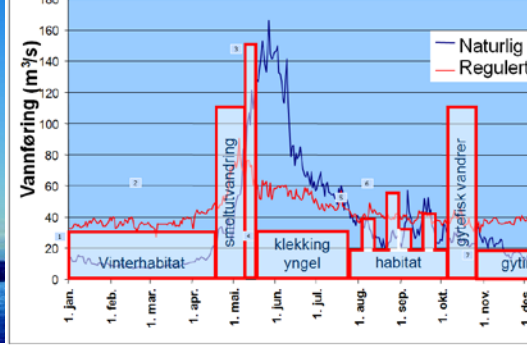






Environmental design of hydropower to meet requirements in the EU Water Framework Directive

SINTEF

NTNU
100 skapende år

NINA

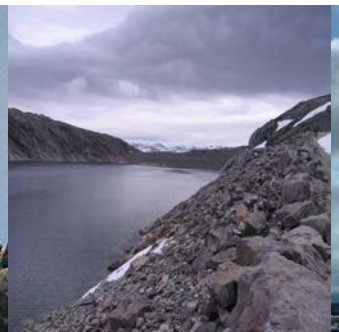
NATURHISTORISK MUSEUM
UNIVERSITETET I OSLO

NIVA

uni Research

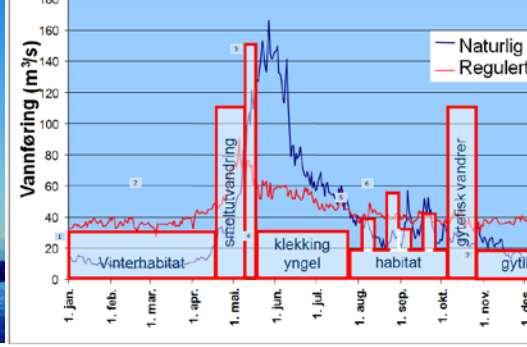
Atle Harby, SINTEF Energy Research and CEDREN







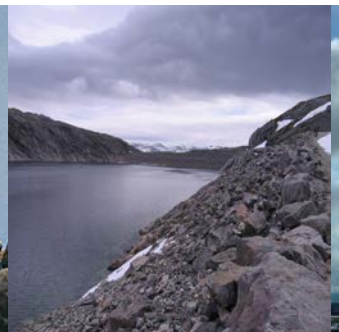




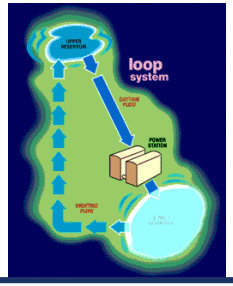
- 10 large research projects
- 7 Norwegian research partners
- 16 Industry partners and 2 management partners
- Budget: ~35 MEuro (4 MEuro in 2016)
- 24 PhD and 7 Post-doc positions
- International student and professional exchange
- 2009-2016, three projects still running until 2018

