U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science Directorate
Geologic Resources Division

Cape Lookout National Seashore

GRI Ancillary Map Information Document

Produced to accompany the Geologic Resources Inventory (GRI) Digital Geologic Data for Cape Lookout National Seashore

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Version: 5/8/2015

Geologic Resources Inventory Ancillary Map Information Document for Cape Lookout National Seashore

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Geologic Resources Inventory Map Document

Cape Lookout National Seashore, North Carolina

Document to Accompany Digital Geologic-GIS Data

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Version: 5/8/2015

This document has been developed to accompany the digital geologic-GIS data developed by the Geologic Resources Inventory (GRI) program for Cape Lookout National Seashore, North Carolina (CALO).

Attempts have been made to reproduce all aspects of the original source products, including the geologic units and their descriptions, geologic cross sections, the geologic report, references and all other pertinent images and information contained in the original publication.

National Park Service (NPS) Geologic Resources Inventory (GRI) Program staff have assembled the digital geologic-GIS data that accompanies this document.

For information about the status of GRI digital geologic-GIS data for a park contact:

Tim Connors
Geologist/GRI Mapping Contact
National Park Service Geologic Resources Division
P.O. Box 25287
Denver, CO 80225-0287
phone: (303) 969-2093
fax: (303) 987-6792
email: Tim_Connors@nps.gov

For information about using GRI digital geologic-GIS data contact:

Stephanie O'Meara
Geologist/GIS Specialist/Data Manager
Colorado State University Research Associate, Cooperator to the National Park Service
1201 Oak Ridge Drive, Suite 200
Fort Collins, CO 80525
phone: (970) 491-6655
fax: (970) 225-3597
e-mail: stephanie.omeara@colostate.edu

About the NPS Geologic Resources Inventory Program

Background

Recognizing the interrelationships between the physical (geology, air, and water) and biological (plants and animals) components of the Earth is vital to understanding, managing, and protecting natural resources. The Geologic Resources Inventory (GRI) helps make this connection by providing information on the role of geology and geologic resource management in parks.

Geologic resources for management consideration include both the processes that act upon the Earth and the features formed as a result of these processes. Geologic processes include: erosion and sedimentation; seismic, volcanic, and geothermal activity; glaciation, rockfalls, landslides, and shoreline change. Geologic features include mountains, canyons, natural arches and bridges, minerals, rocks, fossils, cave and karst systems, beaches, dunes, glaciers, volcanoes, and faults.

The Geologic Resources Inventory aims to raise awareness of geology and the role it plays in the environment, and to provide natural resource managers and staff, park planners, interpreters, researchers, and other NPS personnel with information that can help them make informed management decisions.

The GRI team, working closely with the Colorado State University (CSU) Department of Geosciences and a variety of other partners, provides more than 270 parks with a geologic scoping meeting, digital geologic-GIS map data, and a park-specific geologic report.

Products

Scoping Meetings: These park-specific meetings bring together local geologic experts and park staff to inventory and review available geologic data and discuss geologic resource management issues. A summary document is prepared for each meeting that identifies a plan to provide digital map data for the park.

Digital Geologic Maps: Digital geologic maps reproduce all aspects of traditional paper maps, including notes, legend, and cross sections. Bedrock, surficial, and special purpose maps such as coastal or geologic hazard maps may be used by the GRI to create digital Geographic Information Systems (GIS) data and meet park needs. These digital GIS data allow geologic information to be easily viewed and analyzed in conjunction with a wide range of other resource management information data.

For detailed information regarding GIS parameters such as data attribute field definitions, attribute field codes, value definitions, and rules that govern relationships found in the data, refer to the NPS Geology-GIS Data Model document available at: http://science.nature.nps.gov/im/inventory/geology/GeologyGISDataModel.cfm

Geologic Reports: Park-specific geologic reports identify geologic resource management issues as well as features and processes that are important to park ecosystems. In addition, these reports present a brief geologic history of the park and address specific properties of geologic units present in the park.

For a complete listing of Geologic Resource Inventory products and direct links to the download site visit the GRI publications webpage http://www.nature.nps.gov/geology/inventory/gre_publications.cfm

GRI geologic-GIS data is also available online at the NPS Data Store Search Application: http://irma.nps.gov/App/Reference/Search. To find GRI data for a specific park or parks select the appropriate park

(s), enter “GRI” as a Search Text term, and then select the Search Button.

For more information about the Geologic Resources Inventory Program visit the GRI webpage: http://www.nature.nps.gov/geology/inventory, or contact:

Bruce Heise
Inventory Coordinator
National Park Service Geologic Resources Division
P.O. Box 25287
Denver, CO 80225-0287
phone: (303) 969-2017
fax: (303) 987-6792
email: Bruce_Heise@nps.gov

The Geologic Resources Inventory (GRI) program is funded by the National Park Service (NPS) Inventory and Monitoring (I&M) Division.

Geomorphic Map Units (NCGS Maps)

The units present in the source GIS data and reports for the North Carolina Geological Survey (NCGS) geomorphology maps of Cape Lookout National Seashore, North Carolina and Vicinity (NCGS Geomorphology Maps) are listed below. Units are listed with their assigned (GRI) map unit symbol then unit name (e.g., pf_marsh - Marsh Platform).

Intertidal Map Units

beach - Beach

Spit Complex

sand_flat - Sand Flat
ridge_swale - Ridge and Swale
pf_marsh - Marsh Platform
pf_mrsh_fbrm - Fringing Berm

Tidal Complex

tidal_tflat - Tidal Flat
tidal_sflat - Sand Flat
inlet - Inlet

Supratidal Map Units

Fore-Island Dune Complex

dunerdge - Dune Ridges
intswale - Interdune Swale
dune_sadl - Dune Saddle

Overwash Complex

owflat - Overwash Flat
owfan - Overwash Fan
owchannel - Overwash Channel
isodune - Isolated Dunes
intdune - Interrior Dunes
intmarsh - Interior Marsh
bk_br_brm - Back-Barrier Berm

Relict Map Units

rel_bch_rdge - Relict Beach Ridge Complex
rel_splt - Relict Spit Complex
water - Water Body

Anthropogenic Map Units

airport_land - Airport/Landing Strip

Intertidal Map Units

beach - Beach

Beach is mapped as the area between the ocean shoreline and the toe of the fore-island dune complex. The ocean shoreline used is the wet/dry line defined by the North Carolina Division of Coastal Management (NC DCM) from 1998 black and white aerial photography as part of their long-term erosion rate dataset. The toe of the fore-island dune complex was delineated by a combination of slope (derived from the LiDAR DEM) and aerial imagery.

The narrow, steep profile of the North Carolina Outer Banks beaches (versus beaches elsewhere on the eastern and Gulf coasts of the U.S.) sometimes made it difficult to recognize the slope break between the fore island dune and the beach, so digital photography interpretation was applied as needed.

Storms and high lunar tides subject the beach area to periodic flooding, particularly near inlets, where the beach merges laterally with sand flats of the Spit Complex unit. The ephemeral nature of bedforms, plus insufficient resolution of available data layers prevented delineation of sub-environments within the beach zone. (NCGS Geomorphology Maps).

Spit Complex

Spit complexes include areas of sand flat and arcuate ridge/swale components. They occur adjacent to the three active inlets in the map area. The ***sand flat*** component of the spit complex is an unvegetated, low elevation (less than 4 feet), low relief feature subject to regular tidal flooding and overwash. Sand flats may contain areas of episodically ponded water, small isolated dunes, and seasonally may become encrusted with cyanobacterial algae. Sand flats merge with the beach unit along the shoreline away from the inlet, generally associated with the first development of the fore-island dune complex behind the beach.

The ***ridge and swale*** component of the spit complex, when present, is situated lateral to the sand flat and merges towards the island interior with the fore-island dune and overwash complexes. Ridges and swales typically trend subparallel to the axis of the barrier and then curve toward the back of the island (convex) as they approach the inlet. Ridges range from incipient features to well-formed continuous structures to heavily dissected remnants. Ridge axes are delineated with lines in the project GIS database, but these display only at scales of 1:12,000 and larger. Ridge and swale areas are interpreted to represent older, more stabilized portions of spit complexes. (NCGS Geomorphology Maps).

sand_flat - Sand Flat

The ***sand flat*** component of the spit complex is an unvegetated, low elevation (less than 4 feet), low relief feature subject to regular tidal flooding and overwash. Sand flats may contain areas of episodically ponded water, small isolated dunes, and seasonally may become encrusted with cyanobacterial algae. Sand flats merge with the beach unit along the shoreline away from the inlet, generally associated with the first development of the fore-island dune complex behind the beach. (NCGS Geomorphology Maps).

ridge_swale - Ridge and Swale

The ***ridge and swale*** component of the spit complex, when present, is situated lateral to the sand flat and merges towards the island interior with the fore-island dune and overwash complexes. Ridges and swales typically trend subparallel to the axis of the barrier and then curve toward the back of the island (convex) as they approach the inlet. Ridges range from incipient features to well-formed continuous structures to heavily dissected remnants. Ridge axes are delineated with lines in the project GIS database, but these display only at scales of 1:12,000 and larger. Ridge and swale areas are interpreted to represent older, more stabilized portions of spit complexes. (NCGS Geomorphology Maps).

pf_marsh - Marsh Platform

Marsh platform areas are extensive on the backside of and along tidal creeks that cut into the barrier islands. These areas are low-lying and may be subject to regular tidal flooding. They are recognized by location along the sound side shoreline, green color on the CIR imagery, and elevations typically below 2-feet. NC DCM wetlands mapping was used as a supporting indicator for the presence and areal extent of this unit.

