Sediment transport measurements in rivers, INRAE-MRC meeting

Villeurbanne – 11th February 2026

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INRAE

River hydraulics

OSR
Observatoire des Sédiments du Rhône

Program

14h00 Introduction, RiverLy research group, M. Coquery

14h05 Presentation of the Rhône Sediment Observatory (OSR), M. Coquery

14h15 Sediment transport measurements in rivers, G. Dramais

14h45 Retrieving suspended-sediment concentrations from acoustic backscatter signals, B. Vincent, J. Le Coz

15h00 Dune tracking, J. Le Coz

15h10 A simple physically-based model for predicting sand transport dynamics, J. Le Coz, G. Dramais

15h30 MRC Project, R. Sayasane

16h00 Discussions

  

Sediment transport measurements in rivers

OSR
Observatoire des Sédiments du Rhône

CNR

EDF

USGS
science for a changing world

IRD
Institut de Recherche pour le Développement
FRANCE

uOttawa

GÉOSCIENCES DE L'ENVIRONNEMENT CEREGE

MEKONG RIVER COMMISSION
MRC
FOR SUSTAINABLE DEVELOPMENT

UNESCO
Organisation des Nations Unies pour l'éducation, la science et la culture

CUSI
Chaire UNESCO en sciences de l'ingénieur (Congo)

UNIVERSITE MARIEN NGOUABI

ENSP
Ecole Nationale Supérieure Polytechnique

River hydraulics

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GEOSCIENCES Rennes

Sediment transport in rivers

Sediment transport plays an essential role in the functioning of rivers

- Life and habitats
- Geomorphology

Some issue with sediment transport

Since we change the balance

- Security (flood risk, infrastructures)
- Lost of biodiversity
- Channel silting
- Loss of water storage capacity upstream dams (high dredging cost)

We need to measure sediment fluxes to help to anticipate those problems

Isère dam flushing (© EDF)

Glen Canyon dam, Colorado River (avril 2019)

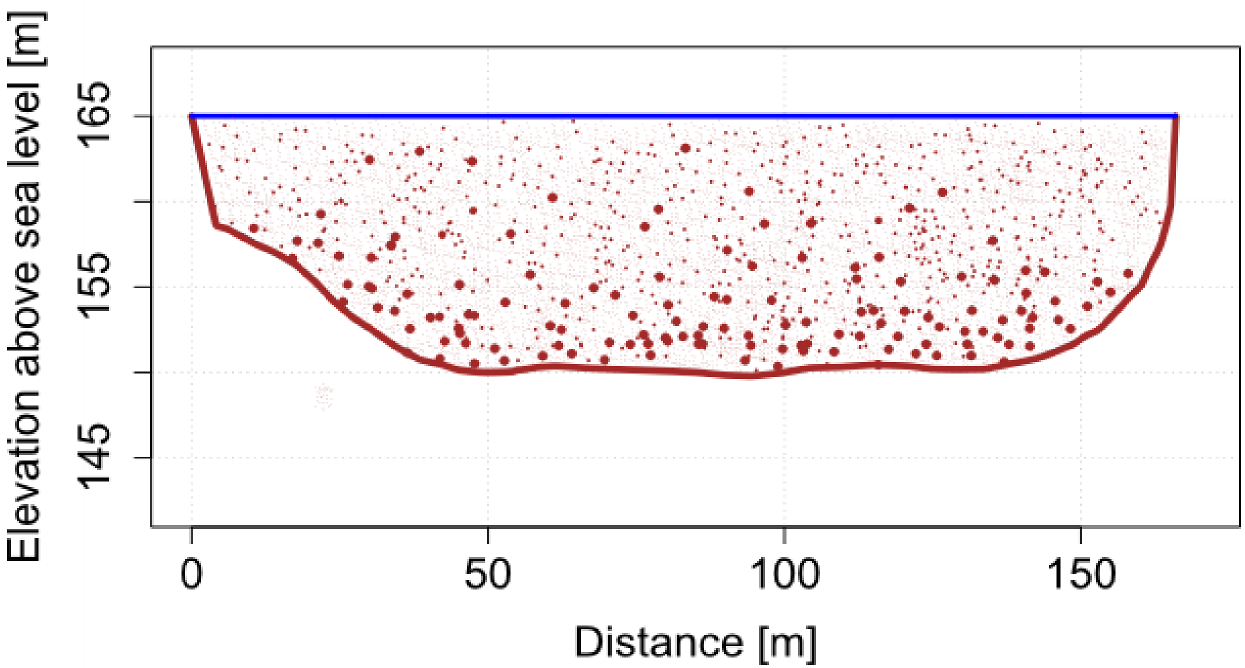
Transfer of goods between two boats following the grounding of one of them on a sand deposit, 2023 (© Jacques BRUYERE - DL)

Steps for sediment transport monitoring

- Sampling different compartments (Washload, Suspended load, and bedload). Ponctual surveys or countinuous measurements ?
- Laboratory analysis (concentration, flux, grain size, quality)
- Data base

An overview of sediment fluxes measurements

- Fine suspended load (silt/clay) (<63µm)
- Graduated suspended load (sand/silt) (>63µm-2mm)
- Bedload (gravels/sand) (>2mm)



Suspended-load (fine and sand)

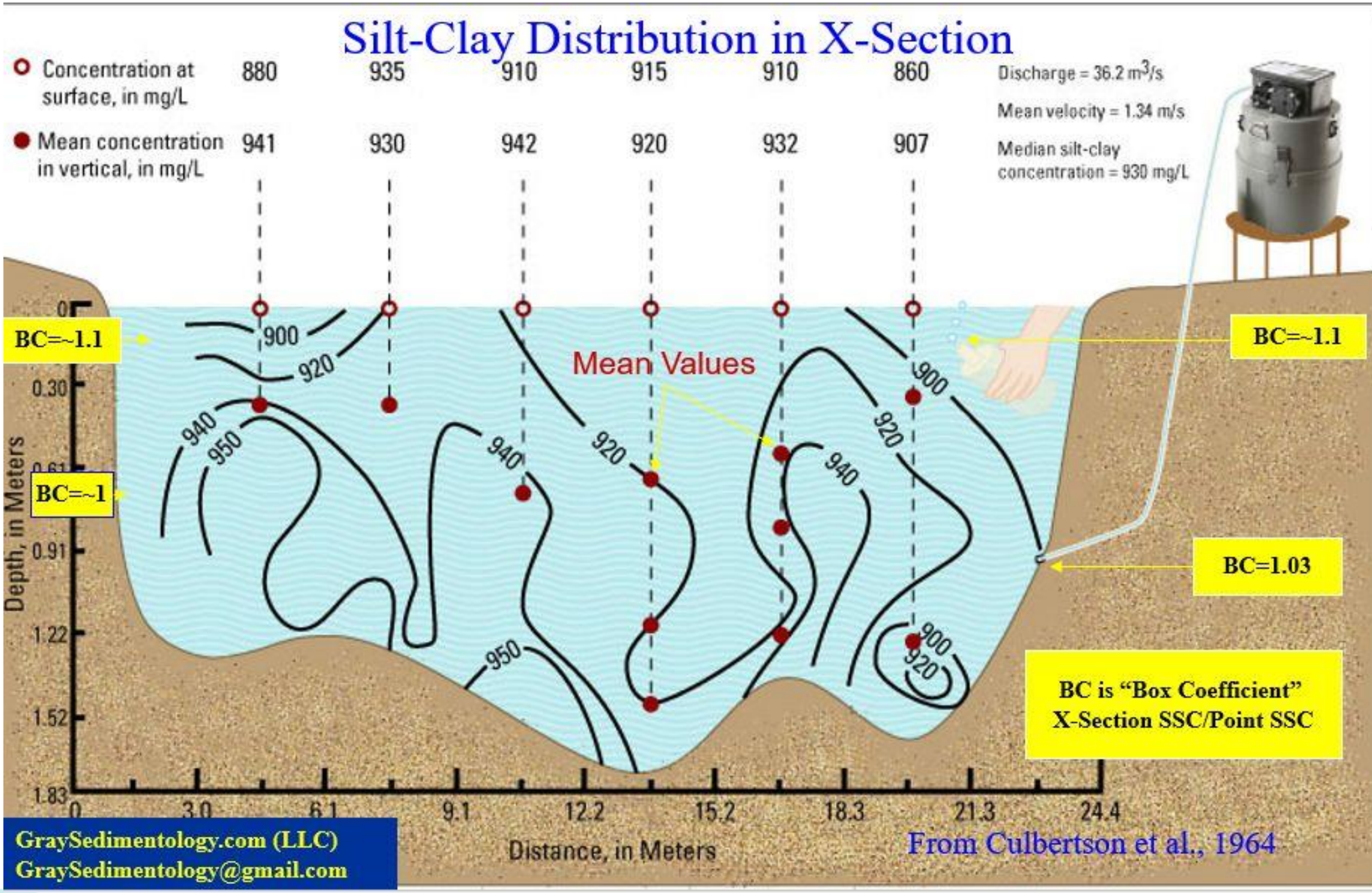
Millimeters (mm)		Micrometers (µm)	Phi (ϕ)	Wentworth size class		Rock type
	4096		-12.0	Boulder	Gravel	Conglomerate/ Breccia
	256		-8.0	Cobble		
	64		-6.0	Pebble		
	4		-2.0	Granule		
	2.00		-1.0	Very coarse sand	Sand	Sandstone
	1.00		0.0	Coarse sand		
1/2	0.50	500	1.0	Medium sand		
1/4	0.25	250	2.0	Fine sand		
1/8	0.125	125	3.0	Very fine sand		
1/16	0.0625	63	4.0	Coarse silt	Silt	Siltstone
1/32	0.031	31	5.0	Medium silt		
1/64	0.0156	15.6	6.0	Fine silt		
1/128	0.0078	7.8	7.0	Very fine silt		
1/256	0.0039	3.9	8.0	Clay	Mud	Claystone
	0.00006	0.06	14.0			

