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Using GIS and Remote Sensing Applications to Determine Recovery from Disaster: Seven Years Post-Katrina in Residential Communities of Hancock County

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The University of Southern Mississippi

Using GIS and Remote Sensing Applications to Determine Recovery from Disaster:
Seven Years Post-Katrina in Residential Communities of Hancock County

by

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Abstract

Hurricane Katrina devastated the gulf coast states of Louisiana and Mississippi on August 29th, 2005. The communities of Shoreline Park and Waveland in Hancock County, Mississippi were used in this study to analyze land use change post-Hurricane Katrina using Geographic Information Systems (GIS) and Remote Sensing. These two communities are experiencing slower recovery than their counterparts along the coast. By examining high-resolution aerial imagery from 2007 and 2012, there can be comparisons that show the timeline of recovery for these two communities post-Katrina. Shoreline Park has seen 30% of its total parcels change their structural footprints from 2007 – 2012 with an increase to its residential land use of 14.4%. Empty parcels still make up the bulk of Shoreline Park with 76.89% of the total land use. Waveland experienced a 7.74% change to its residential land use, while 30% of its total parcels changed their structural footprints post-Katrina. Both Shoreline Park and Waveland are currently dominated by empty parcels. While these numbers may seem high concerning residential land use, 70 % of structures in Shoreline Park and 90 % of structures in Waveland were damaged or destroyed. The data indicate rebuilding is slower than expected seven years post event. This study shows how insurance costs, elevation, and flood zoning are directly contributed to slower rebuilding efforts. Evidence suggests that residents are migrating from their coastal locations to areas further inland.

Table of Contents

Chapter 1: Introduction	1
Chapter 2: Literature Review	
2.1: <i>Storm History</i>	2
2.2: <i>Loss of Life and Damage</i>	4
2.3: <i>Small Community Initial Response to Disaster</i>	6
2.4: <i>Short Term Recovery Leads to Long Term Recovery</i>	7
2.5: <i>Long Term Recovery in Small Community</i>	8
2.6: <i>Decisions for Residents Return to pre-Katrina Locations</i>	9
2.7: <i>Aerial Imagery Analysis</i>	12
2.8: <i>Using GIS and Remote Sensing to Track Land Use Change</i>	12
Chapter 3: Methodology	14
Chapter 4: Results	17
4.1: <i>Shoreline Park</i>	17
4.2: <i>Waveland</i>	19
Chapter 5: Discussion	20

Chapter 6: Conclusion	26
References	30
Acknowledgements	47

List of Figures

Figure 1: Shoreline Park and Waveland Study Area.....	32
Figure 2: Katrina Track and Study Area.....	33
Figure 3: Hurricane Katrina Track 23 August 2005 – 30 August 2005.....	34
Figure 4: Example of fishnet grid.....	15
Figure 5: Waveland 2007.....	15
Figure 6: Waveland 2012.....	35
Figure 7: Example of residential code (HS).....	36
Figure 8: Example of mobile home code (MH).....	36
Figure 9: Example of FEMA trailer code (FT).....	36
Figure 10: Example of other code (OT).....	36
Figure 11: Example of empty parcel with slab code (ES).....	37
Figure 12: Example of empty parcel wooded (EL).....	37
Figure 13: Example of parcel cleared for development (ED).....	37
Figure 14: Shoreline Park, MS East and West of Highway 603.....	38
Figure 15: Shoreline Park, MS Supervised Classification Based on Imagery From 2007.....	39
Figure 16: Shoreline Park, MS Supervised Classification Based on Imagery From 2012.....	40
Figure 17: Waveland, MS North and South of Central Avenue.....	41
Figure 18: Waveland, MS Supervised Classification Based on Imagery From 2007.....	42
Figure 19: Waveland, MS Supervised Classification Based on Imagery From 2012.....	43

List of Tables

Table 1: Parcel coding scheme	44
Table 2: Shoreline Park, MS parcel change 2007 – 2012.....	44
Table 3: Shoreline Park, MS east of Highway 603 change 2007 – 2012.....	44
Table 4: Shoreline Park, MS west of Highway 603 change 2007 – 2012.....	44
Table 5: Shoreline Park, MS land use change 2007 – 2012.....	45
Table 6: Waveland, MS parcel change 2007 – 2012.....	45
Table 7: Waveland, MS south of Central Avenue change 2007 – 2012.....	45
Table 8: Waveland, MS north of Central Avenue change 2007 – 2012.....	45
Table 9: Waveland, MS land use change 2007- 212.....	46

Chapter 1: Introduction

Hurricane Katrina made landfall in the morning hours of 29 August 2005 causing the gulf coast states of Mississippi and Louisiana to experience loss of life and property on an unprecedented level (NOAA 2005). Record storm surge heights of 8.5m (28ft.) rolled in from the swollen Gulf of Mexico, heavily inundating the coast and destroying anything with which it came in contact (NOAA 2005). Katrina set many high water marks in Mississippi previously held by Hurricane Camille of 1969. Furthermore, massive evacuations of populations took place along the central gulf coast never before experienced. The number of people displaced by Katrina was estimated to be 250,000 (NOAA 2005). Many residents who evacuated remained displaced for months and even years after the storm. While some residents have returned to their pre-Katrina locations, many have not.

Recovery rates seem to be on track in many areas along the Mississippi gulf coast; however, the communities of Waveland and Shoreline Park in Hancock County are suffering from slower recovery than their counterparts on the coast seven years post Katrina. Shoreline Park and Waveland were used as the study area in this research, because they are geographically close to the Mississippi landfall of Katrina and suffered severe damage (Figures 1 and 2). This study highlights these areas and their land use changes using Geographic Information Systems (GIS) and Remote Sensing applications. Many studies have been done in and around New Orleans, Louisiana concerning the return of displaced residents post-Katrina, but there is a lack of research on the smaller communities in Hancock County, Mississippi. Moreover, literature reporting on the use

of a GIS to track these changes is also deficient. This study addresses the primary questions: What are the recovery rates in these two communities, and why are they taking longer to achieve recovery? Shoreline Park and Waveland are not the only communities struggling to rebuild after this disaster; however, they can be used as examples to help monitor other similar communities.

Chapter 2: Literature Review

2.1 Storm History

The formation of Katrina began in the Bahamas from a tropical wave that interacted with an upper tropospheric trough and the remains of a tropical depression (NHC 2005). Consequently, at 1800 UTC 23 August 2005 (12:00 PM CST) Tropical Depression Twelve formed (NHC 2005). As the storm trekked irregularly on a north westward path, convection began to build and intense rain bands began to wrap around a center of circulation. As a result, Tropical Depression Twelve intensified into a tropical storm at 1200 UTC 24 August (6:00 AM CST) and was given the name Katrina (NHC2005). Katrina became the 11th named storm of the 2005 hurricane season. Additionally, by the morning of 24 August and evening of 25 August Katrina underwent a further increase in intensity shortly before its initial landfall. Just prior to the first landfall, middle and upper tropospheric winds over the northern central Gulf of Mexico steered Katrina sharply to the west-southwest direction. In the evening hours of 25 August, Katrina made landfall as a Category 1 hurricane around North Miami Beach, Florida with maximum sustained winds of 70 knots (80 mph) (NOAA2005). Katrina

then crossed the Florida Peninsula with its eye and core relatively intact, which helped the storm maintain its dynamics as it entered the Gulf of Mexico.

As the storm moved off of the southwestern coast of Florida, it encountered an upper-level anticyclone situated over the Gulf of Mexico, which produced little to no wind shear and substantial upper-level outflow giving Katrina the ability to intensify (NOAA 2005). The storm began to track over warmer than average sea surface temperatures in the Gulf of Mexico's Loop Current (McTaggart-Cowan et al. 2007). These two factors became critical to Katrina's life cycle as a tropical cyclone and ultimately allowed the storm to go through two extreme stages of intensification. Extreme stages of intensification are known as increases of wind speeds of 30 knots (35 mph) or more in a 24 hour period (NHC 2005). The first of these two periods beginning on 26 August included an intensification from 65 knots (70 mph) to 95 knots (109 mph) by 0600 UTC 27 August (12:00 AM CST). At 1200 UTC 27 August (6:00 AM CST) shortly after the spike in intensity, a clearly defined eye-wall formed, and Katrina was classified as a Category 3 hurricane with winds of 100 knots (115 mph) (NHC 2005). The second intensification period was Katrina's most dramatic going from a Category 3 to Category 5 status with maximum sustained winds of 145 knots (166 mph) by 1200 UTC 28 August (NHC2005). Moreover, by 1800 UTC (12:00 PM CST) 28August, Katrina reached its peak intensity of 150 knots (172 mph) with a centralized barometric pressure of 902 millibars (NOAA 2005).

The storm then went through a cycle of de-intensification after making Category 5 status. The period of de-intensification took place shortly before its second landfall. The loss of intensity was the result of increased wind shear, increased forward speed, and the

storm's movement over the continental shelf (McTaggart-Cowan et al. 2007). As a result of intensity loss, Hurricane Katrina made its second landfall as a powerful Category 3 storm in the vicinity of Buras, Louisiana at 1200 UTC 29 August 2005 (6:00 AM CST). The storm's center moved ashore with wind speeds of 110 knots (126 mph) and a centralized pressure of 920 millibars (NOAA 2005). Shortly afterward, the storm made a third landfall on the Mississippi – Louisiana border around 1600 UTC (10:00 AM CST) with wind speeds slightly decreased to 105 knots (120 mph) (NOAA 2005). Katrina then continued on a northerly track through central Mississippi throughout the day of 29 August and dissipated into a lower – level remnant on 30 August 2005 (McTaggart-Cowan et al. 2007) (Figure 3).

2.2 Loss of Life and Damage

According to NOAA, the number of fatalities directly related to Katrina is 1,833 spread across several states (2005). Louisiana suffered the highest loss of life with 1,577 (NOAA 2005). Fatalities for other states include: Mississippi (238), Florida (14), Georgia (2), and Alabama (2) (NOAA 2005). Damages from Hurricane Katrina exceeded \$100 billion (NHC 2005). The 1926 Florida Keys hurricane is the only hurricane to surpass Katrina in monetary damages after being adjusted for inflation (NHC 2005).

Most of Katrina's extensive damage was centered in Louisiana and Mississippi, on a large geographical scale. Although damage was not isolated to the coast, the majority of severe damage lay in the coastal counties. There were two primary sources of damage associated with Katrina: storm surge and wind (Eamon, et. al. 2007). Storm

surge levels reached 8.5m (28 ft.) in some places in Mississippi mainly on the western coastlines in Hancock and Harrison counties (NOAA 2005). Jackson County received surge heights around 6m (19 ft.) (NOAA 2005). Additionally, in Louisiana high water marks reached nearly 4.5m (15 ft.) in Lake Pontchartrain and inner-city canals (NOAA 2005). These high water marks broke previous records set by Hurricane Camille in 1969 by as much as 3m (10 ft.) in many places along the gulf coast of Mississippi and Louisiana (NOAA 2005).

