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Barrier Progradation Related to Inlet Spacing and Migration Patterns

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ABSTRACT

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The majority of the barrier islands in southeastern North Carolina are eroding at relatively rapid rates. Brunswick County beaches, located in the southernmost portion of North Carolina, have some of the highest erosion rates in the state despite the relatively low energy environment in which they are situated. The exception is Sunset Beach, a small ~5 km long prograding barrier, located approximately 40 km west of Cape Fear. This is the only barrier in Brunswick County that has been prograding within the last century. Sunset Beach is bordered by two locationally unstable inlets; Tubbs Inlet to the east, and Mad Inlet (now closed) to the west. It is hypothesized that the complex behavioral patterns and the associated sediment by-passing events of these small, closely spaced, unstable inlet systems are responsible for the shoreline progradation. Data shows that throughout recent history, as these inlets moved towards each other, the shoreline of the island prograded. Conversely, when the inlets moved apart, the oceanfront shoreline eroded, particularly along the eastern portion of Sunset beach near Tubbs Inlet.

ADDITIONAL INDEX WORDS: *Inlet relocation, inlet closure, ebb tidal delta.*

INTRODUCTION

Almost all major shoreline reaches in southeastern North Carolina are situated within chronic erosion zones. During the past seven years the shoreline recession has been greatly exacerbated by four landfalling hurricanes and numerous winter storms. The worst of the critical erosion zones are associated with contemporary inlets or historic inlets that have been artificially closed. However there are some small, isolated shoreline reaches that are stable or accreting slightly and include coastal cells in the vicinity of forelands and those located immediately downdrift of stable inlets. The only barrier island that is the exception to this generalization is Sunset Beach, a 5 km long barrier located in western Brunswick County, ~ 40 km west of Cape Fear (Figure 1). Two unstable inlets border the barrier, Tubbs Inlet to the east and Mad Inlet (now closed) to the west. Sunset Beach is an exemplary setting to study the influence of multiple inlets on the adjacent barrier's planform. It is hypothesized that the complex migration patterns of the two closely spaced, unstable inlets and the associated sediment by-passing events of the inlet systems are responsible for the observed barrier progradation. The intent of this paper is to provide an overview of the variability in the migration histories of Mad and Tubbs Inlets and their influence on the Sunset Beach shoreline change patterns during the past eight decades.

Geologic Setting

The 550 km long North Carolina coastline consists of a diverse group of barrier spits and islands separated by three major forelands (Capes Hatteras, Lookout and Fear). Between these cuspate forelands, major coastal reaches are further separated into distinct littoral cells by small subaerial and submarine headlands that have exerted a considerable influence on the evolution of the local barrier system. Within the southeastern portion of North Carolina the headland-bounded reaches are comprised of several reaches where the evolution of the barriers are influenced by a diverse group of migrating and stable inlets.

Sunset Beach is part of a low-mesotidal barrier system that extends between two Pleistocene headlands at Yaupon Beach, NC and Myrtle Beach, SC in Long Bay located along the low energy flank of Cape Fear (HAYES, 1994 and MARDEN and CLEARY, 1999). Hardbottoms dominate a major portion of this sediment-poor shelf sector, primarily in the central and eastern portion of Long Bay. Although hardbottoms are present in the western portion of the area the modern sediment cover is more extensive, particularly seaward of the barriers in the vicinity of Little River, SC (MARDEN and CLEARY, 1999). The physiography of Waites Is. (SC) and Sunset Beach (NC) reflect the more sand rich nature of the western portion of the shoreface. The morphology of Sunset Beach is characterized by a sequence of 3 4 m high dune ridges that front an extensive field of vegetated, 5 - 9 m high parabolic dunes.

Tubbs Inlet

Tubbs Inlet is small, relatively shallow (6 m), unstable inlet that forms the eastern boundary of Sunset Beach and separates the island from adjacent Ocean Isle (Figure 1). Throughout much of its history over the past 100 years the inlet has migrated westward along a 2.0 km wide pathway (Figure 2). Between 1856 and 1970 the average migration rate was ~ 20 m/yr (MARDEN and CLEARY, 1999). The migration rate increased to an average of 40 m/yr for the period between 1938 and 1970. In order to mitigate the rapid erosion of the Sunset Beach shoulder the inlet was artificially relocated in December 1969 to a position 1.0 km eastward that approximated the inlet's 1938 location (MASTERSON, 1973). After about a seven year period of adjustment to the new hydrodynamic conditions, Tubbs Inlet reversed its migration direction in the late 1970s and since that period of time has been migrating to the east at variable rates (MARDEN and CLEARY, 1999).

