MRGO ECOSYSTEM RESTORATION FEASIBILITY STUDY

CHANDELEUR AND BRETON ISLANDS

Prepared for:

URS Group

And

U.S. Army Corps of Engineers
New Orleans District

Prepared by:

Coastal Planning & Engineering, Inc.[1]
2481 NW Boca Raton Blvd, Boca Raton, FL

and

Pontchartrain Institute for Environmental Sciences, University of New Orleans[2]
2000 Lakeshore Drive, New Orleans, LA

Gordon Thomson, P.E.[1]
Michael Miner, Ph.D.[2]
Andrew Wycklendt, M.Sc.[1]
Michelle Rees, M.Sc.[1]
David Swigler, M.Sc.[1]

Recommended Citation: Thomson, G., Miner, M., Wycklendt, A., Rees, M. Swigler, D., 2010. *MRGO Ecosystem Restoration Feasibility Study – Chandeleur and Breton Islands*. Boca Raton, Florida: Coastal Planning & Engineering, Inc. 96p. (Report prepared for USACE under contract to URS)

December 2009
Rev April 2010

MRGO ECOSYSTEM RESTORATION
FEASIBILITY STUDY
CHANDELEUR AND BRETON ISLANDS

EXECUTIVE SUMMARY

Along the Chandeleur Islands, Louisiana, a net loss of barrier island sand to deepwater, downdrift sinks and offshore dredge disposal sites has resulted in a reduction of total island area from 17.2 mi^2 in 1855 to 1.8 mi^2 in 2005. Increased hurricane intensity and frequency in the northern Gulf of Mexico during the past decade has accelerated this land loss trend, forcing the Chandeleur Islands into a mode of rapid dissection and transgressive submergence (conversion from emergent barrier islands to submerged shoals). Based on extrapolated historical land loss and shoreface retreat rates, the islands will be completely converted to a system of submerged shoals within approximately 25 years. This 50-mile long barrier arc plays a crucial role in: 1) attenuating storm impacts for mainland Louisiana and Mississippi (Stone et al. 2004; 2005), 2) regulating conditions for a 4,650 mi^2 estuary (including salinity gradients, circulation patterns, nutrient retention and distribution, and magnitude of wave and tidal energy; Reyes et al., 2005); 3) supporting a $2.7 billion fisheries industry (Fearnley et al., 2009), and 4) providing unique habitat for threatened and endangered species including nesting sea turtles, brown pelicans, piping plovers, and least terns (Lavoie et al., 2009; Poirrier and Handley 2007).

The Chandeleurs were produced by marine reworking of seaward portions of abandoned Mississippi River delta lobes beginning approximately 1,800 years ago; a process dominated by lateral spit accretion downdrift from a central deltaic headland sediment source. Lateral transport along the Chandeleurs has produced up to a 33-foot thick spit platform deposits and a series of relict recurved spits that today are overlain by back barrier marsh. During island landward retreat (~50 feet/year for 1855-2008), sands from the subsurface relict spit deposits are liberated in the nearshore providing a local sand source to the active littoral system. Where barrier marshes overlie relict deltaic or lagoonal muds instead of relict sandy spits, shorelines are sand-starved and island disintegration rates are highest. During the past 125 years ~400M cubic yards of sand has accumulated in deepwater sinks at the flanks of the barrier island arc; twice as much as deposited in the back barrier. In contrast to popular transgressive barrier island models, no new back barrier marshes have formed during the last century, so that the loss of sediment to flanking sinks has forced the long-term reduction in island area.

The long-term reduction in barrier island sand volume (a trend that was greatly accelerated by Hurricane Katrina) inhibits the islands from maintaining exposure by means of landward transfer of sand by overwash processes and subsequent colonization of overwash deposits by back barrier marsh vegetation. During the past two decades, landward transfer of sand has been limited to post-storm recovery periods and is facilitated by: (1) landward migration of offshore bars that weld to marsh islets, (2) recurved spit formation at hurricane-cut inlets, (3) aeolian processes constructing dunes wind tidal flats, and (4) shoal aggradation and landward migration. In their present state, the islands are sediment-starved and these recovery processes appear to have exhausted most of the available sand supply, limiting further recovery.

This study proposes a barrier island management strategy that aims to replicate the natural processes of island development by: (1) reintroducing sand at updrift back barrier feeder sites, (2) using shoreface retreat to liberate sand from feeder sites into the littoral system for lateral distribution over the long-term, and (3) establishing salt marshes upon back barrier sand placement sites. This comprehensive plan derives from extensive studies on long term geomorphic evolution and short term changes—driven primarily by loss of sand from the barrier system, rapid relative sea level rise, and hurricanes—to provide the barrier system the means to be sustainable for generations.

It is proposed to construct eight shore-perpendicular back-barrier sand reserve feeder sites and a shore parallel beach berm along the Chandeleur Islands. The sand reserve feeder site will vary from approximately 800 to 1,400 feet long (shore-parallel) and 1,800 to 5,500 feet wide (shore perpendicular). The feeder sites will be constructed to an elevation of +2 feet, NAVD resulting in a fill volume of approximately 4.9M cubic yards of sand. The 7-mile long beach berm will be constructed to an elevation of +3 feet, NAVD and be approximately 500 feet wide. The beach berm will contain approximately 3.8M cubic yards of sand.

Five alternatives were considered for Breton Island encompassing a variety of costs and construction concepts.

1. Alternative 1 is a 4-mile long, crescent shaped beach berm with a crest width of approximately 1,000 feet at an elevation of +4 feet, NAVD. A backing marsh is proposed that will have a maximum width of approximately 3,700 feet wide at an elevation of +2 feet, NAVD.
2. Alternative 2 is also 4 miles long but the beach dune is higher than Alternative 1 with a +6 feet, NAVD crest though the dune crest is narrower at 750 feet wide. Alternative 2 has a 500-foot long spit feature at the northwest end. Alternative 2 does not have a marsh.
3. Alternative 3 was designed to minimize pumping distance and thus cost. It includes a 1,000 foot wide platform at +10 feet NAVD at the northern end of the island. The fill then slopes at 1V:300H to the south-southwest.
4. Alternative 4 is similar to Alternative 2 except that a 2,400-foot long terminal groin has been added to the southwest end of the fill. This limits longshore losses from the island and thus provides increased project benefits.
5. Alternative 5 considered filling in portions of the MRGO Channel and Breton Island Pass in order to promote sediment bypassing from Grand Gosier Shoal to Breton Island.

A sediment budget was developed for Breton and Chandeleur Islands that separated losses into longshore, overwash, offshore and losses due to relative sea level rise. The sediment budget was applied through an analytic model to estimate project performance under Future Without Project (FWOP) and Future With Project (FWP) conditions. Project performance was based on the Wetland Value Assessment (WVA) methodology (EWG, 2002)

The model suggested that under FWOP conditions, all subaerial acreage will be lost by TY28 along the Chandeleur Islands. It is estimated that FWOP provides 828 Average Annual Habitat Units (AAHUs).

Under FWP conditions on the Chandeleur Islands, subaerial acreage will be completely lost by TY48. It is estimated that FWP will provide 2,292 AAHUs for a net benefit of 1,464 AAHUs. The expected construction cost for the Chandeleur Islands project is $119,568,000, which includes a 25% contingency. The most cost effective borrow source for the Chandeleur Islands alternative is Hewes Point. Table 1 summaries the benefits and cost of the various alternatives.

Table 1. Summary of Alternative Benefits and Costs

Alternative	Fill Volume (cy)	Cost Estimate	Net Benefits (AAHU's)	Cost per AAHU ($/AAHU)
Chandeleur Island	8,720,000	$119,568,000	1,464	$81,672
Breton Island 1	20,040,000	$178,486,000	195	$915,313
Breton Island 2	9,657,000	$88,450,000	49	$1,807,435
Breton Island 3	7,255,000	$61,038,000	67	$908,645
Breton Island 4	9,382,000	$100,279,000	70	$1,428,307
Breton Island 5	12,321,000	$83,631,000	0	-

No subaerial acreage is estimated to remain at Breton Island by TY0. Since the FWOP condition provides no AAHUs, the total and net benefits for each of the five alternatives are directly dependent on the acreage created during construction. Breton Island Alternative 1 provides subaerial acreage through TY19. Alternative 2 provides subaerial acreage through TY11, Alternative 3 through TY20, and Alternative 4 through TY24. Alternative 5 does not provide subaerial acreage at any time during its project life. The preferred borrow source would be the MRGO Ocean Dredged Material Disposal Site (ODMDS).

The type of benefits provided by reconstructing either the Chandeleur Islands or Breton Island alternatives can be considered identical as they provide similar habitat (supratidal, gulf intertidal, bay intertidal, and subtidal) along barrier island shorelines that are geographically close.

MRGO ECOSYSTEM RESTORATION
FEASIBILITY STUDY
CHANDELEUR AND BRETON ISLANDS

Table of Contents

List of Figures

List of Tables

List of Appendices

1 INTRODUCTION

The Mississippi River Gulf Outlet (MRGO) Ecosystem Restoration Plan is being developed by the U.S. Army Corps of Engineers (USACE), New Orleans District as a supplement to the MRGO Deep-Draft De-Authorization Report. The USACE is conducting a Feasibility Study that will result in a comprehensive ecosystem restoration plan to restore the Lake Borgne ecosystem and areas affected by the MRGO channel. This restoration plan is being developed in accordance with Section 7013 of the Water Resources Development Act (WRDA) of 2007. It is fully funded by the Federal government. The purpose of the study is to address systematic ecosystem restoration with consideration of measures to reduce or prevent damages from storm surge.

This report is designed to synthesize earlier findings and provide a basis for planning and designing a management scheme for the Chandeleur Islands and Breton Island associated with the MRGO Ecosystem Restoration Plan and Feasibility Study. The intent is to present a background summary of the morphology and physical processes governing the evolution of the Chandeleur and Breton Islands, which is then applied to develop a barrier island management plan. The restoration plan is designed to employ the physical processes that led to the initial development of the islands by reintroducing sand that has been lost to downdrift, deepwater sinks back into the central portion of the islands for natural reintroduction to the littoral system during island retreat. In this way, the natural processes of island development will be mimicked so that spits will laterally accrete to close inlets, expand emergent back barrier marsh area, and increase dune elevations.

Much of this background report is based on findings presented in *Sand Resources, Regional Geology, and Coastal Processes of the Chandeleur Islands Coastal System — an Evaluation of the Resilience of the Breton National Wildlife Refuge* (Lavoie, 2009), a study conducted by the U.S. Geological Survey (USGS) and the University of New Orleans-Pontchartrain Institute for Environmental Sciences (UNO-PIES) and funded by the U.S. Fish and Wildlife Service. A significant component of this synthesis also includes data collected under the Barrier Island Comprehensive Monitoring program (BICM), a Louisiana Coastal Area Science and Technology Program (LCA S&T)-funded study implemented by the Louisiana Office of Coastal Protection and Restoration (OCPR) and conducted by UNO-PIES and USGS. Subsequent to these two efforts additional data included in this report was collected under an ongoing study by UNO-PIES and USGS funded through the USGS Northern Gulf of Mexico Ecosystem Change and Hazard Susceptibility Project (NGOM).

This report discusses plans, benefits and costs for ecosystem restoration along the Chandeleur Islands and Breton Island as part of the larger MRGO Ecosystem Restoration Plan.

2 AUTHORIZATION

The restoration plan is being developed in accordance with Section 7013 of WRDA 2007. Coastal Planning & Engineering, Inc (CPE) conducted the work in this report under a contract with URS Corporation, which has a direct contract with USACE, New Orleans District

(W912P8-09-D-0007). Pontchartrain Institute for Environmental Sciences was a sub-consultant to CPE.

3 PURPOSE AND SCOPE

This report provides technical information and an engineering assessment of the existing conditions at the Chandeleur Islands and Breton Island. The report will be used to support the Feasibility Report of the Mississippi River Gulf Outlet (MRGO) Ecosystem Restoration Plan. Project benefits are evaluated over a 50-year period using the Wetlands Value Assessment (WVA) methodology. No additional data was collected as part of this work. This study evaluates historic shoreline retreat rates, sediment patterns and geomorphic evolution to develop a sediment budget that accounts for losses due to longshore transport, relative sea level rise, silt release and overwash. The sediment budget in association with cross-shore modeling is used to predict project performance.

4 PROJECT LOCATION

The Chandeleur Islands are composed of an 50-mile long arcuate-shaped barrier island chain located in southeast Louisiana on the north-central coast of the Gulf of Mexico and are separated from the Louisiana mainland wetlands by the ~15-25 mile wide Breton and Chandeleur Sound where depths average 10 to 15 feet. They are the oldest transgressive barrier island arc in the Mississippi River delta plain system. The island chain is composed of the northern island arc that extends from Hewes Point in the north to Monkey Bayou in the south, a series of ephemeral barrier islands (Curlew and Grand Gosier) south of Monkey Bayou, and Breton Island, the southernmost island in the chain (Figure 1). These islands are extremely dynamic, but in their present state they are characterized by a relatively sand-rich northern section (north of Redfish Point) and a sand-starved southern section that extends south to Breton Island.

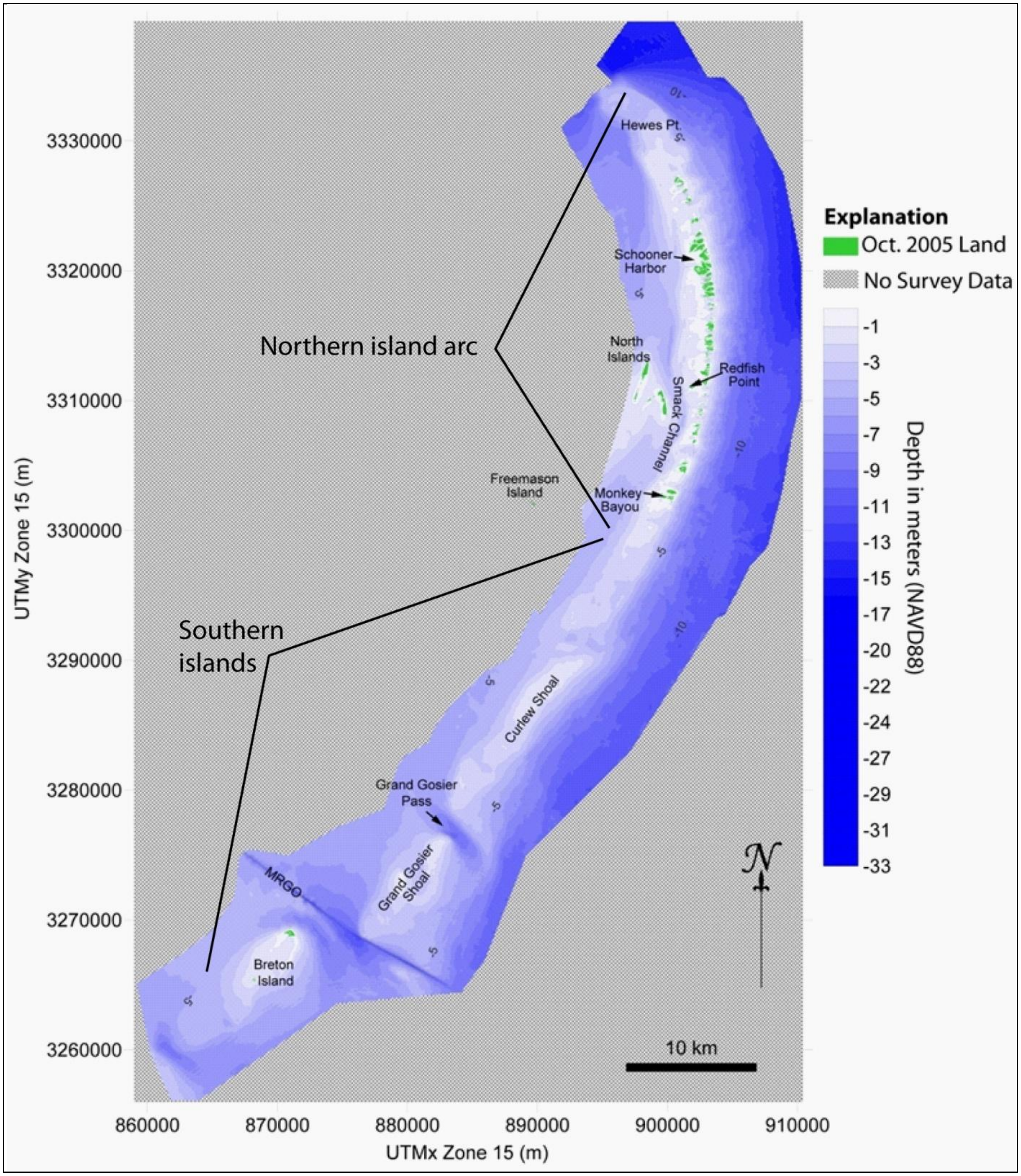


Figure 1. Chandeleur Islands study area with bathymetry collected in 2006-2007 and island area from October 2005 (post-Hurricane Katrina). For this report, the island chain is divided into two major units: the northern island arc and the southern islands. Other geographic locations that are discussed throughout the text are noted on this map. Shoreline data from Martinez et al. (2009) and bathymetry from Miner et al. (2009c). Map modified from Miner et al. (2009d).

5 GEOMORPHIC EVOLUTION

5.1 Deltaic Abandonment and Early Island Evolution

The Mississippi River Delta Plain is the product of deposition by multiple, spatially and temporally offset, deltaic depocenters fed by distributary systems of the lower Mississippi River drainage basin (Russell, 1936; Fisk, 1944). Chronological alterations in the location of these depocenters arise from upstream avulsions of the Mississippi River and its distributaries. With each avulsion event, a new distributary network and attendant delta complex is formed. In total, the Holocene delta plain consists of six delta complexes: Maringouin (7,500 - 5,000 yrs BP), Teche (5,500 – 3,800 yrs BP), St. Bernard (4,000 – 1,800 yrs BP), Lafourche (2,500 – 400 yrs BP), Balize (1,000 yrs BP – present), and Atchafalaya (400 yrs BP – present) (Kolb and Van Lopik, 1958; Frazier, 1967; Coleman, 1988; Penland et al., 1988; Roberts, 1997) (Figure 2). Names, location, and chronology for delta complexes are derived from Frazier (1967), Penland et al. (1988), Törnqvist et al. (1996), Roberts (1997), and Kulp et al. (2005a). Each delta complex consists of smaller scale delta lobes. Products of this cyclic process of delta lobe progradation and subsequent abandonment are the transgressive components of the delta plain that include barrier island/tidal inlet systems, inner-shelf sand shoals, tidal channels, and interdistributary bays (Roberts, 1997).

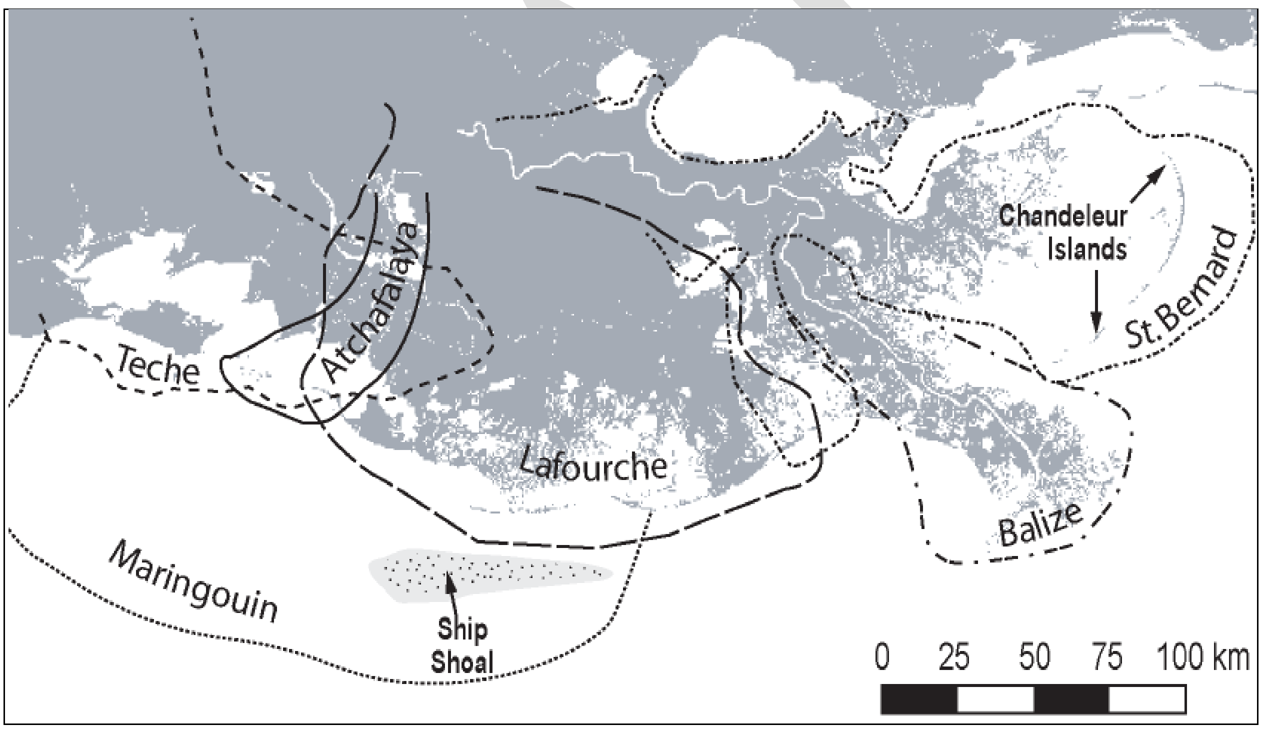


Figure 2. Map of the Holocene Mississippi River delta plain that shows the multiple, spatially offset depocenters for each delta complex.

Subsequent to deltaic abandonment, previously active delta lobes become erosional headlands, and subsidence and marine reworking results in the landward migration of the shoreline. Sediment comprising the headland is reworked laterally by waves and storm impacts to form barrier islands, and eventually inner-shelf shoals (Kwon, 1969; Penland et al., 1988). A three-stage conceptual model depicting the evolution from deltaic abandonment to barrier island formation to inner-shelf shoal formation was conceived by Penland et al. (1988; Figure 3). During Stage 1, the abandoned deltaic headland is reworked to form an erosional headland with flanking barrier islands. Submergence and interior wetland erosion due to RSLR and decreased fluvial sediment supply leads to mainland detachment and formation of a Stage 2 transgressive barrier island arc. In Stage 3, continued RSLR results in transgressive submergence of the island arc to form an inner-shelf barrier shoal (Penland et al., 1988).

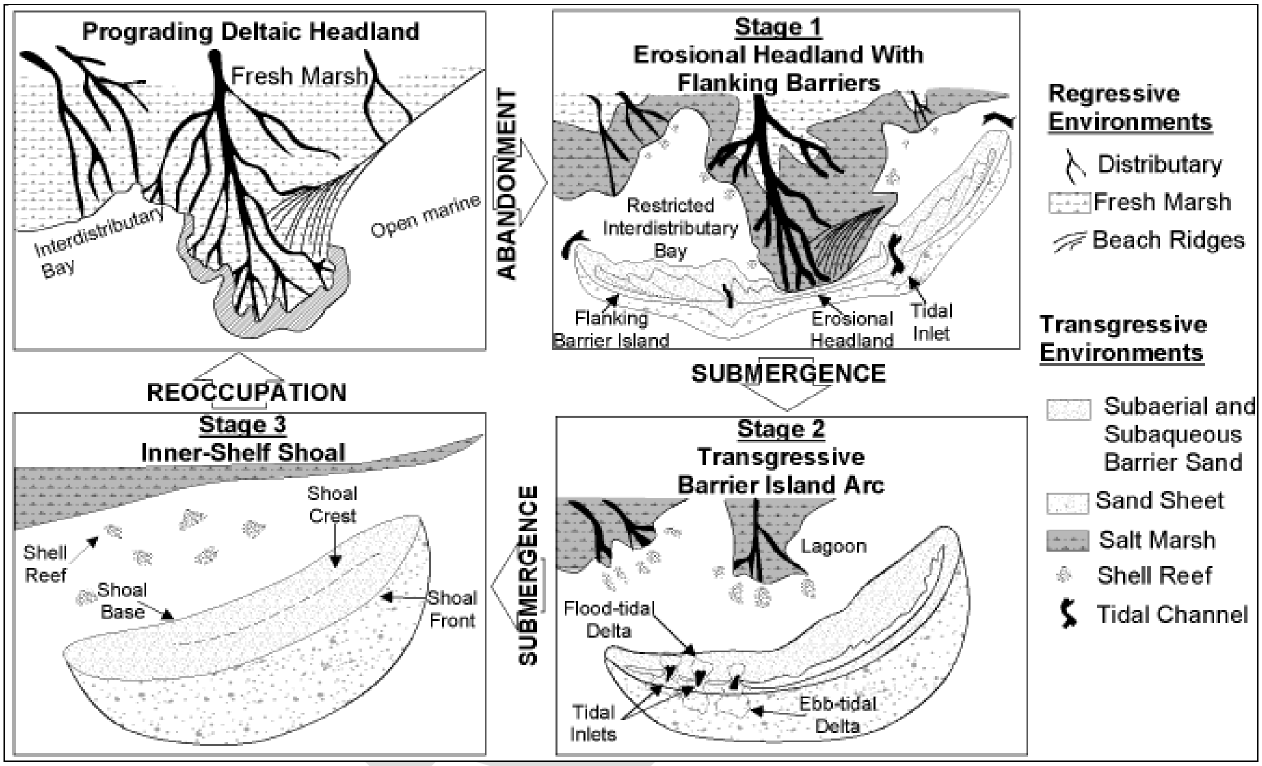


Figure 3. Three-stage model conceived by Penland et al. (1988) for the formation and evolution of transgressive Mississippi River delta barrier islands. From Kulp et al. (2005b) modified from Penland et al. (1988).

The Chandeleur Islands represent a Stage 2 barrier island arc, the product of abandonment and reworking of the St. Bernard delta complex (Frazier 1967; Penland et al., 1988). The most recent distributary active in the region is associated with Bayou La Loutre and was abandoned by fluvial processes approximately 1,800 yrs BP (Frazier, 1967; Rogers et al., 2009). Shoreline development and barrier geometry are controlled by orientation of the abandoned deltaic headland relative to the dominant wave approach. Wave-induced lateral transport is the most significant factor in the development of a Louisiana barrier coastline (Penland and Boyd, 1985) and produces sand-rich flanking barrier islands. Because the transgressive shoreline is naturally isolated from the sediment load of the Mississippi River, there is a finite supply of sand for natural island maintenance. In earlier stages of barrier development a significant sand source is derived from erosion of deltaic deposits by waves. Once the deltaic sediment source has been completely reworked, or has subsided below effective wave base (~23 feet for the Chandeleur Islands; Penland and Boyd, 1985), the barrier and lagoonal deposits are continually recycled at the shoreface during retreat; which for a period of time allows the barrier system to maintain its exposure during relative sea level rise (RSLR). Much of this sand recycling during shoreface retreat is not in the form of hurricane overwash deposits that eventually become exposed at the shoreface (although this is a significant component), but by recycling of relict recurved spit and large terminal spit deposits (Section 5.5) at the shoreface. Figure 4 is a stratigraphic cross section demonstrating the relationship between these sandy lateral accretion deposits that underlie the northern half of the Chandeleur Islands from Redfish Point, north to Hewes Point and the mud-rich deltaic deposits that underlie the southern half of the islands in the vicinity of Monkey Bayou.

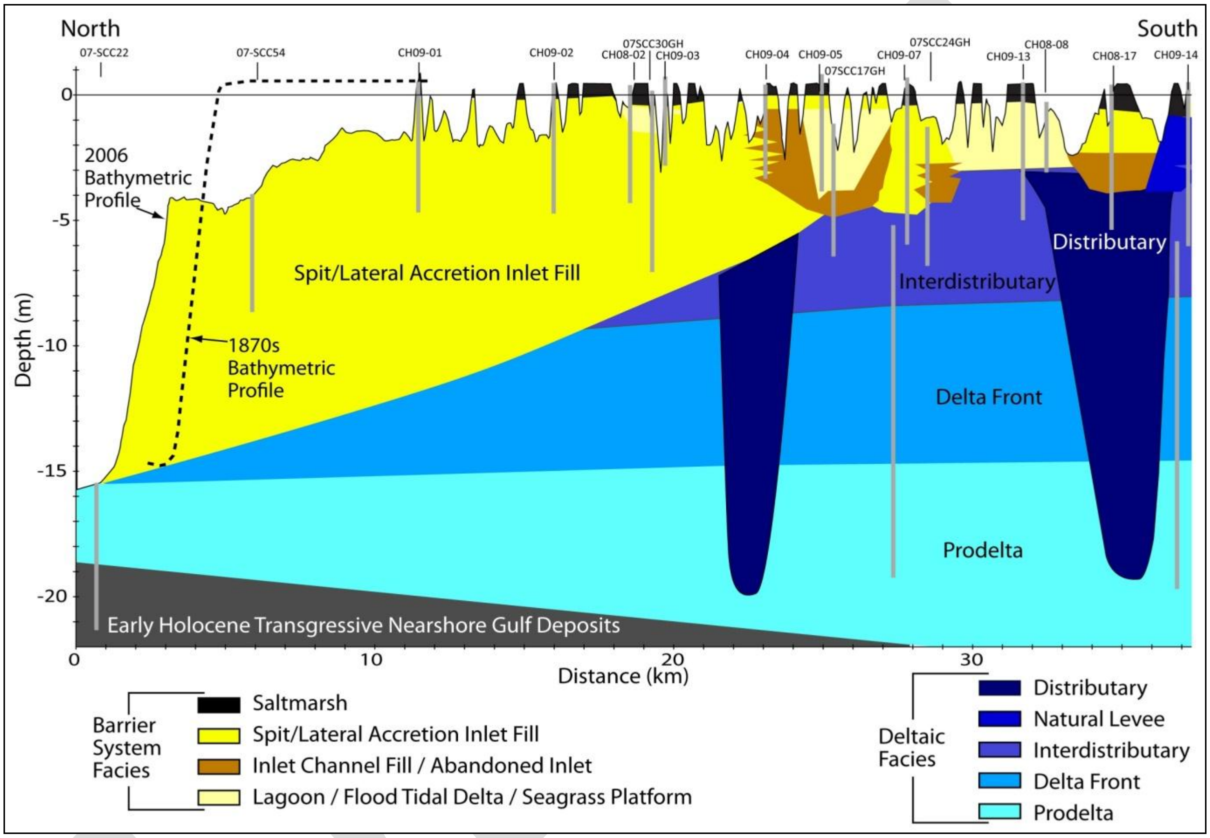


Figure 4. Geologic cross-section trending along the northern Chandeleur island arc from the Hewes Point spit platform in the north to Monkey Bayou in the south (see Figure 1). Bathymetric profiles from Miner et al. (2009c). Subsurface data from unpublished UNO-PIES and USGS vibracores and high-resolution shallow seismic profiles and USACE (1958).

Note in Figure 4 that the salt marsh north of Redfish Point (location of core CH-09-07) is underlain by thick, sandy spit and lateral accretion inlet fill deposits whereas salt marsh south of this location is underlain by muddy relict deltaic and lagoonal deposits. This cross-section demonstrates in profile view the importance of lateral sediment transport in the development and ultimately, the demise of Louisiana transgressive barrier islands. Also note that the dashed line representing the 1870s position of the Hewes Point spit relative to the 2006 bathymetric profile. Approximately 170M cubic yards (130 x 10^6 m^3) of sand has accumulated north of Hewes Point since 1870s (see Figure 4 and Table 1).

5.2 Chandeleur Islands Barrier System Morphology and Historical (1855-2005) Evolution

The historical evolution is documented in seafloor change analysis conducted by Miner et al, 2009c, d). Detailed accounts of the historical shoreline change and seafloor changes along the Chandeleur Islands can be found in Martinez et al. (2009); Fearnley et al., (2009a, b); and Miner et al. (2009c, d). What follows is a summary of those reports with a focus on long term sediment dynamics and shoreface evolution that provide an important background and basis for island management designs herein.

Shoreline retreat rates average ~50 feet/year for 1855-2008 (Martinez et al., 2009). However, these retreat rates are not accompanied by conservation of sand in a landward direction, landward translation of the barrier island, or formation of new back barrier marsh. Instead, lateral transport to the flanks of the island arc (north of Hewes Point and South of Breton Island) continues to be the dominant trend driving island evolution during the historical record (1855-present). The results from the BICM historical seafloor change analysis (Miner et al., 2009c) are presented in Figure 5. Numbered polygons delineate zones for which sediment volumetric change data are presented in Table 2. Note the widespread erosion along the shoreface fronting the island arc and depositional sinks at the flanks of the island arc. These results demonstrate that during the past 125 years approximately 392M cubic yards (300 x 10^6 m^3) of sand has accumulated in deepwater sinks at the flanks of the barrier island arc; twice as much as deposited in the back barrier. This net loss of sediment to flanking sinks has resulted in island area reduction from 17.2 mi^2 in 1855 to 1.8mi^2 in 2005 (Fearnley et al., 2009; Miner et al., 2009d).

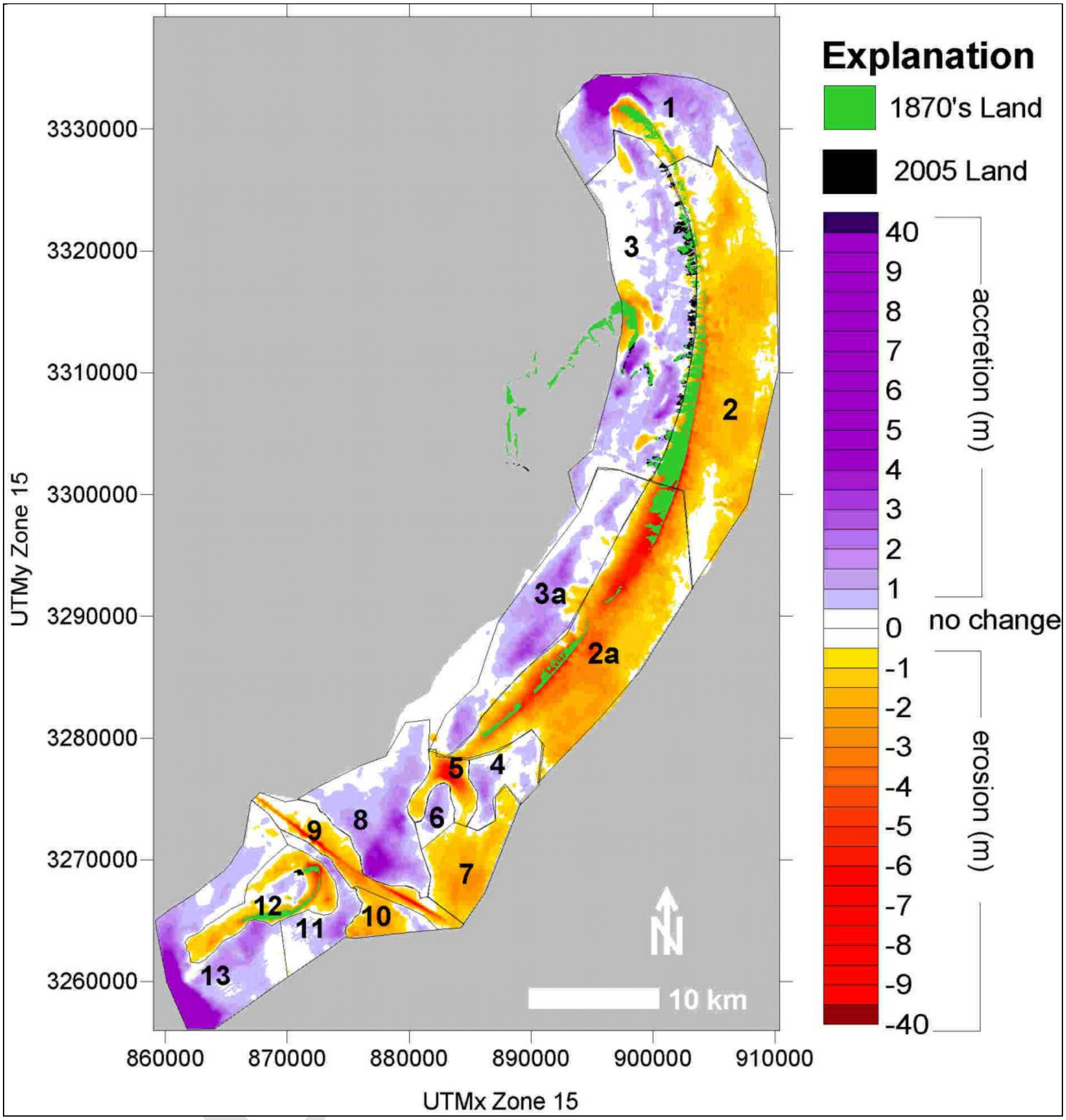


Figure 5. Map of BICM seafloor change analysis results showing zones of sediment erosion and accretion for 1870-2007. Island area shoreline polygons from 1855/69 and 2005 are from Martinez et al. (2009). Bathymetry and shoreline change analysis from Miner et al. (2009c). Map reproduced from Miner et al. (2009d).

Table 2. Sediment erosion/accretion volumetric change results for geomorphic zones presented in Figure 5.

Zone	Accretion ($x10^6$ m^3)	Erosion ($x10^6$ m^3)	Net Vol ($x10^6$ m^3)	Area ($x10^6$ m^2)	Net vol Error +/- ($x10^6$ m^3)	Dz min	Dz max
1. Hewes Point/ North Inlet	147.03	-18.26	128.77	91.67	25.67	-4.28	10.82
2. Northern Chandeleur Shoreface	4.68	-289.98	-285.29	212.19	59.41	-8.06	1.5
3. Northern Chandeleur Backbarrier	110.61	-26.50	84.11	166.76	46.69	-3.68	5.88
2a. Southern Chandeleur Shoreface	1.49	-406.63	-405.14	163.52	45.78	-8.89	1.70
3a. Southern Chandeleur Backbarrier	80.19	-4.72	75.47	84.92	23.78	-2.32	3.30
4. Updrift Curlew Pass Ebb Delta	14.30	-1.62	12.68	24.78	6.94	-1.20	2.85
5. Curlew Pass Inlet Scour	0.66	-34.27	-33.61	18.93	5.30	-7.20	1.40
6. Downdrift Curlew Pass Ebb Delta	7.74	-0.35	7.39	9.33	2.61	-0.64	2.82
7. Grand Gosier Shoreface	0.29	-56.29	-55.99	40.61	11.37	-3.43	0.81
8. Updrift MRGO	91.20	-0.16	91.04	70.41	19.71	-1.00	4.67
9. MRGO	0.10	-52.18	-52.08	25.34	7.10	-8.54	1.91
10. Downdrift MRGO shoreface	1.72	-21.35	-19.62	15.88	4.45	-3.43	1.85
11. Breton Pass Ebb delta and inlet fill	20.17	-0.13	20.04	20.69	5.79	-1.18	3.23
12. Breton Island Nearshore/Backbarrier	3.45	-51.03	-47.58	39.49	11.06	-7.95	1.33
13. Downdrift Breton Island	176.46	-0.10	176.35	74.98	2.10	-0.59	12.18
TOTAL	**660.09**	**-963.57**	**-303.47**	**1,059.49**	**296.66**		

Notes: Dz min = largest magnitude of vertical erosion within each polygon; Dz max = greatest magnitude of vertical accretion within each polygon. Data from Miner et al. (2009c). Reproduced from Miner et al. (2009d).

Results from the previous studies capture a transition from relatively sediment rich barriers (1855 -1922) that build new land in the back barrier by overwash, flood tidal delta, and recurved spit formation to sediment starved barriers that no longer build new back barrier land and begin to thin in place (1922 - 2005). Once the thinning has reached the point where no back barrier marsh exists, the barriers cross the transgressive submergence threshold becoming mobile sand bodies that migrate landward through a cycle encompassed by storm destruction followed by emergence landward of their former positions during calm weather.

The threshold crossing from barrier island to submerged shoal is characterized by: (1) sand lost to flanks decreases barrier sand supply restricting new back barrier marsh development, (2) continued loss to flanks forces barrier thinning and segmentation with fragmented marsh islands serving as spit nucleation sites, and (3) gulf shoreline and back barrier shoreline meet resulting in sandy ephemeral barrier islands/shoals that are destroyed by storms but reemerge during calm weather landward of their pre-storm location (Figure 6). It is not until this final stage of disintegration that cross-shore sand distribution becomes an efficient enough process to translate the barrier sand body landward during shoreface retreat.

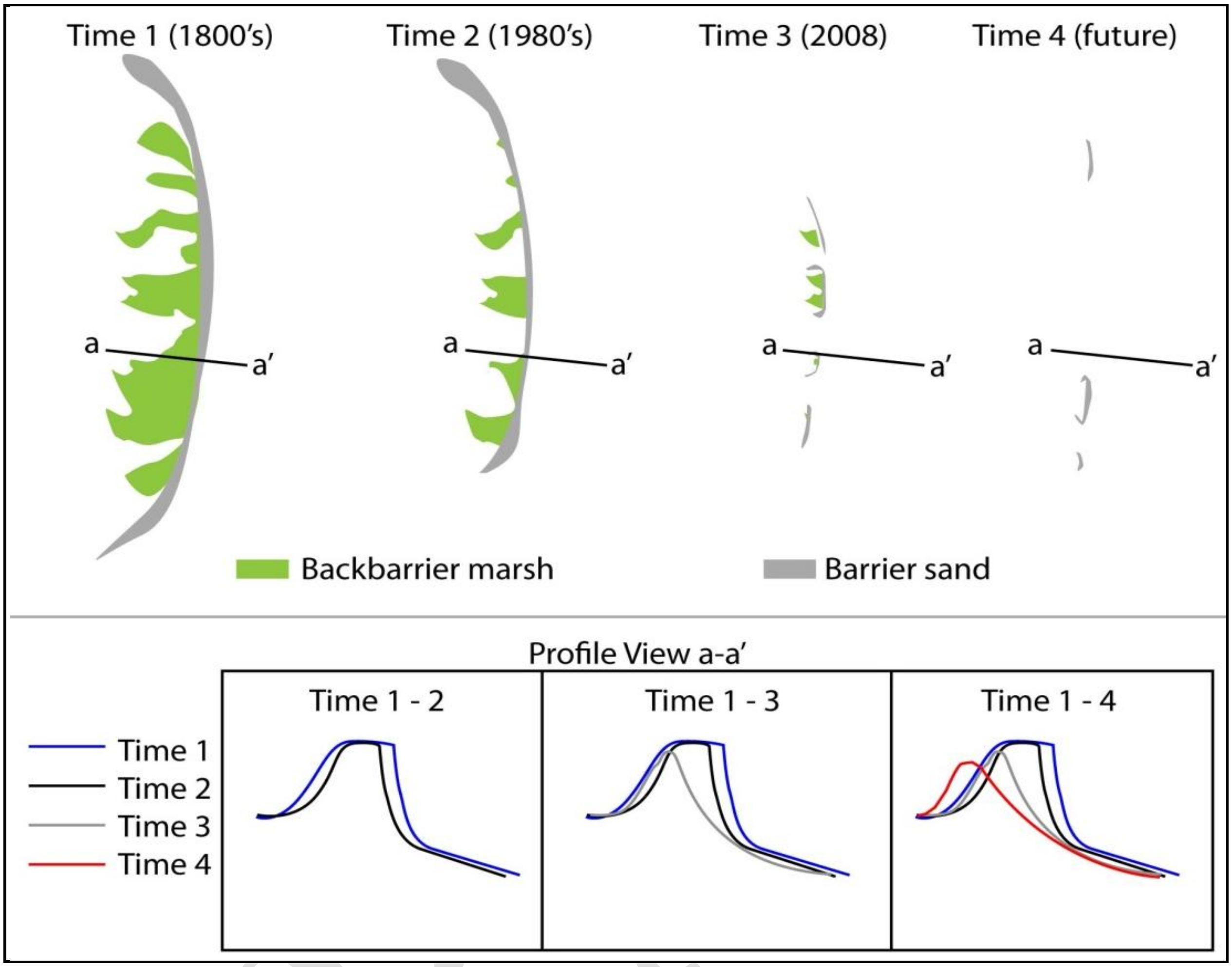


Figure 6. Conceptual model for transgressive submergence of the Chandeleur Islands based on data from Miner et al. (2009c, d). Reproduced from Miner et al. (2009d).

5.3 Role of Tidal Inlets

A tidal inlet is a shore-perpendicular channel along a barrier shoreline that connects the gulf with bays, lagoons, marsh, and tidal creeks (Brown, 1928; Escoffier, 1940; Davis and FitzGerald, 2004). Tidal currents maintain the inlet channel by flushing of sediment that is transported alongshore by waves (Brown, 1928; Escoffier, 1940). There are four large tidal inlets responsible for the majority of tidal exchange between the Gulf of Mexico and the Chandeleur/Breton Sound and numerous (>60) ephemeral hurricane-cut inlets along the northern island arc.

The major tidal inlets in the Chandeleur Islands system are the channels that flank the terminal spits of the barrier arc and include the inlet north of Hewes Point and an inlet that is south of Breton Island (Figure 1). Current measurements and numerical modeling shows that these two flanking channels are responsible for the majority of tidal flow into and out of Chandeleur and Breton Sounds (Hart and Murray, 1978). North Inlet extends from the back barrier and curves around Hewes Point where maximum channel depths are >50 feet. Lateral spit accretion towards the north at Hewes Point has forced a northerly migration of this inlet.

