IX. Region 2

Region 2 is comprised of three subregions (2a, 2b, and 2c) that extend from the Brunswick County/New Hanover County line (just north of Cape Fear) to just north of the Cape Lookout lighthouse.

Region 2a encompasses New Hanover County plus Rich Inlet, of which the north side falls into Pender County. Fort Fisher, Kure Beach, Carolina Beach, Wrightsville Beach, and Figure Eight Island all fall within Region 2a. Masonboro Island and a portion of Zeke's Island are also included in this region. Carolina Beach Inlet, Masonboro Inlet, Mason Inlet, and Rich Inlet divide the barrier islands. Figure IX-1 shows the boundaries of Region 2a.

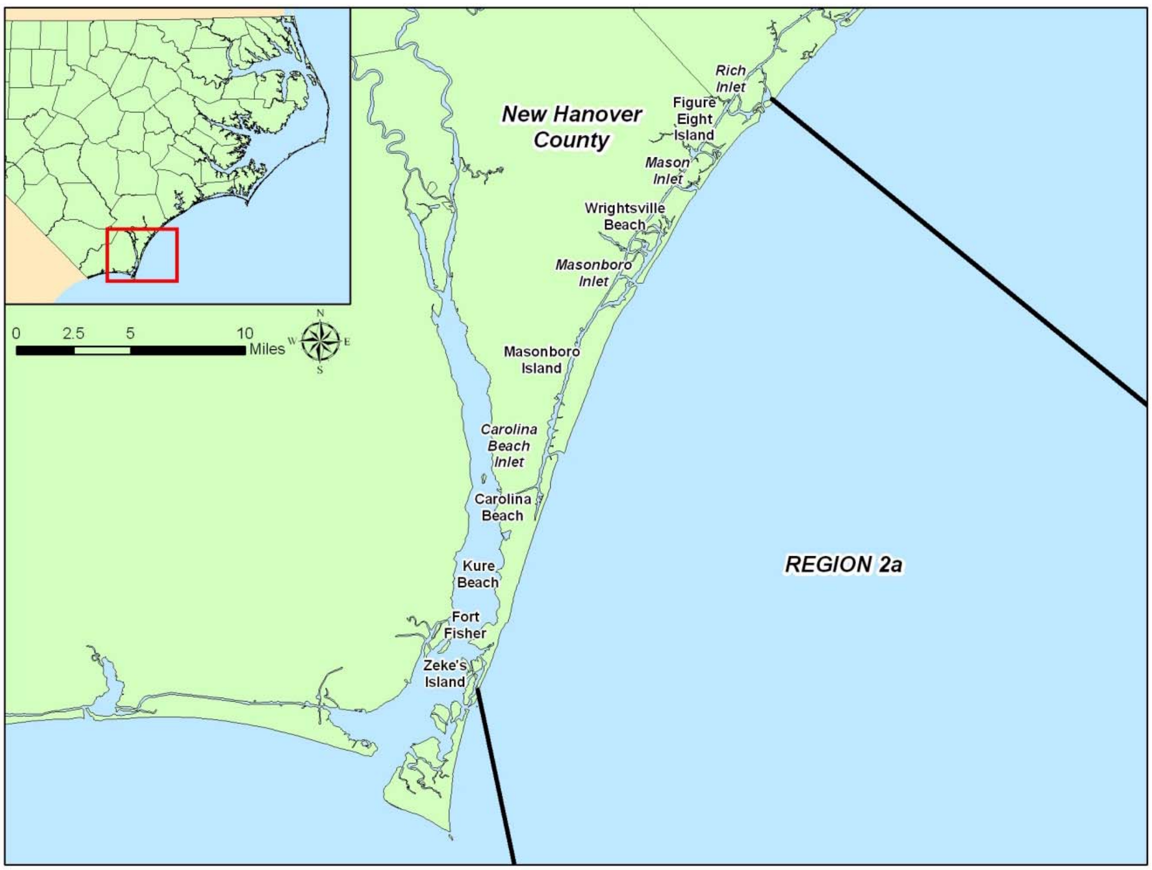


Figure IX-1. Region 2a Boundaries

Region 2a has a fairly equal split between developed and undeveloped areas. Areas designated "Not to be Developed" primarily fall on state-owned lands. The undeveloped portion of Region 2a is located adjacent to Rich Inlet. The municipal and privately owned areas make up the developed areas. See Table IX-1 for approximate shoreline lengths.

Table IX-1. Region 2a Shoreline Type Lengths

Shoreline Type	Shoreline Length (mi)
Not Developed	1
Developed	16
Not to be Developed	14
Total	31

Table IX-2 provides an approximate breakdown of shoreline ownership. The shorefront of Region 2a is owned by municipalities, the state (in the form of the N.C. Coastal Reserves), and private entities. The Zeke's Island and Masonboro Island components of the National Estuarine Research Reserve and Fort Fisher State Park are some of the state-owned lands located in this region. Figure Eight Island, a private community, is located here.

Table IX-2. Region 2a Shore Ownership Lengths

Shore Ownership	Shoreline Length (mi)
Municipal	13
State	12
Federal	0
Private	6
Total	31

Sixteen miles of this subregion's oceanfront shoreline is actively managed. The areas include Carolina, Kure, and Wrightsville Beaches. Table IX-3 shows the approximate length of shoreline that has been actively managed in the past, along with Figure Eight Island.

Table IX-3. Region 2a Shoreline Management

Management	Shoreline Length (mi)
Managed	16
Not Managed	15
Total	31

The second subregion, Region 2b, encompasses Pender County and a majority of Onslow County, stretching from just north of Rich Inlet to just west of Bear Inlet. Municipalities in this region include Topsail Beach, Surf City, and North Topsail Beach. Hutaff Island, Onslow Beach, and Brown's Island are also included. Region 2b contains three inlets: New Topsail Inlet, New River Inlet, and Brown's Inlet. Figure IX-2 shows the boundaries of Region 2b.

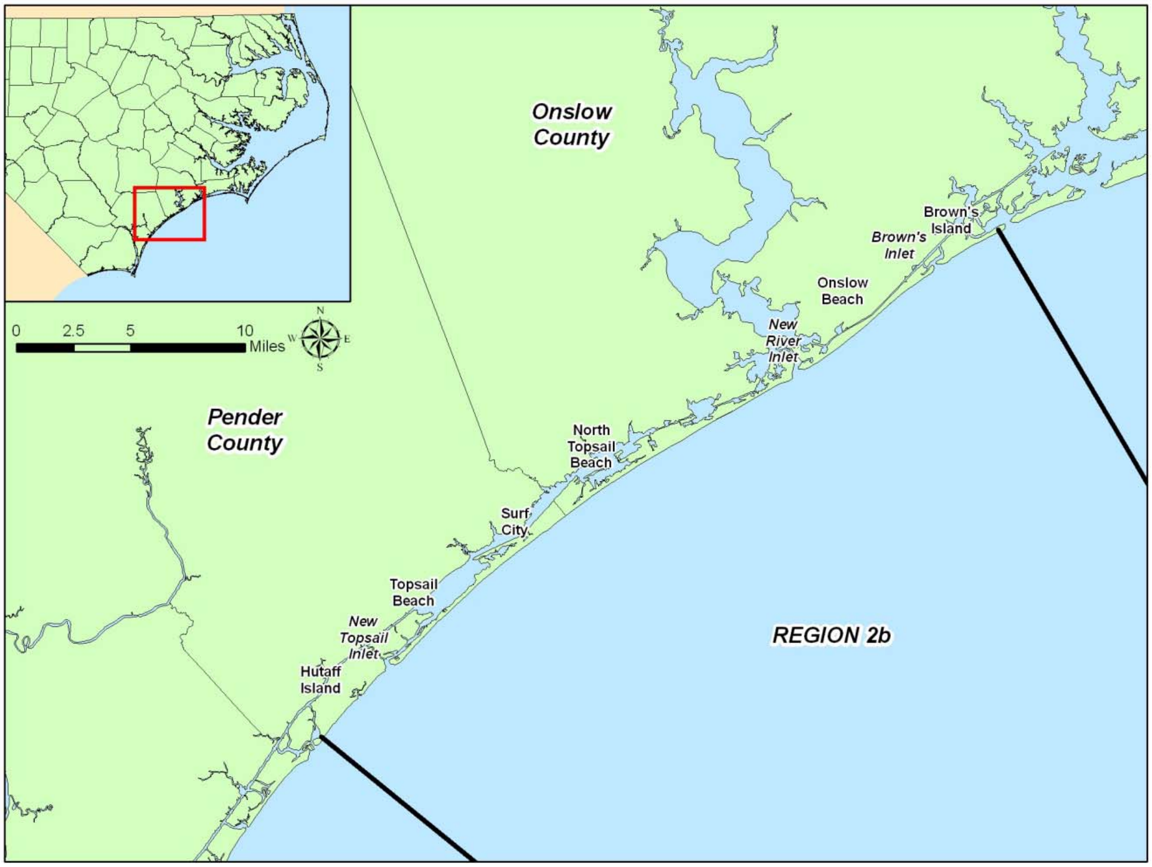


Figure IX-2. Region 2b Boundaries

The majority of the shoreline is developed, however large portions of Lea/Hutaff Island and Onslow County are undeveloped. See Table IX-4 for shoreline lengths.

Table IX-4. Region 2b Shoreline Development Type

Shoreline Type	Shoreline Length (mi)
Not Developed	15
Developed	23
Not to be Developed	0
Total	38

Region 2b includes privately owned Hutaff Island and federally owned Camp Lejeune. The remainder of the area is made up of municipalities. See Table IX-5 for an approximate breakdown of shoreline ownership.

Table IX-5. Region 2b Shoreline Ownership Lengths

Shore Ownership	Shoreline Length (mi)
Municipal	23
State	0
Federal	12
Private	3
Total	38

No shoreline in Region 2b is currently actively managed. However, there are plans to begin managing all of Topsail Island in the near future. See Table IX-6 for the approximate length of shoreline managed in this subregion.

Table IX-6. Region 2b Shoreline Management Lengths

Management	Shoreline Length (mi)
Managed	0
Not Managed	38
Total	38

The third subregion, Region 2c, covers the remainder of Onslow County and southern facing shores of Carteret County, stretching from Bear Inlet to just north of the Cape Lookout lighthouse. Municipalities in this region include Emerald Isle, Indian Beach, Salter Path, Pine Knoll Shores, and Atlantic Beach. Bear Island, Shackleford Banks, and Cape Lookout are also included. Region 2c has four inlets: Bear Inlet, Bogue Inlet, Beaufort Inlet, and Barden Inlet. Figure IX-3 shows the limits of Region 2c.

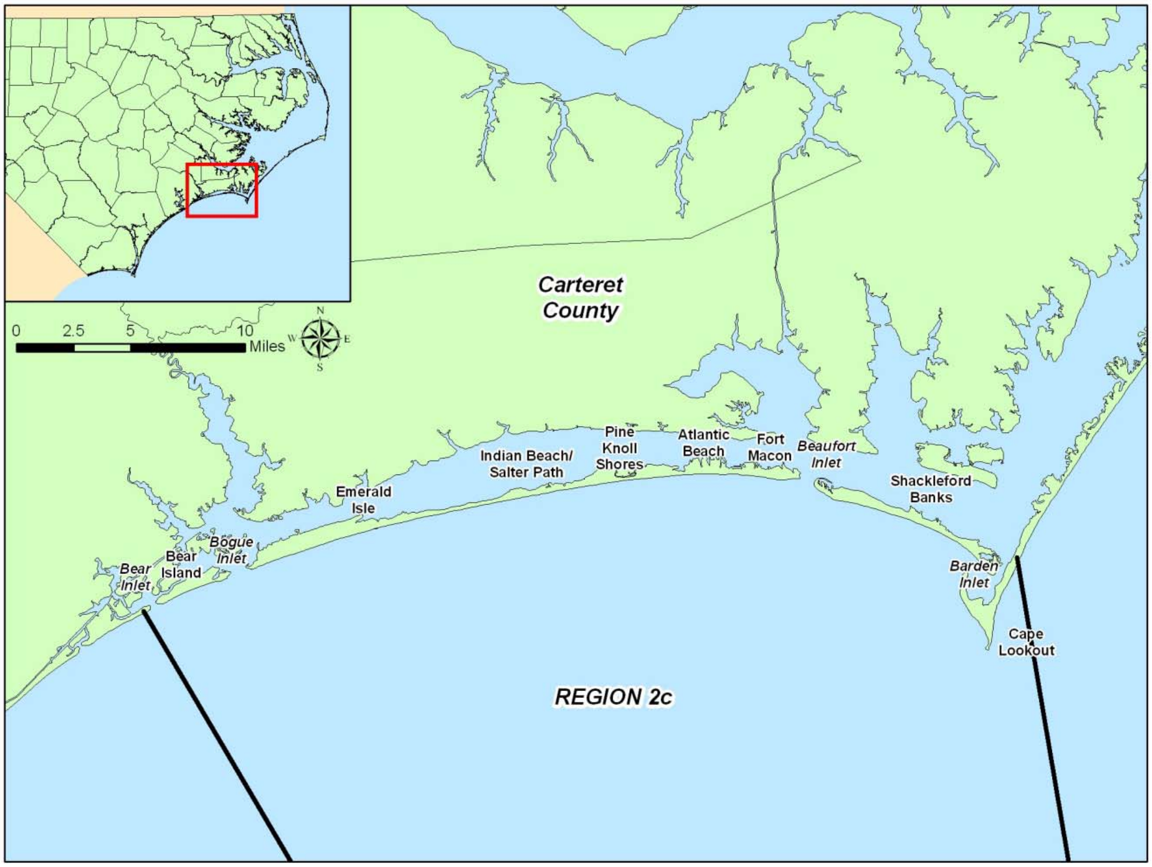


Figure IX-3. Region 2c Boundaries

Generally, the developed areas in Region 2c fall within municipal boundaries. Areas that are designated "Not to be Developed" are located on Shackleford Banks and at Cape Lookout, as well as Bear Island. See Table IX-7 for approximate shoreline lengths.

Table IX-7. Region 2c Shoreline Development Lengths

Shoreline Type	Shoreline Length (mi)
Not Developed	0
Developed	25
Not to be Developed	20
Total	45

Federally owned Camp Lejeune extends into Region 2c. Included in the state-owned lands are Hammocks Beach State Park (Bear Island) and Fort Macon State Park. Municipalities make up the remainder of the shoreline. See Table IX-8 for approximate shoreline lengths.

Table IX-8. Region 2c Shoreline Ownership Lengths

Shore Ownership	Shoreline Length (mi)
Municipal	24
State	5
Federal	16
Private	0
Total	45

Approximately half of the shoreline in this region is managed. This area mainly includes Bogue Banks. See Table IX-9 for the approximate lengths of shoreline managed in this subregion.

Table IX-9. Region 2c Shoreline Management Lengths

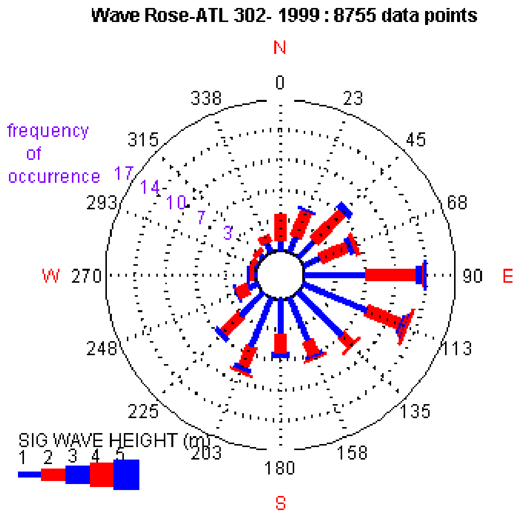
Management	Shoreline Length (mi)
Managed	25
Not Managed	20
Total	45

A. Current Available Pertinent Datasets

1. Waves and Water Levels

Beaches, as the transition zone between land and water, are susceptible to changes by waves, winds, and currents. Waves play a major role in the shaping and evolution of beaches and inlets. Moving water suspends and transports sediment while the severity, frequency, and direction of incoming waves influence beach behavior and geometry. The Region 2 shoreline is exposed to waves from the southeast with Region 2a being more susceptible to waves from the east and Region 2c vulnerable to southern waves. Waves can have short-term, seasonal, and long-term impacts on both the cross-shore and along-shore beach shape. Drastic changes in beach width and elevation can occur during a single hurricane, but it is the more frequent storms and wave events that generally drive the overall beach configuration. Winter storms and their associated higher wave activities typically move sand offshore and gentler summer waves move the sand from the offshore back onto the beach. The typical angle of wave approach transports sand along the shoreline and inlets interrupt sand movement forming deltas due to the currents generated in the inlets by the rising and falling tides. Wave data along the North Carolina coast is available from long term wave hindcast modeling and from measurements at various wave buoys operating at various locations offshore.

Wave hindcasts are numerical models which use historical wind and meteorological data to calculate, or hindcast, what the waves would have been at a specific offshore location. The USACE Wave Information Study (WIS) is an extensive hindcast model that provides wave information (height, period, and direction) for the 20-year period of 1980-99 at more than 300 stations offshore of the North Carolina coast. This data is available from the U.S. Army Corps of Engineers (USACE) website at http://www.frf.usace.army.mil/cgi-bin/wis/atl/atl_main.html.. Figures IX-4 to IX-6 show wind and wave data from a representative WIS station in Regions 2a (station 302), 2b (station 290) and 2c (station 275) respectively. Figures IX-7 to IX-9 show the locations of WIS stations (locations where hindcast wave data is available) for all three sub-regions of Region 2.



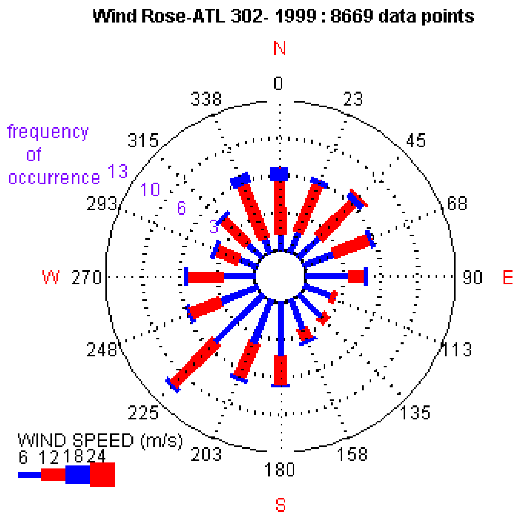


Figure IX-4. Representative Wind and Wave Roses from Station 302 (Region 2a)

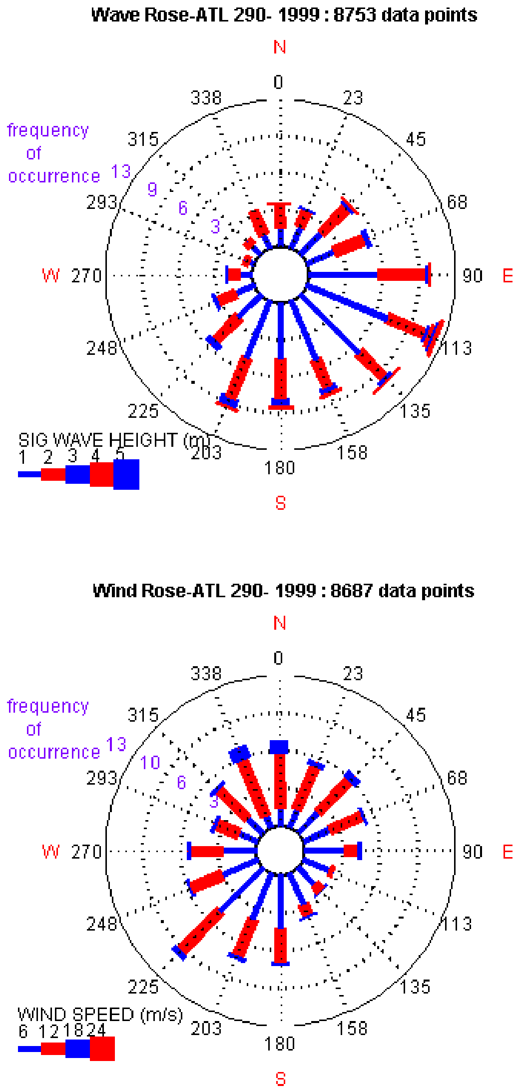


Figure IX-5. Representative Wind and Wave Roses from Station 290 (Region 2b)

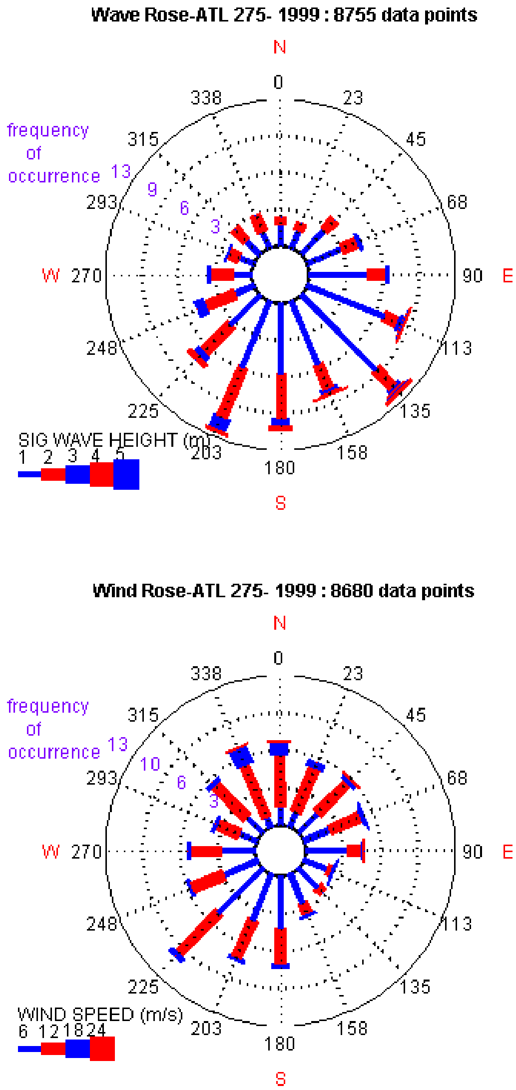


Figure IX-6. Representative Wind and Wave Roses from Station 275 (Region 2c)

Note the similarities between the respective wind and wave roses in each subregion. The winds are predominantly from the north and west whereas the waves are generally from the south and east. Region 2a waves come slightly more from the east and Region 2c waves come slightly more from the south.

Wave measurements can be obtained from wave buoys off the North Carolina coast and are available from the National Data Buoy Center (NDBC) website at http://www.ndbc.noaa.gov/. The wave buoys also collect climatological data. Both real time and historical data can be downloaded from this site. Figures IX-7 to IX-9 show the locations of NDBC wave buoys for all three subregions of Region 2.

In addition to wave activity, beaches and inlets are impacted by both temporal and spatial variations in the water level. Water level variations can be regular, such as the tides, or periodic, such as storm surge. Water level changes can also occur over long periods of time due to sea level rise (climate change or relative change due to land subsidence).

Along the North Carolina coast, tides are typically semidiurnal, having two high tides and two low tides each day of similar heights. Tides are currently measured at six locations along the North Carolina Coast by the National Oceanic Atmospheric Administration (NOAA) and the USACE. There are two NOAA tide stations located in Region 2, one at Wrightsville Beach and the other at Beaufort. The tidal range for Region 2 is approximately 3.5 feet – 4.5 feet. Table IX-10 displays the tidal datums, in feet, with respect to Mean Lower Low Water (MLLW) for the two NOAA tide stations present in Region 2. The NOAA tide stations data can be found at the NOAA Tides and Currents website (http://tidesandcurrents.noaa.gov/). Figures IX-7 to IX-9 show the locations of NOAA tide stations for Region 2.

Table IX-10. Tidal Datums (ft) for Region 2 Stations

	Wrightsville Beach, NC	Beaufort, NC
Datum	Sta 8658163	Sta 8656483
Mean Higher High Water (MHHW)	4.29	3.54
Mean High Water (MHW)	3.95	3.26
Mean Tide Level (MTL)	2.05	1.70
Mean Sea Level (MSL)	2.03	1.71
Mean Low Water (MLW)	0.15	0.15
Mean Lower Low Water (MLLW)	0.00	0.00
North American Vertical Datum (NAVD)	2.44	No Data
National Geodetic Vertical Datum (NGVD)	No Data	No Data
Maximum Tide Level	6.92	6.29
Date Maximum Tide Level Recorded	10/9/2006	9/16/1999

Shorter term water level fluctuations due to passing storms, both extratropical (northeasters) and tropical (tropical storms and hurricanes), can elevate water levels along the coast, resulting in flooding and pushing storm surge further up the beach face, thereby reshaping the shoreline. Storm-driven water levels along the coast are available for events with a one percent annual chance of occurrence (100-year return period) from the Flood Insurance Rate Maps (FIRM) and Flood Insurance Studies (FIS) developed by the Federal Emergency Management Agency (FEMA). North Carolina is currently in the process of updating these along coastal regions including extensive storm surge modeling. Information can be found at http://www.ncfloodmaps.com/.

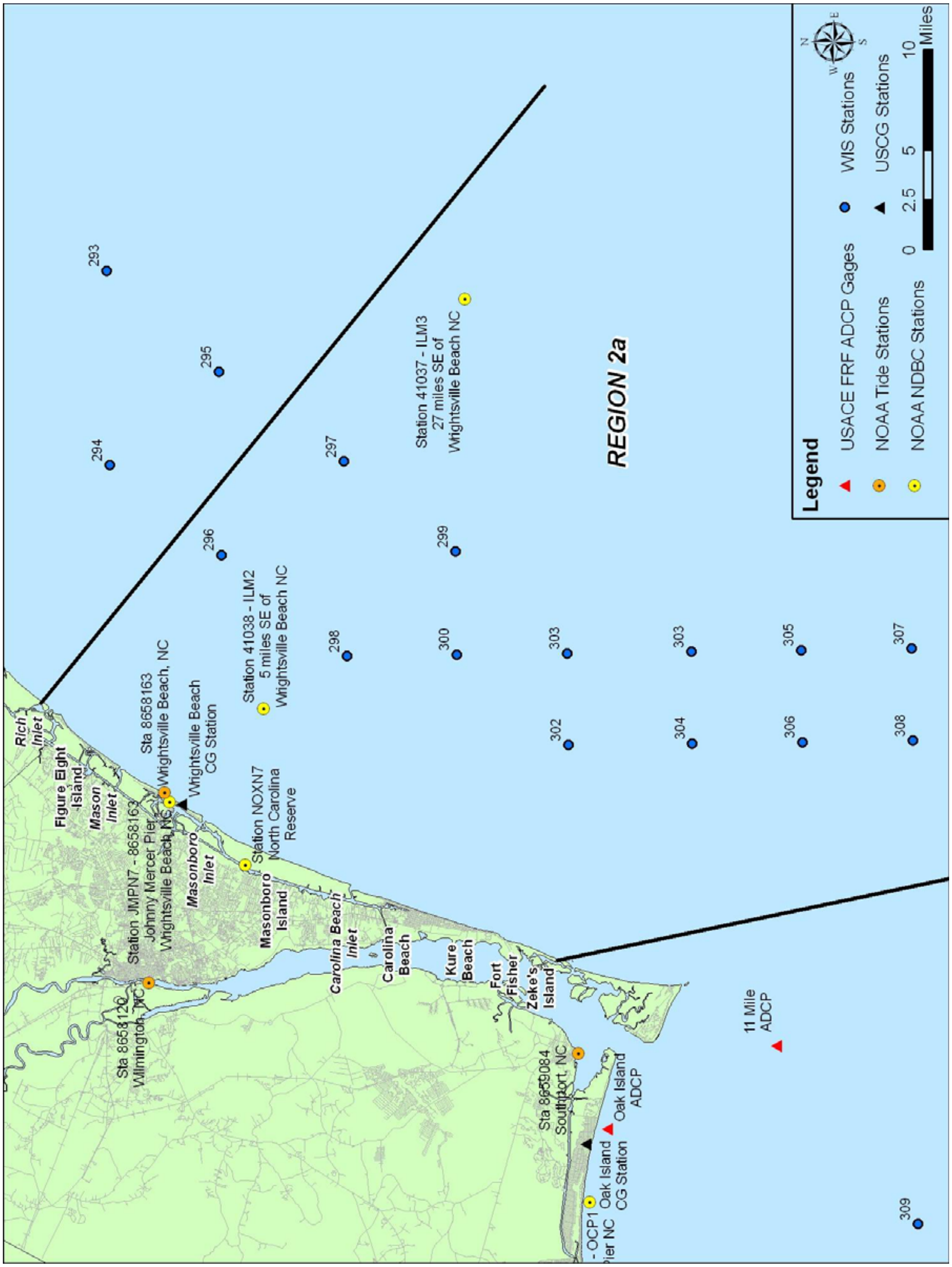


Figure IX-7. Wave and Water Level Stations for Region 2a

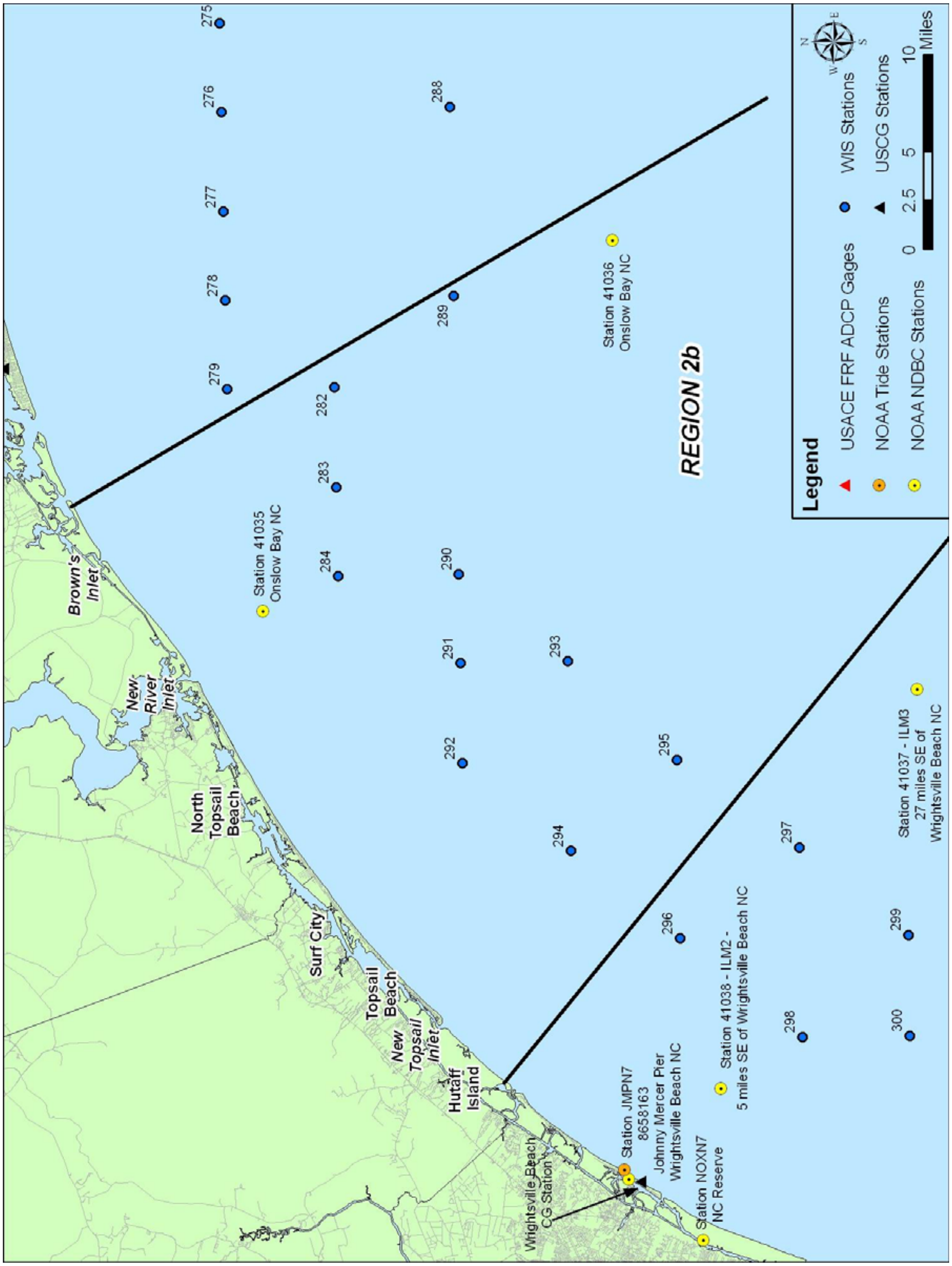


Figure IX-1. Wave and Water Level Stations for Region 2b

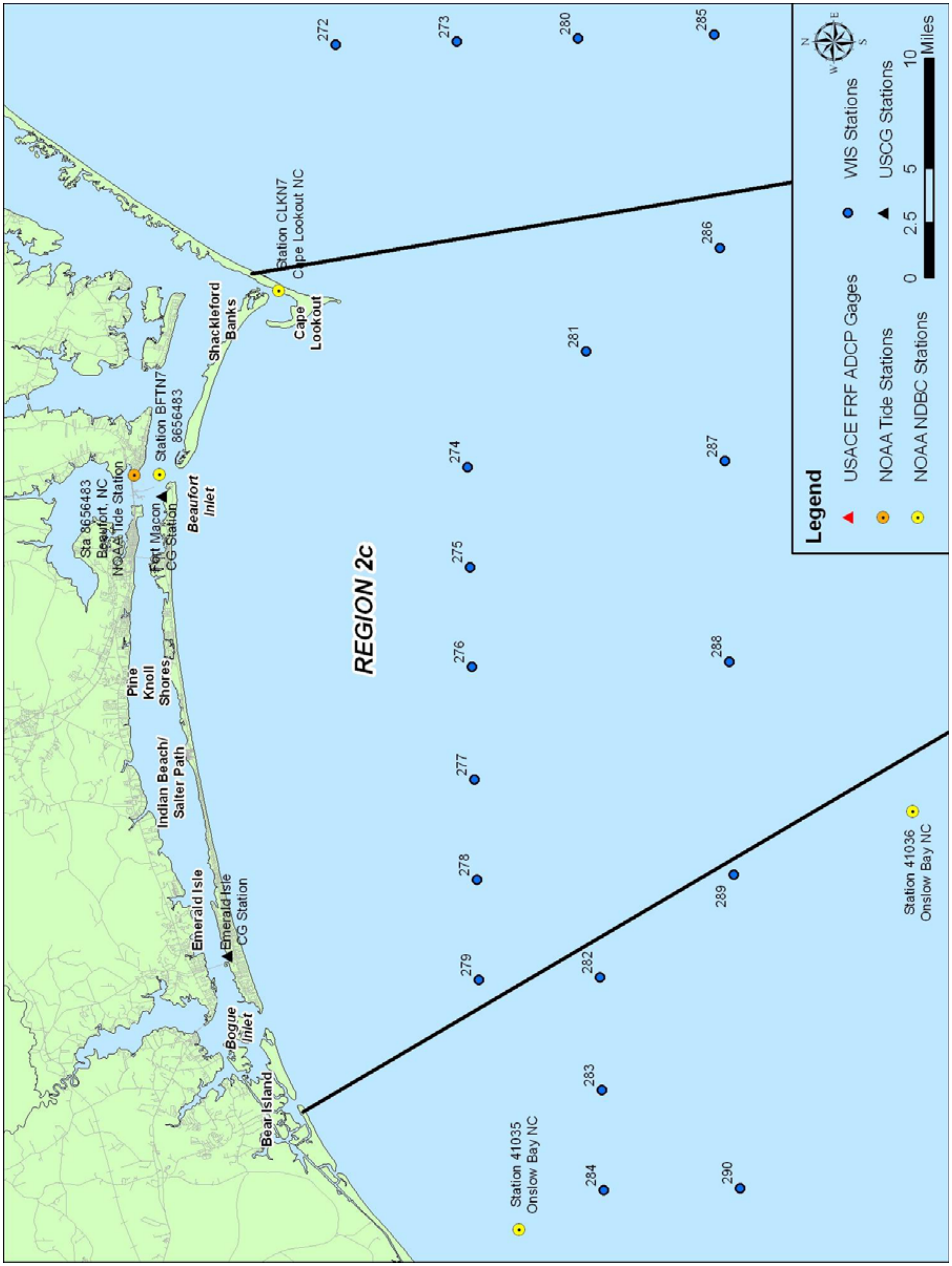


Figure IX-9. Wave and Water Level Stations for Region 2c

Due either to land subsidence, global climate changes or other factors, relative sea level is rising along the North Carolina coast. The long term tidal water level recording stations estimate the rate of this rise as approximately 1 to 1.5 feet over the last century along the N.C. coast. For the long-term NOAA tidal measurement station at Beaufort, the mean sea level rise trend is 3.71 mm/year (1.22 feet/century) with a standard error of 0.64 mm/year (0.21 feet/century) based on monthly mean sea level data from 1973 to 1999. Figure IX-10 shows the sea level rise at a tide station at Beaufort, N.C. This is the only tide station along the North Carolina coast with an uninterrupted, long-duration measurement record for which this data has been developed.

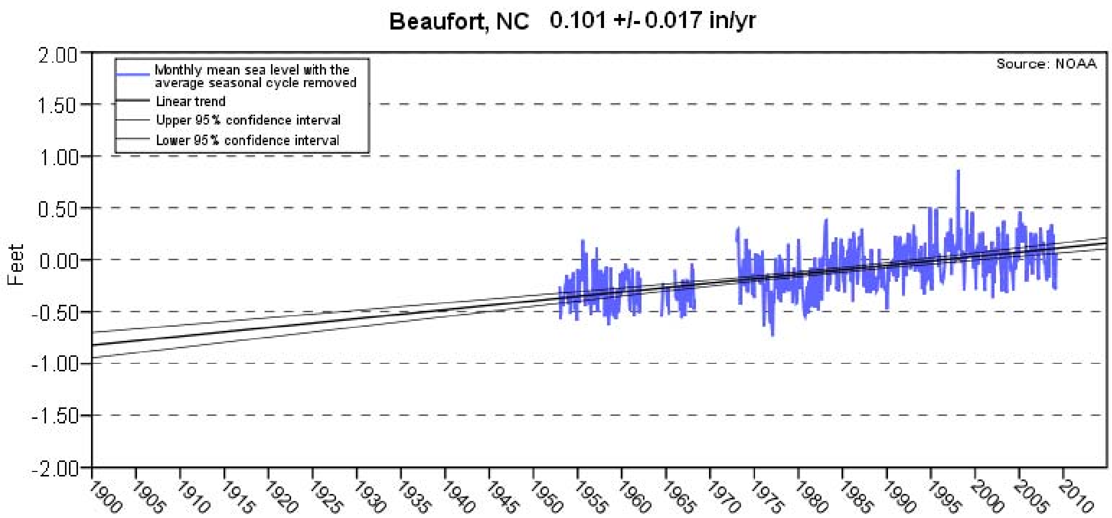


Figure IX-10. Sea Level Rise at Beaufort, N.C.

Planning for long-term sea level rise is difficult since consensus on how much and how quickly it will rise is difficult to achieve. There are currently many researchers, government agencies and international organizations studying the topic with conflicting predictions and disputes over the causes of sea level rise. Short-term sea level rise from 1980 to 2000 at Duck, N.C. (Dare County), based on tide level readings, is estimated to be 1.5 feet per century (Riggs, 2008). Other studies show estimates of sea level rise for the Outer Banks of 10.5 inches/century (Pietrafesa *et al.*, 2005). Note that all of these estimates are based on extrapolation of measurements of less than 100 years. Nonetheless, the impact of rising sea levels, for which there is wide agreement, must be considered in long-term planning. It is possible to continue with strategies that are acceptable under current and shorter term historical changes, such as those predicted by the Beaufort gauge data, and then adapt as needed if conditions change in the coming years.

2. Tropical Storms

Tropical storms, especially hurricanes, can be a major episodic force in reshaping beaches and inlets (including breaching new inlets through the barrier islands). NOAA maintains a GIS database of the storm tracks for Atlantic hurricanes including approximate storm location, date, wind speed, pressure, and category recorded for storms since 1851. GIS shapefiles can be downloaded at NOAA's website. Region 2 has mainly been impacted by tropical storms but has been affected by Category 1, Category 2, and Category 3 hurricanes in the past. Maps displaying the recorded Atlantic hurricane tracks in Region 2 since 1851 are presented in Figures IX-12 to IX-14**.** Hurricanes Diane (1955) and Bertha (1996) were two of the most significant storms to affect Region 2a, making landfall as a Category 1 hurricanes. Hurricanes Bonnie (1998) and Floyd (1999) both made landfall in Region 2b as Category 2 hurricanes. Hurricanes Ione (1955) and Donna (1960) made landfall in Region 2c as Category 2 hurricanes, while an unnamed Category 3 hurricane made landfall near Fort Macon in 1879. Region 2a and Region 2b have had many tropical storms pass offshore on their way north, later making landfall in Region 2c. The NOAA National Hurricane Center Risk Analysis Program has developed estimates for return periods of hurricanes of various intensities along the U.S. coast. Figure IX-11 presents this data for the N.C. coast. The numbers indicate the expected return period (in years) on average that a hurricane can be expected within 75 nautical miles (86 statute miles) of the location. Region 2 generally experiences the average number of hurricanes for the North Carolina coast with more frequent hurricane activity being farther north towards Cape Hatteras. For example, the area near Cape Lookout expects a Category 1 hurricane every eight years, while Cape Fear to the south only expects a Category 1 hurricane every 10 years and Cape Hatteras to the north expects a Category 1 hurricane every five years (see upper left graphic of Figure IX-11).

