FutureHydro Workshop

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Centre for Environmental Design of Renewable Energy

CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH

Impacts of flexible hydropower

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Hydropeaking = ?

= Rapid changes in power production by hydro-electric facilities as a consequence of varying electricity generation and demand on the electricity market.

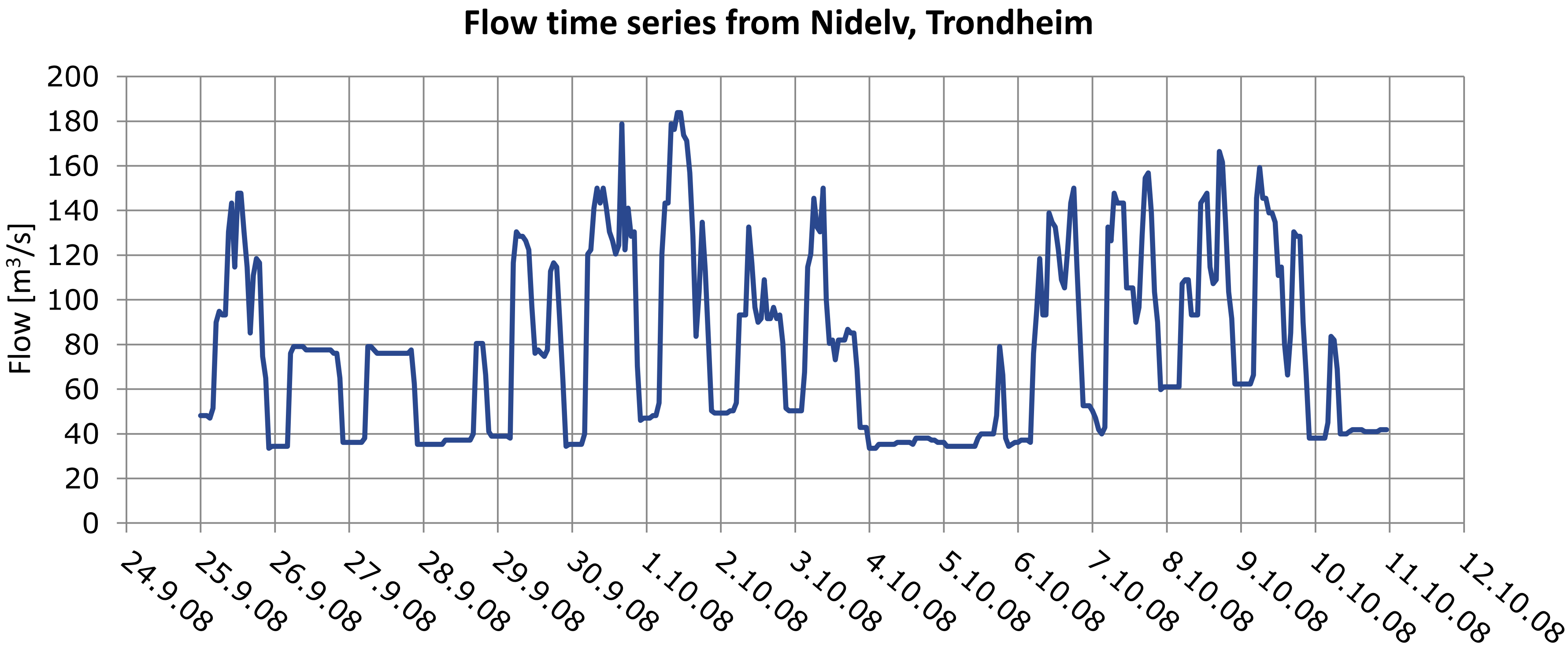
Photo: J. Sauterleute

Impact on ecosystems of water bodies downstream of the power plant outlets.

- Outlet into river → Rapid fluctuations of stream flow and water level
- Outlet into a reservoir → Rapid fluctuations of reservoir water level

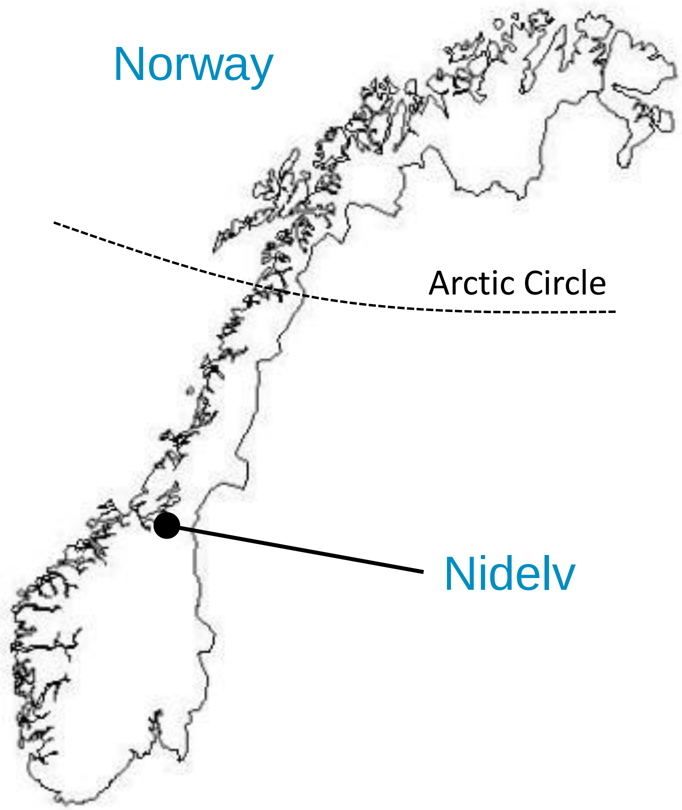
Rapid flow fluctuations in rivers

- May appear as follows:



Analysis river Nidelv

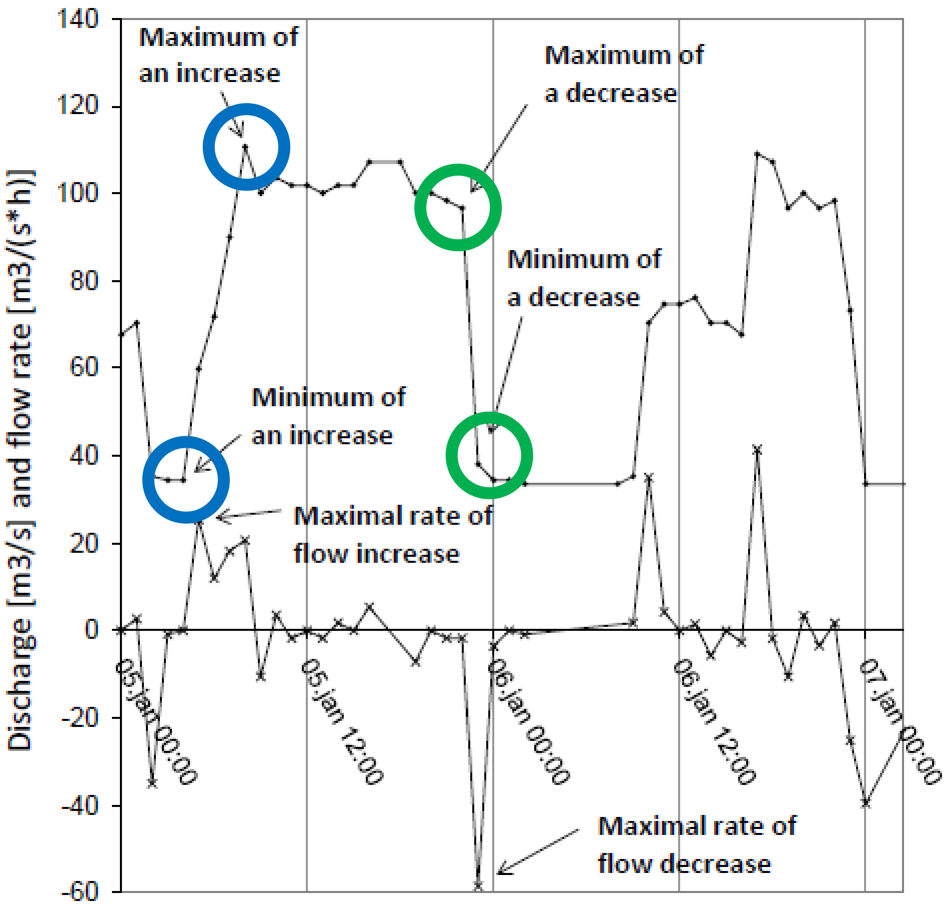
- Event identification by river/data-specific threshold
- Parameter calculation
- 15-minutes interval
- Years 1994-1996



