Topologic study of Wax Lake Delta and metrics describing delta behavior

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Introduction: Sustainable systems are those that have integrated an adaptive approach for the interaction between the engineered and natural environment to ensure the well being of present and future generations. Understanding the processes that shape the land surface better equip engineers and decision-makers to develop sustainable solutions. River deltas, due to their fragile nature, are an ideal location for sustainable research. Being home to 500 million people, the development of conservation and restoration practices is of societal importance.

River distributary networks have been investigated and numerical and experimental models are available. However, there is a need to develop metrics that further characterize deltaic systems and test the results of previous modeling efforts. Early and more recent attempts have identified some important factors characterizing the topology of the delta network [*Smart & Moruzzi*, 1972; *Morisawa,* 1985; *Edmonds et. al.,* 2011; *Syvitsky*, 2005].

This report identifies several topological and geometric metrics found in the literature as they apply to the study delta (Wax Lake Delta, as descried below). *Edmonds et. al.* (2011) use Wax Lake Delta as part of their investigation of metrics describing delta behavior and their results are independently confirmed herein. A topologic network is created as a directed network and statistical methods are used to determine delta characteristics. Those characteristics are compared to the randomly-generated network proposed by *Smart & Moruzzi* (1972). Investigation into the extraction of the delta water mask is investigated with a technique utilizing the Normalized Difference Vegetation Index (NDVI) to identify land-water boundaries from satellite imagery. The result is compared to hand-delineated island boundaries and satellite imagery at the near-infrared spectrum, which is ideal for identification of water features [*Irmack,* lecture notes GISWR, 2011]. The delta land surface and shoreline evolution are observed over its formation lifespan (~50 yrs.), the past year (2010-2011), and between October and November of 2011.

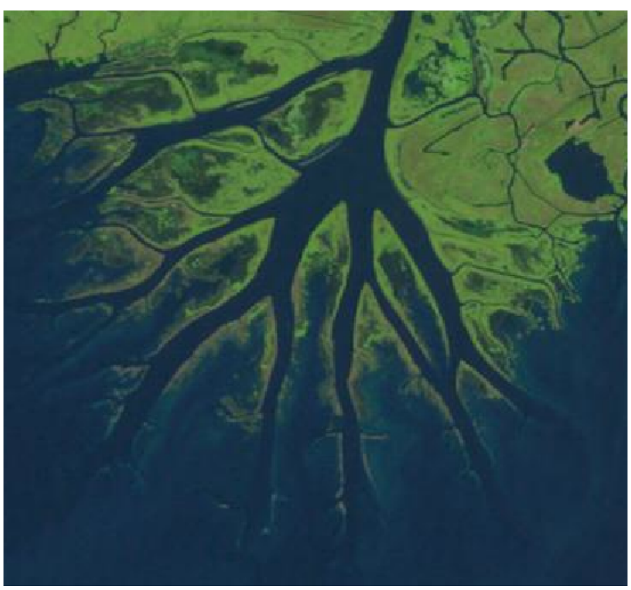

Figure 1: Wax Lake Delta in Louisiana. Image is from LANDSAT TM 5 (spatial resolution 30 m). Image downloaded from USGS, Nov. 2011

Wake Lake Delta (Figure 1), is located in St. Mary Parish along the Gulf Coast in Louisiana. The delta receives its flow from the Atchafalaya River diversion, a man-made channel 20 km upstream of Morgan City Louisiana. The delta has been forming naturally, although caused by the man-made river diversion, since 1973 making it an ideal location for the study of delta evolution and processes. The delta front has prograded seaward into the Atchafalaya Bay at a rate of ~0.27 km/yr [*NCED*]. Appendix A shows a map of the recent and predicted delta growth from the USGS. A LANDSAT 5 Thematic

Mapper (TM) image from November 2011 is seen in Figure 1. The image is displayed as a false RBG composite with bands 5, 4, and 3 for emphasis of water features.

The present study will be useful for describing the topology of the Wax Lake Delta network. As distributary channels are a major factor in determining the geometry of the delta plain [*Syvitsky*, 2005], insight into the interactions between water and land at Wax lake delta will be gained. The observed changes of the delta topography and progradation will exemplify the dynamic nature of the delta.

Data Acquisition & Description: Satellite imagery made freely available by the USGS was used in the analysis of Wax Lake Delta (Figure 1). LANDSAT Thematic Mapper 4-5 images are available at a spatial resolution of 30 m and new images can be obtained monthly. LANDSAT imagery of Wax Lake Delta has been available throughout its formative years, making LANDSAT imagery ideal for tracking changes over time. The imagery is available in several different formats, but two were used in the present study: Level 1 products and orthorectified RBG composite JPEG images. Level 1 products are those in which the range of spectral bands is included for use in ArcMap. The band designations for LANDSAT TM 4-5 are found in Table 1. The level 1 images were the primary data layer used for analysis in ArcMap. Orthorectified RBG composite pictures were used in displaying the shoreline evolution of the study delta. LANDSAT imagery for Louisiana is projected in UTM Zone 15 coordinate system. ArcMap's "transformation-on-the-fly" capability allowed for use in State Plane coordinates.

Table 1: LANDSAT TM 4-5 Band Designations. Table courtesy of USGS <http://landsat.usgs.gov/band_designations_landsat_satellites.php>

	Landsat 4-5	**Wavelength (micrometers)**	**Spatial Resolution (meters)**
Thematic Mapper (TM)	Band 1	0.45-0.52	30
	Band 2	0.52-0.60	30
	Band 3	0.63-0.69	30
	Band 4	0.76-0.90	30
	Band 5	1.55-1.75	30
	Band 6	10.40-12.50	120* (30)
	Band 7	2.08-2.35	30

*The thermal infrared (Band 6) is collected at 120m then resampled to 30m.

In order to analyze the topology of Wax Lake Delta, flowlines for major distributary channels were needed. However, the NHD Flowline Hydrography dataset does not have any data for the area of interest. In order to develop the topological network, a flowline feature class was created and digitized in ArcMap. The feature class was projected in the State Plane Louisiana South based on NAD 83 coordinate system. An island feature class was also created for island shorelines. A BingMaps aerial photo of the study delta was used for tracing channel centerlines and island shorelines.

2009 Lidar data of Wax Lake Delta was obtained courtesy from a study by James Buttles from the University of Texas at Austin Jackson School of Geosciences. The DEM developed from the lidar survey shows the vertical scale on which the delta plain operates, giving insight into the temporal nature of the delta land coverage as seen from satellite imagery (see later discussion). However, the 1-m resolution DEM was not used in the analysis other than to calculate the delta gradient [*Syvitsky*, 2005]. Qualitative correlations between sediment delivery and the shallow delta gradient are explored.

Analysis & Methods: The analysis of the topology and evolution of Wax Lake Delta was carried out using ArcMap 10, Microsoft Excel 2007, and MatLab. The analysis is divided into two sections to be discussed in detail: the topologic network and delta evolution. Analysis in ArcMap was performed using the State Plane Louisiana South based on NAD83 map projection.

Topologic Network

Statistical metrics that characterize delta topology are useful for gaining insight into the physical characteristics of deltas. The first study to investigate predictive metrics for distributary networks was performed by *Smart & Moruzzi* (1972) and later expanded upon by *Morisawa* (1985). *Smart & Moruzzi* (1972) proposed the idea of a randomly-generated network of links and nodes for describing delta behavior. The recombination factor (α), a measure of the bifurcation and recombination of network channels, is a metric for describing the space-filling behavior of the distributary channel network [*Smart & Moruzzi*, 1972; *Morisawa*, 1985].

