Short review of 3 PhD projects from the HydroPeak project

@NVE 21Jan 2015

Ånund Killingtveit, CEDREN/NTNU

CEDREN 21 PhD's and 7 PostDoc's - December 2014

CEDREN

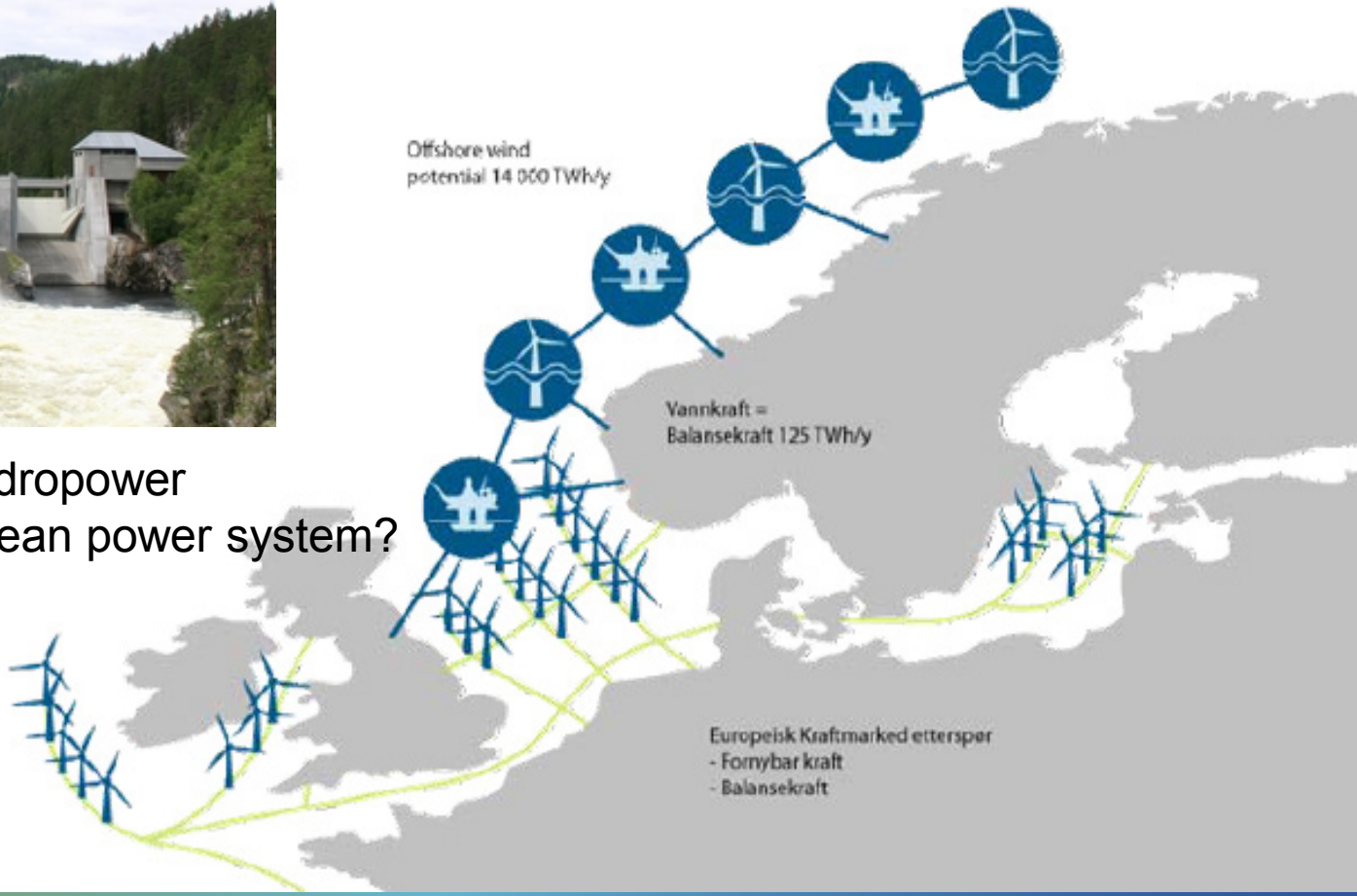
Centre for Environmental Design of Renewable Energy

CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH

HYDROPEAK

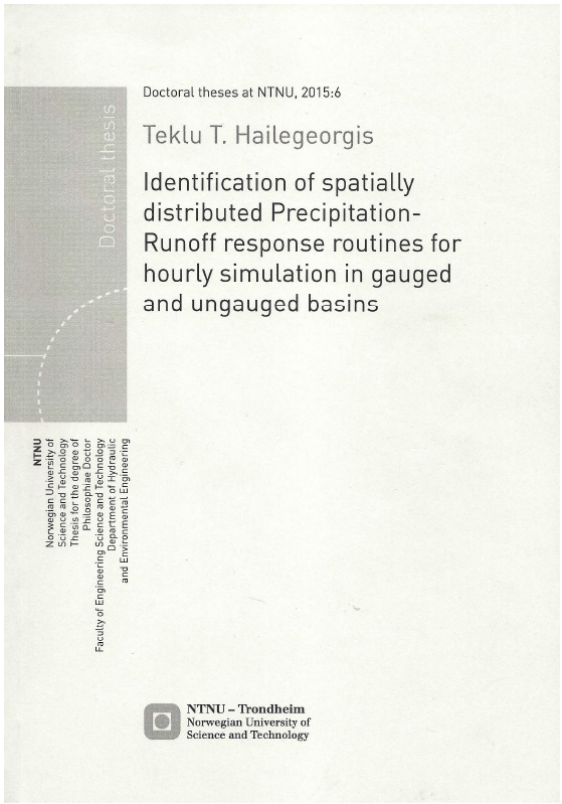
Hydro power development for peaking and load balancing in a European system with increasing use of non-regulated renewables

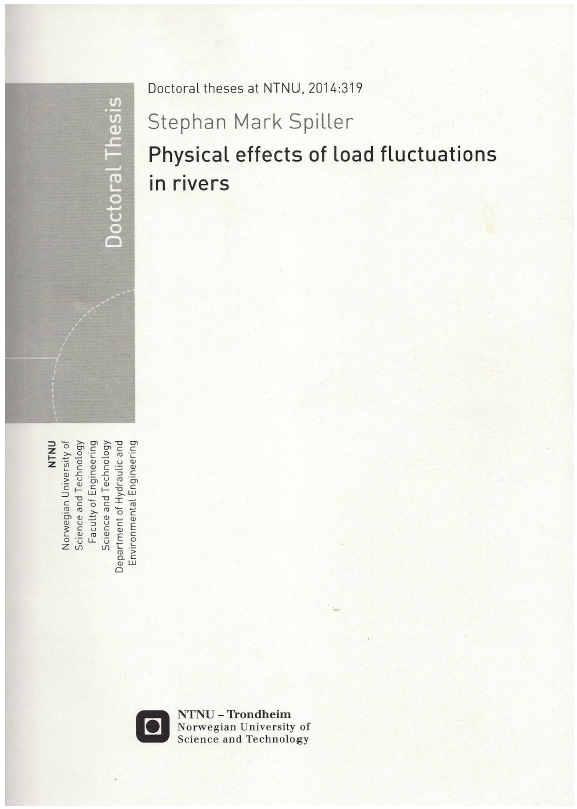
How will Norwegian hydropower
fit into the future European power system?

