The impact of old abandoned weirs on sediment longitudinal connectivity

Alexandre Peeters, Jean Van Campenhout, François Petit, Geoffrey Houbrechts

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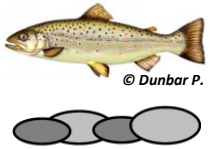
I. Context and objectives

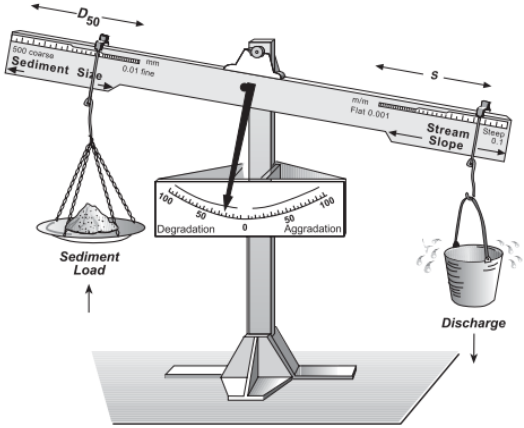
Context : Water Framework Directive (2000/60/CE) : *« good ecological status »* for water bodies

supported by : - biological quality elements
- physico-chemical quality elements
- hydromorphological quality elements (*I.A.* River Continuity)

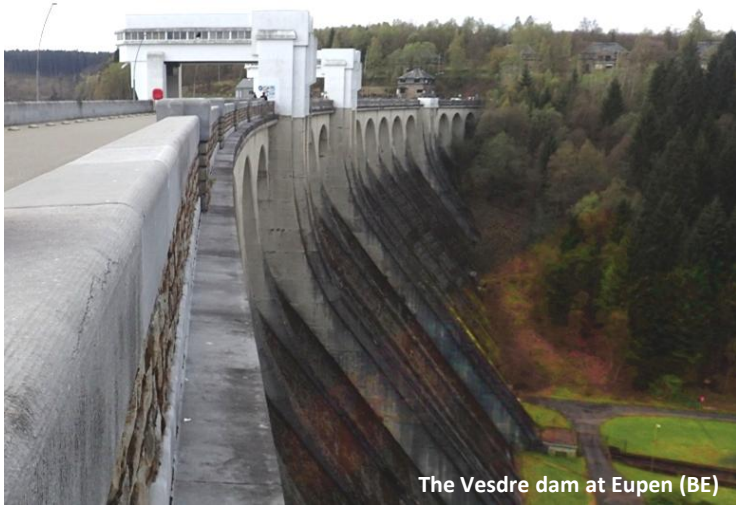


Impacts of in-channel structures on bedload transport:

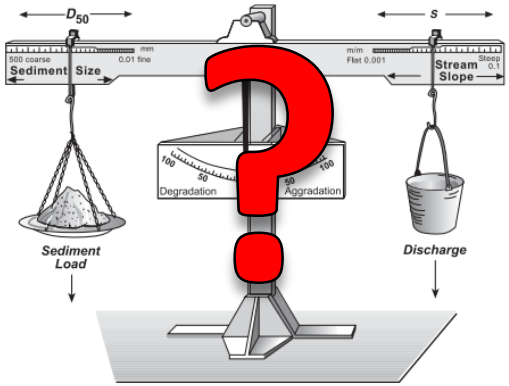
- **Well studied for large dams**



Modified from Lane (1955), in Fryirs & Brierley (2013)



- **Poorly studied for weirs**



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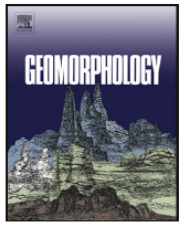

Can coarse bedload pass through weirs?

