by the US Geological Survey. **Table 2** contains the metadata of the images and the number of scenes within the different groups. Minor geographic corrections were made to make sure the images were accurately georeferenced to each other before conducting analysis. This was done by referencing roads and buildings that were present in all images. After corrections, the banklines were traced in the images to show the progression of the river bank with time.

Observation points were recorded to verify the location of the river system and other features (**Figure 1**). To divide the analysis of the river into smaller sections, sub-study areas were created to observe the change. These areas were determined by the extent of the oldest aerial images. Older images were collected to present the observable change in the river system through the years collected. All the imagery was obtained for the spring months so that it remained constant throughout. A buffer was delineated around the river to focus on the data nearest the river. Banklines were then traced within their assigned study areas (shown in **Figure 2**). Once traced, the banklines were assigned different colors to differentiate the years processed. The years were then visually compared to see how the river has changed throughout time.

A risk assessment was conducted to model future movement of the river. The following datasets were utilized to create a risk assessment raster: soil survey polygon files, land cover/land use data, and a euclidean distance around the river. The files were given a specific weight for how much they will influence the risk (soil survey: 30%; land cover/land use: 60%; distance from river; 10%). The weights used were determined by their predicted influence on the system with land cover as the most influential with a spatial resolution of 30 meters. **Tables 3-5** gives a description of the rankings used in the risk assessment.

Table 2: *Metadata of Aerial Imagery used in the study.*

Aerial Image type	Resolution	Originator	Number of Scenes	Coordinate System
DOQ	1 meter	US Geological Survey	51	NAD 1983 UTM Zone 16N
NAIP	0.6 meter	US Geological Survey	36	NAD 1983 UTM Zone 16N
High Resolution Orthoimagery	0.3 meter	US Geological Survey	41	NAD 1983 UTM Zone 16N

Table 3: *Distance from River Description and Ranking.*

Description	Ranking
Less than 500 meters from River	3
500 to 1000 meters from River	2
Greater than 1000 meters from River	1

Table 4: *Soil Survey Descriptions and Ranking.*

Description	Ranking
Organic Material	5
Fine Material	4
Medium Material	3
Coarse Material	2
Developed Land or Bedrock	1
Water or Unknown Material	0

Table 5: *Land Use Descriptions and Ranking.*

Description	Ranking
Floodplain/Wetlands	5
Cropland	4
Open/Barren Fields	3
Forested Areas	2
Developed Land/Quarries	1
Water	0

Results

Figures 3 thru **14** showcase the significant change in the banklines of the river over the course of the years involved in the images. The background imagery is from July 2016. Insignificant amount of change was observed but was not credible because it does not provide aid to the analysis (insignificant change = less than or equal to a meter) . For bankline analysis, refer to **Figure 2** for geographic context. **Figures 19** thru **22** are the calculated risk assessment maps for the various sections. For risk assessment analysis, refer to **Figure 2** for geographic context. **Figures 15** thru **18** are zoomed in shots of specific changes within each section.

Table 1: *Field observation findings with site locations.*

Site	Description of Findings
2	Eddies in the river were observed from the campground; Very little suspended load in the system; river height was lower than the flood zone, which was observed by a higher elevation river bank than the current bank location.
3	The channel width was larger by observation than Site 2; Contained the same relative characteristics as Site 2.
5	Water depth was very shallow; turbidity of the water was much faster than previous sites (1-4); large gravel and pebbles were observe in the bed load.
6	Water depth very shallow; turbidity was observed, but not as fast as Site 5; rocks were observed that ranged in size from cobble to boulders; contained isolated islands within the channel (mid-channel bar).
7	Characteristics are relatively the same as Site 6, but some portions were deeper and more turbid than other areas.
8	Extremely turbid in the main area of the channel, which is observed to be a thalweg; many human controlled components of the channel to create bank control and stabilization; large eddies observed; channel splits into two directions, and east channel was much more shallow and more rocky than the west channel
9	Turbidity decreased from Site 8 to a normal state (in terms of the entirety of the river); dunes were observed near the channel, providing sediment supply to the river.
10	Rogers dam information was collected (two dams were previously built on the river in Newaygo and Big Rapids and removed approximately 20 years beforehand)
15	A US Geological Survey Stream Gauging Station was located near the Croton Dam.
18	Woody debris was found in the shallow area of the river; another thalweg was observed in the center of the river; surface speed was much more turbid than previous sites.