Marsh platforms are relatively stable features and are quite extensive in parts of the barrier system. *Juncus* and *Spartina Patens* are the dominant grass species that inhabit the platform. As the marsh elevation has increased in response to rising sea level, a peat layer up to several feet thick has developed. Where sediment supply is insufficient for marsh aggradation into the sound, wave energy is prone to undercut the peat and cause local shoreline recession. Updip (island-ward) areas are prone to storm overwash, which supplies sand to the marsh platform interior margin and raises the elevation above tidal influence. As this process progresses, the overwash complex builds onto the marsh platform area. (NCGS Geomorphology Maps).

pf_mrsh_fbrm - Fringing Berm

This is a shore-parallel subunit of the Marsh Platform that occurs on the extreme back barrier side of the marsh platform. It is usually about 1-2 feet higher than the surrounding marsh, and is most likely a result of storm deposition on the sound side, both sediment and vegetation wrack (Stan Riggs and Dorothea Ames personal communication). This is well-pronounced on the LiDAR DEM for much of Portsmouth Island. (NCGS Geomorphology Maps).

Tidal Complex

The Tidal Complex consists of two sub units, 1) Tidal Flat, and 2) Sand Flat which are dominated by the local tidal influence. (NCGS Geomorphology Maps).

tidal_sflat - Tidal Flat

These areas within the Tidal Complex have very low elevation (less than 1-foot) and have water bodies and/or tidal creeks draining the areas. These areas are generally adjacent to the Marsh Platform and subject to regular tidal flooding. They are characteristically dark green on the CIR, and dark blue on the LiDAR DEM's. Data extractions for elevations less than 1-foot with the LiDAR DEM provided a guide for the distribution of this unit. (NCGS Geomorphology Maps).

tidal_sflat - Sand Flat

Emergent bodies of extensive sound-side shoals are mapped as Tidal Complex Sand Flats. These flats, or shoals, are clearly visible on the CIR as isolated submerged and emerged bodies in the sound, and adjacent to the Marsh Platform. Areas that appeared to be emergent in the CIR were mapped as Sand Flats, because of the unknown period of the tidal cycle in the CIR, these areas may be underrepresented. Because these sand bodies were quite numerous in the CALO area, and easily seen on the CIR, we felt they needed to be represented. These bodies are not directly attached to inlet spit complexes, which distinguishes them from Spit Complex Sand Flats. (NCGS Geomorphology Maps).

inlet - Inlet

This unit only occurs on Portsmouth Island, in the vicinity of Old Drum Inlet. The area delineated represents a new inlet opened by Hurricane Dennis in 1999 at the site of Old Drum Inlet. This inlet has been named New-Old Drum Inlet. (NCGS Geomorphology Maps).

Supratidal Map Units

Fore-Island Dune Complex

Fore-island dune complexes are shore parallel units of higher elevation that occur between the beach and island interior units. Subunits of the fore-island dune complex include: dune ridge, intradune swale, and dune saddle. (NCGS Geomorphology Maps).

dunerdge - Dune Ridges

The most prominent and areally extensive portions of the fore-island dune complex are linear, shore-parallel ***dune ridges.*** Locally, up to three distinct ridges, separated by intradune swales, were mapped using a combination of LiDAR DEM and slope layers with CIR imagery. Dune heights vary, but generally are less than 20 feet. Dune toe elevations are typically in the 6 to 8 foot range on the front (ocean) side and 4 to 8 feet on the back (island interior) side. (NCGS Geomorphology Maps).

intswale

Intradune swales are closed, relatively low areas lying within dune complexes. These features tend to occur between dune ridges as linear troughs often with bases less than 10 feet in elevation. They are well expressed on the LiDAR DEM and elevation contour layers. Intradune swales are displayed only at scales of 1:12,000 and greater. (NCGS Geomorphology Maps).

dune_sadl

Dune saddles are gaps or breaks along dune ridge lines of the fore-island dune system. An elevation threshold of less than 10 feet was used to define saddle areas.

Saddles are important features of the dune complex in that they represent potential high-water flow pathways or breech points along the ridge lines that would be vulnerable to coastal flooding during major storms. These also are well expressed on LiDAR DEM and elevation contour layers. Dune saddles are displayed only at scales of 1:12,000 and greater. (NCGS Geomorphology Maps).

Overwash Complex

The overwash complex occurs behind the fore-island dune complex and in front of the marsh platform. This area is elevated relative to the marsh platform, tends to have low to moderate relief, typically ranges from 2 to 8 feet in elevation, and gradually decreases in elevation toward the sound side of the island. The overwash complex is a depositional feature that receives sand that is blown or washed over and through the fore-island dune complex—most notably by storm events. Locally, the overwash complex extends into the sound.

Vegetated overwash at lower elevations often exhibits reddish colors on the CIR imagery (indicative of leafy vegetation vs. the green color of the marsh platform grasses); this CIR expression corresponds closely with the shrub/scrub vegetation class on NC DCM wetlands mapping. Subunits mapped within the overwash complex include overwash flat, overwash fan, overwash channel, and isolated dunes. (NCGS Geomorphology Maps).

owflat - Overwash Flat

Overwash flat is the dominant subunit. It represents the long-term accumulation of sand overwash behind the fore-island dune complex. Discrete events deposit sand in lobate forms, which wind, water, and man then rework to coalesce into a single geomorphic unit. (NCGS Geomorphology Maps).

owfan - Overwash Fans

In many places just past the dune island interior side, well-defined ***overwash fans*** can be discerned using a combination on CIR imagery, LiDAR DEM, and elevation contour layers. Often these are overgrown with vegetation along their margins, permitting an estimate of their extent. Here, the individual overwash fans and the linear ***overwash channels*** that cut through the fore-island dune during the storm event were mapped. (NCGS Geomorphology Maps).

owchannel - Overwash Channels

Linear ***overwash channels*** that cut through the fore-island dune during the storm event were mapped. Overwash channels are sufficiently preserved to permit mapping in a few other localities as well. These are displayed only at scales of 1:12,000 and greater**.** (NCGS Geomorphology Maps).

isodune - Isolated Dunes

Locally, ***isolated dunes*** occur within or soundward of the overwash flat area. These appear to form due to a variety of origins including: 1) remnants of former fore-island dune ridges or large overwash fans, or 2) as constructional features caused by the trapping of sand by vegetation or man-made features such as sand fencing. (NCGS Geomorphology Maps).

intdune - Interior Dune

Dunes occur in several areas soundward of the fore-island dune complex. These are distinguished from isolated dunes of the overwash complex by their larger scale. Interior dunes are significant geomorphic features of sizable areal extent, sometimes containing the points of maximum elevation for given islands. Their origins appear to be separate from fore-island dune building processes. The source of sand needed to construct these features is not readily apparent from the data layers used

in this mapping.

Maximum elevations of interior dunes range from 10 to 30 feet, making them readily identifiable on the LiDAR DEM and elevation contour data layers. Most mapped interior dunes are vegetated and thus appear to be relatively stable features. Interior dunes range from isolated single ridges to more laterally extensive elevated features, such as occur on Shackleford Banks. (NCGS Geomorphology Maps).

intmarsh - Interior Marsh

Interior marshes lack a connection to the waters of the ocean or sound, but often are located adjacent to water bodies. The marsh vegetation appears as a bright green on the CIR imagery. DCM wetlands mapping interpreted many of these features as fresh water marshes;however this study lacks sufficient evidence to make that distinction. Interior marshes are most commonly developed in the swales of extensive relict beach ridge complexes, such as those in the Buxton area, or in interior lows behind the fore-island dune complex. (NCGS Geomorphology Maps).

bk_br_bm - Back Barrier Berm

Back-barrier berms are landforms that occur in the back portions of the barrier island system through much of the project area. They vary from very subtle linear features lying just slightly higher than the surrounding marsh platform to significant positive features (over 10 feet in elevation) with complex internal geometry. The LiDAR DEM and slope layers are useful in mapping these features. In addition, CIR imagery is particularly useful in recognizing back barrier berms, because reddish colors caused by leafy vegetation on the berms are different than the green color of the surrounding marsh grasses.

The detailed characterization of back barrier berms is ongoing research by the ECU group. Many berms form a broad arc in areas of apparent relict flood tidal deltas. This suggests that wave reworking of delta sand bodies may have facilitated berm development. Other berms are of less intuitive origin. (NCGS Geomorphology Maps).

Relict Map Units

rel_bch_rdge - Relict Beach Ridge Complex

Relict beach ridge complexes occur as sets of parallel ridges and swales within island interior portions. Truncation of parallel dune sets by later dune sets oriented at a slightly different angle allow delineation of individual sets of relict beach ridges, also providing relative age relationships. Elevations commonly range from 6-10 feet or less.