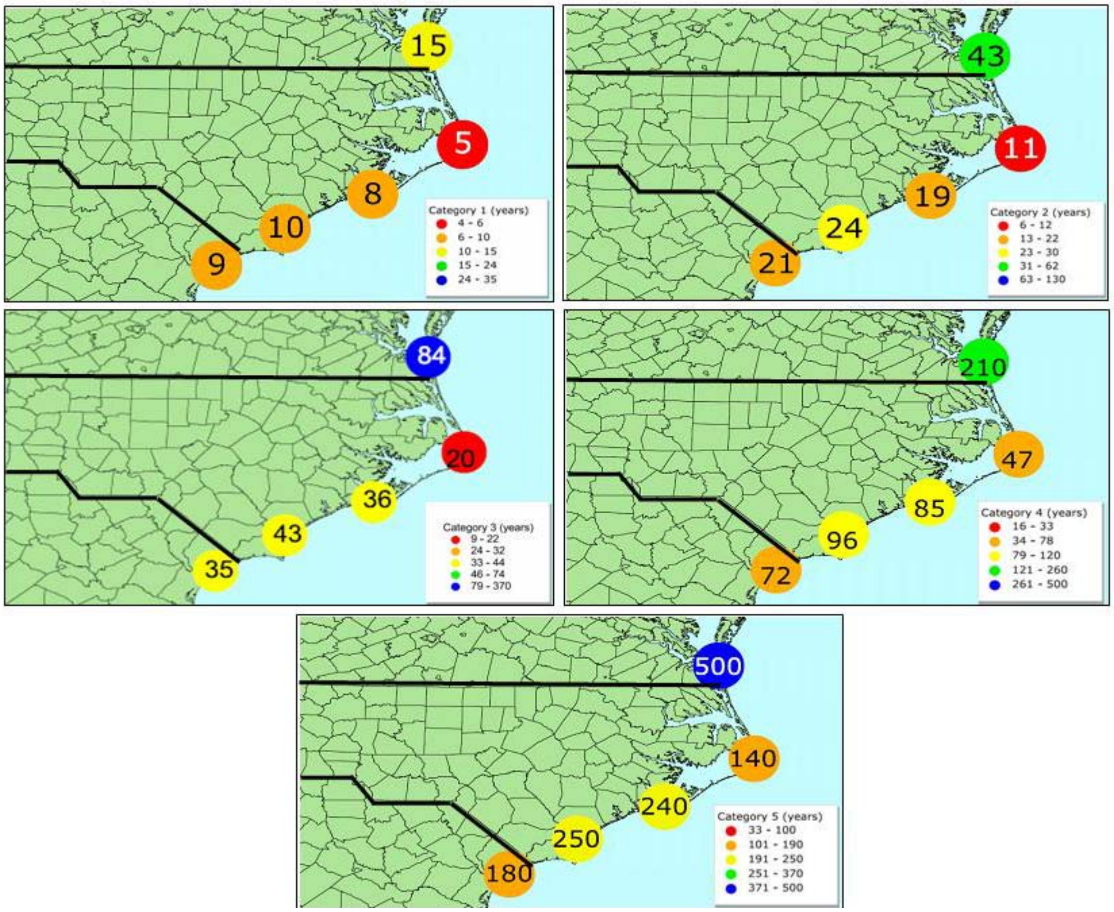


Figure IX-11. Expected Return Period of Hurricanes

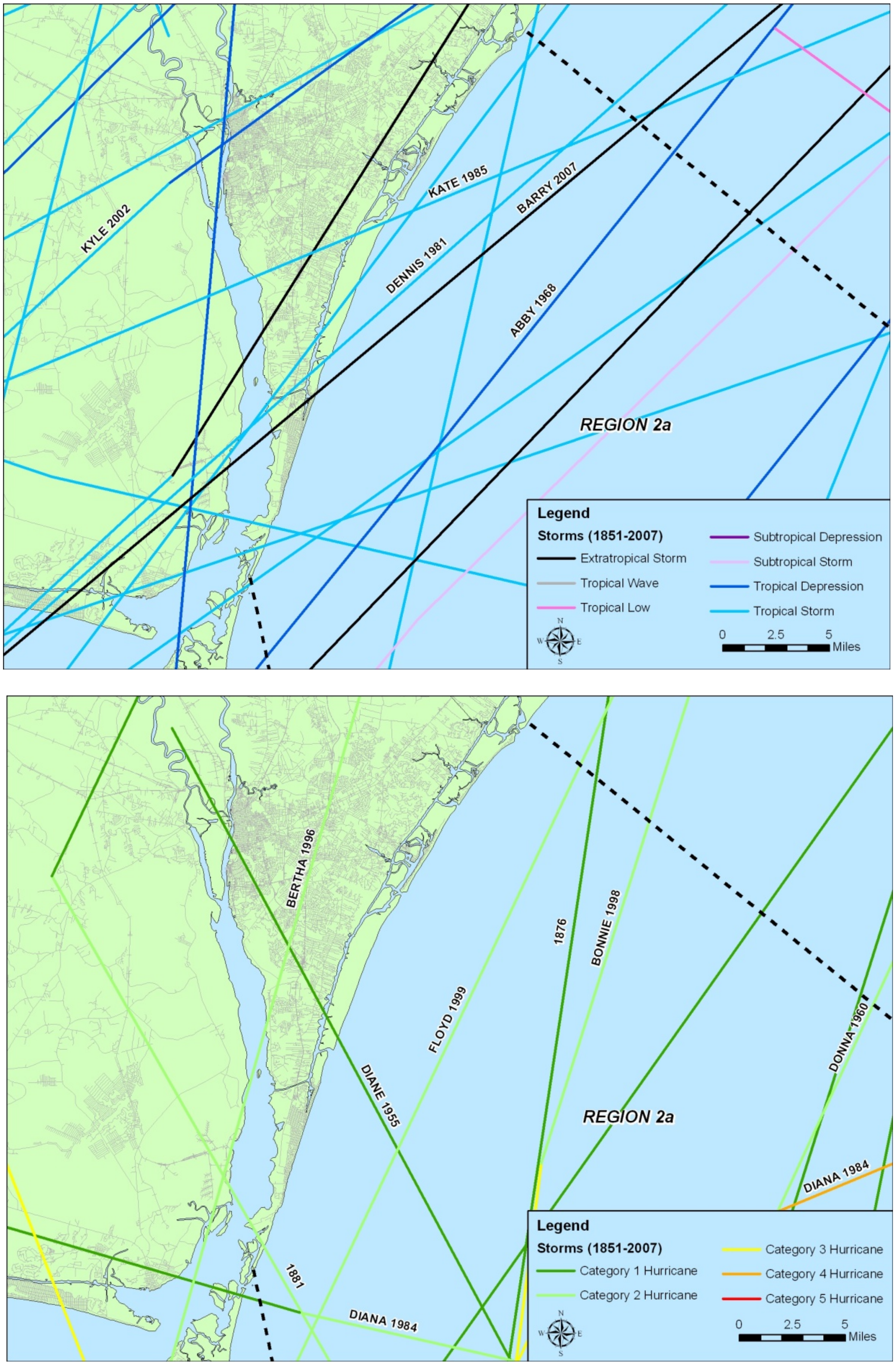


Figure IX-12. Atlantic Storm and Hurricane Tracks for Region 2a

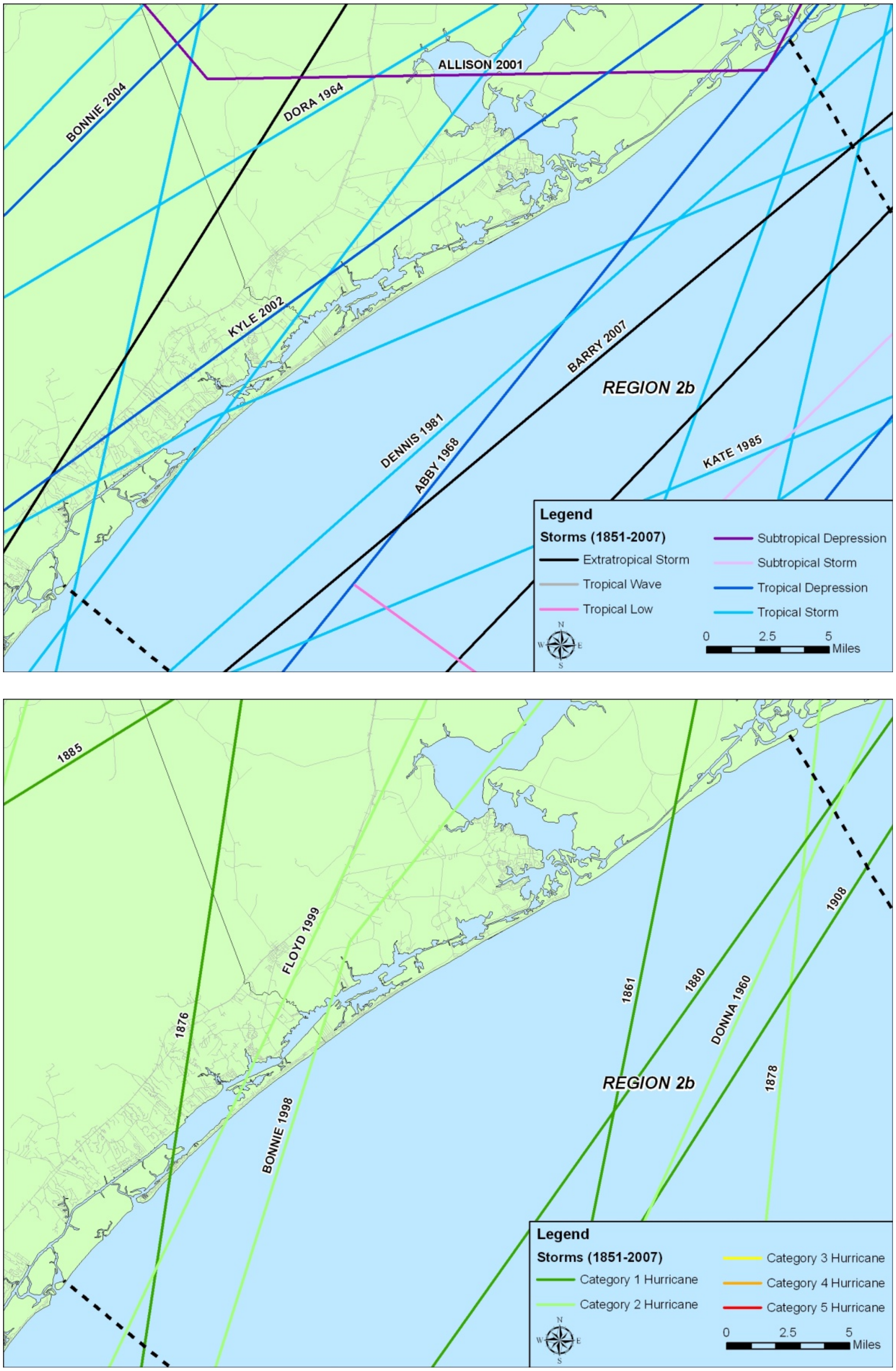


Figure IX-13. Atlantic Storm and Hurricane Tracks for Region 2b

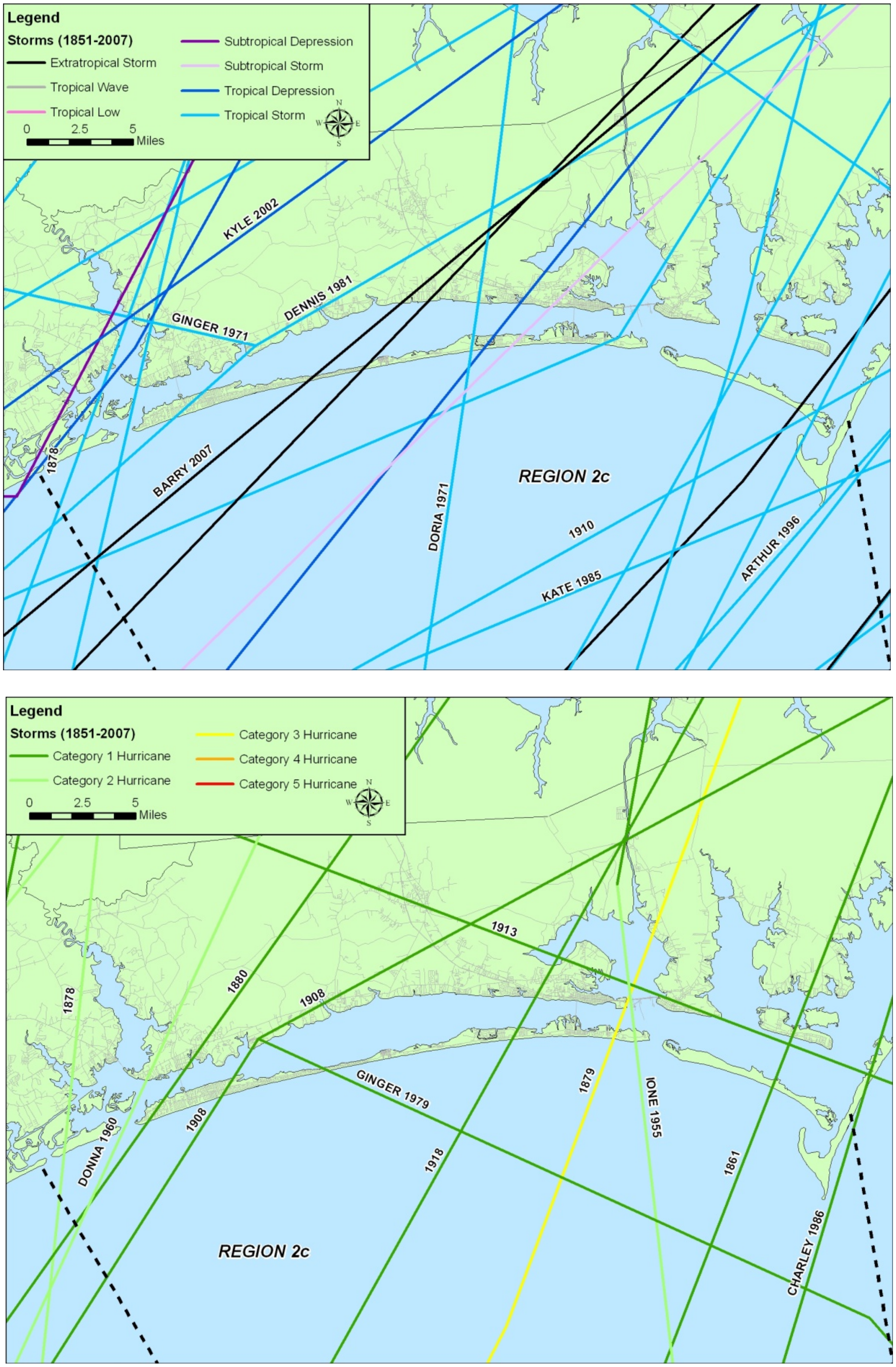


Figure IX-14. Atlantic Storm and Hurricane Tracks for Region 2c

3. Digital Orthophotography

Photography is available from various sources including the Division of Coastal Management (DCM), USGS, NAIP, and individual county governments. Aerials of the entire oceanfront shoreline were taken in 1998 and 2004. In 2003, some post-Isabel aerials were taken of the ocean shoreline by USGS, with the exception of Dare and Hyde counties. In 2006, NAIP created mosaics for orthotiles for the entire coastline. Various counties also have oceanfront aerial photography for a variety of dates. Tables IX-11 to IX-13 identify the available digital orthophotography for Region 2.

Table IX-11. Digital Orthophotography for Region 2a

Inlet Photography (1938-2000)						
Date	**Coverage**	**Format**	**Mosaic/Tiles**	**Color**	**Source**	**Resolution**
1971, 1974, 1977, 1984, 1992	Carolina Beach Inlet	Mr. SID	Mosaic	B&W	DCM	1'
1995, 2000	Carolina Beach Inlet	Mr. SID	Mosaic	Color	DCM	1'
1938, 1949, 1958, 1971, 1977, 1987, 1992	Mason Inlet	TIFF	Mosaic	B&W	DCM	varies
1971, 1974, 1977, 1984, 1992	Masonboro Inlet	Mr. SID	Mosaic	B&W	DCM	1'
1995, 2000	Masonboro Inlet	Mr. SID	Mosaic	Color	DCM	1'
1938, 1958, 1980, 1992	Rich Inlet	TIFF	Mosaic	B&W	DCM	varies
Oceanfront Photography (1998)						
Date	**Coverage**	**Format**	**Mosaic/Tiles**	**Color**	**Source**	**Resolution**
1998	Zeke's Island to Carolina Beach Inlet	Mr. SID	Tiles	B&W	DCM	.5'
1998	Figure Eight Island	Mr. SID	Tiles	B&W	DCM	.5'
1998	Masonboro Island	Mr. SID	Tiles	B&W	DCM	.5'
1998	Wrightsville Beach	Mr. SID	Tiles	B&W	DCM	.5'
New Hanover County (2002)						
Date	**Coverage**	**Format**	**Mosaic/Tiles**	**Color**	**Source**	**Resolution**
2002	Zeke's Island, Fort Fisher, Kure Beach, Carolina Beach, Masonboro Island (south), Rich Inlet	Mr. SID	Tiles	Color	DCM	1'
Post-Isabel Photography (2003)						
Date	**Coverage**	**Format**	**Mosaic/Tiles**	**Color**	**Source**	**Resolution**
2003	New Hanover County	Mr. SID	Mosaic	B&W	USGS	2'
Oceanfront Photography (2004)						
Date	**Coverage**	**Format**	**Mosaic/Tiles**	**Color**	**Source**	**Resolution**
2004	Bald Head Island, Zeke's Island, Fort Fisher	Mr. SID	Mosaic	Color	DCM	.5'
2004	Kure Beach to Figure 8 Island	Mr. SID	Mosaic	Color	DCM	.5'
2004	Figure 8 Island to Surf City	Mr. SID	Mosaic	Color	DCM	.5'
NAIP Photography (2006)						
Date	**Coverage**	**Format**	**Mosaic/Tiles**	**Color**	**Source**	**Resolution**
2006	New Hanover County	Mr. SID	Mosaic	Color	NAIP	1'
New Hanover County (2006)						
Date	**Coverage**	**Format**	**Mosaic/Tiles**	**Color**	**Source**	**Resolution**
2006	New Hanover County-Mason Inlet to Rich Inlet	Mr. SID	Mosaic	RGB	DCM	.5'
2006	New Hanover County-Zeke's Island to Wrightsville Beach	Mr. SID	Mosaic	RGB	DCM	.5'
2006	New Hanover County-Mason Inlet to Rich Inlet	Mr. SID	Mosaic	Color	DCM	.5'
2006	New Hanover County-Zeke's Island to Wrightsville Beach	Mr. SID	Mosaic	Color	DCM	.5'
2006	New Hanover County	Mr. SID	Tiles	RGB	DCM	.5'
2006	New Hanover County	Mr. SID	Tiles	Color	DCM	.5'

Table IX-12. Digital Orthophotography for Region 2b

Date	Coverage	Format	Mosaic/Tiles	Color	Source	Resolution
Inlet Photography (1971-2000)						
Date	**Coverage**	**Format**	**Mosaic/Tiles**	**Color**	**Source**	**Resolution**
1971, 1974, 1977, 1984, 1992	Brown's Inlet	Mr. SID	Mosaic	B&W	DCM	1'
1995, 2000	Brown's Inlet	Mr. SID	Mosaic	Color	DCM	1'
1971, 1974, 1977, 1984, 1992	North Topsail (east), New River Inlet, Onslow Beach (west)	Mr. SID	Mosaic	B&W	DCM	1'
1995, 2000	North Topsail (east), New River Inlet, Onslow Beach (west)	Mr. SID	Mosaic	Color	DCM	1'
1971, 1974, 1977, 1984, 1992	Rich Inlet, Hutaff Island, New Topsail Inlet, Topsail Beach	Mr. SID	Mosaic	B&W	DCM	1'
1995, 2000	Rich Inlet, Hutaff Island, New Topsail Inlet, Topsail Beach	Mr. SID	Mosaic	Color	DCM	1'
Oceanfront Photography (1998)						
Date	**Coverage**	**Format**	**Mosaic/Tiles**	**Color**	**Source**	**Resolution**
1998	Hutaff Island	Mr. SID	Tiles	B&W	DCM	.5'
1998	Onslow Beach, Browns Island, Bear Island	Mr. SID	Tiles	B&W	DCM	.5'
1998	Topsail Beach, Surf City, North Topsail Beach	Mr. SID	Tiles	B&W	DCM	.5'
Post-Isabel Photography (2003)						
Date	**Coverage**	**Format**	**Mosaic/Tiles**	**Color**	**Source**	**Resolution**
2003	Pender County	Mr. SID	Mosaic	B&W	USGS	2'
2003	Onslow County	Mr. SID	Mosaic	B&W	USGS	2'
Oceanfront Photography (2004)						
Date	**Coverage**	**Format**	**Mosaic/Tiles**	**Color**	**Source**	**Resolution**
2004	Figure 8 Island to Surf City	Mr. SID	Mosaic	Color	DCM	.5'
2004	Surf City to Onslow Beach (west)	Mr. SID	Mosaic	Color	DCM	.5'
2004	North Topsail (east) to Emerald Isle (west)	Mr. SID	Mosaic	Color	DCM	.5'
NAIP Photography (2006)						
Date	**Coverage**	**Format**	**Mosaic/Tiles**	**Color**	**Source**	**Resolution**
2006	Pender County	Mr. SID	Mosaic	Color	NAIP	1'
2006	Onslow County	Mr. SID	Mosaic	Color	NAIP	1'
Onslow County (2006)						
Date	**Coverage**	**Format**	**Mosaic/Tiles**	**Color**	**Source**	**Resolution**
2006	Onslow County (portions), North Topsail Beach	Mr. SID	Tiles	B&W	DCM	.5'
2006	Onslow County (portions), Bear Island	Mr. SID	Tiles	B&W	DCM	1'

Table IX-13. Digital Orthophotography for Region 2c

Inlet Photography (1938-2000)						
Date	Coverage	Format	Mosaic/Tiles	Color	Source	Resolution
1971, 1974, 1977, 1984, 1992	Onslow Beach (east), Browns Inlet, Browns Island, Bear Inlet, Bear Island, Bogue Inlet	Mr. SID	Mosaic	B&W	DCM	1'
2000	Onslow Beach (east), Browns Inlet, Browns Island, Bear Inlet, Bear Island	Mr. SID	Mosaic	Color	DCM	1'
1971, 1974, 1976, 1984, 1992	Atlantic Beach (east), Fort Macon, Beaufort Inlet, Shackleford Banks (west)	Mr. SID	Mosaic	B&W	DCM	1'
1995, 2000	Atlantic Beach (east), Fort Macon, Beaufort Inlet	Mr. SID	Mosaic	Color	DCM	1'
1938, 1949, 1956, 1958, 1960, 1971, 1976, 1987, 1992	Bear Island, Bogue Inlet, Emerald Isle (west)	TIFF	Mosaic	B&W	DCM	varies
Oceanfront Photography (1998)						
Date	Coverage	Format	Mosaic/Tiles	Color	Source	Resolution
1998	Bogue Banks	Mr. SID	Tiles	B&W	DCM	.5'
1998	Onslow Beach, Browns Island, Bear Island	Mr. SID	Tiles	B&W	DCM	.5'
1998	Shackleford Banks	Mr. SID	Tiles	B&W	DCM	.5'
Post-Isabel Photography (2003)						
Date	Coverage	Format	Mosaic/Tiles	Color	Source	Resolution
2003	Carteret County (mainland)	Mr. SID	Mosaic	B&W	USGS	2'
Oceanfront Photography (2004)						
Date	Coverage	Format	Mosaic/Tiles	Color	Source	Resolution
2004	North Topsail (east) to Emerald Isle (west)	Mr. SID	Mosaic	Color	DCM	.5'
2004	Emerald Isle to Shackleford Banks (west)	Mr. SID	Mosaic	Color	DCM	.5'
2004	Fort Macon to Cape Lookout	Mr. SID	Mosaic	Color	DCM	.5'
Carteret (2004)						
Date	Coverage	Format	Mosaic/Tiles	Color	Source	Resolution
2004	Carteret County (portions), Bogue Banks	Mr. SID	Tiles	Color	Carteret County	.5'
2004	Carteret County (portions)	Mr. SID	Tiles	Color	Carteret County	1'
2004	Carteret County (portions), Bogue Banks	Mr. SID	Tiles	Color	Carteret County	2'
2004	Carteret County (portions), Bogue Banks	Mr. SID	Mosaic	Color	Carteret County	2'
NAIP Photography (2006)						
Date	Coverage	Format	Mosaic/Tiles	Color	Source	Resolution
2006	Carteret County	Mr. SID	Mosaic	Color	NAIP	1'
Carteret (2007)						
Date	Coverage	Format	Mosaic/Tiles	Color	Source	Resolution
2007	Bear Island, Bogue Inlet, Emerlad Isle (west)	Mr. SID	Tiles	Color	Carteret County	1'
2007	Bear Island, Bogue Inlet, Emerlad Isle (west)	Mr. SID	Mosaic	Color	Carteret County	1'

In addition, the USGS has Digital Ortho Quarter Quads (DOQQs) from 1998 for the entire coastline. These photos are Color Infrared MrSID images. MrSID, Multiresolution Seamless Image Database, is an image format developed for georeferenced raster graphics.

4. Historical Shorelines and Erosion Rates

In support of coastal planning efforts, DCM began developing a historical shoreline database starting in the 1970s. Shorelines were digitized for available years for the entire N.C. oceanfront using a variety of media dating back to 1933. The primary source of historical data is the geo-referenced T-Sheets, provided by NOAA Coastal Services Center (CSC). DCM has also collaborated with USGS and USACE to document the most recent shorelines based both on delineation of wet-dry line as interpreted from orthophotography, as well as deriving the Mean High Water Level (MHWL) based on LiDAR survey data. In addition to the statewide oceanfront shoreline datasets, DCM has compiled a historical shoreline database in the vicinity of inlets, varying in length on either side of the inlet from approximately 10,000 feet to the entire stretch of shoreline leading to the next inlet. The available shoreline data and extents vary widely depending on the availability of historical photographs. Inlet shorelines were digitized and developed from multiple data sources including: DOT rectified aerials, DCM orthophotos and NOAA CSC T-Sheets. Tables IX-14 to IX-17 present the available shorelines which cover all three subregions of Region 2. GIS shape files of historical shorelines may be accessed via DCM's website at http://dcm2.enr.state.nc.us/Maps/chdownload.htm.

Table IX-14. Digitized NC Oceanfront Shorelines for Region 2

Oceanfront Shorelines			
Date	**Coverage**	**Type**	**Source**
1933-1952	NC Shoreline (Bird Island to Kill Devil Hills)	NOS T-Sheet (MHW)	DCM
1998	Entire NC Shoreline	Photo-Wet/Dry	DCM
2003	NC Shoreline (Bird Island to Bear Island)	NOAA Photo-Wet/Dry	DCM
2004	Entire NC Shoreline	NCDCM Photo-Wet/Dry	DCM
1849-1873	Entire NC Shoreline	NOS T-Sheet (MHW), CERC map	USGS, Coastal Carolina
1925-1946	Entire NC Shoreline	CERC map, USACE Photos, NOS T-Sheet (MHW)	USGS, NOAA, DCM
1970-1988	Entire NC Shoreline	CERC map, NOS T-Sheet (MHW)	USGS, NOAA, Coastal Carolina
1997	Entire NC Shoreline	LIDAR MHW Shoreline	USGS

Table IX-15. Digitized Inlet Shorelines for Region 2a

Inlet Shorelines			
Date	**Coverage**	**Type**	**Source**
1933	Carolina Beach Inlet	NOS T-Sheet (MHW)	DCM
1971, 1974, 1977, 1984, 1992,	Carolina Beach Inlet	NC DOT Photography	DCM
1973	Carolina Beach Inlet	-	NOAA/USGS
1997	Carolina Beach Inlet	-	USGS
1998	Carolina Beach Inlet	Photo-Wet/Dry	DCM
2004	Carolina Beach Inlet	NC DCM Photography	DCM
1933	Masonboro Inlet	NOS T-Sheet (MHW)	DCM
1973	Masonboro Inlet	-	NOAA/USGS
1974, 1977, 1984, 1992, 1995, 2000	Masonboro Inlet	NC DOT Photography	DCM
1997, 2003	Masonboro Inlet	-	USGS
1998, 2000	Masonboro Inlet	Photo-Wet/Dry	DCM
2004	Masonboro Inlet	NC DCM Photography	DCM
1933, 1944	Mason Inlet	NOS T-Sheet (MHW)	DCM
1938, 1949, 1958, 1971, 1977, 1987, 1992, 1998, 2003	Mason Inlet	Photo-Wet/Dry	DCM
1938, 1958, 1980, 1992, 1998, 2003	Rich Inlet	Photo-Wet/Dry	DCM

Table IX-16. Digitized Inlet Shorelines for Region 2b

Inlet Shorelines			
Date	**Coverage**	**Type**	**Source**
1934, 1973	New Topsail Inlet	-	NOAA/USGS
1944	New Topsail Inlet	NOS T-Sheet (MHW)	DCM
1971, 1974, 1976, 1984, 1992, 1995, 1997, 2000	New Topsail Inlet	NC DOT Photography	DCM
2003	New Topsail Inlet	-	USGS
2004	New Topsail Inlet	NC DCM Photography	DCM
1934, 1973	New River Inlet	-	NOAA/USGS
1997, 2003	New River Inlet	-	USGS
2004	New River Inlet	NC DCM Photography	DCM
1971, 1974, 1977, 1984, 1992, 1995, 2000	New River Inlet	NC DOT Photography	DCM
1952	New River Inlet	NOS T-Sheet (MHW)	DCM
1998	New River Inlet	Photo-Wet/Dry	DCM

Table IX. Digitized Inlet Shorelines for Region 2c

Inlet Shorelines			
Date	Coverage	Type	Source
1938, 1949, 1956, 1958, 1960, 1971, 1976, 1984, 1992, 1998, 2003	Bogue Inlet	Photo-Wet/Dry	DCM
1949	Bogue Inlet	NOS T-Sheet (MHW)	DCM
1933, 1946, 1973, 1979	Beaufort Inlet	-	NOAA/USGS
1997	Beaufort Inlet	-	USGS
2004	Beaufort Inlet	NC DCM Photography	DCM
1971, 1974, 1976, 1984, 1992, 1995, 2000	Beaufort Inlet	NC DOT Photography	DCM
1946	Beaufort Inlet	NOS T-Sheet (MHW)	DCM
1998	Beaufort Inlet	Photo-Wet/Dry	DCM

Using the digitized shorelines, the N.C. Coastal Resources Commission (CRC) has established oceanfront development setbacks based on long-term shoreline change rates. Setback factors determine the distance back that development can be sited measured from the first line of stable and natural vegetation. Shoreline change has been calculated by DCM using the average end point method, based on the distance from the earliest shoreline archived by the state (varies for segments of shoreline but typically from the 1940s) to the most recent (1998) divided by the number of years between them. Erosion rates are calculated at 50 m (164 feet) transects along shore. These rates are then “smoothed” to account for local variance and influence of inlets. DCM then determines setbacks based on these “smoothed erosion rates.” Details regarding the methods used to conduct the most recent update of setback rates (based on the 1998 shoreline location) are documented by Overton and Fisher (March 2004). Figures IX-15 to IX-17 present the long-term DCM erosion rates for all three subregions of Region 2.

Since inlets can temporarily interrupt and intercept the flow of sediments along the coast and migrate over time, they are typically areas of the greatest variation in erosion and accretion. This can be seen in the erosion rates plotted in Figures IX-15 to IX-17.

Region 2 experiences the majority of its severe erosion at the inlets, specifically Bogue Inlet, New River Inlet, and Carolina Beach Inlet. There are areas, such as Fort Fisher, Hutaff Island, Brown’s Island, and Shackleford Banks that experience increased erosion along the shore. Moderate erosional patterns occur along portions of Masonboro Island, North Topsail Beach, Onslow Beach, Browns Island, Emerald Isle, Indian Beach/Salter Path, and Shackleford Banks. There have been many areas in Region 2 that have had sediment added to the beach through nourishment such as Carolina and Kure beaches, Wrightsville Beach, and Bogue Banks. As a result, the erosion rates in these areas show accretion or a relatively neutral pattern over the long term.

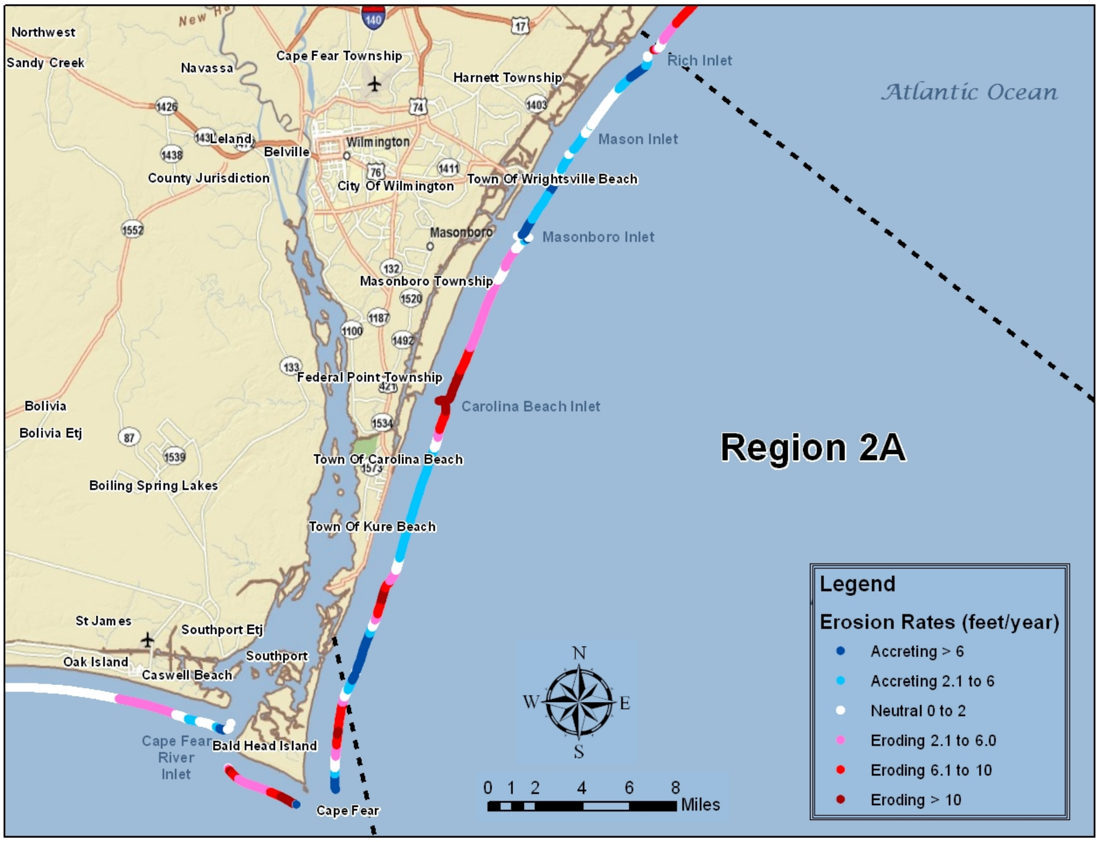


Figure IX-15. DCM Erosion Rates for Region 2a

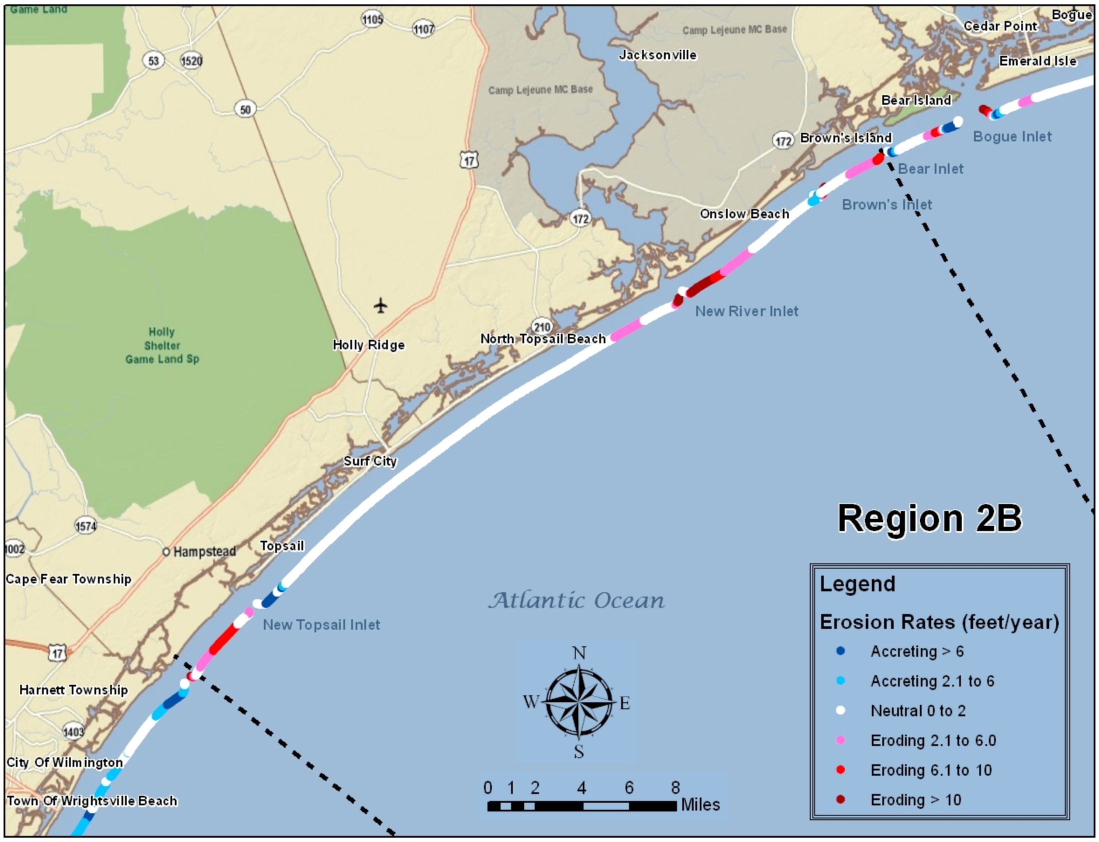


Figure IX-16. DCM Erosion Rates for Region 2b

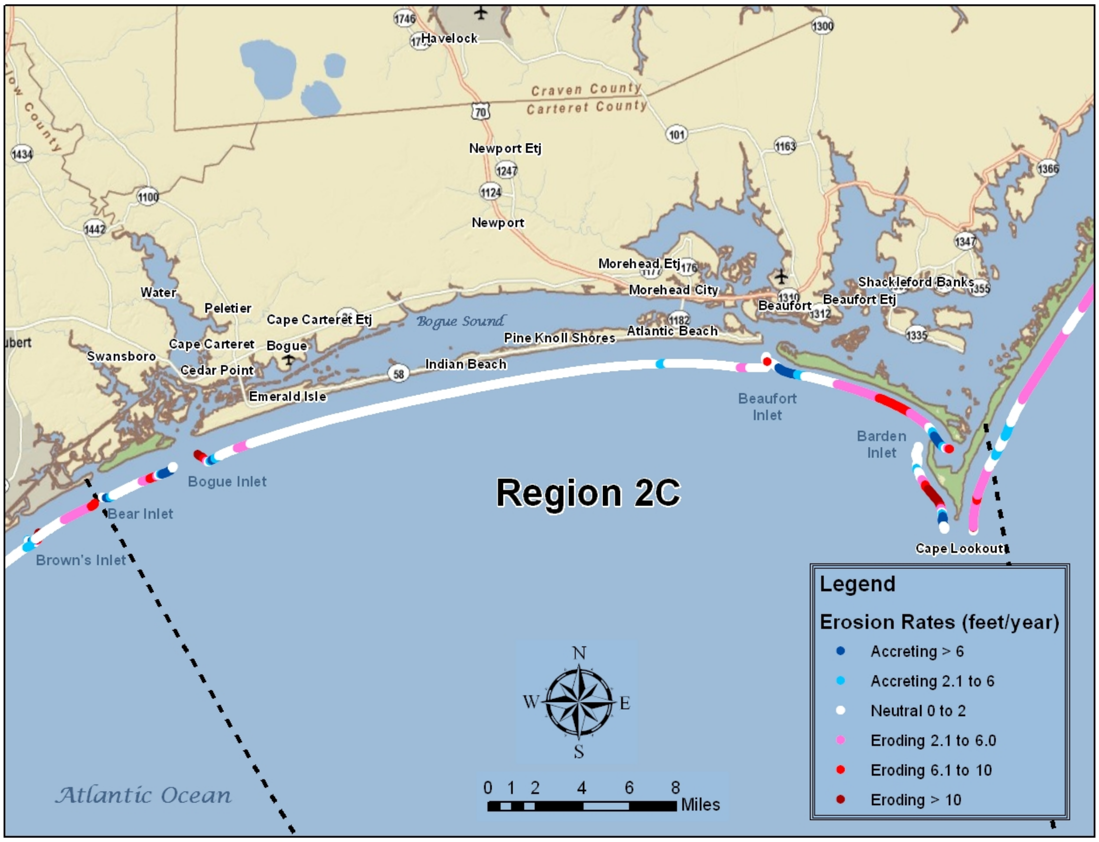


Figure IX-17. DCM Erosion Rates for Region 2c

5. Beach and Inlet Surveys

Beach profile data has been collected for several beaches along the North Carolina coast. This data is available in various formats depending on the location. Available beach profile data locations for the subregions of Region 2 are presented in Figures IX-18 to IX-20.

As part of the federally authorized Shore and Hurricane Wave Protection Project, beach profiles have been surveyed in New Hanover County (Region 2a) along Wrightsville Beach, Carolina Beach, and Kure Beach multiple times. Beach profile data is also available for Carteret County beaches from sources such as Coastal Science and Engineering (CSE), the University of North Carolina (UNC) Institute of Marine Sciences (IMS), the USACE, and Geodynamics. Extensive monitoring efforts exist in Carteret County to analyze effects of multiple federal navigation projects, Federal Emergency Management Agency (FEMA) emergency replenishment projects, and locally funded restoration projects. The Carteret County Shore Protection Office website (http://www.protectthebeach.com/) contains extensive information, reports, and data on the various projects along Bogue Banks. Since 2004, annual surveys have been performed along Bear Island, Bogue Banks, and Shackleford Banks as part of the Bogue Banks Beach and Nearshore Mapping Program (BBBNMP). There are 120 profiles along

Bogue Banks with 18 profiles on Bear Island and 20 profiles on Shackleford Banks. All BBBNMP profile data covers both onshore (dune to wading depth) and offshore (wading depth to depth of 30 feet) regions.

In addition to monitoring the beach through profile data, detailed surveys exist at Mason Inlet, Bogue Inlet, and Beaufort Inlet, covering the morphological inlet features such as the ebb and flood tidal shoals and the navigation channel. Also, the Navigation Branch of the USACE Wilmington District maintains a database of hydrographic surveys for federal navigation channels. Surveys for Carolina Beach Inlet, Masonboro Inlet, New Topsail Inlet, New River Inlet, Bogue Inlet, Morehead City Harbor (including Beaufort Inlet) and Barden Inlet can be accessed via the USACE website at http://www.saw.usace.army.mil/nav/inlets.htm. These inlets are part of federal dredge projects to maintain the navigation channels at authorized width and depth dimensions. Some detailed, extensive surveys in the vicinity of the Cape Lookout lighthouse are also available.

