Simulation of Nearshore Groundwater-Seawater Interactions Using SEAWAT 2000 and MODFLOW USG: A Comparative Case Study

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Background/Objectives. Tidal motion is an important forcing function in coastal aquifers, influencing the timing and location of water flow across the land-sea boundary, affecting distribution of saline waters in the subsurface, and affecting groundwater flow pattern and discharge rate. Based on detailed field and modeling research, it has been verified that the complex nearshore flow dynamics can create a submarine zone where seawater circulates near the zone of groundwater discharge as a result of density-dependent hydraulic gradients. Most published field and modeling studies on submarine groundwater discharge were conducted for a gently-sloped natural shoreline (slope <10 degrees). The flow dynamics near a steeply-sloped (e.g., 45 degrees) engineered shoreline has not been well studied. This presentation provides a hypothetical case study of groundwater-seawater interactions in the vicinity of a steep engineered shoreline using SEAWAT 2000 and MODFLOW USG.

Approach/Activities. The hypothetical vertical cross section model of a regular rectangular grid (domain size = 500 ft x 50 ft) contains the following key elements: (1) A 45 degree land-sea interface to separate subsurface flow and free seawater, (2) four hydraulic conductivity values are used to represent the heterogenous nature of the subsurface, including a low permeability marine sediments (0.1 ft/d), overlying native sandy sediments (15 ft/d), coarse-grained fill (300 ft/d) near the shore, and rip-rap (1000 ft/d), (3) a very high hydraulic conductivity value for cells of free seawater (10^6 ft/d), (4) a constant water density (or salt concentration) boundary conditions on the landside (0 mg/L) and on the seaside (35,000 mg/L), and (4) a constant head condition on the landside and a cyclic fluctuated head boundary condition on the seaside to represent tidal fluctuation. SEAWAT 2000 and MODFLOW USG are used to simulate the quasi-steady-state flow conditions.
The major differences in computational aspects between SEAWAT 2000 and MODFLOW USG are: (1) different formulations of the density dependent flow equation, (2) no wet dry issue for MODFLOW USG, and (3) different numerical solvers. Many rounds of the transient simulations are conducted until the salinity distribution reaches a quasi-steady state. The flow field is approximated and visualized through particle traces generated by MODPATH. The volumetric budgets for distinct flow zones identified in the simulations are used to evaluate the extent of dilution during groundwater movement.

Results/Lessons Learned. Our SEAWAT 2000 simulation results indicates the presence of two distinct circulation zones. The first zone is adjacent to the sloped land-sea interface, which signifies the cyclic inward and outward movement of seawater across the interface. The second zone is at the interface between the native sediments and coarse-grained fill, which suggests significant dispersive mixing of freshwater and seawater in this zone. The MODFLOW USG simulation is still ongoing and the MODFLOW USG results will be compared with the SEAWAT 2000 results.