Classification, C. K. Wentworth (1922)

Rhône sand - Port Saint Louis (2016) – 8 m

- Fine (<63µm)
- Suspended sand (>63µm)
- Organic particles, plastic, pollutants…

I. Washload - Turbidity is a good proxy for fine sediments



Turbidity measurement stations

Automatic sampler

Protection case, electricity supply, datalogger - Green River (2019)

Turbidity sensor

+ datalogger and communication device

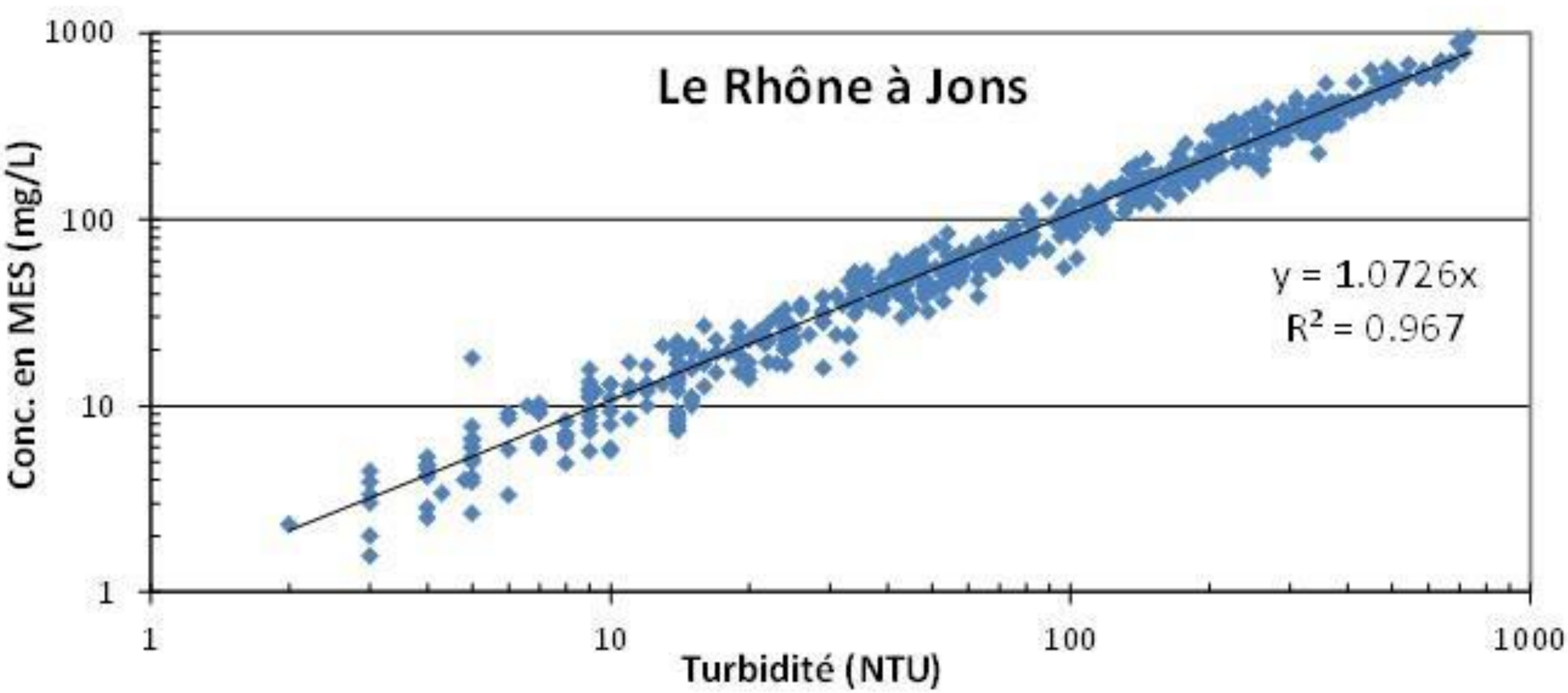
Stainless protection tube – Drôme River

Turbidity measurement stations

Extra cost

- Maintenance (sensors are delicate)
- Laboratory analysis
- Data validation, post-processing
- Data management

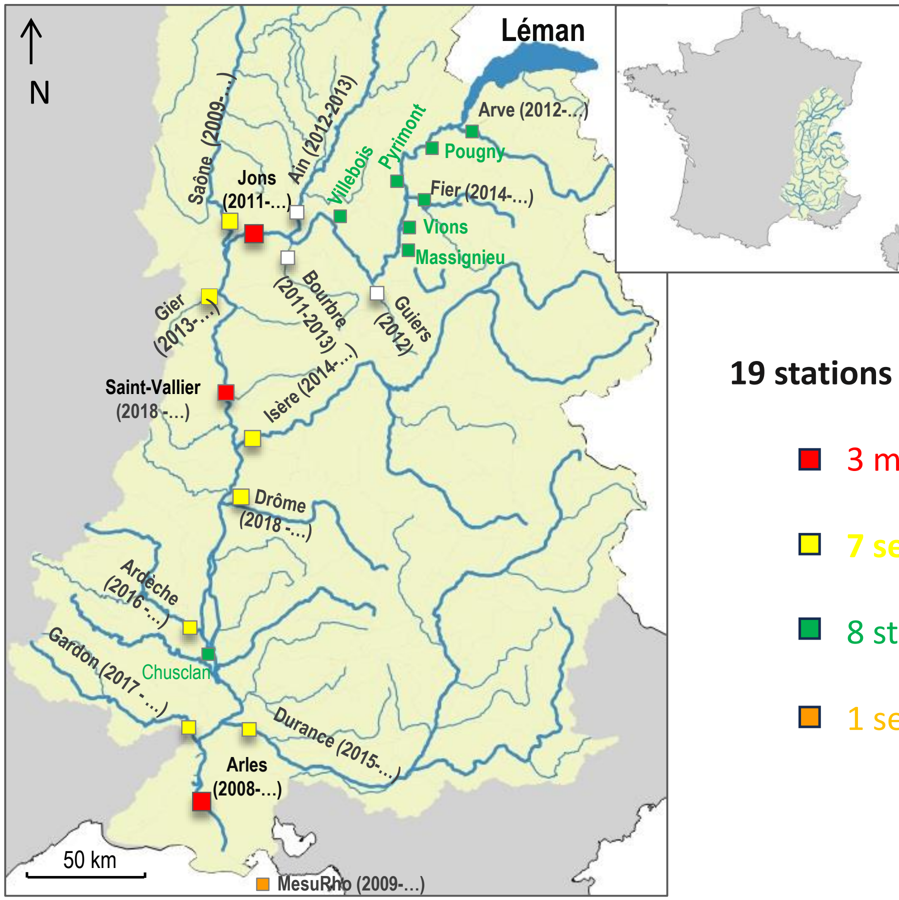
Turbidity measurement - Calibration with samples