The inlet at the southern extent of the Chandeleur Islands located south of Breton Island has migrated south and undergone considerable infilling. Observations during surveying and subsequent aerial reconnaissance flights confirm strong tidal currents flowing through this broad channel.

The MRGO intersects the Chandeleur Islands just north of Breton Island and was cut through the existing tidal inlet of Breton Island Pass. Although the natural inlet configuration was downdrift-offset (the inlet channel was oriented to the south in an alongshore direction), the MRGO trends perpendicular to the shoreline. The MRGO construction did not result in the abandonment of the natural channel in favor of the engineered one, and both channels remained open. The MRGO required frequent maintenance dredging to remove sand before being decommissioned in 2008. Strong tidal currents flow through MRGO because it is a major conduit for tidal exchange for much of the Lake Pontchartrain Basin. The increased tidal prism and strong ebb tidal currents result in seaward transport of sand to distal ebb shoals that would have otherwise bypassed the inlet (Figure 7 and Figure 8).

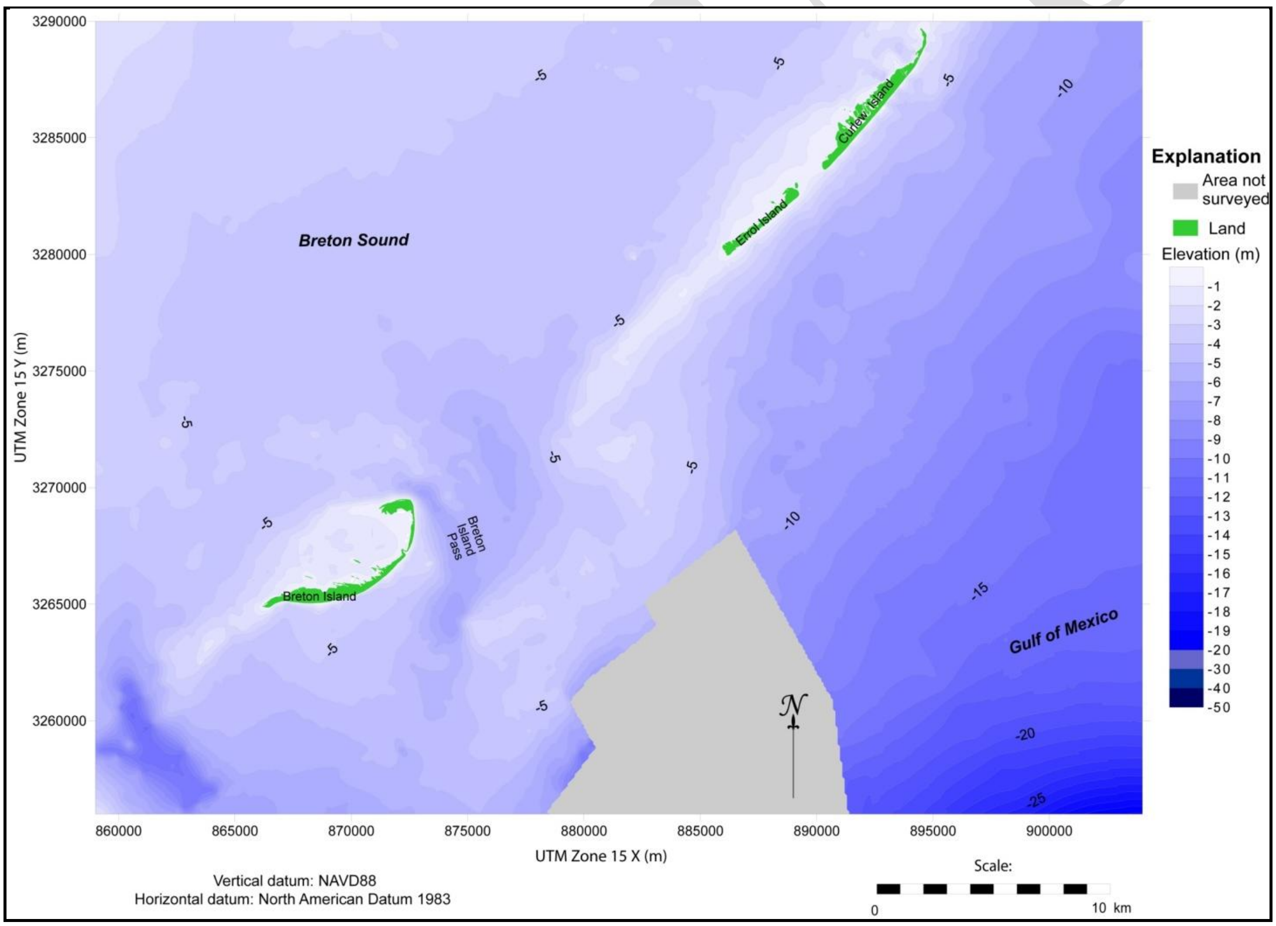


Figure 7. Map showing 1870s bathymetry and island positions for the southernmost Chandeleur Islands. Bathymetry from Miner et al. (2009c).

Note in Figure 7 Breton Island Pass' downdrift-offset, two-channel inlet morphology and offshore ebb tidal delta that becomes the site of the MRGO navigation channel. Prior to MRGO construction, sand that transported alongshore could bypass this inlet via the ebb tidal delta.

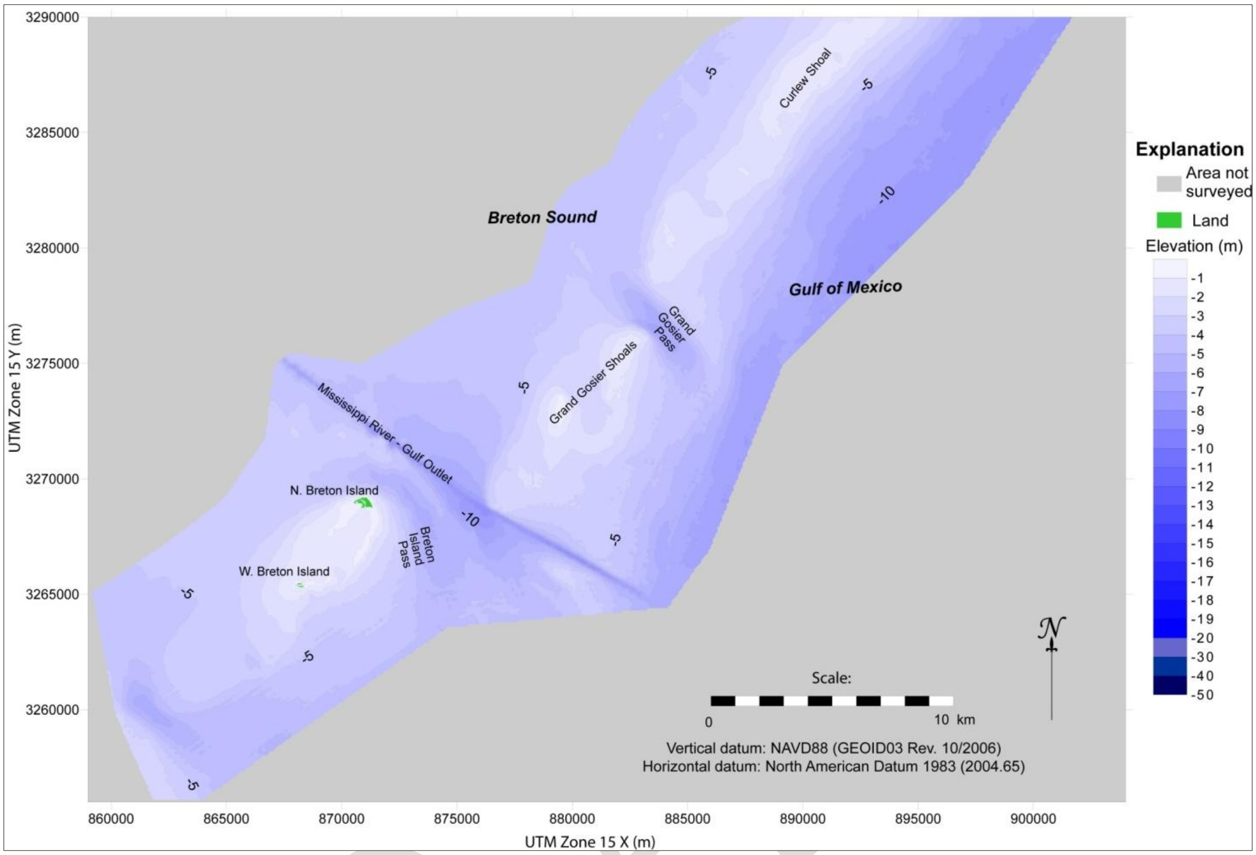


Figure 8. 2007 bathymetric map of the southern Chandeleur Islands. From Miner et al. (2009c).

Grand Gosier Pass is a natural tidal inlet located between Curlew and Grand Gosier Shoals that trends perpendicular to Curlew and Grand Gosier Shoals. This inlet was not present in the 1870s bathymetry, but by 2007 had scoured to a depth of > 30 feet. The date of inlet formation is not known, but the inlet is denoted on navigational charts dating to the 1950s (McBride et al. 1992). An ebb tidal delta has developed here as indicated by a seaward excursion of the 10-foot contour offshore of Curlew Shoal since the 1870s.

Numerous ephemeral hurricane-cut inlets along the barrier chain have historically been active for several years after a storm impact and then fill in to form a continuous barrier shoreline along the northern arc during extended periods of calm weather (Kahn, 1986). Since Hurricane Katrina, more than 60 hurricane cut tidal inlets have remained open. Based on the 2006 bathymetric surveys, widths range from ~ 250 to 10,000 feet and maximum depths exceed 10 feet.

5.4 Back Barrier Platform and Submerged Aquatic Vegetation

The northern island arc (north of Monkey Bayou) is backed by a broad (maximum width ~ 1.5 miles), sandy platform that averages ~3 to 6 feet in depth (Miner et al., 2009c) and is blanketed by submerged aquatic vegetation (SAV) (Porrier and Handley, 2006; Bethel and Martinez, 2008). Storm-generated flood tidal deltas have formed landward of deeper hurricane-cut inlets. The back barrier platform is intersected by channels that were scoured during storms. Coastal

SAV meadows are a rapidly declining critical habitat for juvenile aquatic species, sea turtles, Florida Manatee, and wintering migratory waterfowl in the northern Gulf of Mexico (Byron and Heck, 2006; Poirrier and Handley, 2006; Michot, et al 2008). Besides habitat, these seagrass meadows provide important physical benefits to the stability of the Chandeleur Islands by baffling water flow, reducing wave energy and current velocity (Koch et al., 2006; Chen et al., 2007). This process results in back barrier sediment trapping (vertical accretion) and protection of back barrier marsh shorelines form wave attack in Chandeleur Sound. The latter is important at the Chandeleurs because of the large fetch distance across Chandeleur Sound, especially during the passage of winter cold fronts. These seagrass beds are amazingly resistant to hurricanes and recover rapidly after storms when destroyed; however, the occurrence and distribution of seagrass at the Chandeleur Islands is directly related to the presence of a fronting barrier island (Poirier and Handley, 2006; Bethel and Martinez, 2008). The island dissection and rapid land loss associated with Hurricane Katrina has resulted in decreased suitable conditions for the seagrass colonization (Bethel and Martinez, 2008).

5.5 Spits

A spit is a sandy ridge attached to land at one end and terminating in open water at the other (Evans, 1942). Spits are built by lateral accretion of sand due to wave-induced transport. Spits accrete laterally over the subaqueous spit platform, which progrades ahead of the subaerial spit. Seasonal variations in wave approach and the refraction of waves bending around the spit end often form a hook-shaped recurved spit that extends into the back barrier (Figure 9). Lateral accretion of a terminal spit (at the end of a barrier island) usually results in development of a thick sand body because the leading edge of the prograding spit fills a relatively deep inlet channel (Figure 10; Hoyt and Henry, 1967). Hewes Point is the terminal spit system at the northern end of the Chandeleur Islands (Figure 11) and is prograding, due to northerly longshore transport, into the marginal deltaic basin that flanks the St. Bernard delta complex.

Figure 9. Oblique aerial photograph of Monkey Bayou in the southern Chandeleurs (see Figure 1) taken 10 May 2009. View is to the west with Gulf of Mexico in the foreground and Chandeleur Sound in the background. Note the recurved spits that extend into the back barrier and attach to the marsh island and shell berm shoreline.

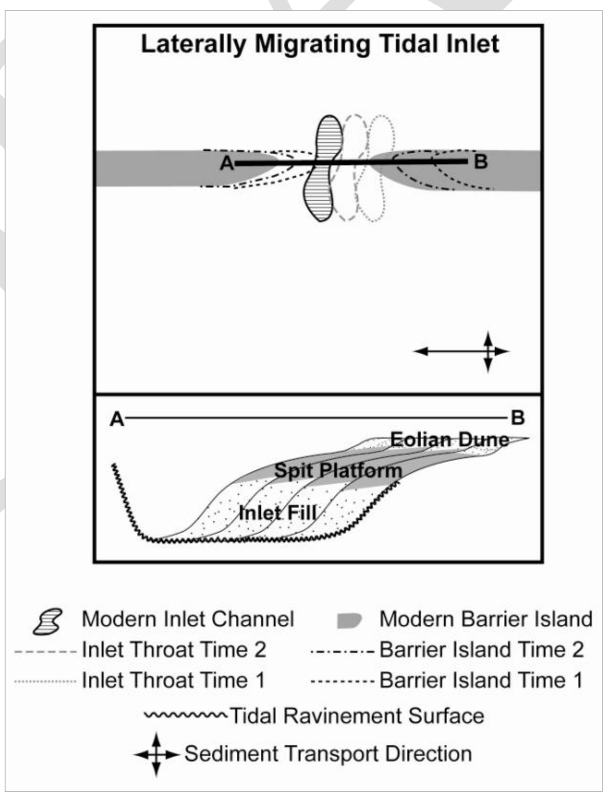


Figure 10. Conceptual model for inlet fill development from lateral spit accretion. Modified from Hoyt and Henry (1967).

Figure 11. Oblique 1996 aerial photograph of Hewes Point terminal spit. View is to the south. Note the landward protruding back barrier marsh lobes that represent former spit locations. Also note the wave refraction pattern that is responsible for development of the recurved morphology. Photo from National Geographic.

Figure 12 shows the northward progradation of the Hewes Point terminal spit through a series of bathymetric profiles over time. Figure 13 uses a digital elevation model to show the accretion of sediment over time with a three-dimensional perspective.

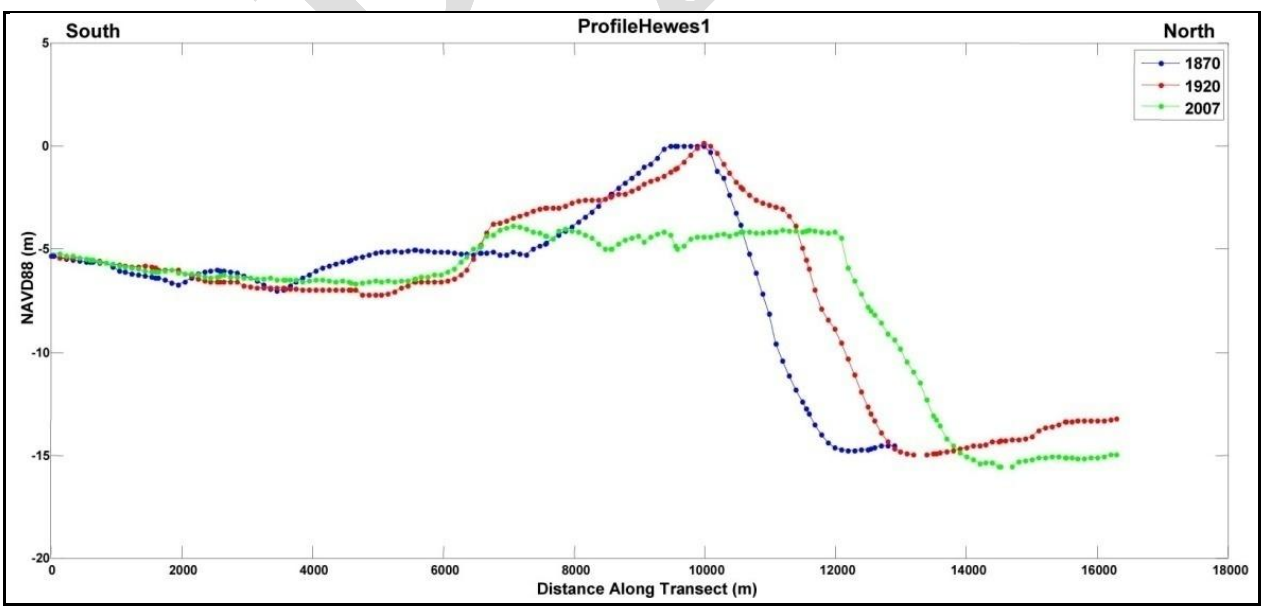


Figure 12. Bathymetric profiles for three time periods that trend north from the back barrier across Hewes Point and into the inlet north of the Chandeleur Islands. Bathymetry from Miner et al. (2009c, d).

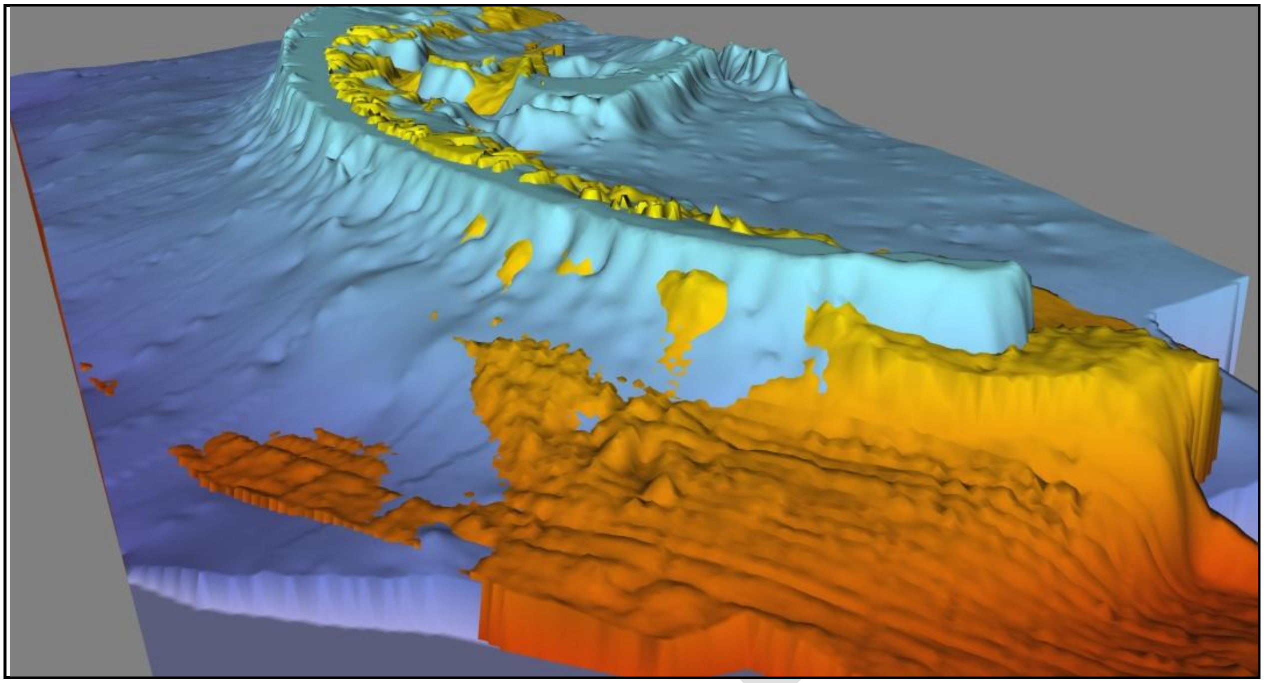


Figure 13. Digital elevation models of bathymetric surfaces for two time periods (1870s – blue; 2006 – red) shown in the same space. View is to the south. Note the large zone of accretion north of Hewes Point where the shoreface has also prograded in an offshore direction. Also note the landward migration of the barrier shoreline. Data from Miner et al. (2009c).

The scale of this terminal spit accretionary process is important because it demonstrates how an abandoned deltaic headland is reworked by marine processes to form Stage 1 flanking barriers, and eventually a Stage 2 barrier island arc (Figure 3; Penland et al., 1988). Lateral spit accretion remains an important process throughout Stage 2, as shown by the lateral accretion of Hewes Point in a northerly direction (Penland et al., 1988); this concept forms the basis for the development of the restoration plan proposed herein.

5.6 Barrier Shoals

The barrier shoals that occur along the Chandeleur Islands are present in the southern portion south of Monkey Bayou and include Curlew and Grand Gosier Shoals (formerly Curlew Island and Grand Gosier Islands). These are actually ephemeral barrier islands that are destroyed during storms and reemerge during extended fair weather periods (Otvos, 1981; Penland and Boyd, 1985; Fearnley et al., 2009; Miner et al., 2009d). Recent increased storm frequency and a decrease in sediment supply has inhibited island emergence since Hurricane Katrina (Fearnley et al., 2009). The same factors leading to submergence and inhibiting reemergence have also forced other historically more stable portions of the Chandeleur Islands into ephemeral island/shoal mode. It is predicted that this coastal behavior will eventually be characteristic of the entire island arc as it is converted to an inner shelf shoal through transgressive submergence.

5.7 The Role of Hurricanes

It has been suggested that the long-term evolution of the Chandeleur Islands and their fate are governed by tropical cyclone impacts, which result in a long-term net land loss driven by insufficient post-storm recovery leading to the islands' conversion to an inner shelf shoal through transgressive submergence (Kahn 1980; Kahn and Roberts 1982; Penland et al. 1983; 1988; Suter et al. 1988). McBride et al. (1992) proposed that the Chandeleur Islands would remain supratidal until the year 2360 on the basis of projected shoreline change and linear regression analysis of island area changes between 1855 and 1989. However, these predictions did not account for the increase in northern Gulf of Mexico storm frequency and intensity that ensued in the decade following their analysis (Fearnley et al., 2009a).

Recent increased storminess associated with the impacts of Hurricanes Georges, Ivan, and Katrina during the past decade is unprecedented for the Chandeleur Islands during the historic record (Fearnley et al., 2009a). These multiple, closely spaced (temporally) storm impacts culminated with Hurricane Katrina completely inundating the islands, removing >90% of the sand, exposing back barrier marsh along the gulf shoreline to wave attack (Miner et al., 2009d), and reducing total island area by ~50% (Fearnley et al., 2009a). These recent hurricane impacts have raised new questions regarding lifespan and sustainability of the Chandeleur Islands; especially their ability to recover from future storms.

Recently, Fearnley et al. (2009a, b) investigated the role of storm frequency, intensity, and track on island evolution for the time period spanning from 1855 to 2005, with the goal of forecasting the transition from islands to shoals based on historical island area changes. For the northern island arc, the average rate of island shoreline retreat was ~40 feet/year between 1922 and 2004 with retreat rates increasing to >159 feet/year after storm impacts. The impact of Hurricanes Ivan and Katrina along the northern Chandeleur Islands were extreme erosional events and the average amount of linear shoreline erosion for the two storms combined (-660 feet/year) was unprecedented throughout the rest of the analysis time period (1855 to 2004). A linear regression analysis of island area change demonstrate a land loss rate of 40 acres/year (0.16 km^2/yr) between 1922 and 1996 and a land loss rate of 250 acres/year (-1.01 km^2/yr) between 1996 and 2005 (Fearnley et al 2005; Figure 14). By projecting trends calculated from the linear regression analysis of island area change through time, the expected date of the northern Chandeleur Islands' conversion to an inner shelf shoal falls between 2013 and 2037 (Fearnley et al., 2009a, b; Figure 14). The earlier date is based on a projected storm frequency consistent with that of the past decade, whereas the later date represents a projected low storm recurrence interval similar to that for the period from 1922 to 1996.

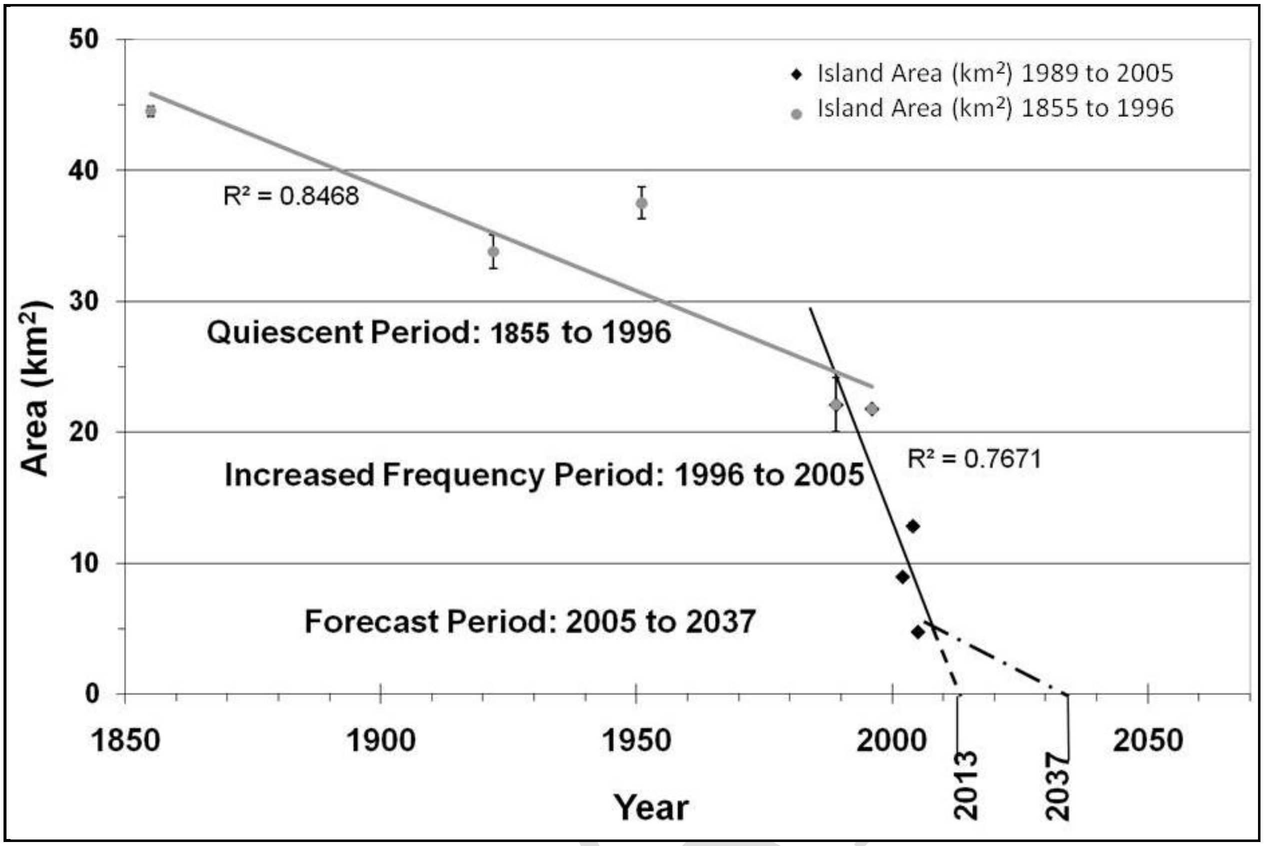


Figure 14. Northern island area and trend lines for the two time periods 1855 to 1996 and 1989 to 2005 differentiated based on storm impact frequency at the Chandeleur Islands. From Fearnley et al. (2009 a, b).

Note the drastic increase in island area loss rates associated with the increased storm frequency period in Figure 14. The dashed projection of the 1989 to 2005 trend predicts transgressive submergence could occur as early as 2013 if storm frequency observed over the past decade persists. The dash-dot-dash line represents the trajectory of the islands in their current state under low frequency storm conditions such as existed during the 1855 to 1996 time period, indicating a transgressive submergence date of 2037.

The southern Chandeleur Islands (Figure 1) encompass a different storm impact response and mode of recovery than the northern Chandeleur Islands. Like the northern barrier arc, the southern Chandeleur Islands are characterized by shoreface retreat; however, major storm impacts result in almost complete island destruction and conversion to inner shelf shoals (Breton Island is an exception to this trend). During extended periods of calm weather following storm impacts, new islands reemerge along this sector (Fearnley et al., 2009a, b; Miner et al, 2009d). During long term periods (>100 yrs) the rate of shoreline retreat along the southern islands was approximately 50 feet/year for the time period from 1869 to 1996 and island area decreased from 19 mi^2 to 0.7 mi^2 between the years 1869 to 2005 (Fearnley et al., 2009a, b).

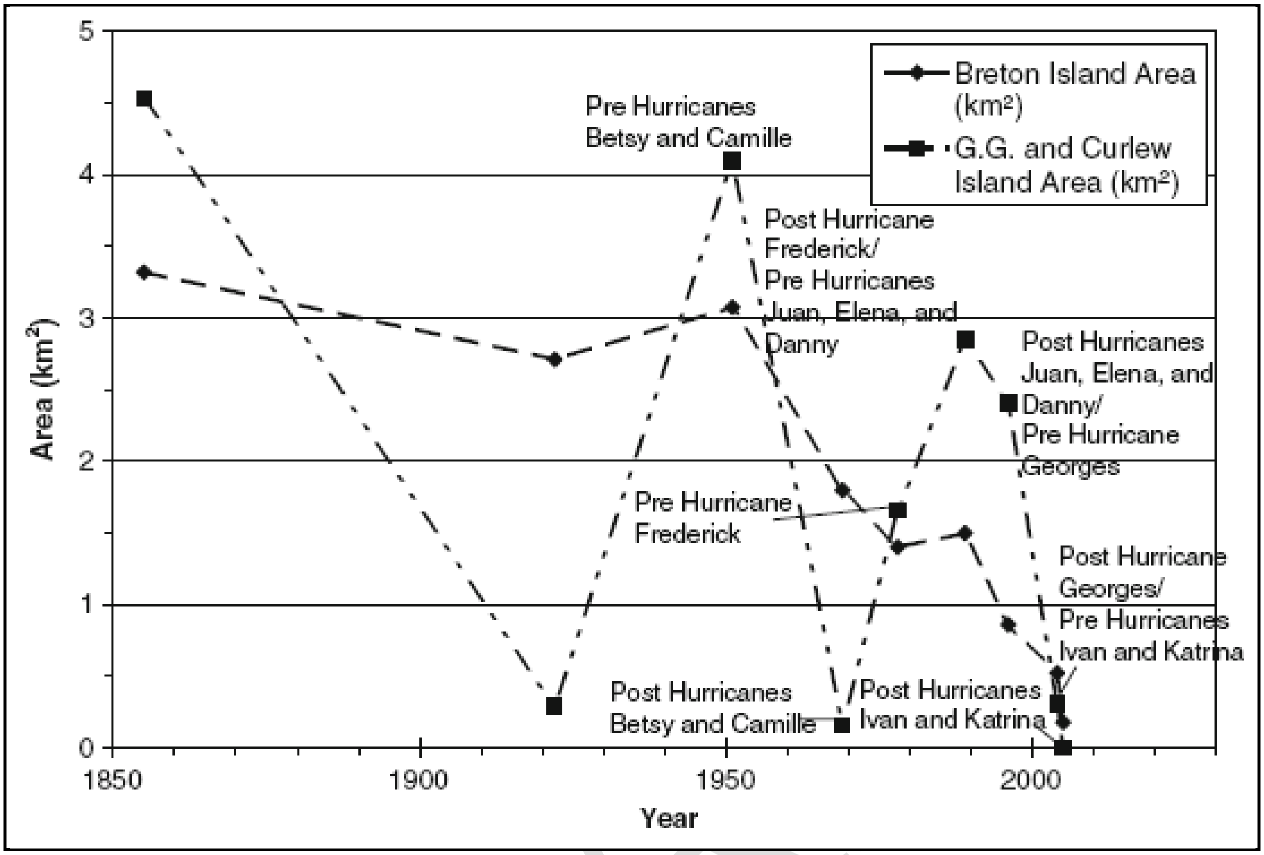


Figure 15. Average island area change associated with storm impacts for the southern Chandeleur Islands. From Fearnley et al. (2009).

Note the dynamic nature of Curlew and Grand Gosier Islands through time. These islands are almost completely destroyed during storms and reemerge landward of their former locations during extensive periods of calm weather. This coastal behavior is predicted to encompass the entire island chain once back barrier marshes have eroded (2013 to 2037 based on Figure 14 and Fearnley et al., 2009a). Note that Curlew Island and Grand Gosier Island remain submerged as shoals today (Fall 2009).

5.8 Sediment Dynamics

With regard to longshore sediment transport, the arcuate barrier island trend is characterized by a bidirectional system, with material moving from the central arc to the flanks (Figure 16; Georgiou and Schindler, 2009). Seasonal variations in wind dominance cause an imbalance in transport gradients through time forcing higher rates of transport potential in a northward direction (Georgiou and Schindler 2009). Significant wave heights along the northern portion of the barrier have a peak of 1.5 feet based on a 25-year hourly average with significant wave heights in excess of 3.3 feet occurring ~4% of the year and >6.6-foot waves having a return period of less than 1% (Georgiou and Schindler, 2009). Net longshore transport rates north of the nodal point (Figure 16) are directed northward with rates increasing away from the nodal point toward the flaks reaching values > 144,000 cubic yards/year (110,000 m^3/yr) (Georgiou and Schindler, 2009). Transport rates south of the nodal point are generally directed to the south with potential rates reaching ~150,000 cubic yards/year (115,000 m^3/yr) (Georgiou and Schindler, 2009).

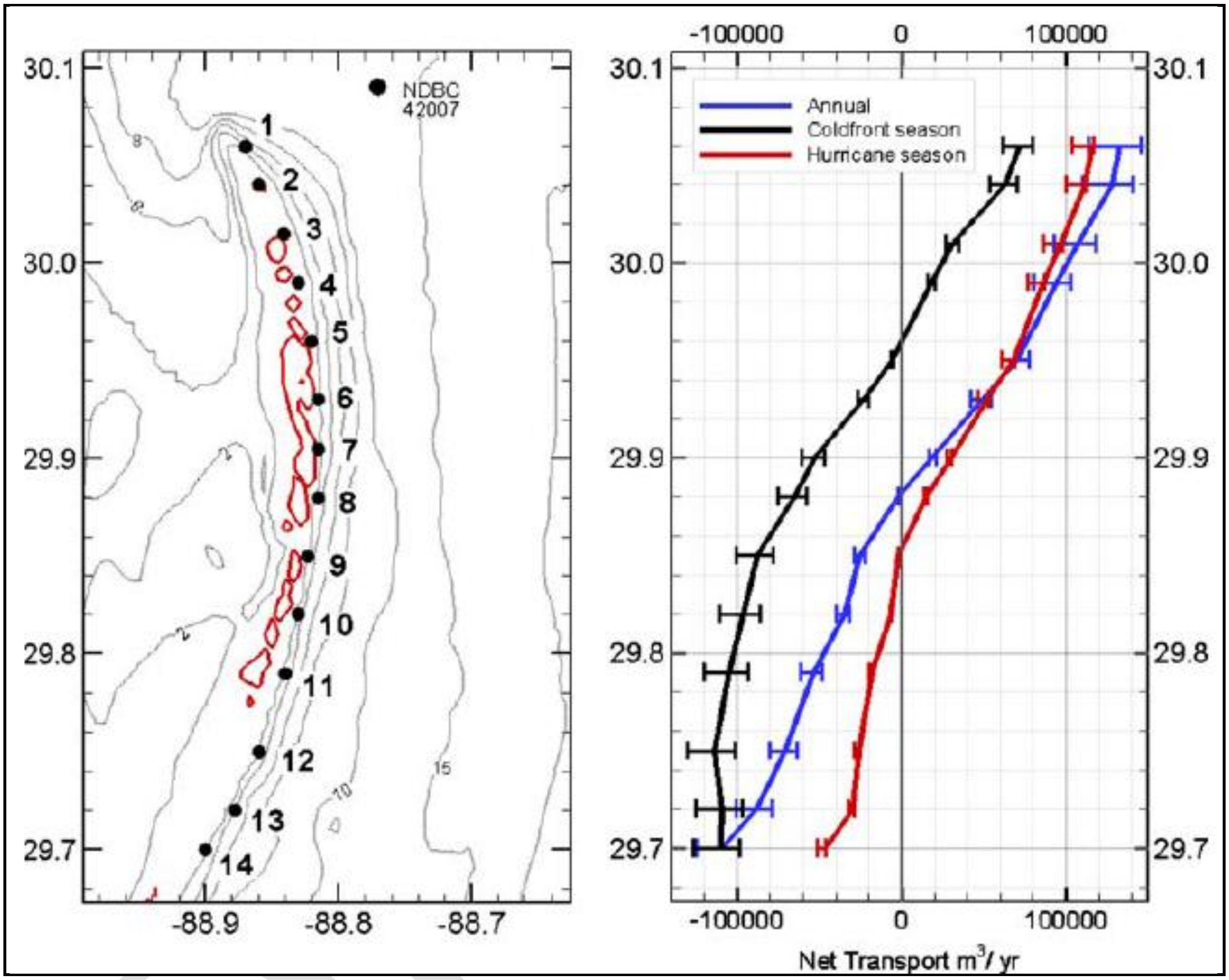


Figure 16. (left panel) Locations along the Chandeleur Islands where longshore transport calculations were performed by Georgiou and Schindler (2009). (right panel) Potential net longshore transport as a function of differing forcings based on long term 1985 to 2006 wind records measured at NDBC buoy 42007: blue line – long term annual average, black line – seasonal averaging during the cold-front season, red line – hurricane season. Note that the two panels are aligned to show trends along the island shoreline. Values that plot to the left of zero on the right panel indicate a net transport potential to the south, and those that plot to the right of zero indicate net transport potential to the north. From Georgiou and Schindler (2009).

Under non-storm conditions, significant sediment transport is restricted to the upper shoreface, landward of the 16-foot isobath (Penland and Boyd, 1981), however recent studies along Louisiana barrier islands demonstrate that storm-associated seafloor scour and transport occurs at depths >50 feet (Miner et al., 2009a; 2009b; Allison et al., 2007). It is important to note that the predicted rates of longshore sediment transport discussed above are an order of magnitude lower than the rates of deposition at the island flanks inferred from the sediment volumetric change analysis discussed in Section 5.2 (~1 x 10^5 cubic yards/year for versus ~1 x 10^6 cubic yards/year; Figure 16 and Table 2, respectively). Georgiou and Schindler (2009) stated that no field measurements on longshore sand transport rates were available and absolute transport rates were not the focus of the study. Recent observational and numerical modeling studies suggest that storm wave-induced currents play a major role in sediment transport within the lower shoreface zone and inner continental shelf off of Louisiana coast (Jaffe et al., 1997; Teague et al., 2006; Miner et al., 2009a; Georgiou and Schindler, 2009b).

5.9 Hurricane Katrina Recovery

Hurricane Katrina segmented the island arc into multiple small marsh islets separated by wide hurricane-cut tidal passes. More than 90% of sand comprising the barriers was removed, exposing back barrier marshes to wave attack. During the following year, >50% of the length of the northern Chandeleur Islands shoreline continued to erode. However, during year two of recovery, marsh islands served as nucleation sites for sand accumulation along the northern arc, north of Redfish Point. Early stages of recovery along this sector were marked by sand and shell recurved spit formation at hurricane-cut tidal passes followed by onshore bar migration and welding; a process that resulted in the closure of some inlets (Figure 17). Prior to the 2008 Hurricanes, elevation along the northern section began to increase as aeolian processes constructed dune fields in the wind shadow of black mangroves and roseau cane thickets (Figure 18). Contrastingly, recovery along the southern segment of the northern arc (between Redfish Point and Monkey Bayou) was not characterized by sandy shoreline development and closing of inlets. Here, marsh islands fronted by a shell berm continue to undergo rapid shoreline retreat (>650 feet/year, locally; Figure 20). Where marsh islands were absent prior to Katrina's impact (south of Monkey Bayou to Grand Gosier Islands), the sandy barriers underwent transgressive submergence. These southern shoals persisted for 2 years after Katrina's impact, but began to emerge as narrow, ephemeral barrier islands until they were once again destroyed by Hurricanes Gustav and Ike.

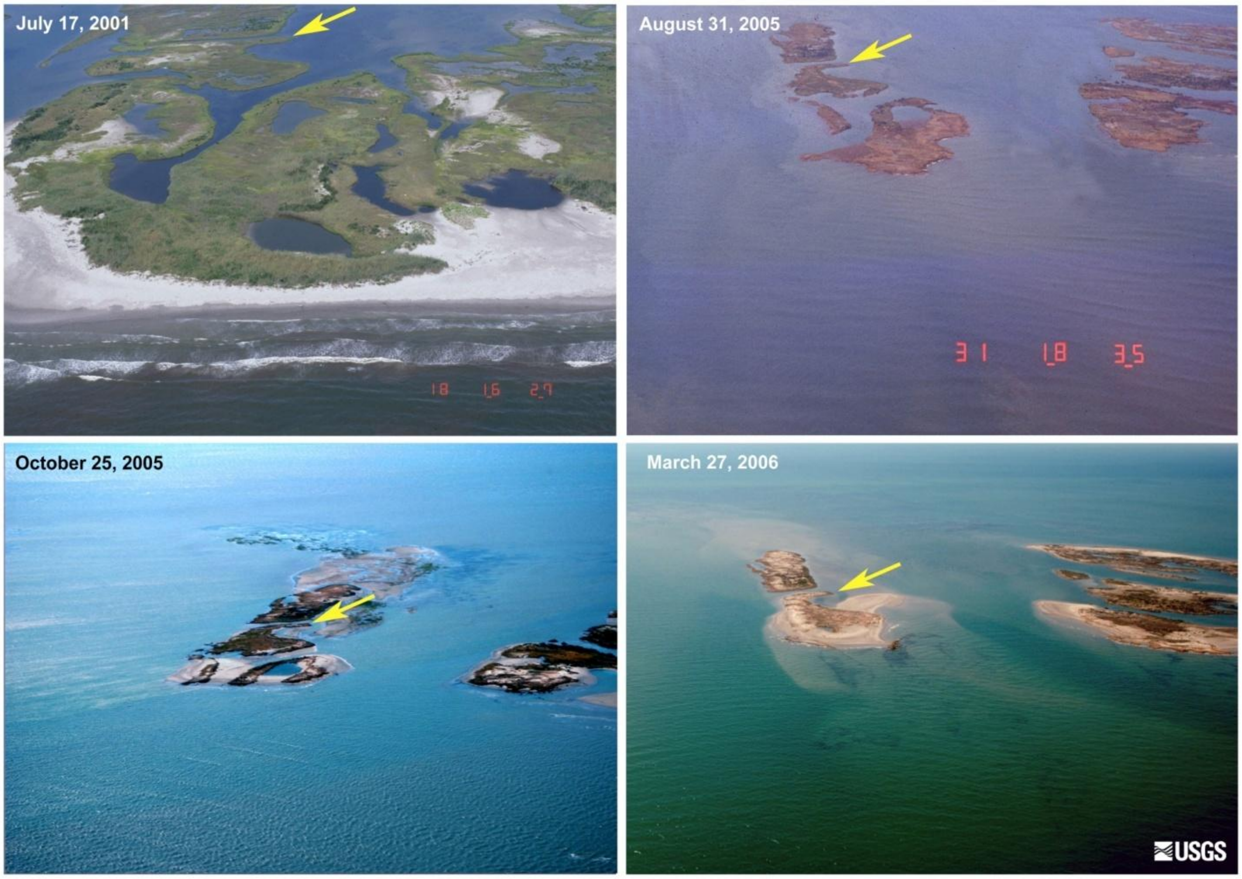


Figure 17. Time series of oblique aerial photographs facing west that demonstrate the impacts of Katrina and the continued shoreline erosion for 1.5 years after storm impact. Yellow arrow is in a fixed geographic location in each photo. Images courtesy of Abby Sallenger, USGS.

Figure 18. Oblique aerial photograph view to the north of the sand-rich northern Chandeleur islands. Arrow in right panel shows the location of the photo. Note the closure of hurricane cut passes and landward sand movement during year 2 of post-storm recovery. Subsurface sand deposits are excavated during shoreface retreat, liberating sand reserves for spit, beach, and dune construction.

Figure 19. Dunes accreting around Roseau cane and black mangroves in the northern Chandeleur Islands. Photo is 1 year after Figure 20. Note the deflated beach surface that sourced the sand for dune construction.

Figure 20. Shell dominated beaches of the southern Chandeleur islands. Here, the absence of a local subsurface sand source has limited beach recovery and resulted in continued island dissection.

