A FLOODPLAIN MINING AND CHANNEL CHANGE ANALYSIS OF THE TANGIPAHOA RIVER, LOUISIANA USING GIS: 1980 - 2004

By

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A THESIS PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
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To my wife, Cristina

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Sand and gravel mining in floodplains is widespread in Louisiana and can often result in changes in channel planform and position. The purpose of this study was to determine whether or not sand and gravel mining and river channel change are statistically linked over two time periods: 1980 and 2004. The area of focus was the Tangipahoa River, located in southeast Louisiana. This particular river was chosen due to its extensive sand and gravel mining operations within its floodplain.

The 2004 time step imagery was Digital Orthorectified Quarter Quadrangles (DOQQ) downloaded from Louisiana's ATLAS website. The imagery for the 1980 time step was USGS 1:24,000 DRG's which was downloaded from the aforementioned website. Using GIS, two different geodatabase's (GDB) were created for each time step. These GDB's contain feature classes that represent the Tangipahoa's centerline, main channel, point bars, cleared land within the floodplain, and sand and gravel pits. In ArcMap, each feature was digitized on top of the corresponding imagery. All features were digitized at a scale of 1:2,000. This allows for accurate digitizing without causing the imagery to become pixilated. Old and new feature classes can then be superimposed on each other to visualize the changes that have occurred near and on

this river over the 24 year period. The resulting data can be used to assist in river rehabilitation. The data can also be used to show the effect that sand and gravel mining can have on a river and its major parts.

To determine whether or not there is a statistical relationship between sand and gravel mining and channel change, Spearman's Rank Correlation Coefficient was utilized. Many mining and point bar variables were found to be positively correlated including both negative and positive lags. The new point bar area lags were strongly correlated with mining variables, while the new number of point bar lags showed weak or no correlation. The newer mining variables were typically more strongly correlated with channel change variables opposed to the older mining variables.

Point bar area and number has increased over the 24 year period, indicating instability in the river system. An increase in mining and stream power compared to 1980 could be the cause, introducing more sediment into the river creating larger and more point bars. This research could lead to less invasive mining practices and a greater awareness regarding environmental restoration to the Tangipahoa River and its floodplain.

CHAPTER 1
INTRODUCTION

Extraction sites for aggregate resources occur in uplands, river floodplains, and in-stream for most of the United States. The Tangipahoa River in southeast Louisiana is no exception, especially in its middle and upland reaches. The Tangipahoa basin is a site of both wet and dry mining. Dry mining (open pit) occurs in the upland areas of the river where the water table is located below the base of the pit. Wet mining takes place in the midland settings where dredges are used to mine the sediment from the river's floodplain paleochannels (Mossa and Autin 1998). Sand and gravel mining has occurred on this river for many decades, potentially causing the channel to meander and sandbars to change in size as sediment is removed or added to the system (Mossa and Autin, 1998).

Sand and gravel mining can have negative effects on both ecological and geomorphic aspects of river systems. The reduction of sediment through in-stream mining can cause upstream- and downstream-progressing river incision, lateral channel instability, and bed armoring. Degradation or even total loss of aquatic and riparian habitats can also occur from sand and gravel mining (Rinaldi, 2005).

The most obvious and possibly largest changes to a river system are planform changes. These types of changes can greatly impact the frequency of floodplain inundations, lower the valley-floor water tables, and cause instability or even destroy bridges and channelization structures (Rinaldi, 2005). Profile changes include channel migration, an increase or decrease in the number and size of point bars, and the erosion of channel banks (Mossa, 2004). As a result of these geomorphic changes the hydrology of the river system is also altered. Mining can remove bed material from rivers, thus causing degradation. This can create a phenomenon known as head cutting that can have an effect upstream for many kilometers (Rinaldi, 2005). An increase in sediment load can result in aggradation downstream, and channel capacity will decrease causing flooding to become more widespread (Mossa, 1995).

Objectives

The main reason for this study was to determine what effects sand and gravel mining had on the Tangipahoa's geomorphology. The first objective of this study was to see if reaches that had heavy mining had greater rates of channel change. The next objective was to determine whether or not mining had an effect on sand bar frequency and size change.

These objectives were accomplished by studying the Tangipahoa over a 24 year period. This helped determine whether or not there was a relationship between sand and gravel mining and channel change. It is believed that there is a statistical relationship between sand and gravel mining and the morphological changes that the Tangipahoa River has undergone over the 24 year period. This relationship can be investigated through both spatial and temporal analyses.

The findings of this study can serve a wide purpose for state governments and other management agencies. Results from this study could possibly lead to better mining practices, such as developing policy about the more egregious practices and exploration for future mining sites. There is a great economic benefit and need for sand and gravel mining, but more scientific information is required to better understand the environmental effects and the economic benefits of mining.

Study Site

The Tangipahoa River stretches 177 kilometers total (127 km in Louisiana) from its headwaters in southeastern Mississippi and flows south towards Lake Pontchartrain (Figure 1-1) in southeastern Louisiana (Environmental Protection Agency, 2005), with a drainage basin of 878 km^2 in Louisiana (Figure 1-2). The Tangipahoa River runs through the Tangipahoa Parish, passing closely by its major city, Hammond. Elevations in the Tangipahoa Parish range from 82 m in Spring Creek to 0.9 m in Ponchatoula (USGS, 2009). The average annual precipitation for the area of study is approximately 1,676 mm with floods mainly caused by frontal systems, convective storms, tropical storms and hurricanes (Louisiana Office of State Climatology, 2000).

The Tangipahoa River floodplain is comprised mainly of Alluvium, which is highly suitable for sand and gravel mining operations. Areas of Alluvium have water tables near the surface where certain areas can contain abundant deposits of gravel (Mossa and Autin, 1998). This alluvium contains gravels reworked from the Pliocene-Pleistocene Citronelle formation, which comprises much of the basins uplands.

The area of focus for this study started at the Kentwood gage station to 7 km south of Interstate-22. From this point on mining is very scarce due to decreases in bed material size in modern and ancestral river deposits (Mossa and Autin, 1998). The United States Geological Survey (USGS) has three continuous gaging stations located in Kentwood, Amite, and Robert, Louisiana. The Robert gage station was used for discharge data since it was the only station that had data from the 1980’s. Aggradation of 0.75 to 1 meter was found at this station between 1982-1994 (Wilder, 1998). The Tangipahoa’s River basin mainly consists of riparian forests and agricultural land, dotted with small urban areas.

The Tangipahoa was once considered a polluted and impaired river due to high levels of animal and human fecal matter runoff. Thanks to 20 years of river clean up and strict enforcement against dumping, the Tangipahoa has been taken off the list of impaired waters by the National Resources Conservation Service and now supports both primary and secondary contact recreational uses (NRCS, 2005).

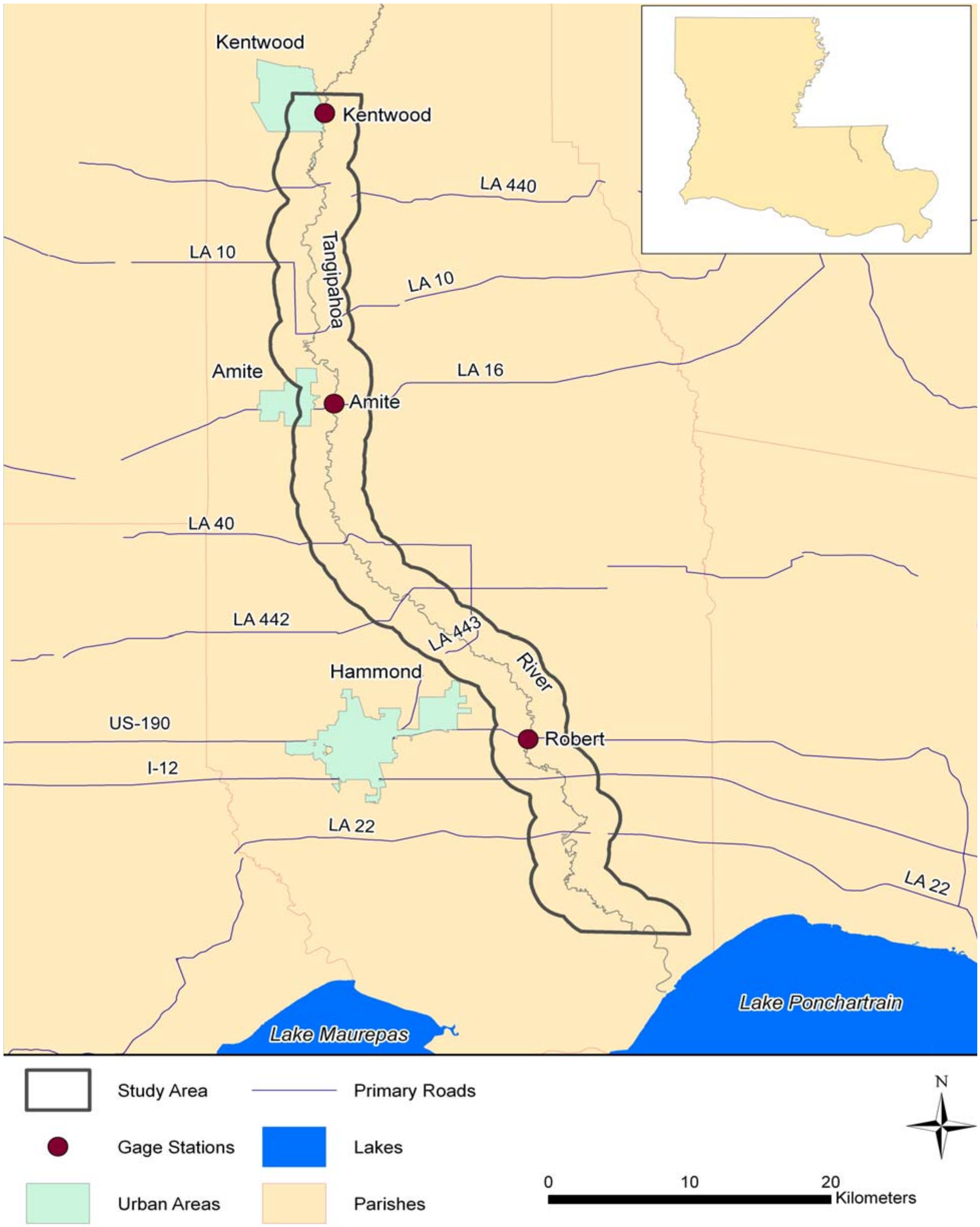

Figure 1-1. Tangipahoa River site map

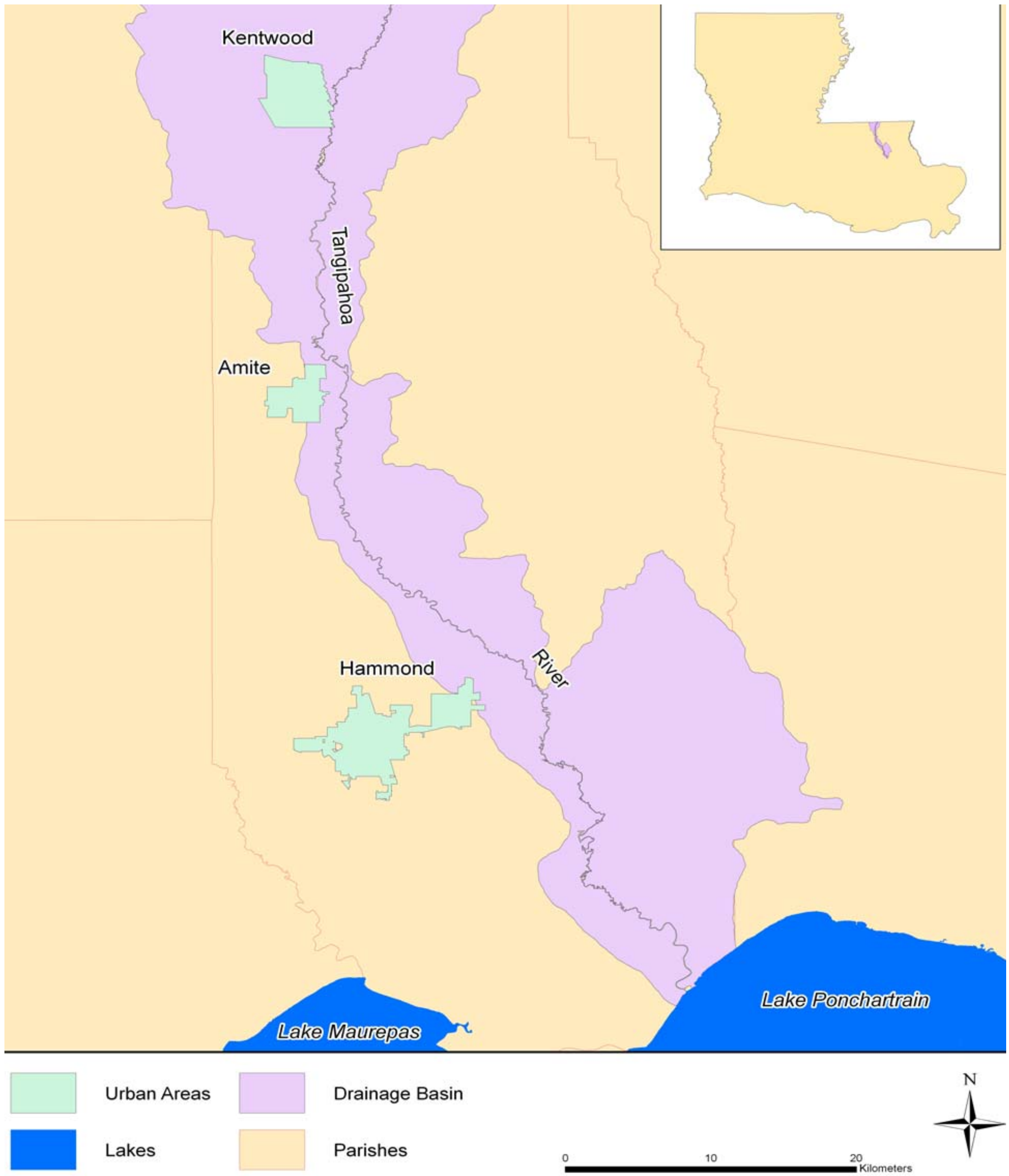

Figure 1-2. Tangipahoa River drainage basin

CHAPTER 2
LITERATURE REVIEW

Sand and gravel is used in many everyday materials and applications, ranging from roads to building materials. This type of mining is very common near alluvial systems. For millions of years, vertical and lateral erosion within a river's floodplain has reworked gravel-bearing deposits such that modern alluvium contains an abundance of sand and gravel (Rinaldi, 2005). These resources are dominantly located in or near river channels, which then become sites for mining. Sand and gravel mining could have a negative effect on an alluvial system. These effects range from a change in the sediment budget, lateral migration of a river channel, or effects on the aquatic and vegetative habitats (Rinaldi, 2005). Some states, such as Arkansas and Missouri, have placed restrictive laws on sand and gravel mining. In Arkansas in particular, mining permits must be obtained from the Surface Mining and Reclamation Division, part of the Arkansas Department of Pollution Control and Ecology (ADPCE). Permitted mining can be conducted in upland areas where in bank sand and gravel deposits occur below high-water marks. Six requirements must be met in order to attain a permit: Proof of right to mine land, a mining plan, and a reclamation plan to name a few (Rogue Valley Council of Governments, Oregon, 1997). Laws in Louisiana for sand and gravel mining are loosely enforced compared to the two aforementioned states. Projects like this could help push Louisiana and other state governments to increase regulations on the sand and gravel mining industry.

With sand and gravel mining continuing to occur in or near rivers, questions about its physical and environmental effects have increased. In the 1950s and 1960s, sand and gravel mining occurred almost exclusively from the point bars and channel bottoms within the river itself. More recently, mining has occurred on adjacent floodplain surfaces and low terraces, where practices have included removal of vegetation and fine-grained overburden, and digging of pits and ponds (Mossa and Autin, 1998). These types of practices can greatly affect a river physically, ecologically, and environmentally (Rinaldi, 2005).

Sand and gravel mining within a river system is very popular for two major reasons; first, in-stream gravel acquired from an active channel are especially important because river transport removes weak materials by abrasion and attrition. The remaining aggregate are a higher quality: durable, rounded, well-sorted, and relatively free of interstitial fine sediment (Kondolf, 1994). Active channel sediments can be easily quarried (deep quarrying is not necessary), require very little processing, and are periodically replaced from upstream during high flow events (Rinaldi et al., 2005). If mining equipment can stay in one place for a longer period, it saves time and money. These areas of mining are also often located closer to markets that use the aggregate or are close to transportation routes, again saving money (Kondolf, 1994). However, the costs to the environment from in-stream mining are often not factored into production costs, making in-stream aggregate more economically attractive compared to other alternatives (dry terrace, quarries, or distant sources) (Kondolf, 1994). This makes aggregate mining a very cost effective way to acquire resources for many different types of commercial projects.