- After laboratory analysis (concentration) we can build a relationship between concentration and turbidity
- Variable with grain size, tributaries contributions (geology), intensity of floods, human activities (dam flushing, dredging)

Example : Rhône River

Several stations in the Rhône watershed for fine sediment and pollutants



https://bdoh.inrae.fr/

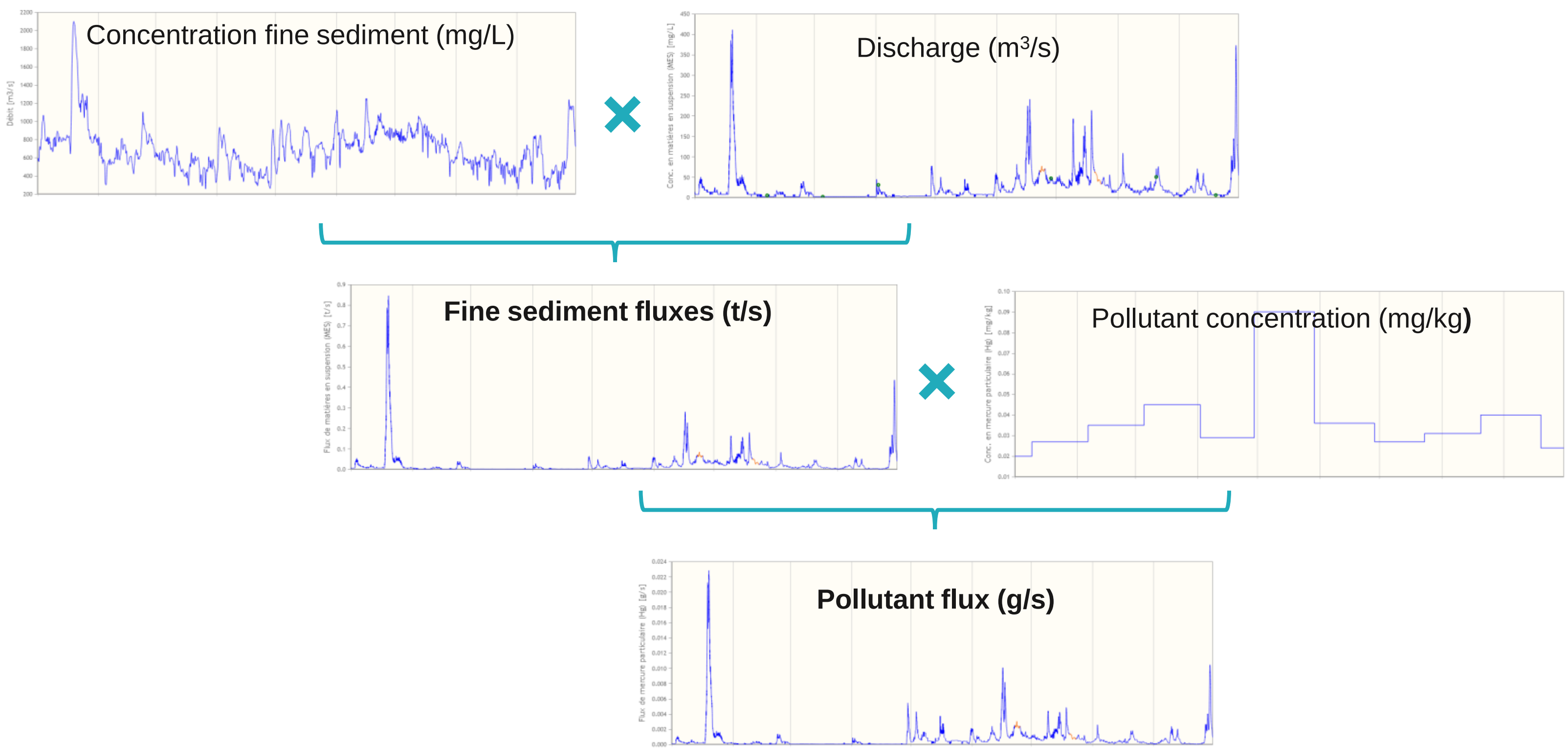
19 stations for fine suspended sediment flux monitoring :

- 3 main stations for fine sediment en pollutants
- **7 secondaary** stations for fine sediment en pollutants
- 8 stations for fine sediment only (Arve, Fier, 5 CNR stations)
- 1 sea station for fine sediment (MesuRho)