An understanding what governs the disparity in recovery behavior between the northern and southern sections of the island arc is important for predicting long-term island sustainability and development of a long-term island management plan. In order to address this, UNO-PIES and USGS conducted a subsurface investigation along the island arc. Results demonstrate that recovery is controlled by the relative abundance of local subsurface sand supply; the marsh islands along the northern sand-rich sector are underlain by thick (up to ~33 feet) relict spit platform and lateral accretion inlet fill deposits, whereas the section south of Redfish Point is underlain by muddy lagoonal and deltaic deposits (Figure 4). Therefore, as the shoreline retreats landward (a process that is greatly accelerated during post-storm recovery phases; Fearnley et al., 2009), relict sandy spit deposits underlying the back barrier marsh in the north are liberated at the shoreface and introduced to the littoral system. In the south, local sand supply is limited, inhibiting rapid recovery. This disparity in sand distribution along the island arc is a consequence of long term lateral accretion away from the original, centralized deltaic sand source in the vicinity of Monkey Bayou. Over the past several centuries the deltaic sand source has been exhausted leaving a sand-starved zone of islands between Redfish Point and Monkey Bayou and relatively sand-rich zones north of Redfish Point. Ultimately, in the north, the sand is lost from the barrier island littoral system to a deepwater sink north of Hewes Point. South of Monkey Bayou, and extending beyond Breton Island exists a similar sand-rich trend, however with the exception of Breton Island, there are no marshy islands for sand to accumulate subaerially resulting in rapidly retreating ephemeral barriers of Curlew and Grand Gosier Island Shoals and a deepwater sand sink south of Breton Island similar to Hewes Point. These downdrift sand reservoirs provide a unique, quasi-renewable resource for nourishing the updrift barrier system as will be discussed in the following section.

5.10 Implications for Island Management

The long-term diminished sediment supply, location of sediment sinks, and storm recovery processes documented in Miner et al. (2009a, b), Fearnley et al., (2009 a, b), and Georgiou and Schindler (2009 a, b) provide an understanding of the mechanism that drives barrier island arc transgressive submergence and the natural sediment dispersal processes at work that prolong submergence. Based on this newly developed understanding of how the islands naturally sequester sediment that is introduced to the littoral system during shoreface retreat and respond to a rapid introduction of new sediment, efficient barrier management strategies can be developed.

The dominance of lateral transport over cross-shore transport is important. Sand is not being removed and deposited offshore in thin sand sheets as proposed by previous works, instead, sand is being concentrated as thick sediment bodies at the flanks of the island arc. These downdrift sand reservoirs lie outside of the littoral system and provide a resource for nourishing the updrift barrier system (i.e., the central arc).

Restoration goals should mimic the natural processes that encompass early stages of barrier island evolution including lateral transport to the flanks from a centralized sand source that will ultimately enhance the island's ability to naturally build back barrier marsh, dunes, and a continuous sandy shoreline. Gulf shoreline erosion is inevitable, however, island integrity can be maintained and enhanced during retreat with strategic sand placement if:

1) Nourishment sand recovered from deepwater sinks at the flanks of the island arc is reintroduced to the barrier sand budget at a centralized location based on longshore sediment transport predictions from Georgiou and Schindler (2009, Figure 16).

2) Distribution of naturally occurring hurricane-cut passes is maintained as storm surge/overwash pathways. These natural high energy environments should be avoided as sand placement areas except where they have widened to the point where islands have been converted to shoals.

3) Sand is placed at a centralized location along the island arc where it will naturally disperse to the flanks. Hurricane cut inlets will heal by spit accretion and bar welding processes. These processes will increase sand in the littoral system and will nourish the beach, providing material for aeolian dune building, resulting in increased island elevation and storm protection.

4) Sand reserves are strategically placed in the back barrier as vegetated shore perpendicular platforms upon which the island can migrate across. These will also serve to reintroduce sand into the littoral system as the island migrates.

5) An initial sand infusion to the littoral system along the central barrier arc fronting the back barrier sand reserves, in the form of nearshore bars and beach, as well as area specific restoration can simultaneously be placed.

6 HISTORIC DATA

6.1 Survey Data

This report is intended as an initial evaluation of project feasibility so additional data collection was not part of the scope of work. Bathymetric, topographic, and shoreline data were obtained from the following five sources: USGS Coastal Erosion and Wetland Change in Louisiana, USGS National Assessment of Shoreline Change, USGS Atlas of Shoreline Changes, NOAA Coastal Services Center LIDAR, and the University of New Orleans. Table 3 summarizes the available survey and shoreline data used in this report.

Table 3. Summary of Available Survey and Shoreline Data

Date	Data Type	Source/Description
June 2007	Topography (LIDAR)	BICM LIDAR Survey
September 2006	Topography (LIDAR)	
March 2006	Topography (LIDAR)	
September 2005	Topography (LIDAR)	NOAA LIDAR Survey
September 1998	Topography (LIDAR)	NOAA LIDAR Survey
2007/2006, 1920, 1880	Bathymetry Grid	BICM
2005, 2004, 1999, 1996, 1989, 1978, 1969, 1951, 1922, 1855	Shoreline	BICM
1989, 1978, 1951, 1922, 1869, 1855	Shoreline Change	USGS Atlas of Shoreline Changes
1973-1978, 1922-1934, 1855-1887	Shoreline	USGS National Assessment of Shoreline Change
1999, 1855	Shoreline	USGS Coastal Erosion and Wetland Change in Louisiana
1951	Topography Grid	USGS Digital Elevation Models
2006-2007	Bathymetry Grid	USGS

LIDAR data provides the most comprehensive data set for topography. Five LIDAR sets are available to evaluate topographic changes. However, the lack of water clarity restricts LIDAR from providing bathymetric data.

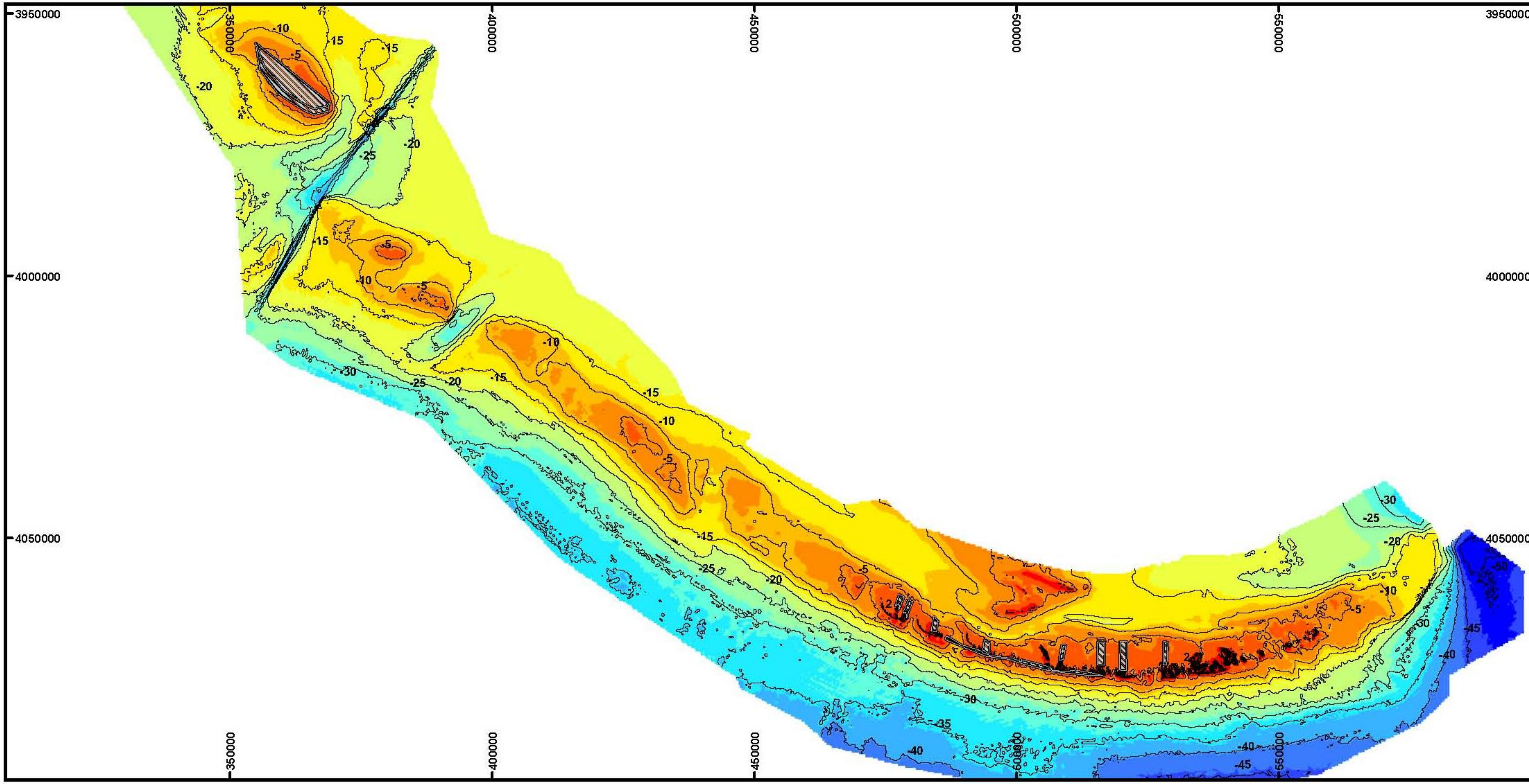
Barrier Island Comprehensive Monitoring (BICM) data was collected in 2006 and 2007 but provides only hydrographic data. The 2006 LIDAR data and 2006/2007 BICM data have been compiled to provide the bathymetric and topographic map shown in Figure 21.

6.2 Nourishment History

The Chandeleur Islands and Breton Island are located within the Breton National Wildlife Refuge. Beneficial disposal of dredged material occurred on and close to Breton Island between 1993 and 2005 (Creef, 2009). A summary of the nourishment history along Breton Island is provided in Table 4.

Table 4. Summary of Nourishment History along Breton Island

Year	Placement Location	Volume (cy)
1993	Northeast Sacrificial Berm	1,600,000
1999	Northeast Sacrificial Berm	3,800,000
1999	Northeast Rim Breaches	1,101,100
2001	Northeast Rim Breaches	1,942,408
2005	Northeast Rim Breaches	4,073,720



NOTES:

1. COORDINATES ARE IN FEET BASED ON THE LOUISIANA STATE PLANE COORDINATE SYSTEM, SOUTH ZONE, NORTH AMERICAN DATUM OF 1983 (NAD 83).
2. BATHYMETRIC DATA IS DERIVED FROM 2006 AND 2007 BICM HYDROGRAPHIC DATA WITH 2007 LIDAR DATA FOR TOPOGRAPHY.

LEGEND:

- PROJECT FOOTPRINT
- CONTOURS

ELEVATION (FT, NAVD88)

- 1 - 4
- -3 - 0
- -7 - -4
- -11 - -8
- -15 - -12
- -19 - -16
- -23 - -20
- -27 - -24
- -31 - -28
- -35 - -32
- -39 - -36
- -43 - -40
- -47 - -44
- -51 - -48

1 inch = 20,000 feet

0 10,000 20,000 Feet

Figure 21. Bathymetric and Topographic Map

COASTAL PLANNING & ENGINEERING, INC
2481 NW BOCA RATON BLVD.
BOCA RATON, FL 33431
PH. (561) 391-8102
FAX.(561) 391-9116

7 SUBSIDENCE AND SEA LEVEL RISE

A primary factor governing land loss along the Louisiana shoreline is relative sea level rise. Relative sea level rise consists of two components (NRC, 1987) as follows:

1. Eustatic sea level change. Eustatic sea level change is defined as the global change in oceanic water level relative to a fixed vertical datum (ie. NAVD).

2. Subsidence. Subsidence is defined as the local change in land elevation relative to a fixed vertical datum (ie. NAVD).

Along the Louisiana coast the land elevation is decreasing while the mean sea level elevation is increasing, resulting in significant land loss.

7.1 National Research Council

Relative sea level rise can be estimated using tidal records and the National Research Council (NRC) methodology. For a tidal record to be sufficient for this purpose it must be at least 37 years long, which is twice the length of the 18.6 year lunar nodal tide cycle. The rate of relative sea level rise along the Chandeleur Islands is 0.0164 feet/year (Miner, 2009a).

The NRC (1995) developed a numerical relationship (Equation 1) for estimating the total relative sea level rise for any location, given a known rate of subsidence, as follows:

$$E(t) = (0.0039 + M)t + Bt^2 \qquad \text{[Equation 1]}$$

where:

E = relative sea level change between 1986 and year t in feet
M = subsidence in feet/year
B = acceleration in the rate of eustatic sea level change in feet/year^2
t = years after 1986

The NRC committee recommended sea level rise projections be updated every decade to incorporate additional data. Equation 1 was derived at a time when the global mean sea level change was approximately 0.0039 feet/year. The current estimate of global mean sea level change is 0.0056 feet/year (IPCC, 2007). Therefore, Equation 1 was modified, as shown in Equation 2, to include the most recent estimate of global mean sea level change (USACE, 2009).

$$E(t) = (0.0056 + M)t + Bt^2 \qquad \text{[Equation 2]}$$

Subsidence was calculated by comparing the local rate of relative sea level rise with the global rate of mean sea level change. It was assumed that the local sea level change rate is equal to the global mean sea level change rate and was constant over the analysis period. Therefore, the local subsidence rate was obtained by subtracting the global mean sea level change rate from the local rate of relative sea level rise (0.0164 – 0.0056 = 0.0108 feet/year).

The USACE (2009) suggests using baseline (low), intermediate, and high sea level changes when planning, engineering, and designing coastal projects. Baseline sea level changes assume that sea level rises at the historic rate with no acceleration (B = 0 feet/year^2). Intermediate sea level changes employ an acceleration term that results in a eustatic sea level rise of 1.64 feet (0.5 meters) by the year 2100 (NRC Curve 1, B = 7.74x10^{-5} feet/year^2). The acceleration term used to model high sea level changes results in a eustatic sea level rise of 4.92 feet (1.5 meters) by the year 2100 (NRC Curve 3, B = 3.30x10^{-4} feet/year^2). Figure 22 shows a schematic of sea level change expected over the 50 year project evaluation period.

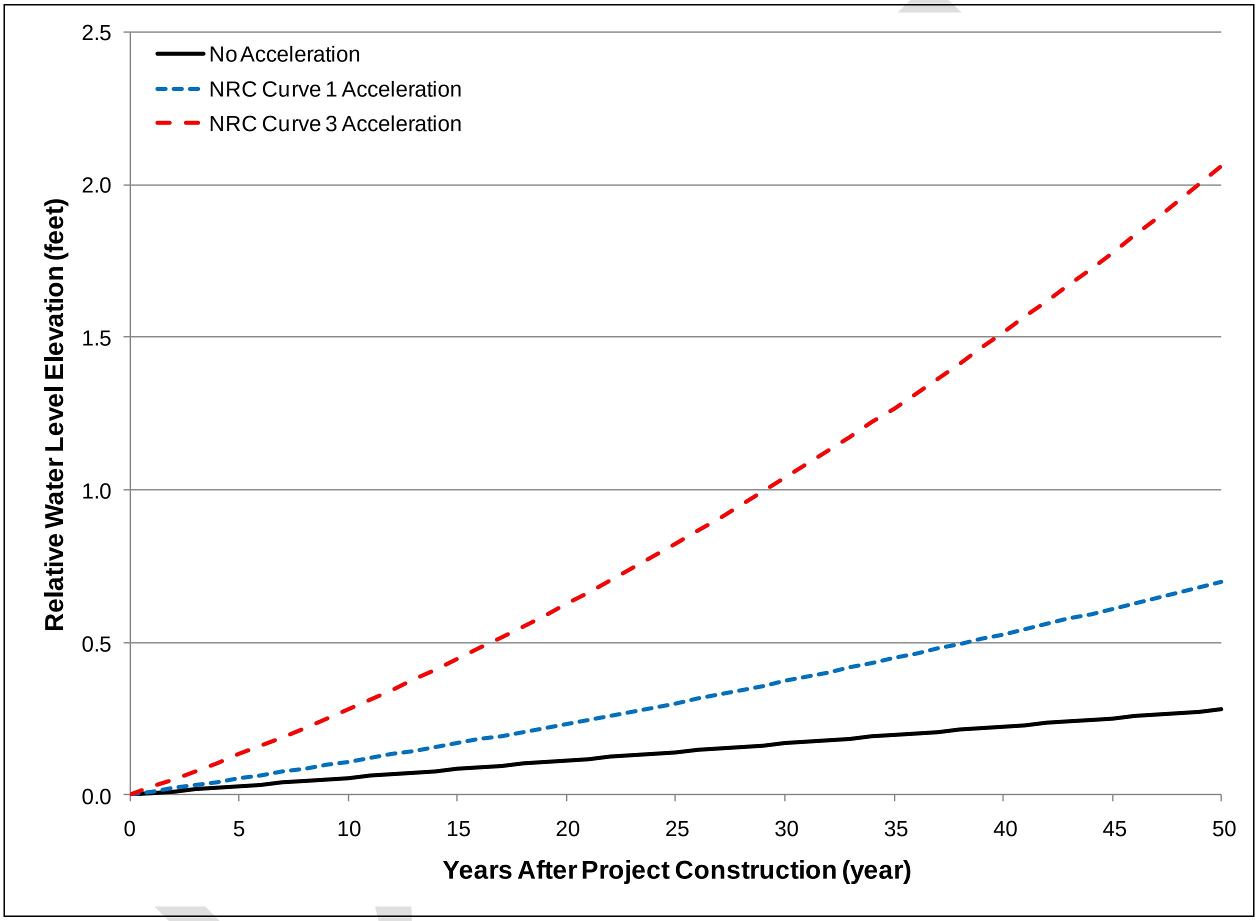


Figure 22. Sea Level Rise Estimates following USACE Guidance

Average relative sea level rise rates are used in this report to decompose historic shoreline change data and estimate future project performance. Over the 50-year project evaluation period (2015 to 2065) the rate of relative sea level rise is projected to increase; however, the rate of relative sea level rise can be treated as a constant over the 50-year project evaluation period. The constant rate of relative sea level rise was obtained by linearizing the sea level rise projections over the project evaluation period. The rate of relative sea level rise at the beginning and end of the project evaluation period and the average rate of relative sea level rise for low (baseline), intermediate, and high sea level changes are provided in Table 5 and are shown graphically in Figure 23.

Table 5. Relative Sea Level Rise Summary

Sea Level Rise Acceleration	Relative Sea Level Rise (ft/yr)		
	TY0 (2015)	TY50 (2065)	Applied
Low (Baseline)	0.0164	0.0164	0.0164
Intermediate	0.0209	0.0286	0.0248
High	0.0355	0.0685	0.0520

Figure 23. Linearized Relative Sea Level Rise Estimates

Project performance and benefit assessments in this report assumed the low RSLR value, per direction from the USACE Study Manager, Sandra Stiles. This report presents a first screening of alternatives. If either the Chandeleur Islands or Breton Island is selected for further evaluation, then the project will be reevaluated using the medium and high RSLR rates.

8 SHORELINE CHANGES

The long-term (1855-2002) average rate of gulf shoreline recession along the entire Chandeleur Islands barrier shoreline, stretching 58.2 miles between Plaquemines Parish and St. Bernard

Parish, is approximately -45 feet/year. Recent analyses suggest that gulf shoreline recession is accelerating along the Chandeleur Islands, given the -69 feet/year short-term (1988-2002) erosion rate (Penland et al, 2002).

Shoreline changes were extracted along USGS transects identified in the Louisiana Barrier Island Erosion Study – Atlas of Shoreline Changes in Louisiana from 1853 to 1989 (Williams et al, 1992). Williams et al (1992) presented two transect sets for analyzing gulf and bay shoreline changes. The historic shoreline change analysis, presented in Section 1.1, utilized the gulf transects when describing gulf shoreline changes and bay transects when describing bay shoreline changes. The recent shoreline change analysis, presented in Section 8.2, used only the gulf transect lines, shown in Figure 24 (Chandeleur Islands) and Figure 25 (Breton Island), when describing both gulf and bay shoreline changes.

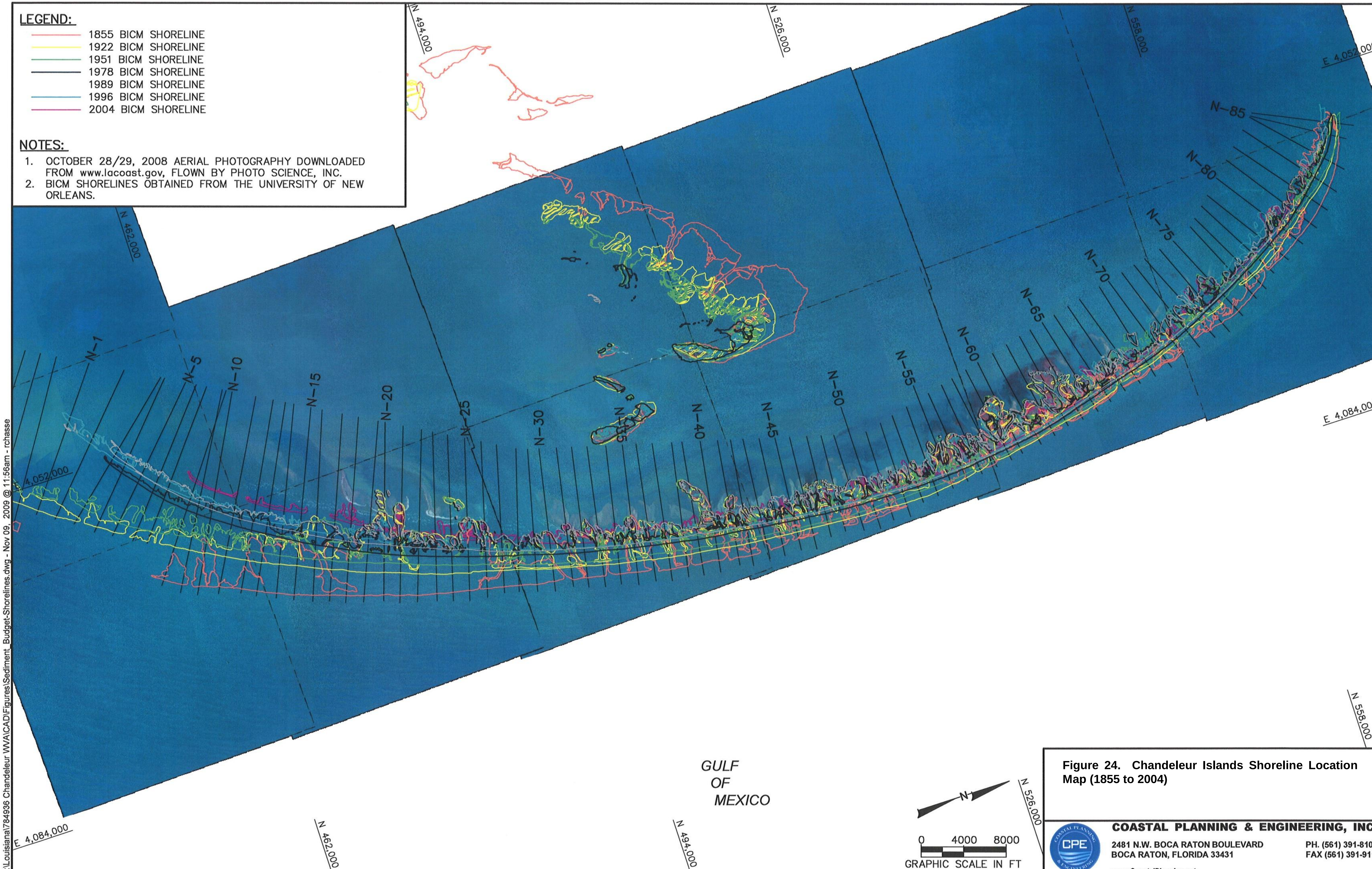


Figure 24. Chandeleur Islands Shoreline Location Map (1855 to 2004)

P:\Louisiana\784936 Chandeleur WVA\CAD\Figures\Sediment_Budget-Shorelines.dwg - Nov 09, 2009 @ 11:56am - rchasse

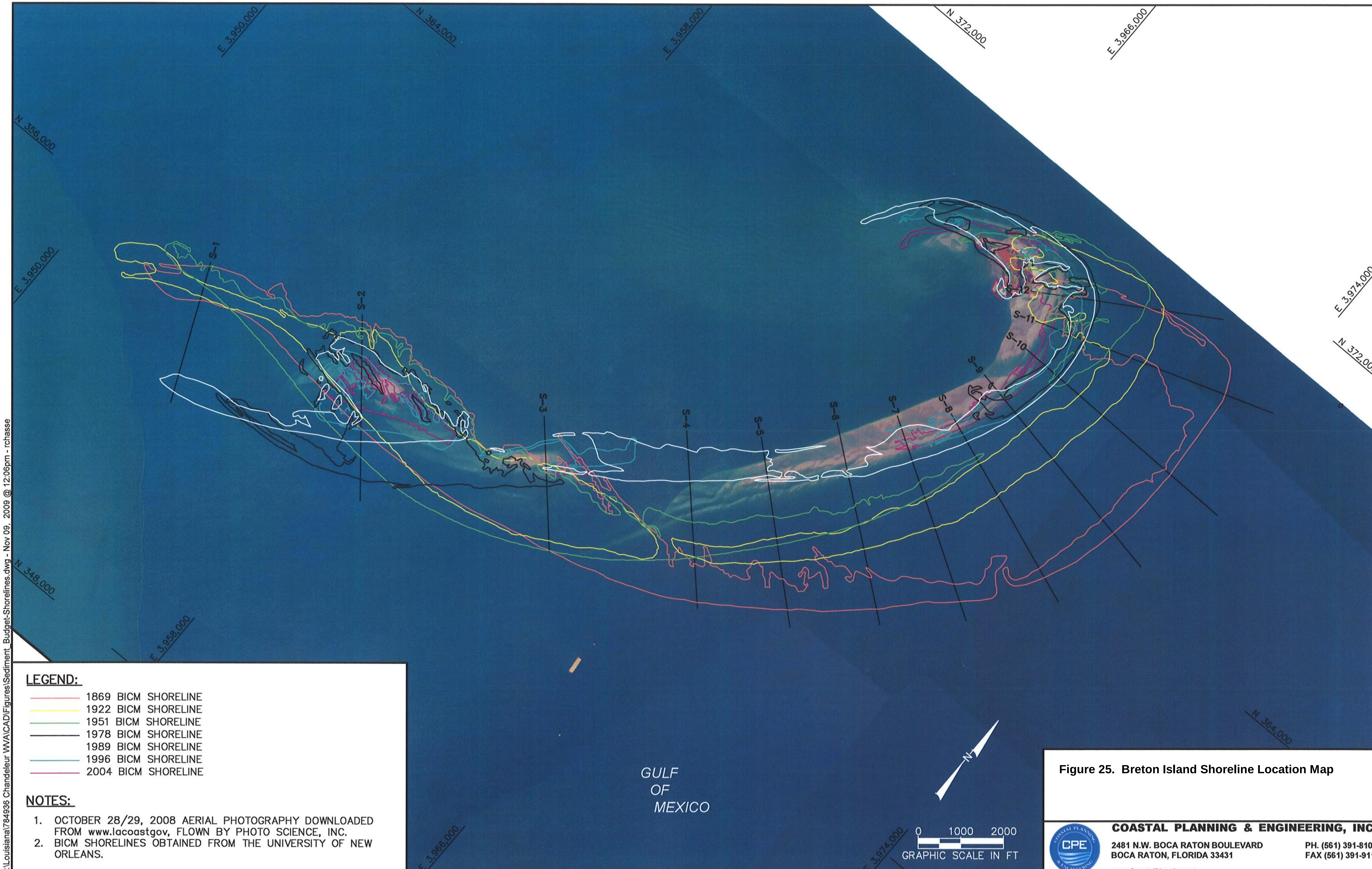


Figure 25. Breton Island Shoreline Location Map

8.1 Historic Shoreline Changes

Historic shoreline change data were obtained from the Louisiana Barrier Island Erosion Study – Atlas of Shoreline Changes in Louisiana from 1853 to 1989 (Williams et al, 1992). The historic shorelines used in the historic shoreline change analysis are presented graphically in Figure 24 (Chandeleur Islands) and Figure 25 (Breton Island). Gulfside and bayside shoreline changes presented in Williams et al (1992) were annualized for comparison purposes, with a statistical description of the data provided in Table 6 (Chandeleur Islands) and Table 7 (Breton Island). A negative gulf shoreline change indicates shoreline recession and movement to the west-northwest while a positive gulf shoreline change indicates shoreline advance and movement to the east-southeast. A positive bay shoreline change indicates movement to the west-northwest while a negative bay shoreline change indicates shoreline recession and movement to the east-southeast.

Table 6. Historic Shoreline Changes along the Chandeleur Islands

Time Period	Shoreline Change (feet/year)					
	Gulf			Bay		
	Average	Minimum	Maximum	Average	Minimum	Maximum
1855-1922	-18	19	-49	7	-31	67
1922-1951	-18	10	-52	18	-28	124
1951-1978	-34	-2	-177	11	-20	164
1978-1989	-38	-11	-85	16	-16	143

Table 7. Historic Shoreline Changes along Breton Island

Time Period	Shoreline Change (feet/year)					
	Gulf			Bay		
	Average	Minimum	Maximum	Average	Minimum	Maximum
1869-1922	-24	-2	-43	19	-9	52
1922-1951	-13	34	-40	8	-22	26
1951-1978	-21	21	-56	-18	-97	15
1978-1989	-13	12	-73	-4	-11	17

8.1.1 Historic Gulf Shoreline Changes

Gulf shoreline recession along the Chandeleur Islands was greatest near the southern extent and decreased towards the north. Between 1855 and 1989 the gulf shoreline receded west at an average rate of -21 feet/year, with a minimum and maximum recession rate of -1 feet/year and -58 feet/year, respectively. The greatest shoreline recession rate was experienced between 1978 and 1989, with an average recession rate of -38 feet/year. The smallest shoreline recession rate was experienced between 1855 and 1922 and between 1922 and 1951, with the shoreline receding at an average rate of -18 feet/year. Shoreline recession between 1951 and 1978 averaged -34 feet/year. Figure 26 provides a graphic representation of annualized historic gulf shoreline changes along the Chandeleur Islands.

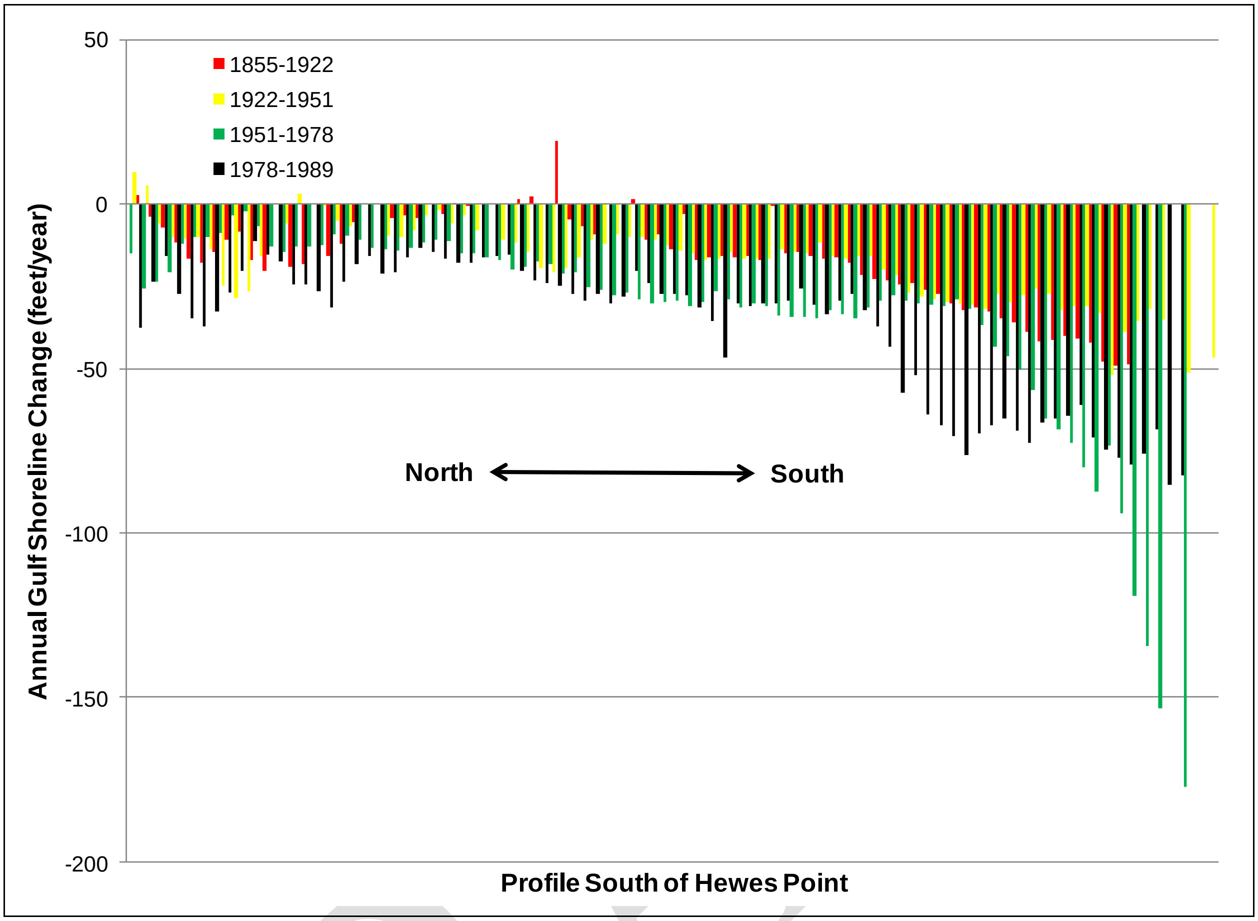


Figure 26. Historic Gulf Shoreline Changes along the Chandeleur Islands

Gulf shoreline recession along Breton Island was greatest near the northeastern extent of the island and decreased towards the southwest. Between 1869 and 1989 the gulf shoreline receded northwest at an average rate of -19 feet/year, with a minimum and maximum recession rate of 19 feet/year (advance) and -30 feet/year, respectively. The greatest shoreline recession rate was experienced between 1869 and 1922, with an average recession rate of -24 feet/year. The smallest shoreline recession rate was experienced between 1922 and 1951 and between 1978 and 1989, with the shoreline receding at an average rate of -13 feet/year. Shoreline recession between 1951 and 1978 averaged -21 feet/year. Figure 27 provides a graphic representation of annualized historic gulf shoreline changes along Breton Island.

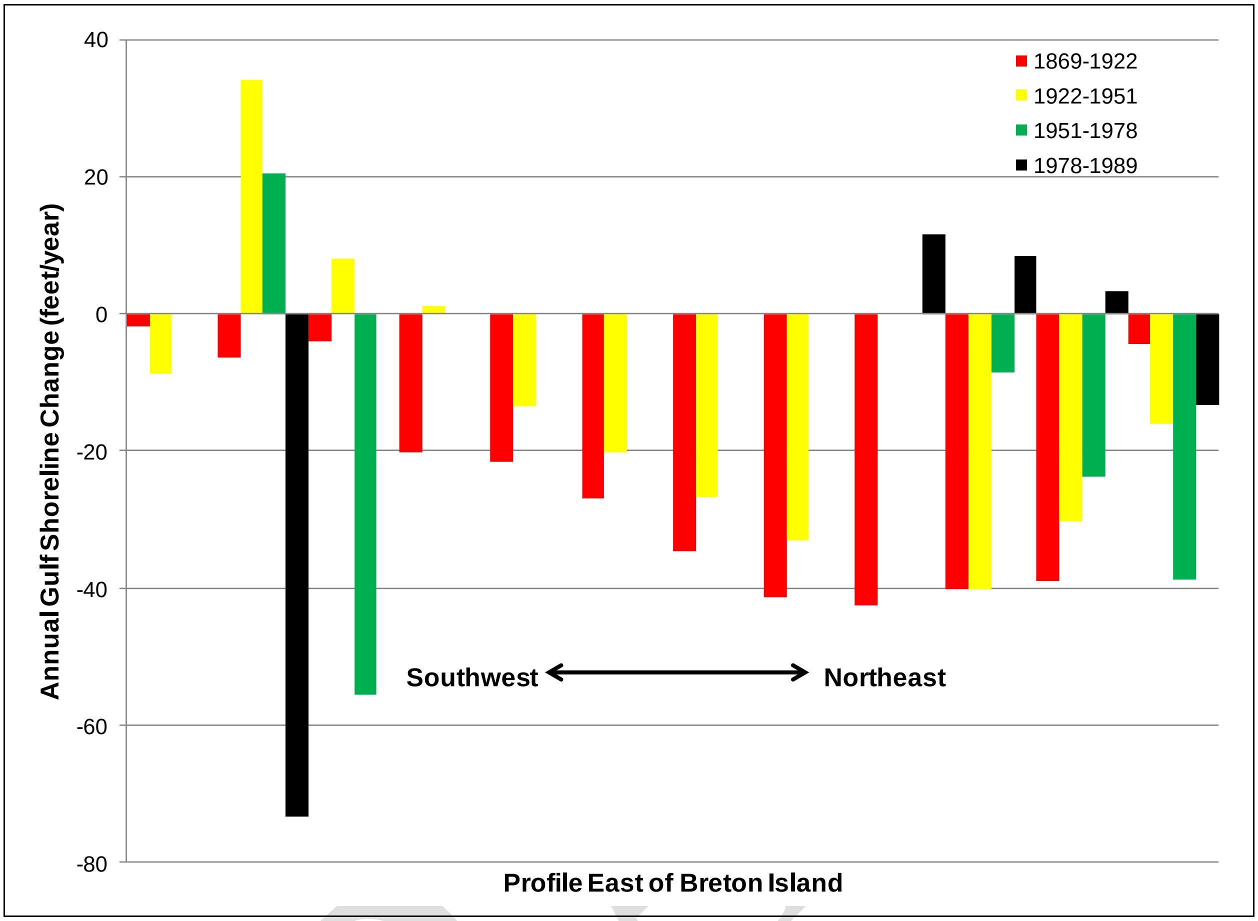


Figure 27. Historic Gulf Shoreline Changes along Breton Island

8.1.2 Historic Bay Shoreline Changes

Bay shoreline migration along the Chandeleur Islands was highly variable. Between 1855 and 1989 the bay shoreline migrated west at an average rate of 10 feet/year, with a minimum and maximum migration rate of -6 feet/year (recession) and 49 feet/year, respectively. The greatest shoreline migration rate was experienced between 1922 and 1951, with an average migration rate of 18 feet/year. The smallest shoreline migration rate was experienced between 1855 and 1922, with the shoreline migrating at an average rate of 7 feet/year. Shoreline migration between 1951 and 1978 averaged 11 feet/year while shoreline migration between 1978 and 1989 averaged 16 feet/year. Figure 28 provides a graphic representation of annualized historic bay shoreline changes along the Chandeleur Islands.

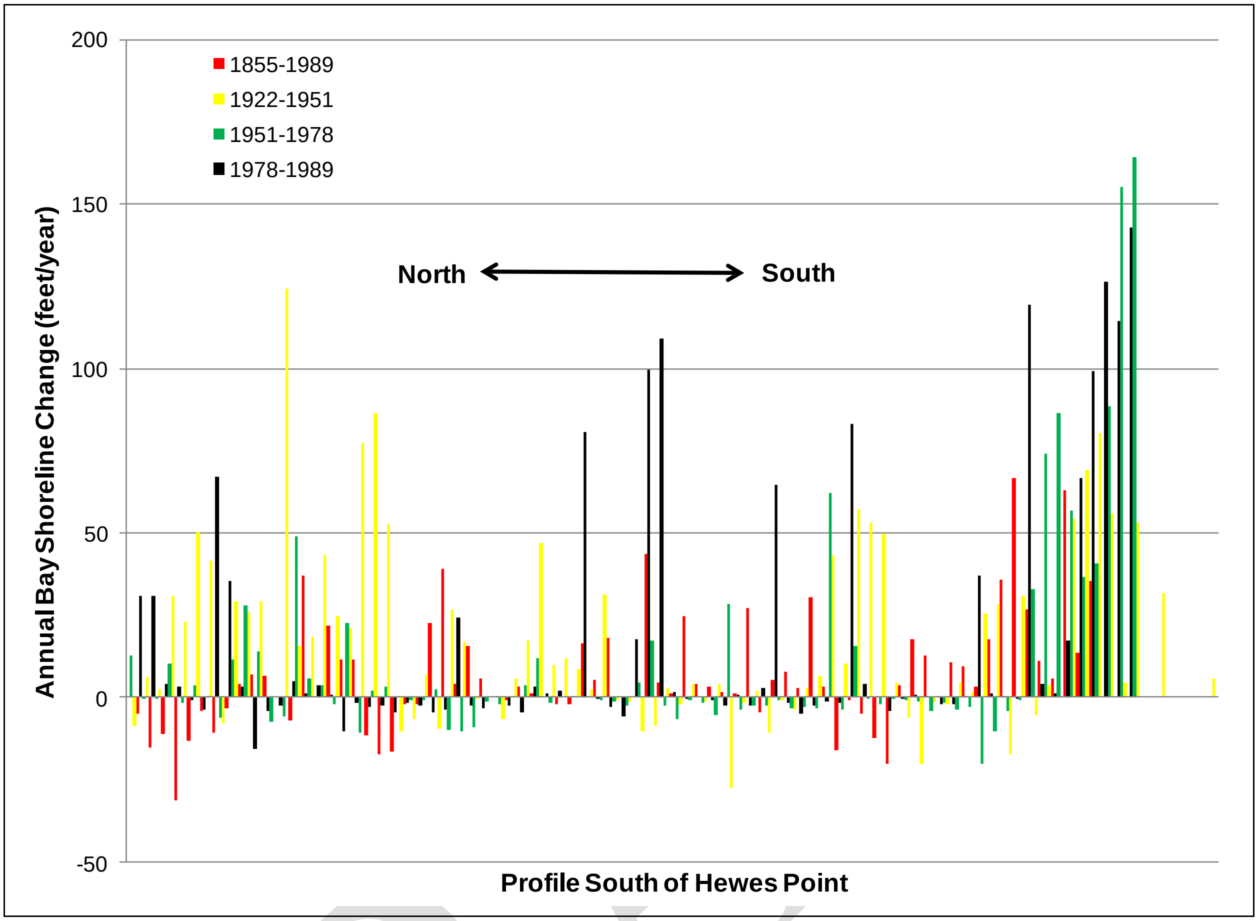


Figure 28. Historic Bay Shoreline Changes along the Chandeleur Islands

Bay shoreline migration along Breton Island was greatest near the northeastern extent of the island and decreased towards the southwest. Between 1869 and 1989 the bay shoreline migrated northwest at an average rate of 13 feet/year, with a minimum and maximum migration rate of -25 feet/year (recession) and 33 feet/year, respectively. The greatest shoreline migration rate was experienced between 1869 and 1922, with an average migration rate of 19 feet/year. The smallest shoreline migration rate was experienced between 1951 and 1978, with the shoreline migrating at an average rate of -18 feet/year (recession). Shoreline migration between 1922 and 1951 averaged 8 feet/year while shoreline migration between 1978 and 1989 averaged -4 feet/year (recession). Figure 29 provides a graphic representation of annualized historic bay shoreline changes along Breton Island.