Relict beach ridge axes are delineated with line work in the GIS database to aid in visualizing the patterns and trends they form. This layer only displays at scales of 1:12,000 and larger. (NCGS Geomorphology Maps).

rel_splt - Relict Spit Complex

Some very subtle arcuate-shaped ridge and swale features located in mid- to back-island areas exhibit topography and geomorphic attributes characteristic of modern spit complexes; but they often lack connection to an active inlet. These areas are interpreted as older, inactive spit complexes that developed adjacent to former inlets. Relict spit complexes are notable in the vicinity of now closed Whalebone Inlet on Portsmouth Island. Relict spit ridge axes are delineated with line work in the GIS

database to aid in visualizing the patterns and trends they form. This layer only displays at scales of 1:12,000 and larger. (NCGS Geomorphology Maps).

water - Water Body

Water bodies are readily apparent on the CIR imagery because the water absorbs the CIR wavelengths, making the water body appear black or dark green. Water bodies that appeared to be ephemeral features, such as on sand flats or in intradune swales, were not included in this map unit. The LiDAR DEM is not particularly helpful in recognition of these planar features, as the water response tends to introduce diffractive noise to the elevation data. However, the elevation contours do offer supporting evidence to the interpretation from CIR imagery. (NCGS Geomorphology Maps).

Anthropogenic Map Units

There are minor human modifications to portions of the landscape of Cape Lookout National Seashore. There is a fishing "village" on Portsmouth Island, called Morris Fish Camp, which has many buildings visible on the CIR. These structures rest on the overwash flat, and appear to have been effectively removed from the LiDAR DEM during data processing, and were not mapped as anthropogenic. (NCGS Geomorphology Maps).

airport_land - Airport/Landing Strip

Airports/landing strips occur near in the northern South Core Banks and Portsmouth Village areas. (NCGS Geomorphology Maps).

Detailed Geomorphic Map Units (ECU Maps)

The units present in the source GIS data and reports for the East Carolina University (ECU) detailed geomorphology maps of Cape Lookout National Seashore, North Carolina and Vicinity (ECU Detailed Geomorphology Maps) are listed below. Units are grouped and listed in order as per the source report. Units are listed with their assigned (GRI) map unit symbol then unit name (e.g., BF_ocbeach - Ocean Beach).

Beach Features (BF)

BF_ocbeach - Ocean Beach
BF_inlet_flt - Inlet Flat
BF_inlet_spt - Inlet Spit

Overwash-Plain Features (OF)

Upper Overwash Ramp

UO_unveg - Sparse to Unvegetated
UO_grass - Grass
UO_scrb_shrb - Scrub Shrub
UO_fdune - Foredune

Middle Overwash Ramp

MO_unveg - Sparse to Unvegetated
MO_grass - Grass
MO_scrb_shrb - Scrub Shrub
MO_forest - Forest
MO_intmarsh - Interior Marsh
MO_dunerdge - Dune/Beach Ridge

Lower Overwash Ramp

LO_pf_marsh - Platform Marsh
LO_fring_brm - Fringing Berm
LO_spln_bch - Standplain Beach
LO_bk_br_bm - Back-Barrier Berm

Polydemic Features (PF)

PF_tidal_chn - Tidal Channels
PF_pond - Pond
PF_trnv_rdge - Transverse Ridges
PF_dunef - Dune Field
PF_algal_flt - Algal Flat
PF_rdg_swl - Ridge and Swale
PF_owchannel - Overwash Channel

Anthropic Features (AF)

AF_drdge - Dredge Channels/Spoils
AF_jetty - Rock Jetty

Sound Features (SF)

SF_tidal_chn - Tidal Channels
SF_up_shoal - Upper Shoals
SF_low_shoal - Lower Shoals

SF_fld_tide - Flood-Tide Delta Shoals
SF_tidal_del - Tidal Detla

Beach Features (BF)

BF_ocbeach - Ocean Beach

A. BF: OCEAN BEACH

Geomorphic Description:
The mapped beach is defined as that geomorphic unit that extends from the wet-dry line to the base of either a natural dune field or the base of a scarped dune or dune field. If no dunes are present then the beach extends to the island berm crest, which is the crest of an overwash island, represents the highest point on the overwash plain, and separates the surface water flow between the ocean and back-barrier estuary.

Dominant Vegetation:
Macroscopic vegetation is sparse within this unit. However, wrack commonly occurs along the upper swash lines associated with the storm beaches. The wrack may consist of offshore algae (*Sargassum spp.)*, dune grasses, estuarine submerged aquatic vegetation, or estuarine marsh grasses. (ECU Detailed Geomorphology Maps).

BF_inlet_flt - Inlet Flat

B. BF: INLET FLAT

Geomorphic Description:
An inlet flat occurs adjacent to either a modern inlet or a paleo-inlet. It is a gently ramped surface that gradually slopes from the ocean-beach berm towards the inlet and sound. An inlet flat forms from regular overwash events and by the combined interaction of waves and tidal currents during high water overflow conditions associated with spring tides or storms.

Dominant Vegetation:
New and active inlet flats will be unvegetated. The vegetation on older inlet flats will often consist of mixed grasses that include *Spartina patens*. Fine grained areas frequently become algal flats. (ECU Detailed Geomorphology Maps).

BF_inlet_spt - Inlet Spit

C. BF: INLET SPIT

Geomorphic Description:
An inlet spit consists of one or more sub-parallel ridges that occur adjacent and parallel to either a modern inlet or a paleo-inlet. It is dominated by curved ridge structures on a gentle ramped flat. The flat results from regular overwash events and the spit forms by the combined interaction of waves and tidal currents during high water overflow conditions associated with spring tides or small storm tides. Sometimes, the higher spits that formed in response to previous storm events will be subsequently truncated, breached, or even enlarged by the accretion of secondary spits. An older inlet spit often will contain active dunes that develop after the spit is formed.

Dominant Vegetation:
New and active inlet spits will be either unvegetated or grassed with *Spartina patens*. The vegetation on older inlet spits will often consist of mixed grasses that include *Spartina patens* and scrub shrub. (ECU Detailed Geomorphology Maps).

Overwash-Plain Features (OF)

Upper Overwash Ramp

A. UPPER OVERWASH RAMP: UOR

Geomorphic Description:

The upper overwash ramp begins at the island berm crest, which is the highest point on the overwash dominated barrier island. The UOR extends either gently down-slope to the middle overwash ramp, more steeply to the lower overwash ramp, or occasionally directly into the adjacent estuary with an eroding sediment bank shoreline. The UOR is a slightly undulating, high and dry surface that frequently contains small isolated dunes, and is often characterized by a shell gravel pavement resulting from overwash events. Generally there is either a natural dune field or anthropic constructed dune-ridge that occurs on the UOR along the island berm crest. In the latter situation, the ocean side of the UOR begins at the depositional or scarped boundary at the top of the ocean beach. Since the major source of dune sands is directly off the beach, most of the natural dune fields occur superimposed upon the uppermost portion of the UOR. (ECU Detailed Geomorphology Maps).

UO_unveg - Sparse to Unvegetated

UOR: Sparse to Unvegetated

Dominant Vegetation:

If the uppermost portion of the UOR is dominated by salty ground water or a relatively deep fresh water table, the surface is characterized by a xeric vegetation community. Xeric vegetation communities have low species diversity that are dominated by the sparse growth of *Gaillardia pulchella* (fire wheel), *Opuntia spp*. (prickly pear cactus), and scattered *Juniper virginiana* (eastern red cedar). Frequently within the xeric community the sand surface is covered by an irregular and splotchy growth of lichens and moss. (ECU Detailed Geomorphology Maps).

UO_grass - Grass

UOR: Grass

Dominant Vegetation:

As the UOR ramp decreases in elevation away from the ocean beach, fresh groundwater dominates and rises allowing an increased vegetative cover that grades successively from the xeric community to the grass flat and scrub shrub communities on the UOR ramp. The grass community is dominated by the following species.

Uniola paniculata (sea oat)
Spartina patens (salt meadow hay)
Andropogon scoparius (broomstraw rush)
Hydrocotye bonariensis (pennywort)
Cakile edentula (sea rocket)

(ECU Detailed Geomorphology Maps).

UO_scrb_shrb - Scrub Shrub

UOR: Scrub Shrub

Dominant Vegetation:

As the UOR ramp decreases in elevation away from the ocean beach, fresh groundwater dominates and rises relative to the land surface resulting in an increased vegetative cover that grades successively from the xeric community to the grass flat and scrub shrub communities on the UOR ramp. If the UOR is very wide with a significant natural dune field or constructed dune-ridge, an extensive scrub shrub community expands in the ocean ward direction. The scrub shrub community is dominated by the following species along with abundant

grasses and vines.