Selected parameters

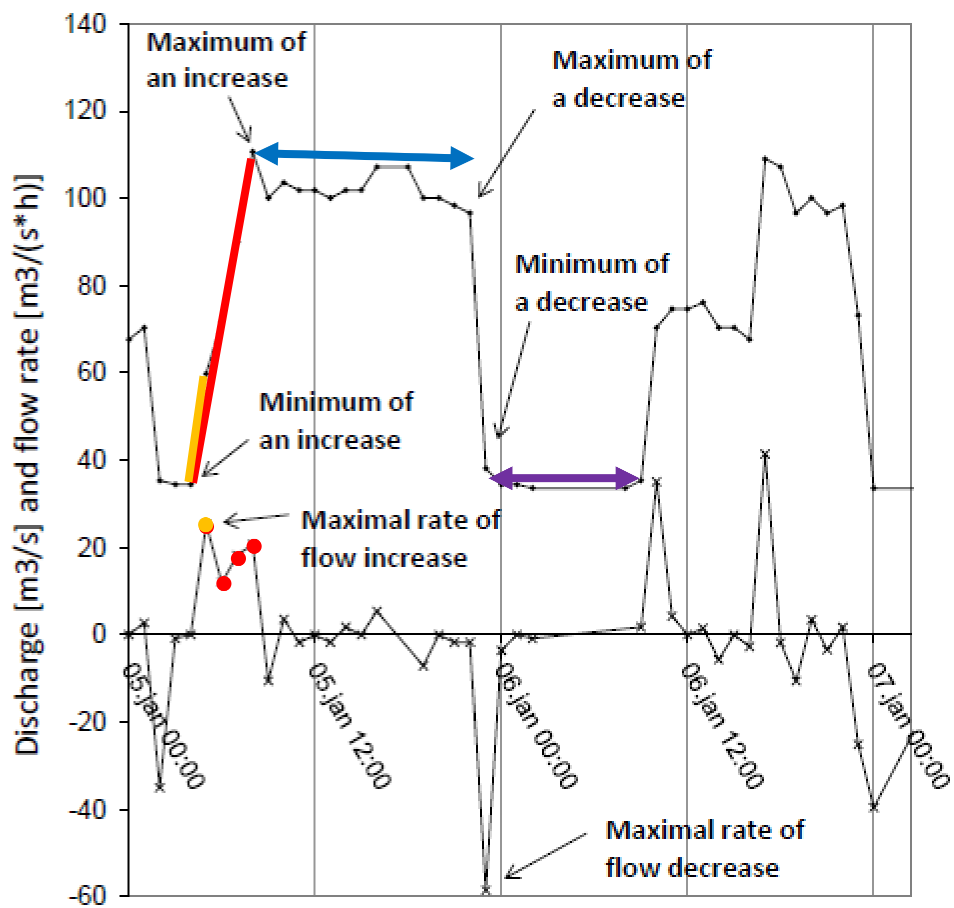
Parameter
Magnitude
Flow
Stage
Flow maximum/minimum of a rapid increase
Flow maximum/minimum of a rapid decrease
Stage maximum/minimum of a rapid increase
Stage maximum/minimum of a rapid decrease
Flow ratio of a rapid increase/decrease

Q_{max}/Q_{min}



Selected parameters

Parameter		
Scale of time		
Mean rate of flow increase/decrease		
Mean rate of stage increase/decrease		
Maximal rate of flow increase/decrease		
Maximal rate of stage increase/decrease		
Time of the start/end of a rapid increase		
Time of the start/end of a rapid decrease		
Duration between a rapid increase and decrease		
Duration between a rapid decrease and increase		
Frequency		
Count of rapid increases/decreases per year		
Portion of days with certain number of rapid increases/decreases per day		
Portion of rapid increases/decreases during daylight/twilight/darkness		



Results river Nidelv

- Flow ratio (Q_{max}/Q_{min})

Rapid increases

Median	P90	Max
1.5	2.1	3.7

Rapid decreases

Median	P90	Max
1.5	2.1	3.7

  - Magnitude in general low
  - 2 to > 50 in Swiss and Austrian rivers *(VAW & LCH, 2006)*
  - Extreme values up to 510 in USA/Canada/Finland/France *(Bain, 2007)*

- Percentage of days with rapid fluctuations: on average 29 %

Results river Nidelv

- Rates of stage increase/decrease

Rapid increases

Mean rate cm/h			Maximal rate cm/h		
Median	P90	Max	Median	P90	Max
19.9	26.2	43.5	22.3	29.2	51.2