A flowline network of links and nodes was created in ArcMap and is shown in Figure 2. Only streams considered to be major distributary channels were included. Crevasse splays that reconnected with the distributary network were considered but multi-directional tide channels were excluded for the analysis due to the ambiguity of flow direction. The exclusion of tide channels is considered valid due to their relatively insignificant size when compared to the major distributary channels. The terminal nodes were chosen at locations where channels appeared to reach the open ocean according to the October 2011 LANDSAT TM 4-5 image. A map of the October image is shown in Appendix B as a true-color composite.

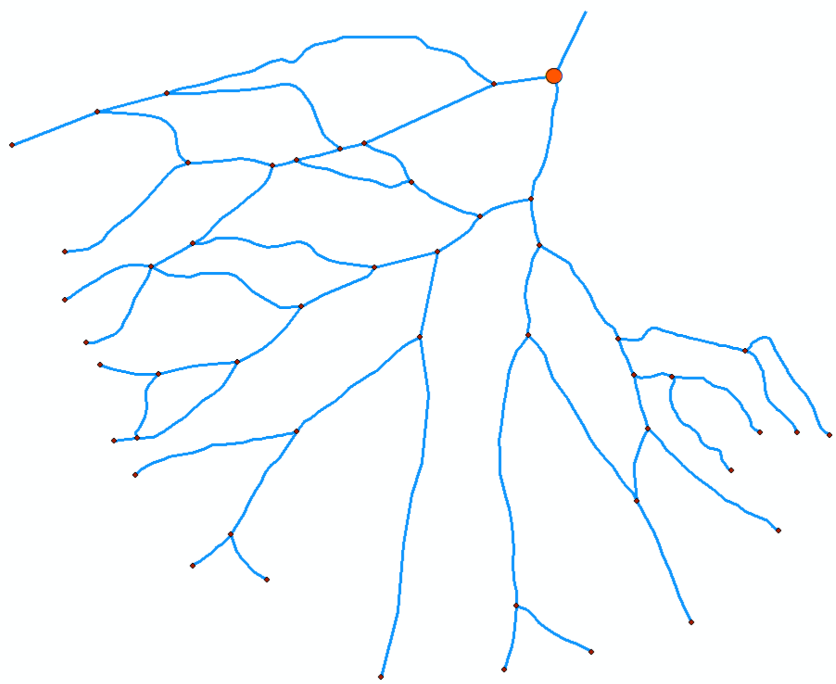

Figure 2: Topologic Network for Wax Lake Delta. Red diamonds represent nodes, blue lines are links, and the orange circle is the delta apex.

The classification scheme for links and nodes followed *Smart & Moruzzi* (1972). A field was added to the node feature class and each node was classified according to its topologic position: *O* for outlet (entering open ocean), *F* for fork (bifurcation), or *J* for join (two links coming together). An analogous field for links was created describing the upstream and downstream nodes for each link (*e*.g. *FJ* for an upstream fork and downstream join). The delta apex is considered the point at which the contributing river divides into a distributary network, defining the start of the delta plain. The delta apex is a node that must be categorized as a fork (*F*) based on its definition of being the initial bifurcation. Classification of links and nodes based on topologic location transforms the network tree into a directed graph to be used for statistical analysis.

Statistical analysis of the network was performed in Excel by exporting each ObjectID and corresponding classification as discussed above for both the Links and Nodes feature classes. Distribution of link types and node types were compared to the predicted values from *Smart & Moruzzi's* (1972) randomly-generated network. Link length was also extracted and its distribution was also analyzed in MatLab.

The major assumption in the development of the topologic network is the direction of flow in distributary channels. Wave strength, tidal influences, and upstream flow conditions may affect the direction of flow in a distributary system. The topographic gradient is not necessarily an indicator of flow direction due to relatively flat delta topography and the aforementioned conditions [*Feola*, 2006]. However, the assumption of flow direction is limited to major distributary channels and is deemed to reflect the average flow trends. The determination of significant channels was made based on judgment and channel widths from orthoimagery.

Along with the creation of the topologic network, geometric flow network boundaries (land/water interface) were traced using the editor toolbar and the BingMaps basemap in ArcMap as a guide. From the geometric network, a raster of distributary network islands (1-m pixel size) was created on from which metrics and statistical trends were derived. A comparison between the topologic network and geometric channel network was also performed using a modified width function (commonly employed for graph analysis of river networks). The subsequent paragraphs describe the analyzed metrics in detail.

A polygon feature class of the delta islands called 'Islands' was traced using the LANDSAT imagery and the BingMaps basemap. A new field in the attribute table was created to convert the units of each shape area to acres using the field calculator. The symbology of the layer was modified to depict in a category each island according to the area range in which it belonged. The feature class was then transformed to a raster at 1-meter resolution for further analysis. The island size distribution was developed in Excel and further statistical analysis was performed in MatLab. The exceedence probability, cumulative fraction of total area, and area distribution was calculated for the set.

If the tributary network's role is the accumulation of flow and sediment then the role of the distributary network is the distribution of flow and sediment. The nearest-edge distance is a measure of the nearest distance to water from a point on the delta land surface [*Edmonds et al*., 2011] and gives insight into the distribution of sediment transported to the delta land surface. It can be considered analogous to the drainage density calculated for tributary networks. The nearest-edge distance was calculated using the Euclidean distance tool in ArcToolbox after the utilization of the Reclassify tool. The 'Islands' raster was reclassified with island areas have a value of 'NoData' and the surrounding areas having a value of 1. The reclassified raster was then analyzed with the Euclidean distance tool.

The geometric and topologic networks were analyzed using the width function, an approach usually applied to river systems. The width function gives a sense of the topologic width of the network (as the name implies) with respect to distance from a given point. Here, the radial distance from the apex was drawn at 1000-meter intervals using the Multiple Ring Buffer tool in ArcToolbox. The radial distance feature class objects were classified according to their respectively distances from the delta apex. The feature class was then converted to a raster with 1-meter pixel size. The output raster was the extracted by the channel outline feature class