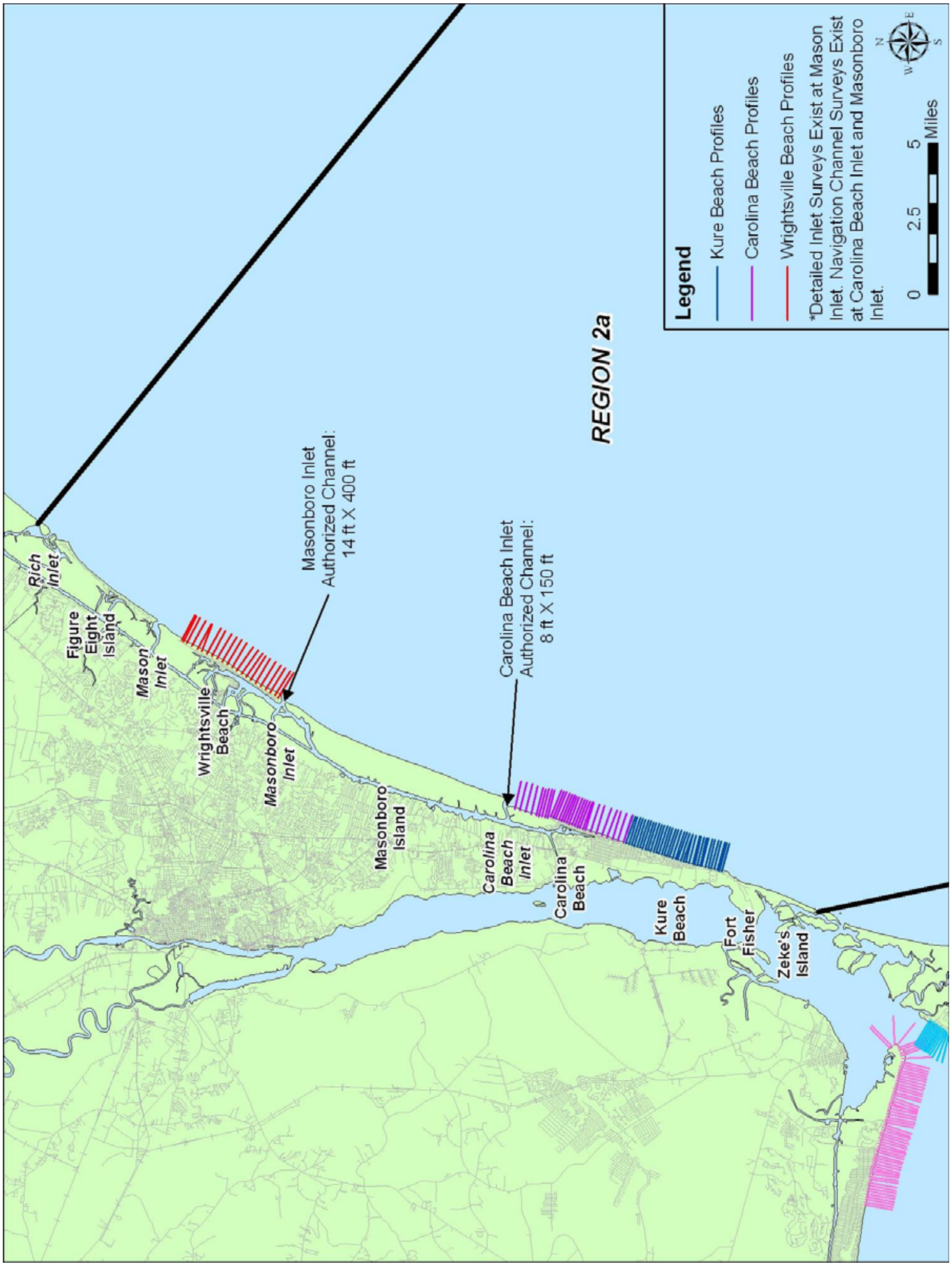


Figure IX-18. Beach Profile Monitoring Locations for Region 2a

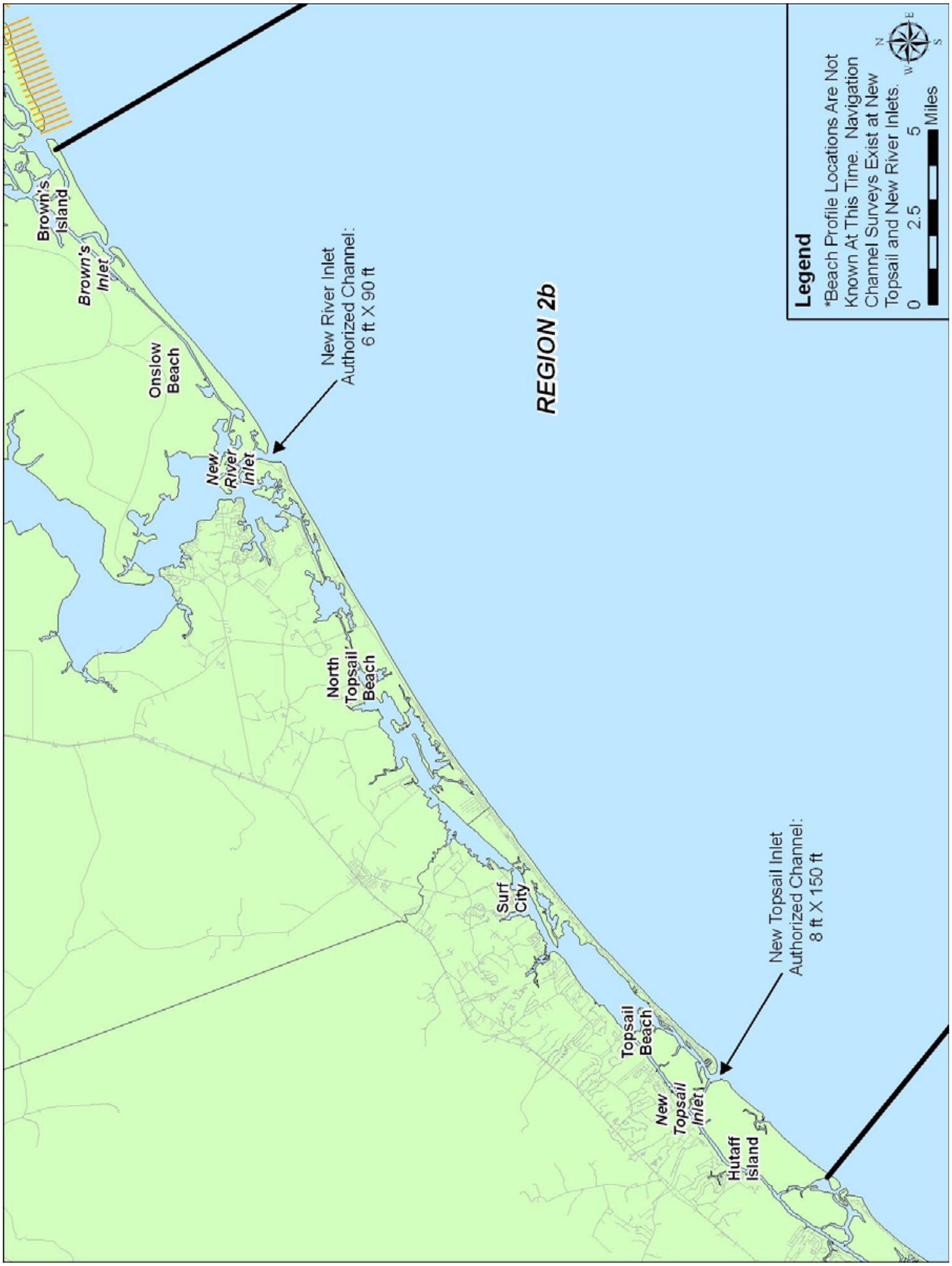


Figure IX-19. Beach Profile Monitoring Locations for Region 2b

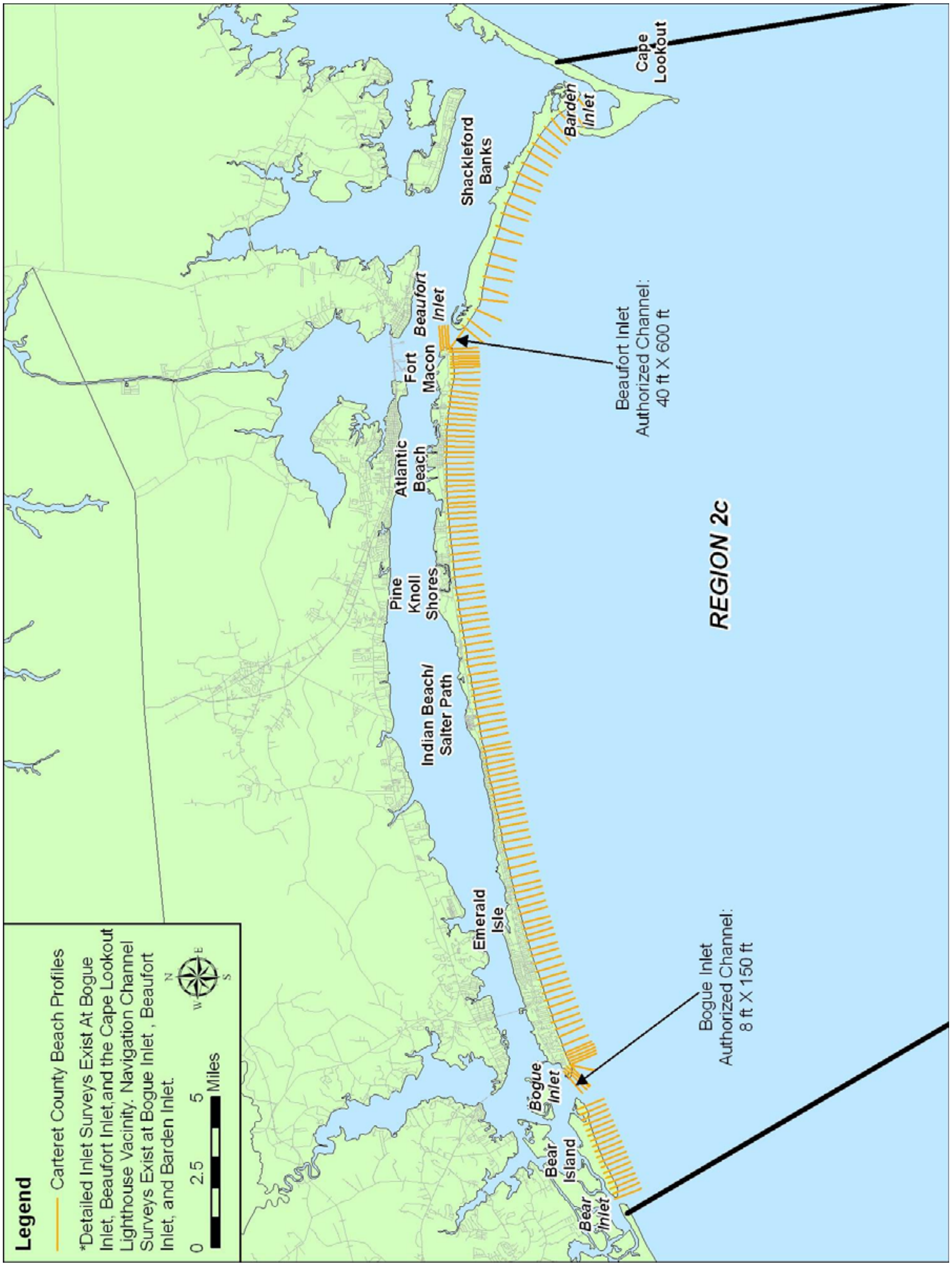


Figure IX-20. Beach Profile Monitoring Locations for Region 2c

6. Geologic Framework

The geological composition of the North Carolina coast and the dynamic nature of its inlets play a vital role in beach behavior and potential sources and availability of sand resources. Coastal geology – the origin, structure, and characteristics of coastal sediments, combined with the geological formation of the coastline over thousands of years of physical and chemical processes – dictates the properties of the sediments. The inlets provide a temporary natural disruption to longshore sediment transport and greatly impact sediment pathways. Coastal processes, of varying temporal and spatial scales, driven by water level changes, tides, waves, currents and winds interact with the local coastal geology and sediment supply to form and modify the configuration of the coastal region forming features such as beaches, dunes, and inlets. A detailed study of the coastal geology from Cape Lookout to the North Carolina/South Carolina border has been compiled by Dr. William Cleary, a coastal geologist and professor at the University of North Carolina Wilmington. The study can be found in Appendix C.

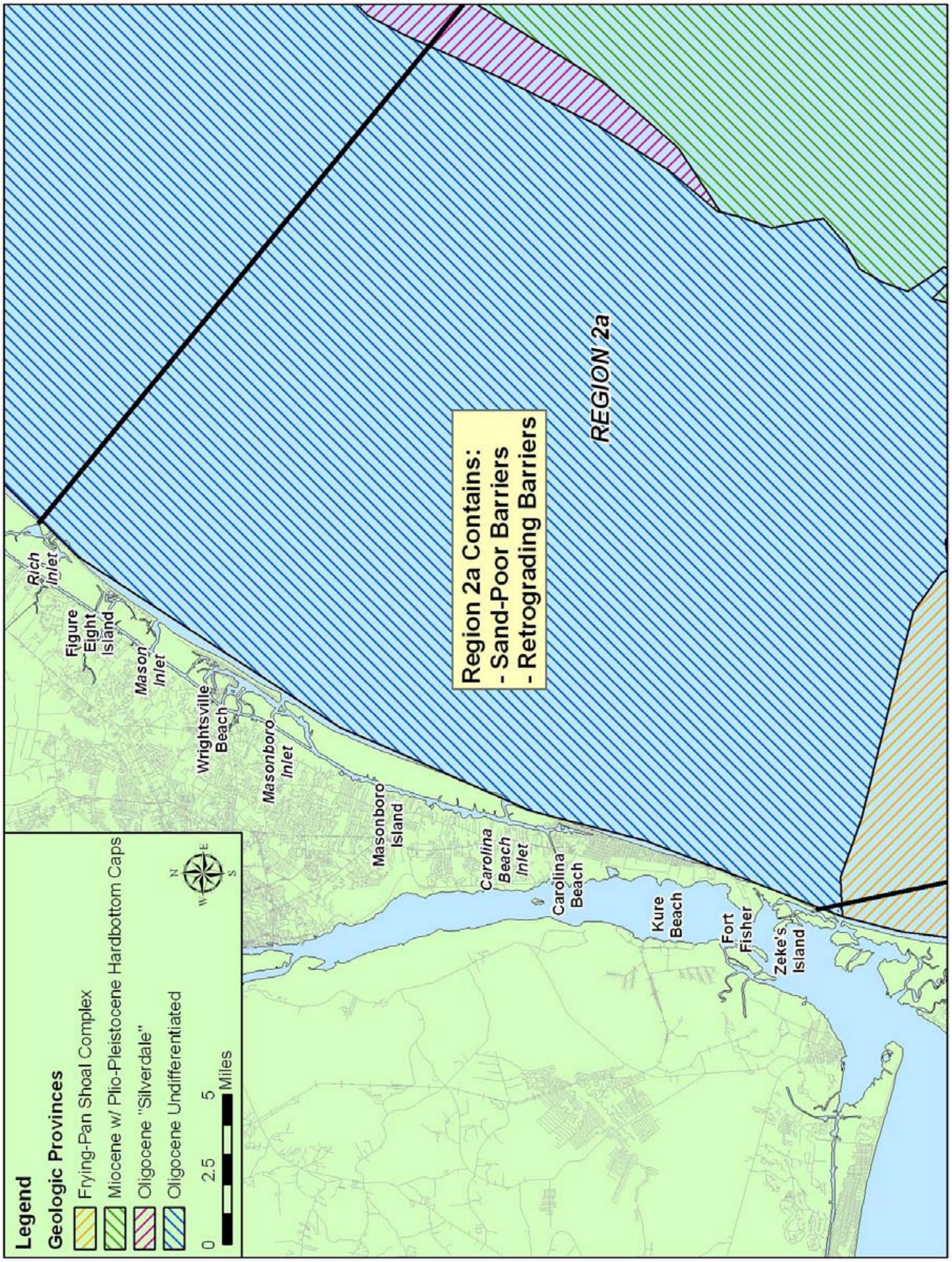


Figure IX-21. Offshore Geology for Region 2a

a) Region 2a Beaches and Inlets

(1) Fort Fisher and Kure Beach

The shoreline segment from Kure Beach to Fort Fisher consists of a wave-cut platform incised into Pleistocene units of the headland with a thin perched beach (Moorefield, 1978; Meisburger, 1979; Cleary and Hoiser, 1979; Snyder *et al.*, 1994; Riggs *et al.*, 1995; Cleary *et al.*, 1996; and Marcy and Cleary, 1997). All of the major hurricanes that have impacted this area, from Hurricane Hazel (October 1954) to Hurricane Fran (September 1996), stripped away the thin veneer of sand and exposed the underlying platform. In an effort to restore the beach in the aftermath of the 1996 hurricanes, the USACE replenished an 18,000-foot long oceanfront segment of Carolina/Kure Beach/ Fort Fisher reach with approximately 3.4 million cubic yards of high quality beach fill (USACE, 1993a and 1993b) (Figure IX-22). The borrow area was located in the hardbottom dominated shoreface off Carolina Beach. The site represented an anastomosed channel complex of the ancestral Cape Fear River that was incised into the Pliocene valley fill complex (Meisburger, 1979; Snyder *et al.*, 1994; USACE, 1993b; Marcy and Cleary, 1997). The Pleistocene paleo-channels were estimated to contain in excess of 23 million cubic yards of clean sand.

Fort Fisher, located adjacent to Kure Beach, is characterized by erosion resistant, coquina Ls (calcarenite) that underlies the aforementioned humate sandstone and crops out along the intertidal beach. Friable, humate and iron-cemented Pleistocene sandstone formed a 8.2-foot high wave-cut scarp and terrace that backed the shoreline along headland and seaward of the Civil War Fort prior to the construction of the seawall. South of Fort Fisher is the East Beach non-headland shoreline segment characterized by a barrier spit that overlies an inlet-fill sequence consisting of 35 feet of muddy estuarine sediments (Swain and Cleary, 1992). The shape and evolution of the coastal segments in vicinity of Fort Fisher is clearly related to the outcropping and underlying Pleistocene geologic units (Swain and Cleary, 1992; Riggs *et al*., 1995 and Cleary *et al.*, 1996).

In the early part of twentieth century, major sections of the coquina that crops out on the beach area were removed for road building and construction materials (Cleary and Hosier, 1977). Closure of an inlet south of Fort Fisher and the removal of the coquina ultimately led to a shoreline recession exceeding 57 feet per year between 1926 and 1931 (Beach Erosion Board, 1931). Following the hurricanes of 1954 and 1955, several small groins and rubble from storm related destruction were placed at the embayment immediately south of the coquina exposures. In 1970, a rock revetment consisting of limestone was emplaced. Since the mid-1970s until the late 1980s a variety of construction rubble has been added to the site (Figure IX-22).

In order to mitigate the rapid erosion, a Beach Erosion Control Project was authorized in 1976 to protect the Civil War earthen-mound fortifications. The historic fort was reduced to approximately 50 percent of its original extent at the time of the authorization. After obtaining a variance from the CRC, the project was initiated in 1995. Plans called for a 3,050-foot long rock revetment with crestal elevations of 10 - 16.5 feet, a base width of

70 feet, and an armored toe consisting of five ton interlocking STA-POD units (USACE, 1993 and Dennis, 1996). The project was completed in the spring of 1996 at a cost of approximately $4 million (Figure IX-22).

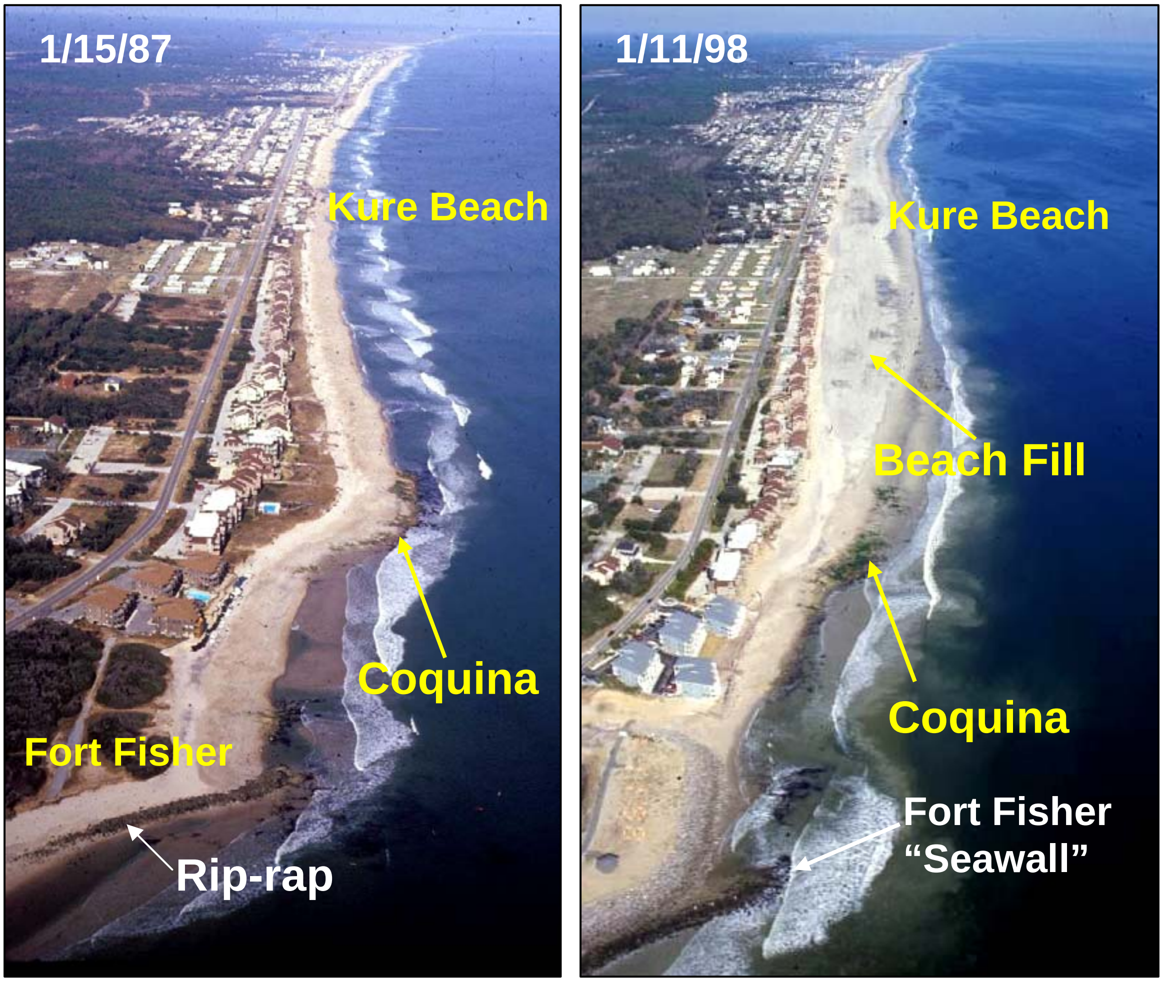


Figure IX-22. Fort Fisher and Kure Beach (Cleary, 2008)

(2) Carolina Beach and Carolina Beach Extension

The barrier island chain of the Cape Lookout to Cape Fear section of the North Carolina coast is interrupted at Carolina Beach Inlet. Carolina Beach represents the continuation of the Kure Beach shoreline segment and the Carolina Beach Extension represents the truncated barrier spit that existed before the opening of Carolina Beach Inlet in 1952. In essence, it represents a portion of the former northward extending Masonboro Spit. This section of the shoreline is sediment starved due to the impoundment of littoral material by Carolina Beach Inlet, resulting in a chronic washover zone just south of the inlet (Figure IX-23).

The marsh-filled estuary found north, and again south, of Carolina Beach Extension does not exist behind the Carolina-Kure Beach mainland section. This portion of the coast is characterized by a perched mainland beach. Elevations landward of the beach are 15 to 20 feet. Pleistocene-aged, erosion-resistant units underlie the mainland beach along the Carolina Beach shoreline segment.

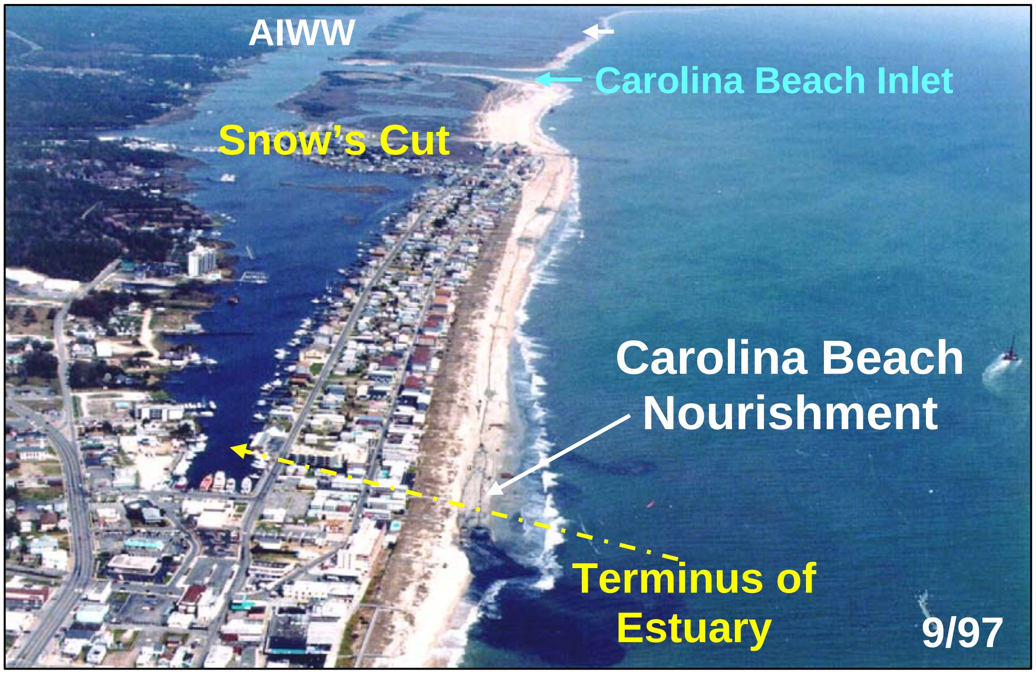


Figure IX-23. Carolina Beach Mainland and Extension (Cleary, 2008)

(3) Carolina Beach Inlet

Carolina Beach Inlet was intentionally opened in 1952 and separates the barrier spit portion of Carolina Beach from Masonboro Island to the northeast. The channel connects the Atlantic Ocean to the Atlantic Intracoastal Waterway. The inlet's width has varied considerably over time, ranging from 383 feet to 1,400 feet. These fluctuations are related to the deflection of the ebb channel.

(4) Masonboro Island

Masonboro Island is an undeveloped barrier island that extends along eight miles of the coastline between Wrightsville Beach and Carolina Beach Extension. Most of the large dunes (12 feet in elevation) are restricted to the northern portion of the island (four miles) in the south fillet of Masonboro Inlet jetty. The dunes along the remaining 60 percent of the barrier are very low and discontinuous (Cleary *et al*., 1999).

The sediment budget of Masonboro Island has been severely impacted by the opening of Carolina Beach Inlet in 1952 and by the construction of the dual jetty system at Masonboro Inlet. Both modified inlets have impounded substantial volumes of sediment on an annual basis since modification occurred. The net reduction of sediment supply over the past 30-50 years is approximately 333,000 cubic yards per year (Jarrett, personal communication, 1996). Combined with storm impacts, this has dramatically affected the evolution of Masonboro Island.

Most of the central (2.7 miles) and southern (2.7 miles) portions of the barrier were characterized by sparsely vegetated washover fans in the early 1990s. Many of these features extended well into the adjacent fringing marsh and into open water. The foredunes along much of the barrier were scarped or extremely low and, in many places, nonexistent. When Hurricane Fran made landfall in September 1996, the storm greatly exacerbated the generally poor conditions of the barrier island. The Category 3 hurricane produced a storm surge (12.1 feet) that exceeded the 100-year flood level. The majority of the island, with the exception of the extreme northern end, was inundated and remained submerged for several hours (S. Rogers, personal communication, 1996). Post-storm aerial photography showed that the island was characterized by extensive washover-related features. The storm eroded almost all of the foredunes and dramatically reduced the barrier profile along the southern portion of the island (Doughty, 2006 and Doughty *et al.*, 2006) (Figure IX-24).

Figure IX-24. Masonboro Island Washover (Post-Hurricane Fran) (Cleary, 2008)

The net shoreline change between 1993 and 2002 varied substantially along the three major reaches of island. Shoreline progradation was limited to the extreme northern portion of the island within the fillet (due to dredge disposal operations) where the shoreline accreted an average of 26 feet. In contrast, the central and southern barrier segments retreated approximately160 feet and 289 feet respectively. The island will continue to retreat along the southern portion and may, depending upon the storm climate, be detached during a major high energy event.

(5) Masonboro Inlet

Historical charts show the existence of the inlet starting in the early 1700s. Old photographs show that Masonboro Inlet was relatively stable in terms of location from about 1928 to 1940. From 1938 to 1945 the channel orientation ranged from shore normal to strongly skewed toward Masonboro Island. In 1947, the inlet was altered by cutting a channel through the island spit causing changes in the ebb-tidal delta. In October 1954, Hurricane Hazel enlarged the inlet channels. Difficulties with maintaining the navigation channel resulted in the construction of a unique weir jetty on the northern side of the inlet in 1966. As a result, the tidal delta elongated northward and the channel shifted toward the jetty. In 1981, the south jetty was completed, fixing the position of the inlet. The jetties have significantly impacted the tidal prism and sediment transport to the point where little sediment bypasses the inlet naturally (Figure IX-25).

Figure IX-25. Masonboro Inlet Jetties (Cleary, 2008)

(6) Wrightsville Beach and Shell Island

Wrightsville Beach is a five-mile long transgressive barrier. Early photographs (1915-1925) show that the northern portions of Wrightsville Beach had large elevated dunes and a wide island profile. To the south, the island was narrow and low. In order to create more elevated land for development, Waynick Boulevard, the road parallel to Banks Channel, was constructed with dredge material and built over tidal marsh in the 1930s (Cleary and Hosier, 1977 and Cleary and Pilkey, 1996). Between 1944 and 1965, four major hurricanes (including Hurricane Hazel, 1954) and a number of winter northeasters resulted in significant shorefront erosion. In 1965, the Wrightsville Beach Erosion Control and Hurricane Protection Project was constructed along 2.8 miles of oceanfront which extended north from the Masonboro Inlet north jetty to the town's northern limit (Cleary and Hosier, 1977 and Cleary and Pilkey, 1996). Between 1938 and 1965, Moore's Inlet, located 0.28 miles north of the town, migrated along the barrier segment of Wrightsville Beach and adjacent Shell Island. In 1965, Moore's Inlet was intentionally closed and sand pumped on the shore. In all, more than 2.9 million cubic yards of fill was placed on Wrightsville Beach, subsequently closing Moore's Inlet.

Investigations of the offshore shoreface off Wrightsville Beach in the 1990s showed that the sediment cover is a patchy, relatively thin veneer blanketing low-relief, Tertiary limestone and silstone. The modern sediment averages approximately one foot in thickness. The primary underlying units are a Plio-Pleistocene limestone, an unconsolidated Oligocene siltstone, and Quaternary mud and muddy sand within incised paleo-fluvial channels (Snyder *et al*., 1994; Thieler *et al*., 1995 and 2001). Since the shoreface sand resource potential is low, future USACE beach replenishment projects will continue to rely on beach fill quality material dredged from the interior feeder channels of Masonboro Inlet and possibly the fillet on the southern margin of Masonboro Inlet.

(7) Mason Inlet

Mason Inlet separates Figure Eight Island to the north and Wrightsville Beach to the south. Historical studies of Mason Inlet documented its opening in the late 1880s and its subsequent southerly migration (Cleary and Hosier, 1979; Brooks, 1988; Cleary and Marden, 1999; Johnsen *et al.,* 1999; and Freeman, 2001). The inlet's width has fluctuated considerably in the past from up to 1,660 feet in 1956 to as little as 180 feet in 1977 and 1984 (Cleary and Marden, 1999). The rate of inlet migration has varied by an order of magnitude over decadal scales and there have been minor short-term reversals in the direction of migration. During the period between 1974 and 1997 the inlet migrated southward 3,610 feet at an average rate of approximately160 feet per year. Rates over this time interval ranged from three to 295 feet per year, with the highest inlet migration rates coinciding with overall shoaling of the inlet. In 1997 the Shell Island inlet margin was armored with oversized sandbags to protect infrastructure and the Shell Island Resort complex.

Subsequent studies (Freeman, 2001) and land surveys (ATM 2000, 2001) indicate that stabilization of the inlet led to a narrowing and slight deepening of the inlet channel.

Between 1996 and 1999 the southerly longshore transport and accompanying growth of the spit platform at the southern end of Figure Eight Island decreased the width of the inlet by approximately 375 feet (from 1,215 to 840 feet) and its throat cross section by 40 percent (5,059 $ft.^2$ to 3,057 $ft.^2$). During the same time period the narrowing of the inlet and constriction of tidal flow was partially compensated by scour of the channel increasing maximum depths from approximately 10 to 18 feet (ATM, 2000). Continued degradation of the soundside channels between 1999 and 2001 resulted in shoaling of the ebb channel and partial infilling of the poorly defined marginal flood channel on the updrift Figure Eight shoulder. The reduction in size of Mason Inlet since the late1970s was a product of the diminishing tidal prism that decreased from 67.1 million $ft.^3$ in 1995 (Cleary, 2002) to 24.7 million $ft.^3$ by 1999 (ATM, 2000). The declining tidal discharge at the inlet resulted from the interplay of the longshore sediment transport, high energy wave events and the landward movement of sand into the inlet by flood currents (Cleary and FitzGerald, 2003). These processes combined to produce long-term sand deposition inside the inlet that was evidenced by the shoaling of back barrier channels.

From the late 1970s through the mid-1990s the tidal prism of Mason Inlet was significantly reduced due to sedimentation in the 3,950-foot long Mason Creek, the access channel that connected the inlet channel to the Atlantic Intracoastal Waterway (AIWW). When this creek was devoid of intertidal shoals the inlet accessed a large portion of its tidal prism from the Intracoastal Waterway. During the late 1970s Mason Inlet was situated in front of the opening to Mason Creek. While the inlet was in this position, multiple lobes of sand formed and prograded landward into Mason Creek as well as into Banks Channel behind Figure Eight Island. As the inlet migrated southward large quantities of sand completely shoaled Mason Creek (Cleary and Fitzgerald, 2003). This accumulation of sand effectively cut off the tidal exchange between the AIWW and Mason Inlet, vastly reducing the tidal prism. As a consequence, the migration rates were accelerated.

The only viable long-term management option for mitigating the increased erosion potential was the relocation of the inlet northward as much as possible. To that end, in early March 2002, a new inlet channel was excavated across the southern spit system of Figure Eight Island at a site located approximately 3,020 feet northeast of the existing inlet. Several measures were undertaken to increase the tidal prism and lessen shoaling of the interior channels. Most importantly, Mason Creek was dredged along its length, reestablishing the hydraulic connection between the inlet and the AIWW. A depositional basin was dredged inside the inlet to help prevent rapid shoaling that is normally a product of flood-tidal delta formation. The material from the inlet relocation dredging operations was used to close off the old inlet and nourish a segment of the southern portion of Figure Eight Island (Figure IX-26).

Figure IX-26. Mason Inlet Relocation Efforts (Cleary, 2008)

Changes in post-relocation, inlet morphology have been considerable. The ebb channel has periodically shifted southwest and northeast since relocation as the system attempted to reach equilibrium. Erosion has been the dominant trend along the adjacent oceanfront shorelines as the planform of the shorelines adjusted to the new location of the inlet and the changing shape of the small ebb-tidal delta. Noticeable infilling of the interior feeder channels as well as the depositional basin has persisted since the ebb channel was relocated in March 2002 (Welsh and Cleary, 2007). The nearly clogged access channels are usually unnavigable unless they are dredged. When maintenance dredging is required, the beach quality material dredged from the throat, depositional basin and Mason Creek is placed along Figure Eight Island at the expense of the homeowners. The most recent maintenance operations occurred in January 2008. If dredging activities were to cease the inlet would likely close in a short period of time due to the reduced tidal flow, and erosion of the oceanfront shorelines would temporarily increase as the barrier curvature is adjusted.

(8) Figure Eight Island

Figure Eight Island is a narrow 4.6-mile long island separated from Hutaff Island by Rich Inlet and from Wrightsville Beach/Shell Island by Mason Inlet (Figure IX-27). The private residential island exhibits two distinct physiographic segments. The entire barrier is underlain by inlet fill. The southern portion of the barrier is a washover-prone spit that extended southward subsequent to the opening of Mason Inlet, a migrating inlet, in 1880. The northern older segment of the island is narrow, and in places the core of the barrier is forested. Toward Rich Inlet the barrier is offset seaward due to the inlet-related accretion zone. The historic accretion zone consists of a series of parallel dune ridges that developed since the 1890s. This zone periodically erodes or accretes as the alignment of the ebb channel changes. Rich Inlet has shown little tendency to migrate, however, the cyclical re-orientation of the ebb channel can produce very rapid erosion on the downdrift shoreline. Since 2002, a number of homes along the impacted shoreline are fronted by a series of sandbags (Cleary *et al.*, 2002 and Jackson and Cleary, 2006).

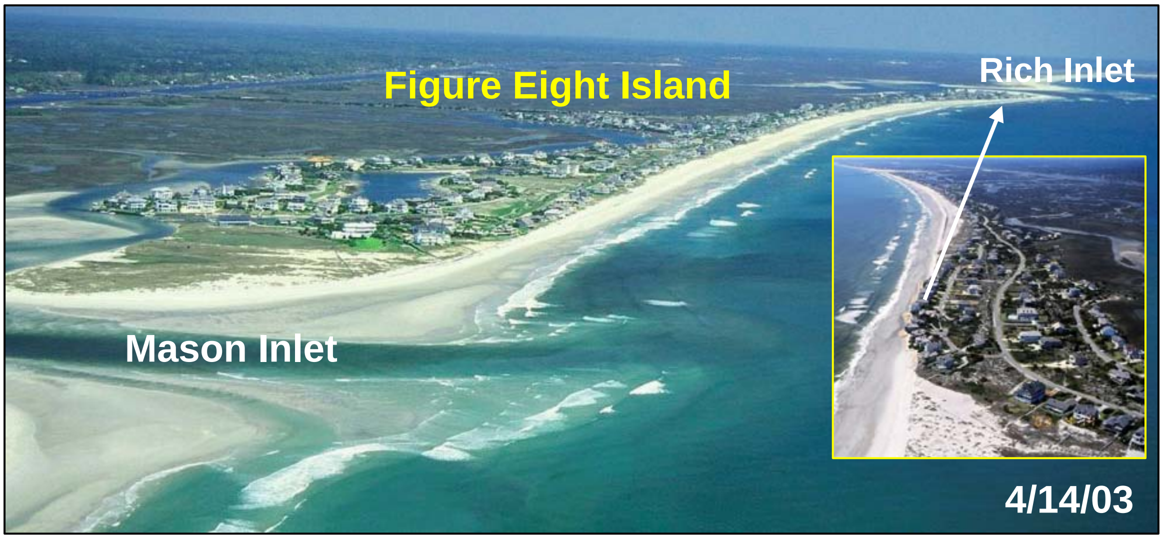


Figure IX-27. Figure Eight Island (Cleary, 2008)

(9) Rich Inlet

Rich Inlet has been a relatively stable feature for the past 200 years. Its origin is possibly the ancestral channel of Pages Creek, that controlled the inlet location as sea level rose over the last several thousand years. The inlet's stability is enhanced by its large drainage area, an expansive marsh area, lagoon, and two tidal creeks. Rich Inlet is a relatively large inlet compared with other systems in this region, with a mean minimum width of approximately 2,000 feet and a depth of 16-23 feet in the main channel over the last 60 years (Cleary and Marden, 1999).

b) Region 2b Beaches and Inlets

Figure IX-28 illustrates the offshore geology for Region 2b.

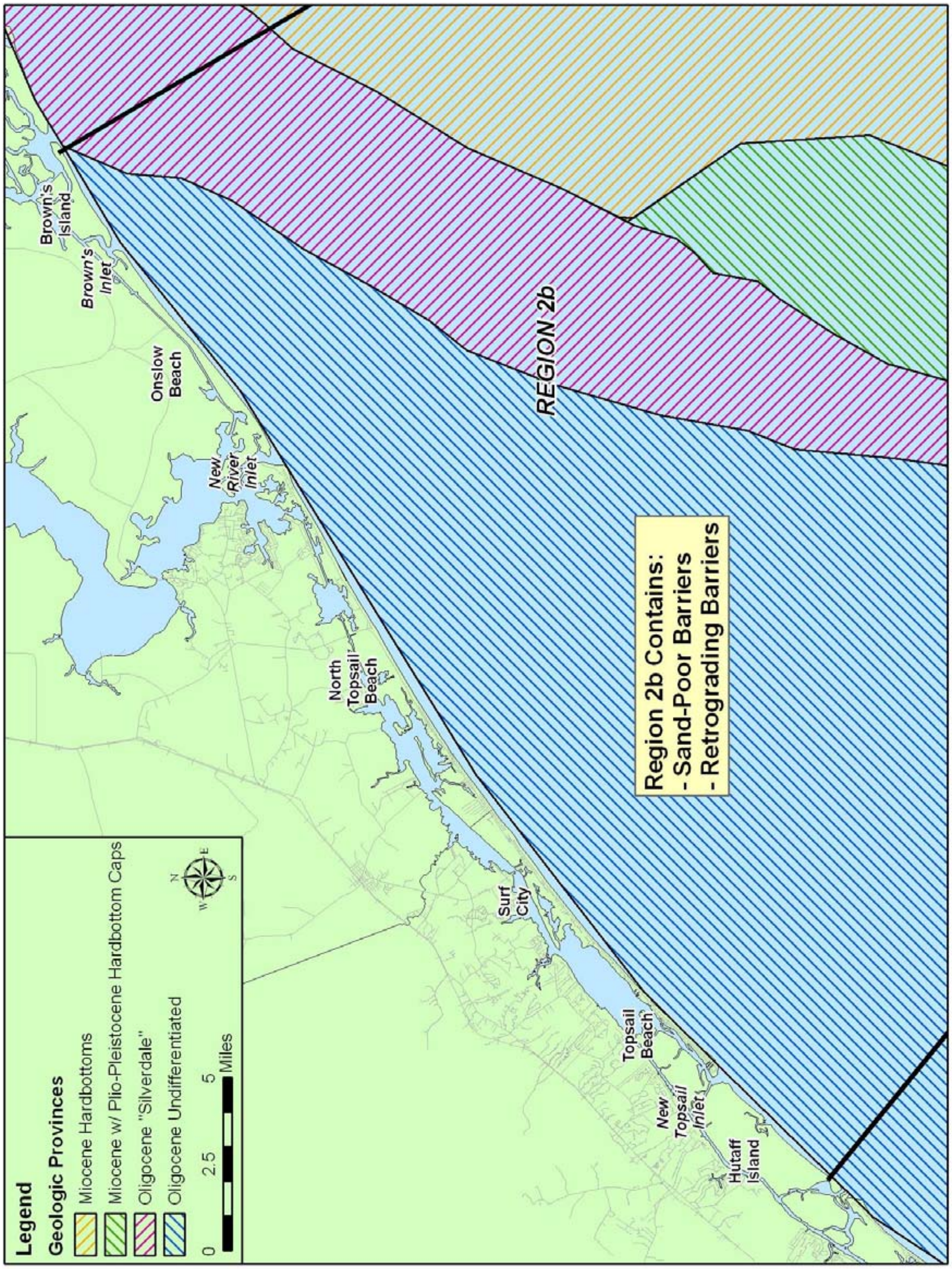


Figure IX-28. Offshore Geology for Region 2b

(1) Hutaff Island

Hutaff Island is a 3.7 mile-long transgressive barrier located in southwestern Onslow Bay. The washover-dominated barrier is bordered by New Topsail Inlet to the northeast and Rich Inlet to the southwest. The undeveloped barrier is now comprised of Lea and Hutaff Islands that were joined following the closure of Old Topsail Inlet in June 1998 (Figure IX-29). Historically, the barrier has been influenced by at least four inlets that have contributed to the infilling of the estuary. The most noteworthy changes along Hutaff Island since 1938 were the results of the southwest migration of Old Topsail and New Topsail Inlets. The former Hutaff and Lea Island barrier segments were considerably shortened as a result of the inlets' migration.

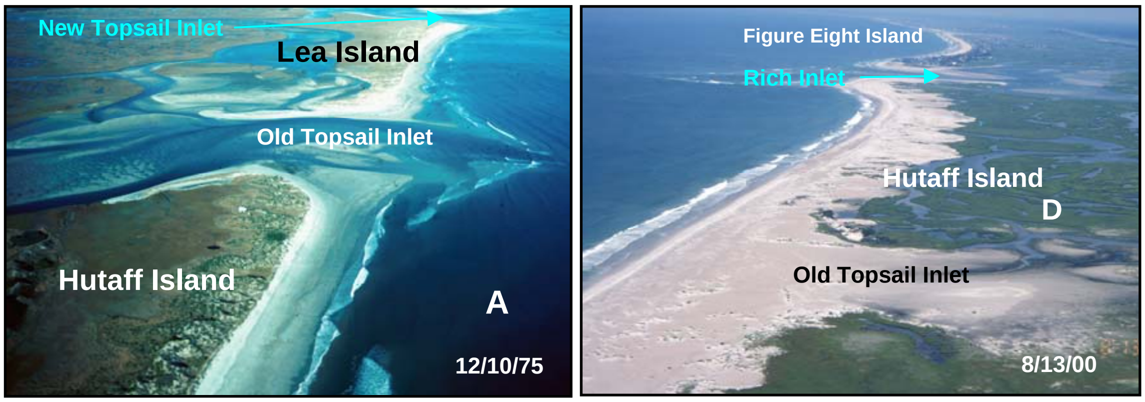


Figure IX-29. Closing of Old Topsail Inlet to Form Hutaff Island (formerly Hutaff and Lea Island) (Cleary, 2008)

Severe storm events have frequently impacted the barrier resulting in dramatic erosion and overtopping of the island. The development of major washover terraces coupled with storm-induced erosion has dramatically lowered the barrier's vertical profile. Consequently, the island is poised to migrate landward at accelerated rates during future storm events. Since 1938 the island has retreated as much as 490 feet with long-term shoreline erosion rates averaging 7.0 feet per year (McGinnis, 2004; Doughty *et al.*, 2006).

The shoreface sediment that fronts the barrier island consists of a thin veneer of sand and gravelly sand. The mobile surface veneer is generally less than three feet thick and overlies an easily eroded Oligocene siltstone unit that frequently crops out on the shoreface forming low-relief hardbottom areas. Mud-filled paleo-fluvial channels, the seaward extensions of the local major tidal creek systems, were identified on the shoreface.

(1) New Topsail Inlet

New Topsail Inlet, a wave-influenced, transitional system, is located approximately 25 miles northeast of Wilmington, N.C. It separates the Town of Topsail Beach, located along the southern 4.5 miles of Topsail Island, from Hutaff Island, an undeveloped 3.8 mile long barrier to the southwest (Figure IX-30). Records relating to the earliest land grants in the area record the existence of New Topsail Inlet as early as 1726. The earliest coastal maps, such as Womble (1738) and Mouzon (1775), suggest the inlet had depths of approximately 10 feet that were sufficient to allow the passage of early 18th century small coastal schooners that serviced the coastal trade and local plantations. An unpublished 1855 plain table survey of the area shows the geomorphic expressions of former inlet locations now preserved and recorded as long linear marsh islands. These features form where the sand from the constricted flood-tidal delta overtops the adjacent marsh during increased wave swash during storm events (Cleary *et al.*, 1979 and Cleary and Hosier, 1989). The early historical charts, maps and aerial photographs clearly show the presence of a 6.8-mile long chain of low-relief vegetated islands paralleling the main feeder channel.