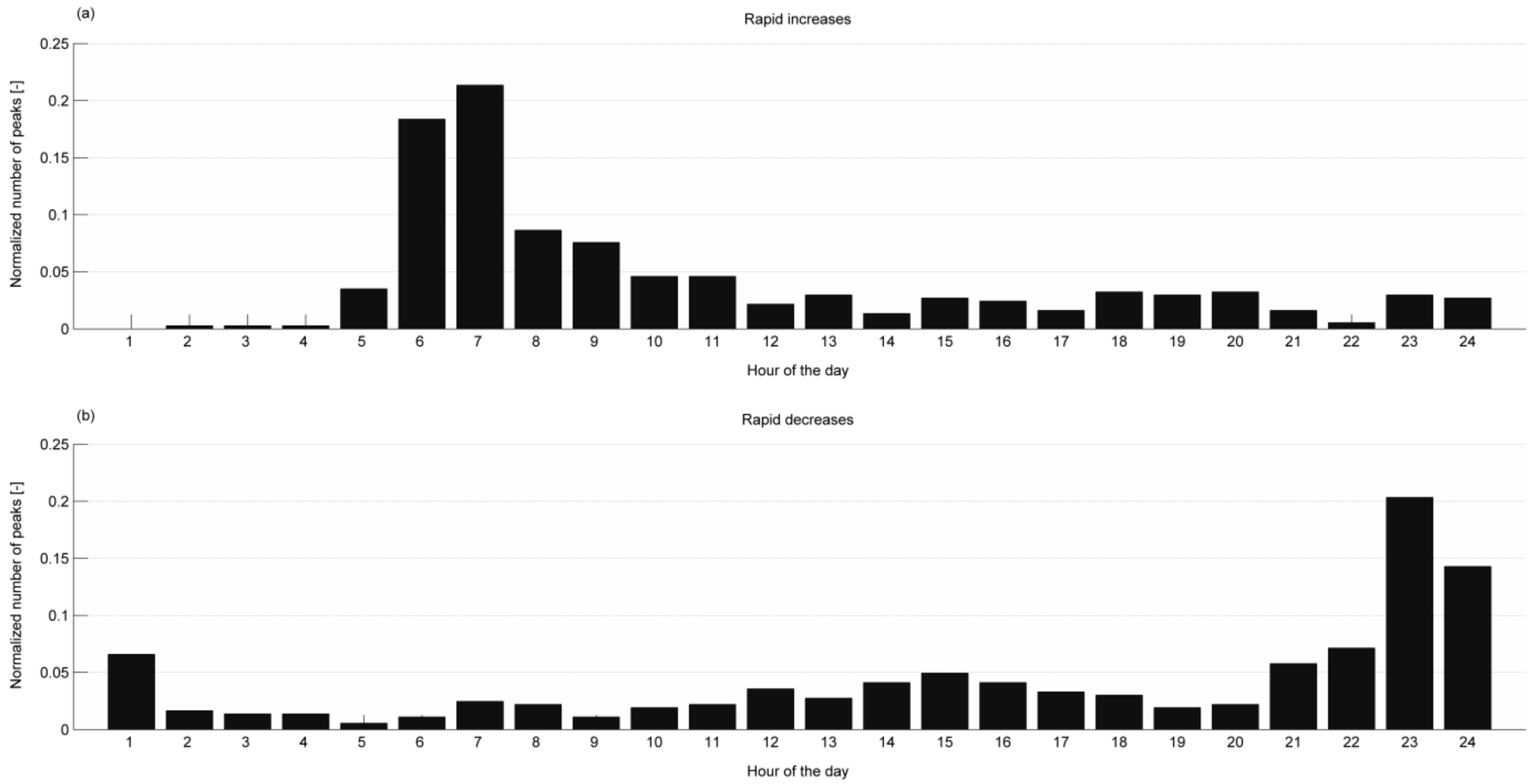
Rapid decreases

Mean rate cm/h			Maximal rate cm/h		
Median	P90	Max	Median	P90	Max
19.4	26.6	45.1	21.1	29.9	54.0

- Relatively low rates of change; Up to 240 cm/h in Swiss rivers *(Baumann & Klaus, 2003)*
- Critical: 10 cm/h to 18 cm/h *(Halleraker et al., 2003; Saltveit et al., 2001)*

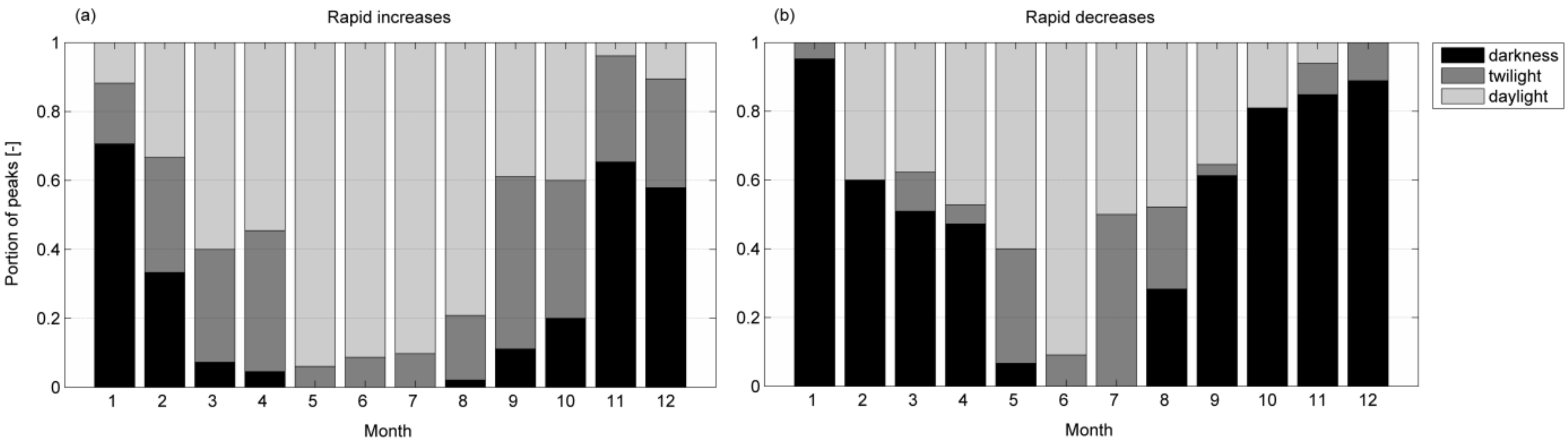
Results river Nidelv

- Distribution on time of day



Results river Nidelv

- Light conditions



Environmental impacts

- Temperature variations
- Fish growth
- Invertebrates
- Sediment transport, erosion
- Ice conditions

Modelling water level fluctuations in reservoirs

- Reservoir pairs in Southern Norway
- Balancing power capacity in addition to installed capacity
- Operation of existing power station remains unchanged
- Balancing power operation within current reservoir regulations
- Input data
  - Simulated wind power time series from North Sea
  - Observed reservoir water level and volume
    - → Current operational regime
    - → Natural inflow
- Time step: 1 day