Baccharis halimifolia (salt myrtle)
Myrica cerifera (wax myrtle)
Ilex vomitoria (yaupon holly)
Iva frutescens (marsh elder)
Myrica pensylvanica (bayberry)
Juniper virginiana (eastern red cedar)
Spartina patens (salt meadow hay)
Smilax spp. (cat brier)
Toxicodendron radicans (poison ivy)
Partenocissus quinquefolia (Virginia creeper)

(ECU Detailed Geomorphology Maps).

UO_fdune - Foredune

A1. UOR: Foredune

Geomorphic Description:

Natural fore dunes are frequently not present, particularly in the regions where constructed dune- ridges have been built and maintained by human efforts. In areas where the constructed dune-ridges have either not been built or have not been regularly maintained, natural fore dunes often form along the uppermost portion of the overwash plain. The size of fore dunes depends largely upon sand availability. The dunes have an irregular geometry and are variable in size and number. Since there are many different wind directions through the seasons of the year, any single dune is built and modified continuously through time with abundant blowouts, cut and fill structures, and scarping along the ocean side or along overwash channels through the dune field. Occasionally a foredune will develop concentric rings alternating between being vegetated and un-vegetated.

Dominant Vegetation:

Dunes are mostly vegetated with *Uniola paniculata* (sea oats). However, on the back side of a large dune field or as the distance from the ocean increases salt spray is diminished with a corresponding increase in vegetation diversity. Plants that commonly occur on the lee side of the dune field include *Spartina patens (*salt meadow hay), *Cakile edentula* (sea rocket), *Solidago sempervirens* (golden rod), *Myrica cerifera* (wax myrtle), occasionally *Juniper virginiana* (eastern red cedar) and ground cover plants such as *Hydrocotyle bonariensis* (penny wort). (ECU Detailed Geomorphology Maps).

Middle Overwash Ramp

B. MOR: OVERWASH RAMP: MOR

Geomorphic Description:

The middle overwash ramp is a relatively flat and dry to slightly wet surface that slopes gently away from the UOR. Occasionally there is a dramatic step down from the UOR to the MOR. The latter situation occurs if the island segment is heavily vegetated. The dense scrub shrub or forest vegetation causes the storm surge flow to be disrupted and rapid deposition of sediments during overwash events. The step down is generally composed of sand with interbeds of beach shell gravel.

If the island is wide, the MOR may be very extensive. This situation is particularly true if there is a well developed molar-tooth structure with major tidal channels on the LOR. However, if the island is narrow, there may not be an MOR. In this situation the UOR is steep and drops directly onto the LOR (Fig. 3) or even into the back-barrier estuary with an eroding sediment bank shoreline supplying sand for development of an estuarine strandplain beach.

Vegetation on the MOR displays zonation down slope as a direct function of water table depth,

frequency and magnitude of overwash events, and time since the last overwash event. Storm events that deposit new overwash sediment may also rip up and/or bury existing vegetation. The resulting increase in MOR elevation resets the clock with respect to the location and succession of dominant vegetation that emerges in the years following the overwash event. (ECU Detailed Geomorphology Maps).

MO_unveg - Sparse to Unvegetated

MOR: Sparse to Unvegetated
Geomorphic Description:
Immediately a major storm event that delivers a new overwash fan across the MOR, the sediment surface is essentially an unvegetated flat. However, within subsequent years grasses begin to develop and the new overwash plain slowly evolves into one of the following dominant vegetation groups depending upon the subsequent storm and flooding pattern; elevation, width, and dissection of the MOR with tidal channels; and composition and location of the ground-water table. (ECU Detailed Geomorphology Maps).

MO_grass - Grass

MOR: Grass
Dominant Vegetation:
If the upper portion of the MOR frequently receives minor amounts of salt spray, aeolian sand, and overwash sediment, the flats will be dominated by *Spartina patens* (salt meadow hay) and *Andropogon scoparius* (broom straw). (ECU Detailed Geomorphology Maps).

MO_scrb_shrb - Scrub Shrub

MOR: Scrub Shrub
Geomorphic Description:
If the upper portion of the MOR has not recently been impacted by major storm events and overwash sediment fans, the flats will be dominated by scrub shrub. Once the scrub shrub is established, the over flow of small overwash events is broken by the scrub shrub resulting in the overwash sediment being deposited as a series of stair-steps within the scrub shrub flat. Large overwash events can kill the scrub shrub, and erode out portions or all scrub shrub. Such an event resets the process of vegetation succession.

Dominant Vegetation:
The scrub shrub flat is dominated by the following species.

Baccharis halimifolia (salt myrtle)
Myrica cerifera (wax myrtle)
Ilex vomitoria (yaupon holly)
Iva frutescens (marsh elder)
Myrica pensylvanica (bayberry)
Juniper virginiana (eastern red cedar)
Spartina patens (salt meadow hay)
Smilax spp. (cat brier)
Toxicodendron radicans (poison ivy)
Partenocissus quinquefolia (Virginia creeper)

(ECU Detailed Geomorphology Maps).

MO_forest - Forest

MOR: Forest

Geomorphic Description:

If the area has not recently been impacted by major storm events and overwash sediment fans, the scrub shrub flats can locally evolve into a forest dominated MOR characterized by larger growth with a well developed over story. Establishment of a forest within the MOR indicates that overwash events are rare either due to low frequency of major storm activity, low rates of ocean shoreline recession, and/or the presence of a large natural dune field or large constructed dune-ridges. However, if a large overwash event does occur, it can kill the forest trees and erode out large portions or all of the forest. Such an event resets the process of vegetation succession.

Dominant Vegetation:

The forested flat is dominated by *Pinus sp.* (pine), *Quercus virginiana* (live oak), and *Juniper virginiana* (eastern red cedar). The forested flats are almost always characterized with a major under-story of shrubs that include *Myrica cerifera* (wax myrtle) and *Ilex vomitoria* (yaupon holly), along with massive growths of various vines including *Smilax* sp. (cat brier), *Toxicodendron radicans* (poison ivy), and *Vius rotundifola* (muscadine grape). The shrubs and vines occur throughout the forest but their densest growth is generally near the periphery. (ECU Detailed Geomorphology Maps).

MO_intmarsh - Interior Marsh

B1. MOR: Interior Marsh

Geomorphic Description:

The lower portion of the MOR is in the supra-tidal zone with a high water table that is frequently flooded by the irregular wind and storm tides with estuarine waters flowing through the associated tidal channels. This can result in the formation of vast algal mats and interior marsh. With time and subsequent overwash events, the elevation of the MOR increases and the irregularly flooded algal flats and interior marsh may evolve into dry grass flats.

The interior marsh is characterized by organic-rich sandy soil with a water table that fluctuates from a few inches below ground level to above ground level depending on the rainfall and irregular wind tides. The interior marsh of this irregularly flooded wind tidal system is roughly equivalent to the high marsh of the regularly flooded astronomically-tidal system. The interior marsh grades into the platform marsh of the LOR with a gentle decline in elevation that ranges from a few feet to a few inches above mean sea level. The interior marsh has a sand substrate, whereas the substrate in the platform marsh generally decreases in sand content and increases in the amount of organic matter forming a sandy peat substrate. Submerged aquatic vegetation (SAVs) and marsh-grass wrack get blown into the interior marsh through the tidal channels during storm flooding.

Dominant Vegetation:

The dominant vegetation of the interior marsh is extremely variable depending upon the frequency of flooding and the water chemistry. The higher salinity marsh plants include *Spartina alterniflora* (smooth cord grass), *Spartina patens* (salt meadow hay), *Juncus roemerianus* (black needlerush), *Distichlis spicata* (salt grass), and *Borrichia frutescens* (sea oxeye). Whereas *Scirpus robustus* (soft stemmed bulrush), *Cladium jamaicense* (saw grass), *Phragmites australis* (common reed), *Spartina cynosuroiodes* (giant cord grass), and *Typha angustifora* (cat tail) are dominant in the areas characterized by lower salinity to fresh water. (ECU Detailed Geomorphology Maps).

MO_dunerdge - Dune/Beach Ridge

B3. MOR: Dune/Beach Ridge

Geomorphic Description:

If the MOR encroaches upon an older component of the barrier island, a dune/beach ridge system can form

ocean ward of the older barrier component. During dry periods, the wind-blown sands are trapped against the stabilized land mass and reworked into a beach ridge by high water during stormy periods that flood the MOR. The resulting dune/beach ridges are sub-parallel to the portion of land mass that has trapped the sands.

Dominant Vegetation:
Dune/beach ridges on the MOR may initially be stabilized by *Spartina patens* (salt meadow hay), *Borrichia frutescens* (Sea Oxeye). If a stabilized dune/beach ridge is large enough, the vegetation may increase in density and diversity with time to include scrub shrub. (ECU Detailed Geomorphology Maps).

Lower Overwash Ramp

C. LOWER OVERWASH RAMP: LOR

Geomorphic Description:
The lower overwash ramp is a flat, wet, inter-tidal surface that extends into the back-barrier estuary. It generally comprises an extensive platform marsh with a thin (< 1 meter) sandy peat substrate on a fine sand base. If the island is wide, the LOR may be very extensive. This is particularly true if there is a well developed molar-tooth structure with tidal channels cutting through the LOR into the lowermost portion of the MOR. However, if the island is narrow, there may not be an MOR or even an LOR. In the latter case the UOR is steep and drops directly onto either the LOR or into the back-barrier estuary with a strandplain beach.