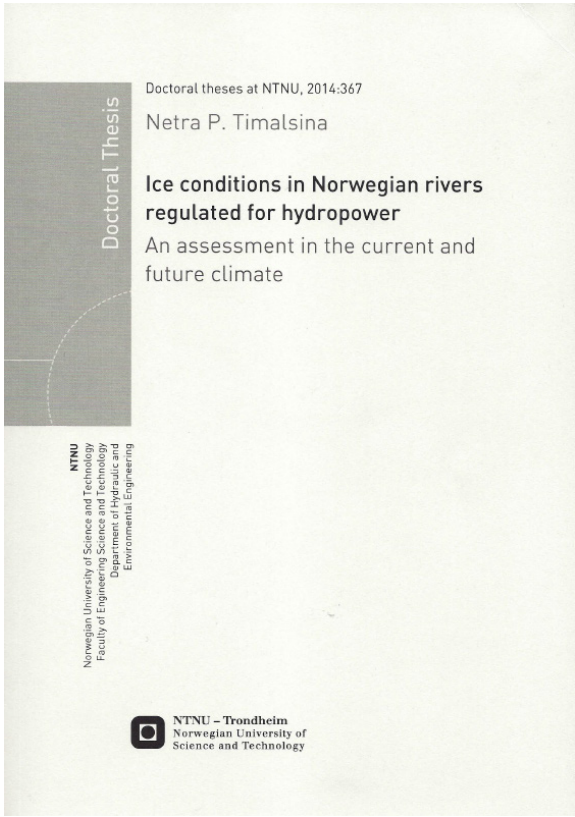


Work-packages in HYDROPEAK

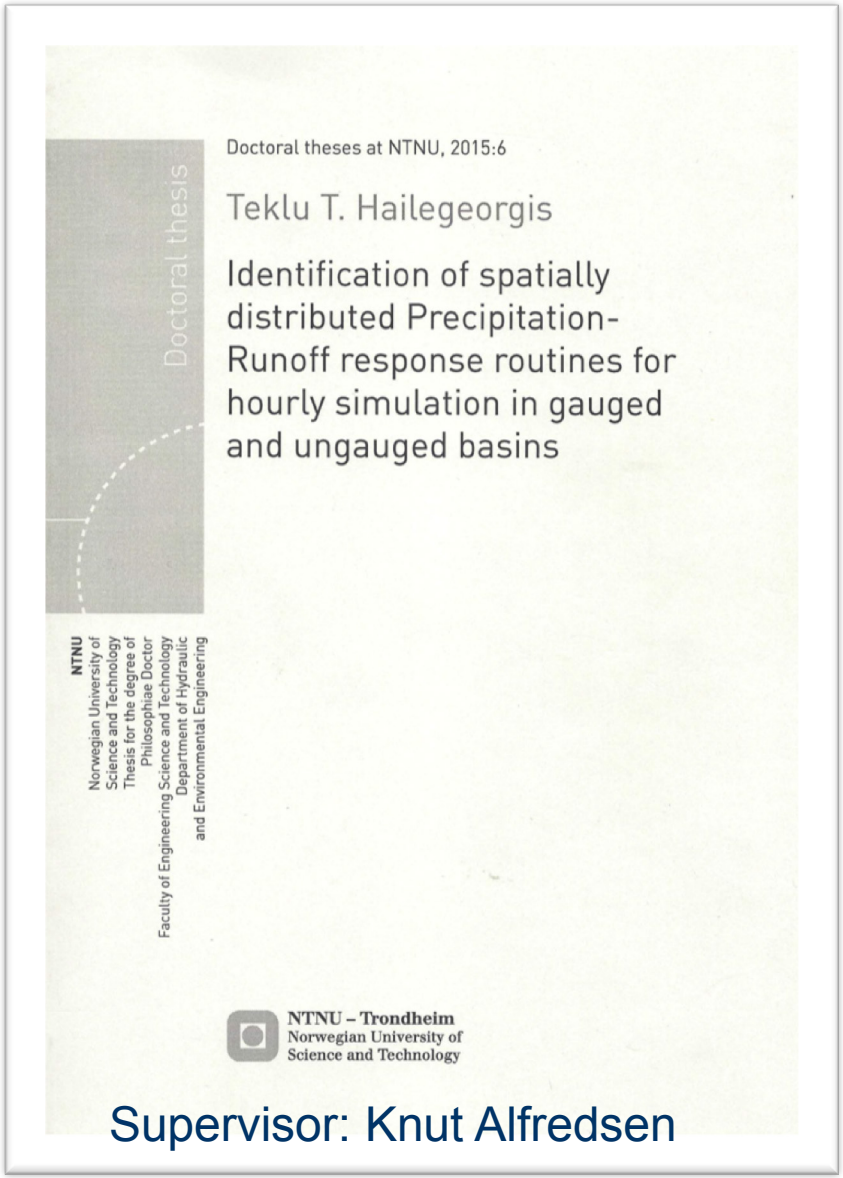
WP1	Scenarios and Dissemination	SINTEF/Solvang
		NTNU/Killingtveit
WP2	Hydrology	SINTEF/Kolberg
		NTNU/Alfredsen
WP3	Modelling power system	NTNU/Doorman/Korpås
WP4	Pumped storage plants	NTNU/Nielsen
WP5	Frequency and load governing	NTNU/Nielsen
WP6.1	Load fluctuation – Tunnels	NTNU/Olsen
WP6.2	Surge chambers	NTNU/Lia
WP7	Load fluctuations – Rivers	NTNU/Ruther
WP8	River ice – Climate change	NTNU/Alfredsen
		SINTEF/Charmasson
Project leader HYDROPEAK		NTNU/Killingtveit


Doctoral theses at NTNU, 2015:6
Teklu T. Hailegeorgis
Identification of spatially distributed Precipitation-Runoff response routines for hourly simulation in gauged and ungauged basins
Doctoral thesis
NTNU
Norwegian University of Science and Technology
Thesis for the degree of Philosophiae Doctor
Faculty of Engineering Science and Technology
Department of Hydraulic and Environmental Engineering
NTNU – Trondheim
Norwegian University of Science and Technology


Doctoral theses at NTNU, 2014:319
Stephan Mark Spiller
Physical effects of load fluctuations in rivers
Doctoral Thesis
NTNU
Norwegian University of Science and Technology
Faculty of Engineering Science and Technology
Department of Hydraulic and Environmental Engineering
NTNU – Trondheim
Norwegian University of Science and Technology


Doctoral theses at NTNU, 2014:367
Netra P. Timalsina
Ice conditions in Norwegian rivers regulated for hydropower
An assessment in the current and future climate
Doctoral Thesis
NTNU
Norwegian University of Science and Technology
Faculty of Engineering Science and Technology
Department of Hydraulic and Environmental Engineering
NTNU – Trondheim
Norwegian University of Science and Technology