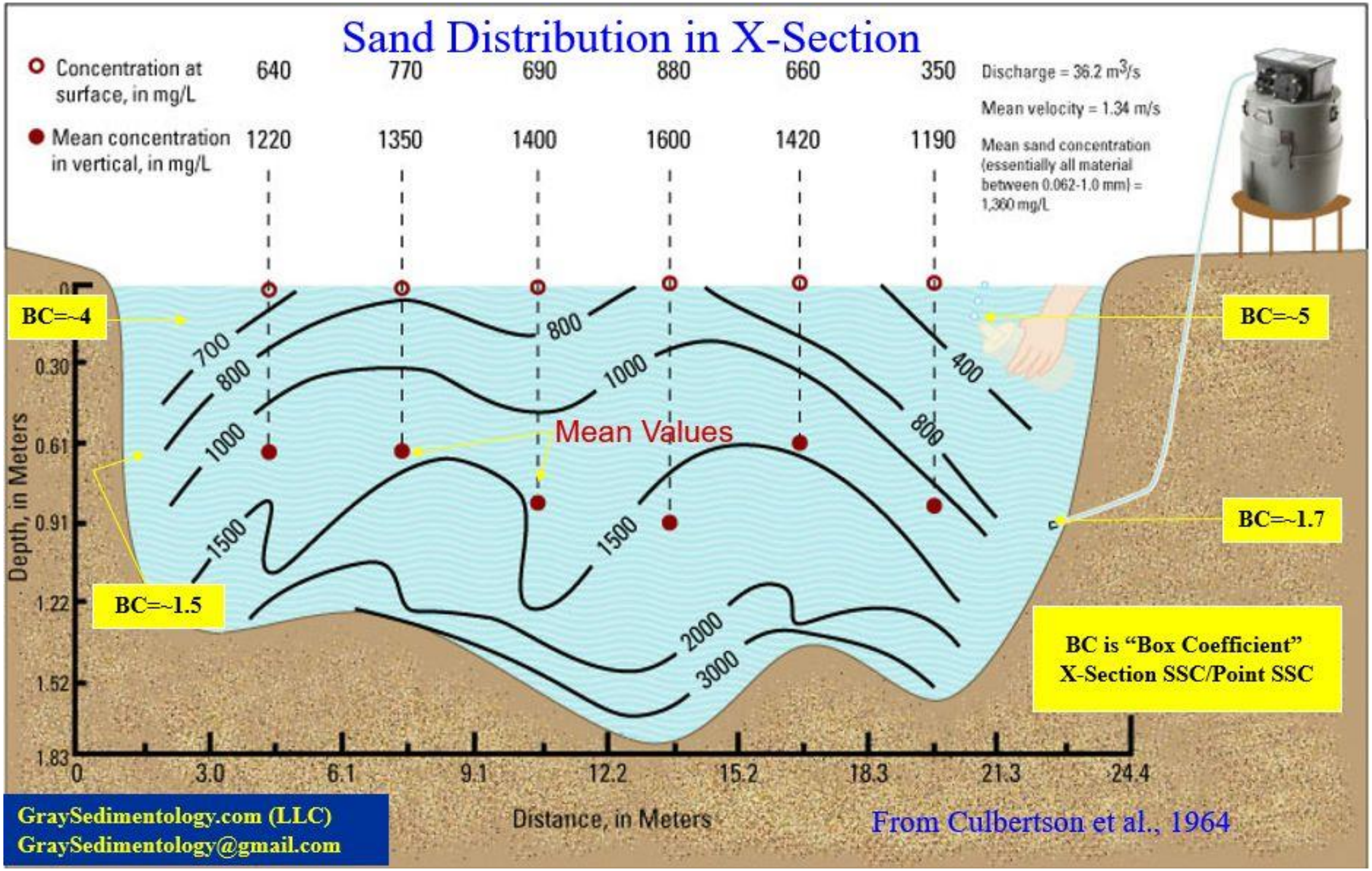
Fine sediment budgets computation

Discharge x Concentration = **Fine sediment fluxes**

Fine sediment fluxes x pollutant concentration= **Pollutant fluxes**

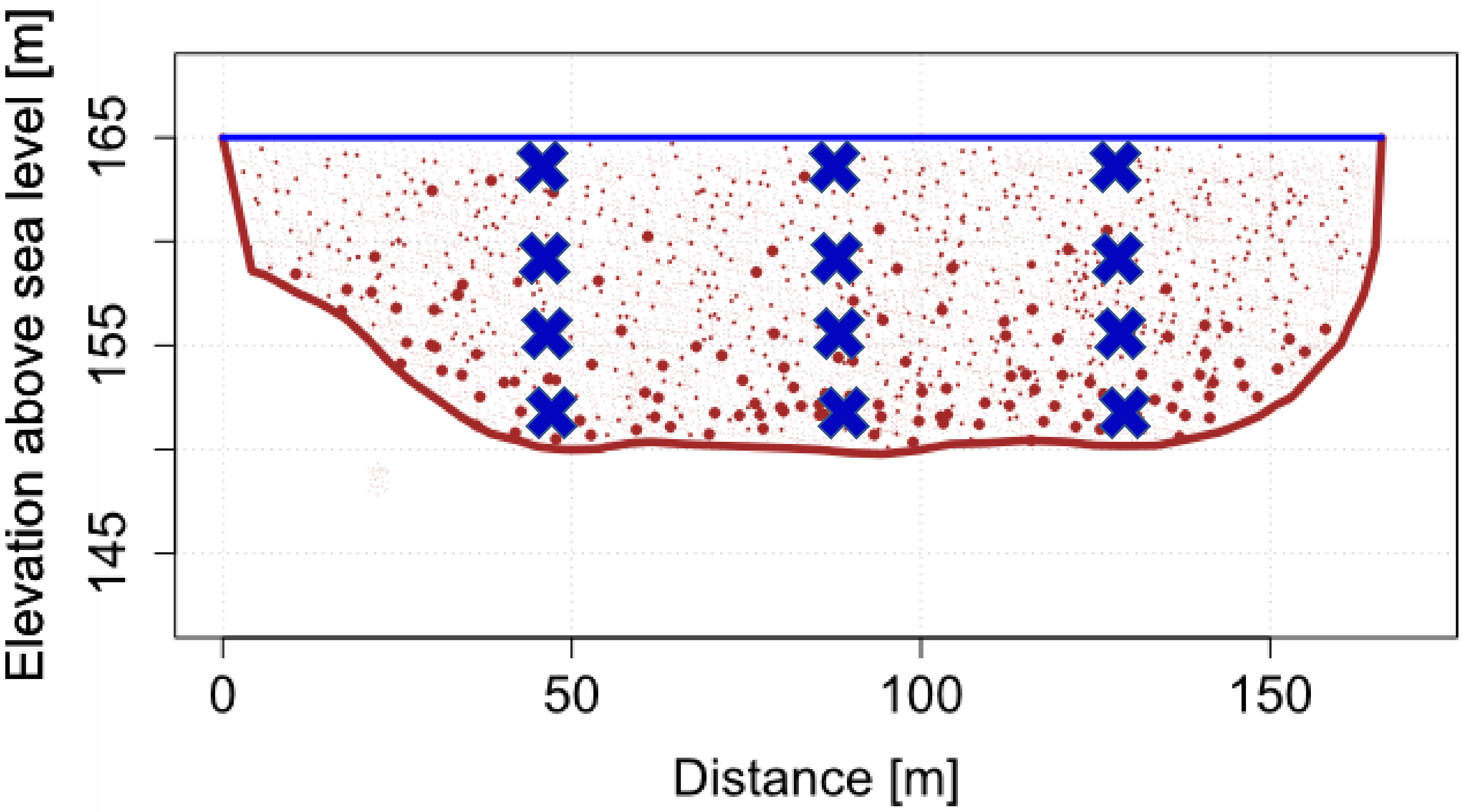


II. Graduated suspended load (sand)



Suspended sand can be difficult and expensive to measure

Samplers deployment



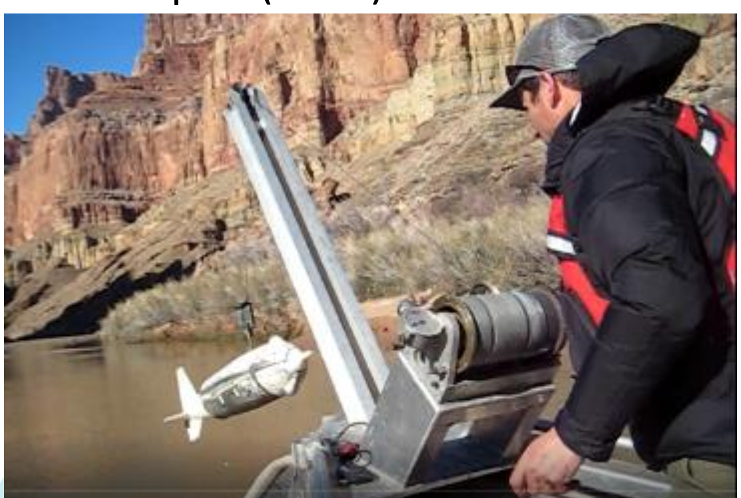
Graduated suspended load

Sampling strategies with boats

12000 €

Isère River in Grenoble during the snow melting US-P6 sampler (2022)

Horizontal bottle, Mekong (2013)



DH 96 sampler , Colorado River (2019)

Home made horizontal bottle, Amazon River (2014)