The LOR is also characterized by strong vegetation zonation that occurs across the flat. The specific plant zonations are determined by the salinity gradients and water-level fluctuations caused by the regular astronomical tides (in the vicinity of inlets) and irregular wind tides that occur within the adjacent estuarine water body. The outer edge of the platform marsh is generally an erosional scarp along the higher energy, open shorelines and along the associated tidal channels. However, the marsh shorelines that are located within more protected embayments occur as gradual sloped ramps onto the shallow back-barrier shoals. (ECU Detailed Geomorphology Maps).

LO_pf_marsh - Platform Marsh

C1. LOR: Platform Marsh

Geomorphic Description:
The platform marsh constitutes the major component of the LOR and is irregularly flooded by wind tides, except near inlets where the platform marsh is also flooded by small, regular astronomical tides. The platform marsh is characterized by a thin (< 1 meter) peat or sandy peat substrate that is permanently saturated with standing water and grades downward into a fine sand base. Tidal-creeks form extensive drainage networks within many of the platform marsh environments with occasional small ponds scattered within the marsh. The marshes have a low-diversity of vegetation that is strongly zoned subparallel to both the outer marsh perimeter and back-barrier berms that occur within the platform marsh.

Platform marshes have a minor slope towards the sound, where the marsh ends abruptly at the estuarine shoreline with an erosional, undercut scarp that ranges from a few cm to < 1 meter above the estuarine floor. In areas with enough sand, the sound-ward edge of the platform marsh may contain a strandplain beach in front of and burying the scarp. The outer perimeter of most platform marshes contains an elevated fringing berm just landward of and parallel to the erosional scarp. This fringing berm is generally < 1 meter high and is composed of a mixture of fine sand and wrack.

Wrack plays a critical role in the platform marsh and occurs either as small to large, irregular patches or in shoreline parallel rows that represent different storm water levels. Wrack deposits are composed of either dead submerged aquatic vegetation or marsh vegetation, occur at varying distances within the marsh as a function of water-level elevation, and are products of specific events and therefore in various stages of decay. Depressions

in the marsh result from wrack deposits that kill the dominant marsh vegetation and, in some cases, cause enough of a depression to pond water. Ponds may vary from hypo- to hyper-saline depending on groundwater flow, weather (wet versus dry season), and location relative to active inlets. Marsh plants that colonize a decomposing wrack pile or shallow pond are quite different from the marsh grasses that are dominant within the platform marshes.

Dominant Vegetation**:**
The dominant platform marsh grasses within the study area include a narrow fringe along the outer perimeter of either *Spartina patens* (salt meadow hay) or *Spartina alterniflora* (smooth cord grass). The outer fringe may be severely eroded and even stripped of vegetation. The eroded areas often have *Juncus roemerianus* (black needlerush) at the water's edge, and *Salicornia bigelovi* (annual marsh glass wort) may colonize the stripped zone. The platform marsh grades inward to vast areas of *Juncas roemerianus* (black needlerush). In the proximity of major inlets, the *Spartina alterniflora* fringe becomes more expansive at the expense of *Spartina patens,* and replaces *Juncus roemerianus* (black needlerush) on most of the platform.

Thick wrack deposits kill the underlying dominant platform marsh vegetation. As wrack decomposes, rows or patches of different plants locally re-colonize the denuded areas. The recolonizing vegetation is a function of elevation and salinity. The dominant plants that re-colonize a decaying wrack deposit include *Borrichia frutescens* (sea oxeye), *Salicornia bigelovi* (annual marsh glass wort)*, Salicornia virginica* (perennial marsh glass wort)*, Distichlis spicata* (salt grass)*,* with a small growth of the scrub shrub *Myrica cerifera* (wax myrtle), *Iva frutescens* (marsh elder), and *Baccharis halimifolia* (salt myrtle). Depressions may form in the marsh as a result of multiple wrack deposits accumulating in the same area over time, preventing re-colonization and causing some peat compaction. If the resulting depressions are below mean sea level, they will pond the water. Ponds may vary from hypo- to hyper-saline depending on groundwater flow and weather (rainfall versus drought). (ECU Detailed Geomorphology Maps).

LO_fring_brm - Fringing Berm

C2. LOR: Fringing Berm

Geomorphic Description:
Most sound-side shorelines within the platform marshes are comprised of scarped and undercut sandy peat banks that range from a few centimeters up to 1 m in height. Storms deposit one or more elongate fringing berms that are shore parallel and occur at regular distances from the sound shoreline. The most prominent fringing berm is generally < 10 m inside of the marsh perimeter and is a product of the average storm surge resulting from the most common winter storms. These fringing berms are up to 1 m thick and are 1 to 3 m wide rows of SAV wrack and/or marsh grass wrack mixed with sand and other debris. As the scarped marsh peat erodes along the shorelines through time, the fringing berm is systematically moved landward in response to the cumulative impact of the many annual winter storms. Depending upon the exposure, the marsh grasses in front of the fringing berm may be ripped off by the wave energy leaving a barren peat surface exposed. This barren peat surface frequently becomes colonized by *Salicornia bigelovi.*

Dominant Vegetation:
The fringing berms are generally dominated by *Spartina patens* (salt meadow hay) and *Spartina cynosuroides* (giant cord grass) with some woody shrubs including *Myrica cerifera* (wax myrtle), *Iva frutescens* (marsh elder)*,* and *Baccharis halimifolia* (salt myrtle). The back side of the fringing berm drops off more abruptly on the island side with the fringing berm vegetation grading into vast areas of *Juncus roemerianus* (black needlerush)*.* The fringing berm plant assemblage also occurs where the platform marsh forms the transition zone onto back-barrier berms. (ECU Detailed Geomorphology Maps).

LO_spln_bch - Standplain Beach

C3. LOR: Strandplain Beach

Geomorphic Description:

Small strandplain beaches frequently occur in front of the eroded scarps of the adjacent platform marshes. This is particularly the case in areas where cross-barrier island features (e.g., transverse ridges, ridge and swale complexes, etc.) intersect the estuarine shoreline or where back-barrier shoals are well developed within the adjacent estuary. The presence and development of a strandplain beach is often temporary and/or seasonal since its presence is in part a direct function of the frequency, abundance, and character of the storm patterns.

Dominant Vegetation:

Generally there is no macro-vegetation on an active strandplain beach. However, during extended calm periods, such as the warm summer months, various types of algae may temporarily stabilize the sand on these strandplain beaches. Vegetation on strandplain beaches is undifferentiated on the maps. (ECU Detailed Geomorphology Maps).

LO_bk_br_bm - Back-Barrier Berm

C4. LOR: Back-Barrier Berm

Geomorphic Description:

Back-barrier berms are sand deposits on top of the LOR in response to the interaction between estuarine and oceanic storm dynamics. They generally occur as major depositional features that are not sub-parallel to the estuarine shoreline like the small-scale fringing berms. Rather, these features are further inland and occur as ridges that are sub-parallel to the larger-scale overwash plain. Back-barrier berms tend to be < 2 m high, < 25 m wide, and are composed totally of clean sand. Occasionally the lateral ends adjacent to the tidal channels have a recurved geometry that turn into the island.

Barrier island segments that have an LOR with a well developed molar-tooth structure, commonly have one or two arcuate back-barrier berms that occur on the platform marsh and extend the entire length of the large-scale lobate overwash plain. Individual back-barrier berms within this system occur along the width of the platform marsh and between adjacent tidal channels.

Dominant Vegetation:

Vegetation on back-barrier berms is primarily scrub shrub, particularly on the smaller and lower features. At the highest elevation the vegetation becomes sparse and consists mainly of *Juniper virginiana* (eastern red cedar) and *Spartina patens* (salt meadow hay), with large unvegetated areas of exposed sand. In addition, there may be abundant *Baccharis halimifola* (salt myrtle), *Iva frutescens* (marsh elder), *Myrica cerifera* (wax myrtle), and *Ilex vomitoria* (yaupon holly).

Occasionally, some of the larger and higher back-barrier berms contain maritime forests consisting of various *Pinus spp.* (pine), *Quercus virginiana* (live oak), and *Juniper virginiana* eastern red cedar) that form an overhead canopy. Shrubs such as *Baccharis halimifola* (salt myrtle), *Iva frutescens* (marsh elder), *Myrica cerifera* (wax myrtle), and *Ilex vomitoria* (yaupon holly) grow as an under story and mainly near the forest periphery. (ECU Detailed Geomorphology Maps).

Polydemic Features (PF)

POLYDEMIC FEATURES (PF)

Polydemic features are those that “occur in or inhabit two or more regions” on the barrier island. Thus, polydemic features are products of processes that can occur within any portion of the overwash plain or over several different portions of the overwash plain of the simple barrier island model. (ECU Detailed

Geomorphology Maps).