Several factors went into producing a surge on this level. The storm hit at high tide adding an additional 30cm (.9 ft.) to the storm surge level (Eamon, et. al. 2007). The geography of the coast enhanced the surge with its shallow bathymetry and low sloping continental shelf (Eamon, et al. 2007). As Katrina approached the coast of Mississippi, the shallow sloping continental shelf hindered flow along the bottom, while speeding up flow near the surface allowing for the additional build-up of water (Eamon, et. al. 2007). Additionally, the geographic size of the storm and wave action allowed for a bigger surge (NHC 2005). Although wind did play an important factor in damage, storm surge was the biggest and costliest source of destruction in the event.

Hancock County in southern Mississippi experienced a particularly devastating blow suffering from the right front quadrant of the storm along with its maximum storm surge and peak wind gusts. Areas of Hancock County, such as Bay St. Louis and Waveland, were hit with surge heights in excess of 8m (26 ft.) in some places with wind speeds in gusts up to 112 knots (128 mph) (Eamon, et. al. 2007). Consequently, in Hancock County, Katrina left 56 people dead and property losses estimated at 70 % of county-wide residential dwellings being damaged or destroyed (FEMA 2006). In the city

of Bay St. Louis, roughly half of the residential housing units were lost. The city of Waveland suffered an even bigger hit with an estimated 90% residential loss (FEMA 2006). Furthermore, roads and bridges were destroyed making transportation into the area a challenge impeding short and long-term recovery (Eamon, et. al. 2007).

2.3 Small Community Initial Response to Disaster

In the wake of Hurricane Katrina, small communities like Waveland and Bay St. Louis, Mississippi, which are mostly composed of single-family residential dwellings, were left vulnerable. The U.S. Census considers a small community to be a city with a population of 12,000 or fewer people (Hughey and Tobin 2006). According to Hughey and Tobin, the initial response of a small community to large-scale natural disasters usually consists of local residents helping their fellow neighbors. The assistance is normally in the form of helping those stranded evacuate damaged areas and providing initial needs (Hughey and Tobin 2006). Federal and state assistance is usually a little slower to respond to a disaster on the scale of Katrina as plans take time to execute. The challenge in Katrina was the scope of the disaster and the multiple states involved. Evacuations of stranded survivors of Katrina were slow to materialize in New Orleans. Due to poor planning, transportation was not provided leaving many with no evacuation means (Roberts 2006). Additionally, after the storm passed, federal and state agencies took days to mobilize in the affected areas, mostly due to infrastructure failure (Roberts 2006). Once in the disaster zone, federal and state assistance was poorly organized, which often led to confusion (Roberts 2006).

Small communities can often be restrained from acting in the initial phase of post-disaster, due to legal constraints from federal and state agencies (Hughey and Tobin 2006). In the case of Hancock County's small communities, many police, fire, hospital, and emergency operations centers sustained major damage to buildings, equipment, and vehicles, hindering most capabilities of first responders (FEMA 2006). The collapse of response in the beginning stage of the disaster is crucial to the long-term survivability of small communities.

2.4 Short Term Recovery Leads to Long Term Recovery

In order to achieve long-term recovery, short-term needs for housing had to be met. Short-term recovery is often the most critical precursor to long-term recovery, especially given the large scale of the disaster (Olshansky 2006). One of the biggest problems in a large-scale natural disaster is finding temporary housing for the thousands of displaced families (Lee, et. al. 2007). In the case of Hurricane Katrina, many people moved away from their primary areas of residence after the storm, and without temporary housing would likely settle in other areas (Olshansky 2006). Housing solutions, such as Federal Emergency Management Administration (FEMA) trailers, offered residents a sense of security as they waited for the rebuilding of their communities and the opening of jobs. Temporary housing provided residents with two basic attributes. It allowed residents to live in their pre-Katrina locations, and it provided infrastructure and basic amenities (2006).

Infrastructure and amenity stability are also keys to short and long-term recovery, as citizens want good roads, sewer, water, public lighting, and an overall sense of security

in their homes (Morrish 2008). Infrastructure stability also leads to future development in the disaster area as outside influence begins to take advantage of growth potential post-disaster. Residents also want amenities, such as grocery stores, gas stations, banking centers, and other needs of everyday life. They begin to feel more comfortable with their new situation as signs of recovery begin to emerge as various services are restored (Morrish 2008). Residents will begin to move back into their previous locations as infrastructure stability is restored. Without these amenities, short-term development in badly-damaged areas may be hindered, causing potentially damaging effects for long-term recovery (Morrish 2008).

2.5 Long Term Recovery in Small Communities

The Mississippi Governor's Commission for Recovery, Rebuilding, and Renewal (CRRR) was conceived after a request from then Mississippi Governor Haley Barbour. The commission began working with Congress to supply local communities with urban planners in hopes of adopting New Urbanism as a way of rebuilding south Mississippi cities (Evans-Cowley and Gough 2009). The idea of New Urbanism is utilized for long-term city conservation and land use planning. Moreover, followers of New Urbanism believe the idea is more economically friendly and can bridge gaps across socially diverse areas of the coast (Evans-Cowley and Gough 2009). Mississippi gulf coast cities were paired with planners to help them in their rebuilding plans.

One issue that concerned New Urbanism is that many local planners and residents were unfamiliar with the ideas and had to be educated about its benefits. In a response to the need for education concerning New Urbanism, the Governor's Commission adopted

the Mississippi Renewal Forum (Evans-Cowley and Gough 2009). The Renewal Forum was the state's first attempt at adopting plans for rebuilding and recovery of the Mississippi gulf coast (Evans-Cowley and Gough 2009). Teams were developed in the forum to work with local communities and investigate issues of transportation, retail, social, and environmental issues (Evans-Cowley and Gough 2009).

New Urbanism practices are composed of citizen-driven involvement, which are implemented through meetings and charrettes (Evans-Cowley and Gough 2009). New Urbanism uses transect-based ordinances to focus on a rural to urban transition. Additionally, these plans call for procedures that illustrate planning from the local and regional level covering issues concerning sustainability during development, economic growth, social inequalities, and environmental resources (Evans-Cowley Gough 2009). Immediate plans set out to address the initial needs of coastal communities, such as meeting the need for affordable housing first. The ideas of walkability within urban areas and smart transportation are also implemented through these practices (Evans-Cowley and Gough 2009). New Urbanism along the Mississippi gulf coast is an on-going process and research suggests that many of these principles are currently lacking. The belief is that many struggles remain between regional and local planning strategies in the context of adopting better plans for local communities (Evans-Cowley and Gough 2009).

2.6 Decisions for Residents Return to Pre-Katrina Locations

Many displaced residents have tough decisions to make when deciding whether or not to return to their pre-Katrina locations. Sense of place is arguably one of the most important deciding factors when determining relocation (Chamlee-Wright and Storr

2009). There are three notions that are associated in describing sense of place. The first is that of place attachment and is a positive cognitive link that ties individuals to their environment (Chamlee-Wright and Storr 2009). The second is place identity and can be understood as the values, beliefs, and goals an individual holds for a certain place (Chamlee-Wright and Storr 2009). Additionally, place dependence is the idea that a place can provide an individual with their everyday wants and needs (Chamlee-Wright and Storr 2009). Humans tend to be habitual in nature and rely on what is comfortable to them. Many residents in the Lower Ninth Ward of New Orleans, Louisiana chose to return based on this principle (Chamlee-Wright and Storr 2009). In a study conducted by Chamlee-Wright, questions were asked of residents in the Ninth Ward regarding their decision to return (2009). Residents gave answers pointing to a sense of place such as food, neighbors, security, and weekend activities. These traits all indicate a sense of place with which Ninth Ward residents could identify (Chamlee-Wright and Storr 2009).

While sense of place is one of the most important deciding factors of returning, many scholars have pointed out social traits tend to predict outcomes of decisions on whether to return to an area or not. A study in Louisiana shows that the decision to return was based on the level of destruction and its geographical distribution. However, the same study showed that impoverished African Americans were less likely to return than whites (Groen and Polivka 2010). Further, according to Groen, age showed a similar trait in that older established families returned quicker than younger families (2010). Groen also suggests that economic stability was the main deciding factor for an individual to return to an area with factors like job security and insurance payouts greatly affecting their decision (2010).

Higher insurance costs and tougher building codes concerning Base Flood Elevation (BFE) levels are two other reasons many residents are not returning to their pre-Katrina locations. Residential insurance premiums in the affected areas have seen rises, and in some cases, companies are not providing coverage at all. State assisted programs are helping to mitigate the rise in insurance premiums, but in some cases, costs associated with the programs have also risen. During 2006 in Mississippi, an approval for a 90% raise in premiums to its Mississippi Windstorm Underwriting Association (MWUA) along with federal subsidies to fill the gap put additional pressure on insurance policies (Macdonald, et. al. 2011). Remodels of homes and businesses are typically grandfathered into previous building codes. Residents who only have to do a remodel, instead of new construction, may return quicker than those having to completely rebuild.

Following Katrina, FEMA updated its flood analysis maps or Advisory Base Flood Elevation (ABFE) (FEMA 2005). After conducting analysis, FEMA determined the 1% annual chance of stillwater levels (100 year flood) rose by 3 to 8 feet (FEMA 2005). This process added elevation to the previously used Flood Insurance Rate Maps (FIRMS). The new ABFE also accounted for wave height analysis in coastal zones, which also added elevation to the 1% annual chance of stillwater levels. These new elevation flood maps are generally an additional 5 – 12 feet higher than previous base flood elevation maps developed by FEMA (FEMA 2005). With the new increases in elevation to the FIRMS, the updated ABFE's were adopted into the new BFE in 2006 (FEMA 2006). Residents using the new BFE adhere to building codes and can reduce insurance premiums. However, these rules add cost to construction with raising property or building structures on elevated pilings, in order to meet the new BFE guidelines.

2.7 Aerial Imagery Analysis

Geographic Information Systems (GIS) is a way of storing spatial information. A GIS can also provide real-time updates on specific neighborhoods that residents can analyze in the decision to return (Mills 2009). With the advancement of such systems as the Spatial Video Acquisition System (SVAS) and aerial imagery, residents can make informed decisions on their neighborhoods and communities. Real-time images based on street-level views depict the state of the neighborhoods allowing residents to make informed decisions on relocating back to a particular area. Information obtained by the SVAS and aerial imagery is often put onto GIS servers, which allow users access to the data. However, according to Mills, those who need to access the data, such as residents considering their return to an area, may not have the means to get the necessary data (2009).

