Natural Resource Management at South Topsail Beach, NC

by

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ABSTRACT

The undeveloped southern tip of Topsail Island, NC, known as South Topsail Beach, has been accreting land and extending southwest into New Topsail Inlet at the rate of approximately 100 feet per year for the past decade, growing to its current size of roughly 135 acres. The dynamic coastal processes that dominate this landscape create habitat that the federally threatened shorebird the piping plover (*Charadrius melodus*), the loggerhead sea turtle (*Caretta caretta*), and the annual plant seabeach amaranth (*Amaranthus pumilus*) depend on for survival. Human disturbance and loss of habitat due to shoreline stabilization are among the biggest threats to success of these species throughout their habitat range. This Masters Project, in the form of a management plan, seeks to address the needs of these threatened species, while allowing for traditional and passive recreational uses at South Topsail Beach.

In an effort to better understand shoreline change at this location, and to inform management recommendations for South Topsail Beach, a geospatial analysis using LIDAR (light detection and ranging) data was performed. Areas of erosion and accretion on both sides of New Topsail Inlet were identified and volumetric change was calculated for the years 1996 through 2005. Beach profiles were created to more closely examine spatial changes. Monitoring shoreline change over time can be used as a management tool to indicate habitat size and quality on a local level. On a broader scale, this type of analysis may be used to identify additional undeveloped dynamic inlet habitat appropriate for conservation.

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INTRODUCTION

South Topsail Beach is a privately owned tract of land located at the southern tip of Topsail Island in Pender County, NC, within the town limits of the Town of Topsail Beach. South Topsail Beach is currently zoned for "Conservation with Limited Residential" in the Town of Topsail Beach 2005 Core Land Use Plan. The Town of Topsail Beach is very interested in conserving all or a significant portion of the approximately 135-acre tract, and has employed the North Carolina Coastal Land Trust (Coastal Land Trust) to identify and implement a land acquisition strategy for South Topsail Beach. The Coastal Land Trust has identified multiple funding sources, and is working closely with the owners to negotiate a conservation strategy that preserves, at a minimum, a portion of the property.

If successful in negotiations with the owners and in raising the necessary funds, the Coastal Land Trust will transfer land acquired for conservation at South Topsail Beach to the State of North Carolina to be managed by NC Division of Parks and Recreation as part of Lea Island State Natural Area. The NC Division of Parks and Recreation will lease South Topsail Beach to the National Audubon Society for the purpose of natural resource management. The Town of Topsail Beach will obtain a right of way access easement from the State of North Carolina to South Topsail Beach for the purposes of law enforcement and public access.

If all or a portion of South Topsail Beach is acquired and incorporated into Lea Island State Natural Area, lands on both sides of New Topsail Inlet will be under conservation, and will be managed as a unified system. It is important to understand patterns of inlet movement and determine areas of accretion and erosion on both sides of New Topsail Inlet in order to better inform management decisions.

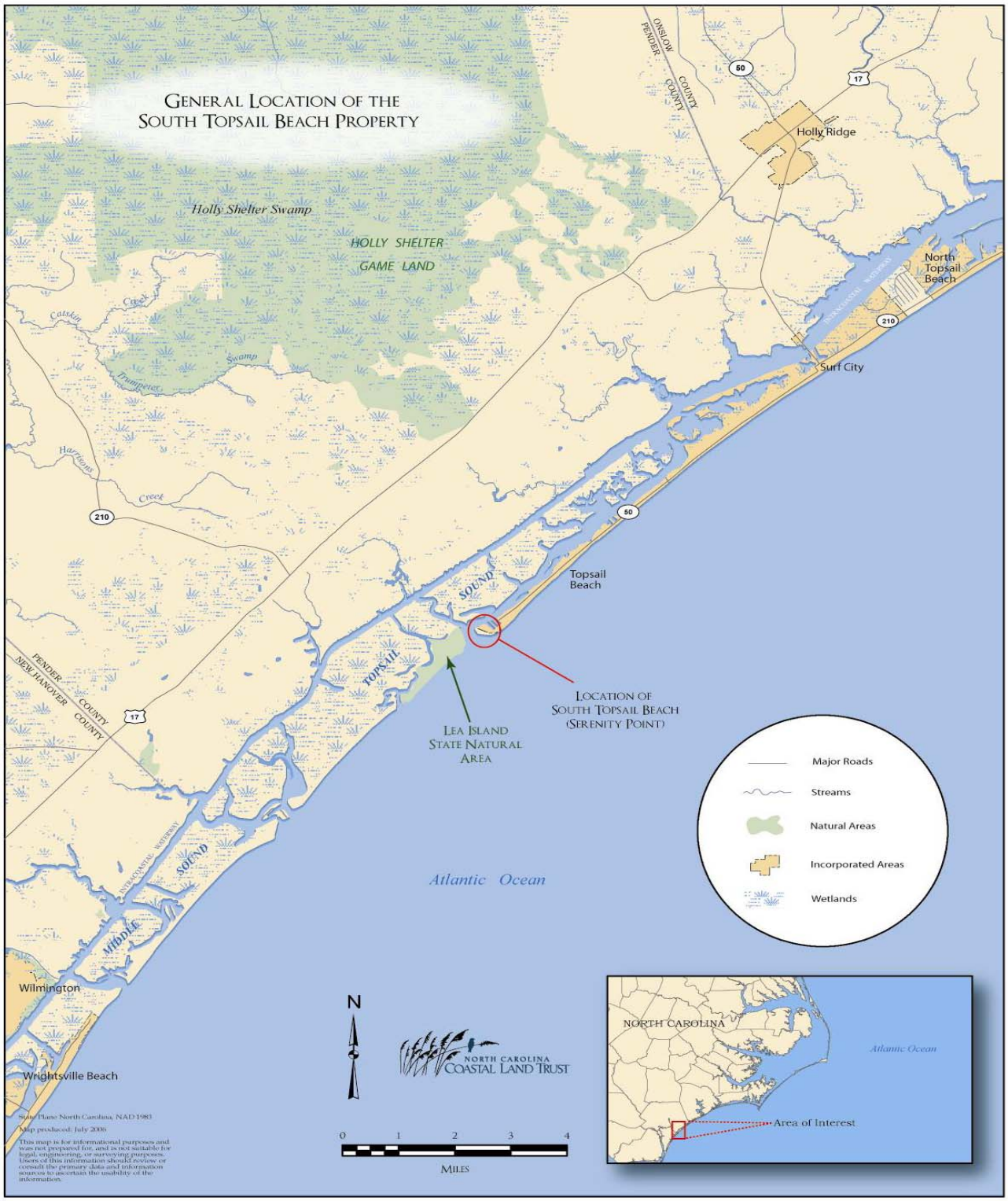


Figure 1. Location map of South Topsail Beach.

If movement of the inlet and patterns of accretion and erosion can be determined and quantified, the information can be used to cautiously predict future change in landscape. This knowledge is useful for informing future management decisions and policy. Hazard areas, or areas more prone to overwash events and erosion will be better defined and development can be placed outside of these areas and in areas more showing an accretion trend. Determining where overwash events are more likely to occur also identifies preferred shorebird and colonial waterbird nesting habitat. Determining patterns of fluctuation of the size of bird nesting habitat from year to year on both sides of New Topsail Inlet will help determine an indicator for habitat loss. This type of analysis can also be applied to total park acreage for recreational use. Actions such as habitat restoration and beach nourishment could then be considered when rates and patterns of erosion fall outside of acceptable limits.

Site Significance

South Topsail Beach is a rare example of undeveloped, privately owned barrier island beach. Positioned adjacently to New Topsail Inlet, this island spit has been accreting land at the rate of 100 feet per year for the past decade, growing to its current size of approximately 135 acres (Rogers, 2005). The dynamic coastal processes that characterize inlet and barrier beach systems create the upper beach, dune grass, and tidal flat communities. These communities support federally threatened species such as the piping plover, loggerhead sea turtle, and seabeach amaranth which have been documented to occur at South Topsail Beach.

The State of North Carolina identifies significant aquatic communities and natural resources within and surrounding South Topsail Beach. By conserving South Topsail Beach these waters and their inhabitants have an increased chance of being protected from pollution and runoff associated with development. Topsail Sound, located north of Topsail Island, and Middle

Sound, located north of the Lea/Hutaff Island complex are designated by the North Carolina Division of Water Quality (NCDWQ) as Outstanding Resource Waters (ORW). The waters of Banks Channel, running parallel and to the north of Topsail Island, are designated High Quality Waters (HQW) by the NCDWQ. Primary Fish Nursery Areas are identified by the NC Division of Marine Fisheries (NCDMF) for the waters of Middle Sound and Lea Island, as well as for the waters of Topsail Sound and Banks Channel. Located in the interior and northeast portion of South Topsail Beach are several freshwater coastal wetlands. The North Carolina Division of Coastal Management (NCDCM) has identified one of these wetland areas to be of Exceptional Significance (NCCLT, 2005).

The North Carolina Natural Heritage Program (NCNHP) has identified two Significant Natural Heritage Areas (SNHA) near South Topsail Beach. Lea Island/Hutaffs Beach, located across New Topsail Inlet from South Topsail Beach, is a SNHA of statewide significance, and Topsail Sound Maritime Forests is a SNHA of regional significance (North Carolina Natural History Program, 2006a). Plans are under way to have a field biologist from the NCNHP inventory South Topsail Beach for identification of elements qualifying the site for designation as a SNHA.

To qualify as a Significant Natural Heritage Area, a site must contain examples, or element occurrences, of rare natural communities, habitats, or species as identified by the Natural Heritage Program (North Carolina Natural Heritage Program, 2006b). Already, the NCNHP has documented five element occurrences within South Topsail Beach. These include the federally and state threatened piping plover (*Charadrius melodus*), the state significantly rare Wilson's plover (*Charadrus wilsonia*), the federally and state threatened plant seabeach amaranth

(*Amaranthus pumilus*), and a gull-tern-skimmer colony, a special animal habitat (Town of Topsail Beach, 2005).

Other important species present at South Topsail Beach include the federally and state threatened loggerhead sea turtle (*Caretta caretta*); the state threatened gull-billed tern (*Sterna nilotica*); species of state special concern the least tern (*Sterna antillarum*), common tern (*Sterna hirumdo*), and black skimmer (*Rhynchops niger*); and the American oystercatcher (*Haematopus alliates*), a state significantly rare species (NC Wildlife Resources Commission, 2004) (NCCLT, 2005). In addition, the United States Fish and Wildlife Service designates the southern tip of Topsail Island as critical wintering habitat for piping plovers (US Army Corps of Engineers, 2006).

Adult piping plover and chick.
Photo source: http://www.defenders.org/releases/pr2005/pr0805052.html

South Topsail Beach and its surrounding waters are encompassed by multiple Areas of Environmental Concern (AEC) as defined by the North Carolina Coastal Resources Commission (NCCRC) in the *CAMA (Coastal Area Management Act) Handbook for Development in Coastal North Carolina* (NCCLT, 2006). AECs at South Topsail Beach can be categorized into the Estuarine and Ocean System, or the Ocean Hazard System. AECs in the Estuarine and Ocean System include Public Trust Areas, Estuarine Waters, Coastal Shorelines, and Coastal Wetlands. Conservation of these areas protects fish and wildlife habitat, buffers development from flood damage and erosion, and provides the public with a place to boat, fish and swim. AECs in the Ocean Hazard System include the Ocean Erodible AEC, the High Hazard Flood AEC, and the Inlet Hazard AEC. These sites are highly susceptible to flooding and erosion from natural geological processes and storms. The main purpose for conservation of these AECs is hazard mitigation (NC Division of Coastal Management, 2005).

Other qualities that make this site significant are its public access and recreation values. Local residents and tourists have long favored this undeveloped beach for fishing and passive recreational use. As more of the North Carolina coast is developed and privatized, public access for pedestrians and boaters becomes scarce. Furthermore, South Topsail Beach is accessible by vehicle, while many public undeveloped beaches in North Carolina are accessible only by boat. It is important to protect undeveloped beaches for public use and enjoyment.

