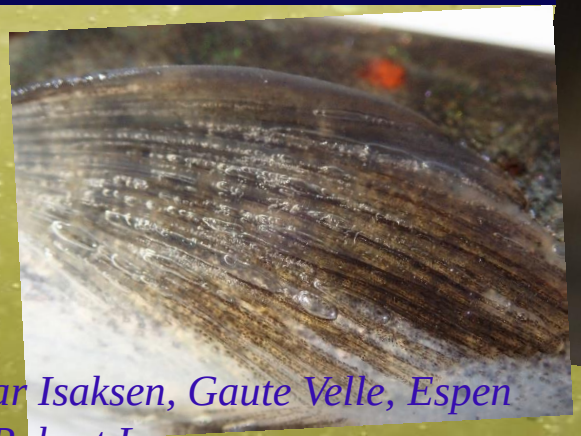
Laboratory for Freshwater ecology and Inland fisheries (LFI)

Gas super saturation caused by hydropower, mitigation measures



Sebastian Stranzl, Ulrich Pulg, Trond Einar Isaksen, Gaute Velle, Espen Olsen, Bjørn T. Barlaup, Knut W. Vollset, Robert Lennox

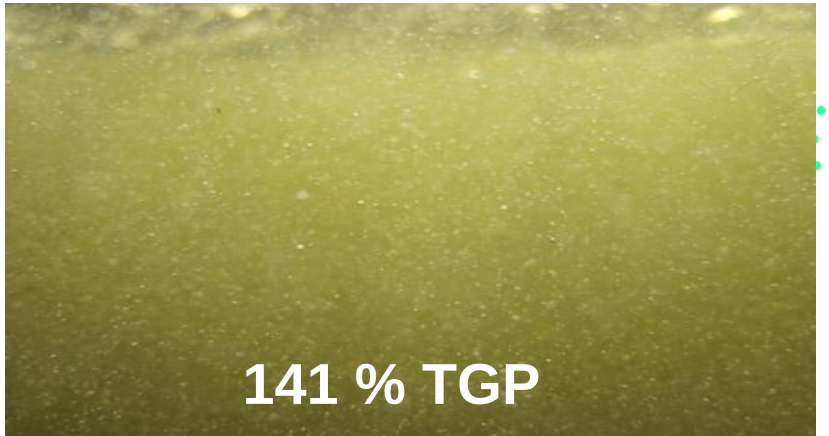
Background – what is supersaturation ?

Gas + liquid + pressure and reduction of pressure

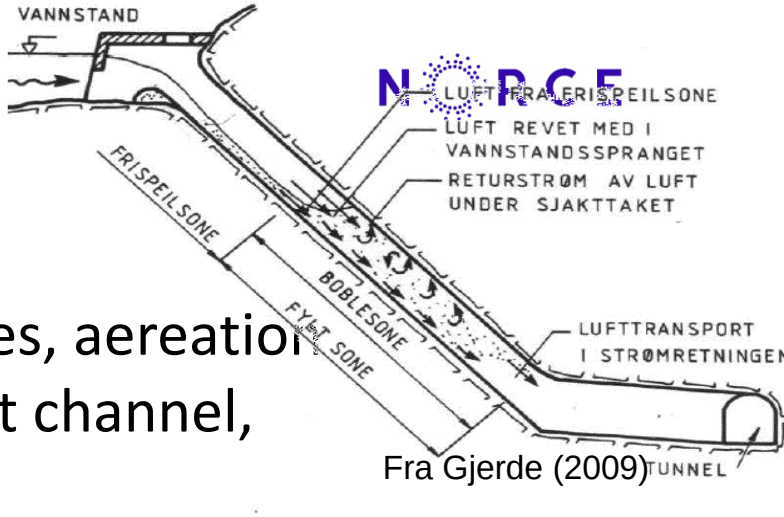
Natural rivers 100-110 % saturation (Total Gas Pressure TGP)

e.g. sparkling water (120%-130% TGP)

