Summary:

Fresh groundwater has been identified in the offshore extensions of numerous confined coastal aquifers globally. In recent years, several studies have proposed the use of this offshore fresh groundwater (OFG) to assist in onshore freshwater supply. As groundwater investigations in coastal regions have typically focused on the onshore portion of the aquifer, OFG remains poorly understood. This body of work examines three aspects of OFG, specifically: 1) the degree to which OFG already supports existing onshore freshwater extractions, 2) combined geophysical and analytical methods to estimate OFG extent, and 3) the behaviour of OFG in regions with alongshore head gradients in the onshore portion of the aquifer.

The first part of this study investigates the potential present-day onshore influence of OFG. This investigation tests the previous assertions that OFG by and large represents a potential (and currently under-utilised), freshwater resource for many coastal communities. Twenty-seven confined and semi-confined coastal aquifers with plausible connections to inferred or observed OFG are assessed using available salinity and hydraulic data and analytical modelling. Seven conceptual models are synthesised based on the observation data and insights gained from analytical modelling. These conceptual models demonstrate for the first time that OFG formed from paleo- or pre-development conditions can delay the onset of SWI in the onshore portion of coastal aquifers. Analytical modelling indicates that onshore pumping will lead to active-SWI at fourteen of the twenty-seven sites, while passive SWI is expected onshore in an additional ten regions. In these twenty-four regions, OFG is likely delaying the onset of SWI within the onshore domain. The available data indicates that onshore extraction regimes are already mining OFG. As such, where OFG is connected to

onshore aquifers, it should primarily be considered as an existing freshwater input rather than an untapped resource.

The second part of this study uses existing petroleum exploration data, hydraulic information and analytical modelling to provide a leading example of the use of multiple techniques to evaluate OFG. This investigation combines a large seismic data set, onshore and offshore geophysical bore-log profiles, and available onshore hydro-stratigraphic data to explore the extent of OFG in the Gambier Embayment (Australia). A novel application of Archie's law provides useful insights into the salinity profiles within four offshore wells. These profiles are compared to steady-state, sharp-interface estimates of the freshwater extent obtained from an analytical solution, using simplified conceptual models. The downhole geophysical data indicate that in the south of the study area, pore water with total dissolved solids (TDS) of 2.2 g L^{-1} is found up to 13.2 km offshore. The analytical solution produces freshwater-saltwater interface locations that are approximately consistent with the freshwater-saltwater stratification in two of the offshore wells. This investigation demonstrates both the benefits and uncertainties involved with the application of geophysical interpretations and analytical solutions to estimate OFG extent.

The final part of this study uses numerical simulations of synthetic coastal aquifers to explore the behaviour of OFG in regions that have an alongshore head gradients (AHG). Twelve numerical simulations are used to assess the response of OFG to values of hydraulic conductivity of the aquitard (K_v), the onshore head relative to sea level, and the steepness of the AHG. Each 3D simulation is compared to three 2D simulations to test the discrepancy between 2D and 3D approaches. This investigation shows for the first time that significant

volumes (up to 70%) of the freshwater discharging from the onshore aquifer to its offshore extent may in-fact return onshore through alongshore freshwater circulation (AFWC). The modelling shows that the proportion of AFWC is greater in systems with a steep AHG, low onshore heads relative to sea level, and an offshore aquitard with a low K_v. This study also identifies that 2D approaches have the tendency to overpredict the steady-state OFG extent at the location of the maximum onshore head and underpredict the OFG extent at the location of the minimum onshore head when AHGs are present. This investigation shows that the onshore movement of OFG can persist under steady-state conditions in some regions, and that the onshore movement of OFG does not exclusively represent the mining of relic OFG.