Renewable energy respecting nature

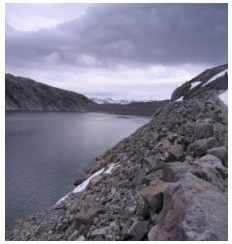


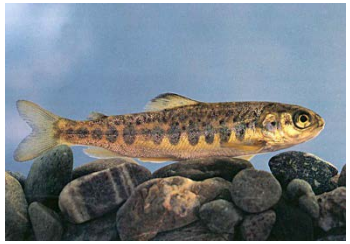


Hydropower technology



Environmental impacts of hydropower



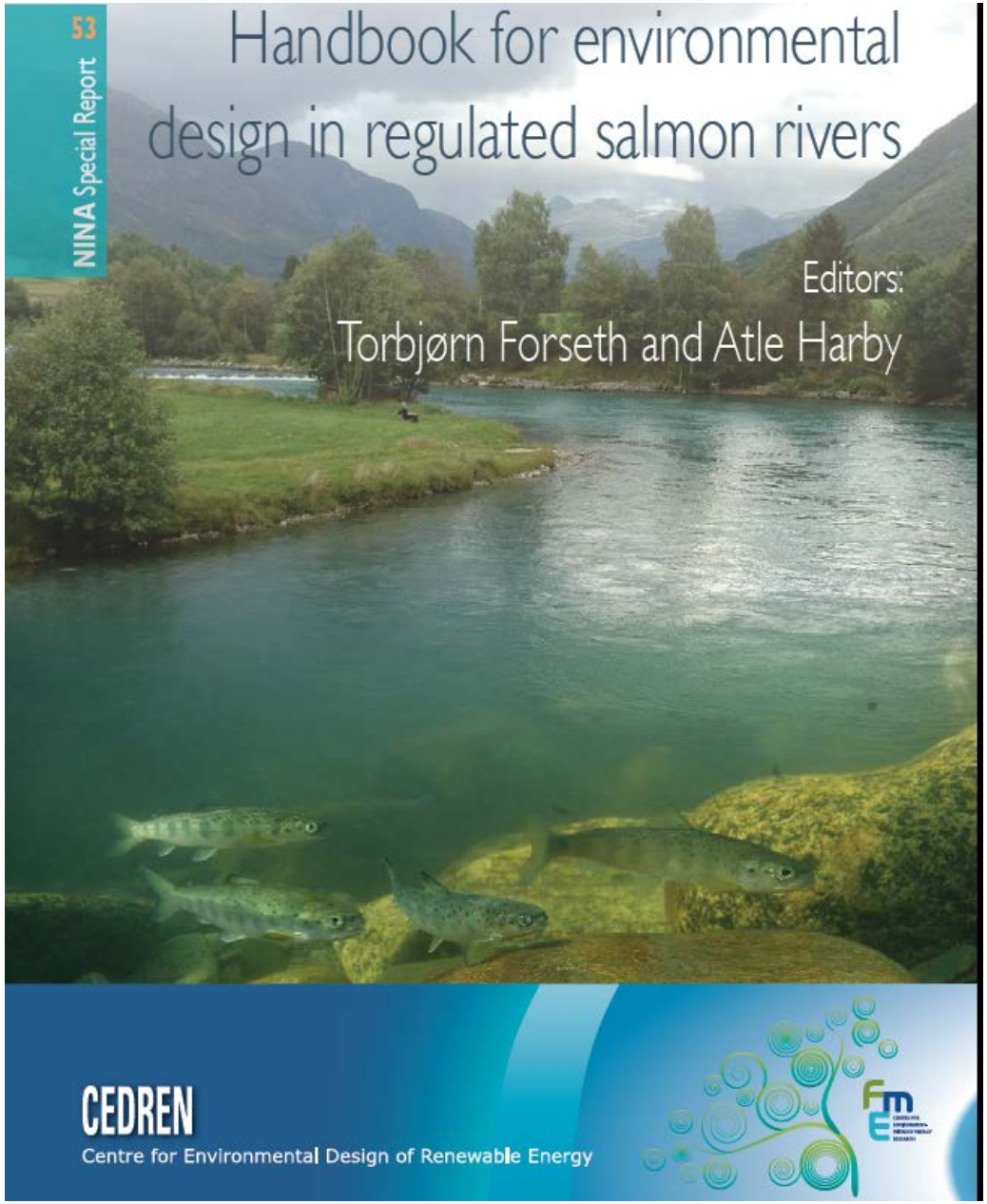


Environmental impacts of wind power and power transmisson

How to reconcile energy and environment policy?

How much water is needed?

