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Analysis of long-term groundwater storage trends in the Wairau aquifer, New Zealand

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The Wairau Aquifer covers a small proportion of the Wairau catchment in the Marlborough District of New Zealand just prior to the river discharging into the sea. The aquifer is almost exclusively recharged by surface water from the Wairau River and serves as the major drinking water resource for Blenheim and the surrounding settlements on the Wairau Plain. Because a small but constantly declining trend in aquifer levels and spring flows have been observed over the past decades, it has been made a high priority by the Marlborough District Council to better understand the limits and the mechanics of the recharge mechanism. While previous research efforts have been centred at water budgets during low-flow conditions and steady-state modelling, this study aims at understanding the dynamics of river-groundwater exchange fluxes using information of Wairau river flows at three new gauging stations, time series of groundwater observations, spring flows and qualitative (soft-)knowledge. Both qualitative and quantitative observations were integrated into a transient numerical MODFLOW model and simulations were conducted with the calibrated model for a 20-year time period.

The gravels of the Wairau aquifer are highly conductive with estimated lateral conductivity values exceeding 1km per day. Although there is also evidence for anisotropy of the aquifer materials, it was found that river recharge at the upper slopes of the Wairau aquifer was consistently happening under perched conditions. In addition, exchange fluxes seem to have a functional relationship with river discharge only under low flow conditions while the exchange fluxes appear to be capped at about 16-20 m^3/s for medium and large river flows. Therefore, the Wairau aquifer storage seems to be vulnerable more to the occurrence and duration of extreme low flow periods.

To analyse this further, we have analysed the frequency and re-occurrence of low flow periods from the Wairau river record and found that the days of flow below a critical threshold in a given year have increased in recent years. To link the river flow record to large-scale climatic drivers, we analysed the precipitation record from several rainfall stations in the Wairau catchment as well as daily time series of precipitation data from the National Institute of Water and Atmospheric Research (NIWA) virtual climate station (VCS) network. The areal annual precipitation totals calculated from the VCS station data show a clear decline of precipitation since 1960. Shorter precipitation records from weather stations in the hilly ranges of the Wairau catchment seem to confirm the trend, while data from stations in the valleys or the Wairau Plains doesn't support the trend. The decline in areal precipitation and the corresponding increase in low flow periods of the Wairau river flows have a strong correspondence to the long-term trend in Wairau aquifer water levels, but other factors such as changes in the river bed morphology could also contribute. The reason for the decline of precipitation in the Wairau catchment is not yet known.