APPENDIX F

DESIGN ENGINEERING ANALYSIS FOR TERMINAL GROIN LENGTH

(Prepared by Olsen Associates, Inc.)

Potential Project Performance
Associated with Differing
Terminal Groin Length

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The appropriate design length for the proposed terminal groin on Bald Head Island has been investigated through extrapolation of numerical model results and application of practical coastal engineering principles. The resulting desktop study focuses on the potential ability of different terminal groin lengths to protect varying lengths of South Beach at western Bald Head Island while minimizing negative impacts to the downdrift (west) beaches relative to a No Action alternative. For purposes of discussion, the predicted performance of three (3) terminal groin lengths is compared herein: a short groin (~1,100 feet total length), a mid-length groin (~1,900 feet total length), and a long groin (~2,900 feet total length). The landward point of attachment and general structural orientation of each groin alternative are self-similar. Each alternative is considered to be relatively permeable with respect to its ability to allow some level of sand transport over and through the structure. This is in contrast to conventional groin or jetty structures which are typically designed to be "sand-tight". The spatial extent of updrift benefits associated with a "leaky" terminal groin will be directly proportional to the length of the terminal structure. Conversely, it is expected that at some point, potentially negative downdrift impacts are also proportional to increasing structure length. A mid-length terminal groin appears to offer an acceptable balance between maintaining the updrift objective of the structure while minimizing the possibility of downdrift impacts.

The primary purpose of a terminal groin at Bald Head is to protect both private and public upland structures and infrastructure from chronic coastal erosion occurring immediately eastward of the federal navigation project. Sediment transport along western Bald Head Island is directed strongly towards the inlet, in the net. Numerical studies and physical monitoring indicate that the rate of sediment transport accelerates with proximity to the inlet. Once beach sediments reach the inlet they are either transported into the navigation channel or deposited into a large shoal formation at, or seaward of the Point. In either event these sediments are effectively lost from the littoral system on Bald Head resulting in beach profile erosion that is significant enough to warrant repeated application of erosion control measures along the affected shoreline via beach fill, placement of sand filled tube groins, and sand bag revetments.

Over the last 12 years, the shoreline orientation at the west end of Bald Head has progressively rotated clockwise to an increasing north-to-south orientation thereby resulting in increased obliqueness between the island and incident breaking waves (see **Figure 1**). This relationship is currently a significant factor in the chronically *increasing* rate of sediment transport off the island at this location. The installation of a terminal groin and beach fill are intended to

strategically reorient the shoreline counter-clockwise to a more northwest-to-southeast orientation. This will decrease the effective angle between the shoreline and incident breaking waves -- thereby reducing sediment transport along the South Beach shoreline segment nearest the inlet. The resultant amount of shoreline reorientation is directly dependent upon the length of any terminal groin and its associated updrift impoundment fillet.

Along westernmost South Beach on Bald Head Island, three fundamental shoreline orientations are currently evident, A, B, and C, as presented in **Figure 1**. Shoreline orientation A, which trends north-to-south, is associated with the aforementioned highest present-day erosional segment of South Beach. Future terminal groin performance will be predicated on developing a stable westerly extension more typical of either of the two remaining shoreline orientations (B or C) throughout the chronically eroded westernmost reach – thereby essentially reversing the significant negative effects that currently exist along orientation A. Establishing some variation of either orientation B or C in the long-term, in order to decrease the strong erosional gradient existing along west Bald Head Island, requires large-scale structural stabilization – such as a terminal groin of suitable length.

It can be readily seen that a "short" groin alternative (see **Figure 2**) fails to achieve the minimum desired shoreline orientation (i.e., B). Hence its expected updrift impoundment effect does not extend throughout the most critically eroded shorefront. Instead, the westerly extension of orientation B forms the basis for defining the requisite length of the "mid-length" terminal groin (see **Figure 3**), for which the updrift effects are predicted to extend through the critically eroded area. To emulate the westerly extension of orientation C would require a significantly longer terminal structure (see **Figure 4**). The updrift effects of a "long" terminal groin would likely extend eastward through most of the existing tube groin field; however, it entails an exceptionally long structural footprint and presents much greater potential for adverse impacts to both of the inlet-facing shorelines located northward thereof (i.e., the Point and West Beach).

A calibrated Delft3D model was employed in order to predict the short- and long-term responses to construction of the proposed mid-length terminal groin. Delft3D model simulations are described under separate cover. The results suggest that the mid-length terminal groin is capable of protecting currently threatened upland infrastructure and residential structures while reducing sediment transport along western Bald Head Island to rates consistent with those computed under historic shoreline conditions -- without significant or wide-spread downdrift impacts, relative to existing conditions.