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Avec le soutien de la Wallonie

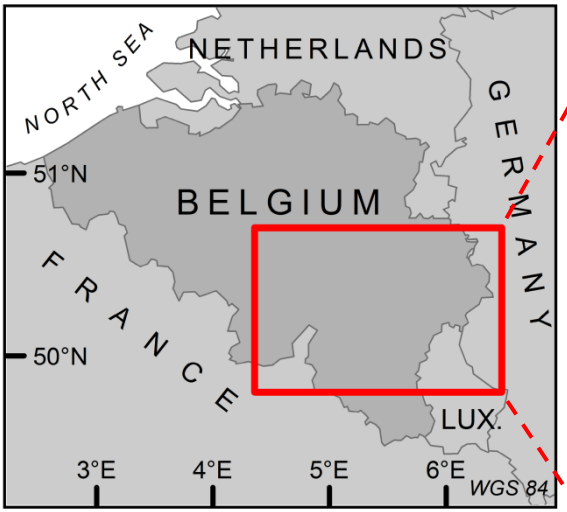
Objectives:

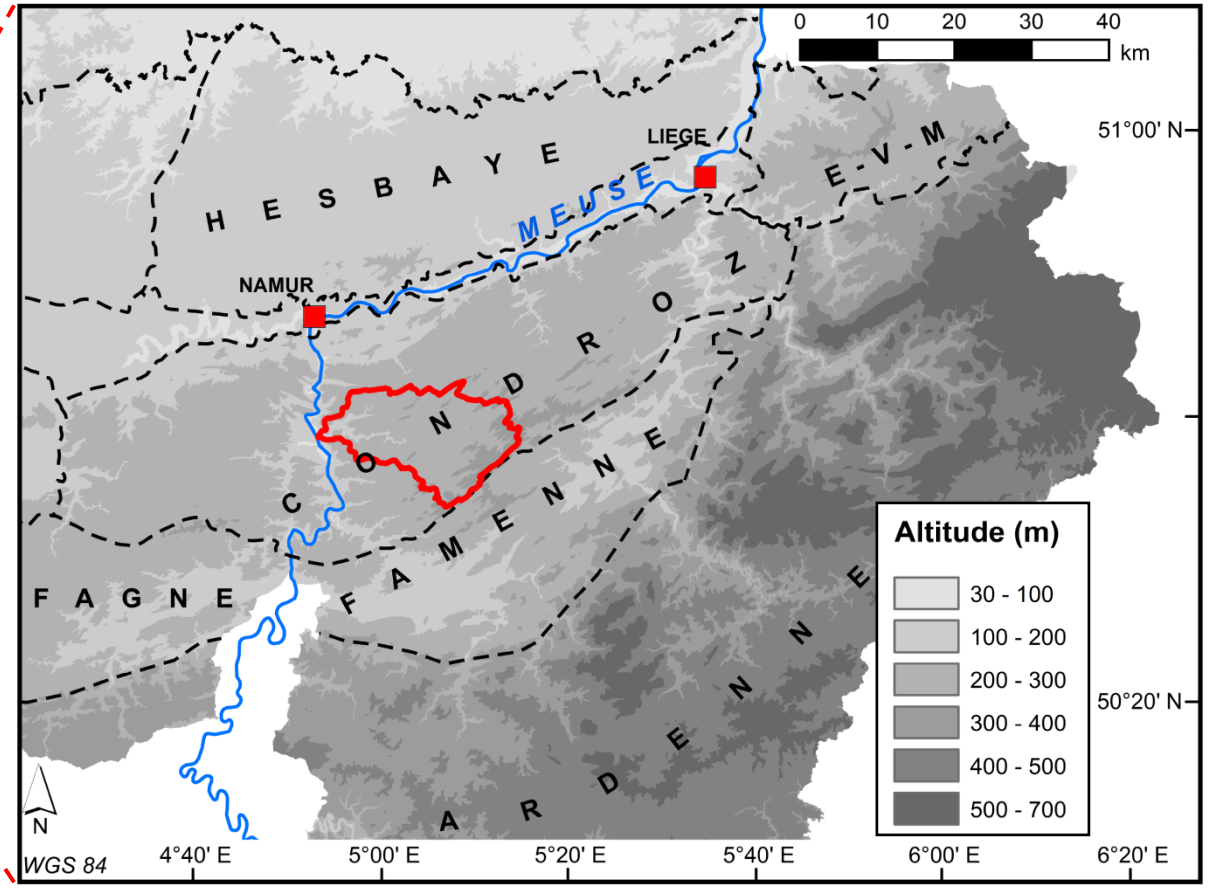
a) Determining the extent to which former weirs represent barriers to bedload continuity