The forms of sand and gravel mining with the most potential to affect a river system include floodplain and in-stream mining. Floodplain mining occurs in pits, which are areas where floodplain vegetation (usually bottomland forest) and an overburden consisting of more organic and fine materials than beneath have been removed. The sand and gravel are removed from these pits that essentially leave large holes next to the river. In-stream mining is the extraction of sediment from an active channel's bed, often by heavy machinery (Kondolf, 1997). Both of these practices have detrimental effects on the river itself and the floodplain that borders it.

Floodplain mining has occurred for decades along the Tangipahoa River. Records kept beginning in 1932 indicate that gravel has been the most popular aggregate mined from the Tangipahoa floodplain. The largest amount of gravel removed occurred in 1967, with 1,419,433 tons extracted. The largest amount of sand was removed in 1974, with 921,230 tons extracted. The majority of sand and gravel mining took place between the years of 1953-1983 with a steep decrease in production bottoming out in 1992 with almost the same amount of production for both types of aggregate (Figure 2-1). There is a data gap between 1992 and 2004 due to the repeal of a sand and gravel tax. The tax was reinstated for sand in 2005, but not for gravel (Louisiana Department of Revenue). This process occurs by extracting sand and gravel from pits along active floodplains or adjacent river terraces. For the Tangipahoa the mining pits are wet which occurs when the pit is below the water table (Kondolf, 1994). These pits tend to be located right next to the river. During flood events or lateral channel migration, these pits can be breached and can become part of the river channel (avulsion or pit capture). As a result these pits become in-stream and can cause similar issues as in-stream mining, such as headcutting (Kondolf, 1997). These pits, lying close to the river, can often intersect the water table essentially contaminating the aquifer (Rinaldi et al, 2005), although this is not the case for the Tangipahoa since the aquifer is significantly lower than the depths of the pits. In areas that have heavy floodplain mining, it has been seen that channel length can be shortened (Mossa, 1983).

Other geomorphic changes to the river can occur both upstream and downstream. Some of these changes are riverbank erosion, cutoffs, avulsions, aggradation and degradation (Mossa, 1995). In areas of aggradation, channel capacity is decreased due to an increase of sediment from erosion which can lead to large scale flooding and increased point bar area and numbers. Sediment transport is a slow process and can be deposited on the channel beds, banks and bars, and can remain in place for highly variable time periods until they are remobilized and moved further downstream (Jacobson et al, 1999). Degradating reaches have an increased channel capacity leading to erosion that can undermine bridges, pipelines, and other structures. Implications to humans can range anywhere from property loss, land disputes, and increased taxation. These issues can become expensive and a risk to public safety (Mossa and Autin, 1998).

In-stream gravel mining is done with heavy machinery, such as dredges, and involves the removal of sand and gravel from active river channels and streams. This removal can occur using two different methods; excavating trenches or pits in the gravel bed, or by gravel bar skimming. Bar skimming withdraws sediment from the transport system altering the supply to downstream reaches. Although volumes of sediment are typically smaller than pit mining, profound effects can still occur to aquatic habitats downstream (Kondolf, 1997). Active channel deposits are favorable for construction projects because they are typically durable, well-sorted, and are normally near markets or transportation routes, thus lowering costs (Kondolf, 1994). In-stream mining can directly alter the channel geometry and bed elevation and may involve extensive clearing, diversion of flow, stockpiling of sediment, and excavation of deep pits (Sandecki, 1989). The removal or introduction of sediment to a system due to sand and gravel mining can greatly alter a river's geomorphology. When sediment has been removed from an active channel due to in-stream mining, a river's transport capacity will increase causing bed erosion, a process referred to as headcutting or knickpoint migration (Kondolf, 1994). These affects can be seen for miles upstream. Incision can also occur downstream causing massive erosion which could affect the frequency of floodplain inundation along the river courses, lowering valley floor water tables, and frequently leading to the destruction of bridges and channelization structures (Rinaldi, 2005).

In-stream mining also introduces major environmental issues to a river system. With the removal of sediment, erosion can become widespread and cause loss of land and wooded areas. The loss of aquatic and riparian habitats can also result from in-stream mining (Sandecki, 1989).

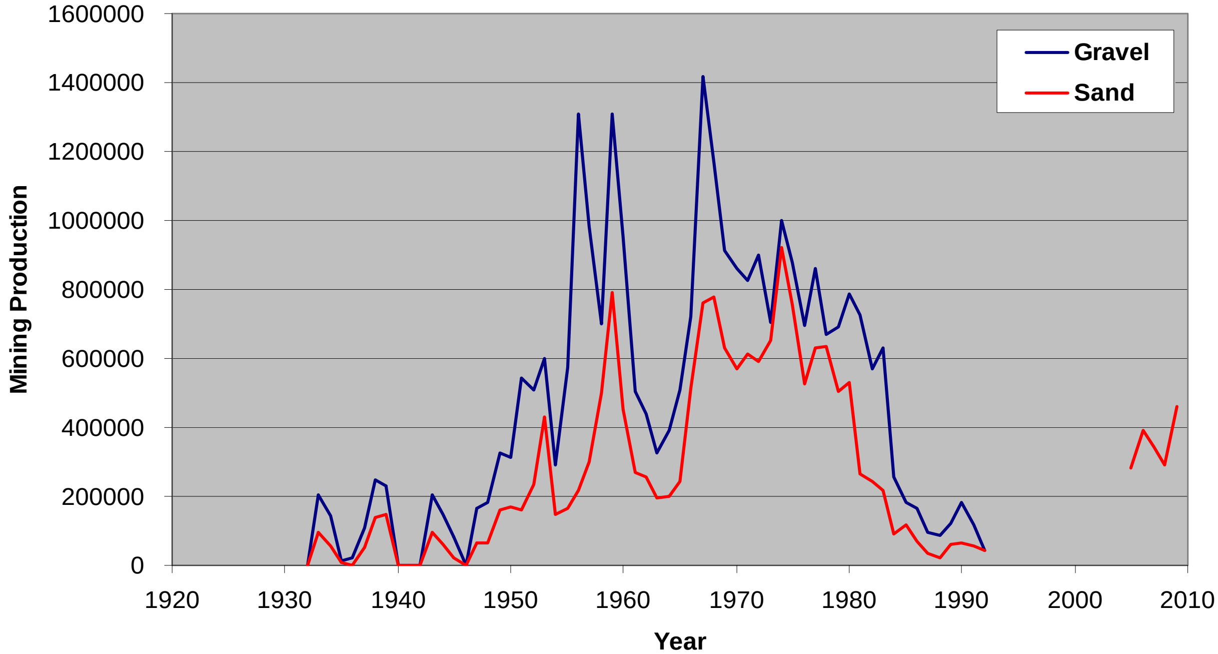

Figure 2-1. Sand and gravel mining production on the Tangipahoa, 1932-2009.

CHAPTER 3
METHODS AND MATERIALS

Certain methods for this thesis were adopted from the theses of Ursula Garfield and April Hendrix-Davis thanks to similarities between these three projects. Geographical Information Systems (GIS) was an integral part of this project. A 1998 time step was also considered, but there was a close similarity between the1998 and 2004 main channel, mine pits, and sand bars. As a result, the 1998 time step was not used. Vector GIS was used for the spatial analysis thanks to its accuracy when delineating centerlines, main channels, mine pits, and point bars. Vector GIS is also advantageous when calculating abnormal polygons, i.e. mine pits. These vector features from each time period were overlaid and analyzed to determine the changes that the Tangipahoa has incurred. Excel and the Sigma Stat 3.1 were other types of software that were used for quantitative analysis. Excel was used to create spreadsheets and graphical displays. Sigma Stat 3.1 was utilized to carry out the statistical analysis.

The imagery was downloaded from Louisiana's ATLAS website: The Louisiana Statewide GIS (LSU, 2009). Digital Orthophoto Quarter Quadrangles (DOQQ's) were downloaded for the 2004 time step. Imagery acquisition dates for the 2004 imagery varied from May 11th to May 23rd, 2004. Each image covers an area of 4 miles wide by 4.5 miles in the north/south direction. Images have been acquired using color infrared with a horizontal accuracy of approximately three (3) feet (ATLAS) and a scale of 1:12,000 (1 inch = 1,000 feet) with an inherent error of 10m for length and 100m^2 for area (USGS). As for the 1980 time step, no DOQQ's were available. Instead, USGS Digital Raster Graphics were used (ATLAS). DRG's are scanned images from USGS topographical maps and georeferenced to the earth's surface and fit to the UTM projection (USGS). These DRG's are 7.5' quadrangles at a scale of 1:24,000 (1 inch = 2,000 feet) acquired from aerial photography taken between the dates of January 12^{th} to January 27^{th}, 1980. The DRG's have an inherent error of 12.2m for length and 148.84m² for area (USGS). The DOQQ's, DRG's, and feature classes share NAD 1983 UTM Zone 15 North as their spatial reference. The images were used to determine the location of mining and channel change variables and to determine how much the Tangipahoa has moved over the 24 year period.

Discharge data was acquired from the USGS for three gage stations: Kentwood, Amite, and Robert, Louisiana (USGS, 2009). Kentwood is the northernmost station but has no discharge data recorded. The Amite gage station is in the center of the study area and also has no discharge data. The Robert gage station is the southernmost station on the Tangipahoa, and was the only station that had discharge data starting in 1938. Discharge data was included for the Robert gaging station from 1938-2004 with the flood stage of 5750 ft³/sec (Figure 3-1).

Geographic Information Systems

All of the vector-based data creation and analysis occurred in the ESRI ArcGIS software suite. Two different geodatabase's were created for each separate time step. Each geodatabase contained feature classes to represent the variables that were digitized. The feature classes that were created were the river centerline, main channel, point bars, sand and gravel mining pits, and bare area. All relevant information (shape length, shape area, reach block ID for example) were saved in attribute tables that correspond with each feature class. The number of gravel pits, for example, was determined by using these attribute tables. Gravel pits from each time step can be compared to determine whether the amount of gravel pits have increased, decreased, or stayed the same.

The main channel of the Tangipahoa was digitized separately for each timestep. This gave the river's width which allowed for analysis based on area. The scale at which the main channel was digitized was 1:2,000 for DOQQ's. This scale provides detail of the channel without being zoomed out too far where important features could be missed. DRG's were used to digitize the main channel for the 1980 timestep.

Next the river's centerline was digitized separately for each time step using the midpoint tool. With snapping turned on, a vertex would be placed on one side of the river polygon followed by a vertex on the opposite side. A vertex would be dropped in the center of the two other vertices. This process would be continued for the entire river linking each center vertex, thus creating the centerline. The centerline is important in creation of the widths of each transect and lateral migration rates.

Point bars were the next feature to be digitized. They were represented on the DRG's by white areas outlined by brown dots. These were digitized as polygons and snapped to the main river channel. On the DOQQ's, the point bars were often found in the river bends and were identified by sandy areas. These digitized polygons were also snapped to the river channel to ensure no overlap or gaps between polygons.

After the point bars were digitized, polygons were created to capture mine pits and bare area. These areas on the DRG's were normally demarcated by blue and white areas representing mine pits and cleared land respectively. In some cases, a mining symbol (crossed shovels) was present. Areas without the symbol were mapped by interpretation, estimating where the pits and cleared land were. Mining pits that occurred in the floodplain were delineated by contour lines and accompanied by the words “sand and gravel pits.” On the Tangipahoa the majority of these pits were filled with water. On the DOQQ’s, aerial photo interpretation guided the digitizing of bare area and mining pits. The bare area appeared to be cleared, sandy land next to the mine pits with high reflectance. The boundaries of the sandy areas were digitized right up to the areas of vegetation. The mine pits, which in most cases bordered the bare area, were digitized to the extent of the water that filled them. All areas for mine pits and point bars were rounded to the nearest hundredth to account for the inherent error that occurs in the DRG’s and DOQQ’s.

As previously mentioned feature classes were created for both sand and gravel pits and bare area. These were digitized to determine if avulsions or captures had occurred. Avulsions occur when a newer channel has intersected an earlier sand and gravel pit. Avulsions are discovered by simply comparing older sand and gravel pits to the newer channels. If they intersect at any point an avulsion had occurred and a point was placed on that particular spot in ArcMap. Corresponding attributes were created with each point describing if the avulsion happened inside or outside the meander bend. Avulsions can be caused by lateral migration, channel widening due to in-stream mining, or flood events.

To compare the digitized shapefiles from the two time steps, they were converted into feature classes in a personal database. This process must be done in a personal geodatabase in order to create relationships between feature classes, generate and run topology rules (Table 3-1), and to calculate the area of each polygon. Topology rules were used to ensure that there were no gaps or overlaps between particular feature classes.

Once the previous actions have been completed, a valley centerline was generated based off the flow direction of the main channels. This centerline was needed to create transects that run perpendicular to the river's flow. These transects were spaced at a distance of 1 kilometer for the entire length of the river. The width of each transect was determined by using equation 3-1:

Width = Area/Channel Length Centerline (eq. 3-1)

The river channel and centerline was intersected by the transect feature class to calculate area and channel length by transect. This feature class was created using the measure tool. A point was added on the centerline for every kilometer until the end of the river was reached. Next, lines were manually added at each point to create reach blocks. If a transect crossed the river centerline at more than one point, the transect was moved slightly up or down along the centerline. These transects allow for the summarization of certain areas and indices by reach (Figure 3-2).

Change Indices

To analyze the Tangipahoa's channel change, four indices were created. First, the main channels from each time period were combined in ArcMap using the union tool. This tool computes a geometric intersection between the two main channels. The "no gaps" check box located in the tool menu must be checked in order to create the between area index. Once the channels were combined, the four indices were created. This was done by loading the unioned main channel feature class into the single to multi-part tool. This explodes the unioned main channel feature into single polygons. The features and attributes of the main channels were stored in the new output feature class. These indices represent how the river channels have changed over time. If the channel crosses at the same point during both time steps, the index was labeled as unchanged (U). The new channel area index value was labeled as erosion (E). The third index value represented the old channel, which was labeled as deposition (D). The fourth and final index will represented the area that is between the old and the new channels, and was labeled as area in between (B). Any area that fell outside the unioned main channel was labeled as other (O) (Mossa, 2006) (Figure 3-3 and Table 3-2).

Average Lateral Migration

The average lateral migration was calculated in ArcGIS using the centerline shapefiles of the two time periods. The feature to polygon tool in the Data Management toolbox was used to create new polygons between the two centerlines. New fields were added and calculated for shape length and area of the polygons. This new polygon shapefile was then intersected by the transect shapefile to split the polygons by reach block. This data were then exported and sorted in Excel. Using equation 3-2, The migration rates were then calculated by dividing the area of the polygon by the perimeter of the two centerline lengths, and then divided by the difference in years between the two time steps:

$$\text{Lateral Migration} = (A/L)/24 \quad \text{(eq. 3-2)}$$

The results were then graphed in Excel. These methods were drawn from Larsen et al. 2006.

Average Channel Width

The average channel width was calculated by dividing the area of the main channel by the length of the centerline. Both of these features were already digitized, but were exported to new shapefiles to keep the integrity of the original shapefiles. Both shapefiles were then intersected with the transect shapefile to divide the main channel and centerline by reach. The “calculate geometry” feature was again used to calculate both the length of the centerline and the area of the main channel. These attributes were then exported, sorted, calculated, and graphed using Excel.

Point Bar Area

Point bar area (m^2) was calculated using the “calculate geometry” feature in ArcGIS located in the attribute table. The point bar shapefile was then intersected with the transect shapefile in order to identify which point bars occur in which reach. This data was then exported to Excel and sorted by reach then by area. Point bar area, number of point bars, and cumulative point bar area were all calculated and graphed vs. reach block number.

Mining Area

Mining area was the sum of mine pits and bare area. The methods used to digitize and calculate mine pits and bare area were identical to point bar area.