PF_tidal_chn - Tidal Channels

A. PF: TIDAL CHANNELS

Geomorphic Description:

Tidal channels generally form on flood-tide deltas and persist after the inlet is closed and the shoals evolve into platform marshes. Tidal channels are often truncated by the overwash ramp as it migrates onto the platform marsh. Tidal channels are common in the platform marshes, particularly in the areas adjacent to major inlets where astronomical tides are prevalent. However, occasionally there are island segments where the tidal channels extend from the LOR well into the MOR and even into the UOR. These island segments are generally characterized by rapidly eroding ocean shorelines where the UOR of the migrating barrier has moved landward onto the LOR in direct response to major storms and the resulting overwash events. The upper most reaches of these tidal channels tend to be fresh water and fed directly from the groundwater occurring within the high portions of the UOR.

Within an active overwash plain, the headwaters of tidal channels will be completely buried by the overwash plain. The water flow onto and off the overwash plain carries significant volumes with enough energy to erode the tidal channels occurring between segments of the platform marsh. With time these portions of the tidal channels are eroded laterally and vertically to produce the wide tidal channels between the platform marsh segments. The resulting geomorphology is that of the classic molar-tooth structure. These shore perpendicular tidal channels connect the MOR directly with the estuary and move overwash water off the island during ocean-overwash events, and carry estuarine storm-tide water into the algal flats and interior marshes on the MOR. The tidal channels tend to be deep (up to 3 to 4 m) and extend all the way through the Platform Marsh with steeply scarped, peat shorelines along the edges. Each end of the tidal channel (inner and outer edge of the LOR) shallows, flattens, and broadens out into small-scale deltaic lobes. Some tidal channels occur within the swales between beach ridges as well as between lobes of the submarine structures.

Dominant Vegetation:

The tidal creek perimeters within the UOR and uppermost reaches of the MOR are generally dominated by fresh water with the perimeter marshes dominated by Scirpus robustus (soft stemmed bulrush), Cladium jamaicense (saw grass), Spartina cynosuroiodes (giant cord grass), Typha angustifora (cat tail), and Phragmites australis (common reed). The vegetation along the fringes of the tidal creek down slope towards the estuary become dominated by Juncus roemerianus (black needle rush) marsh grass that expands laterally into the platform marshes of the LOR. Vegetation in the tidal channels is undifferentiated on the maps. (ECU Detailed Geomorphology Maps).

PF_pond - Ponds

B. PF: PONDS

Geomorphic Description:

Ponds form in many different places within the general overwash plain in response to very different sets of processes. Consequently, most ponds on barrier islands are extremely variable in water composition and tend to be ephemeral through time. The presence of many ponds is a direct function of the pattern, frequency, and abundance of both storms and rainfall. During times of frequent storms and abundant rainfall, most ponds will be filled with either salt or fresh water depending on their location within the barrier system. However during intermediate periods they may become wetland marshes and during periods of low rainfall, the ponds may become algal flats or even dry up completely. No attempt was made to try to separate these different conditions in the mapping process—they are generally mapped as ponds. The following is a general description of the more important pond features that occur on the simple barrier islands.

1. In regions without constructed dune-ridges, storm overwash channels flow through the frontal dune fields on the island berm crest of the UOR. These channels will frequently leave a series of shore-perpendicular, ephemeral ponds after the storm subsides. They will commonly fill in with subsequent wind blown sand or as a result of minor overwash events. These ponds initially contain salt water, but if they are persistent through time may become brackish and ultimately fresh water ponds controlled by rain and ground water.

2. Back-barrier berms that form on the platform marshes of the LOR are frequently breached by storm surges producing a series of smaller, elongate and shore-perpendicular tidal channels. After the storm surge recedes, the low depressions within the center of the tidal channels become a series of ponds in the back-barrier berms. These ponds tend to be more permanent and will generally contain salt water when they form but are quickly replaced and dominated by fresh water with time.

3. Active tidal channels between the platform marshes within the molar tooth structure on the LOR may become blocked on both the inside and outside as the fan delta sands build up and become stabilized by marsh grasses. Because these ponds are at MSL, they generally are reflooded by both spring and storm tides and generally remain brackish water through time.

4. Small, irregular, and shallow ponds occur frequently within the interior marshes of the MOR and the platform marshes of the LOR. In some marshes these ponds are extremely abundant and can form in several different ways.

a) Many platform marshes contain shallow ponds (< 0.5 m deep) that appear to form in response to large wrack accumulations, killing the underlying grasses. As the unvegetated patches in the marsh dry out, peat compaction in concert with possible oxidation of some peat, leaves shallow depressions that become water filled. This water is generally brackish with high salinity ranges from hypo- to hyper-saline depending upon season and weather conditions.

b) A few platform marshes appear to be in a constructive mode in which marsh grass is growing onto the shallow back-barrier sand shoals. The shallowest portions of the shoal have grown marsh grass leaving the slightly deeper areas (< 0.5 m) as ponds with gradual slopes around the edges. These ponds are interconnected with the adjacent estuary and have similar salinities.

c) Occasionally a platform marsh appears to be in a destructive mode with slightly deeper ponds (< 1 m). The edges of these ponds are erosional and consist of scarped peat that drops off abruptly into deeper water. This results in a platform marsh with a Swiss cheese fabric of ponds that have high salinity ranges from hypo- to hyper-saline depending upon season and weather conditions.

5. After an inlet through a barrier island closes, the flood-tide delta sand shoals quickly evolve into inter-tidal marsh islands that separate the many tidal channels occurring in a radiating pattern out from the main inlet channel. As the ocean shoreline recedes and the barrier migrates on top of the flood-tide delta, overwash begins to fill portions of the channels from the front side while storm surges fill portions of the channels from the estuarine side. What remains are long, linear, and relatively deep ponds that have varied orientations along the boundary between the MOR and LOR or occur within the flood-tide delta marshes.

Dominant Vegetation:
Vegetation in the ponds is undifferentiated on the maps. Also, no attempt was made to separate the different states of a pond (e.g., pond, marsh, algal flat) in the mapping process—they are mapped as ponds. (ECU Detailed Geomorphology Maps).

PF_trnv_rdge - Transverse Ridges

C. PF: TRANSVERSE RIDGES

Geomorphic Description:

Frequently, long, low, and fairly straight ridges form that are transverse to the barrier island. These transverse ridges can form in several different ways.

1. Waves on storm surge flood waters that are temporarily ponded on an overwash plain can rework the scattered and isolated dune sands into elongate beach ridges. When these beach ridges form they are often low (< 1 meter high), narrow (1 to 3 meters), and up to several hundred meters long.

2. Occasionally transverse ridges become large features that incorporate huge volumes of sand as elongate dune structures that run transverse across the UOR and MOR. These sediment-rich dune features may occur along active inlets on the inlet side of older inlet spits, or down-wind from unvegetated sandflats. In either case, during dry periods, aolian-driven sands accumulate along the edges of pre-existing structures. The sand is trapped and stabilized by dune vegetation. Subsequently, during stormy periods active overwash across the overwash plain or inlet spit can truncate the dune structure increasing the elongation and producing a complicated dune structure characterized by erosion and overwash blowouts. Large-volume transverse dune-ridges occurring within a barrier island may be important evidence for the existence of former inlets.

Dominant Vegetation:

Vegetation on the active transverse ridges consists of large unvegetated areas of exposed sand with some areas stabilized by *Uniola paniculata* (sea oat) and *Spartina patens* (salt meadow hay). However, the older and less active portions of transverse dune ridges will be vegetated with primarily scrub shrub including *Baccharis halimifola* (salt myrtle), *Iva frutescens* (marsh elder), *Myrica cerifera* (wax myrtle), *Ilex vomitoria* (yaupon holly), and *Juniper virginiana* (eastern red cedar). Old transverse ridges are dominated by maritime forests consisting of various *Pinus spp.* (pine), *Quercus virginiana* (live oak), and *Juniper virginiana* (eastern red cedar) that form an overhead canopy along with massive growths of various vines including *Smilax* sp. (cat brier), *Toxicodendron radicans* (poison ivy), and *Vius rotundifola* (muscadine grape). The shrubs and vines occur throughout the forest but their densest growth is generally near the periphery. (ECU Detailed Geomorphology Maps).

PF_dunef - Dune Field

E. PF: DUNE FIELD: DF

Geomorphic Description:

Frequently, if an island segment has very large sediment supply available, a natural dune field will form on top of the aeolian dune flat. In the Kitty Hawk to Whalebone Junction site, the paleo-Roanoke River delta deposits associated with previous climatic conditions and sea-level stands produced large supplies of sediment from which to build sediment-rich or complex barrier island segments. Consequently, much of this barrier segment is dominated by the extensive development of dune fields.

Island segments with large sediment supplies are dominated by aeolian processes during non-storm tide conditions when winds transport large volumes of sand landward of the island berm. This results in development of an active dune field with dunes ranging from 3 to 25 meters and greater. During pre-urbanization in the 1930s, some large individual dunes formed (e.g., Jockey's Ridge) that ranged up to 45 m in elevation. The dune fields are generally complex in geomorphic character consisting of depositional dunes produced by different kinds of storms (tropical storms, winter nor'esters, summer so'westers, etc.) with multiple wind directions. The dune fields are further complicated by severe erosional dynamics in concert with the influence of upper water tables that result from the wet temperate climate conditions, both producing abundant over-steepened slopes. These dune fields frequently over-ride forested habitats on the back side of the barrier which still further complicates the depositional, erosional, and stabilization patterns within the dune field.