The reversal in migration direction is opposite the direction of the net regional littoral drift and the change is most likely due to alterations in the back barrier channel dominance. Prior to relocation, Eastern Channel located behind Ocean Isle, was the major feeder channel (Figure 2A). The dredging of Jinks Creek, the western and historically minor feeder channel, during the relocation effort and subsequent maintenance cycles has allowed it to become the dominant channel, while Eastern Channel has shoaled considerably. Since the dominance of Jinks Creek was established, the inlet's ebb channel shifted position within the throat and is currently located along the Ocean Isle shoulder where erosion is now the norm (Figure 3). The inlet's migration pattern since 1980 may also have been influenced by the construction of the dual jetties at sediment-

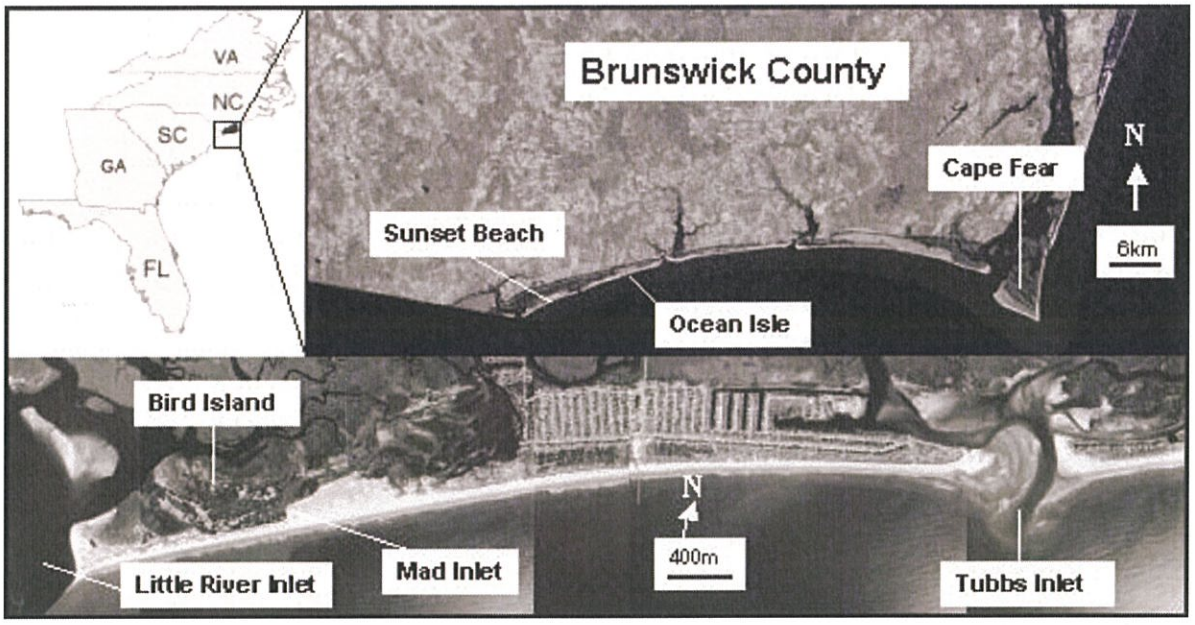

Figure 1. Location map of Sunset Beach, North Carolina and study area.