Statistical Analysis

In order to determine if channel change and mining activity are statistically linked, a measure of correlation must be used. Since the data wasn’t normally distributed, Spearman’s Rank Correlation was chosen because it is a non-parametric statistic (Earickson and Harlin, 1994). Spearman’s Rank Correlation equation 3-3:

$$\rho = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)} \quad \text{(eq. 3-3)}$$

In order to run this statistic, all data from ArcMap were imported into Microsoft Excel then sorted. Next, the data was imported into Sigma Stat 3.1 software which was used to calculate the Spearman Rank Correlation. Since tied ranks can occur in the Spearman Rank Correlation, an adjustment for ties was implemented. Values in the Spearman Correlation can range from (-1) to (+1). Rank values that are close to (-1) indicate a complete discordance. Rank values close to a (+1) indicate a complete concordance. Rank values that are close to (0) indicate little or no relationship between the two variables that are being compared. The rank correlation was run on all variables that may be linked by physical processes. Below are the variables that were compared:

- New Pit area vs. Between area
- New Pit Area vs. Old Channel Area
- New Pit Area vs. New Channel Area
- New Pit Area vs. Overlapping Old and New Channels
- New Number of Pits vs. Between Area
- New Number of Pits vs. Old Channel Area
- New Number of Pits vs. New Channel Area
- New Number of Pits vs. Overlapping Old and New Channels
- New Mining Area vs. Between Area
- New Mining Area vs. Old Channel Area
- New Mining Area vs. New Channel Area
- New Mining Area vs. Overlapping Old and New Channels
- Old Mining Area vs. New Point Bar Area
- Old Mining Area vs. New Number of Point Bars
- Old Mining Area vs. New Point Bar Area

- Old Number of Mining Pits vs. New Point Bar Area
- Old Number of Mining Pits vs. New Number of Point Bars
- New Pit Area vs. Larsen Lateral Migration
- New Mining Area vs. Larsen Lateral Migration
- New Number of Mine Pits vs. Larsen Lateral Migration
- Old Mining Area vs. Larsen Lateral Migration
- Old Number of Pits vs. Larsen Lateral Migration
- Old Mining Area vs. New Channel Width
- Old Number of Mining Pits vs. New Channel Width
- New Channel Length/Reach Block vs. New Number of Point Bars
- Old Number of Mining Pits vs. New Number of Point Bars Lag 1
- Old Mining Area vs. New Number of Point Bars Lag 1
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- New Mining Area vs. New Point Bar Area Lag (-2)

These associations were used due to the likelihood of geomorphic interactions. The variables for mining areas were used as independent variables to determine the chance of both mined areas and pits being linked to channel change. Associations of dependent and independent variables were used based off of the results of a previous study on the Amite River (McLean, 1995). Spatial lags were created with the variables new number of point bars and point bar area. These lags are used to decide if the mining that occurred in one reach impacted the number of point bars or point bar area within a reach or two downstream. The first lag is spatially one reach block downstream, while the second lag is two reach blocks downstream. Negative lags were also considered to determine if head cutting occurred upstream. Spearman’s rank values were tested for statistical significance utilizing the t-distribution. The equation for t-value was altered by isolating the “r,” which is the critical value of Spearman’s r for statistical significance. This was calculated using equation 3-4 (Rogerson, 2001)

$$\rho = \frac{t}{\sqrt{n - 2 + t^2}} \quad \text{(eq. 3-4)}$$

The t’s in the equation represent the values for the t-distribution for 67 degrees of freedom and n is the sample size. Because ties existed in the data, Pearson’s Moment Correlation Coefficient was used to adjust the ranked data (Myers and Well, 2003). The above combinations were all run using the Pearson’s Correlation Coefficient on ranked data. The Mann-Whitney U-Test was run to determine whether the distance and area of the 1980 mine pits and avulsions that occurred on the 2004 main channel were statistically significant.

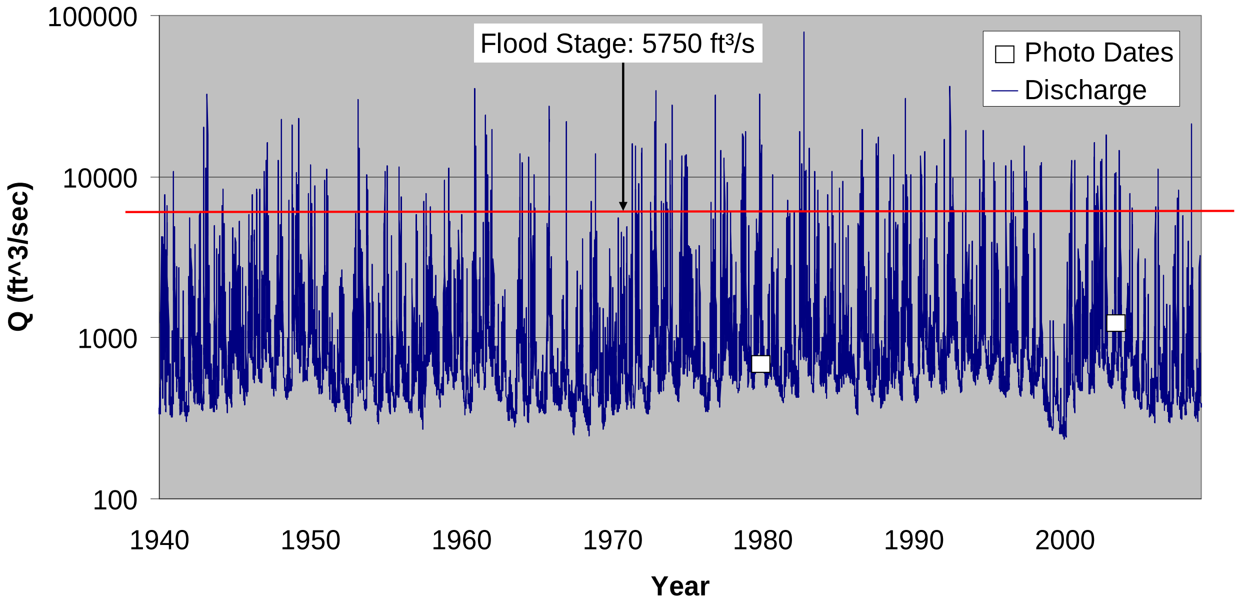


Figure 3-1. Imagery fly dates in comparison to discharge at Robert, LA.

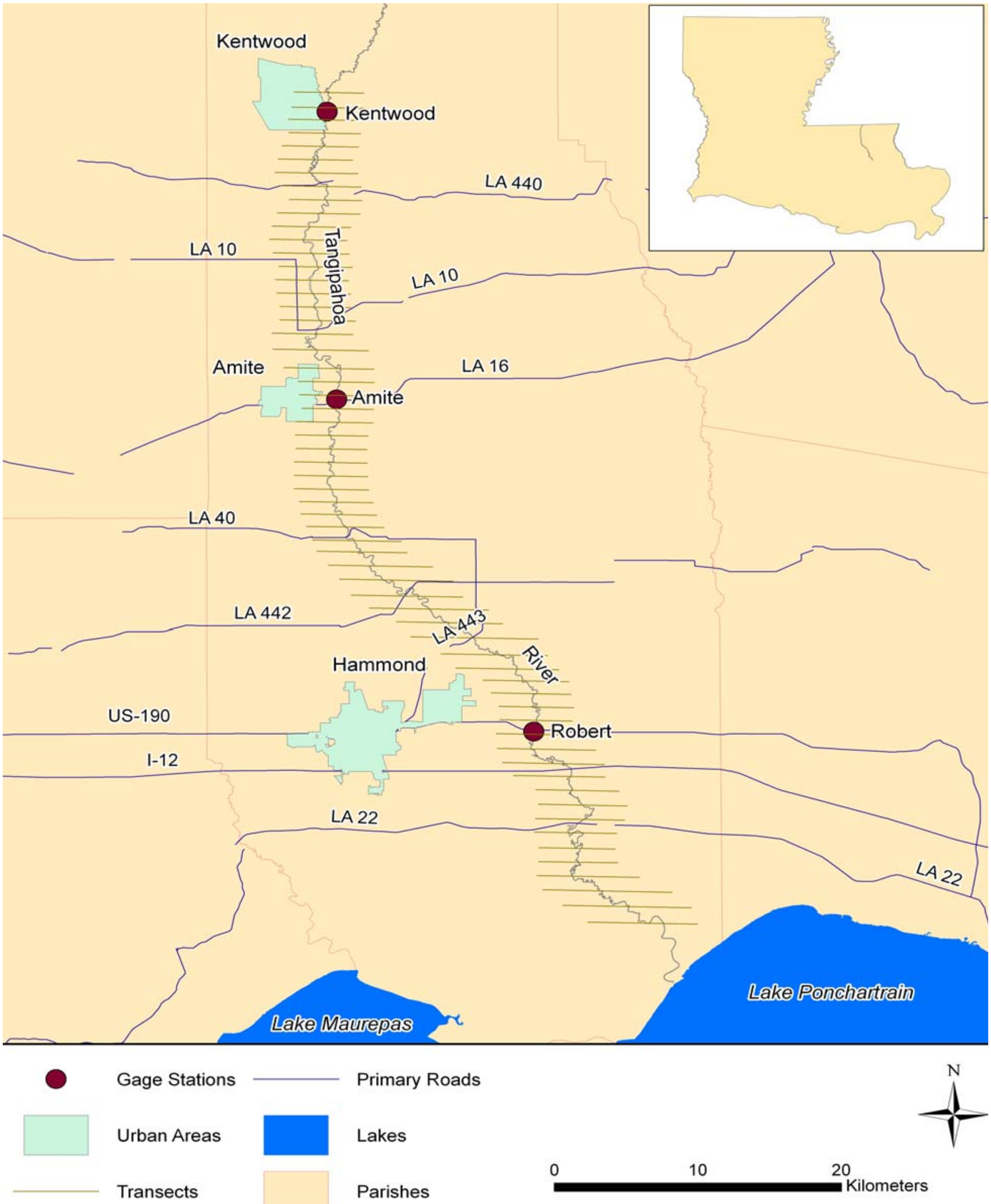


Figure 3-2. Tangipahoa site map with transects

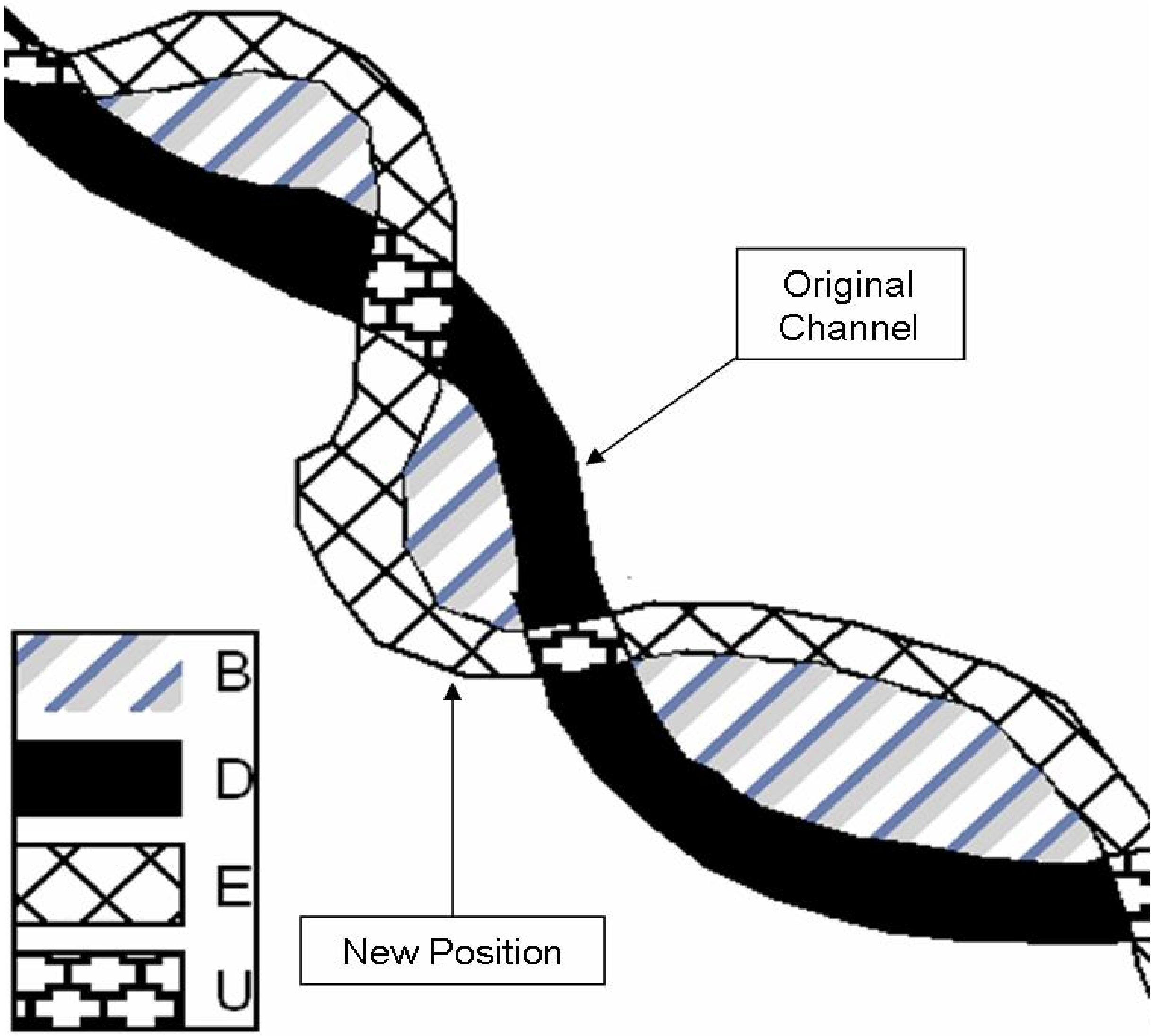


Figure 3-3. Change indices methods on the Tangipahoa River

Table 3-1. Topology rules

Feature	Rule	Feature Class
Point_Bars04	Must not overlap with	Mainchannels_04
Mainchannels_04	Must not overlap with	Point_Bars04
Meander_Islands04	Must not overlap with	Mainchannels_04

Table 3-2. Proportional area change ratios (Mossa and McLean 1997)

Indices	Description	Comment
U/I	Ratio of U to I	Shows proportion of initial channel area in same position
D/I	Ratio of D to I	Shows proportion of initial channel area abandoned
B/I	Ratio of B to I	Shows proportion of initial channel area between channels
E/I	Ratio of E to I	Shows proportion of initial channel area eroded or created
I	D + U	Initial area

CHAPTER 4
RESULTS

Multiple variables were tested to determine the stability, or lack thereof, of the Tangipahoa River. Point bar area, mining pit and bare area, average channel change, average lateral migration, and change indices were all analyzed to determine if mining played a role in the spatial and temporal aspects of the Tangipahoa.

Spearman's Rank Correlation was used to determine if there was a statistical relationship between the aforementioned variables. Different combinations of mining and channel change variables were used to determine whether or not these variables were correlated.

Change Indices

Change ratios were used as measure to determine the stability of a river system. The B/I ratio should not be very high when comparing short time periods. But this ratio will increase if meander cutoffs, avulsions, or very rapid lateral migration occur in the river system. The D/I ratio represents the area of the river that was formerly water in an earlier time period, while the E/I ratio represents area in the more recent time period that is now currently water or the new river channel. Lastly, the U/I ratio represents the area of the river that is unchanged, or in its initial position (Mossa and McLean 1997).

The B/I ratio is generally low in the reach blocks 1-8 and 32-61 where mining doesn't take place, reaching 0.5 twice. However, the B/I ratio increases significantly in reach blocks 9-32. Three spikes occur where the B/I index is 1.9, 1.4, and 1.8, at reach blocks 9, 12, 24 respectively. The area between channels in those reach blocks is an average of more than 170% of the initial area. Large values of the B/I ratio indicates channel instability. Reach blocks 15, 17, 18, 21, 22, 29, and 30 have extremely low B/I values with an average of 10% change from the initial channel area. As a result, the U/I value is generally lower where the B/I value is higher, and vice versa. The U/I value is much higher in the reaches where mining does not occur topping out at 87% and 89% at reach blocks 2 and 60 respectively, indicating stability. The average U/I index for the whole river system is 42% versus the B/I index of 37%. The D/I index ratio shows variability between reach blocks 8 and 42, with values ranging from 0.93 to 0.27, with an average change of 72%. This means that 72% of the channel has been abandoned between these reaches or has found a different position. The E/I index value spikes 4 times between reach blocks 14 and 31, with an average index value of 1.2 or 120% channel enlargement from the initial area (Figure 4-4).

Average Lateral Migration

Lateral migration rates (figure 4-5) for the Tangipahoa varied greatly throughout the entire river system. The highest rates occurred in the mining reaches, where most disturbances occurred. The three highest rates were in reach blocks 9, 12, and 24 with lateral migration rates of 2.3, 2.1, and 2.15 meters/yr respectively. The lowest lateral migration rate that occurred in the mined reaches was in block 17, with 0.31 m/yr, highlighting the amount of variability. The migration rates quickly taper off farther downstream outside the mined reaches. The overall average lateral migration rate for the entire Tangipahoa River was 0.73 m/yr, indicating a measure of stability over the study period.

Average Channel Width

The average channel width for the 1980 timestep fluctuates greatly, from 26 to 82 meters. This is due to three spikes that occur throughout the stretch of the river, with the greatest one occurring in a mined reach. The cause of this spike is pit capture from earlier mining pits. Previous floods could have forced to main channel to capture these mine pits, thus causing the channel to become much wider (Figure 4-6). The 2004 timestep channel width is more consistent, ranging from 25 to 50 meters. The channel gradually widens downstream in the mined area and peaks at 50 meters in reach 29. The width begins to decrease further downstream where it again peaks at 50 meters in reach 41. From there the width greatly tapers off to meet its low at 23 meters in reach 58 (Figure 4-7). Although pit capture occurs between the 2004 main channel and the 1980 mine pits, this plays little to no role in the 2004 main channels' width. More recent biological and physical changes might have affected the 2004 main channel width, such as incision, lower water tables, or both.