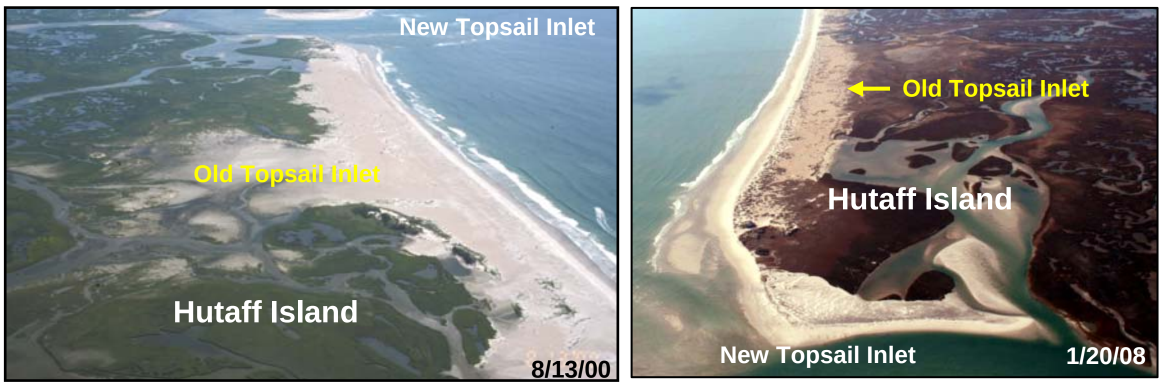


Figure IX-30. New Topsail Inlet (Cleary, 2008)

Access to the Atlantic Intracoastal Waterway (AIWW) is via Howard's Creek and Old Topsail Creek, which was designated as a federally maintained channel in 1966. The AIWW in this region of North Carolina was completed in 1932. The dredging of the AIWW probably had a significant impact on the inlet systems in this area, particularly New Topsail Inlet and Old Topsail Inlet (closed 1998), by altering the hydrodynamics of the tidal basin and the back barrier feeder channels. The new hydraulic connection was likely to have had substantially altered the tidal prism and the sand retention capacity of the ebb delta as well as the migration rates of the inlets.

During the late 19th century, Howard Channel appeared to be the dominant conduit for tidal flow from Old Topsail Creek and Old Topsail Inlet. The configuration of the shoals and barrier (Elmore's Island) northeast of Old Topsail Inlet suggests that the barrier was breached by a storm sometime between 1857 and 1888. The breaching event led to significant shoaling of the seaward portion of Howard Channel and a general retreat of the southern portion of the barrier. The low-lying portion of the barrier for the subsequent 40 years was the site of chronic overwash events that extended into the estuary. A 1927 U.S. Army survey showed a wide breach in the barrier fronting Howard Channel. The breaching and overtopping of this portion of the low-lying barrier led to rapid shoaling and the development of tidal marsh in the area. This segment of the barrier remained a chronic washover zone for decades.

Concurrent with the above events, New Topsail continued its southerly migration and presumably captured a larger percentage of the tidal flow within this portion of Topsail Sound. The interior shoals (flood tidal delta) located in the sound area represent the sand that has been retained as the inlet migrated. These shoal areas become the site of new marsh with time. Unpublished data from Cleary indicated that since 1857 an excess of 325 acres of marsh has developed within Topsail Sound along the southern 2.5 miles of New Topsail Inlet's migration pathway.

An additional consequence of the southwesterly migration is the chronic shoaling and deterioration of the AIWW access channels. Since the completion of the AIWW in the early 1930s, Old Topsail Creek has been used as the primary access channel. The sand shoal (flood ramp) located at the landward end of the ebb channel has steadily encroached on Old Topsail Creek, and by the mid-1950s was juxtaposed with the entrance to creek. Continued migration from the mid-1960s until the late 1980s positioned the ebb channel along the entrance to Howard Channel. Currently, tidal flows impinge on the creek's entrance. Presently, the highly asymmetric flood delta is positioned in such a fashion that the access channels are shoaling rapidly and are in constant need of dredging. It is likely that with continued migration Howard Channel will shoal and eventually clog.

(2) Topsail Island

Topsail Island is the second longest (24 miles) barrier island within Onslow Bay. The island is bordered by the New River Inlet to the north and New Topsail Inlet to the south. The Towns of North Topsail Beach, Surf City and Topsail Beach comprise the developed section of the barrier (Figure IX-31). Despite the low long-term erosion rates, the majority of the infrastructure along Topsail Island is highly vulnerable to storms. Inspection of historic photographs shows that much of the barrier is a chronic overwash zone.

Figure IX-31. Topsail Island - Comprised of Topsail Beach, Surf City, and North Topsail Beach (Cleary, 2008)

Topsail Island is located within the southern geologic province that extends from Cape Lookout to Sunset Beach, N.C. Relatively old rock units underlie the entire region. These units, which range in age from the Upper Cretaceous through the Pliocene, are associated with the Carolina Platform, a structural feature that underlies the region. This salient platform has risen slightly, causing the rocks to dip to the south and east and become truncated by the landward migrating shoreline and shoreface system (Riggs *et al.*, 1995). Consequently, an erosional topography exists that is manifested with exposures of these rock units on the shoreface.

The area offshore Topsail Beach and the remainder of the southwestern portion of Onslow Bay are characterized as a broad, shallow, high-energy shelf system. Regionally the unconsolidated sediment cover is thin and variable as indicated by a large frequency of hardbottom areas. Holocene sediment accumulation in Onslow Bay is negligible due to low fluvial input and lack of sediment exchange between neighboring Raleigh and Long Bays (Cleary and Pilkey, 1968; Cleary and Thayer, 1973; Blackwelder *et al.*, 1982; and Riggs *et al.*, 1995). Modern sediment distribution and composition is controlled largely by the outcrop pattern of Tertiary and Quaternary sequences. It consists of a mixture of residual or palimpsest sediments derived from the erosion and reworking of the underlying units (Luternauer and Pilkey, 1967; Cleary and Pilkey, 1968; Cleary and Thayer, 1973; Mixon and Pilkey, 1976; Crowson, 1980; Blackwelder *et al.*, 1982; Riggs *et al.*, 1985; Snyder *et al.*, 1982; and Hine and Snyder, 1985).

Storms occurring during the period between 1944 and 1962 and during the late 1980s were particularly devastating to the island. Hurricane Hugo (1989) severely impacted several sections of the island, particularly North Topsail Beach. Hurricane Hazel (1954) and the Ash Wednesday storm (1962) caused significant damage along the entire barrier. During Hurricanes Fran (1996), Bonnie (1998), and Floyd (1999) much of the island was overtopped, resulting in the formation of massive and extensive washover topography. Some of the most extensive washover fans and terraces were mapped along the southern 1.8-mile portion of Topsail Beach.

Seismic reconnaissance work done by Meisburger (1977 and 1979) for the Inner Continental Shelf Sediment and Structure Program (ICONS) indicated that the shoreface off Topsail Beach was underlain by Oligocene age units. Analyses of the ICONS cores showed that the unit consisted of very fine to fine, angular quartz sand that was capped by a thin sediment veneer. McQuarrie (1998) recognized a variety of paleo-fluvial channel features that were incised into the River Bend Formation. According to McQuarrie (1998), many of these channels are continuous and can be traced across the shoreface. Subsequent groundtruthing with vibracores in some of these features indicated that the channels were infilled with dark gray estuarine mud. More detailed investigations of the larger channels may provide useful data as far as their sand resource potential is concerned, but it is likely that most contain sequences dominated by muddy units.

The area extending from the northeastern boundary of Topsail Beach to a region offshore New Topsail Inlet is an area characterized by a patchy distribution of low-relief, sandy limestone hardbottoms mantled with a thin veneer of sand and gravel. The largest contiguous area of exposed rock occurs offshore the southern 2.2 miles of Topsail Beach. Relief of individual scarps seldom is more than 2.5 feet. Much of the continually exposed hardbottoms in this area are littered with coarse gravels derived from the bio-degradation of the underlying units. A series of shore-normal to shore-oblique channel-like features occur in areas flanking the hardbottoms where the sediment thickness exceeds 1.6 feet. Many of these low-relief linear features are discontinuous, while others extend as much as 1.2 miles across the shoreface. The larger and more extensive channel-like features are floored with rippled very coarse shell and lithic gravels, while those of limited extent are more sand rich. These rippled, linear depressions were interpreted to be features related to paleo-fluvial channels (McQuarrie, 1998).

A relatively thin veneer of sediment rests disconformably upon Oligocene strata in this region. The veneer is easily reworked during storms, exposing rock units where the sediment cover is thin. The subcrop and outcrops within the area are composed of two basic Oligocene units that range in composition from a fine grained quartz dolo-siltstone to a bio-moldic, sandy limestone.

Limestone forms the low-to moderate- relief (2.5 feet) hardbottoms offshore the southern portion of Topsail Beach. The surface of the hardbottoms is hummocky and characterized by numerous fractures and shallow depressions. The karstic limestone provides an immediate source of “new” sediment, made ready by a variety of boring and encrusting organisms. The surface sediment at the base of the limestone scarps often contains angular clasts of the nearby units comprising the scarps. The rock units forming the broad outcrop offshore the southern portion of Topsail Beach are light gray to moderate yellowish-brown, bio-moldic sandy limestone.

The siltstone, which is rarely consolidated, is exposed in isolated areas. The fine grained and unconsolidated nature of the unit results in uniform erosion and relatively low-relief hardbottom surfaces. Bio-erosion and wave quarrying of the siltstone adds a significant volume of fine-grained material to the shoreface.

The nature of the surface sediment veneer, including sediment type and grain size, was ascertained by an analysis of the acoustic signature of sidescan-sonar mosaic ground truthed by divers, and seafloor sediment samples subsequently analyzed for sediment characteristics. The data suggested there are two major types of surface sediment: very fine to medium quartz sand with varying amounts of silt and shell, and a mixture of shell and lithic gravel. The dominant surface sediment type is moderately sorted, fine quartz sand with varying amounts of fine shell fragments. The average mean grain size ranges from 1.18 to 2.48 phi (approximately 0.44 - 0.18 mm) reflecting the variable amounts of shell and quartz silt.

Vibracore data indicate that the shoreface consists of variably thick sequences of clean fine quartz sands and muddy quartz sands intercalated with sandy gravels, gravelly sands and muddy gravels. Occasionally mud-rich back barrier sediment sequences were recovered in several vibracores. Thickness of the modern sediment package seaward of the active beach ranges from less than half an inch in hardbottom areas to more than five feet in intervening regions. These data suggest the sediment cover is patchy and highly variable in terms of its thickness. Granulometric data indicated the thin, clean quartz sands are typically moderately well sorted and have mean sizes that range from 2.8 – 3.3 phi (0.18 – 0.01 mm). Commonly, the clean sand units grade both laterally and vertically into muddy or silty sand or gravel sequences. Core logs and vibracore transects indicate that gravel rich units are widespread and comprise major portions of the shoreface sequences. Although the units contain varying amounts of fine material, visual inspection and granulometric analyses of representative samples indicated that the samples analyzed were classified as sandy gravels and gravelly sands. Gravel content comprised as much as 60 percent of some samples. Seaward of the active beach, relatively thick deposits (4.4 feet) appear to be confined to small-scale channel complexes or depressions between hardbottom areas or in the lee of these features. Ponding of sediments against the hardbottom scarps and in depressions between ridges may produce localized deposits that exceed five feet in thickness.

The shoreface in the northern part of the island (North Topsail Beach) is dominated by a platform-like submarine headland comprised of well-indurated limestone. Fathometer sonargraphs show the highly irregular surface is characterized by a series of low- (less than 1.6 feet) to high-relief (greater than 6.6 feet) hardbottom scarps and intervening flat hardbottoms. The scarps trend in a north-northeast orientation and lie nearly parallel to the shoreline. A notable area of relatively high-relief hardbottoms occurs northeast of the inlet offshore of the Onslow Beach portion of the shoreface. High-relief hardbottoms also occur between Alligator Bay and New River Inlet. Low-relief limestone scarps are more common south of the inlet. The scarps generally border relatively flat, low-lying hardbottoms, the most common shoreface feature. Regionally the surface of the karstic platform is marked by small, irregularly shaped depressions, some of which are filled with a mixture of sands and gravels (Johnston, 1998 and Cleary and Riggs, 1999, HDR 2002). Reconnaissance level investigations (Johnston, 1998 and Cleary and Riggs, 1999) have also mapped several linear, irregular depressions that were interpreted to be either remnants of channels or broad dissolution features. On the seafloor they appear as relatively flat areas of the shoreface where thin sequences of modern and pre-modern sediments have accumulated. Sediment accumulation is extremely limited and is generally restricted to four irregularly shaped areas. These “channel-like” features contain only a thin sequence of modern sediment. The sediment ponds located offshore Mile Hammocks Bay (Onslow Beach) and Alligator Bay (North Topsail Beach) represent bathymetric lows that are filled with 3.3 feet of sediment. Fields of rippled coarse gravel and sand are commonly found in the linear sediment filled depressions. Frequently a cap of rippled, fine to medium grained, silty, quartz sand mantles the gravel fields.

The nature of the shoreface from Alligator Bay to the Town of Surf City’s southern limit is similar to the shoreface segment off North Topsail Beach but lacks high-relief hardbottoms. The southern portion of this area is characterized by undulating, relatively flat hardbottom platform punctuated by scattered low-relief hardbottom scarps and sediment-filled depressions. Shore-normal fathometer profiles and diver surveys indicated the landward facing scarps seldom rise more than 3.5 feet off the sea floor. Often the depression-like flat areas of the sea floor, between the scarps, are sites where sediment has filled the rock bounded topographic lows.

(3) New River Inlet

New River Inlet separates Onslow Beach, a military controlled barrier, from developed Topsail Island (North Topsail Beach). The inlet drains New River, the largest coastal plain river in the area, and its catchment basin. The hydrodynamics of the inlet system were altered substantially in the early 1940s by the construction of a 2.3-mile long navigation channel connecting the AIWW and the inlet throat. The new hydraulic connection is thought to have substantially increased the tidal prism and the retention capacity of the ebb delta. Since 1963 the access channel that connects the inlet to the AIWW and the New River Basin has been maintained annually (USACE, 1989a). The one-mile long channel is maintained to a depth of -8 feet (MLW). The average annual maintenance dredging efforts generally involves the removal of 150,000 cubic yards of material from the corridor.

The inlet predates the Colonial era and is likely to have been in existence since the late Holocene. The ultimate origin of the inlet is related to the incision of the ancestral channel of the New River into the underlying Oligocene limestone. The contemporary inlet's main ebb channel currently lies along the southwestern margin of the incised ancestral channel (Hine and Snyder, 1985; Johnston, 1998 and Cleary and Riggs, 1999).

New River Inlet has been classified as a wave-influenced, transitional inlet system. The ebb channel has been relatively unstable throughout its history particularly prior to its relocation in the early 1940s. Since relocation and construction of the access channel the southwesterly migration has been related to spit growth on the Onslow Beach shoulder. Breaching of the inlet's ebb-tidal delta has also led to repositioning of the ebb channel during a number of time periods since the mid 19th century. The most recent channel realignment involved small-scale changes that occurred in early 1998 when the ebb channel was repositioned approximately 1,000 feet to the southwest. The direction and rate of channel migration has varied since the early 1960s. During the past five decades the movement of the ebb channel has been erratic. Since 1962, the inlet has migrated in a southwesterly direction at an average rate of approximately 19 feet per year.

New River Inlet is unique compared to the majority of other inlets in southeastern North Carolina from the standpoint of migration history, inlet modification and oceanfront shoreline change during the past 65 years. A previous study reported the inlet's minimum width (throat width) varied from approximately 267 feet in April 1938 to a maximum of 1,255 feet in April 1987 (Cleary and Riggs, 1999 and Sault, 1999). The baseline inlet width, measured seaward of the narrowest portion of the inlet, has varied considerably during the past five decades from a minimum of 1,065 feet (September 2001) to a maximum of 2,265 feet (January 1988). The average width since 1962 was 1,660 feet. The changes recorded reflected the expansion and constriction due to storms, realignments of the ebb channel and the subsequent spit development on the shoulders.

The main ebb channel links the ocean and the New River estuary and separates the adjacent barriers. It is comprised of several major segments. The deeper segment of the ebb channel, located between Onslow Beach and North Topsail Beach on Topsail Island is defined as the throat section. The seaward-portion of the ebb channel, which extends across the ebb-tidal platform, is referred to as the outer bar or ebb platform channel. The azimuth of the axis of the ebb channel was measured at the point where it crosses the zone of breaking waves (terminal lobe as defined by Hayes, 1980). he orientation of the outer bar channel is commonly an important inlet parameter because slight changes in its alignment can have a significant impact on the erosion and accretion trends along the adjacent oceanfront shorelines. The orientation and position of this segment of the ebb channel have changed repeatedly over time. Over the past five decades the orientation of the outer bar channel has ranged from approximately 99 degrees in March 1998 to 180 degrees in June 1984. During the past decade the orientation of the ebb channel has fluctuated between approximately 99 degrees and 141 degrees. The average orientation since 1962 was 142 degrees. As a point of reference an angle of approximately 145 degrees is a shore-normal alignment. During the early 1960s through 1991 the outer bar channel was aligned toward North Topsail Beach (less than 145 degrees). From the early 1990s until March 2003 the channel orientation has fluctuated but has been aligned toward Onslow Beach less than 141 degrees. Since 1991 the channel has been continually deflected toward Onslow Beach until early 1998 when it was repositioned (to approximately 99 degrees) during an ebb delta breaching event. Since 1998 the channel has again been deflected toward Onslow Beach and is currently aligned along a 125 degrees orientation.

Cleary and Marden (1999) in a regional study of North Carolina's inlets indicated that during the period 1945 to 1996 the ebb channel (within the throat) moved a net distance of approximately 1,168 feet in a southwesterly direction. The authors reported that although the inlet tracked to the southwest there were many periodic reversals in the migration direction. Information germane to this study indicated that inlet migration rates during the past 50 years have decreased from 57.6 feet per year for the period between 1945 and 1962 to 12.2 feet per year for the interval between 1962 and 1996. The decrease in migration rates reflected the positive impacts of dredging as it relates to the larger tidal prism and increased inlet stability.

During the period from 1962 to 2003, the ebb channel movement and shoulder changes were highly erratic. During this 41-year period of time the ebb channel moved a net distance of 783 feet in a southwesterly direction. The most significant change occurred between March 1962 and November 1974 when the inlet migrated approximately 540 feet at a time averaged rate of approximately 43 feet per year. During the next decade the inlet shifted southwestward a net distance of only 139 feet. Between June 1984 and January 1995 the movement of the ebb channel was again erratic but resulted in a slight net movement (approximately 25 feet) of the inlet toward North Topsail Beach. Since January 1995 the inlet has migrated to the southwest a net distance of approximately 78 feet. The time averaged migration rate for the period 1962-2003 was approximately19 feet per year.

As previously mentioned, the morphology of New River Inlet has changed substantially since the early 1940s. Four periods of inlet throat and adjacent beach changes can be recognized each with unique trends and morphologic characteristics. The initial phase covered the period between 1938 and 1945 when the hydrodynamics of the system were altered. During this interval the ebb-tidal delta, interior channels and the North Topsail Beach and Onslow Beach shorelines were adjusting to the newly established inlet conditions. Immediately following the relocation of the inlet in the early 1940s the ebb channel migrated to the southwest and was strongly skewed toward North Topsail Beach.

The second stage of inlet evolution covers the period between 1945 and 1962. The inlet presumably attained the general morphologic configuration it now has by the late 1940s to the early 1950s. Aerial photographs show that by the mid-1950s the ebb-tidal delta had enlarged substantially and the ebb channel was positioned on the downdrift side of North Topsail Beach. A relatively wide marginal flood channel was located on the updrift side of Onslow Beach. Sault (1999) reported that the ebb channel migrated approximately 958 feet in a southwest direction during this interval.

The third phase of inlet evolution covers the period 1962 to 1989. Maintenance of the outer bar channel which began in 1964 and repetitive dredging of the ebb channel have contributed to the observed planform changes in the inlet and symmetry of the ebb-tidal delta during this period. Inspection of historic aerial photographs from the mid 1950s to the early 1970s show the development of an asymmetrically shaped ebb-tidal delta whose apex is offset to the southwest along the side of North Topsail Beach. During this time interval the ebb channel migrated to the southwest a net distance of approximately 644 feet. Migration rates ranged from 46 feet per year southwest between March 1986 and April 1987 to 106 feet per year northeast during the interval April 1987 to January 1988. The width of the inlet increased substantially due to a combination of ebb channel migration southwest and expansion of the marginal flood channel on the Onslow Beach margin. The mouth of the inlet widened between 1962 and 1989 to approximately 898 feet. The majority of the inlet expansion occurred during periods of time when the ebb channel was aligned along the western margin of the inlet and skewed toward North Topsail Beach at an angle greater than 150 degrees. The seaward offset of North Topsail Beach and the landward recession of the Onslow Beach shoulder was a by-product of changes within the throat section of the inlet system (Figure IX-32).

Figure IX-32. New River Inlet and Associated Erosion/Accretion Effects (Cleary, 2008)

The most recent phase of inlet throat and adjacent barrier island changes occurred between 1989 and 2003 when the inlet migrated an additional 139 feet to the southwest. Migration rates during the most recent phase of inlet change ranged from +50 feet per year southwest between September 2001 and March 2003 to –5.4 feet per month northeast between September 1996 and December 1996. The data show that the ebb channel reversed its movement numerous times since 1989. The pattern of change along both shorelines was erratic as both margins periodically accreted and eroded. The inlet shoreline changes appear to be related to the deflection of the outer bar channel (ebb channel) and primarily the consequent changes in the geometry of the updrift marginal flood channel.

The inlet attained its minimum width in September 2001 during a period of time when the outer bar channel resumed its northeasterly deflection. Since the early 1990s the alignment of the outer bar channel has generally been less than 133 degrees and has averaged 125 degrees. This general alignment has promoted accretion on both margins of the inlet throat. Throat constriction during the recent phase of inlet change was primarily related to spit growth on the Onslow Beach side of the inlet. Major development of an estuarine spit on the Onslow Beach side was initiated in the mid 1980s and reached its maximum extent in 1995. Since the early 1990s the net constriction of the inlet throat has been approximately 470 feet.

(4) Onslow Beach

In the vicinity of New River Inlet is a submarine headland that forms a small seaward bulge in the coastline of central Onslow Bay. This mid-compartment shoreline protrusion is produced by the Oligocene Belgrade Formation, a bio-moldic limestone. The unit crops out at or slightly below sea level in the mouth of the New River estuary. It occurs extensively on dredge material islands of the Intracoastal Waterway behind Topsail Island and Onslow Beach, and forms a series of high ridges on the shoreface off of New River Inlet (Crowson, 1980; Cleary and Hosier, 1987; Riggs *et al.*, 1995; Cleary *et al.*, 1996; and Cleary and Riggs, 1999).

The submarine headland subdivides these two barriers into coastal compartments that have different orientations and shoreface dynamics. The northern segment of Onslow Beach is characterized by a shoreline with a wide beach, a recurved, accretionary dune ridge system and a continuous high foredune ridge (Cleary and Hosier, 1987 and Cleary and Riggs, 1998). The ridges front a narrow marsh filled estuary and are covered with mature maritime forest indicating old and stable topography. Toward the central portion of Onslow Beach, the estuary along the northern and southern segments narrows and is nearly absent where the limestone comprising the headland rises close to the surface. At the narrowest width of the estuary the limestone lies within six feet of the surface of the fringing marsh (Cleary and Hosier, 1987; Riggs *et al.*, 1995; Cleary and Pilkey, 1996; Cleary *et al.*, 1996; and Cleary and Riggs, 1998). The southern segment of Onslow Beach is characterized by a narrow beach strewn with gravel, isolated “haystack” dunes with numerous washover passes and terraces extending into the marsh.

(5) Brown’s Inlet

Brown Inlet is a relatively stable inlet separating Brown’s Island to the northeast from Onslow Beach to the southwest. Brown’s Inlet has migrated within a 1.25-mile zone straddling the inlet (Cleary and Marden, 1999). The inlet width has fluctuated from a minimum of approximately 500 feet in 1938 to a maximum of nearly 1,250 feet in 1995. Inlet constriction and enlargement are related to changes in the orientation of the flood and ebb channels.

(6) Bear Island and Brown's Island

Bear and Brown Islands can be classified as altered regressive (prograded dune ridge) barriers. Large medano-like and parabolic dunes characterize major portions of both islands. The earliest aerial photographs (1938) show the majority of both island surfaces were covered by large sand sheets with little vegetation cover (Cleary and Hosier, 1979 and Cleary and Pilkey, 1996). The existence of large steep spillover lobes in the adjacent estuary provides evidence for the landward migration of the sand dunes. Elevations along the eastern portions of the barriers are as much as 52 feet. The nature of the dunes imaged in the 1938 photographs is similar to the migrating parabolic dunes found along all of the Brunswick County barriers in the 1930s and 1940s. The sand that formed the various migrating dune types on these islands was thought to have been originally contained in sets of prograded dune ridges similar to what is found on Bogue Banks.

The enormous volume of sand found within these short, wide and high barriers is unique, and more than likely represents the type of short barrier reaches that formed the prograded core segments of ancestral composite Bogue Banks that initially consisted of multiple islands separated by wide shallow inlets. The large volumes of sand contained in these barriers were derived from the sand-rich Silverdale Formation that is exposed on the shoreface (Riggs and Cleary, 1998a, 1998b and Cleary and Riggs, 1998). The contact between the Silverdale Formation and the Belgrade Formation (bio-modic limestone) is located near Brown's Inlet. Southwest of Brown's Inlet the narrow, sand-poor barriers are perched on limestone (Figure IX-33).

Figure IX-33. Brown's Inlet, Brown's Island, Bear Inlet, and Bear Island (Cleary, 2008)

(7) Bear Inlet

Bear Inlet separates Brown's Island from Bear Island (Hammocks Beach State Park) at the north end of Onslow County. It is of intermediate size, as compared to Brown's Inlet, a smaller system to the southwest, and Bogue Inlet, a much larger system to the northeast (Cleary and Marden, 1999). The initial location of the inlet was controlled by the position of an ancestral river channel, and the inlet has migrated about 1.25 miles northeast due to decreased sediment volume exchange from filling of the estuary over the past several thousand years, resulting in migration in the direction of the dominant eastward sediment transport. Since 1938, the inlet has been relatively stable, moving approximately 200 feet with inlet widths ranging from 980 feet in 1956 to 2,550 feet in 1938.

c) Region 2c Beaches and Inlets

Figure IX-34 illustrates the offshore geology for Region 2c. The subsections present a detailed summary of the geologic framework for Region 2c beaches and inlets.

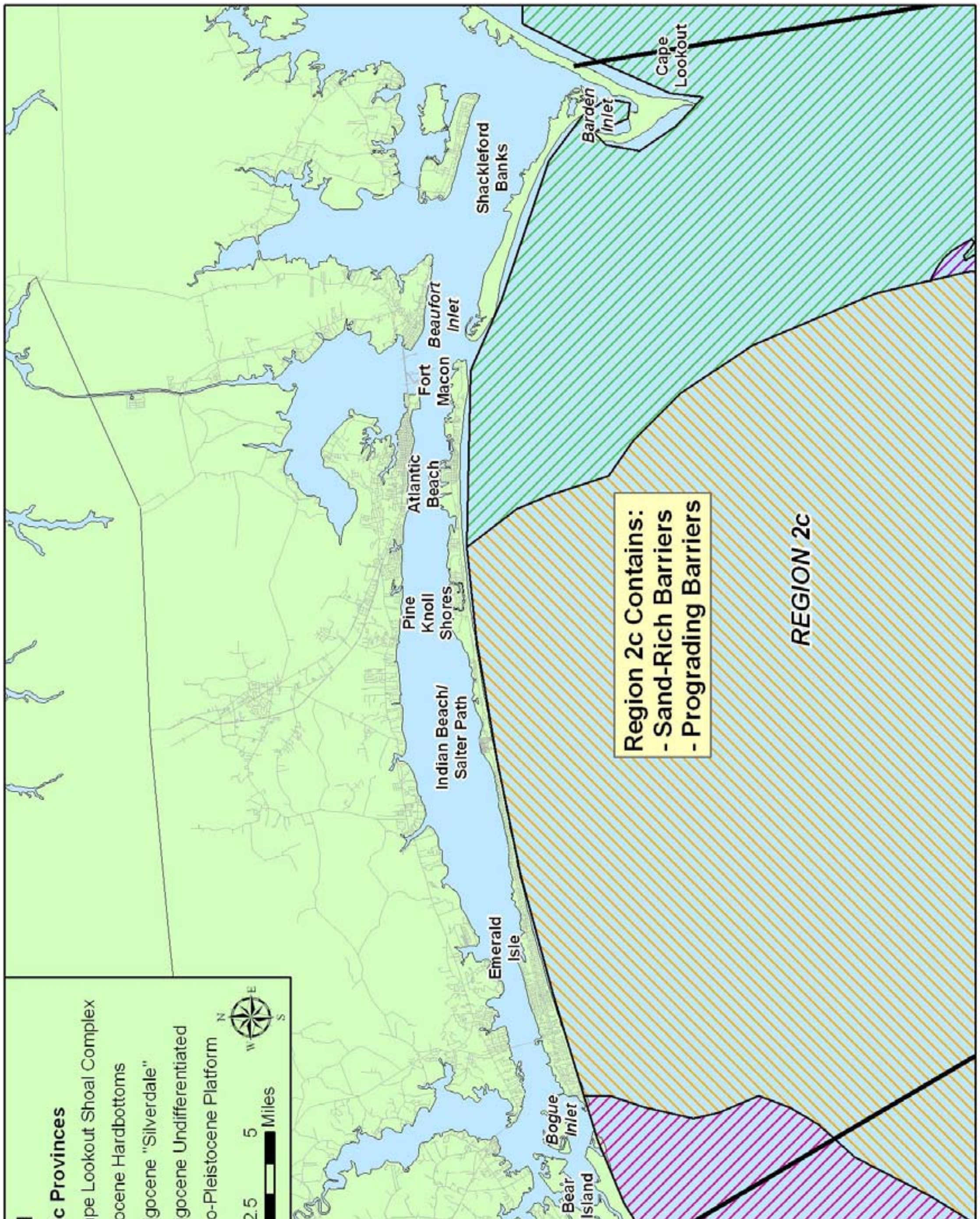


Figure IX-34. Offshore Geology for Region 2c

(1) Bogue Inlet

Bogue Inlet is one of the larger inlets in southeastern North Carolina and separates Bogue Banks and Bear Island (Hammocks Beach). The inlet drains an expansive portion of the adjacent estuary where two large, relatively deep tidal creeks connect the inlet to the AIWW and the White Oak River Basin. The inlet has been a relatively stable feature over the past several centuries and has been confined to a 2,625-foot wide zone. Seismic studies indicate that the inlet is a "permanent" feature in the area, its location initially controlled by the paleo-channel of the White Oak River which extends across the shoreface (Hine and Snyder, 1985). The inlet has an exceptionally wide throat of approximately 8,500 feet, a relatively narrow ebb channel of approximately 700 feet, and a large mid-inlet shoal that occupies most of the western portion of the floodway (Cleary, 1996; Cleary and Marden 1999; CS&E, 2001; Cleary *et al.*, 2003). The ebb channel is unstable and has a history of migration related to spit growth on opposing shoulders. The ebb channel began its recent eastward trek in 1981-1982 while the outer bar segment of the channel was skewed toward Bear Island (Cleary *et al.*, 2003). Between 1981 and 2001, the throat section of the channel migrated to the east a net distance of 4,013 feet at an average rate of 201 feet per year.

The analysis of the oceanfront and adjacent island changes that have occurred since 1973 clearly showed that the movement of the ebb channel and the attendant ebb-tidal delta symmetry changes were the forcing variables that dictated the change trends along the inlet and oceanfront of both Bogue Banks and Bear Island. Erosion of the eastern inlet shoreline (Bogue Banks) and the progradation of the adjacent oceanfront were directly related to the eastward migration of the ebb channel. The data also indicated that the inlet and oceanfront erosion along adjacent Bear Island stemmed directly from the morphologic changes related to the eastward migration and the associated ebb shoal shape changes.

Chronic erosion along the western end of Bogue Banks (Emerald Isle) reached a critical stage in the late 1990s when a number of homes were endangered by the receding inlet shoreline. Subsequent to onset of the rapid loss, the shoreline was armored with a series of sandbags. The Town of Emerald Isle was also experiencing erosion along much of its oceanfront, and as a result, it initiated an extensive 16.8-mile long nourishment project. In an effort to support shoreline restoration and to provide a long-term solution to inlet-related erosion, the Town contracted with Coastal Planning & Engineering (CPE-NC) to relocate the ebb channel to a mid-inlet position and nourish a portion of the oceanfront with the associated dredge materials (Figure IX-35). Details of the Bogue Inlet channel realignment can be found in the EIS prepared for the project (CPE, 2004) at http://www.saw.usace.army.mil/WETLANDS/Projects/BogueInlet/index.html.

The location of the ebb channel lies along the approximate axial position of the ebb channel imaged on the 1978 aerial photograph. Relocation of the ebb channel in early 2005 to this mid-inlet location has altered the sediment transport patterns on both shoulders and prompted a significant reconfiguration of the ebb-tidal delta. The apex of the ebb delta is in the process of shifting westward. The eastern ebb shoal segment fronting Bogue Banks is gradually collapsing and will eventually infill the former ebb channel. In September 2005 Hurricane Ophelia breached the Bogue Banks estuarine spit that led to a connection between the former ebb channel and interior tidal channels (Figure IX-35). This event eroded the sand dike that was constructed to hasten the closure of the old channel, and in effect lengthened the time for complete infilling and abandonment of the former ebb channel. The eventual infilling of the former ebb channel led to the westward growth of Bogue Banks, and planform changes along the oceanfront.

Figure IX-35. Bogue Inlet Ebb Channel Realignment (Cleary, 2008)

(2) Bogue Banks

Bogue Banks is the longest and widest barrier island in southeastern N.C. This composite and former progradational barrier is approximately 25.4 miles long and averages 1,970 feet in width. Unlike the areas to the south, the estuary behind Bogue Banks is generally open water. The lack of significant areas of tidal marsh suggests that inlets have not been active on an island scale in recent historical times. However, historical maps show isolated occurrences of former inlets at several sites. These areas include the low, narrow sites at Emerald Isle and Atlantic Beach.

Bogue Banks, located on the low-energy limb of the Cape Lookout foreland, is morphologically unlike the majority of islands in North Carolina. It is characterized by an extensive maritime forested dune ridge system with isolated ridge elevations in excess of 39 feet. This sequence of ancient dune ridges indicates a period of progradation. Recent studies indicate progradation began 3,800 years Before Present (B.P.) (Steele, 1980; Heron *et al.*, 1984). It is worthwhile to mention that the barrier is a composite of different "core-segments" that are of different ages and origins.

The island's fronting dune system is largely intact with multiple or massive dunes present. Within these areas are sites of blowouts and migrating and vegetated parabolic dunes. A few areas have a narrow dune system. Overwash is not prevalent except in those areas where dunes are lacking or poorly developed.

The geology and nature of Bogue Banks and the adjacent shoreface have been investigated by a number of researchers including Fisher (1967), Mixon and Pilkey (1976), Meisburger (1979), Steele (1980), Snyder (1982), Snyder *et al.* (1982), Heron *et al*. (1984), and Hine and Snyder (1985). Most of Bogue Banks is underlain by the Miocene, Pungo River Formation, much of which consists of muddy, phosphatic sand and silt. Hine and Synder (1985) indicated that Holocene units were thin (3-7 feet) and often absent on the shoreface and inner shelf in the region. Consequently, Miocene age rocks are often exposed, particularly off the east and central portions of Bogue Banks.

Seismic and limited core data (Hine and Snyder, 1985) revealed the existence of a number of paleo-channels that were infilled with mid-Pleistocene deposits. The former, and now buried, lower coastal plain stream channels were interpreted to be infilled with a relatively thick sequence consisting of estuarine and shelf muds and sands. Other smaller localized channels recognized in seismic records were interpreted to be the vestiges of the deeper portions of tidal inlets. It has been postulated that the larger paleo-channels have been major sources of sand for the initial development of the wider and higher regressive portions of Bogue Banks (Snyder, personal communication, 1994; and Rodriguez, 2008). This hypothesis is similar to the speculation that the segments now characterized by large parabolic dunes along the composite barriers in Brunswick County initially derived their material from the numerous, now closed tidal inlets, and the offshore sand associated with the major coastal plain streams in the area.

(3) Beaufort Inlet

Beaufort Inlet, located approximately nine miles west of Cape Lookout, serves as the connection between the Atlantic Ocean and Morehead City Harbor, North Carolina’s second major port. The inlet is used by commercial and recreational vessels and is one of two inlets in southeastern North Carolina which have been modified for commercial traffic. The inlet forms the eastern border of Bogue Banks and separates the barrier from Shackelford Banks to the east (Figure IX-36).

Figure IX-36. Beaufort Inlet (Cleary, 2008)

Historical maps that date to the early part of the 17th century confirm the existence of the inlet. Since the Colonial Period the inlet has served as an entry to the port of Beaufort. Beaufort Inlet has remained in relatively the same location throughout its recorded history. The large tidal prism contributes to the stability of the inlet. Over the past 70 years, since the channel has been in a fixed position (1936), the inlet's cross-sectional area has fluctuated little although the inlet's minimum width has decreased (Cleary and Pilkey, 1996). During the same period, the average depth of the throat has increased as the navigation channel was deepened and widened. As a result the inlet's aspect ratio (width to depth) has decreased markedly since 1952 as the inlet constricted and deepened with dredging. Since dredging of the channel began, there has been a deepening and steepening of the profile and a generally lowering of the ebb-tidal delta platform.

Calculations involving changes in the volume of sediment stored in the 1854 ebb-tidal delta indicated there were 48.97 million cubic yards of material contained in the outer bar to depths of approximately 18 feet. Between 1854 and 1936, the ebb delta volume ranged from a low of 46.69 to a high of 56.63 million cubic yards in 1874 (Cleary and Pilkey, 1996). Since major dredging operations began in the mid 1930s the volume of the ebb-tidal delta has steadily decreased from 48.26 million cubic yards in 1936 to 31.65 million cubic yards in 1974, a 34.2 percent decrease. Between 1974 and 2004 the outer bar volume has further decreased to 21.12 million cubic yards. The net volume loss since 1936 was 27.14 million cubic yards to depths of -18 feet. The most significant loss occurred within the Bogue Banks segment of the shoals on the western margin of the ebb channel.

Between 1936 and 2004, as much as 70 million cubic yards of material have been dredged during the periodic maintenance of Beaufort Inlet. According to Olsen and Associates (2006) 13.8 million cubic yards of material dredged from the Morehead City Harbor Project have been placed along the Bogue Banks oceanfront between 1978 and 2004. Since 2004 a minimum of an additional three million cubic yards (estimated) have been placed along the oceanfront. Most of the material was derived from the harbor project. More details are available in the Olsen and Associates report (2006) and the various USACE reports dealing with the Morehead City Harbor Project and related projects.

(4) Shackleford Banks

Before the turn of the 20th century, Shackleford Banks was fully forested. A series of dune ridges indicating previous progradation was evident. Much of the barrier was probably similar to Bogue Banks. A combination of severe hurricanes, overgrazing by feral livestock, and anthropogenic disturbance of the forest resulted in the destruction of the vegetation mantle in the late 1800s and the subsequent migration of the dunes across the island. A 3.2-mile long slipface marks the landward migration limit of the dunes. Beaufort Inlet borders the western end of Shackleford Banks, which has been growing westward during the past 40 years. Since 1947, the island has extended more than 3,000 feet. This region is characterized by low dunes generally in an arcuate pattern.

(5) Barden Inlet

Barden Inlet is a relatively small inlet located between Shackleford Banks and Cape Lookout (Figure IX-37). The inlet, which opened in 1933, migrates to the east (Cleary and Marden, 1999). A unique feature of Barden Inlet is the large sand shoal that extends into the inlet throat from Shackleford Banks. The inlet has alternately constricted and expanded with a general trend toward expansion with a width of 920 feet in 1945 up to 2,300 feet in 1993, averaging approximately 1,890 feet since 1945 (Cleary and Marden, 1999).

Figure IX-37. Barden Inlet (Cleary, 2008)

7. Sediment Budgets

Significant gaps exist in sediment transport and sediment budget information. The USACE performed various sediment budget analyses in Region 2a from Kure Beach to Mason Inlet using data ranging from the 1800s to 1980. In Region 2c, sediment budgets have been performed in the past few years by Olsen Associates along Bogue Banks, and by Jun Yong Park and John T. Wells of the UNC Institute of Marine Sciences along Shackleford Banks and Cape Lookout. Region 2b does not have any available sediment budget information at this time. Locations of available sediment budgets for Region 2 are presented in Figures IX-38 and IX-39.

A portion of the sediment budget developed for Beaufort Inlet and adjacent Bogue Banks and Shackleford Banks by Olsen Associates, Inc. in 2006 can be seen in Figure IX-40. Findings from Park and Wells can be found in Figures IX-41 and IX-42 for Shackleford Banks and Cape Lookout.

