BEACH NOURISHMENT FOR HURRICANE PROTECTION: NORTH CAROLINA PROJECT PERFORMANCE IN HURRICANES DENNIS AND FLOYD

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Since 1996 southeastern North Carolina seems to have been a magnet for hurricanes. In four hurricane seasons, four storms made landfall at Cape Fear near Wilmington, N.C., and a fifth passed nearby (Figure 1.) In 1996, Hurricane Bertha arrived, with Hurricane Fran only about a month later. After a quiet year in 1997, Hurricane Bonnie made landfall in 1998. This paper reports on the erosion threats to oceanfront buildings during Hurricanes Dennis and Floyd in 1999 and on the relative performance of five beach nourishment projects during those storms.

After Hurricane Dennis passed just offshore Cape Fear, it became stationary for five days, 150 miles offshore of Cape Hatteras. It caused moderate shoreline erosion statewide in passing. Conditions were significantly worse north of Cape Hatteras due to the duration of the storm. Because the highest winds remained offshore, the shoreline conditions were similar to an unusually severe northeast storm. Storm surge levels were generally less than 5 feet above normal but offshore wave heights exceeded 40 feet.

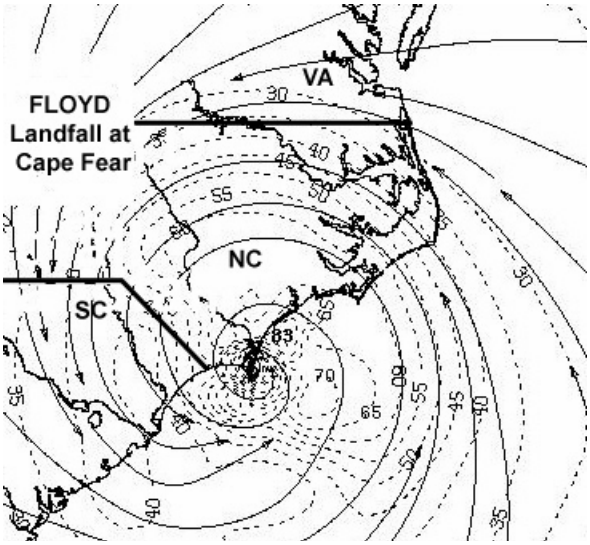


Figure 1 Floyd's landfalling winds (mph) at Cape Fear

Two weeks later, Hurricane Floyd made landfall at Cape Fear as a Category 2 hurricane. The peak storm surge exceeded +10 feet NGVD. Based on National Flood Insurance Program predictions the storm surge return frequency was 75 years. This combination of closely timed storms caused coastal flooding, shoreline erosion and wave damage along the entire North Carolina coast. Approximately 300 miles of shoreline were affected.

Destroyed and Threatened Buildings

The severity and chaos of the earlier hurricanes unfortunately made tallies of building damage a low priority immediately after the storms. However, by the time Dennis and Floyd hit, local governments were well practiced in storm preparation and recovery. For the first time, local governments had the luxury of documenting major structural damage to buildings. Destroyed buildings were identified using FEMA's substantially damaged definition (> 50 percent damaged) and were considered unrepairable. Communities identified structurally damaged but repairable buildings by various labels, such as condemned, uninhabitable or power disconnects. With few exceptions, the common condition among the buildings was that at least part of the foundation had been undermined by erosion during one of the storms.

The degree of damage to buildings classified as threatened varied considerably. Most of the buildings were single-family houses constructed on piling foundations with elevated living floors over under-house parking and storage. In some cases, only a single piling or row of pilings experienced erosion, with erosion depths as shallow as one foot. Repair could be as simple as replacing a set of steps to meet the building code requirement of two means of access. In the other extreme, a significant share of the threatened houses experienced wave-induced erosion landward of the building. Vertical erosion losses around the seaward side of the foundation could be as much as 8 feet. Most of the buildings were somewhere between those extremes. Those classified as threatened generally are expected to be repaired by the following spring. The state's oceanfront setback line for new buildings is based on the long-term erosion rate rather than an individual storm's erosion, but the requirement uses the seaward line of stable dune vegetation as a reference line to measure landward for the setback. The erosion-relocated vegetation line is a significant repair incentive as the setback line has been moved far enough landward to make many of the most eroded lots at least temporarily unbuildable for new construction.