WP2: Hydrology



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

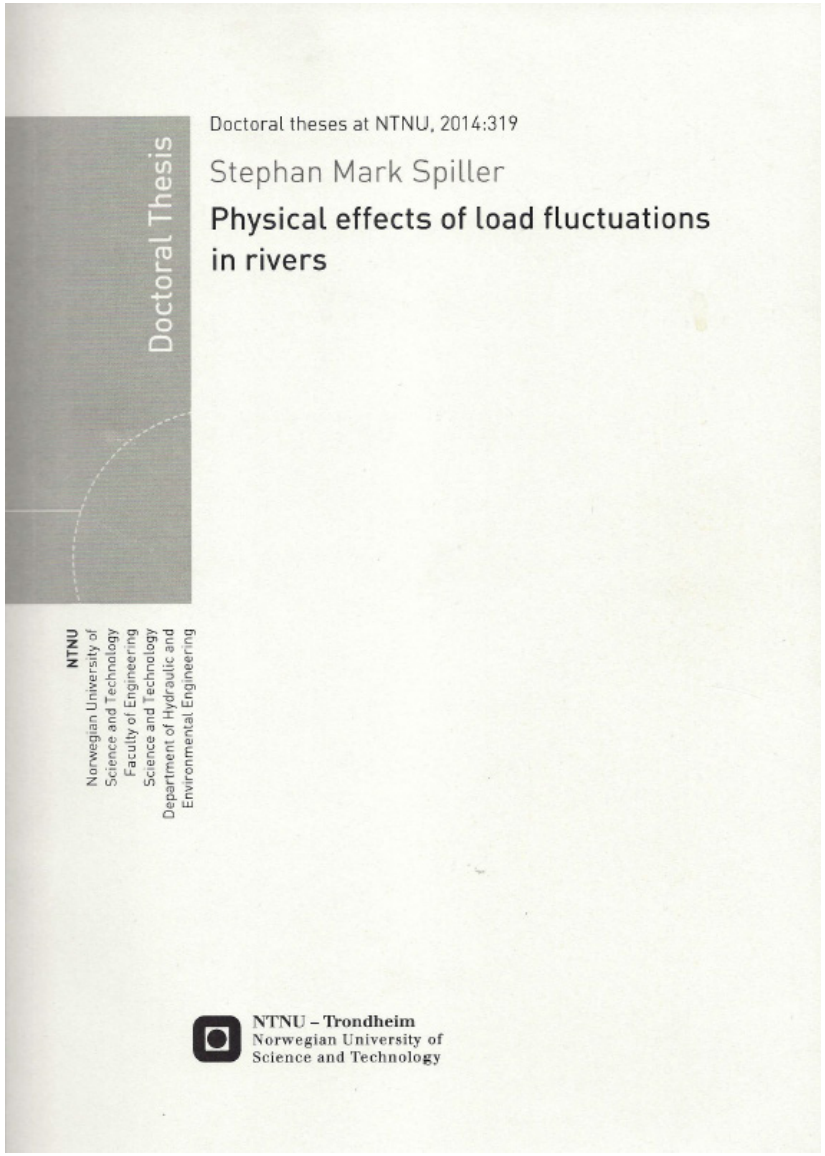
Main Deliverables from project

- PhD Thesis

- 6 Papers in International Journals

- Program modules for use in the ENKI modelling system

WP7: Flow fluctuations in rivers



Supervisor: Nils Ruther

WP7: Flow Fluctuations - Rivers

PhD project: 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?*

Photo: © Ånund Killingtveit, NTNU

Photo: © Stephan Spiller, NTNU

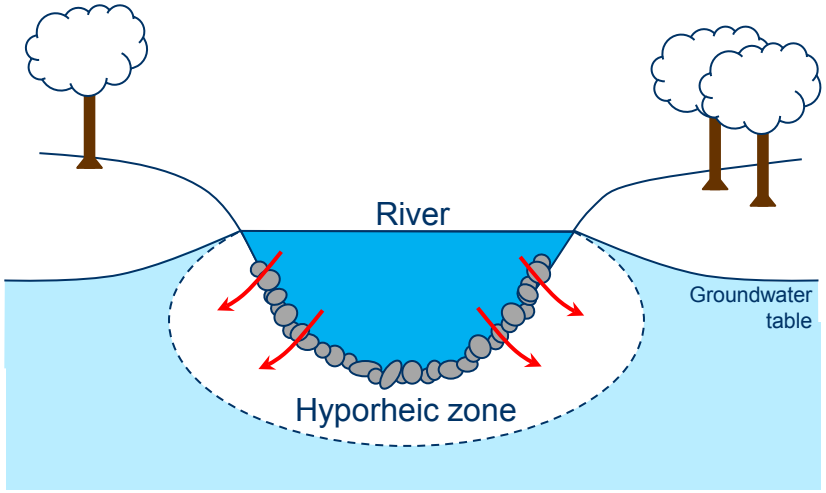
The hyporheic zone during hydropower peaking

(hyporheic zone = mixing zone of surface- and ground water)

Situation 1:

Surface water stage > groundwater stage

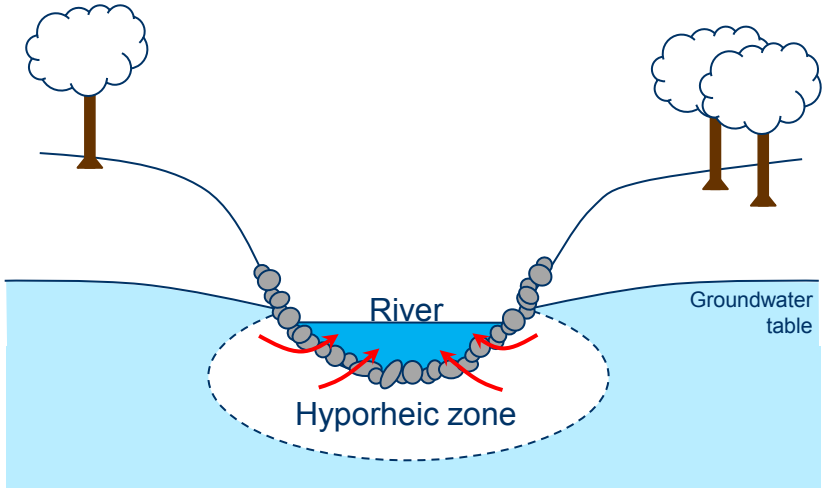
"DOWNWELLING"



Situation 2:

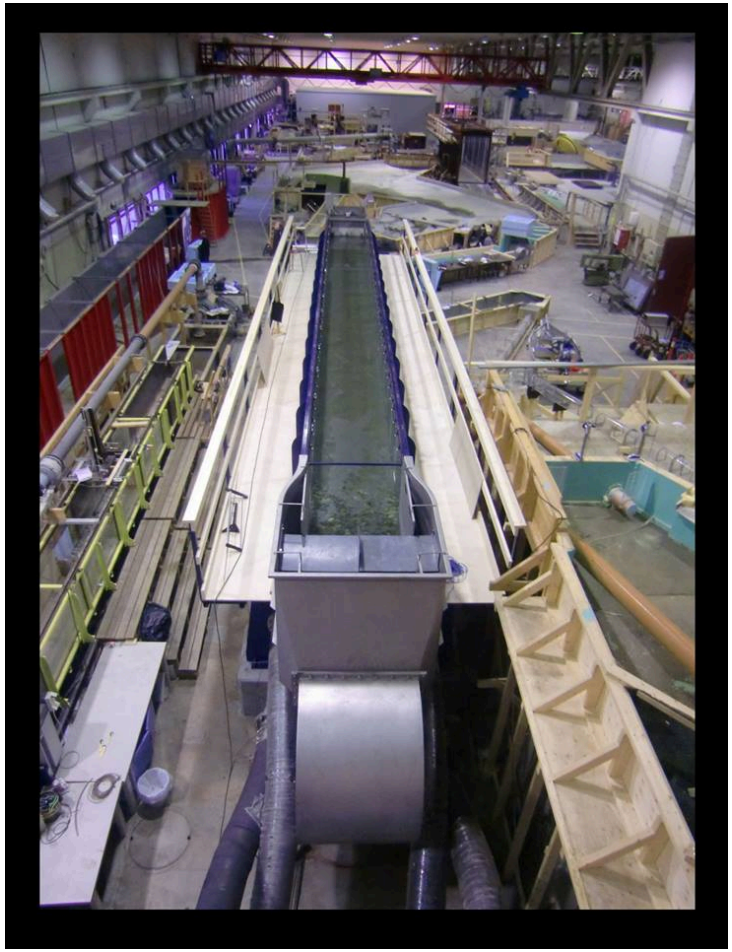
Surface water stage < groundwater stage

"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?