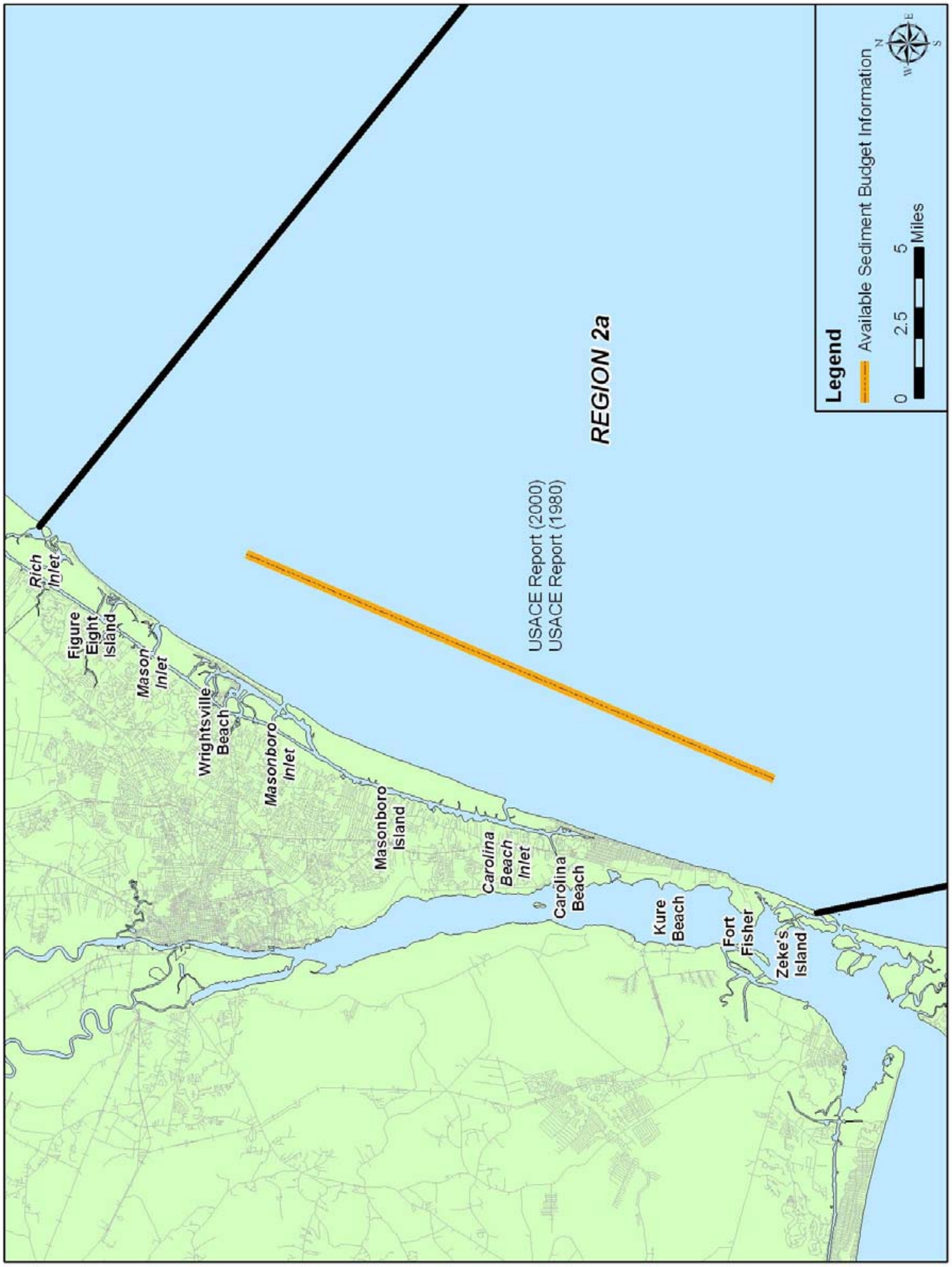


Figure IX-38. Available Sediment Budgets for Region 2a

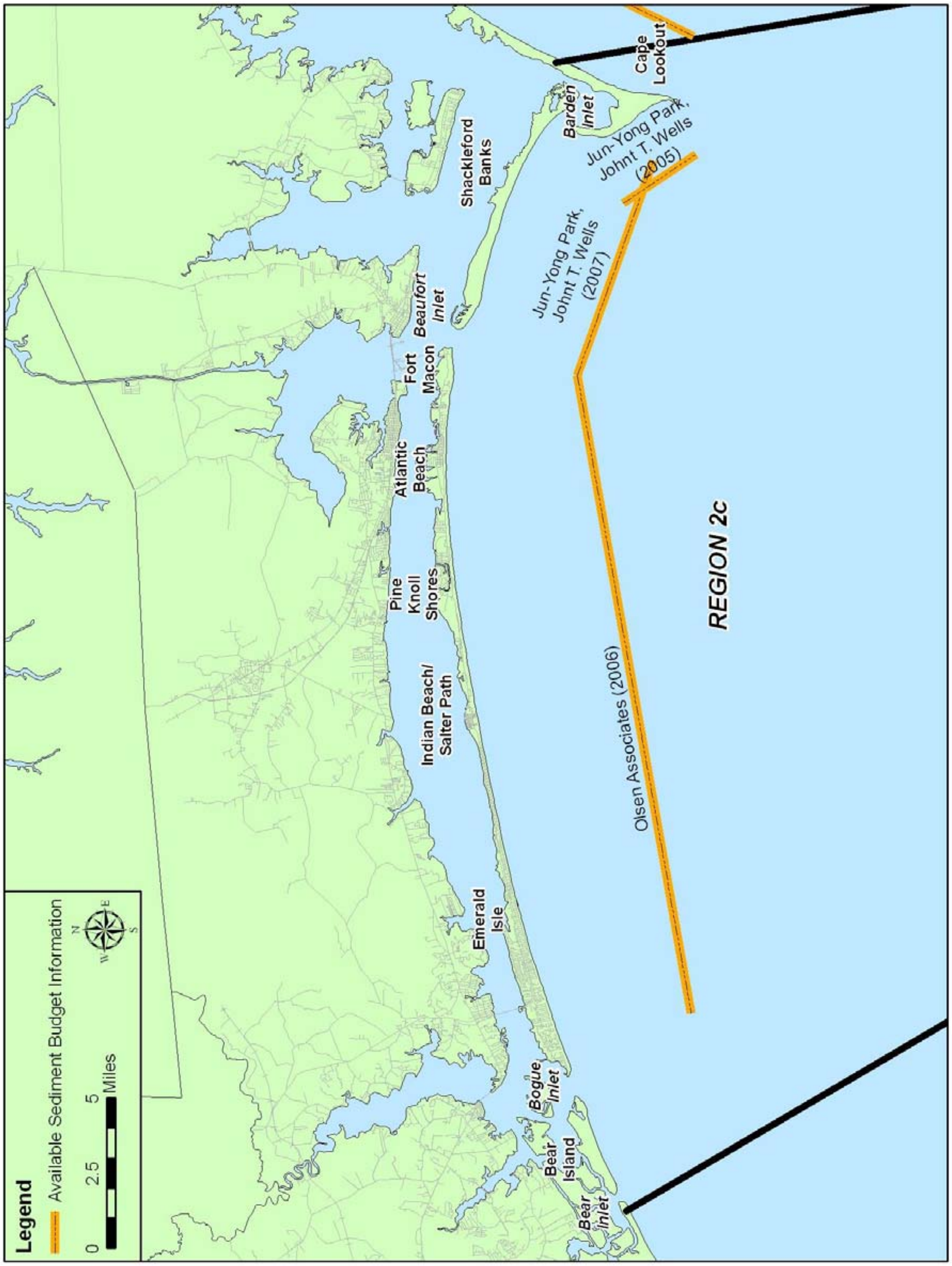


Figure IX-39. Available Sediment Budgets for Region 2c

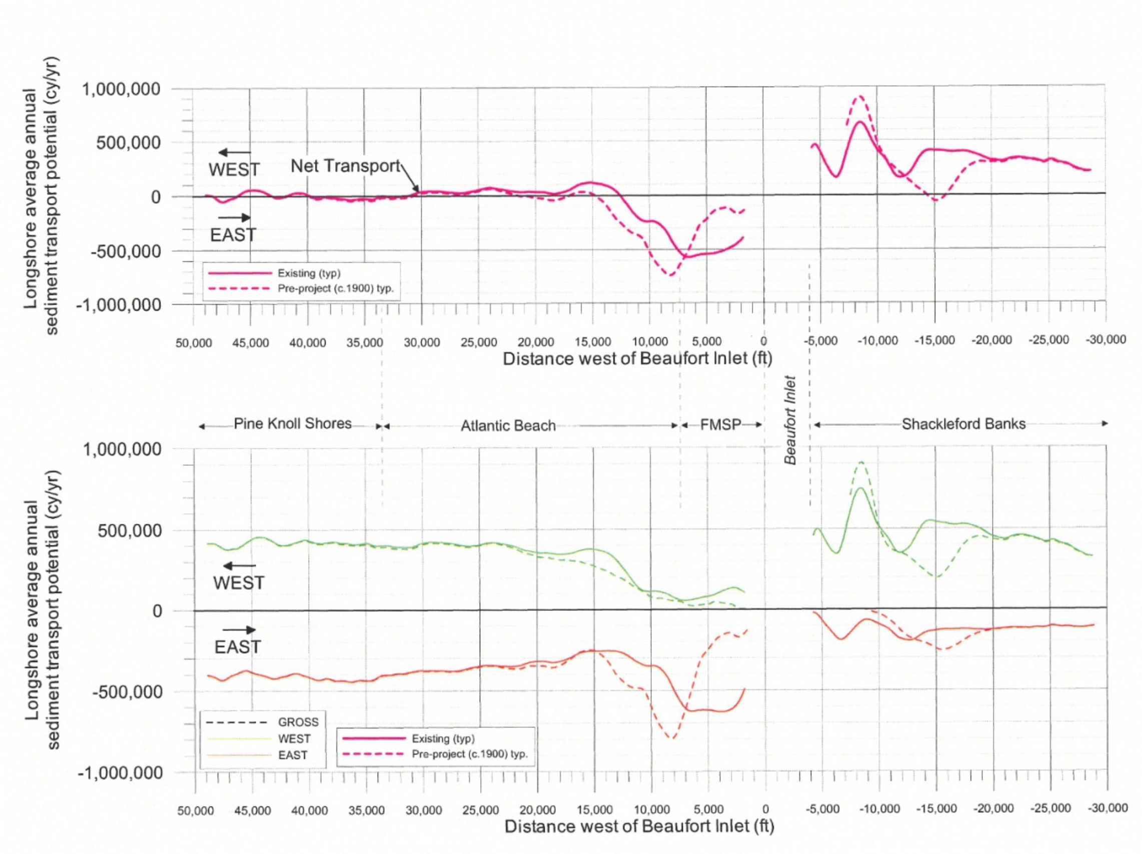


Figure IX-40. Average Annual Longshore Transport Potential, Beaufort Inlet (Olsen Associates, 2006)

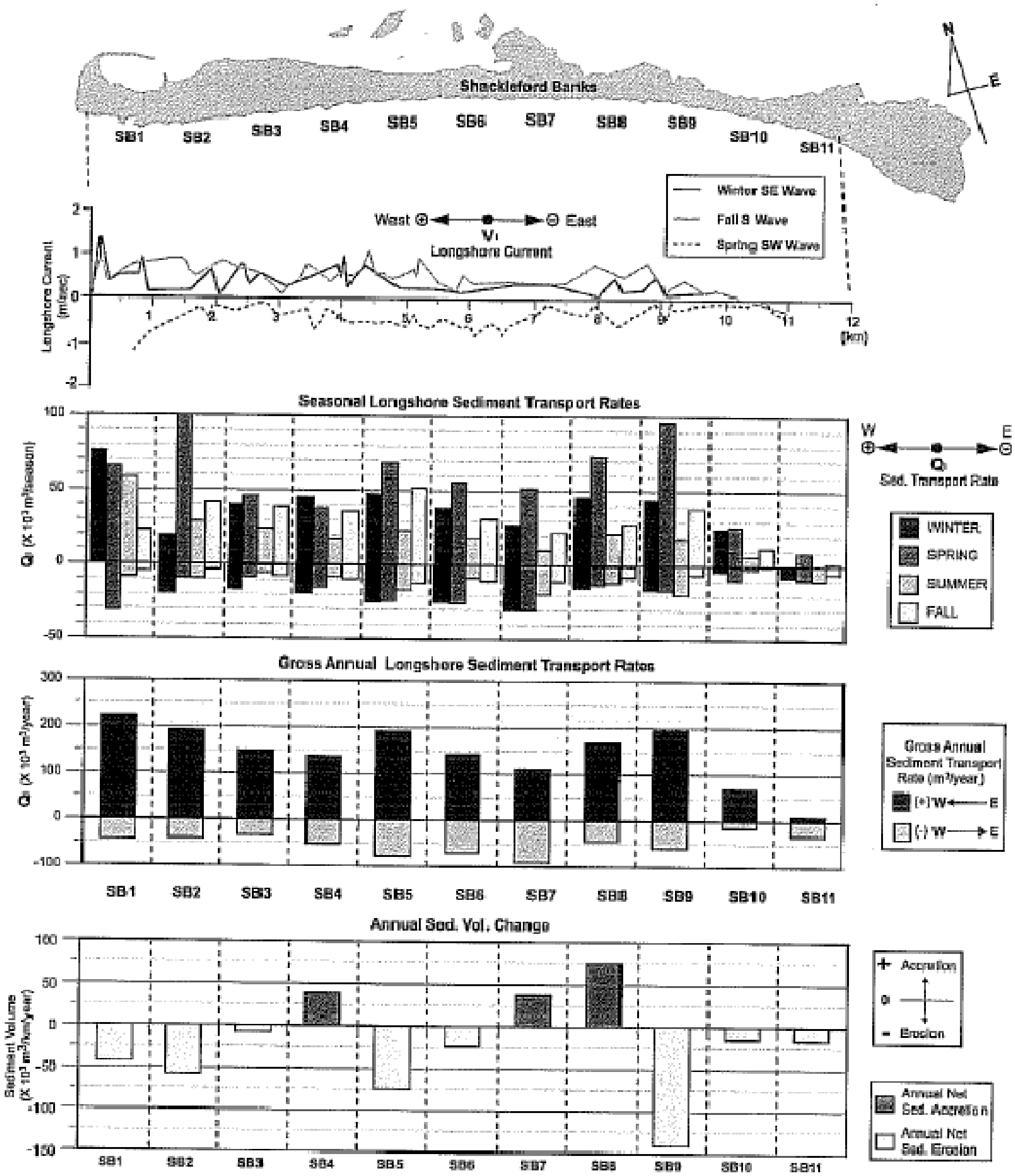


Figure IX-41. Model Predicted Seasonal and Annual Longshore Sediment Transport (Park and Wells, 2007)

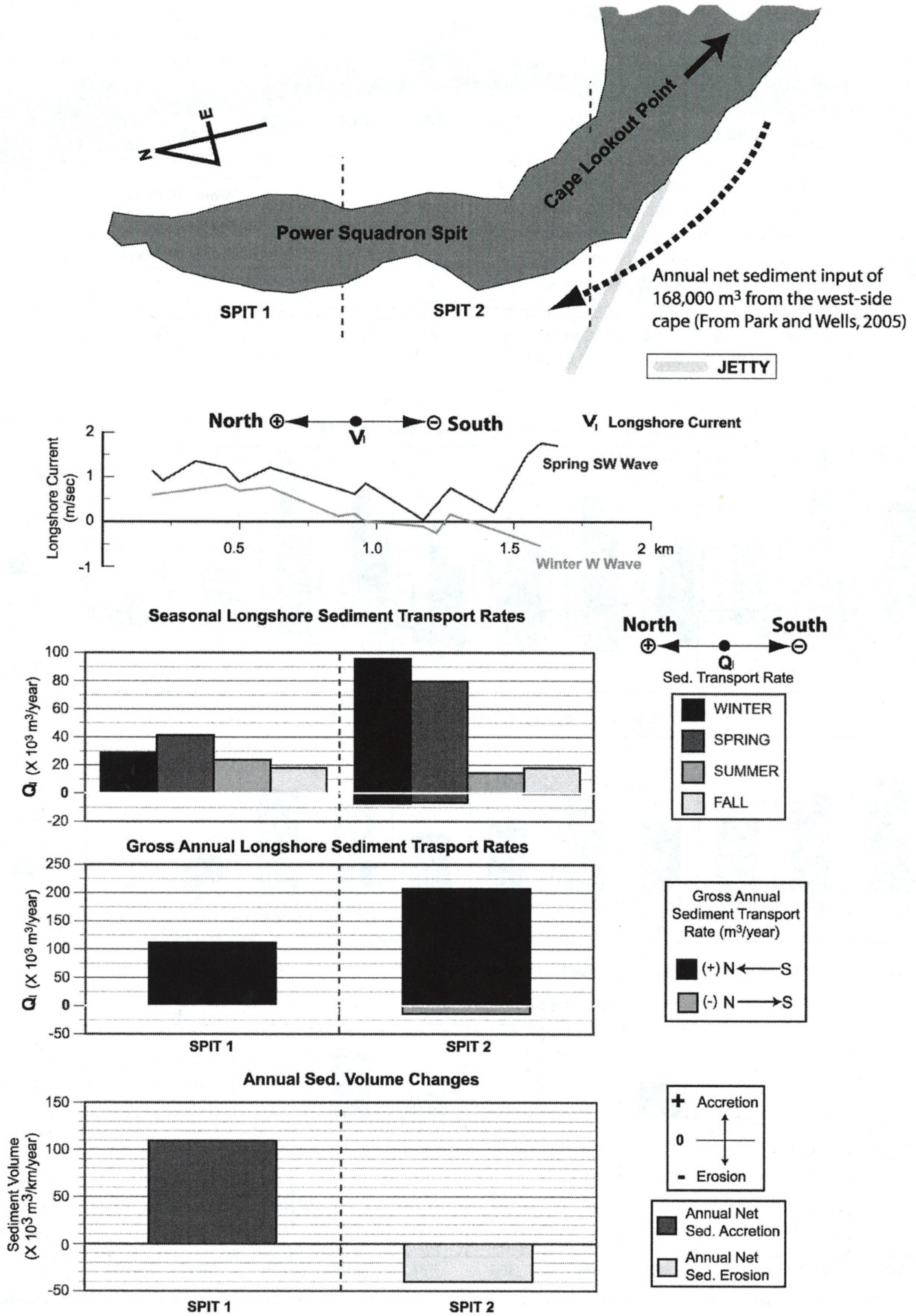


Figure IX-42. Model Predicted Longshore Current and Sediment Transport Rates (Park and Wells, 2005)

8. Potential Sand Resources

Sand resources for beach nourishment projects come from inlet dredging, offshore material deemed compatible with the beach, and offshore disposal sites containing previously dredged material. Potential sand resources are identified in various NCGS Open File Reports, USACE findings, USGS databases, and consulting firm investigations.

Region 2a contains four inlets (Carolina Beach, Masonboro, Mason, and Rich) which have been used as sediment sources for nearby beaches. Offshore sand sources are limited for this region. However, according the USGS USSEABED database, there is a potential area offshore of Carolina Beach which contains material with an acceptable grain size for many North Carolina beaches (phi size=1.0-2.0 or 0.25 mm-0.5 mm). This area should be examined further in the future to determine suitability.

Region 2b contains two inlets (New Topsail and New River) which have been used in the past as sediment sources for nearby beaches. Offshore sand sources in this region have been examined extensively by the USACE and other consulting firms (most recently CPE). Most recently, the North Topsail Borrow Area and Borrow Area X have been used and/or are planned for use in beach nourishment projects.

Region 2c contains two inlets (Bogue and Beaufort) which have been used in the past as sediment sources for nearby beaches. Offshore sand sources in this region have been examined extensively by the USACE and other consulting firms in conjunction with Carteret County shore protection projects. The USACE Morehead City Harbor navigation project has also provided material through direct disposal of dredge material as well as material from an offshore disposal site. In addition, borrow sites A1, A2, B1a, and B2 have been used extensively for projects, while borrow areas Y, U, and Q1 are currently being considered for future shore protection projects. Cape Lookout Shoals has also been examined as a possible sediment source. It extends southeast from Cape Lookout approximately 10 miles with local water depths of three to four feet.

Figures IX-43 to IX-45 show the potential sediment resources for all three subregions of Region 2.

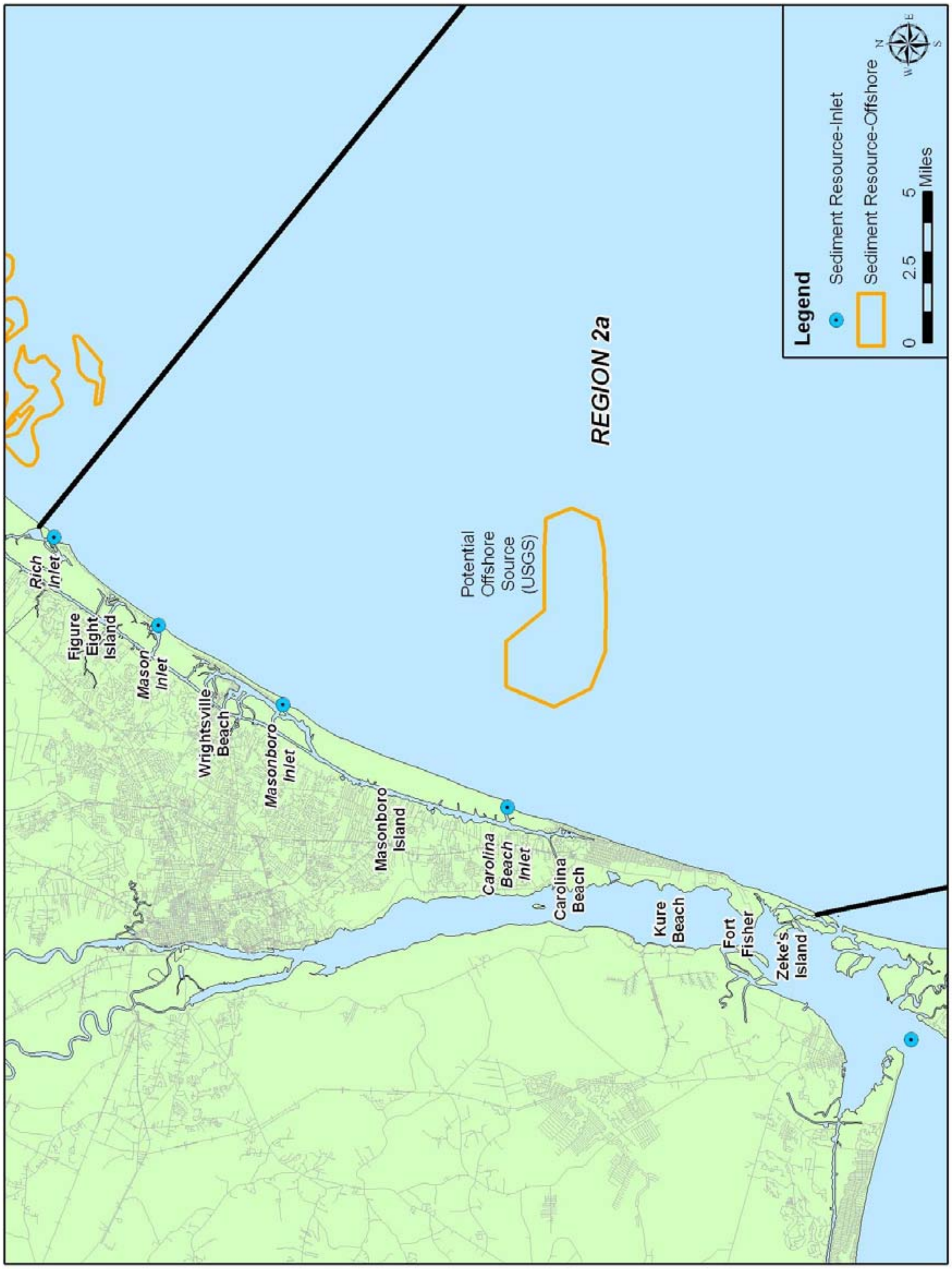


Figure IX-43. Potential Sediment Resources for Region 2a

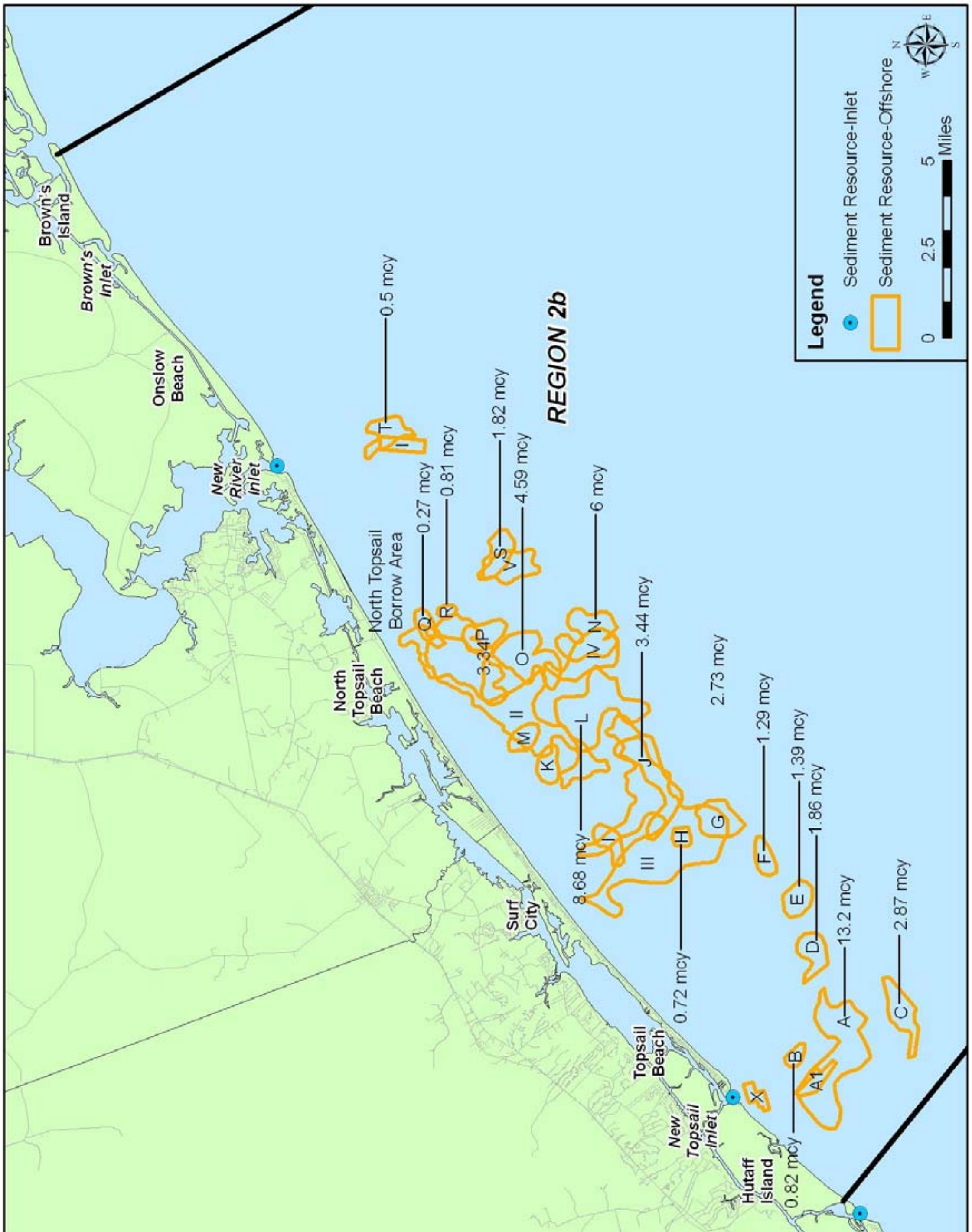


Figure IX-44. Potential Sediment Resources for Region 2b

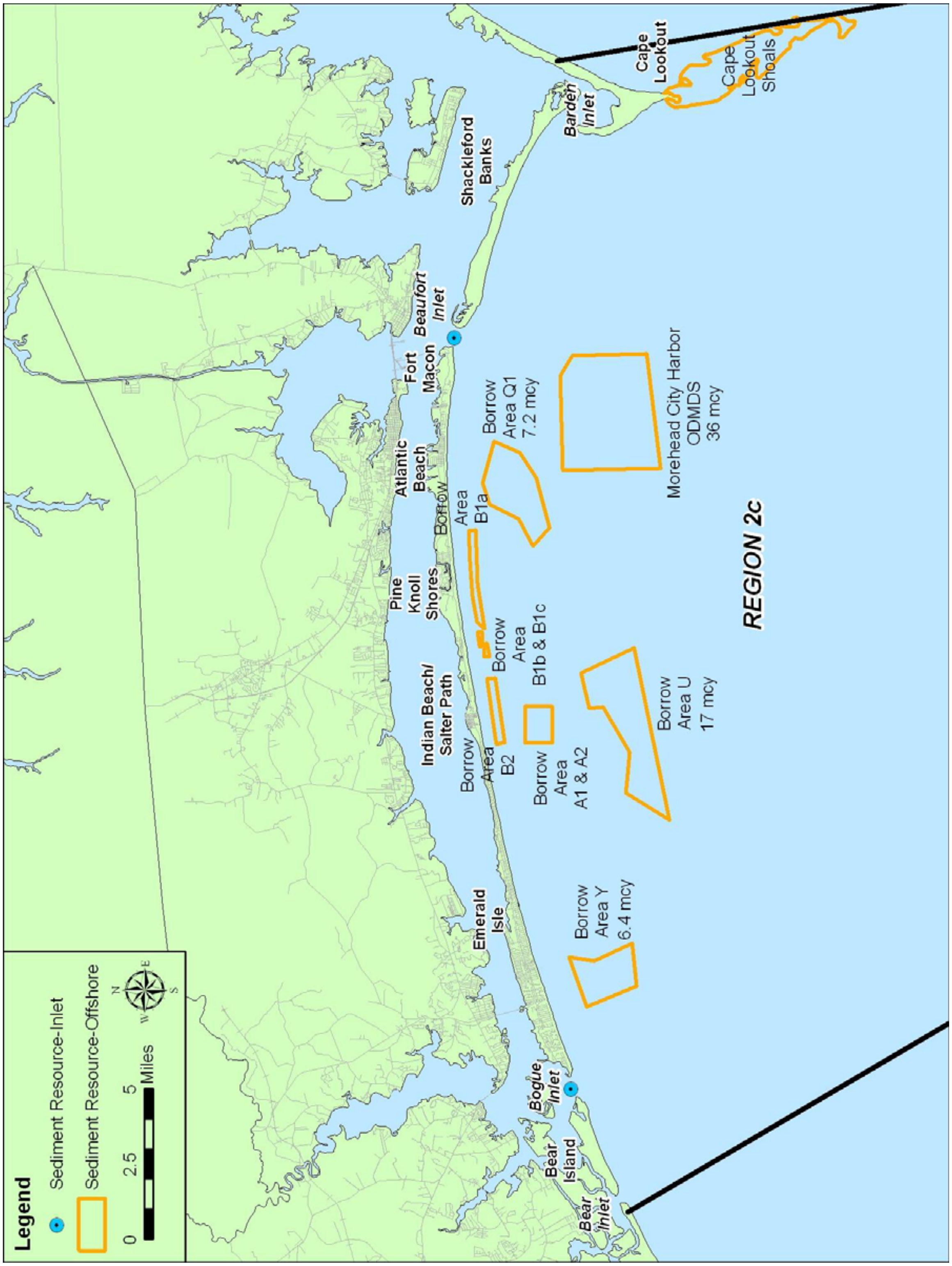


Figure IX-45. Potential Sediment Resources for Region 2c

9. Environmental Considerations

The BIMP recognizes environmental concerns as a vital part of holistic beach and inlet management strategies. Environmental considerations can be constraints on strategy choices, projects or timing of projects, but management strategies can also represent opportunities to preserve, restore, or create habitat. The Coastal Habitat Protection Plan identifies six primary habitats along coastal North Carolina that are vital to the health and function of North Carolina's coastal ecosystems and fisheries. This section is identifies federally protected species, N.C. Natural Heritage Program (NHP) Element Occurrences, Critical Habitats, and Significant Natural Heritage Areas. Site specific concerns for each beach and inlet in Region 2 are also identified. Appendix F contains maps of the primary coastal habitats as well as protected species and critical wildlife habitat mapping.

a) Region 2a - Federal Protected Species, NHP Element Occurrences, Critical Habitats, and Significant Natural Heritage Areas

- NHP identifies element occurrences for plant and animal species within Region 2a including the following species that could potentially occur within the identified project study area: seabeach amaranth, shortnose sturgeon, loggerhead sea turtle, green sea turtle, piping plover, and West Indian manatee. A site specific assessment and U.S. Fish and Wildlife Service (USFWS) coordination should be conducted during project planning to avoid impacts to protected species.

- USFWS identifies May 1 – November 15 as the moratoria period for sea turtle nesting areas.

- Site specific sea turtle nesting data can be obtained from the N.C. Wildlife Resources Commission (http://www.seaturtle.org/nestdb/index.shtml?view=1).

- USFWS has identified critical habitat areas within Region 2a for the piping plover near Forth Fisher, Carolina Beach Inlet, Masonboro Inlet, and Mason Inlet. Site specific information regarding these critical habitat areas can be obtained through USFWS at http://criticalhabitat.fws.gov/. Activities within critical habitat areas will require consultation with USFWS. All applicable USFWS and WRC moratoria should be observed. USFWS identifies April 1 – July 15 as the moratoria period for piping plover nesting areas.

- Region 2a contains significant habitat for colonial waterbirds and shorebirds. Several islands in the Cape Fear River provide important habitat for colonial waterbirds according to NHP data. The beachfront of the lower Cape Fear basin is considered an important area used by shorebirds within the southeastern coastal plain. All applicable USFWS and NCWRC moratoria should be observed.

- Site specific colonial waterbird and shorebird data can be obtained from NCWRC.
- Site specific seabeach amaranth data can be obtained from USFWS and USACE as well as NHP.

b) Shipwrecks

An assessment was made for the potential of the inlets and surrounding areas in Region 2a to contain underwater shipwrecks. Time periods assessed included the sixteenth and seventeenth centuries, the eighteenth and early nineteenth centuries, the Civil War, and the late nineteenth and twentieth centuries. Four categories of potential for underwater shipwrecks are given: low, moderate, high, and general:

- Low potential means that the area around the inlet has little potential to contain shipwrecks from that time period.
- Moderate potential means it is known the inlet was used by shipping during that time period and that wrecks from that time period are present in the area.
- High potential means that the inlet witnessed high volumes of ship traffic during that time period and that wrecks from that time period are present in the area.
- General potential means that shipping traffic used the inlet during that time period, but the volume and presence of wrecks in the area cannot be categorized.

Note that shipwrecks are only listed in the following sections if there is a high probability of encountering them based on available data. Mapping of shipwrecks and other cultural resources is not as complete as needed for detailed assessments.

c) Region 2a - Site Specific Concerns

The following details the environmental considerations specific to each beach/shoreline segment and inlet under the general headings of CHPP elements, protected species and wildlife elements, and any other notable considerations. The first section identifies elements related to the beach or inlet with respect to the CHPP. The second lists key protected species and wildlife issues and time of year restrictions on construction related activities. The third group lists the potential for shipwrecks at the inlets where applicable. The fourth, entitled “Other,” lists any other environmental considerations, such as designated heritage or significant areas.

(1) Fort Fisher

CHPP Elements
- Class SA waters south of Fort Fisher
- Open shellfish waters to the south; closed to the north
- Extensive salt marsh surrounding Fort Fisher
- Submerged Aquatic Vegetation (SAV) mapping needed

Protected Species & Wildlife Elements
- Seabeach amaranth; no plants observed by USACE in 2007 (will require surveys)
- Loggerhead and green sea turtle nest sites (May 1-November 15 moratoria)
- Piping plover nesting (April 1-July 15 moratoria in nesting areas)
- Colonial waterbird nesting (April 1-August 31 moratoria in nesting areas)
- Essential Fish Habitat (EFH) for 25 species

Other
- Primary nursery area in marsh to the north and southeast
- Area of state and federal significance

(2) Kure Beach

CHPP Elements
- Some interior wetlands on the island
- Hard bottom located off Carolina Beach

Protected Species & Wildlife Elements
- Loggerhead and green sea turtle nest sites (May 1-November 15 moratoria)

Other
- EFH present for 70 species (Atlantic Ocean)

(3) Carolina Beach

CHPP Elements
- Some interior wetlands on the island
- Hard bottom approximately one mile offshore
- Artificial reef offshore

Protected Species & Wildlife Elements
- Loggerhead sea turtle nest sites (May 1-November 15 moratoria)
- West Indian manatee occurrence (June – October moratoria; observers possibly required)
- Piping plover nesting (April 1-July 15 moratoria in nesting areas)
- Colonial waterbird nesting (April 1-August 31 moratoria in nesting areas)
- Seabeach amaranth; no plants observed by USACE in 2007 (will require surveys)
- EFH for 70 species (Atlantic Ocean)

(4) Carolina Beach Inlet

CHPP Elements
- Class SA waters in Grove Sound
- Open shellfish waters
- Shell bottom in marsh and along AIWW
- Salt marsh inside inlet to north and south
- Hard bottom south of inlet off Carolina Beach and north of inlet off Masonboro Island
- Soft bottom habitat possibly present with ebb-tidal delta
- SAV mapping needed

Protected Species & Wildlife Elements
- Colonial waterbird nest site (April 1-August 31 moratoria in nesting areas)
- Piping plover nest sites (April 1-July 15 moratoria in nesting areas)
- Sea turtle habitat (limit takes during dredging)
- EFH present for 25 species

Shipwrecks
- Potential for 18th and early 19th century shipwrecks
- Potential for Civil War shipwrecks
- Potential for late 19th and 20th century shipwrecks
- Potential for areas to have been subjected to underwater archaeological survey
- Known collection of shipwrecks to south and southeast of inlet
- Note: While this inlet was constructed in 1952, the area still saw significant boat traffic

Other
- Primary nursery area extensive inside inlet

(5) Masonboro Island

CHPP Elements
- Class SA/ORW in Masonboro Sound
- Shell bottom back in the sound
- Extensive salt marsh in the sound
- Open shellfish waters in sound
- Hard bottom less than one mile off beach

Protected Species & Wildlife Elements
- Seabeach amaranth; none observed by USACE in 2007 (will require surveys)
- Loggerhead and green sea turtle nest sites (May 1- November 15 moratoria)
- Piping plover nesting (April 1-July 15 moratoria in nesting areas)
- Colonial waterbird nesting (April 1-August 31 moratoria in nesting areas)
- West Indian manatee occurrence (June – October moratoria; observers possibly required)
- EFH for 14 species in Masonboro Sound

Other
- Primary nursery area in Masonboro Sound
- Area of State and Federal Significance
- National Estuarine Research Reserve (NERR) site

(6) Masonboro Inlet

CHPP Elements
- Class SA at inlet, ORW in portions of the sound
- Salt marsh inside inlet near AIWW
- Open shellfish waters inside inlet
- Hard bottom less than one mile from inlet
- Soft bottom habitat possibly present with ebb-tidal delta
- SAV mapping needed

Protected Species & Wildlife Elements
- Piping plover nesting (April 1-July 15 moratoria in nesting areas)
- West Indian manatee occurrence (June – October moratoria; observers possibly required)
- Colonial waterbird nesting (April 1-August 31 moratoria in nesting areas)
- Sea turtle habitat (limit takes during dredging)
- EFH for 26 species

Shipwrecks
- Moderate potential for 18th and early 19th century shipwrecks
- Moderate potential for Civil War shipwrecks
- Moderate potential for late 19th and 20th century shipwrecks
- Potential for areas to have been subjected to underwater archaeological survey
- Masonboro Sound National Register Historic District in vicinity

Other
- Primary nursery area extensive inside inlet
- NERR site adjacent to inlet

(7) Wrightsville Beach

CHPP Elements
- Class SA waters behind island
- Salt marsh in sound behind island
- Hard bottom approximately one mile from south end of beach
- Artificial reef offshore
- Mixture of open and closed shellfish waters
- Shell bottom present in the sound

Protected Species & Wildlife Elements
- Seabeach amaranth; nine plants observed by USACE in 2007 (will require surveys)

- Loggerhead sea turtle nest sites (May 1-November 15 moratoria)
- West Indian manatee occurrence (June – October moratoria; observers possibly required)
- EFH for 70 species (Atlantic Ocean)

Other
- Primary nursery area behind north end of island
- North end of beach near Mason Inlet is Area of Regional Significance

(8) Mason Inlet

CHPP Elements
- Class SA/ORW waters
- Salt marsh extensive inside inlet and back to AIWW
- Hard bottom approximately 1.5 miles from inlet
- Artificial reef offshore
- Shell bottom in marsh and AIWW
- Open shellfish waters
- Soft bottom habitat possibly present with ebb-tidal delta
- SAV mapping needed

Protected Species & Wildlife Elements
- Loggerhead sea turtle nest sites (May 1- November 15 moratoria)
- Colonial waterbird nesting (April 1-August 31 moratoria in nesting areas)
- Sea turtle habitat (limit takes during dredging)
- EFH for 26 species

Shipwrecks
- Moderate potential for 18th and early 19th century shipwrecks
- Moderate potential for Civil War shipwrecks
- Moderate potential for late 19th and 20th century shipwrecks
- Potential for areas to have been subjected to underwater archaeological survey

Other
- Primary nursery area extensive inside inlet to AIWW

(9) Figure Eight Island

CHPP Elements
- Class SA/ORW waters behind island
- Salt marsh extensive in Middle Sound
- Shell bottom in Middle Sound
- Open shellfish waters in Middle Sound
- Hard bottom approximately 1.5 mile from inlet
- Artificial reef offshore

Protected Species & Wildlife Elements
- Seabeach amaranth (will require surveys)
- Loggerhead sea turtle nest sites (May 1-November 15 moratoria)
- Piping plover nesting (April 1-July 15 moratoria in nesting areas)
- Colonial waterbird nesting (April 1-August 31 moratoria in nesting areas)
- EFH for 70 species (Atlantic Ocean)

Other
- Primary nursery area extensive in Middle Sound
- Middle Sound marsh is Area of Regional Significance

(10) Rich Inlet

CHPP Elements
- Class SA/ORW waters
- Salt marsh extensive to AIWW
- Open shellfish waters
- Shell bottom in marsh and AIWW
- Hard bottom within approximately three miles of inlet
- Soft bottom habitat possibly present with ebb-tidal delta
- SAV mapping needed

Protected Species & Wildlife Elements
- Piping plover nesting (April 1-July 15 moratoria in nesting areas)
- EFH for 26 species
- Sea turtle habitat (limit takes during dredging)

Shipwrecks
- Moderate potential for 18th and early 19th century shipwrecks
- Moderate potential for Civil War shipwrecks
- Moderate potential for late 19th and 20th century shipwrecks
- Potential for areas to have been subjected to underwater archaeological survey
- Section of Cape Fear Civil War Shipwreck National Register District in vicinity

Other
- Primary nursery area extensive inside inlet
- Rich Inlet adjacent to Area of Regional Significance (Figure Eight Island) and Area of State Significance to the north in Topsail Sound
- Moderate potential for shipwreck sites

Figure IX-47 presents a sample of the environmental considerations which are present in Region 2a.

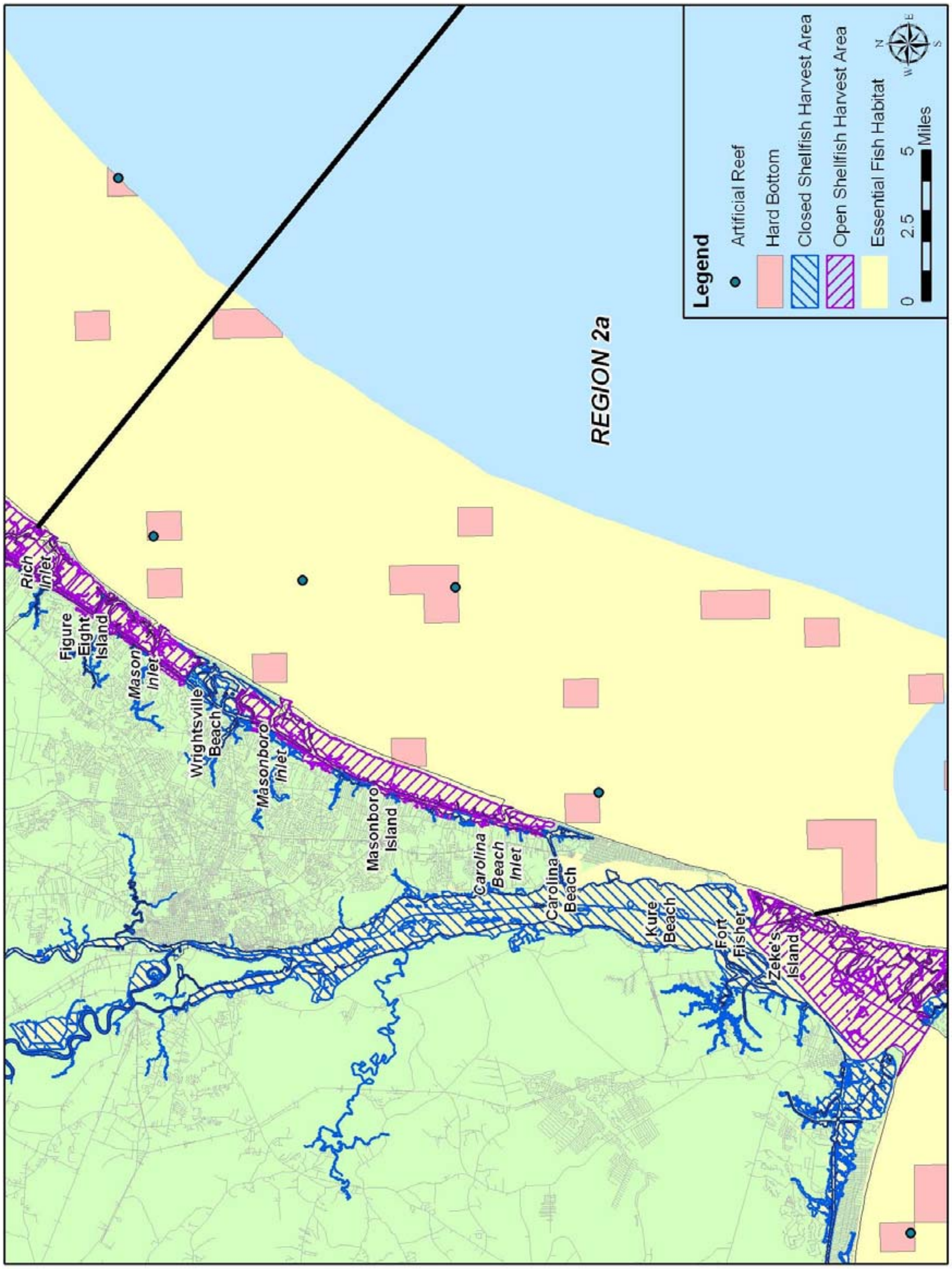


Figure IX-47. Sample Environmental Considerations for Region 2a

d) Region 2b - Federal Protected Species, NHP Element Occurrences, Critical Habitats, and Significant Natural Heritage Areas

- NHP identifies element occurrences for plant and animal species within Region 2b including the following species that could potentially occur within the identified project study area: seabeach amaranth, shortnose sturgeon, loggerhead sea turtle, green sea turtle, leatherback sea turtle, piping plover, and West Indian manatee. A site specific assessment and USFWS coordination should be conducted during project planning to avoid impacts to protected species.