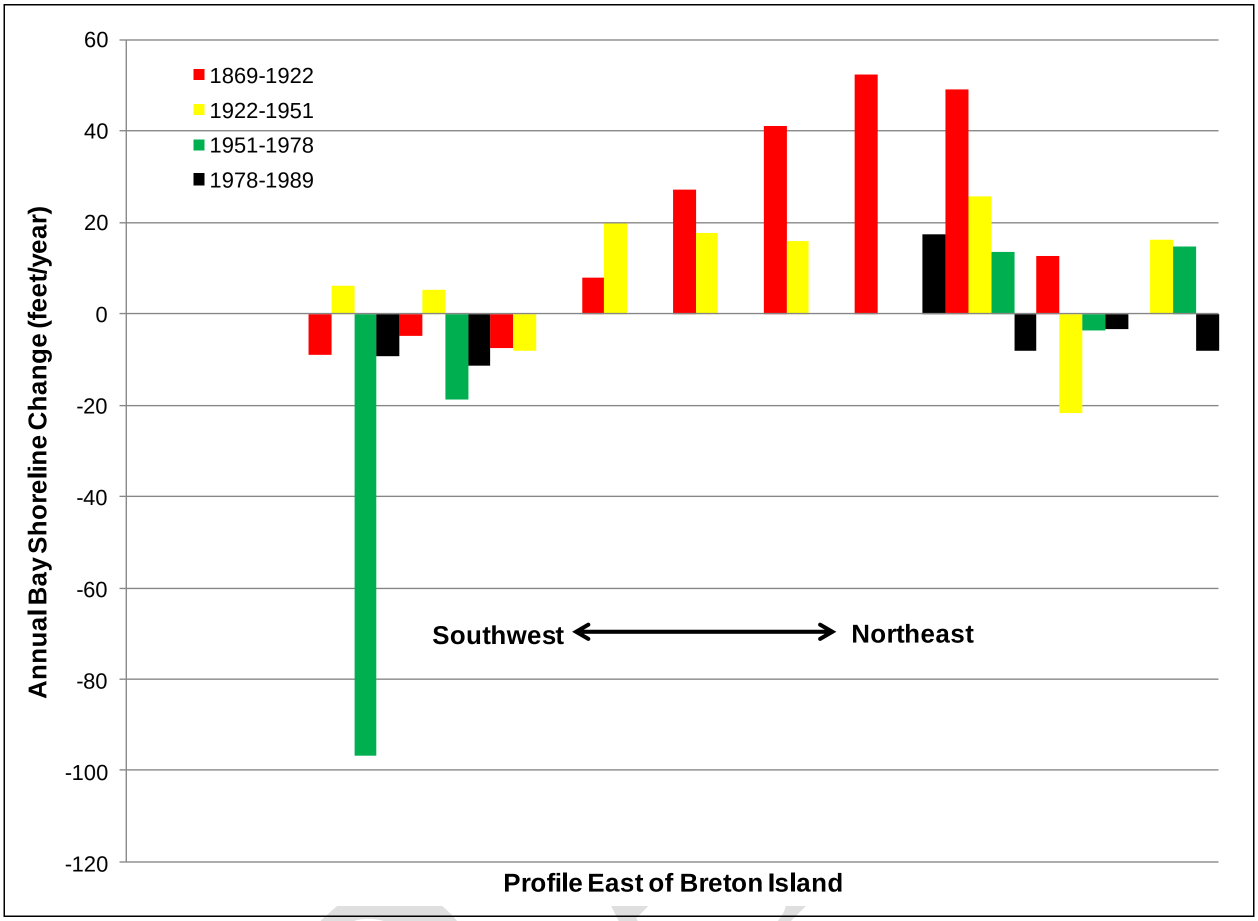


Figure 29. Historic Bay Shoreline Changes along Breton Island

8.2 Recent Shoreline Changes

Recent shorelines were obtained from the Louisiana Barrier Island Comprehensive Monitoring Program (BICM). Shorelines compiled under the BICM program were derived from a number of sources, including National Oceanic and Atmospheric Administration (NOAA)/National Ocean Service (NOS) topographic sheets (T-sheets), U.S. Geological Survey digital orthophoto quarter quads (DOQQ's), Color Infrared (CIR) aerial photography, and Digital Globe QuickBird satellite imagery (Martinez et al, 2009). Shoreline locations, defined by the high-water line, were obtained using image processing algorithms, spatial models, and aerial photograph interpretation techniques. The following shorelines were generated under the BICM program for the Chandeleur Islands: 1855, 1922, 1951, 1996, 2004, and 2005.

Recent shoreline changes were obtained using the 1996 and 2004 BICM shorelines. These shorelines were chosen because they best represent present and project shoreline locations, orientations, and changes along the entirety of the Chandeleur Islands barrier shoreline. The 2005 shoreline was not used in this analysis because island breaching and overwash, as a result of Hurricanes Katrina and Rita. The segmentation of the island chain prohibited a shoreline change analysis along the entire Chandeleur Islands. An attempt was made to extract shorelines from the LIDAR data sets described in Section 6; however, LIDAR data collected after hurricanes Katrina and Rita produced a highly segmented shoreline and LIDAR data collected prior to hurricanes Katrina and Rita did not include the westernmost extent of the bay shoreline along the Chandeleur Islands.

The shorelines used in the recent shoreline change analysis (1996 and 2004) are presented graphically in Figure 24 (Chandeleur Islands) and Figure 25 (Breton Island). Gulfside and bayside shoreline changes were calculated along USGS transects, shown in Figure 24 and Figure 25, and were then annualized for comparison purposes. A summary of the recent shoreline change data is provided in Table 8. A negative gulf shoreline change indicates shoreline recession and movement to the west-northwest while a positive gulf shoreline change indicates shoreline advance and movement to the east-southeast. A positive bay shoreline change indicates shoreline advance and movement to the west-northwest while a negative bay shoreline change indicates shoreline recession and movement to the east-southeast.

Table 8. Recent (1996-2004) Shoreline Changes along the Chandeleur Islands and Breton Island

	Shoreline Change (feet/year)					
	Gulf			Bay		
Location	Average	Minimum	Maximum	Average	Minimum	Maximum
North Islands	-58	14	-223	14	-198	227
Breton Island	-41	25	-65	19	-41	109

8.2.1 Recent Gulf Shoreline Changes

Gulf shoreline recession along the Chandeleur Islands was greatest near the southern extent and decreased towards the north. Between 1996 and 2004 the gulf shoreline receded west at an average rate of -58 feet/year, with a minimum and maximum recession rate of 14 feet/year (advance) and -223 feet/year, respectively. Figure 30 provides a graphic representation of annualized recent gulf shoreline changes along the Chandeleur Islands.

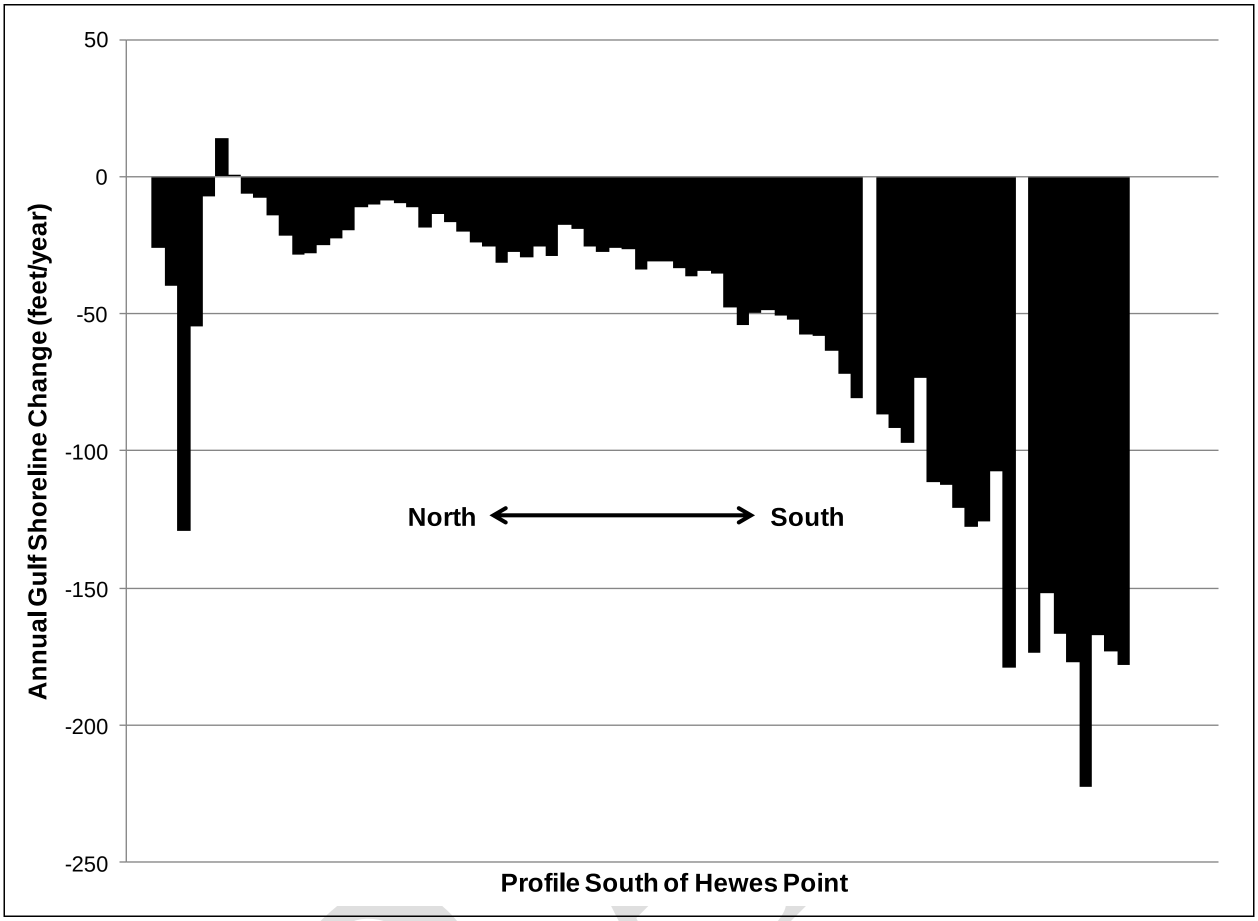


Figure 30. Recent Gulf Shoreline Changes along the Chandeleur Islands

Gulf shoreline recession along Breton Island was greatest near the northeastern extent of the island and decreased towards the southwest. Between 1996 and 2004 the gulf shoreline receded northwest at an average rate of -41 feet/year, with a minimum and maximum recession rate of 25 feet/year (advance) and -65 feet/year, respectively. Figure 31 provides a graphic representation of annualized recent gulf shoreline changes along Breton Island.

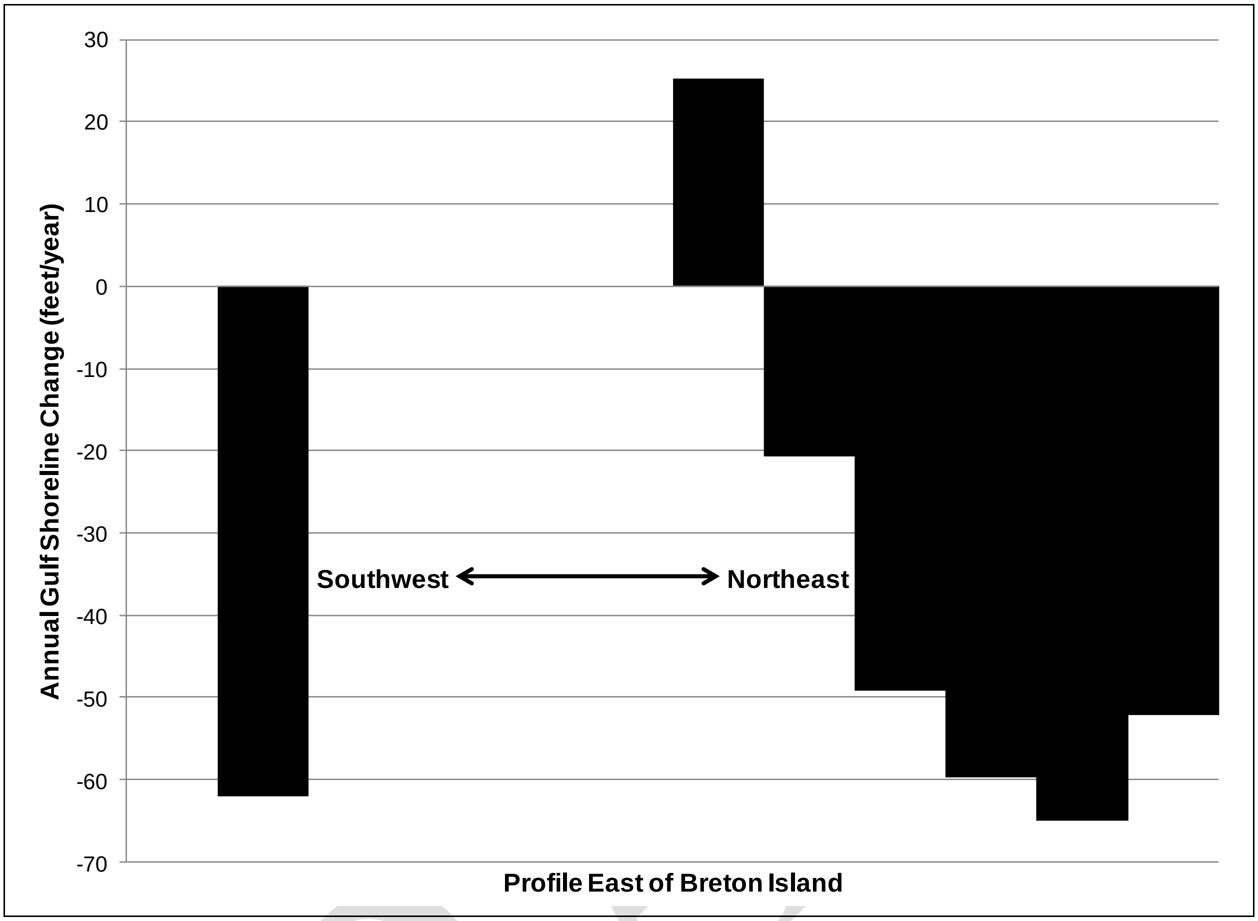


Figure 31. Recent Gulf Shoreline Changes along Breton Island

8.2.2 Recent Bay Shoreline Changes

Bay shoreline migration along the Chandeleur Islands was greatest near the southern extent and decreased towards the north. Between 1996 and 2004 the bay shoreline migrated west at an average rate of 14 feet/year, with a minimum and maximum migration rate of -198 feet/year (recession) and 227 feet/year, respectively. Figure 32 provides a graphic representation of annualized recent bay shoreline changes along the Chandeleur Islands.

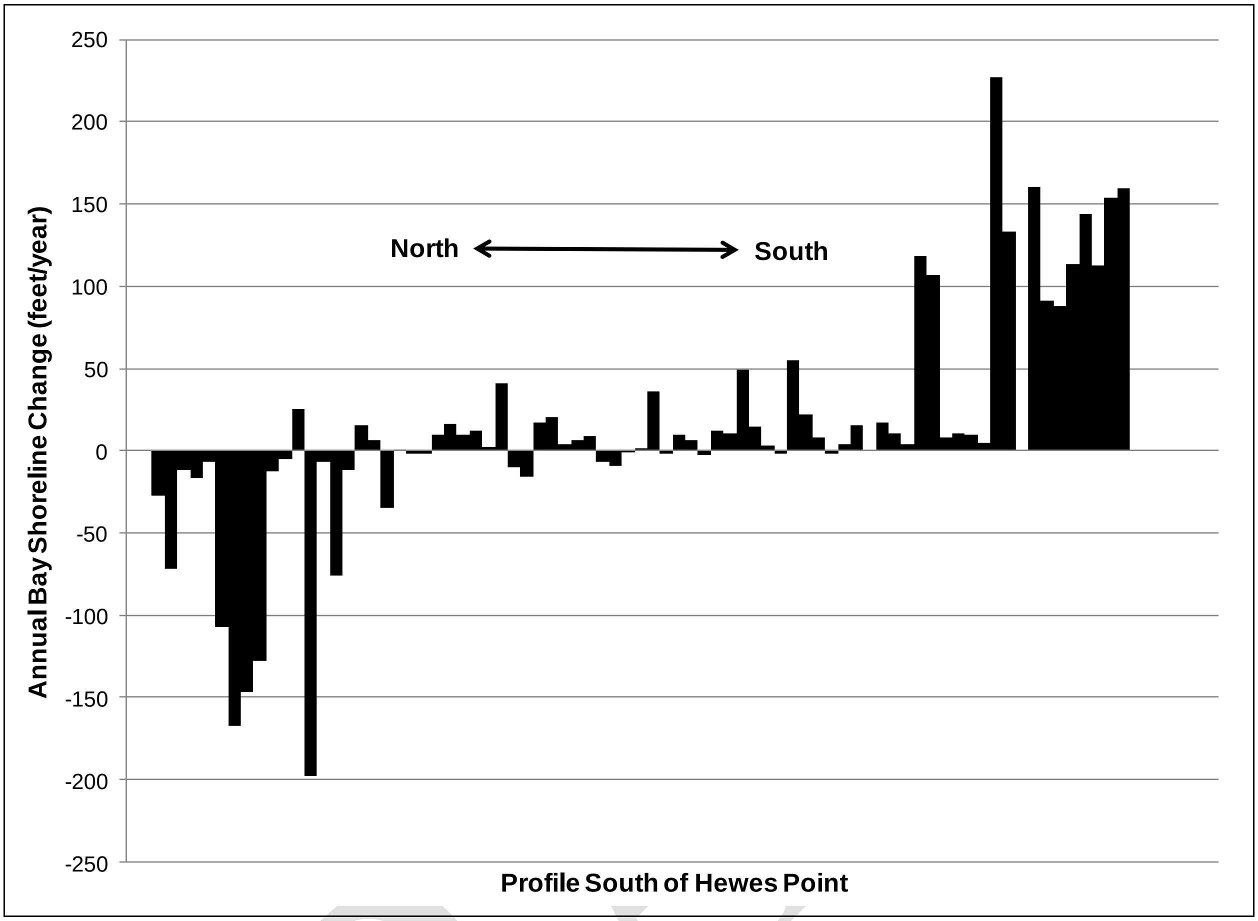


Figure 32. Recent Bay Shoreline Changes along the Chandeleur Islands

Bay shoreline migration along Breton Island was greatest near the northeastern extent of the island and decreased towards the southwest. Between 1996 and 2004 the bay shoreline migrated northwest at an average rate of 19 feet/year, with a minimum and maximum migration rate of -41 feet/year (recession) and 109 feet/year, respectively. Figure 33 provides a graphic representation of annualized historic bay shoreline changes along Breton Island.

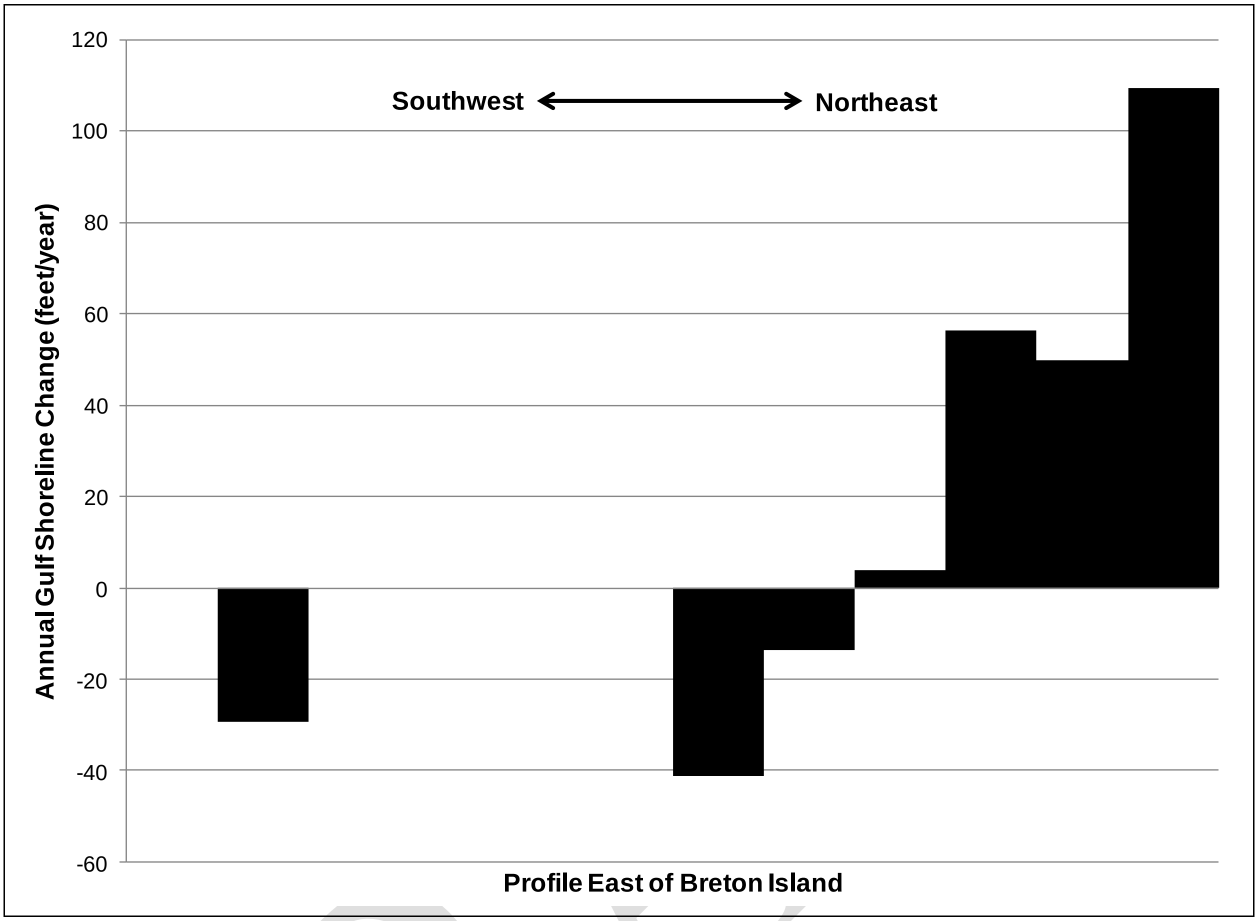


Figure 33. Recent Bay Shoreline Changes along Breton Island

8.3 Shoreline Response to Relative Sea Level Rise

Bruun (1982) showed that beach profiles should adjust to increased water elevation with a recession of the shoreline and a deposition of sand in the offshore area (Figure 34). Shoreline recession due to relative sea level rise for a sand only system can be estimated using Bruun's (1982) rule (Equation 3).

$$x = rb/(h-d) \quad \text{[Equation 3]}$$

where:

x = shoreline recession (feet)
r = relative sea level rise (feet)
b = distance from the berm crest to the depth of closure (feet)
h = berm elevation (feet, NAVD)
d = depth of closure elevation (feet, NAVD)

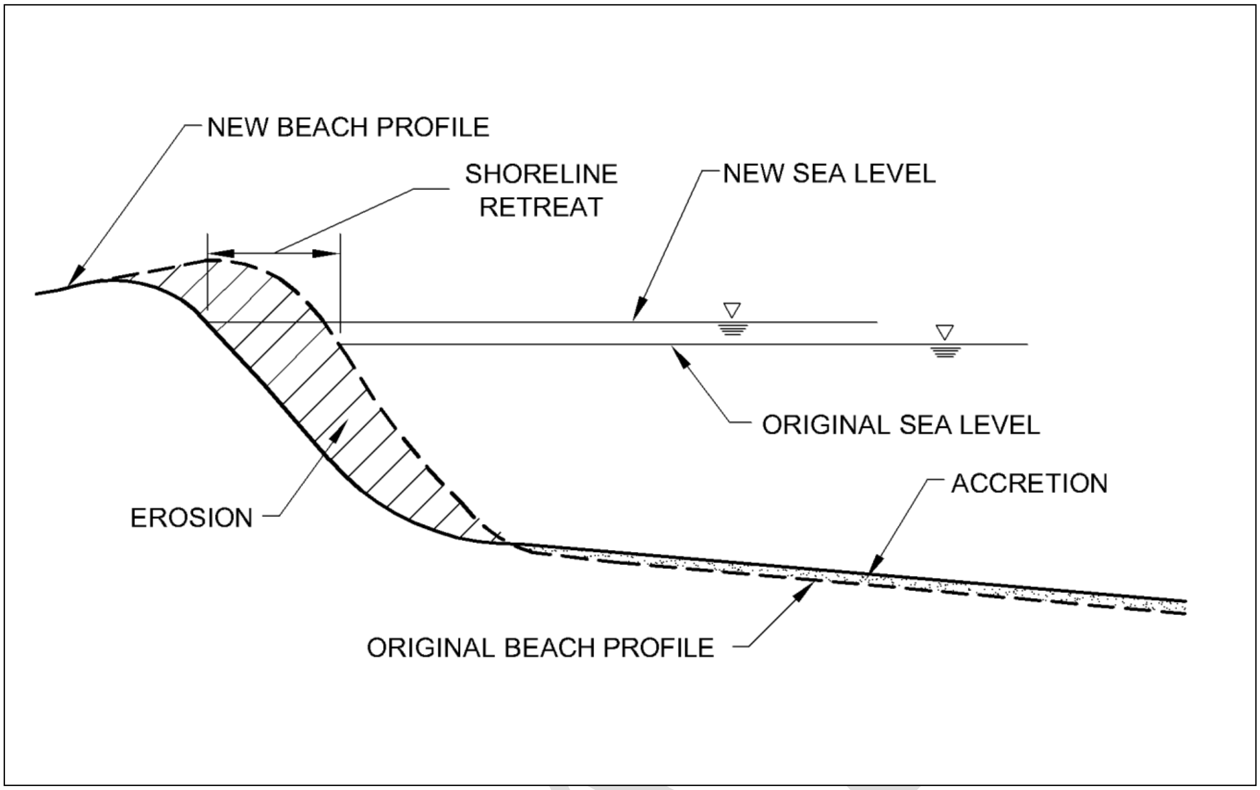


Figure 34. Impact of Sea Level Rise on Shoreline Recession

The berm elevation, depth of closure, and distance from the berm to the depth of closure were all determined by inspecting profiles generated using BICM bathymetric data. Bathymetric data was collected offshore of the Chandeleur Islands in 1880, 1920, and 2006 while bathymetric data was collected offshore of Breton Island in 1870, 1920, and 2007. Profiles were extracted along the USGS transects shown in Figure 24 and Figure 25. Comparison of recent and historic profiles suggests that the average nearshore slope is 1V:580H along the Chandeleur Islands and 1V:560H along Breton Island. Since the nearshore slopes calculated along Breton Island and the Chandeleur Islands are similar, it was decided to use an average nearshore slope when calculating shoreline response to relative sea level rise. The average nearshore slope for applied Breton Island and the Chandeleur Islands is 1V:580H. A detailed discussion of the closure depth and berm elevation is provided in Section 9.

Shoreline response to relative sea level rise was calculated for the three relative sea level rise rates discussed in Section 7. Presently, it is estimated that the shoreline along the Chandeleur Islands and Breton Island is receding approximately 9.5 feet annually due to the effect of relative sea level rise. This response to relative sea level rise is expected to increase during the project evaluation period as sea level rise is accelerating. Shoreline recession due to relative sea level rise could be anywhere between 14.4 feet/year and 30.2 feet/year depending on how quickly sea level rise accelerates. A summary of shoreline recession rates due to varying levels of sea level rise acceleration, as discussed in Section 7, is provided in Table 9.

Table 9. Shoreline Response to Relative Sea Level Rise

Sea Level Rise Acceleration	Relative Sea Level Rise (ft/yr)	Shoreline Retreat due to Relative Sea Level Rise (ft/yr)
Low (Baseline)	0.0164	9.5
Intermediate	0.0248	14.4
High	0.0520	30.2

9 ACTIVE PROFILE HEIGHT

Volume changes can be calculated by multiplying the shoreline change by the active profile height and the longshore distance between profiles. Typically the active profile extends from the berm crest to the depth of closure, where the depth of closure is defined as the depth at which there is no net cross-shore movement of sediment. In Louisiana, the barrier islands are low lying and are frequently overtopped. The resultant overwash of sediment deposited on the backing marsh platform is what maintains island elevation and helps rebuild the migrating dune (Campbell, 2005). The volume above the marsh remains relatively constant due to overwash, whereas the true volume change occurs between the top of the marsh and the depth of closure. Therefore, the marsh elevation can be considered to be the top of the active profile and the depth of closure can be considered to be the bottom of the active profile when calculating volume changes.

Observation of historic shorelines along the Chandeleur Islands and Breton Island shows that these barrier islands are migrating west-northwest while becoming narrower. This landward migration occurs when sediment is washed over the island and is deposited in the backing bay. Over time sediment deposited in the backing bay builds up and eventually emerges to become new marsh. Therefore, the true volume change is the volume change along the gulf face less the volume change along the bay face.

The gulf and bay depth of closure were both determined by examining historic cross-shore profiles along the Chandeleur Islands and Breton Island. Profiles were extracted from the 1922 and 2006/2007 BICM bathymetry along the USGS transects shown in Figure 24 and Figure 25. The profiles were inspected to determine the closure elevation on the gulf and bay sides of the barrier islands. Figure 35 is an example profile showing both the gulf and bay depth of closure. The gulf and bay depth of closure were determined for all profiles. An average depth of closure was then calculated to facilitate a volume change estimate along the gulf and bay shore faces. The average gulf and bay closure depths along the Chandeleur Islands were calculated to be -34 feet, NAVD and -16 feet, NAVD, respectively. The average gulf and bay closure depths along Breton Island were calculated to be -22 feet, NAVD and -17 feet, NAVD, respectively.

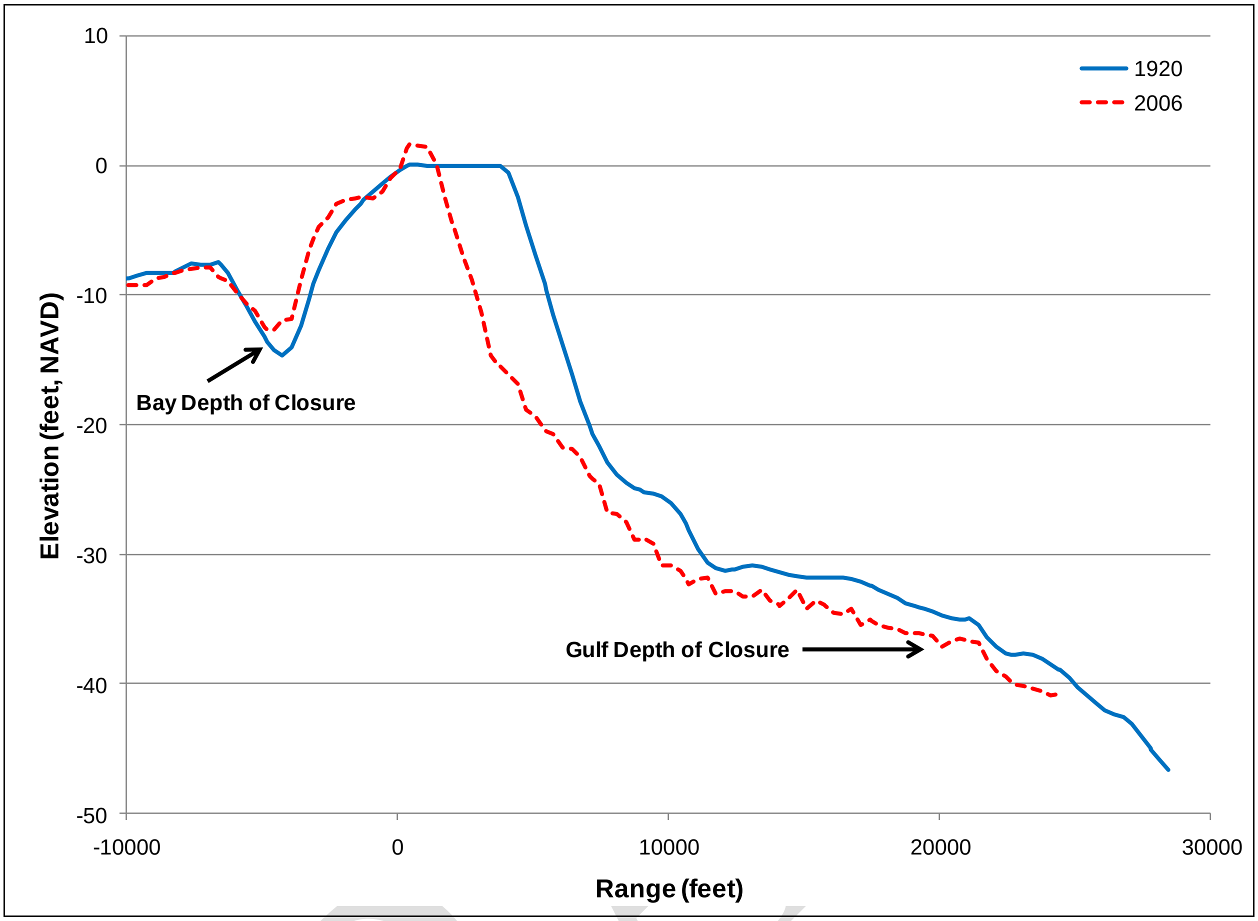


Figure 35. Profile Comparison along USGS Transect N-30

10 VOLUME CHANGES

Profile data is normally used to calculate volume change estimates in project areas. However, recent profile comparison data was not available (the only comparison could have been 1920 to 2007 and Section 5.7 discussed why a post MRGO data set should be used to evaluate recent changes). LIDAR data is available but it only captures subaerial changes in the profile. Consequently, it was not possible to directly calculate volumes based on survey data. Shoreline data are available and allowed for a greater number of comparison points along the island chain. Therefore, it was decided to base volumetric change estimates on the shoreline change data.

Shoreline based volumetric changes can be approximated by multiplying the shoreline change by the active profile height and the alongshore distance between profiles (USACE, 2001). As described in Dean (2002), volume changes for a stabilized coast are proportional to changes in the shoreline location. However, barrier islands, such as the Chandeleur and Breton Islands, have the tendency to migrate landward due to the effects of significant storms and relative sea level rise. Significant storms simultaneously erode the shoreline and wash sediment over the island and into the backing bay causing the island to roll over. Therefore, the total volume change for a migrating barrier island should be the gulf side volume change less the bay side volume change. This theory assumes that the island form remains the same (in terms of dune elevation, dune width, and marsh elevation; i.e. the volume above the marsh remains constant) and the only parameter changing is the width of the barrier island.

Volumetric changes along the Chandeleur and Breton Islands were calculated using the shoreline change data presented in Section 8.2 and the active profile heights discussed in Section 9. A negative volume change indicates a volumetric loss (erosion) while a positive volume change indicates a volumetric gain (accretion). The volume changes along the Chandeleur Islands and Breton Island are presented in Table 10 and Table 11, respectively. The total volume change along the North Chandeleur Islands is -7,812,000 cubic yards/year while the total volume change along Breton Island is -1,248,000 cubic yards/year.

Table 10. Volume Changes along the Chandeleur Islands

Station	Cell Width (ft)	Gulf Side Change: Shoreline Change (ft/yr)	Gulf Side Change: Active Profile Height (ft)	Gulf Side Change: Volume Change (cy/yr)	Bay Side Change: Shoreline Change (ft/yr)	Bay Side Change: Active Profile Height (ft)	Bay Side Change: Volume Change (cy/yr)
N-1	1,335	-	35.2	-	-	17.5	-
N-2	2,665	-	35.2	-	-	17.5	-
N-3	1,903	-	35.2	-	-	17.5	-
N-4	1,485	-	35.2	-	-	17.5	-
N-5	1,662	-	35.2	-	-	17.5	-
N-6	1,339	-	35.2	-	-	17.5	-
N-7	1,720	-	35.2	-	-	17.5	-
N-8	1,519	-178.2	35.2	-352,416	159.3	17.5	156,463
N-9	1,028	-173.1	35.2	-231,679	154.2	17.5	102,556
N-10	1,681	-167.5	35.2	-366,499	112.8	17.5	122,637
N-11	1,980	-222.5	35.2	-573,585	144.2	17.5	184,690
N-12	1,609	-177.4	35.2	-371,602	113.2	17.5	117,861
N-13	1,379	-166.8	35.2	-299,532	87.9	17.5	78,392
N-14	1,525	-151.9	35.2	-301,460	91.1	17.5	89,852
N-15	1,525	-173.5	35.2	-344,433	160.0	17.5	157,792
N-16	1,592	-	35.2	-	-	17.5	-
N-17	1,650	-178.9	35.2	-384,501	133.2	17.5	142,241
N-18	1,647	-107.6	35.2	-230,635	226.7	17.5	241,570
N-19	1,477	-126.0	35.2	-242,164	4.9	17.5	4,710
N-20	1,414	-127.8	35.2	-235,202	9.9	17.5	9,088
N-21	1,654	-120.7	35.2	-259,857	10.4	17.5	11,082
N-22	1,588	-112.3	35.2	-232,039	8.3	17.5	8,567
N-23	1,483	-111.5	35.2	-215,252	106.8	17.5	102,400
N-24	1,522	-73.6	35.2	-145,849	118.1	17.5	116,213
N-25	1,580	-96.9	35.2	-199,353	4.2	17.5	4,337
N-26	1,554	-91.5	35.2	-185,111	10.6	17.5	10,640
N-27	1,551	-86.9	35.2	-175,490	16.9	17.5	16,988
N-28	1,516	-	35.2	-	-	17.5	-
N-29	1,433	-80.9	35.2	-151,050	15.2	17.5	14,054
N-30	1,545	-71.9	35.2	-144,605	3.8	17.5	3,782
N-31	1,560	-63.7	35.2	-129,275	-1.6	17.5	-1,567
N-32	1,472	-58.2	35.2	-111,482	8.2	17.5	7,794
N-33	1,566	-57.8	35.2	-117,877	22.4	17.5	22,693
N-34	1,608	-52.3	35.2	-109,408	55.4	17.5	57,612
N-35	1,525	-50.8	35.2	-100,866	-2.0	17.5	-1,944
N-36	1,488	-48.6	35.2	-94,211	3.2	17.5	3,033
N-37	1,598	-49.8	35.2	-103,576	15.0	17.5	15,515
N-38	1,461	-54.0	35.2	-102,818	49.5	17.5	46,788
N-39	1,449	-47.8	35.2	-90,189	10.8	17.5	10,099
N-40	1,690	-35.5	35.2	-78,209	12.4	17.5	13,504
N-41	1,480	-34.5	35.2	-66,403	-2.4	17.5	-2,270
N-42	1,317	-36.4	35.2	-62,407	6.4	17.5	5,472
N-43	1,434	-33.6	35.2	-62,794	10.1	17.5	9,338

N-44	1,505	-31.0	35.2	-60,848	-1.7	17.5	-1,650
N-45	1,474	-30.8	35.2	-58,995	36.2	17.5	34,522
N-46	1,494	-34.0	35.2	-66,043	1.8	17.5	1,722
N-47	1,478	-26.3	35.2	-50,548	-0.2	17.5	-191
N-48	1,390	-26.1	35.2	-47,155	-9.4	17.5	-8,416
N-49	1,449	-27.6	35.2	-52,024	-6.6	17.5	-6,232
N-50	1,477	-25.6	35.2	-49,218	8.6	17.5	8,192
N-51	1,516	-19.0	35.2	-37,587	6.2	17.5	6,102
N-52	1,493	-17.6	35.2	-34,172	3.9	17.5	3,799
N-53	1,474	-29.1	35.2	-55,759	20.3	17.5	19,387
N-54	1,485	-25.3	35.2	-48,869	16.9	17.5	16,190
N-55	1,347	-29.6	35.2	-51,843	-15.9	17.5	-13,850
N-56	1,372	-27.7	35.2	-49,435	-10.2	17.5	-9,032
N-57	1,419	-31.4	35.2	-57,989	40.8	17.5	37,425
N-58	1,436	-25.4	35.2	-47,552	2.1	17.5	1,950
N-59	1,400	-23.8	35.2	-43,402	12.2	17.5	11,081
N-60	1,531	-20.1	35.2	-40,036	9.4	17.5	9,354
N-61	1,657	-16.5	35.2	-35,675	16.1	17.5	17,283
N-62	1,516	-13.8	35.2	-27,177	9.8	17.5	9,619
N-63	1,402	-18.8	35.2	-34,320	-1.7	17.5	-1,585
N-64	1,383	-11.2	35.2	-20,116	-1.6	17.5	-1,459
N-65	1,446	-9.6	35.2	-18,056	0.8	17.5	764
N-66	1,527	-8.6	35.2	-17,173	-35.1	17.5	-34,624
N-67	1,531	-10.1	35.2	-20,217	6.1	17.5	6,040
N-68	1,658	-11.4	35.2	-24,659	15.7	17.5	16,884
N-69	1,621	-19.3	35.2	-40,829	-12.1	17.5	-12,677
N-70	1,442	-22.7	35.2	-42,543	-75.6	17.5	-70,582
N-71	1,529	-25.2	35.2	-50,107	-7.1	17.5	-7,005
N-72	1,479	-28.1	35.2	-54,153	-198.1	17.5	-189,516
N-73	1,469	-28.3	35.2	-54,124	25.1	17.5	23,881
N-74	1,607	-21.5	35.2	-44,948	-4.9	17.5	-5,121
N-75	1,879	-14.3	35.2	-34,969	-12.4	17.5	-15,051
N-76	1,577	-7.7	35.2	-15,817	-127.4	17.5	-129,991
N-77	1,278	-6.0	35.2	-10,036	-146.9	17.5	-121,447
N-78	1,494	0.6	35.2	1,087	-167.5	17.5	-161,829
N-79	1,719	13.8	35.2	30,873	-107.3	17.5	-119,340
N-80	1,932	-7.4	35.2	-18,586	-6.4	17.5	-8,006
N-81	1,844	-54.7	35.2	-131,205	-16.8	17.5	-20,030
N-82	1,798	-129.2	35.2	-302,347	-12.0	17.5	-14,001
N-83	1,861	-40.1	35.2	-97,097	-72.1	17.5	-86,737
N-84	1,828	-26.2	35.2	-62,341	-27.0	17.5	-31,958
N-85	1,403	-	35.2	-	-	17.5	-
N-86	507	-	35.2	-	-	17.5	-
Total	132,335			-8,847,839			1,035,844

Table 11. Volume Changes along Breton Island

		Gulf Side Change			Bay Side Change		
Station	Cell Width (ft)	Shoreline Change (ft/yr)	Active Profile Height (ft)	Volume Change (cy/yr)	Shoreline Change (ft/yr)	Active Profile Height (ft)	Volume Change (cy/yr)
S-1	1,845	-	23.3	-	-	18.1	-
S-2	3,966	-62.1	23.3	-211,943	-29.5	18.1	-78,316
S-3	3,783	-	23.3	-	-	18.1	-
S-4	2,525	-	23.3	-	-	18.1	-
S-5	1,771	-	23.3	-	-	18.1	-
S-6	1,609	-	23.3	-	-	18.1	-
S-7	1,289	-117.4	23.3	-130,281	-41.3	18.1	-35,668
S-8	1,167	-178.3	23.3	-179,193	-13.6	18.1	-10,634
S-9	1,144	-209.8	23.3	-206,747	3.8	18.1	2,915
S-10	904	-225.1	23.3	-175,332	56.4	18.1	34,189
S-11	667	-370.6	23.3	-212,721	49.8	18.1	22,238
S-12	327	-322.8	23.3	-90,877	109.3	18.1	23,939
Total	20,996			-1,207,094			-41,337

The Mississippi River Gulf Outlet (MRGO) was a federally authorized and maintained deep draft navigable waterway between 1965 and 2009. As described in Section 6.2, spoil dredged from the MRGO has been beneficially disposed of on and close to Breton Island during maintenance dredging operations. In order to determine natural shoreline movement from shoreline change due to beneficial material disposal, the benefit of these disposal projects was included in the volumetric calculations. Table 12 provides a summary of the disposal volumes and locations of maintenance dredging operations between 1996 and 2004.

Table 12. Shoreline Changes Resulting from MRGO Beneficial Disposal

	Beneficial Disposal Volume (cy)		Resultant Shoreline Gain (ft)	
Station	1999	2001	1999	2001
S-7	1,266,667	-	1,142	-
S-8	1,266,667	-	1,260	-
S-9	1,266,667	-	1,285	-
S-10	253,600	777,243	326	998
S-11	626,000	777,243	1,091	1,354
S-12	221,500	387,922	787	1,378

11 SEDIMENT BUDGET

A sediment budget was developed to describe the movement of sediment into, out of, and within the project areas. The sediment budget was developed by decomposing the volumetric change, described in the previous section, into component parts. This section discusses the separation of the volume change into offshore losses associated with island composition, losses due to relative sea level rise, overwash, and longshore transport.

11.1 Island Composition

The Chandeleur Islands and Breton Island are composed of sand, silt, and clay. A distinction must be made within a sediment budget to account for the difference in material. It is assumed that sand will remain within the confines of the system whereas when silt and clay are exposed to direct wave attack, they are suspended in the water column and can be transported out of the system.

The sediment budget assumes that silt and clay exposed along the shoreline face are placed in suspension and transported offshore, while the sand fraction remains behind. The sand component is then transported alongshore or overwashes the island. Therefore, volume changes must be reduced by the percent silt and clay to obtain the sand volume changes. Campbell (2005) suggested that marsh samples should be taken to estimate the silt content in the island as the beach face is transient and does not represent the composition of the island.

Fifteen vibracore samples were taken from the Chandeleur Islands in July 2009. The core samples were collected along the western edge of the Chandeleur Islands. The average core depth was approximately 15.5 feet, with minimum and maximum core depths of 8.2 feet and 21.9 feet, respectively. It was determined that on average the island is composed of approximately 32% silt/clay and 68% sand. Therefore, the total volumetric loss was multiplied by 32% to determine the volume of silts and clay lost offshore from each profile line. The volume lost offshore along the Chandeleur Islands was estimated at 2,841,536 cubic yards/year, as shown in Table 13. The volume lost offshore along Breton Island was estimated at 386,270 cubic yards/year, as shown in Table 14. Note that where the gulf shoreline advanced there is no volumetric gain of silt.