MATERIALS AND METHODS

Data

LIDAR data were downloaded from the NOAA Coastal Services Center Topographic Change Mapping web page. Data collected during 1996 through 2000 are from the Airborne LIDAR Assessment of Coastal Erosion (ALACE) Project, a partnership between NOAA, NASA,

and the USGS. These data-collecting missions were flown within a few hours of low tide on October 13, 1996, September 20 and 21, 1997, September 5, 1998, September 18 and October 8, 1999, and August 3, 2000 (CSC 2007).

LIDAR data for 2004 and 2005 were collected using the Compact Hydrographic Airborne Rapid Total Survey (CHARTS) system by the Joint Airborne LIDAR Bathymetry Technical Center of Expertise, a project lead by the US Army Corps of Engineers. These data-collecting missions collected both topographic and hydrographic data on August 28, 2004 and October 1, 2005 (CSC 2007).

Inlet shoreline data for New Topsail Inlet were downloaded from the NC Department of Environment and Natural Resources Division of Coastal Management Coastal Hazards GIS Data Download Page. These line shapefiles were digitized from aerial photographs and are available for the years 1934, 1944, 1971, 1973, 1974, 1976, 1984, 1992, 1995, 1997, 2000, 2003 and 2004 (DCM 2007).

Methods

LIDAR data was projected in the North American Datum 1983, Universal Transverse Mercator System Zone 18. An extent mask for raster analysis was created by intersecting data from 1996, 1997, 1998, 1999, and 2000 (Appendix A). Data from 2004 and 2005 were not included in the creation of a mask because data for the inlet opening were not collected for these years, and inclusion of the data from these years results in an incomplete extent mask. All analysis from this point forward was limited to the extent of this mask.

A surface showing continuous elevation was interpolated for each year from raw LIDAR data using the Inverse Distance Weighted method using a 10-meter radius, at the 2^{nd} power, with 6 minimum nearest neighbors and 5-meter cells. Cells with the value of "no data" in the 2004

and 2005 data rasters were amended to values of zero using a Single Output Map Algebra equation. Another Single Output Map Algebra equation was then applied to the surface elevation grids to change any values below sea level to zero, to keep the analysis restricted to sea level and above. Volumetric change was calculated with the Single Output Map Algebra tool by taking the difference between consecutive years, as well as the between 1996 and 2005 (Appendix B).

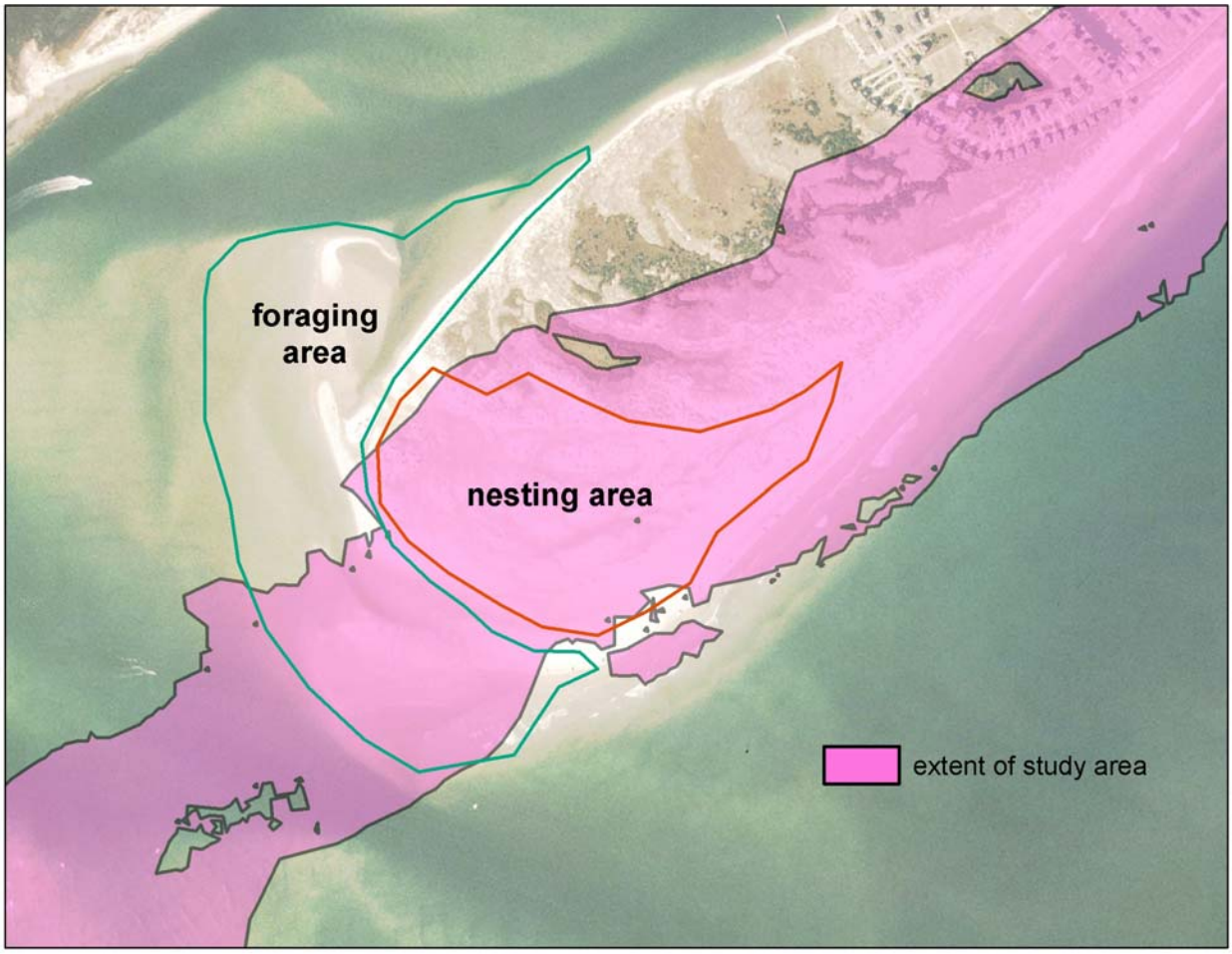


Figure 2. Close up of South Topsail Beach showing the extent of the analysis mask.

RESULTS AND OBSERVATIONS

Volumetric Change

The locations of elevation gain and loss is visible in Figure 3 below. Elevation change translates into volume change when elevation values for each cell are multiplied by cell area (5 meters by 5 meters). Volume gain (in green) is concentrated on the tip of South Topsail Beach as it accumulates into New Topsail Inlet. Conversely, volume loss (in red) is concentrated on the tip of Lea Island as it New Topsail Inlet migrates and the land erodes.

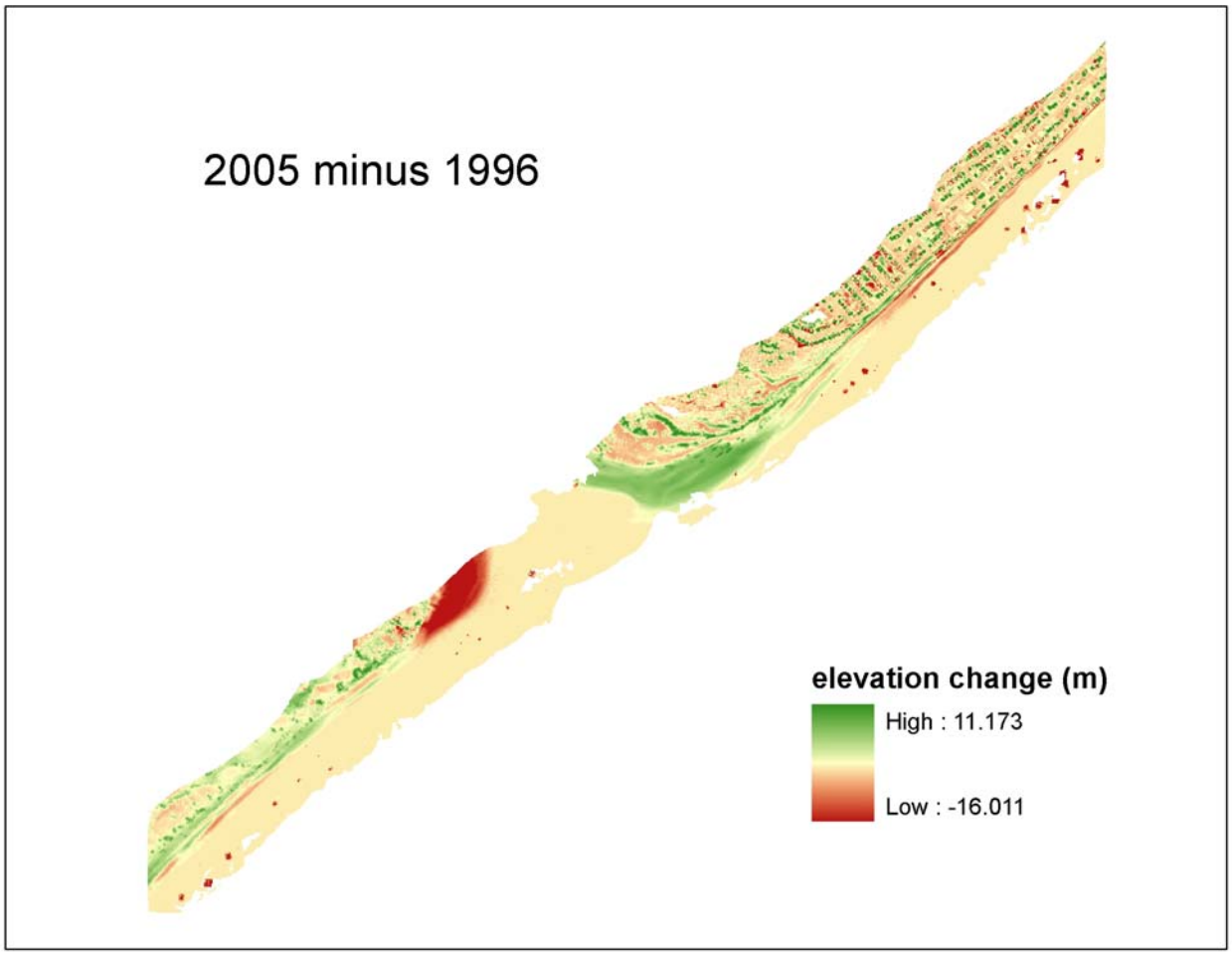


Figure 3. Locations of volumetric gains and losses between the years 1996 and 2005.

Volumetric change values between years, and for the entire time span of this analysis (1996 to 2005) is shown in Table 1 below. This analysis encompassed both sides of New Topsail Inlet:

the accreting South Topsail Beach side and the eroding Lea Island side. It is interesting to note that although there is a loss of volume between the years 1998-1999, 1999-2000, and 2004-2005, the overall trend for the 1996-2005 time period is for a volume increase. The total increase in volume is 283,659 cubic meters.

	96-97	97-98	98-99	99-00	00-04	04-05	96-05
volume change (m^3)	155,768	126,662	-95,561	-21,358	132,649	-25,769	283,659

Table 1. Volumetric change at New Topsail Inlet.