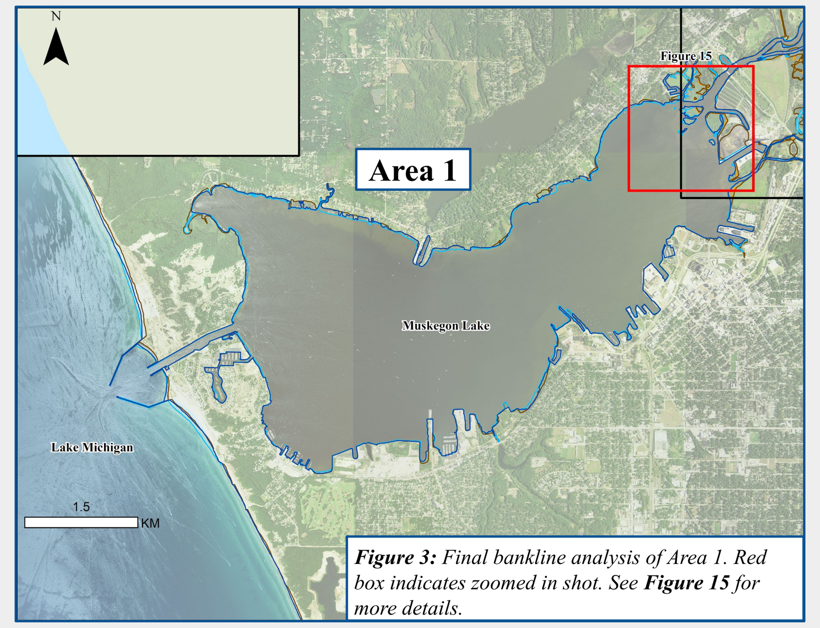

Figure 3: *Final bankline analysis of Area 1. Red box indicates zoomed in shot. See* ***Figure 15*** *for more details.*