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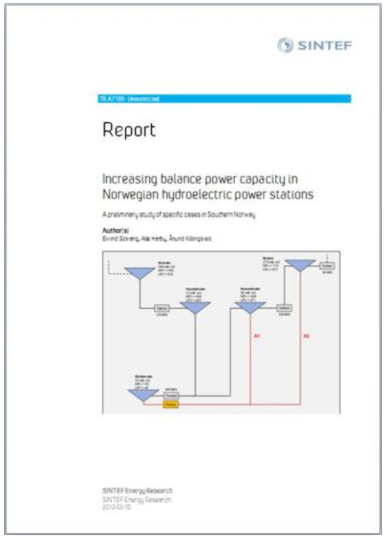
Background

Increasing balance power capacity in Norwegian hydroelectric power stations – A preliminary study of specific cases in Southern Norway

Solvang et al., 2011, SINTEF TR A7195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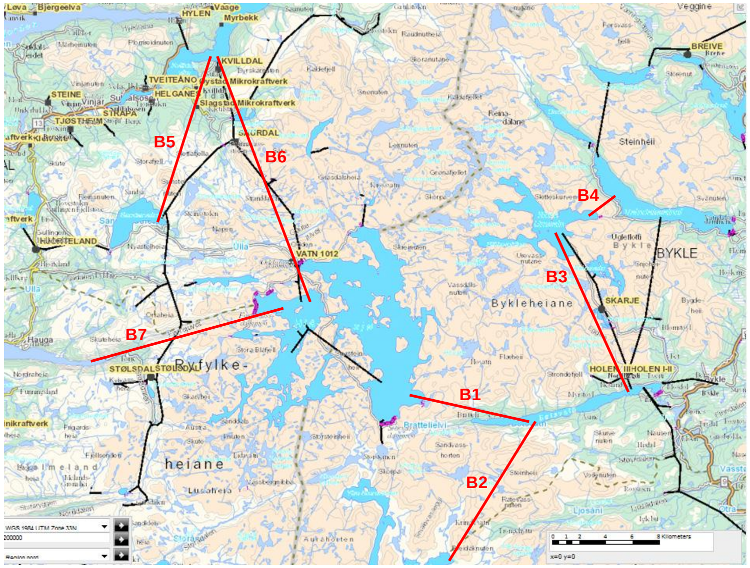
Report

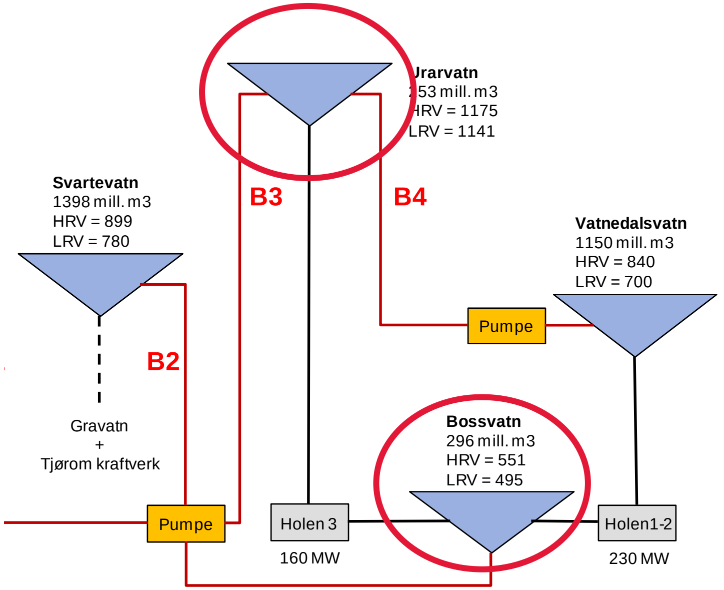
Increasing balance power capacity in Norwegian hydroelectric power stations

- **20.000 MW possible by 2030**
- Hydro storage + pumped storage
- Existing dams and reservoirs
- Outlet into reservoir or fjord/sea