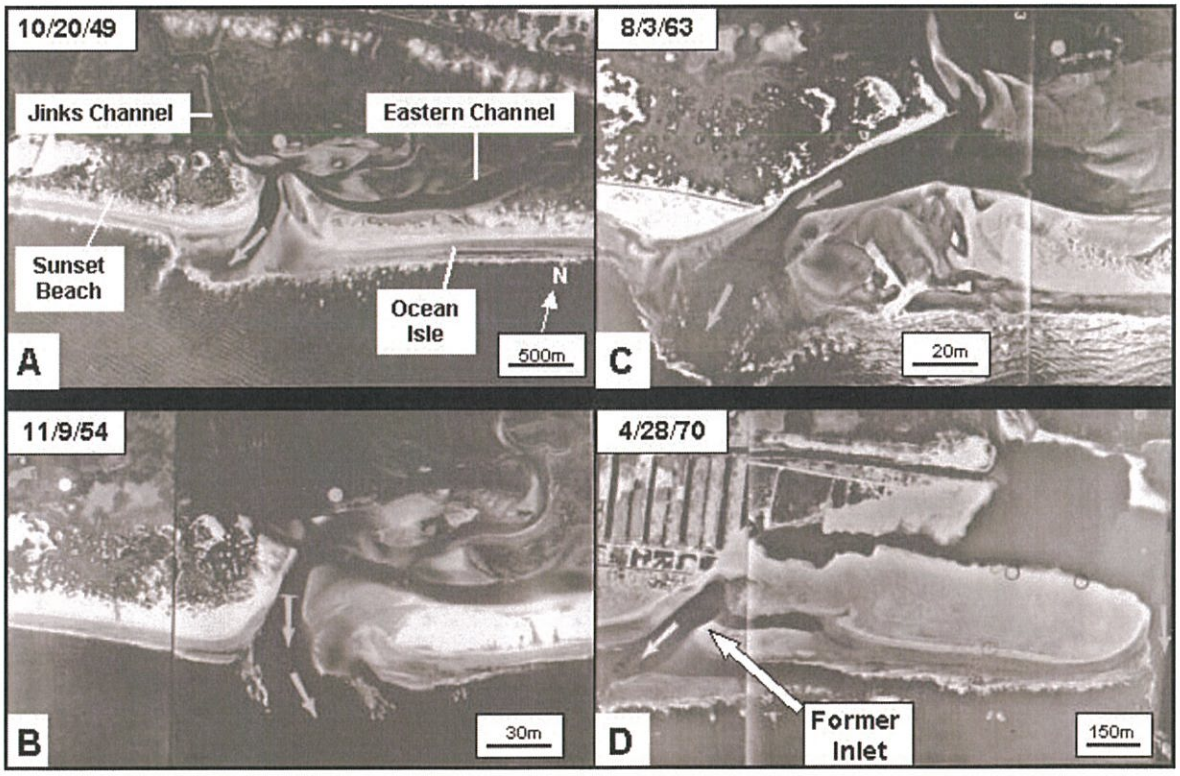

Figure 2. Westward migration of Tubbs Inlet 1949 to 1970. (A). 1949. Tubbs Inlet borders Ocean Isle and Sunset beach both undeveloped barriers. The inlet's migration pathway extends across the majority of the field of view. (B). 1954. The barriers and inlet are affected by Hurricane Hazel. (C). 1963. The inlet has reached the approximate western margin of the migration pathway. Note the bulbous shape of Sunset Beach margin. (D). 1970. The inlet has been relocated eastward to approximately its 1938 position and the old inlet channel has been infilled. Note dredging within backbarrier area of Sunset Beach.