Sampling from cables or bridges

ELSEVIER

Science of The Total Environment

Volume 657, 20 March 2019, Pages 485-497

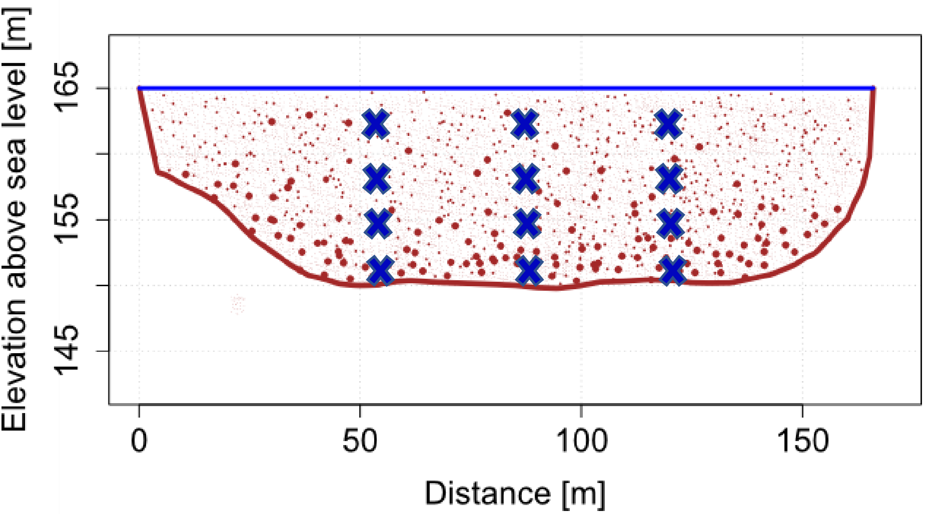
A multi-technique approach for evaluating sand dynamics in a complex engineered piedmont river system

B. Camenen [a], G. Naudet [a b], G. Dramais [a], J. Le Coz [a], A. Paquier [a]

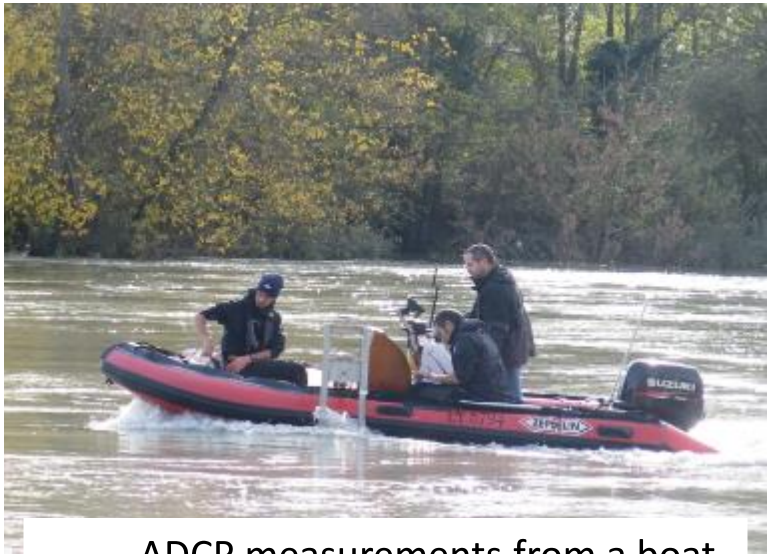
Deployment in Diamond Creek, Colorado River (2019)

Suspended sand flux computation

SDC method for suspended-sediment gaugings, we combine samples and ADCP measurements



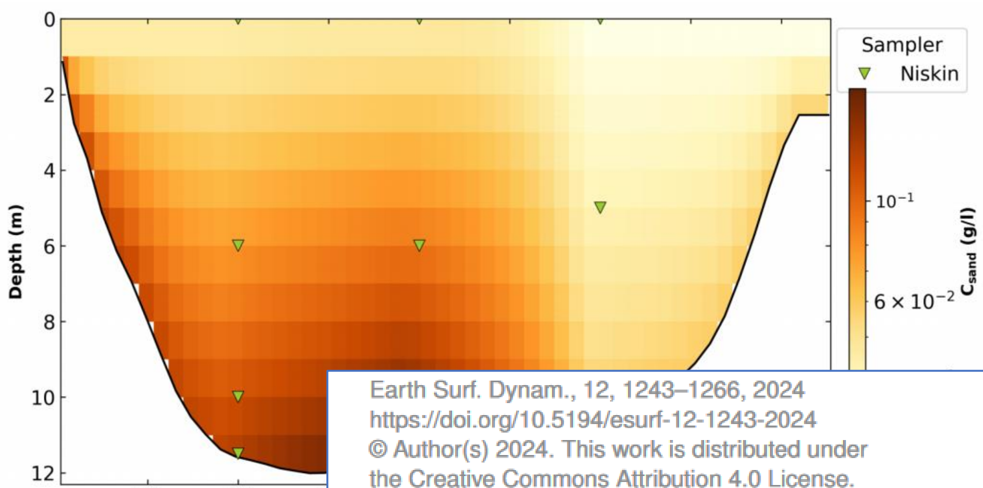
Sampling distribution in the cross- section



ADCP measurements from a boat

Suspended sand flux computation

SDC method for suspended-sediment gaugings



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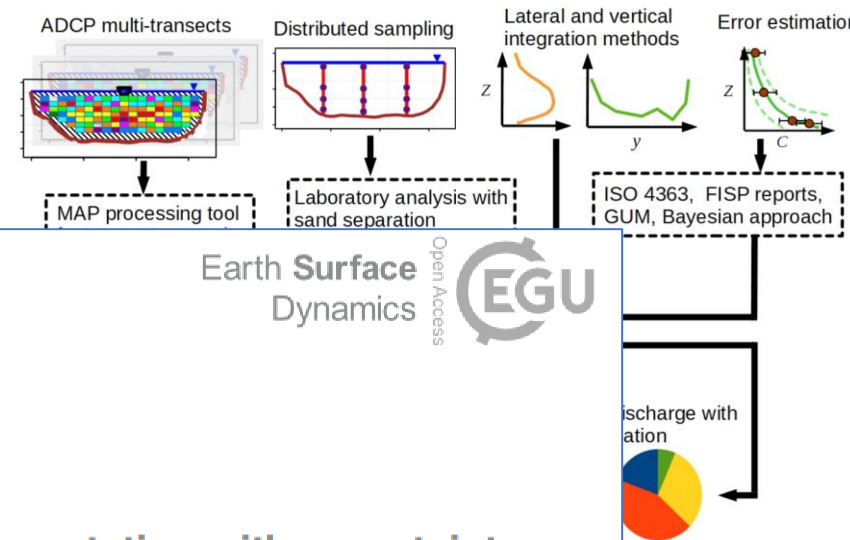

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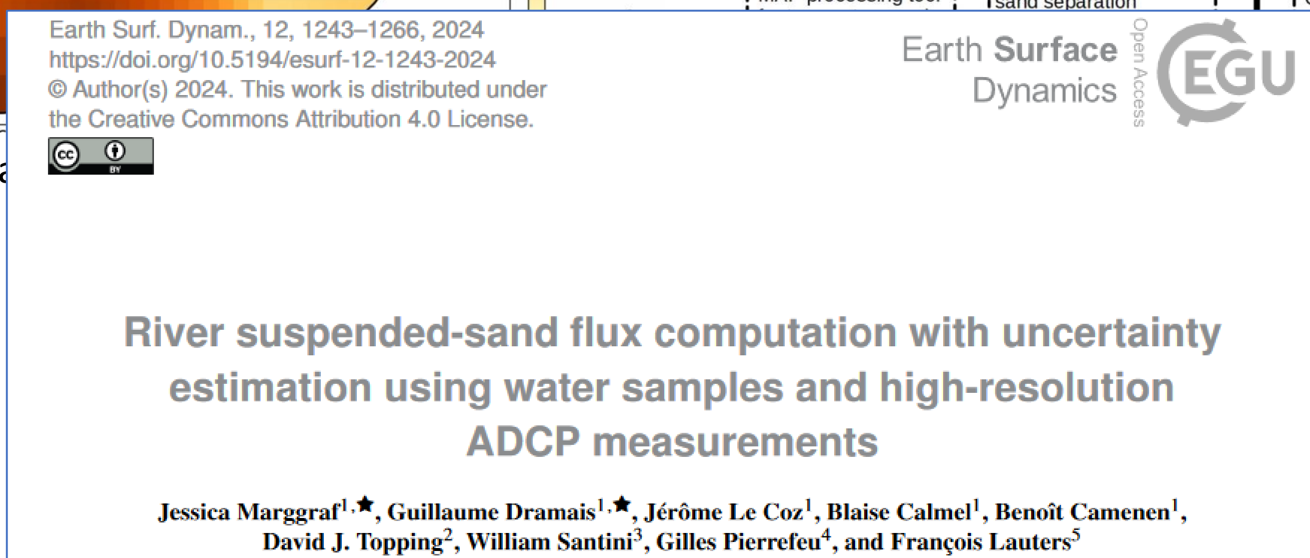