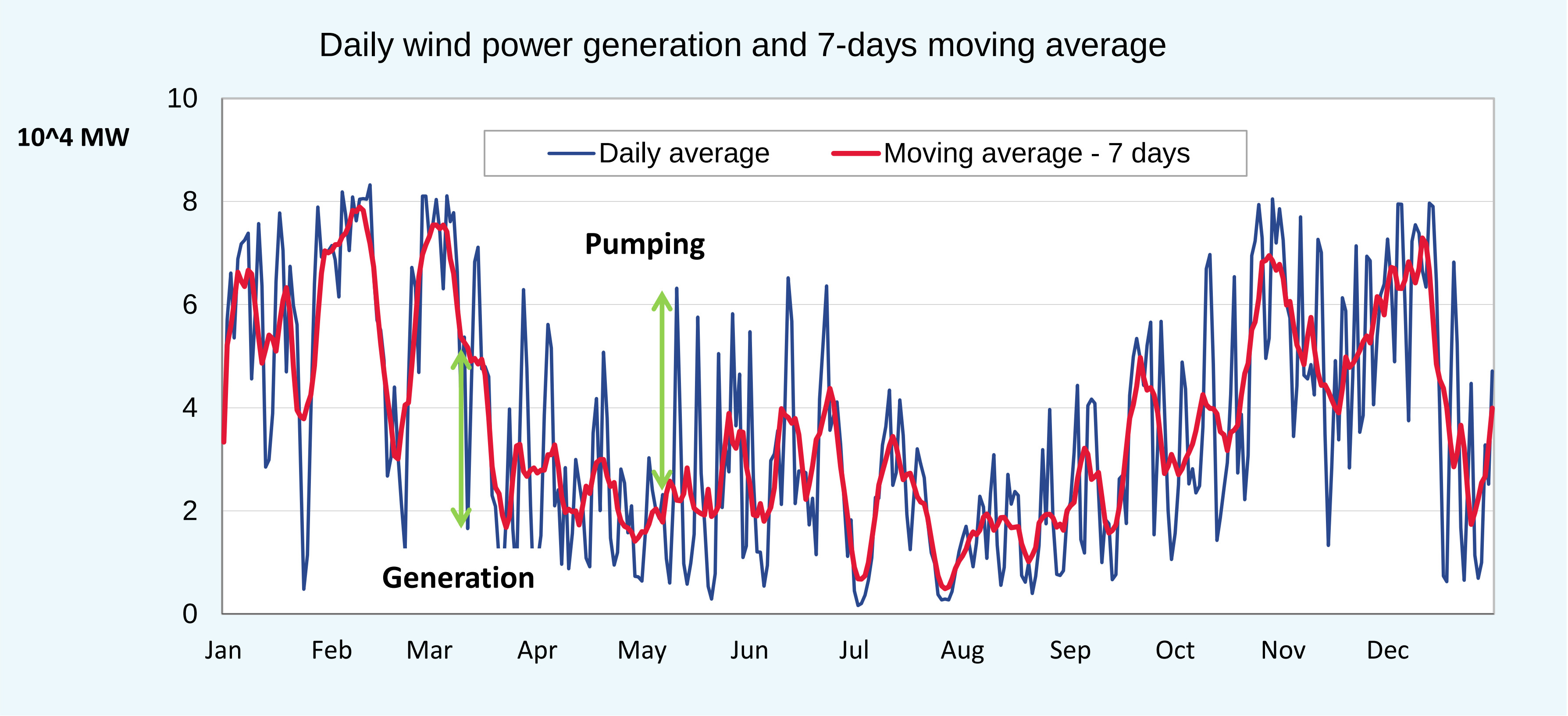
Example case

Holen (Urarvatn–Bossvatn)

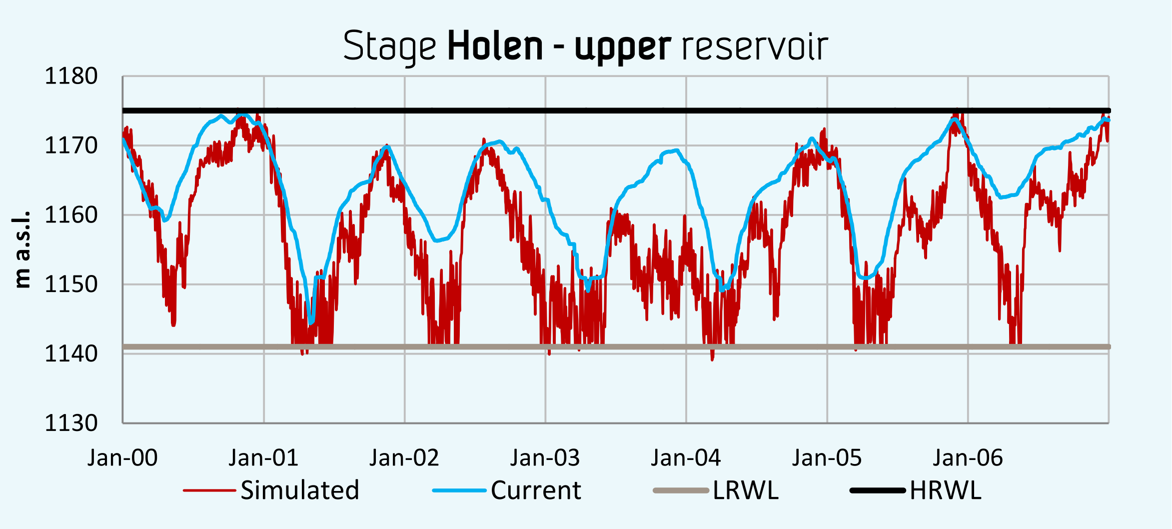


	Holen
Volume upper reservoir	253 mill. m^3
Volume lower reservoir	296 mill. m^3
Installed capacity	1400 MW

