ABSTRACT OF THE THESIS

SWI is a phenomenon where seawater intrudes into a coastal aquifer and contaminates fresh groundwater. Previous studies identify two types of SWI: passive and active. The processes associated with active SWI have received considerably less attention compared to situations of passive SWI despite several investigations demonstrating that active SWI is occurring in many areas. This research aims to characterise key elements of active SWI and the controlling factors that govern rates of movement, interface shape and the dispersiveness of the freshwater-seawater mixing zone.

The first component of research in this thesis uses laboratory experimentations and accompanying numerical modelling analysis to examine quantitatively and systematically SWI processes within transient events, including both passive and active SWI. The investigation quantifies the geometry of the freshwater-saltwater interface and monitors the flow processes and related effects (e.g., watertable salinization (WTS), advection and density) that occur during SWI. The results show that significant WTS can arise under active SWI and that this is associated with cessation of seaward freshwater discharge. Under passive SWI, only minor WTS is expected occur where the conditions involve high dispersivity, high hydraulic conductivity, and low freshwater discharge to the sea.

Further analysis of laboratory-scale SWI is undertaken by considering two-layered aquifer systems, and the vertical leakage that occurs between them was evaluated using sharp-interface and dispersive SEAWAT models. Here, the sharp interface numerical model examines three cases of SWI in layered aquifers with upward freshwater leakage through aquitards. Case 1 involves freshwater bypassing any overlying saltwater, Case 2 assumes no upward freshwater leakage where there is overlying saltwater and Case 3 converts upward freshwater leakage into saltwater. The results show that Case 1 produces optimal matches to both numerical simulation results and sand-tank observations in terms of saltwater wedge locations relative to the two other cases. Streamlines from SEAWAT model show that upward freshwater leakage tends to flow around and bypass overlying saltwater.

The work is extended by systematically investigating characteristics of active SWI at larger scales, using numerical simulation. This work shows that the active SWI response time-scales are affected by both the initial and final boundary head differences between the inland and the sea boundary. The freshwater-saltwater interface is found to be steeper under stronger advection (i.e., caused by the inland FHD), higher dispersivity and hydraulic conductivity, and lower aquifer thickness, seawater density and porosity. The interface movement is faster and the mixing zone is wider with larger hydraulic conductivity, seawater-freshwater density difference and aquifer thickness, and with lower porosity. The results also show that Peclet number and mixed convection ratio from previous steady-state analyses offer only limited application to the controlling factors of passive SWI, and are not applicable to active SWI.

Finally, a regional three-dimensional model of SEAWAT is used to explore the SWI conditions that occur in Uley South Basin (USB), South Australia. This work aims to examine the individual relative contribution of climate variability and anthropogenic stresses on the extent of seawater in USB. Also, the effects of buoyancy and seawater extent on groundwater head behaviour near the coast are explored. The results show that the effect of pumping on the extent of SWI in the Quaternary (QL) and Tertiary Sand (TS) layers of USB are shown to be larger, relative to SWI arising from climate variability. The results also demonstrate that including seawater in the numerical model slightly modifies the groundwater behaviour near the coast where the relative effects of pumping on groundwater head response are larger compared to that without seawater in the model.