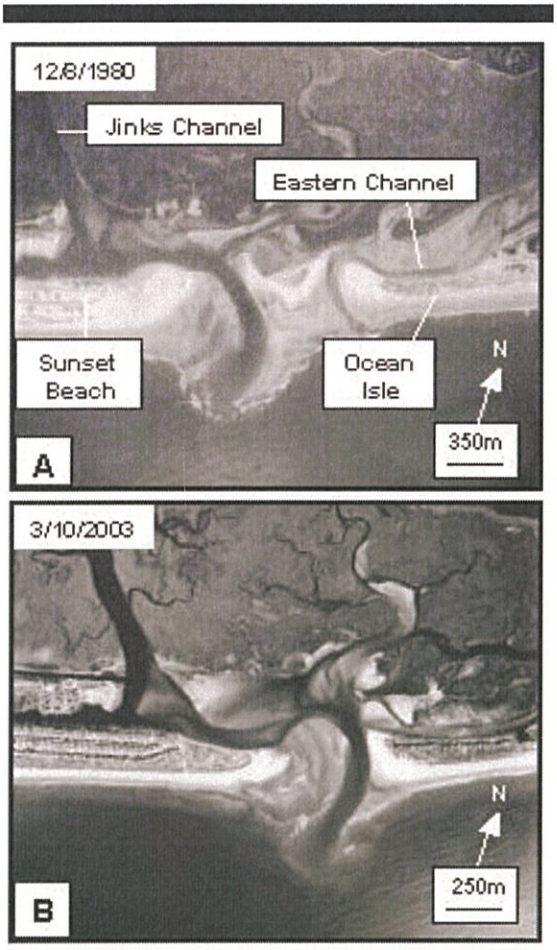

Figure 3. Tubbs Inlet 1980 and 2003 (A). 1980. The inlet was relatively stable at this time. Two marginal flood channels flank the ebb channel. (B). 2003. The ebb channel has been repositioned along the Ocean Isle margin. A primary flood channel remains on the Sunset Beach margin. The inlet begins its eastward migration and erosion of Ocean Isle.

rich Little River Inlet, which forms the western boundary of Bird Island, approximately 6 km to the west.

It has been postulated that the inlet's migration rate will increase as the flood channel continues to transport sediment into the throat, reducing the tidal prism and destabilizing the inlet (CLEARY and MARDEN, 1999). However, future manipulation of Eastern Channel for development purposes may result in a reversal in migration direction (MARDEN and CLEARY, 1999).

Mad Inlet

Mad Inlet, now closed, formed the western boundary of Sunset Beach and separated the barrier from undeveloped Bird Island, near the South Carolina border (Figure 1). The very small, migrating inlet has been recognized on maps that date from the 18th century (CLEARY and MARDEN, 1999). The inlet was highly unstable and ultimately closed in 1998, joining Sunset Beach to undeveloped Bird Island (Figure 4). The cyclic migration pattern of Mad Inlet consisted of westward movement and the development of a long narrow spit extending from the western extremity of Sunset Beach. Between 1938 - 1954, Mad Inlet migrated westward at an average rate of 13 m/yr. Hurricane Hazel (October, 1954) breached the westward extending Sunset Beach spit at the point of attachment on Sunset Beach, approximately 915 meters east of the inlet's 1954 position. By 1956 the old ebb channel had infilled and the new breach assumed the dominant role. From 1956 1998 the inlet once again migrated to the west an average rate of ~21 m/yr. In the late 1980's the migration rate increased to 31 m/yr due to infilling of the backbarrier area and the system's reduced tidal prism. The dramatic reduction in the tidal exchange capacity ultimately led to inlet closure in 1998 and the formation of a contiguous barrier stretching from Tubbs Inlet to Little River Inlet (Figure 4 - f).

METHODS

The GIS database for this investigation consisted of approximately 10 sets of historic aerial photographs dating from 1938 to 2003. The historic aerial photographs were digitized and rectified for each inlet and measurements made along a series of baselines and shore-normal transects for the determination of inlet and oceanfront shoreline changes. These data were integrated for each inlet for the purpose of tracking the linkage between the position of the inlet and oceanfront shoreline changes.

RESULTS AND DISCUSSION

The large volume of data collected during the conduct of this study are summarized for five distinct periods that reflect the relocation of Tubbs Inlet in 1970 and its eventual eastward migration and the closure of Mad Inlet in 1998. Inspection of the various data sets derived from digitized aerial photographs indicated significant changes in the planform of the barriers, as well as the configuration of the inlet systems, have occurred since the late 1940s. During the period 1949 to 1970, when the inlets converged and major storms impacted the area, the island's length was decreased by ~1.7 km. During this interval of time, when the inlet systems approached each other at variable rates, almost the entire oceanfront shoreline of Sunset Beach with the exception of the extreme eastern end of the island, prograded an average of 60m and as much as 115 m along the central portion of the barrier (Figure 5-A). During westward migration of Tubbs Inlet large swash bar complexes welded onto the downdrift Sunset Beach shoreline promoting buildup of the central portion of the island. Additionally, periodic ebb delta breaching events also by passed large segments of the ebb-tidal delta that migrated onshore and attached to the Sunset Beach oceanfront. By contrast the eastern end of the island remained relatively stable, experiencing only a net gain of ~ 8 m during this 22 year period.

Following the eastward artificial relocation of Tubbs Inlet, an additional 1.0 km length of shoreline was added to the eastern end of Sunset Beach. Subsequently the island entered into a period of relative stability from 1971 - 1979. During this period, Tubbs Inlet was still adjusting to the new hydrodynamic conditions and consequently the island only elongated an additional ~140 m. During this time interval erosion rates as high as 3 m/yr characterized the central segment of Sunset Beach. Only the eastern end of the barrier showed evidence of extensive buildup (20 m/yr) due to inlet-related accretion.