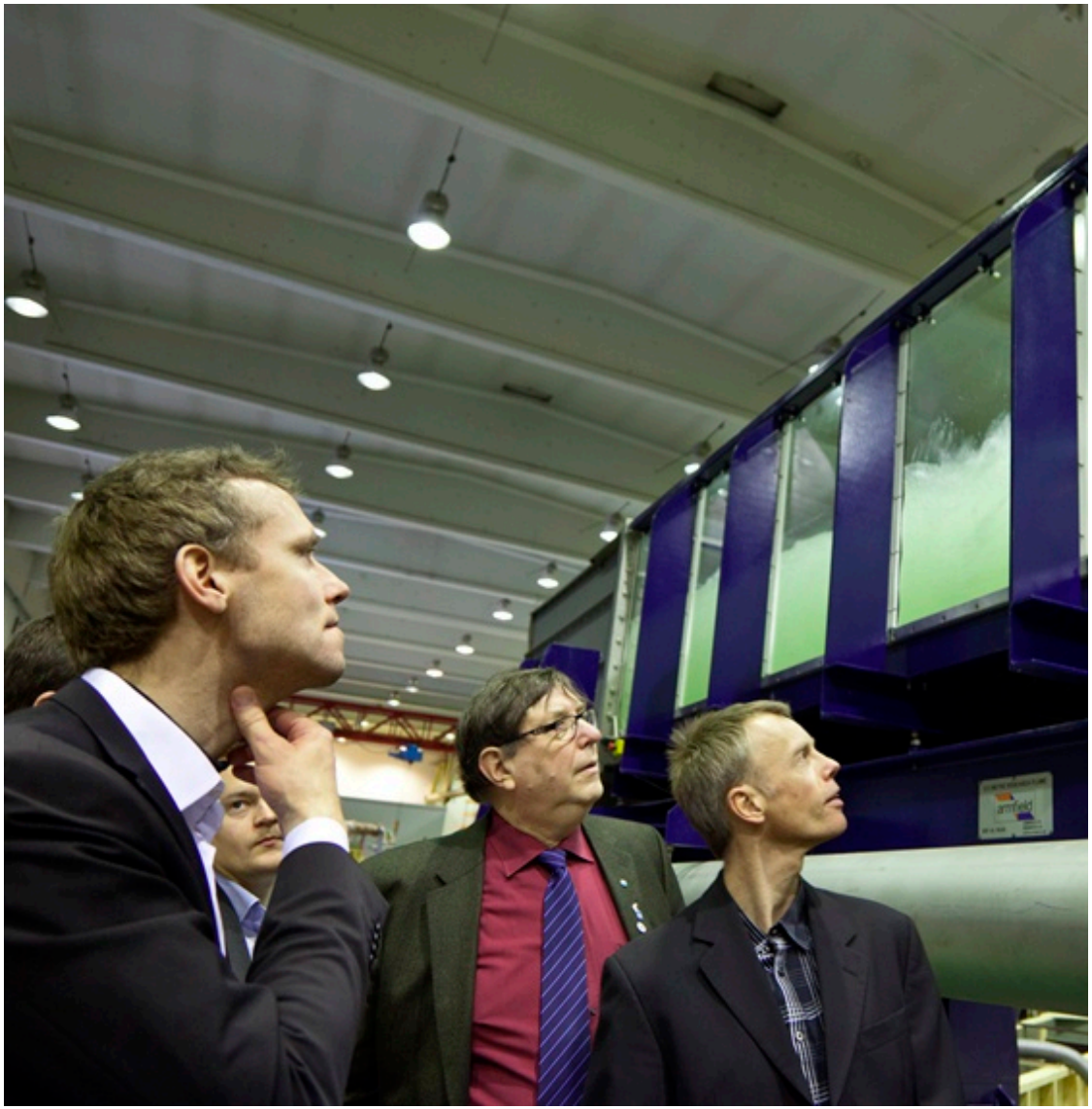
New flume installed at NTNU



- 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

Åpning av ”Ola-renna” 16 Mars 2012

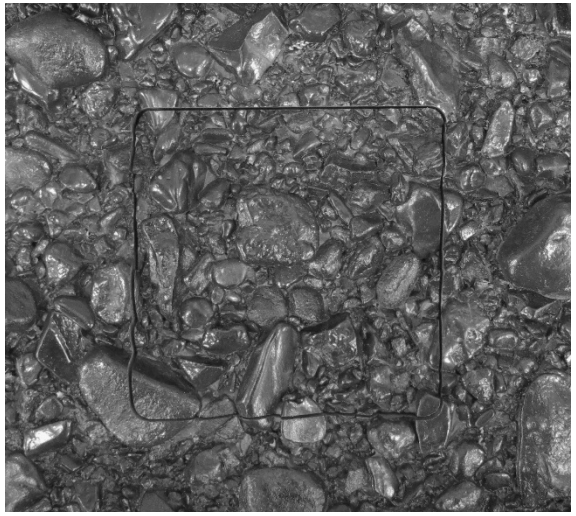


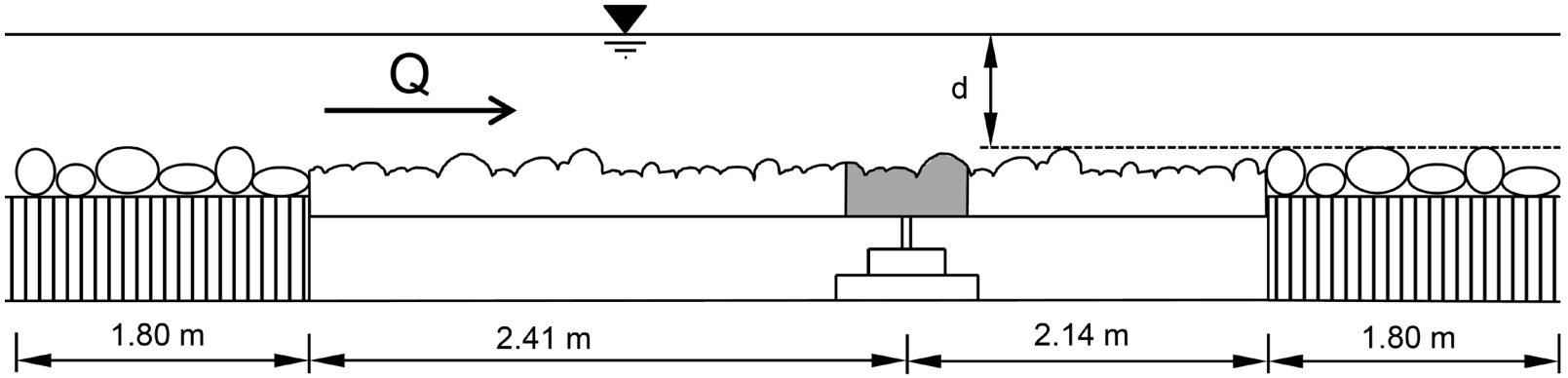
Olje- og energiminister Ola Borten Moe (f.v.) og CEDREN-lederne Ånund Killingtveit og Atle Harby betrakter den kraftige vannstrømmen i den nye vannrenna.

Foto: Thor Nielsen

Experimental setup:

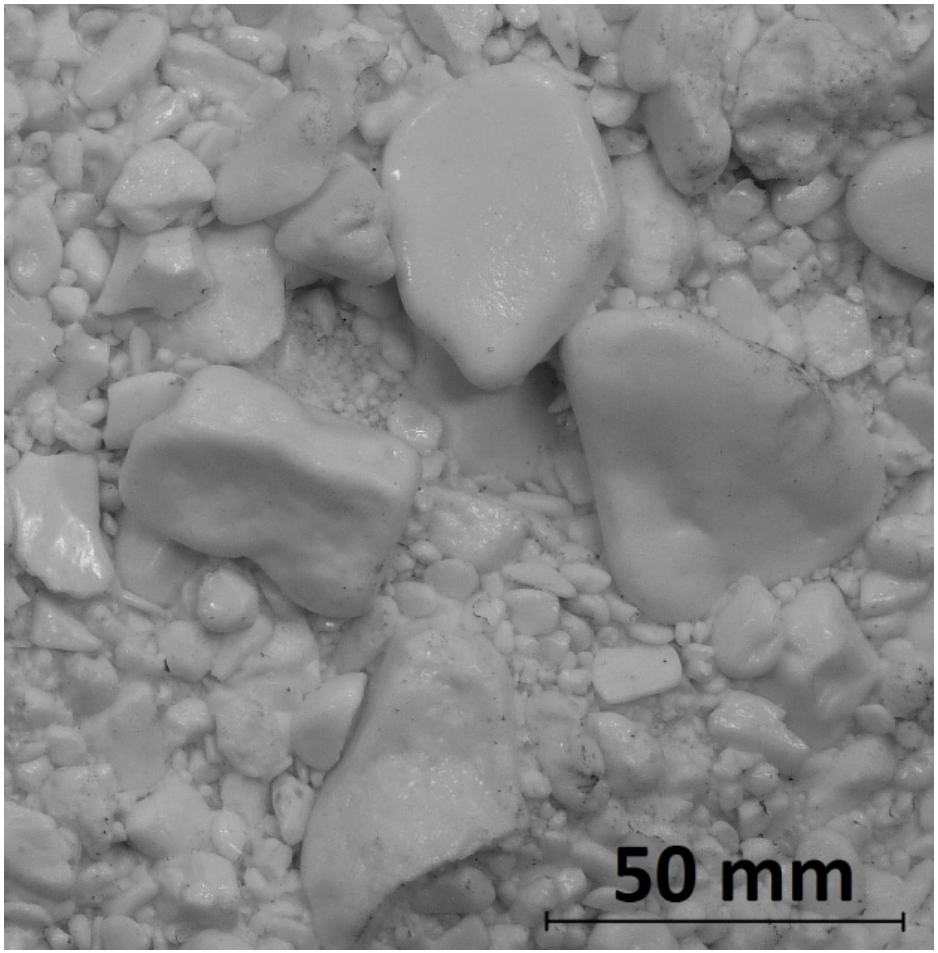
- *Flume: 18.5m long , 0.46m wide , slope 0.5%*
- *Artificial streambed*
- *10cm x 10cm target piece supported by force sensor*





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 Sediement Research.* Accepted for publication

Spiller, Stephan; Ruther, Nils; Friedrich, Heide.
Mitigation measures for unsteady flow effects on riverbeds during hydropower peaking. I: *Proceedings of the River Flow 2014 International Conference on Fluvial Hydraulics*. CRC Press 2014 ISBN 978-1-138-02674-2. s. 1807-1812

Spiller, Stephan; Ruther, Nils; Casas-Mulet, Roser; Friedrich, Heide.
PORE WATER EXCHANGE IN GRAVEL BED RIVERS DURING HYDROPOWER PEAKING EVENTS. 10th International Symposium on Ecohydraulics 2014; 2014-06-23 - 2014-06-27

Friedrich, Heide; Spiller, Stephan; Ruther, Nils.
Near-bed flow over a fixed gravel bed. I: *Proceedings of the River Flow 2014 International Conference on Fluvial Hydraulics*. CRC Press 2014 ISBN 978-1-138-02674-2. s. 279-285

Török, G.T.; Baranya, S; Ruther, Nils; Spiller, Stephan.
Laboratory analysis of armor layer development in a local scour around a groin. I: *Proceedings of the River Flow 2014 International Conference on Fluvial Hydraulics*. CRC Press 2014 ISBN 978-1-138-02674-2. s. 1455-1462

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.
PIV Measurements of Steady Flow over an Artificial Static Armor Layer. I: *Proceedings of the 35th IAHR World Congress*. China: Tsinghua University Press 2013 ISBN 978-7-89414-588-8.

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.
Artificial Reproduction of the Surface Structure in a Gravel Bed. München: IAHR 2012 (ISBN 978-3-943683-03-5) 6 s