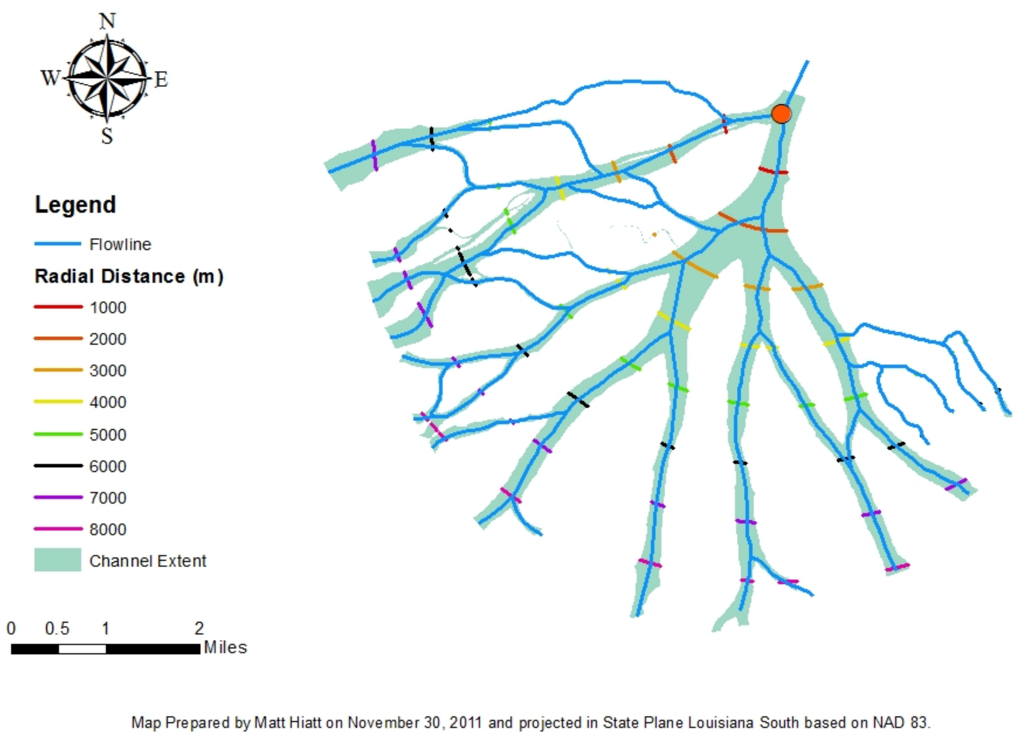

Figure 3: The width function applied to both the geometric (channel extent, blue-green) and topologic (flowline, blue) networks. The orange dot is the delta apex and the radial distances are measured from that location.

using extract by mask. The final raster was then converted back to a feature class and that result can be seen in Figure 3. The number of pixels (from raster at 1m pixel size), geometric width (from feature class), and topographic width were measured.

The development of the methods mentioned in this section required the manual digitization of much of the data into ArcMap. Manual interpretation is time-consuming and subjective, making it a non-ideal method for the analysis of more than one delta or larger deltas (eg. Nile River & Ganges-Brahmaputra Deltas). A small investigation into the extraction of the water areas from the land at Wax Lake Delta was undertaken to determine a remedy to the problem. Water extraction techniques exist for image processing programs, but no such techniques are available in ArcMap (to the author's knowledge).

The normalized difference vegetation index is a measure of the amount of vegetation from remote sensing images. The NDVI operates on the fact that vegetation readily absorbs natural light and strongly reflects near-infrared light. A ratio of the difference in reflectance between near-infrared light (NIR) and visible light (VIS) to their sum is the formula for calculating NDVI as seen in Equation 1.

$$NDVI = \frac{(NIR - VIS)}{(NIR + VIS)} \quad (1)$$

NDVI values for vegetation are high and values for water are near-zero or negative. Ideally, the application of the NDVI to LANDSAT imagery would readily distinguish between land and water at Wax Lake Delta. Using image analysis in ArcMap, the a form of NDVI is calculated (NDVI*100+100) for the October 2011 LANDSAT image and then reclassified setting any values below ArcMap's NDVI of 90 to zero. Values below 90 were determined to be the threshold for NDVI values associate with water pixels. The results are compared to the hand-delineated feature classes for islands and channel network.

Delta Evolution

River deltas seemed to begin to rapidly develop starting around six thousand years ago due to the stabilization of sea level [*Syvitsky*, 2005] making the direct observation of their evolution incomplete. However, satellite imagery has provided the ability to view the development of Wax Lake Delta over nearly its entire lifespan. LANDSAT imagery collected over the last thirty years was used in the analysis of the growth and evolution of Wax Lake Delta. The progradation of the delta surface was observed from January 1983 to November 2011 with images from LANDSAT TM 4-5. A comparison of the amount of water present within the delta between LANDSAT images from October and November 2011 was performed from the water mask extracted from the NDVI calculation. The calculation was performed by converting the water mask rasters to feature classes then measuring total area. The shoreline was delineated by hand in order to match that found by *Edmonds et al. (2011)*.

Results & Discussion: The topologic analysis of the directed graph of Wax Lake Delta's channels yielded the results seen in Table 2. The recombination factor, α, is defined as the ratio of the number of join nodes over the number fork nodes and, in this case, α = 8/25 = 0.32. The range of values for recombination factor is 0 – 1.0, with 0 suggesting that the distributary network is purely bifurcating and 1.0 describing a braided stream. A recombination factor threshold of 0.5 is used to distinguish between bifurcating and joining systems. The relatively low recombination factor suggests that Wax Lake Delta is primarily a bifurcating system with some joining of channels. Most of the joins or loops occur in the northwest region of the delta. This region is characterized by crevasse splays that cut across the larger delta islands to rejoin with the major distributary channels. Nearly all of the channels joins occur in the northwest region.

Table 2: Results of topological analysis on directed graph. The number and percent of total for each type of link and node is shown.

Link Type	*FF*	*FJ*	*FO*	*JF*	*JJ*	*JO*	Total
Number	21	14	13	4	0	5	57
Fraction	0.37	0.25	0.23	0.07	0.00	0.09	1.00

Node Type	*F*	*J*	*O*	Total
Number	25	8	18	51
Fraction	0.49	0.16	0.35	1.00

The observed link types are compared to the predicted values according the randomly generated network model developed by *Smart & Moruzzi* (1972) in Table 3. The formulas for prediction of link type distribution are displayed in Table 4. The interest reader is referred to the original work [*Smart & Moruzzi*, 1972] for the derivation of the formulas.

Table 3: Comparison of observed topologic properties and predicted values of the randomly-generated network model. The values are the number of each type of link.

Link Type	Observed	Calculated
FF	21	21.2
FJ	14	13.6
FO	14	13.6
JF	4	3.4
JJ	0	2.2
JO	5	2.3

Table 4: Probability of a link in the randomly generated network [*Smart & Moruzzi*, 1972]. The table is reproduced from *Morisawa* (1985) with one correction to the probability of an FO link, which was incorrectly reported as $2(1-\alpha)/(2-\alpha)^2$.

Upstream Vertex	Downstream Vertex			
	F	*J*	*O*	Totals
F	$2/(2+\alpha)^2$	$4\alpha/(2+\alpha)^2$	$2(1-\alpha)/(2+\alpha)^2$	$2/(2+\alpha)$
J	$\alpha/(2+\alpha)^2$	$2\alpha^2/(2+\alpha)^2$	$(1-\alpha)/(2+\alpha)^2$	$\alpha/(2+\alpha)$
Totals	$1/(2+\alpha)$	$2\alpha(2+\alpha)$	$(1-\alpha)/(2+\alpha)$	1

The randomly-generated model predicts fairly well the distribution of links with the exception of *JJ* and *JO* links. The model over-predicts the amount of *JJ* links and under-predicts the number of *JO* links while closely estimating the values for *FF*, *FJ*, *FO*, and *JF*. The closely-predicted links all include a fork node at either the upstream or downstream ends, with higher accuracy seen at links with an upstream fork. Since the predicted link type distribution is a function of the recombination factor (which is a function of the joins to forks), a higher accuracy in predicting is seen in the links associated with bifurcations due to Wax Lake Delta's bifurcating nature (α = 0.32). The model assumes that each link type will occur in a randomly-generated network (for α ≠ 1 or 0), but no *JJ* links are observed in Wax Lake Delta. Although the randomly-generated network model may have well-predicted the link types of Wax Lake Delta, *Morisawa* (1985) showed that the model was not adequate for describing behavior across a wide variety of deltas. Other metrics are needed to categorize and make predictions about distributary networks.

