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Grand Canyon Corridor Springs: Baseline Monitoring and the HFE's

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Springs and associated riparian environments provide critical habitats for both aquatic and terrestrial wildlife in the Grand Canyon region. The springs also provide drinking water for Grand Canyon National Park. Grand Canyon springs are fed by world-class karst aquifer systems (both shallow and deep) on the Colorado Plateau, but increasing pressure on groundwater resources from climate change, mining and other development activities pose major challenges to resource managers. The shallow and deep karst systems of the region interact in ways that are not well known. Ongoing work by several groups is helping to understand these complex relationships using multiple methods. Developing a robust monitoring and geochemical sampling program is important in providing data for preserving these rare and ecologically diverse habitats, as well as for understanding the sustainability of spring-fed water supplies for anthropogenic use. General hydrologic models for the Colorado Plateau aquifers highlight the importance of recharge areas ('springsheds') for water supply. Our geochemical studies of spring waters (including dissolved gases) throughout the Colorado Plateau and western U.S. have also identified the importance of tectonic activity in contributing CO_2 and dissolved salts to the regional aquifer systems with fluid input from deep levels along faults providing important controls on water quality. Quantitative forecasting of the effects of climate change (diminishing surface flows affecting recharge rates) on water quality depends on our understanding of these deep inputs, as well as aquifer recharge flowpaths and quantities. A significant amount of recharge on the North Rim occurs through sinkholes, and characterization and distribution on the surface using geographic information system (GIS) and LiDAR data relate infiltration points to the overall system hydrogeology, augmented with flow path delineation using non-toxic fluorescent dyes. A detailed hydrograph recession curve analysis of discharge data from Roaring Springs, the sole water supply source for Grand Canyon National Park, highlights the complex nature, and that the deep karst has a base flow recession coefficient an order of magnitude lower than many other karst aquifers throughout the world. The dye trace analysis reveals rapid, conduit-dominated flow through the system that shows the importance of fracture connectivity along faults between surface karst and deep karst. Examining a suite of springs along the canyon corridor highlights how two integrated datasets are useful in understanding hydrologic flow paths and modeling potential impacts of groundwater development on Grand Canyon springs. (1) Traditional 'campaign' water sampling utilizing major and trace element geochemistry as well as stable isotope analysis, and (2) the deployment of continuous sensors for temperature, salinity, and water depth. Results from several spring systems monitored from 2012-present are discussed (Fence spring, Lava Warm spring, Beecher spring and Pumpkin spring). The increased flow during the High Flow Experiments in 2013, 2014 and 2015 provided useful hydrologic pulses for several of these springs directly in the river corridor. Combined, these results indicate the need for a wider application of environmental sensors in hydrologic systems to inform water management decisions.