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

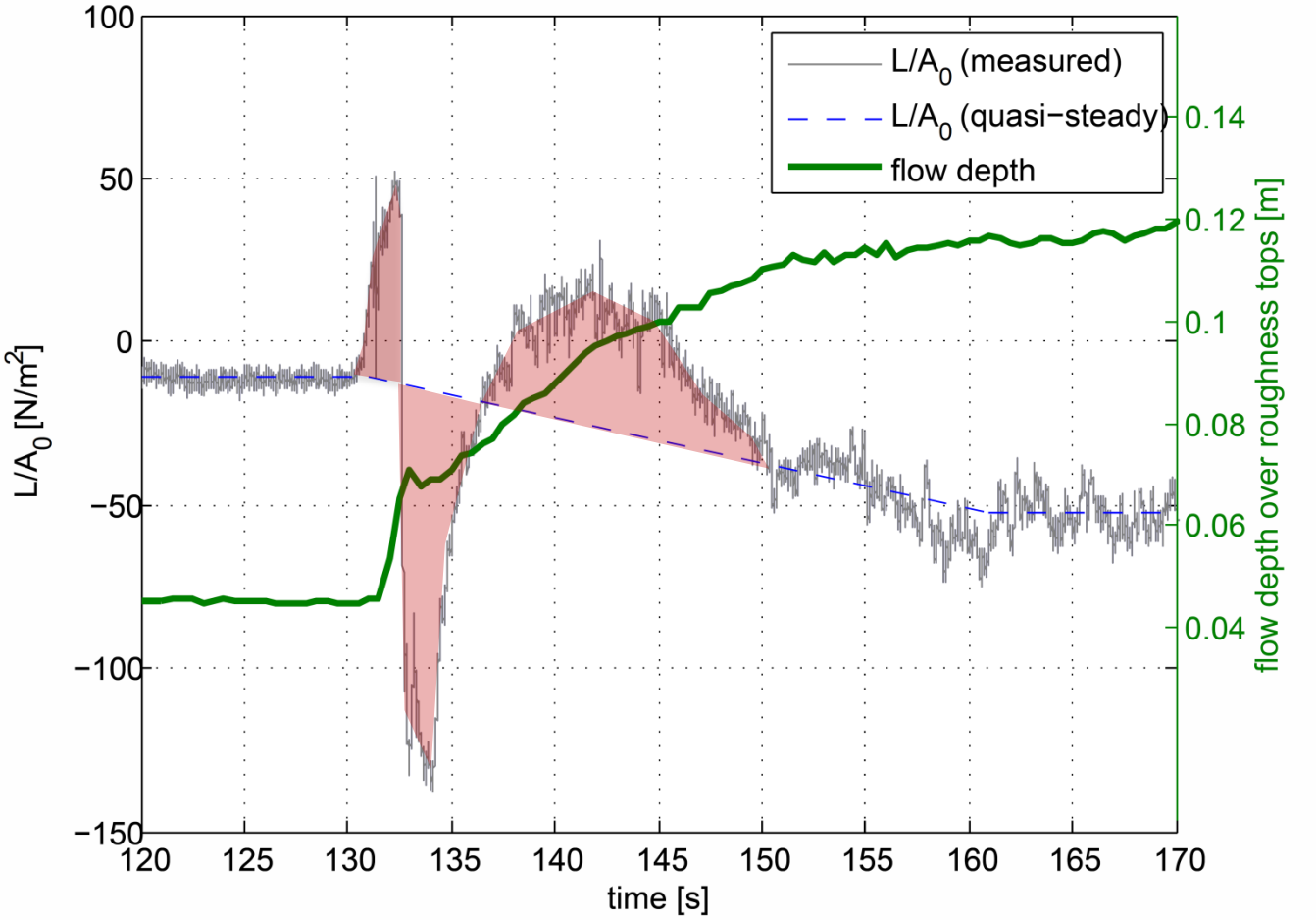
Spiller, Stephan; Ruther, Nils; Koll, Klaus; Koll, Katinka.
Bed load movement over a fully developed armor layer – A tracer experiment. I: *River Flow 2012*. Taylor & Francis 2012 ISBN 978-0-415-62129-8. s. 465-471

2011

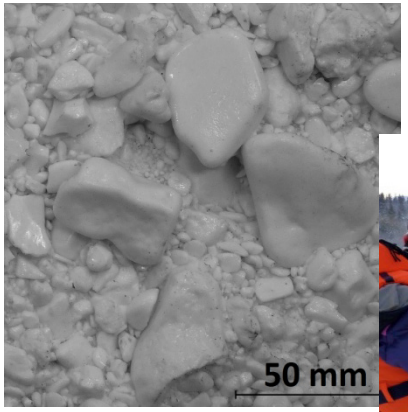
Spiller, Stephan; Ruther, Nils; Belete, Kiflom Wasihun; Strellis, Brendon.
Assessing environmental effects of hydropower peaking by 3D numerical modeling. *Flow simulation in hydraulic engineering : Dresdner wasserbauliche Mitteilungen* 2011 ;Volum 1.(1) s. 79-86

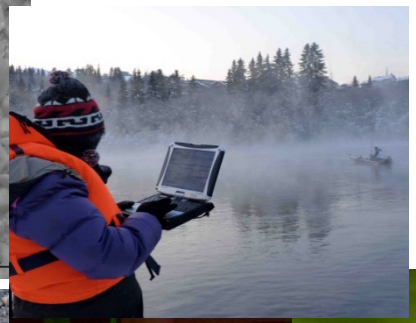
Results – Lift Force

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

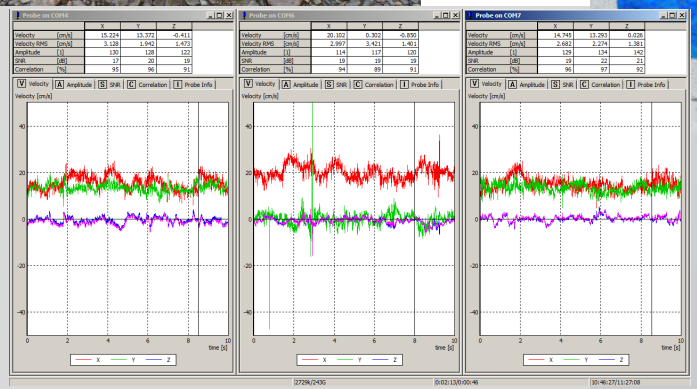


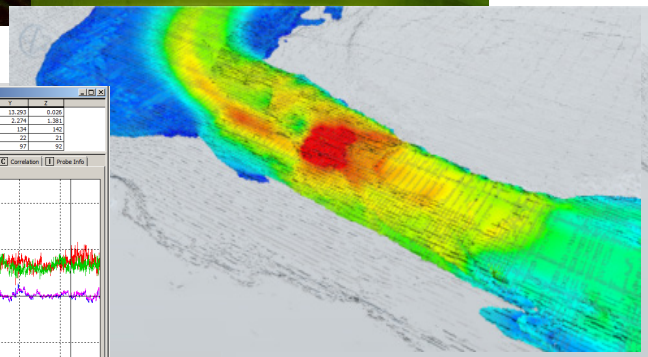
Methods and measurement devices

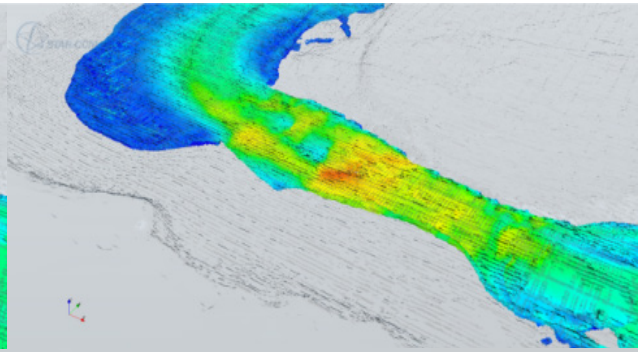




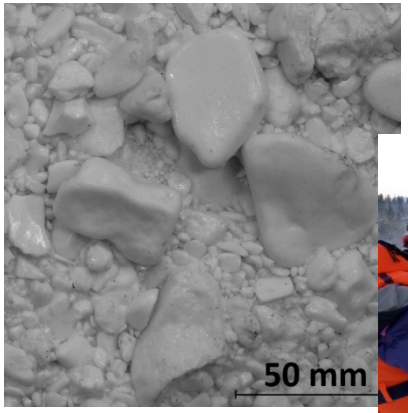
- Artificial gravel bed
- Direct force measurement
- Freeze cores
- Suspended sediment
- Particle Image Velocimetry (PIV)
- Acoustic Doppler Velocimetry (ADV)
- Numerical methods