Spatial Change

Shoreline position for the years 1934, 1944, 1974, 1984, 1995, and 2004 is shown in Figure 4 below. The linear distance of shoreline accretion between the years 1974-1984, 1984-1995,

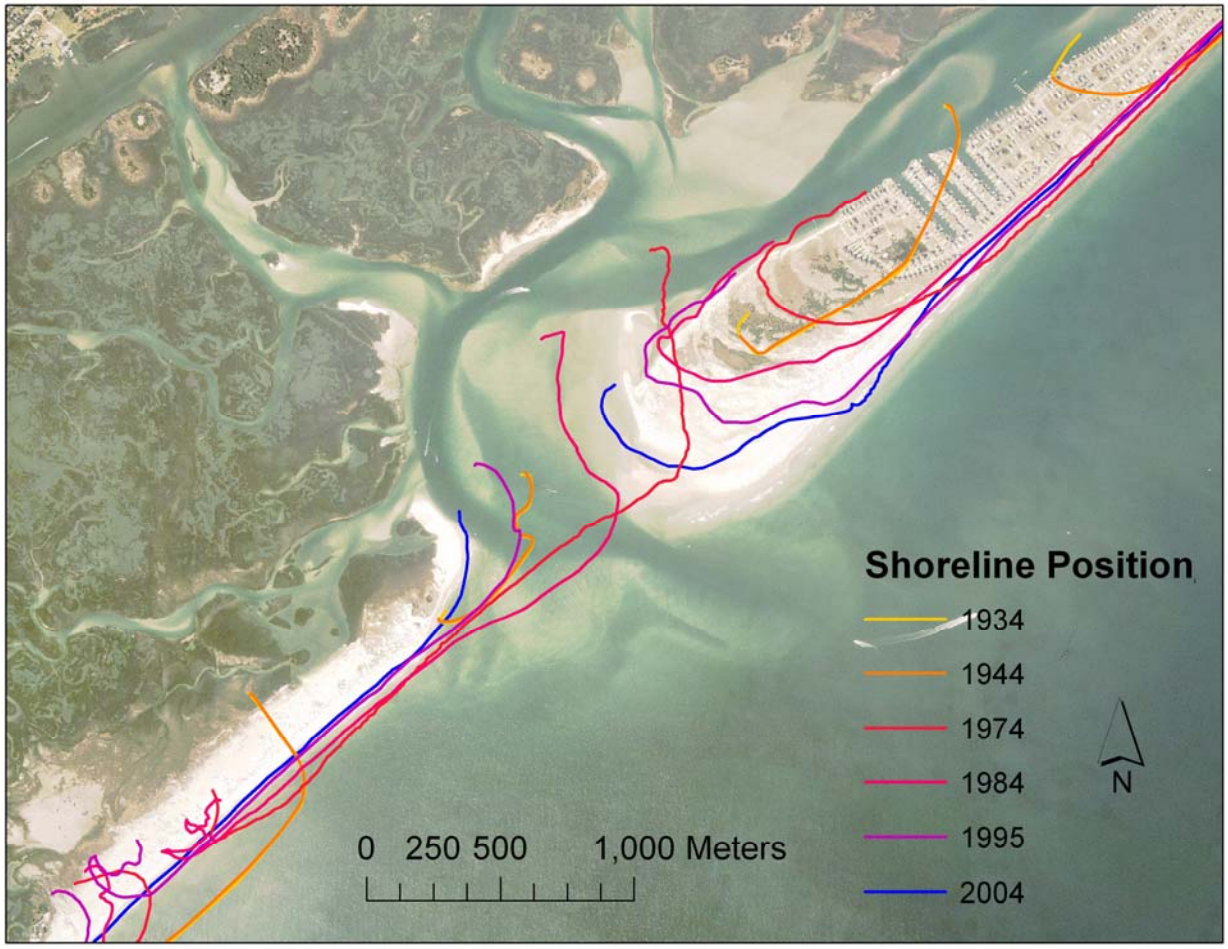


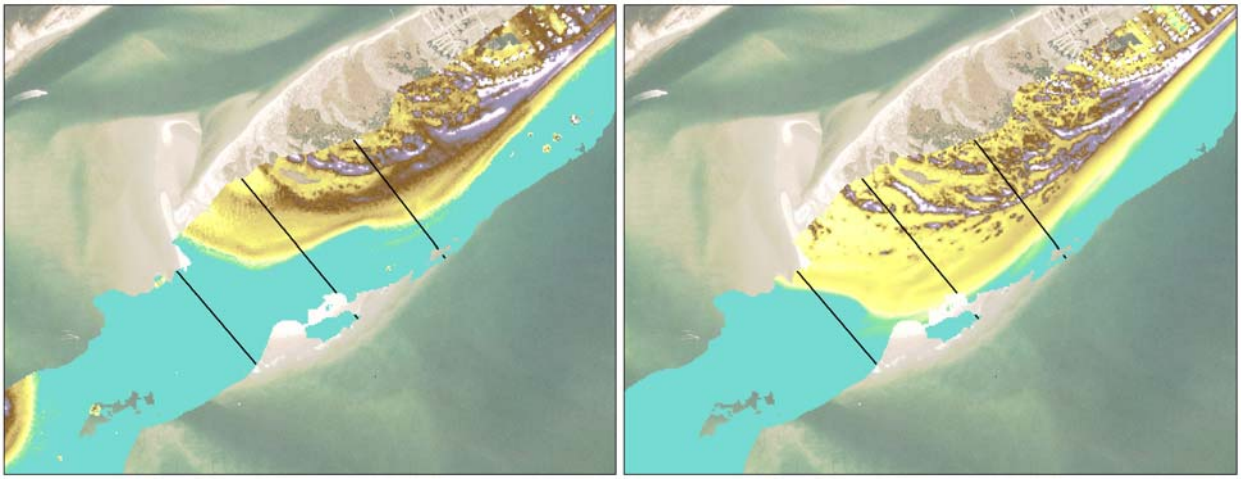
Figure 4. Shoreline position at New Topsail Inlet.

and 1995-2004 was measured using the measuring tool within ArcMap. Total linear accretion over the thirty year period between 1974 and 2004 is approximately 870 meters, with the average yearly linear accretion equaling 29 meters (Table 2).

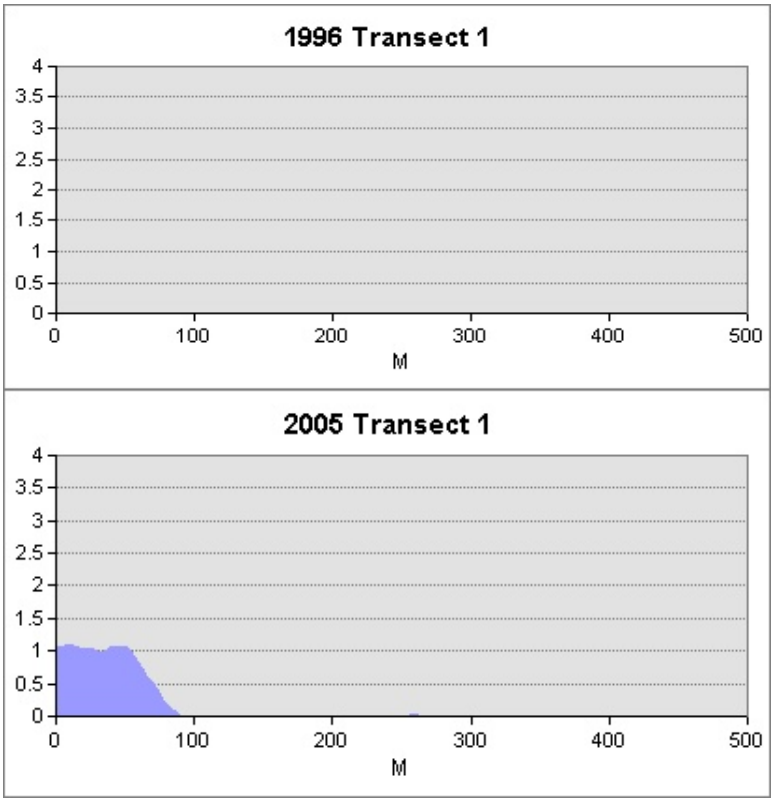
	1974-1984	1984-1995	1995-2004	total accretion 1974-2004	average accretion per decade	average accretion per year
approximate linear accretion (m)	445	100	325	870	290	29

Table 2. Accretion of shoreline at New Topsail Beach.

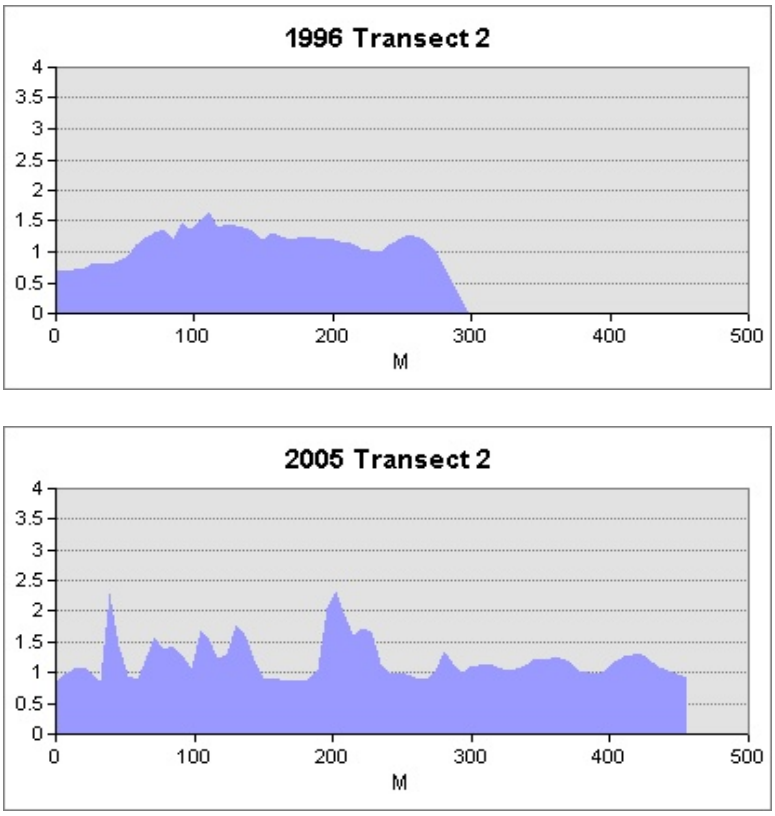
Three transects were inserted into three separate locations perpendicular to the shoreline within elevation grid maps for 1996 and 2005 (Figures 5 and 6). Each of the three transects are located in the same respective positions for both years in order to compare spatial change over time. Beach profiles were created with the ArcGIS Analyst tool for each of the three transects in both years (Graphs 1-6 below).



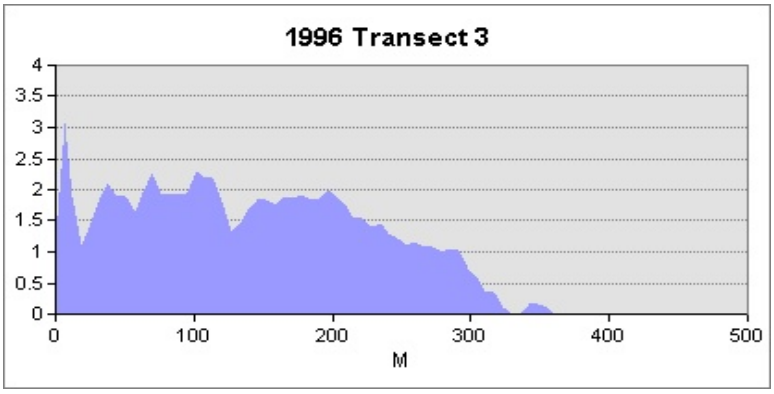
Figures 5 and 6. Transects over elevation grids for 1996 and 2005.

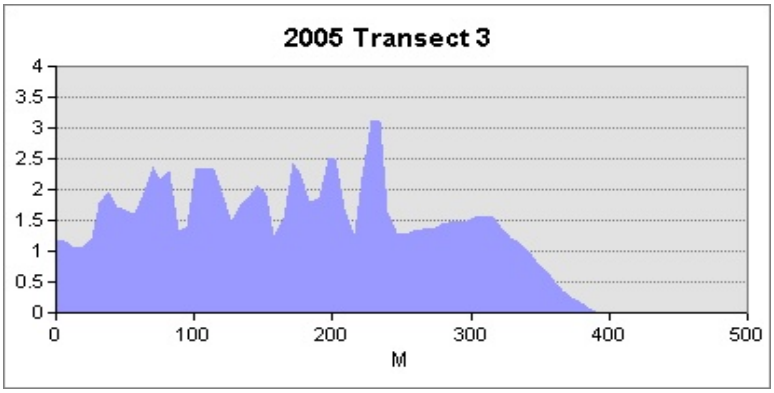


Graph 1 and 2. Transect 1, 1996 and 2005.