Also determined for Wax Lake Delta were the link length distribution and the island size distribution along with subsequent analyses. The link length distribution is shown in Figure 4. The 57 links were binned and a skewed distribution describes the links at Wax Lake Delta. As depicted by the figure, the majority of the links are relatively short (750m-2000m) with very few long channels (4000m +). The relative dearth of long channels may be due to the mechanisms of sediment deposition from a channel to a reservoir [*Wright*, 1977; *Edmonds & Slingerland*, 2007; *Falcini & Jerolmack*, 2010]. *Wright* (1977) first summarized the mechanism of sediment deposition at a river mouth and river mouth bar formation. Long, straight channels with high-velocity flows will not have the tendency to form bifurcations at river mouths [*Wright*, 1977]. The wide channels at Wax Lake Delta (assumed to be main channels with relatively high flow) may fall into this category. More shallow channels with low flow will more readily deposit more sediment at the river mouth bar due to bed friction [*Wright*, 1977; *Edmonds & Slingerland*, 2006] or to a low vorticity [*Falcini & Jerolmack*, 2010]. Following this reasoning, it may be inferred that the Wax Lake Delta network, for the most part, has relatively shallow flow that experiences a large amount of bed friction, leading to river mouth bar deposits that encourage bifurcation. The relatively flatness of the delta plain supports this claim. However, recent work by John Shaw and David Morhig of the Jackson School of Geosciences suggests that the mechanisms of sediment transport and mouth bar formation at Wax Lake Delta are far more complex than those described above, but this work has not been published.

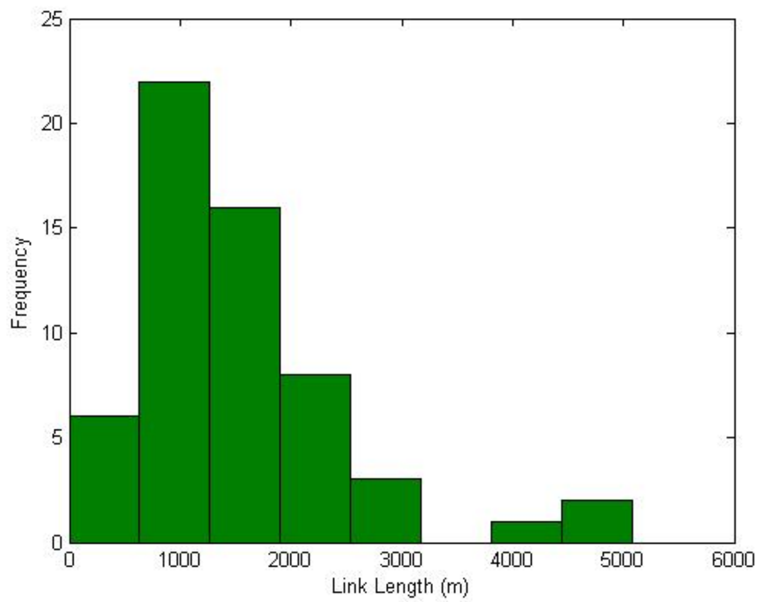

Figure 4: Link Length Distribution for topologic network of Wax Lake Delta

The island size distribution is mapped in Figure 5. For the analysis, islands under 10 acres in area were ignored. Relatively small islands seem to be found at the delta front, where new land is being formed as the delta progrades. Larger islands tend to be found along the boundaries of the major distributary channels, suggesting high flows and a lack of circumstances leading to rapid bifurcation as discussed above. However, no definitive spatial trend seems to exist for the islands at Wax Lake Delta.

Figure 6 shows the distribution of island sizes in column graph form. The exceedence probability for each island is plotted in Figure 7. Both plots show the island size distribution is

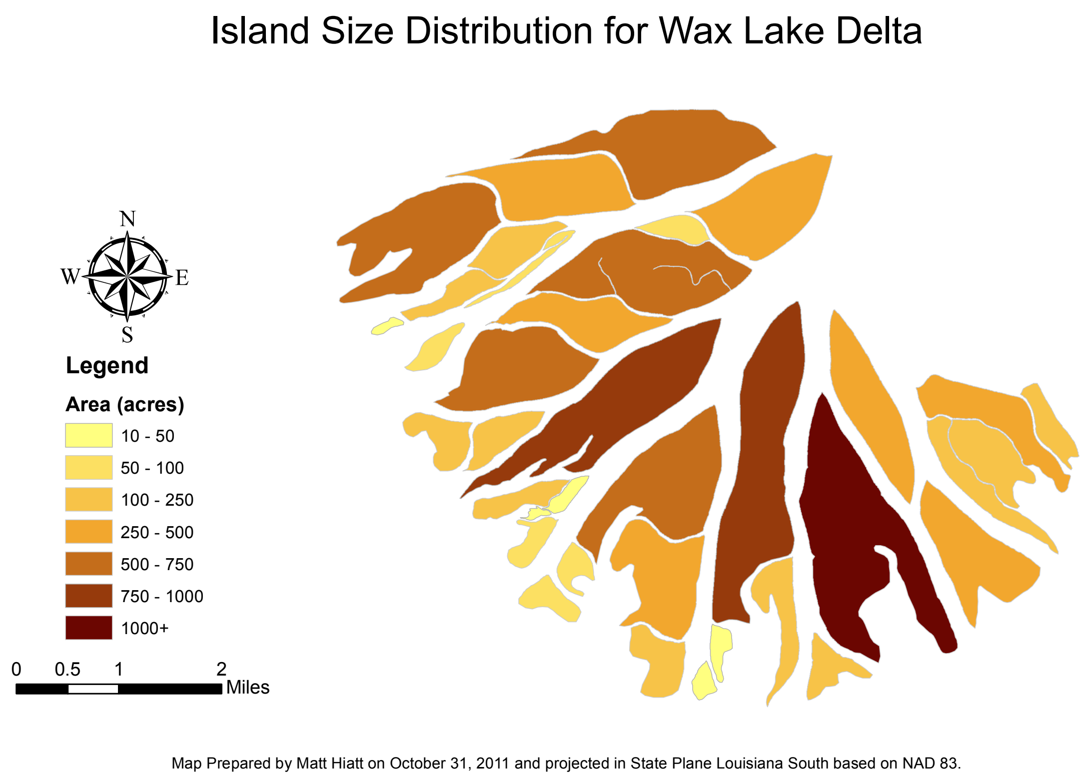

Figure 5: Map of island sizes at Wax Lake Delta.

heavily skewed toward lower island sizes [*Edmonds et al.*, 2011]. The prevalence of small islands at Wax Lake Delta may be due to its bifurcating nature and lack of conditions promoting the formation of long, straight channels. Also, crevasse splays are common in the northwest portion of the delta. The crevasse splays have channelized the flow across larger islands separating them into smaller islands. The island size distribution shows the same trends as those observed by *Edmonds et al.* (2011). The island size distribution and exceendence probabilities for current deltas may be useful tools for predicting the sizes of future islands at a particular delta. Trends across various types of deltas and spatial scales are needed to determine the robustness of island size as a predictive metric.