Balancing power needs

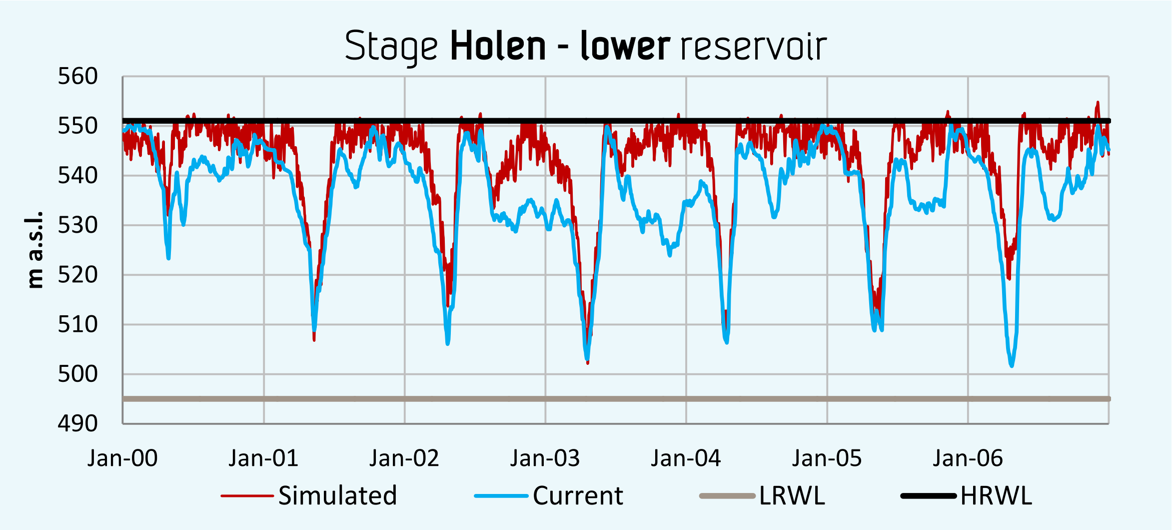


Water level fluctuations



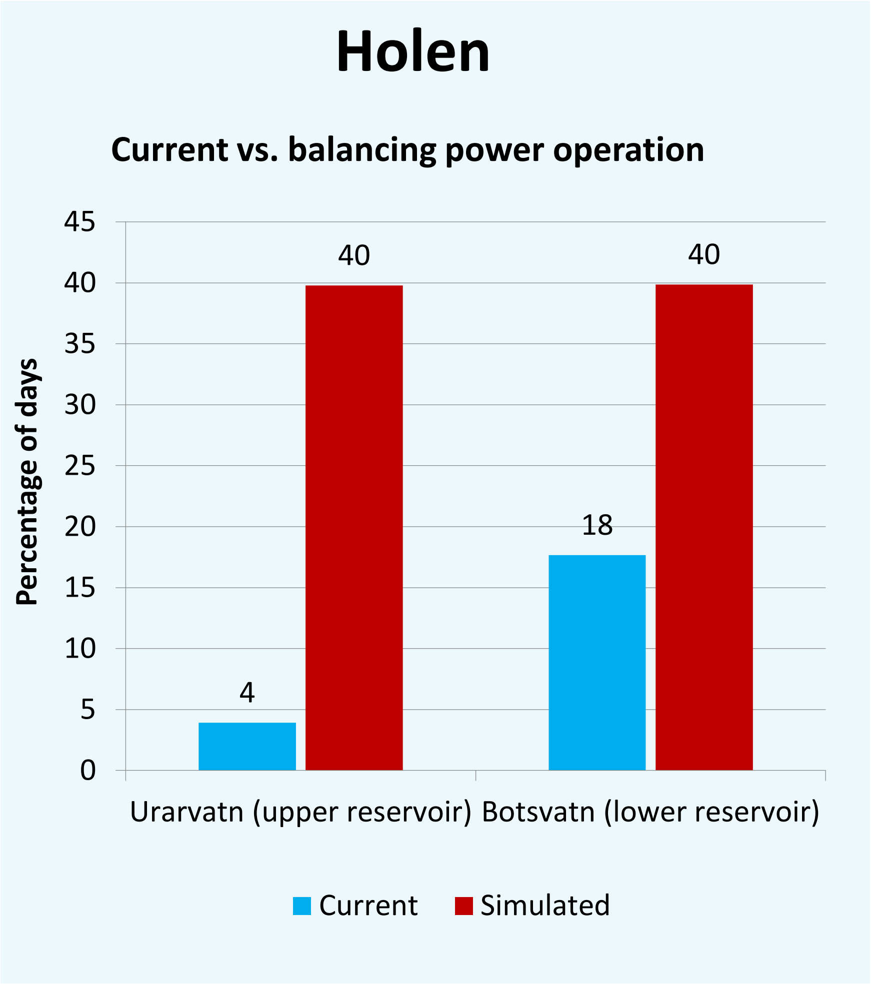
- Strong increase in rates of change in water level
- Shorter periods with high WL