Graphs 3 and 4. Transect 2, 1996 and 2005.





Graphs 5 and 6. Transect 3, 1996 and 2005.

DISCUSSION AND CONCLUSIONS

GIS Analysis of Shoreline Change

The geospatial analysis of shoreline change at New Topsail Inlet shows that the trend since at least the 1940s is for New Topsail Inlet to migrate south-southwest. This action causes the adjacent tip of Lea Island to erode while South Topsail Beach continues to extend and grow south into the inlet waters. Although there is a net increase in potential bird habitat, unfortunately, it is the undeveloped prime bird habitat on the Lea Island side that is eroding. The accreting South Topsail Beach is under much higher pressure to be developed, and has a lot of visitor activity. This fact makes the need to conserve South Topsail Beach as open space even more pressing. If even a small portion of the tip of the accreting island is protected, North

Carolina law dictates that the owner of the land adjacent to the newly accreted land also owns the new land, meaning any new acreage would be owned by state of North Carolina.

This type of GIS analysis of shoreline change can be performed as new LIDAR data are collected. Monitoring shoreline change over time can be used as a management tool to indicate habitat size and quality on a local level. On a broader scale, this type of analysis may be used to identify additional undeveloped dynamic inlet habitat appropriate for conservation.

Management Objectives

The primary management goal for South Topsail Beach is to conserve the dynamic beach and inlet ecosystem and its inhabitant threatened species, while allowing for traditional and passive recreational uses. Of particular concern is the protection of shorebird and colonial waterbird species, specifically piping plovers. Public outreach and education, and a comprehensive resource management effort will play key roles in the breeding success of these birds.

The following is a list of specific management objectives for South Topsail Beach:

- To protect and enhance the viability of shorebirds, colonial waterbirds, and other plant and animal species through protection of existing habitat,
- To provide public access to the beach for passive recreational and traditional uses,
- To create new foraging habitat for shorebirds, specifically piping plovers,
- To balance traditional passive recreational use of the site with needs of threatened and endangered species,
- To protect and enhance the success of endangered and threatened species present on site through effective predator management,
- To remove and/or manage non-native invasive species, if any, and

- To raise public awareness through public outreach and education of the natural history of this site, specifically shorebird and colonial waterbird biology.

Recommended Actions

Habitat Protection

The dynamic coastal processes that characterize inlet and barrier beach systems create the upper beach, dune grass, and tidal flat communities that shorebird and colonial waterbird species depend on for nesting and foraging habitat (Schafale and Weakley, 1990). Many bird species present at inlet areas are federally or state threatened, including the piping plover. The shorebird and colonial waterbird nesting area at South Topsail Beach posted by the NCWRC in 2006, is located in the southern-most portion of the island, adjacent to New Topsail Inlet (see Habitat and Use map on p. 11 of this document). The nesting area, at approximately 45 acres in size, is located almost entirely below the State CAMA (Coastal Area Management Act) line, and is characterized by upper beach and dune grass communities. The federally threatened plant species seabeach amaranth colonizes the same areas in the upper beach community that shorebirds and waterbirds prefer to nest. Loggerhead turtles, also federally threatened, crawl up the upper beach and lay their nests at the base of dunes.

The upper beach is extremely dynamic and its existence is dependent upon periodic natural disturbance. Storm overwash events and wind cause sand to constantly shift (Schafale and Weakley, 1990). This flat, sandy area is sparsely vegetated and covered in shell fragments. The dune grass community is located inland of the upper beach, in areas more protected from storm overwash and wind. Dunes form when sand gradually accumulates around sand-binding plants. At South Topsail Beach there is a transition area between the upper beach community and dune grass community where dunes are interspersed with shell flats that have been created by

overwash events. Shelly overwash areas on the upper beach and between sand dunes are favored nesting areas for shorebirds and colonial waterbirds at South Topsail Beach.

Extensive estuarine intertidal flats extend off the tip of Topsail Island into New Topsail Inlet, as well as off the sound-side beach into Banks Channel. Intertidal flats are also extremely dynamic communities, constantly shifting and changing in size as a result of tidal currents, inlet migration, and other natural forces. Shorebirds and colonial waterbirds forage at intertidal flats and pools that are exposed during low tide. Piping plovers frequently lead their chicks to the edge of the pools located on the sound side of South Topsail Beach to forage for invertebrates living in the sand (NC Ecological Services, USFWS, 2006).

Although the current trend is for land to accrete at South Topsail Beach, coastal geological processes, especially in areas adjacent to inlets, are hard to predict. While South Topsail Beach has been steadily accreting land, across New Topsail Inlet the northeastern tip of Lea Island has been steadily eroding (Cleary and Marden). Moreover, Topsail Island beaches north of South Topsail Beach are steadily narrowing due to geological processes and gradual sea level rise. Millions of dollars are being spent on beach nourishment to protect development from the encroaching ocean (Parrish, 2006). However, beach nourishment and other efforts to stabilize beach and inlet systems, such as planting vegetation, installing sand fences, creating artificial dune lines, and constructing groins at inlets, disrupt the cycle of natural disturbance that is needed to maintain the upper beach and tidal flat communities.

Sound side beach and intertidal flats at South Topsail Beach.

Shelly overwash area at South Topsail Beach. Bird nesting habitat.

If all or a portion of South Topsail Beach is acquired and incorporated into Lea Island State Natural Area, lands on both sides of New Topsail Inlet will be under conservation, and should be managed as a unified system. Land on either side of the inlet may accrete or erode, but within the whole inlet system habitat will remain intact. The dynamic natural processes characterizing the inlet should be permitted to shape the landscape without intervention in order to best protect habitat on which threatened species depend.

New Topsail Inlet and surrounding lands.

Public Access

Currently, landowners of South Topsail Beach allow the public to access the property for passive recreational use. For a nominal fee, the Town of Topsail Beach is leasing a quarter-acre, 20-space parking lot from the landowners for free public use. The parking lot is located at the northeast corner of the South Topsail Beach property, directly adjacent to Banks Channel. From this lot visitors have easy walking access to the sound side beach and intertidal flats. Boaters gain entry to the sound side beach and intertidal flats via Banks Channel, often anchoring in shallow water and wading to shore. Visitors are also able to enter South Topsail Beach by walking (or driving, in the winter months) south along the ocean beach from public access points north of the site. The Town of Topsail Beach proposes acquiring land adjacent to any conserved portion of South Topsail Beach for construction of a new parking lot. The Town managed lot will be one-half to one acre in size and able to accommodate approximately fifty vehicles (E.Parrish, personal communication, July 2006).

Current public access point from parking lot to sound side of South Topsail Beach.

Historically, there has been strong demand for public access to South Topsail Beach, particularly to the sound side where there is strong competition between foraging shorebirds and visitors for use of the beach and its adjacent intertidal flats and waters. Currently, the majority of visitors arriving by vehicle recreate on the northeastern end of the sound side beach within 500 to 1,000 feet of the parking lot. This area of the beach is less critical for foraging shorebirds. However, if the northeastern portion of South Topsail Beach is privately developed, visitor use on the sound side may be concentrated further south towards the inlet, where shorebirds and colonial waterbirds frequently forage. The new parking lot should be positioned to direct visitor use away from foraging areas. Recommendations concerning the new parking lot and public access are as follows:

- Ideally, the new parking lot should be located adjacent to the ocean beach. Visitors will enter the property at the ocean beach and may continue to access inlet and sound side beaches by walking the length of the beach.
- If the new parking lot is located adjacent to the sound side beach, it should be placed where the current parking lot is located. Visitor use will continue to concentrate near the parking lot, on the northeastern portion of the sound side beach, where shorebird and waterbird foraging is less common.
- If the new parking lot is located adjacent to the sound side beach, but not at the site of the current parking lot, it should be located as far northeast as possible. Since visitor use will continue to concentrate near the parking lot, it should be partially removed from critical foraging areas.
- A modest parking fee could be collected by the Town of Topsail Beach to fund enforcement of town ordinances at South Topsail Beach.

- Boaters may continue to access the sound side beach and intertidal flats that are not designated as shorebird foraging areas (discussed further in Visitor Use section of management plan).

Depending on the configuration of land that is acquired for conservation, the Town of Topsail Beach may need to obtain right-of-way access easements to allow public access to South Topsail Beach. If land purchased for the new parking lot is not directly adjacent to the conserved land, the Town will need to obtain a right-of-way access easement from parking lot to the conserved land or adjacent ocean beach from which the property can be entered. The Town may also need to obtain a right-of-way access easement for an access road that would leads through privately developed property to the parking lot. The road to the parking lot should traverse uplands, avoiding wetland areas.

Visitor Use

The most popular recreational activities of visitors to South Topsail Beach include swimming, sunbathing, fishing, beachcombing, walking, dog walking, boating, and exploring the extensive intertidal flats and pools at low tide. Families with small children frequently set up chairs and umbrellas on the sound side beach where wave energy is lower and the water is shallower than on the ocean side beach.

As previously mentioned, many visitors arriving by vehicle recreate on the northeastern end of the sound side beach within 500 to 1,000 feet of the parking lot. However, many visitors walk along the length of the sound side beach to reach the intertidal flats and pools present near the inlet, areas preferred by shorebirds and colonial waterbirds for foraging. Boaters make use of the entire sound side shoreline, anchoring near shore and at the edges of intertidal flats. Visitors also

access South Topsail Beach by walking along the ocean beach from public access points to the north. In winter months vehicular access to South Topsail Beach is permitted for the purpose of fishing.

Visitors recreating on the sound side at South Topsail Beach.

Visitor Use and Shorebird and Colonial Waterbird Management

Nesting and foraging shorebirds and colonial waterbirds are sensitive to the presence of humans, and are especially disturbed by the presence of dogs. The nesting area at South Topsail Beach is approximately 45 acres in size and encompasses flat, shelly overwash and dunes at the southern tip of the island. Shorebirds and colonial waterbirds nest directly on the ground and line their nests with shell fragments. This disguise makes the nests very vulnerable to being trampled. Chronically disturbed birds will abandon nests, and if repeatedly unsuccessful they will abandon the nesting area permanently.

Shorebirds and colonial waterbirds forage on the beaches and intertidal flats at the southwestern end of the sound side beach and adjacent to New Topsail Inlet. There is strong competition between shorebirds and visitors for use of these areas. Unleashed dogs may chase birds and kill chicks, but even when dogs are leashed, their presence is enough to disrupt and deter birds from foraging (USFWS, 1996a). This is especially detrimental for precocial piping plover chicks, which must forage for food shortly after hatching (USFWS, 1996a). Rather than foraging, chicks expend energy evading dogs and pedestrians, often resulting in chick fatality (S. Cameron, personal communication, June 2006).

Nesting areas and key foraging areas at South Topsail Beach must be posted and/or enclosed to discourage visitors from accessing these areas. Posted areas should be monitored daily throughout the nesting season to ensure birds are able to nest and forage without disturbance. Recommendations for posting nesting and foraging areas are as follows:

- Survey South Topsail Beach for shorebird and colonial waterbird nesting area early each spring.
- Enclose and post shorebird and colonial waterbird nesting area for the duration of nesting season, April 1 to August 31.
- Enclose and/or post key foraging areas to discourage use by pedestrians and boaters. Enclosed area could consist of a relatively small portion of the sound side and inlet beach, and easily navigated around. Foraging areas would only need to be posted for a short period in the summer months.
- Monitor nesting and foraging areas on a daily basis throughout the nesting season to identify and remedy sources of disturbance to birds.

- Maintain constant staff or volunteer presence at South Topsail Beach to educate visitors about and promote respect for posted nesting and foraging areas.

Enclosed and posted bird nesting area at South Topsail Beach, 2006.