Point Bar Area

When considering point bar variables, it is important to take into account the discharge rates for the days that the imagery was acquired. Unfortunately, the Tangipahoa has three gage stations with only one that has discharge rates from the 1980's. This gage station, located in Robert, LA., is near the end of the Tangipahoa where point bars rarely occur. This makes it impossible to get a true indication of the discharge rates in the mined reaches of the Tangipahoa. A large discharge rate can both hide point bars and decrease their area. A low discharge rate can reveal hidden point bars and allow for an increase in point bar area. The discharge rate was 2540 ft^3/s for the 1980 fly dates and 5210 ft^3/s for the 2004 fly dates. For a true comparison, the actual months being investigated should be the same with similar discharge rates.

In the mined reaches, the number of point bars was relatively similar between the 1980 and the 2004 time steps (59 to 66). Further downstream in reach blocks 32 to 61, the number of point bars increases greatly for the 2004 timestep with 72, compared to the 1980 timestep with 26 point bars. The highest amount of point bars for each timestep was 9, located in reach block 20 for 1980 and 37 for 2004 (Figure 4-9). The total number of point bars for 1980 is 91 compared to 158 for 2004 (Table 4-1).

Point bar area is almost non-existent in reach blocks 1 through 6 and 43 through 61. This is an indication of higher flow rates and lack of mining, allowing sediment to easily pass through the river system. This trend changes greatly in the reach blocks 7 to 23 where heavy mining occurred. For the 1980 timestep, point bar area spikes twice with an average area of 117,500 m^2. For the 2004 timestep, point bar area spikes three times for the same reach blocks, with an average area of 143,400 m^2 (Figure 4-8). Throughout the entire Tangipahoa, point bar area increases in every reach block, except for three, from the 1980 to the 2004 timestep.

The cumulative point bar area for the 1980 timestep is 911,300 m^2. The cumulative point bar area for the 2004 timestep is 1,570,400 m^2, a difference of 659,102 m^2 or a 58% increase in area (Figure 4-10).

Mining Area

As expected, the greatest number of mine pits and mined area occurred between reaches 9 and 31, which was where mining took place on the Tangipahoa. It is clear from the data that mining has greatly increased between 1980 and 2004. The total area of mine pits has increased by over 2 million square meters, from 2,271,700 m^2 in 1980 to 4,272,900 m^2 in 2004. The largest mine pit area that was measured in 1980 was in reach 11 with 461,100 m^2. As for 2004, the largest amount of mine pit area measured was in reach 11 with 1,064,000 m^2 (Figure 4-1). The average distance from the pit captures centroid from the 1980 main channel was 199 meters. The average distance from the pit captures closest point to the 1980 main channel was only 62 meters (Table

4-5). Through the use of the Mann-Whitney U-Test, the distance of the 1980 mine pits and avulsions is statistically significant, while the area of the mine pits is not (Table 4-6 and 4-7). This means that the distance to the main channel plays a much greater role in pit capture compared to the size of the mine pits.

The number of mine pits also increased greatly, from 64 in 1980 to 145 in 2004. The largest number of mined pits for 1980 was located in reaches 9 and 28 with 7 pits. As for 2004, the largest amount of mine pits was located in reach 22 with 15 pits. Despite the fact these reaches have the most mine pits, their mine pit area is quite small. In 1980, reach 9 had a mine pit area of 221,600 m^2. Reach 28 had a mine pit area of 105,000 m^2, which is extremely low considering its amount of pits. Results are similar for 2004, where the mine pit area for reach 22 is only 152,700 m^2. But the second and third most amounts of mine pits that occurred in 2004 are located in reaches 11 and 26 with 11 and 12 pits respectively. These reaches also hold the third and second most amount of mine pit area, which is not true for 1980 (Figure 4-2).

Bare area is the only variable that has decreased between 1980 and 2004. The total area for this variable in 1980 was 3,925,100 m^2 and 1,880,600 m^2 for 2004. This is a decrease of more the 2 million square meters or 48% of the previous area. For 1980 the greatest amount of bare area was located in reach block 11 with 1,171,900 m^2. Bare area is very little for 2004, where the largest area was located in reach 28 with 243,400 m^2 (Figure 4-3). Although there has been a large increase in mine pit area and number of point bars between 1980 and 2004, the total mining area between the two time steps was almost identical with 6,079,300 m^2 in 1980 and 6,153,500 m^2 in 2004.

Statistical Analysis

Spearman's Rank Correlation, with an adjustment for ties, was chosen to determine if there was a statistical link between mining related variables and variables representing channel change because the data was not normally distributed. Out of 54 comparisons, 42 were found to be statistically significant at a 95% confidence level (Table 4-2, Table 4-3, and Table 4-4).

There was a weak to moderate statistical significance between mining related variables and change indices. Negative correlations occur in the unchanged channel area exclusively. The only two variables that showed no significance were new pit area and new number of pits vs. new channel area. A weak correlation was found between new channel width and mining related variables. This is of no surprise since pit capture can have an extreme effect on channel width. Lateral migration also shows a positive moderate correlation especially in relationship to the new mining variables. This is expected since floodplain mining can add sediment to the system forcing the channel to shift laterally. Floods can also cause lateral migration when the channel and mine pits become one.

The mining related variables that were compared to point bar variables (including positive and negative lags) also showed mixed correlations. These relationships show fewer statistically significant results compared to the change index relationships. Positive and negative lags were used in the point bar variables to determine if there was a relationship between mining variables and point bars downstream one or two transects in a positive lag or one or two transects upstream in a negative lag. Negative lags were used to determine whether or not headcutting occurred upstream.

New point bar area showed a moderate to high level of significance, with correlation coefficients ranging from 0.583 to 0.767. This indicated that both new and old mining had a great influence on the area of the new point bars. This can be explained by the increase in sediment that is introduced into a river system from mining. The new number of point bars shared a weak positive correlation with the new mining variables. New number of point bars is also weakly correlated to the channel length per reach block. This could indicate that the longer the river channel is in a particular reach block, the more point bars will be present. The new point bar area lag 1 and 2 also shared a moderate significance with old and new mining variables, but was again more strongly influenced by the new mining variables. The new number of point bars lag 1 only shared significance with new mining area. On the contrary, the new number of point bars lag 2 showed a weak positive correlation with old and new mining variables.

The new point bar area lags -1 and -2 were both moderately correlated to the old and new mining variables, with correlation coefficients ranging from 0.516 to 0.692. The new number of point bars lag -1, similar to the positive lag 1, was weakly correlated with the new mining variables. The new number of point bars -2 lag was almost the opposite of the positive lag 2, sharing a weak positive correlation with old mining area.

Since a majority of the relationships tested were statistically significant, it can be concluded that mining played a major role in the change of the Tangipahoa River in and just below the mined reaches. Based on these results, both old and new mining variables have an effect on the change of the Tangipahoa's channel and point bars, with newer variables having a slightly greater effect.

