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Numerical Simulation of Post-Storm Recovery and Time-Averaged Swash Velocity on an Engineered Beach with Ridge-Runnel System

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Measured post-storm beach recovery and swash velocities were simulated using the process-based, depth-averaged 1-D cross-shore numerical model CSHORE over 30 tide cycles. The field data were collected during a three-week experiment along the Delaware coast of the United States following a nor'easter storm. A pronounced ridge formed immediately after the storm and rapidly grew in height and shoreward extent. The model was able to capture the ridge accretion process (crest location, elevation, and ridge slope) and time-averaged swash flows accurately once sediment transport related parameters were calibrated. In addition to sensitivity analyses of the most important numerical parameters, profile evolution and swash velocity results are presented.

INTRODUCTION

Intertidal sand bars are a common morphological feature often observed along sandy coasts with micro- and mesotidal beaches. The formation and dynamic behavior of bars, or bar and trough systems, located in the surf and swash zones of the beach are controlled by a variety of morphological and hydrodynamic characteristics of the surrounding environment. The dynamic evolution of these features is thought to play a critical role in beach recovery mechanisms after erosive storm events. In particular, the ridge and runnel (RR) type of swash bar is a single bar and trough system, asymmetric in shape and generally found in the upper intertidal zone on sandy beaches subject to relatively small tidal ranges (<3 m; Kroon and Masselink, 2002). Wave runup coinciding with the rising storm tide carries a large amount of sediment landward that is left in the inner swash zone, building a pronounced berm face, or a ridge, followed by the landward slip-faced dipping, or runnel (King and Williams, 1949). The formation and onshore migration of RR-type bars is linked to beach recovery processes since the onshore migration of a (partially) submerged nearshore bar during low-energy wave conditions following a storm can carry large amounts of sediment back up on the subaerial portion of the beach.

The processes contributing to the formation and evolution of RR systems have been studied worldwide. Several laboratory and field studies have measured morphological changes along with hydrodynamic and sediment parameters associated with infilling and onshore migration of RR systems (Aagaard et al., 2006; Houser and Greenwood, 2007; Robin et al., 2009). Some attempted to relate the onshore sediment transport to tidal range (Puleo et al., 2012; Davis et al., 1972) or to type, intensity, and duration of wave processes (Masselink et al., 2006; Aagaard et al., 1998; Davidson-Arnott, 1988). Figlus et al. (2012) performed a physical model laboratory experiment in a sediment wave flume to reproduce onshore migration of a pronounced RR system with ponded water under fairly energetic wave conditions, where near-bed flow velocities and profile evolution were measured and modeled. The onshore migration of the RR system was categorized through a series of beach evolution processes including the initial ridge crest lowering, runnel filling, blending of the initial ridge into the sloping beach, and resloping to form an equilibrium beach profile. The study also demonstrated the effect of ponded water in the runnel on reducing overwash flow velocities and ultimately promoting sediment settling and onshore ridge migration.

Several numerical approaches have been developed in an effort to predict beach and dune erosion (Wise et al., 1996; Roelvink et al., 2009) and long-term changes in the shoreline position (Hanson, 1989), as well as morphodynamics of multiple intertidal bars (Masselink, 2004; Short and Aagaard, 1993). Adaptation of a specific model approach depends on the desired detail and time scale of the morphological change to be modeled. Beach recovery after severe storm erosion is a steady process that takes place over multiple tidal cycles, and beach accretion is a difficult process to recreate in a numerical domain because of the complex feedback mechanisms between hydrodynamic, morphological, and sediment transport dynamics in the intermittently wet and dry zone of the beach. For practical engineering applications and efficient prediction of beach accretion processes on the order of days to weeks and months, process-based models that do not

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KEY WORDS: Beach profile evolution, field experiment, numerical modeling, post-storm recovery, intertidal bar migration, storm impact, swash velocity.