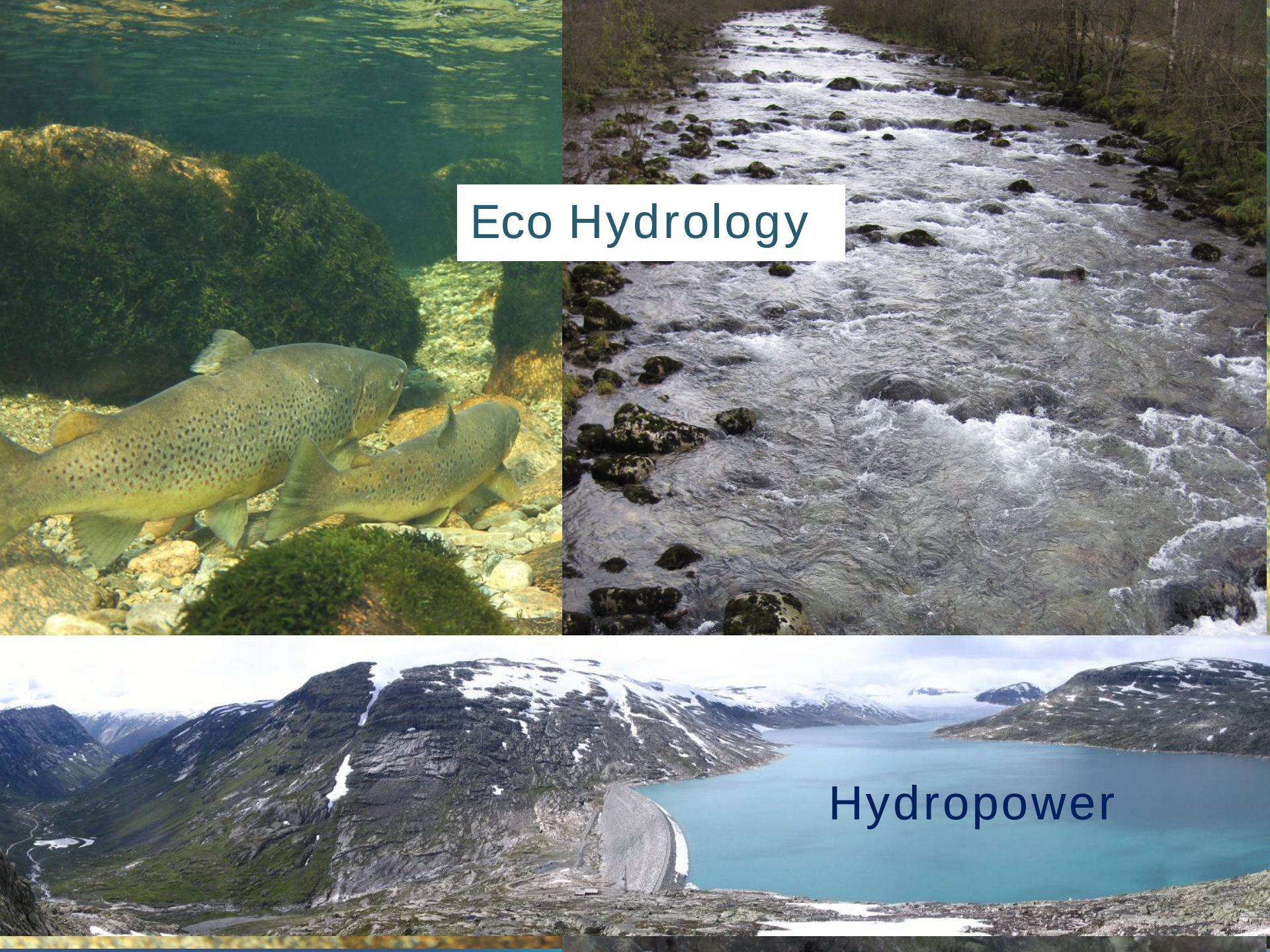
for hydropower
and ecology



- Guidance developed for Atlantic salmon
- Methods suitable for other species and end users

- Download free copy:

www.cedren.no


Eco Hydrology
Hydropower

Part I - Diagnosis

Tools (D1-D7)

DATA COLLECTION AND TOOLS

Data collection and tools

CLASSIFICATION SYSTEMS

- The salmon population
- The hydropwer system

DIAGNOSIS

Diagnosis

Del 2 – Design solutions

Measures (methods) (T1-T5)

