

Multi-Tracer Analysis of Urban Catchment Hydrodynamics Supporting Estuarine Wetlands

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Spatio-temporal hydrological shifts driven by climate change and anthropogenic activities influence wetlands' water availability and water quality, affecting their ecological functions. These shifts affect the Eerste River Estuary, a vulnerable coastal wetland in the Mediterranean type climate of the Western Cape, South Africa. We applied geochemical tracers to characterise catchment fluid dynamics, providing insights into addressing water scarcity challenges that affect humans and the estuarine ecosystem. Analyses included water stable isotopes ($\delta^{18}\text{O}$, $\delta^2\text{H}$), tritium, major ions, and dissolved gases (N_2 , O_2 , CH_4 , CO_2 , He, Ne, Ar, Kr, Xe) from 17 rainwater, 83 surface water, and 33 groundwater (shallow and deep aquifers) sites between 2022 and 2024 dry and wet seasons. The study assessed the Eerste River Estuary's water sources (rainwater, surface water, and groundwater) spatial contributions (i.e., recharge-discharge areas, groundwater-surface water proportional input, residence time distribution and aquifer interconnectivity), and seasonal variations (i.e., groundwater-surface water temporal input and exchange and flow paths changes). Seasonal isotopic changes in the major Eerste River indicate that water transfers from the headwater region's inter-basin holding dam to irrigation boards primarily drive variability in surface water support. Groundwater has a mean $3\text{H}/3\text{He}$ age of 39 years and recharge rapidly during episodic heavy rainfall events (high Ar- and Ne-excess air). However, He R/Ra values of < 1 in the major headwater regions indicates groundwater from a crustal helium origin (U/Th decay). This suggests the coexistence of modern and older groundwater systems. Incorporating environmental tracer data into this data-poor, perturbed catchment enhanced our understanding of the complex superficial water dynamics, enabling more informed water management decisions.