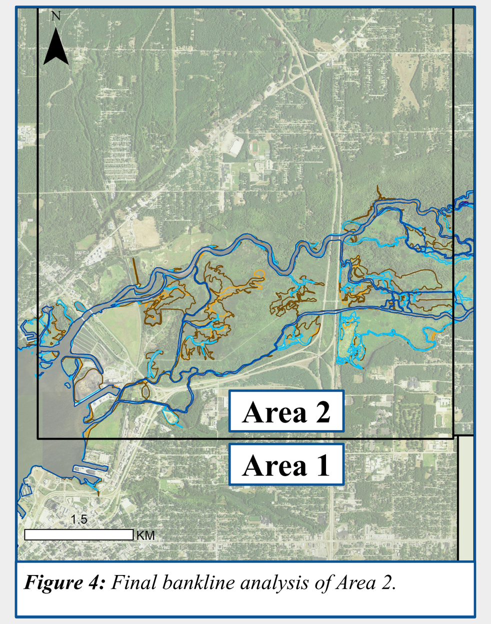

Figure 4: *Final bankline analysis of Area 2.*

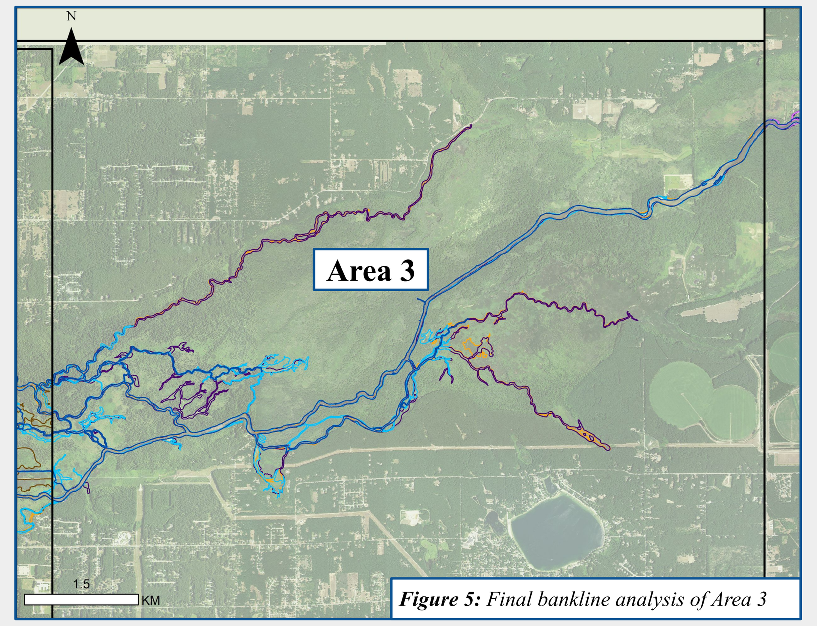

Figure 5: *Final bankline analysis of Area 3*

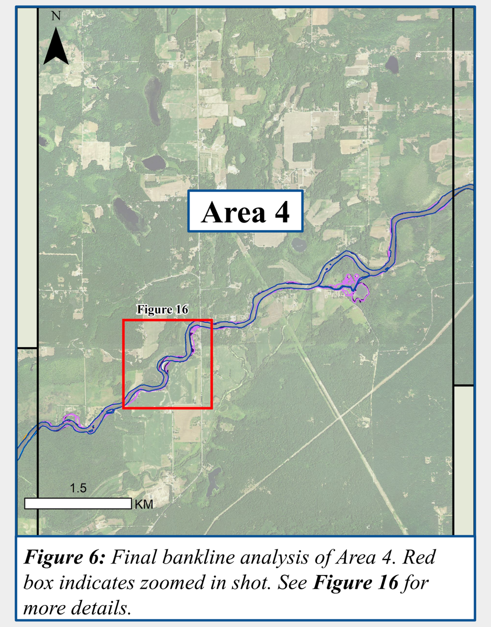

Figure 6: *Final bankline analysis of Area 4. Red box indicates zoomed in shot. See* ***Figure 16*** *for more details.*