DESIGN SOLUTIONS AND MEASURES

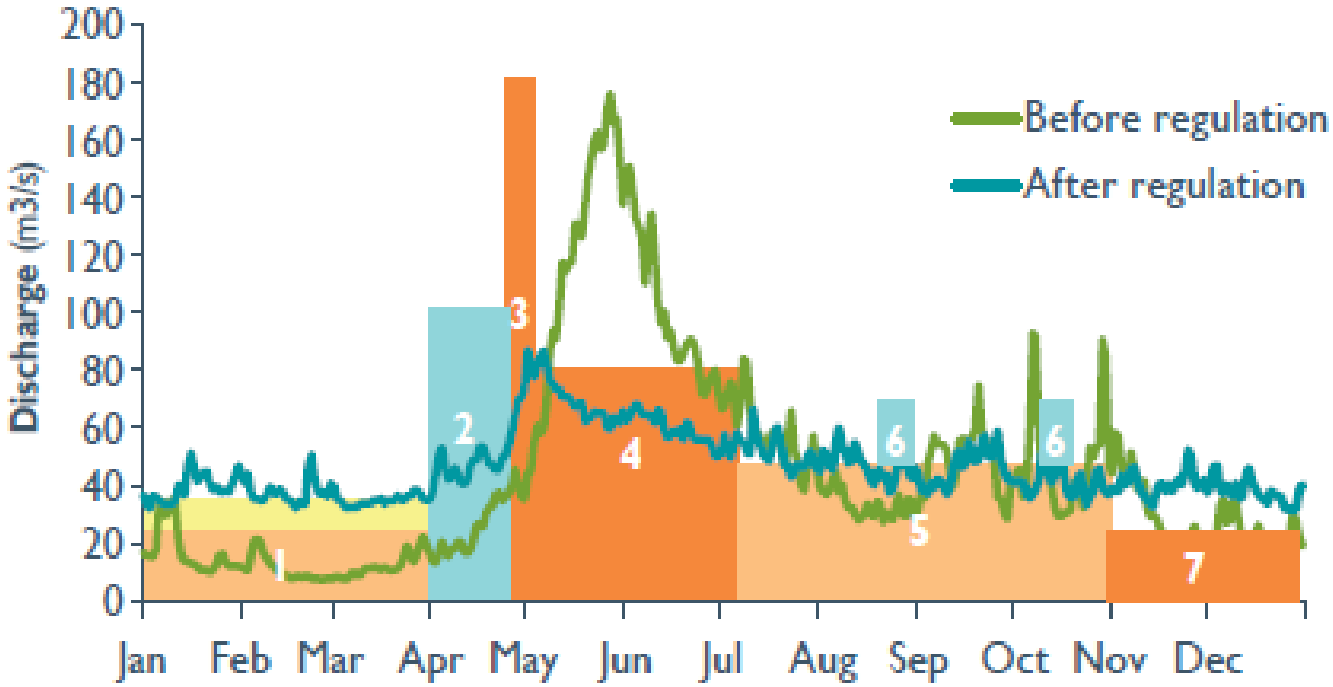
Design solutions

ASSISTING TOOLS

Tools

...take the river system to the doctor!

Water use – building blocks



Habitat measures

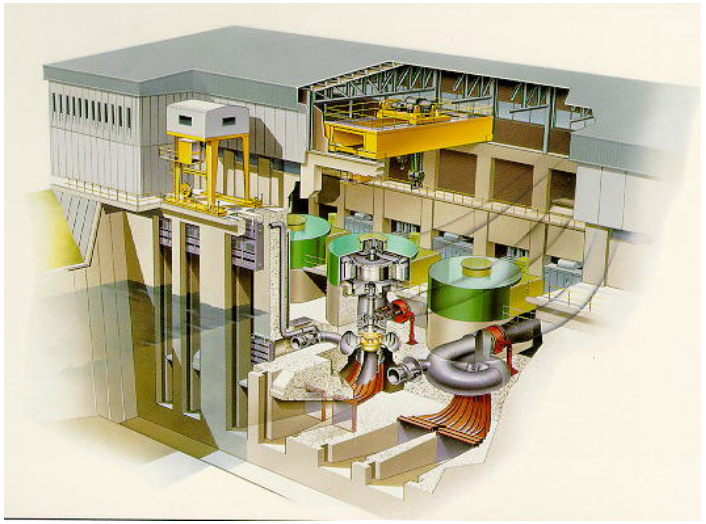
Reach	Length (m)	Segment	Length (m)	Population regulation stage	Habitat bottleneck	Productivity (1-3)
1	4000	1	800	Fry	Spawn	1
		2	1000	Fry	Spawn	1
		3	600	Fry	Spawn	1
		4	900	Fry	Spawn	2
		5	700	Fry/Parr	Both	1
2	3500	6	500	Fry/Parr	Both	1
		7	600	Parr	Shelter	2
		8	800	Parr	Shelter	2
		9	500	Parr	Shelter	2
		10	600	None	None	3
		11	500	None	None	3
3	2300	12	1000	Fry	Spawn	2
		13	800	Fry	Spawn	1
		14	500	Fry	Spawn	2
etc.		etc.				

The right measures in the right place!

Environmental design of regulated rivers

Adapting downstream flow

Constructing habitats



Increasing power production

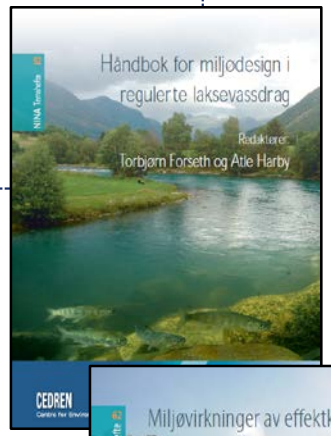
Increasing both salmon and power production

Hydromorphological quality elements

Migration, etc.

Other activities

Environmental design



Hydro-peaking

Class	Code	Description
1		Near-natural
2		Slightly modified
3		Moderately modified
4		Extensively modified
5		Severely modified

1. Hydrological changes
2. Morphological changes
3. Migration / river continuity

Hydrological changes – long-term changes (1/3)

Table 3.1. **Changes in water flow** due to regulation, and corresponding class values. The changes should be assessed based on changes in annual median flow values, derived from data records of at least 10 years before regulation and 10 years after regulation. The numbers given are percentage change.

