

PERFORMANCE OF A TERMINAL GROIN - FOLLY BEACH, SC USA

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INTRODUCTION

A terminal groin was designed by the authors and constructed at Folly Beach County Park (South Carolina) in June 2013 to restore and stabilize a highly eroded spit (Figure 1). Groins are rarely permitted in the Carolinas and require extensive monitoring to assess impacts. In the case of the Folly Beach project, permits prescribe groin removal or periodic downcoast nourishment if erosion rates exceed pre-project rates. The common expectation is that groins will accelerate downcoast erosion because of sand trapping by the structure. Annual surveys have been performed by an independent surveyor, GEL Engineering (Charleston), and provide source data for the present analysis.

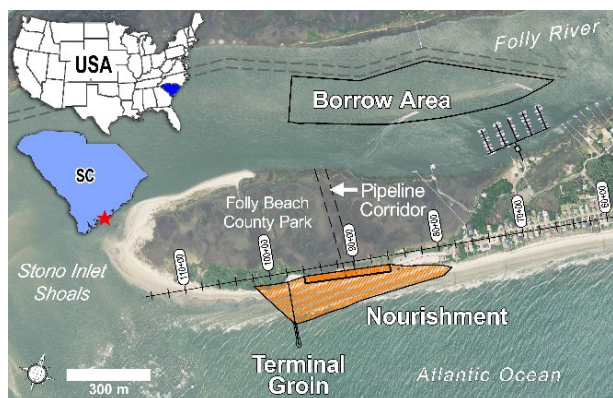


Figure 1 - Project area at Folly Beach County Park (SC).

SETTING

Folly Beach, near Charleston SC, terminates along a 1,000-meter (m) narrow spit backed by salt marsh adjacent to Folly River and Stono Inlet. The spit has been used as a public park since the 1970s. The spring tide range is ~ 2 m, H_s is < 1 m, sand size is ~ 0.2 millimeters (mm), wet-sand beach slope is ~ 1 on 35, and local Depth of Closure (DOC) is approximately -3 m MSL (Barrineau et al 2021). The spit terminates at an ebb-dominant inlet with a delta volume of the order of 100 million cubic meters (cm). Stono Inlet shoals (Figure 1) are an extension of Folly spit with multiple channels and subaerial islands, creating critical wildlife habitat within the inlet corridor.

Shoreline changes along the spit are also influenced by a groin field along Folly Beach dating to the 1950s. The 10 km long island has been nourished periodically upcoast of the spit since 1994. The spit was not part of the historic groin field, but remained relatively stable until around 2000 because of frequent inputs of dredged material from Folly River. An estimated 600,000 cm were placed along the spit between 1979 and 2000 (Kana 2012). This stability helped maintain public parking and facilities behind a stable foredune. Shoreline conditions changed in the late 1990s after large-scale nourishment of the island involving excavation of over 2.5 million cm from shoals in Folly River.

Van Dolah et al (1998) documented channel excavations behind the sand spit and shoals of Stono Inlet in 1994 that dwarfed previous channel maintenance projects. The resulting infilling of borrow areas was drawn from the inlet shoals and adjacent beach. This likely caused Folly spit to lose sand at an accelerating rate through the 2000s and ultimately become unstable. A nourishment project around 2005 provided temporary restoration of the beach and foredune, but monitoring surveys confirmed the underlying erosion rate remained much higher than historical rates at upwards of 50 cm/m/yr (CSE 2012).

GROIN DESIGN TO MITIGATE IMPACTS

The authors evaluated alternatives for beach restoration along the spit and recommended nourishment combined with the installation of a terminal groin as the least-cost solution over a 20-30-year period. Several key design criteria were considered to implement a project within a limited budget available to the County Park. First, the groin should provide a fillet approximately 600 m long to protect restored parking facilities and provide a safe beach for recreation. Second, the groin should be sufficiently upcoast from the inlet channels to gain natural protection by the ebb-tidal delta platform and avoid direct channel scour. This allowed a lower embedment depth for sheetpiles, the chosen material for the structure. Third, the groin profile should follow ASCE (1994) guidance whereby the structure would incorporate a berm section at the natural dry beach level, a sloping section at 1 on 35, similar to the local wet beach slope, and a low-tide section at ~ 0.3 m above local mean low water (MLW). This profile, though recommended, is rarely built because it leaves much of the structure underwater most of the tidal cycle, making construction difficult. An impermeable sheetpile structure with concrete cap was selected because it fixes the sand trapping capacity. The profile was designed to match the natural beach and allow sand transport over and around the groin. Armor stone was placed for scour protection around the low tide section. The total groin length was ~ 220 m, of which 100 m was the berm section. The estimated trapping capacity upon placement was ~ 440 cm/m at the structure, yielding $\sim 140,000$ cm for the updrift fillet. A total of $\sim 320,000$ cm of nourishment was placed to restore the eroded beach and provide a construction pad for groin work in the dry by land-based equipment. Total project cost in 2013 was \sim US\$3.5 million, with the groin at \sim \\$1.2 million.

MONITORING AND MITIGATION

The South Carolina Beach Management Act of 1990 regulates construction activities in the coastal zone. For the rare locations where new groins are permitted, project sponsors must provide concomitant nourishment to fully fill groin cells at the time of construction. Mitigation of downcoast impacts must be implemented if post-project erosion losses exceed the historical rate of change. Mitigation may include renourishment, groin shortening, or groin removal as directed by state regulatory agencies.