Temperature changes: heating of cold water



Cause



Fra Gjerde (2009)

- Hydropower induced:

Creek intakes, tight intake screens, valves, aeration of turbines, air entrainment at the outlet channel, spillways, dams

- Natural causes:

Temperature mixing, photosynthesis, waterfalls + great depth, ground water,

flood events

Supersaturation and hydropower

- Eruptions
- Cavitation
- Air pockets
- Lower efficiency

Figur 2: Utblåsing på Holmalid[illegible]

fra Gjerde (2009)

SUPERSAT study findings:

- Common in nature and most monitored Norwegian rivers
- **Typical causes**: Power outlets, Francis turbines, Floods, Creek intakes
- **Gass bubble disease in Baetis**
- Experiments: **threshold values for atlantic salmon**
- **Modelling of degassing** of supersaturated water in a river
- Possible **mitigation measures**
- **Risk evaluation**

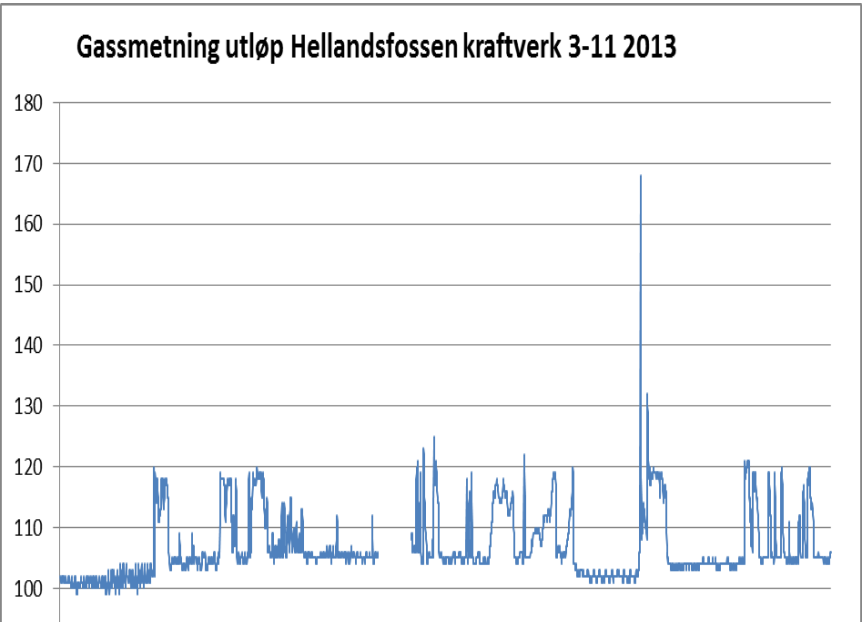
Experiences in Norway – Matre river(2010-2012)

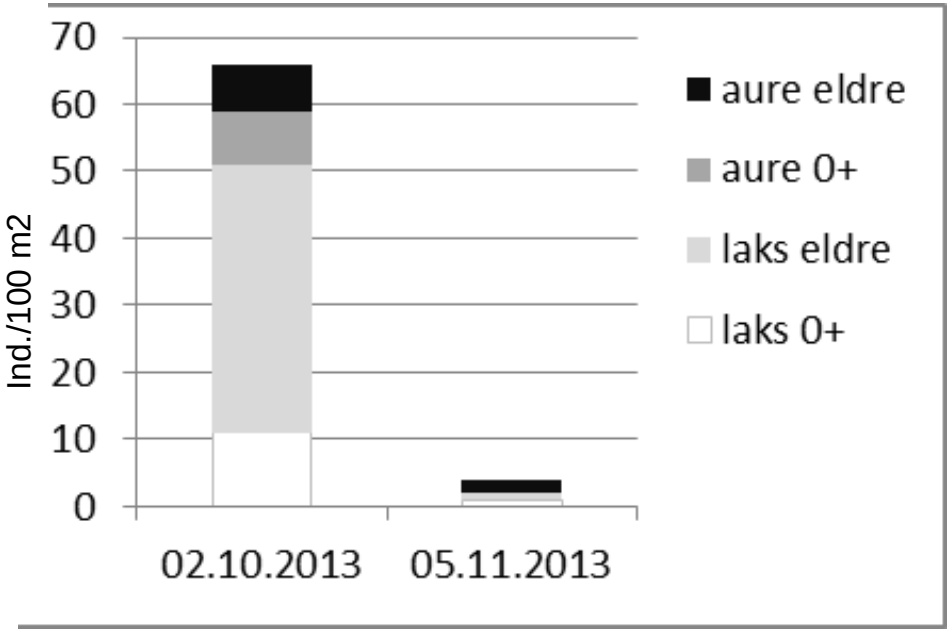
- Acute fisk kills observed in 2010
- Up to 130 % saturation (TGP)
- Cause: Air vortex at intake grid when it was partly clogged
- Solution: New grid cleaner
- In cooperation with BKK AS

