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Physical Modelling of Wave-Driven Groundwater Flows in a Sand Beach Using Transparent Soil

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The characteristics of waves breaking on a beach can have significant impacts on how water infiltrates and influences coastal groundwater flows. The effects of continuous wave action on groundwater in coastal aquifers is important to understand to predict subsurface flows in beaches. This investigation will study how coastal wave dynamics in the swash zone impact the groundwater table using physical laboratory modelling and detailed image analysis that allows for high density spatial and temporal resolution degree of saturation measurements using unsaturated transparent soil as illustrated in Figure 1. Transparent soil methods will be applied to observe simulated wavedriven subsurface flows in a cross-section of a sandy beach. The objective of this study is to extend the current knowledge of how waves drive groundwater fluctuations by experimentally quantifying the time and length scales of flow within a beach.

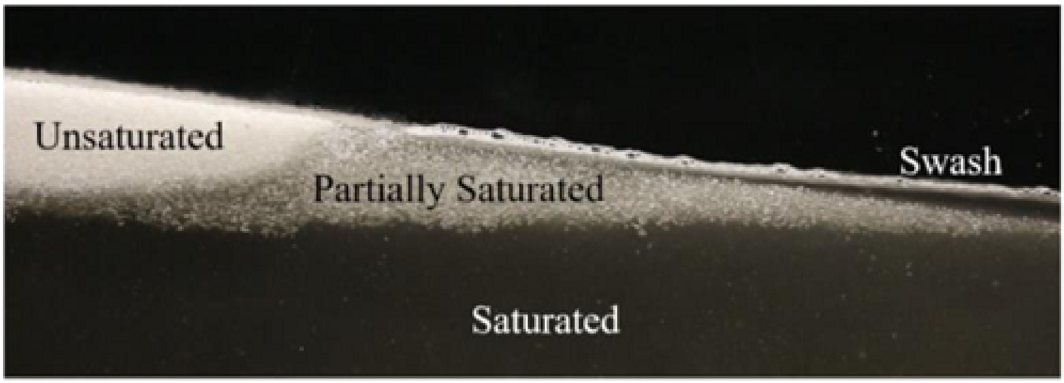

Figure 1.

Transparent soil can be used to experimentally measure subsurface fluid/air flow and is used to quantify spatial and temporal saturation conditions every few seconds during an experiment. Digital image analysis allows for millimeter spatial resolution throughout the domain. Transparent soil is formed are applied by using crushed quartz rock in place of sand and an oil mixture with an identical refractive index to the grains (Peters et al. 2011). When the pores of the crushed quartz are saturated with the oil, the mixture appears transparent. When dry, the crushed quartz appears opaque. Change in colour is quantified, through digital image analysis, to measure degree of saturation throughout the domain (Sills et al. 2017)

This study applied transparent soil techniques in its first application to understand coastal processes by observing how incident waves infiltrate beaches and induce groundwater table fluctuations. Four tests are reported with variations in beach slope and wave properties, and the images are processed to quantify spatial and temporal degree of saturation variation. In each test, the swash interacted with the groundwater table by forming a partially saturated zone above the saturated zone of the beach. This partially saturated mound followed a consistent shape, that varied in size and rate of change primarily due to beach slope. The partially saturated zone is formed by a combination of capillary forces and downward infiltration, forming a continuously dampened zone in the beach. Finally, the results show a strong inverse correlation between the wetting front formed in a beach and the slope of the swash zone. Steeper slopes displayed much larger partially saturated mounds and were observed to do so in a slower manner compared to flatter slopes.

Peters, S. B., Siemens, G., and Take, W. A. (2011). “Characterization of Transparent Soil for Unsaturated Applications.” Geotechnical Testing Journal, 34(5).

Sills, L.-A. K., Mumford, K. G., and Siemens, G. A. (2017). “Quantification of Fluid Saturations in Transparent Porous Media.” Vadose Zone Journal, 16(2), 1–9.