3 possible scenarios :
- bedload sediment is trapped in the reservoir ⇒ weirs impede bedload transport
- bedload is transported out of the reservoir ⇒ weirs do not inhibit bedload transfer
- coarser elements are trapped in the reservoir ⇒ weirs partially impede bedload transport

b) Assessing the cumulative impact of multi-weir series along the same river course

Bocq River



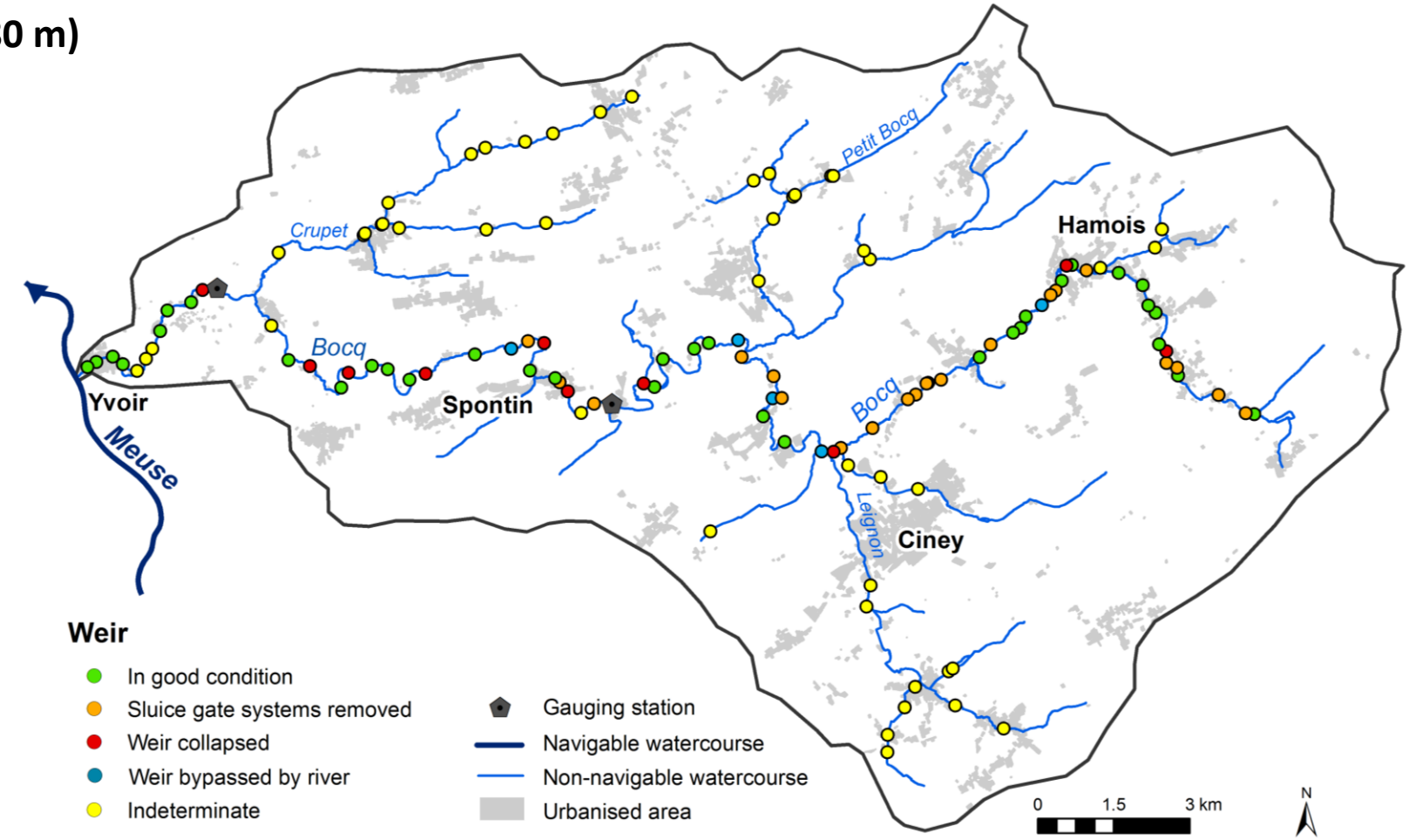


- **Catchment: 233 km²**
- **Gravel bed river (D_{50}= 44 mm ; D_{90}= 84 mm)**
- **Width at Q_b = 10.2 m**
- **Slope = 5.3 ‰**
- **Unit stream power at Q_b = 93 W/m²**