Foto: Sissel Mykletun, BKK

Experiences in Norway – Modalen river(2012-2016)

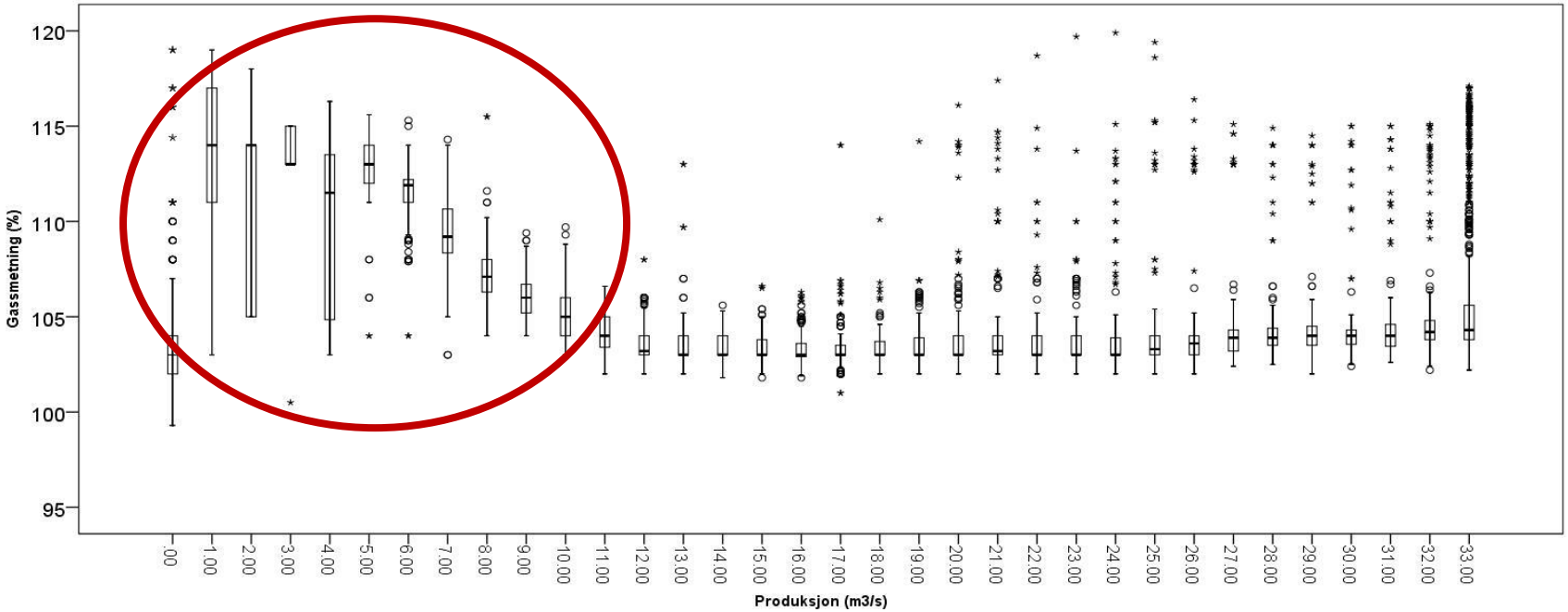
Juvenile salmon and brown trout sampled by electrofishing before and after the 168 % TGP peak





