MODELING COASTAL WATER TABLE FLUCTUATIONS USING PFLOTRAN

Margit Maple, University of California, Los Angeles, margitmaple@g.ucla.edu
Maia Coylar, Geosyntec Consultants, maiacolyar@gmail.com
Russell Detwiler, University of California, Irvine, detwiler@uci.edu
Timu Gallien, University of California, Los Angeles, tgallien@ucla.edu

INTRODUCTION

Coastal aquifers are highly dynamic groundwater systems. Sea level rise will cause a rise in coastal groundwater tables resulting in increased risk of shallow or emergent groundwater (Befus et al., 2020). Marine water level fluctuations cause the beach groundwater table to oscillate over a relatively large range. Understanding these oscillations is crucial, as shallow (i.e., high) water tables may impact subsurface infrastructure, mobilize sediment, and increase liquefaction risks. Although the impacts of tides and wave setup on coastal water tables have been studied (e.g., Nielsen, 1990; Housego et al, 2021), the cumulative impacts of wave runup, partially saturated flow, complex beach topography, and dual tidal forcing for bay-backed regions have not been explored. This work numerically models beach water table fluctuations which are compared to in-situ swash and beach groundwater observations at Cardiff State Beach in Encinitas, CA.

METHODS

PFLOTRAN (Hammond et al., 2014), a multiphase flow and reactive transport simulator, is used to model groundwater table response to tide, runup, and setup. Crucially, it simulates capillary effects and partially saturated flow, which impact coastal water table fluctuations (Kong et al., 2015). Model results are compared with analytical solutions (Nielsen, 1990; Kong et al., 2015). PFLOTRAN is then used to model water table fluctuations at Cardiff State Beach during an observed energetic winter wave event in December 2015. This site is on a 190 m wide sand spit backed by a lagoon. Sixteen buried pressure sensors were placed in a cross-shore transect. In situ nearshore and lagoon pressure sensor data is used to force the model while beach pressure sensor observations are used to assess model performance.

RESULTS AND DISCUSSION

Figure 1 shows PFLOTRAN compared with analytical solutions and field data. Generally, PLFOTRAN more accurately reproduces the peak water table elevations and shape of the falling limb. Minimum water table elevations are not well predicted by any model. All three models underestimate inland lag of the tidal signal and water table height at low tide (Figure 1). PFLOTRAN is then run at Cardiff State Beach using foreshore topographic observations. The domain consists of a 190m cross-shore profile with a ~0.05m^2 voronoi mesh.

The ocean side is forced using tide with wave setup, mean runup, or Stockdon $R_{2\%}$. PFLOTRAN underestimates water table height when forced using setup or mean runup, but overestimates when $R_{2\%}$ is used.

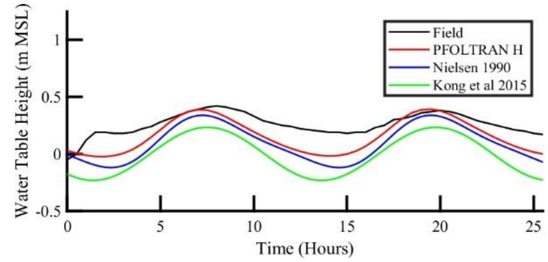

Figure 1 – Water table fluctuations 11.6m inland; PFLOTRAN comparison with analytical solutions.

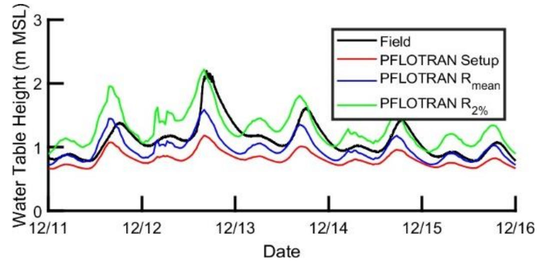

Figure 2 -Water table fluctuations at 75m inland.

REFERENCES

Befus et al. (2020): Increasing threat of coastal groundwater hazards from sea-level rise in California, Nature Climate Change, vol. 10.10, pp. 946-952.

Hammond et al. (2014): Evaluating the performance of parallel subsurface simulators: An illustrative example with PFLOTRAN, Water Resources Research, vol. 50.1, pp.208-228.

Housego et al. (2021): Coastal flooding generated by ocean wave- and surge-driven groundwater fluctuations, Journal of Hydrology, vol 603, pp. 126920.

Kong et al. (2015): Effects of vadose zone on groundwater table fluctuations in unconfined aquifers, Journal of Hydrology, vol 528, pp. 397-407.

Nielsen (1990): Tidal dynamics of the water table in beaches, Water Resources Research, vol. 26.9, pp. 2127-2134.