



Executive Summary

Introduction

This report details the findings of the consultant team portion of the North Carolina Coastal Resources Commission Terminal Groin Study. The study was initiated by the legislature under House Bill 709 (HB709) and mandated by Session Law 2009-479. It directed the Coastal Resources Commission (CRC) in consultation with the Division of Coastal Management (DCM), Division of Land Resources, and the Coastal Resources Advisory Council (CRAC) to study the use and applicability of a terminal groin as an erosion control device. The CRC is to present a report to the Environmental Review Commission (ERC) and the General Assembly by April 1, 2010. The CRC through DCM has contracted with a consultant team to perform the technical review portion of the study.

This report focuses on the data gathering and analysis performed by the consultant team for this study. The team selected was led by Moffatt & Nichol (M&N) and supported by Dial Cordy & Associates (Environmental Consultants), Dr. Christopher Dumas (Professor of Economics, University of North Carolina, Wilmington), and Dr. Duncan FitzGerald (Professor of Department of Earth Sciences – Coastal Marine Geology, Boston University). The M&N team gathered data and performed analysis with respect to the tasks outlined in HB709. Members of the Science Panel on Coastal Hazards, which advises the CRC and DCM with matters of scientific data pertaining to coastal topics and recommendations, provided input into the scoping of the study and selection of study sites; and reviewed and commented on the study methodology and reports.

The study was divided into eight tasks. The first six tasks involved the gathering and analysis of information related to the six points of consideration in the legislation. The bill directs the CRC to consider:

- (1) Scientific data regarding the effectiveness of terminal groins constructed in North Carolina and other states in controlling erosion. Such data will include consideration of the effect of terminal groins on adjacent areas of the coastline.
- (2) Scientific data regarding the impact of terminal groins on the environment and natural wildlife habitats.
- (3) Information regarding the engineering techniques used to construct terminal groins, including technological advances and techniques that minimize the impact on adjacent shorelines.
- (4) Information regarding the current and projected economic impact to the State, local governments, and the private sector from erosion caused by shifting inlets, including loss of property, public infrastructure, and tax base.
- (5) Information regarding the public and private monetary costs of the construction and maintenance of terminal groins.
- (6) Whether the potential use of terminal groins should be limited to navigable, dredged inlet channels.



The final two tasks were participation in the public input and meetings and the generation of a report for the CRC. Presentations, meeting minutes, public comments, and project information were regularly updated and maintained on a project website by DCM at www.nccoastalmanagement.net under the Terminal Groin Study heading in the 'What's New' section.

The legislation directs the CRC to conduct at least three public hearings. Five hearings were scheduled during the study process at various locations generally corresponding with a CRC meeting. In addition to the public hearings written comments could be submitted to the executive secretary of the CRC. The project website maintains a listing of these comments. Ultimately, the CRC will use the study as part of its charge to develop recommendations. This report is a fact gathering effort and does not advocate any policy with respect to the use of terminal groins. Policy recommendations and conclusions will be the responsibility of the CRC/CRAC.

Selection of Study Sites

- For this study, a *terminal groin* was defined as a structure built with the primary purpose to retain sand and not for navigation. It is a narrow, roughly shore-normal structure that generally only extends a short distance offshore.
- In consultation with the Science Panel, 25 sites with terminal structures along the Atlantic and Gulf coasts were initially considered. Five sites were then selected to be included in the study: Oregon Inlet, NC; Fort Macon, NC; Amelia Island, FL; Captiva Island, FL; and John's Pass, FL
- Only existing data was collected; no new data was acquired for this study.
- Uncertainties are associated with the data and should be recognized with any analyses.
- All five of the existing study sites have sand management activities (dredging, nourishment) as part of the overall project.

Physical Assessment

- Although terminal groins trap sand, they are dissimilar to a jetty, because once the terminal groin fills with sediment, additional sand bypasses the structure and enters the nearshore and / or the tidal inlet.
- Terminal groins are commonly built on either (or both) sides of inlets because in addition to the regional dominant longshore sediment transport system delivering sand preferentially to one side of an inlet, wave refraction around the ebb delta results in sand transport back toward the inlet along the downdrift shoreline.
- A consequence when the structure is built on the downdrift side of the inlet is the stabilization of the inlet by preventing migration of the inlet channel. The groin inhibits erosion of the side of the channel by tidal currents and thus the inlet is not allowed to migrate.