- USFWS identifies May 1 – November 15 as the moratoria period for sea turtle nesting areas.

- Site specific sea turtle nesting data can be obtained from WRC (http://www.seaturtle.org/nestdb/index.shtml?view=1).

- USFWS has identified critical habitat areas within Region 2b for the piping plover near Rich Inlet and Lea Island, Topsail Inlet and the Onslow County side of Bogue Inlet. Site specific information regarding these critical habitat areas can be obtained through USFWS at http://criticalhabitat.fws.gov/. Activities within critical habitat areas will require consultation with USFWS. All applicable USFWS and WRC moratoria should be observed. USFWS identifies April 1 – July 15 as the moratoria period for piping plover nesting areas.

- The significant coastal sites listed for the Pender County portion of Region 2b include Lea Island, Hutaffs Beach, Surf City Maritime Forest, and Topsail Sound Maritime Forest. The Lea Island/Hutaff Beach natural area is important to many rare species such as seabeach amaranth, loggerhead turtle, and piping plover. This area also supports a gull-tern-skimmer colony. The significant coastal sites listed for the Onslow County portion of Region 2b include Hammocks Beach State Park, Emerald Isle/West Beach, Hawkins Island, Huggins/Dudley Island, North Topsail Beach Maritime Forest, Browns Island, and New River Inlet. Many of these significant coastal sites support seabeach amaranth, as well as loggerhead sea turtle and green sea turtle nesting sites.

- Region 2b contains significant habitat for colonial water birds, wading birds and shore birds including known colonial wading bird colonies and gull-tern-skimmer colonies. All applicable USFWS and WRC moratoria should be observed.

- Site specific colonial waterbird and shorebird data can be obtained from WRC.

- Site specific seabeach amaranth data can be obtained from USFWS and USACE as well as NHP.

e) Shipwrecks

An assessment was made for the potential of the inlets and surrounding areas in Region 2b to contain underwater shipwrecks. Time periods assessed included the sixteenth and seventeenth centuries, the eighteenth and early nineteenth centuries, the Civil War, and the late nineteenth and twentieth centuries. Four categories of potential for underwater shipwrecks are given: low, moderate, high, and general:

- Low potential means that the area around the inlet has little potential to contain shipwrecks from that time period.
- Moderate potential means it is known the inlet was used by shipping during that time period and that wrecks from that time period are present in the area.
- High potential means that the inlet witnessed high volumes of ship traffic during that time period and that wrecks from that time period are present in the area.
- General potential means that shipping traffic used the inlet during that time period, but the volume and presence of wrecks in the area cannot be categorized.

Please note that shipwrecks are only listed in the following sections if there is a high probability of encountering them based on available data. Mapping of shipwrecks and other cultural resources is not as complete as needed for detailed assessments.

f) Region 2b - Site Specific Concerns

The following details the environmental considerations specific to each beach/shoreline segment and inlet under the general headings of CHPP elements, protected species and wildlife elements, and any other notable considerations. The first section identifies elements related to the beach or inlet with respect to the CHPP. The second lists key protected species and wildlife issues and time of year restrictions on construction related activities. The third group lists the potential for shipwrecks at the inlets where applicable. The fourth, entitled "Other," lists any other environmental considerations, such as designated heritage or significant areas.

(1) Hutaff's Island

CHPP Elements

- Class SA waters in marshes; ORW closer to AIWW and in main channels
- Extensive salt marsh behind island
- Open shellfish waters in Topsail Sound
- Shell bottom in Topsail Sound
- Hard bottom just outside New Topsail Inlet

Protected Species & Wildlife Elements
- Piping plover nesting (April 1-July 15 moratoria in nesting areas)
- Loggerhead sea turtle nest sites (May 1-November 15 moratoria)
- Colonial waterbird nesting (April 1-August 31 moratoria in nesting areas)
- Seabeach amaranth (will require surveys)
- EFH for 14 species in Topsail Sound behind island

Other
- Area of State Significance
- Primary nursery area extensive in marshes

(2) New Topsail Inlet

CHPP Elements
- Class SA waters
- Extensive salt marsh inside inlet
- Open shellfish waters inside inlet to AIWW
- Shell bottom in marsh and AIWW
- Hard bottom less than one mile from inlet
- Soft bottom habitat possibly present with ebb-tidal delta
- SAV mapping needed

Protected Species & Wildlife Elements
- Colonial waterbird nesting (April 1-August 31 moratoria in nesting areas)
- EFH for 26 species
- Sea turtle habitat (limit takes during dredging)

Shipwrecks
- Moderate potential for 18th and early 19th century shipwrecks
- Moderate potential for Civil War shipwrecks
- Moderate potential for late 19th and 20th century shipwrecks
- Potential for areas to have been subjected to underwater archaeological survey

Other
- Primary nursery area in Topsail Sound marshes
- Topsail Sound marshes are Area of State Significance

(3) Topsail Beach

CHPP Elements
- Class SA waters
- Open shellfish waters in Topsail Sound
- Extensive saltmarsh in Topsail Sound
- Shell bottom in sound
- Numerous hard bottom areas within one mile of the beach

Protected Species & Wildlife Elements
- Loggerhead sea turtle nest sites (May 1-November 15 moratoria)
- Colonial waterbird nesting (April 1-August 31 moratoria in nesting areas)
- Seabeach amaranth; 29 plants observed by USACE in 2007 (will require surveys)
- EFH for 14 species in Topsail Sound; 70 species in Atlantic Ocean

Other
- Primary nursery area extensive in Topsail Sound

(4) Surf City

CHPP Elements
- Class SA waters
- Open shellfish waters in the sound
- Extensive salt marsh in the sound
- Hard bottom within one mile of the beach

Protected Species & Wildlife Elements
- Loggerhead sea turtle nest sites (May 1-November 15 moratoria)
- Seabeach amaranth; no plants observed by USACE in 2007 (will require surveys)
- EFH for 14 species in sound; 70 species in Atlantic Ocean

(5) North Topsail

CHPP Elements
- Class SA/ORW waters
- Open shellfish waters behind island
- Salt marsh and estuarine shrub-scrub wetland along rear of island
- Hard bottom extensive approximately one mile from beach
- Artificial reef offshore

Protected Species & Wildlife Elements
- Loggerhead and leatherback sea turtle nest sites (May 1-November 15 moratoria)
- Seabeach amaranth; 131 plants observed by USACE in 2007 (will require surveys)
- Colonial waterbird nesting (April 1-August 31 moratoria in nesting areas)
- EFH for 14 species in Topsail Sound; 70 species in Atlantic Ocean

(6) New River Inlet

CHPP Elements
- Class SA waters
- Salt marsh inside inlet to AIWW
- Open shellfish waters inside inlet
- Hard bottom approximately 1.5 miles southwest of inlet
- Soft bottom habitat possibly present with ebb-tidal delta
- SAV mapping needed

Protected Species & Wildlife Elements
- Colonial waterbird nesting (April 1-August 31 moratoria in nesting areas)
- Shortnose sturgeon occurrence (February 1-June 15 moratoria)
- EFH for 26 species
- Sea turtle habitat (limit takes during dredging)

Shipwrecks
- Potential for 18th and early 19th century shipwrecks
- Potential for Civil War shipwrecks
- Moderate potential for late 19th and 20th century shipwrecks
- Potential for areas to have been subjected to underwater archaeological survey

Other
- New River Inlet Outcrop Registered Heritage Area (+/- 1,300 acres)
- Extensive primary nursery areas inside inlet to AIWW
- NCWRC islands for birds (UNI New River Channel 1, 2, & 3)

(7) Onslow Beach

CHPP Elements
- Class SA waters
- Mixture of open and closed shellfish waters
- Salt marsh and shrub-scrub wetlands on rear of island adjacent to AIWW
- Hard bottom within approximately one mile of portions of the beach

Protected Species & Wildlife Elements
- Loggerhead and green sea turtle nest sites (May 1-November 15 moratoria)
- Colonial waterbird nesting (April 1-August 31 moratoria if nesting present)
- Seabeach amaranth (will require surveys)
- Piping plover nesting (April 1-July 15 moratoria in nesting areas)
- West Indian manatee occurrence (June –October moratoria; observers possibly required)
- Sea turtle sanctuary along Onslow Beach
- EFH for 70 species (Atlantic Ocean)

Other
- Primary nursery areas along AIWW
- Area of Federal Significance

(8) Brown's Island

CHPP Elements
- Class SA waters
- Extensive salt marsh behind island
- Open shellfish waters behind island
- Hard bottom within one mile of inlet to the south

Protected Species & Wildlife Elements

- Loggerhead sea turtle nest sites (May 1-November 15 moratoria)
- Colonial waterbird nesting (April 1-August 31 moratoria in nesting areas)
- Sea turtle sanctuary along Brown's Island
- EFH for 70 species (Atlantic Ocean)

Other

- Area of Regional and Federal Significance

Figure IX-48 presents a sample of the environmental considerations which are present in Region 2b.

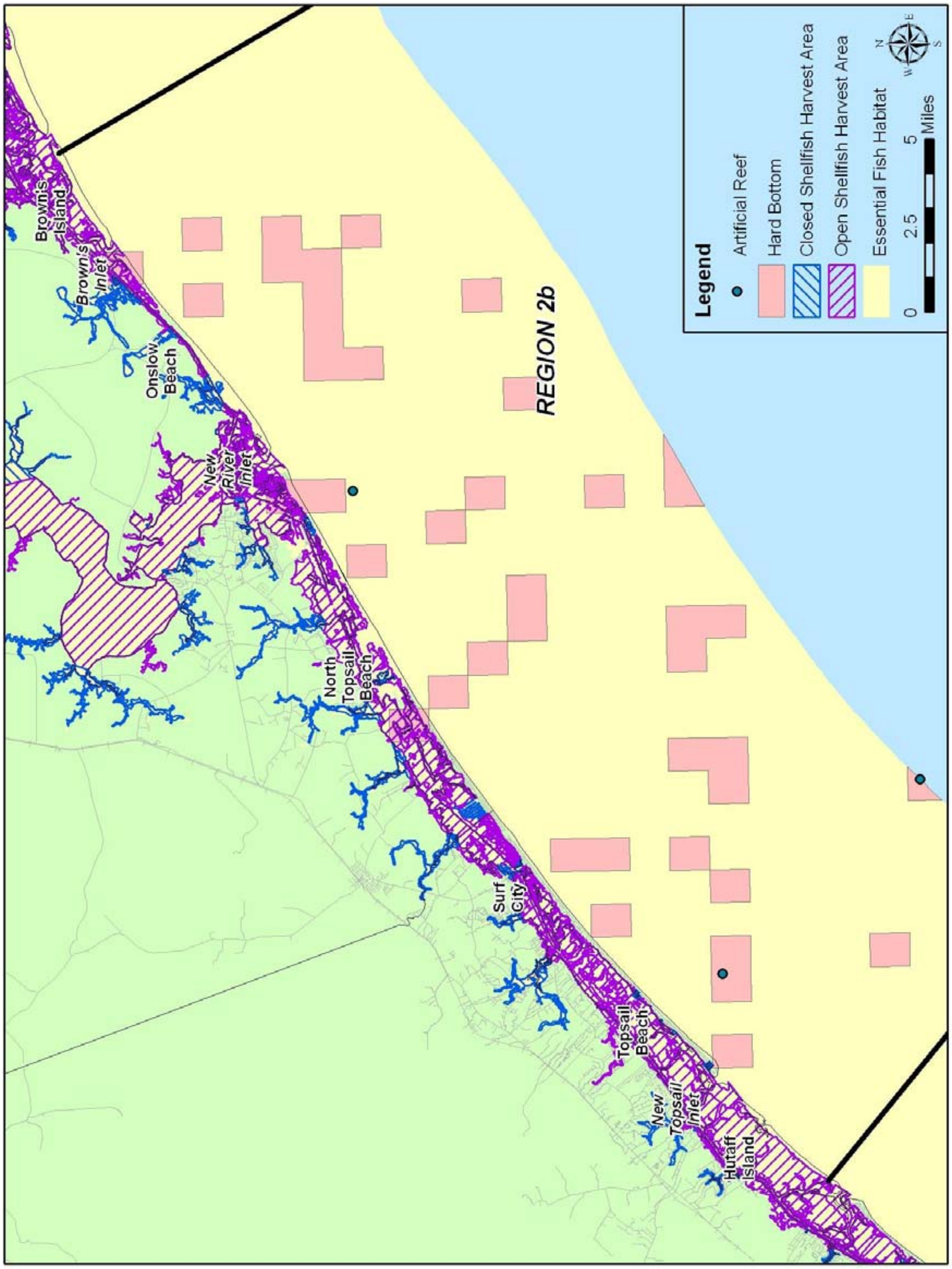


Figure IX-48. Sample Environmental Constraints for Region 2b

g) Region 2c - Federal Protected Species, NHP Element Occurrences, Critical Habitats, and Significant Natural Heritage Areas

- NHP identifies element occurrences for plant and animal species within Region 2c including the following species that could potentially occur within the identified project study area: seabeach amaranth, shortnose sturgeon, loggerhead sea turtle, green sea turtle, leatherback sea turtle, hawksbill sea turtle, Kemp's Ridley sea turtle, piping plover, roseate tern, and West Indian manatee. A site specific assessment and USFWS coordination should be conducted during project planning to avoid impacts to protected species.

- USFWS identifies May 1 – November 15 as the moratoria period for sea turtle nesting areas.

- Site specific sea turtle nesting data can be obtained from WRC (http://www.seaturtle.org/nestdb/index.shtml?view=1).

- USFWS has identified critical habitat areas within Region 2c for the piping plover near Carteret County side of Bogue Inlet, Horse Island, Carrot Island, Shackleford Banks, Barden Inlet, and Cape Lookout. Site specific information regarding these critical habitats can be obtained through USFWS at http://criticalhabitat.fws.gov/. Activities within critical habitat areas will require consultation with USFWS. All applicable USFWS and WRC moratoria should be observed. USFWS identifies April 1 – July 15 as the moratoria period for piping plover nesting areas.

- Region 2c contains significant habitat for colonial water birds, wading birds and shore birds including known colonial wading bird colonies and gull-tern-skimmer colonies. All applicable USFWS and NCWRC moratoria should be observed.

- Site specific colonial waterbird and shorebird data can be obtained from NCWRC.

- Site specific seabeach amaranth data can be obtained from USFWS and USACE as well as NHP.

h) Shipwrecks

An assessment was made for the potential of the inlets and surrounding areas in Region 2c to contain underwater shipwrecks. Time periods assessed included the sixteenth and seventeenth centuries, the eighteenth and early nineteenth centuries, the Civil War, and the late nineteenth and twentieth centuries. Four categories of potential for underwater shipwrecks are given: low, moderate, high, and general:

- Low potential means that the area around the inlet has little potential to contain shipwrecks from that time period.

- Moderate potential means it is known the inlet was used by shipping during that time period and that wrecks from that time period are present in the area.
- High potential means that the inlet witnessed high volumes of ship traffic during that time period and that wrecks from that time period are present in the area.
- General potential means that shipping traffic used the inlet during that time period, but the volume and presence of wrecks in the area cannot be categorized.

Note that shipwrecks are only listed in the following sections if there is a high probability of encountering them based on available data. Mapping of shipwrecks and other cultural resources is not as complete as needed for detailed assessments.

i) Region 2c - Site Specific Concerns

The following details the environmental considerations specific to each beach/shoreline segment and inlet under the general headings of CHPP elements, protected species and wildlife elements, and any other notable considerations. The first section identifies elements related to the beach or inlet with respect to the CHPP. The second lists key protected species and wildlife issues and time of year restrictions on construction related activities. The third group lists the potential for shipwrecks at the inlets where applicable. The fourth, entitled “Other,” lists any other environmental considerations, such as designated heritage or significant areas.

(1) Bear Island

<u>CHPP Elements</u>
- Class SA and ORW waters
- Open shellfish waters behind island
- Shell bottom in marsh behind island
- Extensive salt marsh behind island

<u>Protected Species & Wildlife Elements</u>
- Loggerhead and green sea turtle nest sites (May 1-November 15 moratoria)
- Colonial waterbird nesting (April 1-August 31 moratoria in nesting areas)
- Seabeach amaranth (will require surveys)
- Piping plover nesting (April 1-July 15 moratoria in nesting areas)
- Sea turtle sanctuary along Bear Island
- EFH for 26 species at Bear Inlet

<u>Other</u>
- Area of Regional and State Significance

(2) Bogue Inlet

CHPP Elements
- Class SA and ORW waters
- Extensive salt marsh inside inlet
- Open shellfish waters
- Hard bottom approximately 3.5 miles from inlet
- Artificial reef offshore
- Soft bottom habitat possibly present with ebb-tidal delta
- SAV mapping needed

Protected Species & Wildlife Elements
- Colonial waterbird nesting (April 1-August 31 moratoria in nesting areas)
- Piping plover nesting (April 1-July 15 moratoria in nesting areas)
- EFH for 26 species
- Sea turtle habitat (limit takes during dredging)
- NCWRC island (Bogue Inlet shoal)

Shipwrecks
- High potential for 18th and early 19th century shipwrecks
- Moderate potential for Civil War shipwrecks
- Moderate potential for late 19th and 20th century shipwrecks
- Potential for areas to have been subjected to underwater archaeological survey
- Swansboro National Register Historic District nearby

Other
- Bogue Inlet Outcrop Registered Heritage Area (+/- 72 acres)

(3) Emerald Isle

CHPP Elements
- Class SA/ORW waters in western Bogue Sound
- Mostly open shellfish waters in Bogue Sound
- Some interior wetlands on Emerald Isle
- Extensive SAV in Bogue Sound
- Hard bottom within two miles of beach
- Artificial reef offshore

Protected Species & Wildlife Elements
- Loggerhead sea turtle nest sites (May 1-November 15 moratoria)
- Colonial waterbird nesting (April 1-August 31 moratoria in nesting areas)
- Piping plover nesting (April 1-July 15 moratoria in nesting areas)
- West Indian manatee occurrence (June – October moratoria; observers possibly required)
- Seabeach amaranth; 130 plants observed on Bogue banks by USACE in 2007 (will require surveys)
- EFH for 70 species (Atlantic Ocean)

(4) Indian Beach/Salter Path

CHPP Element
- Class SA/ORW waters
- Shell bottom in AIWW
- Extensive SAV in Bogue Sound
- Some interior wetlands on island
- Hard bottom within approximately two miles of beach
- Artificial reef offshore

Protected Species & Wildlife Elements
- Loggerhead sea turtle nest sites (May 1-November 15 moratoria)
- Seabeach amaranth; 130 plants observed on Bogue banks by USACE in 2007 (will require surveys)
- EFH for 70 species (Atlantic Ocean)

Other
- Areas of Regional and State Significance

(5) Pine Knoll Shores

CHPP Elements
- Class SA waters in Bogue Sound; ORW in Theodore Roosevelt State natural Area
- Extensive SAV in Bogue Inlet
- Salt marsh and estuarine shrub-scrub wetlands along rear of island
- Hard bottom approximately two miles off beach
- Artificial reef

Protected Species & Wildlife Elements
- Loggerhead sea turtle nest sites (May 1-November 15 moratoria)
- Shortnose sturgeon occurrence (February 1-June 15 moratoria)
- Seabeach amaranth; 130 plants observed on Bogue banks by USACE in 2007 (will require surveys)
- EFH for 70 species (Atlantic Ocean)

Other
- Areas of Regional and State Significance (Theodore Roosevelt State Natural Area)

(6) Atlantic Beach

CHPP Elements
- Class SA waters
- Salt marsh along sound side
- Extensive SAV in Bogue Sound
- Hard bottom within four miles of Beaufort Inlet
- Artificial reef

Protected Species & Wildlife Elements
- Loggerhead sea turtle nest sites (May 1-November 15 moratoria)
- Shortnose sturgeon occurrence (February 1-June 15 moratoria)
- Colonial waterbird nesting (April 1-August 31 moratoria in nesting areas)
- West Indian manatee occurrence (June – October moratoria; observers possibly required)
- Seabeach amaranth; 130 plants observed on Bogue banks by USACE in 2007 (will require surveys)
- EFH for 70 species (Atlantic Ocean)

Other
- Area of State and Regional Significance to the east (Fort Macon)

(7) Fort Macon

CHPP Elements
- Class SA waters
- Open and closed shellfish waters
- Shell bottom behind island
- Hard bottom within five miles

Protected Species & Wildlife Elements
- Loggerhead sea turtle nest sites (May 1-November 15 moratoria)
- Shortnose sturgeon occurrence (February 1-June 15 moratoria)
- Colonial waterbird nesting (April 1-August 31 moratoria in nesting areas)
- West Indian manatee occurrence (June – October moratoria; observers possibly required)
- Seabeach amaranth (will require surveys)
- EFH for 26 species from Beaufort Inlet; 70 species for Atlantic Ocean

Other
- Area of State and Regional Significance

(8) Beaufort Inlet

CHPP Elements
- Class SA waters
- Open shellfish waters inside inlet
- Hard bottom within four miles of inlet
- Extensive SAV in Bouge Sound and behind Shackleford Banks
- Soft bottom habitat possibly present with ebb-tidal delta

Protected Species & Wildlife Elements
- Shortnose sturgeon occurrence (February 1-June 15 moratoria)
- Colonial waterbird nesting (April 1-August 31 moratoria in nesting areas)
- West Indian manatee occurrence (June – October moratoria; observers possibly required)

- Piping plover nesting (April 1-July 15 moratoria in nesting areas)
- Sea turtle habitat (limit takes during dredging)
- EFH for 26 species

Shipwrecks
- High potential for 18th and early 19th century shipwrecks
- Low potential for Civil War shipwrecks
- Moderate potential for late 19th and 20th century shipwrecks
- Potential for areas to have been subjected to underwater archaeological survey
- Beaufort National Register Historic District nearby

Other
- Area of Federal Significance to the east (Cape Lookout National Seashore)

(9) Shackleford Banks

CHPP Elements
- Mixture of Class SA and ORW waters in Back Sound
- Extensive SAV in eastern Back Sound
- Shell bottom in Back Sound
- Open shellfish waters in Back Sound
- Salt marsh along rear of island
- Hard bottom within 1.5 miles of beach

Protected Species & Wildlife Elements
- Shortnose sturgeon occurrence (February 1-June 15 moratoria)
- Colonial waterbird nesting (April 1-August 31 moratoria in nesting areas)
- West Indian manatee occurrence (June –October moratoria; observers possibly required)
- Piping plover nesting (April 1-July 15 moratoria in nesting areas)
- Loggerhead sea turtle nest sites (May 1-November 15 moratoria)
- Seabeach amaranth (will require surveys)
- EFH for 14 species in Back Sound; 70 species in Atlantic Ocean

Other
- Area of Regional and Federal Significance (Cape Lookout National Seashore)

(10) Cape Lookout

CHPP Elements
- Class SA/ORW waters in Back Sound
- Open shellfish waters
- Shell bottom in Back Sound and near Barden Inlet
- Extensive SAV in Back Sound
- Salt marsh along rear of island and along Barden Inlet
- Some interior wetlands at Cape Lookout
- Hard bottom just off beach

Protected Species & Wildlife Elements
- Shortnose sturgeon occurrence (February 1-June 15 moratoria)
- Colonial waterbird nesting (April 1-August 31 moratoria in nesting areas)
- West Indian manatee occurrence (June –October moratoria; observers possibly required)
- Loggerhead sea turtle nest sites (May 1-November 15 moratoria)
- Seabeach amaranth (will require surveys)
- Crab spawning sanctuary inside Lookout Bight and inside Barden Inlet
- EFH for 14 species in Back Sound

Other
- Area of Regional and Federal Significance (Cape Lookout National Seashore)

Figure IX-49 presents a sample of the environmental considerations which are present in Region 2c.

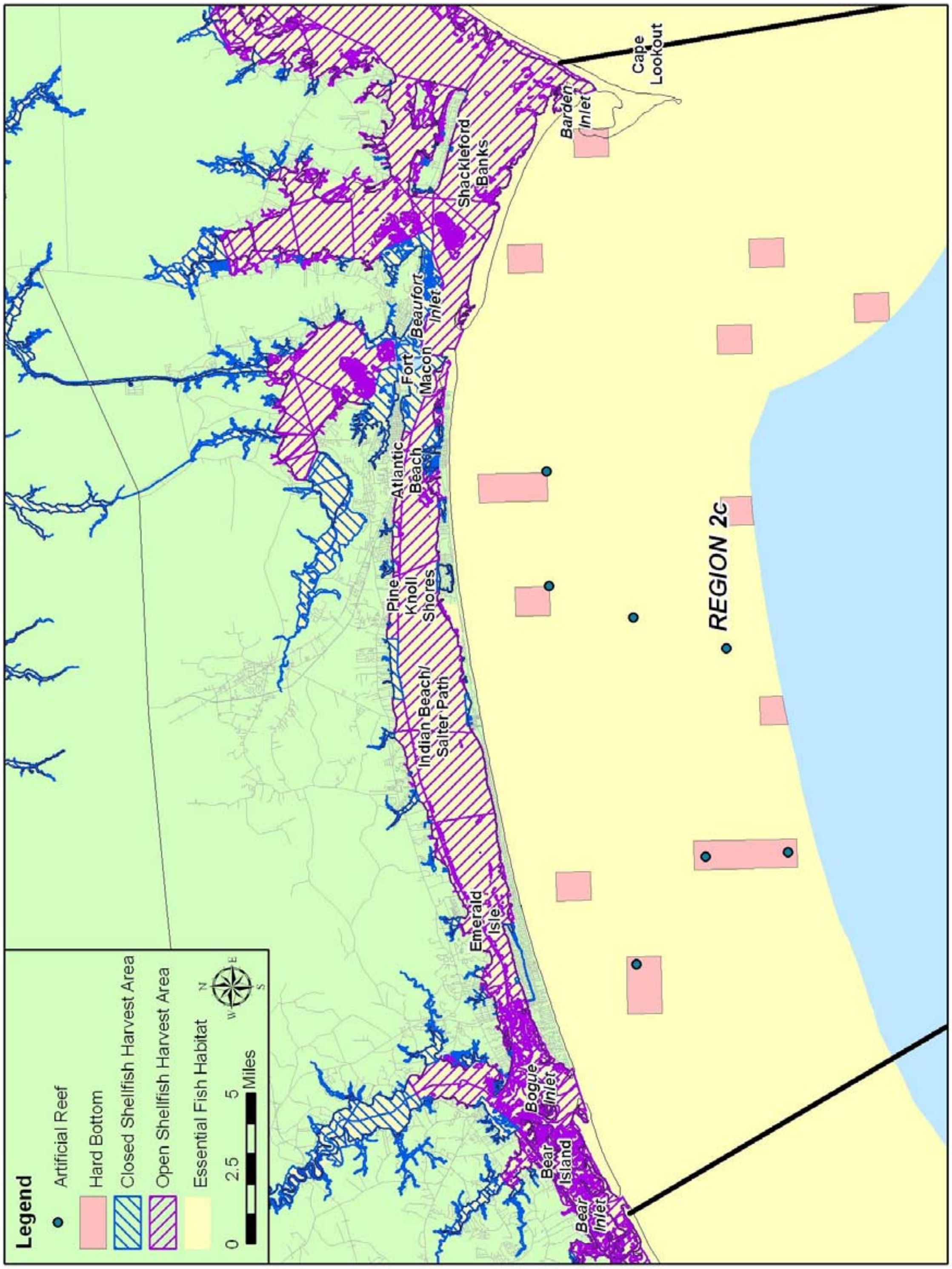


Figure IX-49. Sample Environmental Considerations for Region 2c

10. Economic Valuation.

a) Property Value At Risk

Tables IX-18 to IX-20 provide the value of property at risk from sea level rise for Region 2. Estimates were based on Bin *et al.* (2007) with a sea rise scenario of 18.1 inches by 2080. As outlined in Chapter IV, the CRC Science Panel on Coastal Hazards released a report with a likely range of sea level rise that should be adopted for policy development and planning purposes. The Science Panel found the most likely scenario for 2100 AD is a rise of 0.4 - 1.4 meters (15 inches to 55 inches) above present. In comparison to the BIMP scenarios presented in Table IV-1, the Science Panel ranges represent a rise in sea level between 0.29 and 1.02 feet by 2030 and between 1.02 and 3.57 feet by 2080. In addition, the North Carolina Sea Level Rise Risk Management Study being carried out by the N.C. Division of Emergency Management is ongoing with final scenarios expected in mid-2011.

Values are provided in the original study dollars (2004) and adjusted to 2008 year equivalent dollars. Pender and Onslow Counties (Region 2b) were not included within the Bin *et al.* (2007) study. These counties should be included within future studies.

Table IX-18. Property Value At Risk From Sea Level Rise – Region 2a

Coastal Region	County	Beach	Value of Residential Coastal Property at Risk 2004	Value of Commercial Coastal Property at Risk 2004	Value of Residential Coastal Property at Risk 2008	Value of Commercial Coastal Property at Risk 2008
2a	New Hanover	All	$90,700,000	$32,300,000	$98,227,440	$34,980,665

Table IX-19. Property Value At Risk From Sea Level Rise – Region 2b

Coastal Region	County	Beach	Value of Residential Coastal Property at Risk 2004	Value of Commercial Coastal Property at Risk 2004	Value of Residential Coastal Property at Risk 2008	Value of Commercial Coastal Property at Risk 2008
2b	Pender	All	N/A	N/A	N/A	N/A
2b	Onslow	All	N/A	N/A	N/A	N/A

Table IX-20. Property Value At Risk From Sea Level Rise – Region 2c

Coastal Region	County	Beach	Value of Residential Coastal Property at Risk 2004	Value of Commercial Coastal Property at Risk 2004	Value of Residential Coastal Property at Risk 2008	Value of Commercial Coastal Property at Risk 2008
2c	Carteret	All	$92,300,000	$168,000,001	$99,960,228	$181,942,778

b) Beach Recreation

The direct annual expenditures and the associated employment and estimated total economic impact including multiplier effects are presented in Tables IX-21 to IX-23, along with the consumer surplus value of beach recreation. The data has been aggregated to a beach segment level for the region.

Table IX-21. Beach Recreation Values – Region 2a

Coastal Region	County	Beach	Beach Recreation 2005-2006 Total Impact Employment (jobs)	Beach Recreation 2008 Annual Direct Expenditures	Beach Recreation 2008 Annual Total Impact Output/ Sales/ Business Activity	Beach Recreation 2008 Annual Consumer Surplus
2a	New Hanover	Zeke's Island	N/A	N/A	N/A	N/A
2a	New Hanover	Kure Beach (& Ft. Fisher)	389	$14,572,410	$28,479,677	$1,683,089
2a	New Hanover	Carolina Beach	1305	$48,891,415	$95,551,231	$7,193,860
2a	New Hanover	Masonboro Island	N/A	N/A	N/A	N/A
2a	New Hanover	Wrightsville Beach	2685	$100,607,605	$196,623,079	$19,436,813
2a	New Hanover	Figure Eight Island	No Data	No Data	No Data	No Data
REGION 2a TOTALS=			4,379	$164,071,429	$320,653,987	$28,313,762

Table IX-22. Beach Recreation Values – Region 2b

Coastal Region	County	Beach	Beach Recreation 2005-2006 Total Impact Employment (jobs)	Beach Recreation 2008 Annual Direct Expenditures	Beach Recreation 2008 Annual Total Impact Output/ Sales/ Business Activity	Beach Recreation 2008 Annual Consumer Surplus
2b	Pender	Hutaff Beach	N/A	N/A	N/A	N/A
2b	Pender	Topsail Beach	422	$17,120,848	$26,082,197	$1,553,009
2b	Pender	Surf City	551	$22,388,207	$34,106,581	$3,164,276
2b	Onslow	North Topsail Beach	978	$39,735,953	$60,534,439	$5,901,986
2b	Onslow	Onslow Beach	N/A	N/A	N/A	N/A
2b	Onslow	Browns Island	N/A	N/A	N/A	N/A
REGION 2b TOTALS=			1,951	$79,245,008	$120,723,217	$10,619,270

Table IX-23. Beach Recreation Values – Region 2c

Coastal Region	County	Beach	Beach Recreation 2005-2006 Total Impact Employment (jobs)	Beach Recreation 2008 Annual Direct Expenditures	Beach Recreation 2008 Annual Total Impact Output/ Sales/ Business Activity	Beach Recreation 2008 Annual Consumer Surplus
2c	Onslow	Bear Island	N/A	N/A	N/A	N/A
2c	Carteret	Emerald Isle	3314	$124,341,243	$214,672,550	$13,010,359
2c	Carteret	Indian Beach/Salter Path	284	$10,638,487	$18,367,124	$1,667,382
2c	Carteret	Pine Knoll Shores	485	$18,199,319	$31,420,743	$3,317,204
2c	Carteret	Atlantic Beach	1276	$47,882,384	$82,667,933	$8,749,705
2c	Carteret	Fort Macon	133	$4,980,628	$8,598,950	$2,681,956
2c	Carteret	Shackleford Banks	N/A	N/A	N/A	N/A
2c	Carteret	Cape Lookout	Included in Carteret County Totals			
REGION 2c TOTALS=			5,492	$206,042,061	$355,727,300	$29,426,605

c) Shore and Pier Fishing

In addition to beach recreation value, people attach value to fishing from the shore and from pier structures. This value defined here as consumer surplus is presented in Tables IX-24 to IX-26 for the Region 2 beaches.

Table IX-24. Shore and Pier Fishing – Region 2a

Coastal Region	County	Beach	Annual Pier/Bridge/Jetty Fishing Consumer Surplus (2008)	Annual Shore/Bank Fishing Consumer Surplus (2008)
2a	New Hanover	Zeke's Island	$0	$0
2a	New Hanover	Kure Beach	$1,777,628	$904,858
2a	New Hanover	Carolina Beach	$1,726,289	$70,592
2a	New Hanover	Masonboro Island	$0	$0
2a	New Hanover	Wrightsville Beach	$1,777,628	$904,858
2a	New Hanover	Figure Eight Island	$0	$0
REGION 2a TOTALS=			$5,281,545	$1,880,307

Table IX-25. Shore and Pier Fishing – Region 2b

Coastal Region	County	Beach	Annual Pier/Bridge/Jetty Fishing Consumer Surplus (2008)	Annual Shore/Bank Fishing Consumer Surplus (2008)
2b	Pender	Hutaff Beach	$0	$0
2b	Pender	Topsail Beach	$1,033,206	$19,252
2b	Pender	Surf City	$821,431	$1,326,067
2b	Onslow	North Topsail Beach	$1,123,050	$2,637,564
2b	Onslow	Onslow Beach	$0	$0
2b	Onslow	Browns Island	$0	$0
REGION 2b TOTALS=			$2,977,688	$3,982,883

Table IX-26. Shore and Pier Fishing – Region 2c

Coastal Region	County	Beach	Annual Pier/Bridge/Jetty Fishing Consumer Surplus (2008)	Annual Shore/Bank Fishing Consumer Surplus (2008)
2c	Onslow	Bear Island	$0	$0
2c	Carteret	Emerald Isle	$4,626,967	$853,518
2c	Carteret	Indian Beach/Salter Path	$0	$94,835
2c	Carteret	Pine Knoll Shores	$0	$327,730
2c	Carteret	Atlantic Beach	$8,156,554	$314,828
2c	Carteret	Fort Macon	$0	$3,632,266
2c	Carteret	Shackleford Banks	$0	$0
2c	Carteret	Cape Lookout	$0	$0
REGION 2c TOTALS=			$12,783,521	$5,223,177

d) Marine Recreation Services

Marine recreational services are businesses that can be dependent on water access but are not direct beach recreation or fishing related. Some examples include ecotourism, canoe, kayak, and surf board rentals. Tables IX-27 to IX-29 provide the economic values associated with marine recreation services on a per county basis.

Table IX-27. Marine Recreation Services – Region 2a (New Hanover County)

Coastal Region	County	Number Businesses (2007)	Annual Direct Sales (2007)	Direct Employment (jobs) (2007)	Annual Total Impact Output/ Sales/ Business Activity (2007)	Total Impact Employment (jobs) (2007)	Annual Direct Sales (2008)	Annual Total Impact Output/ Sales/ Business Activity (2008)
2a	New Hanover	37	$2,510,174	419	$5,272,502	438	$2,564,623	$5,386,871

Table IX-28. Marine Recreation Services – Region 2b (Pender and Onslow Counties)

Coastal Region	County	Number Businesses (2007)	Annual Direct Sales (2007)	Direct Employment (jobs) (2007)	Annual Total Impact Output/ Sales/ Business Activity (2007)	Total Impact Employment (jobs) (2007)	Annual Direct Sales (2008)	Annual Total Impact Output/ Sales/ Business Activity (2008)
2b	Pender	13	$881,953	147	$1,852,501	154	$901,084	$1,892,684
2b	Onslow	Included in Pender Co. totals.						

Table IX-29. Marine Recreation Services – Region 2c (Carteret County)

Coastal Region	County	Number Businesses (2007)	Annual Direct Sales (2007)	Direct Employment (jobs) (2007)	Annual Total Impact Output/ Sales/ Business Activity (2007)	Total Impact Employment (jobs) (2007)	Annual Direct Sales (2008)	Annual Total Impact Output/ Sales/ Business Activity (2008)
2c,3a	Carteret	37	$2,510,174	419	$5,272,502	438	$2,564,623	$5,386,871

As a note, Tables IX-29 includes Region 2c and Region 3a since the analysis was done on a per county basis and Carteret County is split into both regions.

e) Commercial Fishing

The employment value of fish landings and associated seafood processing industry economic values are presented in Tables IX-30 to IX-32.

Table IX-30. Commercial Fishing – Region 2a

Coastal Region	Waterway/Inlet	County	Estimated Direct Seafood Processing and Packing Output/Sales/Yr Supported by NC Seafood Landings 2007	Estimated Seafood Processing and Packing Jobs Supported by NC Seafood Landings 2007	Commercial Fishery Landings Direct Output/Sales (Dockside Value)/Yr 2007	Number of Commercial Fishing Jobs Supported 2007	Total Impacts on Business Activity/Sales 2008 (incl mult effects)	Total Jobs Supported 2008 (incl mult effects)
2a	Carolina Beach Inlet	New Hanover	$4,643,452	23	$1,346,601		$7,816,150	
2a	Mason Inlet	New Hanover	N/A	N/A	N/A		N/A	
2a	Masonboro Inlet	New Hanover	$4,643,452	23	$1,346,601	363	$7,816,150	460
2a	Rich Inlet	New Hanover	N/A	N/A	N/A		N/A	
2a	AIWW	New Hanover	N/A	N/A	N/A		N/A	
REGION 2a TOTALS=			$9,286,903	46	$2,693,202	363	$15,632,301	460

Table IX-31. Commercial Fishing – Region 2b

Coastal Region	Waterway/Inlet	County	Estimated Direct Seafood Processing and Packing Output/Sales/Yr Supported by NC Seafood Landings 2007	Estimated Seafood Processing and Packing Jobs Supported by NC Seafood Landings 2007	Commercial Fishery Landings Direct Output/Sales (Dockside Value)/Yr 2007	Number of Commercial Fishing Jobs Supported 2007	Total Impacts on Business Activity/Sales 2008 (incl mult effects)	Total Jobs Supported 2008 (incl mult effects)
2b	AIWW	Pender/Onslow	N/A	N/A	N/A		N/A	
2b	Brown's Inlet	Onslow	N/A	N/A	N/A	601	N/A	742
2b	New River Inlet	Onslow	$13,536,907	66	$3,925,703		$22,786,174.51	
2b	New Topsail Inlet	Pender	$3,735,621	18	$1,083,330	197	$6,288,032.09	236
REGION 2b TOTALS=			$17,272,528	85	$5,009,033	798	$29,074,207	978

Table IX-32. Commercial Fishing – Region 2c

Coastal Region	Waterway/Inlet	County	Estimated Direct Seafood Processing and Packing Output/Sales/Yr Supported by NC Seafood Landings 2007	Estimated Seafood Processing and Packing Jobs Supported by NC Seafood Landings 2007	Commercial Fishery Landings Direct Output/Sales (Dockside Value)/Yr 2007	Number of Commercial Fishing Jobs Supported 2007	Total Impacts on Business Activity/Sales 2008 (incl mult effects)	Total Jobs Supported 2008 (incl mult effects)
3a	AIWW	Carteret	N/A	N/A	N/A		N/A	
3a	Drum Inlet	Carteret	N/A	N/A	N/A		N/A	
2c	AIWW	Carteret	N/A	N/A	N/A		N/A	
2c	Barden Inlet	Carteret	$9,039,462	44	$2,621,444	885	$15,215,792.04	1364
2c	Bear Inlet	Onslow	N/A	N/A	N/A		N/A	
2c	Beaufort Inlet	Carteret	$28,317,441	139	$8,212,058		$47,665,701.33	
2c	Bogue Inlet	Carteret/Onslow	$8,692,366	43	$2,520,786		$14,631,537.26	
REGION 2c,3a TOTALS=			$46,049,269	226	$13,354,288	885	$77,513,031	1,364

As a note, Table IX-32 includes Region 2c and Region 3a since the analysis was done on a per county basis and Carteret County is split into both regions.

f) For Hire Fisheries

For hire fisheries include charter boats and head boats where people pay a fee to go fishing. Tables IX-33 to IX-35 outline the various spending, employment and economic impact of this industry.

Table IX-33. For Hire Fisheries – Region 2a

Coastal Region	Waterway/Inlet	County	2008 For-Hire Fishery Passenger Direct Spending On Fishing Fees	2008 For-Hire Fishery Passenger Direct Spending On Other	2008 For-Hire Fishery Direct Captain & Crew Jobs Supported	2008 For-Hire Fishery Total Impact (incl mult effects) Business Activity	2008 For-Hire Fishery Total Impact (incl mult effects) Jobs Supported	2008 For-Hire Fishery Passenger Consumer Surplus
2a	Carolina Beach Inlet	New Hanover	$3,289,682	$8,350,809	96	$23,391,045	374	$9,405,594
2a	Mason Inlet	New Hanover						
2a	Masonboro Inlet	New Hanover	$2,768,187	$7,027,000	107	$19,682,988	359	$10,192,888
2a	Rich Inlet	New Hanover						
2a	AIWW	New Hanover						
REGION 2a TOTALS=			$6,057,869	$15,377,809	204	$43,074,033	734	$19,598,481

Table IX-34. For Hire Fisheries – Region 2b

Coastal Region	Waterway/Inlet	County	2008 For-Hire Fishery Passenger Direct Spending On Fishing Fees	2008 For-Hire Fishery Passenger Direct Spending On Other	2008 For-Hire Fishery Direct Captain & Crew Jobs Supported	2008 For-Hire Fishery Total Impact (incl mult effects) Business Activity	2008 For-Hire Fishery Total Impact (incl mult effects) Jobs Supported	2008 For-Hire Fishery Passenger Consumer Surplus
2b	AIWW	Pender/Onslow						
2b	Brown's Inlet	Onslow	$1,473,921	$3,257,824	60	$9,638,580	183	$5,406,950
2b	New Topsail Inlet	Pender						
2b	New River Inlet	Onslow	$402,960	$890,667	15	$2,635,124	47	$1,432,510
REGION 2b TOTALS=			$1,876,882	$4,148,492	74	$12,273,704	231	$6,839,460

Table IX-35. For Hire Fisheries – Region 2c

Coastal Region	Waterway/Inlet	County	2008 For-Hire Fishery Passenger Direct Spending On Fishing Fees	2008 For-Hire Fishery Passenger Direct Spending On Other	2008 For-Hire Fishery Direct Captain & Crew Jobs Supported	2008 For-Hire Fishery Total Impact (incl mult effects) Business Activity	2008 For-Hire Fishery Total Impact (incl mult effects) Jobs Supported	2008 For-Hire Fishery Passenger Consumer Surplus
3a	AIWW	Carteret						
3a	Drum Inlet	Carteret						
2c	AIWW	Carteret	$12,798,461	$28,288,577	379	$83,694,419	1358	$38,211,223
2c	Barden Inlet	Carteret						
2c	Beaufort Inlet	Carteret						
2c	Bogue Inlet	Carteret/Onslow	$1,753,263	$3,875,256	57	$11,465,311	194	$5,501,941
2c	Bear Inlet	Onslow	N/A	N/A	N/A	N/A	N/A	N/A
REGION 2c,3a TOTALS=			$14,551,724	$32,163,833	436	$95,159,729	1,552	$43,713,164

As a note, Table IX-35 includes Region 2c and Region 3a since the analysis was done on a per county basis and Carteret County is split into both regions.

g) Private Boating

The direct expenditures of private recreational boaters as well as the multiplier effects and associated jobs are presented in Tables IX-36 to IX-38, together with the consumer surplus value.