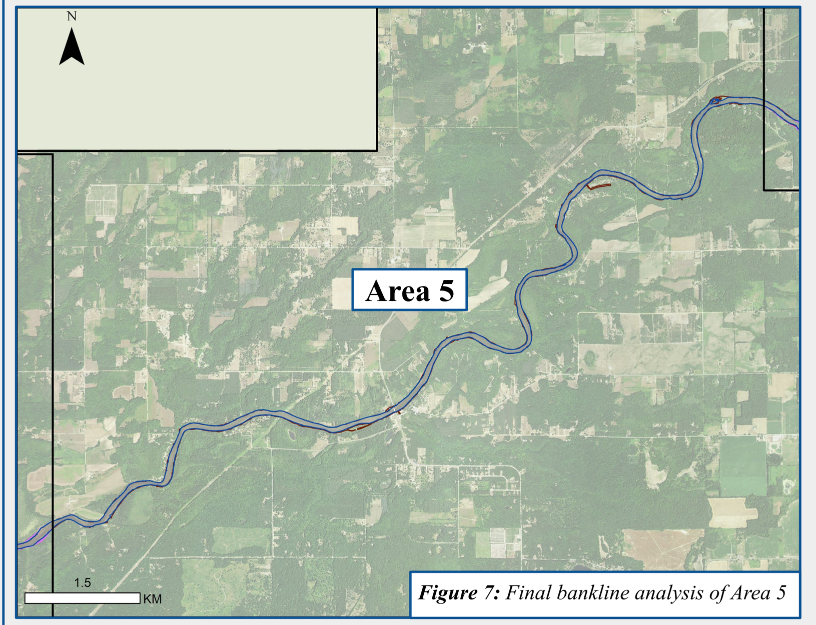

Figure 7: *Final bankline analysis of Area 5*

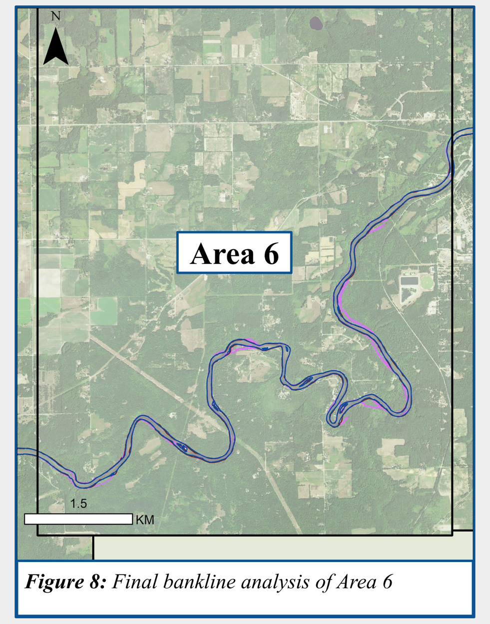

Figure 8: *Final bankline analysis of Area 6*

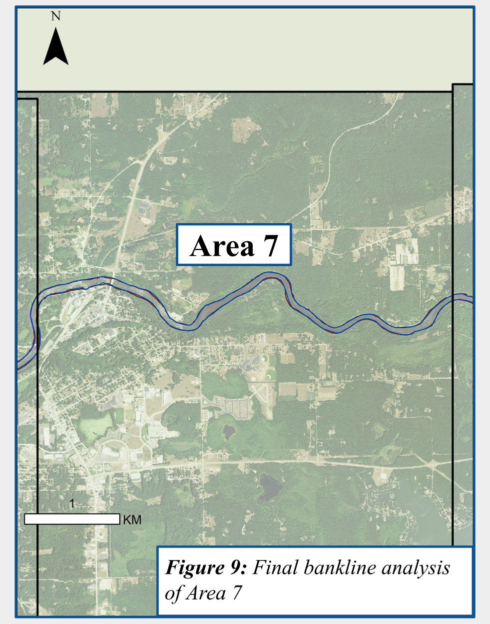

Figure 9: *Final bankline analysis of Area 7*

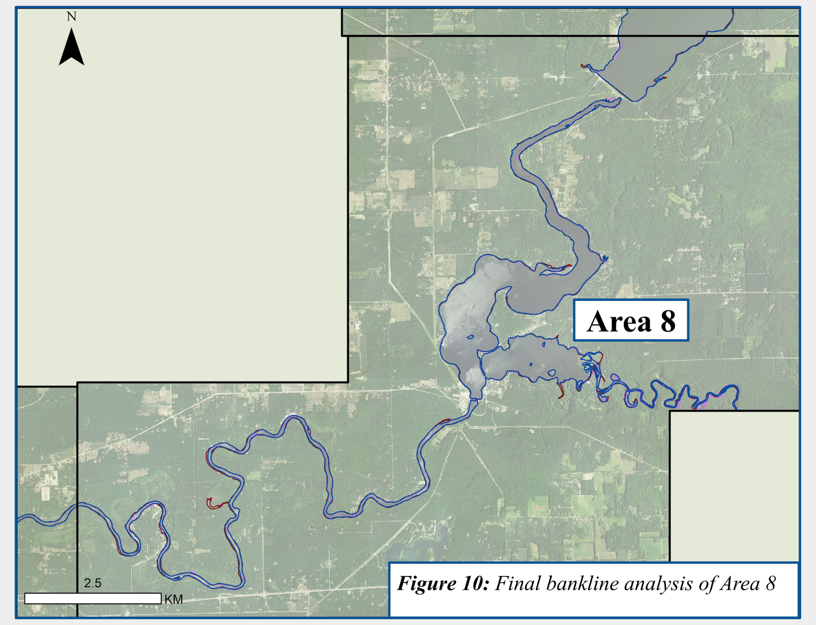

Figure 10: *Final bankline analysis of Area 8*

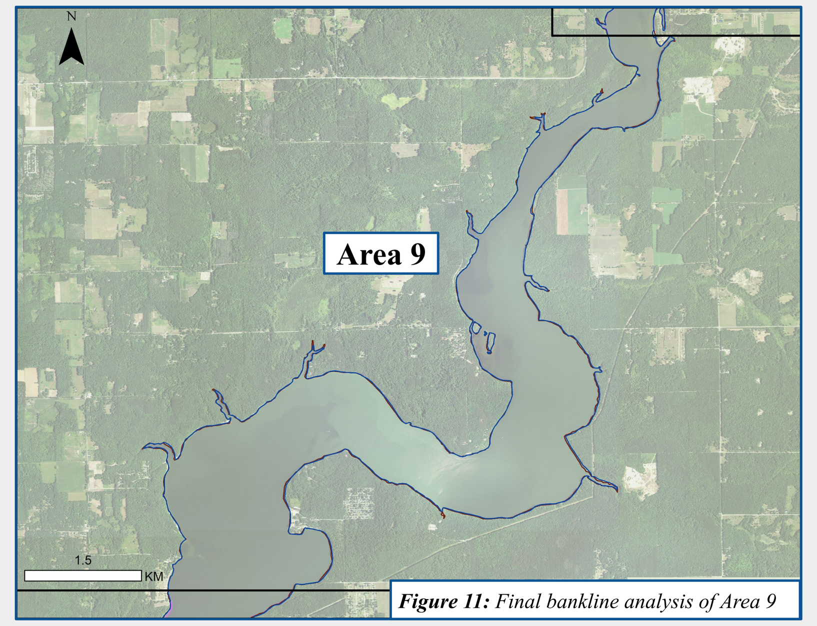