The back barrier dune fields may contain numerous buried soil profiles. These buried soils reflect various shifts in past climatic conditions such as stormy and/or dry periods with fire resulting in an activation of dune deposition while non-stormy and/or wet periods resulting in vegetative stabilization of the dune fields (Havholm et al., 2004).

Dominant Vegetation:
The dominant vegetation on the natural dune fields pre-1930s was very different from the post-1930s vegetation character. Frost (2000) described the dominant vegetation based upon the regional photographs taken by the Wright Brothers between 1900 and 1912 in the Kill Devil Hills to Kitty Hawk island segments. At this time many of the natural dune fields were active and essentially barren of vegetation. This includes the dune fields in front of Kitty Hawk Woods and Kitty Hawk Bay and including the Kill Devil Hill, the dunes on the front side of Nags Head Woods and including Run Hill and Jockey's Ridge, and the Seven Sisters dune field in Nags Head Cove and The Village of Nags Head. The minor vegetation that did exist on these active dunes consisted of scattered grasses including *Spartina patens* (salt meadow hay). The swales between many of the dunes consisted of damp areas dominated by shallow fresh water ephemeral ponds that were dominated by algae and fresh-water wetland vegetation.

With establishment of the Kill Devil Hill National Memorial in 1928, work began in 1929 to stabilize the Kill Devil Hill active dune utilized by the Wright Brothers with grass. Construction of the monument on top of Kill Devil Hill was dedicated in 1932. The Memorial was turned over to the National Park Service in 1933 and designated a National Historic Landmark in 2001. (NPS Historic Structure Report, 2002).

In the past (pre-1970s), the dune fields (e.g., Seven Sisters) occurring closest to the ocean front tended to be the most active while those furthest from the ocean tended to be heavily forested (e.g., Nags Head Woods). By the early 1970s, urbanization of the ocean front became complete and quickly moved sound ward and into the natural dune fields. Soon the remaining Kill Devil Hills were developed followed by Nags Head Cove, the north end of Jockey's Ridge, and the Kitty Hawk dune field. Lastly the Village at Nags Head developed the southern half of the Seven Sister's dune field. The urban development in front of the dune fields cut off the sand source from the beach, modified and raised the wind field, and with the construction of houses, pavement, grass, and urban gardens and trees on the dunes themselves, quickly stabilized the active dune fields.

The major portion of Nags Head Woods dune field, which is situated on the back side of a wide island segment, has historically been heavily forested. Today, the high dunes generally contain a mature stand of mixed hardwood and pine forest with a perimeter zone of scrub-shrub on the low dune flank along the estuarine side. The scrub shrub zone generally constitutes the transition vegetation that occurs within the storm tide zone and grades down slope to the intertidal platform marsh of the LOR. (ECU Detailed Geomorphology Maps).

PF_algal_flt - Algal Flat

F. PF: ALGAL FLAT

Geomorphic Description:
In a natural, overwash dominated barrier segment dominated by recent overwash activity with a broad MOR, the lower supra-tidal portion may be dominated by an algal flat. This is particularly true when there is a well developed molar-tooth structure with tidal channels that dissect the LOR. The low elevation and high water table enable the irregular wind and storm tides to flood the MOR frequently with estuarine waters flowing through the tidal channels. This can result in the formation of vast algal mats on the supra-tidal portion of the flats. The algal flats form in response to highly fluctuating habitat conditions that can range from fresh ground water or rain water to hyper-saline waters due to local ponding and evaporation of ocean or estuarine waters. With time and subsequent overwash events, the elevation of the MOR increases and the irregularly flooded algal flats may be taken over by interior marsh or may shift to dry grass flats.

Algal flats can also occur in many other habitats and in smaller areas within a barrier island. Most of these occurrences are as ephermeral ponds or depressions characterized by fresh to hypo- to hyper-saline water conditions. As the water table within the ponds drops, the damp floor of the depression frequently will develop an algal mat. The algal mat periodically will get ripped up or buried by subsequent storm events. Hyper-saline ponds may evaporate leaving salt flats that become vegetatively zoned with *Salicornia bigelovi* (annual marsh glass wort), and *Salicornia virginica* (perennial marsh glass wort) forming rings around the periphery of the depressions and in turn may be surrounded by an outer zone of *Distichlis spicata* (salt grass) and *Borrichia frutescens* (sea oxeye). (ECU Detailed Geomorphology Maps).

PF_rdg_swl - Ridge and Swale

G. PF: RIDGE AND SWALE

Geomorphic Description:

Ridge and swale geomorphic units occur as sets of sub-parallel couplets consisting of low, regular sand ridges and adjacent shallow low swales. The sand ridges tend to be linear to slightly curved, uniform features that rarely exceed 3 m in elevation. The beach ridges are shoreline features that formed by either a temporary higher stand of sea level or a series of storm surge deposits. On the maps that contain ridge and swale structures, the ridge crests are marked by a white line with black edges.

In between successive beach ridges are the lower swales that represent beach deposition during periods characterized by either slightly lowered sea level or non-stormy periods. The swales are generally dominated by wetlands and are filling with organic peat deposits that are thickest on the estuarine side and thin up onto the subsequent ridge. Many of the swales, particularly in the estuarine direction, contain open water down the center of the low swale. Over the years, many of the swales have been dredged and opened up as navigational channels with the dredge spoil disposed either on the adjacent marsh or on the low flank of the adjacent ridge.

The most extensive and best developed sets of ridge and swale structures form Buxton Woods and Kitty Hawk Woods. Fisher (1967) recognized multiple sets of ridge and swale structures that occur at slightly different angles to the previous set bounded by a major erosional truncation. This suggests oscillating sets of events at several different time scales. Similar features occur on the land masses occupied by Ocracoke and Hatteras Villages. However, these ridge structures are rarely 2 m high, are spaced much further apart with wide marsh filled swales. In fact, many of the sand ridges have already been buried by the vertical growth of peat in response to the ongoing rise of sea level.

No ridge and swale structures are forming today on the northern Outer Banks. Rather, the ridge and swale structures that have been age dated indicate formation during a prior sea level highstand event (Mallinson et al., in review) that built a former barrier island sequence. These ridge and swale structures are not products of the present overwash-barrier island dynamics. Rather the remnant ridge and swale island segments were produced by processes prevailing in an earlier evolutionary stage of the barrier system. Most of the former barrier islands have since collapsed and started to reform the modern barrier islands about 500 years ago (Sager and Riggs, 1998; Riggs et al., 2000; Grand Pre, 2006; Culver et al., in review). Thus, the modern inlet and overwash dominated barrier island components have migrated into and become welded onto the older barrier island with its ridge and swale structures, exemplified by the Kitty Hawk Woods island segment.

Dominant Vegetation:

Because most of the ridge and swale structures are older and occur on the back side of barrier segments, they tend to be dominated by heavy vegetative cover, except where they have been urbanized. The sand ridges have historically been heavily forested with mature stands of mixed hardwood and pine. Since the sand ridges are not very high, the forest grades down-slope into an extensive growth of transition scrub shrub vegetation within supra-tidal zone where the adjacent swales are connected to the estuary.

The swales are dominated by wetland vegetation. Land-locked swales and those segments that are distant from the estuaries are dominated by swamp forests or linear ponds surrounded by swamp forest.

If the swale is connected to the estuary, the swamp forest sequentially grades towards the estuary from swamp forest to fresh-water marshes to brackish-water marshes. The brackish marshes generally have a fresh-water zone immediately adjacent to the ridges due to groundwater discharge from the adjacent sand ridge. This grades outward into a middle zone dominated by *Juncus roemerianis* (black needlerush) and a broad outer zone dominated by *Spartina cynusoiroides* (giant cord grass) in the low brackish estuaries, *Spartina patens* (salt meadow hay) in the middle brackish estuaries, and *Spartina alternaflora* (smooth cord grass) in the high brackish estuaries. (ECU Detailed Geomorphology Maps).

PF_overwash - Overwash Channel

PF: OVERWASH CHANNEL: OC

Overwash channels are shore-perpendicular features that may occur in between foredunes on the upper overwash plain. They are formed by ocean-side overwash events that scour inter-dunal channels and may become isolated, ephermeral ponds due to overwash deposition during the waning stages of a storm event. (ECU Detailed Geomorphology Maps).

Anthropic Features (AF)

AF_drdge - Dredged Channels/Spoils

C. AF: DREDGED CHANNELS/SPOIL

Geomorphic Description:

Any dredged channel or pit indicates removal of sediment. Sometimes the removed sediment was pumped or transported off site and deposited as fill material to raise land elevations for urban development. More often the sediment removed from dredged channels is deposited immediately adjacent to the structure being dredged. This results in either a linear ridge or a series of circular piles along one or both sides of the dredged channels. These dredge spoil piles generally raise the elevation of the adjacent land from a few centimeters up to 1 m and are generally mapped as one geomorphic unit with the dredged channel.