The survey results are summarized in Figure 2. Communities are listed from north to south. Dennis and Floyd combined to cause damage along the entire North Carolina oceanfront, from Virginia to the South Carolina border. Statewide, local governments determined that 65 buildings were destroyed or substantially damaged. The survey identified 903 additional oceanfront buildings as erosion-threatened. Although the buildings affected by Dennis and Floyd are scattered down the coast, they generally cluster near historical problem areas for long-term erosion. The storms significantly broadened the previous problem areas and damaged many buildings that previously had been only close to the edge.

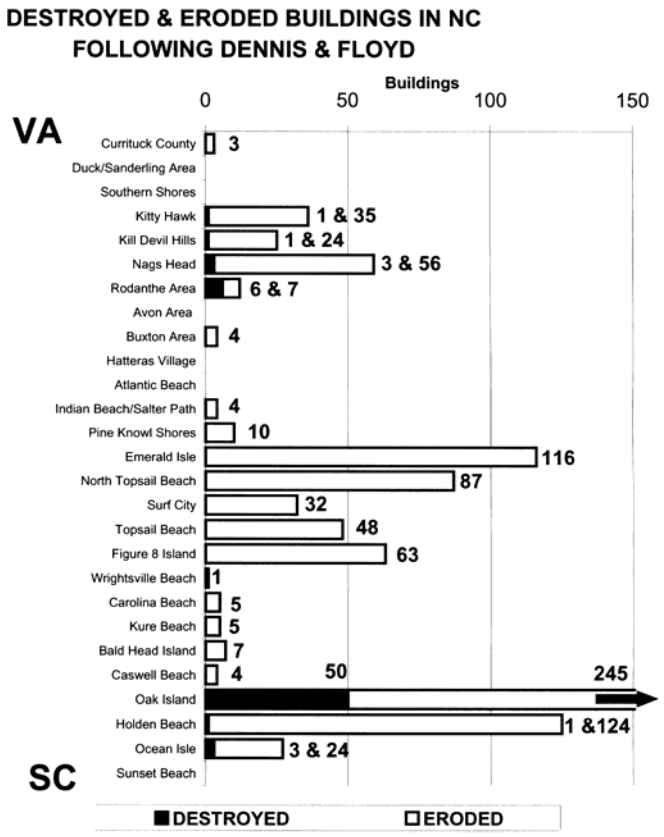


Figure 2 Locations of destroyed and threatened buildings

Beach Nourishment Projects

Several North Carolina coastal communities have used beach nourishment over the past 35 years. Nourishment has been conducted for several different purposes and practiced on several different scales. There are three hurricane protection projects designed by the U.S. Army Corps of Engineers; two somewhat smaller-scale — but regularly maintained — public/private projects; one very large port-dredging beach-disposal site; and several hundred small, unmaintained beach-disposal fills from nearby navigation projects. The building inventory following Hurricanes Dennis and Floyd provides a unique opportunity to look at the

performance of the larger nourishment projects and compare the protected areas with other natural shorelines nearby.