Figure 11: *Final bankline analysis of Area 9*

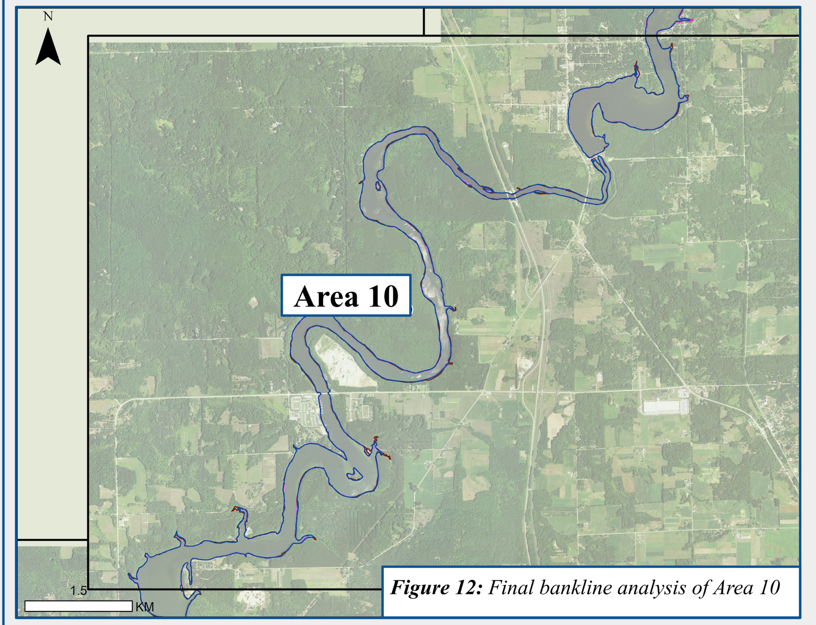

Figure 12: *Final bankline analysis of Area 10*

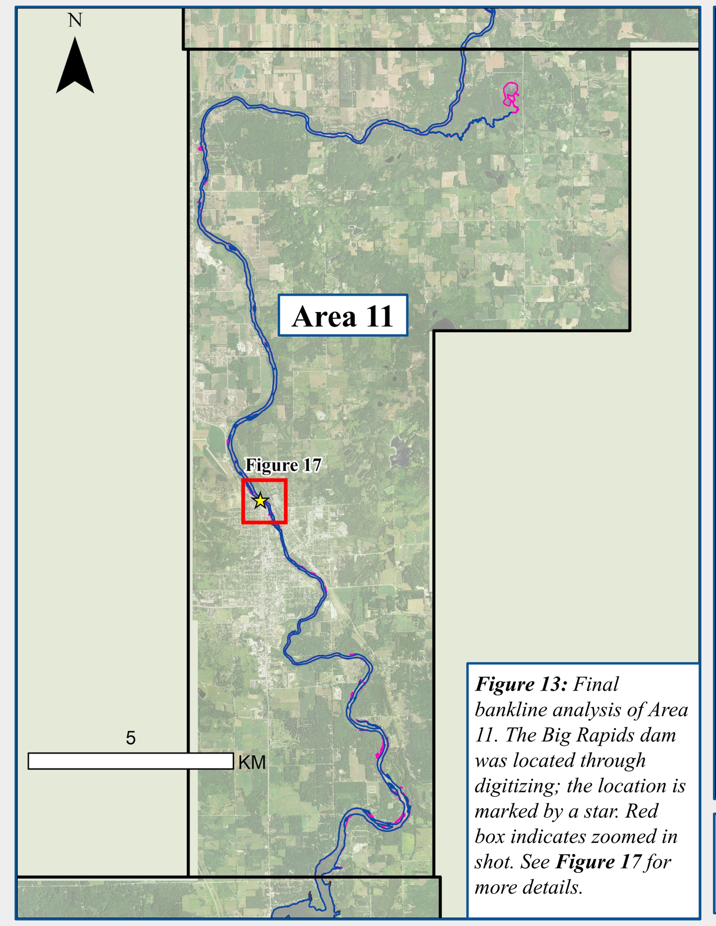

Figure 13: *Final bankline analysis of Area 11. The Big Rapids dam was located through digitizing; the location is marked by a star. Red box indicates zoomed in shot. See* ***Figure 17*** *for more details.*

