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

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Motivation

- Necessity to comply with the Water Framework Directive (WFD) to achieve good ecological status for water bodies.
- Hydropower accounts for more than 90% of the power generation in Norway (NMPE, 2021) and approximately 1200 lakes are used as reservoirs (Helland et al., 2019). Therefore there is an alteration of the natural water level fluctuation of the lakes.

Objective

- To propose strategies for improving and optimizing the output in modelling in terms of discharge and water level of lakes with natural flow conditions when using the hydrological model HYPE

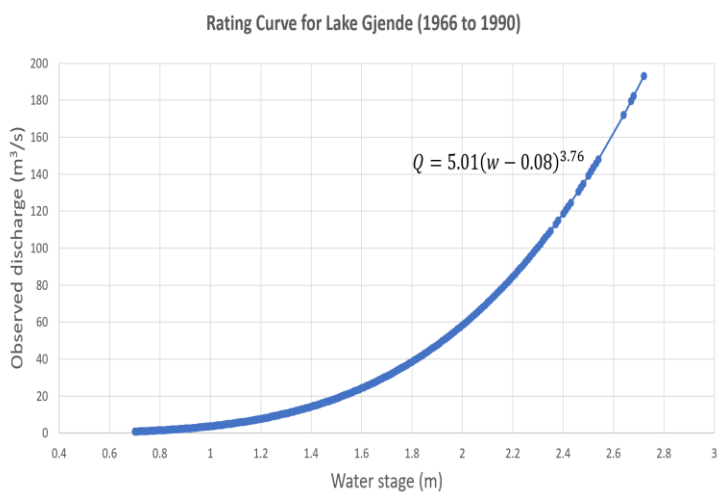
Hydrological Predictions for the Environment (HYPE)

HYPE is semi-distributed hydrological model for small-scale and large-scale basins developed by the Swedish Meteorological and Hydrological Institute (SMHI) for rainfall-runoff and water quality simulation. It is needed a previous delineation of subbasins to perform a simulation.

Lakes in HYPE

- Local lakes (ilakes).- Lakes inside a sub basin which receive inflow only from inside the sub basin.

- Outlet lakes (olakes).- Lakes located at the outlet of a sub basin. For discharge calculation, HYPE only accepts one-segmented rating curve per lake $Q(t) = k\,(w(t) - w_o)^p$

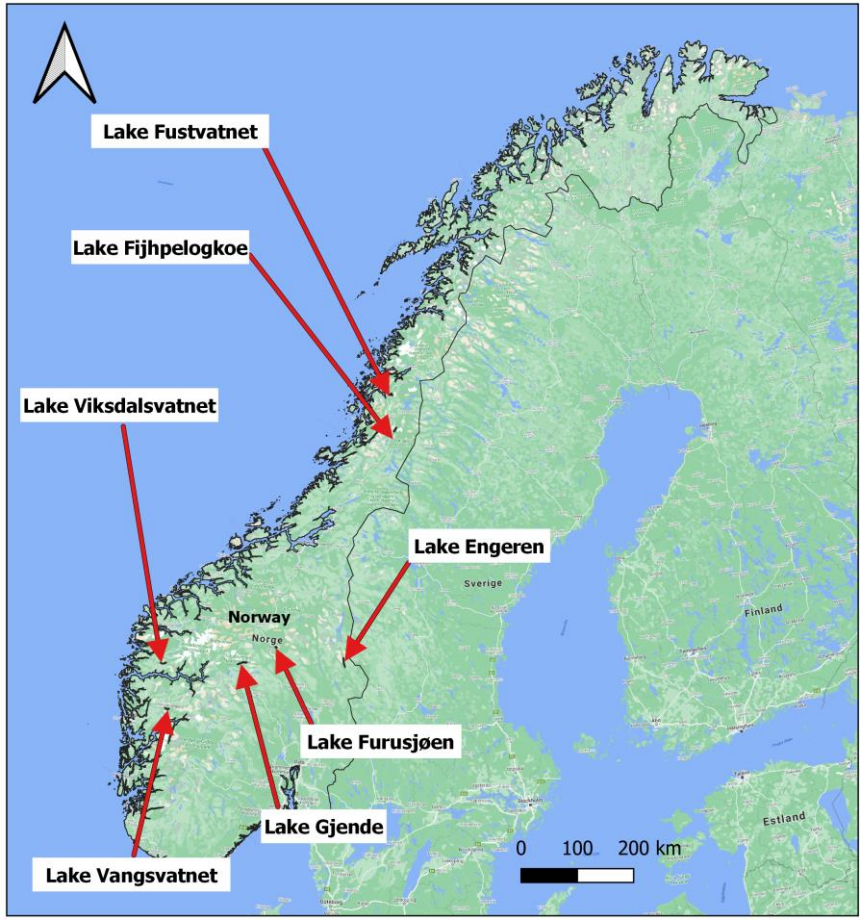


Methodology

STUDY LAKES

- Seven outlet lakes *(olakes)* were studied in the mainland of Norway.
- Each lake is located at the outlet of a sub basin, with an area of more than 5 km^2 and with gauging station.

