Short- and Long-Term Salt Water Intrusion in Response to Water Stress and Modified Geology at the Palmyra Atoll National Wildlife Refuge

Barret L. Kurylyk[1], Martin A. Briggs[2], Justin T. Kulongoski[3], John W. Lane[2]
[1]Department of Civil and Resource Engineering and Centre for Water Resources Studies, Dalhousie University, Halifax, Nova Scotia, Canada
[2]Earth System Processes Division, Hydrogeophysics Branch, U.S. Geological Survey, Storrs, CT, USA
[3]California Water Science Center, U.S. Geological Survey, San Diego, CA, USA

ABSTRACT

Long- and short-term climatic patterns (e.g. climate change, Pacific Decadal Oscillation) stress fresh groundwater resources on small islands worldwide through altered precipitation, higher storm surges, and rising sea levels. Groundwater/surface-water exchange processes on small islands differ from many interior continental settings because they are driven in part by tidal and wave pumping, as well as strong contrasts in water salinity and density. Hence, unique methodology and modeling strategies are needed to characterize fresh water resources and predict changes. Electromagnetic induction (EMI) and time-domain electromagnetic (TEM) methods are well-suited to evaluate the variable distribution of fresh and saline groundwater and can be augmented by long-term monitoring well data (salinity, pressure, temperature). Variable-density groundwater modeling can serve as a powerful complement to field monitoring, aiding the understanding of the dominant physical drivers of observed variations in the fresh water lens distribution in space and time.

We are conducting a multi-faceted study on Palmyra Atoll National Wildlife Refuge, located in the Central Pacific Ocean (5°52' N, 162°05' W), to characterize the interactions between fresh groundwater and surrounding sea water to inform ecological management decisions, and increase the understanding of stressed island fresh water resources. Findings from this remote setting without active groundwater pumping will be transferred to atolls with greater human population and activity. Field campaigns in 2008, 2013, and 2016 involved repeat EMI surveys that were augmented by deeper TEM surveys in 2016. We also installed meteorological sensors and groundwater monitoring wells and performed groundwater geochemical sampling. In contrast with other atoll fresh water lenses, the combined field data indicate that the fresh groundwater lens at Palmyra is consistently thicker on the ocean side than the lagoon side, which was heavily modified by military dredging and construction activities in the 1940's. During periods of low-precipitation, lens contraction stresses surface vegetation, with observed impacts such as large tree death most pronounced on the lagoon side.

Conceptual, two-dimensional numerical simulations of coupled water flow and salt transport using the finite-element model SUTRA indicate that dredging of the lagoon may have enhanced submarine discharge to the lagoon compared to what might be expected under natural conditions. This thins the fresh groundwater lens on the lagoon side, increasing vulnerability to salt water intrusion during periods of low precipitation. SUTRA is also applied to investigate the impacts of long-term sea level rise and changing precipitation patterns on the fresh water lens and dependent ecosystems. This study indicates that even in remote settings without contemporary human development we may expect historic human

legacies of geologic modification to drive spatiotemporal dynamics of fresh groundwater resources.

Contact Information: Barret L. Kurylyk, Dalhousie University, Department of Civil and Resource Engineering, 1360 Barrington Street, P.O. Box 15000, Halifax, NS, Canada B3H 4R2, Phone: 1-902-494-4325 Email: barret.kurylyk@dal.ca