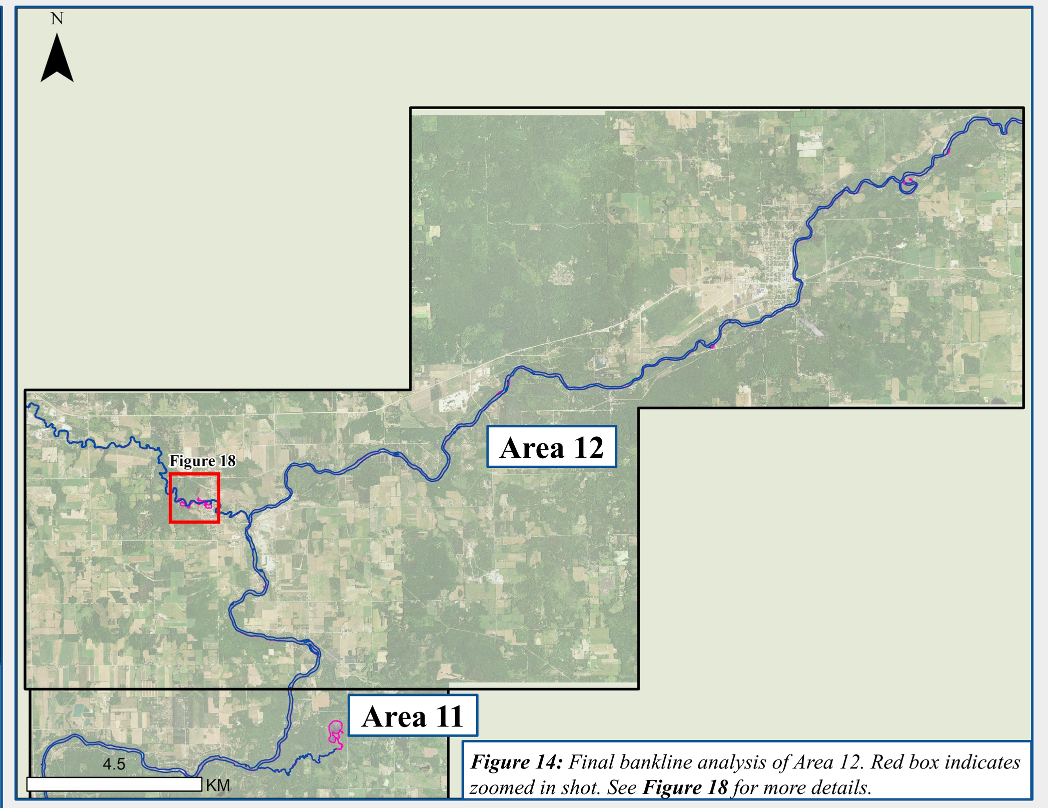

Figure 14: *Final bankline analysis of Area 12. Red box indicates zoomed in shot. See* ***Figure 18*** *for more details.*

Legend for Bankline Maps

Banklines Year — 1993 — 1994 — 1997 — 1998 — 1999 — 2000 — 2008 — 2016 Sectioned Study Areas Michigan

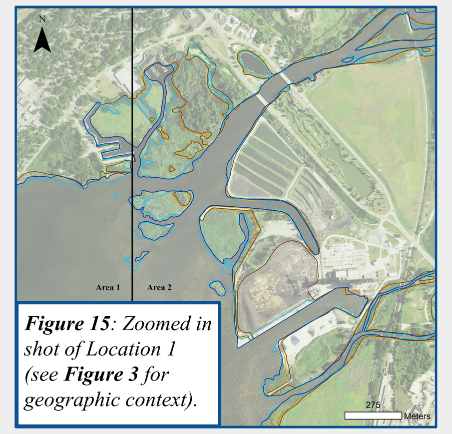

Figure 15*: Zoomed in shot of Location 1 (see* ***Figure 3*** *for geographic context).*

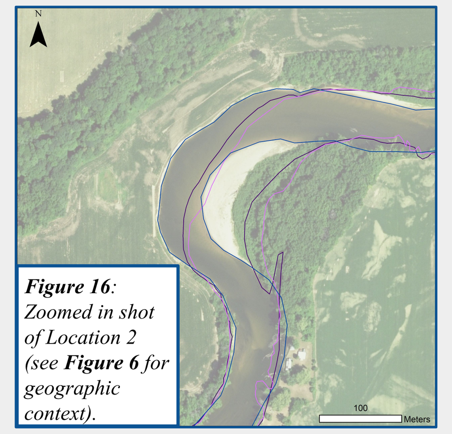

Figure 16*: Zoomed in shot of Location 2 (see* ***Figure 6*** *for geographic context).*