Table IX-36. Private Boating – Region 2a

Coastal Region	Waterway/Inlet	County	2008 Direct Private Boater Spending per Yr	2008 Total Impact Business Activity/Sales per Yr	2008 Total Impact Jobs	2008 Consumer Surplus
2a	Carolina Beach Inlet	New Hanover	$3,036,846	$6,211,731	100	$916,680
2a	Mason Inlet	New Hanover	$3,036,846	$6,211,731	100	$916,680
2a	Masonboro Inlet	New Hanover				
2a	Rich Inlet	New Hanover				
2a	AIWW	New Hanover				
REGION 2a TOTALS=			$6,073,692	$12,423,462	201	$1,833,360

Table IX-37. Private Boating – Region 2b

Coastal Region	Waterway/Inlet	County	2008 Direct Private Boater Spending per Yr	2008 Total Impact Business Activity/Sales per Yr	2008 Total Impact Jobs	2008 Consumer Surplus
2b	AIWW	Pender/Onslow	$1,469,989	$2,783,596	52	$443,720
2b	Brown's Inlet	Onslow				
2b	New Topsail Inlet	Pender				
2b	New River Inlet	Onslow	$1,046,771	$1,982,183	37	$315,970
REGION 2b TOTALS=			$2,516,760	$4,765,779	88	$759,690

Table IX-38. Private Boating – Region 2c

Coastal Region	Waterway/Inlet	County	2008 Direct Private Boater Spending per Yr	2008 Total Impact Business Activity/Sales per Yr	2008 Total Impact Jobs	2008 Consumer Surplus
3a	AIWW	Carteret	$40,904,547	$77,457,546	1433	$12,347,143
3a	Drum Inlet	Carteret				
2c	AIWW	Carteret				
2c	Barden Inlet	Carteret				
2c	Bear Inlet	Onslow				
2c	Beaufort Inlet	Carteret				
2c	Bogue Inlet	Carteret/Onslow	$1,532,032	$2,901,082	54	$462,448
REGION 2c,3a TOTALS=			$42,436,579	$80,358,628	1,487	$12,809,591

As a note, Table IX-38 includes Region 2c and Region 3a since the analysis was done on a per county basis and Carteret County is split into both regions.

h) Boat Building

The boat building industry employs people at various locations along the state's waterways. Boat builders rely on the maintenance of the waterways to create interest in the boating industry and subsequent sales of boats. Tables IX-39 to IX-41 present the direct sales and economic impact of the boat building industry.

Table IX-39. Boat Building – Region 2a

Coastal Region	Waterway/Inlet	County	2008 Number of Firms	2008 Direct Sales	2008 Direct Employment	2008 Total Impact Output	2008 Total Impact Employment
2a	Carolina Beach Inlet	New Hanover	No Data	No Data	No Data	No Data	No Data
2a	Mason Inlet	New Hanover	No Data	No Data	No Data	No Data	No Data
2a	Masonboro Inlet	New Hanover	No Data	No Data	No Data	No Data	No Data
2a	Rich Inlet	New Hanover	No Data	No Data	No Data	No Data	No Data
2a	AIWW	New Hanover	5	$6,570,987	28	$10,278,568	61
REGION 2a TOTALS=			5	$6,570,987	28	$10,278,568	61

Table IX-40. Boat Building – Region 2b

Coastal Region	Waterway/Inlet	County	2008 Number of Firms	2008 Direct Sales	2008 Direct Employment	2008 Total Impact Output	2008 Total Impact Employment
2b	AIWW	Pender/Onslow	4	$1,526,724	6	$1,977,283	11
2b	Brown's Inlet	Onslow	No Data	No Data	No Data	No Data	No Data
2b	New Topsail Inlet	Pender	No Data	No Data	No Data	No Data	No Data
2b	New River Inlet	Onslow	No Data	No Data	No Data	No Data	No Data
REGION 2b TOTALS=			4	$1,526,724	6	$1,977,283	11

Table IX-41. Boat Building – Region 2c

Coastal Region	Waterway/Inlet	County	2008 Number of Firms	2008 Direct Sales	2008 Direct Employment	2008 Total Impact Output	2008 Total Impact Employment
2c	AIWW	Carteret	5	$362,188,955	1509	$498,751,330	2930
2c	Barden Inlet	Carteret	No Data	No Data	No Data	No Data	No Data
2c	Beaufort Inlet	Carteret	27	$80,701,530	368	$108,826,411	685
2c	Bogue Inlet	Carteret/Onslow	No Data	No Data	No Data	No Data	No Data
2c	Bear Inlet	Onslow	No Data	No Data	No Data	No Data	No Data
REGION 2c TOTALS=			32	$442,890,485	1877	$607,577,742	3615

i) Marinas

Coastal marinas support both private boating and for hire fishing charters. The data presented for marinas has some overlap with the private boating and for hire fishing data. Tables IX-42 to IX-44 provide the economic marina data for Region 2.

Table IX-42. Marina Sales and Employment – Region 2a

Coastal Region	Waterway/Inlet	County	2008 Number of Marinas	2008 Estimated Direct Marina Sales/Year	2008 Estimated Direct Marina Employment
2a	Carolina Beach Inlet	New Hanover	No Data	No Data	No Data
2a	Mason Inlet	New Hanover	No Data	No Data	No Data
2a	Masonboro Inlet	New Hanover	No Data	No Data	No Data
2a	Rich Inlet	New Hanover	No Data	No Data	No Data
2a	AIWW	New Hanover	53	$15,803,260	394
REGION 2a TOTALS=			53	$15,803,260	394

Table IX-43. Marina Sales and Employment – Region 2b

Coastal Region	Waterway/Inlet	County	2008 Number of Marinas	2008 Estimated Direct Marina Sales/Year	2008 Estimated Direct Marina Employment
2b	AIWW	Pender/Onslow	26	$7,752,543	193
2b	Brown's Inlet	Onslow	No Data	No Data	No Data
2b	New Topsail Inlet	Pender	No Data	No Data	No Data
2b	New River Inlet	Onslow	No Data	No Data	No Data
REGION 2b TOTALS=			26	$7,752,543	193

Table IX-44. Marina Sales and Employment – Region 2c

Coastal Region	Waterway/Inlet	County	2008 Number of Marinas	2008 Estimated Direct Marina Sales/Year	2008 Estimated Direct Marina Employment
2c	AIWW	Carteret	109	$32,501,044	810
2c	Barden Inlet	Carteret	No Data	No Data	No Data
2c	Bear Inlet	Onslow	No Data	No Data	No Data
2c	Beaufort Inlet	Carteret	No Data	No Data	No Data
2c	Bogue Inlet	Carteret/Onslow	No Data	No Data	No Data
REGION 2c TOTALS=			109	$32,501,044	810

B. Potential Beach and Inlet Management Strategies

Development of draft management strategies for coastal North Carolina must take into account a variety of measures including current management practices, associated costs, environmental considerations, economic valuation of beaches and inlets, and potential funding options. This section will discuss the current and potential strategies applicable to Region 2.

1. Historical Strategies

Historical strategies in North Carolina have included beach nourishment, coastal zone management practices (*i.e.*, setbacks, retreat), storm recovery (*i.e.*, dune reconstruction, planting, beach bulldozing, breach fill), dredging, sand bypassing, inlet relocation, and hard structures. Current methods applicable to Region 2 are presented in the following sections. Costs associated with each of the strategies have been updated to reflect 2008 values.

a) Beach Nourishment

A beach nourishment database has been compiled from several sources to provide a comprehensive summary of the state's nourishment activities. Sources include the U.S. Army Corps of Engineers, Western Carolina's Center for Developed Shorelines, Carteret County Beach Preservation Plan, Spencer Rogers of North Carolina Sea Grant, and Tom Jarrett with Coastal Planning & Engineering, Inc. The database extends over a time period from 1939 through 2007. A summary of the beach nourishment data for each subregion of Region 2 is presented in Tables IX-45 to IX-47. The relative size of the projects listed in Tables IX-45 to IX-47 can be found in Figures IX-50 to IX-52.

As can be seen from the figures, there is a wide range of project sizes with many large hopper dredge projects as well as smaller ones completed with the USACE special purpose dredges and other small pipeline dredges. Beach nourishment project locations for each subregion of Region 2 can be seen in Figures IX-56 to IX-58. The complete beach nourishment database is in Appendix D following the report.

Table IX-45. Summary of Beach Nourishment Data – Region 2a

Location	First Year of Record	Number of Times Nourished	Total Amount Nourished (cy)	Average Unit Cost ($ / cy)	Cost per Project ($ / proj)
CAROLINA BEACH	1955	32	23,928,573	1.72	1,841,263
FIGURE EIGHT ISLAND	1979	13	2,836,821	7.58	2,239,531
KURE BEACH	1997	6	1,757,248	5.66	6,893,508
MASONBORO ISLAND	1986	6	4,652,938	4.15	2,202,106
WRIGHTSVILLE BEACH	1939	25	12,427,158	3.72	3,511,690
TOTAL REGION	**N/A**	**82**	**45,602,738**	**N/A**	**N/A**

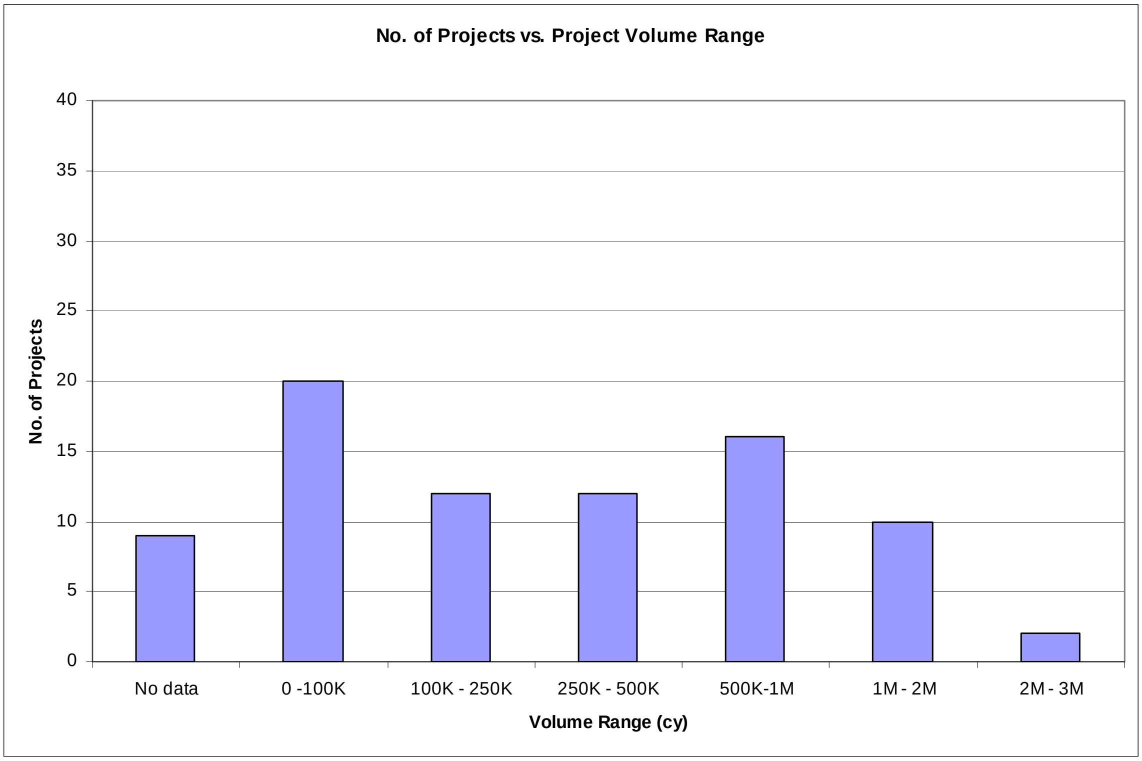


Figure IX-50. Number of Nourishment Projects – Region 2a by Project Size

Table IX-46. Summary of Beach Nourishment Data – Region 2b

Location	First Year of Record	Number of Times Nourished	Total Amount Nourished (cy)	Average Unit Cost ($ / cy)	Cost per Project ($ / proj)
TOPSAIL ISLAND	1982	7	455,296	9.09	733,595
WEST ONSLOW BEACH	1990	1	101,653	7.28	739,552
TOTAL REGION	**N/A**	**8**	**556,949**	**N/A**	**N/A**

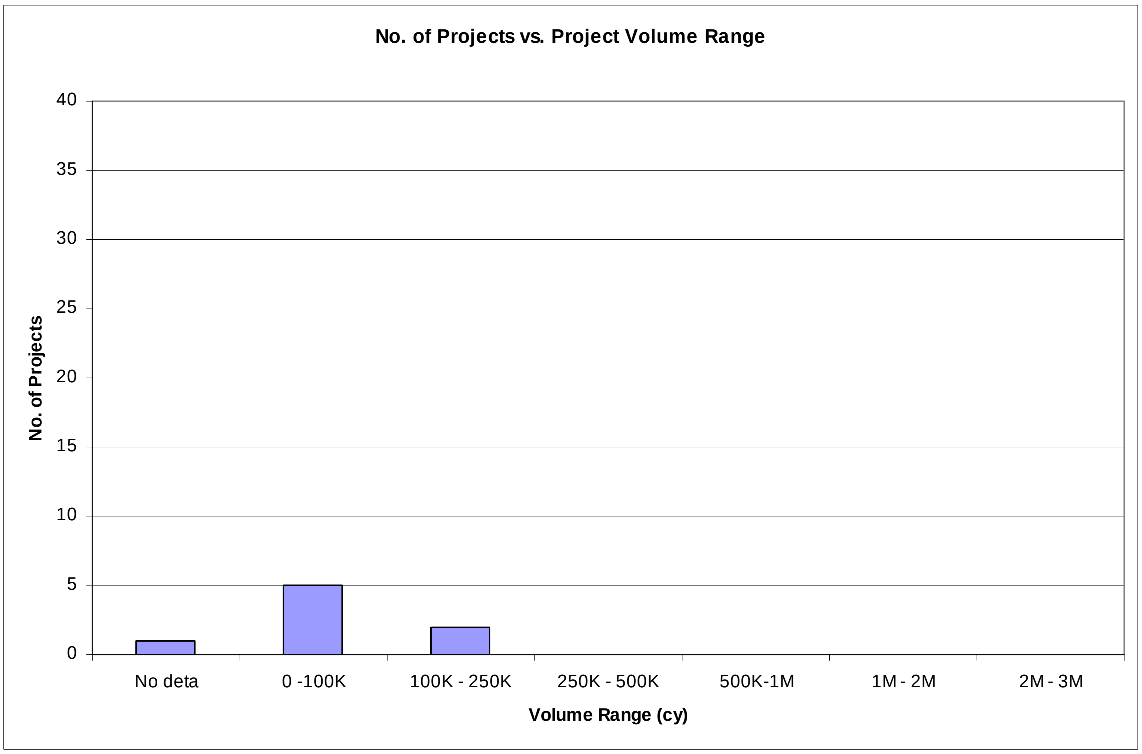


Figure IX-51. Number of Nourishment Projects – Region 2b by Project Size

Table IX-47. Summary of Beach Nourishment Data – Region 2c

Location	First Year of Record	Number of Times Nourished	Total Amount Nourished (cy)	Average Unit Cost ($ / cy)	Cost per Project ($ / proj)
ATLANTIC BEACH / FORT MACON	1973	8	13,857,543	$3.18	$6,296,476
CAPE LOOKOUT	2006	1	75,700	$12.74	$964,227
EMERALD ISLE	1984	15	3,693,153	$10.82	$8,879,437
INDIAN BEACH/SALTER PATH	2004	2	1,454,881	$11.80	$5,889,196
PINE KNOLL SHORES	2001	4	4,236,382	$11.23	$11,894,908
TOTAL REGION	**N/A**	**30**	**23,317,659**	**N/A**	**N/A**

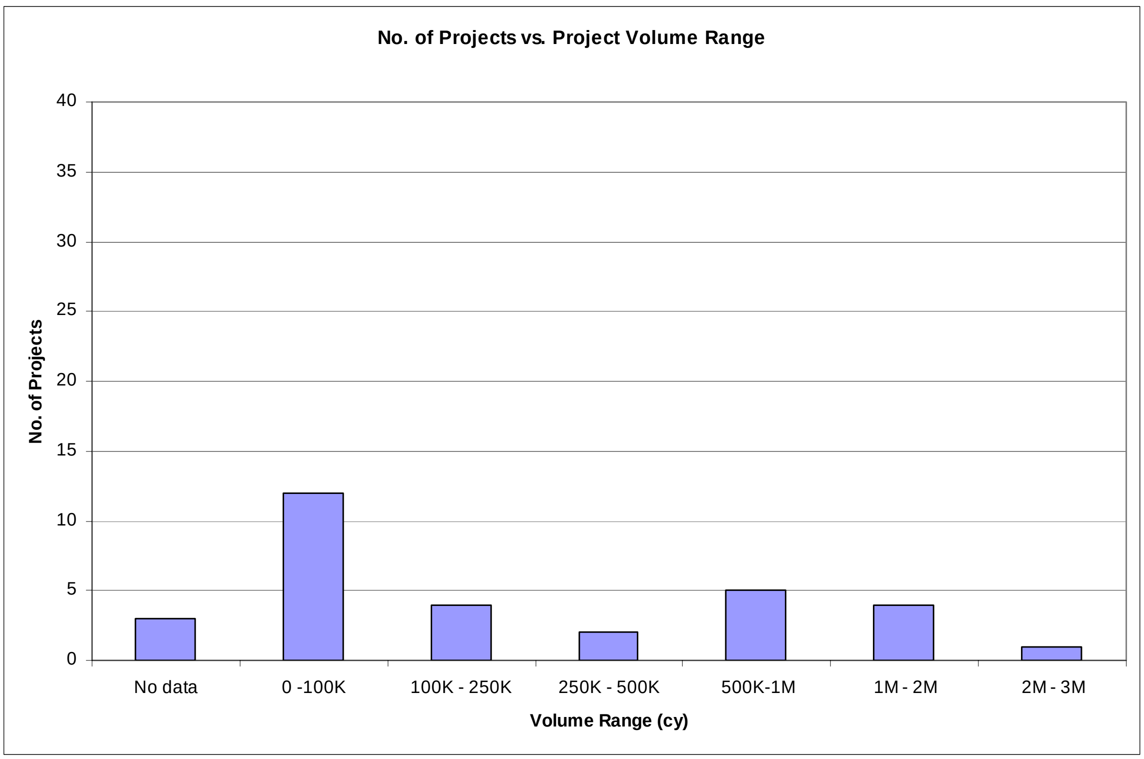


Figure IX-52. Number of Nourishment Projects – Region 2c by Project Size

Nourishment material comes from nearby inlets and channels. Table IX-48 shows the known historical borrow sources for each of the beaches in the subregions of Region 2.

Table IX-48. Historical Borrow Sources – Region 2 Beaches

Beach	Historical Borrow Sources
	Region 2a
Kure Beach	Wilmington Harbor Entrance Channel, Offshore
Carolina Beach	Carolina Beach Inlet, Cape Fear River, Carolina Beach Waterways
Masonboro Island	Masonboro Inlet
Wrightsville Beach	Masonboro Inlet, Banks Channel
Figure Eight Island	Mason Inlet Relocation, Banks Channel, Middle Sound, Rich Inlet, Nixon Channel
	Region 2b
Topsail Island	Topsail Beach Waterways, Topsail Inlet, New River Inlet
West Onslow Beach	New River Inlet
	Region 2c
Emerlad Isle	Offshore Bogue Banks (A1&A2, B2), Morehead City Harbor ODMDS, Bogue Inlet, Swansboro
Indian Beach/Salter Path	Morehead City Harbor, Morehead City Harbor ODMDS, Beaufort Inlet
Pine Knoll Shores	Offshore Bogue Banks (A1&2, B1, B2), Morehead City Harbor, Morehead City Harbor ODMDS, Beaufort Inlet
Atlantic Beach	Morehead City Harbor, Brandt Island
Fort Macon	Brandt Island
Cape Lookout	Core Sound, Barden Inlet

In Region 2, the towns of Wrightsville Beach (2a), Topsail Beach (2b), Surf City (2b), and North Topsail Beach (2b) have used beach bulldozing to help mitigate storm damage along the oceanfront. Beach bulldozing is a common method of erosion management that moves sand, usually to repair storm damage to an existing dune or to create a protective berm if the dune system has been completely washed away.

b) Coastal Zone Management

As mentioned previously, DCM has estimated long-term shoreline change rates based on the distance from the earliest digitized shoreline archived by the state (typically the 1940s) to the 1998 shoreline. Using these shoreline change rates, the CRC has established oceanfront setback factors that determine the minimum allowable distance between a structure and the first line of stable and natural vegetation during development. Currently, the minimum setback is 30 times the long-term average annual erosion rate (minimum of 60 feet) for all structures less than 5,000 square feet. Above 5,000 sqaure feet, and every 5,000 square feet thereafter, the setback factor increases from 60 to 90 in increments of five. The maximum setback factor becomes 90 times the erosion rate for structures greater than or equal to 100,000 square feet. Setback factors for the entire coast can be seen on the DCM website (http://dcm2.enr.state.nc.us/Maps/SB_Factor.htm).

In Region 2a, the southern portion of Zeke's Island has an erosion rate of 2.0 feet per year. The setback factor increases in the Fort Fisher area to 11 feet per year and then goes back down to 2.0 feet per year at Kure Beach and the southern portion of Carolina Beach. The setback factor for the northern portion of Carolina Beach and southern portion of Masonboro Island increases to 12.0 feet per year. The erosion rate then uniformly decreases to 2.0 feet per year towards the northern end of Masonboro Island and remains the same on Wrightsville Beach and Figure Eight Island.

In Region 2b, Hutaff Island has an erosion of 2.0 feet per year on the southern and northern ends with an erosion rate of 7.0 feet per year in the middle. Topsail Beach, Surf City, and North Topsail Beach have erosion rates of 2.0 feet per year for the entire stretch of beach with a small exception of a small area of North Topsail near New River Inlet which has an erosion of 3.0 and 3.5 feet per year. The southwestern end of Onslow

Beach has an erosion rate of 12.0 feet per year which steadily decreases to 2.0 feet per year as you approach the middle of the island. The erosion rate remains 2.0 feet per year along the coast until the area of Brown's Island near Bear Inlet where it increases to 7.0 feet per year.

In Region 2c, the western portion of Bear Island has an erosion rate of 2.0 feet per year while the eastern portion has an erosion rate of 4.0 feet per year. The erosion rate along Bogue Banks is 2.0 feet per year. The western end of Shackleford Banks also has an erosion rate of 2.0 feet per year which increases towards the middle to 6.0 feet year and decreases again toward the eastern end to 2.0 feet per year. The Cape Lookout Spit had an erosion rate of up to 14.0 feet per year on the southwestern facing stretch of shoreline. The eastern facing stretch of shoreline on Cape Lookout has an erosion rate of 6.0 feet per year near the southernmost tip and decreases to 2.0 feet per year north toward Core Banks.

c) Dredging

A dredging database has been compiled from 1975 to 2007 for projects performed or contracted by the USACE. Projects occurring prior to these dates were obtained from the North Carolina Historic Dredging Data book from the Wilmington district of the USACE. In a previous study by Moffatt & Nichol on shallow draft navigation (November 2005), a database was created of all shallow draft projects from 1975 through 2004. Deep draft projects and projects from 2005 to 2007 were then added to this database. Figures IX-53 to IX-55 show the relative size of dredge projects for each subregion**.** Dredge project locations for all three subregions can be seen in Figures IX-56 to IX-58**.** The complete dredge database is available in Appendix E.

A summary of the dredge data from the database applicable to Region 2a is presented in Tables IX-49 to IX-51 for the whole dataset, the past 10 years, and the past five years of data.

Table IX-49. Summary of Dredge Volume Data – Region 2a (1975-2007)

Location	Pipeline	Hopper	Sidecast	Currituck	Avg Volume
	(cy)	(cy)	(cy)	(cy)	(cy / YR)
CAROLINA BEACH INLET	61,352	0	4,237,155	1,756,153	242,186
MASONBORO INLET	1,997,521	0	28,970	0	101,325
MASON INLET	0	0	0	0	0
RICH INLET	0	0	0	0	0
OVERALL TOTAL (Potential Nourishment)	**2,058,873**	**0**	**4,266,125**	**1,756,153**	**343,511**

Table IX-50. Summary of Dredge Volume Data – Region 2a (1997-2007)

Location	Pipeline	Hopper	Sidecast	Currituck	Avg Volume
	(cy)	(cy)	(cy)	(cy)	(cy / YR)
CAROLINA BEACH INLET	0	0	2,874,239	433,067	330,731
MASONBORO INLET	0	0	28,970	0	202,649
MASON INLET	0	0	0	0	0
RICH INLET	0	0	0	0	0
OVERALL TOTAL (Potential Nourishment)	**0**	**0**	**2,903,209**	**433,067**	**533,380**

Table IX-51. Summary of Dredge Volume Data – Region 2a (2002-2007)

Location	Pipeline	Hopper	Sidecast	Currituck	Avg Volume
	(cy)	(cy)	(cy)	(cy)	(cy / YR)
CAROLINA BEACH INLET	0	0	1,538,363	48,205	317,314
MASONBORO INLET	0	0	0	0	0
MASON INLET	0	0	0	0	0
RICH INLET	0	0	0	0	0
OVERALL TOTAL (Potential Nourishment)	**0**	**0**	**1,538,363**	**48,205**	**317,314**

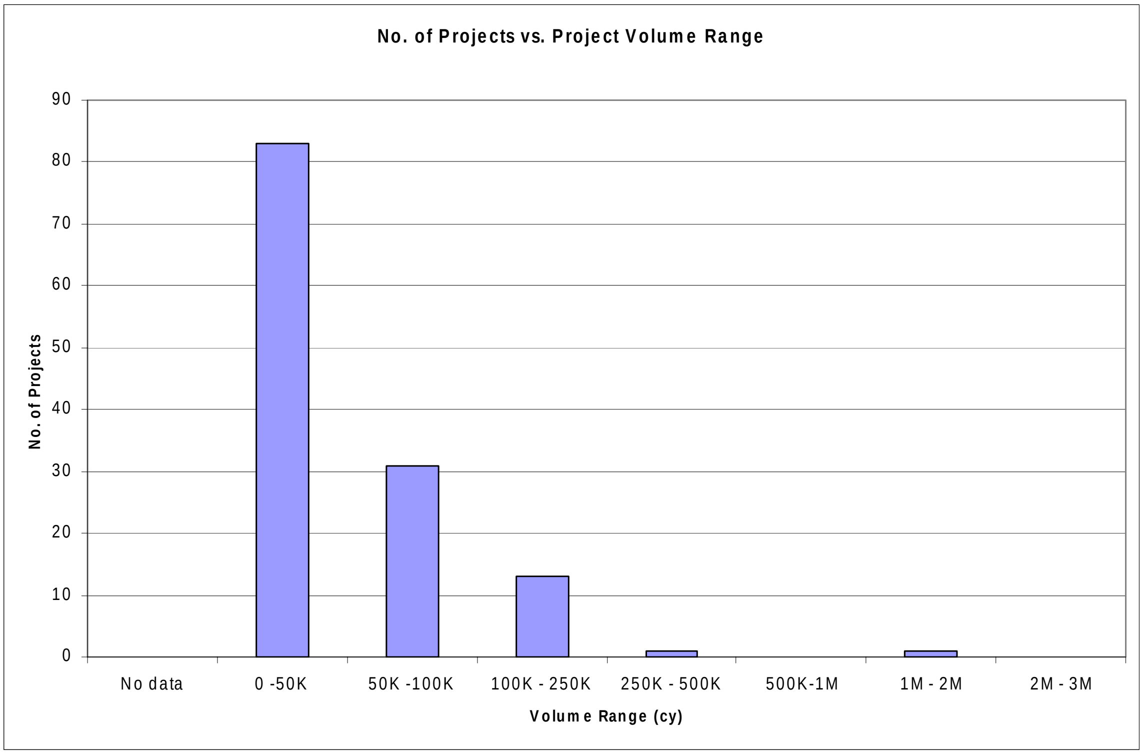


Figure IX-53. Number of Dredge Projects – Region 2a by Project Size

A summary of the dredge data from the database applicable to Region 2b is presented in Tables IX-52 to IX-54 for the whole dataset, the past 10 years, and the past five years of data.

Table IX-52. Summary of Dredge Volume Data – Region 2b (1975-2007)

Location	Pipeline	Hopper	Sidecast	Currituck	Avg Volume
	(cy)	(cy)	(cy)	(cy)	(cy / YR)
NEW TOPSAIL INLET	344,531	0	3,740,615	359,401	177,782
NEW RIVER INLET	124,912	0	6,911,825	506,528	301,731
BROWN'S INLET	0	0	0	0	0
OVERALL TOTAL (Potential Nourishment)	**469,443**	**0**	**10,652,440**	**865,929**	**479,512**

Table IX-53. Summary of Dredge Volume Data – Region 2b (1997-2007)

Location	Pipeline	Hopper	Sidecast	Currituck	Avg Volume
	(cy)	(cy)	(cy)	(cy)	(cy / YR)
NEW TOPSAIL INLET	0	0	2,191,479	183,515	237,499
NEW RIVER INLET	0	0	4,051,938	166,891	421,883
BROWN'S INLET	0	0	0	0	0
OVERALL TOTAL (Potential Nourishment)	**0**	**0**	**6,243,417**	**350,406**	**659,382**

Table IX-54. Summary of Dredge Volume Data – Region 2b (2002-2007)

Location	Pipeline	Hopper	Sidecast	Currituck	Avg Volume
	(cy)	(cy)	(cy)	(cy)	(cy / YR)
NEW TOPSAIL INLET	0	0	1,415,677	0	283,135
NEW RIVER INLET	0	0	1,805,500	129,840	387,068
BROWN'S INLET	0	0	0	0	0
OVERALL TOTAL (Potential Nourishment)	**0**	**0**	**3,221,177**	**129,840**	**670,203**

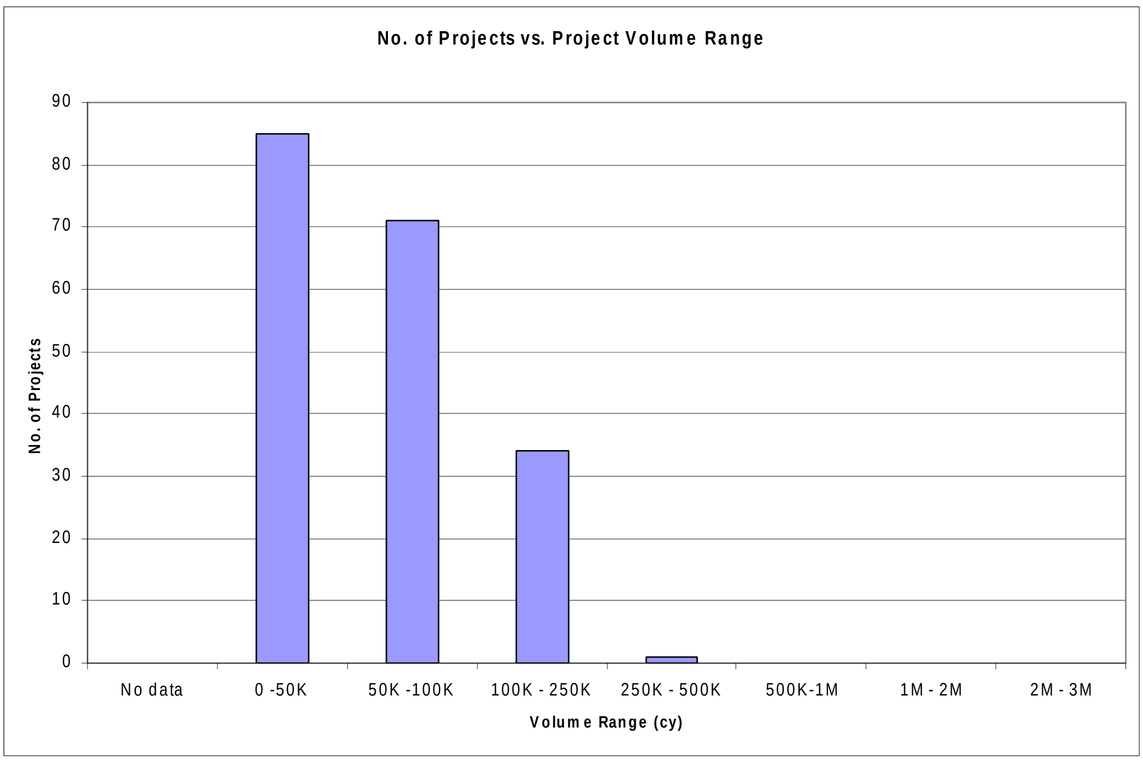


Figure IX-54. Number of Dredge Projects – Region 2b by Project Size

A summary of the dredge data from the database applicable to Region 2c is presented in Tables IX-55 to IX-57 for the whole dataset, the past 10 years, and the past five years of data.

Table IX-55. Summary of Dredge Volume Data – Region 2c (1975-2007)

Location	Pipeline	Hopper	Sidecast	Currituck	Avg Volume
	(cy)	(cy)	(cy)	(cy)	(cy / YR)
BEAR INLET	0	0	0	0	0
BOGUE INLET	0	0	4,662,734	279,518	197,690
BEAUFORT INLET	0	0	0	0	0
BARDEN INLET	290,069	16,961,546	172,329	213,317	587,909
OVERALL TOTAL (Potential Nourishment)	**290,069**	**16,961,546**	**4,835,063**	**492,835**	**785,599**
BEAUFORT HARBOR	988,287	0	0	40,900	34,306
MOREHEAD CITY HARBOR	15,819,319	0	0	0	527,311
ATLANTIC BEACH CHANNELS	130,298	0	0	0	8,687
OVERALL TOTAL	**17,227,973**	**16,961,546**	**4,835,063**	**533,735**	**1,355,902**

Table IX-56. Summary of Dredge Volume Data – Region 2c (1997-2007)

Location	Pipeline	Hopper	Sidecast	Currituck	Avg Volume
	(cy)	(cy)	(cy)	(cy)	(cy / YR)
BEAR INLET	0	0	0	0	0
BOGUE INLET	0	0	3,214,339	17,160	323,150
BEAUFORT INLET	0	0	0	0	0
BARDEN INLET	73,727	2,675,567	0	11,860	276,115
OVERALL TOTAL (Potential Nourishment)	**73,727**	**2,675,567**	**3,214,339**	**29,020**	**599,265**
BEAUFORT HARBOR	0	0	0	40,900	4,090
MOREHEAD CITY HARBOR	2,940,507	0	0	0	294,051
ATLANTIC BEACH CHANNELS	0	0	0	0	0
OVERALL TOTAL	**3,014,234**	**2,675,567**	**3,214,339**	**69,920**	**897,406**

Table IX-57. Summary of Dredge Volume Data – Region 2c (2002-2007)

Location	Pipeline	Hopper	Sidecast	Currituck	Avg Volume
	(cy)	(cy)	(cy)	(cy)	(cy / YR)
BEAR INLET	0	0	0	0	0
BOGUE INLET	0	0	1,074,705	0	214,941
BEAUFORT INLET	0	0	0	0	0
BARDEN INLET	73,727	2,565,567	0	0	527,859
OVERALL TOTAL (Potential Nourishment)	**73,727**	**2,565,567**	**1,074,705**	**0**	**742,800**
BEAUFORT HARBOR	0	0	0	40,900	8,180
MOREHEAD CITY HARBOR	2,940,507	0	0	0	588,101
ATLANTIC BEACH CHANNELS	0	0	0	0	0
OVERALL TOTAL	**3,014,234**	**2,565,567**	**1,074,705**	**40,900**	**1,339,081**

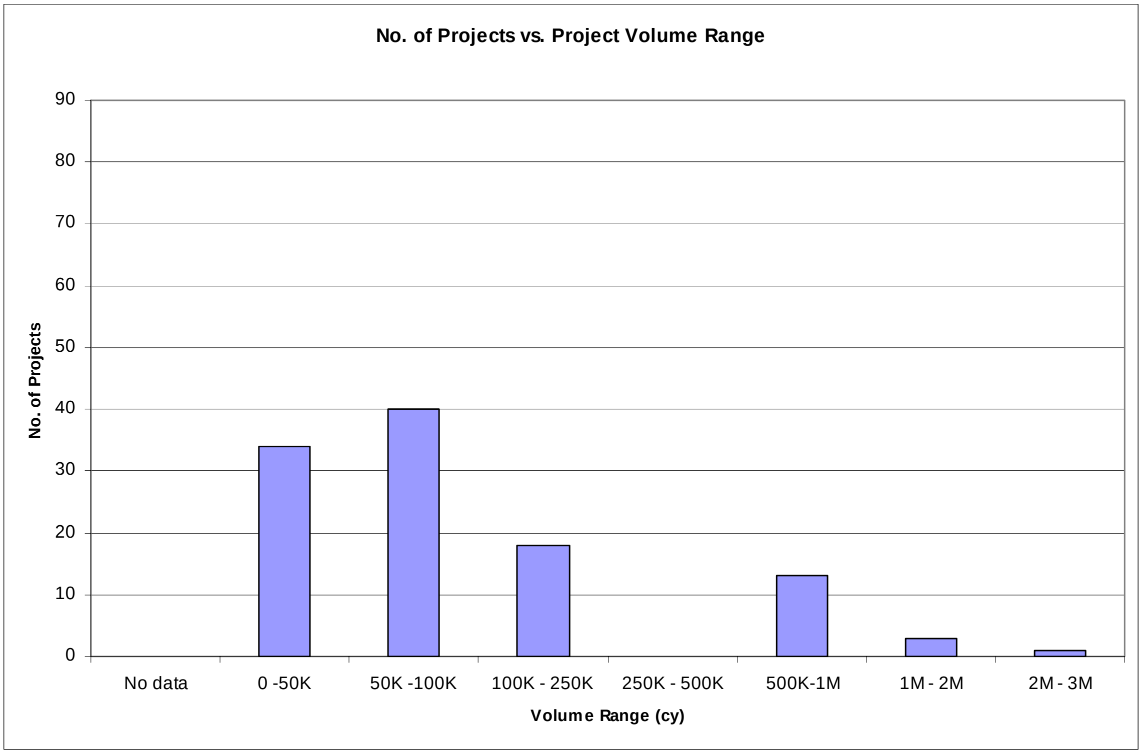


Figure IX-55. Number of Dredge Projects – Region 2c by Project Size

d) Structures

The state has prohibited the use of permanent erosion control structures since 1985, leaving the coast of North Carolina relatively free of hardened engineered structures used to influence beach or inlet behavior. The ban on the use of permanent structures has been both through the CRC's rules and more recently (2003) by law.

Some permanent erosion control structures which existed prior to 1985 remain in Region 2a. These include a bulkhead at Kure Beach, a rip-rap revetment at Fort Fisher, and a seawall on Carolina Beach and Figure Eight Island. The most prominent structures in Region 2a are the Masonboro Inlet jetties. Region 2c contains seawalls along western Emerald Isle at Bogue Inlet, Pine Knoll Shores, and Atlantic Beach. A bulkhead also exists on Indian Beach/Salter Path. There is a groin field around the perimeter of Fort Macon on the western side of Beaufort Inlet, and there is a jetty near the spit at Cape Lookout. Permanent erosion control structure locations in all three subregions of Region 2, including sandbags, are depicted in Figures IX-56 to IX-58.

e) Channel Realignment/Relocation and Inlet Opening

(1) Bogue Inlet Realignment (Region 2c)

Bogue Inlet underwent a relocation to address an erosion problem that threatened the west end of the Town of Emerald Isle. In an effort to support shoreline restoration and to provide a long-term solution to inlet-related erosion, the Town contracted with Coastal Planning & Engineering (CPE-NC) to relocate the ebb channel to a mid-inlet position and nourish a portion of the oceanfront with the associated dredge materials. The total cost of the Bogue Inlet nourishment project and realignment was approximately $9.8 million. Details of the Bogue Inlet channel relocation can be found in the Environmental Impact Statement prepared for the project (CPE, 2004) which is available at http://www.saw.usace.army.mil/WETLANDS/Projects/BogueInlet/index.html.

(2) Mason Inlet Relocation (Region 2a)

Mason Inlet is a natural unstabilized inlet that had migrated to the south along Figure Eight Island over the past 30 years. Since 1985, the migration has resulted in a loss of 2,200 feet of shoreline at the north end of Wrightsville Beach, threatening many properties. A plan was designed to relocate Mason Inlet 2,500 feet north that included the excavation of a new inlet channel, the realignment of Mason Creek, and the closure of the old Mason Inlet. During the winter of 2001-2002, Applied Technology and Management (ATM) began the construction phase of the Mason Inlet Relocation project. The new Mason Inlet was opened on March 7, 2002, and the old inlet was closed by March 14, 2002.

The Mason Inlet Relocation Project provided sand for beach nourishment at Figure Eight Island. Overall, the project mitigated a potential adverse economic impact of $237 million that could have resulted from property and tax revenue losses. This value represents the present worth value of these losses over 30 years. In addition, Mason Creek was reopened for navigational use and improved flushing of the Middle Sound Estuary. Beaches were restored for public recreational use (swimming, fishing, etc.). The total cost of the project, including nourishment, was approximately $6.7 million.

(3) Carolina Beach Inlet Opening (Region 2a)

Carolina Beach Inlet was artificially opened in 1952 and separates the barrier spit portion of Carolina Beach from Masonboro Island to the northeast. The channel now connects the Atlantic Ocean to the AIWW.

