## Title: Study of unregulated flow conditions in Norwegian rivers: Strategy for improving lake outflow using HYPE model

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## Abstract

Norway's authorities are delayed in implementing the European Water Framework Directive (EU-WFD). A common challenge for the implementation of EU-WFD is finding natural reference conditions in water bodies which can be difficult for lakes that have been regulated and used for hydropower production for decades without much information on the state before regulation. Hydrological modelling of unregulated lakes can be a solution. Modelling water level fluctuations in unregulated lakes allow us to determine the ecological functioning of the lake and the water storage that could be used for different sectors such as hydropower, agriculture, and others.

Previous studies showed that lakes strongly influence the model performance when using the Hydrological Predictions for the Environment (HYPE) model. This study aims to develop model strategies for improving lake dynamic modelling with natural flow conditions for discharge and water level in HYPE. We modelled seven lakes in Norway with areas of more than 5 *km*<sup>2</sup> and a gauging station at the output. Each lake was calibrated independently, and each model was set up from an existing one for the mainland of Norway. Stepwise calibration was implemented to create discharge and water level models. Parametrization of rating curves for lakes was introduced to the model for calibration. The model performance was evaluated using of Kling–Gupta efficiency (KGE) index as the objective function.

Our results showed model performance improvement for water discharge with KGE ranging from 0.59 to 0.95 in the calibration period and from 0.64 to 0.90 in the validation period. The models for water level prediction had higher performance than the discharge models with KGE ranging from 0.83 to 0.95 in the calibration period and from 0.75 to 0.94 in the validation period.