Earth Surf. Dynam., 12, 1243–1266, 2024
https://doi.org/10.5194/esurf-12-1243-2024

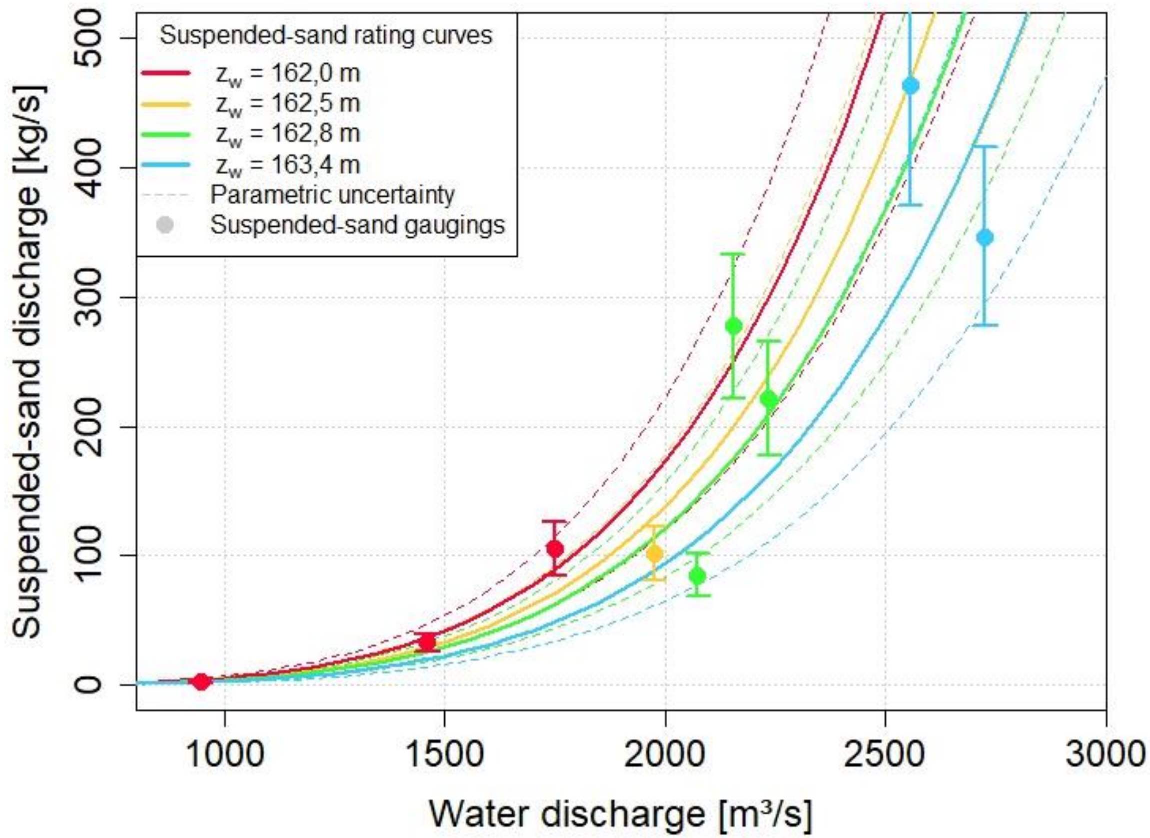
Earth Surface Dynamics
Open Access
EGU

River suspended-sand flux computation with uncertainty estimation using water samples and high-resolution ADCP measurements

Jessica Marggraf[1,★], Guillaume Dramais[1,★], Jérôme Le Coz[1], Blaise Calmel[1], Benoît Camenen[1],
David J. Topping[2], William Santini[3], Gilles Pierrefeu[4], and François Lauters[5]