Values calculated at the Spontin site

74 weirs along the 43-km river course

(1 weir/580 m)



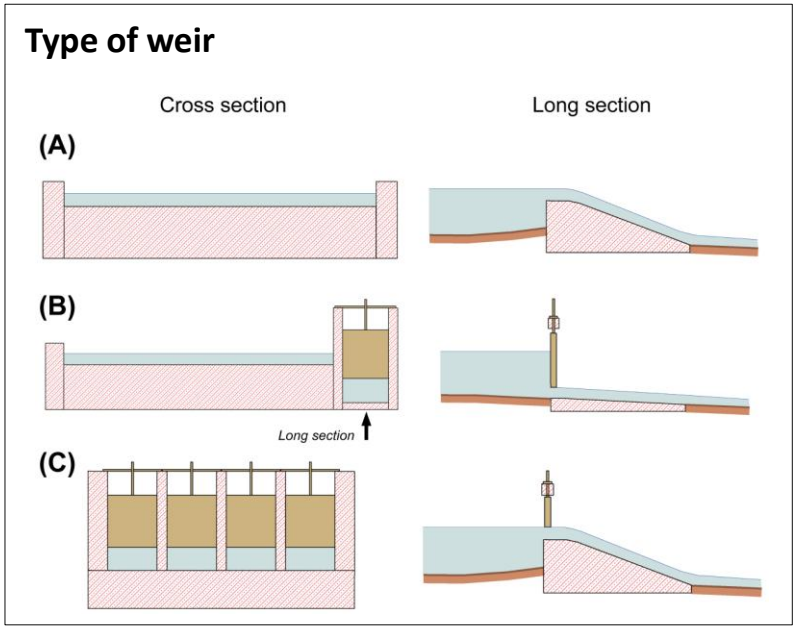
Methodology implemented to evaluate the effects of weirs on bedload transport:

River course scale

- **Inventory and description of the weirs located along the Bocq River**

Parameters related to potential alterations of bedload transport continuity:

- type of weir
- state of the weir (sluice gate systems)
- height of the weir
- vertical spacing between the weir crest and the stored sediment behind the weir



Site scale

- **volume estimates of bedload sediment stored in reservoirs (topographic surveys)**
- **assessment of bedload transport across reservoirs :**
  - **grain size analyses (i.e., pebble counts)**
  - **2 tracing methods : iron slag particles and *low-frequency passive integrated transponders (PIT tags)***