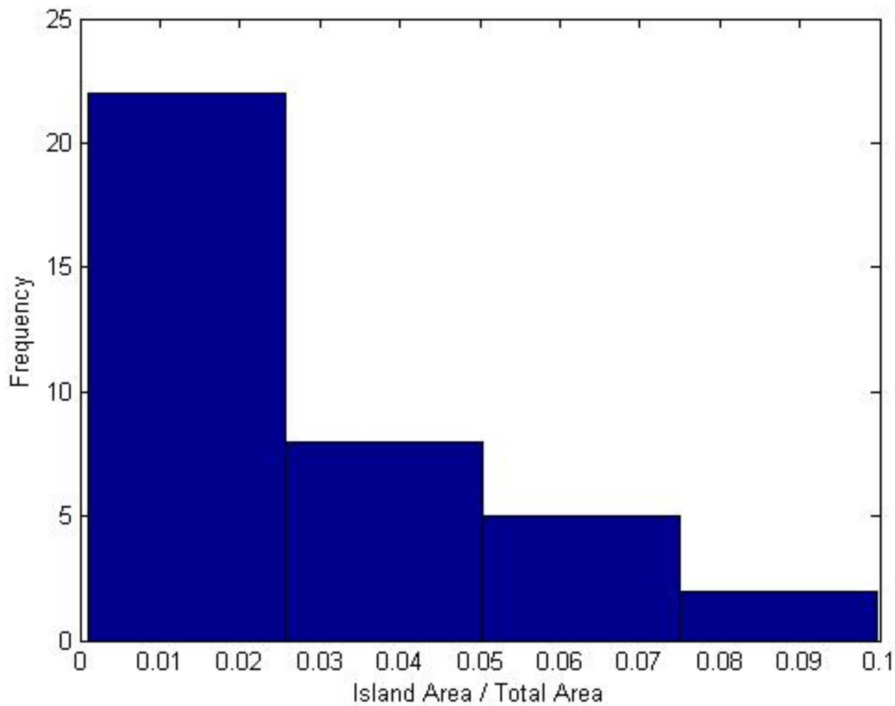

Figure 6: The island size distribution

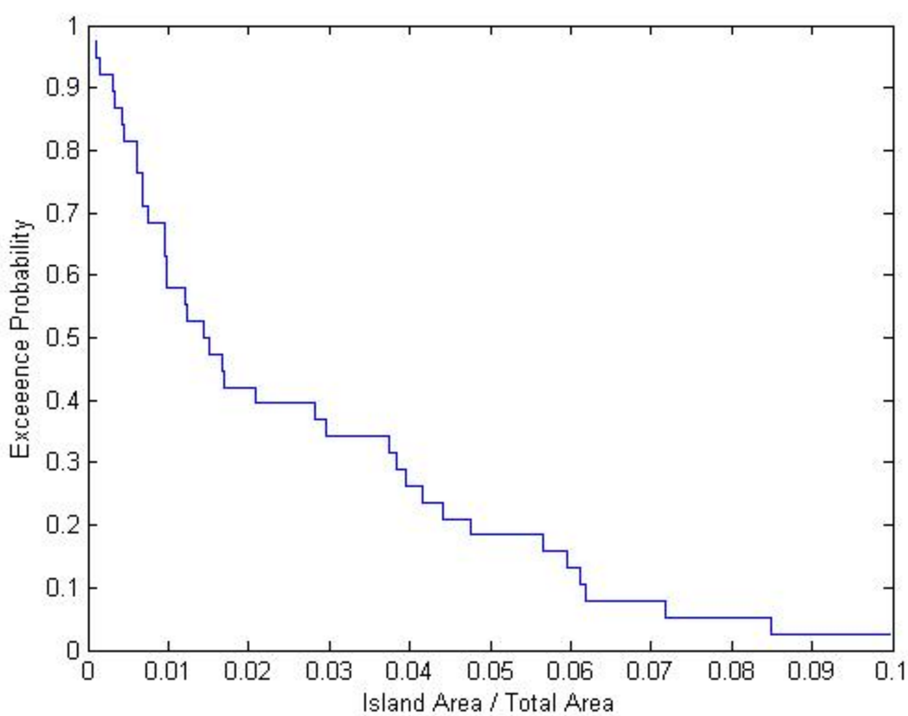

Figure 7: Island size exceedence probability. The chart shows the probability that a given fractional island size will be exceeded. The exceedence probability may be used to predict the size of new island formation.

The nearest-edge distance shows no trends relative to the distance from the delta apex. Islands tend to neither be narrower nor wider with respect to the radial distance as seen in the map in Figure 8. However, the nearest edge distance does show some correlation with the location of inland lakes fed by tidal channels. The location of the inland lakes can be roughly seen in Figure 1, with darker areas representing the location of lakes. Areas with high values for nearest-edge distance seem to correlate fairly well with the location of inland lakes and could perhaps be a tool for predicting their locations. Inland lakes at Wax Lake Delta are ecologically important due their role as nitrogen-fixation hotspots [*David Mohrig*, personal conversation]. More investigation into this correlation is necessary before using it as a predictive measure.

The width function was applied to the topologic and geometric network in order to gain an insight into the distribution of channels as a function of distance from the apex. Table 5 summarizes the results of the width function.

Table 5: Results of the Width Function Applied to Wax Lake Delta

Distance From Apex	Width		
(m)	(# of pixels)	(# of channels)	(m)
1000	870	3	867
2000	1900	4	1897
3000	2760	6	2752
4000	2906	10	2896
5000	3326	16	3310
6000	3637	15	3622
7000	4372	12	4360
8000	2698	7	2690
9000	0	0	0

The number of channels is the topologic width of the network and was analyzed using the network tree (Figure 2). The widths based on the number of 1m pixels in the raster and the geometric widths were measured using the geometric network (Figure 3). The width of the network increases with radial distance from the apex. The increasing trend is expected due to the bifurcating nature of Wax Lake Delta's distributary system. The decrease in width at the 8000-m length step is most likely due to the asymmetry of the delta front (Figure 1). Figure 9 compares the topologic width trend to the geometric width.