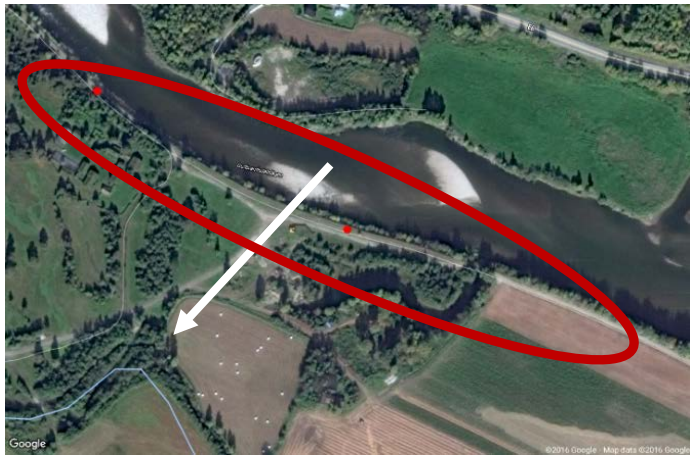
Status	Code	Classification values
Near-natural		Increase[1] to 10% reduction
Slightly modified		10-20% reduction
Moderately modified		20-40% reduction
Extensively modified		40-80% reduction
Severely modified		More than 80% reduction

- Why is this factor important?
- How to calculate?
- Measurements, modelling?

Table 3.2. **Changes in the lowest weekly average flow** comparing the regulated with the unregulated situation in ***winter,*** and corresponding class values. Source: Forseth and Harby (2013).

Status	Code	Classification values
Near-natural		Increase[2] to 5% reduction
Slightly modified		5-10% reduction
Moderately modified		10-30% reduction
Extensively modified		30-50% reduction
Severely modified		More than 50% reduction

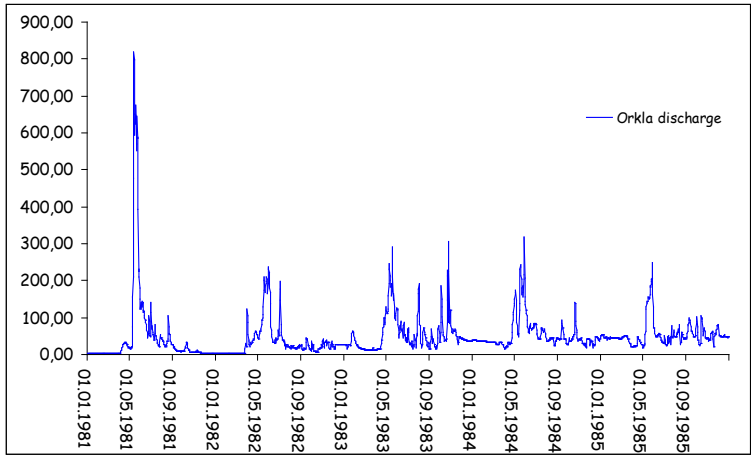
Four categories of HyMo



Along the river
- impacting lateral connectivity

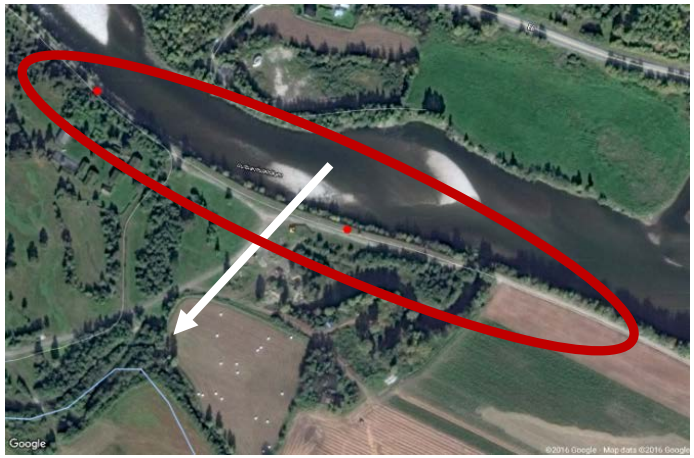
Inside the river
- impacting in-channel habitats

Across the river
- impacting longitudinal connectivity



Hydrology
- impacting all factors

Lateral connectivity and embankment



Along the river

- Access to floodplain, side arms and oxbow lakes
- Possibility to move laterally
- Erosion and sediment balance impacts
- Riparian zone
- Channelization
- Incision

Indicators:

- % of river length with levees (above land surface)
- % of river length with embankment
- % of river length without trees along bank (only below tree-line)
- Incision – need to measure in field

Changes across the river

Across the river

- Barriers for fish migration
- Barriers for sediments, ditrius and nutrients
- Fragmentation of habitats
- Have to include barrier in upstream water body

