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Surface water–groundwater interactions: a major contributor to secondary salinity development in semi-arid areas of south-western Australia?

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Secondary dryland salinity is major cause of land and water degradation in the semi-arid agricultural areas of south-western Australia, and its management and prevention, is a key element in maintaining healthy ecosystems, biodiversity values and productive agricultural systems. An analysis of the interactive hydro-dynamics of surface–groundwater systems is essential in providing an understanding of the key elements and drivers for salinity development in the broader lower valleys typical of the WA wheatbelt. In these low gradient systems, redistribution of surface runoff and localised inundation has a high potential to interact with soil and shallow groundwater, however the degree of interaction and rates of salt transfer, within the soil-regolith surface layers are yet to be quantified.

A preliminary analysis is presented of SW-GW interactions; coupled with an assessment of the role of runoff redistribution, insitu ponding, infiltration and recharge in the low gradient valley systems. The Toolibin Lake catchment, a high priority biodiversity recovery catchment that has been focus a wide range of interdisciplinary studies in the last 20 years, was chosen as the study site. The catchment covers approximately 46,000 ha, with an annual rainfall of 420 mm and an annual pan evaporation loss of 1900 mm. About 90% of the catchment has been cleared for agriculture, with majority of the remaining 10% located in designated biodiversity protection areas associated with conservation reserves.

This paper specifically focuses on the hydrometric data analysis for the surface water-shallow groundwater components and uses surrogate electrical conductivity data (EC) to interpret process elements and assist in the construction of a conceptual model to define SW-GW functionality. Shallow, intermediate and deep piezometers were installed to observe groundwater dynamics, determine their connectivity and their response to rainfall and inundation. An additional observation well was installed as a reference for the three nested piezometers. The study period covered one complete wetting and drying hydrological cycle from May 2009 to April 2010. This enabled the identification of the basic system dynamics associated surface water runoff, ponding, perching and recharge at the two sites.

Clear spatial and temporal patterns for EC values were identified as changes in soil/regolith moisture conditions are experienced from upstream to downstream locations; these were particularly evident as the system approached saturation. Three hydroperiods that phased across the water year, demonstrated clear differences in the surface-groundwater hydrodynamics. Each hydro-period is associated with an approximate subsurface antecedent moisture condition; defined as a fraction of total mean annual rainfall required to saturate the soil profile. The ponded/waterlogged and subsurface perched watertables experienced during the winter months produced changes in surface flow direction and sub-soil water fluxes. Ponding was influenced by localised topography and relative position within the low-gradient valley floor. The perching phenomenon is achieved by relative small rainfall events or a single large event that accounts for approximately 20% of the mean annual rainfall. Thus sites located in the upstream locations acted effectively as shallow recharge zones; the intermediate locations transitioned between recharge/discharge functioning areas and the downstream locations were essentially discharge areas associated with the three hydrodynamic phases.

A conceptual hydrodynamic model is presented that describes the interactive phases of this low intensity-high frequency rainfall driven SW-GW system that is applicable to low gradient semi-arid landscapes. At this early phase of the research the simple conceptual model does not incorporate any specific or detailed hydrological processes but constitutes a stepping stone for further hypothesis testing, scenario evaluation for catchment management purposes and provides building blocks for the numerical model development.