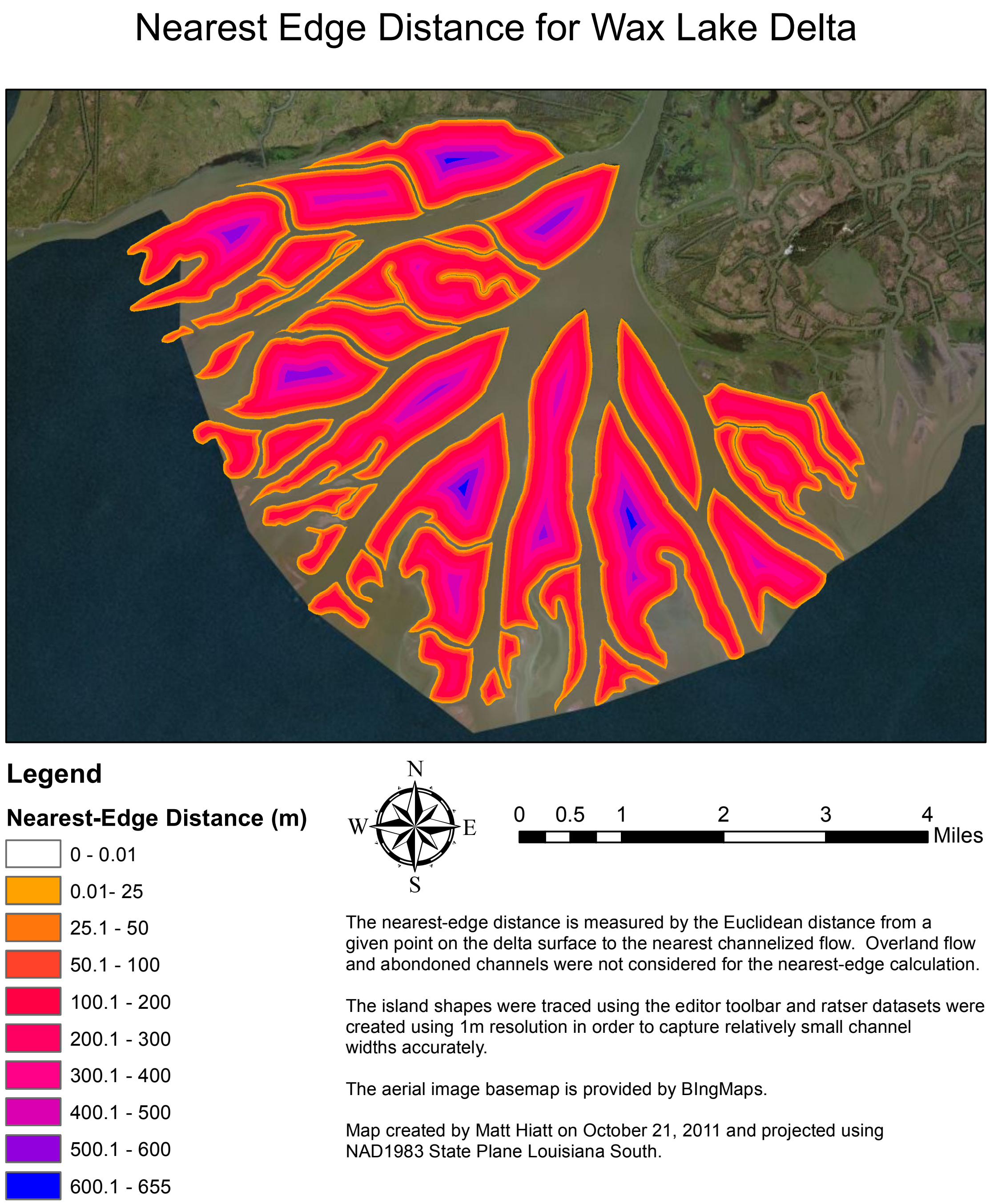

Figure 8: Nearest-Edge Distance at Wax Lake Delta. Further discussion is found in text and on the map.

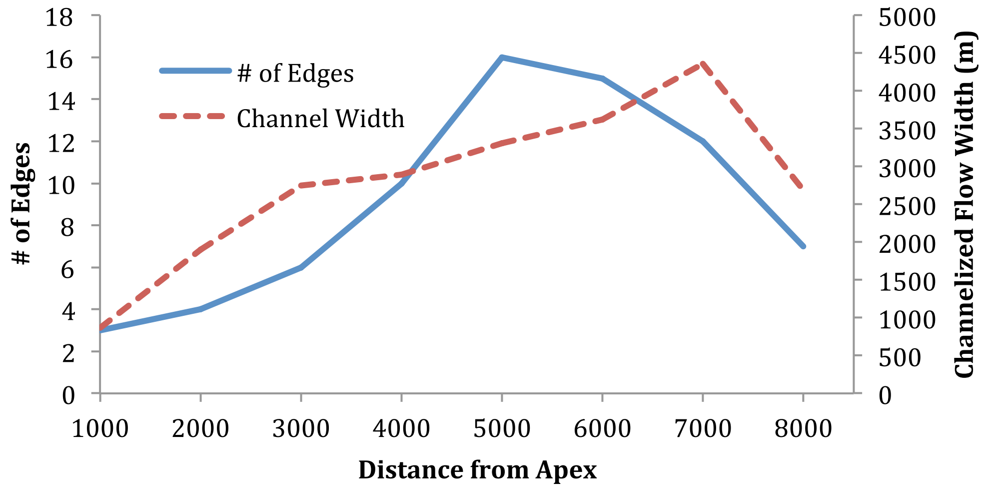

Figure 9: Trends in the width of the network with respect to radial distance. The topologic width is seen in the solid line and the dashed line represents the geometric network.

Differences between the geometric and topologic network trends are seen but both tend increase in width with increasing distance from the apex then begin to drop off. The asymmetric nature of the delta causes the drop in width. The topologic network begins to decrease in width much closer to the apex than does the geometric network, which implies that the network continues to increase in width as channels progress down the delta front even though the number of channels is decreasing. It is difficult to tell from this analysis the extent of width increase experienced by individual channels.

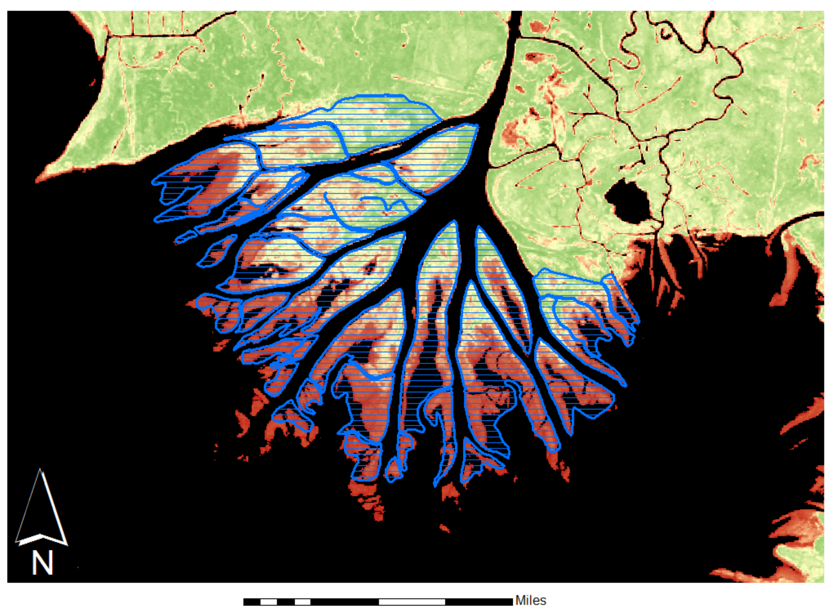

Figure 10: Comparison of NDVI water feature identification (black) and hand-drawn island shapes (blue hatch). Land surface pixels are represented by colors corresponding to NDVI values.

The automatic extraction of water features (i.e. the channel network) from satellite imagery would greatly enhance the robustness, objectivity, and speed of the analyses performed in this study. An investigation into a possible extraction technique was performed and the results are compared to that of the manual water feature extraction is shown in Figure 10. The hatched shapes represent the islands traced by hand in ArcMap and the dark areas represent water features as determined by the automated technique. The green to red gradient areas are the land surfaces as determined by the filtered NDVI. The location of water features between the two methods shows a strong correlation with that correlation becoming weaker with progression down the delta front. Small islands at the delta front are identified by the NDVI method but excluded in the hand-drawn islands because of the 10-acre area limitation previously discussed. The water feature extraction using NDVI may be useful for visual purposes but more study across varying delta types and scales is needed to determine if the method is reliable. The extracted water mask also seems to loosely support the claim that nearest-edge distance may be an indicator of lakes.

Though not a proven analysis technique, the water mask was extracted from LANDSAT images from October and November 2011. The result is a large change in the amount of water seen on the delta surface as defined by the delta boundaries seen in Figure 11. Table 6 summarizes the results of the analysis. The results imply that the delta surface is highly dynamic and conditions change over relatively small time scales. Although Wax Lake Delta is in an area characterized by low tidal energy and wave power [*Syvitsky*, 2005], these results may have been affected by the time of day at which satellite images were taken. Storm conditions and other factors may have also impacted the results. The goal of the analysis was to emphasize the dynamics of the delta network, not to model the changes in surface water with time. Nevertheless, the increase in water on the delta surface is dramatic, changing about 150% from October to November.