Advancements in satellite and aerial imagery platforms have led to developments in sensors that are capable of sub-meter (> 3.29 ft.) spatial resolution characteristics (Gillespie et al. 2007). These characteristics allow the sensors to produce images of the ground in which buildings, vehicles, and other man-made or natural objects can be identified. Applications of high-spatial resolution sensors can be applied to post-disaster surveys, utilizing aerial imagery analysis in a time series for a particular geographic area (Gillespie 2007).

2.8 Using GIS and Remote Sensing to Track Land Use Change

Land use changes can be described as the temporal physical reproduction of growth or decline in development within spatially associated areas (Bo, et. al. 2009).

These changes are normally associated with political, social, and economic factors. However, Katrina destroyed or damaged many areas along the gulf coast, placing land use change into an instant circumstance (Bo, et. al. 2009). The information a GIS can provide helps developers make decisions that speed up and improve the overall planning of a community with respect to land use changes. In the 1980s, GIS started making headway in the planning and analyzing of urban areas for growth (Sui 1998). The technological advancements in GIS allowed users to visually represent data quickly and reliably in cartographic form. With GIS capabilities on the rise, spatial analytical concepts were developed in the 1990s to further the abilities of GIS systems. These concepts gave planners tools that allowed them to predict potential outcomes (Sui 1998). Spatial analysis models can aid in the assessments of elevation and can give predictors for flooding.

In conjunction with GIS, Remote Sensing as a tool assists analysts in the planning and research of community development. The field has made major advancements in recent decades in the form of high-resolution aerial imagery (Longley 2002). Land use identification has become easier and more economically friendly. First generation satellite sensors such as Landsat Multi-Spectral Scanner (MSS), have been replaced by second generation sensors. These new sensors are able to produce high-quality imagery that can be used to study urban areas in fine detail, but come at the cost of massive data files (Longley 2002). The QuickBird sensor, for example, has a spatial resolution of 0.6m (23 in.). This high-resolution imagery allows for easy identification of buildings, vehicles, and other structures (Gillespie et al. 2007). Post-disaster analysis of storm damage patterns and recovery using sensors such as QuickBird, gives officials virtually

real-time accurate data to coordinate search and rescue. Coupled with a GIS, these sensors can provide users with accurate datasets that illustrate damaged areas and land use changes as the post-disaster phase progresses (Gillespie et al. 2007).

Chapter 3: Methodology

The purpose of this study was to analyze residential recovery rates in the Shoreline Park and Waveland communities of Hancock County, Mississippi. A quantitative approach, using a supervised classification was applied by the evaluation of residential structures that have rebuilt post-Katrina. Statistical analysis was conducted to determine patterns of recovery. The analysis was performed by utilizing Remote Sensing and GIS techniques through the use of supervised classification methods in aerial imagery analysis. Imagery with a spatial resolution of 6 inches was compared from February 2007, 18 months after Hurricane Katrina made landfall, to 6 inch imagery from February 2012. In the spring of 2007, much of the storm debris was in the process of being removed or was just recently removed, but the reconstruction of Shoreline Park and Waveland was still in its infancy. The 2007 imagery supports this with evidence of slabs and entire neighborhoods cleared of housing, being sparsely rebuilt, as shown in figure 4. Further, figures 4 and 5 show the residential structure changes from 2007 to 2012. All imagery analysis and map generation was generated in the Geographic Information Technologies Lab, at The University of Southern Mississippi using ArcGIS 10 software from ESRI.



Figure 4: Waveland 2007



Figure 5: Waveland 2012

The study used aerial imagery taken from high-resolution sensors (6 in.) from February 2007 and February 2012. The process began by first entering the 2007 imagery into the GIS. Parcel data from 2010 was then over-laid on top of the imagery dataset, allowing for a good visualization of those structures present in 2007, and the changes that were made through 2012 (Figures 4 and 5). Parcels were then selected within the areas of interest based upon community boundaries. Shoreline Park's geographical area is spread out, which allowed for a study of 9,254 parcels. However, Waveland's 5,675 parcels were smaller and tightly contained.

A fishnet layer was then added to the imagery and parcel dataset. The fishnet is a grid system, used as a control, to ensure every parcel is completed in the selections (Figure 6). Every residential parcel within the selections received a code for classification purposes. To classify the parcels in the selections, fields were created in the attribute tables for the two communities. The fields created consisted of visual 2007, visual 2012, visual 2007 – 2012, and change 07 – 12. Parcels were coded using the

fishnet grid system. Once an entire grid was completed, the next grid in sequence was started. The fishnet grid system ensured systematic coverage of the study area.

In the aftermath of Katrina, many residents lived in temporary housing, known as “FEMA trailers,” or trailers provided by the Federal Emergency Management Administration (Lee, et. al. 2007). These trailers became part of the physical landscape after the storm. For purposes of this study, FEMA trailers were assigned a code. The codes represented in this study are: residential home, mobile home, FEMA trailer, other, empty with slab, empty parcel wooded, and empty parcel cleared for development (Table 1). The residential home code (HS) represents parcels that consist of fixed residential homes (Figure 7). The mobile home code (MH) used in this study was reserved for any home on a set of axles that can be relocated to another area (Figure 8). FEMA trailer codes (FT) were reserved for parcels with FEMA trailers (Figure 9). Further, the code other (OT) was used for parcels with commercial, industrial, or utility land use, such as a gas station or an electrical sub-station (Figure 10). Empty parcel with slab (ES) was used for any parcel which showed conclusive evidence of a concrete slab without a structure of some type (Figure 11). The empty parcel wooded code (EL) was used for parcels that consisted of wooded properties (Figure 12). Parcels cleared for development (ED) consisted of properties that had a structure of some type which was removed, or was in the process of being cleared for new construction (Figure 13). To maintain precision and accuracy, this study tried to minimize the number of codes used for classification.

These codes enabled the GIS to classify the data and represent it through maps. Additionally, statistics based on both datasets were compared to get values for recovery rates. The values for each code were summed and percentages were made for each

community in 2007 and 2012, showing the overall land use change. Further, percentage change was calculated showing the rate of growth or decline in land use for a particular code, from 2007 - 2012. Overall change rate was also calculated for each community showing how many parcels changed and how many did not. The calculations were used to generate maps of parcels that have rebuilt structures since 2007 and which ones remained empty. To evaluate the two datasets, each one was imported into the GIS. Once in the GIS, tables were joined based on a unique field identifier in the attribute tables. A unique values method of classification was applied to the newly joined tables, showing which parcels changed from 2007 to 2012.

Chapter 4: Results

4.1 Shoreline Park

The supervised classification used on Shoreline Park produced a statistical analysis that shows the community is experiencing slow recovery. Shoreline Park, with a total of 9,254 parcels had 2,804 change their structural footprints from 2007 to 2012. This represents 30% of the community's total parcels. In addition, 6,450 parcels did not change their structural footprint in the seven year period following Katrina, accounting for 70% of Shoreline Park's land use (Table 2).

Areas just east of Highway 603 in Shoreline Park on the western edge of Bay St. Louis and Jourdan River are experiencing more recovery than areas to the west in Shoreline Park. Statistical analysis shows that 37% of these parcels east of Highway 603 showed signs of change based on the classification method, compared to 22% of the parcels west of Highway 603. Meanwhile, 63% of the properties east of Highway 603

did not change their characteristics. In comparison, 78% of the parcels to the west of Highway 603 did not see any changes, post-Katrina. Tables 3 and 4 show the results for parcel change to the east and west of Highway 603 in Shoreline Park, MS. Figure 14 depicts the Shoreline Park community in respect to the geographical areas that are seeing slower recovery and those who are undergoing quicker recovery.

Within each classification code, Shoreline Park experienced rises in three areas: empty parcel wooded, residential home, and mobile home. The residential home class had an increase of 73.79% from 2007 – 2012. The mobile home class seen a spike of 68.25%, and the empty parcel wooded class experienced a rise of 17.66% within their respective classifications. Some classes underwent decreases in percentages from 2007 to 2012: other, empty parcel with slab, empty parcel cleared for development, and FEMA trailer. Parcels designated other saw a decrease by 21.48% within its class from 2007 - 2012. The class for empty slab fell by 52.49%, and empty parcel for development decreased by 49.83%, while FEMA trailer dropped by 100%. The figures for these percentage rises and decreases within each class are represented in table 5.

In 2007, residential housing made up 9.86% of Shoreline Park's total land use compared to 17.13% in 2012, producing a 7.27% increase in residential housing in five years. Further, the number of mobile homes in the community remained relatively the same with only a slight increase of 0.47%, giving an overall raise to residential structures post-Katrina to 7.74%. Empty parcels that were cleared for structures in 2007 composed 12.45% of total land use and dropped to 6.24% in 2012, a drop of 6.21% overall. Parcels with empty slabs fell by 2.74%, and FEMA trailers in 2007 occupying 8.34% of the total parcels in Shoreline Park had been totally removed out of the community by 2012.

Empty wooded parcels made up the highest number of classed parcels in Shoreline Park with 5,481 in 2007 and 6,449 in 2012. Table 5 represents the statistical data for Shoreline Park in respect to its overall land use percentage changes.

4.2 Waveland

The supervised classification for Waveland produced results that were similar to Shoreline Park, although it did show slightly better recovery trends. According to the data 3,792 of the 5,675 parcels that make up Waveland's city limits did not change post Katrina. The number of parcels that did not change correlates to 67% of the properties within the city. Further, 1,883 parcels or 33% of the classified land use within Waveland did experience a change post Katrina. The data representing these changes are illustrated in table 6. Areas south of Central Avenue in Waveland depicted a 40% change in the land use, with 940 parcels, whereas areas north of Central Avenue showed a 29% change (Tables 6 and 7). Parcels that did not change south of Central Avenue consisted of 60% of the land use, in contrast to 71% of areas to the north (Tables 6 and 7). Figure 17 shows Waveland in respect to its geographical areas that are seeing slower recovery and those who are undergoing quicker recovery.

Waveland has seen percentage rises in all but two of its individual land use classes. The residential home class experienced an increase of 60.47% from 2007 – 2012 and the classification for empty parcel wooded had a rise of 10.59%. Parcels designated “other” saw an increase of 11.82%, while parcels cleared for development experienced an increase of 7.51%. The mobile home class underwent a 328.57% raise post-Katrina. The two classes that saw decreases within individual land use classes were empty slab and

FEMA trailer. The empty slab class underwent a decrease of 53.09% and FEMA trailers fell off by a 100%. Table 9 shows percentage increases and decreases for each individual class.