From 1979 to 1989, the planform of Sunset Beach was altered considerably as the barrier lengthened and subsequently eroded along the mid-barrier portion as the inlets continued to diverge (Figure 5 - B). During this interval of time Tubbs Inlet began a more rapid eastward migration while Mad Inlet migrated westward, lengthening Sunset Beach by ~550 meters during this decade. Minor erosion continued along the center of the island at a rate of ~2.5 m/yr. The eastern portion of the spit updrift of Tubbs Inlet was characterized by a slightly higher erosion rate (4.0 m/yr), due to the fact that the reach no longer was nourished by bar bypassing events as Tubbs Inlet moved eastward.

From 1989 to 1998 Sunset Beach exhibited net progradation along the entirety of the barrier. This island-wide trend was unique and dissimilar to the erosion trend normally associated with inlet divergence. The western end of Sunset Beach and the Bird Island section experienced up to 120 meters of accretion during this period. The coastwise accretion was due in part to

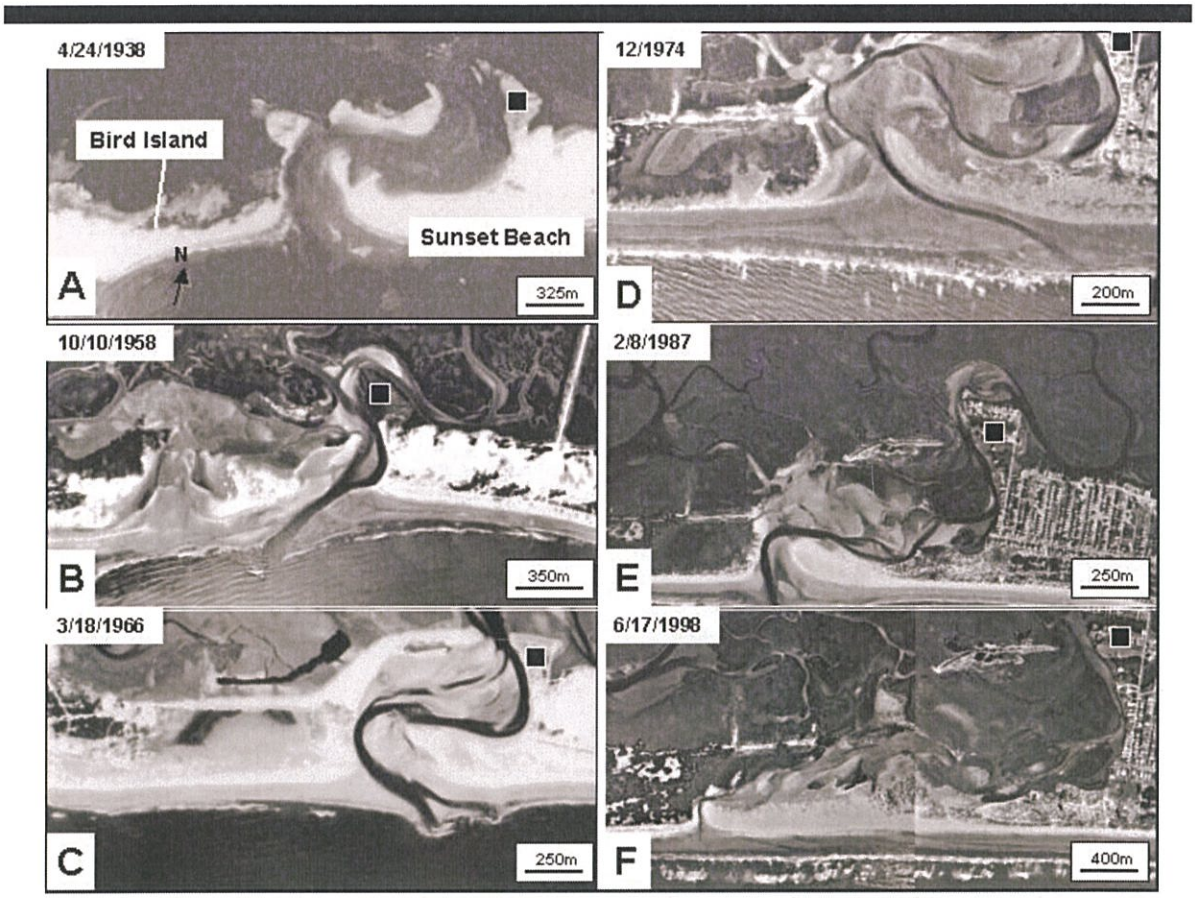

Figure 4. Mad Inlet (1938 1998). Black box denotes common reference point. (A). 1938. A relatively wide Mad Inlet separates Sunset Beach from undeveloped Bird Island. (B). 1958. New breach (Hurricane Hazel (1954) becomes dominant (C).1966. Former ebb channel is now closed. Note sinuous nature of existing ebb channel D.1974. Ebb channel continued to migrate westward. Note alignment of outer bar channel. (E).1987. The spit attched to Sunset beach extends in a westward direction. Note infilling of backbarrier. The inlet continues to shoal. (F).1998. Mad Inlet ultimately closes due to extensive shoaling and lack of sufficient tidal prism.

the closure of Mad Inlet and the subsequent attachment of swash bars as the ebb tidal delta was reworked. The remainder of the island by contrast prograded only ~ 20 m. Other factors that may have contributed to the accretion were the three hurricanes that made landfall near Cape Fear during the two-year period between 1996 - 1998.

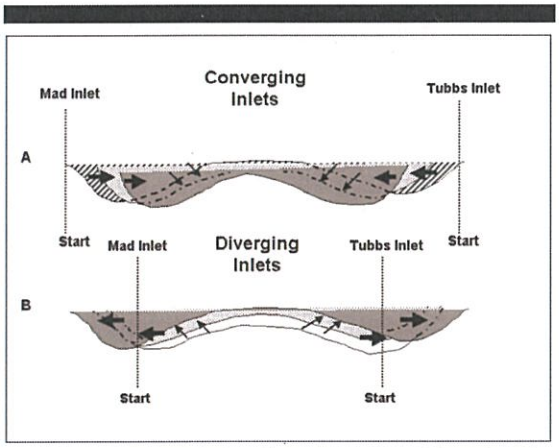

Figure 5. Generalized shoreline response to inlet migration patterns. (A). Shortening of the barrier resulting in shoreline progradation. (B). Lengthening of the barrier due to inlet divergence resulting in erosion of the ocenafront shoreline.