Permits for the Folly Beach County Park groin required third-party surveys upcoast and downcoast of the structure to quantify volumetric changes in the project area. Annual surveys have been performed at the site in April of each year for nine years since project completion in 2013. These data provide measures of sand retention and beach stabilization by the structure (the primary purpose of the design) and the associated changes downcoast of the structure.

CONSTRUCTION

The project was constructed in two months, with nourishment placed prior to groin construction. Excess nourishment was pumped around the groin location to produce a temporary construction pad for land-based equipment. The groin was installed beginning at the seaward end and included a 1 m-diameter pipe extending 3 m above mean sea level (MSL) to mark the head of the structure. The 6.2 m long steel sheets were driven to grade using a vibratory hammer, then topped with a formed and poured reinforced concrete cap. The outer 30 m length of groin included a 7.5 m wide apron of armor stone at the cap elevation set on gabian mattresses. With the outer end of the structure in place to help retain some nourishment sand, the remaining groin sections could be installed in the dry working at low tide on the wet sand beach. This construction sequence required careful timing around the tidal cycle, but had the advantage of lower cost because temporary coffer dams were not required. By the time the landward berm section was under construction, the excess nourishment sand placed around the head of the structure had already spread downcoast, leaving a more natural profile and salient.

PERFORMANCE TO DATE

Figure 2 shows a sequence of pre- and post-project conditions. Before construction in March 2013 (top image), the project site was highly eroded with a broad washover fan extending across the marsh landward of the prior parking area for the County park. Marsh outcrops (dark patches on the image) were exposed along the outer beach, confirming recent high erosion rates. The middle image shows post-construction conditions (March 2014), including reclamation of the parking area and beach fillet on the upcoast side of the groin. The lower image shows conditions in January 2021, eight years after project completion. The site has experienced several tropical storms and another out-of-project area nourishment since 2013.

Annual profiles at ~60 m spacing were used to quantify volumetric changes upcoast and downcoast of the groin along the approximate 1-kilometer project area. The upcoast fillet spans ~600 m, and the downcoast spit extends ~500 m. While numerous calculation limits are available, the authors chose a low tide wading depth contour (-1.5 m MSL) as a reference boundary for the present performance review. Volume changes above this contour incorporate the foredune, dry sand beach, intertidal beach, and inner surf zone along the spit. In other words, the analysis emphasizes the visible beach and avoids the high varying changes over the shoal platform of the ebb-tidal delta.



Figure 2 - Aerial images showing the pre-project condition (March 2013), one year post-project (March 2014), and nearly eight years after project completion (January 2021).

The baseline condition was taken as the immediate post-construction survey (July 2013) before full equilibration of the nourishment. To simplify the presentation, we averaged the fillet profiles separately from the downdrift profiles and then computed running average annual changes comparing each year against the baseline year.

Figure 3 shows the results of the present volume analysis and annual loss rates. The graph in Figure 3 shows high initial losses due to fill adjustment. This includes offshore transport beyond the inner surf zone calculation boundary as the nourishment sand spreads into deeper water; and losses to longshore transport as the construction salient receded rapidly. By four years after construction, erosion rates diminished to under 10 cm/m/yr, and continued to slow through Year 6 (2019). Over the past three years, the fillet has stabilized with negligible change, confirming equilibrium has been reached on the updrift side of the groin.

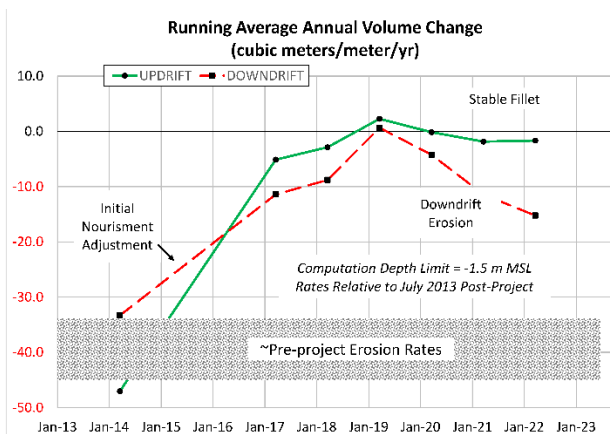


Figure 3 - The results of the present volume analysis and annual loss rates for the Folly Beach terminal groin. Initially, there were high sand losses due to fill adjustment, but erosion rates steadily diminished four years post-construction. Over the past three years, equilibrium has been reached on the updrift side of the groin.

The downdrift spit tracked with the upcoast fillet over the first seven years but has begun to erode at accelerating rates in Year 8 and 9. Despite the recent increase in erosion, the downdrift loss rates remain well below pre-project rates, as shown in Figure 3. Thus, the project has not reached a point where downcoast erosion exceeds threshold conditions for mitigation. Based on the data in Figure 3, the authors project that mitigation in the form of downcoast nourishment will not be required for at least three more years (Year 12 of the project). Figure 2 shows the downcoast spit remains largely similar to the pre-project condition. Recent oblique aerials (Figure 4) further confirm sand is freely bypassing the groin over the cap, which follows the natural profile, or around the end.



Figure 4 - Downdrift spit at Folly Beach County Park on 3 May 2022, nine years after groin installation. Note the continuous dry sand beach. Photo courtesy of GEL Inc, Charleston, SC.

The authors also track groin performance in terms of the reveal of the structure. The reveal has remained well below structural design criteria for a freestanding cantilever wall. There is little reveal or interruption of vistas on the upcoast side. The structure has not impeded

access to downcoast areas of the spit, and generally remains completely buried over half of its length. Maximum reveal on the downcoast side has been ~2 m along short sections. The downcoast side is favorably impacted by the protective delta platform of Stono Inlet.

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