Waveland's overall land use changes as had 1,313 housing units in 2007 and that number rose to 2,107 in 2012, giving an overall increase in housing of 13.99% post-Katrina. The number of mobile homes in the city remained close to 2007 levels with only a 0.41% increase to 2012, giving Waveland an overall increase to residential land use to 14.4%. Empty parcels cleared for structures increased post Katrina by 0.42%, while properties with empty slabs fell by 6.37% from 2007 to 2012. FEMA trailers in Waveland made up 13.37% of the city's land use as a whole in 2007. By 2012 that number fell to zero. Empty wooded parcels in Waveland make up most of the city's land use with 2,528 properties, representing 44.55% overall in 2012. The number of empty wooded parcels rose slightly from 2007 to 2012 by 4.26%. Table 9 represents the statistical data for Waveland. Figures 18 and 19 represent thematic maps constructed to illustrate changes in Waveland's overall land use post-Katrina.

Chapter 5: Discussion

Remote Sensing, coupled with GIS techniques, has provided a good foundation for the supervised classification method used in this study. Hurricane Katrina devastated these two communities, and recovery rates in the areas have been slow to materialize. Comparisons between the two imagery datasets did show increases in percentages in the individual classes, as well as overall change in the land use, although sporadic in many areas. The reasons for the slow recovery post-Katrina point to many factors in a person's ability to resettle in a disaster zone. While the idea of space and place is the primary

determining factor in a family's decision to return, it does not consider cost of living, insurance premiums, and building codes. Infrastructure amenities such as better roads, water, sewer and community lighting are also slowly working back into these areas, providing residents with a better sense of security. After the completion of the new Highway 90 Bay St. Louis Bridge in 2007, residents of eastern Hancock County were once again easily connected to jobs, schools, and other amenities along the Mississippi Gulf Coast (Adam and Nossiter 2007).

The imagery showed that the parcels with standing structures in February of 2007 are still standing in 2012, for the most part. This trend occurred in both Shoreline Park and Waveland, as those parcel structural footprints remained the same. Roof color changes for those parcels between the two imagery datasets depict remodels of many premises were conducted. The roof color changes typically consisted of a new color shingle, or a change from shingle to tin roof. In some cases blue tarps, serving as temporary fixes, were replaced with new shingled roofing. Remodels usually consist of new roofing, as well as total renovation of the structure inside. While the supervised classification method used does not account for remodels in the statistical analysis, it does indicate that parcels with standing structures in 2007 rebounded in the 2012 imagery dataset. New construction did occur on properties from 2007 to 2012. Although this was not the norm, it is a sign that some recovery is taking place. Most of the new construction in these two communities is not consistent throughout the communities and is being centered in certain areas. Trends show that immediate areas along the coastal beach front in Waveland and the back bays in Shoreline Park are seeing slightly more recovery than other areas within the communities.

The community of Shoreline Park is seeing some recovery, while trying to rebound post-Katrina. Although data does depict the area to the east of Highway 603 is recovering quicker than areas to the west, efforts are still slow. The difference in recovery in these geographical locations is directly related to major contributors of flooding and the newly adopted BFE. Eastern Shoreline Park sits adjacent to the Jourdan River and Bay St. Louis, which produced storm surge levels around 8m (26ft.) (NOAA 2005). While areas to the west of Highway 603 did see flooding through bayous, creeks, and canals it was not as high and did not have the wave action. The absence of wave action as well as a higher surge meant these structures in the western portion of the community did not have to undergo new construction. The supervised classification does not account for remodels, although it does illustrate new construction rates in the eastern half of Shoreline Park is higher than its counterpart to the west.

Shoreline Park's individual land use classes did see signs of encouragement with the residential home class increasing by 73.79% and the mobile home class increasing by 68.25%. This gives an overall change to Shoreline Park of 7.74% in total residential land use change (Table 5). These statistics may seem high however 70% of structures in the county were either damaged or destroyed in the disaster. Shifts to land use in the community from 2007 to 2012 are occurring mainly in respect to the number of empty properties. Empty wooded parcels went up by 17.66% within its class. This caused an overall spike of 10.46% to Shoreline Park's change in land use in the 5 years this study covered (Table 5). This shift clearly shows residents are not returning to these properties.

Parcels with empty slabs fell by 52.49% within its class, giving only a change of 2.74% of Shoreline Park's total land use, indicating many of the community's empty

slabs are still in place, yet to see construction or removal. The evidence of these slabs supports the beliefs of the newly adopted BFE being a factor in rebuilding, as the slabs have not been raised, nor has new construction taken place on them. In 2007, FEMA trailers made up 8.34% of the land use. By 2012 that number fell to zero, with a 100% decrease within its class (Table 5).

The percentage lost in FEMA trailers by 2012 shifted more towards empty parcels rather than residential. Considering the three codes that represent empty parcels in 2007, 76.89% of Shoreline Parks' total land use was either wooded, cleared for development or empty slabs. By 2012 that number rose to 78.4%, implying residents are relocating to other areas. The rise in empty wooded parcels in the community accounts for the highest spike in land use change post-Katrina in Shoreline Park. The shifts to empty parcels are evident in thematic maps of Shoreline Park based on unique value techniques. The 2007 land use map shows many parcels with FEMA trailers, pointing to signs of recovery (Figure 15). However, in the 2012 land use map of Shoreline Park, many of these same parcels with FEMA trailers have been replaced by empties (Figure 16). Figures 15 and 16 also show the sporadic rebuilding of many parcels throughout Shoreline Park.

Data for Waveland also suggests the city is responding similarly in respect to its residential recovery post-Katrina. However, Waveland is experiencing recovery rates that are stronger than Shoreline Park's in comparison. Figures for Waveland do show similar trends of certain areas responding quicker than others. Areas south of Central Avenue show a 40% change in land use, whereas areas to the north in the city only show a 29% change (Tables 7 and 8). Geographically, this area lies directly on the Mississippi Sound and experienced Katrina's north-west eye wall, as well as maximum storm surge.

The area south of Central Avenue in Waveland saw a devastating storm surge, with levels around 8.5m (28 ft.), coupled with wave action. These two factors led to the total destruction of homes in this area (NOAA 2005). As in Shoreline Park, this led to new construction in the area, as standing structures were at a minimal. The figures for changes in land use in the two separate regions of the city are manifested through this new construction south of Central Avenue. Remodels of many structures were done in the inner core of the city, as these structures remained standing post-Katrina and did not need to meet new BFE and building codes.

Waveland as a city has seen percentage rises in the residential home class by 60.47% and the mobile home class by 328.57% (Table 9). This contributed to an increase to the residential land use overall by 14.4% in the years following Katrina. However, with roughly 90% of Waveland's structures either damaged or destroyed in the event, this percentage is low. In contrast to Shoreline Park, the rise in residential land use change in the city is the dominant change in Waveland, as opposed to empty wooded parcels. Although empty wooded parcels as a class did see an increase of 10.59%, it only accounted for a 4.27% change in Waveland's land use overall. In 2007, 57.85% of parcels were designated empty wooded that were cleared for development or empty slabs. This number dropped to 56.17% by 2012. The number of empty slabs as a class decreased by 53.09%. Waveland has seen strides, considering the number of empty slabs fell by 6.37% in respect to total land use, and empty parcels cleared for development rose by only 0.42%, indicating a shift to rebuilding on these properties. The changes to Waveland's land use can be noted in the thematic maps generated in this study (Figures 18 and 19). The 2007, land use map of Waveland shows many FEMA trailers, as well as

empties (Figure 18). However, by comparing the 2007 to the 2012 land use map, Waveland trends can be seen showing the shift from FEMA trailers to residential, especially in the central and southern portions of the city (Figure 18 and 19). Parcels coded “other” still dominate the land use on the northern boundary of the city in both 2007 and 2012 (Figures 18 and 19). Although some change did occur from empties to residential, it was minute and not the norm throughout Waveland.

These two small communities of Hancock County Mississippi are currently undergoing recovery post-Katrina, although Waveland is faring better to date. While Shoreline Park has more parcels and area, it lacks the infrastructure and amenities that might draw residents to settle in the area. This is apparent in comparing the classification code “other” between the two communities. Shoreline Park had a decrease in the class of 21.48% from 2007 – 2012, while Waveland showed an increase of 11.82%. This supports the notion that amenities are indeed helping Waveland recover slightly quicker than Shoreline Park.

Two factors, higher insurance premiums and new building codes based upon the newly adopted BFE, are apparent in the figures that the statistical analysis produced through the supervised classification. Many areas in the 2007 imagery that showed entire neighborhoods cleared of housing were sporadically rebuilt by 2012. When looking at areas that are recovering more quickly, such as Waveland south of Central Avenue and Shoreline Park east of Highway 603, the rebuilding is sparse and these residents are either paying higher insurance premiums or have no coverage at all. Katrina set and broke many previous storm surge records held by past storms in the area. The notion of these past storms caught many off guard and preparations were not adequate, causing

major damage, and rising insurance cost. Results of this study support the idea that insurance rates and building codes are major factors in residents' decisions to relocate and rebuild in these communities. Further, the plans of New Urbanism and Smart Code are slow to materialize in these communities and are currently lacking in many areas. While these programs have made some strides such as affordable housing, they have taken several years to come to fruition. In respect to these two small communities, affordable housing, jobs, sense of place, and amenities can be seen as the major determining factors in residents' decisions to return to their pre-Katrina locations.

Chapter 6: Conclusion

Hurricane Katrina roared ashore on 29 August 2005 causing loss of life and damage to property on an unprecedented scale along the Mississippi gulf coast. The storm caused major evacuations of communities and municipalities on levels never seen before. Countless residents who evacuated areas within the disaster zone were slow to return if they did at all. Many of these residents lost their homes and had to recover and rebuild their lives from scratch. Decisions had to be made as to whether to relocate to their previous areas or find new places to settle. The county of Hancock in Mississippi suffered a terrible blow from Katrina, experiencing the storm's northwest eye wall and surge levels upward of 8.5m (28 ft.). The high wind and surge left 56 people dead and 70% of the structures county-wide being damaged or destroyed. Many of the counties' first response equipment, infrastructure, and amenities had to be rebuilt. Shoreline Park and Waveland's community leaders were immediately thrust into action of how to restart their communities.

The initial responses of small communities in a disaster of this magnitude are for neighbors to help each other, although this quickly deteriorates and outside assistance is needed. In the case of Katrina this help was slow to materialize and left many residents vulnerable. When short-term recovery started to mobilize in the form of temporary housing, recovery measures were initiated. Long-term recovery ideas such as New Urbanism began to be adopted by many state and local planners in hopes it would speed up recovery efforts; however, these strategies seem to have put a damper on long term recovery. Many residents were unfamiliar with these new plans and were slow to adapt.