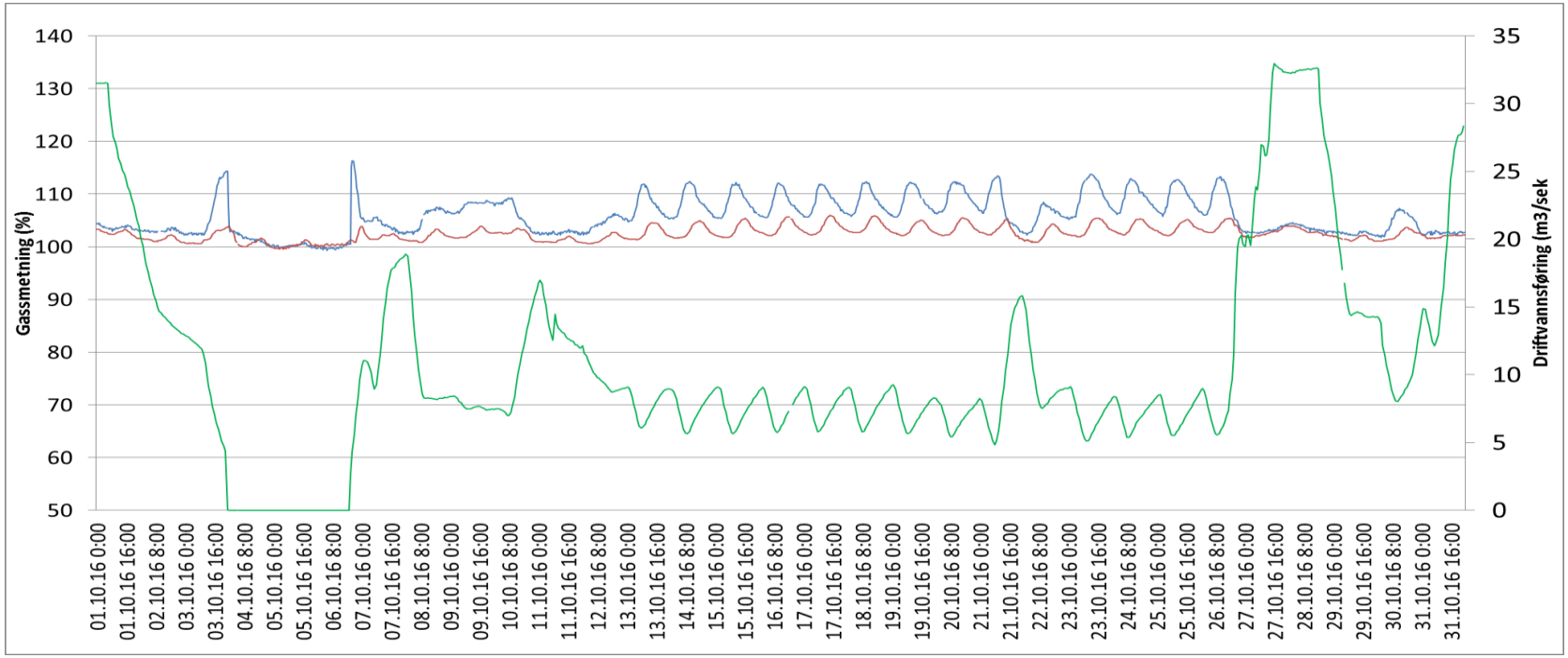
Experiences in Norway – Modalen river(2012-2016)