Additionally, the Town of Topsail Beach ordinances regulating visitor behavior must be consistently enforced for shorebird and colonial waterbird viability at South Topsail Beach. Enforcement of ordinances is currently, and will continue to be, the responsibility of the Town of Topsail Beach Police Department. Town of Topsail Beach ordinances require dogs to be leashed at all times from May 15th through September 30th, and under voice command the remainder of the year (Town of Topsail Beach, 2006) NCWRC employees have observed visitors to South Topsail Beach taking their dogs off-leash on the sound side. When NCWRC employees approach dog owners concerning their off-leash dogs they explain the vulnerability of

shorebirds and waterbirds to dogs. Most dog owners are very understanding and agree to leash their dogs. Education efforts to raise public awareness about these issues is needed and discussed further under the Education and Outreach management goal in this plan. Recommendations concerning dogs and South Topsail Beach are as follows:

- Prohibit dogs from South Topsail Beach year round. Audubon North Carolina is successfully managing the Wrightsville Beach Waterbird Management Area in this manner (Golder, 2006).
- If dogs are allowed to enter South Topsail Beach, require them to be leashed at all times day and night, year round.
- At the very least, require dogs to be leashed from April 1st to August 31st, during shorebird and colonial waterbird nesting season. The current ordinance requires owners to leash dogs from May 15th through September 30th. Revise existing ordinance to more accurately reflect bird nesting season.
- Actively and consistently monitor visitors with dogs and enforce ordinances governing the leash law.

Visitor Use and Sea Turtle Management

The North Carolina Wildlife Resources Commission coordinates and oversees the management of sea turtles in NC. Through the NC Sea Turtle Project volunteers monitor and protect sea turtles and their nests. The Karen Beasley Sea Turtle Rescue and Rehabilitation Center, located in the Town of Topsail, monitors sea turtle activity for all Topsail Island oceanfront beaches. Executive Director, Jean Beasley, has the authority through a sea turtle permit issued by the NCWRC, to monitor and coordinate the sea turtle volunteer program for Topsail Island, and

abides by guidelines set forth by the NCWRC in the *Handbook for Sea Turtle Volunteers in North Carolina*. According to Matthew Godfrey, sea turtle biologist with the NCWRC, Jean Beasley and the Sea Turtle Center would continue to work with the NCWRC to manage and monitor sea turtle activity at South Topsail Beach should it become part of Lea Island State Natural Area (M. Godfrey, personal communication, 7/27/2006).

Currently, the Town of Topsail Beach permits driving on the hard sand beach for the purpose of fishing only, between October 1st and March 31st (Town of Topsail Beach, 2006). Sea turtle nesting season is April 1st through November 15th. To enhance protection of late-season turtle hatchlings from vehicular disturbance the following recommendations are being made:

- Permit access starting November 15th to more accurately reflect sea turtle activity on the beach (M. Godfrey, personal communication, 7/27/2006).
- If nests have not hatched after the date of allowable vehicular access, give nests a 50-foot radius buffer, and keep vehicles out of a 50-foot wide area from the nest to the ocean from late afternoon until morning. Smooth out tire ruts within the 50-foot wide corridor to allow easy passage of hatching sea turtles (NC Wildlife Resources Commission, 2006).

Sea turtles, especially hatchlings, are sensitive to artificial light sources on the beach. Sea turtles hatch from their nest at night and crawl towards moonlight reflecting off the surface of the ocean. Lighting from housing, hotels, street lamps, and other sources that are visible from the beach can confuse the hatchlings and cause them to crawl away from the ocean rather than towards it. Currently in the Town of Topsail Beach, nighttime lighting issues are dealt with on

an individual basis, rather than through town ordinances (M. Godfrey, personal communication, 7/27/2006). The following are recommendations concerning lighting issues and sea turtle management at South Topsail Beach:

- Extinguish or dim light sources near the ocean beach at night during sea turtle nesting season, April 1st through November 15th.

Visitor Use and Seabeach Amaranth Management

Seabeach amaranth grows on the upper beach in overwash areas, often in the same areas that piping plovers prefer to nest. Because of their close association, habitat management for piping plovers benefits seabeach amaranth, and vice versa (US Fish and Wildlife Service, 1996b). Dale Suiter, endangered species biologist with the US Fish and Wildlife Service, is not in favor of posting individual plants for aesthetic and recreational reasons (D. Suiter, personal communication, 6/14/2006). From April 1st through August 31st, posted shorebird and colonial waterbird nesting areas also serve as protection for the plants. However, seabeach amaranth fruits and seeds in late summer into fall, after signs posting the bird nesting area have been removed reasons (D. Suiter, personal communication, 6/14/2006). This leaves plants vulnerable to vehicles that are able to gain access to the beach starting October 1st. It is important to protect the seed bank so that future generations of seabeach amaranth are successful reasons (D. Suiter, personal communication, 6/14/2006). In order to protect seabeach amaranth the following recommendations are being made:

- Survey South Topsail Beach to locate seabeach amaranth communities.
- Permit access starting November 15th to more accurately reflect seabeach amaranth life cycle (M. Godfrey, personal communication, 7/27/2006).

- Post significant populations of seabeach amaranth that are vulnerable to vehicular disturbance.

Seabeach amaranth, a federally threatened species.
Photo by Bill Adams

Habitat Enhancement

The creation of foraging ponds for shorebird and colonial waterbird use should be strongly considered for implementation at South Topsail Beach. The sound side beach and extensive intertidal flats extending to the southwest are the preferred foraging sites for these birds, and are also some of the most heavily used sites by visitors. A portion of these foraging areas should be enclosed and posted to allow birds and their chicks to forage undisturbed. However, it is unknown if this tactic will offer enough protection from disturbance by pedestrians and dogs, for chicks to be successful, specifically piping plover chicks. Furthermore, while enclosing these sites meets conservation goals, it restricts recreational use of some of the more popular spots at South Topsail Beach. Creating a foraging pond on the interior of the island within the shorebird nesting area could help achieve balance between these conflicting land uses.

The United States Army Corps of Engineers created two foraging ponds in 2005 as part of the Lower Cape May Meadows ecosystem restoration project at Cape May, New Jersey (U.S.

Army Corps of Engineers, Philadelphia District, 2005). The ponds are 1.4 acres and 2.5 acres in size, and are excavated to a depth of one to two feet. Minimum vegetation was planted around one of the ponds (U.S. Army Corps of Engineers, Philadelphia District, 2005). Located inland from the ocean and behind dunes, these ponds are extensions of freshwater wetlands already present at the site. Ponds filled naturally with freshwater from ground sources. However, the pond water tested positive for salinity, possibly as a result of dune relocation for the construction of the pond. Foraging ponds may contain either fresh or brackish water. The most important factor for pond success is the presence of invertebrates, the food source for foraging birds. Invertebrates need consistently moist soil to survive. Ponds do not need to have a constant supply of standing water for invertebrates to be present (B. Brandreth, personal communication, 8/07/2006).

In 2005, piping plovers discovered the ponds and foraged there during the 2005 and 2006 nesting seasons. All broods of piping plovers forage at the created ponds, and some chicks feed at the exclusively at the ponds. The birds do not appear to have a preference for either the vegetated or the unvegetated pond (B. Brandreth, personal communication, 8/07/2006).

Mr. Joe Pratt of The Nature Conservancy experimented with different configurations of pond construction in 2001 and 2002. Mr. Pratt excavated six plots, all measuring 6 m by 2 m by .25 cm deep, with a 10 cm berm built around the perimeter. Some of the plots were lined with plastic, some not, and all were pumped full of freshwater from a nearby pond. Fresh algae and fish emulsion nutrient treatments with added to selected plots. Mr. Pratt found that plastic liners did not make a significant difference in moisture level of the plots. He also found that only plots with added nutrients attracted invertebrates; invertebrates did not establish in plots with only water. The New Jersey Division of Fish and Wildlife used results from Mr. Pratt's experiment to

design a similar experiment at Barnegat Inlet in New Jersey. The ponds were created in natural depressions directly on the upper beach, and mini-wells with solar pumps supplied groundwater to the ponds (Kisiel, 2005) (B. Brandreth, personal communication, 8/07/2006).

Many uncertainties remain about the optimal design of foraging ponds. Questions concerning pond dimensions, location of ponds, water source, attracting invertebrates, planting vegetation, and predator use of ponds have not yet been answered. However, experiments and current projects appear to show that pond design is flexible and site-specific. It is important to thoroughly research other attempts to create foraging ponds to inform pond design at South Topsail Beach.

Predator Management

Predators of Shorebirds and Colonial Waterbirds

Red fox (*Vulpes vulpes*) predation of shorebird and colonial waterbird nests has been identified as a significant cause of reproductive failure of bird populations at South Topsail Beach (S. Cameron, personal communication, July 2006). Foxes predate on eggs, chicks, and occasionally on adult birds. Sue Cameron, waterbird biologist with the NC Wildlife Resources Commission (NCWRC) identified and documented fox tracks within the posted nesting area during the 2006 nesting season, with the frequency of track sightings increasing as the season progressed. It is Ms. Cameron's opinion that fox predation caused a large colony of least terns to eventually abandon the nesting area late in the season with very little reproductive success (S. Cameron, personal communication, 7/18/2006). The following are recommendations concerning fox predation on shorebird and colonial waterbird populations:

- Document evidence of fox predation. Examples of fox predation include tracks, broken eggs, and dead adult birds or chicks.

- Identify locations of fox dens near or at South Topsail Beach.
- Trap and remove foxes from the vicinity of South Topsail Beach (W. Golder, personal communication, July 2006). Must obtain landowner permission if fox dens located on private property.

Red fox, a shorebird and colonial waterbird predator.
Photo from http://www.fws.gov/

Gulls are another predator of shorebird and colonial waterbirds at South Topsail Beach. Gulls predate on eggs and chicks, and pose a threat by out-competing other bird species for nesting sites. Both gulls are attracted to human garbage, and it has been observed that gull numbers increase as the summer season progresses and visitor use of the site increases. Predation on birds by raccoons has not been documented at South Topsail Beach, but they are present on Topsail Island and could pose a threat in the future. Like gulls, raccoons are attracted to human garbage and similar recommendations to discourage their presence apply. The following measures should be taken to discourage gull and raccoon presence and predation at South Topsail Beach (US Fish and Wildlife Service, 1996a):

- Keep South Topsail Beach and surrounding area free of litter and garbage. Empty on-site garbage cans at the end of every day.
- Discourage visitors that fish from leaving fish guts and scraps on the beach.
- Discourage visitors from directly feeding gulls through public education.

Although not yet observed at South Topsail Beach, feral and free-roaming house cats are potential predators of shorebirds and colonial waterbirds. Two feral cat colonies are known to exist in the Town of Topsail Beach, one at Topsail Realty, 712 S. Anderson Blvd., and the other at Godwin's New Topsail Market, 721 S. Anderson Blvd. Both are approximately 2.25 miles north of bird nesting areas on South Topsail Beach (J. Beasley, personal communication, 6/02/2006). It is not known how far feral cats roam from the site of their colony, however, territorial male cats have been documented to roam within a mile radius, and a two-mile radius is not implausible (S. von Oettingen, personal communication, 7/17/2006). If cat predation on birds becomes a problem at South Topsail Beach the following recommendations should be considered:

- Document evidence, such as cat tracks, of cat predation. Examples of cat predation include tracks, broken eggs, and dead adult birds or chicks.
- Trap and remove feral cats from the vicinity of South Topsail Beach. Must obtain landowner permission if cats are located on private property.
- Educate local cat owners about cat predation on birds and encourage them to keep pet cats indoors.

Cat trapping and removal may create a sensitive situation as feral cats have strong advocates in the local community. Operation Topcat is a Trap, Neuter and Return (TNR) group working out of Sneads Ferry, NC helping local caretakers manage feral cat colonies. TNR is a method by which feral cats are trapped, neutered, their ears notched for identification purposes, and returned to their original cat colony where they are fed and monitored by a caretaker. If the predating cats are from a TNR colony, strong opposition could arise over the trapping and removal of the cats. It is important to determine a destination for cats that are trapped so that they are not released back into nesting areas. A local animal shelter is a possible destination for trapped cats.

