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Groundwater Transit Times and Paleoclimate using Age-Dating Tracers and Water Isotopes

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Groundwater aquifers are critical resources to human and environmental sustainability. The transit time distributions (TTDs) of aquifers are fundamental properties that allow water resource managers to understand the timing of groundwater discharge into wells, springs, and streams and therefor assess the susceptibility of these waters to drought and contamination. Importantly, the shape of groundwater TTDs are not well understood, and models commonly report higher fractions of young groundwater (< 10 years) than have been observed in the field.

In this study, we examine the transit times of groundwater at increasing spatial scales (up to 99 km stream length) in the south branch of the Middle Loup River in the Sand Hills, Nebraska, USA. We measured the groundwater flux using an automated seepage meter and collected groundwater samples from over 100 locations along the study stream. Groundwater samples were collected using a piezometer installed 30 – 50 cm into the streambed and samples were analyzed for a suite of environmental tracers including stable water isotopes, noble gases, ^{3}H, and ^{14}C. 70 samples were collected during high streamflow conditions (1.00 m^{3} s^{-1}) and 49 samples were collected during low streamflow conditions (0.08 m^{3} s^{-1}) including repeated sampling locations to examine stationarity of transit times under varying streamflow conditions.

From this unique dataset of flow-weighted tracers we computed the mean and distribution of groundwater transit times and found the mean transit time was 40 years at upstream sites and 6000 years at downstream sites. The observed TTDs at all study sites indicated that less than 8% of groundwater was younger than 10 years and that 50% of groundwater was older than 2000 years. Groundwater ages were relatively stationary during varying sampling conditions. We also observed spatial and temporal trends in groundwater stable isotopes and noble gas thermometry that indicate paleoclimate change and recharge provenance. These field observations have important implications for groundwater transport and timing and indicate longer flow paths and older water than are commonly assumed by models.