Table 13. Sediment Budget along the Chandeleur Islands (1996-2004)

Station	Total Volume Lost From Gulf Face (cy/yr)	Volume Lost Offshore (Silt Loss) (cy/yr)	Volume Lost to RSLR (cy/yr)	Overwash Volume (cy/yr)	Net Longshore Sand Volume Change (cy/yr)	Longshore Transport Rate (cy/yr)
N-1	-	-	-	-	-	-1,037,484
N-2	-	-	-	-	-	-1,037,484
N-3	-	-	-	-	-	-1,037,484
N-4	-	-	-	-	-	-1,037,484
N-5	-	-	-	-	-	-1,037,484
N-6	-	-	-	-	-	-1,037,484
N-7	-	-	-	-	-	-1,037,484
N-8	352,416	112,773	18,811	156,463	64,369	-1,037,484
N-9	231,679	74,137	12,736	102,556	42,250	-973,115
N-10	366,499	117,280	20,819	122,637	105,764	-930,865
N-11	573,585	183,547	24,519	184,690	180,828	-825,101
N-12	371,602	118,913	19,927	117,861	114,902	-644,272
N-13	299,532	95,850	17,080	78,392	108,210	-529,370
N-14	301,460	96,467	18,884	89,852	96,257	-421,161
N-15	344,433	110,218	18,882	157,792	57,540	-324,904
N-16	-	-	-	-	-	-267,364
N-17	384,501	123,040	20,441	142,241	98,778	-267,364
N-18	230,635	73,803	20,400	241,570	-105,138	-168,586
N-19	242,164	77,492	18,291	4,710	141,671	-273,724
N-20	235,202	75,265	17,507	9,088	133,342	-132,052
N-21	259,857	83,154	20,482	11,082	145,138	1,289
N-22	232,039	74,253	19,662	8,567	129,558	146,428
N-23	215,252	68,881	18,364	102,400	25,607	275,986
N-24	145,849	46,672	18,847	116,213	-35,883	301,594
N-25	199,353	63,793	19,564	4,337	111,660	265,711
N-26	185,111	59,236	19,247	10,640	95,989	377,370
N-27	175,490	56,157	19,215	16,988	83,130	473,359
N-28	-	-	-	-	-	556,489
N-29	151,050	48,336	17,754	14,054	70,905	556,489
N-30	144,605	46,274	19,141	3,782	75,409	627,395
N-31	129,275	41,368	19,319	0	68,588	702,804
N-32	111,482	35,674	18,231	7,794	49,783	771,391
N-33	117,877	37,721	19,391	22,693	38,073	821,175
N-34	109,408	35,011	19,920	57,612	-3,134	859,247
N-35	100,866	32,277	18,887	0	49,702	856,113
N-36	94,211	30,147	18,426	3,033	42,605	905,815
N-37	103,576	33,144	19,790	15,515	35,127	948,420
N-38	102,818	32,902	18,101	46,788	5,028	983,547
N-39	90,189	28,860	17,945	10,099	33,284	988,575
N-40	78,209	25,027	20,932	13,504	18,746	1,021,859
N-41	66,403	21,249	18,335	0	26,819	1,040,605
N-42	62,407	19,970	16,311	5,472	20,654	1,067,424
N-43	62,794	20,094	17,754	9,338	15,608	1,088,078
N-44	60,848	19,471	18,644	0	22,732	1,103,686

N-45	58,995	18,878	18,251	34,522	-12,657	1,126,418
N-46	66,043	21,134	18,503	1,722	24,684	1,113,761
N-47	50,548	16,175	18,299	0	16,073	1,138,446
N-48	47,155	15,090	17,220	0	14,846	1,154,519
N-49	52,024	16,648	17,951	0	17,426	1,169,365
N-50	49,218	15,750	18,297	8,192	6,980	1,186,791
N-51	37,587	12,028	18,777	6,102	680	1,193,771
N-52	34,172	10,935	18,490	3,799	948	1,194,451
N-53	55,759	17,843	18,259	19,387	270	1,195,399
N-54	48,869	15,638	18,393	16,190	-1,352	1,195,669
N-55	51,843	16,590	16,684	0	18,569	1,194,317
N-56	49,435	15,819	16,988	0	16,627	1,212,886
N-57	57,989	18,557	17,574	37,425	-15,567	1,229,513
N-58	47,552	15,217	17,779	1,950	12,606	1,213,947
N-59	43,402	13,889	17,344	11,081	1,088	1,226,553
N-60	40,036	12,811	18,960	9,354	-1,089	1,227,641
N-61	35,675	11,416	20,525	17,283	-13,549	1,226,551
N-62	27,177	8,697	18,770	9,619	-9,908	1,213,003
N-63	34,320	10,982	17,370	0	5,968	1,203,094
N-64	20,116	6,437	17,124	0	-3,446	1,209,062
N-65	18,056	5,778	17,911	764	-6,396	1,205,617
N-66	17,173	5,495	18,907	0	-7,229	1,199,221
N-67	20,217	6,470	18,966	6,040	-11,258	1,191,992
N-68	24,659	7,891	20,539	16,884	-20,656	1,180,734
N-69	40,829	13,065	20,077	0	7,687	1,160,078
N-70	42,543	13,614	17,865	0	11,065	1,167,765
N-71	50,107	16,034	18,937	0	15,136	1,178,830
N-72	54,153	17,329	18,315	0	18,509	1,193,966
N-73	54,124	17,320	18,189	23,881	-5,265	1,212,474
N-74	44,948	14,383	19,902	0	10,663	1,207,209
N-75	34,969	11,190	23,269	0	510	1,217,872
N-76	15,817	5,061	19,533	0	-8,778	1,218,382
N-77	10,036	3,211	15,832	0	-9,008	1,209,604
N-78	-1,087	0	18,504	0	-19,591	1,200,596
N-79	-30,873	0	21,287	0	-52,160	1,181,005
N-80	18,586	5,948	23,931	0	-11,293	1,128,845
N-81	131,205	41,986	22,833	0	66,387	1,117,553
N-82	302,347	96,751	22,265	0	183,331	1,183,939
N-83	97,097	31,071	23,046	0	42,980	1,367,270
N-84	62,341	19,949	22,642	0	19,750	1,410,250
N-85	-	-	-	-	-	1,430,000
N-86	-	-	-	-	-	1,430,000
Total	8,847,839	2,841,536	1,426,865	2,111,954	2,467,484	

Table 14. Sediment Budget along Breton Island (1996-2004)

Station	Total Volume Lost From Gulf Face (cy/yr)	Volume Lost Offshore (Silt Loss) (cy/yr)	Volume Lost to RSLR (cy/yr)	Overwash Volume (cy/yr)	Net Longshore Sand Volume Change (cy/yr)	Longshore Transport Rate (cy/yr)
S-1	-	-	-	-	-	-310,011
S-2	211,943	67,822	32,492	0	111,629	-310,011
S-3	-	-	-	-	-	-198,382
S-4	-	-	-	-	-	-198,382
S-5	-	-	-	-	-	-198,382
S-6	-	-	-	-	-	-198,382
S-7	130,281	41,690	10,556	0	78,035	-198,382
S-8	179,193	57,342	9,561	0	112,290	-120,347
S-9	206,747	66,159	9,375	2,915	128,298	-8,057
S-10	175,332	56,106	7,408	34,189	77,629	120,240
S-11	212,721	68,071	5,460	22,238	116,952	197,869
S-12	90,877	29,081	2,679	23,939	35,179	314,821
Total	1,207,094	386,270	77,531	83,282	660,011	

11.2 Relative Sea Level Rise

A portion of the shoreline recession is due to the island maintaining its elevation while relative sea level rise processes are occurring. Shoreline recession due to relative sea level rise does not result in a net volume change in the cross-shore profile but simply a redistribution of the sediment across the profile (Figure 34). The volume change calculated from shoreline recession must therefore be reduced to account for relative sea level rise prior to calculating the volume change used to develop the sand longshore transport rate. The shoreline retreat due to relative sea level rise was estimated to be 9.5 feet/year (Section 8.3). This was multiplied by the cell width and active profile height to determine the volumetric loss due to relative sea level rise. The volumetric loss due to relative sea level rise along the Chandeleur Islands was approximately 1,426,865 cubic yards/year (Table 13). The volumetric loss due to relative sea level rise along Breton Island was approximately 77,531 cubic yards/year (Table 14).

11.3 Overwash

The average crest elevation along the Chandeleur Islands and Breton Island is low at approximately 2 feet, NAVD. As a result, sediment is transported over the island by waves during storm events. This is the primary mechanism for island rollover. The landward movement of sediment conserves sediment within the system despite the landward shift of the shoreline. Therefore, the volume change, calculated from shoreline change, must be reduced to account for the conservation of the sediment within the system. The overwash volume was estimated using island migration rates and the bay active profile, which extends from the marsh platform to the bottom of the backing bay (bay depth of closure). The overwash volume along the Chandeleur Islands was estimated at 2,112,000 cubic yards/year, as shown in Table 13. The overwash volume along Breton Island was estimated at 83,300 cubic yards/year, as shown in Table 14. Note that where the bay shoreline retreated there is no volumetric loss of overwash.

11.4 Longshore Transport

This section discusses the longshore transport rate for the Chandeleur Islands and Breton Island. An annualized sediment budget was developed using shoreline changes, active profile heights, island composition percentages, and relative sea level rise rates.

The conservation of sand principle was used to estimate the volume of sand transported in a longshore direction. The conservation of sand equation allows for the longshore transport to be estimated using Equation 4.

$$LT_{out} = \Delta V_{total} - V_{offshore} - V_{RSLR} - V_{overwash} + LT_{in} \qquad \text{[Equation 4]}$$

where:

LT_{out} = Longshore transport out of the reach
ΔV_{total} = Volume change calculated based on shoreline change
$V_{offshore}$ = Offshore (silt) volume loss
V_{RSLR} = Volume change associated with relative sea level rise
$V_{overwash}$ = Volume of overwash
LT_{in} = Longshore transport into the reach from an adjacent cell

The various components of volume change along the Chandeleur Islands and Breton Island between 1996 and 2004 are summarized in Table 13 and Table 14, respectively. From this a volume change within each cell due to longshore transport was calculated. If the net longshore sand volume change is greater than zero then net sediment transport was out of the cell, while a negative value indicates that net sediment transport was into the cell. However, a positive or negative value for volume change due to longshore transport does not indicate the direction of longshore transport. The net longshore transport rate along the barrier island is determined by integrating these volumes in a longshore direction (Equation 4).

A starting point for the longshore transport integration must be identified. An area of zero net sediment transport (a nodal point) is the typical point at which to start such a summation because it is easier to identify an area of no net sediment transport than estimate the longshore transport at a given point. The nodal point is often located at the location with the greatest sand volume change. The greatest sand volume change along the Chandeleur Islands between 1996 and 2004 occurred near profile N-21 (located 100,201 feet south of Hewes Point). Therefore, profile N-21 was chosen as the nodal point along the Chandeleur Islands. The greatest sand volume change along Breton Island between 1996 and 2004 occurred near profile S-9 (located 17,954 feet northeast of the southwestern extent of Breton Island). Therefore, profile S-9 was chosen as the nodal point along Breton Island. Plots of the longshore sediment transport curve for the Chandeleur Islands and Breton Island are shown in Figure 36 and Figure 37, respectively.

Georgiou and Schindler (2009) suggested that the nodal point for sediment transport was closer to N-30, which is located approximately 2.5 miles north of N-21. They determined the nodal point by modeling potential sediment transport based on wave data.

Ellis and Stone (2006) suggested that the nodal point was located at approximately N-29. They also determined the nodal point based on wave modeling using 5 monochromatic wave cases.

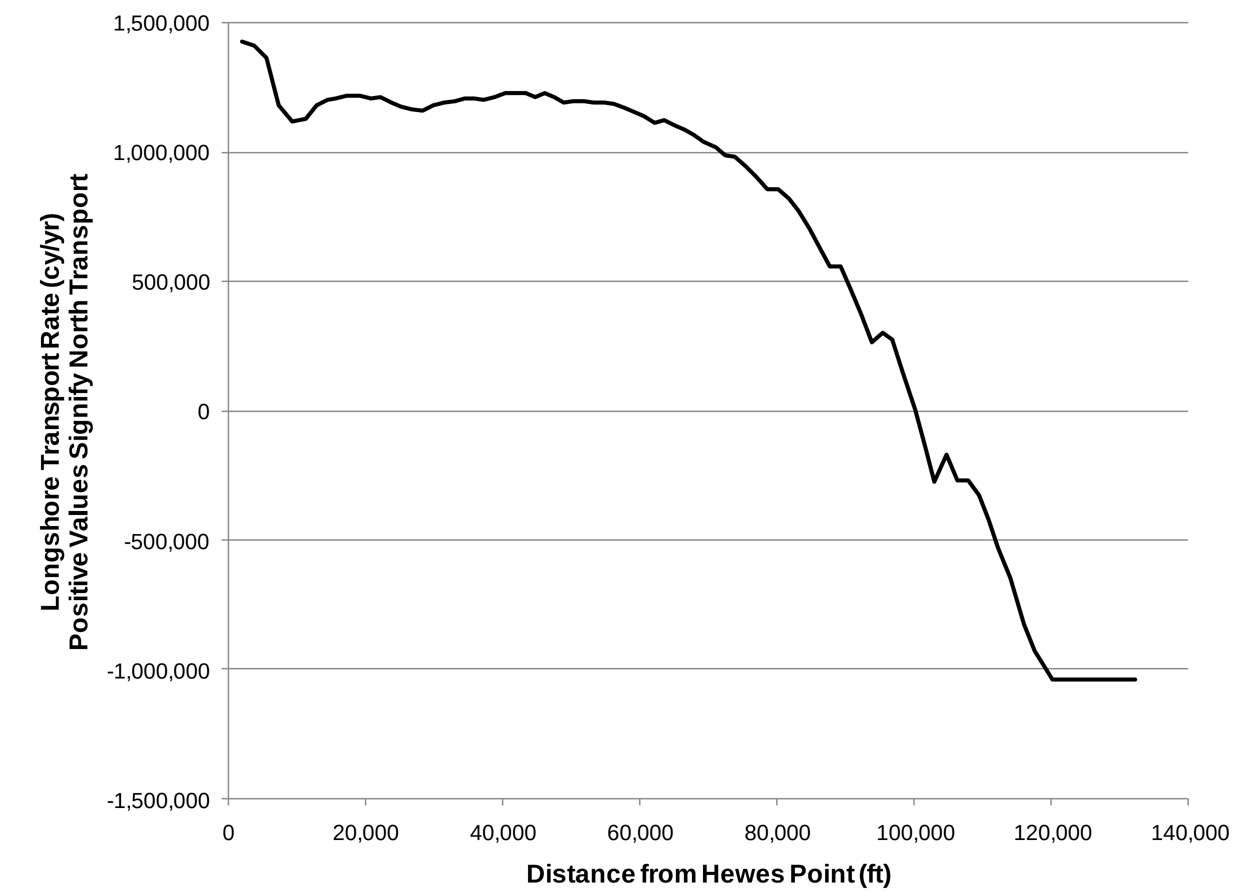


Figure 36. Longshore Sediment Transport Curve for the Chandeleur Islands (1996 to 2004)

The longshore transport curve generated for the Chandeleur Islands, shown in Figure 36, was verified using volume change estimates near Hewes Point. Analysis of BICM bathymetric data presented by Miner (2009, a) suggests that approximately 168,423,791 ± 33,574,891 cubic yards of material has accreted at Hewes Point between the 1870 and 2007. This suggests an annual accretion rate of 1,229,371 ± 245,072 cubic yards/year. The longshore transport curve generated for the North Chandeleur Islands suggests that approximately 1,218,000 cubic yards/year of sand is transported into Hewes Point, located near Profile N-75 (approximately 19,120 feet from the northern extent of Hewes Point), which verifies the analysis. Furthermore, inspection of historic shorelines suggest that the island chain is rotating around a point located somewhere along the southern half of the Chandeleur Islands, which corresponds with the nodal point further verifying the analysis.

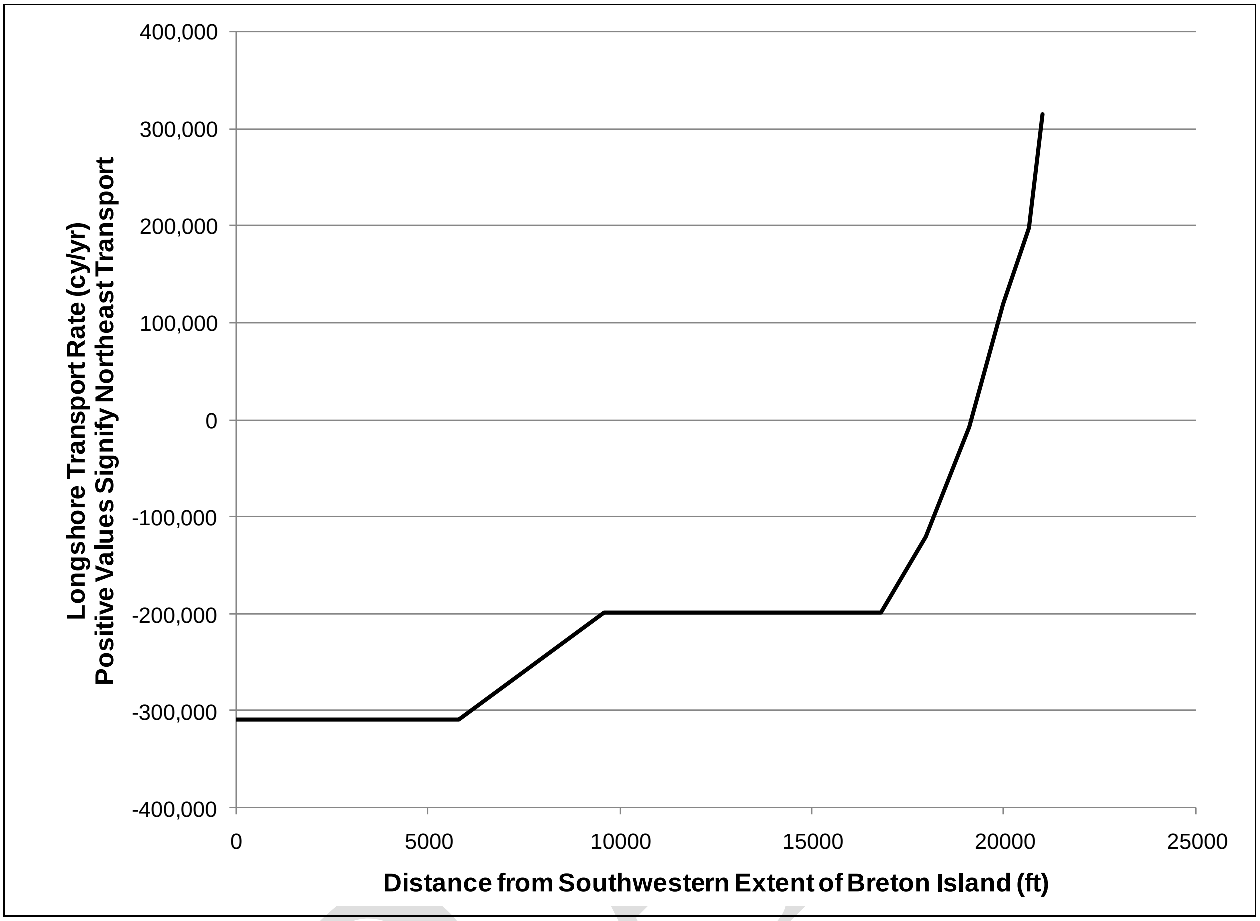


Figure 37. Longshore Sediment Transport Curve for Breton Island (1996 to 2004)

The slope of the longshore transport curve indicates whether erosion or accretion is occurring and the severity of this erosion or accretion. The steeper the slope of the longshore transport curve, the greater the associated erosion or accretion. Therefore, the longshore transport curve suggests that erosion is occurring along the entire project length. The severity of the erosion along the Chandeleur Islands increases towards the southern extent of the island chain. The severity of erosion along Breton Island increases towards the northeastern extent of the island.

The development of the longshore transport curve allows for the prediction of sediment transport under a nourished with project condition. The longshore transport rate can be applied to alternatives that are similar to the island conditions between 1996 and 2004. A summary of the various components of the sediment budget for the Chandeleur Islands and Breton Island are provided in Figure 38 and Figure 39, respectively.

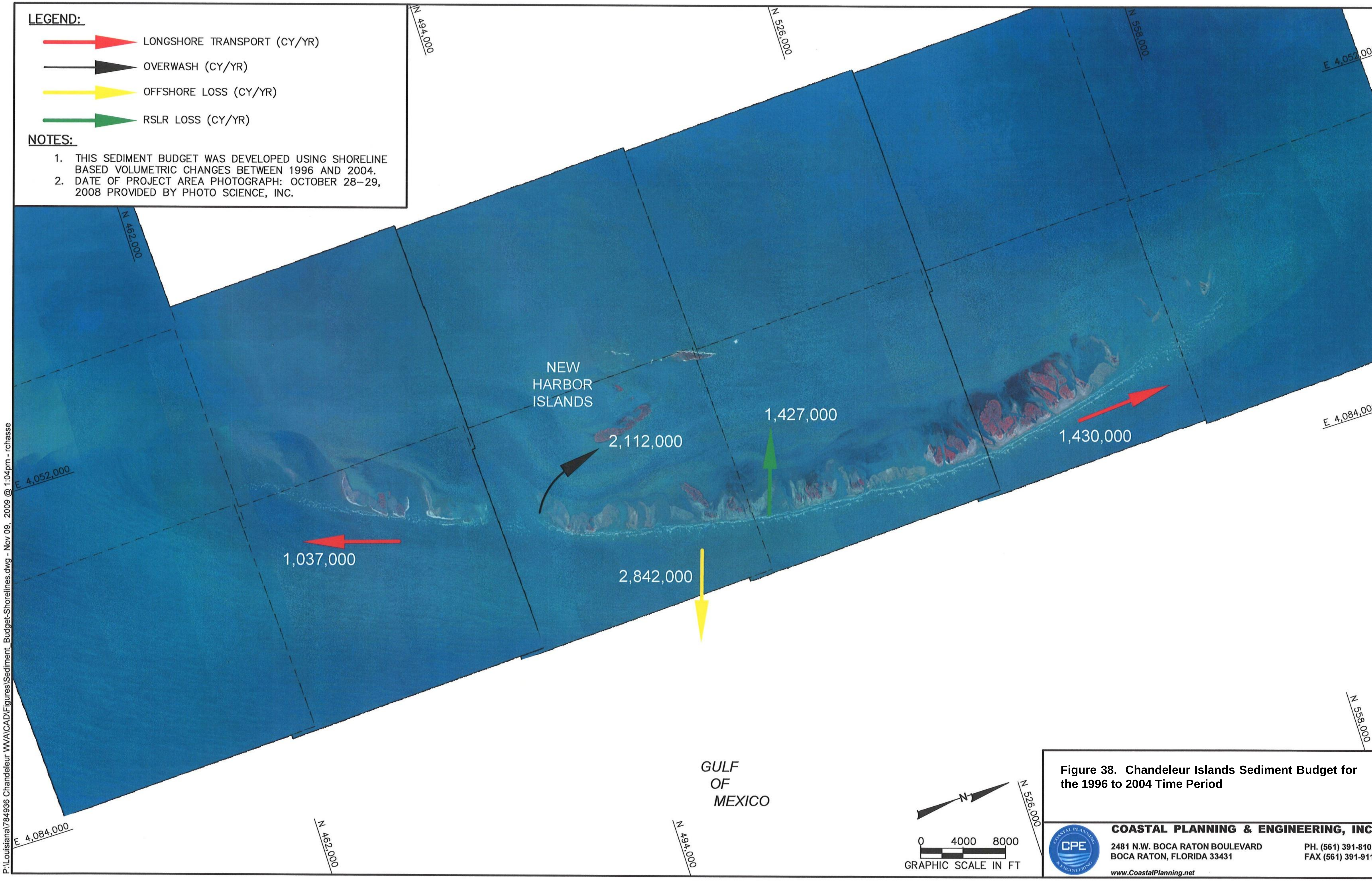


Figure 38. Chandeleur Islands Sediment Budget for the 1996 to 2004 Time Period

COASTAL PLANNING & ENGINEERING, INC.
2481 N.W. BOCA RATON BOULEVARD
BOCA RATON, FLORIDA 33431
PH. (561) 391-8102
FAX (561) 391-9116
www.CoastalPlanning.net

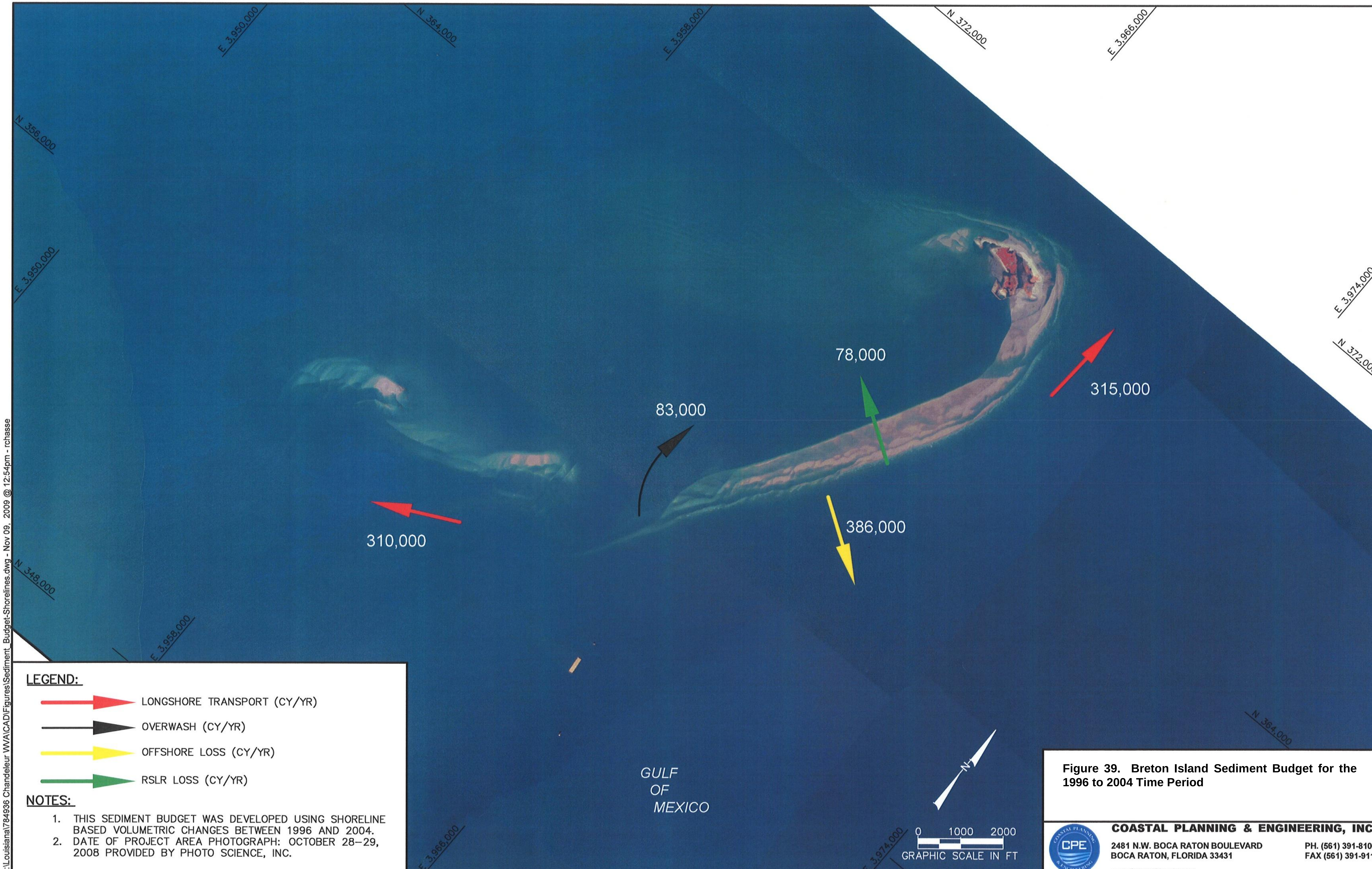


Figure 39. Breton Island Sediment Budget for the 1996 to 2004 Time Period

COASTAL PLANNING & ENGINEERING, INC.
2481 N.W. BOCA RATON BOULEVARD
BOCA RATON, FLORIDA 33431
PH. (561) 391-8102
FAX (561) 391-9116
www.CoastalPlanning.net

P:\Louisiana\784936 Chandeleur WA\CAD\Figures\Sediment_Budget-Shorelines.dwg - Nov 09, 2009 @ 12:54pm - rchasse

12 CONCEPTUAL RESTORATION DESIGN

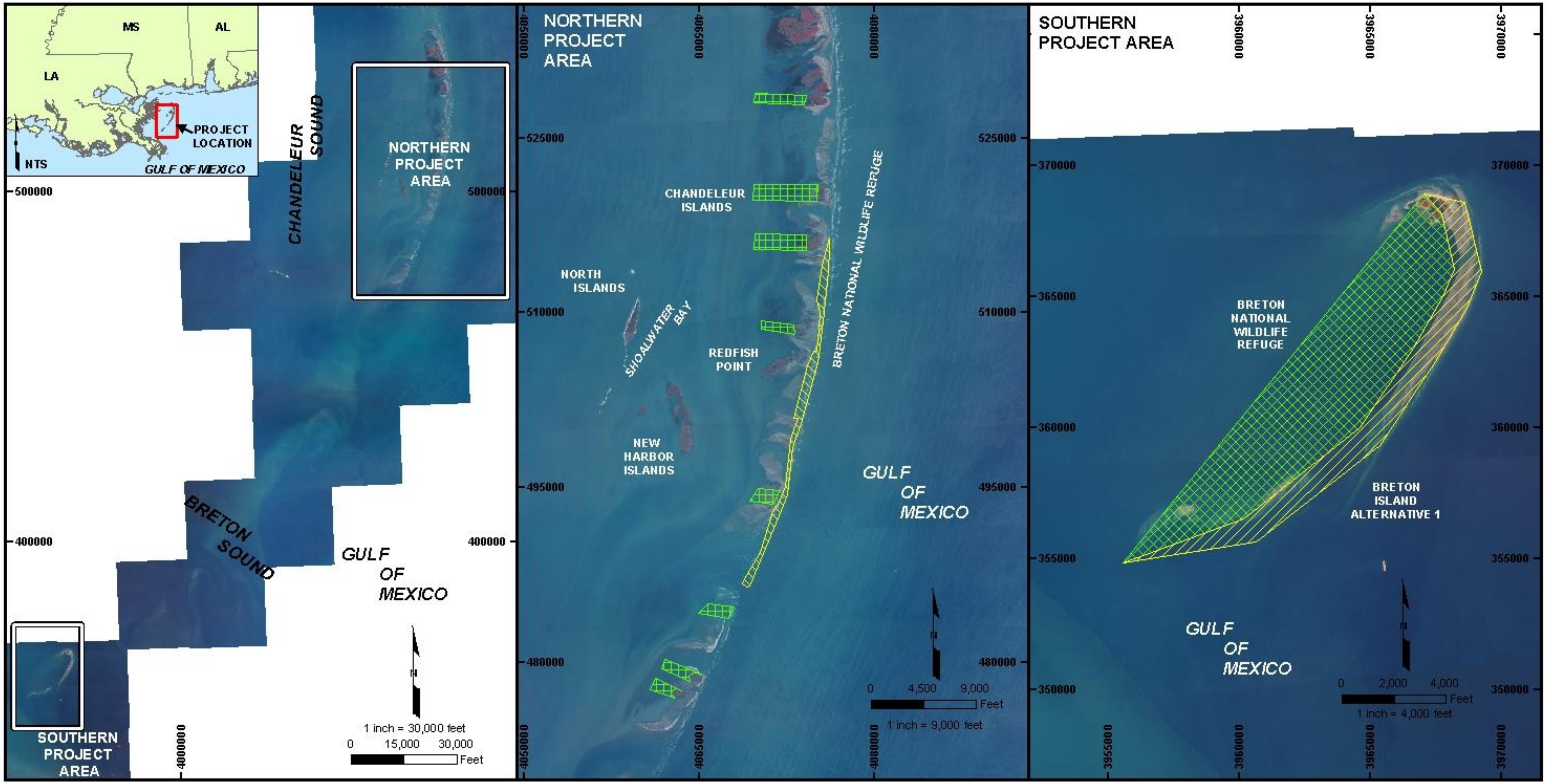
On the basis of findings from the recent framework geology, geomorphic evolution, and physical process studies by USGS, UNO-PIES, and OCPR that are summarized in the preceding sections, a conceptual design and fill template for the Chandeleur Islands was developed. This restoration design is unique with regard to other Louisiana barrier island projects because the goal is to construct a morphodynamic restoration project that utilizes the physical processes (shoreface retreat and lateral sand distribution to the flanks) to replicate the early stages of island evolution and lateral expansion for extensive period of time. By mining sand lost to the deepwater sinks at the island flanks and replacing it in a centralized location along the island arc, the same physical processes that are currently forcing the island toward submergence will be the mechanism for its reconstruction in a regime of increased sand supply. This "turning back the clock" to an early Stage 2 (see Figure 3) barrier island arc will allow for the island to maintain exposure during retreat, even in the face of increased sea-level rise rates. The proposed design is broken down into two sections that are prioritized based on predicted effectiveness and longevity: (1) Chandeleur Islands, and (2) Breton Island

12.1 Chandeleur Islands

The Chandeleur Islands have been defined as extending from Hewes Point to Monkey Bayou and includes constructing shore-perpendicular back barrier sand reserve feeder sites. Segmented clay berms will be constructed to contain the sand during hydraulic placement, prevent dispersal during storms, and provide stability to the island chain. After construction the surface of these will be planted with salt marsh vegetation. Additionally, a shore-parallel beach berm within the center of the Chandeleur Islands is proposed. In areas where islands are segmented by hurricane-cut channels, this sandy berm will be backed by a segmented clay berm.

The goal of the back barrier feeder sites is to augment and expand the role that natural relict spit deposits that underlie the marshes north of Redfish Point play in providing a long-term sand source for barrier shoreline maintenance by natural processes. As the shoreline migrates landward this sand will be liberated and introduced to the littoral system for distribution and redeposition as recurved spits, beach berms, dunes and wind tidal flats in a similar manner that characterized the post Hurricane Recovery along the northern island arc (see Figure 18 and Figure 19). The initial infusion zone and backing cohesive berm will provide a pathway for sediment transported alongshore and inhibit the loss of sand to deepwater back barrier sinks in that area.

The proposed design along the Chandeleur Islands includes a shore-parallel beach berm and eight shore-perpendicular back-barrier sand reserve feeder sites (Figure 40). The seven mile long beach berm will be constructed to an elevation of +3 feet, NAVD and be approximately 500 feet wide. The berm will be constructed on top of the existing island following the contour of the gulf shoreline. As the berm will be constructed on top of the existing island and will not be contained with a clay dike, a side slope of 1V:30H is proposed.



NOTES:

1. COORDINATES ARE IN FEET BASED ON THE LOUISIANA STATE PLANE COORDINATE SYSTEM, SOUTH ZONE, NORTH AMERICAN DATUM OF 1983 (NAD 83).
2. OCTOBER 28-29, 2008 AERIAL PHOTOGRAPHY DOWNLOADED FROM WWW.LACOAST.GOV, FLOWN BY PHOTO SCIENCE, INC.

LEGEND:

- BRETON ISLAND DUNE CREST
- BRETON ISLAND MARSH PLATFORM
- CHANDELEUR ISLAND DUNE CREST
- SAND FEEDER BERM

Figure 40. Location of Berm and Back Barrier Feeder Sites for Chandeleur and Breton Islands

COASTAL PLANNING & ENGINEERING, INC
2481 NW BOCA RATON BLVD.
BOCA RATON, FL 33431
PH. (561) 391-8102
FAX.(561) 391-9116

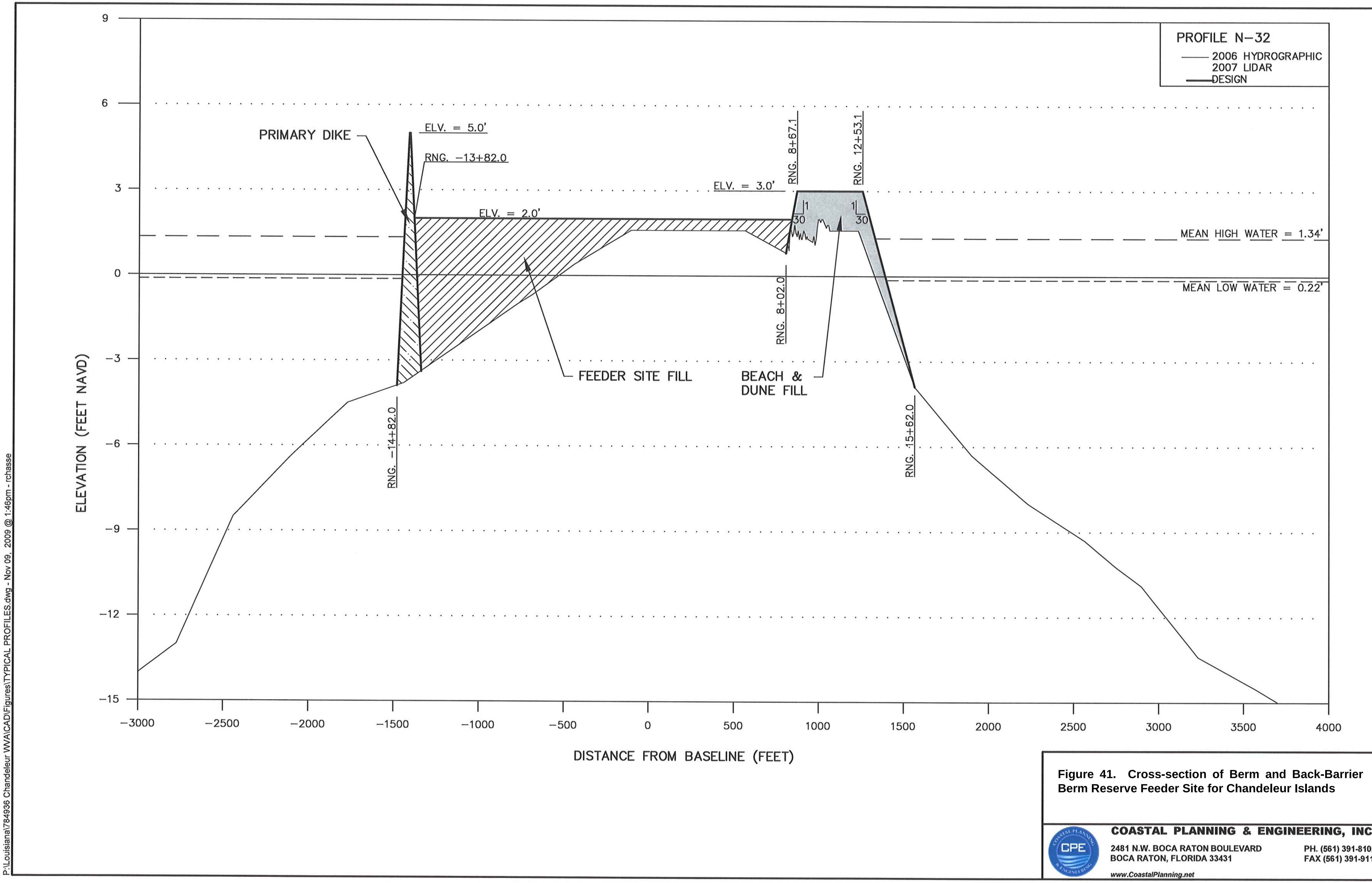


Figure 41. Cross-section of Berm and Back-Barrier Berm Reserve Feeder Site for Chandeleur Islands

COASTAL PLANNING & ENGINEERING, INC.
2481 N.W. BOCA RATON BOULEVARD
BOCA RATON, FLORIDA 33431
PH. (561) 391-8102
FAX (561) 391-9116
www.CoastalPlanning.net

The shore-perpendicular sand feeder sites will be constructed to an elevation of +2 feet, NAVD and be approximately 6,000 feet long and 1,200 feet wide. The elevation of the feeder sites was based on existing island elevations of the back bay sections and estimated using the 2007 LIDAR survey. The 2007 LIDAR provides elevations above 0 feet, NAVD that are considered valid. Most of the back bay area visible in the 2008 aerial images is between 0 and +2 feet, NAVD (Figure 40). The present mean high water and mean low water elevations are +1.34 and -0.22 feet, NAVD, respectively, suggesting that the back bay is inundated during most of the tidal cycle.

One element of the feeder site design is to optimize performance. One goal is to maximize the time period that the platform has an elevation in the bay intertidal zone for environmental function. The bay intertidal zone, as defined for the Wetland Value Assessment model (WVA), is between 0.0 and +2.0 feet, NAVD. Figure 42 shows the expected settlement of the feeder site.

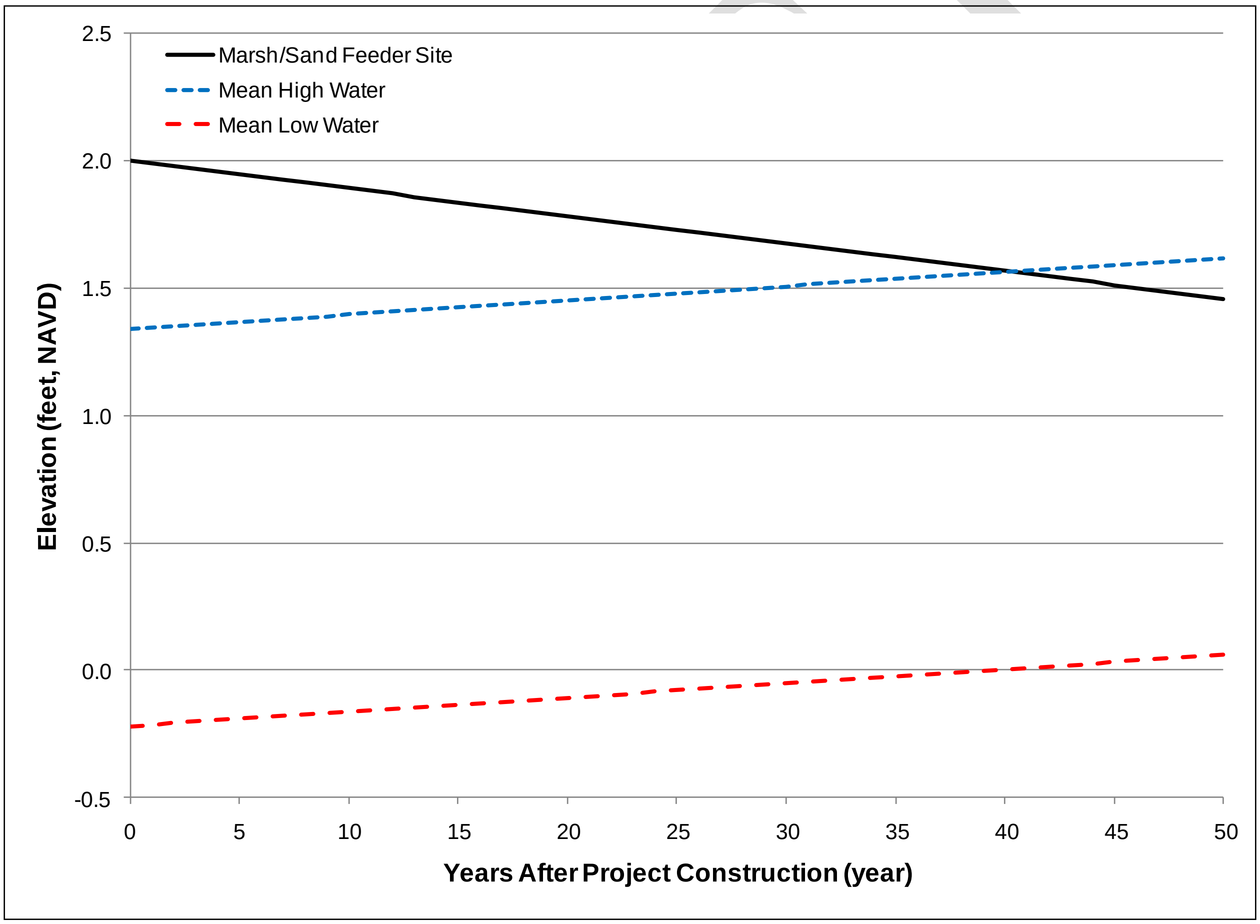


Figure 42. Marsh Settlement Curves

The feeder sites will be contained with a silt/clay dike. A primary dike with an elevation of +5 feet, NAVD and side slopes of 1V:8H are proposed along the extents of the marsh fill not bordered by beach fill. Geotechnical analyses of dike stability for previously constructed projects suggest that a freeboard of 3 feet with 1V:4H slopes would be stable during construction. A flatter dike slope is proposed for constructability purposes and will increase the safety factor. Furthermore, the high sand content and shallow water depths in the project areas suggest that these dimensions should be sufficient for dike stability.

The back-barrier sand feeder sites will be planted with salt marsh vegetation following construction.

The proposed feeder sites along the Chandeleur Islands contain approximately 4,910,000 cubic yards of fill while the berm contains 3,810,000 cubic yards. Thus, the total volume of fill required to construct the Chandeleur Islands alternative is 8,720,000 cubic yards. This volume was calculated by comparing the construction template to the 2006/2007 BICM data and then assuming 0.0108 feet/year of subsidence under the project footprint between 2007 and 2014. Losses from the island were ignored as it was assumed that the footprint could be relocated at the time of construction and the berm located on the highest ground remaining.

The footprint of the sand feeder sites along the Chandeleur Islands range from 42.2 acres to 172.5 acres, with a total footprint area of 647.7 acres.