- Dredging can have significant impacts on the inlet morphology and sedimentation processes of the ebb-tidal delta.
- Shoreline change is purely the difference between the shorelines and includes the impacts of beach nourishment and dredging that have occurred in each area and so do not solely represent the impacts of the terminal groins.
- Quantitative analyses were performed for shoreline change; volumetric changes based on the shoreline changes; volumetric changes after subtracting out all beach nourishment and nearshore placement activities; and volumetric changes after subtracting out all beach nourishment and nearshore placement activities and then adding back in various scenarios for dredged material naturally bypassing the inlet.
- In all cases, the shorelines on the structure side of the inlet was eroding prior to construction of the terminal groin; and after construction, the shorelines on the structure side of the inlet were generally accreting.
- The data on the opposite side of the inlet does not display a clear trend (i.e. mixed accretion and erosion).
- After subtracting out all beach nourishment activities (but not accounting for dredging), the changes between pre- and post-construction periods on the terminal groin side show (note – “positive result” indicates an improvement; either reduced erosion, a change from erosion to accretion, or increased accretion; while “negative” indicates the converse):
 - There is a significant positive result over the first mile of shoreline (except for Amelia Island where this positive result only occurs over the first half mile);
 - For Oregon Inlet, Fort Macon, and Amelia Island there is a moderate negative result over the second mile and then much less of a change (either positive or negative) over the third mile;
 - For Oregon Inlet, further down the Pea Island shoreline, a positive result is present over the fourth mile and then minimal changes over the fifth and sixth miles;
 - On a cumulative basis, for Fort Macon and Oregon Inlet the positive results are significantly greater (about 150,000 cy / year) than any negative results over the shoreline reaches analyzed;
 - Amelia Island does not show a net positive result, but the adjustment in the post-nourishment shoreline that occurred during the very short post-construction analysis interval analyzed is likely the cause; and
 - For Captiva Island and John’s Pass, the positive result is apparent over basically the entire three mile analysis length of shoreline with cumulative positive results amounting to 90,000 – 120,000 cy / year.



- After subtracting out all beach nourishment activities (but not accounting for dredging), the changes between pre- and post-construction periods show on the side opposite the terminal groin (note that no data was available for the Amelia Island study site):
 - Typically a minor to moderate negative result occurs over the first half to three-quarters of a mile. Whether this is the effect of terminal groin construction or other impacts such as increased dredging or migrating inlets, though, is not possible to definitively conclude.
 - For Captiva Island, John's Pass and Shackelford Banks the results turn positive after this initial distance with net cumulative positive results over the shoreline analyzed for Captiva Island and John's Pass and a negative result for Shackelford Banks.
 - At Oregon Inlet, the negative result continues for the second mile with minimal change over the third mile.
- Much like nourishment, the influence of dredging material from the inlet system must be accounted for when attempting to assess the impact of the terminal groins. These results show:

One must assume about 25% of the material dredged from the inlet would have naturally reached Shackelford Banks for the negative pre- to post-construction change over the three-mile shoreline analysis interval to turn positive.

Environmental Assessment

- The environmental effects of a terminal groin structure alone could not be assessed for the sites without considering the associated beach nourishment activity.
- Potential effects of terminal groins in conjunction with shoreline management (i.e. beach nourishment) on natural resources vary according to the type of construction equipment used, the nature and location of sediment discharges, the time period of construction and maintenance in relation to life cycles of organisms that could be potentially affected, and the nature of the interaction of a particular species.
- The construction of a terminal groin, beach nourishment and dune construction prevents overwash and inlet migration thereby contributing to a loss of habitat for breeding and non-breeding shorebirds and waterbirds, including the piping plover.
- Terminal groins are typically used in combination with a long-term shoreline protection program (beach fill), in areas where pre-project shoreline conditions are generally degraded with limited potential sea turtle nesting activity.