Testperiod with reduced discharge at creek intakes



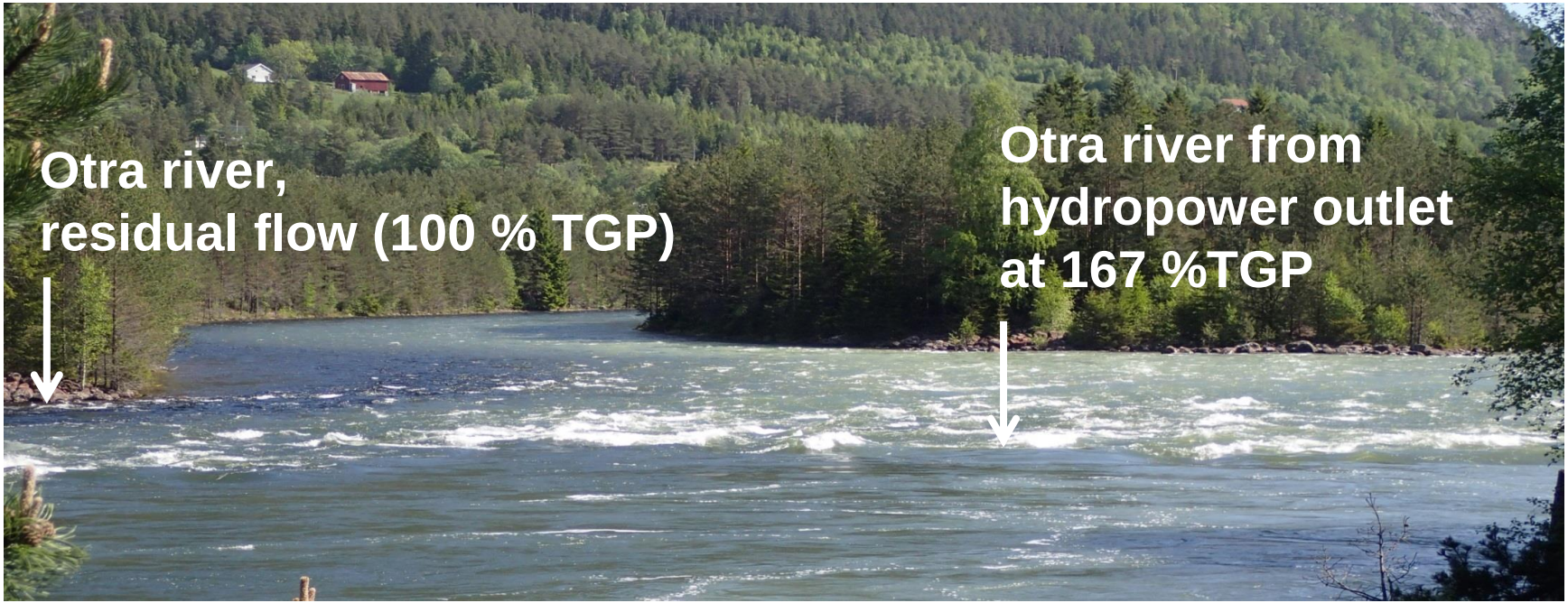
Experiences in Norway – Modalen river(2012-2016)

