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Groundwater disconnection drives streamflow decline

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Background

Rainfall has declined across much of southern Australia in recent decades and this is consistent with predictions of the impact of climate change on rainfall. Rainfall decline has been accompanied by even greater declines in streamflow (Figs 1, 2). Declining streamflow has potentially significant impacts on the supply of surface water for domestic, agricultural, and industrial use, and on aquatic and riparian ecosystems. The disproportionate decline in annual streamflow has perplexed hydrologists and forest managers.

The contribution of groundwater to streamflow has been studied using hydrological data from an experimental catchment in the jarrah forest east of Dwellingup[1]. Data on groundwater levels, streamflow and stream salinity were available for the period 1976 to 2011. During this period, the groundwater system progressively declined and disconnected from the surface water system. Whilst groundwater was connected, it contributed to streamflow generation. However, the contribution ceased when groundwater disconnected. The salt in groundwater was a natural tracer that indicated the presence and relative proportion of groundwater in streamflow. Hence, as groundwater levels declined, stream salinity also declined, reflecting the diminishing extent of the connection and, ultimately, complete disconnection between groundwater and surface water. Disconnection of groundwater from surface water provided an exceptional opportunity to better understand the role of connected groundwater in streamflow generation because the contribution of groundwater could be differentiated from other streamflow generation mechanisms by comparing the streamflow responses in the periods before and after groundwater disconnected.

Fig. 1. The volume and number of days of annual streamflow has been declining

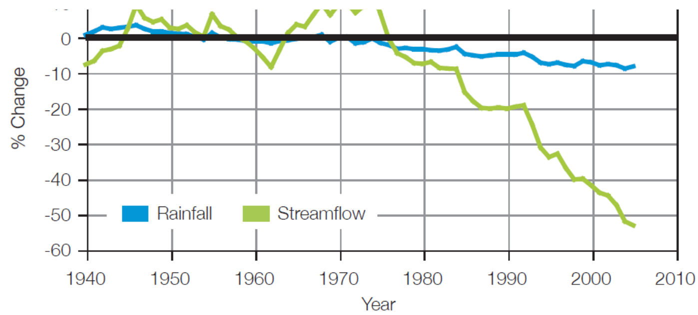

Fig. 2. Annual streamflow and rainfall into Perth's reservoirs. From CSIRO and Bureau of Meteorology, 2007. Climate change in Australia, Technical report, Canberra, Australia.

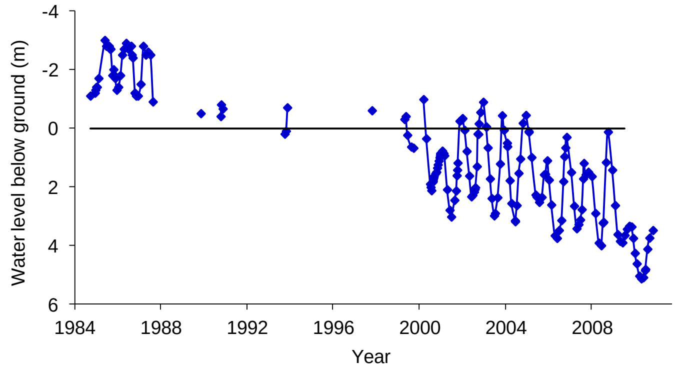

Fig. 3. Water levels in a piezometer at the catchment outlet were mostly above ground in the 1980s and 90s and mostly below ground in the 2000s.

Findings

- Groundwater disconnected from surface water around 2001. This was signalled by a drop in piezometer water levels below ground (Fig. 3) near the catchment outlet and by a change in stream salinity from moderately high and variable to low and constant in the absence of saline groundwater discharge into the stream (Fig. 4).
- Following disconnection, the proportion of rainfall that became runoff dropped by an average 50%.
- Groundwater played a dominant role in streamflow generation whilst connected. The contribution of connected groundwater to streamflow generation is apparent as the difference between the 1989-2000 and 2002-2011 curves in Fig. 5.
- Connected groundwater contributed to streamflow generation mostly indirectly, amplifying other streamflow-generating processes, by facilitating additional surface runoff and subsurface throughflow.
- When groundwater disconnected from surface water it ceased amplifying streamflow.
- The large disparity between the rates of decline in rainfall and inflow into Perth's reservoirs is also likely to have resulted from the progressive disconnection of groundwater as it retreats from higher parts of the landscape towards lower parts of the landscape and towards higher rainfall areas.

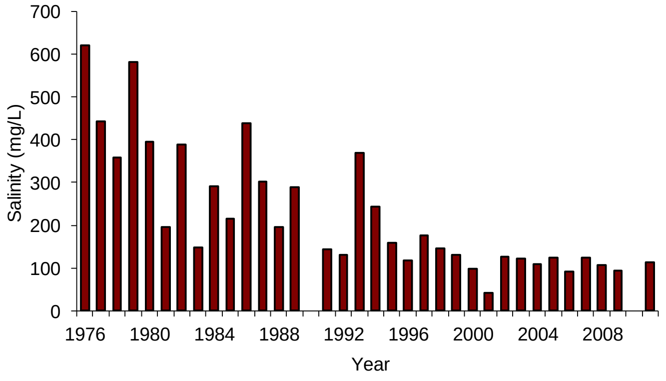

Fig. 4. Time series of annual stream salinity.

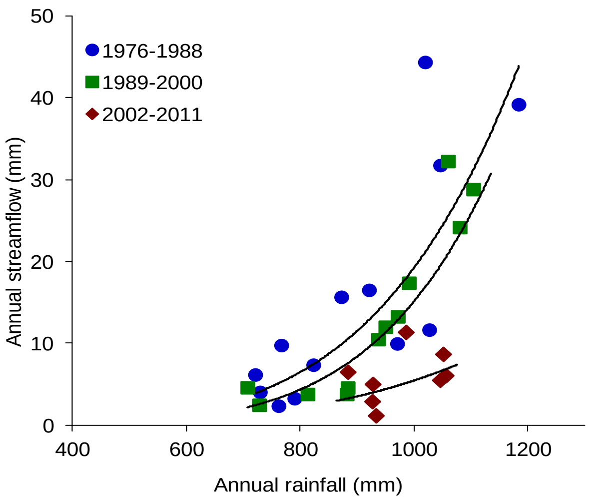

Fig. 5. Annual streamflow in relation to annual rainfall.

Management Implications

- Thinning of catchments has the potential to mitigate the impact of climate change on streamflow by enhancing water production. Thinning is likely to be most effective where groundwater is connected to surface water. Where groundwater is disconnected, thinning will be most effective if the treatments ensure a sufficient rise in groundwater levels to enable, and to sustain, the connection between groundwater and surface water systems.
- Findings from this study can improve the accuracy of hydrologic models used to simulate streamflow responses to future climate change scenarios. Past modelling has not anticipated the magnitude of the amplifying effect of groundwater on streamflow generation and consequently could potentially underestimate the extent of the decline in streamflow in response to further rainfall decline.

[1] Kinal, J., Stoneman, G.L., 2012. Disconnection of groundwater from surface water causes a fundamental change in hydrology in a forested catchment in south-western Australia. *Journal of Hydrology*. 472-473, 14-24.

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