12.2 Breton Island

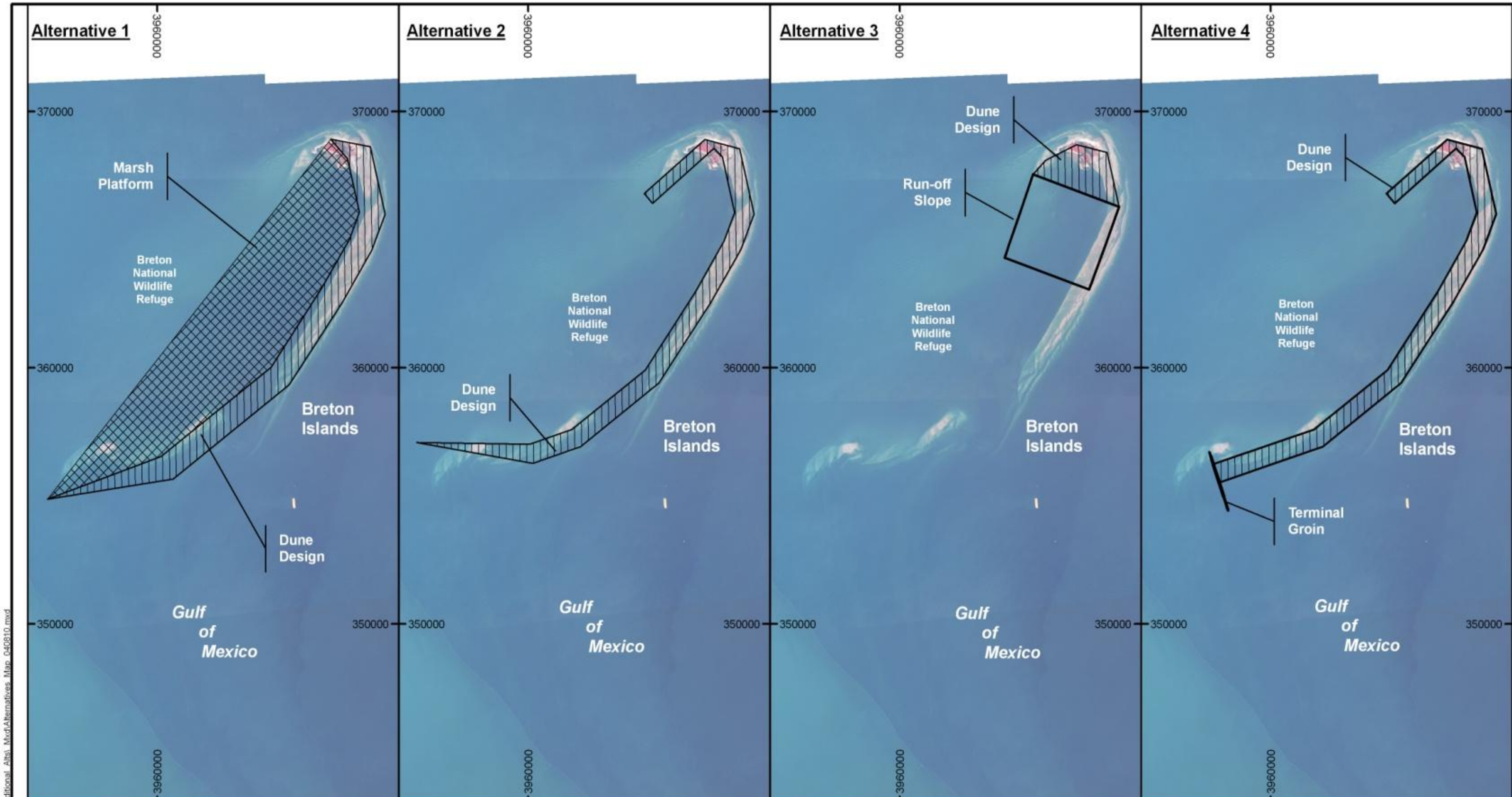
Five Alternatives were evaluated for Breton Island. These are discussed in the next sub-chapters and shown in Figure 43.

12.2.1 Breton Island Alternative 1

Alternative 1 for Breton Island consists of a beach berm that extends the entire length of the island combined with a backing marsh platform (Figure 43). The four mile long beach berm will be constructed to an elevation of +4 feet, NAVD and be approximately 1,000 feet wide. This elevation is 2 feet lower than typical construction elevations for Louisiana barrier islands. However, the lower berm elevation combined with wider dune widths are similar to dune dimensions historically observed along Louisiana barrier islands. The lower dune reduces the fill volume and thus construction cost. No steps (berm platforms) are proposed in the construction template. Additional working of the fill can increase the cost of construction and does not provide any added benefits compared to a single slope. Regardless of the constructed template, the material will be reworked into a natural profile by wave and wind action. A cross-section proposed for Alternative 1 is shown in Figure 44.

It is projected that Breton Island will exist only as a shoal at the time of construction in 2014 (see Section 13.5.1). The berm and marsh have been located to minimize construction fill volumes. A side slope of 1V:45H is proposed as some of the material will be placed below 0 feet, NAVD. Thus a flatter slope to minimize construction losses is proposed. This is the same slope as that proposed for the Holly Beach Sand Management Project, (CPE, 2003), which had a similar grain size and silt content.

The backing marsh platform will be constructed to an elevation of +2 feet, NAVD and be approximately 3,000 feet wide on average. The fine-grained marsh platform will be planted with salt marsh vegetation following construction.



Notes:

1. Coordinates are in feet based on the Louisiana State Plane Coordinate System, South Zone, North American Datum of 1983 (NAD 83).
2. October 28-29, 2008 aerial photography downloaded from www.lacoast.gov, flown by Photo Science, Inc.

N

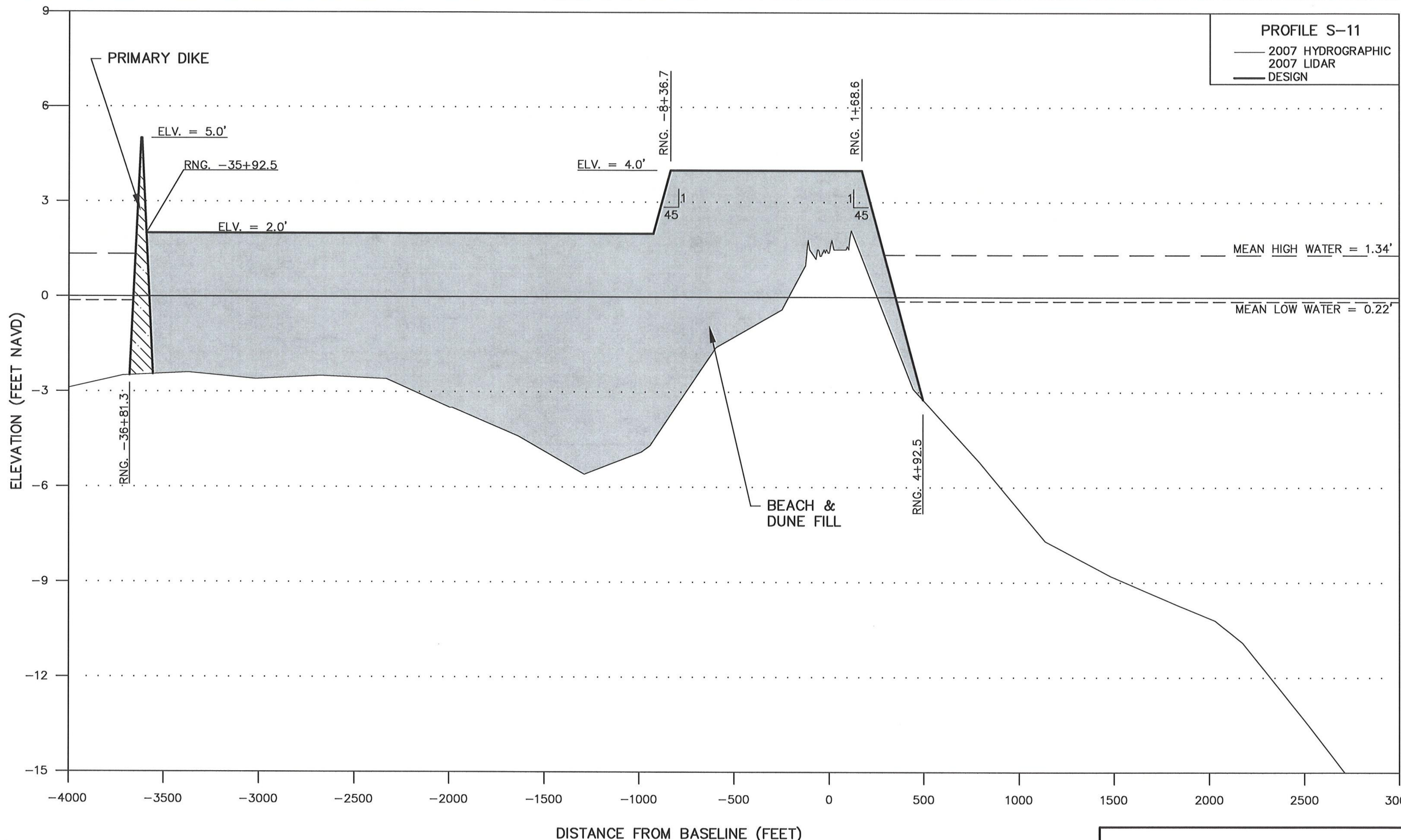
0 2,000 4,000 Feet

1 inch = 4,000 feet

Figure 43. Location of Berm and Back Barrier Feeder Sites for the various Breton Island Alternatives

COASTAL PLANNING & ENGINEERING, INC.
2481 N. W. BOCA RATON BOULEVARD
BOCA RATON, FL 33431
PH. (561) 391-8102
FAX (561) 391 9116

DATE: 04/08/10 | BY: HMV | COMM NO. : 7849.37



P:\Louisiana\784936 Chandeleur WA\CAD\Figures\TYPICAL PROFILES.dwg - Nov 09, 2009 @ 1:47pm - rchasse

Figure 44. Cross-Section of Beach and Backing Marsh for Breton Island.

COASTAL PLANNING & ENGINEERING, INC.
2481 N.W. BOCA RATON BOULEVARD
BOCA RATON, FLORIDA 33431
PH. (561) 391-8102
FAX (561) 391-9116
www.CoastalPlanning.net

It is expected that the constructed Breton Island beach template will readjust to an equilibrium beach profile in the year following construction. The Chandeleur Islands beach template is not expected to readjust as the beach template will be constructed on top of the existing dune with only small portions of the template extending below mean high water. The equilibration process assumes that there is only cross-shore redistribution of sediment and the sand volume is conserved. Below mean high water the profile is anticipated to approximate Dean's (1987) equilibrium beach profile of the form described in Equation 5. Above mean high water the seaward dune crest is expected to translate such that the sand volume is conserved.

$$y = Ax^{2/3} \qquad \text{[Equation 5]}$$

where:

y = depth below mean high water (ft)
A = 0.1071 ($ft^{1/3}$) (Dean's empirically derived coefficient for 0.12 mm grain size)
x = distance from mean high water (ft)

The constructed beach slope along Breton Island is 1V:45H from the dune crest to the construction toe of fill. For a 1V:45H offshore slope, it is anticipated that the mean high water shoreline will retreat due to profile equilibration as the offshore slope of the construction template is slightly steeper than the slope of Dean's (1987) equilibrium beach profile for the MRGO Ocean Dredged Material Disposal Site (ODMDS) borrow area sand.. The 2007 profile, construction template, and equilibrium beach profile at Station S-11 are shown in Figure 45. Assuming that volume is conserved during the equilibration process, the seaward dune crest is expected to translate approximately 11 feet landward if the MRGO ODMDS borrow area is used.

The footprint of the proposed project is 1,635 acres. It will require approximately 20,040,000 cubic yards to construct the proposed project at Breton Island. As with the Chandeleur Islands alternative (and all other Breton Island alternatives, the construction volume was calculated based on a comparison of the construction template with the BICM 2006/2007 bathymetric data and then accounting for 7 years of subsidence within the project footprint between the BICM survey and the time of construction (2014).

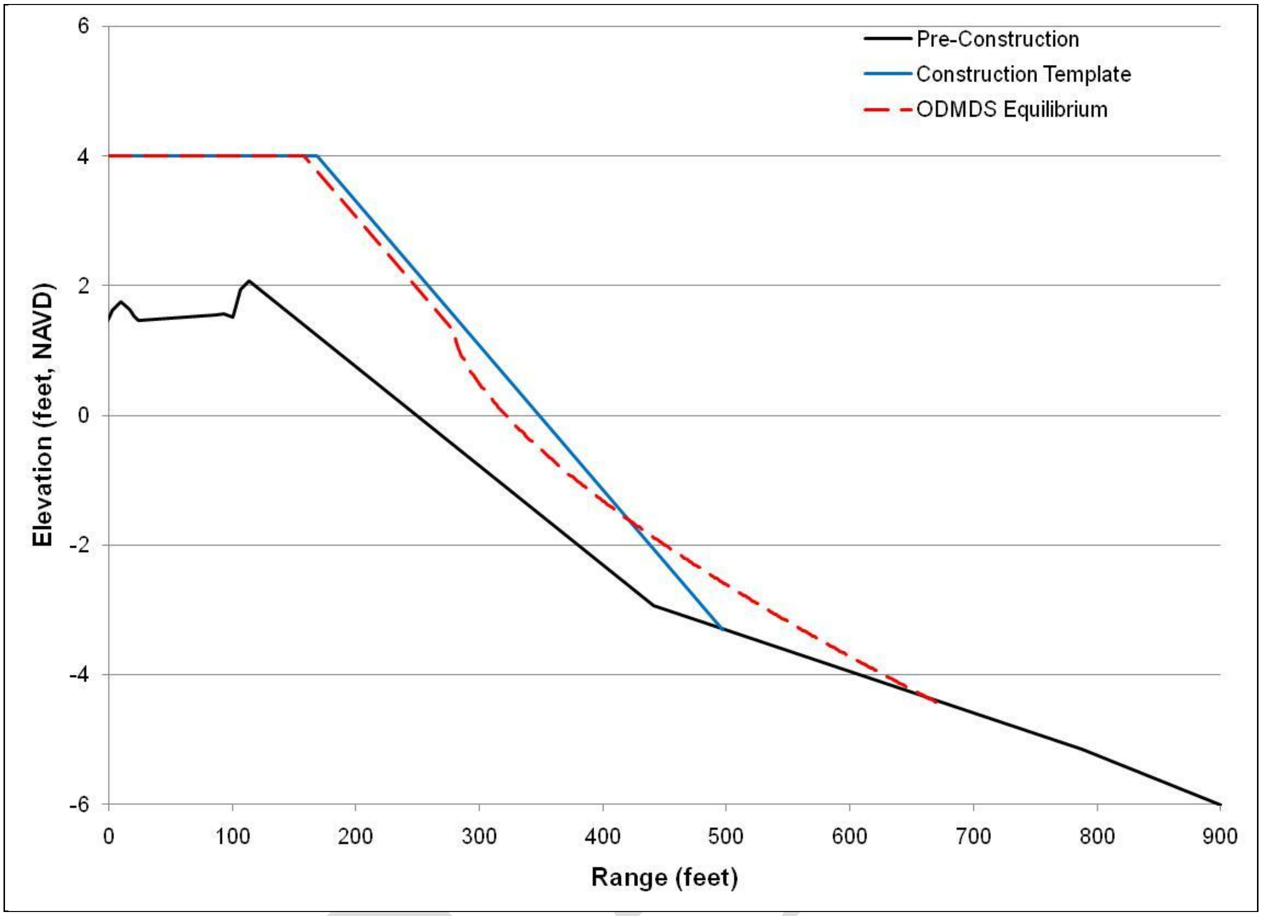


Figure 45. Equilibrium Beach Profile for Breton Island

12.2.2 Breton Island Alternative 2

Alternative 2 for Breton Island consists of a beach berm that extends the entire length of the island (Figure 43), similar to Alternative 1. The four mile long beach berm will be constructed to an elevation of +6 feet, NAVD and be approximately 750 feet wide. This elevation is 2 feet higher than Alternative 1, but typical of construction elevations for Louisiana barrier islands. Since a back barrier marsh is not proposed for this alternative, a higher dune crest is necessary to reduce the frequency of overtopping and thus material transported landward into back bay areas during overwash events. The southwest portion of the dune is curved further to the west compared to Alternative 1 in order to position the dune crest on top of the existing subaerial landmasses. This will reduce the volume of material required to construct the dune and position it so that material transported landward during overwash events will be deposited in shallower water depths and increase the stability to the barrier island system. No steps (berm platforms) are proposed in the construction template. Additional working of the fill can increase the cost of construction and does not provide any added benefits compared to a single slope. Regardless of the constructed template, the material will be reworked into a natural profile by wave and wind action. A cross-section of the proposed Alternative 2 is shown in Figure 46.

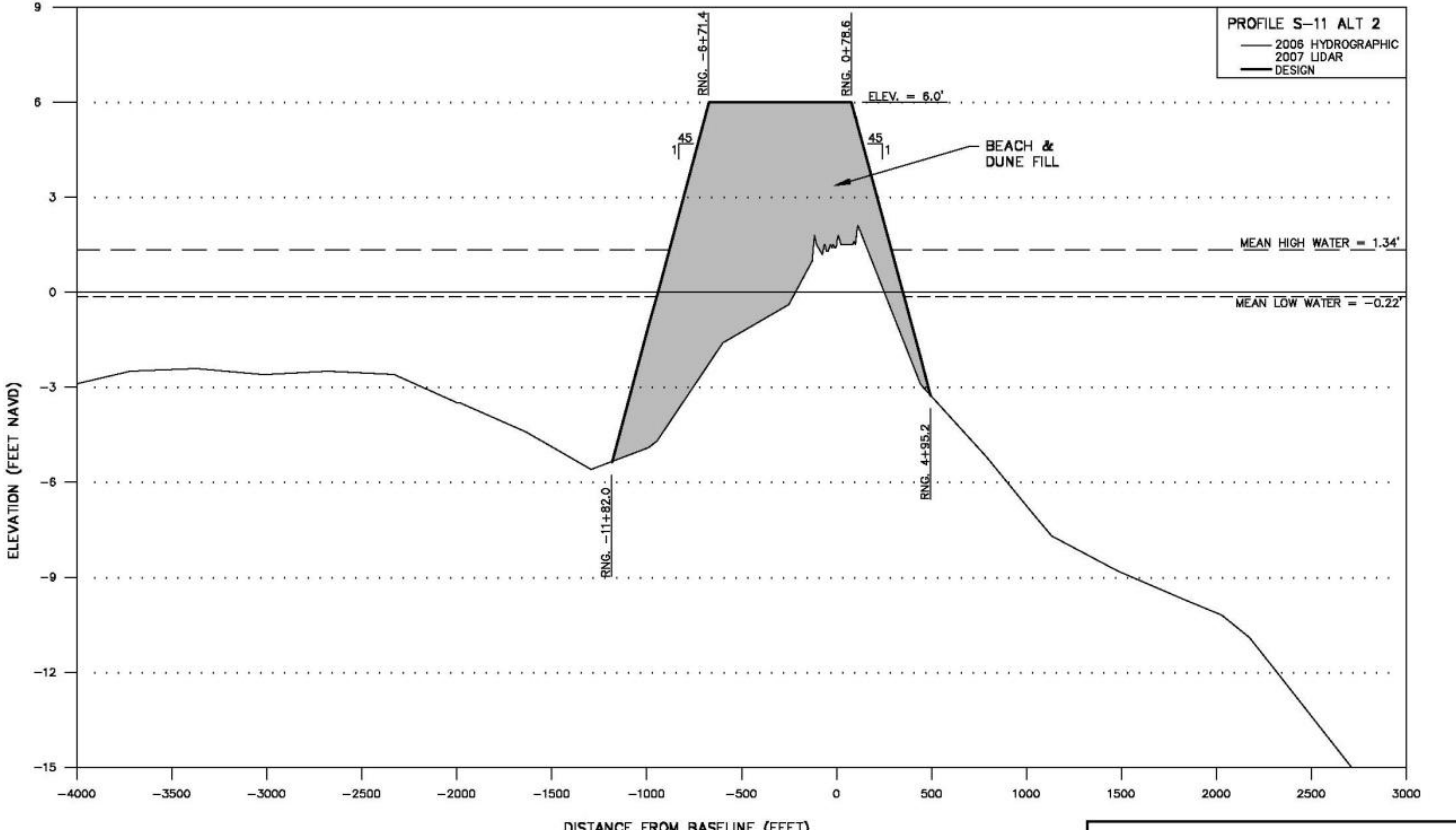


Figure 46: Cross-Section of Breton Island Alternatives 2 and 4

COASTAL PLANNING & ENGINEERING, INC.
2481 N.W. BOCA RATON BOULEVARD
BOCA RATON, FLORIDA 33431
PH. (561) 391-8102
FAX (561) 391-9116
www.CoastalPlanning.net

Included in Alternative 2, is an extension of the dune to the west around the northern end of the island. A spit feature has been indentified in aerial photographs and observed to occur by natural processes over a significant period of time. The dune template is continued around the northern extent of the project area and then approximately 500 feet southwest along the existing spit. By placing material in the area of the spit, sediment will be introduced to existing spit feature and reworked by the natural processes to armor and fortify the island along the northwest boundary of the project area. The spit provides protection to the bay shoreline of Breton Island from the wave energy generated in the large open water bay to the northwest. By reducing the wave energy directly impacting the bay shoreline, which has a higher silt content compared to the gulf shoreline, the erosion rate along the bay shoreline would be reduced and help to increase the longevity of the project. It is projected that Breton Island will exist only as a shoal at the time of construction in 2014 (see Section 13.5.1). The berm has been located to minimize construction fill volumes. A side slope of 1V:45H is proposed as some of the material will be placed below 0 feet, NAVD. Thus a flatter slope to minimize construction losses is proposed. This is the same slope as that proposed for the Holly Beach Sand Management Project, (CPE, 2003), which had a similar grain size and silt content.

The constructed beach template will readjust to an equilibrium beach profile in the year following construction. The gulf beach face will translate landward approximately 8 feet due to the same processes described for Breton Island Alternative 1, which assumes a Dean's equilibrium profile and that the ODMDS borrow area sand (~0.12 mm) is used. The landward translation is less for Alternative 2 than Alternative 1, because the dune crest for Alternative 2 is higher, which provides greater volume to redistribute per foot and thus requires less recession.

It will require approximately 9,657,000 cubic yards to construct the proposed project at Breton Island for Alternative 2. The footprint of the proposed project is 892 acres.

12.2.3 Breton Island Alternative 3

Breton Island Alternative 3 has a fundamentally different design basis than Alternatives 1 and 2. Alternative 3 was designed to minimize cost by limiting pumping distance while constructing a higher island to limit losses due to overwash. The design includes a 3,700 foot wide platform at +10 feet, NAVD, with slopes of 1V:45H along the north, east, and west sides (Figure 46) and a run-off slope of 1V:300H along the south side (Figure 47). The 1V:300H slope was based on uncontained construction slopes observed during the Chaland Headland and East Grand Terre barrier island restoration projects.

By constructing the platform at a higher elevation, the frequency of overtopping will be reduced and the transport of the sediment landward into the open water bay areas would be minimized. The platform would be subject to dispersion through the cross shore and longshore processes, which will result in sand deposition along the gulf beach face and should slow loss of silts.

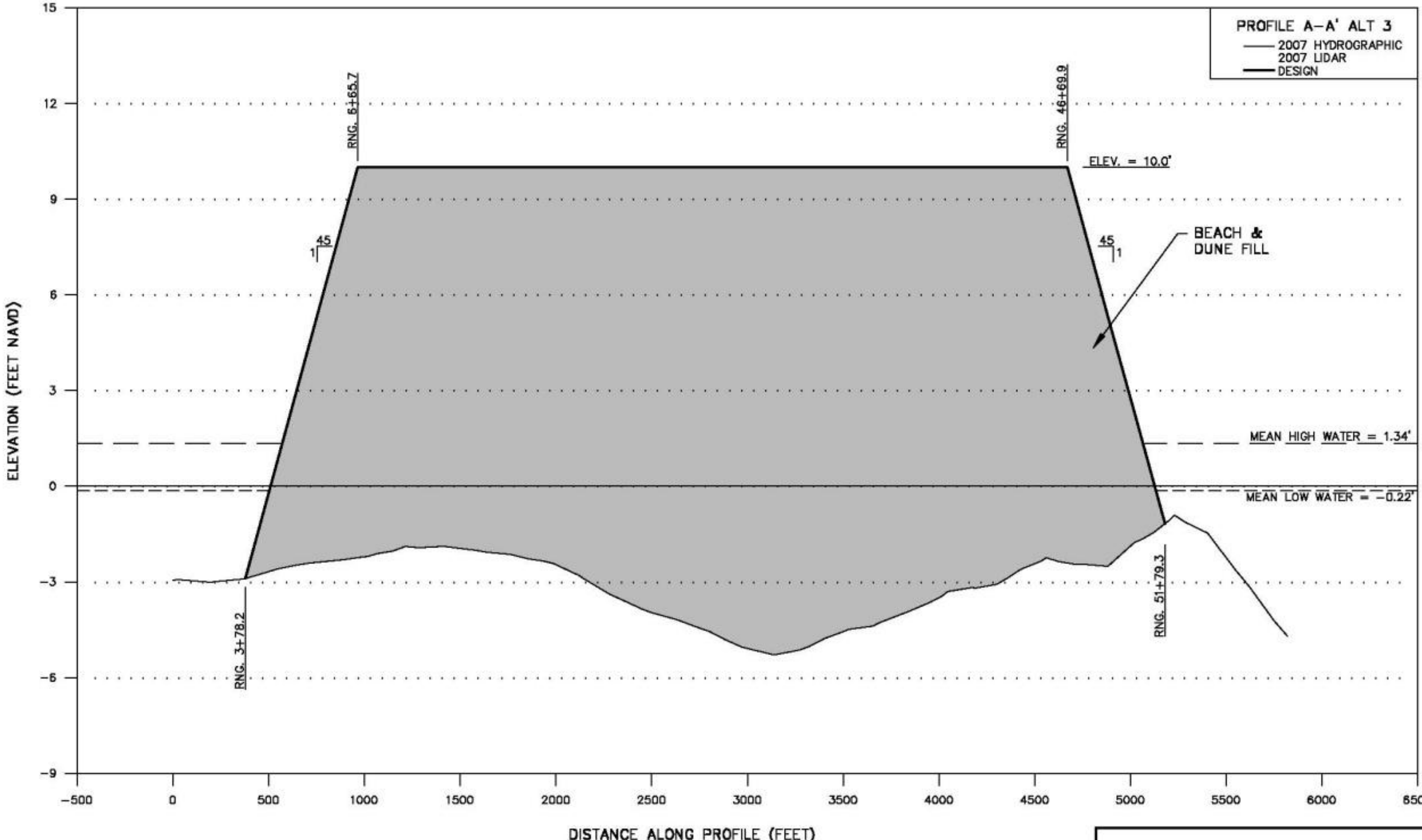


Figure 47: Cross-Section of Beach for Alternative 3 from east to west.

COASTAL PLANNING & ENGINEERING, INC.
2481 N.W. BOCA RATON BOULEVARD
BOCA RATON, FLORIDA 33431
PH. (561) 391-8102
FAX (561) 391-9116
www.CoastalPlanning.net

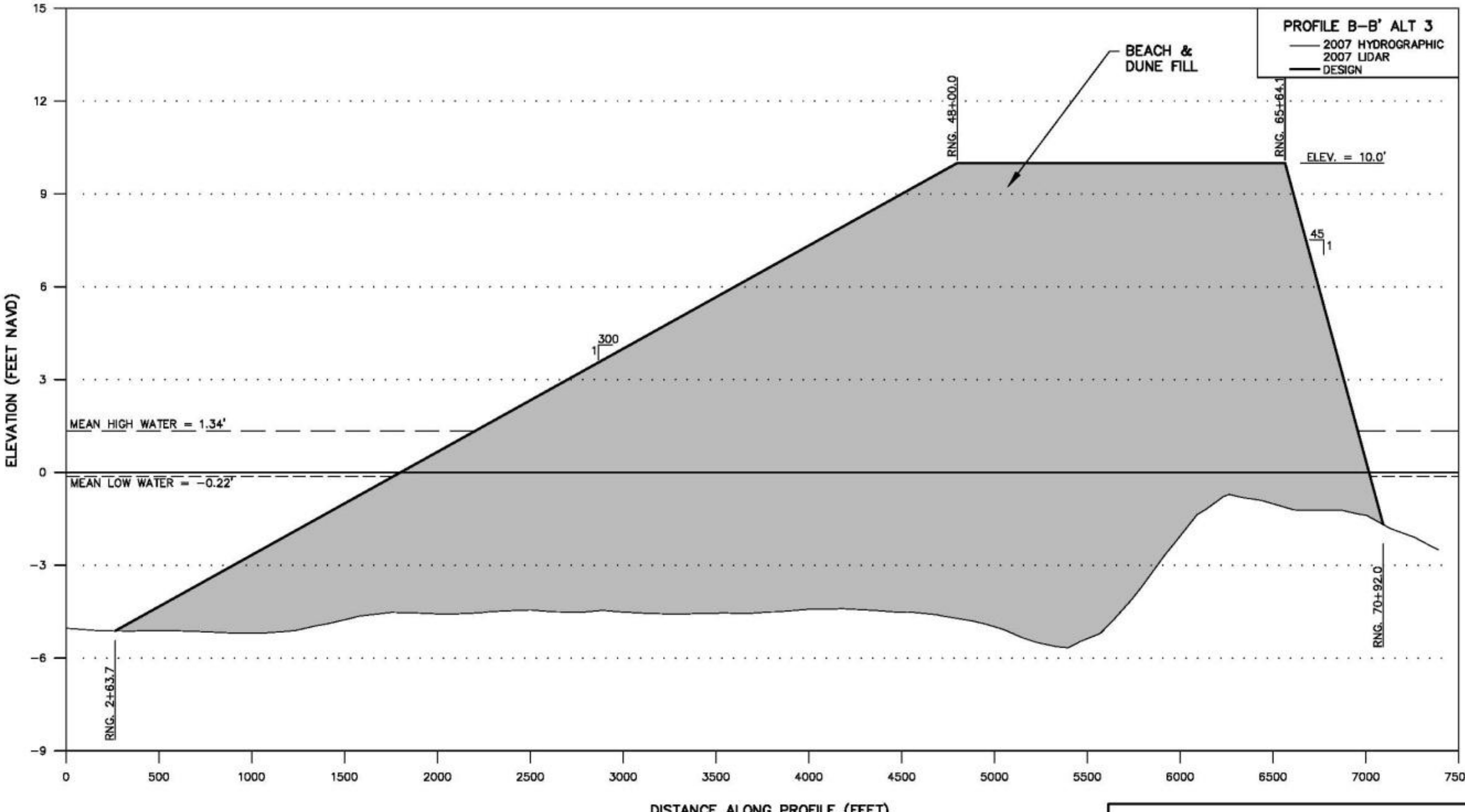


Figure 48: Cross-Section of Beach for Alternative 3 from north to south.

COASTAL PLANNING & ENGINEERING, INC.
2481 N.W. BOCA RATON BOULEVARD
BOCA RATON, FLORIDA 33431
PH. (561) 391-8102
FAX (561) 391-9116
www.CoastalPlanning.net

A slope of 1V:300H was observed in front of the discharge pipe at the Chaland Headland and East Grand Terre Restoration Projects. The intent is to let the material flow down this slope with only side containment and without extending the shore pipe. By not extending the shore pipe, friction losses within the pipe will be avoided (offsetting the loss due to initially pumping the material to a higher elevation) and production rates should remain higher. This should minimize the unit cost for the beach fill.

It is not expected that constructed beach template will readjust to an equilibrium beach profile in the year following construction given the ODMDS borrow area sand is used. The platform will be constructed on top of the existing subaerial landmasses thus reducing the water depth that the template extends below MHW. As a result, the landward translation of the constructed beach template due to the steeper construction slope compared to Dean's equilibrium profile is not expected.

It will require approximately 7,255,000 cubic yards to construct the proposed project at Breton Island for Alternative 3. The footprint of the proposed project is 616 acres.

12.2.4 Breton Island Alternative 4

12.2.4.1 Beach Fill Design

Alternative 4 for Breton Island has a similar footprint to Alternative 2 except that a terminal groin has been added to the southern end of the project. To accommodate the terminal groin, the tapered section at the southern end of Alternative 2 has been removed. The groin will help to contain the placed fill and reduce the volume of material lost to the south due to longshore sediment transport. In addition, material transported in the longshore direction will accrete at the groin forming a fillet.

As with Alternative 2, the berm crest will be constructed to an elevation of +6 feet, NAVD and will be approximately 750 feet wide. There is no backing marsh in Alternative 4. A cross-section proposed for Alternative 4 is shown in Figure 46.

It is projected that Breton Island will exist only as a shoal at the time of construction in 2014 (see Section 13.5.1). The berm has been located to minimize construction fill volumes. A side slope of 1V:45H is proposed as some of the material will be placed below 0 feet, NAVD. Thus a flatter slope to minimize construction losses is proposed. This is the same slope as that proposed for the Holly Beach Sand Management Project, (CPE, 2003), which had a similar grain size and silt content.

It is expected that the constructed beach template will readjust to an equilibrium beach profile in the year following construction. It is expected that the gulf beach face will translate landward approximately 8 feet due to the same processes described for Breton Island Alternative 2.

It will require approximately 9,382,000 cubic yards to construct the proposed project at Breton Island for Alternative 4. The footprint of the proposed project is 834 acres.

12.2.4.2 Terminal Structure Design

The longshore loss of sediment to the southwest is approximated to be 310,000 cubic yards/year (Figure 39). A terminal structure was proposed for Alternative 4 to minimize this loss of sediment from the project area. A terminal groin can be considered because there are no downdrift areas that could be negatively impacted due to an interruption of sediment supply.

The terminal groin will trap sediment transported alongshore due to the waves arriving at an angle to the shoreline. As this sand starts to build against the structure and the shoreline advances seaward forming a fillet, the incident wave angle decreases due to reorientation of the shoreline, which reduces the longshore transport. Assuming that the terminal groin is long enough and that there is sufficient sediment, the shoreline will reorient itself to minimize longshore transport by becoming perpendicular to the incident wave angle.

WIS data from Station 139 located in the Gulf of Mexico southeast of the project area was used to estimate the average incident wave direction. Offshore waves were projected from the offshore buoy location to the constructed shoreline up to the point of breaking. Due to sheltering by the Mississippi Delta a swell window from 50º to 150º was applied to isolate waves that could impact the project area. Assuming basic linear theory, shoaling, refraction and a wave height and direction relative to the shoreline at breaking was determined. These values were then applied within the CERC expression (USACE, 2002) to estimate the bulk sediment transport rate with respect to each wave condition. The sediment transport rates were averaged allowing a weighted average breaking wave height and direction to be determined based on their potential longshore transport rates. (This method incorporates the effect of wave height rather than just averaging the wave direction and accounts for larger waves arriving from a given direction.) It was determined that the approximate average breaking wave angle to the constructed shoreline was 6.8º. Therefore, the fillet should have to store sufficient sand to reduce the shoreline angle by 6.8º.

The shape of the shoreline due to the structure was determined using Walton and Chiu's (1979) analytic solution. Walton and Chiu's method is based on the formula in Equation 6:

$$\frac{Y}{2tan\alpha_o\sqrt{Kt}} = \frac{1}{\sqrt{\pi}} exp\left(\frac{-x^2}{2\sqrt{Kt}}\right) - \left(\frac{x}{2\sqrt{Kt}}\right) erfc\left(\frac{x}{2\sqrt{Kt}}\right) \quad \textbf{[Equation 6]}$$

where:

Y = Shoreline change excluding background erosion
$K = 2 C_1 H_b^{2.5} / d$
C_1 = CSPM' $(g/0.78)^{0.5} / (16 (G_s-1)(1-p))$
X = the distance alongshore
α_o = Initial wave angle at breaking depth = 6.8°
t = time
H_b = Breaking wave height = 1.5 ft
d = Berm Elevation - Depth of Closure Elevation = 28 feet
G_s = Specific gravity of beach sediment solids, G_s ~ 2.65.

p = Porosity of beach sediments, p~0.4.
CSPM' = Empirical constant usually known as "K1".

The value of CSPM' was evaluated using the USACE (1989) longshore transport equation. A net littoral transport rate of 280,000 cubic yards/year to the southwest was used based on the longshore transport rates developed in Section 11.4 and assuming that there was a 10% loss of sediment through the structure. Using this procedure, CSPM' = 0.91.

A structure that only maintains the beach fill construction template would be approximately 1,800 feet long (measured along the +2 feet, NAVD contour). It was determined that an additional 600 feet should be added to the structure in order to facilitate growth of the fillet, which helps to reduce longshore sediment transport by altering the shoreline angle.

Figure 49 shows the expected growth of the fillet assuming that sufficient sediment is available updrift and that the background retreat rate is only 10 feet/year due to relative sea level rise. Shoreline retreat due to offshore loss of silt is neglected in this initial part of the analysis.

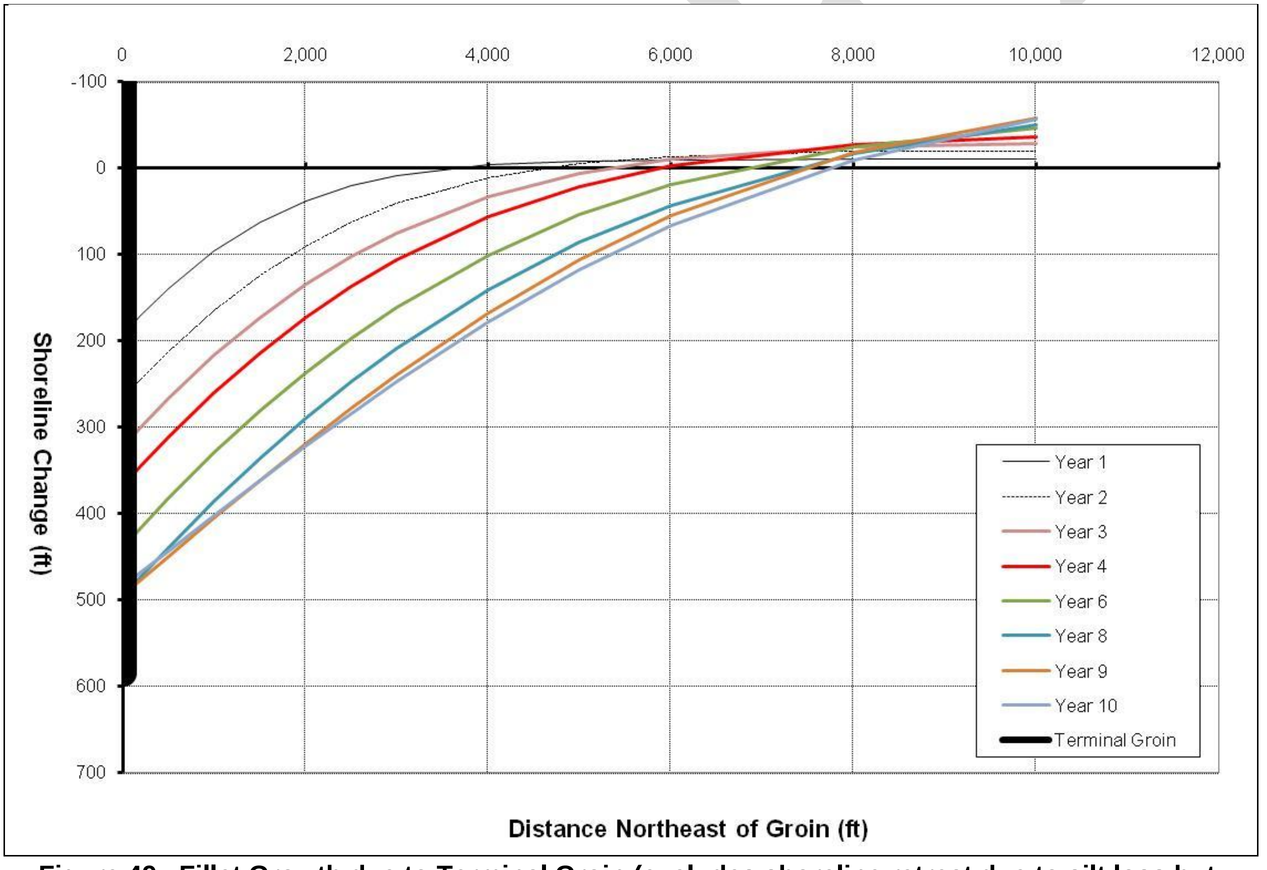


Figure 49. Fillet Growth due to Terminal Groin (excludes shoreline retreat due to silt loss but includes loss due to RSLR).

Walton and Chiu's method does not account for the complexity of Louisiana's coastal system where silt losses play a major role in shoreline retreat. A shoreline advance in Louisiana due to longshore transport infers accretion of sand from the berm crest down to the depth of closure. This effectively limits any further loss of fines by armoring the erosive face with sand.

However, updrift of the fillet, silt losses are still occurring and the shoreline is retreating more quickly. Therefore, the reorientation of the shoreline is expected to occur much more quickly than within a sand only, low retreat rate, environment.

Including the additional 600 feet gulfward to allow for growth of the fillet extends the structure length to 2,400 feet. The breakwater is tapered longitudinally to follow the equilibrium beach profile of the fillet assuming that it extends approximately 300 feet along the length of the groin. The structure will have a crest elevation of +6 feet, NAVD and side slopes of 1V:2H. A 6-foot crest elevation was chosen as the SBEACH modeling (Appendix C) suggested that the typical post-storm profile elevation is +4 feet, NAVD, and the constructed dune would be constructed to +6 feet, NAVD. Ideally, the structure should be higher than the expected profile elevation to reduce losses over the structure and as high as the constructed dune elevation for ease of construction.

The armor stone size was developed using Hudson's Equation (USACE, 2000) and assuming that granite with a minimum density of 160 pcf would be used. The worst case scenario is when the breaking wave crest is at the same elevation as the structure crest. Applying these values and a damage coefficient of 2 within Hudson's equation, gives a median stone weight of 6.1 tons and a nominal stone diameter of 4.2 feet. As the structure is between 1 and 3 armor stones high, the entire groin will be constructed with armor stone rather than trying to place a core layer and then a secondary cover layer. To allow armor stone placement directly on top of the foundation, it is proposed to use a marine mattress foundation.

The exclusive use of armor stone will result in some loss of sediment through the structure. The potential for losses due to longshore transport in the first few years, it was assumed that losses through the structure would be approximately 30,000 cubic yards/year.

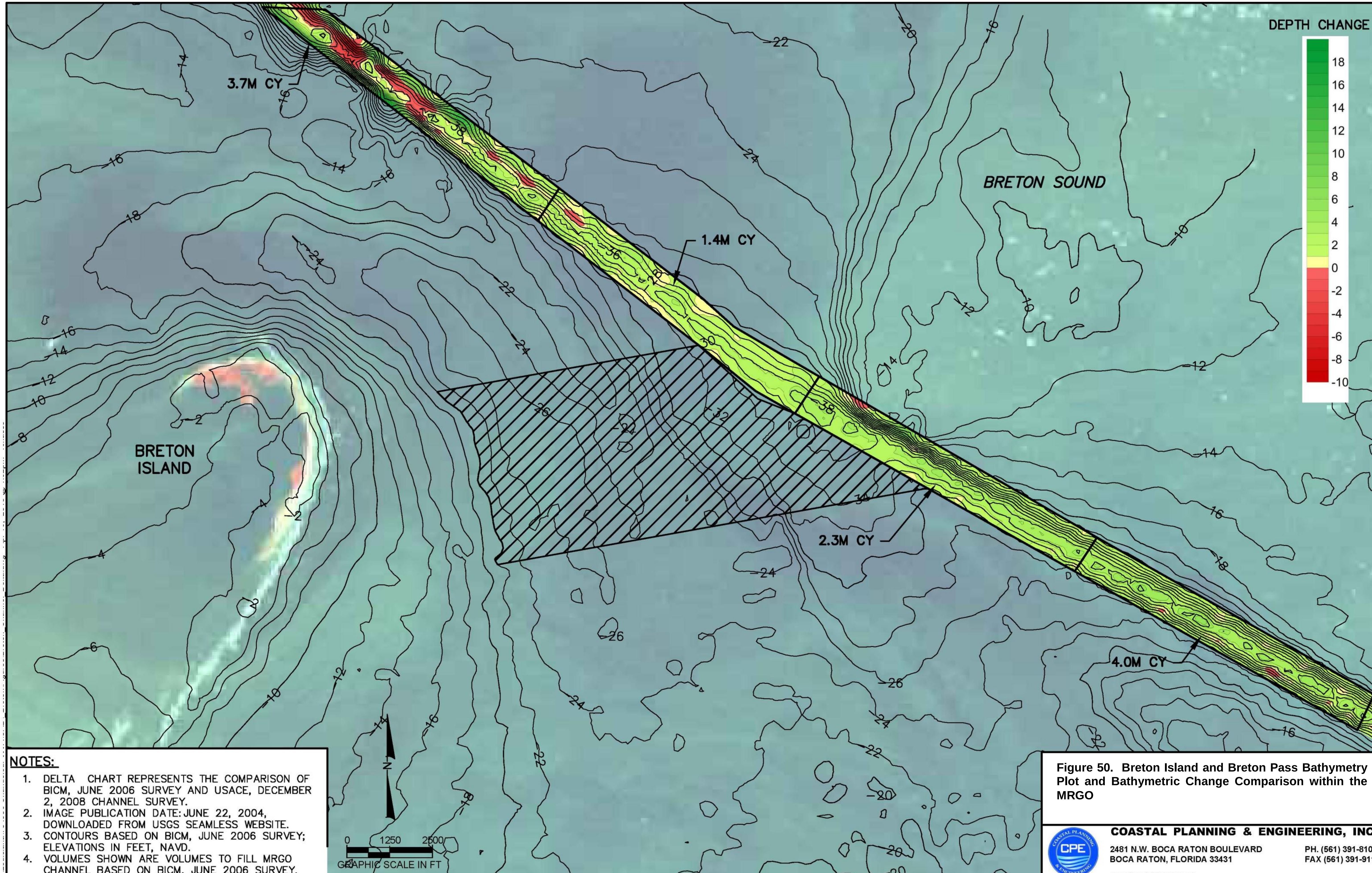
The terminal groin will require approximately 63,170 tons of armor stone and 102,000 square feet of marine mattress.