- Based upon the historical nature of the terminal groins at Fort Macon, John's Pass (northern groin), and Redfish Pass; discernible trends of the effects of these terminal groins on the natural resources is somewhat limited. Lacking pre-construction data makes an empirical determination of post-construction effects at these sites difficult if not impossible.
- While the use of control and/or regional sites strengthens the ability of a study to infer an impact from a detected change, one cannot infer an impact if there is no statistical evidence for a change (Mapstone 1995); and due to the lack of complete datasets and high levels of confidence in the quality of the data, statistical analysis was precluded.
- The current development and use of some of the selected sites precludes unrestricted utilization by the site's natural resources. Sea turtles, avian species, and marine species, however, continue to make use of these managed sites, albeit sometimes on a limited basis.
- The terminal groins at Oregon Inlet and Amelia Island are more recent construction projects, and pre- and post-construction natural resource data readily available were evaluated (sea turtle and shorebird nesting data). The more recent data collected since construction, indicates an increase in public interest/participation, and funding for monitoring of these resources.
- Although shorebirds and sea turtles utilize both locations, neither significant trends nor adverse effects were discernable from the available data. The resources present at both the Amelia Island and Fort Macon terminal groin locations were compared to undisturbed neighboring barrier islands where data indicated resources were more prevalent, as expected.
- Anchoring the end of an island may curtail an inlet's natural migration patterns thereby minimizing the formation of sand flats;
- Fillet material should be compatible to minimize effects on benthic infauna recovery and upper trophic levels;
- Resources continue to use locations where terminal groins exist, however, if habitat succession occurs, species suitability may be affected.



Engineering Construction Techniques

- The five study sites all consist of rubble mound (rock) groins.
- Terminal groin design is very site-specific. The length, height, and permeability of the groin will determine how effective the groin is at trapping sediment updrift of the groin and the overall impact of the groin on sediment transport.
- Long groins that are built above the seasonal high water level or are completely impermeable will most effectively block sediment. However, short groins with high permeability may not block enough sediment to be effective. Terminal groins should be just long enough to retain the required beach width, without causing an undue reduction in sediment transport downdrift.
- Ideally, the groin height should be limited to just above beach level. Adjustable heights to nourishment volumes and design berm heights are also beneficial. The design groin height should also account for wave overtopping and the desired amount of sediment transmission over the structure.
- Rock is generally the most widely used building material since it is readily available and highly durable. Concrete and steel are suitable building materials for shorter, mid to shallow-water groins; however, these materials tend to be cost-prohibitive. Timber and geotextile groins are less expensive alternatives and can be adapted to a variety of beach conditions, but also have limited applicability to shorter, shallow-water conditions.
- Concrete, steel, and timber structures have the advantage of being adjustable with the beach profile without having to rebuild or remodel the groin.
- Groin notching is an emerging technique that allows for adaptive management. Notching allows for sediment to bypass the groin where it would normally be trapped. This may prove to be a cost-effective alternative to groin removal.
- It appears that for shorter groins, the interruption to littoral transport is smaller compared to the overall magnitude of sediment transport and the muted impacts seen both updrift and downdrift of the inlet.
- There also seems to be a threshold that appears with both length and height to be crossed where adjacent impacts become more pronounced. While it is possible that dredging impacts may be responsible for this threshold crossing, it underlies the importance to considering the overall length of the structure in relation to the exterior man-made and natural processes that also drive sediment transport so that the structure's relative effects are minimized or eliminated.
- The permeability of the structure has a significant impact on adjacent shorelines. The Amelia Island structure has allowed material to bypass the structures to limit effects on downdrift shorelines and volumes. However, the structure has also had a limited impact on the updrift shoreline (mainly within the first 0.5 miles). The other structures have impermeable cores and appear to hold more sand for a greater distance updrift of the structure.



Economic Assessment

- The economic value at risk within the 30 year risk areas for developed shorelines varies greatly from about \$27 million at Ocean Isle to over \$320 million at Bald Head Island. It must be noted, though, that not all of these properties can be protected by a terminal groin.
- The economic value at current or imminent risk (as defined by the presence of sandbags for temporary protection) for developed shorelines varies from just under \$3 million at North Topsail Beach to about \$26 million at the north end of Figure Eight Island.
- Barrier island municipality tax bases range from \$409 million for Caswell Beach to over \$4.2 billion for Emerald Isle. The countywide tax bases range from \$3.8 billion for Pender County to \$29.1 billion for New Hanover County.
- The full value of residential property may not be lost in the event that the properties themselves are lost to shifting inlets, as some of the property value associated with oceanfront or soundfront location may transfer to nearby properties.
- Additional factors affecting the economic value of inlet areas were reviewed but not specifically quantified due to lack of data. Where possible, qualitative and case study information is provided for the following factors:
 - Beach Recreation Value
 - Shore / Surf / Beach Fishing
 - Primitive Area Hiking / Camping Value
 - Wetland Recreation Value
 - Value of Non-Game Wildlife in Beach and Coastal Wetland Areas
 - Value of Coastal Wetlands in Supporting Recreational Fishing
 - Value of Wetlands in Protecting Property from Hurricane Wind Damage
 - National Seashores and Refuges
 - State Parks