Dominant Vegetation:

If the spoil is utilized to raise land elevations for urban development, any kind of vegetation may result. However, if the spoil is placed within the marsh as linear ridges or concentric piles, the dominant vegetation will range from transition zone species, if it is still within the supra-tidal zone and including *Baccharis halimifolia* (salt myrtle), *Iva frutescens* (marsh elder), *Spartina patens* (salt meadow hay), and *Spartina cynosuroides* (giant cord grass) or scrub-shrub. If the spoil is above the supra-tidal zone, the vegetation will include *Myrica cerifera* (wax myrtle), *Ilex vomitoria* (yaupon holly), *Myrica pensylvanica* (northern bayberry), *Pinus spp.* (pine), *Juniper virginiana* (eastern red cedar), *Spartina patens* (salt meadow hay), *Smilax spp*. (cat brier), and *Toxicodendron radicans* (poison ivy). (ECU Detailed Geomorphology Maps).

AF_jetty - Rock Jetty

F. AF: ROCK JETTY

The rock jetty, such as occurs at Cape Lookout, is a structure made with boulders that is built perpendicular or oblique to a shoreline. The Cape Lookout jetty caused accretion of sand that elongated Power Squadron Spit towards Shackleford Banks and increased the areal extent of Cape Lookout Bight. (ECU Detailed Geomorphology Maps).

Sound Features (SF)

Sound Features include submarine sand bodies behind the barrier islands. They are included in the model because they are abundant and critically important features to barrier island evolution and to associated

estuarine ecosystems. The 1998 DOQQs for Core Banks are extremely high quality and clearly show these submarine features. Thus, they are mapped on the three Core Banks' sites, but are not presently included in the geomorphic maps on the other ten sites due to the poor resolution of the submarine shoals on many aerial photo sets, as well as the 1998 DOQQs. (ECU Detailed Geomorphology Maps).

SF_tidal_chn - Tidal Channels

A. SF: TIDAL CHANNELS

Geomorphic Description:

Within an active overwash plain, the headwaters of tidal creeks will be completely buried by the overwash plain. The water flow onto and off the overwash plain carries significant volumes with enough energy to erode the tidal creeks occurring between segments of the platform marsh. With time these portions of the tidal creeks are eroded laterally and vertically to produce the tidal channels between the platform marsh segments. The resulting geomorphology is that of the classic molar-tooth structure. These shore perpendicular tidal channels connect the MOR directly with the estuary and move overwash water off the island during ocean-overwash events, and carry estuarine storm-tide water into the algal flats and interior marshes on the MOR. The tidal channels tend to be deep (up to 3 to 4 m) and extend all the way through the Platform Marsh with steeply scarped, peat shorelines along the edges. Each end of the tidal channel (inner and outer edge of the LOR) shallows, flattens, and broadens out into small-scale deltaic lobes. (ECU Detailed Geomorphology Maps).

SF_up_shoal - Upper Shoals

A. SF: UPPER SHOALS

Geomorphic Description:

Shallow, sub-tidal sand shoals that range from 0 to -1 foot below mean sea level (MSL). Due to the dominance of wind tides within the NE North Carolina estuarine system, these upper shoals are frequently and irregularly exposed to sub-aerial conditions that extend over time periods that range from hours to many days.

Dominant Vegetation:

The surficial sediments on the upper shoals are generally bound by algae (microbial organisms) that inhibit sediment transport under non-stormy weather conditions. However, during high energy storms, and particularly during the winter, the bound surface can be disturbed allowing the sediment to be transported producing strandplain beaches, fringing berms, etc. on adjacent platform marshes. This ecosystem also contains an extensive population of burrowing infauna. (ECU Detailed Geomorphology Maps).

SF_low_shoal - Lower Shoals

B. SF: LOWER SHOALS

Geomorphic Description:

Shallow, sub-tidal sand shoals grade down slope from the upper shoals, range from -1 to -2 feet below mean sea level (MSL), and grade into deeper water. These shoals are rarely exposed to sub-aerial conditions and, then only during extreme storm events.

Dominant Vegetation:

The surficial algae decrease on the lower shoals and diminish the binding of surficial sediments. Thus, the unbound sediments are readily transported forming ripple marks and other micro-topographic features. Because the lower shoals are dominantly sub-aqueous, submerged aquatic vegetation (SAVs) becomes abundant. (ECU Detailed Geomorphology Maps).

SF_fld_tide- Flood-Tide Delta Shoals

C. SF: FLOOD-TIDE DELTA SHOALS

Geomorphic Description:

The flood-tide delta shoals are extensive back-barrier sand shoals and associated tidal channels that form on the estuarine side of active inlets though barrier islands. The shoals form is a broad fan-shaped geomorphic unit cut by a network of tidal channels that exchange water between the ocean and estuary. The flood-tide delta shoals are dynamic, responding to the regular astronomical tidal currents and storm tides that actively erode, transport, and deposit sediments throughout the shoal system. The surface morphology of the shoals is characterized by sedimentary structures that range from ripples to sand waves.

Dominant Vegetation:

In general, these geomorphic units are so active that they are not dominated by inter-tidal marshes, algae (microbial mats), or submerged aquatic vegetation. However, both on the outer perimeters and areas left behind a barrier as inlets migrate laterally, various levels of vegetation develop. Eventually abandoned flood-tide deltas develop various vegetative covers that include marshes on the inter-tidal shoals, algal-bound surfaces on the submerged upper shoals, and submerged aquatic vegetation on the lower shoals. (ECU Detailed Geomorphology Maps).

SF_tidal_del - Tidal Delta

E. SF: TIDAL DELTA

Geomorphic Description:

Platform marshes are often cut with shore-perpendicular tidal channels to produce molar-tooth structures on the LOR. Active tidal channels are flanked on the LOR and on the estuarine side by tidal deltas. Each end of the tidal channel shallows, flattens, and broadens out into deltaic lobes. The tidal deltas are deposited by sound-side flooding through the tidal channels and may be inter-tidal or supra-tidal sand bodies.

Dominant Vegetation:

Fine-grained sediments of the tidal deltas may be bound by algae (microbial organisms). Tidal deltas are sparsely to partly vegetated with *Spartina patens* (salt meadow hay). (ECU Detailed Geomorphology Maps).

Source Digital Geologic Maps

The digital geologic-GIS maps for Cape Lookout National Seashore, North Carolina (CALO) were compiled from the following sources:

NCGS Geomorphology Maps and Report (NCGS Geomorphology Maps)

Coffey, Brian P. and Nickerson, John G., 2008, Geomorphic Mapping of Cape Lookout National Seashore (CALO), NCGS digital publication, 17p. (*GRI Source Map ID 74878*).

Coffey, Brian P. and Nickerson, John G., 2008, Geomorphology of Portsmouth Island, Cape Lookout National Seashore, NCGS digital publication, plates 1, 2 and 3, scale 1:24,000

Coffey, Brian P. and Nickerson, John G., 2008, Geomorphology of the Shackleford Banks Area, Cape Lookout National Seashore, NCGS digital publication, plate 6, scale 1:24,000

Coffey, Brian P. and Nickerson, John G., 2008, Geomorphology of the South Core Banks Area, Cape Lookout National Seashore, NCGS digital publication, plates 4, 5 and 6, scale 1:24,000

ECU Detailed Geomorphology Maps and Reports (ECU Detailed Geomorphology Maps)

Ames, V., Dorothea and Riggs, Stanley R., 2007, Geomorphic framework of the North Carolina Outer Banks, East Carolina University, 112p. (*GRI Source Map ID 74876*).

Ames, V., Dorothea and Riggs, Stanley R., 2007, Model for Development of the Geomorphic Framework, North Carolina, East Carolina University, 80p.

Ames, V., Dorothea and Riggs, Stanley R., 2007, Geomorphic framework of the North Carolina Outer Banks (Drum Inlets Site digital data), East Carolina University, 1:10,000

Ames, V., Dorothea and Riggs, Stanley R., 2007, Geomorphic framework of the North Carolina Outer Banks (Hogpen Bay to Cape Lookout Site digital data), East Carolina University, scale 1:10,000

Ames, V., Dorothea and Riggs, Stanley R., 2007, Geomorphic framework of the North Carolina Outer Banks (Portsmouth to Cricket Island Site digital data), East Carolina University, scale 1:10,000

NCGS Geomorphology Report

Hoffman, Charles W., Coffey, Brian P. and Ward, Amy N., 2007, Geomorphic Mapping of Cape Hatteras National Seashore, NCGS digital publication, 15p. NPS_CALO_report_2007_NCGS.pdf (double-click link to launch the embedded PDF document).

ECU Detailed Geomorphology Report

The ECU reports can be viewed by clicking Model for the Development of the Geomorphic Framework NC OBX.pdf (model) and Geomorphic Framework North Carolina Outer Banks.pdf (double-click links to launch the embedded PDF documents).

GRI Digital Map Credits

This help file was developed and completed by Stephanie O'Meara (Colorado State University) for the NPS Geologic Resources Division (GRD), Geologic Resources Inventory (GRI) Program.

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