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Including glacier storage change and reservoir management into the Community Water Model to assess vulnerabilities and enhance resilience in the Climate-Land-Energy-Water nexus

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Water, energy, and food security are threatened by changes in climate. Shifts in rainfall patterns and increases in temperature affect availability of catchment water resources, particularly when hydrological regimes are rainfall-limited, snow-dominant or influenced by glaciers. The sectors dependent on those water resources are therefore more at risk. To evaluate resource availability, sector interdependencies and overall vulnerability of a catchment, a nexus approach can be used. More holistic solutions can then be developed, increasing the catchment's resilience to changes in future. However, difficulties lie in capturing the dynamics of climate, land, energy, and water systems together. In Norway for instance, this often includes snow, glaciers, and the management of reservoirs for hydropower production, and few nexus methods include these features. To address this, we selected the Community Water Model (CWatM) and made several new developments. CWatM is a widely available, easily adjustable hydrological model on a 1km x 1km daily resolution. It has the facility to include multiple crop types, and domestic, agriculture and industry water demands, therefore highly suitable for nexus assessment. The new developments to CWatM mean that seasonal changes in both reservoir and glacier water storage can now be assessed, so how these have affected, and may affect resilience to changes in climate in future could be evaluated. To test the model developments, we applied the CWatM model to the Otta catchment in Innlandet, Norway. Three large glacial bodies, and four hydropower reservoirs provide water storage to an otherwise rain-limited catchment (~300mm/year). Water resources are required for consistent hydropower production throughout the year, agriculture, and forestry, as well as white water rafting-dependent tourism. These competing demands, alongside the melting of glaciers due to climate change, have the potential to put a large amount of strain on the limited water resources. Results showed that CWatM with the new developments successfully represented the dynamics of stream discharge, glaciers, and reservoir water storage in the Otta catchment. Future work will focus on assessing the vulnerability and resilience of the Otta

catchment to climatic extremes given historic and potential future changes in storage with climate change. Wider application of CWatM and the new developments could improve nexus evaluation of other catchments in Norway and worldwide and highlight opportunities for greater resilience to changes in climate.