Short review of 3 PhD projects from the HydroPeak project

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Ånund Killingtveit, CEDREN/NTNU
How will Norwegian hydropower fit into the future European power system?
## Work-packages in HYDROPEAK

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**Project leader HYDROPEAK**

NTNU/Killingtveit
Teklu T. Hailegeorgis

Identification of spatially distributed Precipitation-Runoff response routines for hourly simulation in gauged and ungauged basins

Stephan Mark Spiller

Physical effects of load fluctuations in rivers

Netra P. Timalsina

Ice conditions in Norwegian rivers regulated for hydropower
An assessment in the current and future climate
Teklu T. Hailegeorgis

Identification of spatially distributed Precipitation-Runoff response routines for hourly simulation in gauged and ungauged basins

Supervisor: Knut Alfredsen
Main objective of PhD study:
- Distributed Precipitation-Runoff model for hourly simulation
- Further development/improvement of HBV response-routine
- Simplified response routine – better parameter identification
- Multi-Basin and Regional calibration of model
- Prediction of hourly streamflow in ungauges basins

Main Deliverables from project
- PhD Thesis
- 6 Papers in International Journals
- Program modules for use in the ENKI modelling system
WP7: Flow fluctuations in rivers

Supervisor: Nils Ruther

Stephan Mark Spiller
Physical effects of load fluctuations in rivers
Motivation:

- Increased importance of hydropower peaking due to flexible energy market
- How is bed stability affected by rapid flow fluctuations?
- How can effects on flow fluctuations be mitigated?
The hyporheic zone during hydropower peaking
(hyporheic zone = mixing zone of surface- and ground water)

Situation 1:
**Surface water stage > groundwater stage**
“DOWNWELLING”

Situation 2:
**Surface water stage < groundwater stage**
“UPWELLING”

- Upwelling and downwelling are responses to the hydrostatic pressure difference between ground water table and surface water stage. They can be described as *quasi-steady effects* of hydropower peaking.

- Are there additional *dynamic* or *unsteady effects* during hydropower peaking, affecting the hyporheic zone?
New flume installed at NTNU

- Flume installed
- gangway
- working platform
- staircase
- downstream weir
- 5 tons of sediments
- Automatic valves
- Inductive discharge measurement
- Connection to high reservoir
- Connection to low reservoir
- Traverse

- Several Master theses
- 4 Months cooperation with Hungarian PhD student
- Collaboration with MARINTEK
- New PhD Student at NTNU
Olje- og energiminister Ola Borten Moe (f.v.) og CEDREN-lederne Ånund Killingtveit og Atle Harby betrakter den kraftige vannstrømmen i den nye vannrenna.

Foto: Thor Nielsen
Experimental setup:

- Flume: 18.5m long, 0.46m wide, slope 0.5%
- Artificial streambed
- 10cm x 10cm target piece supported by force sensor
Artificial streambed – An exact copy of a gravel bed river
Making it possible to run repeated experiments with same river bed

Static armor layer

Artificial copy
Deliverables: 13 papers + 1 PhD Thesis

2014
Spiller, Stephan; Ruther, Nils; Friedrich, Heide.
Dynamic lift on an artificial static armor layer during highly unsteady flow. Journal of Hydraulic Engineering (ASCE) In review

Spiller, Stephan; Ruther, Nils; Baumann, Benjamin.
Form-induced stress in non-uniform steady and unsteady open channel flow over a steady rough bed. International Journal of Sediment Research. Accepted for publication

Spiller, Stephan; Ruther, Nils; Friedrich, Heide.

Spiller, Stephan; Ruther, Nils; Casas-Mulet, Roser; Friedrich, Heide.

Friedrich, Heide; Spiller, Stephan; Ruther, Nils.

Török, G.T.; Baranya, S; Ruther, Nils; Spiller, Stephan.

2013
Spiller, Stephan; Ruther, Nils.
The Impact of Hydropower Peaking on Gravel Beds. Hydro2013 International Conference; 2013-10-07 - 2013-10-09

Spiller, Stephan; Ruther, Nils; Baumann, Benjamin.

Ruther, Nils; Huber, Sonja; Spiller, Stephan; Aberle, Jochen.
Verifying a Photogrammetric Method to Quantify Grain Size Distribution of Developed Armor Layers. 35th IAHR World Congress; 2013-09-08 - 2013-09-13

2012
Spiller, Stephan; Ruther, Nils; Baumann, Benjamin.

Spiller, Stephan; Ruther, Nils; Killingtveit, Ånund.
Physical Effects of Load Fluctuations in Rivers. Berichte des Lehrstuhls und der Versuchsanstalt für Wasserbau und Wasserwirtschaft 2012 (125) s. 52-59

Spiller, Stephan; Ruther, Nils; Koll, Klaus; Koll, Katinka.