Predators of Sea Turtles

Predation on sea turtles at South Topsail Beach is not currently an issue (M. Godfrey, personal communication). However, the potential exists for predation by raccoons and foxes. Evidence of raccoon predation has been identified on Lea Island, across New Topsail Inlet from South Topsail Beach (M. Godfrey, personal communication). In case of sea turtles predation the following recommendations should be considered (NC Wildlife Resources Commission, 2006):

- Place a 1-yard square wire screen on the surface of the ground over the turtle nest. The wire screen should have a 2 inch by 4 inch mesh.
- Cover wire screen with sand to hide from view.

Consumers of Seabeach Amaranth

Herbivory by caterpillars of moth species, or webworms, has been documented to impair reproductive success of seabeach amaranth populations, but is not currently a threat to populations at South Topsail Beach (D. Suiter, personal communication, 6/14/2006). Dale Suiter, endangered species biologist with the US Fish and Wildlife Service, has noted that while

webworms may eat seabeach amaranth leaves, the plants are still able to flower and fruit (D. Suiter, personal communication, 6/14/2006). If seabeach amaranth at South Topsail Beach is predated on by webworms to the point of reproductive failure the following recommendations may be considered (US Fish and Wildlife Service, 1996b). In a small population, manually remove webworms from seabeach amaranth plants.

- If needed, apply biological control BT *(Bacillus thuringensis)*, a relatively benign biological control.

Invasive Species Control

There are no known invasive species present at South Topsail Beach. However, the non-native, invasive plant species beach vitex (*Vitex roundifolia*) is present in several locations on Topsail Island, and is spreading throughout coastal North and South Carolina. This salt and drought tolerant plant was initially introduced as a landscaping plant and fast-growing dune stabilizer. However, the ability of beach vitex to bind sand makes it a threat to many species dependent on dynamic nature of the upper beach community such as the piping plover, and seabeach amaranth.

Flowering beach vitex, an invasive species on the NC coast.
Photo from http://www.beachvitex.org

The Carolinas Beach Vitex Task Force keeps detailed records of plant location and tracks the spread of Beach Vitex throughout North and South Carolina. David Nash is the Coordinator for the NC Beach Vitex Task Force. It is important to notify the Mr. Nash of plant locations and involve the task force in the management of this invasive species. New plants grow from root and stem cuttings as well as seeds making it difficult to eradicate. The task force will provide guidance about proper removal techniques. The following are recommendations concerning beach vitex control:

- Survey South Topsail Beach for beach vitex every year.
- Identify and remove plants before it flowers and sets seed. Remove fruits if not able to remove entire plant.
- Notify and consult with the NC Beach Vitex Task Force about plant location and removal techniques.
- Educate public and discourage from planting beach vitex.

Education and Outreach

Intense recreational use of South Topsail Beach provides the need for, as well as the opportunity for, a strong public education and outreach program. South Topsail Beach offers the rare chance to explore undeveloped barrier beach communities, and to learn about and observe rare and threatened species. Shorebird and colonial waterbird success is particularly dependent on the understanding and cooperation of visitors. Educational tours, kiosks, and pamphlets are effective means to achieve education and outreach goals.

The Wrightsville Beach Waterbird Management Area at the north end of Wrightsville Beach, in New Hanover County, NC is similar to South Topsail Beach in habitat and management requirements and is a strong model for education and outreach efforts (W. Golder,

personal communication, July 2006). Throughout the summer, the staff of Audubon North Carolina offers free weekly tours to the public of this undeveloped barrier island spit. These tours educate the public about waterbirds, sea turtles, native plants, and many other aspects of barrier island ecology (Golder, 2006). South Topsail Beach would greatly benefit from a similar program. Elements specific to South Topsail Beach that could be included or discussed as part of an educational tour include:

- The shorebird and waterbird nesting areas. These provide and excellent opportunity for bird watching.
- The expansive intertidal flats that extend into New Topsail Inlet and Banks Channel. Visitors gravitate to these flats to explore and recreate.
- Sea turtle nesting sites on the ocean front beach.
- Upland freshwater wetland communities.

In addition to tours, information kiosks and brochures can educate visitors about the natural history of South Topsail Beach, as well as provide guidance on how to help threatened and rare species be successful at the site. Potential topics for interpretation at kiosks and in brochures include:

- Shorebird and colonial waterbird identification, biology, and threats to success. Audubon produces *The Colonial Waterbirds of North Carolina,* a brochure specific to the NC coast (Golder, 2006).
- Dogs and their negative effect on nesting and foraging shorebirds and waterbirds.

- Seabeach amaranth and beach vitex identification and facts. The Carolinas Beach Vitex Task Force distributes a wallet-sized information card called *Beach Vitex Kudzu of the Coast* (D. Suiter, personal communication, July 2006).
- Predators and human garbage: how to keep gulls, foxes, and raccoons at bay.

Stewardship and Monitoring

Sue Cameron of the NC Wildlife Resources Commission (NCWRC) has been monitoring shorebird and colonial waterbird activity at the site for several years, but 2006 is the first time in many that the NCWRC obtained permission from landowners to enclose and post the nesting area. If all or a portion of South Topsail Beach is acquired, the State of North Carolina will lease the conserved portion to the North Carolina State Office of National Audubon Society (Audubon North Carolina) for purposes of colonial and waterbird management. Audubon North Carolina is successfully managing many nesting areas along the North Carolina coast. One such site, the Wrightsville Beach Waterbird Management Area, north of and adjacent to Wrightsville Beach, is an excellent example of the successful management of a nesting area that is under high recreation demand. The management plan for the Wrightsville Beach Waterbird Management Area is included in Appendix A of this report.

Because South Topsail Beach is privately owned, there is not an extensive history of stewardship and monitoring at the site. Intensive monitoring is needed to determine management needs for the inhabitant threatened species, particularly for the piping plover. The following are suggestions concerning monitoring and stewardship of South Topsail Beach:

- Conduct baseline environmental documentation for entire site to determine the natural communities and species present.

- Monitor the piping plover population every day during the nesting season. Pay particular attention to breeding activities including nest location and chronology, and causes of nest disturbance and chick loss.
- Observe piping plover reaction to recreational activities, especially involving dogs, and adapt management actions appropriately. Pay close attention to foraging behavior.
- Monitor bird nesting area for signs of predator activity. Utilize remote video cameras to view nocturnal predator activity. Document all evidence of predator activity so that action, such trapping, can be justified if necessary.
- Determine patterns of use by wintering piping plovers and other bird species.
- Monitor the ocean beach every morning for sea turtle nests, mark nest locations and to determine nest hatching dates. Identify potential causes of nest disturbance (NC Wildlife Resources Commission, 2006).
- Survey and monitor seabeach amaranth and other native plant populations.
- Survey and monitor beach vitex populations to determine extent of invasiveness.
- Survey local residents and visitors about recreational use of the site. Determine attitudes and opinions of quality of visit, particularly with regards to enclosed habitat areas.

Volunteer involvement is an important component of public education and outreach. Volunteers help Audubon North Carolina keep a constant presence in management areas where visitors and birds are likely to compete for use of the same beaches. Audubon North Carolina staff relies on volunteers at the Wrightsville Beach site to educate visitors about nesting birds by handing out informational brochures, answering visitor questions, and explaining the needs of the nesting birds (Golder, 2006). A volunteer network should be established to help monitor nesting birds at South Topsail Beach, if acquired.