12.2.5 Breton Island Alternative 5

The fifth alternative considered for Breton Island is to restore the natural sediment transport across Breton Island Pass. The goal is that sediment within Grand Gosier Shoal would cross Breton Island Pass and help maintain Breton Island. As discussed in Section 5.3, the MRGO channel shares Breton Island Pass with the natural inlet and strong ebb tidal currents resulted in seaward transport of sand to the distal ebb shoals. However, the distal ebb shoals are located approximately 4 miles offshore of Breton Island and are now been abandoned (no longer bypassing material to the shoreline). Any sediment transport around the ebb shoal would not result in sediment being supplied to Breton Island because water depths between the abandoned ebb shoal and Breton Island range up to -26 feet, NAVD. This is deeper than the depth of closure and thus onshore movement of this sediment is not anticipated. Therefore, a new bypassing pathway (ebb shoal) would need to be created between Grand Gosier Shoal and Breton Island.

Creating a new sediment pathway would require infilling portions of the MRGO channel so that it would not continue to act as a sediment sink. Comparison of BICM survey data collected in June 2006 and a channel survey conducted by the USACE in December 2008 provided an initial assessment of the extent and location of infilling of the existing channel (Figure 50). This figure shows that infilling is occurring along almost the entire channel length though a specific bypassing location could not be identified.

It is estimated that it will require 1.4M cubic yards of sediment to fill the MRGO in the area proposed, which is located between the main mass of Grand Gosier Shoal and Breton Island. This area is approximately 2 miles long. An additional 10.9M cubic yards of sand would be required to fill the natural inlet and water depths below -22 feet NAVD located to the south of the MRGO in order to promote sediment bypassing.



NOTES:

1. DELTA CHART REPRESENTS THE COMPARISON OF BICM, JUNE 2006 SURVEY AND USACE, DECEMBER 2, 2008 CHANNEL SURVEY.
2. IMAGE PUBLICATION DATE: JUNE 22, 2004, DOWNLOADED FROM USGS SEAMLESS WEBSITE.
3. CONTOURS BASED ON BICM, JUNE 2006 SURVEY; ELEVATIONS IN FEET, NAVD.
4. VOLUMES SHOWN ARE VOLUMES TO FILL MRGO CHANNEL BASED ON BICM, JUNE 2006 SURVEY.

Figure 50. Breton Island and Breton Pass Bathymetry Plot and Bathymetric Change Comparison within the MRGO

COASTAL PLANNING & ENGINEERING, INC.
2481 N.W. BOCA RATON BOULEVARD
BOCA RATON, FLORIDA 33431
PH. (561) 391-8102
FAX (561) 391-9116
www.CoastalPlanning.net

13 PROJECT PERFORMANCE

13.1 Wetland Value Assessment

Louisiana restoration projects are typically evaluated using the Wetland Value Assessment model. The Chandeleur Islands and Breton Island benefits were calculated using the Barrier Island Community Model in accordance with guidelines prepared by William and Sweeney (2005) and the Environmental Working Group (2002 and 2007). Given that the same methodology is applied for both Chandeleur and Breton Islands, the existing island habitat is similar, and their proximity, the benefits provided by either island can be considered equivalent.

The first step in the analysis is to define the boundaries of the WVA. The project boundary used for the Chandeleur Islands WVA calculations is shown in Figure 51**.** The project boundaries were defined based on the 2006/2007 BICM bathymetry contours and an estimated seagrass boundary. The north and south boundaries were terminated at the nearest channel to the sand feeder sites. The landward boundary is defined by the extent of seagrass growth, and is open water area. The seaward boundary is defined by intertidal elevations (i.e., the 0-foot contour).

The project boundary used for the Breton Island alternatives WVA calculations is shown in Figure 52. The project boundaries were defined based on the 2006/2007 BICM bathymetry contours and the most expansive construction toes of fill to encompass all five of the alternatives. Natural boundaries such existing landmass were not used because it is expected that there will not be existing acreage applicable to the WVA analysis at the time of construction. As a result, all acreages analyzed in the WVA calculations were created during construction.

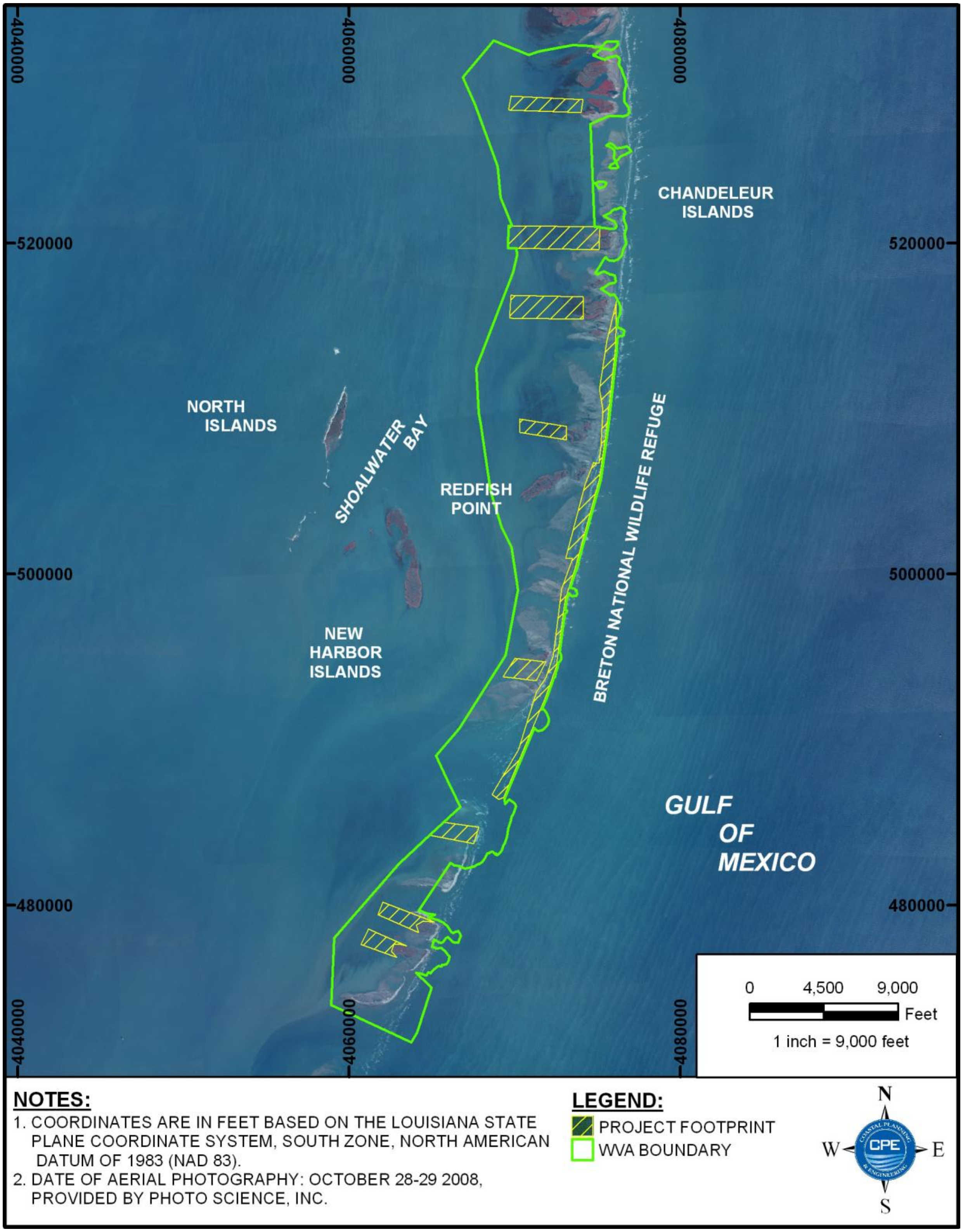


Figure 51. WVA Boundary for Chandeleur Islands

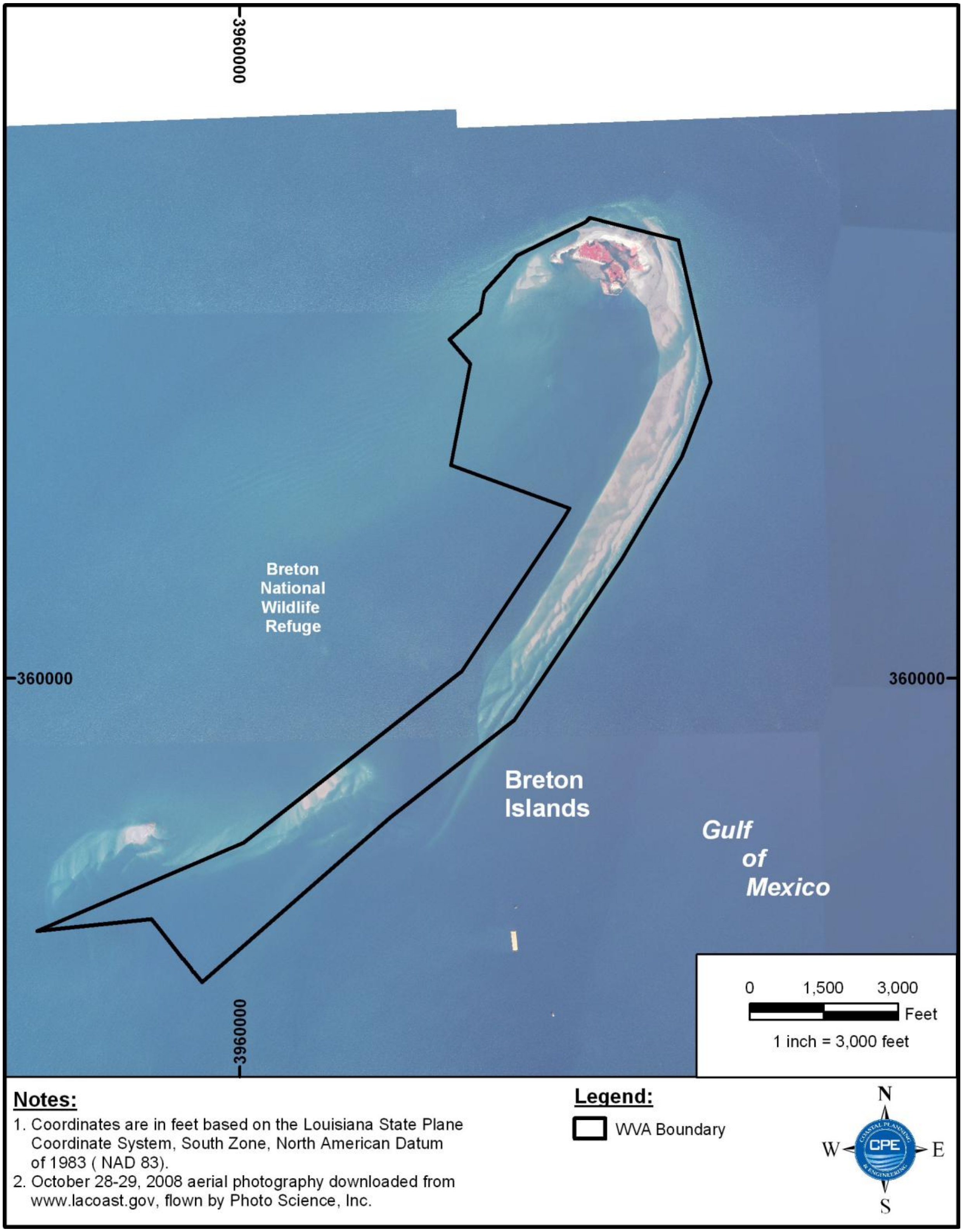


Figure 52. WVA Boundary for Breton Island

The barrier island model does not include areas of deep water (<-1.5 feet, NAVD). However, open water areas that contain seagrass beds surrounding the Chandeleur Islands are beneficial to the island's habitat. The barrier island model has been supplemented with an open water component to include the benefits of aquatic growth for the Chandeleur Islands only. A modified AAHU calculation has applied per guidance provided by Catherine Breaux of the USFWS (2009).

The delineation between gulf and bay intertidal and subtidal zones was determined using 2007 aerial images and contours. Gulf and bay intertidal area were mainly divided by the vegetation line, or where the island is impacted by gulf or bay wave action. Areas converted to deep water on the gulf side are not included in the calculation. Though the effective boundary shrinks due to subsidence and erosion, any acreage within the initial domain (encompassed by the boundary in Figure 51) is evaluated at each target year.

Once the boundaries of the WVA are defined, the next step is to determine the response of the future without-project (FWOP) and future with-project (FWP) scenarios with respect to various habitat elevations. For each target year (TY), open water (bayside), subtidal (bayside), intertidal (gulf and bay sides), supratidal, and dune acreages are required for the FWOP and FWP conditions. The range of various habitat elevations and associated descriptions are defined in Table 15.

Table 15. Habitat Description (after Williams and Sweeney, 2005)

Habitat	Description
Dune	≥ +5 feet, NAVD 88 The portions of the dune platform anticipated to be within the elevation range.
Supratidal	≥ +2 feet to ≤+4.9 feet, NAVD 88 Beach berms and portions of the fore and back slope of the dune within elevation the elevation range. Also includes primary retention/ containment dikes for the period anticipated to remain in the elevation range. Generally includes major portion of the marsh platform until the time dewatering and consolidation reduce the elevation to intertidal.
Gulf Intertidal	≥ 0 feet to ≤ +1.9 feet, NAVD 88 Gulf side beach slope / shallow open water.
Bay Intertidal	≥ 0 feet to ≤ +1.9 feet, NAVD 88 Bayside elevations including vegetated wetlands, flats and bayside open water areas.
Subtidal	0.0 to -1.5 feet, NAVD 88 or 1,000 feet bayward of the 0.0 feet contour Shallow Open water bayside area only.

FWOP values are based on survey data from 2006/07, as this is the latest date for which survey data was available, and are then eroded forward to approximate 2014 conditions, which are considered the TY0 (pre-construction) conditions.

Acreage values at the various target years are developed from an analytic model based on average predicted shoreline retreat rates, elevation change rates, and overwash. These are discussed in the sub-sections following the discussion of the WVA methodology.

WVA acreages calculated for each target year of the project life are multiplied by a Habitat Suitability Index (HSI) to yield Habitat Units (HUs). There are separate equations to calculate HSI for the barrier headland portion of the project and the emergent saline marsh component.

The barrier island model was developed to determine the sustainability of barrier island habitat to provide resting, foraging, breeding, and nursery habitat to a diverse assemblage of fish and wildlife species. Each model variable (V_x) is used to obtain a corresponding suitability index (SI) ranging from 0.0 – 1.0 from the Suitability Index graphs (Environmental Working Group, 2002). These suitability indices are then used to calculate the habitat suitability index (HSI). Equation 6 shows how the HSI is calculated for a given target year for the barrier island model.

$$HSI = 0.14(SIV_1) + 0.14(SIV_2) + 0.17(SIV_3) + 0.20\,(SIV_4) + 0.10(SIV_5) + 0.15(SIV_6) + 0.10(SIV_7) \qquad \text{[Equation 7]}$$

where:

HSI = Habitat Suitability Index
SIV_1 = Suitability index for percent of the subaerial area that is classified as dune habitat,
SIV_2 = Suitability index for percent of subaerial area that is classified as supratidal habitat,
SIV_3 = Suitability index for percent of the subaerial area that is classified as intertidal habitat,
SIV_4 = Suitability index for percent of vegetative cover of dune, supratidal and intertidal habitats,
SIV_5 = Suitability index for percent vegetative cover by woody species,
SIV_6 = Suitability index for edge and interspersion,
SIV_7 = Suitability index for beach/surf zone features, and

Calculations of the suitability index for percent dune (SIV_1), percent supratidal (SIV_2), and percent intertidal (SIV_3) acreage are based on the output from the analytical model. There is no dune present in with or without project conditions, so the SIV_1 value will remain the same for every scenario (0.1).

A list of vegetative cover species used in determining SIV_4 and SIV_5 can be found in the WVA methodology (Environmental Work Group, 2002). Percent vegetative cover is typically determined based on historic aerials and ground truthing. Future vegetative cover and woody coverage will be based on estimates made for other barrier island projects with post-construction vegetative plantings.

Edge and interspersion (SIV_6) is determined by comparing the project area to sample illustrations given in the model methodology. Each class (1-5) depicts the combination of intertidal, subaerial habitat and intra-island aquatic habitats (i.e., ponds, lagoons, tidal creeks, etc.).

Optimal aquatic organism access exists when all of the study area is accessible and the access points are entirely open and unobstructed. However, high access may indicate island degradation. Additional details are provided by the Environmental Working Group (2007).

For beach/surf zone features (SIV_7), it is assumed that a natural beach/surf zone profile provides optimal habitat conditions for fish and wildlife. Man-made structures such as breakwaters, containment dikes, and shoreline protection reduce the suitability of the zone. The classes range from a natural beach (Class 1) to where a seawall or no emergent habitat exists (Class 5). The WVA methodology (Environmental Work Group, 2002) provides examples of various beach/surf zone features and how they are classified in order to determine the suitability index.

Coastal SAV meadows are a rapidly declining critical habitat for juvenile aquatic species, sea turtles, Florida Manatee, and wintering migratory waterfowl in the northern Gulf of Mexico (Byron and Heck, 2006; Poirrier and Handley, 2006; Michot, et al 2008). Aside from their important role in providing habitat, these seagrass meadows provide essential physical benefits to the stability of the Chandeleur Islands by reducing wave energy and current velocity due to the baffling effects of the seagrass. This process results in back barrier sediment trapping (vertical accretion) and protection of back barrier marsh shorelines form wave attack in Chandeleur Sound. The latter is important at the Chandeleur Islands because of the large fetch distance across Chandeleur Sound, especially during the passage of winter cold fronts. These seagrass beds are amazingly resistant to hurricanes and recover rapidly after storms when destroyed; however, the occurrence and distribution of seagrass at the Chandeleur Islands is directly related to the presence of a fronting barrier island (Poirier and Handley, 2006; Bethel and Martinez, 2008). The island dissection and rapid land loss associated with Hurricane Katrina has resulted in decreased suitable conditions for the seagrass decolonization (Bethel and Martinez, 2008). Vegetation also provides food and cover for a variety of fish and wildlife species.

Given the factors discussed above, the barrier island model assessing Chandeleur Islands was altered to include open water area. Because of the importance of seagrass beds to the Chandeleur Islands the HET agreed to add the variable V8 % cover of submerged aquatic vegetation (SAV). The variable SIV_2 from the marsh model was incorporated into the barrier island HSI calculation to include effects of SAV. The variables from the barrier island calculation were adjusted to give V8 a weight of 10%. The modified HSI calculation used to evaluate the Chandeleur Islands is as follows:

$$HSI = 0.13(V_1) + 0.13(V_2) + 0.16(V_3) + 0.19(V_4) + 0.08\,(V_5) + \ldots$$
$$0.13(V_6) + 0.08(V_7) + 0.1(V_8) \qquad \text{[Equation 8]}$$

where:

SIV_8 = Suitability index for percent open water area covered by aquatic vegetation.

For submerged aquatic vegetative cover (SIV_8), optimal conditions are 100% cover with a linear increase starting at 0.1 for no SAV.

The HUs are annualized and averaged over the project life to determine the Average Annual Habitat Units (AAHUs). The AAHUs for future with and without project conditions are compared to determine the benefit attributable to the project in terms of quality and quantity.

13.2 Analytic Model of Habitat Acreage Change

An analytic model was developed that estimated the acreages of various habitat elevations for each alternative. The quantities and the model results for the FWOP and FWP alternatives are shown in Appendix B. A similar analytic model was applied on other Louisiana shoreline restoration projects including the Barataria Basin Barrier Shoreline Restoration Project, Shell Island component (Thomson, et al., 2008) and West Belle Pass Barrier Headland Restoration Project (TE-52) (Thomson, et al., 2009).

A summary of the key elements of the analytic model is included in the paragraphs below.

13.2.1 Longshore Losses

The fill volume required to counteract the effects of longshore transport was calculated using the longshore transport rates discussed in Section 11.4. Variations in the longshore transport rate are expected to be similar to those observed between 1996 and 2004 as the constructed shoreline is parallel to the analyzed shoreline. Transport at the north end of the project area along the Chandeleur Islands was estimated to be approximately 1,210,000 cubic yards/year to the north while longshore transport at the southern end of the project area was estimated at 325,000 cubic yards to the north at the southern end of the project area. Therefore, the total volumetric loss due to longshore transport was estimated at 1,535,000 cubic yards/year. Given an active profile height of 35 feet and future without project length of 12.3 miles, the average shoreline recession rate due to longshore loss was estimated at 18.3 feet/year. Under future with project conditions, the project length is slightly longer though the active profile height and sediment loss remains the same. This results in the FWP condition having a smaller average shoreline loss of 11.2 feet/year.

A similar analysis was performed at Breton Island. The FWOP shoreline retreat was 142 feet/year based on a net longshore transport loss of 513,000 cubic yards/year. The FWP loss was 36 feet/year based on a net longshore loss of 625,000 cubic yards. The reason for FWP having a lower shoreline recession than FWOP despite having a larger longshore transport loss is because that loss is averaged over a longer shoreline length (4 miles for FWP compared to 0.8 miles for FWOP).

13.2.2 Relative Sea Level Rise Losses

A portion of the shoreline recession is due to relative sea level rise. Shoreline recession due to relative sea level rise does not result in a net volume change in the cross-shore profile but simply a redistribution of the sediment across the profile (Figure 34). This does result in a loss of acreage and must therefore be accounted for within the project performance and benefits analysis.

The post-construction beach is expected to have a beach profile that is similar to the pre-construction beach as the grain size and percent silt in the placed fill is expected to be similar to that observed on the existing islands. Therefore, the existing shoreline recession rates due to relative sea level rise can be used when calculating advanced fill requirements. The advanced fill volume required to counteract the effects of baseline relative sea level rise along the Chandeleur Islands project area is approximately 435,000 cubic yards/year. This requires an average annual shoreline recession of almost 10 feet/year along both project areas under FWOP and FWP conditions.

13.2.3 Overwash

Analysis of recent shoreline changes, as discussed in Section 8, suggests that the dune will migrate landward due to overwash. The backing marsh helps maintain island elevation and provides a platform for the dune when rolling over. Sediment deposited on the backing marsh during overwash events provides additional elevation and volume for the dune when rolling over. SBEACH modeling was used to estimate the extent of overwash under FWOP and FWP conditions.

It was estimated that the shoreline face receded 11 feet/year due to overwash. This loss was applied to the highest remaining elevation (ie supratidal first and then gulf intertidal).

However, this loss results in acreage gain in other areas of the project boundary. There is a gain in supratidal acreage due to overwash as bay intertidal is converted to supratidal. This was estimated at both project areas to be approximately 34 feet/year based on the migration of the westernmost 2-foot contour from SBEACH. The return probability of the 1, 2, 3, 4, 5, 10, 15, 20, 50, and 100 year storms along with the overwash distances were used to determine the annual overwash distance at the 2-foot contour.

Overwash also results in the growth of the back bay. This growth can also occur due to sediment transport through the breaches but this was ignored in favor of simplification of the overwash process accounting for both processes. This growth was measured at 14 feet/year for the Chandeleur Islands (see Section 8.2.2).

13.2.4 Offshore Losses

As the islands erode, the mixed sediment body of the island becomes exposed. As discussed previously, the silt and clay are released into the water column and are considered to be transported out of the project area while the sand is transported via longshore and overwash processes.

To calculate losses due to release of silt, the total shoreline retreat rate due to longshore, overwash and relative sea level rise processes are summed and the offshore loss is then considered an additional 32% of that sum. The 32% is based on the percentage of silt and clay within the islands based on vibracore samples.

The offshore losses were held constant for FWOP and FWP conditions because the fill being added is a cap and does not extend the full face of the islands. This is considered a retreat design (USACE, 2004). Under a retreat design, the percentage of silt/clay in the island that erodes with shoreline retreat is unchanged because the erosional face of the island is unchanged.

13.3 Other Processes and Assumptions

Other processes and assumptions in the analytic habitat acreage change model include:

1. Subsidence results in conversion of one habitat type to another (bay intertidal to bay subtidal).

2. The SAV acreage decreases proportionally to the bay intertidal acreage for the Chandeleur Islands. Therefore, when all bay intertidal acreage is lost, it is assumed that all of the SAV will not survive. This is based on waves being able to impact the beds from the gulf side with only bay subtidal remaining.

3. Baseline numbers for vegetative and woody cover are based on best professional judgment of those with experience and knowledge of the island chain and an over flight (Nov 3, 2009). It was assumed that dune, supratidal, and intertidal habitats would be planted. It is recommend dune plantings include sea oats, bitter panicum, beach morning glory (if available), and Roseau (use source material for better survivability in saline conditions).

4. Existing conditions for submerged aquatic vegetative cover are based on cover of sea grass beds in 2005 post hurricane Katrina.

5. Beach/surf zone is Class 1 throughout the project life for both project areas as long as subaerial habitat exists.

13.4 Chandeleur Islands

13.4.1 Chandeleur Islands FWOP

Starting acreages were obtained from 2007 BICM bathymetry and LIDAR data. The acreages were then projected forward to the TY1 Post-Construction (2015) by incorporating 8 years of habitat acreage change. The total loss due to shoreline recession is 58.5 feet/yr. Table 16 summarizes the planform project performance for each of the habitat areas. Appendix A contains the analytic model acreage calculations.

Table 16. Planform Performance Projection for Chandeleur Islands FWOP

Target Year	Habitat (acres)						Total
	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	
TY0 Pre-Con	0	0	365	765	367	5,239	6,736
TY1 Post-Con	0	0	338	755	367	5,170	6,631
TY3	0	0	285	735	368	5,031	6,419
TY5	0	0	231	715	370	4,892	6,208
TY10	0	0	97	665	373	4,543	5,680
TY14	0	0	0	615	376	4,195	5,186
TY15	0	0	0	570	377	3,886	4,834
TY20	0	0	0	345	381	2,344	3,071
TY25	0	0	0	120	386	807	1,313
TY28	0	0	0	0	393	0	393
TY30	0	0	0	0	317	0	317
TY31	0	0	0	0	279	0	279
TY39	0	0	0	0	0	0	0
TY50	0	0	0	0	0	0	0

The Chandeleur Islands were estimated to have 50% vegetative cover from TY0 through TY3. Vegetative cover was then decreased to 0% at TY28, when the island is projected to have no remaining subaerial acreage.

There is very little woody vegetative cover on the existing islands; therefore woody cover is at 0.5% for TY0 but 0% from TY1 and on.

Percent of submerged aquatic vegetation covering open water area remains at 41% through TY28 until the back bay is unprotected from gulf wave action and the percentage reduces to 0%.

Interspersion is 100% Class 4 through TY28. With the loss of all subaerial acreage, interspersion is switched to Class 5.

The FWOP conditions for the Chandeleur Islands provide 828 AAHUs. The individual HSI calculations for the various years and habitat areas are included in Appendix A while Table 17 summarizes the overall AAHU calculation.

Table 17. Barrier Island WVA Benefits for Chandeleur Islands FWOP

Target Year	Acres	x HSI	Total HUs	Cumulative HUs
0	6736	0.383	2577	0
1	6631	0.379	2513	2545
3	6419	0.379	2433	4946
5	6208	0.360	2238	4669
10	5680	0.343	1948	10456
14	5186	0.325	1687	7263
15	4834	0.308	1487	1586
20	3071	0.299	917	5998
25	1313	0.242	317	3003
28	393	0.172	68	545
30	317	0.172	55	122
31	279	0.172	48	51
39	0	0.172	0	192
50	0	0.172	0	0
Average Annual Habitat Units				828

13.4.2 Chandeleur Islands FWP

TY1 Post-Construction combines the remaining acreage that was projected forward from 2007 overlaid with the constructed project. It was assumed that construction would account for losses during the year of construction.

Table 18 shows the performance of the various habitat types over the 50-yer project evaluation period. Note that supratidal acreage is completely lost by TY13. Gulf intertidal habitat is lost by TY24 though it is difficult to define the difference between gulf and bay intertidal without a dune. Therefore, it is preferable to state that intertidal acreage is lost by TY48. Submerged aquatic vegetation is therefore also considered lost in TY48.

Since the berm is constructed on both existing island and open water areas, two overwash values were used to include overwash of the berm in each respective area. Overwash of the berm that is backed by existing island will result in the conversion of supratidal to intertidal acreage. Overwash of the berm where is it constructed on open water will result in a loss of supratidal acreage. When supratidal acreage is lost, it is assumed that overwash will resume at the same rate as FWOP conditions. The existing islands that were not constructed upon are overwashed at the same rate as the FWOP conditions.

Vegetative cover percentages are based on the Shell Island project. In TY1, 50% of the existing island, 10% of the constructed supratidal acreage, and 25% of the constructed intertidal acres are planted. This leads to a vegetative cover percentage of 52% in TY1. Vegetative cover increases with growth on the island so that in TY3 the vegetative cover is anticipated to be 60%. In TY5 the cover is 69% before reaching a maximum cover of 70% in TY10 through TY15. The cover percentage then decreases until all cover is lost in TY48.

Table 18. Planform Performance Projection for Chandeleur Islands FWP

Target Year	Habitat (acres)						Total
	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	SAV Area	
TY0 Pre-Con	0	0	365	765	367	5,239	6,736
TY1 Post-Con	0	374	231	1,392	344	4,869	7,211
TY3	0	301	258	1,327	345	4,672	6,903
TY5	0	228	285	1,261	346	4,474	6,594
TY10	0	45	352	1,097	348	3,975	5,817
TY13	0	0	297	1,070	349	3,885	5,602
TY15	0	0	225	1,066	350	3,869	5,510
TY20	0	0	43	1,057	353	3,829	5,282
TY24	0	0	0	1,022	354	3,738	5,114
TY25	0	0	0	979	355	3,581	4,914
TY30	0	0	0	765	357	2,792	3,914
TY40	0	0	0	337	362	1,219	1,918
TY48	0	0	0	0	361	0	361
TY50	0	0	0	0	358	0	358

Woody vegetation is planted during construction so that percent woody vegetation is 5% in TY1 and increases to 10% in TY5 with additional planting and natural recruitment. Woody vegetation was assumed to remain constant at 10% from TY5 through TY20 before decreasing to 0% at TY48, the point at which all subaerial acreage is lost.

Interspersion was based on the initial construction project length. The shore parallel length of the constructed project was approximately 58% of the WVA boundary length. The 42% of the shoreline that did not have a constructed feature was assumed to be Class 4. At TY1, the 58% of the shoreline with a constructed feature was assumed to be Class 3. At Ty3, it was assumed that the constructed areas would be Class 1. Over time, the Class 1 acreage was reduced to Class 2 and then Class 3 interspersion. By TY40, all of the project area was assumed to be Class 4 and at TY50, it was assumed that the project area was Class 5 because there was no subaerial acreage remaining.

Submerged aquatic vegetation provides benefit through to TY48 when all intertidal acreage is lost. As stated previously, SAV acreage was assumed to be proportional to the subaerial acreage. The percent of submerged aquatic vegetation was estimated to start at 41% but increased to 90% by TY5 due to the benefit of sheltering provided by with project conditions. The percent SAV then decreased to 0% between TY5 and TY48.

The FWP condition for the Chandeleur Islands provides 2,292 AAHUs, and 1,464 net AAHUs, as shown in Table 19.

Table 19. Barrier Island WVA Benefits for Chandeleur Islands FWP

Target Year	Acres	x HSI	Total HUs	Cumulative HUs
0	6736	0.383	2,577	0
1	7211	0.653	4,706	3,620
3	6903	0.704	4,859	9,571
5	6594	0.717	4,729	9,589
10	5817	0.598	3,481	20,446
13	5602	0.564	3,158	9,954
15	5510	0.557	3,067	6,224
20	5282	0.547	2,890	14,891
24	5114	0.523	2,676	11,130
25	4914	0.509	2,501	2,588
30	3914	0.471	1,843	10,829
40	1918	0.406	778	12,888
48	361	0.172	62	2,875
50	358	0.000	0	62
FWP Average Annual Habitat Units				2,292
FWOP Average Annual Habitat Units				828
Net Average Annual Habitat Units				1,464

13.5 Breton Island

13.5.1 Breton Island FWOP

Starting acreages were obtained from 2007 BICM bathymetry and LIDAR data. The acreages were then projected forward to the TY1 Post-Construction (2015) by incorporating 8 years of habitat acreage change. Table 20 summarizes the planform project performance for each of the habitat areas. Appendix A contains the analytic model acreage calculations.

Table 20. Planform Performance Projection for Breton Island FWOP

Target Year	Habitat (acres)					Total
	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	
TY0 Pre-Con	0	0	0	0	0	0
TY1 Post-Con	0	0	0	0	0	0
TY50	0	0	0	0	0	0

It is estimated that the remaining acreage at Breton Island will be lost in approximately 3 to 4 years. Therefore, there is no FWOP acreage and there are no AAHU's provided by Breton Island under FWOP conditions (Table 21).

Table 21. Barrier Island WVA Benefits for Breton Island FWOP

Target Year	Acres	x HSI	Total HUs	Cumulative HUs
0	0	0.190	0	0
1	0	0.190	0	0
50	0	0.190	0	0
FWOP Average Annual Habitat Units				0

13.5.2 Breton Island Alternative 1

Given that there are no FWOP acreage by 2014, TY0 has no project acreage. Thus, the project creates all of the project acreage in TY1 (Table 22). However, loss rates and overtopping of the island results in the loss of supratidal and gulf intertidal acreage by TY9. The loss of gulf intertidal acreage is slightly misleading as gulf intertidal and bay intertidal acreage are functionally similar, given that they are constructed from the same material. Intertidal acreage is expected to remain through TY19. Due to limited overwash from bay intertidal to bay subtidal, complete loss of bay subtidal also occurs in TY19.

Table 22. Planform Performance Projection for Breton Island Alternative 1

Target Year	Habitat (acres)					Total
	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	
TY0 Pre-Con	0	0	0	0	0	0
TY1 Post-Con	0	517	49	1066	3	1634
TY3	0	373	49	1027	3	1453
TY5	0	230	49	988	4	1271
TY8	0	14	49	930	5	998
TY9	0	0	0	902	6	907
TY10	0	0	0	811	6	817
TY15	0	0	0	355	8	363
TY19	0	0	0	0	0	0
TY50	0	0	0	0	0	0

Vegetative cover is similar to the Chandeleur Islands percentages at the start of the project. In TY1, 10% of supratidal and 25% of intertidal acreage has vegetative cover resulting in a net of 21%. It then increases to 80% by TY8 and returns to 0% by TY19 when there is no subaerial acreage remaining.

Woody cover is the same as the Chandeleur Islands. It is assumed that there will be some woody vegetation plated during construction giving a TY1 woody cover of 5%. Natural recruitment increases woody cover to 10% in TY5. This percentage holds through TY8 before percent woody cover decreases to 0% in TY 19 when there is no remaining subaerial acreage.

Edge and interspersion is 100% Class 3 in TY1, 100% Class 1 in TY3. Edge and interspersion then deteriorates going through varying percentages of Class 2, Class 3, and Class 4 before becoming Class 5 in TY19 with the loss of all subaerial acreage.

The FWP conditions for Breton Island Alternative 1 provide 195 AAHUs (Table 23).

Table 23. Barrier Island WVA Benefits for Breton Island Alternative 1

Target Year	Acres	x HSI	Total HUs	Cumulative HUs
0	0	0.190	0	0
1	1635	0.647	1058	405
3	1452	0.785	1140	2207
5	1271	0.787	1000	2140
8	998	0.581	580	2342
9	908	0.517	469	524
10	817	0.499	408	438
15	363	0.451	164	1410
19	0	0.190	0	264
50	0	0.235	0	0
FWP Average Annual Habitat Units				195
FWOP Average Annual Habitat Units				0
Net Average Annual Habitat Units				195

13.5.3 Breton Island Alternative 2

Given that there are no FWOP acreage by 2014, TY0 has no project acreage. Thus, the project creates all of the project acreage in TY1 (Table 24).

Loss rates of the island results in the loss of dune acreage by TY7. Major lowering of the island also occurs in TY7 due to the decreased dune width and the 10-year storm conditions, causing the remaining dune acreage to be overwashed and lowered to supratidal acreage. After the island is lowered to supratidal elevation, it is estimated to suffer an annual shoreline loss due to overwash. Due to the lack of a backing marsh platform and limited amount of bay intertidal and subtidal acreage placed during project construction, overwashing of the island results in a net loss of acreage to the deep open water behind the project area. The intertidal and subtidal acreage are expected to remain through TY13.

Table 24. Planform Performance Projection for Breton Island Alternative 2

Target Year	Habitat (acres)					Total
	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	
TY0 Pre-Con	0	0	0	0	0	0
TY1 Post-Con	400	141	43	52	39	674
TY2	343	141	43	52	39	617
TY5	171	141	43	52	39	445
TY7	0	219	43	52	39	353
TY10	0	23	43	52	39	156
TY11	0	0	0	52	39	90
TY12	0	0	0	0	32	32
TY13	0	0	0	0	0	0
TY50	0	0	0	0	0	0

Vegetative cover is similar to the Chandeleur Islands percentages at the start of the project. In TY1, 10% of supratidal and 25% of intertidal acreage has vegetative cover resulting in a net of 7%. It then increases to 80% by TY10 and returns to 0% by TY12 when there is no subaerial acreage remaining.

Woody cover is the same as the Chandeleur Islands. It is assumed that there will be some woody vegetation plated during construction giving a TY1 woody cover of 5%. Natural recruitment increases woody cover to 10% in TY5. This percentage holds through TY10 before percent woody cover decreases to 0% in TY 12 when there is no remaining subaerial acreage.

Edge and interspersion is 100% Class 3 in TY2, 100% Class 1 in TY5. Edge and interspersion then deteriorates going through varying percentages of Class 2 and Class 3 before becoming Class 5 in TY12 with the loss of all subaerial acreage.

Alternative 2 erodes more quickly than Alternative 1 due to the narrower dune and lack of backing marsh to accumulate overwashed sediments.

The FWP conditions for Breton Island Alternative 2 provide 49 AAHUs (Table 25).

Table 25. Barrier Island WVA Benefits for Breton Island Alternative 2

Target Year	Acres	x HSI	Total HUs	Cumulative HUs
0	0	0.190	0	0
1	674	0.379	255	107
2	617	0.513	316	287
5	445	0.647	288	918
7	353	0.633	223	511
10	156	0.751	117	523
11	90	0.481	43	77
12	32	0.190	6	22
13	0	0.190	0	3
50	0	0.190	0	0
FWP Average Annual Habitat Units				49
FWOP Average Annual Habitat Units				0
Net Average Annual Habitat Units				49

13.5.4 Breton Island Alternative 3

Alternative 3 consists of the +10 ft, NAVD platform placed at the northern end of Breton Island. Given that there are no FWOP acreage by 2014, TY0 has no project acreage. Thus, the project creates all of the project acreage in TY1 (Table 26).

Loss rates of the island results in the loss of dune acreage by TY13. The island resists overwash better than the other alternatives due to the high elevation and width of the dune. Some overwash is incorporated due to overwash on the runoff slope section. Given the varying elevation of the runoff slope, overwash is incorporated starting in TY1. Once the dune is lost due to shoreline recession, the entire island will behave similarly to Alternative 1, having a low elevation fronting dune backed by a lower marsh area. Complete loss of all acreage occurs in TY20.

Table 26. Planform Performance Projection for Breton Island Alternative 3

Target Year	Habitat (acres)					Total
	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	
TY0 Pre-Con	0	0	0	0	0	0
TY1 Post-Con	271	108	15	61	46	501
TY2	247	107	15	61	46	477
TY5	176	103	15	61	46	402
TY10	58	97	15	61	46	277
TY13	0	81	15	58	46	200
TY15	0	33	15	47	46	142
TY18	0	0	3	47	46	97
TY19	0	0	0	29	46	76
TY20	0	0	0	8	46	55
TY21	0	0	0	0	30	31
TY22	0	0	0	0	0	0
TY50	0	0	0	0	0	0

Vegetative cover is similar to the Chandeleur Islands percentages at the start of the project. In TY1, 10% of supratidal and 25% of intertidal acreage has vegetative cover resulting in a net of 7%. It then increases to 80% by TY13 and returns to 0% by TY18 when there is no subaerial acreage remaining.

Woody cover is the same as the Chandeleur Islands. It is assumed that there will be some woody vegetation plated during construction giving a TY1 woody cover of 5%. Natural recruitment increases woody cover to 10% in TY5. This percentage holds through TY10 before percent woody cover decreases gradually to 0% in TY 21 when there is no remaining subaerial acreage.

Edge and interspersion is 100% Class 3 in TY2, 100% Class 1 in TY5. Edge and interspersion then deteriorates going through varying percentages of Class 2, Class 3, and Class 4 before becoming Class 5 in TY21 with the loss of all subaerial acreage.

The Alternative 3 conditions for Breton Island provide 67 AAHUs (Table 27).

Table 27. Barrier Island WVA Benefits for Breton Island Alternative 3

Target Year	Acres	x HSI	Total HUs	Cumulative HUs
0	0	0.175	0	0
1	501	0.380	190	78
2	477	0.515	246	219
5	402	0.633	255	755
10	277	0.757	210	1173
13	200	0.780	156	549
15	142	0.789	112	268
18	97	0.481	47	231
19	76	0.454	35	40
20	55	0.415	23	29
21	31	0.190	6	13
22	0	0.190	0	3
50	0	0.190	0	0
FWP Average Annual Habitat Units				67
FWOP Average Annual Habitat Units				0
Net Average Annual Habitat Units				67

13.5.5 Breton Island Alternative 4

Alternative 4 consists of a 750-foot wide dune platform at an elevation of +6.0 feet, NAVD with a terminal groin at the southwest end of the fill area. Given that there are no FWOP acreage by 2014, TY0 has no project acreage. Thus, the project creates all of the project acreage in TY1 (Table 28).

The performance analysis for Breton Island Alternative 4 was broken into two parts in order to better account for the effect of the groin. The first section extends 11,800 feet from the north of the island through to the central portion. It was analyzed similarly to Alternative 2 except that the project length was shorter. The second section extends 7,000 feet north from the terminal groin. The length of the shoreline was based on the updrift limit of the fillet after approximately 7 years. Given an average annual recession rate of 116 feet/year, the shoreline has retreated through the dune width and therefore it was assumed that there would be limited additional sand to grow the fillet.

The size of the fillet was estimated in order to develop the required length of the terminal groin, as described in Section 12.2.4.2. Shoreline retreat due to relative sea level rise and overwash was incorporated as described for the other alternatives. However, the growth of the fillet with sand fundamentally alters the silt loss rate. In year 1, it was assumed that silt losses would occur as with Alternative 2, at approximately 72 feet/year over the full 7,000 feet of the analysis length. In year 2, this loss was eliminated over the 4,000 feet where the fillet had grown (predicted using Walton and Chiu's method). The remaining 3,000 feet were assumed to have suffered a silt loss of 72 feet/year. This calculation was continued each year with a longer fillet and shorter silt loss section until TY7. Between TY7 and TY20, it was assumed that there would be no offshore silt losses as the full profile had been armored with sand. After TY20, the retreat due to relative sea level rise and overwash re-exposes the silt core and offshore silt losses restart.

Once the silt losses restart in this section of Alternative 4, intertidal and subaerial acreage is lost more quickly and Breton Island with no subaerial acreage remaining by TY24. Table 28 summarizes the total acreage for both sections of Alternative 4.

Table 28. Planform Performance Projection for Breton Island Alternative 4

Target Year	Habitat (acres)					Total
	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	
TY0 Pre-Con	0	0	0	0	0	0
TY1 Post-Con	401	63	50	51	42	608
TY2	352	69	50	51	42	565
TY5	239	83	50	51	42	467
TY7	0	278	50	51	42	422
TY10	0	163	29	51	42	287
TY11	0	153	22	22	42	241
TY12	0	142	22	14	16	195
TY13	0	132	22	14	14	183
TY20	0	59	22	14	14	109
TY22	0	15	22	14	14	65
TY23	0	0	16	14	14	45
TY24	0	0	0	4	14	19
TY25	0	0	0	0	1	1
TY26	0	0	0	0	0	0
TY50	0	0	0	0	0	0

This scenario is very complex and it is recommended that if Alternative 4 is carried forward for final design that three dimensional numerical modeling, including mixed sediment tracking, be considered to optimize the groin length and beach fill layout.