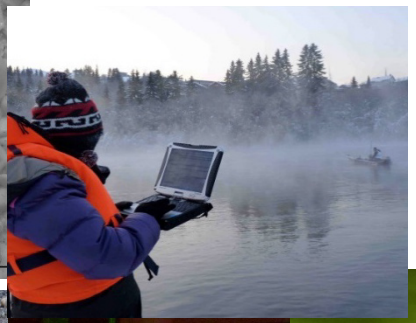


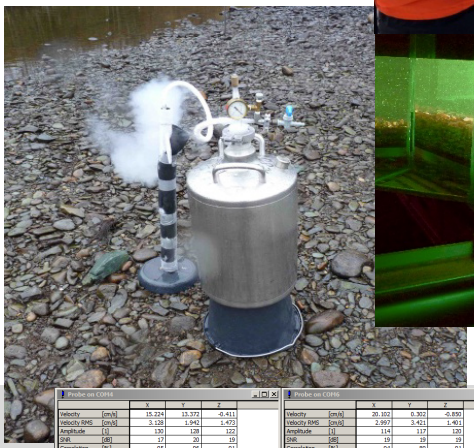


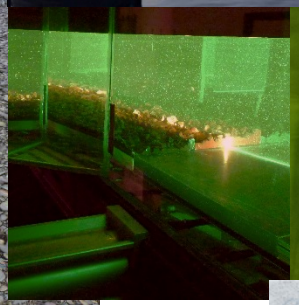


Basis for further research

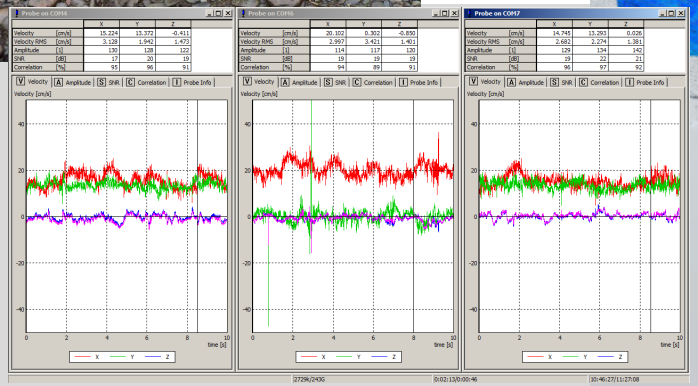


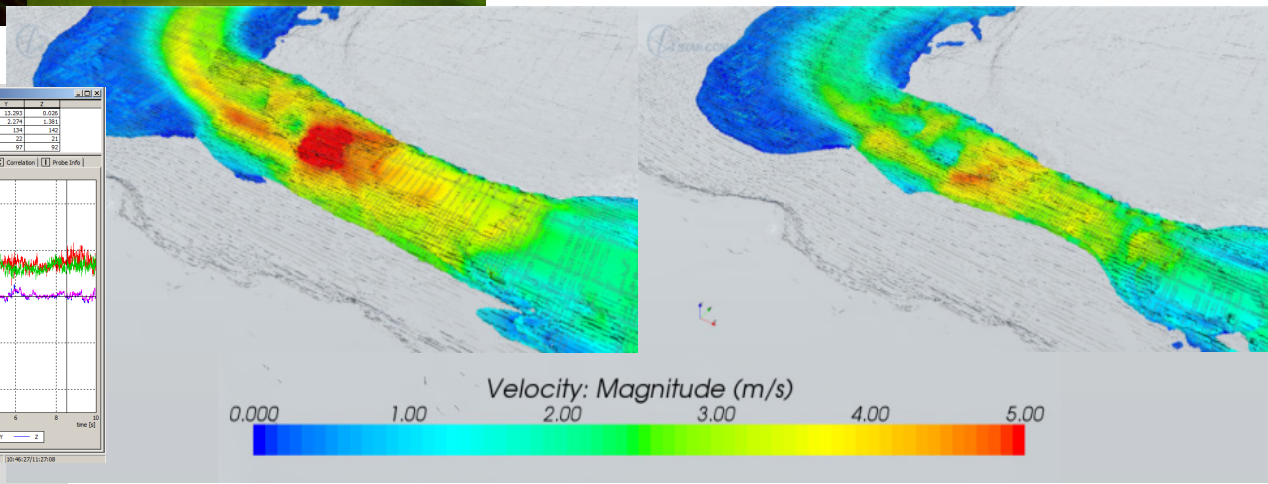




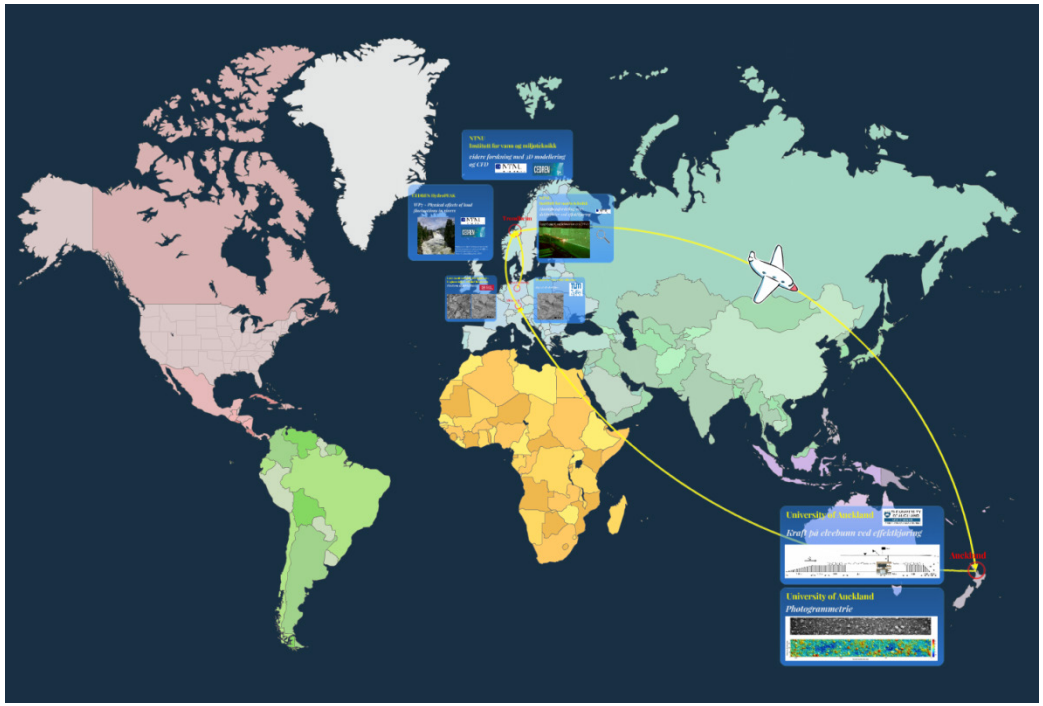


- New PhD student at NTNU
- Master students
- Projects at other institutes in Norway, Germany, New Zealand