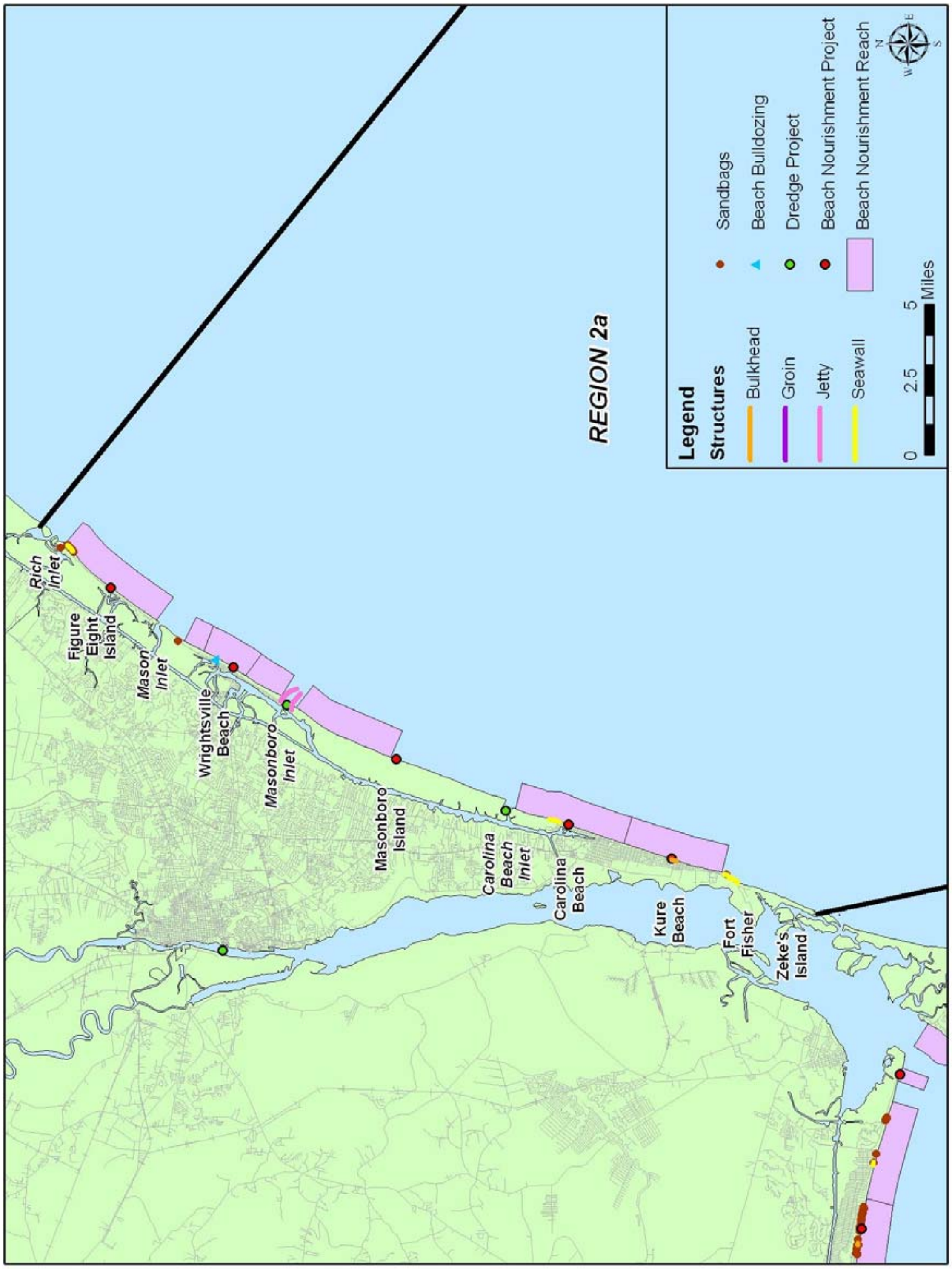


Figure IX-56. Historical Management Strategies for Region 2a

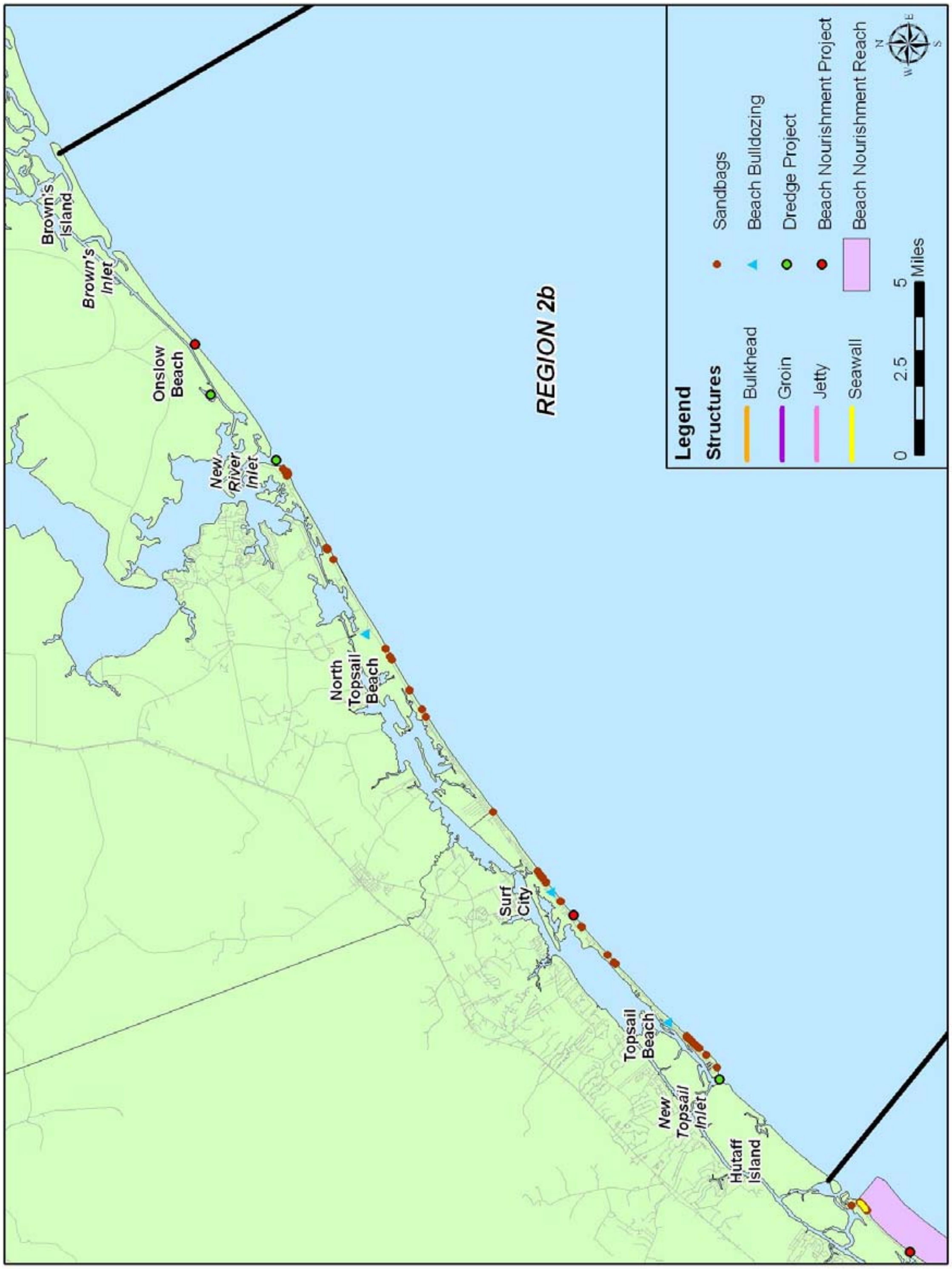


Figure IX-57. Historical Management Practices for Region 2b

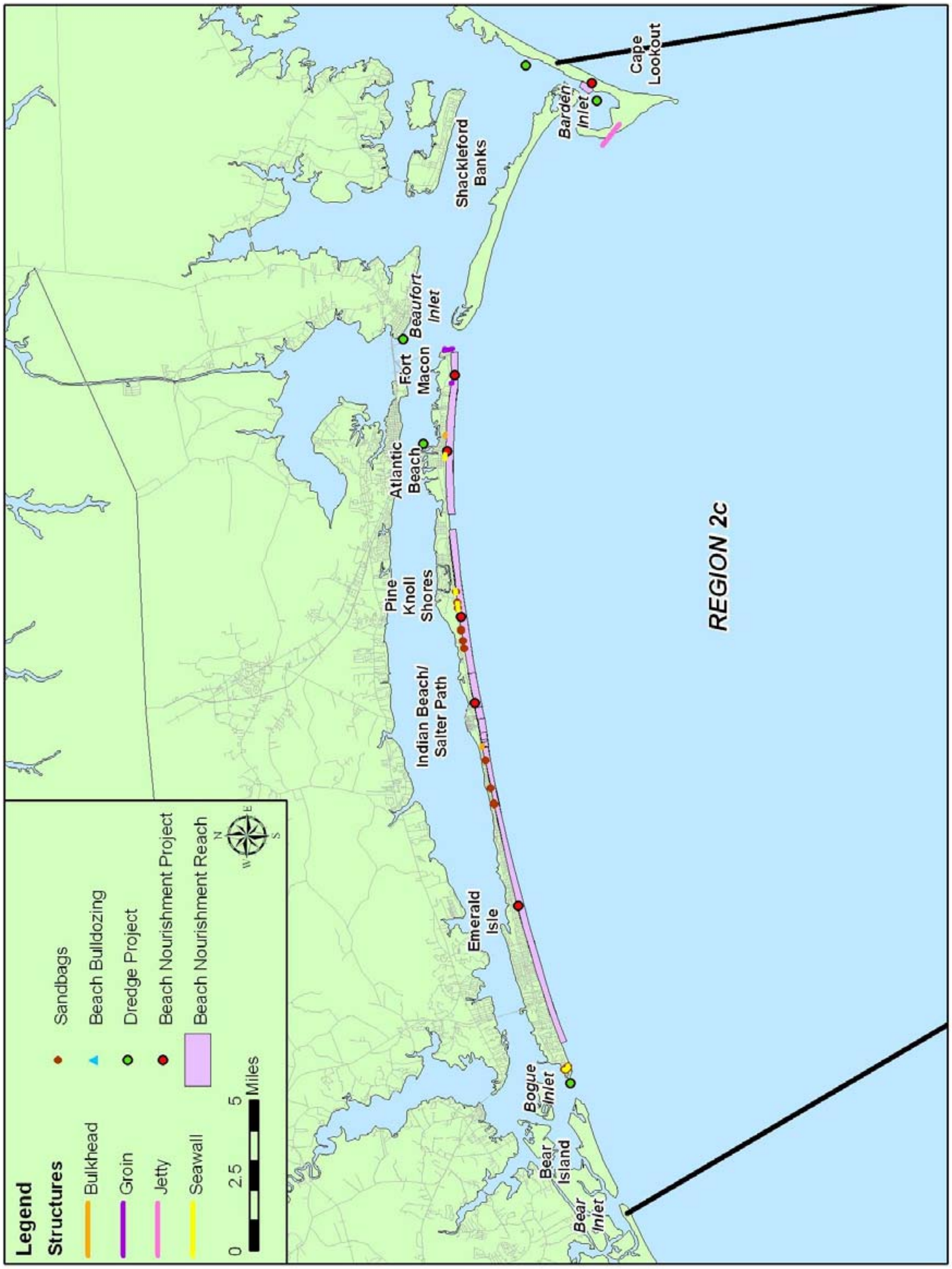


Figure IX. Historical Management Practices for Region 2c

2. Potential Management Strategies

Current North Carolina policy relies on beach nourishment and dredging due to the prohibition on permanent erosion control structures. Continuation of these methods is expected with improvements in efficiency through the establishment of plans for location, frequency, quantity, and cost of nourishment projects on a cyclic basis. The adoption of a regional approach would also serve to ensure that all beach compatible sand from dredging projects is placed on the beach or back into the nearshore system. For example, coordinating dredging to maintain an inlet with beach nourishment or habitat creation would be an effective and efficient use of resources.

To begin this regionalized approach, sand sources within each region have been identified and tentatively assigned to various stretches of beach based on distance to the source. As discussed in Section VI, using offshore borrow areas or sediment from inlets is only cost effective up to a certain distance from the beach. Figures IX-59 and IX-61 show the locations and distances of the most likely sediment borrow areas for the various subregions of Region 2.

Tables IX-58 and IX-59 show the nearest inlet and offshore borrow sources of sediment for the beaches in Region 2a, as well as the most likely and reasonable source to be used for each beach based on distances and sediment quality. Section VI also contains a general discussion on the development of potential strategies and costs for the entire state.

Table IX-58. Nearest Sediment Sources – Region 2a Beaches

Location	Nearest Inlet Source		Nearest Offshore Source	
	Name	Distance (mi)	Name	Distance (mi)
Zeke's Island	Carolina Beach Inlet	10.3	No Name (USGS)	12.4
Fort Fisher	Carolina Beach Inlet	8.2	No Name (USGS)	10.9
Kure Beach	Carolina Beach Inlet	6.3	No Name (USGS)	9.2
Carolina Beach	Carolina Beach Inlet	2.4	No Name (USGS)	7.0
Masonboro Island	Carolina Beach Inlet/Masonboro Inlet	4.0	No Name (USGS)	7.6
Wrightsville Beach	Masonboro Inlet/Mason Inlet	2.1	No Name (USGS)	11.5
Figure Eight Island	Mason Inlet/Rich Inlet	2.7	No Name (USGS)	15.4

Table IX-59. Most Likely Sediment Sources – Region 2a Beaches

Location	Most Likely Source		Likely Dredge Type	Annual Need (CY)	Developed
	Name	Distance (mi)			
Zeke's Island	Carolina Beach Inlet/USGS Source	10.3/12.4	Pipeline/Hopper	56,880	N
Fort Fisher	Carolina Beach Inlet/USGS Source	8.2/10.9	Pipeline/Hopper	51,162	Y
Kure Beach	Carolina Beach Inlet	6.3	Pipeline/Hopper	34,001	Y
Carolina Beach	Carolina Beach Inlet	2.4	Pipeline/Hopper	429,752	Y
Masonboro Island	Carolina Beach Inlet/Masonboro Inlet	4	Pipeline/Hopper	398,678	N
Wrightsville Beach	Masonboro Inlet/Mason Inlet	2.1	Pipeline/Hopper	89,561	Y
Figure Eight Island	Mason Inlet/Rich Inlet	2.7	Pipeline/Hopper	18,149	Y

Tables IX-60 and IX-60 show the nearest inlet and offshore sources of sediment for the beaches in Region 2b as well as the most likely and reasonable source to be used for each beach based on distances and sediment quality.

Table IX-60. Nearest Sediment Sources – Region 2b Beaches

Location	Nearest Inlet Source		Nearest Offshore Source	
	Name	Distance (mi)	Name	Distance (mi)
Hutaff's Island	New Topsail Inlet	2.4	Borrow Area X (CPE)	2.2
Topsail Beach	New Topsail Inlet	2.4	Borrow Area X (CPE)	2.6
Surf City	New Topsail Inlet	7.7	Borrow Area X (CPE)	7.9
North Topsail Beach	New River Inlet	5.7	N. Topsail Borrow Area (CPE)	1.1
Onslow Beach	New River Inlet	3.8	N. Topsail Borrow Area (CPE)	10.1
Brown's Island	New River Inlet	9.3	N. Topsail Borrow Area (CPE)	15.7

Table IX-61. Most Likely Sediment Sources – Region 2b Beaches

Location	Most Likely Source		Likely Dredge Type	Annual Need (CY)	Developed
	Name	Distance (mi)			
Hutaff's Island	New Topsail Inlet/Borrow Area X (CPE)	2.4/2.2	Pipeline	126,727	N
Topsail Beach	New Topsail Inlet/Borrow Area X (CPE)	2.4/2.6	Pipeline	60,407	Y
Surf City	New Topsail Inlet/Borrow Area X (CPE)	7.7/7.9	Pipeline/Hopper	62,377	Y
North Topsail Beach	New River Inlet/N. Topsail Borrow Area (CPE)	5.7/1.1	Pipeline/Hopper	113,558	Y
Onslow Beach	New River Inlet/N. Topsail Borrow Area (CPE)	3.8/10.1	Pipeline/Hopper	220,870	Y
Brown's Island	New River Inlet/N. Topsail Borrow Area (CPE)	9.3/15.7	Pipeline/Hopper	56,968	N

Tables IX-62 and IX-63 show the nearest inlet and offshore sources of sediment for the beaches in Region 2c as well as the most likely and reasonable source to be used for each beach based on distances and sediment quality.

Table IX-62. Nearest Sediment Sources – Region 2c Beaches

Location	Nearest Inlet Source		Nearest Offshore Source	
	Name	Distance (mi)	Name	Distance (mi)
Bear Island	Bogue Inlet	2.5	A1 & A2 (Carteret County)	14.4
Emerald Isle	Bogue Inlet	5.9	A1 & A2 (Carteret County)	6.1
Indian Beach/Salter Path	Beaufort Inlet	12.3	B2 (Carteret County)	0.6
Pine Knoll Shores	Beaufort Inlet	8.8	B1a (Carteret County)	0.9
Atlantic Beach	Beaufort Inlet	4.1	B1a (Carteret County)	4.2
Fort Macon	Beaufort Inlet	1.1	Morehead City ODMDS (USACE)	5.3
Shackleford Banks	Beaufort Inlet	5.4	Morehead City ODMDS (USACE)	7.7
Cape Lookout	Beaufort Inlet	9.2	Morehead City ODMDS (USACE)	9.7

Table IX-63. Most Likely Sediment Sources – Region 2c Beaches

Location	Most Likely Source		Likely Dredge Type	Annual Need (CY)	Developed
	Name	Distance (mi)			
Bear Island	Bogue Inlet	2.5	Pipeline	36,249	N
Emerald Isle	Bogue Inlet/A1&A2	5.9/6.1	Pipeline/Hopper	107,777	Y
Indian Beach/Salter Path	Beaufort Inlet/Morehead City ODMDS	12.3/10.7	Hopper	35,378	Y
Pine Knoll Shores	Beaufort Inlet/Morehead City ODMDS	8.8/7.9	Pipeline/Hopper	54,500	Y
Atlantic Beach	Beaufort Inlet/Morehead City ODMDS	4.1/5.5	Pipeline/Hopper	168,258	Y
Fort Macon	Beaufort Inlet/Morehead City ODMDS	1.1/5.3	Pipeline/Hopper	21,004	Y
Shackleford Banks	Beaufort Inlet/Morehead City ODMDS	5.4/7.7	Pipeline/Hopper	156,230	N
Cape Lookout	Morehead City ODMDS	9.7	Pipeline/Hopper	210,738	N

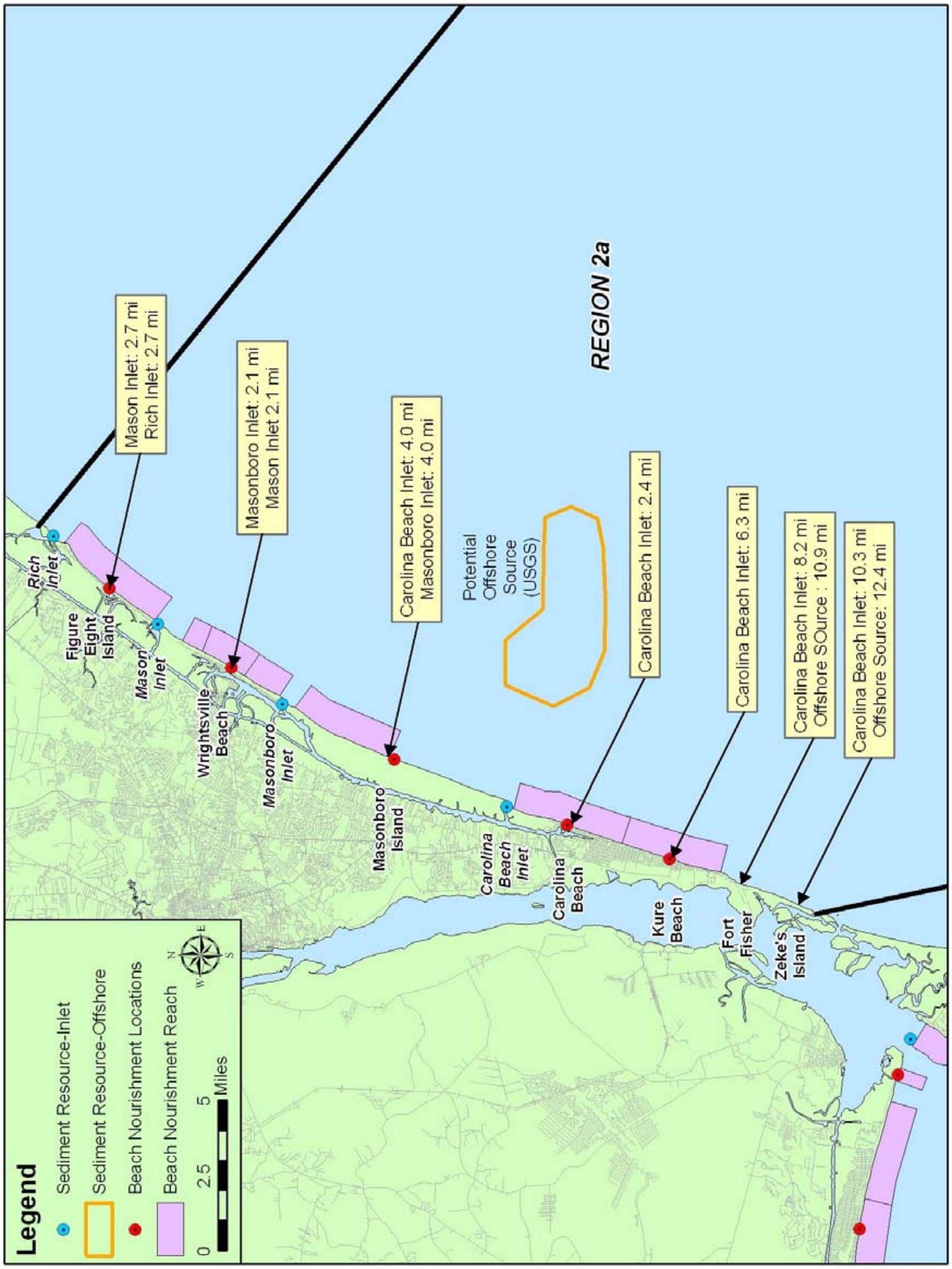


Figure IX-59. Potential Sediment Resources for Region 2a

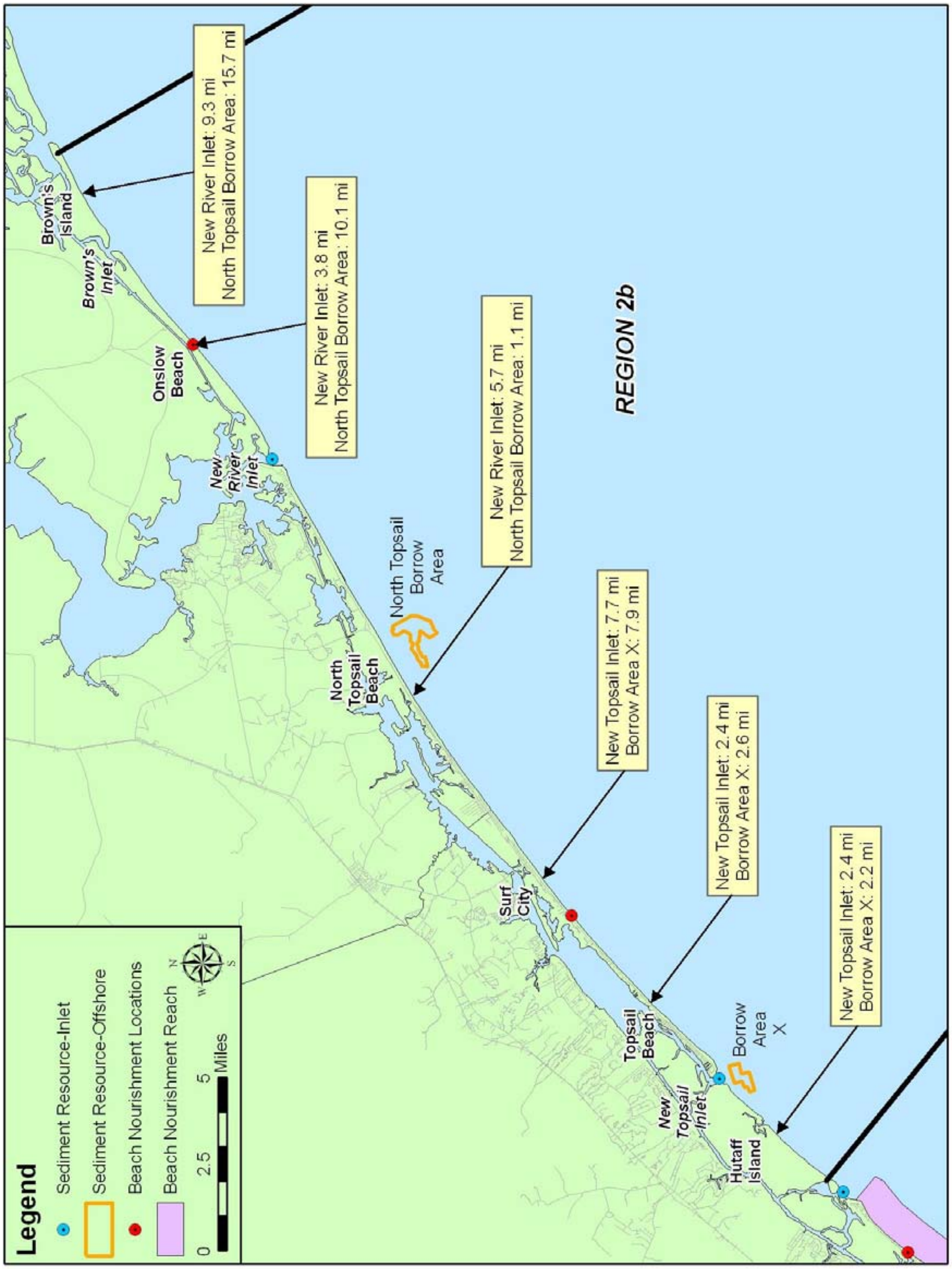


Figure IX-60. Potential Sediment Resources for Region 2b

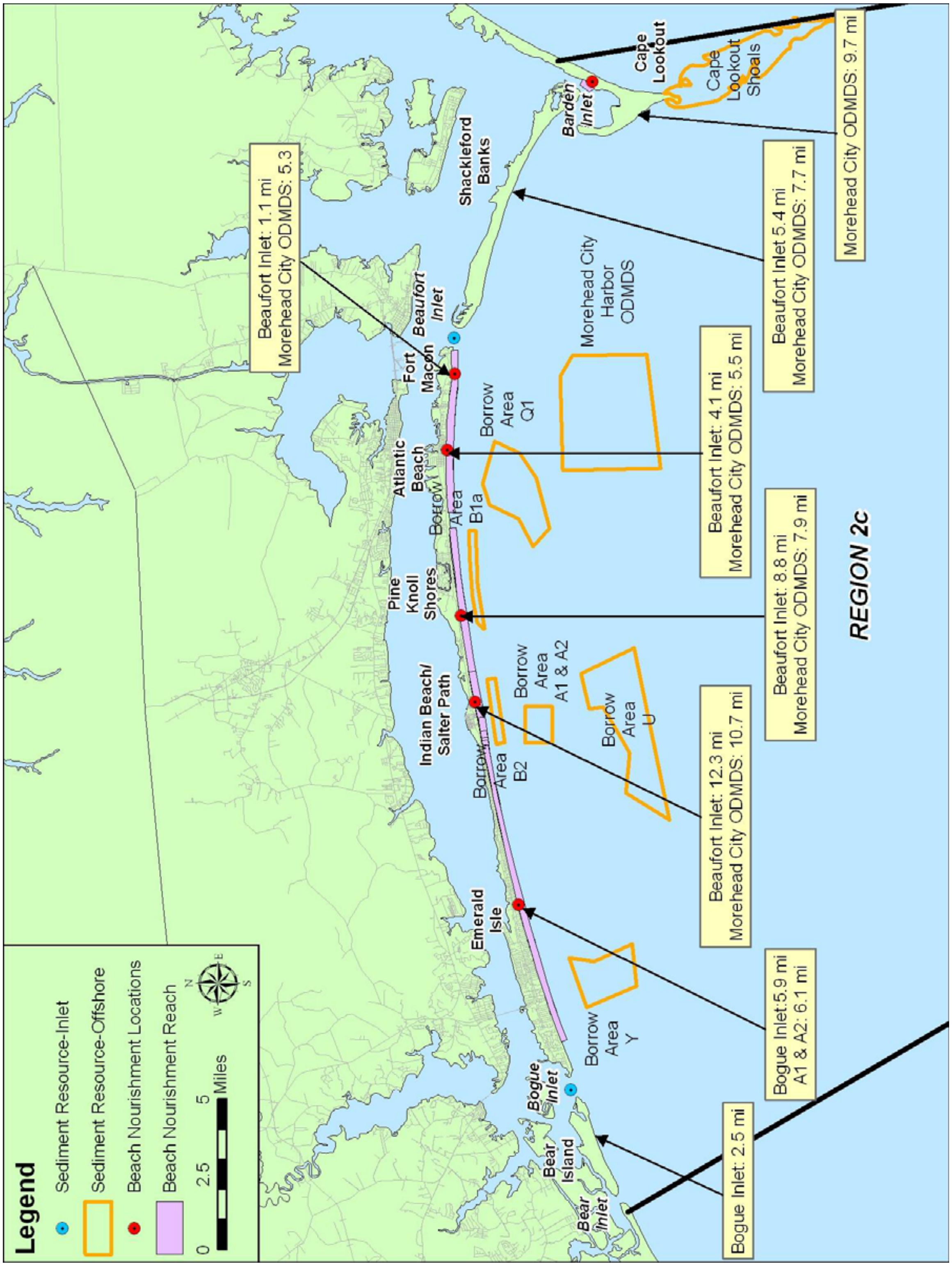


Figure IX-61. Potential Sediment Resources for Region 2c

C. Costs and Effectiveness of Strategies

1. Historical Costs

The beach nourishment and dredge databases were used to analyze historical costs for projects. Not all projects in the two databases contained cost information; therefore analysis was done in each case for the whole dataset, the past 10 years, and the past five years. Attention was paid to projects which were particularly costly or inexpensive so not to bias the average costs that were calculated in the end. Costs associated with each of the strategies have been updated to reflect 2008 values.

a) Beach Nourishment

Tables IX-64 to IX-66 show the costs over various time periods for beach nourishment projects which have taken place in Region 2a. Region 2a as a whole averaged approximately $4 million per year in beach nourishment activities when the entire dataset was taken into account. The costs over the past 10 years and the past five years of data were slightly higher at approximately $6 million per year.

Table IX-64. Beach Nourishment Costs – Region 2a (Whole Dataset)

Location	First Year of Record	Number of Times Nourished	Average Unit Cost ($ / cy)	Avg Volume (cy/YR)	Avg Cost ($/YR)
CAROLINA BEACH	1955	32	1.72	478,571	822,786
FIGURE EIGHT ISLAND	1979	13	7.58	105,067	796,861
KURE BEACH	1997	6	5.66	175,725	994,528
MASONBORO ISLAND	1986	6	4.15	232,647	964,657
WRIGHTSVILLE BEACH	1939	25	3.72	191,187	710,365
TOTAL REGION	**N/A**	**82**	**N/A**	**1,183,198**	**4,289,197**

Table IX-65. Beach Nourishment Costs – Region 2a (1997-2007)

Location	Number of Times Nourished	Average Unit Cost ($ / cy)	Avg Volume (cy/YR)	Avg Cost ($/YR)
CAROLINA BEACH	4	3.71	298,424	1,106,706
FIGURE EIGHT ISLAND	5	7.58	117,057	887,794
KURE BEACH	6	5.66	514,210	2,910,212
MASONBORO ISLAND	3	5.39	119,448	643,412
WRIGHTSVILLE BEACH	5	5.29	247,026	1,306,387
TOTAL REGION	**23**	**N/A**	**1,296,166**	**6,854,511**

Table IX-66. Beach Nourishment Costs – Region 2a (2002-2007)

Location	Number of Times Nourished	Average Unit Cost ($ / cy)	Avg Volume (cy/YR)	Avg Cost ($/YR)
CAROLINA BEACH	2	4.87	242,450	1,181,900
FIGURE EIGHT ISLAND	4	7.58	154,114	1,168,847
KURE BEACH	3	9.07	144,558	1,310,794
MASONBORO ISLAND	2	6.88	127,765	879,151
WRIGHTSVILLE BEACH	3	6.37	270,738	1,725,603
TOTAL REGION	**14**	**N/A**	**939,626**	**6,266,294**

Tables IX-67 to IX-69 show the costs over various time periods for beach nourishment projects which have taken place in Region 2b. Region 2b as a whole has averaged approximately $200,000 per year in beach nourishment activities when the whole dataset was taken into account. The costs over the past 10 years and the past five years of data were $166,000 and $333,000 per year respectively.

Table Ix-67. Beach Nourishment Costs – Region 2b (Whole Dataset)

Location	First Year of Record	Number of Times Nourished	Average Unit Cost ($ / cy)	Avg Volume (cy/YR)	Avg Cost ($/YR)
TOPSAIL ISLAND	1982	7	9.09	19,795	179,913
WEST ONSLOW BEACH	1990	1	7.28	5,980	43,503
TOTAL REGION	**N/A**	**8**	**N/A**	**25,775**	**223,416**

Table IX-68. Beach Nourishment Costs – Region 2b (1997-2007)

Location	Number of Times Nourished	Average Unit Cost ($ / cy)	Avg Volume (cy/YR)	Avg Cost ($/YR)
TOPSAIL ISLAND	2	28.71	5,800	166,529
WEST ONSLOW BEACH	0	0.00	0	0
TOTAL REGION	**2**	**N/A**	**5,800**	**166,529**

Table IX-69. Beach Nourishment Costs – Region 2b (2002-2007)

Location	Number of Times Nourished	Average Unit Cost ($ / cy)	Avg Volume (cy/YR)	Avg Cost ($/YR)
TOPSAIL ISLAND	2	28.71	11,600	333,058
WEST ONSLOW BEACH	0	0.00	0	0
TOTAL REGION	**2**	**N/A**	**11,600**	**333,058**

Tables IX-70 to IX-72 show the costs over various time periods for beach nourishment projects which have taken place in Region 2c. Region 2c as a whole has averaged approximately $17 million per year in beach nourishment activities when the whole dataset was taken into account. The costs over the past 10 years and the past five years of data were $12 million and $20 million per year respectively.

Table IX-70. Beach Nourishment Costs – Region 2c (Whole Dataset)

Location	First Year of Record	Number of Times Nourished	Average Unit Cost ($ / cy)	Avg Volume (cy/YR)	Avg Cost ($/YR)
ATLANTIC BEACH	1973	8	3.18	407,575	1,296,333
CAPE LOOKOUT	2006	1	12.74	37,850	482,113
EMERALD ISLE	1984	15	10.82	160,572	1,736,778
INDIAN BEACH/SALTER PATH	2004	2	11.80	484,960	5,724,148
PINE KNOLL SHORES	2001	4	11.23	706,064	7,929,938
TOTAL REGION	**N/A**	**30**	**N/A**	**1,797,021**	**17,169,311**

Table IX-71. Beach Nourishment Costs – Region 2c (1997-2007)

Location	Number of Times Nourished	Average Unit Cost ($ / cy)	Avg Volume (cy/YR)	Avg Cost ($/YR)
ATLANTIC BEACH	3	6.28	334,108	2,099,598
CAPE LOOKOUT	1	12.74	7,570	96,423
EMERALD ISLE	8	10.82	342,575	3,705,365
INDIAN BEACH/SALTER PATH	2	11.80	99,789	1,177,839
PINE KNOLL SHORES	4	11.23	423,638	4,757,963
TOTAL REGION	**18**	**N/A**	**1,207,680**	**11,837,187**

Table IX-72. Beach Nourishment Costs – Region 2c (2002-2007)

Location	Number of Times Nourished	Average Unit Cost ($ / cy)	Avg Volume (cy/YR)	Avg Cost ($/YR)
ATLANTIC BEACH	3	6.28	668,215	4,199,196
CAPE LOOKOUT	1	12.74	15,140	192,845
EMERALD ISLE	5	10.82	664,551	7,187,916
INDIAN BEACH/SALTER PATH	2	11.80	199,577	2,355,678
PINE KNOLL SHORES	3	12.45	487,276	6,066,258
TOTAL REGION	**14**	**N/A**	**2,034,760**	**20,001,893**

b) Dredging

Tables IX-73 to IX-75 show the costs over various time periods for dredging projects which have taken place in Region 2a. Region 2a as a whole has averaged approximately $1 million per year for dredging activities.

Table IX-73. Dredging Costs – Region 2a (Whole Dataset)

Location	Pipeline ($)	Hopper ($)	Sidecast ($)	Currituck ($)	Avg Cost ($ / YR)
CAROLINA BEACH INLET	0	0	18,116,189	7,635,946	1,030,085
MASONBORO INLET	5,622,125	0	81,985	0	285,206
MASON INLET	0	0	0	0	0
RICH INLET	0	0	0	0	0
OVERALL TOTAL (Potential Nourishment)	**5,622,125**	**0**	**18,198,174**	**7,635,946**	**1,315,291**

Table IX-74. Dredging Costs – Region 2a (1997-2007)

Location	Pipeline	Hopper	Sidecast	Currituck	Avg Cost
	($)	($)	($)	($)	($ / YR)
CAROLINA BEACH INLET	0	0	7,535,755	2,893,607	1,042,936
MASONBORO INLET	0	0	64,893	0	6,489
MASON INLET	0	0	0	0	0
RICH INLET	0	0	0	0	0
OVERALL TOTAL (Potential Nourishment)	**0**	**0**	**7,600,648**	**2,893,607**	**1,049,426**

Table IX-75. Dredging Costs – Region 2a (2002-2007)

Location	Pipeline	Hopper	Sidecast	Currituck	Avg Cost
	($)	($)	($)	($)	($ / YR)
CAROLINA BEACH INLET	0	0	4,033,320	0	806,664
MASONBORO INLET	0	0	0	0	0
MASON INLET	0	0	0	0	0
RICH INLET	0	0	0	0	0
OVERALL TOTAL (Potential Nourishment)	**0**	**0**	**4,033,320**	**0**	**806,664**

Tables IX-76 to IX-78 show the costs over various time periods for dredging projects which have taken place in Region 2b. Region 2b as a whole has averaged approximately $2 million per year for dredging activities.

Table IX-76. Dredging Costs – Region 2b (Whole Dataset)

Location	Pipeline	Hopper	Sidecast	Currituck	Avg Cost
	($)	($)	($)	($)	($ / YR)
NEW TOPSAIL INLET	1,740,999	0	18,177,633	1,771,924	867,622
NEW RIVER INLET	389,109	0	29,495,579	1,756,455	1,265,646
BROWN'S INLET	0	0	0	0	0
OVERALL TOTAL (Potential Nourishment)	**2,130,108**	**0**	**47,673,212**	**3,528,378**	**2,133,268**

Table IX-77. Dredging Costs – Region 2b (1997-2007)

Location	Pipeline	Hopper	Sidecast	Currituck	Avg Cost
	($)	($)	($)	($)	($ / YR)
NEW TOPSAIL INLET	0	0	5,858,403	563,391	642,179
NEW RIVER INLET	0	0	12,443,829	647,650	1,309,148
BROWN'S INLET	0	0	0	0	0
OVERALL TOTAL (Potential Nourishment)	**0**	**0**	**18,302,232**	**1,211,042**	**1,951,327**

Table IX-78. Dredging Costs – Region 2b (2002-2007)

Location	Pipeline	Hopper	Sidecast	Currituck	Avg Cost
	($)	($)	($)	($)	($ / YR)
NEW TOPSAIL INLET	0	0	3,784,479	0	756,896
NEW RIVER INLET	0	0	5,544,837	503,867	1,209,741
BROWN'S INLET	0	0	0	0	0
OVERALL TOTAL (Potential Nourishment)	**0**	**0**	**9,329,316**	**503,867**	**1,966,637**

Tables IX-79 to IX-81 show the costs over various time periods for dredging projects which have taken place in Region 2c. Region 2c as a whole has averaged approximately $5.5 million per year for dredging activities.

Table IX-79. Dredging Costs – Region 2c (Whole Dataset)

Location	Pipeline	Hopper	Sidecast	Currituck	Avg Cost
	($)	($)	($)	($)	($ / YR)
BEAR INLET	0	0	0	0	0
BOGUE INLET	0	0	21,387,875	982,873	894,830
BEAUFORT INLET	0	0	0	0	0
BARDEN INLET	3,014,768	57,463,069	454,814	708,094	2,054,692
OVERALL TOTAL (Potential Nourishment)	**3,014,768**	**57,463,069**	**21,842,690**	**1,690,966**	**2,949,521**
BEAUFORT HARBOR	4,729,979	0	0	185,452	163,848
MOREHEAD CITY HARBOR	72,973,525	0	0	0	2,432,451
ATLANTIC BEACH CHANNELS	889,602	0	0	0	59,307
OVERALL TOTAL	**81,607,875**	**57,463,069**	**21,842,690**	**1,876,418**	**5,605,127**

Table IX-80. Dredging Costs – Region 2c (1997-2007)

Location	Pipeline	Hopper	Sidecast	Currituck	Avg Cost
	($)	($)	($)	($)	($ / YR)
BEAR INLET	0	0	0	0	0
BOGUE INLET	0	0	9,287,974	31,746	931,972
BEAUFORT INLET	0	0	0	0	0
BARDEN INLET	971,375	8,995,215	0	0	996,659
OVERALL TOTAL (Potential Nourishment)	**971,375**	**8,995,215**	**9,287,974**	**31,746**	**1,928,631**
BEAUFORT HARBOR	0	0	0	185,452	18,545
MOREHEAD CITY HARBOR	17,145,703	0	0	0	1,714,570
ATLANTIC BEACH CHANNELS	0	0	0	0	0
OVERALL TOTAL	**18,117,078**	**8,995,215**	**9,287,974**	**217,198**	**3,661,747**

Table IX-81. Dredging Costs – Region 2c (2002-2007)

Location	Pipeline	Hopper	Sidecast	Currituck	Avg Cost
	($)	($)	($)	($)	($ / YR)
BEAR INLET	0	0	0	0	0
BOGUE INLET	0	0	3,105,408	0	621,082
BEAUFORT INLET	0	0	0	0	0
BARDEN INLET	971,375	8,434,040	0	0	1,881,083
OVERALL TOTAL (Potential Nourishment)	**971,375**	**8,434,040**	**3,105,408**	**0**	**2,502,165**
BEAUFORT HARBOR	0	0	0	185,452	37,090
MOREHEAD CITY HARBOR	17,145,703	0	0	0	3,429,141
ATLANTIC BEACH CHANNELS	0	0	0	0	0
OVERALL TOTAL	**18,117,078**	**8,434,040**	**3,105,408**	**185,452**	**5,968,396**

2. Potential Costs

In addition to historical quantity and cost data for beach nourishment and dredging projects, unit costs were developed for each stretch of beach for various nourishment scenarios encompassing different types of dredges and distances from sediment sources. For each stretch of beach in Region 2, the historical DCM erosion rates were used to estimate future volumetric needs. Unit costs were then applied to these needs to estimate potential costs for each region on a yearly basis, which could then be summed to predict the cost for the entire coast. Tables IX-82 to IX-84 present the predicted annual costs for each beach area of Region 2. Section VI also contains a general discussion on the methodology employed for the development of potential strategies and costs for the entire state. Based on the findings outlined in Section VI, the predicted annual costs for the beach strategies below should be factored up by 1.3 to 1.7 (assumed to be 1.5 for this report) to account for cubic yards lost per foot of shoreline due to storm impacts. Note that the costs for the inlet maintenance (dredging) strategies are assumed to be equivalent to historical trends.

Table IX-82. Predicted Annual Costs – Region 2a Beaches

	Shoreline Length	Total Volume Needed	Total Volume Cost
Location	**MI**	**CY**	**$**
Kure Beach	3.4	38,139	513,742
Carolina Beach	2.7	242,824	1,974,155
Wrightsville Beach	4.1	89,561	655,584
Figure Eight Island	5.1	18,149	158,802
TOTAL DEVELOPED	**15.3**	**388,673**	**3,302,283**

Table IX-83. Predicted Annual Costs – Region 2b Beaches

	Shoreline Length	Total Volume Needed	Total Volume Cost
Location	**MI**	**CY**	**$**
Topsail Beach	5.1	60,407	491,105
Surf City	6.1	62,377	820,257
North Topsail Beach	11.1	114,279	115,4216
TOTAL DEVELOPED	**22.3**	**237,063**	**2,465,578**

Table IX-84. Predicted Annual Costs – Region 2c Beaches

	Shoreline Length	Total Volume Needed	Total Volume Cost
Location	**MI**	**CY**	**$**
Emerald Isle	10.3	98,197	1,374,757
Indian Beach/ Salter Path	2.6	35,378	495,297
Pine Knoll Shores	4.8	54,500	777,174
Atlantic Beach/Ft. Macon	6.1	189,262	2,158,052
TOTAL DEVELOPED	**23.8**	**377,337**	**4,805,280**

D. Data Gaps

During the data collection efforts several data gaps were identified that, would greatly aid future updates to the BIMP and beach and inlet management projects. The following lists some of these key data gaps in Region 2 by general topic:

Geology

- Inlet bathymetry – Detailed inlet surveys covering morphological features of Carolina Beach Inlet, Masonboro Inlet, Rich Inlet, New Topsail Inlet, New River Inlet, Brown's Inlet, Bear Inlet, and Barden Inlet were not located. (Navigation channel surveys for Carolina Beach Inlet, Masonboro Inlet, New Topsail Inlet, New River Inlet, Bogue Inlet, Beaufort Inlet, and Barden Inlet can be located through USACE website - http://www.saw.usace.army.mil/nav/).

- Sand source investigations – Offshore sand resources for Region 2a have not been investigated in any detail.

Physical Processes

- Sediment budget – Region 2a sediment budgets were performed in the 1970s and should be updated.

Economics

- Extend property at risk study to include all coastal counties – Onslow and Pender County values were often estimated from Carteret County.

- Extend and refine beach recreation value surveys/study to include all coastal counties – Pender County values were often estimated from Wrightsville Beach.

Monitoring

- Improved beach profile monitoring plans – Region 2b does not have any monitoring programs where beach profile data is regularly collected.