Testperiod with reduced discharge at creek intakes



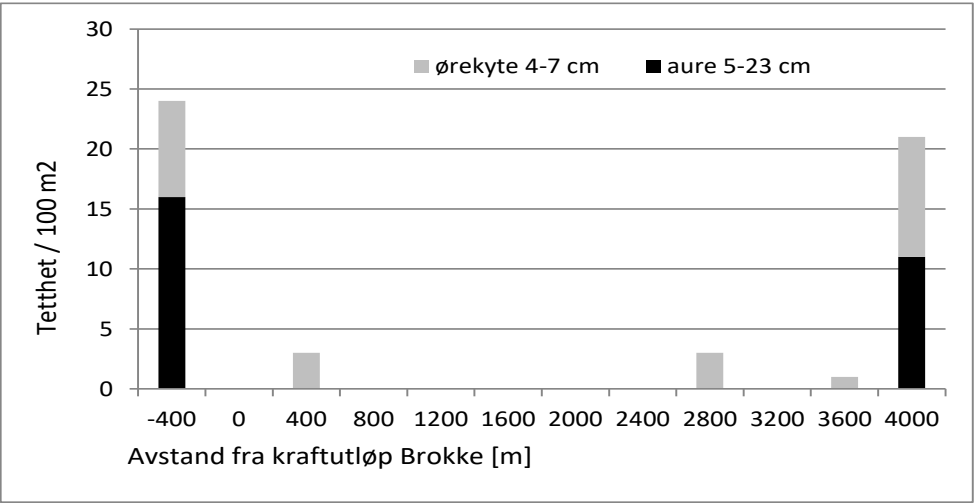
Experiences in Norway – Otra river(2011-2017)

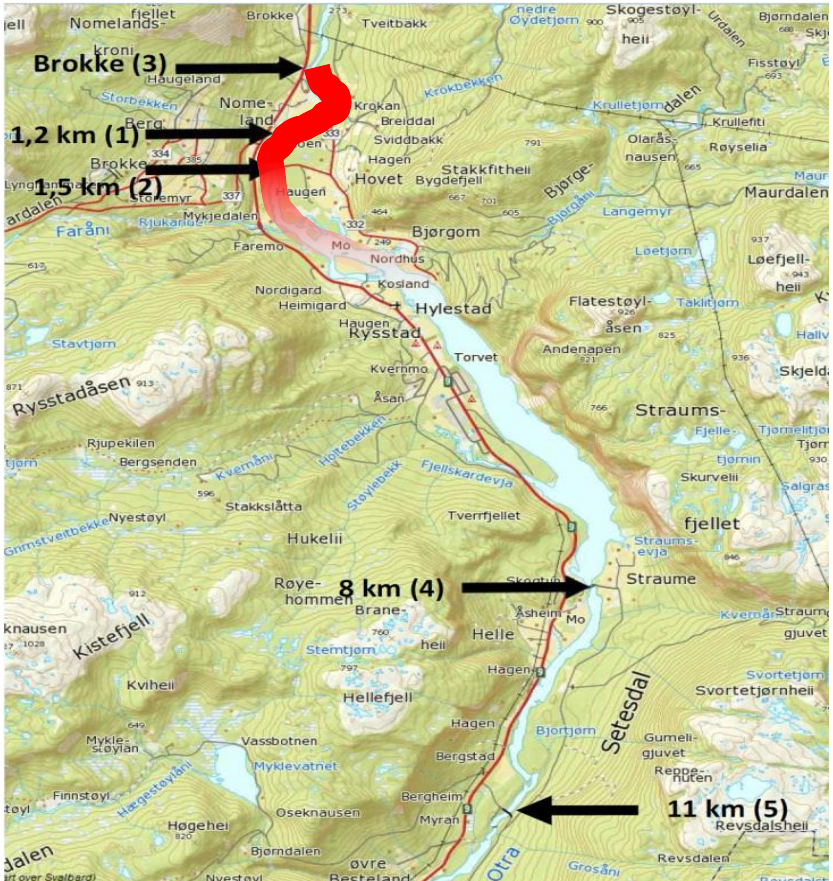
- Peaks up to 167 % TGP
- Creek intakes
- Transport over 30 km



Experiences in Norway – Otra river(2011-2014)

4 km nearly without fish
(Autumn 2011 og 2012, brown trout and common minnow)





Experiences in Norway – Otra river(2011-2016)