With local sponsorship, the Corps built separate 2.6-mile nourishment projects for Wrightsville Beach and Carolina Beach in 1965. Initial construction and maintenance costs, as well as the benefit/cost ratios are based primarily on hurricane protection for buildings rather than any recreational beach benefits. Both projects have construction cross sections 250 feet wide, with a dune crest 25 feet wide and an elevation of +13.5 feet NGVD. The plans call for maintenance by adding sand to the lower beach width every two to four years to offset the pre-existing long-term erosion and other project losses. The dune and part of the beach width is designed to provide the building protection during hurricanes. Maintenance is expected to take place before the minimum protection cross-section is eroded. Funding coordination problems for both towns halted maintenance in the 1970s, allowing a reversion to severe, pre-project erosion threats on some sections of the shoreline. Both projects were substantially rebuilt about 1980 and maintenance has been conducted on a regularly scheduled basis since that time. The Corps designed a similar cross-section for 3 miles of shoreline in Kure Beach and the south end of Carolina Beach. The project was advertised for bids when Hurricane Fran hit. Kure Beach lost approximately 20 houses, with many more threatened. The nourishment project was redesigned for the post-Fran shoreline conditions and completed before Hurricane Bonnie in 1998.

The Corps uses a cost-optimization method for design rather than a return frequency, but for these projects the equivalent design frequency is on the order of 50 years. Hurricanes Fran and Floyd, with return frequencies of 120 and 75 years, appear to be the first storms exceeding design-level to hit any U.S. beach nourishment project designed around manmade dunes for hurricane protection of coastal buildings.

Because design levels were exceeded by the two storms, some degree of damage to the nourishment project and to the protected buildings is to be expected. The dune and beach are designed as sacrificial features that may be consumed during the duration of the storm. Some sections of the manmade dunes were completely eroded in both storms. The dunes were rebuilt to the design cross-section during the regularly scheduled maintenance in 1998, about 18 months after Fran. The new Kure Beach project was constructed at about the same time. All three Corps projects were tested again by Bonnie's 37-year storm surge with minor erosion of the lower beach but no significant erosion of the dunes. In some cases, Bonnie's overtopping and wind transport raised the elevation of the manmade dune. During Floyd, some sections of the manmade dunes were flattened again, but less extensively than during Fran.

The inventory of destroyed and threatened buildings can be used as a simple measure of the effectiveness of the beach nourishment projects. Wrightsville, Carolina and Kure Beaches appear to have received Floyd's highest storm surges, yet show marked reductions in threatened and destroyed buildings compared to unnourished communities both north and south.

The benefits are actually more dramatic than implied in the figure. All of the threatened buildings listed for the three communities were located outside the nourishment project limits or in transition areas at the ends of the projects where the dunes were not constructed. Hurricanes Floyd and Dennis threatened or destroyed 968 buildings outside the three Corps-designed nourishment projects' manmade dunes. Remarkably, not even one building behind the project dunes was threatened by erosion — that's ZERO.

The actual value of building damage would be a better measure of the success of the hurricane-protection nourishment projects. Efforts are underway to complete that analysis for all

of the recent North Carolina hurricanes. This study documents only the reduction in erosion threat to individual building foundations in hurricane conditions up to a 75-year storm surge. However, previous studies have shown that the highest building loss rates and most severe damage will occur in the storm-eroded areas closest to the ocean (Rogers, 1990). The three nourishment projects prevented all erosion damage to the protected buildings. Even in areas where the manmade dune was eroded, peak wave heights under the buildings were obviously reduced. More detailed damage studies are certain to show major reductions in damage costs.

Figure Eight Island has had its beach nourished on an irregular basis since 1979, through private funding by property owners. Beach nourishment also has been used for erosion control on Bald Head Island. Project widths vary but have typically placed 100 to 150 feet of new berm, without any dune. Sections of Figure Eight had been filled several months prior to Floyd. Following the storm, 63 houses were threatened by erosion. Bald Head has relatively few beachfront buildings but seven were threatened. These smaller projects may have reduced the erosion and number of threatened buildings but appear to offer far less protection than the larger cross-sections and higher dunes of the hurricane-protection projects.