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IV. Results

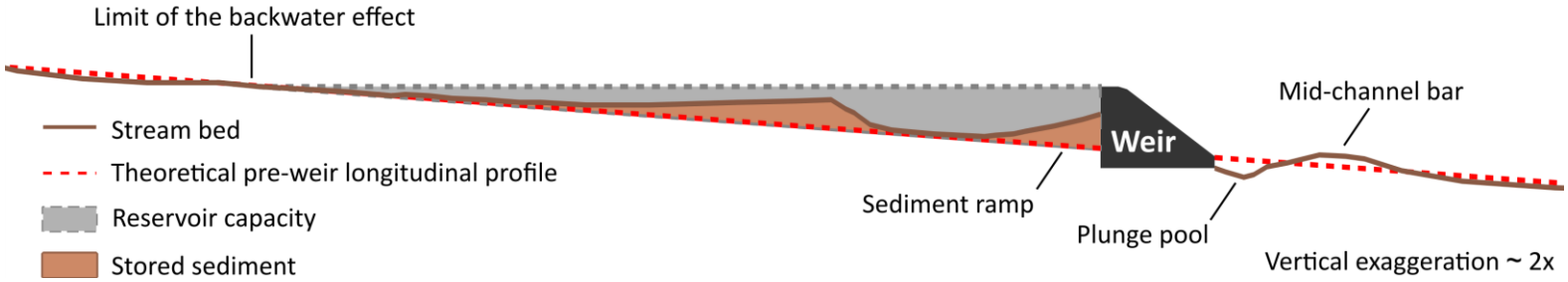
Inventory of weirs along the Bocq River

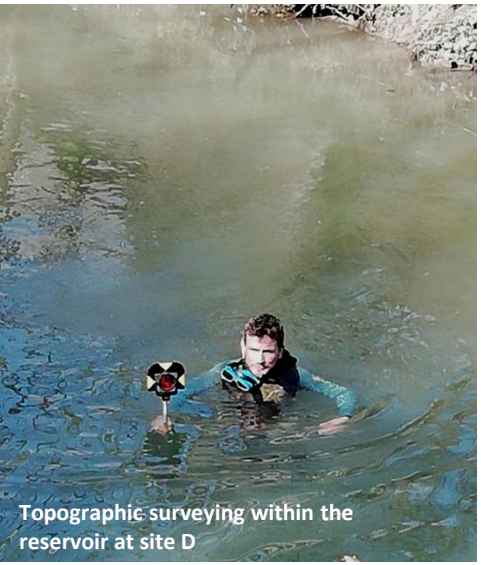
		Type of weir			
		Weir without sluice gates in the main channel	Weir with sluice gates on the side in the main channel	Sluice gate systems above the weir	**Total**
State of the weir	In good condition	12	12	10	**34**
	Sluice gate systems removed	N/A	2	19	**21**
	Weir collapsed	1	6	3	**10**
	Weir bypassed by river	0	1	4	**5**
	Indeterminated	2	2	0	**4**
	Total	**15**	**23**	**36**	**74**

34 weirs in good condition

- **Height : 40 -230 cm**
- **Sum of their backwater lengths: ~8.4 km (~20% of the river course)**
- **Commonly left abandoned with their gates closed**

Volume estimates of bedload sediment stored in reservoirs (+ change over time)




Topographic surveying within the reservoir at site D

ID	Site	Date of survey completion	Weir height (m)	Total volume of stored sediment (m^3)	Original reservoir storage capacity (m^3)	Ratio (%)
A	Gemenne	1989-1990	1.45	2479 (496)	4950	50 (10)
B	Spontin	1989-1990	1.20	459 (92)	1223	38 (8)
		2009	1.20	308	1223	25
C	Chansin 1	1989-1990	1.54	849 (170)	1850	46 (9)
D	Chansin 2	1989-1990	1.61	645 (129)	2612	25 (5)
		2019	1.61	349 (24)	2612	13 (1)
E	Purnode 1	1989-1990	1.40	472 (94)	1434	33 (7)
		2019	1.40	414 (29)	1434	29 (2)
F	Purnode 2	1989-1990	2.30	844 (169)	2588	33 (7)
G	Yvoir	1989-1990	1.90	846 (169)	2214	38 (8)

Volume estimates of bedload sediment stored in the reservoir compared to the original reservoir storage capacity (with estimates of uncertainty in parentheses)

IV. Results

Grain size analyses:

- upstream of reservoir
- downstream of reservoir
- Within reservoir

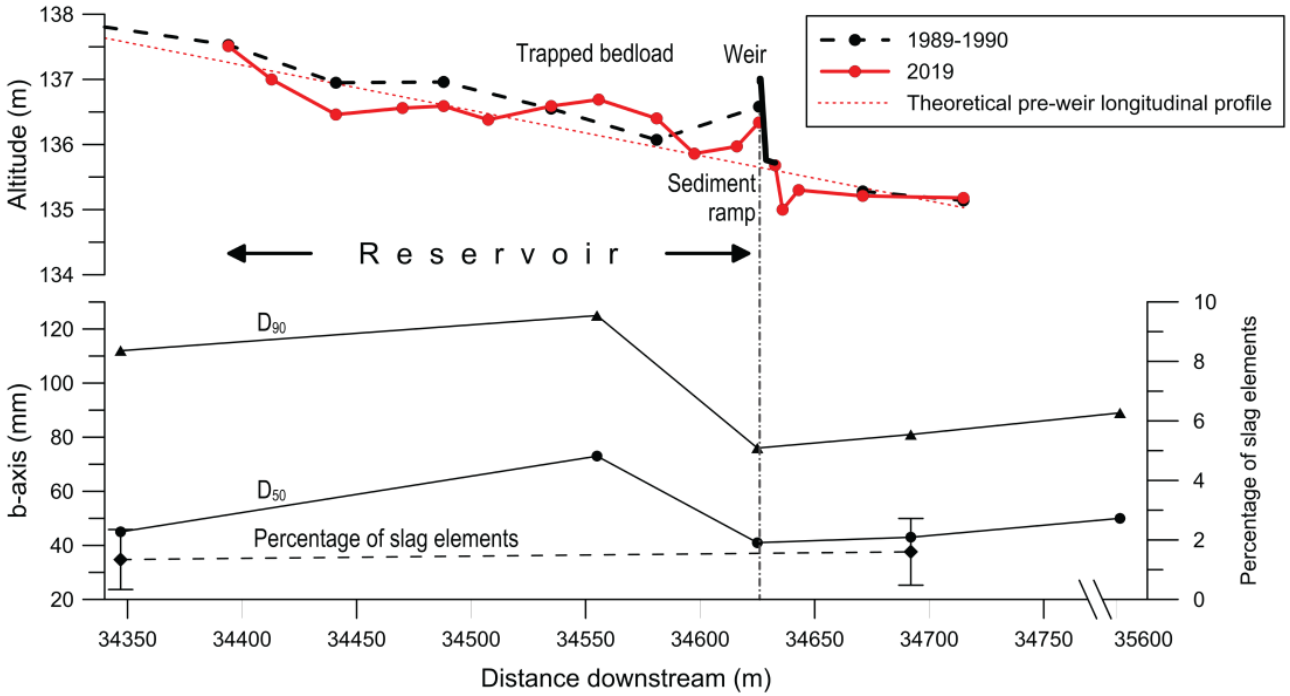
Specific percentiles of the surface grain size distributions upstream and downstream of weirs, and percentage of slag particles (with standard deviation in parentheses).

Sampling location (in relation to the study weir)	River kilometre	Distance from weir (m)	D_{50} (mm)	D_{90} (mm)	Percentage of slag elements
Upstream (reference)	34.3	-279	45	112	1.3 (0.50)
Within reservoir (trapped bedload)	34.6	-71	73	125	N/A
Within reservoir (sediment ramp)	34.6	-1	41	76	N/A
Downstream	34.7	66	43	81	1.6 (0.56)

Percentage of slag particles:

- upstream of reservoir
- downstream of reservoir

Houbrechts et al., 2011



Bedload trapped in the Purnode 1 reservoir (site E):
Above : longitudinal profile based on the mean bed elevation of cross sections ;
Below : sediment characteristics upstream, downstream and within the reservoir, and percentage of slag particles (error bars denote standard deviation 2σ).