Extrapolation of the numerical modeling results for the mid-length terminal groin was employed to infer the predicted physical performance of the shorter and longer terminal groin alternatives. For example, given the small post-construction impoundment fillet supported by the short groin (**Figure 2**) this structure is expected to offer benefits akin to those afforded by the existing sand

tube groins (with fill). That is, the area of direct benefit is very limited in scope and leaves several beachfront structures completely reliant upon the continued maintenance of the tube groins. Given that the Delft3D modeling of the mid-length groin suggests minimal short- and long-term downdrift impacts relative to existing conditions, it is reasonable to conclude that the increased sediment supply afforded by a shorter terminal structure would achieve similar minimal downdrift impacts. However, relative to the mid-length structure a short terminal groin would allow a greater volume of sediment to pass onto the downdrift beaches. While potentially beneficial to the downdrift beaches, this would result in a relative increase of channel shoaling and/or a shorter design life of any beach fill placed updrift of the terminal groin.

In contrast, extending the terminal groin a significant length beyond the mid-length shore normal dimension in order to maximize updrift impoundment potential (i.e., in general accordance with shoreline orientation C), would require a structure similar in length to that shown in **Figure 4**. The resulting fillet is defined by a shoreline that is nearly east-west in orientation and spans nearly the entire existing tube groin field. While theoretically possible, the resultant shoreline configuration is not typical of what would be expected at the terminal end of a barrier island for this coastline. In contrast to post-construction sediment transport rates predicted for the mid-length terminal groin, the very long terminal groin is likely to result in development of multiple updrift transport reversals including an increased potential for episodic crenulate bay formation immediately eastward of the structure. Additionally, the transport of sediment through and/or over the long terminal groin would likely occur predominantly near the structure's seaward terminus. This, combined with the overall length of the structure, suggests a decreased potential for sand to reach the downdrift shoreline, with sediment instead principally directed towards the navigation channel and/or onto Bald Head Shoal. Such a condition would be highly impactive to the Point and to West Beach.

From this investigation, it is concluded that the mid-length permeable terminal groin (on the order of 1,900 feet in total length) is the most appropriate length to reasonably and successfully achieve the objectives of decreasing erosion along the western end of South Beach and extending the longevity of placed beach fill, while minimizing impacts to the downdrift inlet shoreline and potentially reducing the rate of channel shoaling. It is noted that this effective length discussed herein is defined on the basis of the currently (2012) "eroded" shoreline location and includes a tie-back into both the existing upland and the beach fill to be constructed concurrently with structure implementation. Hence, much of the structure stem will be below grade thereby resulting in an effectively much shorter length relative to the new (post-construction) mean high water location.

Figures follow:

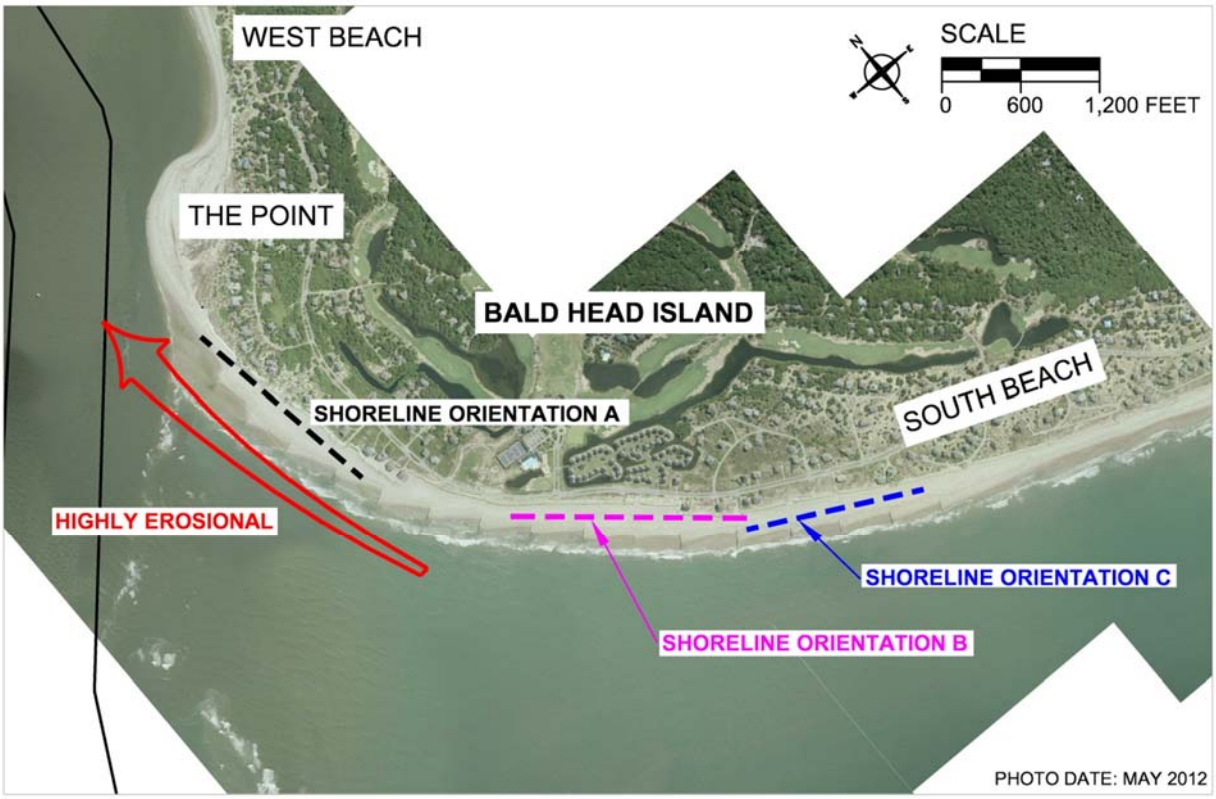

Figure 1: Fundamental shoreline orientations, A, B, and C, observed along western Bald Head Island.