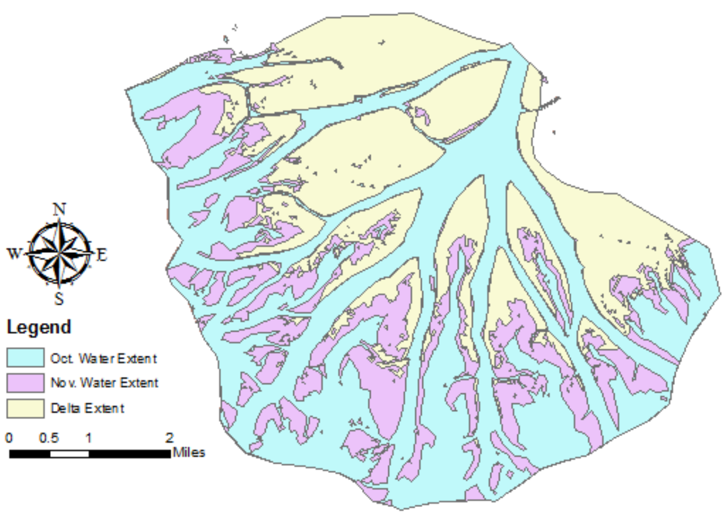

Figure 11: The extent of the water masks for October (blue) 2011 and November (lavender) 2011. The yellow background is the extent of the delta.

Forming over an observable time period, Wax Lake Delta is an ideal location for the study of delta evolution. Satellite imagery captures the growth of the delta as seen in Figure 12. From 1983 to the 2011, Wax Lake Delta has prograded from the outlet of the Wax Lake diversion of the Atchafalaya River to around 10 km into the Atchafalaya Bay. Figure 12 also highlights the time scales on which delta dynamics operate. The delta changes by decade, yearly, and even monthly. The flat delta plain with low elevation is highly vulnerable to the sea level and tidal conditions. A slight change in sea level or tidal forcing can greatly alter the lack (or presence) of the land surface from satellite imagery. Although monthly and yearly changes may be small relative to the delta formation, it is clear that the river delta is a highly dynamic physical system. The scope of this report is not to investigate the mechanisms that drive the dynamic nature of the delta. The discussion of delta evolution is included only to emphasize the dynamics of the system.

Table 6: Comparison of water coverage on the surface of Wax Lake Delta based on satellite imagery and extraction using the NDVI

Month in 2011	square meters	acres	% of total delta area
October	35282126	8718	44.7
November	53206694	13148	67.4

Conclusions: Metrics describing delta behavior were explored and analyzed for Wax Lake Delta using ESRI ArcGIS software. A directed graph of the distributary channel network was created and analyzed. The directed graph was compared to the randomly-generated network model developed by *Smart & Moruzzi* (1972). The recombination factor, nearest-edge distance, link length distribution, island size distribution, and network width were developed for Wax Lake Delta. The delta was classified as a birfurcating system that increases in width as a function of increasing distance from the delta apex. A technique for the extraction of the water mask from satellite imagery was investigated. However, the author feels a more complex approach than that discussed in this study is necessary for the automatic extraction of the channel network. Delta evolution was observed using satellite imagery and the dynamic nature of the network was emphasized. The distributary network is highly complex and advanced image processing techniques are necessary for an automated extraction of the network.

The aim of this study was to gain an insight into the characteristics of Wax Lake Delta using remote-sensing and GIS technologies. The knowledge gained provides some understanding of the present characteristic of the distributary network and can be used as building blocks for the development of predictive metrics to describe distributary networks.

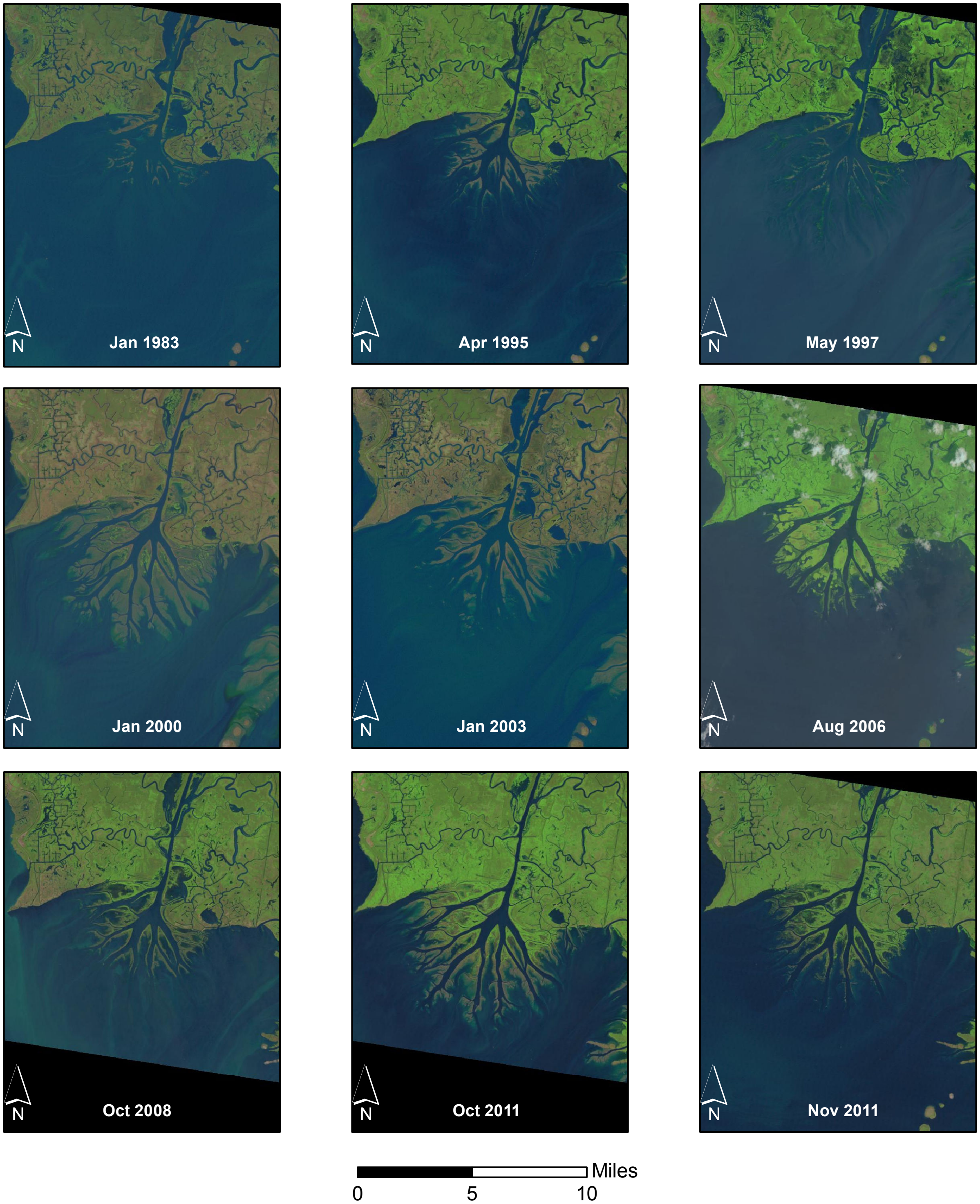

Figure 12: Growth and evolution of Wax Lake Delta as seen by LANDSAT TM 4-5. The images are displayed in a false-color RGB composite to emphasize contrast between land surface and water features. The images are at a 30-meter pixel resolution. The delta progresses roughly 10 km into the Atchafalaya Bay.

