A SENSITIVITY ANALYSIS OF BARRIER ISLAND BREACHING

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Abstract: This paper will discuss the beginnings of a sensitivity analysis of barrier island breaching. The study area of Mantoloking, New Jersey, USA is used as the barrier island breached significantly during Hurricane Sandy in 2012. The numerical model XBeach is used to conduct this study. The study investigates the affects that back-bay currents, water-level timing, and barrier-island configuration have on barrier island breaching.

Introduction

Major coastal storms can change the morphology of a landmass in a relatively short time span. Specifically, major storms can form breaches in barrier islands, leading to damage to both the built and natural environments and potentially exacerbating flooding in areas farther inland. Therefore, characterization of barrier island breaching is important to understanding water-land processes. The factors that contribute to certain aspects of barrier islands breaching are not fully known and are investigated in this study through a sensitivity analysis. The sensitivity analysis will explore the influence of barrier-island configuration and water-level timing, with a focus on exploring the influence of back-bay currents (flow channelization) on the breaching process.

Study Area

Mantoloking, New Jersey, USA is located on a barrier island between the Atlantic Ocean and Barnegat Bay, New Jersey USA. The island was impacted by Hurricane Sandy, which reached New Jersey on October 29, 2012. Specifically, a breach formed on the barrier island, resulting in a post-hurricane connection between the bay and the ocean (Figure 1). The breach formed next to

Mantoloking Bridge where the back-bay narrows. The bridge could have influenced both the breach formation and location.

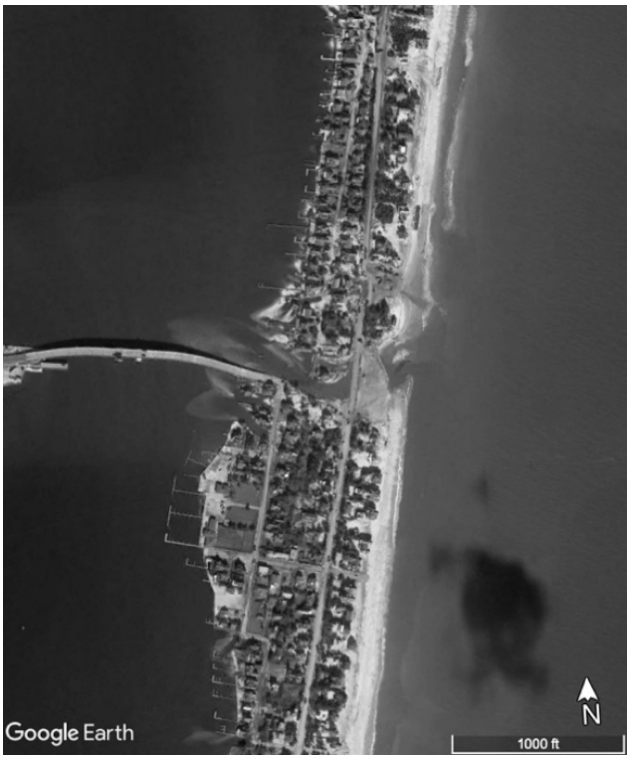

Figure 1. Satellite image ("Google Earth Pro" 2022; and references therein) of the breach at Mantoloking, NJ from November 2012

As seen in Figure 1, the breach occurred not at the narrowest part of the barrier island but at a narrower section of the back-bay. The town of Mantoloking, NJ is inhabited and contained 521 homes at the time of the breach event (U.S. Army Corps of Engineers [USACE] 2012). The breach divided the town physically with this new channel and resulted in multiple homes being displaced or washed away by the current.

Methods

A sensitivity analysis is conducted to determine the parameters that influence breaching. The computational model XBeach (e.g., Roelvink *et al.* 2009) is used to simulate nearshore processes. The numerical model was chosen for its ability to simulate barrier island breaching. The ability of the model to simulate

morphological change during intermittent overwash and during inundation allow for more realistic simulation of breaching.