The idea of space and place is one the most important factors in a resident's decision to return to an area. Many people become comfortable with their surroundings and can identify themselves by a particular area. However, in the aftermath of Hurricane Katrina many residents were forced to abandon this idea with many previous amenities of their respected communities totally wiped out and the rising cost of insurance. Even programs meant to mitigate the rises in insurance costs have seen increases themselves contradicting any help to people who cannot afford these spikes in rates. Insurance rates and the newly adopted BFE are direct reasons why many residents have chosen not to return their previous locations. New elevation standards added to the BFE and higher insurance rates are leaving many with no other option but to settle in more affordable areas that are closer to jobs and other amenities.

The use of high-resolution aerial imagery allowed for a detailed study of the Shoreline Park and Waveland areas in a spatiotemporal technique. In 2007, much of Katrina's debris was cleared away; however, the major rebuilding phases had yet to take place, which allowed for a comparison between the two imagery sets. Utilizing this

method also produced a statistical analysis that shows what Shoreline Park and Waveland are experiencing seven years post-Katrina. The land use codes chosen to classify the parcels in this study were meant to maintain the precision and accuracy of the study while maintaining coverage. The changes in land use in these two communities were manifested in the percentage increases or decreases seen within each class and overall. Each one of these two communities has their own characteristics in how they are recovering post-Katrina. But, data from both communities indicates areas closer to major contributors of flooding such as the Jourdan River and the Mississippi Sound are showing signs of quicker recovery, mainly due to new construction. Many residents in these areas are rebuilding with no insurance coverage. Further, the method does not account for remodels, although the imagery does show roof color changes indicating remodels were done on many structures. Results also demonstrate Waveland is undergoing quicker recovery than Shoreline Park, and this recovery is mainly due to better amenities within the community.

Land use changes show these two communities of Shoreline Park and Waveland seem to be trapped in an effort to rebuild themselves, while watching their counterparts succeed. Data does show these communities are showing some signs of recovery, albeit slow. Many lessons have been learned from Katrina, although small communities are still suffering from the long-term effects of this disaster. This study used a supervised classification to analyze residential recovery rates post-Katrina in just two small communities of Hancock County, Mississippi. The methods of this study can be applied to researching other small communities recovering from large-scale natural disasters. These regions of interest, while lacking in literature, can be a focus for research with GIS

and Remote Sensing applications. Utilizing these techniques provides planners with not only statistical data showing recovery, but also illustrates it in maps. Hurricane Katrina caused many residents, planners, and government officials to re-think the old ways of conducting everyday life along the Mississippi Gulf Coast. The Shoreline Park and Waveland areas are not the only ones struggling to rebuild after a major disaster; nonetheless, they can be examples of what questions can be answered to help other communities like them rebuild.

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Shoreline Park and Waveland Study Area



Figure 1 : Study area for research, identifies Shoreline Park and Waveland community boundaries, as well as their geographical locations.

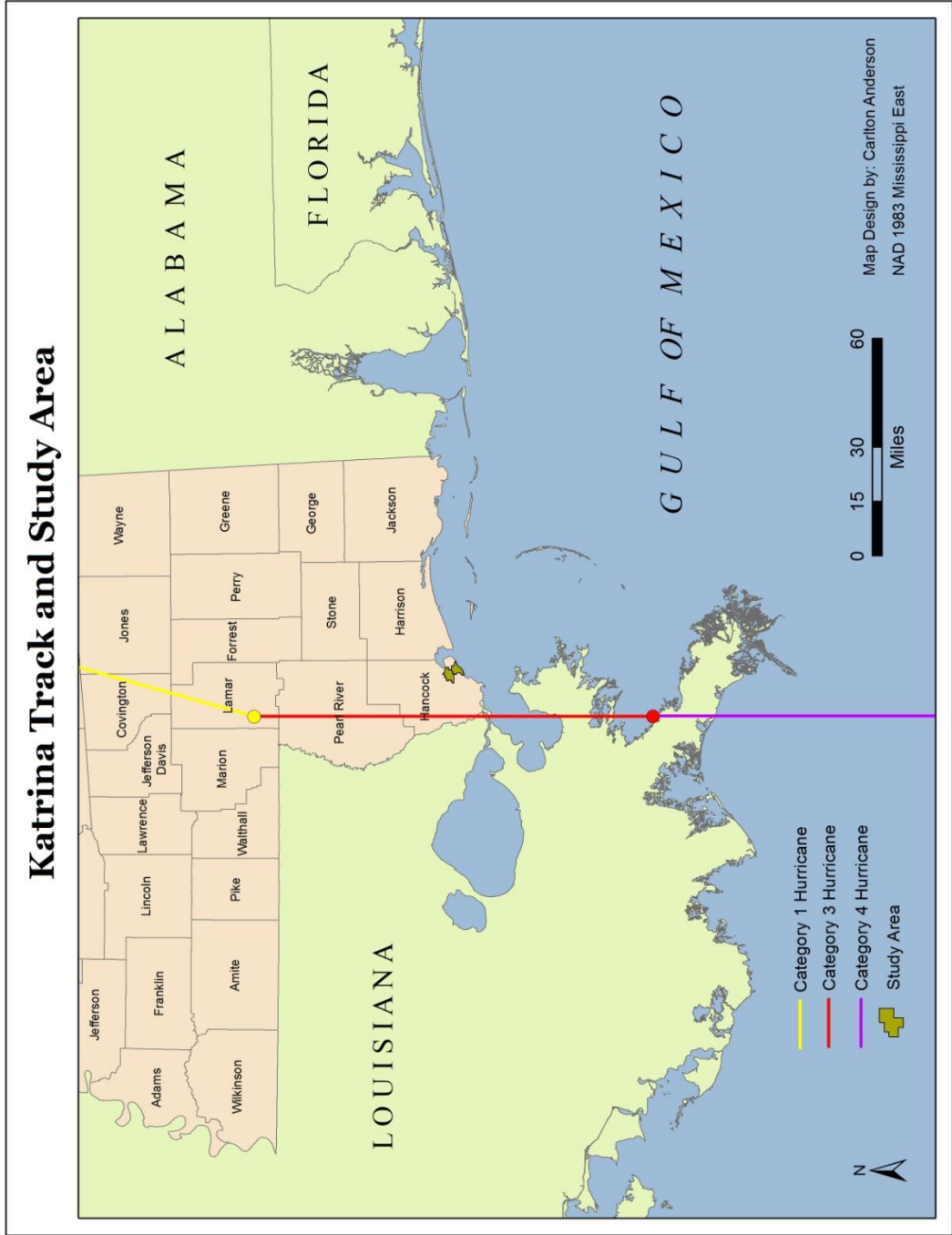


Figure 2: Illustrates the study area in relation to Hurricane Katrina's track, as the storm made landfall 29 August 2005, along the Louisiana and Mississippi coastlines.

Hurricane Katrina Track 23 August 2005 – 30 August 2005

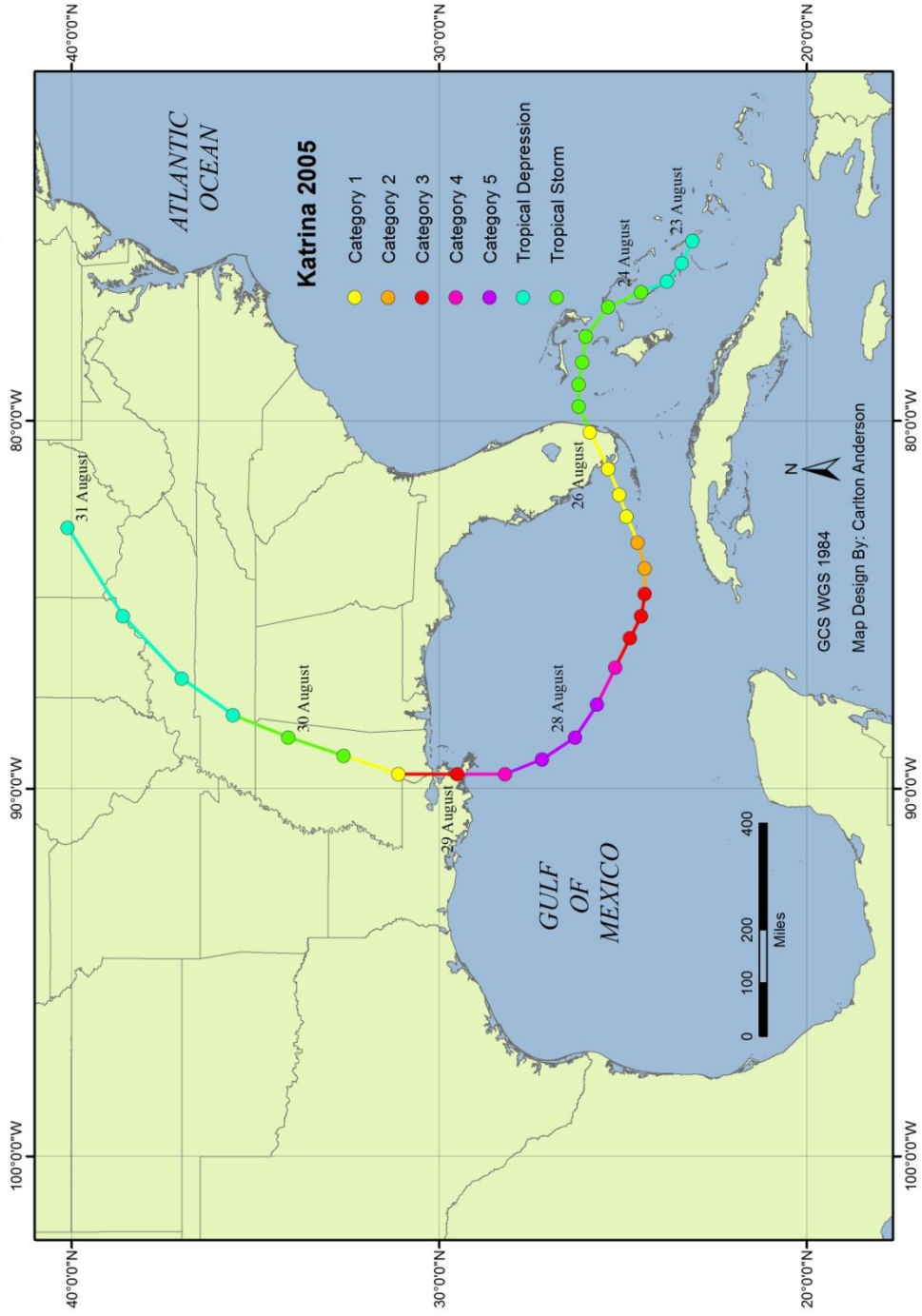


Figure 3: Illustrates Hurricane Katrina's life cycle as a tropical cyclone from formation on 23 August 2005 to dissipation on 31 August 2005.