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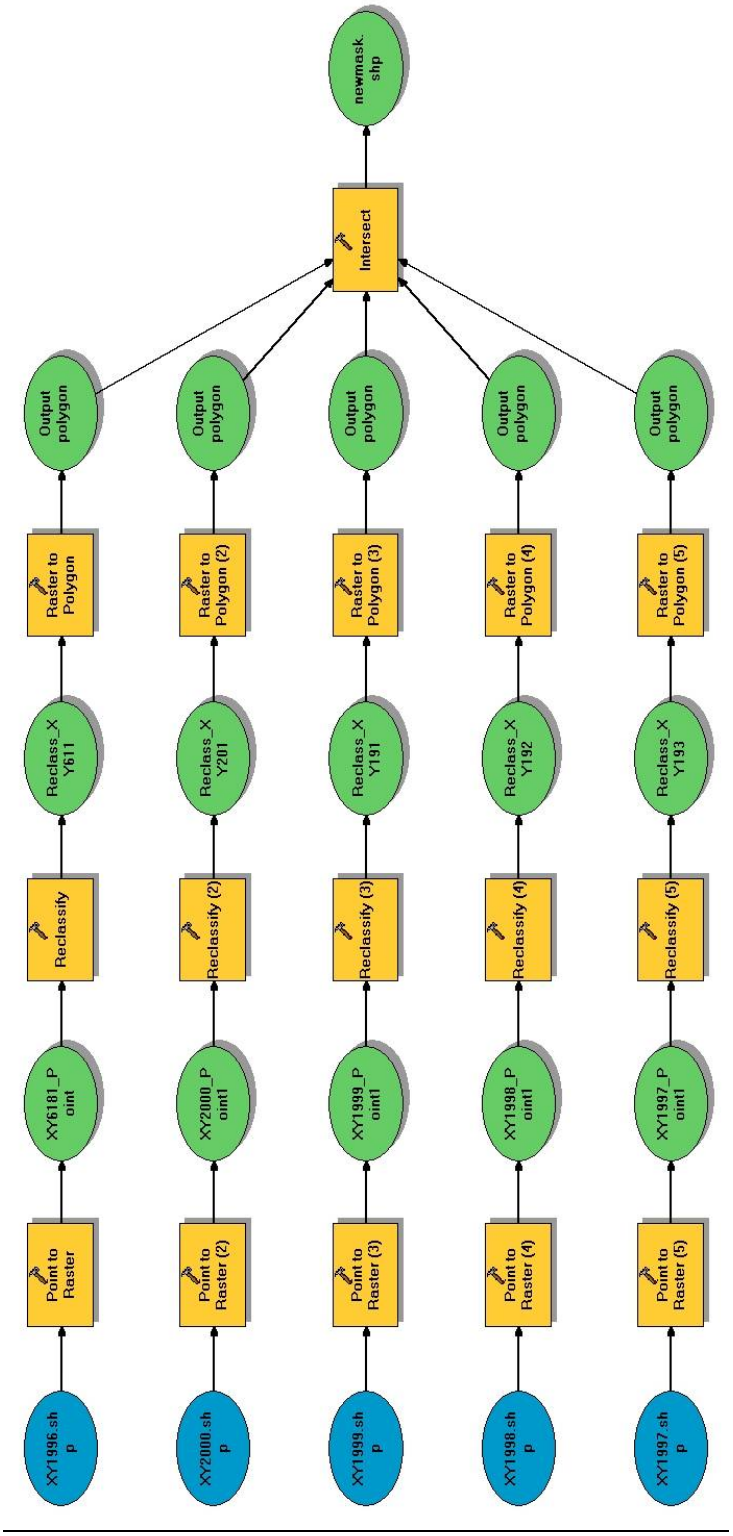
APPENDIX A: Model and Python Script for Creation of Analysis Extent Mask



```
# ---------------------------------------------------------------------------
# maskmodel.py
# Created on: Thu Aug 30 2007 09:41:00 PM
#   (generated by ArcGIS/ModelBuilder)
# ---------------------------------------------------------------------------

# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Check out any necessary licenses
gp.CheckOutExtension("3D")

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Conversion Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/3D Analyst Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysis Tools.tbx")

# Set the Geoprocessing environment...
gp.XYResolution = ""
gp.scratchWorkspace = "Z:\\MP8_11\\MasterP\\scratch"
gp.MTolerance = ""
gp.randomGenerator = "0 ACM599"
gp.outputCoordinateSystem =
"PROJCS['NAD_1983_UTM_Zone_18N',GEOGCS['GCS_North_American_1983',DATUM['D
_North_American_1983',SPHEROID['GRS_1980',6378137.0,298.257222101]],PRIMEM['Gree
nwich',0.0],UNIT['Degree',0.0174532925199433]],PROJECTION['Transverse_Mercator'],PAR
AMETER['False_Easting',500000.0],PARAMETER['False_Northing',0.0],PARAMETER['Centr
al_Meridian',-
75.0],PARAMETER['Scale_Factor',0.9996],PARAMETER['Latitude_Of_Origin',0.0],UNIT['Me
ter',1.0]]"
gp.outputZFlag = "Same As Input"
gp.qualifiedFieldNames = "true"
gp.extent = "DEFAULT"
gp.XYTolerance = ""
gp.outputZValue = ""
gp.outputMFlag = "Same As Input"
gp.geographicTransformations = ""
gp.ZResolution = ""
gp.workspace = "Z:\\MP8_11\\MasterP"
gp.MResolution = ""
gp.ZTolerance = ""
```

```
# Local variables...
XY1997_shp = "Z:\\MP8_11\\raw_shapefiles\\XY1997.shp"
XY1998_shp = "Z:\\MP8_11\\raw_shapefiles\\XY1998.shp"
XY1999_shp = "Z:\\MP8_11\\raw_shapefiles\\XY1999.shp"
XY2000_shp = "Z:\\MP8_11\\raw_shapefiles\\XY2000.shp"
XY1996_shp = "Z:\\MP8_11\\raw_shapefiles\\XY1996.shp"
XY6181_Point = "Z:\\MP8_11\\MasterP\\scratch\\XY1996_Point"
XY2000_Point1 = "Z:\\MP8_11\\MasterP\\scratch\\XY2000_Point1"
XY1999_Point1 = "Z:\\MP8_11\\MasterP\\scratch\\XY1999_Point1"
XY1998_Point1 = "Z:\\MP8_11\\MasterP\\scratch\\XY1998_Point1"
XY1997_Point1 = "Z:\\MP8_11\\MasterP\\scratch\\XY1997_Point1"
Reclass_XY611 = "Z:\\MP8_11\\MasterP\\scratch\\Reclass_XY194"
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Reclass_XY192 = "Z:\\MP8_11\\MasterP\\scratch\\Reclass_XY192"
Reclass_XY193 = "Z:\\MP8_11\\MasterP\\scratch\\Reclass_XY193"
Output_polygon_features = "Z:\\MP8_11\\MasterP\\scratch\\RasterT_Reclass1.shp"
Output_polygon_features__2_ = "Z:\\MP8_11\\MasterP\\scratch\\RasterT_Reclass2.shp"
Output_polygon_features__3_ = "Z:\\MP8_11\\MasterP\\scratch\\RasterT_Reclass3.shp"
Output_polygon_features__4_ = "Z:\\MP8_11\\MasterP\\scratch\\RasterT_Reclass4.shp"
Output_polygon_features__5_ = "Z:\\MP8_11\\MasterP\\scratch\\RasterT_Reclass5.shp"
newmask_shp = "Z:\\MP8_11\\MasterP\\scratch\\newmask.shp"

# Process: Point to Raster...
gp.PointToRaster_conversion(XY1996_shp, "FID", XY6181_Point, "SUM", "ID", "5")

# Process: Reclassify...
gp.Reclassify_3d(XY6181_Point, "VALUE", "0 124759 1", Reclass_XY611, "DATA")

# Process: Raster to Polygon...
gp.RasterToPolygon_conversion(Reclass_XY611, Output_polygon_features, "SIMPLIFY",
"VALUE")

# Process: Point to Raster (2)...
gp.PointToRaster_conversion(XY2000_shp, "FID", XY2000_Point1, "MOST_FREQUENT",
"ID", "5")

# Process: Reclassify (2)...
gp.Reclassify_3d(XY2000_Point1, "Value", "0 419404 1", Reclass_XY201, "DATA")

# Process: Raster to Polygon (2)...
gp.RasterToPolygon_conversion(Reclass_XY201, Output_polygon_features__2_, "SIMPLIFY",
"VALUE")

# Process: Point to Raster (3)...
```
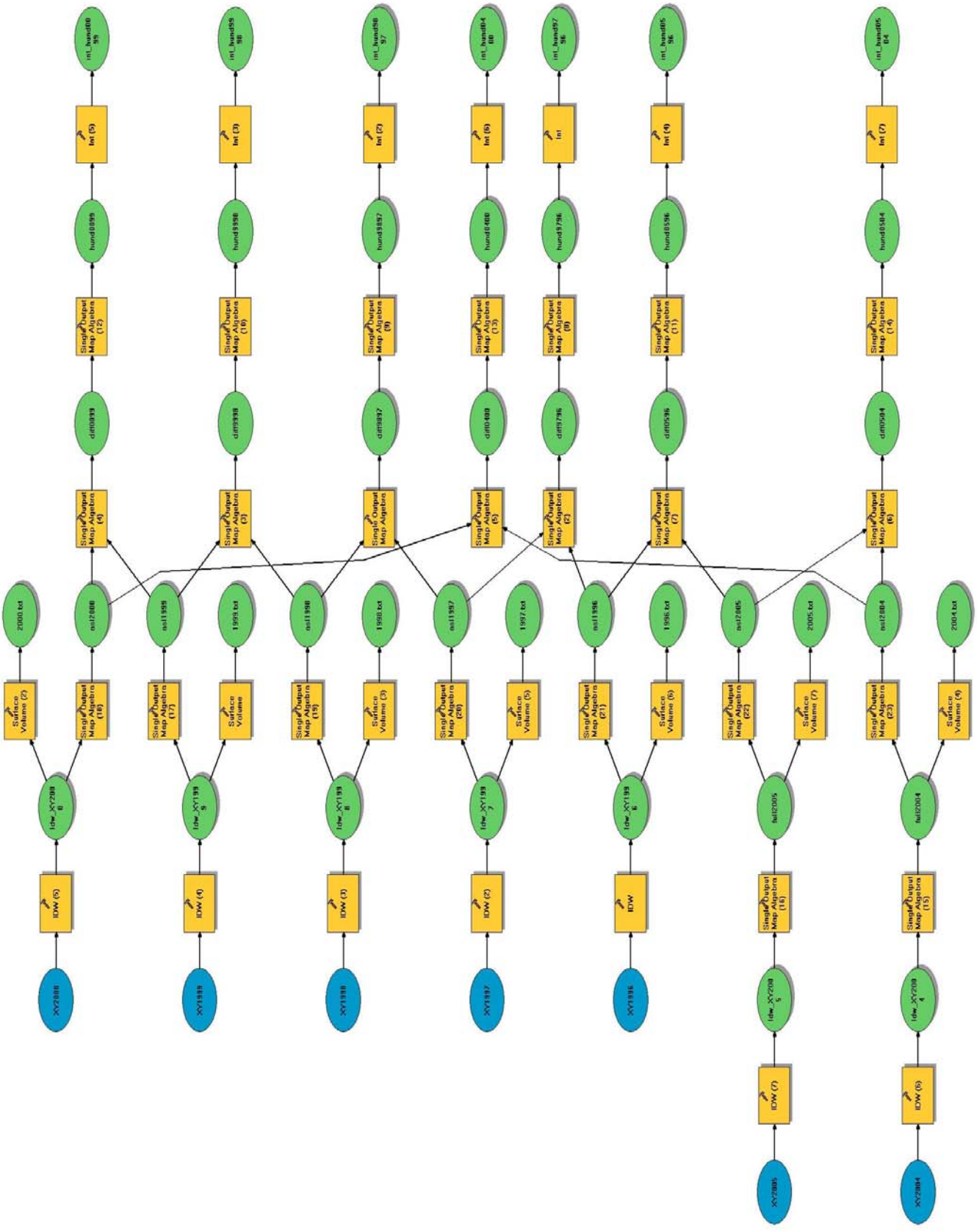

```
gp.PointToRaster_conversion(XY1999_shp, "FID", XY1999_Point1, "SUM", "ID", "5")

# Process: Reclassify (3)...
gp.Reclassify_3d(XY1999_Point1, "Value", "0 129462 1", Reclass_XY191, "DATA")

# Process: Raster to Polygon (3)...
gp.RasterToPolygon_conversion(Reclass_XY191, Output_polygon_features__3_, "SIMPLIFY",
"VALUE")

# Process: Point to Raster (4)...
gp.PointToRaster_conversion(XY1998_shp, "FID", XY1998_Point1, "SUM", "ID", "5")

# Process: Reclassify (4)...
gp.Reclassify_3d(XY1998_Point1, "Value", "0 132177 1", Reclass_XY192, "DATA")

# Process: Raster to Polygon (4)...
gp.RasterToPolygon_conversion(Reclass_XY192, Output_polygon_features__4_, "SIMPLIFY",
"VALUE")

# Process: Point to Raster (5)...
gp.PointToRaster_conversion(XY1997_shp, "FID", XY1997_Point1, "SUM", "ID", "5")

# Process: Reclassify (5)...
gp.Reclassify_3d(XY1997_Point1, "Value", "0 148861 1", Reclass_XY193, "DATA")

# Process: Raster to Polygon (5)...
gp.RasterToPolygon_conversion(Reclass_XY193, Output_polygon_features__5_, "SIMPLIFY",
"VALUE")

# Process: Intersect...
gp.Intersect_analysis("Z:\\MP8_11\\MasterP\\scratch\\RasterT_Reclass1.shp
#;Z:\\MP8_11\\MasterP\\scratch\\RasterT_Reclass2.shp
#;Z:\\MP8_11\\MasterP\\scratch\\RasterT_Reclass3.shp
#;Z:\\MP8_11\\MasterP\\scratch\\RasterT_Reclass4.shp
#;Z:\\MP8_11\\MasterP\\scratch\\RasterT_Reclass5.shp #", newmask_shp, "ALL", "", "INPUT")
```