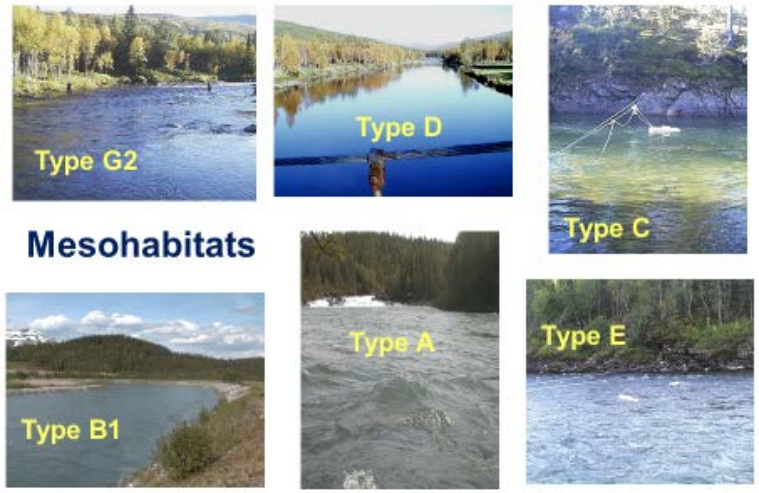
Indicators:

- Degree of fragmentation
- Barrier effect
- How much of the water body is backed up by weirs?
- Degree of regulation in catchment

Changes inside the river

Inside the river

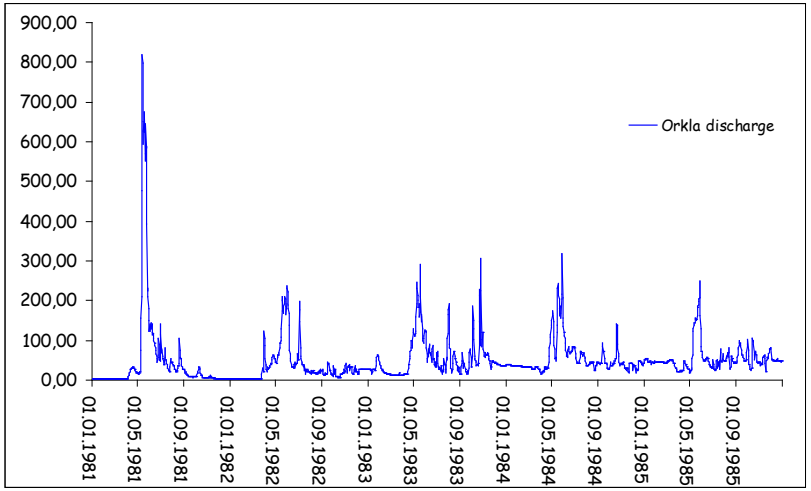
- Wetted area, surface pattern, water velocity, depth (mesohabitats/geomorphic units, i.e. river type in handbook)
- Substrate and shelter
- Structures in the river
- Removal of sand and gravel



Indicators:

- % of river length impacted by structures (aerial photos, maps, etc)
- % of river length of removed gravel/sand (recorded by local authorities)
- Substrate and shelter: Measure in situ
- Changes in river types: only possible if pre-impact studies exist

Changes in hydrology



Hydrology

- Total amount of flow
- Lowest weekly flow
- Floods of 1 and 10 years return period
- Peaking: Ratio, ramping rate and dewatered area
- Ice cover
- Water temperature

Table 3.3. **Changes in the lowest weekly average flow** comparing the regulated with the unregulated situation in ***summer***, and corresponding class value. Source: Forseth and Harby (2013).

Table 3.4. **Classification based on changes in flood frequency and magnitude**, potentially degrading habitat qualities. Source: Forseth and Harby (2013).

Status	Code	Classification values
Near-natural		Minor/moderate reduction in flood magnitude AND minor reduction in flood frequency
Slightly to moderately modified		Minor reduction in flood magnitude AND moderate/major
Extensively to severely modi		

Table 3.1. **Changes in water flow** due to regulation, and corresponding class values. The cl be assessed based on changes in annual median flow values, derived from data records years before regulation and 10 years after regulation. The numbers given are percentage cha

Status
Near-natural
Slightly modifi
Moderately m
Extensively m
Severely modi

Table 3.2. **Changes in the lowest weekly average flow** comparing the regula situation in ***winter***, and corresponding class values. Source: Forseth and Harby (2013).

Status
Near-natural
Slightly modif
Moderately m
Extensively m
Severely mod

Table 3.5. **Changes in water temperatures** during summer due to regulation, and corresp values. The numbers are given as changes in water temperatures from natural conditior Celsius [°C] per day, averaged through the growing season. Source: Bakken, Forseth and Harby (2016).