Atlantic Beach has been fortunate to receive beach nourishment as part of dredging from the nearby state port in Morehead City. Clean sand dredged for channel maintenance is placed in an inland, diked disposal area. When the disposal area fills every eight to 10 years, sand is moved to the shoreline of Atlantic Beach, allowing the disposal area to be reused for more frequent maintenance. Volumes have been as high as 4 million cubic yards placed as a wide berm. Over time, the beach has widened on the order of 300 feet. Dunes have not been constructed but have naturally developed seaward of the existing buildings. Atlantic Beach was in the fringe of both Dennis and Floyd and was not tested as severely as the other nourishment projects. However, no buildings were threatened or destroyed during the two hurricanes.

Conclusions

The beach nourishment projects in North Carolina designed for hurricane protection by the U. S. Army Corps of Engineers performed as expected in the flurry of recent hurricanes. The building survey following Hurricanes Floyd and Dennis found that no buildings were threatened by erosion inside the project dunes, while 968 buildings were threatened and destroyed outside the protection. Properly designed and maintained beach nourishment is clearly an effective tool for hurricane protection. The only question is how overwhelmingly beneficial the projects will prove in economic terms.

Damage analysis from Fran can be expected to show even greater benefits than Floyd's tally. Preliminary reviews indicate not one building behind the project dunes was destroyed by Fran's waves or erosion. Outside the project limits, in similar surge conditions, an estimated 500 oceanfront buildings were destroyed. Smaller nourishment projects have historically been successful against moderate rates of long-term erosion but should not be assumed to provide significant erosion and wave protection during infrequent but severe storms like hurricanes.

References

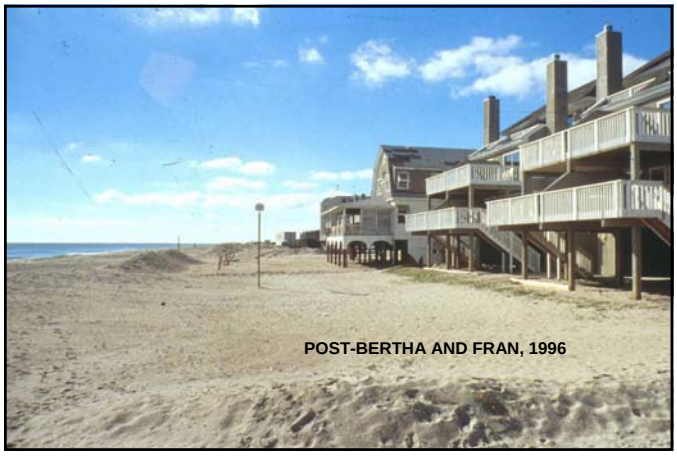
Rogers, S.M., Jr. (1990). "Designing for Storm Surge and Wave Damage in Coastal Buildings." Coastal Engineering Conference, Delft, The Netherlands. ASCE.


WRIGHTSVILLE BEACH
CENTRAL AREA, POST-DENNIS & FLOYD

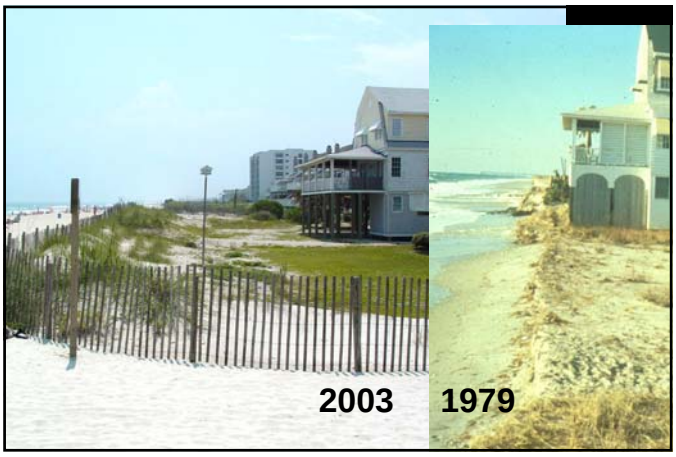

1979, NO MAINTENANCE


1980 RECONSTUCTION


1995, PRE-HURRICANES


POST-BERTHA AND FRAN, 1996


POST-BONNIE, 1998



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