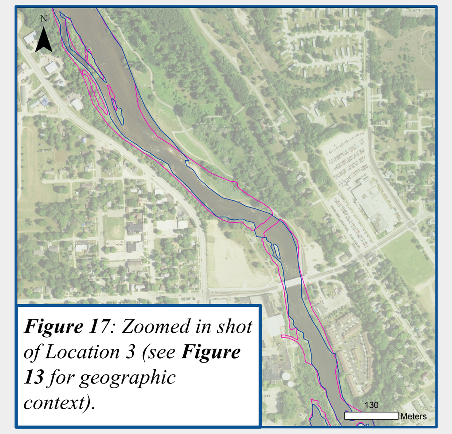

Figure 17*: Zoomed in shot of Location 3 (see* ***Figure 13*** *for geographic context).*

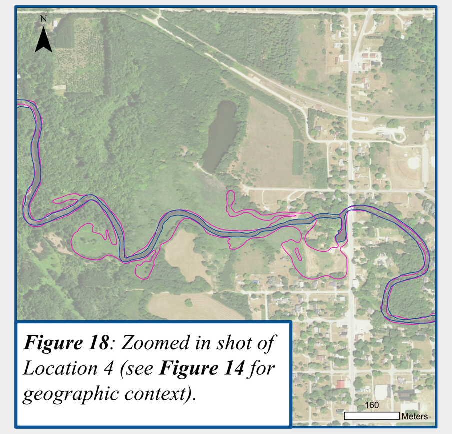

Figure 18*: Zoomed in shot of Location 4 (see* ***Figure 14*** *for geographic context).*