Nr	Lake name	Name of gauge station	Station ID	Data availability of discharge	
				From	To
1	Fustvatn	Fustvatnet	152.4.0	1-Mar-1970	Active
2	Fijhpelogkoe	Fiplingvatn	151.17.0	1-Oct-1968	31-Dec-1985
3	Gjende	Gjende	2.102.0	13-Oct-1966	27-Feb-1990
4	Engeren	Engeren	311.460.0	1-Jan-1983	Active
5	Viksdalsvatnet	Viksvatn(Hestadfjorden)	83.2.0	1-Jan-1957	Active
6	Vangsvatnet	Bulken (Vangsvatnet)	62.5.0	1-Jan-1957	Active
7	Furusjøen	Furusjøen	2.276.0	4-Nov-1964	21-Feb-1988



Methodology

SPECIFICATIONS OF THE MODEL

- Delineation of sub basins and parameters for calibration were taken from HYPE model for Norway developed in 2017.
- **Landuse and soil:** Water, Mountain, Forest, marsh, glacier, and another type that combines urban, agriculture and others
- **Study lakes:** Calibration time: 1976 to 1980 and validation time: 1981 to 1985. Lake Engeren Calibration time: 1983 to 1987 and validation time: 1988 to 1992.
- **Forcing data:** Daily temperature and precipitation data. (SeNorge2).
- **Daily discharge values:** The Norwegian Water Resources and Energy Directorate (SILDRE)

Manual and automatic calibration were used to create a model for discharge and water level for lakes.

Automatic calibration: Progressive Monte-Carlo method with parameter space limited by best found so far (task BP)

Goodness-of-fit in HYPE model

The Kling-Gupta efficiency index

$$KGE = 1 - \sqrt{(r-1)^2 + (\alpha-1)^2 + (\beta-1)^2}$$

correlation — Flow variability error — bias

Methodology

Stepwise calibration approach

First stage: HYPE model for discharge prediction without specific rating curve coefficients

Automatic Calibration

Second stage: HYPE model for water level prediction with specific rating curve coefficients

Manual Calibration

Third stage: HYPE model for discharge and water level prediction with specific rating curve coefficients

Manual and automatic calibration

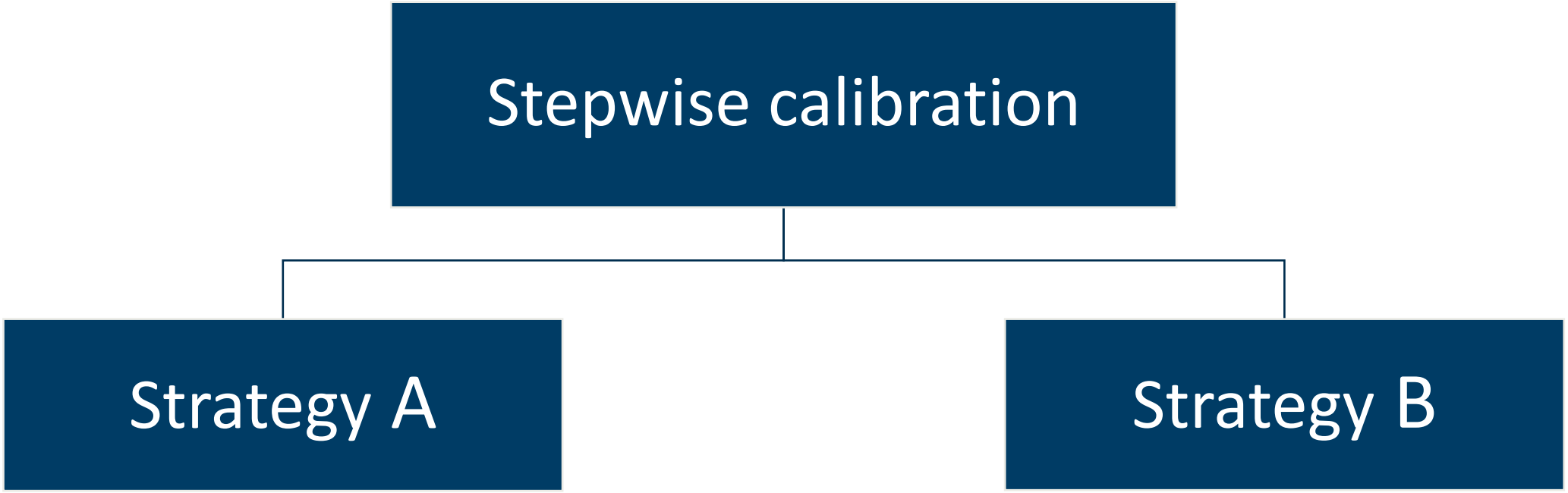
1. Adapted rating curve (*wo*, *k* and *p*) -> Introduction to HYPE
2. Correction of the water reference of the equation $Q = k(w - w_o)^p$