During the recent period between 1998 and 2002 Sunset Beach became contiguous with Bird Island to the west following the closure of Mad Inlet in 1998. This event effectively produced a composite barrier comprised of several spits and the core segments of Sunset Beach and Bird Island. The newly formed barrier measured ~ 6.0 km in length. During this period the newly formed barrier experienced erosion as the shoreline in the vicinity of Mad Inlet's closure zone was reconfigured, and Tubbs Inlet continued to migrate in an easterly direction. The shoreline segment in the Mad Inlet closure zone eroded ~10 m while the shoreline segment along the eastern end of Sunset Beach eroded an additional 19 m.

OVERVIEW

The combined influence of the spacing and migration habits of Mad and Tubbs Inlets has dictated the observed shoreline change patterns on Sunset Beach. The data clearly show that between 1949 and 2002 the mid-barrier portion of the island exhibited a net progradation of as much as 120 m, a trend unique to southeastern North Carolina barrier islands. Shoreline accretion increased toward the western portion of the barrier, east of the Mad Inlet closure zone, where as much as 130 m of accretion occurred along the western spit extension of Sunset Beach. The shoreline change patterns west of the core of Sunset Beach may have been influenced by the dual jetty system at Little River Inlet ~2 km to the west.

In contrast, along the Sunset Beach shoreline farther to the east (towards Tubbs Inlet), net accretion has decreased

dramatically due to the truncation of the oceanfront shoreline as the inlet-influenced erosion hot-spot shifts in an eastward direction. Net erosion has become the norm along the realigned shoreline of the elongating spit immediately west of Tubbs Inlet. Erosion along this shoreline reach is predicted to increase as the inlet continues to track in an easterly direction and the island lengthens. These results show that during periods of inlet convergence the island experienced net accretion, while showing net erosion during episodes of inlet divergence.

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