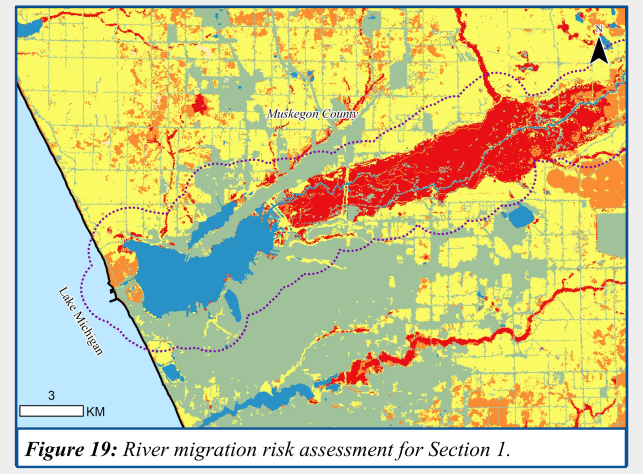

Figure 19: *River migration risk assessment for Section 1.*

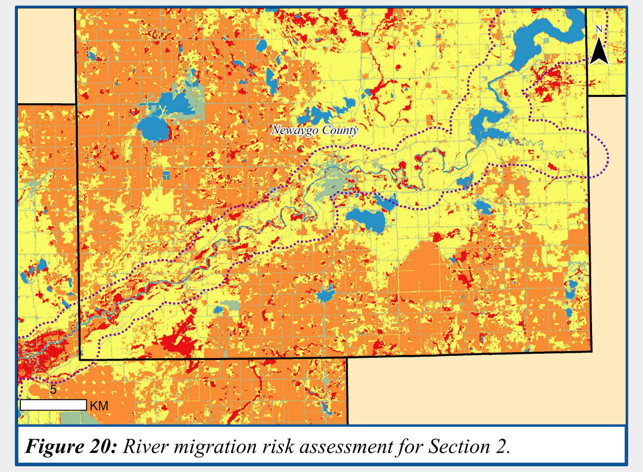

Figure 20: *River migration risk assessment for Section 2.*

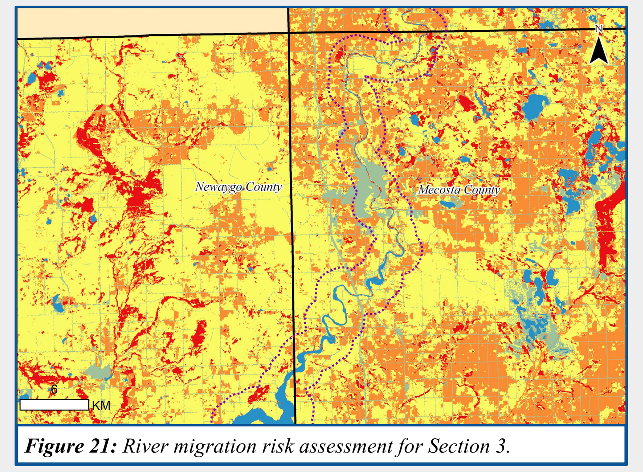

Figure 21: *River migration risk assessment for Section 3.*

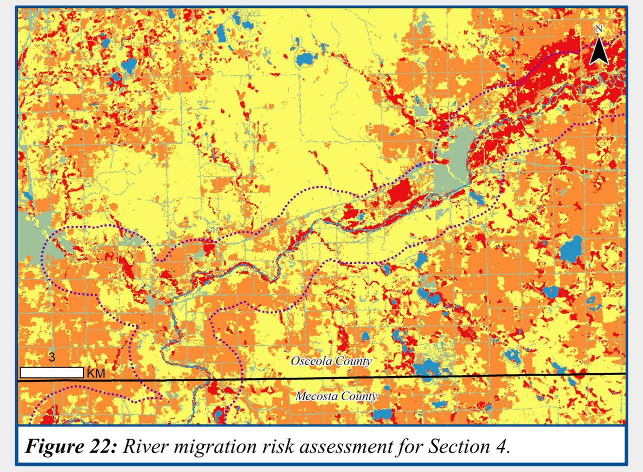

Figure 22: *River migration risk assessment for Section 4.*

Legend for Risk Assessment Maps

Risk Value
- Low
- Low - Intermediate
- Intermediate
- Intermediate - High
- High

Study Area
Selected Study Counties
Michigan

Discussion

Muskegon County

Muskegon county experienced periods of flooding, which allowed the river and its tributaries to spread out within the extent of the floodplain. However, within the 2008 and 2016 images, flooding was not as apparent, and channels were better defined within the floodplain. Within Muskegon Lake, small islands have grown from the outlet of the Muskegon River. From the risk assessment (**Figure 19**), these islands are unstable and prone to change, likely growing in size due to increase in sediment supply. This growth is theorized by change observed in the past (**Figure 15**).

Newaygo County

While digitizing the aerial images in this county, the majority of the observable change was around Area 4. One of the bends in the river changes drastically from 1993 to 2016 (see **Figure 16**). The river cuts into the bank by about 60 meters. The water level appeared to either drop or a larger amount of sediment was being transported in the river. This change could be due to the Big Rapids/Newaygo dam(s) being taken out between these time frames. A lot of islands from 1993 merged into the shoreline in 2016. The western side of Area 8 had a fair amount of sediment deposited. Croton Lake has significant change on the southeastern shore by the outlet of a tributary. From the risk assessment (**Figure 20**), nearly all of the bends in Newaygo county are of high risk, which fits with prior evidence of numerous oxbows along the river.

Mecosta County

While digitizing the aerial images in this county, observable changes were noticed in Area 11, but essentially remained the same. The southern part of Area 11 has a river bend where a significant amount of sediment was deposited from 1998 to 2016 and added/subtracted sediment to the islands that existed prior. Just north of where the Big Rapids dam was located, sediment had been added on the shoreline (due to drop of water level) (see **Figure 17**). The risk assessment (**Figure 21**) shows high risk in these areas as well as the tributary in the northern part of Area 11.

Osceola County

While digitizing this county, there was little observable change that occured between 1998 and 2016. One area near the diversion of the river to the west had significant change where the river changed from high sinuosity to low sinuosity (**Figure 18**). Overall, the area remained fairly stable; this is possible because a dam has not been added/removed upstream or in the county. **Figure 22** shows the risk assessment.

Conclusions

From the results of the analysis, the removal of the dams in Newaygo and Big Rapids have caused a noticeable impact on the dynamics of the river. Areas that are very urbanized will likely take more precautions to control the river dynamics, consequently, areas downstream that are less urbanized have more opportunity to meander. Three remaining hydroelectric dams have been established for many years, the environment has become accustomed to them, therefore the removal of any of these dams would cause a chain reaction of changing river dynamics that could severely impact those along the river. The farther downstream, the less likely it will impact developments along the river. With further monitoring and research, proper precautions can be taken to further protect developed land and prevent building in areas that are projected to be at risk of erosion.

References

Arbogast, A. F. et al. (2008). Post-glacial fluvial response and landform development in the upper Muskegon River valley in North-Central Lower Michigan, U.S.A. Retrieved March 5, 2017, from https://www.sciencedirect.com/science/article/pii/S0169555X08002869

Michalek, M. J. (2015). Historic channel changes in the Muskegon River, North-Central Michigan, USA. Retrieved March 5, 2017, from https://msu.edu/~michal76/research/MuskegonRiverPOSTER.pdf

Data Sources

Land cover/Land Use: US Geological Survey
Aerial Imagery: US Geological Survey Earthexplorer
Soil Survey Data: US Department of Agriculture Web Soil Survey
Geographic Data Files: ESRI Online Database

Acknowledgements

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