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Four-year performance and associated controlling factors of several beach nourishment projects along three adjacent barrier islands, west-central Florida, USA

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ABSTRACT

To quantify the performance of several beach nourishment projects on three adjacent barrier islands located in west-central Florida, a total of 5200 beach and nearshore-profiles spaced at 300 m were surveyed monthly to bi-monthly from 2006 to 2010. Beach nourishment performance at annual temporal and kilometer spatial scales within the microtidal low-wave energy barrier island coast is most significantly influenced by the interruption of longshore sediment transport by complex tidal-inlet processes. The inlet processes directly influencing adjacent beach nourishment performance include longshore transport interruption resulting from divergence induced by wave refraction over an ebb-tidal shoal, flood-tidal currents along the beach, and total littoral blockage by structured inlets. Secondary factors controlling the nourishment performance include project length and width, shoreline orientation, and antecedent geology. A morphologic indicator of a large longshore transport gradient within the study area is the absence of a nearshore sandbar. These non-barred beaches are characterized by persistent shoreline erosion. The presence of a sandbar indicates the dominance of cross-shore processes, with bar migration in response to wave condition variations and a relatively stable shoreline. The entirety of a barrier island system should be considered when evaluating the performance of a nourishment.

1. Introduction

Especially common in Florida, beach nourishment is a widely implemented method for mitigating beach erosion (Davis et al., 2000). This ubiquitously used method is less intrusive as compared to hard structures and is typically less expensive, with the advantages of acting as a buffer to storms while also providing both a recreational beach and habitat for (often) endangered species (Hamm et al., 2002; Stauble and Kraus, 1993). Beach nourishment introduces a perturbation to the nearshore system subsequently modified by natural forces in both the cross-shore and longshore directions (Dean, 2002). However, as coastal dynamics vary substantially along the world's evolving coastlines, the specific cross- and longshore morphological changes vary with both space and time. Therefore, detailed physical monitoring of site-specific coastal processes and morphology following nourishments are essential to quantify and predict nourishment performance, gain a more complete understanding of the underlying causes of beach erosion, and improve project design (NRC, 1995).

Important parameters in evaluating the efficacy of a nourishment often include (but are not limited to) the dry beach width, volume of sand remaining after a storm, and subaqueous sand volume determining total volume remaining (NRC, 1995). Identification of appropriate nourishment strategies in European countries are generally based on inherent beach properties such as volume, dry-beach width, and shoreline location (Hamm et al., 2002; Hanson et al., 2002). According to Browder and Dean (2000), project performance must be evaluated through adequate monitoring obtaining information on the volume of sand used for nourishment and the planform area remaining over the design-life of the project. In addition, time-dependent sediment transport gradients necessary to evaluate planform and profile evolution requires sufficiently detailed temporal and spatial resolution of the beach-profile changes following nourishments (Work and Dean, 1995).

Controlling factors of nourishment performance vary among projects, as well as over space and time. Benedet et al. (2007) evaluated a nourishment on Florida's east coast concluding that rather than wave transformation over bathymetric irregularities or alongshore grain-size distribution, the most significant factor influencing the development of erosional hotspots was the change in shoreline orientation due to the nourishment itself, resulting in accelerated alongshore currents and increased sediment transport potential. Analyzing eight years of post-nourishment data from northwest Florida, Browder and Dean (2000) identified project performance as most significantly related to the occurrence of storms and the proximity to tidal inlets. Capobianco et al. (2002) concluded that advancement of quality control and identification of uncertainty in modeling beach nourishments are of great significance for predicting project performance. Based on profile surveys extending to approximately −1.5 m water depth, Davis et al. (2000) identified several factors controlling a

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nourishment on a single barrier island in west-central Florida including relative location in the regional longshore sediment transport regime, magnitude of wave energy, sediment characteristics of the borrow material, local reversal and/or gradient in longshore transport, presence of hard structures, adjacent beach nourishment, variations in shoreline orientation, and beach-fill construction technique.

The first systematic monitoring study in west-central Florida was initiated in 1988 (Lin and Dean, 1989a, 1989b; USF-CRL, 1988, 1989). Several studies on nourishment project performance have since been published (Davis et al., 2000; Elko and Wang, 2007; Elko et al., 2005), but focused primarily on nourishments of individual barrier islands. This study evaluates the four-year performance of a larger-scale beach nourishment project in 2006 on three adjacent barrier islands located in Pinellas County, west-central Florida. Monthly to bi-monthly surveys of beach and nearshore profiles spaced at less than 300 m apart were conducted from 2006 to 2010, totaling over 5200 profiles extending to roughly −3 m water depth, or the short-term depth of closure. These high resolution temporal and spatial data are examined to evaluate nourishment performance and controlling factors on individual barrier islands and the barrier island-inlet system as a whole. The active interaction between adjacent barrier islands may have a substantial influence on nourishment performance, particularly those in close proximity to tidal inlets. The objectives of this study are to examine the 2006 nourishment performance and identify the primary (and where applicable, secondary) controlling factors.