Suspended sand flux computation

After computing data from the suspended sand gauging we can build a rating curve

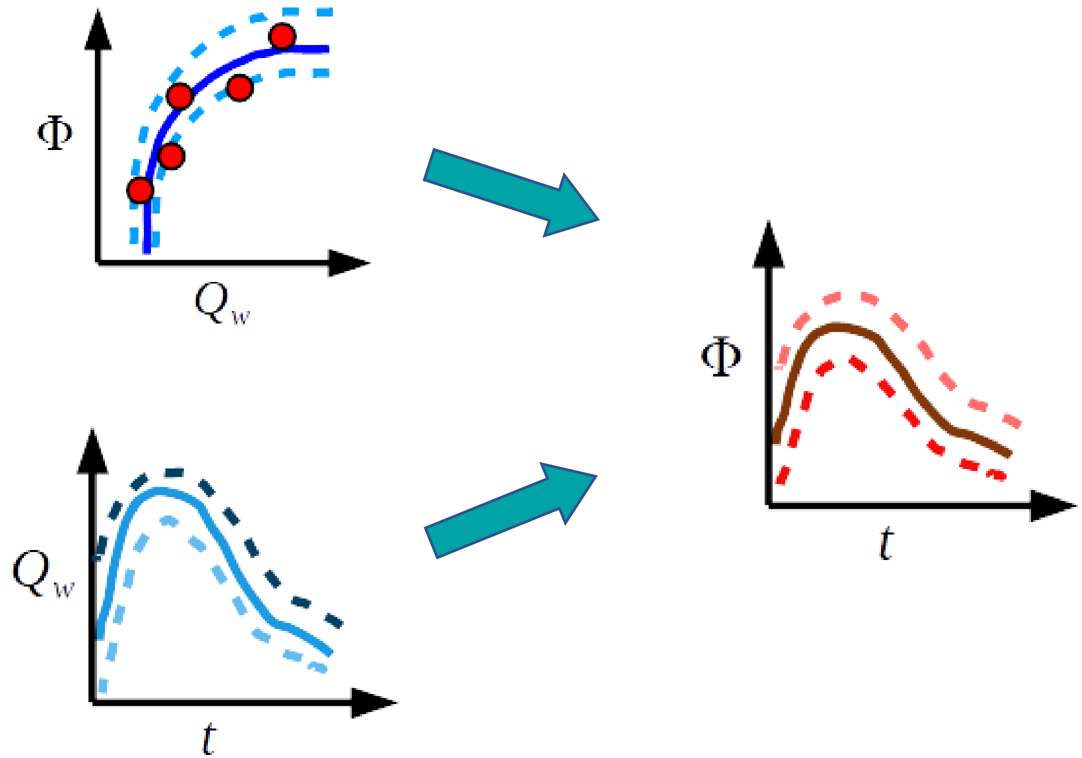


Suspended-sand rating curve in Lyon Perrache

More details in the last presentation

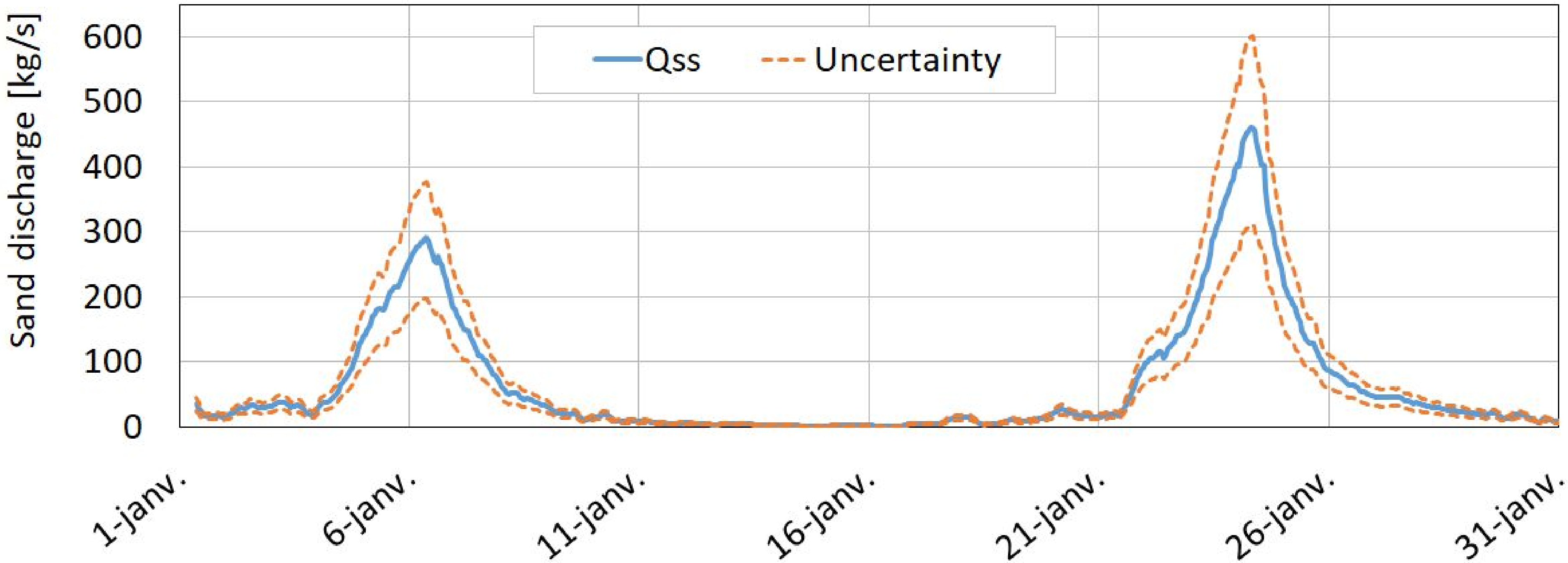
Computing suspended-sand budget

By combining rating curve and discharge time series



Computing suspended-sand budget

- Uncertainties calculated on the flux time series



01/2018 Suspended sand budget :

- 0.175 Mt [0.120-0.226]

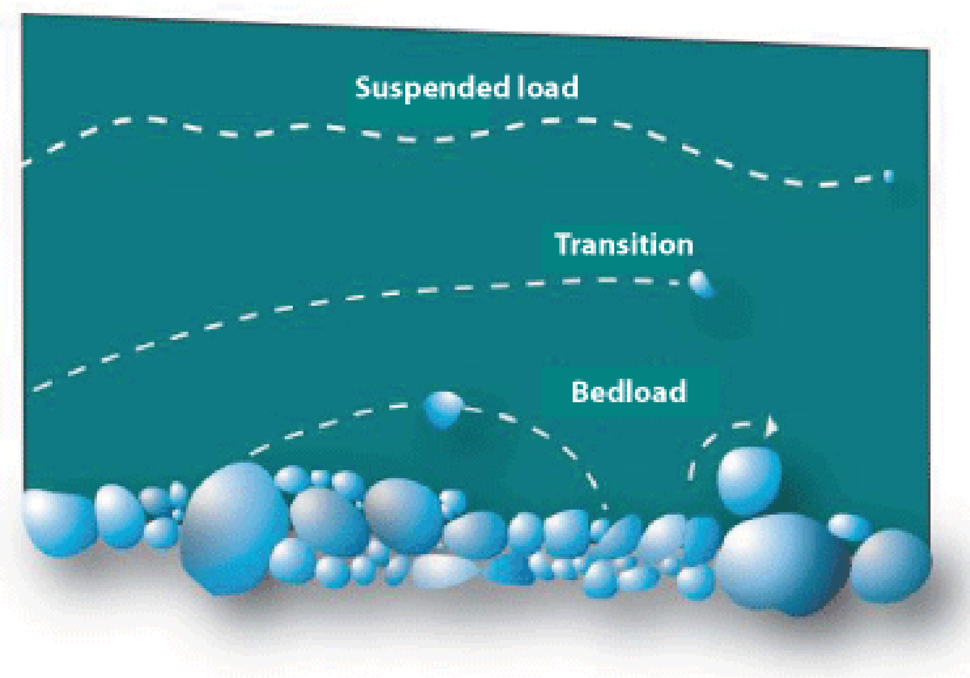
Surrogate technologies for suspended sand measurements

- Acoustic backscatter (gaugings and continuous measurements) -> Bjarne and Jérôme’s presentation
- Laser diffraction
- AOBS (mix of optical and acoustic)
- Pressure difference

Hydroacoustic station on the Isère River in Grenoble (2023)

LIST SL2 (USGS)