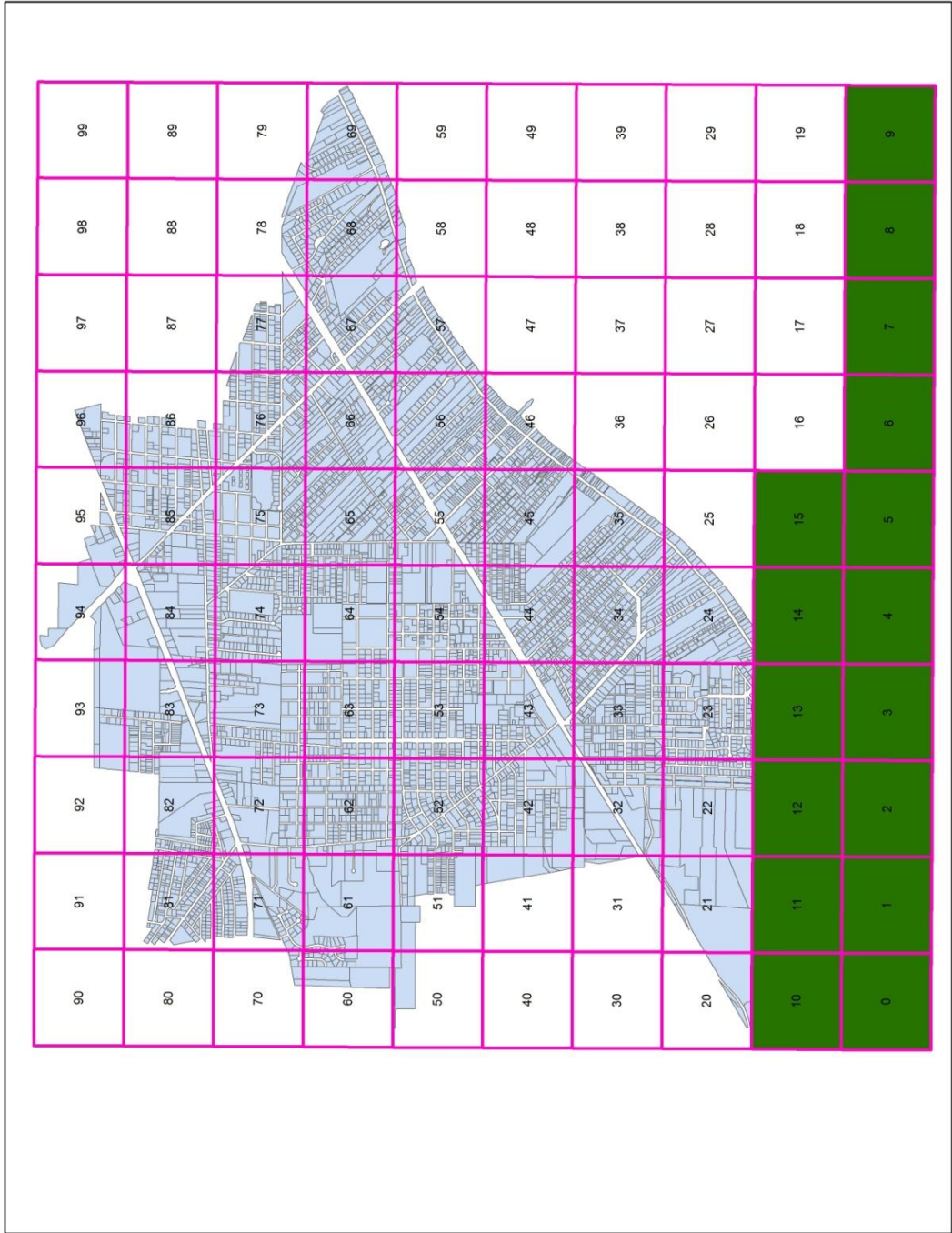


Figure 6: Fishnet grid layer used for systematic coverage of the study areas. Grids completed are represented in green.



Figure 7: Residential home (HS) shown highlighted in the orange area of interest.



Figure 8: Mobile home (MH) shown highlighted in the orange area of interest. Mobile homes are longer in length than the FEMA trailers.



Figure 9: FEMA trailer (FT) shown highlighted in the orange area of interest. FEMA trailers are identified by their length, absence of any structures and are typically on a slab.



Figure 10: Other (OT) shown highlighted in the orange area of interest. Other includes commercial, industrial. Commercial structures are normally accompanied by parking lots. The structure in this figure is a fast food establishment.



Figure 11: Empty slab (ES) shown highlighted in the orange area of interest. These parcels were identified by bare concrete slabs, where structures once stood.



Figure 12: Empty parcel wooded (EL) shown highlighted in the orange area of interest. These parcels were identified by the presence of standing trees typically covering the entire parcel.



Figure 13: Empty parcel cleared for development (ED) shown highlighted in the orange area of interest. Parcels have a distinguishable clearing where a structure once stood or cleared for future development.

Shoreline Park, MS East and West of Highway 603

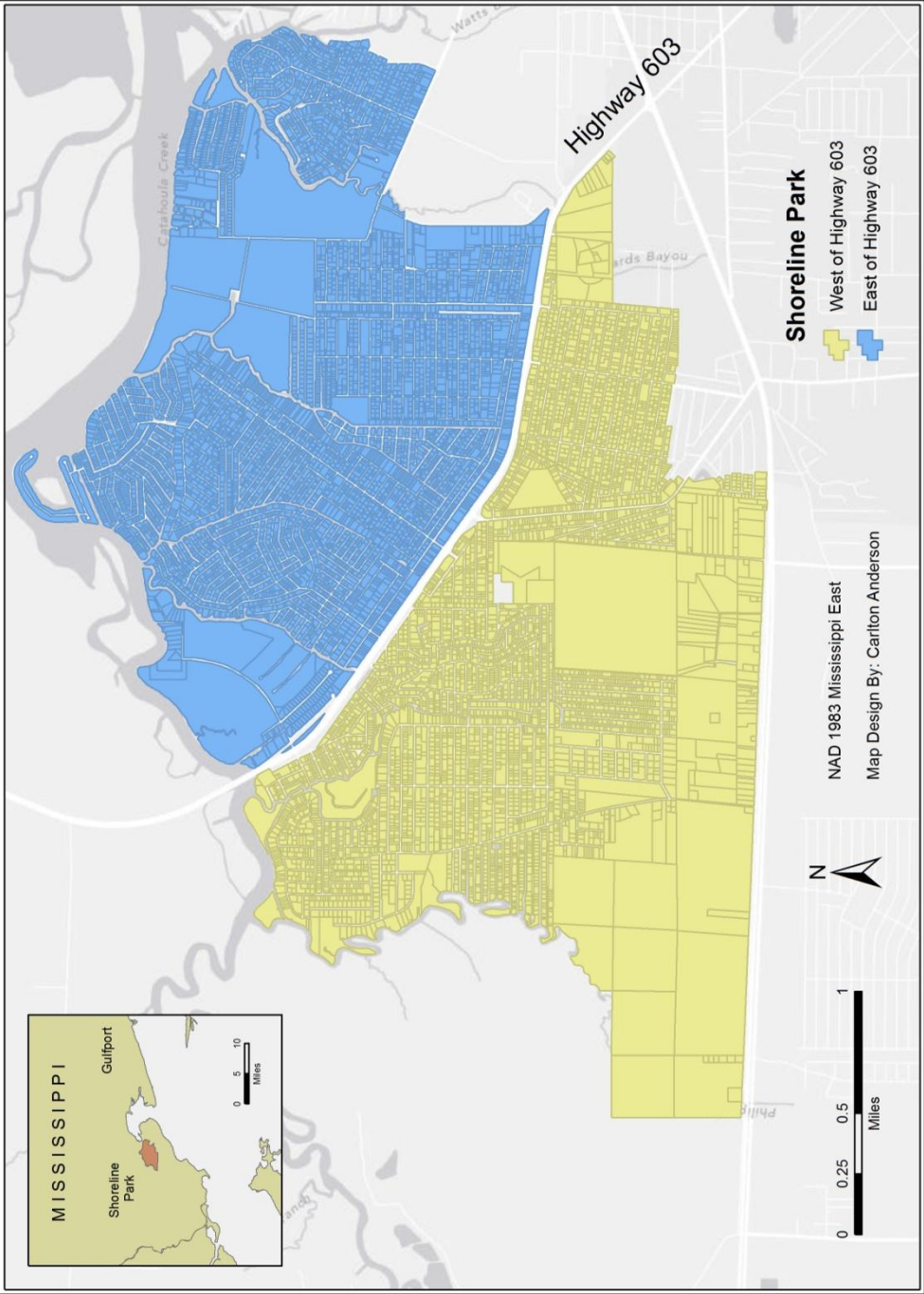


Figure 14: Illustrates Shoreline Park, MS coverage areas east and west of Highway 603.