2. Study area

The west-central Florida coast is composed of an extensive barrier-island chain, including both wave-dominated and mixed-energy barrier islands (Davis and Bernard, 2003). Several beaches along three barrier islands, including Sand Key, Treasure Island, and Long Key were nourished in 2006 (Fig. 1). Sand Key is bound to the north by Clearwater Pass inlet and separated to the south from Treasure Island by John's Pass inlet. Both inlets are mixed-energy with large ebb-tidal shoals (Gibeaut and Davis, 1993). The stabilized wave-dominated migratory Blind Pass (Wang et al., 2009, 2011a, 2011b) inlet separates Treasure Island to the north and Long Key to the south. Long Key is bound to the south by Pass-A-Grille inlet, which is one of the inlets entering the greater Tampa Bay. Sand for the 2006 beach nourishment was borrowed from the Egmont shoals at the mouth of Tampa Bay. The three barrier islands have an overall shoreline orientation change of 65° from northwest-facing to southwest-facing beaches, controlled by the antecedent geology (Fig. 1). The broad bedrock headland on Sand Key is composed of the Miocene Tampa Limestone, which outcrops in the Indian Rocks area at the headland. The underlying geology also influences the gradient of the inner continental shelf. Offshore sand ridges in the northern portion of the county (west of Sand Key) and ebb-tidal shoals introduce additional variability to the overall inner continental shelf and nearshore bathymetry. Regional longshore transport is to the south, driven primarily by the frequent passages of winter cold fronts. The beach sediment is bi-modal composed of fine quartz sand (0.13–0.20 mm) and shell debris of various sizes; the 2006 nourishment consisted of mainly of fine quartz sand (0.18–0.20 mm).

Up to date, site-specific erosion rates are not available for the entire study area. From 1973 to 1987, the shoreline erosion rate was identified as 2 m/yr for Pinellas County (Dean et al., 1998). A more recent study of shoreline erosion rates following the nourishment of Upham Beach (Long Key) from 1996 to 1998 reported erosion rates of approximately 70 m/yr from 1996 to 97 and 135 m/yr during the El Nino winter of 1997–98 (Elko et al., 2005). Most of Sand Key and the totality of Treasure Island and Long Key have been identified as critically eroding (Florida Department of Environmental Protection, 2011).

The west-central Florida coast is mixed microtidal, with spring tides typically diurnal with a 1 m tidal range while neap tides are

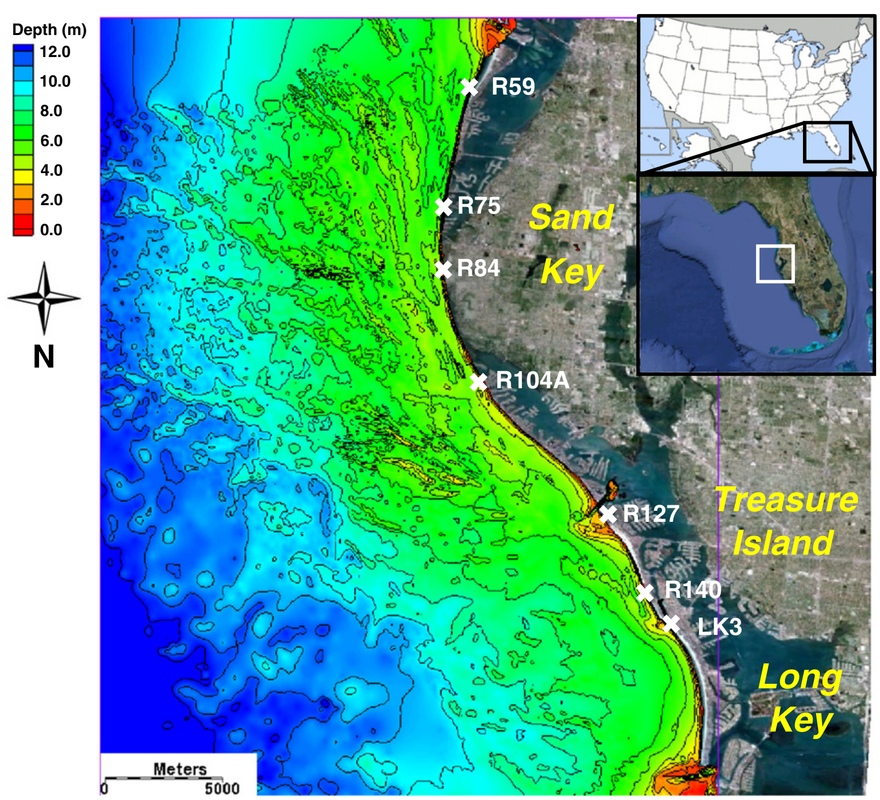

Fig. 1. General location and bathymetric map of the study area, encompassing all three barrier islands in Pinellas County Map. White crosses indicate the location of example beach profiles discussed.