APPENDIX B: Model and Python Script for GIS Analysis of Shoreline Change



```
# ---------------------------------------------------------------------------
# pythonmodel.py
# Created on: Thu Aug 30 2007 08:56:01 PM
#   (generated by ArcGIS/ModelBuilder)
# ---------------------------------------------------------------------------

# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Check out any necessary licenses
gp.CheckOutExtension("3D")
gp.CheckOutExtension("spatial")

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/3D Analyst Tools.tbx")

# Set the Geoprocessing environment...
gp.XYResolution = ""
gp.scratchWorkspace = "Z:\\MP8_11\\MasterP\\scratch"
gp.MTolerance = ""
gp.randomGenerator = "0 ACM599"
gp.outputCoordinateSystem =
"PROJCS['NAD_1983_UTM_Zone_18N',GEOGCS['GCS_North_American_1983',DATUM['D
_North_American_1983',SPHEROID['GRS_1980',6378137.0,298.257222101]],PRIMEM['Gree
nwich',0.0],UNIT['Degree',0.0174532925199433]],PROJECTION['Transverse_Mercator'],PAR
AMETER['False_Easting',500000.0],PARAMETER['False_Northing',0.0],PARAMETER['Centr
al_Meridian',-
75.0],PARAMETER['Scale_Factor',0.9996],PARAMETER['Latitude_Of_Origin',0.0],UNIT['Me
ter',1.0]]"
gp.outputZFlag = "Same As Input"
gp.qualifiedFieldNames = "true"
gp.extent = "MINOF"
gp.XYTolerance = ""
gp.cellSize = "5"
gp.outputZValue = ""
gp.outputMFlag = "Same As Input"
gp.geographicTransformations = ""
gp.ZResolution = ""
gp.mask = "newmask"
gp.workspace = "Z:\\MP8_11\\MasterP"
gp.MResolution = ""
```

```
gp.ZTolerance = ""


# Local variables...
Idw_XY1996 = "Z:\\MP8_11\\MasterP\\scratch\\Idw_XY1996"
Idw_XY1997 = "Z:\\MP8_11\\MasterP\\scratch\\Idw_XY1997"
Idw_XY1998 = "Z:\\MP8_11\\MasterP\\scratch\\Idw_XY1998"
Idw_XY1999 = "Z:\\MP8_11\\MasterP\\scratch\\Idw_XY1999"
Idw_XY2000 = "Z:\\MP8_11\\MasterP\\scratch\\Idw_XY2000"
Idw_XY2004 = "Z:\\MP8_11\\MasterP\\scratch\\Idw_XY2004"
Idw_XY2005 = "Z:\\MP8_11\\MasterP\\scratch\\Idw_XY2005"
XY1996 = "XY1996"
XY1997 = "XY1997"
XY1998 = "XY1998"
XY1999 = "XY1999"
XY2000 = "XY2000"
XY2004 = "XY2004"
XY2005 = "XY2005"
diff9897 = "Z:\\MP8_11\\MasterP\\scratch\\diff9897"
diff9796 = "Z:\\MP8_11\\MasterP\\scratch\\diff9796"
diff9998 = "Z:\\MP8_11\\MasterP\\scratch\\diff9998"
diff0099 = "Z:\\MP8_11\\MasterP\\scratch\\diff0099"
diff0400 = "Z:\\MP8_11\\MasterP\\scratch\\diff0400"
diff0504 = "Z:\\MP8_11\\MasterP\\scratch\\diff0504"
diff0596 = "Z:\\MP8_11\\MasterP\\scratch\\diff0596"
hund9796 = "Z:\\MP8_11\\MasterP\\scratch\\hund9796"
int_hund9796 = "Z:\\MP8_11\\MasterP\\scratch\\int_hund9796"
hund9897 = "Z:\\MP8_11\\MasterP\\scratch\\hund9897"
int_hund9897 = "Z:\\MP8_11\\MasterP\\scratch\\int_hund9897"
hund9998 = "Z:\\MP8_11\\MasterP\\scratch\\hund9998"
int_hund9998 = "Z:\\MP8_11\\MasterP\\scratch\\int_hund9998"
hund0596 = "Z:\\MP8_11\\MasterP\\scratch\\hund0596"
int_hund0596 = "Z:\\MP8_11\\MasterP\\scratch\\int_hund0596"
hund0099 = "Z:\\MP8_11\\MasterP\\scratch\\hund0099"
int_hund0099 = "Z:\\MP8_11\\MasterP\\scratch\\int_hund0099"
hund0400 = "Z:\\MP8_11\\MasterP\\scratch\\hund0400"
int_hund0400 = "Z:\\MP8_11\\MasterP\\scratch\\int_hund0400"
hund0504 = "Z:\\MP8_11\\MasterP\\scratch\\hund0504"
int_hund0504 = "Z:\\MP8_11\\MasterP\\scratch\\int_hund0504"
full2004 = "Z:\\MP8_11\\MasterP\\scratch\\full2004"
full2005 = "Z:\\MP8_11\\MasterP\\scratch\\full2005"
asl1999 = "Z:\\MP8_11\\MasterP\\scratch\\asl1999"
asl2000 = "Z:\\MP8_11\\MasterP\\scratch\\asl2000"
asl1998 = "Z:\\MP8_11\\MasterP\\scratch\\asl1998"
asl1997 = "Z:\\MP8_11\\MasterP\\scratch\\asl1997"
asl1996 = "Z:\\MP8_11\\MasterP\\scratch\\asl1996"
```

```
asl2005 = "Z:\\MP8_11\\MasterP\\scratch\\asl2005"
asl2004 = "Z:\\MP8_11\\MasterP\\scratch\\asl2004"
v1999_txt = "Z:\\MP8_11\\volumetext\\1999.txt"
v2000_txt = "Z:\\MP8_11\\volumetext\\2000.txt"
v1998_txt = "Z:\\MP8_11\\MasterP\\1998.txt"
v2004_txt = "Z:\\MP8_11\\MasterP\\2004.txt"
v1997_txt = "Z:\\MP8_11\\MasterP\\1997.txt"
v1996_txt = "Z:\\MP8_11\\MasterP\\1996.txt"
v2005_txt = "Z:\\MP8_11\\MasterP\\2005.txt"

# Process: IDW (2)...
gp.Idw_3d(XY1997, "Shape", Idw_XY1997, "5", "2", "FIXED 10 6", "")

# Process: Single Output Map Algebra (20)...
gp.SingleOutputMapAlgebra_sa("con((Idw_XY1997)<0,0,(Idw_XY1997))", asl1997,
"Z:\\MP8_11\\MasterP\\scratch\\Idw_XY1997")

# Process: IDW...
gp.Idw_3d(XY1996, "Shape", Idw_XY1996, "5", "2", "FIXED 10 6", "")

# Process: Single Output Map Algebra (21)...
gp.SingleOutputMapAlgebra_sa("con((Idw_XY1996)<0,0,(Idw_XY1996))", asl1996,
"Z:\\MP8_11\\MasterP\\scratch\\Idw_XY1996")

# Process: Single Output Map Algebra (2)...
gp.SingleOutputMapAlgebra_sa("asl1997-asl1996", diff9796,
"Z:\\MP8_11\\MasterP\\scratch\\asl1997;Z:\\MP8_11\\MasterP\\scratch\\asl1996")

# Process: Single Output Map Algebra (8)...
gp.SingleOutputMapAlgebra_sa("diff9796*100", hund9796,
"Z:\\MP8_11\\MasterP\\scratch\\diff9796")

# Process: Int...
gp.Int_3d(hund9796, int_hund9796)

# Process: IDW (3)...
gp.Idw_3d(XY1998, "Shape", Idw_XY1998, "5", "2", "FIXED 10 6", "")

# Process: Single Output Map Algebra (19)...
gp.SingleOutputMapAlgebra_sa("con((Idw_XY1998)<0,0,(Idw_XY1998))", asl1998,
"Z:\\MP8_11\\MasterP\\scratch\\Idw_XY1998")

# Process: Single Output Map Algebra...
gp.SingleOutputMapAlgebra_sa("asl1998-asl1997", diff9897,
"Z:\\MP8_11\\MasterP\\scratch\\asl1998;Z:\\MP8_11\\MasterP\\scratch\\asl1997")
```

```
# Process: Single Output Map Algebra (9)...
gp.SingleOutputMapAlgebra_sa("diff9897*100", hund9897,
"Z:\\MP8_11\\MasterP\\scratch\\diff9897")

# Process: Int (2)...
gp.Int_sa(hund9897, int_hund9897)

# Process: IDW (4)...
gp.Idw_3d(XY1999, "Shape", Idw_XY1999, "5", "2", "FIXED 10 6", "")

# Process: Single Output Map Algebra (17)...
gp.SingleOutputMapAlgebra_sa("con((Idw_XY1999)<0,0,(Idw_XY1999))", asl1999,
"Z:\\MP8_11\\MasterP\\scratch\\Idw_XY1999")

# Process: Single Output Map Algebra (3)...
gp.SingleOutputMapAlgebra_sa("asl1999-asl1998", diff9998,
"Z:\\MP8_11\\MasterP\\scratch\\asl1998;Z:\\MP8_11\\MasterP\\scratch\\asl1999")

# Process: Single Output Map Algebra (10)...
gp.SingleOutputMapAlgebra_sa("diff9998*100", hund9998,
"Z:\\MP8_11\\MasterP\\scratch\\diff9998")

# Process: Int (3)...
gp.Int_sa(hund9998, int_hund9998)

# Process: IDW (7)...
gp.Idw_3d(XY2005, "Shape", Idw_XY2005, "5", "2", "FIXED 10 6", "")

# Process: Single Output Map Algebra (16)...
gp.SingleOutputMapAlgebra_sa("con(isnull(Idw_XY2005),0,(Idw_XY2005))", full2005,
"Z:\\MP8_11\\MasterP\\scratch\\Idw_XY2005")

# Process: Single Output Map Algebra (22)...
gp.SingleOutputMapAlgebra_sa("con((Z:\\MP\\MasterP\\scratch\\full2005)<0,0,(Z:\\MP\\Master
P\\scratch\\full2005))
", asl2005, "Z:\\MP8_11\\MasterP\\scratch\\full2005")

# Process: Single Output Map Algebra (7)...
gp.SingleOutputMapAlgebra_sa("asl2005-asl1996", diff0596,
"Z:\\MP8_11\\MasterP\\scratch\\asl2005;Z:\\MP8_11\\MasterP\\scratch\\asl1996")

# Process: Single Output Map Algebra (11)...
gp.SingleOutputMapAlgebra_sa("diff0596*100", hund0596,
"Z:\\MP8_11\\MasterP\\scratch\\diff0596")

# Process: Int (4)...
```

```
gp.Int_sa(hund0596, int_hund0596)

# Process: IDW (5)...
gp.Idw_3d(XY2000, "Shape", Idw_XY2000, "5", "2", "FIXED 10 6", "")

# Process: Single Output Map Algebra (18)...
gp.SingleOutputMapAlgebra_sa("con((Idw_XY2000)<0,0,(Idw_XY2000))", asl2000,
"Z:\\MP8_11\\MasterP\\scratch\\Idw_XY2000")

# Process: Single Output Map Algebra (4)...
gp.SingleOutputMapAlgebra_sa("asl2000-asl1999", diff0099,
"Z:\\MP8_11\\MasterP\\scratch\\asl1999;Z:\\MP8_11\\MasterP\\scratch\\asl2000")

# Process: Single Output Map Algebra (12)...
gp.SingleOutputMapAlgebra_sa("diff0099*100", hund0099,
"Z:\\MP8_11\\MasterP\\scratch\\diff0099")

# Process: Int (5)...
gp.Int_sa(hund0099, int_hund0099)

# Process: IDW (6)...
gp.Idw_3d(XY2004, "Shape", Idw_XY2004, "5", "2", "FIXED 10 6", "")

# Process: Single Output Map Algebra (15)...
gp.SingleOutputMapAlgebra_sa("con(isnull(Z:\\MP\\MasterP\\scratch\\idw_xy2004),0,(Z:\\MP\\
MasterP\\scratch\\idw_xy2004))", full2004, "Z:\\MP8_11\\MasterP\\scratch\\Idw_XY2004")

# Process: Single Output Map Algebra (23)...
gp.SingleOutputMapAlgebra_sa("con((Z:\\MP\\MasterP\\scratch\\full2004)<0,0,(Z:\\MP\\Master
P\\scratch\\full2004))
", asl2004, "Z:\\MP8_11\\MasterP\\scratch\\full2004")

# Process: Single Output Map Algebra (5)...
gp.SingleOutputMapAlgebra_sa("asl2004-asl2000", diff0400,
"Z:\\MP8_11\\MasterP\\scratch\\asl2000;Z:\\MP8_11\\MasterP\\scratch\\asl2004")

# Process: Single Output Map Algebra (13)...
gp.SingleOutputMapAlgebra_sa("diff0400*100", hund0400,
"Z:\\MP8_11\\MasterP\\scratch\\diff0400")

# Process: Int (6)...
gp.Int_sa(hund0400, int_hund0400)

# Process: Single Output Map Algebra (6)...
gp.SingleOutputMapAlgebra_sa("asl2005-asl2004", diff0504,
"Z:\\MP8_11\\MasterP\\scratch\\asl2005;Z:\\MP8_11\\MasterP\\scratch\\asl2004")
```

```
# Process: Single Output Map Algebra (14)...
gp.SingleOutputMapAlgebra_sa("diff0504*100", hund0504,
"Z:\\MP8_11\\MasterP\\scratch\\diff0504")

# Process: Int (7)...
gp.Int_sa(hund0504, int_hund0504)

# Process: Surface Volume...
gp.SurfaceVolume_3d(Idw_XY1999, v1999_txt, "ABOVE", "0", "1")

# Process: Surface Volume (2)...
gp.SurfaceVolume_3d(Idw_XY2000, v2000_txt, "ABOVE", "0", "1")

# Process: Surface Volume (3)...
gp.SurfaceVolume_3d(Idw_XY1998, v1998_txt, "ABOVE", "0", "1")

# Process: Surface Volume (4)...
gp.SurfaceVolume_3d(full2004, v2004_txt, "ABOVE", "0", "1")

# Process: Surface Volume (5)...
gp.SurfaceVolume_3d(Idw_XY1997, v1997_txt, "ABOVE", "0", "1")

# Process: Surface Volume (6)...
gp.SurfaceVolume_3d(Idw_XY1996, v1996_txt, "ABOVE", "0", "1")

# Process: Surface Volume (7)...
gp.SurfaceVolume_3d(full2005, v2005_txt, "ABOVE", "0", "1")
```