Linking degassing to hydraulics

Degassing in the Otra River

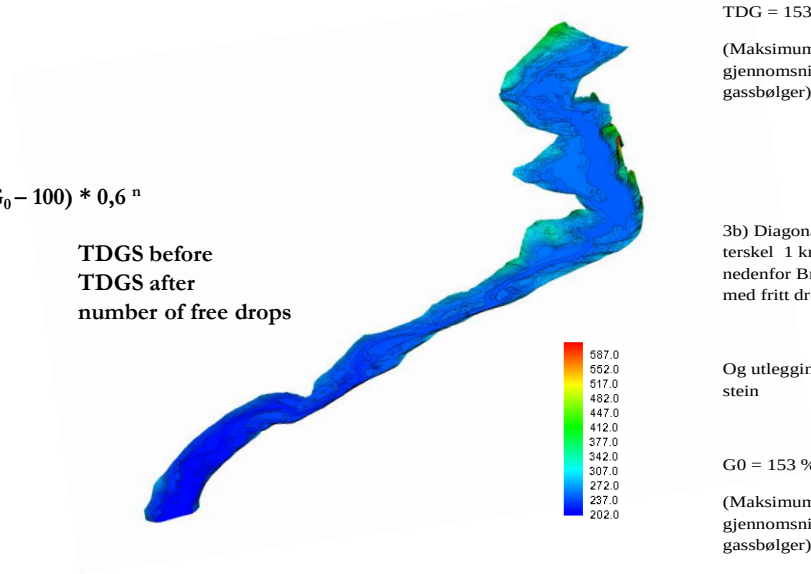
$$G_{km} = 100 + (G_0 - 100)e^{-(0.0271997 + 0.0077792 \times \text{Shearstress}) \times \text{delta L}}$$

G_{km}:	TDGS in river
G_0:	TDGS at source
e :	Eulers number
delta L:	distance

Degassing at water drops

$$G_e = 100 + (G_0 - 100) * 0{,}6^{\,n}$$

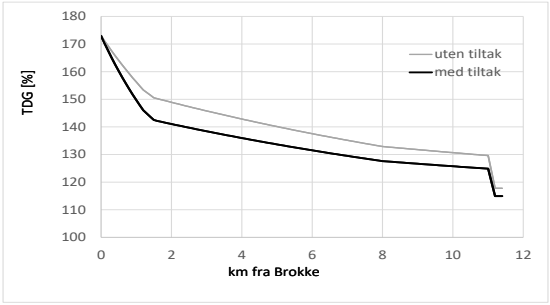
G_0 :	TDGS before
G_e :	TDGS after
n:	number of free drops



2b)Utlegging av stein på 1, 6 km ndf. Brokke med 100 % økning av skjærspenning

TDG = 173 %

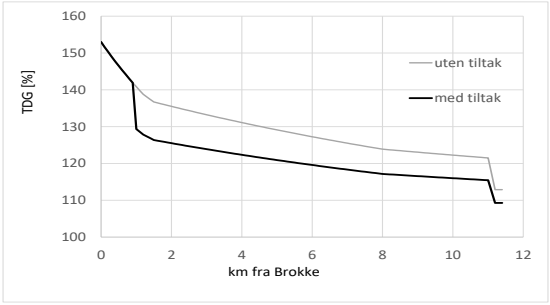
(Maksimum totalt)



3a) Diagonal terskel 1 km nedenfor Brokke med fritt dropp

TDG = 153 %

(Maksimum av gjennomsnitt gassbølger)