Vegetative cover is similar to the Chandeleur Islands percentages at the start of the project. In TY1, 10% of supratidal and 25% of intertidal acreage has vegetative cover resulting in a net of 6%. It then increases to 65% by TY10 and returns to 0% by TY25 when there is no subaerial acreage remaining.

Woody cover is the same as the Chandeleur Island. It is assumed that there will be some woody vegetation plated during construction giving a TY1 woody cover of 5%. Natural recruitment increases woody cover to 10% in TY5. This percentage holds through TY10 before percent woody cover decreases to 0% in TY 23 when there is no remaining subaerial acreage.

Edge and interspersion is 100% Class 5 in TY1, 100% Class 1 in TY5. Edge and interspersion then deteriorates going through varying percentages of Class 2, Class 3, and Class 4 before becoming Class 5 in TY25 with the loss of all subaerial acreage.

The FWP conditions for Breton Island Alternative 4 provide 70 AAHUs (Table 29).

Table 29. Barrier Island WVA Benefits for Breton Island Alternative 4

Target Year	Acres	x HSI	Total HUs	Cumulative HUs
0	0	0.190	0	0
1	608	0.322	196	85
2	565	0.462	261	229
5	467	0.621	290	834
7	422	0.633	267	557
10	287	0.656	188	684
11	241	0.589	142	165
12	195	0.530	103	122
13	183	0.522	96	99
20	109	0.598	65	569
22	65	0.757	49	117
23	45	0.417	19	33
24	19	0.415	8	13
25	1	0.190	0	3
26	0	0.190	0	0
50	0	0.190	0	0
FWP Average Annual Habitat Units				70
FWOP Average Annual Habitat Units				0
Net Average Annual Habitat Units				70

13.5.6 Breton Island Alternative 5

As shown in Section 13.5.1, it is not anticipated that Breton Island will have any emergent acreage remaining at the time of construction. Since Alternative 5 does not place any material to a subaerial elevation, benefits for Alternative 5 are based on the onshore movement of sediment.

Once Breton Island Pass and the MRGO are filled to depths shallower than -22 feet, NAVD, it will require several years for the material contained within the Grand Gosier Shoal to cross Breton Inlet and feed Breton Island (probably better described as Breton Shoal). Given that the sediment at Grand Gosier Shoal has not reformed as an emergent land mass, it is not expected that this material will cross Breton Island Pass and reform Breton Shoal into an emergent land mass either (Table 30). Therefore, no project benefits are anticipated from Alternative 5 (Table 31).

Table 30. Planform Performance Projection for Breton Island Alternative 5

Target Year	Habitat (acres)					
	Dune	Supratidal	Gulf Intertidal	Bay Intertidal	Bay Subtidal	Total
TY0 Pre-Con	0	0	0	0	0	0
TY1 Post-Con	0	0	0	0	0	0
TY50	0	0	0	0	0	0

Table 31. Barrier Island WVA Benefits for Breton Island Alternative 5

Target Year	Acres	x HSI	Total HUs	Cumulative HUs
0	0	0.190	0	0
1	0	0.190	0	0
50	0	0.190	0	0
FWP Average Annual Habitat Units				0
FWOP Average Annual Habitat Units				0
Net Average Annual Habitat Units				0

14 BORROW AREAS

Three areas were identified as potential sources of fill for the construction of the Chandeleur Islands and Breton Island ecosystem restoration projects: Hewes Point, Saint Bernard Shoals, and the MRGO Ocean Dredged Material Disposal Site (ODMDS) (Figure 53). A summary of the borrow area characteristics is provided in Table 32.

Table 32. Summary of Borrow Area Grain Size, Silt Content and Volumes

Borrow Area	Mean Grain Size (mm)	Percent Silt (%)	Beach Fill Volume (M cy)	Pump Distance (miles)	
				Chandeleur	Breton
Hewes Point	0.15-0.18	10	500	12	42
St. Bernard Shoals	0.13-0.21	10	251	18	34
MRGO ODMDS	0.10-0.15	<25%	>50	30	8

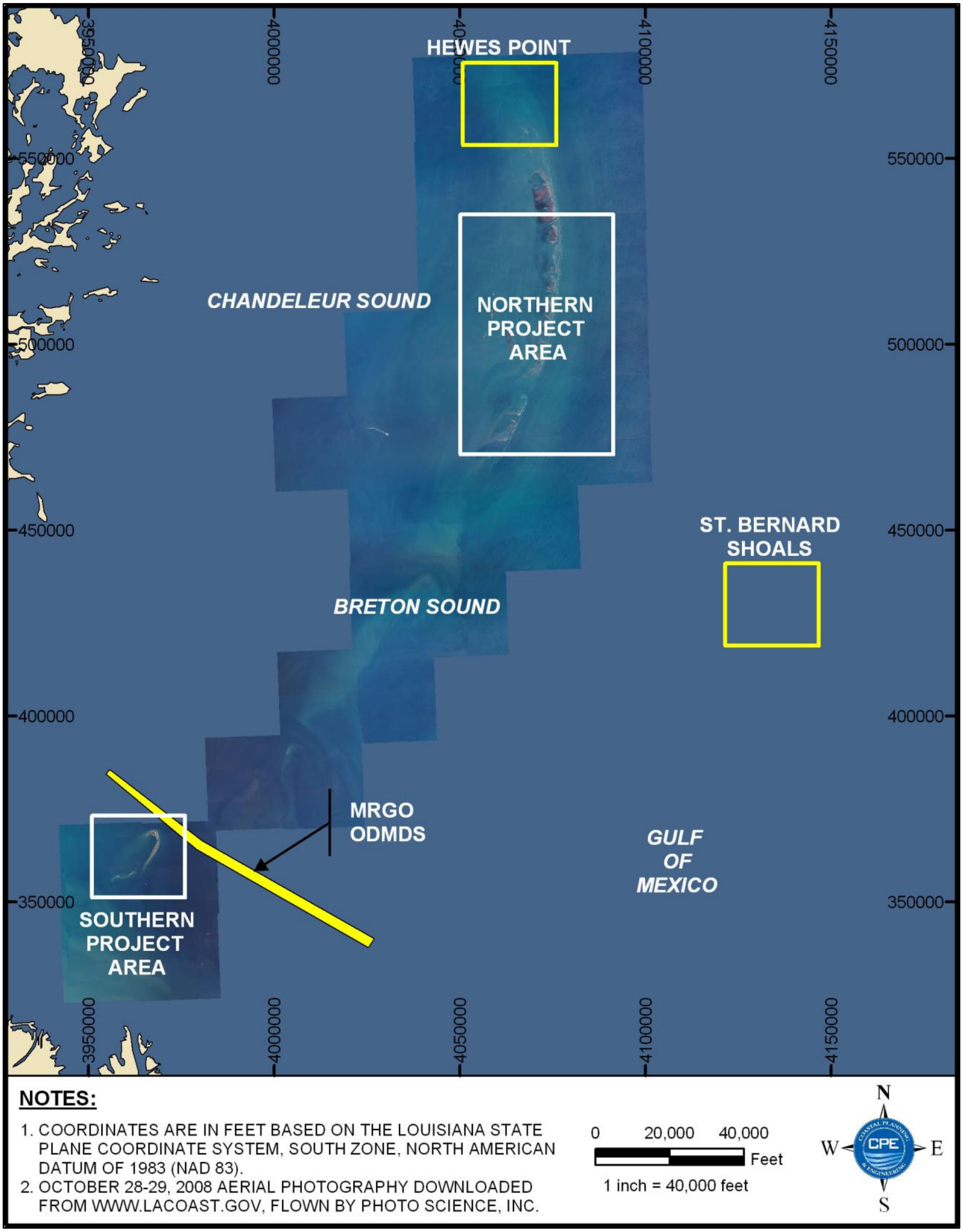


Figure 53. Borrow Area Location Map

14.1 Hewes Point Borrow Area

The Hewes Point borrow area, which is located at the northernmost end of the Chandeleur Island Chain, is approximately 12 miles north of the center of the Chandeleur Islands project site and 42 miles north-northeast of the center of the Breton Island project site. The Hewes Point borrow site consists of approximately 500M cubic yards of sand that was sourced from updrift erosion of the Chandeleur Islands (Twichell et al., 2009). This sand body lies in water depths that range from 9 to 45 feet with an average depth of approximately 15 feet, covers an area of approximately 2,500 acres and maximum sand thickness is approximately 30 feet in the northernmost section (Twichell et al., 2009; unpublished USGS and UNO-PIES vibracore and shallow seismic data). Based on seafloor change analysis, during the past 125 years this area has been the site of 170M cubic yards of sediment accretion (Miner et al., 2009a, b). These deposits consist of relatively clean sand (~90% sand) with a mean grain size diameter of 0.15 to 0.18 mm based on the top 3 feet from vibracores sampled in 2007 (Flocks et al., 2009a). Because this deposit was sourced from erosion of the barriers it is highly compatible with the existing beach sand. Moreover, mining at this site should have minimal if any negative impacts with regard to the littoral sediment budget because this sand is sequestered at the terminus of the littoral system and there are no downdrift barrier islands that will be affected.

14.2 St. Bernard Shoals

The St. Bernard Shoals are located approximately 18 miles southeast of the center of the Chandeleur Islands project site and 34 miles northeast of the center of the Breton Island project site. The St. Bernard Shoals consist of a group of discrete sand bodies ranging in size from 12 to 11,000 acres. They are low-relief sand bodies about 10 to 12 feet thick within a larger inner shelf sand body. Each shoal is approximately 3 to 4 miles wide and aligned with a northward trend (Kulp et al., 2004). Within the St. Bernard Shoals there are two distinct shoal fields, the southernmost shoal field lies in 50 to 65 feet of water and a smaller field located 3 miles northwest of the larger field is in 45 feet of water (Rogers et al., 2009).

The southern shoal field contains 251M cubic yards of sand and comprises nearly 96% of the total volume of sand in St. Bernard Shoals (Pope et al., 1993; Rogers et al. 2009a, b). The individual sand bodies are typically composed of 3 to 13 feet thick, massive, very well-sorted to well sorted (sorting coefficient of 0.27 – 0.66) moderate yellowish brown fine sand (~0.13 to 0.21 mm mean grain size; Rogers et al., 2009a, b).

14.3 MRGO Ocean Dredge Material Disposal Site

The MRGO ODMDS is located offshore of Breton Island Pass located between Mile Marker -4 and MM -9.38. Approximately 118M cubic yards of sediment was placed here during the construction and maintenance of MRGO between the 1960s and 2004. The exact volume of available sand, its grain size and silt content are unknown though it is anticipated based on disposal volume that more than 50M cubic yards should be available to reconstruct Breton Island. While exact grain size and percent silt quantities are unknown, previous projects using sands dredged in the vicinity of Breton Island suggest that the sand is beach compatible with a manageable (<25%) silt content. Grain sizes are expected to be in the 0.10 to 0.15mm range based on discussions with Weeks Marine and Ed Creef (USACE).

It should also be noted that the MRGO dissects the Breton Island Pass ebb tidal delta, a large, sand body that could also be a potential resource. This ebb tidal delta is important for inlet sediment bypassing at Breton Island Pass and nourishing adjacent barrier islands, a process that should not be interrupted by dredging. However, the adjustment of the shoal in response to the deep MRGO channel cut and associated tidal currents could have resulted in seaward progradation of this sand body leaving a "stagnant" distal ebb tidal delta that does not play a role in facilitating alongshore sand transport. If that were the case, then a viable sand resource may flank the seaward extent of the MRGO bar channel. A detailed study on the hydrodynamics of this system, the morphology of the ebb delta and dredge placement site, and subsurface investigation is needed to accurately assess the viability of this as a sand resource. The impacts of mining to the sediment transport system and how MRGO has responded (possible shoaling) to the cessation of maintenance dredging activity should also be studied prior to use of the source.

14.4 South of Breton Island

The southernmost terminal spit of the Chandeleur Island system lies south of Breton Island that is filling a large inlet between Breton Island and the Modern Mississippi Delta by lateral accretion. No subsurface data exists for this location but seafloor change analysis results demonstrate that this area has undergone significant accretion during the past 125 years approximately 235M cubic yards; similar to the processes described for the development of the Hewes Point sand body in the north. More data is needed to assess the potential as a viable sand resource target but this deposit is approximately 6 miles from the Breton Island project area.

15 CONSTRUCTION COST ESTIMATE

This section discusses the development of the construction cost estimates. The construction cost estimates are based on costs for similar barrier island projects, specifically the West Belle Pass Barrier Headland Restoration project. The West Bell Pass cost estimate (Thomson et al, 2009) was used as a baseline when developing the cost estimates for the various alternatives.

Cost estimates were developed for the Chandeleur Islands project area using the Hewes Point (cutterhead and hopper dredges) and St. Bernard Shoals (hopper dredge) borrow areas. The cost estimates developed for the Breton Island project area used the Hewes Point (hopper dredge), St. Bernard Shoals (hopper dredge), and the MRGO disposal site (cutterhead dredge). The cost spreadsheets used to develop dredging costs are included in Appendix B.

15.1 Mobilization Cost

Mobilization and demobilization expenses include the cost to prepare and transport all equipment to and from the job site. This includes towing the dredge and transporting other support vessels, transporting and installing submerged pipeline, and bringing personnel and land based equipment to the job site.

Hewes Point is located 21 miles from the furthest sand fill area. While it is possible to construct the project using a cutterhead dredge, it is more likely that a hopper dredge will be used. It is likely that dredging of St. Bernard Shoals would also require a hopper dredge given the distance from the borrow area to the project site, depth of water, and exposure of the borrow area to large waves. The -25-foot contour is located approximately 1.2 miles offshore, which is close enough that a hopper dredge hooked up to a pump-out station could unload and still pump alongshore. The pump-out station would have to be moved every 4 to 5 miles. Therefore, the hopper dredge will have to relocate the pump-out station approximately 6 times to construct the project.

The estimated mobilization cost when using a hopper dredge for the Chandeleur Islands project is $4,325,000 (Table 33). The mobilization cost for a hopper to construct the Breton Island project will be similar as the hopper dredge can use the MRGO to access the project site.

Table 33. Hopper Dredge Mobilization Cost Estimate

Item	Unit	Unit Price	Quantity	Total Price
Dredge	LS	$750,000	1	$750,000
Booster	LS	$275,000	1	$275,000
Pipeline	mile	$500,000	4	$2,000,000
Relocation	LS	$200,000	6	$1,200,000
Quarters Barge	LS	$100,000	1	$100,000
			Subtotal	**$4,325,000**

The Breton Island project could be constructed using either a hopper dredge taking material from St. Bernard Shoal or a 30” cutterhead for dredging the MRGO ODMDS borrow area. The maximum pumping distance would be approximately 10 miles (4 miles along the ODMDS and 4 miles along Breton Island). However, the large volume of material that has been disposed of and the potential to dredge the “stagnant” distal ebb shoal suggests that not all of the ODMDS length would need to be dredged. Therefore, a cost estimate has been developed based on a line length of 8 miles. The mobilization cost when using a 30” cutterhead dredge for the Breton Island project is $5,125,000.

Table 34. Cutterhead Dredge Mobilization Cost Estimate

Item	Unit	Unit Price	Quantity	Total Price
Dredge	LS	$750,000	1	$750,000
Booster	LS	$275,000	1	$275,000
Pipeline	mile	$500,000	8	$4,000,000
Quarters Barge	LS	$100,000	1	$100,000
			Subtotal	**$5,125,000**

Mobilization costs are difficult to predict because there are several variables involved. The biggest cost is the transport of pipeline to the project. This is dependent upon where the Contractor has their pipe at the time the project is due to be constructed. Obviously, the more scattered and further away the pipe, the higher the mobilization cost.

15.2 Beach Fill Dredging Unit Costs

The dredging unit cost was developed using the USACE cost estimating spreadsheets. A summary of all beach fill dredging unit costs is provided in Table 35. The lowest cost solutions are highlighted in this table. The most cost effective method ($9.50/cy) to construct the Chandeleur Islands alternative is to use a hopper dredge and material from Hewes Point. The most cost effective method to construct Breton Island Alternative 1 is using a cutterhead dredge to mine the ODMDS. This is expected to cost $6.75/cy (2009 dollars).

Table 35. Beach Fill Unit Cost Summary using a $3.75 Marine Diesel Price

Project Area	Borrow Area	Dredge	Unit Cost
Chandeleur Islands	Hewes Point	Cutterhead	$22.50
Chandeleur Islands	Hewes Point	Hopper	$9.50
Chandeleur Islands	St. Bernard Shoals	Hopper	$12.50
Breton Island	MRGO ODMDS	Cutterhead	$6.75
Breton Island	St. Bernard Shoals	Hopper	$21.50
Breton Island	Hewes Point	Hopper	$24.75

Once it was determined that dredging the ODMDS with a cutterhead dredge was the most economical method to construct Breton Island Alternative 1, the unit cost to dredge the other Breton Island alternatives was estimated. Table 36 summarizes the beach fill unit costs for the various Breton Island alternatives.

Table 36. Beach Fill Unit Cost Summary for Breton Island Alternatives

Project Area	Borrow Area	Dredge	Unit Cost
Alternative #1	MRGO ODMDS	Cutterhead	$6.75
Alternative #2	MRGO ODMDS	Cutterhead	$6.75
Alternative #3	MRGO ODMDS	Cutterhead	$6.00
Alternative #4	MRGO ODMDS	Cutterhead	$6.75
Alternative #5	MRGO ODMDS	Cutterhead	$5.00

These cost estimates are highly dependent on the workload of the dredge fleet at the time of bidding and the estimate provided is based on the existing fleet capabilities and workload. The cost estimate spreadsheets are included in Appendix B but a summary of some critical parameters are discussed here.

It was assumed that either a 30” cutterhead dredge or a medium sized hopper dredge would be used to construct the beach, marsh, and sand reserve feeder sites. The non-pay loss was assumed to be 15% based on the measured non-pay loss at Holly Beach, where the sediment size and silt content were similar. Downtime was assumed to be 30%. This value is based on the observed downtime at Chaland Headland. Downtime at Holly Beach was higher (approximately 64%) but included the passage of two hurricanes and recurring issues with the submerged line).

A fuel price of $3.75/gallon was used within the USACE spreadsheets, based on the peak price of marine diesel in August 2008. Current (December 2009) marine diesel prices are approximately $2.75/gallon. Unit costs within the USACE spreadsheets are sensitive to marine diesel prices. For example the cost for hopper dredging Hewes Point would be $8.75/cy if marine diesel was $2.75/gallon while the unit cost for a cutterhead at Breton would be $6.00/cy.

The spreadsheet estimates were quasi-calibrated to recent construction bid amounts (specifically East Grand Terre, BA-30, and Pass La Mer to Grand Bayou, BA-35). However, the unit costs shown here represent an opinion and are subject to market forces, such as the availability of equipment, the increasing cost of fuel, etc.

15.3 Marsh Fill Dredging Unit Costs

The unit cost of the marsh and the sand reserve feeder site fill was assumed to be the same as the beach fill unit cost. Both the Chandeleur Islands and Breton Island Alternative 1 projects will be constructing a backing platform to catch washover deposits; however, the project description states that these platforms will be constructed using fine grained sands.

15.4 Terminal Groin Cost

The cost of the terminal groin proposed for Alternative 4 was estimated to cost approximately $12,965,000. The cost of the structure would be significant to the overall project cost, but the groin would reduce the volume of beach fill material required by eliminating the tapered portion of the dune proposed in Alternative 2. The itemized cost of the groin is shown in Table 37. The unit cost for the individual items deemed necessary to construct the groin were acquired from past rip-rap shoreline protection projects for Louisiana inland areas. The costs were adjusted based on the assumption that construction in exposed gulf locations would require greater resources and risks to the contractor.

Table 37. Construction Cost Estimate for the Alternative 4 Terminal Groin

Description	Quantity	Type	Unit Price	Amount
Mob/Demobilization	1	LS	$400,000	$400,000
Marine Mattress	101,993	S.F.	$35	$3,569,748
Armor Stone	63,170	Tons	$100	$6,317,000
Surveys	1	LS	$75,000	$75,000
Groin Markers	2	Each	$5,000	$10,000
Subtotal (rounded)				**$10,372,000**
25% Contingency (rounded)				**$2,593,000**
Total Project Cost (rounded)				**$12,965,000**

15.5 Other Costs

Costs for primary dikes and pre and post construction surveys were based on costs for similar projects that have been bid recently (East Grand Terre Island Restoration (BA-30) and Pass Chaland to Grand Bayou Pass (BA-35) projects).

15.6 Cost Estimates

Cost estimates for the Chandeleur and Breton Island projects are provided in Table 38 through Table 43. A 25% contingency has been applied, which is standard at this preliminary design phase.

Table 38. Construction Cost Estimate for the Chandeleur Islands Alternative

Description	Quantity	Type	Unit Price	Amount
Mob/Demobilization	1	LS	$4,325,000	$4,325,000
Beach Fill	3,810,000	CY	$9.50	$36,195,000
Marsh Fill	4,910,000	CY	$9.50	$46,645,000
Primary Dikes	73,000	LF	$108.00	$7,884,000
Pre-Construction Survey	1	LS	$330,000	$330,000
As-Built Survey	1	LS	$275,000	$275,000
Subtotal (rounded)				**$95,654,000**
25% Contingency (rounded)				**$23,914,000**
Total Project Cost (rounded)				**$119,568,000**

Table 39. Construction Cost Estimate for the Breton Island Alternative 1

Description	Quantity	Type	Unit Price	Amount
Mob/Demobilization	1	LS	$5,125,000	$5,125,000
Beach Fill	8,550,000	CY	$6.75	$57,712,500
Marsh Fill	11,490,000	CY	$6.75	$77,557,500
Primary Dikes	18,000	LF	$108.00	$1,944,000
Pre-Construction Survey	1	LS	$250,000	$250,000
As-Built Survey	1	LS	$200,000	$200,000
Subtotal (rounded)				**$142,789,000**
25% Contingency (rounded)				**$35,697,000**
Total Project Cost (rounded)				**$178,486,000**

Table 40. Construction Cost Estimate for the Breton Island Alternative 2

Description	Quantity	Type	Unit Price	Amount
Mob/Demobilization	1	LS	$5,125,000	$5,125,000
Beach Fill	9,657,000	CY	$6.75	$65,184,750
Pre-Construction Survey	1	LS	$250,000	$250,000
As-Built Survey	1	LS	$200,000	$200,000
Subtotal (rounded)				**$70,759,750**
25% Contingency (rounded)				**$17,690,000**
Total Project Cost (rounded)				**$88,450,000**

Table 41. Construction Cost Estimate for the Breton Island Alternative 3

Description	Quantity	Type	Unit Price	Amount
Mob/Demobilization	1	LS	$5,125,000	$4,850,000
Beach Fill	7,255,000	CY	$6.00	$43,530,000
Pre-Construction Survey	1	LS	$250,000	$250,000
As-Built Survey	1	LS	$200,000	$200,000
Subtotal (rounded)				**$48,830,000**
25% Contingency (rounded)				**$12,208,000**
Total Project Cost (rounded)				**$61,038,000**

Table 42. Construction Cost Estimate for the Breton Island Alternative 4

Description	Quantity	Type	Unit Price	Amount
Mob/Demobilization	1	LS	$5,125,000	$5,125,000
Beach Fill	9,382,000	CY	$6.75	$63,328,500
Terminal Groin	1	LS	$11,319,000	$11,319,000
Pre-Construction Survey	1	LS	$250,000	$250,000
As-Built Survey	1	LS	$200,000	$200,000
Subtotal (rounded)				**$80,222,500**
25% Contingency (rounded)				**$20,056,000**
Total Project Cost (rounded)				**$100,279,000**

Table 43. Construction Cost Estimate for the Breton Island Alternative 5

Description	Quantity	Type	Unit Price	Amount
Mob/Demobilization	1	LS	$5,125,000	$4,850,000
Offshore Fill	12,321,000	CY	$5.00	$61,605,000
Pre-Construction Survey	1	LS	$250,000	$250,000
As-Built Survey	1	LS	$200,000	$200,000
Subtotal (rounded)				**$66,905,000**
25% Contingency (rounded)				**$16,726,000**
Total Project Cost (rounded)				**$83,631,000**

16 CONCLUSIONS

Chandeleur and Breton Islands will continue to deteriorate without a restoration project. It is projected that Breton Island will have no remaining subaerial acreage within approximately 5 years (even prior to TY0) while there will be no subaerial acreage left at the Chandeleur Islands by TY28.

It is proposed to construct eight shore-perpendicular back-barrier sand reserve feeder sites and a shore parallel beach berm along the Chandeleur Islands. The feeder sites will require 4.91M cubic yards of sand while the beach berm has a fill volume of approximately 3.8M cubic yards of sand. The most cost effective sand source that can be used to build the proposed design is

Hewes Point. The expected construction cost for the Chandeleur Islands project is $119,568,000, which includes a 25% contingency.

Five alternatives were developed for Breton Island. Alternative 1 included a 4-mile long, +4 feet, NAVD dune with a backing marsh. Alternative 2 had a similar dune footprint as Alternative 1 except that the dune has a proposed elevation of +6-foot, NAVD and there is no backing marsh. Alternative 3 proposes a 1,000-foot diameter, +10 feet, NAVD dune at the north end of the island with a 1V:300H slope on the southern side. Alternative 4 is similar to Alternative 2 except that a 2,400-foot long terminal groin is located at the southern end of the island instead of a beach fill taper. Alternative 5 considers filling a portion of the MRGO and Breton Pass Inlet to facilitate better bypassing of sand from Grand Gosier Shoal to Breton Island.

Project performance was based on the WVA methodology. The model suggested that under FWOP conditions, all subaerial acreage will be lost by TY28 along Chandeleur Island. It is estimated that FWOP provides 828 Average Annual Habitat Units (AAHUs). Under FWP conditions, subaerial acreage will be completely lost by TY48. It is estimated that FWP will provide 2,292 AAHUs for a net benefit of 1,464 AAHUs.

No subaerial acreage is estimated to remain at Breton Island by TY0. The five alternatives provide a variety of costs and performance projections. The FWP conditions will provide subaerial acreage anywhere from 11 years to 24 years. Since the FWOP condition provides no AAHUs, the total and net benefits for the Breton Island alternative are due to the fill placed during construction.

The benefits provided by Chandeleur Islands and Breton Island can be considered identical as they provide the same type of habitat (supratidal, gulf intertidal, bay intertidal, and subtidal) along a barrier island shoreline.

17 REFERENCES

Allison, M.A., Dellapenna, T.M., Goni, M.A., and Sheremet, A., 2007, Impact of Hurricanes Katrina and Lili on the Inner Shelf of the Mississippi-Atchafalaya Delta *in* Proceedings, Coastal Sediments 07, New Orleans, American Society of Civil Engineers, p. 882-887.

Bethel, M. and Martinez, L., 2008, Assessment of Seagrass Critical Habitat in Response to Dramatic Shoreline Change Resulting from the 2005 Hurricane Season for the Chandeleur Islands (abs.): Geological Society of America, 2008 Annual Meeting, Abstracts and Programs, v. 40, no. 6, p. 486.

Brown, E. I., 1928, Inlets on Sandy Coasts: Proceedings of the American Society of Civil Engineers, v. 54, no. 4, p. 505-553.

Bruun, P., 1982. Sea-Level Rise as a Cause of Shoreline Erosion. *Journal of Waterways and Harbor Division*, ASCE, Vol 88, No WW1.

Byron, D. and Heck, K.L., Jr., 2006, Hurricane Effects on Seagrass Along Alabama's Gulf Coast: Estuaries and Coasts, v. 29, no. 6a, p. 939-942.

Campbell, T. (2005). Development of a Conceptual Morphosedimentary Model for Design of Coastal Restoration Projects along the Louisiana Coast. *Journal of Coastal Research*. S.I. No. 44, pp. 234-244. The Coastal Education and Research Foundation, West Palm Beach, FL and Louisiana Department of Natural Resources, Baton Rouge, LA.

Coastal Planning & Engineering, Inc. 2003a. Holly *Beach Project Completion Report*. Coastal Planning & Engineering, Inc., Boca Raton, Florida. (Prepared for Louisiana Department of Natural Resources).

Coastal Planning & Engineering, Inc., 2003b. *Chaland Headland and Pelican Island Barrier Shoreline Restoration (BA-38): 30% Design Report*. Report submitted to Tetra Tech for the NOAA National Marine Fisheries Service. Coastal Planning & Engineering, Inc. Boca Raton FL.

Coastal Planning & Engineering, Inc., 2005. *East and West Island Restoration Project (BA-30): 95% Design Report*. Report submitted to Louisiana Department of Natural Resources. Coastal Planning & Engineering, Inc. Boca Raton FL.

Chen, S., Sanford, L.P., Koch, E.W., Shi, F., and North, E.W., 2007, A Nearshore Model to Investigate the Effects of Seagrass Bed Geometry on Wave Attenuation and Suspended Sediment Transport: Estuaries and Coasts, v. 30, no. 2, p. 296- 310.

Coleman, J. M., 1988, Dynamic Changes and Processes in the Mississippi River Delta: Geological Society of America Bulletin, v. 100, p. 999 – 1015.

Creef, E. 2009. "Beneficial Use of Dredged Material Disposal History: Mississippi River-Gulf Outlet, LA: Breton Island: FY 1993-2005." USACE, New Orleans District.

Davis, R. A., Jr. and FitzGerald, D. M., 2004, Beaches and Coasts: Blackwell, Oxford, UK, 419 p.

Dean, R., 1977. Equilibrium Beach Profiles: U.S. Atlantic and Gulf Coasts. Ocean Engineering Technical Report No. 12, Department of Civil Engineering and College of Marine Studies, University of Delaware.

Dean, R., 1987. Coastal Sediment Processes: Toward Engineering Solutions. Proceedings, Coastal Sediments, ASCE, pp. 1-24.

Dean, R., 2002. Beach Nourishment, Theory and Practice. Advanced Series on Ocean Engineering, Vol. 18. World Scientific Press.

Environmental Working Group. (2002) *Coastal Wetlands Planning, Protection and Restoration Act: Wetland Value Assessment Methodology: Barrier Island Community Model.* 20 Pgs. US Fish and Wildlife Service, Lafayette, Louisiana.

Escoffier, F. F., 1940, The Stability of Tidal Inlets: Shore and Beach, v. 8, no. 4, p. 114-115.
Evans, O. F., 1942, The Origin of Spits, Bars, and Related Structures: Journal of Geology, v. 50, p. 846 – 863.

Fearnley, S., Miner, M.D., Kulp, M.A., Bohling, C., and Penland, S., 2009a, Hurricane impact and recovery shoreline change analysis of the Chandeleur Islands, Louisiana, USA: 1855 to 2005: *Geo-Marine Letters*, v. 29, no. 5-6.

Fearnley, S., Bohling, C., Miner, M., Martinez, L., Kulp, M., and Penland, S., 2009b, Hurricane impact and recovery shoreline change analysis and historic island configuration (Age of Discovery): 1700's to 2005, *in* Lavoie, D., ed., Sand resources, regional geology, and coastal processes of the Chandeleur Island coastal system – An evaluation of the resilience of the Breton National Wildlife Refuge: U.S. Geological Survey Scientific Information Report *in press*.

Fisk, H. N., 1944, Geological Investigation of the Alluvial Valley of the Lower Mississippi River: U. S. Army Corps of Engineers, Mississippi River Commission, Vicksburg, Mississippi, 78 p.

Flocks, J., Twichell, D., Sanford, J., Pendleton, E., and Baldwin, W., 2009, Sediment Sampling Analysis to Define Quality of Sand Resources, *in* Lavoie, D., ed., Sand resources, regional geology, and coastal processes of the Chandeleur Island coastal system – An evaluation of the resilience of the Breton National Wildlife Refuge: U.S. Geological Survey Scientific Information Report *in press*.

Flocks, J., M. Miner, D. Twichell, D. Lavoie, and J. Kindinger, 2009. Evolution and Preservation Potential of Fluvial and Transgressive Deposits on the Louisiana Inner Shelf: Understanding Depositional Processes to Support Coastal Management. Geo-Marr Lett.

Frazier, D. E., 1967, Recent Deltaic Deposits of the Mississippi River: Their Development and Chronology: Gulf Coast Association of Geological Societies Transactions, v. 17, p. 287 – 315.

Georgiou, I.Y. and Schindler, J.K., 2009, Wave Forecasting and Longshore Sediment Transport Gradients along a Transgressive Barrier Island: Chandeleur Islands, Louisiana: *Geo-Marine Letters*, v. 29, no. 5-6.

Hart, W. E. and Murray, S. P., 1978, Energy Balance and Wind Effects in a Shallow Sound: Journal of Geophysical Research, v. 83, p. 4097-4106.

Hoyt, J. H. and Henry, V. J., Jr., 1967, Influence of Island Migration on Barrier-Island Sedimentation: Geological Society of America Bulletin, v. 78, p. 77 –86.

Intergovernmental Panel on Climate Change, 2007. Climate Change 2007: The Physical Science Basis. Chapter 5 Observations: Oceanic Climate Change and Sea Level.

Jaffe, B. E., List, J. H., and Sallenger, A. H., Jr., 1997, Massive Sediment Bypassing on the Lower Shoreface of a Wide Tidal Inlet – Cat Island Pass, Louisiana: Marine Geology, v. 136, p. 131 –149.

Kahn, J. H., 1986, Geomorphic Recovery of the Chandeleur Islands, Louisiana after a Major Hurricane: Journal of Coastal Research, v. 2, no. 3, p.337 – 344.

Kahn, J.H. and Roberts, H., 1982, Variations in Storm Response along a Microtidal Transgressive Barrier-Island Arc: Sedimentary Geology, v. 33, p. 129-146.

Koch, E.W., Sanford, L.P, Chen, S., Shafer, D.J., and Smith, J.M., 2006, Waves in Seagrass Systems: Review and Technical Recommendations: U.S. Army Corps of Engineers, Engineer Research and Development Center, Technical Report no. ERDC TR-06-15, 81 p.

Kolb, C. R. and Van Lopik, J. R., 1958, Geology of the Mississippi River Deltaic Plain, Southeastern Louisiana: Vicksburg, Mississippi, U. S. Army Corps of Engineers Waterways Experiment Station, Technical Report no. 3-483, 120 p.

Kulp, M. A., FitzGerald, D. M., and Penland, S., 2005, Sand-rich Lithosomes of the Holocene Mississippi River Delta Plain, in Liviu, G. and Bhattacharya, J. P. (eds.), River deltas; Concepts, Models, and Examples: Society for Sedimentary Geology (SEPM), Special Publication, v. 83, p. 279 – 293.

Kulp, M.; Penland, S.; Williams, S.J.; Jenkins, C.; Flocks, J., and Kindinger, J., 2005. Geological Framework and Sediment Resources for Restoration of the Louisiana Coastal Zone. *In*: Finkl, C.W. and Khalil, S. (eds.), *Journal of Coastal Research*, Special Issue no 44, Saving

America's Wetland: Strategies for Restoration of Louisiana's Coastal Wetlands and Barrier Islands, 56-71.

Kwon, H. J., 1969, Barrier Islands of the Northern Gulf of Mexico Coast: Sediment Source and Development: Louisiana State University Press, Coastal Studies Series no. 25, 51 p.

Lavoie, D., 2009. Sand resources, regional geology, and coastal processes of the Chandeleur Island coastal system – An evaluation of the resilience of the Breton National Wildlife Refuge: U.S. Geological Survey Scientific Information Report *in press*.

Martinez, L., S. O'Brien, M. Tethel, S. Penland, and M. Kulp, 2009. Louisiana Barrier Island Comprehensive Monitoring Program (BICM) Volume 2: Shoreline Changes and Barrier Island Land Loss 1800's-2005. University of New Orleans, Pontchartrain Institute for Environmental Sciences, New Orleans.

Martinez, L., Penland, S., Fearnley, S., O'Brien, S. Bethel, M., and Guarisco, P., 2009, Louisiana Barrier Island Comprehensive Monitoring Program (BICM), Vol. 2, Shoreline Change Analysis: 1800s to 2005: University of New Orleans, Pontchartrain Institute for Environmental Sciences Technical Report.

McBride, R. A., Penland, S., Hiland, M. W., Williams, S. J., Westphal, K. A., Jaffe, B. E., and Sallenger, A. H., Jr., 1992, Analysis of Barrier Shoreline Change in Louisiana from 1853 to 1989, in Williams, S. J., Penland, S., and Sallenger, A. H., (eds.) Louisiana Barrier Island Erosion Study, Atlas of Shoreline Changes in Louisiana from 1853 to 1989: Reston, Virginia, U.S. Geological Survey and Louisiana State University, Miscellaneous Investigations Series I-2150-A, p. 36 –97.

Michot, T.C., Woodin, M.C., and Nault, A.J., 2008, Food Habits of Redheads (*Athya Americana*) Wintering in Seagrass Beds of Coastal Louisiana and Texas, USA: Acta Zoologica Academiae Scientarum Hungaricaie, v. 54, sup. 1, p. 239-250.

Miner, M.D., Kulp, M., Flocks, J., Twichell, D., Penland, S., Martinez, L., Motti, J., Weathers, DeWitt, N., Reynolds, B.J., Baldwin, W., Danforth, B., Worley, C., Bergeron, E., Ferina, N., McCarty, P., Brown, M. and Torres, J., 2009a, Louisiana Barrier Island Comprehensive Monitoring Program, Volume 3: South-Central Louisiana and Northern Chandeleur Islands, Bathymetry and Historical Seafloor Change 1873- 2006, Part 1: Methods and Error Analysis for Bathymetry, University of New Orleans - Pontchartrain Institute for Environmental Sciences and US Geological Survey, Submitted to Louisiana Department of Natural Resources, 44 p.

Miner, M.D., Kulp, M.A., Weathers, H.D., and Flocks, J., 2009b, Historical (1870-2007) seafloor evolution and sediment dynamics along the Chandeleur Islands, *in* Lavoie, D., ed., Sand resources, regional geology, and coastal processes of the Chandeleur Island coastal system – An evaluation of the resilience of the Breton National Wildlife Refuge: U.S. Geological Survey Scientific Information Report *in press*.

Miner, M.D., Kulp, M.A., FitzGerald, D.M., and Georgiou, I.Y., 2009c, Hurricane-associated ebb-tidal delta sediment dynamics: *Geology*, v. 37, no. 9, p. 851-854.

Miner, M.D., Kulp, M.A., FitzGerald, D.M., Flocks, J.G., and Weathers, H.D., 2009d, Delta lobe degradation and hurricane impacts governing large scale coastal behavior, south-central Louisiana, USA: *Geo-Marine Letters*, v. 29, no. 5-6.

National Oceanographic and Atmospheric Administration, 2009. WAVEWATCH III Model Data Access, http://polar.ncep.noaa.gov/waves/download.shtml?.

National Research Council (1987) "Responding to Changes in Sea Level: Engineering Implications." National Academy Press, Washington, D.C., 148 pp.

National Research Council, 1995. *Beach Nourishment and Protection.* National Research Council, Washington.

Otvos, E.G., 1981, Barrier Island Formation through Nearshore Aggradation—Stratigraphic and Field Evidence: Marine Geology, v. 43, p. 195-243.

Penland, S. and Boyd, R., 1981, Shoreline changes on the Louisiana barrier coast: IEEE Oceans, v. 81, p. 209-219.

Penland, S. and Boyd, R., 1985, Transgressive Depositional Environments of the Mississippi River Delta Plain: A Guide to the Barrier Islands, Shoals, and Beaches in Louisiana, Louisiana State Geological Survey Guidebook Series, no. 3, Baton Rouge, Louisiana: Louisiana Geological Survey, p.

Penland, S, Suter, J., and Moslow, T., 1983, Generation of Inner Shelf Sand Bodies by Erosional Shoreface Retreat and Sea Level Rise Processes: Eos, Transactions of the American Geophysical Union, v. 64, p. 1065-1066.

Penland, S., Boyd, R., and Suter, J.R., 1988, Transgressive Depositional Systems of the Mississippi Delta Plain: Model for Barrier Shoreline and Shelf Sand Development: Journal of Sedimentary Petrology, v. 58, p. 932 –949.

Penland, S., P. Connor, Jr. and A. Beall, 2002. Changes in Louisiana's shoreline: 1855-2002. Louisiana Coastal Area Ecosystem Restoration Study, Appendix D – Louisiana Gulf Shoreline Restoration Report, pp. D41-D93.

Poirrier, M.A. and Handley, L.R., 2006, Chandeleur Islands, in: Handley, L., Altsman, D., and Demay, R. (eds.), Seagrass Status and Trends in the Northern Gulf of Mexico: 1940-2002: USGS Scientific Investigation Report 2006-5278, p. 62-71.

Pope, D., Connor, P., Jr., and Penland, S., 1993, Stratigraphical Assessment of the Mineral Aggregate Resources in the St Bernard Shoal, Offshore, Louisiana: US Minerals Management Service Professional Paper.

Reyes, E., Georgiou, I.Y., Reed, D.J., and McCorquodale, J.A., 2005, Using Models to Evaluate the Effects of Barrier Islands on Estuarine Hydrodynamics and Habitats: A Numerical Experiment: Journal of Coastal Research, SI 44, p. 176-185.

Roberts, H. H., 1997, Dynamic Changes of the Holocene Mississippi River Delta Plain: The Delta Cycle: Journal of Coastal Research, v. 13, no. 3, p. 605 –627.

Rogers, B., Kulp, M.A., and Miner, M.D., 2009a, Late Holocene shelf sand body development from reworked relict distributary channel deposits exposed on the shelf, St. Bernard Shoals, Northern Gulf of Mexico, USA: *Geo-Marine Letters*, v. 29, no. 5-6.

Rogers, B., Kulp, M.A., and Miner, M.D., 2009b, The St. Bernard Shoals: and Outer Continental Shelf Sedimentary Deposit Suitable for Sandy Barrier Islands Renourishment, *in* Lavoie, D., ed., Sand resources, regional geology, and coastal processes of the Chandeleur Island coastal system – An evaluation of the resilience of the Breton National Wildlife Refuge: U.S. Geological Survey Scientific Information Report *in press*.

Stone, G.W, and Orford, J., 2004, Storms and their Significance in Coastal Morpho-Sedimentary Dynamics: Marine Geology, v. 210, p. 1-5.

Stone, G.W., Zhang, X., and Sheremet, A., 2005, The Role of Barrier Islands, Muddy Shelf, and Reefs in Mitigating the Wave Field Along Coastal Louisiana, *in* Finkl, C.W., and Khalil, S., eds., Saving America's Wetland: Strategies for Restoration of Louisiana's Coastal Wetlands and Barrier Islands: Journal of Coastal Research, Special Issue 44, p. 40-55.

Suter, J., Penland, S., Williams, S.J., and Kindinger, J., 1988, Stratigraphic Evolution of the Chandeleur Islands, Louisiana: Gulf Coast Association of Geological Societies Transactions v. 72, p. 1124-1125.

Teague, W.J., Jaroz, E., Keen, T.R., Wang, D.W., and Hulbert, M.S., 2006, Bottom Scour Observed under Hurricane Ivan: Geophysical Research Letters, v. 33, L07607.

Thomson, G.G., Campbell, T.J., Grabowski, V., and Kendrick, B., 2008. *Barataria Basin Barrier Shoreline Restoration Feasibility Report, Appendix C, Shell Island, Plaquemines Parish, Louisiana.* Boca Raton, Florida: Coastal Planning & Engineering. Report prepared for Louisiana Department of Natural Resources.

Thomson, G., Wycklendt, A., and Rees, M., 2009. *West Belle Pass Barrier Headland Restoration Project (TE-52) - 30% Design Report.* Boca Raton, Florida: Coastal Planning & Engineering, Inc. 158p. Report prepared for the Louisiana Office of Coastal Protection and Restoration.

Twichell, D.; Pendleton, E.; Baldwin, W. and Flocks, J., 2009. Subsurface control on seafloor erosional processes offshore of the Chandeleur Islands, Louisiana. Geo-Marine Letters (Published online in July 2009).

U.S. Army Corps of Engineers, 1958, Geological Investigation of the Mississippi River-Gulf Outlet Channel: Miscellaneous Paper No. 3-259, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, 22 p., 11 plates.

U.S. Army Corps of Engineers, 2001. Coastal Engineering Manual, Engineer Manual 1110-2-1100, U.S. Army Corps of Engineers, Washington, DC (6 Volumes).

U.S. Army Corps of Engineers, 2003. Coastal and Hydraulics Laboratory Wave Information Studies, http://frf.usace.army.mil/wis/.

U.S. Army Corps of Engineers, 2009. Mississippi River Gulf Outlet Ecosystem Restoration Plan Feasibility Study, http://www.mrgo.gov.

U.S. Army Corps of Engineers, 2009. Water Resource Policies and Authorities Incorporating Sea-Level Change Considerations in Civil Works Programs. EC 1165-2-211.

Walton, T.L. & Chiu, T.Y. (1979). "A Review of Analytical Techniques to Solve the Sand Transport Equation and Some Simplified Solutions", *Coastal Structures '79*, ASCE, Vol 2, pp 809-837.

Williams, S., S. Penland and A. Sallenger, 1992. Louisiana Barrier Island Erosion Study, Atlas of Shoreline Changes in Louisiana from 1853 to 1989, U.S. Geological Survey. Series I-2150-A.