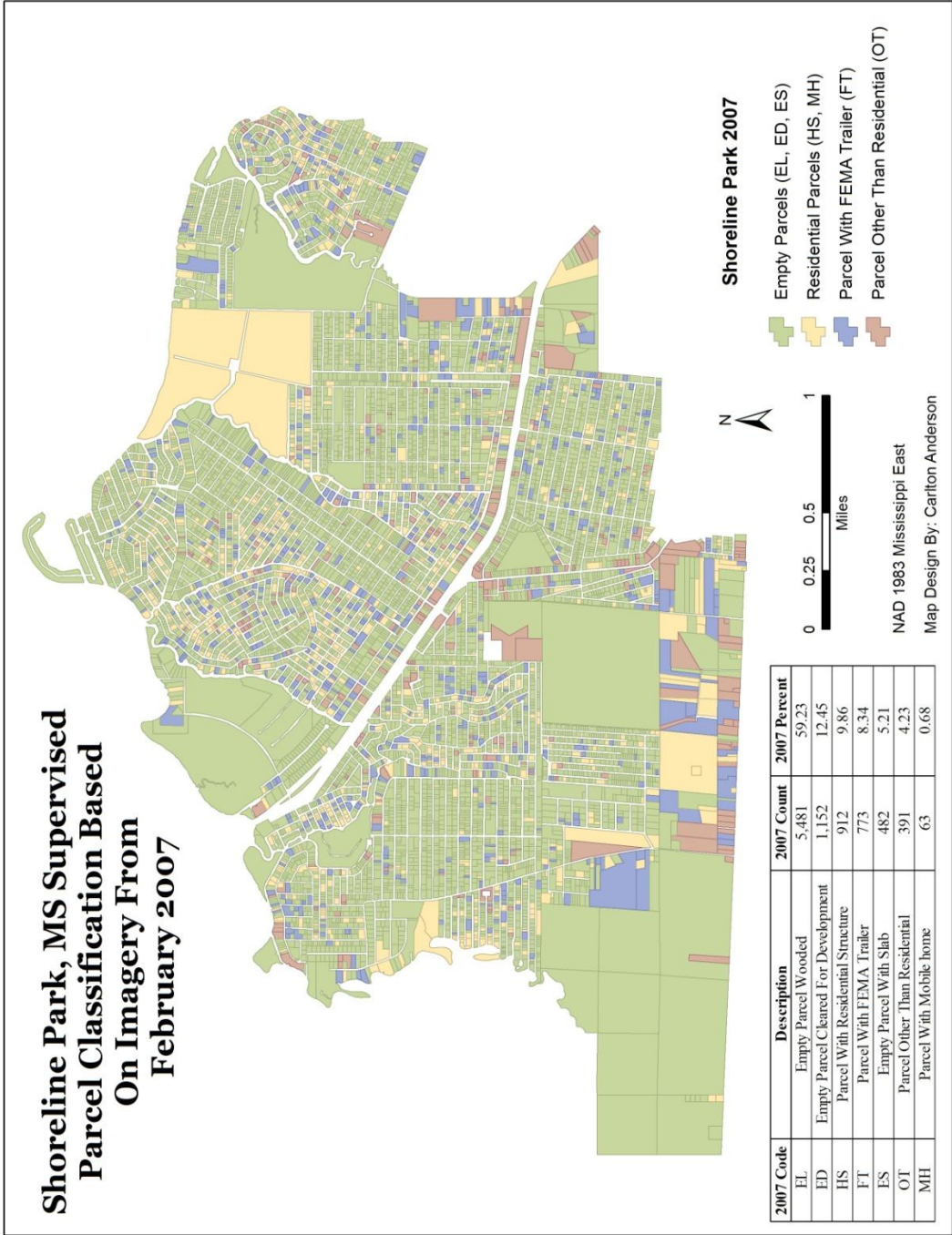
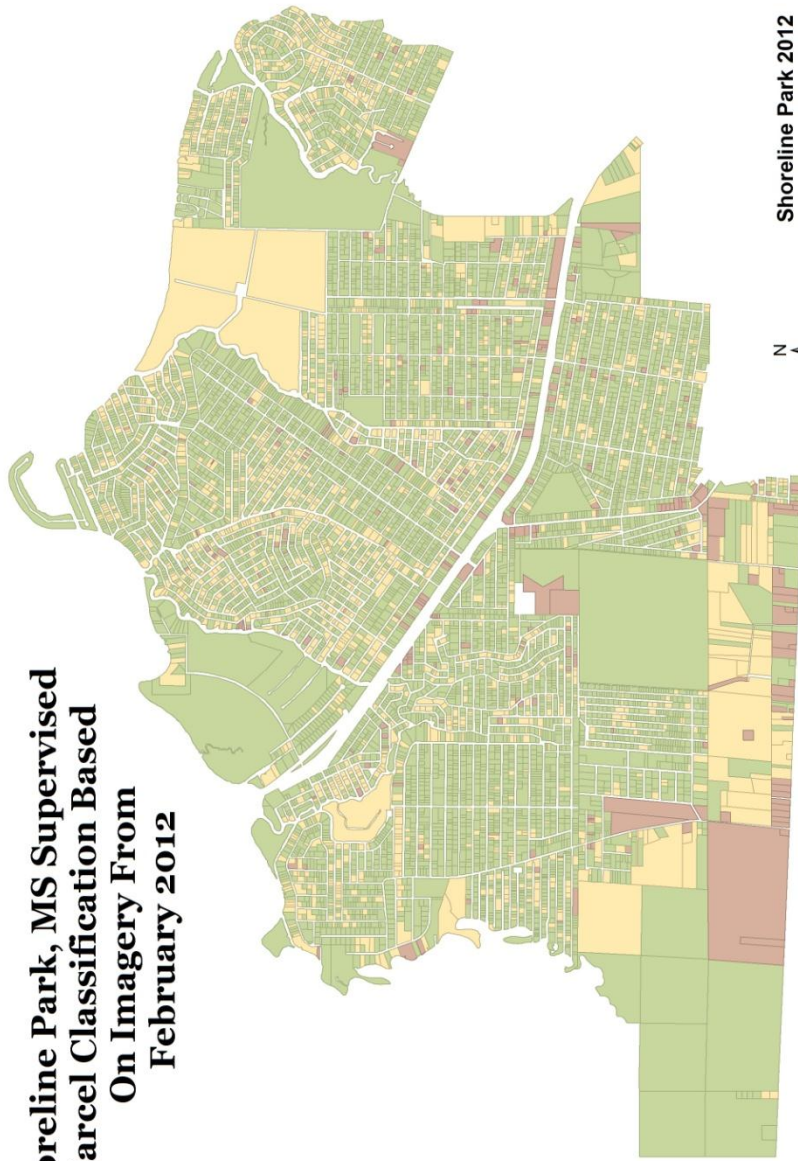


Figure 15: Shoreline Park, MS supervised classification based upon 2007 imagery. Map depicts land use as of 2007.

Shoreline Park, MS Supervised Parcel Classification Based On Imagery From February 2012



Shoreline Park 2012

Empty Parcels (EL, ED, ES)

Residential Parcels (HS, MH)

Parcel Other Than Residential (OT)

N

0 0.25 0.5 1
Miles

NAD 1983 Mississippi East
Map Design By: Carlton Anderson

2012 Code	Description	2012 Count	2012 Percent
EL	Empty Parcel Wooded	6,449	69.69
HS	Parcel With Residential Structure	1,585	17.13
ED	Empty Parcel Cleared For Development	578	6.24
OT	Parcel Other Than Residential	307	3.32
ES	Empty Parcel With Slab	229	2.47
MH	Parcel With Mobile home	106	1.15
FT	Parcel With FEMA Trailer	0	0

Figure 16: Shoreline Park, MS supervised classification based upon 2012 imagery. Map depicts land use as of 2012.

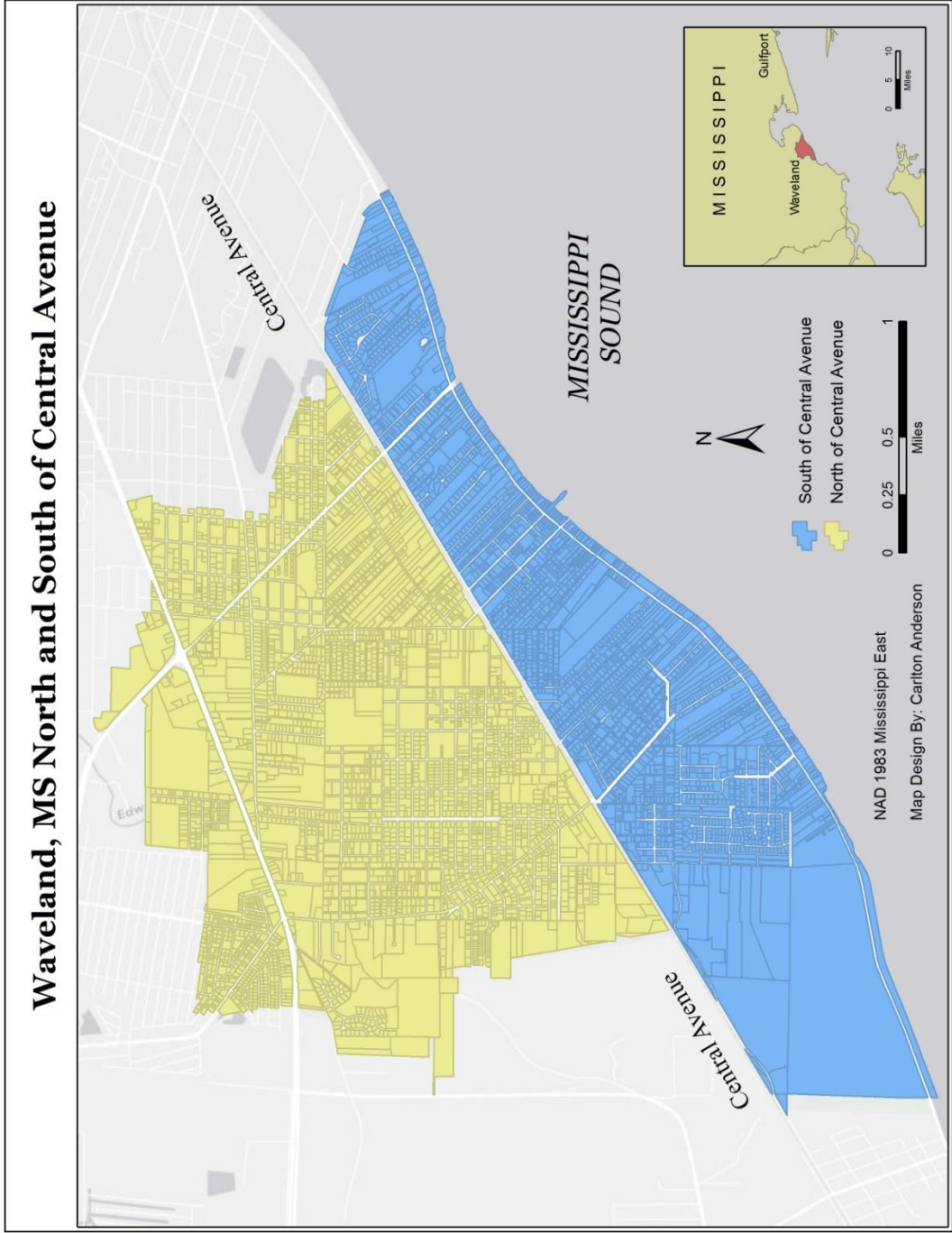


Figure 17: Illustrates Waveland, MS coverage areas north and south of Central Avenue.