$$bias = \frac{\sum_{i=1}^{n}(wstr - clwc)}{n}$$

$$w'_o = w_o - bias$$

3. Variation of k and p until finding the best performance

Methodology



Automatic calibration

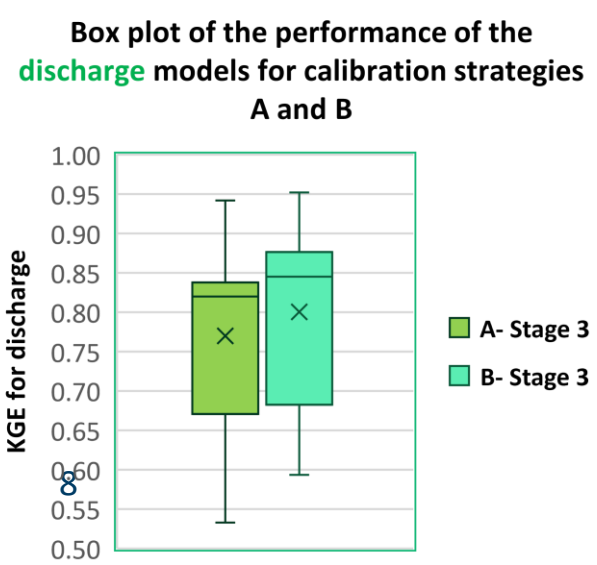
Total parameters
Lake paremeters

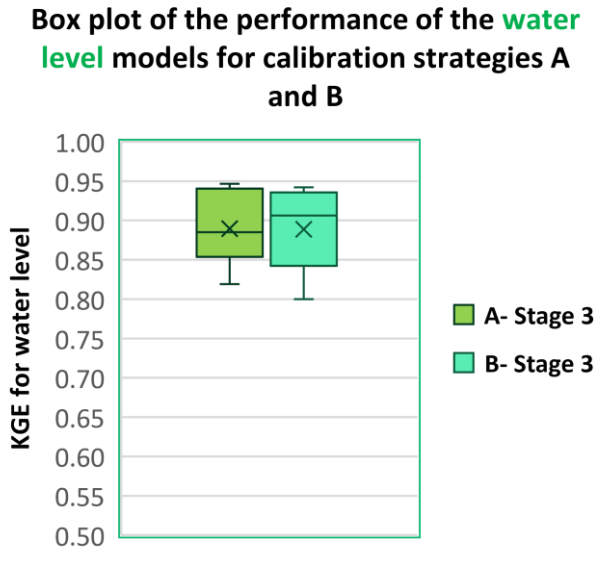
Automatic calibration

Total parameters
Soil parameters
Snow parameters
Other processes parameters
Lake paramaters

Results and conclusions

- Individual catchment calibration for lakes provided higher performance than the multi-catchment calibration approach.
- Strategies A and B are viable to obtain models for predicting discharge and water level. However, strategy B had a higher discharge performance than strategy A.
- KGE for discharge model: A(0.82) and B (0.85)
- KGE for water level model: A(0.89) and B (0.91)





- There was a marginal decrease in discharge performance when we introduced the rating curve into the model.
- The model HYPE is sensitive to the variation of the rating curve coefficients. The bias correction of the water level reference w_o joined with the consecutive variation of the rate k and exponent p increased the performance in 10%.
- The presence of upstreams lakes in the catchment decreases the discharge performance in HYPE.
- Catchments with larger areas and sub basins resulted in a higher performance.

Thank you

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