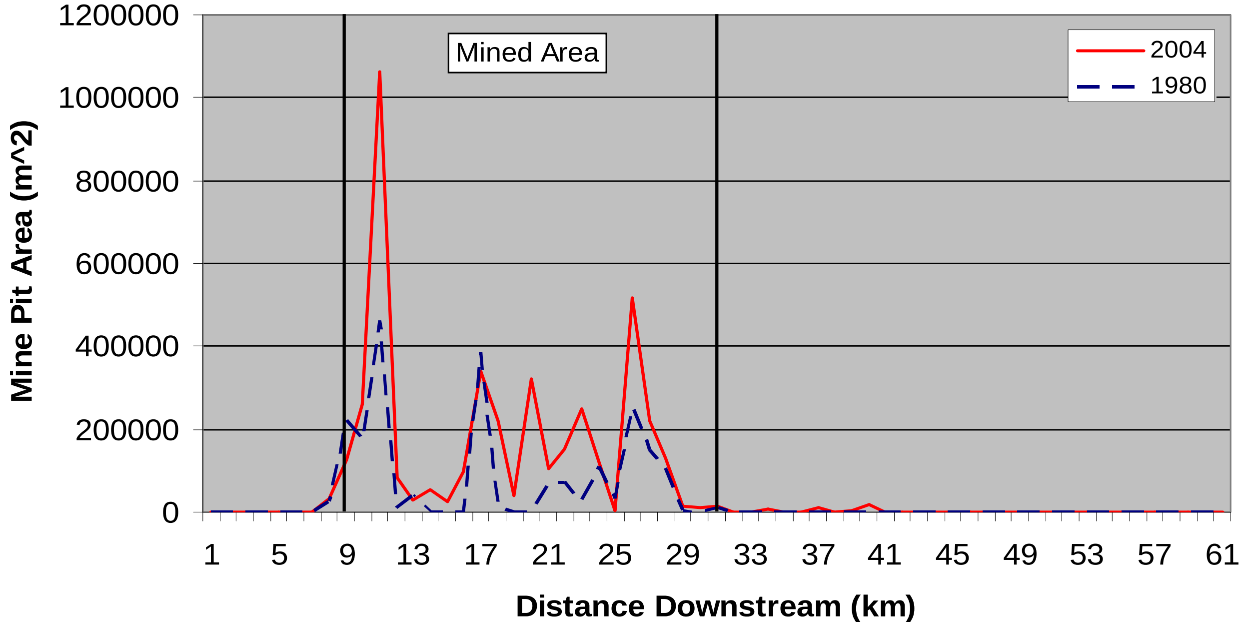


Figure 4-1. Mine pit area on the Tangipahoa River 1980-2004

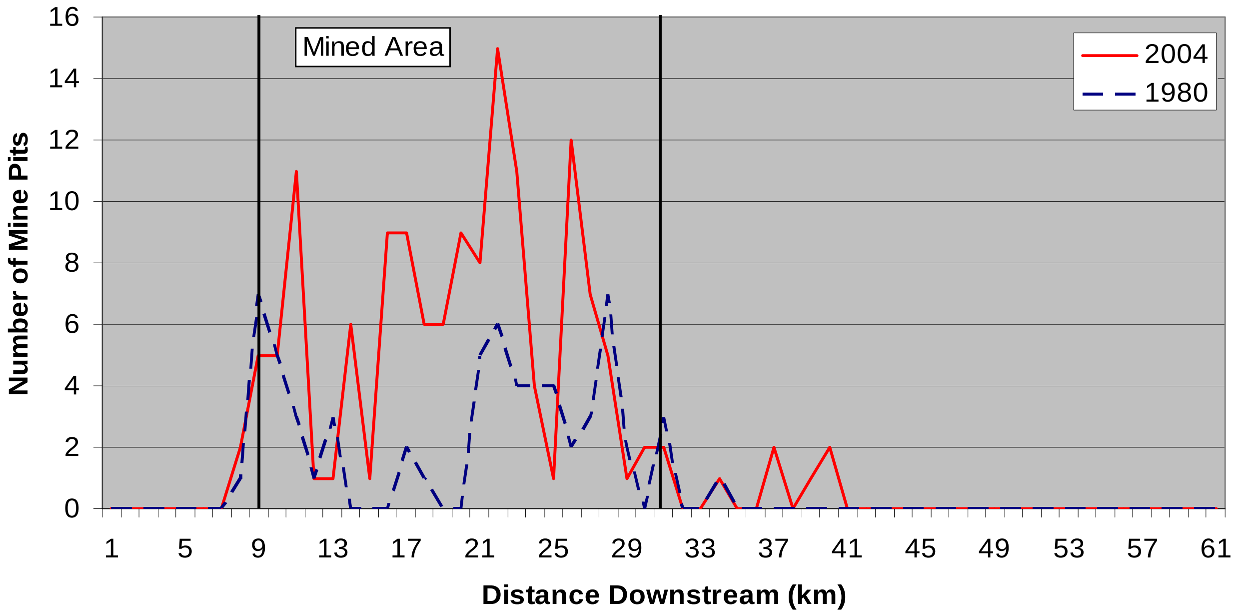


Figure 4-2. Number of mine pits on the Tangipahoa River 1980-2004

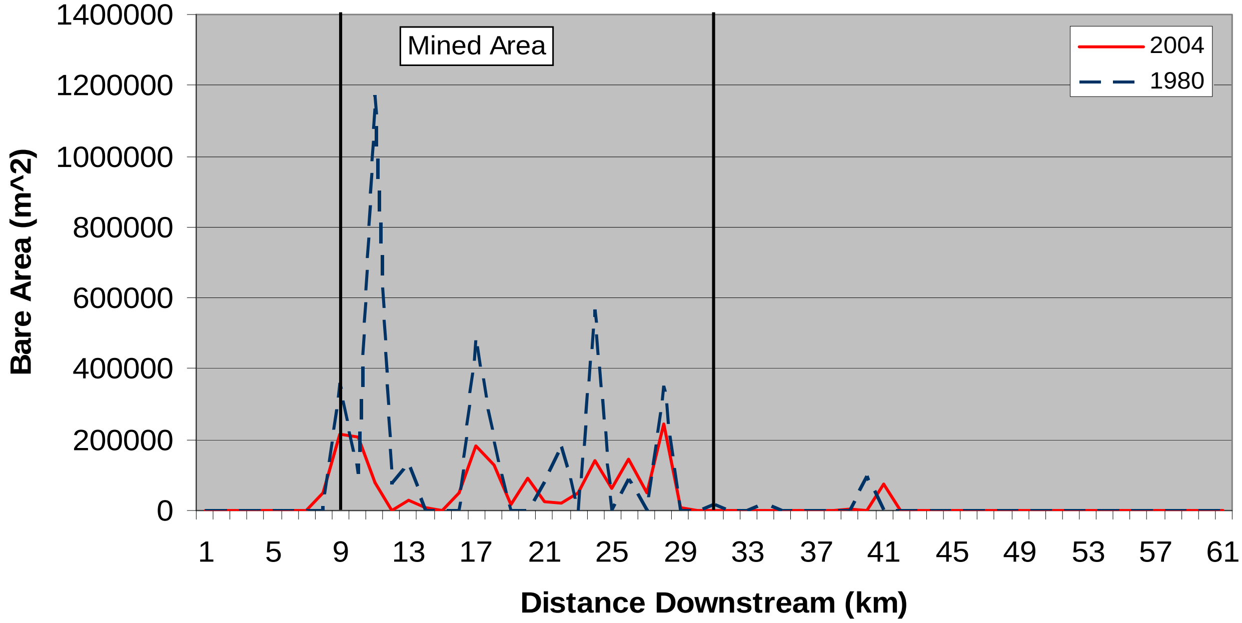


Figure 4-3. Bare Area on the Tangipahoa River 1980-2004

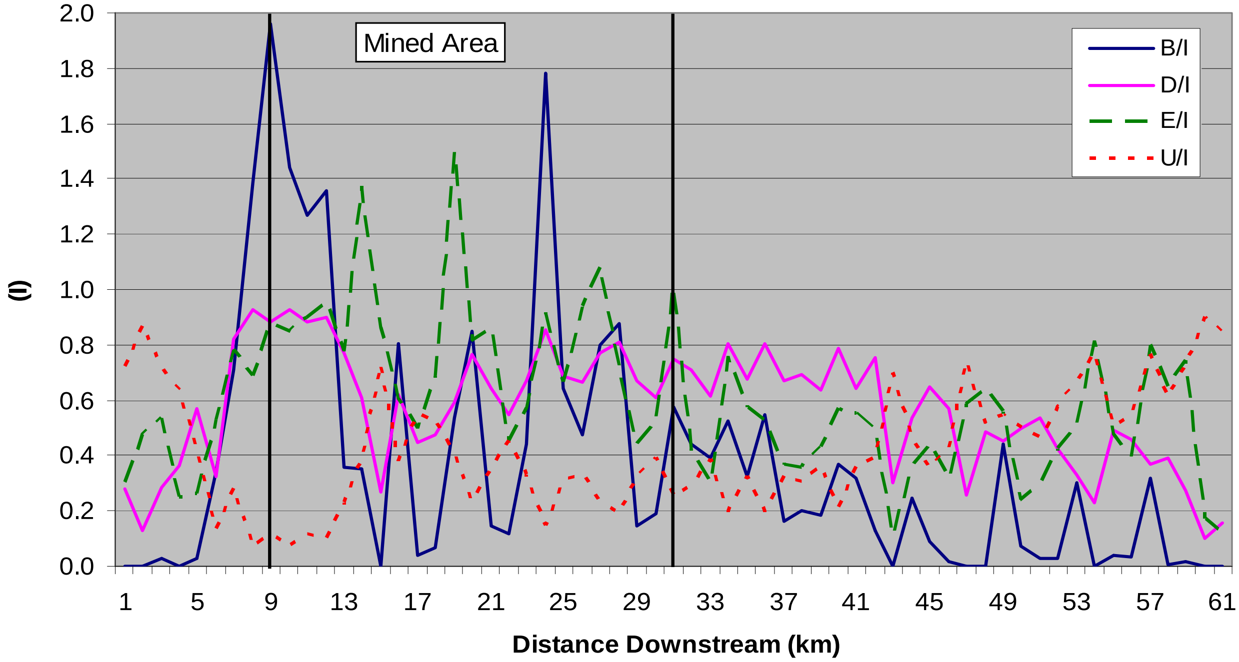


Figure 4-4. Change indices on the Tangipahoa River 1980-2004

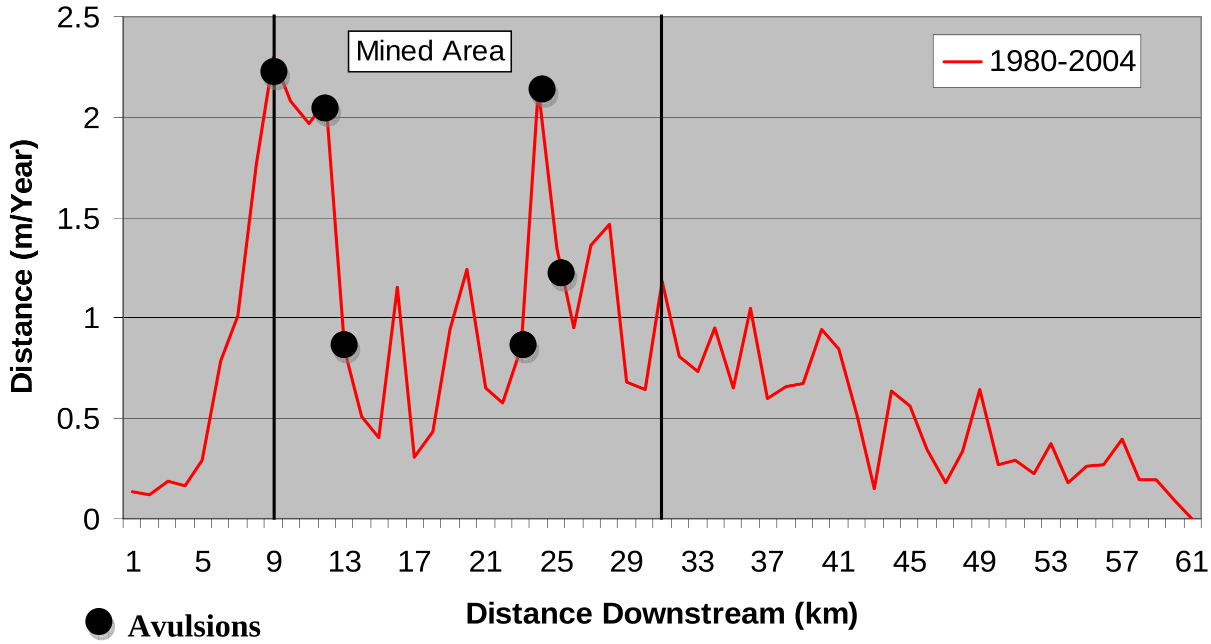


Figure 4-5. Tangipahoa River lateral migration rates per year 1980-2004

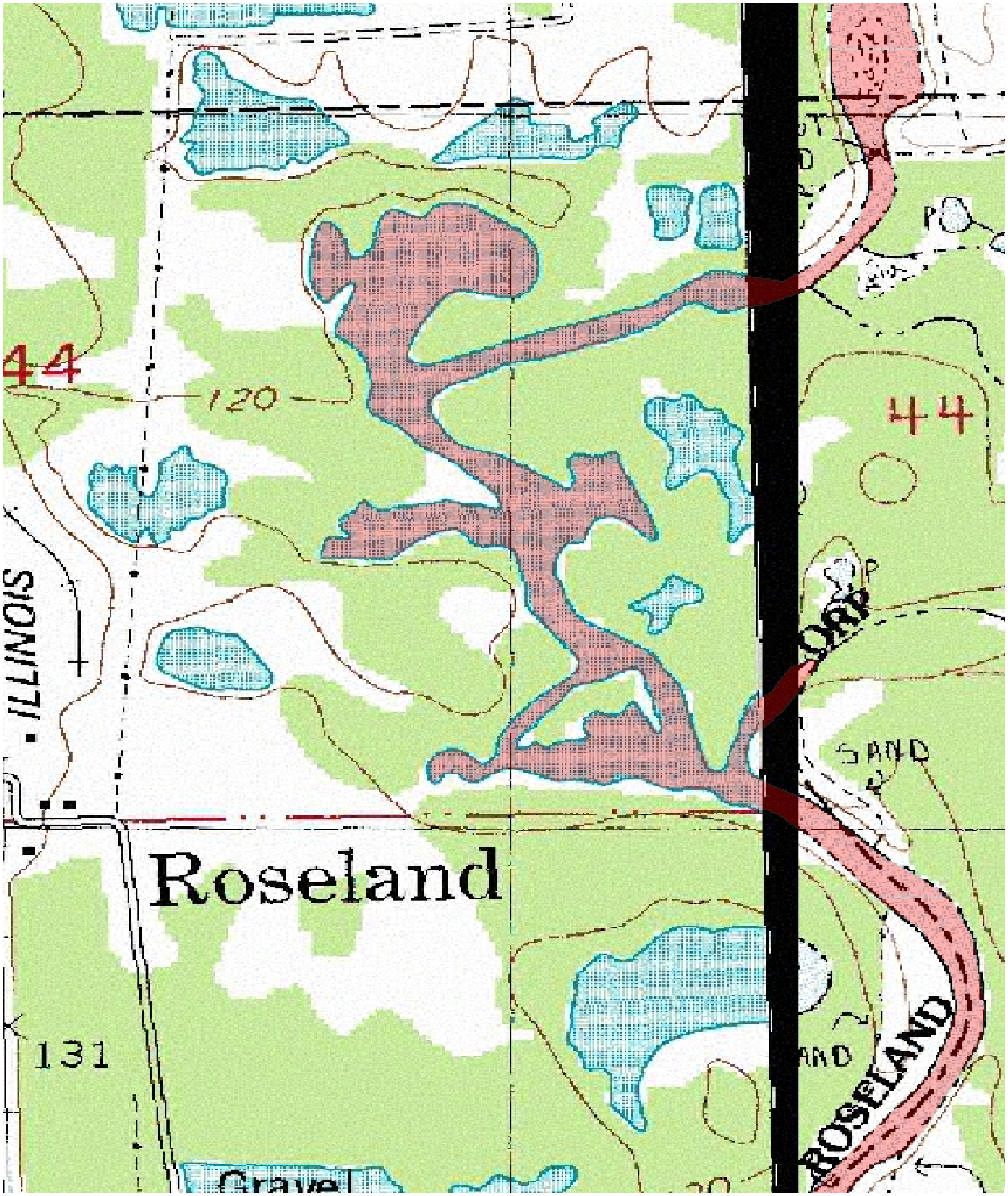


Figure 4-6. Example of pit capture influencing channel width on the Tangipahoa (1980)

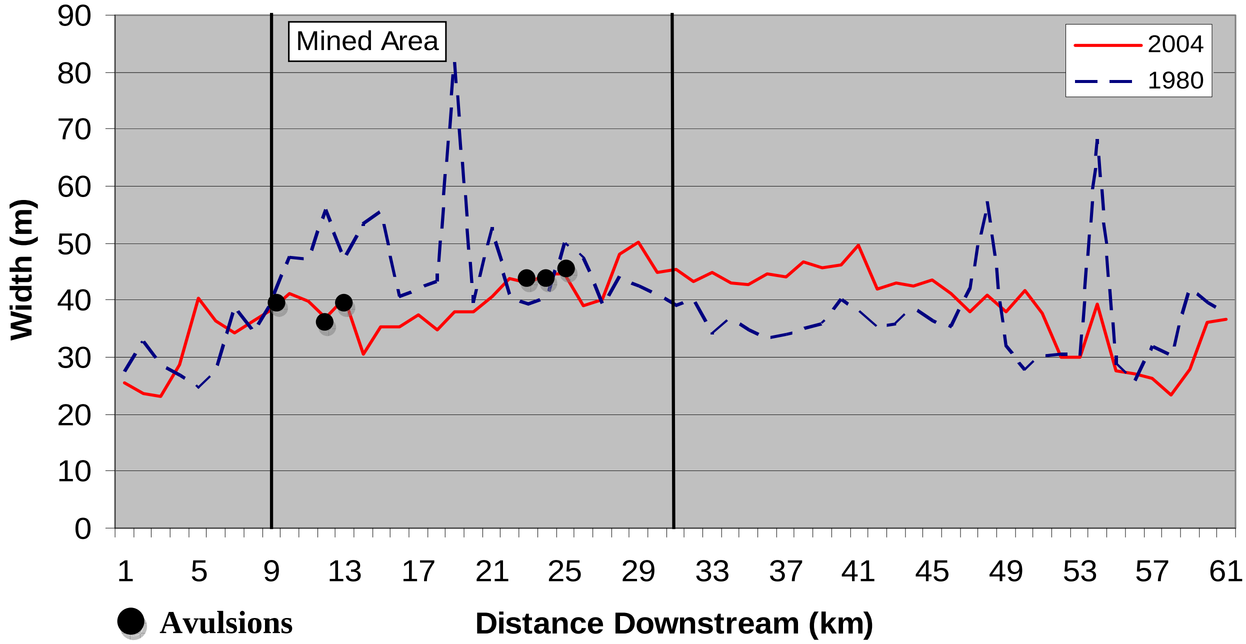


Figure 4-7. Average channel width on the Tangipahoa River 1980-2004

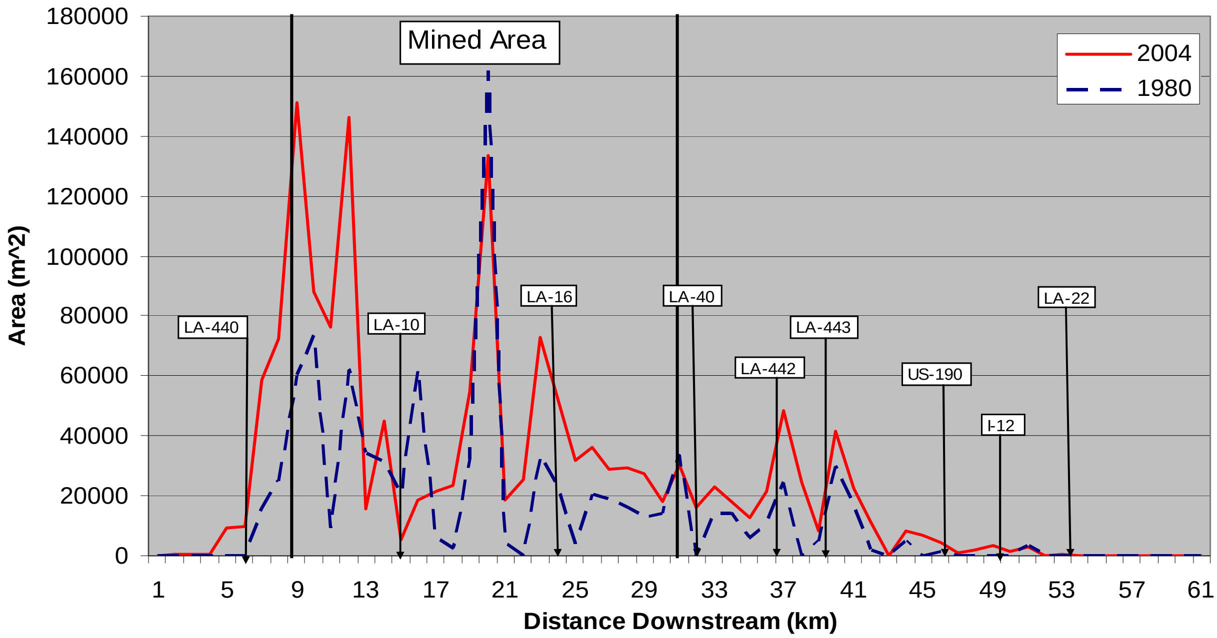


Figure 4-8. Point bar area on the Tangipahoa River 1980-2004

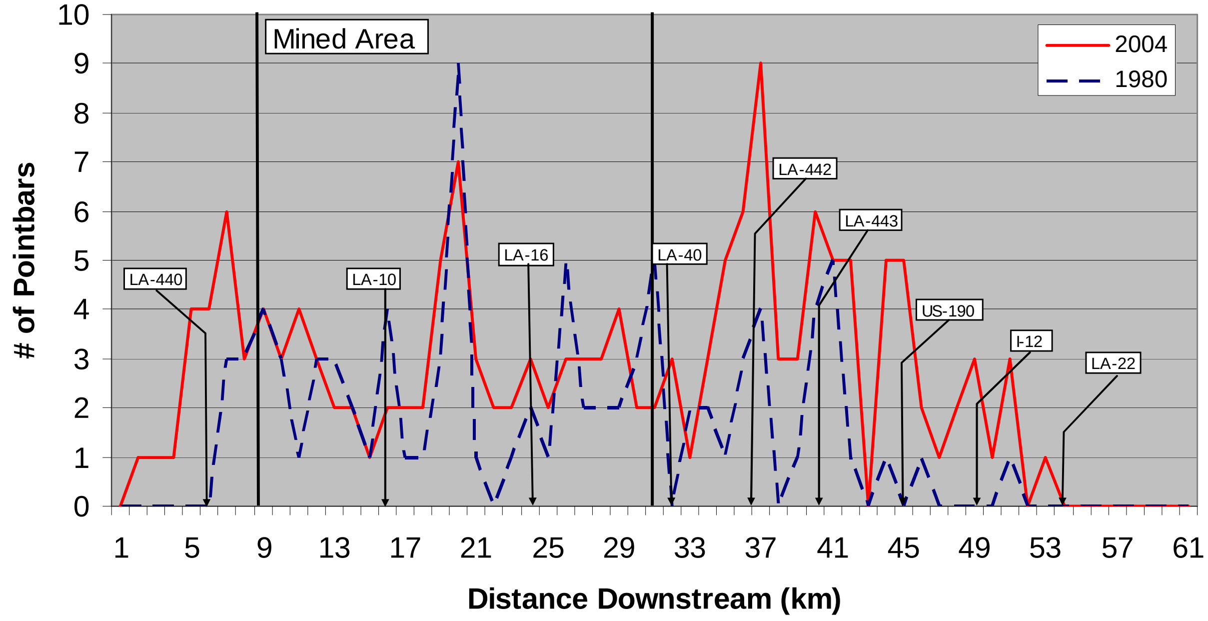


Figure 4-9. Number of point bars on the Tangipahoa River 1980-2004

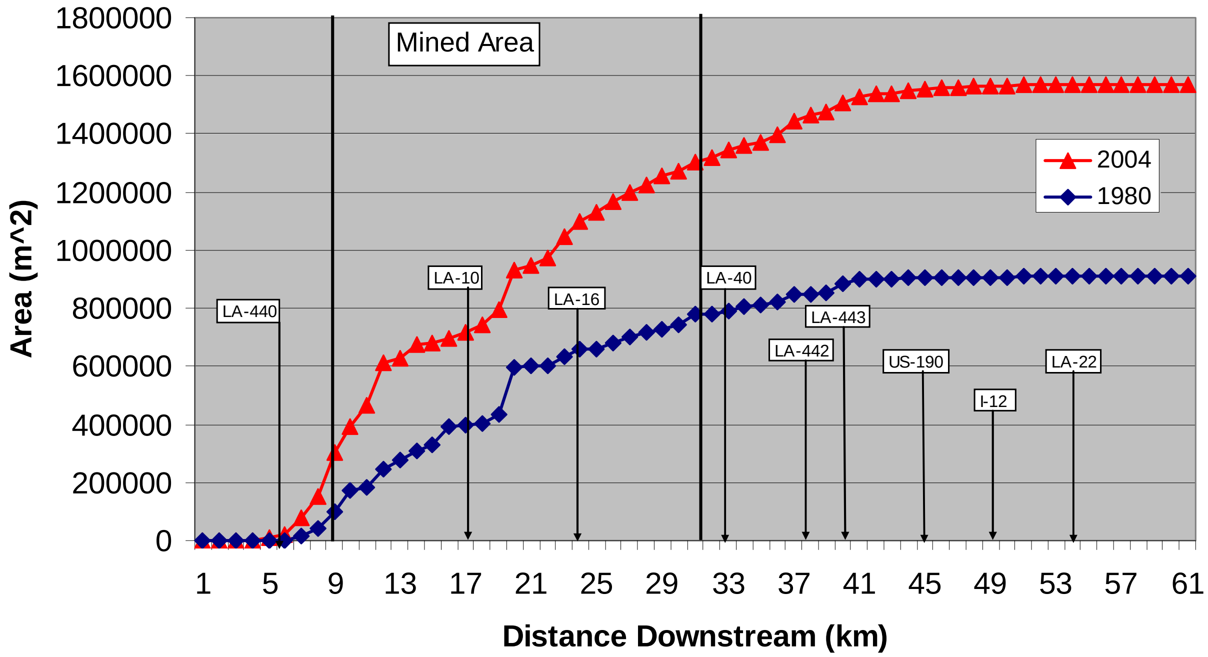


Figure 4-10. Cumulative point bar area on the Tangipahoa River 1980-2004

Table 4-1. Totals of variables compared for 1980 and 2004

	1980	2004
Number of Point Bars	91	158
Point Bar Area (m^2)	911,300	1,582,400
Number of Mine Pits	64	145
Mine Pit Area (m^2)	2,271,700	4,272,900
Bare Area (m^2)	3,925,100	1,880,600
Mining Area (m^2)	6,079,300	6,153,500

Table 4-2. Results of Spearman's Rank Test for Correlation. The bold values represent the statistically significant values at the 95% confidence level.