The parameters studied are barrier island shape (e.g., dune height and width, barrier island width), back-bay shape (cross-shore width), and the water levels in the ocean and back-bay. The XBeach grid's cross-shore profile is idealized using a submerged Dean profile (Dean 1977) paired with a subaerial normal distribution to represent the dune. In the alongshore, the dune height is varied to create a low point at the intended breach location. In the cross-shore direction, the subaerial profile sediment volume is conserved with change in dune height. To investigate the influence of back-bay currents on the breaching process, bay water levels will be varied in the alongshore direction in order to induce an alongshore water-level gradient within the bay. In addition, multiple back-bay configurations will be considered, with cross-shore bay widths ranging from wide to narrow.

Idealized water level time series will be developed based on existing observations (National Data Buoy Center) and the NACCS water levels. The idealized water level time series will be used to force XBeach simulations.

The results of the sensitivity analysis will be analyzed to determine the significance of each parameter's impact on breaching.

Relevant Studies

Previous work conducted by Smallegan and Irish (2017) studied the impacts of Hurricane Sandy on Bay Head, New Jersey USA. Bay Head is a town just north of Mantoloking and similarly is located on a barrier island that sits between Barnegat Bay and the Atlantic Ocean. Their work used XBeach to study the impact of bay-surge forcing conditions on the barrier island. Smallegan and Irish found that the timing of the bay-surge directly impacted the amount of erosion experienced by the barrier island. Water level gauge observations from Hurricane Sandy show that peak ocean surge occurred before peak bay surge in Barnegat Bay. In addition, the peak ocean surge occurred during setdown in the bay, and when the ocean water levels subsequently dropped the bay levels increased to their peak surge. Smallegan and Irish noted that the weakening of the dune system by the ocean surge allowed for the subsequent back-bay surge to inundate the barrier island.

The work of Gharagozlou *et al.* (2021) also studied the process of barrier island breaching. They used ADCIRC+SWAN coupled with XBeach to investigate a breach on Hatteras Island, North Carolina, USA during Hurricane Isabel in 2003. They used both numerically simulated water levels to force XBeach as

well as artificially raised water levels to test the breaching regime. Gharagozlou *et al.* found that the dune system was inundated from the ocean side after most of the dune system had been eroded. Channels through the island were already formed from the inundation on the ocean side of the barrier island before the bay water levels rose. They found that once the bay water levels exceeded the ocean side the existing channels deepened through the scouring process of the water returning to the ocean. The scenario with elevated water levels ultimately caused deeper channel depths through the island than the historical case, indicating that water level gradient could be a factor in the severity of the breach.

Hegermiller *et al.* (2022) investigated the breaching events of two barrier islands, Fire Island, New York USA during Hurricane Sandy and Matanzas, Florida USA during Hurricane Matthew in 2016. They used the numerical modeling system Coupled Ocean-Atmosphere-Wave-Sediment Transport (COAWST) to complete the study. They found that Fire Island breached from the ocean side whereas Matanzas breached from the landward side. Both breaches were caused by a damaged dune system with a water level gradient dominant from the side that breached the island.

Overall, from these three studies it is clear that water level gradients play an important role in determining which side of a barrier island back-bay system will breach first. In addition, these studies indicate that dune erosion during intermittent overwash plays an important role in determining the extent to which the water levels on either side—bay or ocean—can breach the island, which also determines which side breaches first.

Preliminary Work

XBeach model setup is ongoing. The preliminary results of this study will be presented at the conference.

Conclusions

In conclusion, a sensitivity analysis of barrier island breaching based on conditions in Mantoloking, New Jersey during Hurricane is being conducted. The results will lead to a better understanding of how certain parameters such as dune geometry and channelization of the back-bay contribute to the short-term morphological process of breaching during coastal storm events.

Acknowledgements

This material is based upon work supported in part by the National Science Foundation under Grants GLD-1630099 and DGE-1735139 and by the U.S. Army Corps of Engineers through the U.S. Coastal Research Program (under Grant No. W912HZ-20-2-0005).

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