Initial Construction and Maintenance Costs

- Construction costs of terminal groins can vary greatly depending upon construction materials, length and beach profile.
- The construction costs (in 2009 dollars) of the five terminal groins analyzed range from less than \$1 million for John's Pass and Captiva Island to about \$24 million for Oregon Inlet.
- Four cost scenarios were developed:
 - Short, smaller cross-section groin (450 feet) on a flat-sloped beach
 - Short, smaller cross-section groin (450 feet) on a steep-sloped beach
 - Long, larger cross-section groin (1500 feet) on a flat-sloped beach
 - Long, larger cross-section groin (1500 feet) on a steep-sloped beach
- Rubble-mound terminal groins could range from about \$1,230 per linear foot to \$5,180 per linear foot.
- Geotextile Tube terminal groins could range from about \$350 per linear foot to \$660 per linear foot (short groin only; not recommended for longer groin)
- Steel or Concrete Sheet Pile or Timber terminal groins could range from about \$4,000 per linear foot to \$4,800 per linear foot. (Timber only recommended for short groin scenarios)
- Initial project costs including construction of the terminal groin, initial beach nourishment and permitting and design fees may range from about \$3.5 million for a shorter groin to over \$10 million for a larger one.
- Annual project costs including structure maintenance / repair, annual beach nourishment, and monitoring could be in the range of \$0.7 million to over \$2 million.
- Terminal groins are typically constructed as part of a broader beach management plan and may make nourishment adjacent to inlets feasible, but they do not eliminate the need for ongoing beach nourishment.
- These costs could vary substantially based on site conditions and design storm parameters.



Potential Locations

- The vast majority of the structures considered for this study were located at inlets with most of these adjacent to navigable, dredged channels.
- No terminal groins were identified as being located at the end of a non-inlet littoral cell.
- The most substantial (longer, higher and / or less permeable) terminal groins were typically found where the greatest amount of dredging activity occurs. While this may be obvious, it is worth stating that the more significant the dredging activities, the potentially greater the impacts on adjacent shorelines; the greater the potential need for more nourishment and / or more substantial stabilization structures. These dredging activities may greatly outweigh any potential long-term shoreline changes resulting from the construction of a terminal groin.
- With respect to locating a terminal groin on the updrift or downdrift side of an inlet, it is interesting to note that both sides were represented among the five structures selected for this study. While an initial thought might be that a terminal groin should be located on the updrift side of an inlet in order to capture sediment, it must be noted that sediment typically moves in both directions along a shoreline depending upon the incident wave activity, and significant reversals in sediment transport direction often occur near an inlet due to the presence of the ebb shoals and other inlet features which transform the waves as they approach the shoreline.
- Locating a terminal groin on the “net” downdrift side of inlet may have the additional impact of “stabilizing” the location of a migrating inlet, such as the case at Oregon Inlet where this impact has also resulted in changes to the inlet cross-section – a general narrowing and deepening over time since terminal groin construction. Great care should be exercised when siting a terminal groin in this setting as the channel may shift and potential undermining of the groin may become a concern.
- Based on the existing sites and the literature review completed, the impacts of terminal groins on adjacent shorelines is difficult to identify if they exist at all if located adjacent to a highly managed, deeper-draft navigable inlet.
- The relative impact of these structures on adjacent areas is likely increased when sited next to natural or minimally managed shallow-draft inlets. For these locations, additional care and study (geologic setting, sediment budgets, etc.) is warranted to be sure that the terminal groin’s impacts are acceptable or can be mitigated through minimal human activities (dredging and nourishment).



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