Spearman's Rank Values with Adjustment for Ties						
Independent Variables	Dependent Variables					
	Between Area	Old Channel Area	New Channel Area	Overlapping Old and New Channels	New Channel Width	Larsen Lateral Migration
New Pit Area	**0.457**	**0.326**	0.241	**-0.561**	~	**0.640**
New Number of Pits	**0.428**	**0.306**	0.221	**-0.513**	~	**0.606**
New Mining Area	**0.497**	**0.359**	**0.299**	**-0.535**	~	**0.674**
Old Mining Area	~	~	~	~	**0.281**	**0.547**
Old Number of Pits	~	~	~	~	**0.295**	**0.590**

Table 4-3. Results of Spearman's Rank Test for Correlation with relationships involving point bar variables. The bold values represent the statistically significant values at the 95% confidence level.

Spearman's Rank Values with Adjustment for Ties						
Independent Variables	Dependent Variables					
	New Point Bar Area	New Number of Point Bars	New Point Bar Area Lag 1	New Number of Point Bars Lag 1	New Point Bar Area Lag 2	New Number of Point Bars Lag 2
Old Mining Area	**0.583**	0.200	**0.597**	0.149	**0.597**	**0.271**
Old Number of Pits	**0.596**	0.162	**0.654**	0.206	**0.602**	**0.332**
New Mining Area	**0.767**	**0.328**	**0.752**	**0.295**	**0.694**	**0.317**
New Number of Pits	**0.737**	**0.296**	**0.655**	0.231	**0.697**	**0.336**
New Channel Length/Reach Block	~	**0.283**	~	~	~	~

Table 4-4. Results of Spearman's Rank Test for Correlation with relationships involving point bar variables with negative lags. The bold values represent the statistically significant values at the 95% confidence level.

Spearman's Rank Values with Adjustment for Ties				
Independent Variables	Dependent Variables			
	New Point Bar Area Lag -1	New Number of Point Bars Lag -1	New Point Bar Area Lag -2	New Number of Point Bars Lag -2
Old Mining Area	**0.562**	0.214	**0.516**	0.214
Old Number of Pits	**0.594**	0.195	**0.566**	0.135
New Mining Area	**0.692**	**0.312**	**0.576**	0.162
New Number of Pits	**0.686**	**0.273**	**0.585**	0.208

Table 4-5. Distances from pit captures' centroids and closest point to the 1980 main channel.

Avulsion	**Lat**	**Long**	**Area (m^2)**	**Distance From Centroid to 1980 Channel (m)**	**Closest Distance from 1980 Channel (m)**
1	30.863627	-90.496676	127,100	330	20
2	30.834594	-90.503035	10,800	220	150
3	30.828472	-90.502441	900	140	120
4	30.731020	-90.487567	4,500	80	30
5	30.719284	-90.488439	83,000	430	70
6	30.710063	-90.489833	8,600	70	10

Table 4-6. Closest distance of the 1980 mine pits to the 1980 main channel (p=0.006)

Mann-Whitney U-Test				
Type	N	Median (m)	25% (m)	75% (m)
Captured	6	19	13	123
No Capture	50	196	56	393

Table 4-7. Area of the 1980 mine pits (p=0.884)

Mann-Whitney U-Test				
Type	N	Median (m)	25% (m)	75% (m)
Captured	6	6643	3080	10808
No Capture	50	8107	2074	29493

CHAPTER 5
DISCUSSION

GIS and high resolution aerial photography were pivotal in the assessment of channel change on the Tangipahoa River. They allow for accurate detection, digitization, and analysis of a number of physical and biological variables that occurred in or near the river. Although maps aren't preferable, they are still important when studying river systems.

The Tangipahoa has shown a significant amount of change between the two time periods particularly in the mined reaches. Both mining and point bar variables have greatly increased since 1980. The change indices indicate relative channel stability upstream and downstream of the mined reaches, but the unchanged ratio in the mined reaches is quite low, while the between ratio is high. The average U/I ratio for the entire Tangipahoa is 0.43, indicating that less than 50% of the river is in its initial position, indicating a level of instability. This means that the channel is more unstable in the mined reaches. Mixed results occurred with other mined rivers in similar studies. Garfield (2008) found that the Bogue Homo and Bowie River in Mississippi had high U/I ratios while Thompson Creek had an average U/I ratio of about 50%, indicating some instability. Davis (2009) found that the Amite River in Louisiana had changed significantly. The average U/I ratio was 0.35 over an 18 year period, indicating that 35% of the river remained in its initial position. In some cases, the B/I ratio was a 2, meaning that the Amite has shifted by over 200% of its initial position. Lateral migration rates also indicate instability in the mined reaches. Rates of more than 2 m/yr occur in the mined reaches or 48 meters for the entire 24 year period. Garfield (2008) and Davis (2009) both found that lateral migration rates were higher in the mined reaches compared to the areas with no mining, but with varying results. Over 22 years, Davis (2009) found that the Amite River migrated about 200 meters in the mined reaches. Garfield (2008) found that rates on the Leaf River were more in line with rates of the Tangipahoa ranging from 0.5 to 3.5 meters per year in the mined reaches between 1982-1996.

Lateral migration rates upstream and downstream from the mined reaches are significantly less. Average width has decreased, especially in the mined reaches in the 2004 timestep. Incision could be occurring upstream of the mined area. Decreased flow could have also caused a decrease in channel width. The 2004 main channel captured seven mine pits from the 1980 time period (Figure 5-1 to 5-5). All of these pit captures occurred in the mined reaches of the Tangipahoa. Although the 2004 channel has captured these mine pits, it is difficult to tell how much of an effect these captures have had on the 2004 channel width and lateral migration rates. Further investigation into the years between 1980 and 2004 could take place to get a better idea of how these pits influenced channel with and lateral migration.

Spearman's Rank Correlation showed that multiple relationships between mining and point bar variables were correlated. All of the change indices were found to be statistically significant, except for new channel area vs. new pit area and new number of pits. This could be due to the lack of extreme floods inducing pit capture. Most of the point bar variables were significant as well, except for old mining areas vs. number of point bars and lag 1, -1. Newer mining introduced more sediment into the system, thus creating more and larger point bars.

Similar results to this thesis were also discovered in studies not only done in Louisiana, but also in Italy and California on mined rivers. Rinaldi (2005) found that the Tagliamento and Brenta Rivers experienced incision and channel narrowing. James (2005) also found that mined tributaries in the Yuba Basin, CA. were incised and narrowed compared to pre-mining conditions. Studies conducted in Louisiana on the Amite River concluded that weak to moderate correlations occurred between mining variables and channel changes (Davis, 2009 and McLean, 1995). Very little floodplain mining studies on the Tangipahoa River have occurred, but Wilder (1998) found that the Tangipahoa River aggraded 0.75 to 1 meter at the Robert gaging station between 1982 and 1994. Aggradation of a river can result from upstream floodplain mining. These studies have all concluded that mining can have a temporal and spatial effect on a river’s geomorphology.

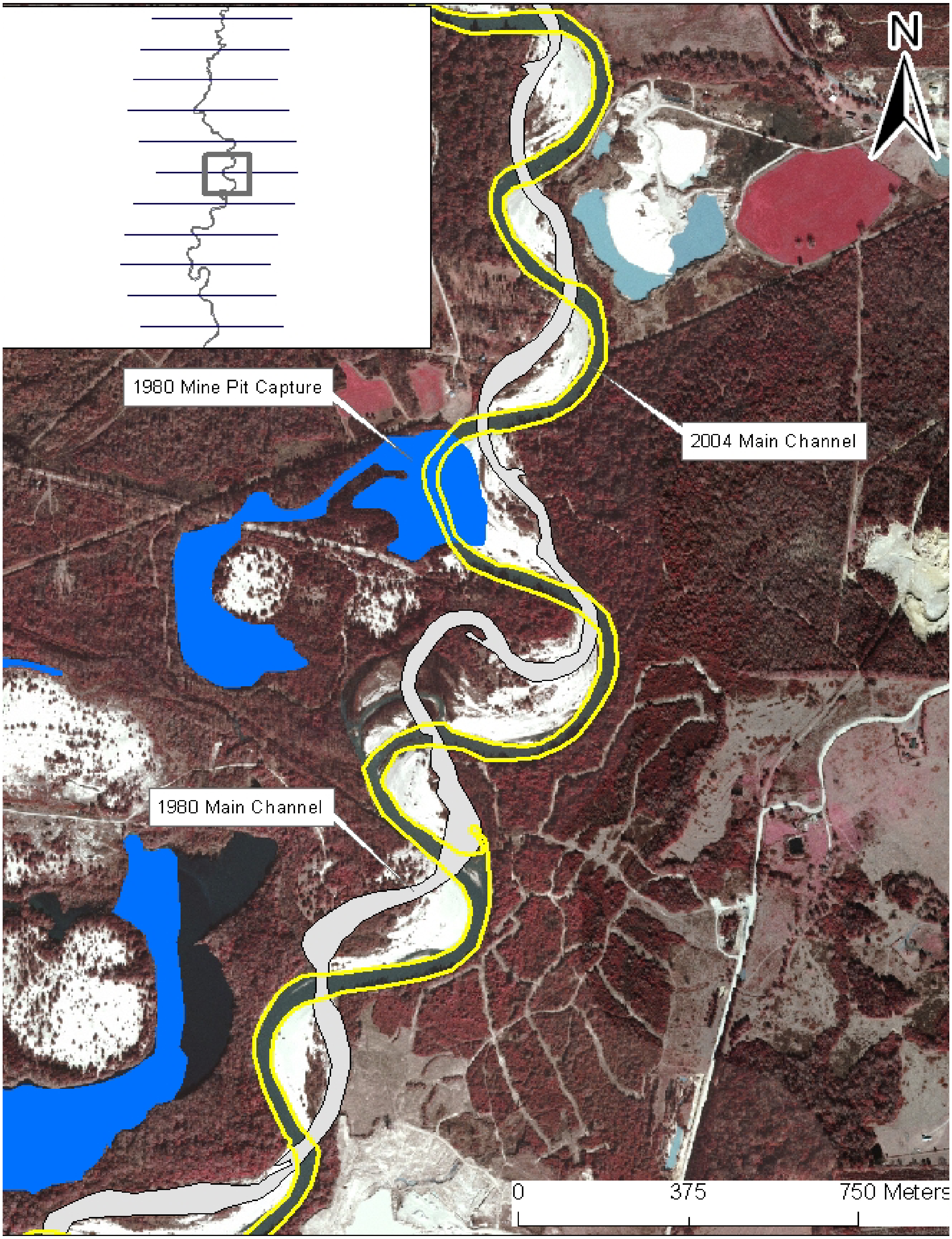


Figure 5-1. Area of pit capture in transect 9 (2004 imagery)

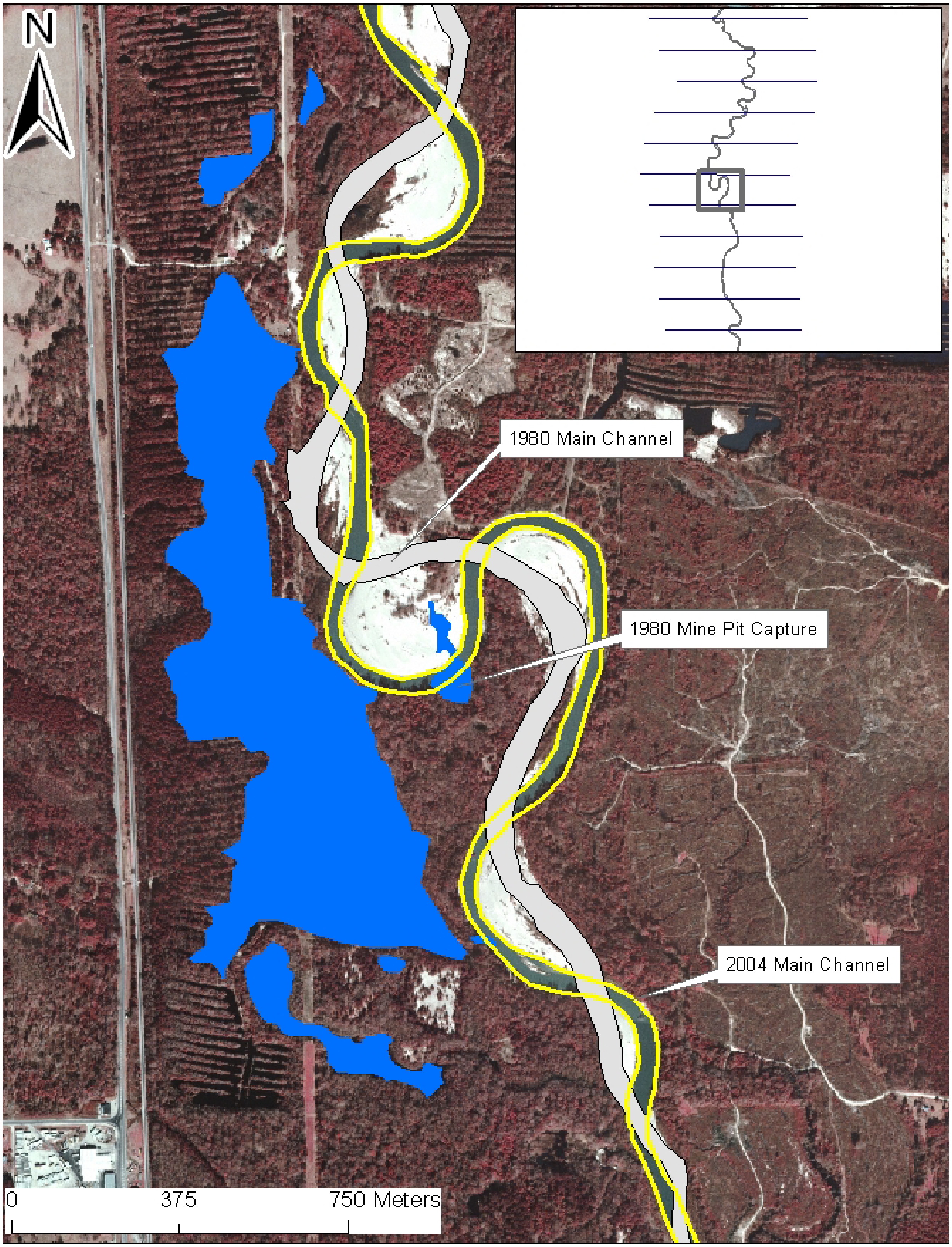


Figure 5-2. Area of pit capture in transect 12 (2004 imagery)