Assessment of bedload transport across weirs using *PIT-tagged* pebbles

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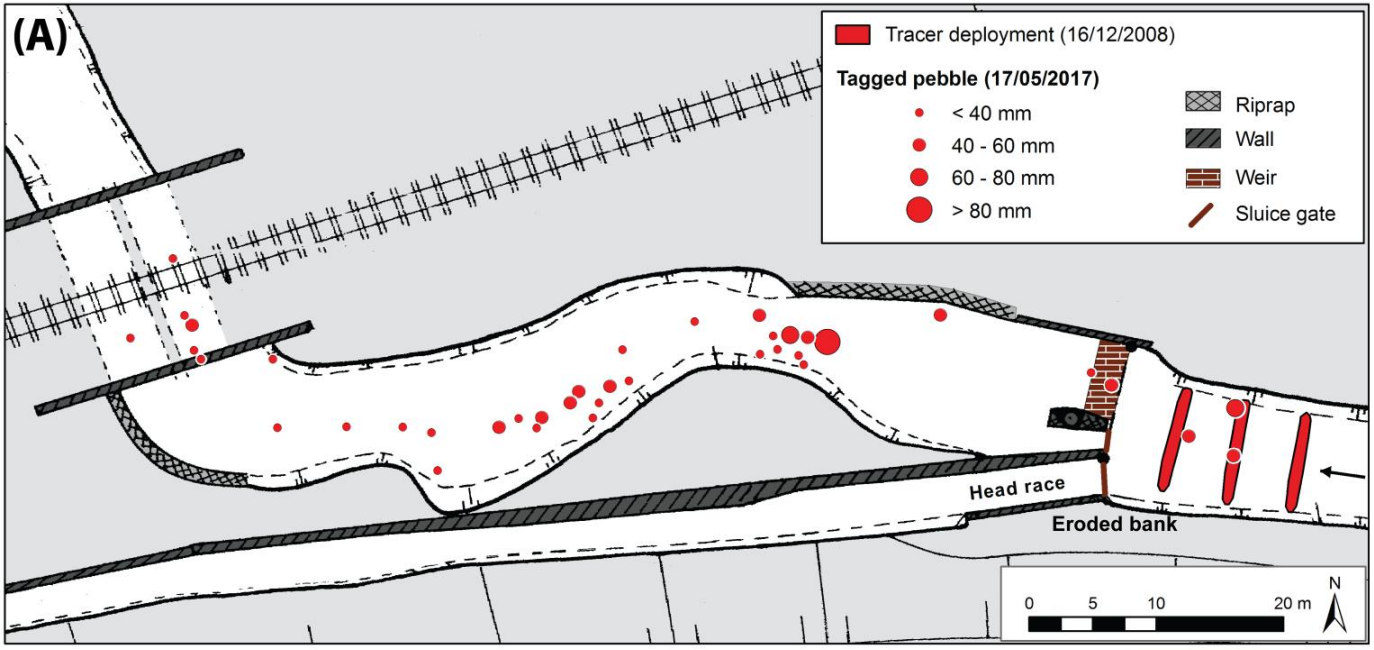

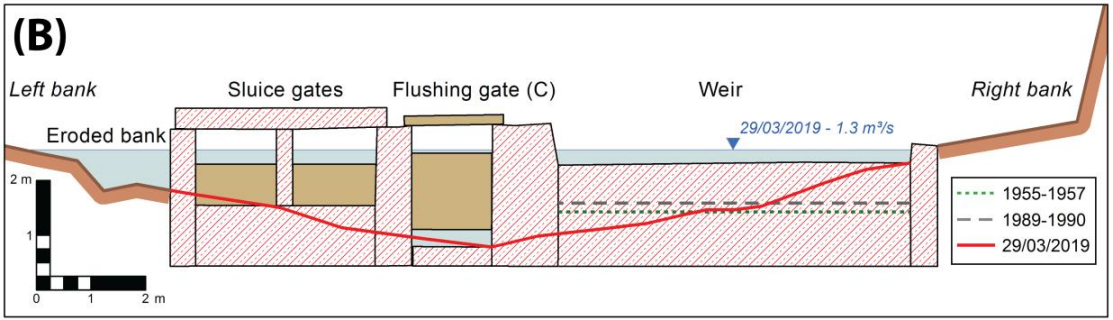

Bedload transport over weir site D. (A) Localization of tracer deployment and the PIT-tagged pebbles surveyed on S3. The size of the red circles indicates their b-axis. (B) Cross section of the weir and the elevation of trapped bedload sediment behind the weir. (C) Flushing gate damaged by the 21/09/2014 peak flow (Q = 19 m³/s; RI = 2.5 yr).

V. Conclusions

Site scale

- **Weirs partially impede bedload transport**
  - **~D_{50} are transported out of the reservoir**
  - **coarser elements are trapped in the reservoir**
- **Importance of the individual geomorphic setting that determines the local sediment continuity :**
  - **Slope and competence of the river reach**
  - **type of weir, state of the weir (sluice gate systems), presence of other upstream weirs**
- **Results in accordance with those of other recent studies (e.g., Casserly et al., 2020 ; Magilligan et al., 2021).**

River course scale

- **Sediment longitudinal connectivity:**
  - **less impacted than initially thought**
  - **likely to increase over time as old weirs gradually fall into disrepair**

Thank you for your attention

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