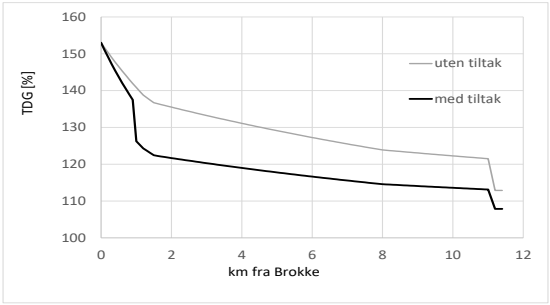


3b) Diagonal terskel 1 km nedenfor Brokke med fritt dropp

Og utlegging av stein

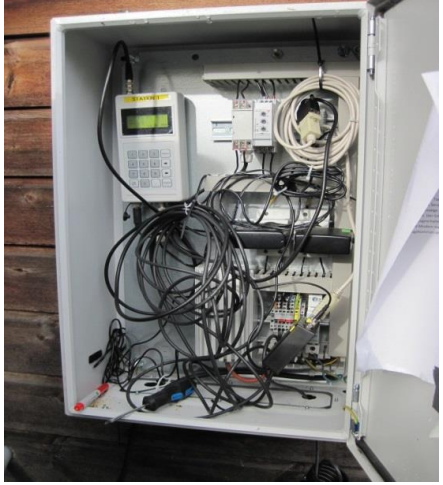
G0 = 153 %

(Maksimum av gjennomsnitt gassbølger)



Monitoring – risk model

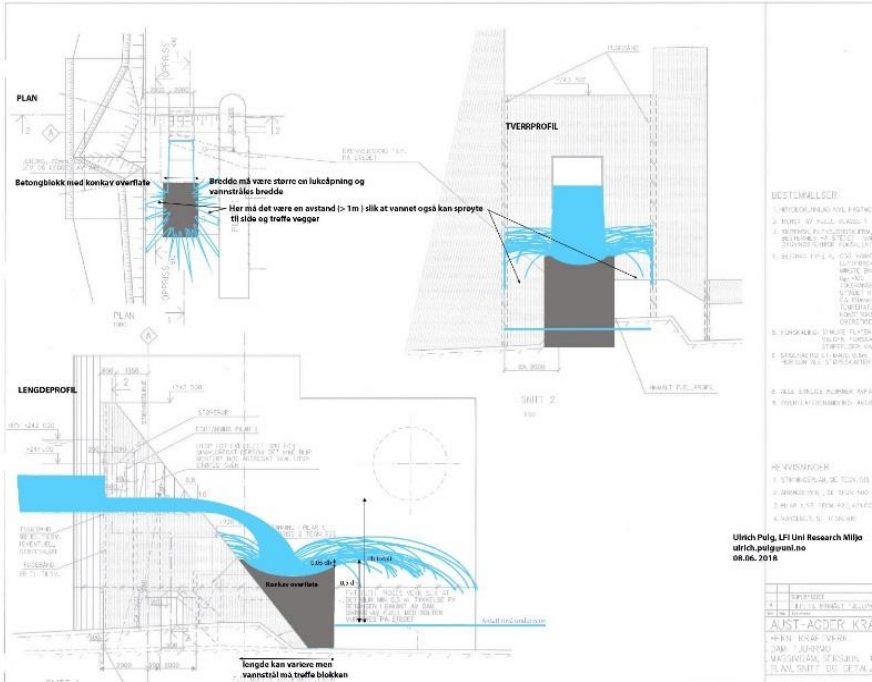
- Hydroplants with secondary **creek intakes** + Francis/Kaplan
- Hydroplants with **aeration of Francis/Kaplan**
- **Spillways at deep rivers (> 1000 m^3/s, 5 m)**
- Potential for **intake screen clogging**
- **Air entrainment** at tertiary sources such as valves
- Air **entrainment in the outlet channel, including Pelton**



Avoidance and mitigation measures

- **Avoid air entrainment by design**
- Screen cleaner combined with logger and alarm
- Regulation of creek intakes
- Vacuum intake
- Pelton turbines

- Aerate rivers**, roughness, weirs, deflectors**
- **Dilution** and power management
- Aeration of turbines ?
- Super sonic aereation ?



Deflector

NORCE LFI + Otra Kraft

Max from 131 % to 107 %

Ongoing papers + projects

Laboratory for Freshwater ecology and Inland fisheries (LFI)

- DEGAS: Aeration/degassing in lab + rivers
  air / super sonic aeration
- SUPERSAT: Effects on biota, risk model and tresholds
- Meta-analysis/review of extent, causes and effects
- 10 Norwegian cases
- Effects on Atlantic salmon
- Effects on invertrebrates.

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