Flow regime changes in the Murray–Darling Basin over the past 50 years and implications for river systems models

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Abstract: The Murray–Darling Basin (MDB) is one of the most stressed water resource in Australia and the most contentious in the sharing of water between users. The Water Sharing Plans at both the State and Commonwealth level are informed by the use of river systems models that have served their purpose over the decades in simulating the total flow in the rivers well. Recently the increased emphasis placed on environmental flows and restrictions on extractions during low flows has highlighted the poor performance of some models in estimating and predicting low flows. These models implicitly assume stationary conditions in simulating losses as a function of flow without considering the physical processes involved. This study investigated if stationary conditions have existed over the past 50 years in the elements of the flow regime that are important to most river systems models.

Surface water – groundwater interactions were investigated by comparing the elevation of the surface water and groundwater levels at 59,340 bores across the MDB and aggregating the results to the 492 reaches used in the AWRA-R river systems model. The proportion of bores predicting losing conditions was falling through the 1970's and 1980's before reaching a minimum of 48% in 1995/96. From this period, the proportion of bores predicting losing conditions increased to a maximum at the end of the analysis period of 78% in 2018/19. This finding at the point scale (bore location) is also observed at the reach scale. Through this century, the length of river reaches experiencing losing conditions has been expanding. Many reaches have changed direction of flux between gaining from groundwater to losing to groundwater; this reversal of flux direction cannot be simulated in most river systems models.

Flow continuity is important for the connectivity of the river. Classifying the gauges within the MDB as perennial, intermittent or ephemeral provides a measure of this connectivity and an analysis through time enables us to investigate whether this connectivity is stationary. This analysis was conducted for 519 gauges as a long-term average and as a moving 10-year window. As a long-term average, it was found that 67% of gauges in the southern MDB were perennial but only 39% of gauges in the northern MDB were perennial. From the time series it was found that a higher proportion of gauges in the northern MDB (45%) had an increasing trend in intermittency than in the southern MDB (26%). This intermittency leads to a requirement within the model to dry out the channel and then re-wet during the next flow event which is a process that the models generally cannot simulate.

These pieces of analysis have highlighted elements of river losses that are not stationary in time and need to be incorporated into the loss functions of river systems models to provide better simulations of low flows. The surface water – groundwater interactions analysis has identified that the groundwater levels are falling and that the losses are proportional to the difference in the elevation of the surface water and the groundwater. To enable the representation of losses in river systems models as a function of changes in groundwater levels, some tracking of the groundwater store will be necessary. Similarly, the increase in intermittency requires the antecedent conditions to be tracked in the store of water in the river bed and banks. After cease to flow, this storage will become depleted and the storage deficit will need to be overcome to enable the river to flow again. Better representation of these physical processes in river systems model will be the focus of future phases of this work aimed at better predictions of low flows in the MDB.

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