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# Role of groundwater in drought-induced hydrological shifts: Numerical modelling to support hypothesis testing

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**Abstract:** Hydrological "shifts"—where streamflow during multi-year drought is disproportionately low, even given low rainfall—have now been reported across multiple continents and are highly relevant to planning under a hotter future with more droughts. This research explores the idea that hydrological shifts can be induced by slow movement of groundwater through bedrock in headwater catchments, which facilitates redistribution of water within a catchment from upslope areas to downslope areas. Central to this hypothesis is bedrock permeability such that the groundwater system responds to multi-annual drought signals (ie. timescales of response that are longer than seasonal but shorter than decadal).

According to this hypothesis, upslope areas subject to groundwater decline then see groundwater-surface water decoupling and reduced runoff. Under wet conditions, the export of groundwater from upslope areas can be balanced by recharge and thus go unnoticed. However, in drought years, recharge may be too low to balance the export, leading to reduced groundwater levels and groundwater surface-water decoupling. When wetter conditions resume, the groundwater deficits may take a while to be replenished, delaying recovery from hydrological shifts (as observed in Australia). In downslope areas, the drained water may contribute to streamflow, but may also be lost to evaporation and transpiration, particularly in drier catchments with flatter valley bottoms of alluvium or colluvium which may absorb and store water. In such catchments, the net effect of these processes is to allow groundwater originating from upslope to supplement evaporative budgets downslope rather than increasing streamflow.

We advance this hypothesis, firstly by presenting evidence of its applicability in south-east Australia; and secondly by building and testing numerical models that incorporate a simplified representation of these processes. Modelling results show improved performance when tested across several catchments affected by hydrological shifts, and improved realism such as multi-year declines in simulated groundwater storage, consistent with observations. These results help to confirm the plausibility of this hypothesis of hydrological response, suggesting a promising avenue for further research.

***Keywords:*** *Rainfall-runoff relationship, hydrological shift, groundwater, drought*