networking



THE UNIVERSITY OF AUCKLAND
NEW ZEALAND
Te Whare Wānanga o Tāmaki Makaurau

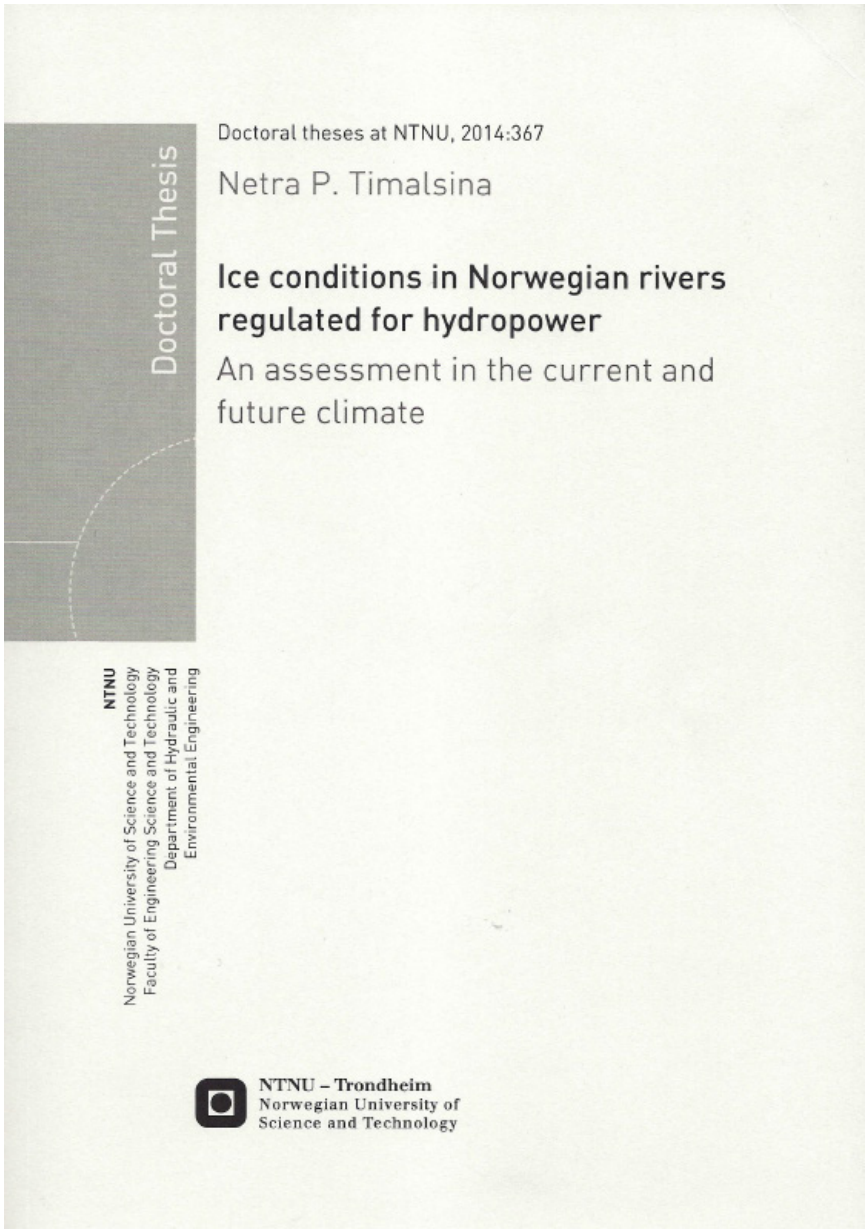
Technische Universität Braunschweig

TECHNISCHE UNIVERSITÄT MÜNCHEN

UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

MŰEGYETEM 1782

- 9 conferences
- 3 workshops
- 2 research exchanges



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

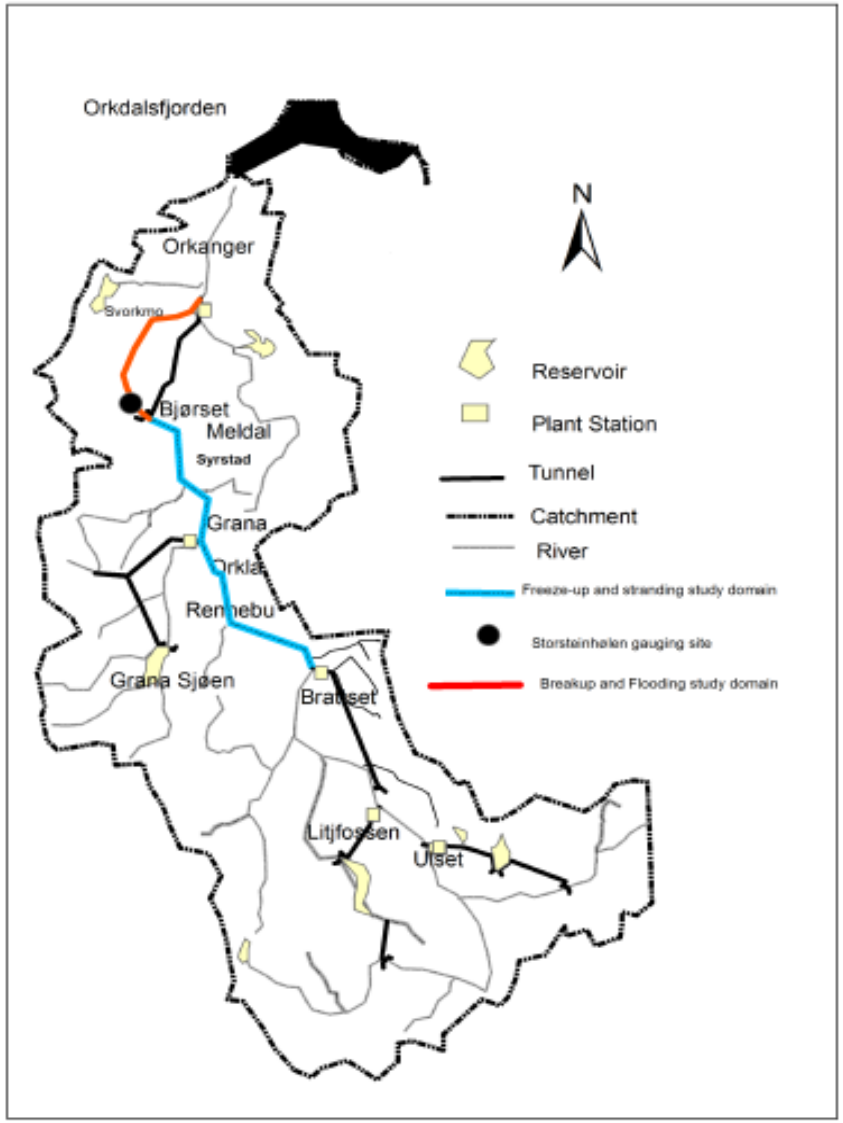
Data collection methods
- River ice extent
- Climate
- Water temperature

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

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

Gebre, Timalsina & Alfredsen (2014) Energies

Gebre, Timalsina & Alfredsen (2014) Energies