  Longer periods with low WL

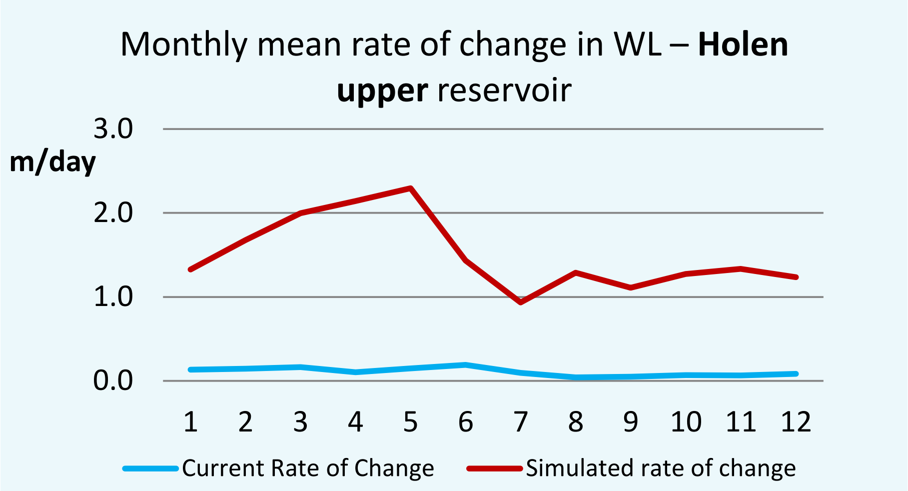


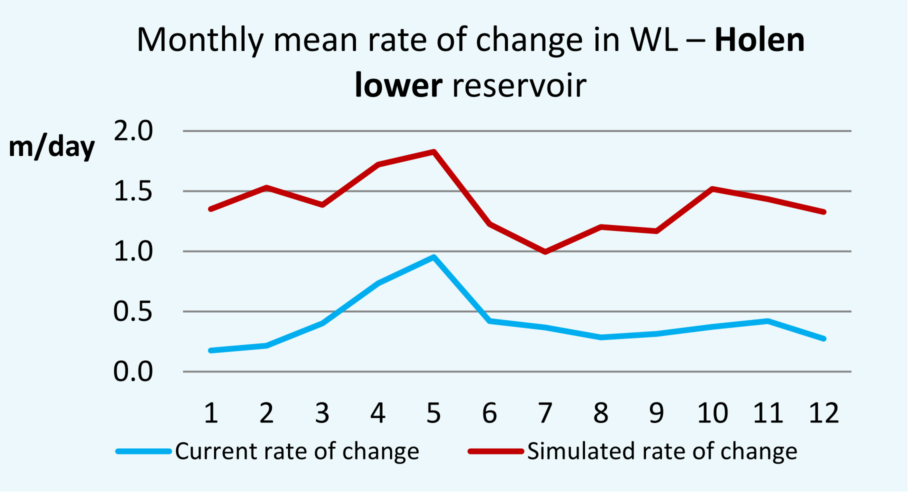
- Strong increase in rates of change in water level
- Longer periods with higher WL

Number of changes in stage



Necessity for seasonal regulations?

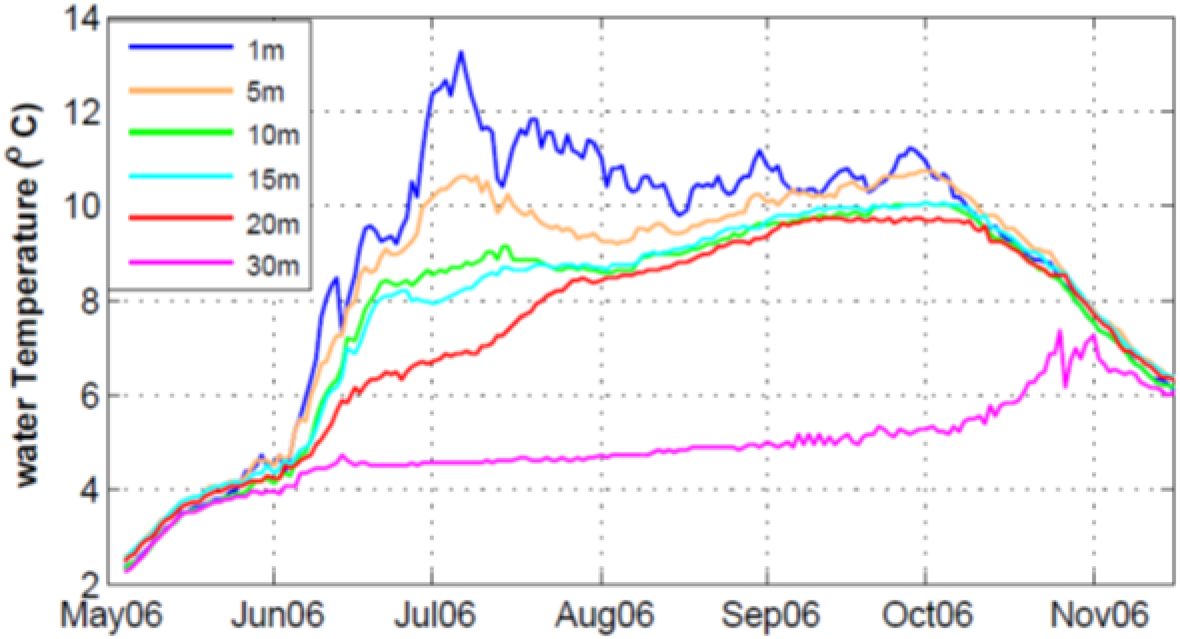




Environmental impacts

- Hydrodynamics
- Circulation
- Mixing
- Temperature

Temperature stratification in Vassbygdvatn, Aurland



Environmental impacts

- Erosion

Environmental impacts

- Ice
- Recreation

Environmental impacts

- Biodiversity

Conclusions

- Identification and quantification of water level fluctuations
- Basis for assessment of environmental impacts
- (Re-)licencing of hydropower stations