Waveland, MS Supervised Parcel Classification Based on Imagery From February 2007

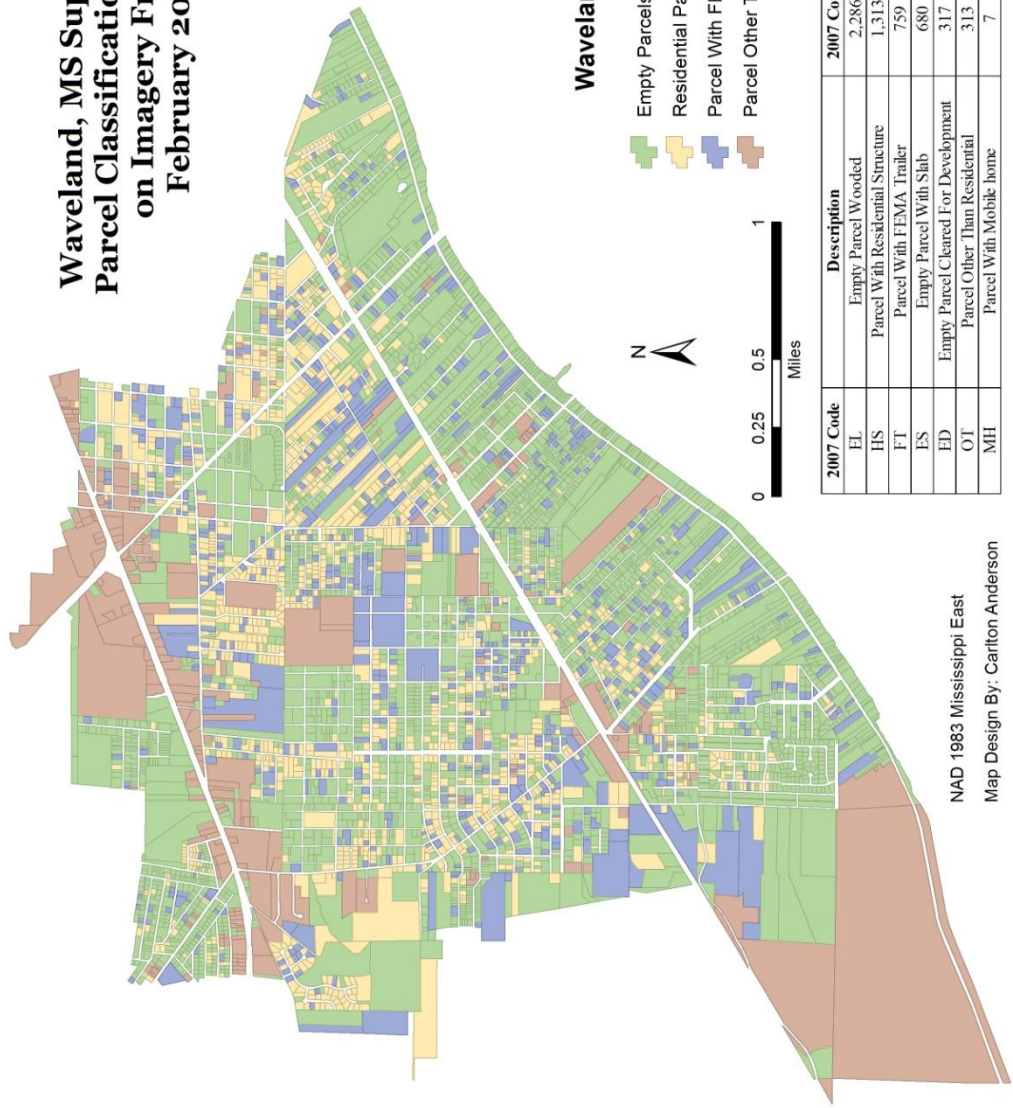


Figure 18: Waveland, MS supervised classification based upon 2007 imagery. Map depicts land use as of 2007.

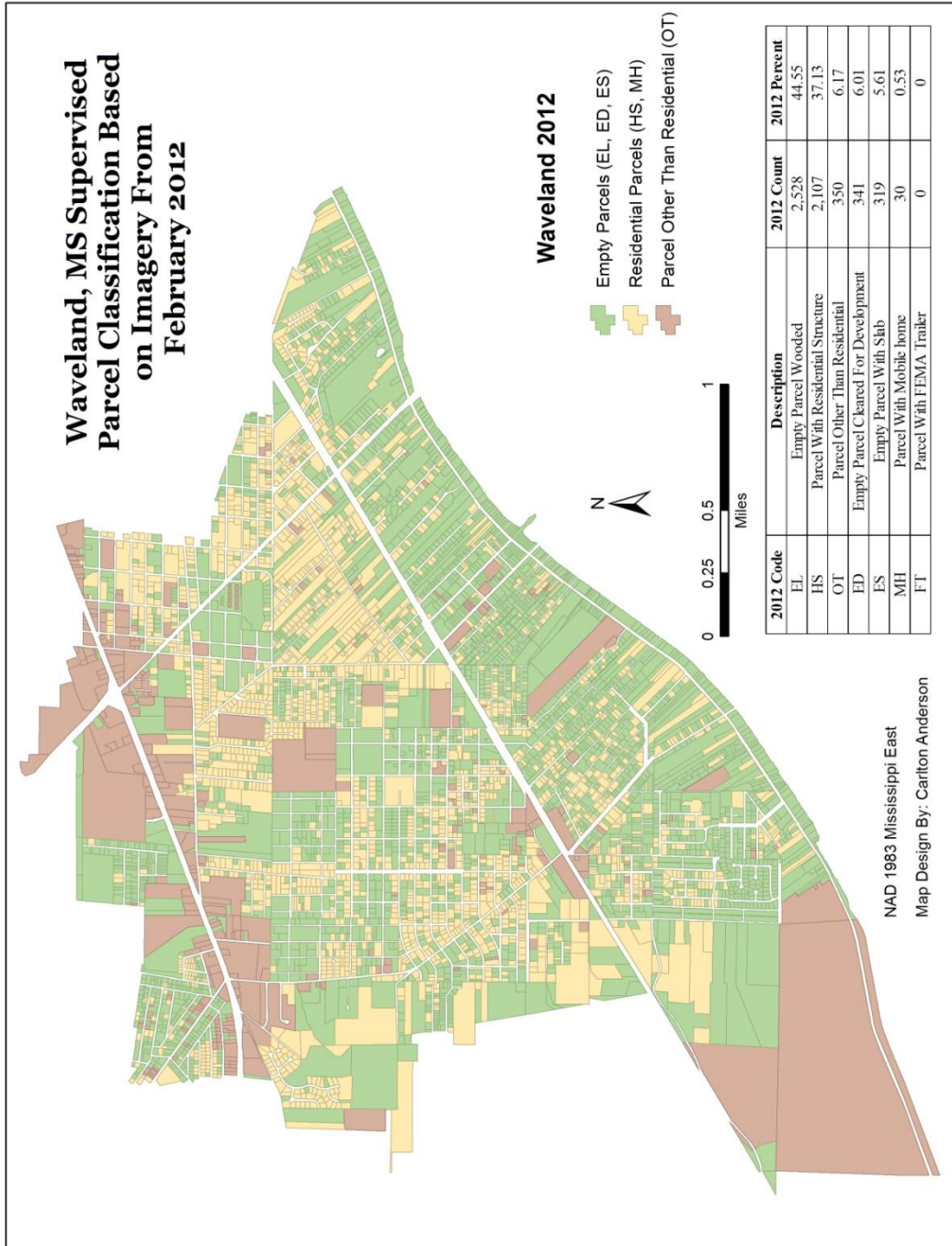


Figure 19: Waveland, MS supervised classification based upon 2012 imagery. Map depicts land use as of 2012.

Parcel Coding Scheme

Structure	Code
Residential Home	HS
Mobile Home	MH
FEMA Trailer	FT
Other	OT
Empty Parcel With Slab	ES
Empty Parcel Wooded	EL
Empty Parcel Cleared for Development	ED

Table 1: Parcel coding scheme used for supervised classification of Shoreline Park and Waveland in both the 2007 and 2012 imagery. Other code used to classify parcels with commercial, industrial, or utility structures.

Shoreline Park, MS Parcel Change 2007-2012

Description	Parcels	Percent
Did Not Change	6,450	70
Changed	2,804	30
Total	9,254	100

Table 2: Statistics for the number of parcels that changed their structural footprints in Shoreline Park, MS from 2007 – 2012.

Shoreline Park, MS east of Highway 603 Change 2007 - 2012

Description	Parcels	Percent
Did Not Change	3,179	63
Changed	1,884	37
Total	5,063	100

Table 3: Statistics showing parcel land use in the coverage area east of Highway 603 in Shoreline Park, MS. The table represents how many parcels changed their structural footprints in this area from 2007 – 2012.

Shoreline Park, MS west of Highway 603 Change 2007 - 2012

Description	Parcels	Percent
Did Not Change	3,271	78
Changed	920	22
Total	4,191	100

Table 4: Statistics showing parcel land use in the coverage area west of Highway 603 in Shoreline Park, MS. The table represents how many parcels changed their structural footprints in this area from 2007 – 2012.

Shoreline Park, MS Land Use Change 2007 - 2012

2007 Code	2007 Count	2007 Total Land Use Percentage	2012 Code	2012 Count	2012 Total Land Use Percentage	Percent Increase 07 - 12	Total Land Use Percent Change 07-12
EL	5,481	59.23	EL	6,449	69.69	17.66	10.46
HS	912	9.86	HS	1,585	17.13	73.79	7.27
MH	63	0.68	MH	106	1.15	68.25	0.46
OT	391	4.23	OT	307	3.32	-21.48	-0.91
ES	482	5.21	ES	229	2.47	-52.49	-2.74
ED	1,152	12.45	ED	578	6.24	-49.83	-6.21
FT	773	8.34	FT	0	0.00	-100.00	-8.34

Table 5: This table represents the total land use change in Shoreline Park, MS from 2007 – 2012. Figures include percentages of the different land use types in both 2007 and 2012, as well as the change in those percentages.

Waveland, MS Parcel Change 2007 - 2012

Description	Parcels	Percent
Did Not Change	3,792	67
Changed	1,883	33
Total	5,675	100

Table 6: Statistics for the number of parcels that changed their structural footprints in Waveland, MS from 2007 – 2012.

Waveland, MS South of Central Avenue Change 2007 - 2012

Description	Parcels	Percent
Did Not Change	1,434	60
Changed	940	40
Total	2,374	100

Table 7: Statistics showing parcel land use in the coverage area south of Central Avenue in Waveland, MS. The table represents how many parcels changed their structural footprints in this area from 2007 – 2012.

Waveland, MS north of Central Avenue Change 2007 - 2012

Description	Parcels	Percent
Did Not Change	2,358	71
Changed	943	29
Total	3,301	100

Table 8: Statistics showing parcel land use in the coverage area north of Central Avenue in Waveland, MS. The table represents how many parcels changed their structural footprints in this area from 2007 – 2012.

Waveland, MS Land Use Change 2007 – 2012

2007 Code	2007 Count	2007 Total Land Use Percentage	2012 Code	2012 Count	2012 Total Land Use Percentage	Percent Increase 07 - 12	Total Land Use Percent Change 07-12
HS	1,313	23.14	HS	2,107	37.13	60.47	13.99
EL	2,286	40.28	EL	2,528	44.55	10.59	4.26
OT	313	5.52	OT	350	6.17	11.82	0.65
ED	317	5.59	ED	341	6.01	7.57	0.42
MH	7	0.12	MH	30	0.53	328.57	0.41
ES	680	11.98	ES	319	5.61	-53.09	-6.37
FT	759	13.37	FT	0	0.00	-100.00	-13.37

Table 9: This table represents the total land use change in Waveland, MS from 2007 – 2012. Figures include percentages of the different land use types in both 2007 and 2012, as well as the change in those percentages.

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