2011
Spiller, Stephan; Ruther, Nils; Belete, Kiflom Wasihun; Strellis, Brendon.
Assessing environmental effects of hydropower peaking by 3D numerical modeling. Flow simulation in hydraulic engineering : Dresdner wasserbauliche Mitteilungen 2011 ;Volum 1.(1) s. 79-86
Results – Lift Force

Unsteady flow can have significant dynamic effects on the lift acting on a streambed compared to the bed-shear stress.
Methods and measurement devices

- Artificial gravel bed
- Direct force measurement
- Freeze cores
- Suspended sediment
- Particle Image Velocimetry (PIV)
- Acoustic Doppler Velocimetry (ADV)
- Numerical methods
Basis for further research

- New PhD student at NTNU
- Master students
- Projects at other institutes in Norway, Germany, New Zealand
networking

- 9 conferences
- 3 workshops
- 2 research exchanges
Ice conditions in Norwegian rivers regulated for hydropower
An assessment in the current and future climate

Supervisor: Knut Alfredsen
HydroPeak WP8 were closely connected to:

**Sustainable Infrastructure – SIP ved NTNU.**
PhD on Ice and Infrastructure.

**Cryosphere-atmosphere interactions in a changing Arctic climate.**
Nordic project under Top Research initiative.
River Ice modeling

To identify the impact of peaking regimes on ice conditions in the regulated rivers.

The establishment of 1D dynamic model, Mike 11 with Ice module for simulation of ice formation and breakup.

Analyze the future scenarios with climate and operational strategies.

Finally, propose mitigation measures and guidelines for peaking operation strategies in ice covered rivers.
WP8: River Ice – Climate Change
PhD project: About hydropower and its effect on river ice regime

Case study: Orkla river

Data collection methods
- River ice extent
- Climate
- Water temperature

Modelling ice processes by MIKE 11 + Ice

Climate change impacts

Hydropower operation modelling

Future climate impacts on
- Flow
- Hydropower operation
- Ice conditions
### Deliverables:
- 6 papers + 1 PhD Thesis
- Tested and verified new field data equipment
- Tested and operational Ice-model (MIKE 11 Ice)
- Program system for CC → Hydrology → Hydropower → Ice cond

Recommendations about CC impacts on hydropower system

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<thead>
<tr>
<th>Hydropower component</th>
<th>Current effects</th>
<th>Climate impact (+)</th>
<th>Climate impact (-)</th>
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</thead>
<tbody>
<tr>
<td>Dams</td>
<td>Ice loads on dams and dam faces.</td>
<td>Reduced ice loads on dams. Reduced floe size.</td>
<td>More frequent river breakups—more dynamic load on river constructions.</td>
</tr>
<tr>
<td>Spillways</td>
<td>Frozen gates, ice formation in spillway tunnels.</td>
<td>Shorter winter season.</td>
<td>-</td>
</tr>
<tr>
<td>Reservoirs</td>
<td>Ice forces on banks. Transport.</td>
<td>Reduced ice thickness.</td>
<td>Reduced transport potential.</td>
</tr>
<tr>
<td>Trash racks</td>
<td>Clogging by frazil and drifting ice.</td>
<td>Reduced winter season and reduced frazil production—less need for operational constraints and ice removal.</td>
<td>Potential for more ice runs, clogging of intakes. More frazil in rivers with run of the river plants—potential intake problems.</td>
</tr>
<tr>
<td>Intake gates</td>
<td>Frost and ice loads on gate.</td>
<td>Shorter season and less ice reduce load.</td>
<td>More mechanical breakups—increased dynamic load.</td>
</tr>
<tr>
<td>Rivers</td>
<td>Unstable winter ice conditions downstream of outlets.</td>
<td>Reduced length of winter season. Reduced ice formation.</td>
<td>More unstable regime.</td>
</tr>
<tr>
<td>Operational</td>
<td>Limits flow variability during ice season.</td>
<td>Reduced ice season—more unrestricted production.</td>
<td>More unstable conditions, blocking by breakups and restraints on operation.</td>
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</tbody>
</table>

*Gebre, Timalsina & Alfredsen (2014) Energies*