A Tale of Three Watersheds: Investigating Controls on Surface Water and Groundwater Interactions in Three Mountainous Watersheds in Different Geologic Settings

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Interactions between surface water and deep, regional groundwater remain poorly quantified. In fact, these interactions have largely been ignored in traditional watershed studies contributing to the perception that residence times in watersheds are very short ranging from days to perhaps a decade. In order to address this fundamental gap in our process understanding, I proposed the hypothesis that deep, regional groundwater flowpaths become an increasingly important control on the generation and geochemical evolution of streamflow in large watersheds. I initially tested this hypothesis during my Ph.D. using a suite of geochemical, hydrometric, and isotopic data in the Saguache Creek watershed, a large 1600 km² volcanic-bedrock watershed located in the San Juan Mountains of southern Colorado. My research revealed that the deep groundwater component of streamflow did, in fact, increase with increasing drainage area in the Saguache Creek watershed and these interactions were responsible for the observed increases in solute concentrations and estimated residence times of streamflow that were also positively structured with increasing drainage area in the watershed. More importantly, the residence times of streamflow ranged from 100s of years in the headwaters to almost 6000 years near the outlet of the watershed. These residence times are much longer than the commonly perceived short residence times indicating that we are missing critically important information about the deep groundwater system and the associated interactions between that system and the surface water system using traditional small-catchment approaches. I continue to test the transferability of the inferred conceptual models in the Rio Hondo watershed (a crystalline-bedrock watershed, 300 km², located in the Sangre de Cristo Mountains of northern New Mexico) and the El Rito watershed (a sedimentary-bedrock watershed, 300 km², located in the Tusas Mountains of northern New Mexico). The Rio Hondo watershed displays remarkably similar trends as those observed in the Saguache Creek watershed despite a smaller drainage area, different geologic setting, and increased human impact. Secondary fracture porosity is common to both watersheds and is a likely explanation for these interactions. In comparison, the El Rito watershed does not display similar trends and instead, transitions to an overall losing stream in the vicinity of a series of normal faults associated with the Rio Grande Rift. My data suggest that geologic structures may be diverting deep groundwater away from the stream in the El Rito watershed and into adjacent watersheds as interbasin flow. These studies illustrate the necessity to investigate, rather than ignore, the role of deep groundwater in streamflow processes. The complexities of surface water and groundwater interactions cannot be properly quantified using traditional small-catchment approaches; the geology below the soil matters.