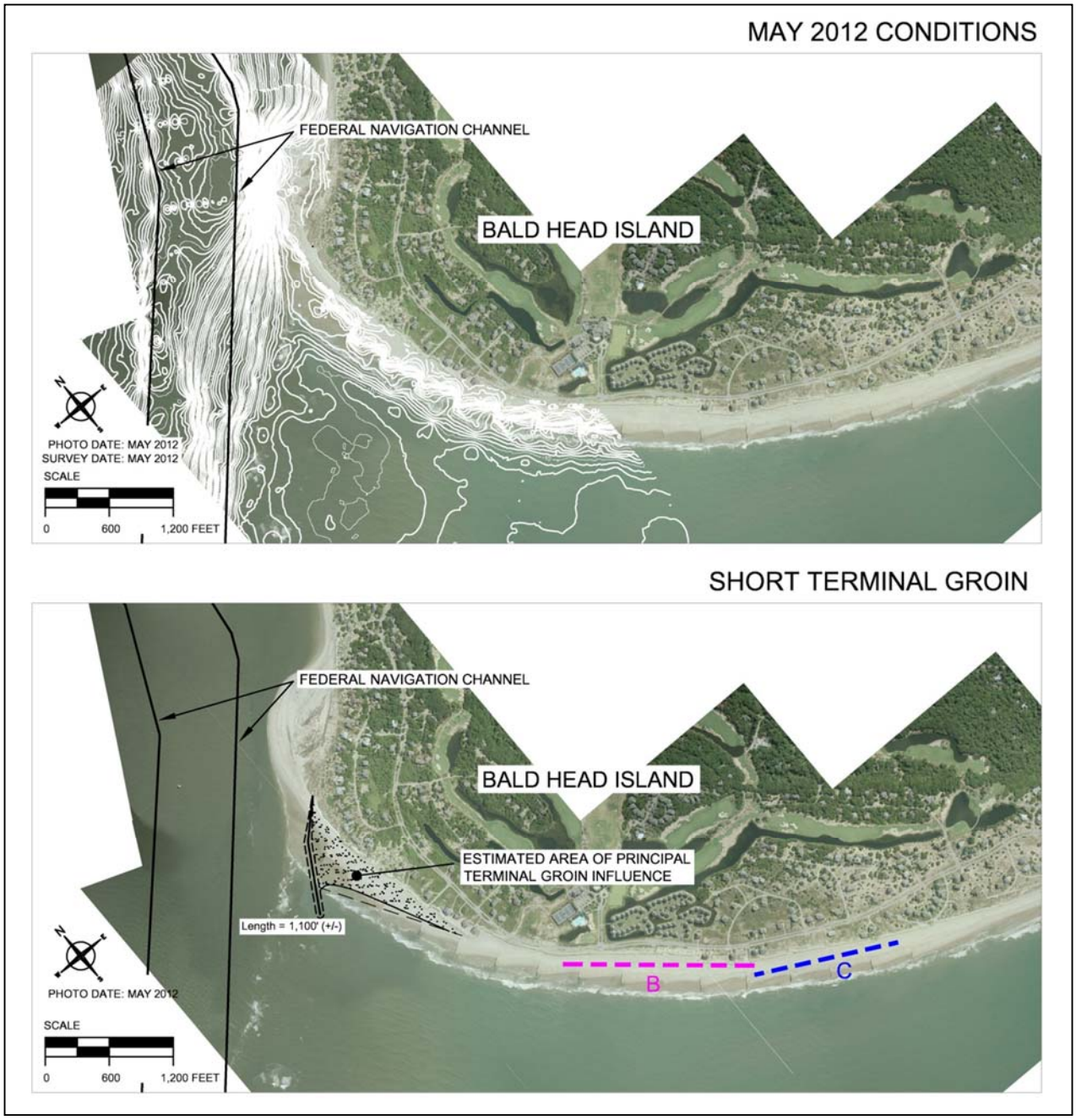

Figure 2: Conceptual illustration of updrift performance of a short terminal groin.

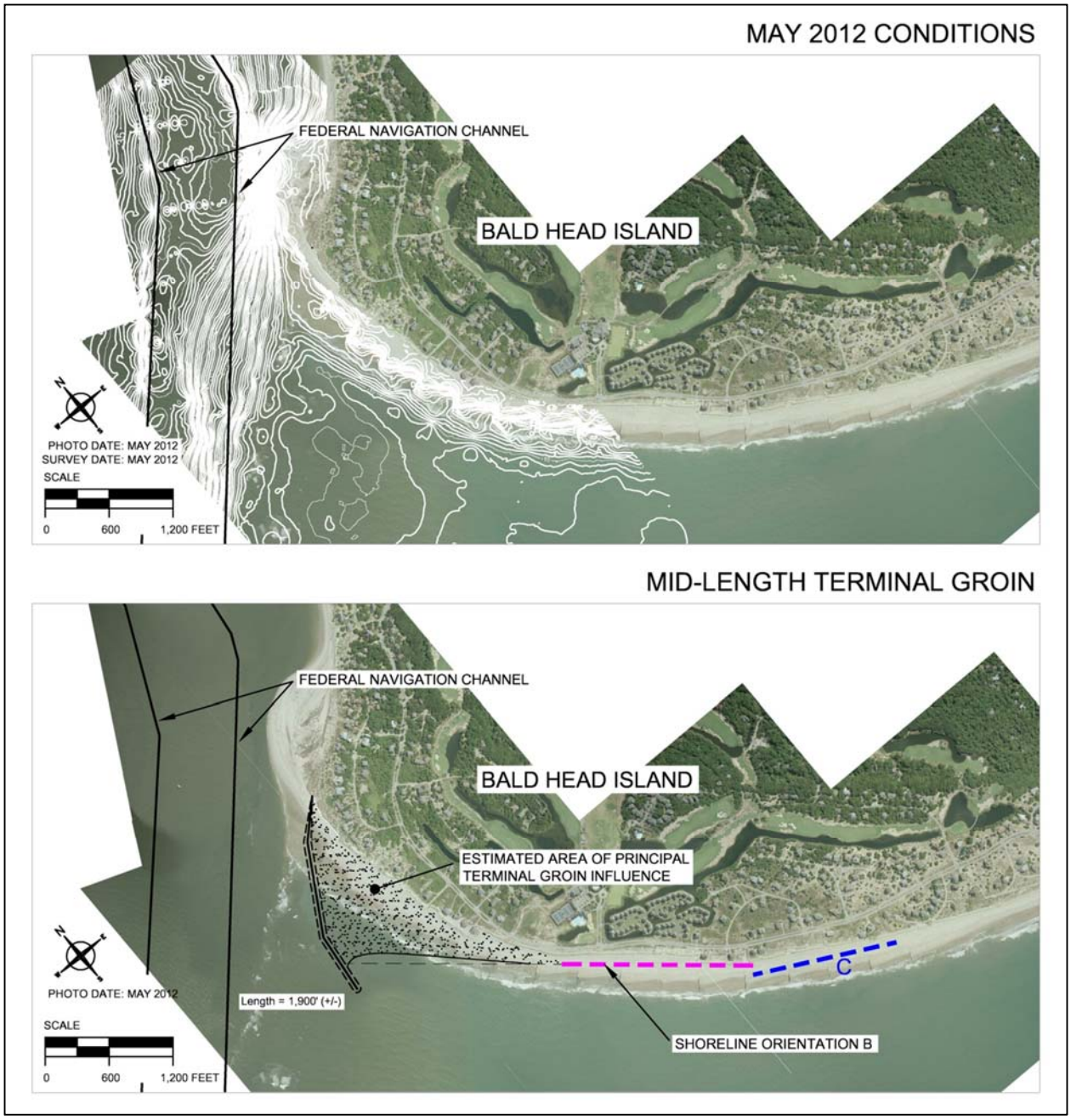

Figure 3: Conceptual illustration of updrift performance of a mid-length terminal groin.