Status	Code	Classification values
Near-natural		Less than 1 deg. C reduction
Slightly to moderately modified		1-3 deg. C reduction
Extensively to severely modified		Greater than 3 deg. C reduction

Table 3.6. **Changes in ice-conditions and anchor ice production** due to regulation, and corresponding class values. The numbers are given as percentage reduction in river areas with surfaces ice-covered or river beds covered with anchor ice, or reduction/increase in number of days with ice-covered river or anchor ice on the river bed.

Table 3.7. **Classification of flow ratio**, expressed as rate of change in water flow from high to low flow levels. The numbers are dimensionless. Source: Bakken, Forseth and Harby (2016).

Status	Code	Classification values
Near-natural		<1.5
Slightly modif		
Moderately n		
Extensively m		
Severely mod		

Table 3.8. **Reductions in water level** (ramping rates), typically happen when the power production is quickly reduced or shut down, and corresponding class values. The numbers are given in cm/hour. Source: Bakken, Forseth and Harby (2016).

Status	Code	Classification values
Near-natural		
Slightly modifie		
Moderately mo		
Extensively moc		
Severely modifi		

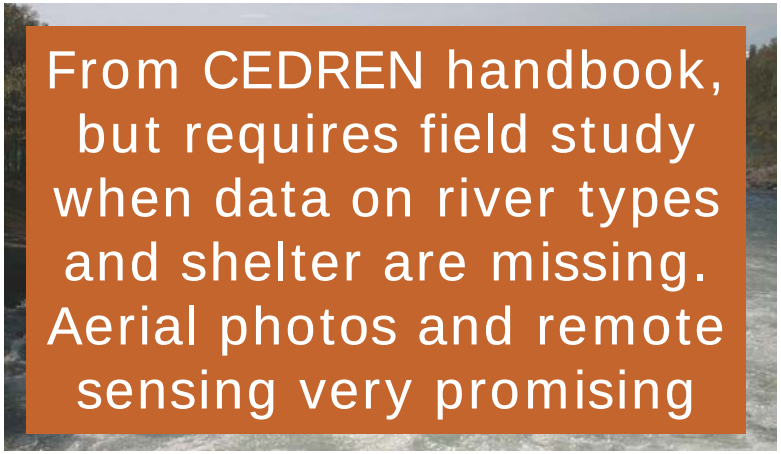
Table 3.9. Changes in water covered areas (dewatered areas) from the situation with high flow to t situation with low flow, and corresponding class values. The numbers are given in percentage reduction water-covered areas. Source: Bakken, Forseth and Harby (2016).

Status	Code	Classification values
Near-natural		<5
Slightly modified		5-10
Moderately modified		10-20
Extensively modified		20-30
Severely modified		>30

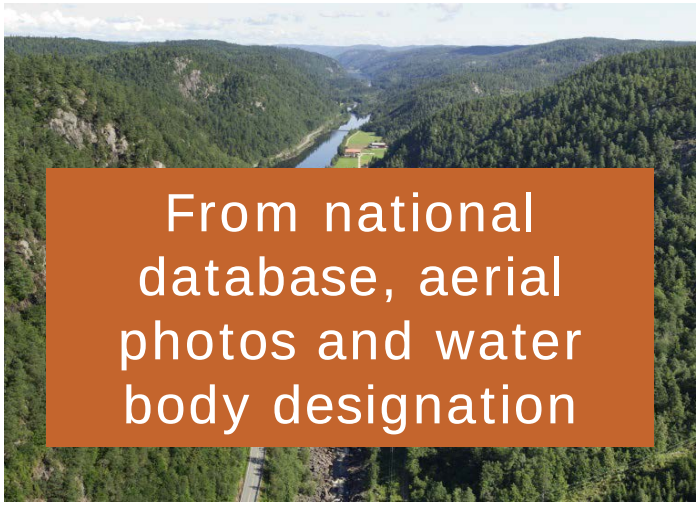
Calculate changes based on 30 years of flow data, with and without pressure

Where to find indicators and data?