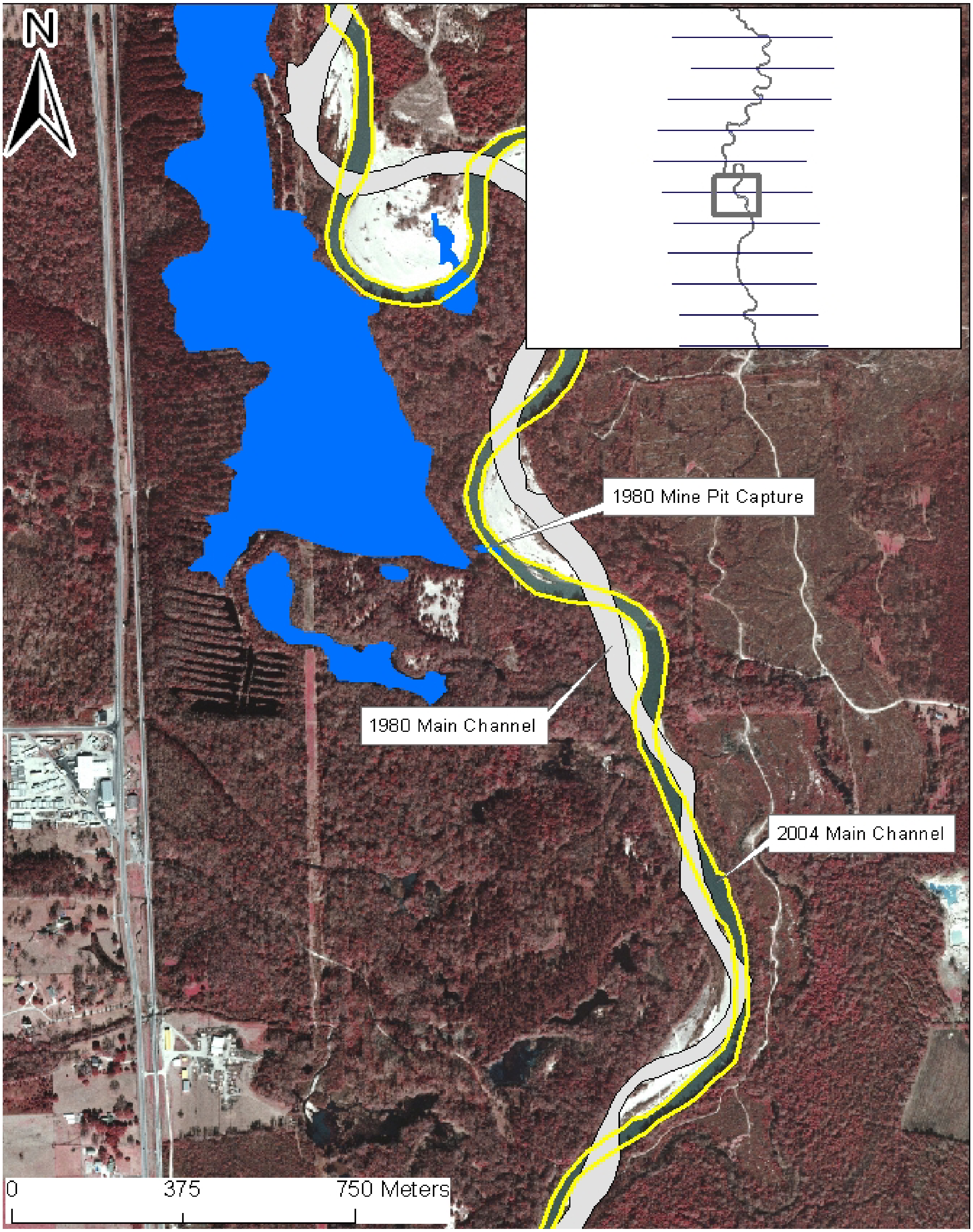


Figure 5-3. Area of pit capture in transect 13 (2004 imagery)

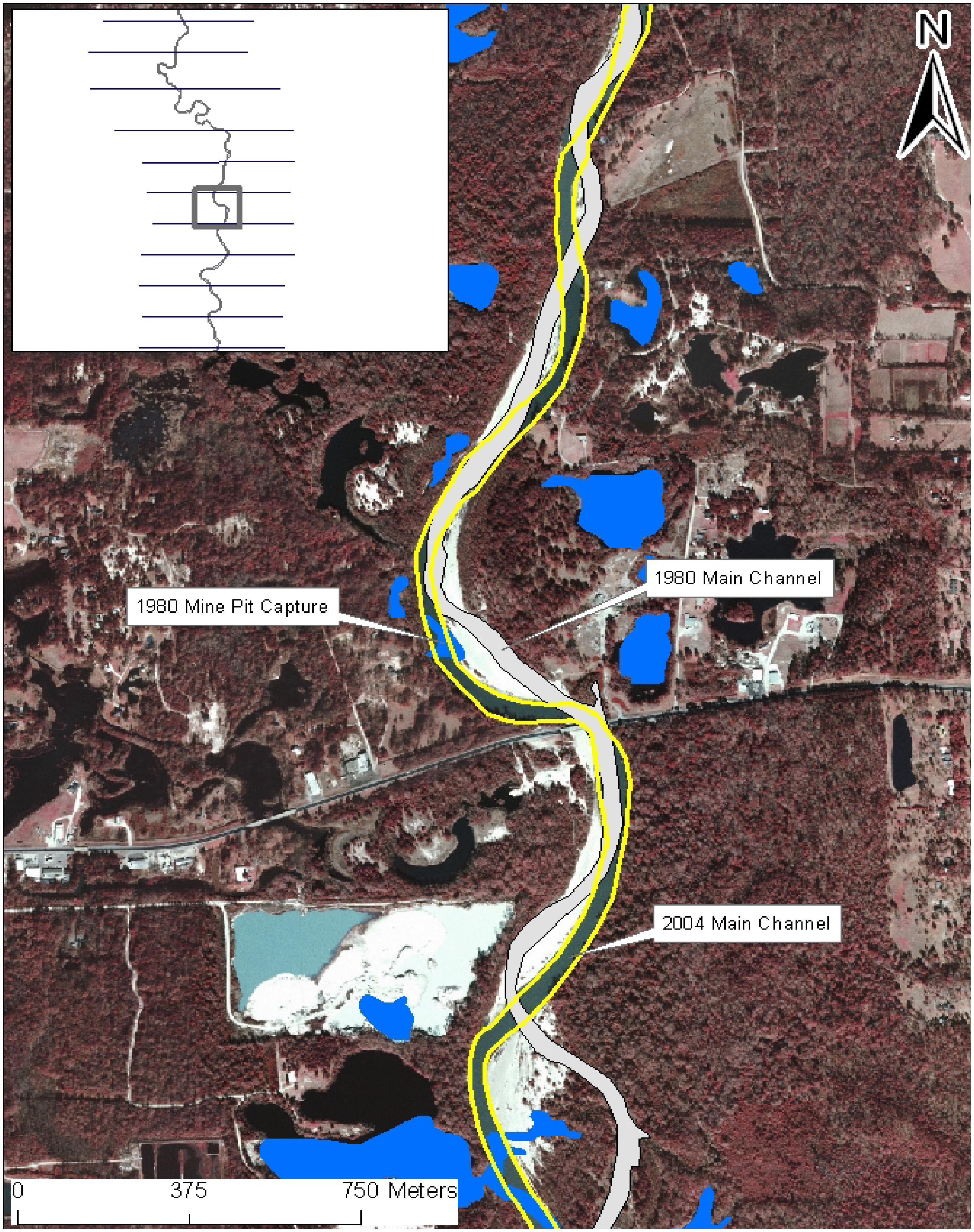


Figure 5-4. Area of pit capture in transect 23 (2004 imagery)

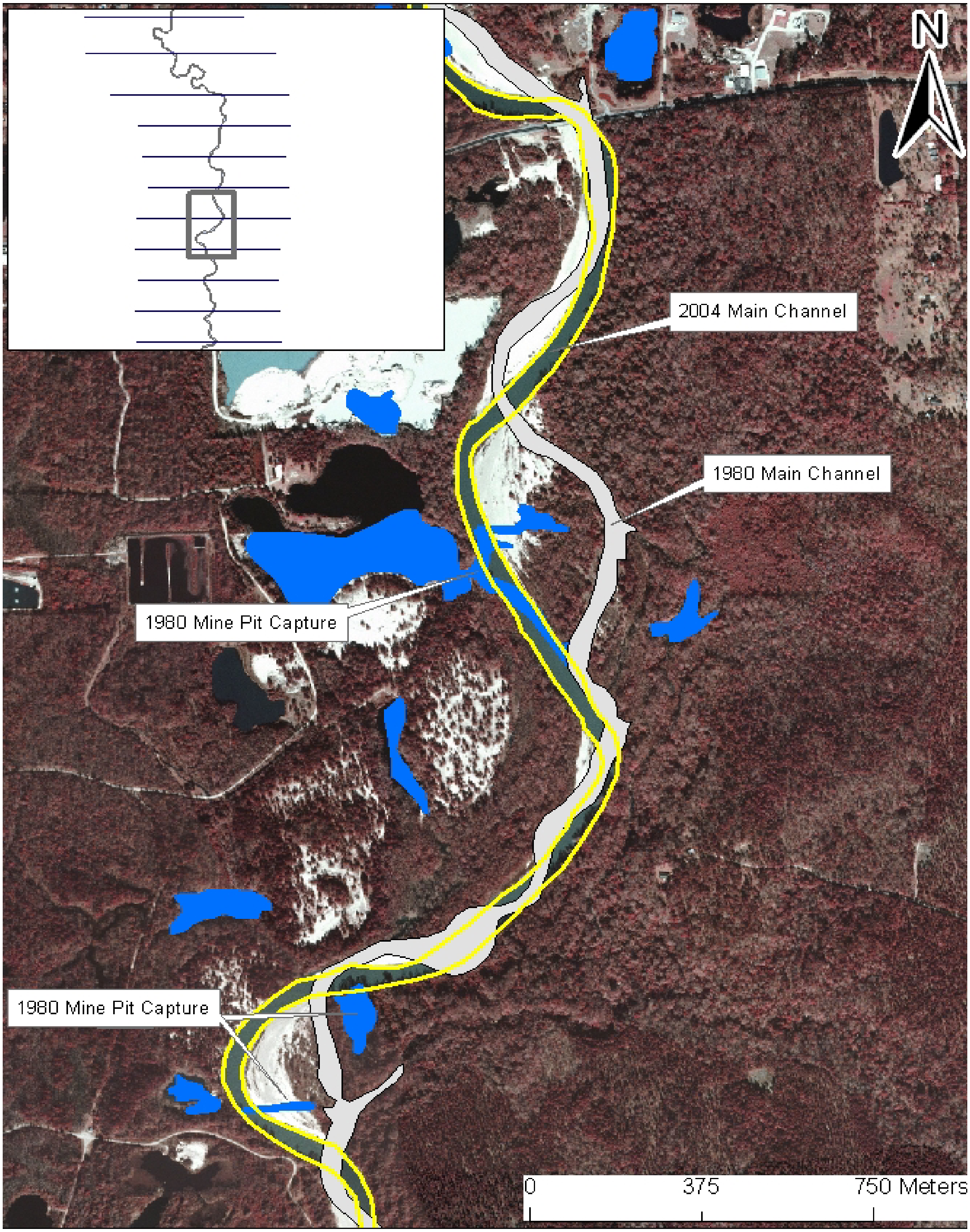


Figure 5-5. Area of pit capture in transects 24 and 25 (2004 imagery)

CHAPTER 6
CONCLUSIONS AND FURTHER RESEARCH

This study was undertaken to determine if floodplain sand and gravel mining and channel change on the Tangipahoa River were statistically linked between the years of 1980 and 2004. GIS and Excel were invaluable tools for data creation, collection, and processing. Aerial photographs and DRG's were also important elements of this study to establish the main channels, centerlines, mine pits and point bars. Reach blocks were created every kilometer to determine the degree of channel change both up and downstream. Change indices were created in each reach block to identify new, old, unchanged, and between channel areas. These indices were also used to help determine channel change both spatially and temporally.

Spearman's rank correlation coefficient was utilized to determine statistical significance. It was discovered that most of the relationships had a positive moderate to high levels of significance, with very few having no significance at all. This indicated that mining variables played a role in causing channel change, especially in the mined reaches. There is a stronger statistical link between the newer mining variables and channel change variables suggesting that the newer mining variables have a stronger influence on channel change. Relationships with weak or no statistical links could be the result of a large gap in time between the two studied periods.

The analysis of the aforementioned variables provides evidence that sand and gravel mining in the floodplain does play a role in channel change on the Tangipahoa River. There has been an increase in lateral migration rates, sand bar area, and the number of sand bars, which coincides with the increase of mining area from 1980 to 2004. Although some stability exists on the Tangipahoa, the mined reaches and area near have become unstable due to the mining practices that take place in the Tangipahoa's floodplain.

Limitations

The first and most glaring limitation to this project was the use of two different data sources: DRG's and DOQQ's. The scale is different between these two sources of data, which could lead to the incorrect areas of point bars and mine pits. Multiple interpretations are involved when looking at these two data sources as well. One person's idea of the extent of a mining pit, point bar or any other variable may differ slightly from another.

The lack of consistent stages could also cause error in the interpretation of the digitized variables. A high river stage could hide or decrease the area of point bars due to a wider channel. If the stage is low, more point bars and a larger area would be digitized, including a smaller channel width. To get the most accurate results, it is important to examine a river when the stages are as similar as possible.

The elapsed time between 1980 and 2004 could also cause error. There is no question that many things happened in terms of mining and flooding on the Tangipahoa that had an effect on its channel change. To remedy this, a more in depth study could take place to look at the intervening years to get a more complete idea of the changes that have occurred.

Other factors that were not taken into account could also play an imperative role on channel change. Deforestation and urbanization can play a key role in geomorphic change. Vegetation cover controls bank erosion during weather events. If this vegetative cover is removed, it will accelerate soil erosion and introduce an increase in sediment into the river system (Knighton, 1998). Urbanization can introduce more water into the system from efficient drainage systems. Urbanization can increase sediment load from construction sites, or decrease the amount of sediment into the system with the stability in the urban landscape. Flood events have also been shown to have an effect on geomorphic changes. The increased stream power can cause channels to widen by increasing erosion. Pit captures induced by flooding can cause the channel to migrate laterally (Knighton, 1998). These are all factors that could have some effects on channel change and should be accounted for.

Further Research

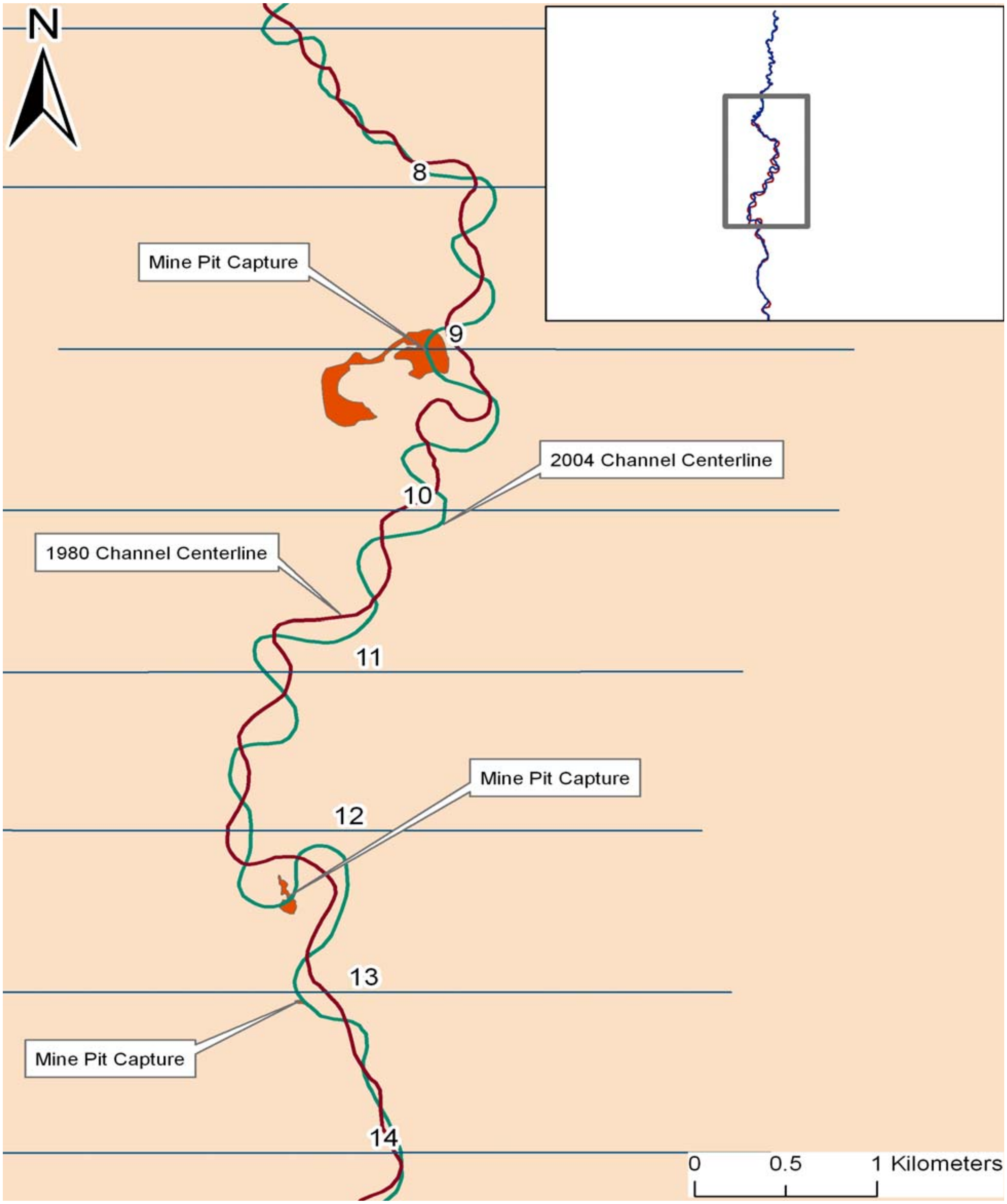
There are several factors that can be studied in the future to understand more clearly what effects mining has had on the Tangipahoa. New time steps could be studied to fill in the gaps between 1980 and 2004. Time steps could be digitized at more frequent intervals. This would give a more complete story about how mining can influence channel change. From this pit captures could be more closely examined and if they have caused any channel changes such as lateral migration and channel widening to the Tangipahoa.