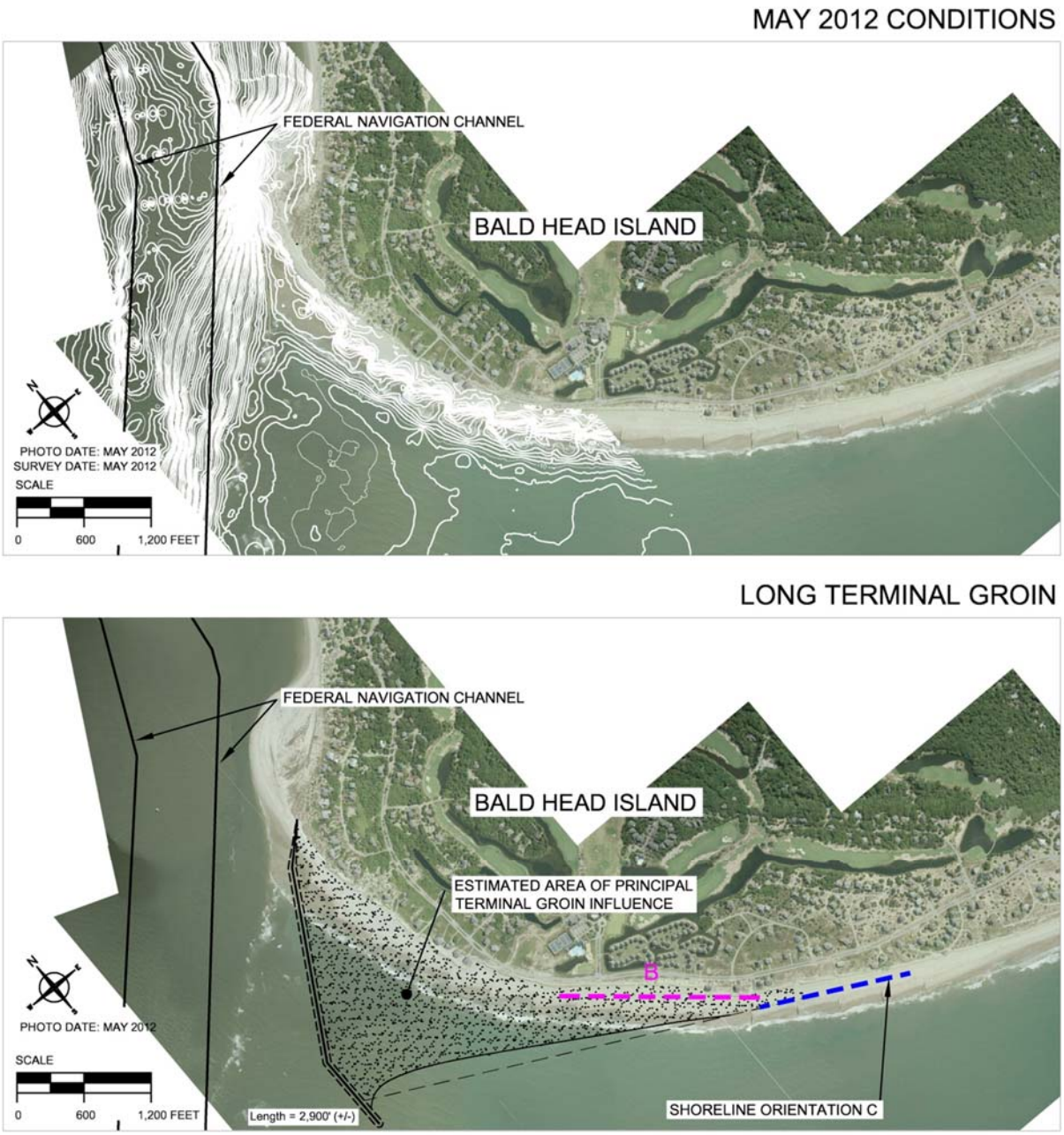

Figure 4: Conceptual illustration of updrift performance of a long terminal groin.