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Data Sources:

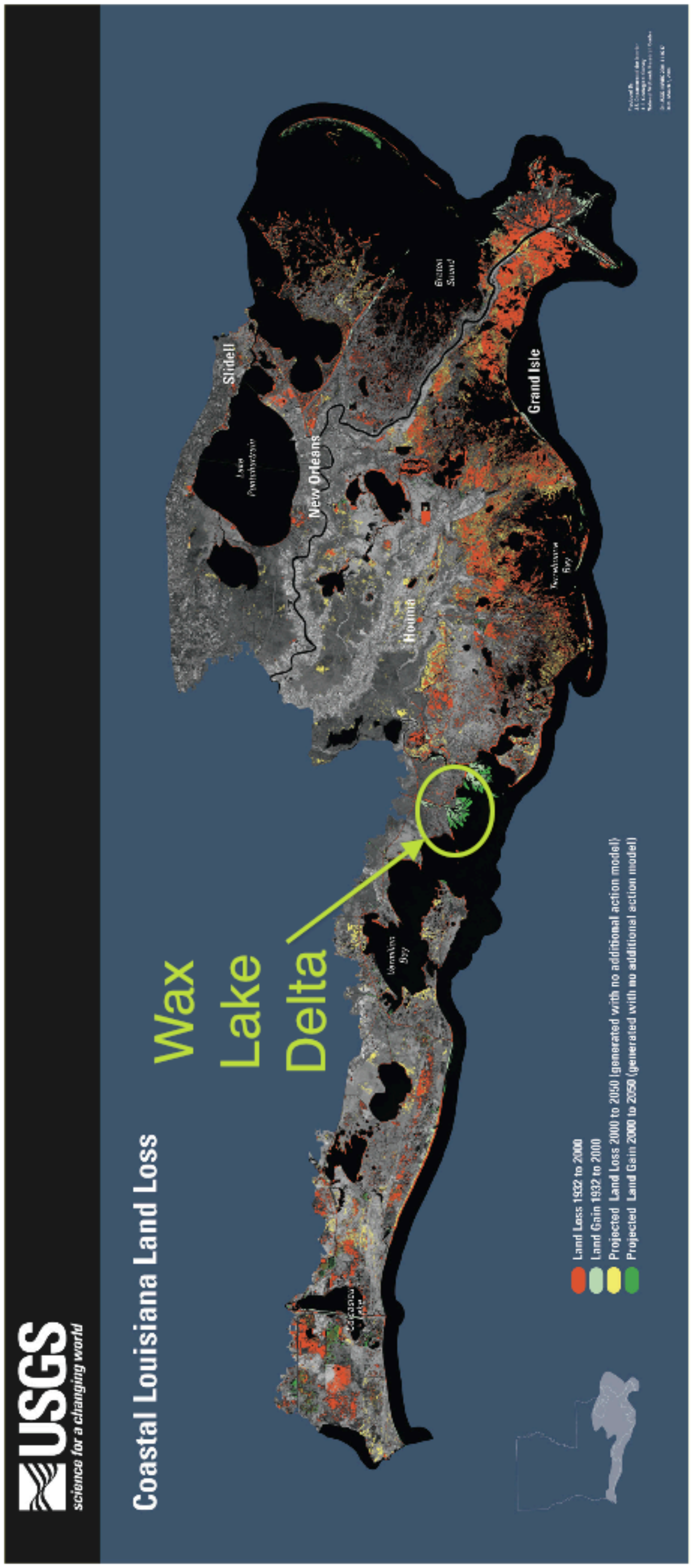
LANDSAT Images from http://glovis.usgs.gov/

DEMs (30 m, 10 m, and 1m lidar) downloaded from USGS National Map Seamless Server – Datasets not used due to incompleteness

2009 Lidar Survey, PI: James Buttles University of Texas at Austin, Airborne Laser Swath Mapping Project, National Center for Airborne Laser Mapping.

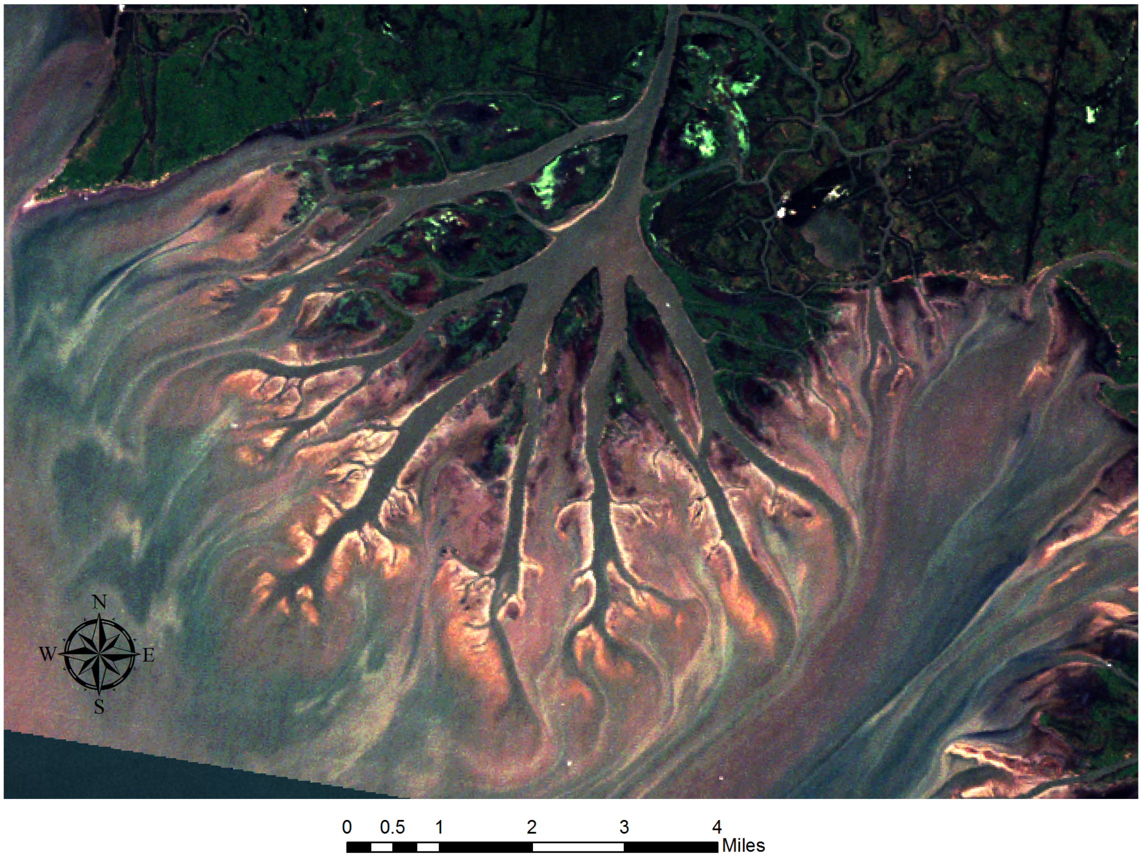
Basemaps from ArcGIS 10

Appendix A – A USGS Map projecting land loss for coastal Louisiana



Appendix A: A land loss history and projection map developed by the USGS. Green areas represent predicted and historical land growth while red and yellow areas show land loss. The presence of green occurs almost exclusively in the Atchafalaya Bay for both Wax Lake and Atchafalaya Deltas. Understanding what promotes the growth of healthy deltas is vital to the development of delta and wetland restoration practices.[*Barras*, 2006].

Appendix B – Wax Lake Delta



Appendix B: A true-color composite of an October 2011 LANDSAT 5 TM image. The spatial resolution is 30 meters. The delta is characterized by well-defined islands near the delta apex with more inland lakes occurring as a function of radial distance from the delta. Sediment plumes (tan-colored) are seen near the delta front. The presence of sediment plumes and inland lakes makes the classification of land and water surfaces difficult.