Since stream power plays such a large role in channel change, it would be interesting to study the Tangipahoa before and after a large flood event. Floods can induce pit captures resulting in the reduction of point bar areas and numbers and large scale channel change. This type of research could be important for future development and the protection of wildlife habitats since a better understanding of the Tangipahoa will react during a flood event will be known.

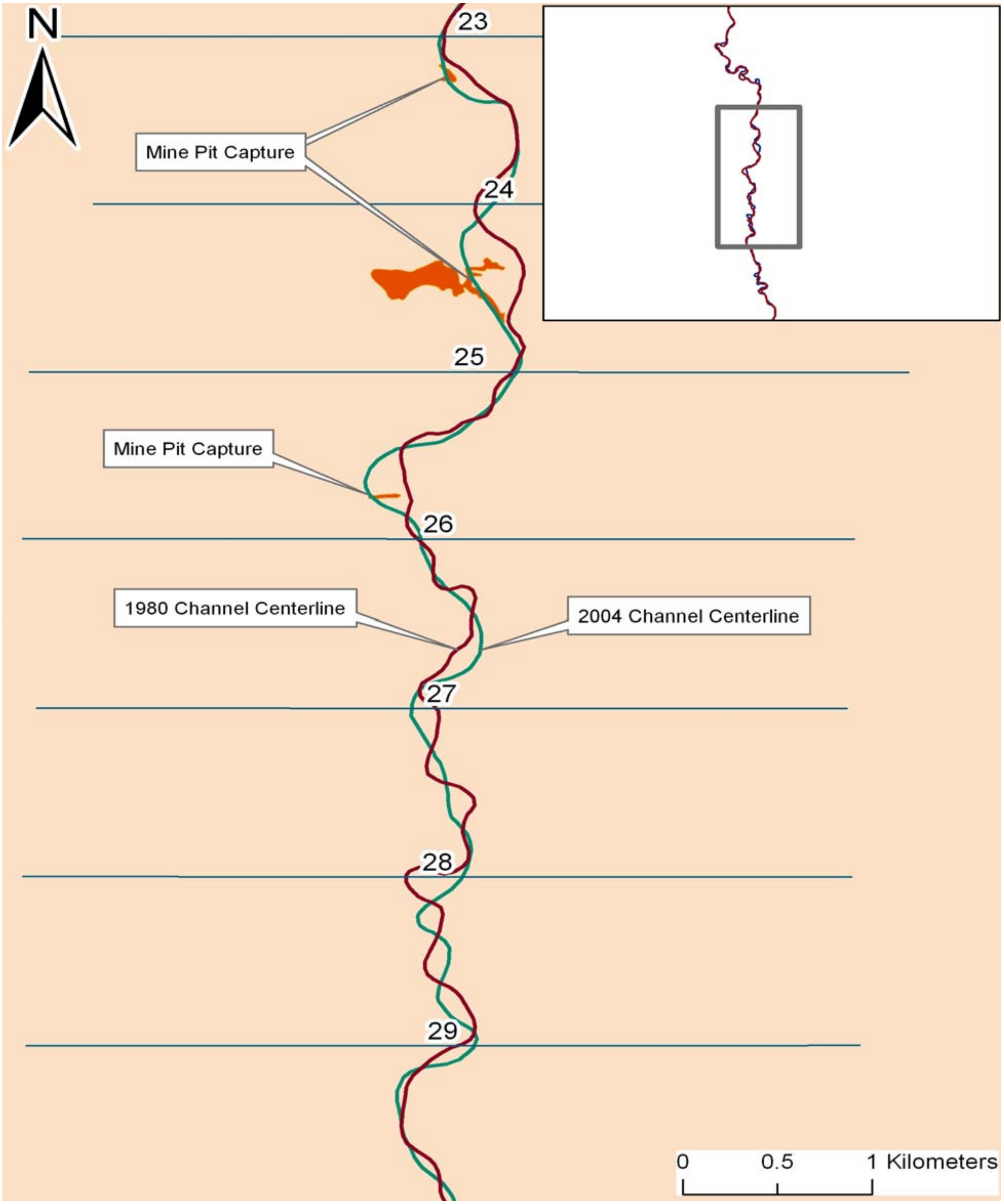
Other variables could be adjusted in future projects such as the distance of the transects, increase lags both up and downstream to see if there is a statistical link between mining area and channel change in different reaches, and explore more time periods.

Factors that were not included in this project that could induce channel change should be studied as well. These include urbanization, deforestation, dams and bridges, all have geomorphic effects on river systems.

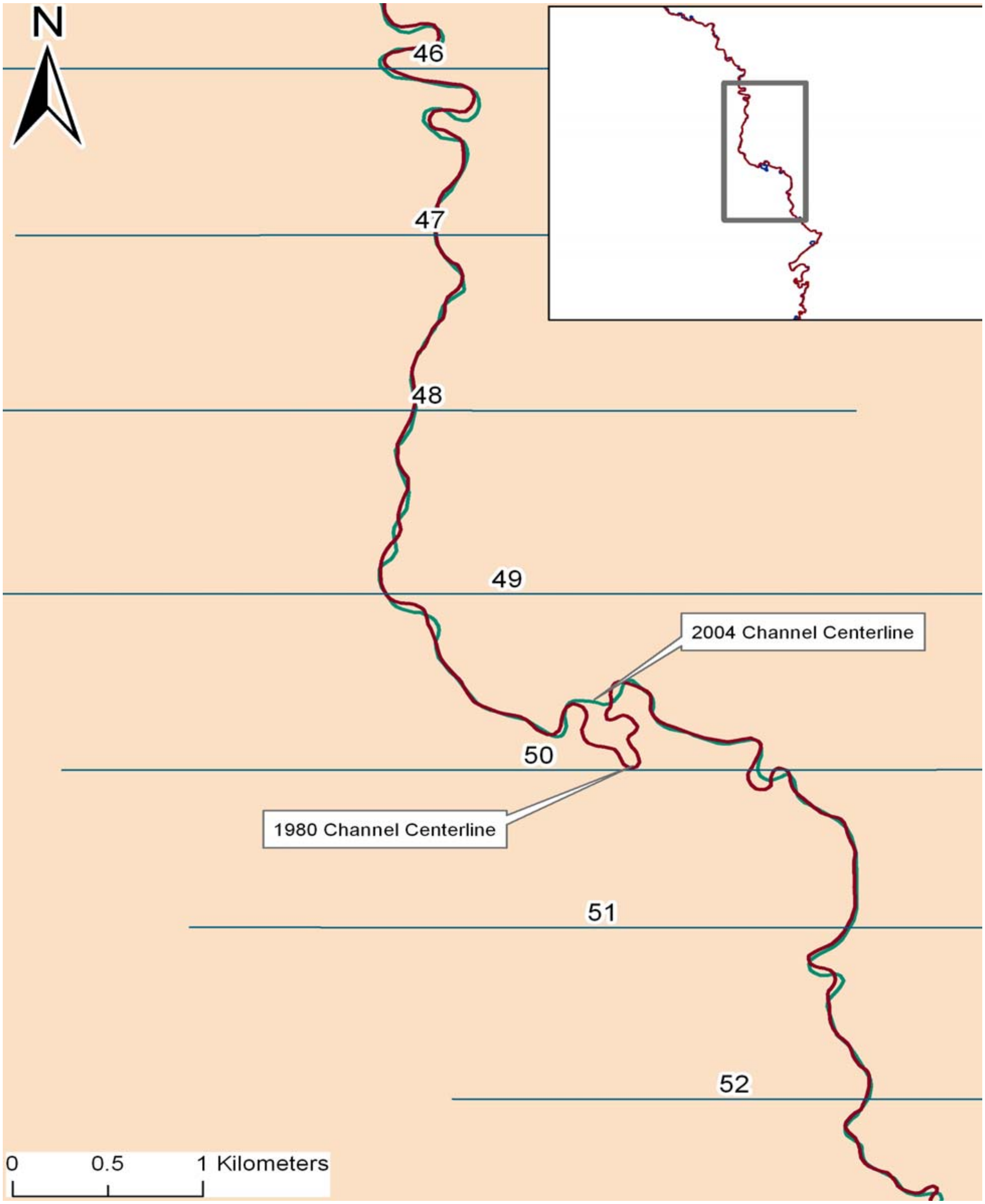
APPENDIX
FIGURES SHOWING CHANNEL CHANGE AND PIT CAPTURE



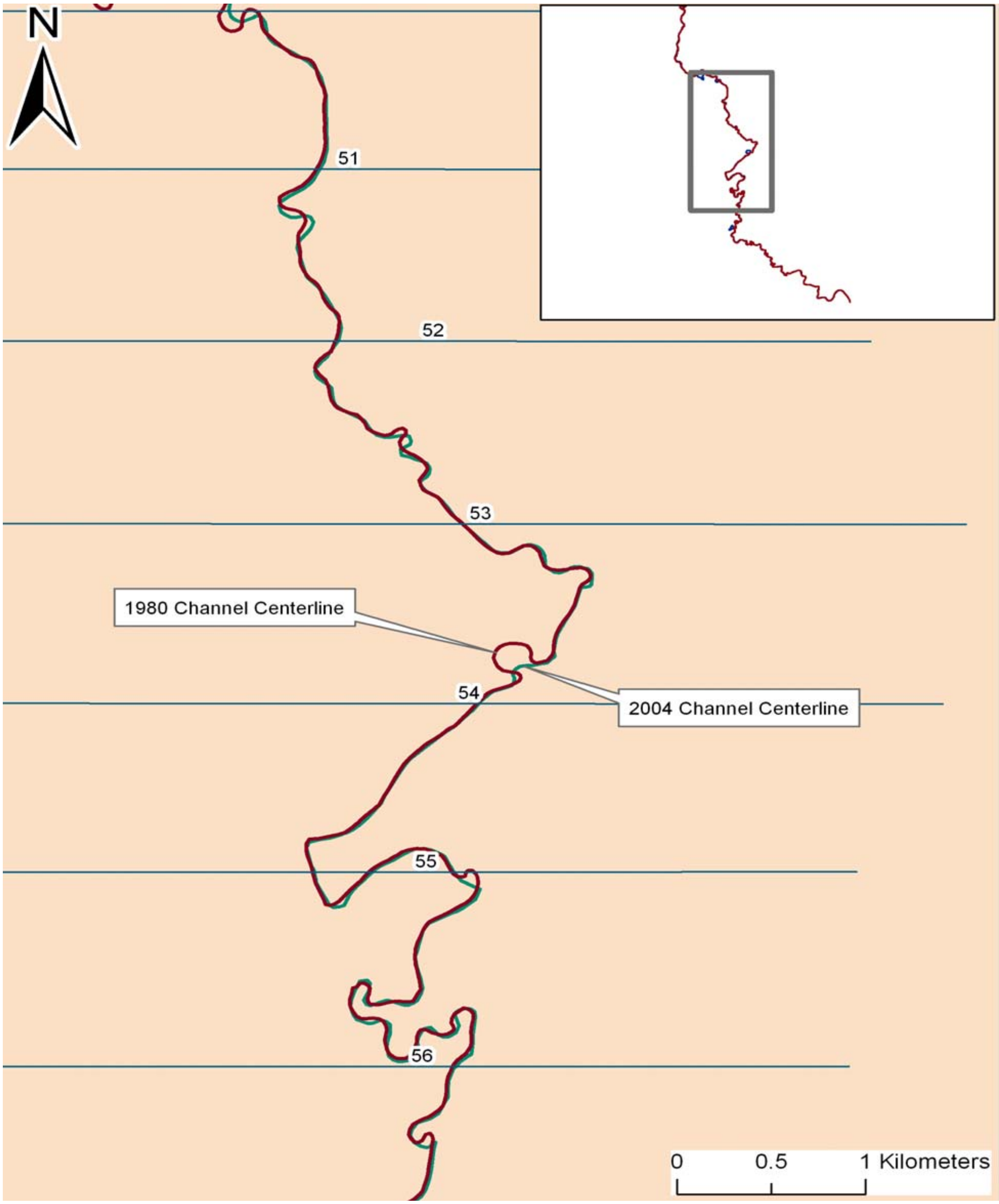
Appendix A-1. Unstable reach in transects 6-12



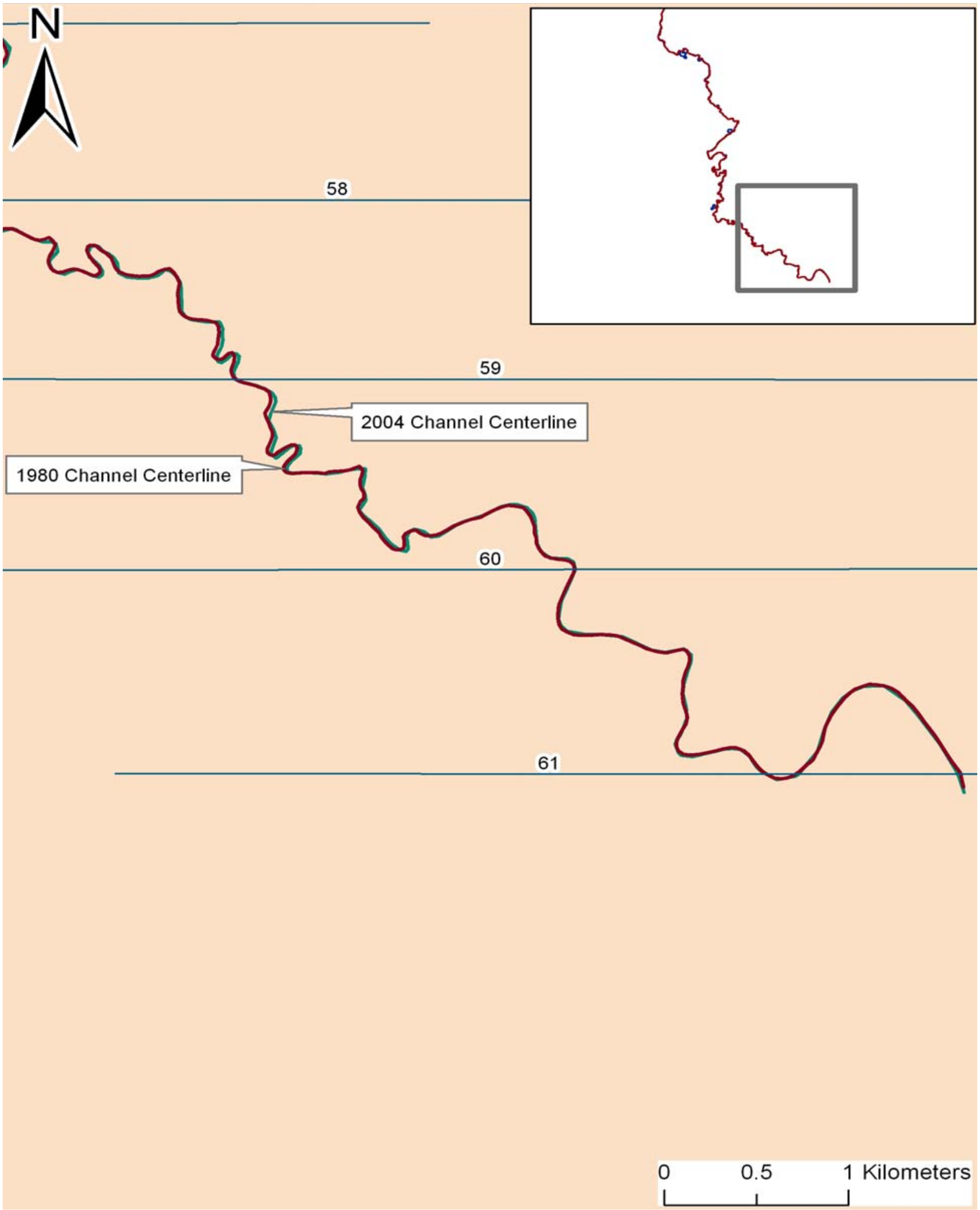
Appendix A-2. Unstable reach in transects 23-29



Appendix A-3. Stable reach in transects 46-52



Appendix A-4. Stable reach in transects 50-56



Appendix A-5. Stable reach in transects 57-61

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BIOGRAPHICAL SKETCH

Steven R. Marks was born in 1983 in Gainesville, Florida. He has lived in Gainesville his entire life and received his Bachelor's Degree in Geography from the University of Florida with a strong focus on GIS and Urban Planning. He started working at Jones Edmunds and Associates in May 2008 as a GIS technician. He also currently runs a small car detailing business that he started in 2002.