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Assessing the Climate Impacts on the Water-Energy-Environment Nexus in California's Upper San Joaquin Watershed

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Due to the large spatial and temporal mismatch between its water supply and demand, California's water resources are managed by one of the world's most extensive networks of dams and conveyance infrastructure, supporting the state's 39 million people and irrigating 9 million acres of land. This system includes 269 hydro-power plants, which collectively generate 15% to 24% of the state's total energy needs. The management of this infrastructure has negatively affected river ecosystems throughout the state, including in the Sacramento-San Joaquin Delta in particular. This has led to a recent renewed focus on management of the San Joaquin river (one of the two main sources for the Delta), including the hydro-power systems in its upper watersheds. Non-federal hydro-power operations in the U.S. are regulated by the Federal Energy Regulatory Commission (FERC), which issues licenses every 30-50 years, taking into consideration the impact of operations on downstream ecosystems and negotiations between resource stakeholders. Many studies have shown that climate change (CC) will make managing California's water systems more challenging. The Fourth California Climate Change Assessment (4CCCA) suggests that by 2100 atmospheric temperatures in the region are expected to increase from 1.4o C to 4.9 o C, precipitation variability will increase, annual snow-pack will reduce to less than 1/3rd of its historic level, necessarily affecting hydro-power operations. Despite these studies, FERC is reluctant to consider climate change within their licensing framework, due to their perceived lack of confidence on climate change studies. This suggests a need to better quantify the impact of climate change on the water-energy-environment (WEE) nexus in the state. With much focus on the Delta, which is fed by 50% of the state's stream-flow and is central to water allocation and conservation efforts, there is a need to examine statewide water system operations in an integrated way, with a multi-watershed, WEE focused modeling framework.

A multi-watershed water allocation and hydro-power optimization (WAHO) model for the San Joaquin River system that consists of four major watersheds - Upper San Joaquin, Merced, Tuolumne, and Stanislaus Rivers - is being developed. As a first step, the WAHO model was developed for the water and hydro-power system of the Upper San Joaquin River. The model, which includes 15 hydro-power facilities, 8 dams, and 34 instream flow requirement locations, was used to understand the limitations of hydro-power systems in meeting required instream flows. CC driven hydrological responses of the watershed were examined to assess the impact of CC on HP generation and the facilities' capacities to meet EF requirements in the future. The model was built using OpenAgua, a web-based water system modeling platform developed by multiple universities to facilitate technical collaboration and modeling transparency. CC scenarios were developed using the USGS rainfall-runoff downscaling methodology developed for 4CCCA with atmospheric forcing from 10 GCMs and two representative concentration pathway scenarios. Eventually, models for all four river systems will be developed and linked in an integrated WEE platform for analyzing more complex questions related to regional HP operations while meeting Delta water requirements.