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Contradicting groundwater tracer results in a large karst aquifer in northern Australia reveal recharge processes, regional flow patterns and origin of culturally important springs.

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The up to 300m thick karstified Cambrian Limestone Aquifer (CLA) extends over more than 800km in the Northern Territory of Australia, from the semi-arid climate in the southeast to the monsoon-dominated tropical climate in the northwest. It is the main freshwater source for the pastoral industry of the region, feeding the headwaters of the Roper River at the culturally important Mataranka Springs. The Beetaloo Sub-Basin underlying part of the CLA has one of the largest Australian prospective resources of shale gas in the Velkerri formation (2km to 2.5km depth). A robust water balance for this aquifer together with a detailed understanding of the flow system is needed to manage possible impacts between competing industries and the cultural heritage.

Tracer findings in the CLA are counter-intuitive: radiocarbon concentrations increase in groundwater flow direction instead of decreasing. Tritium is low, but detectable in the north, whereas modern gas tracers CFCs, SF_6 and H1301 are high throughout the aquifer, indicating high excess air and suggesting more recent recharge than what would be expected from the tritium results. Terrigenic helium is present in several bores and two springs, indicating upward fluid flow. To shed further light on the recharge conditions, samples for ^{85}Kr and ^{39}Ar were taken and confirm more recent recharge or gas exchange than radiocarbon would indicate.

The recharge model in best agreement with the data suggests a strong regional recharge gradient from south to north. Local direct recharge via sinkholes creates water level fluctuations over wide areas, causing large excess air and allowing the gas tracers to exchange with the recent atmosphere in the unsaturated zone, including in areas where recharge is not actually happening. Tritium is therefore considered as the most reliable recharge indicator, with ^{85}Kr and ^{39}Ar revealing a combination of recharge and gas exchange, whereas CFCs, SF_6 and H1301 with their sensitivity to excess air are no reliable indicator of recharge. Two culturally important Mataranka springs are fed from very short flow paths with seasonal variations in chemistry and Rn. Two other springs feed from regional flow paths not showing seasonal variations and present terrigenic helium.