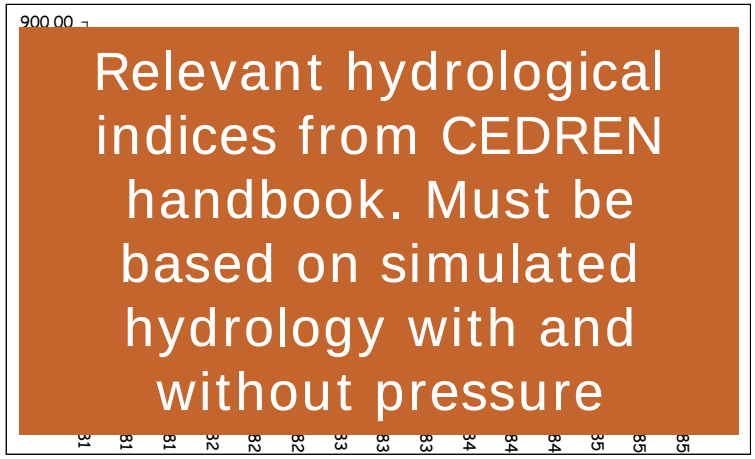
Along the river



Inside the river

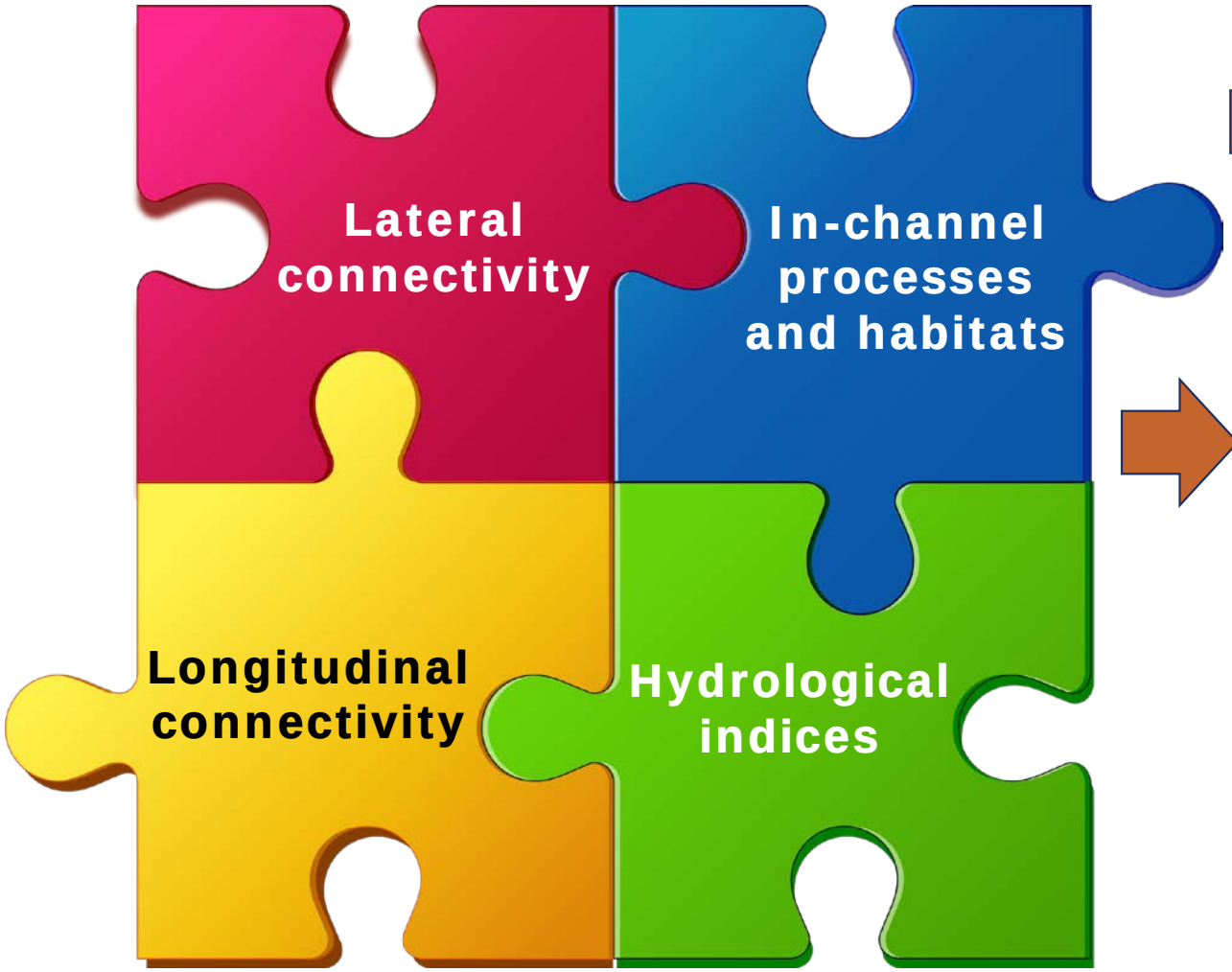


Across the river

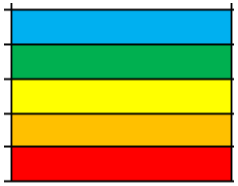


Hydrology

Weighing and combining



Combine to overall index for status



Breakdown for each indicator

Mitigation measures

social priorities in these plans.

Illustration by M. Friedrich for HarmoniCOP





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