III. Bedload



© *Meunier*

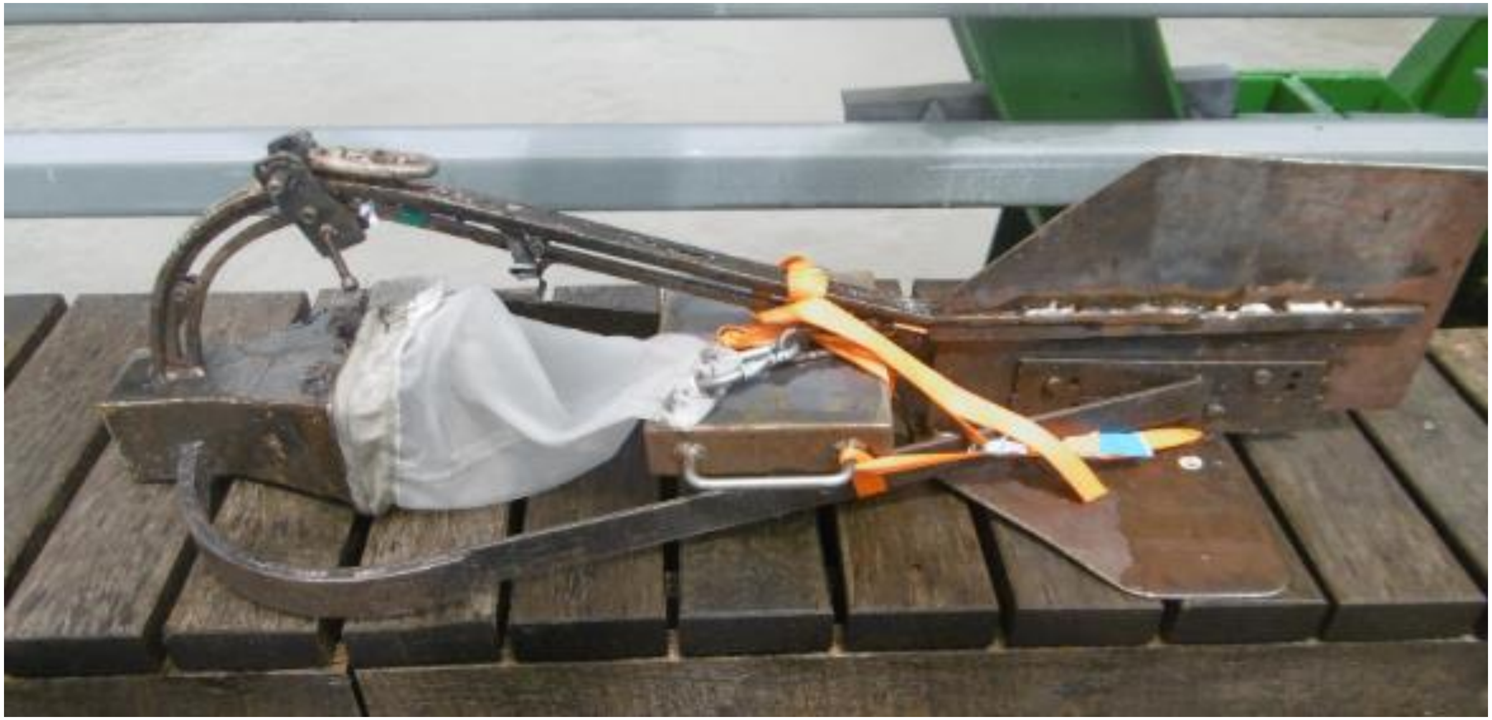
Ardèche river - Chauzon

- Some samplers
- Surrogate technologies
  - Sound (Hydrophones)
  - Bathymetry (dune tracking) -> Jérôme presentation

Bedload sampling

Helley-Smith sampler

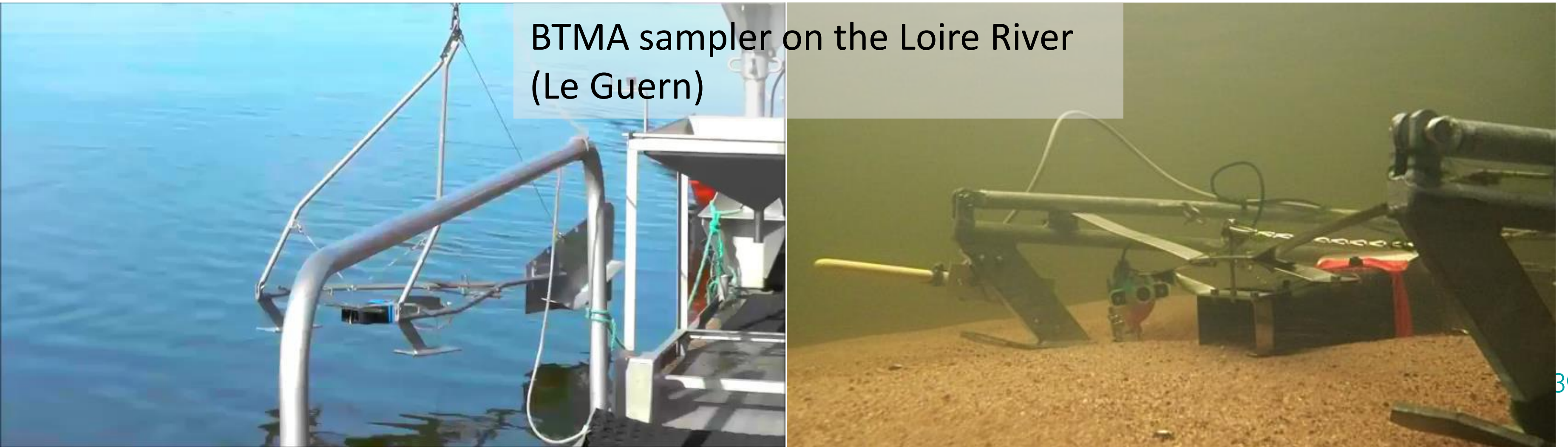
The sample is collected in a bag (mesh sizes 0,25 – 2mm)



Bedload sampling

Sampler in Fischbach (AT) Rickenmann et al. 2014

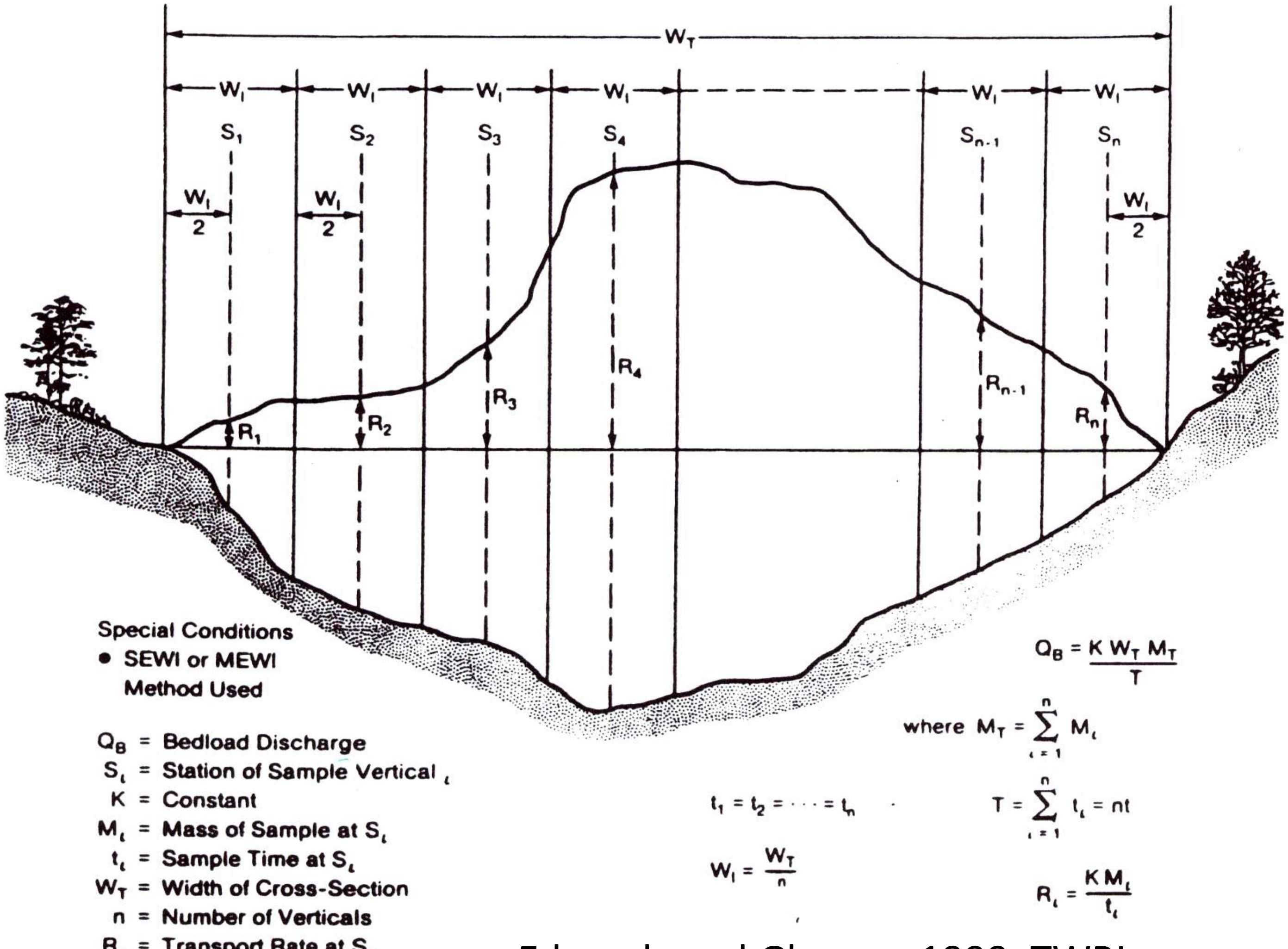
Ehrenberger sampler on the Danube River (Camenen et al. 2011)



BTMA sampler on the Loire River (Le Guern) https://water.usgs.gov/fisp/publications.html

Bedload sampling

Total cross-section method for computing bedload discharge from samples collected with a pressure-difference bedload sampler.

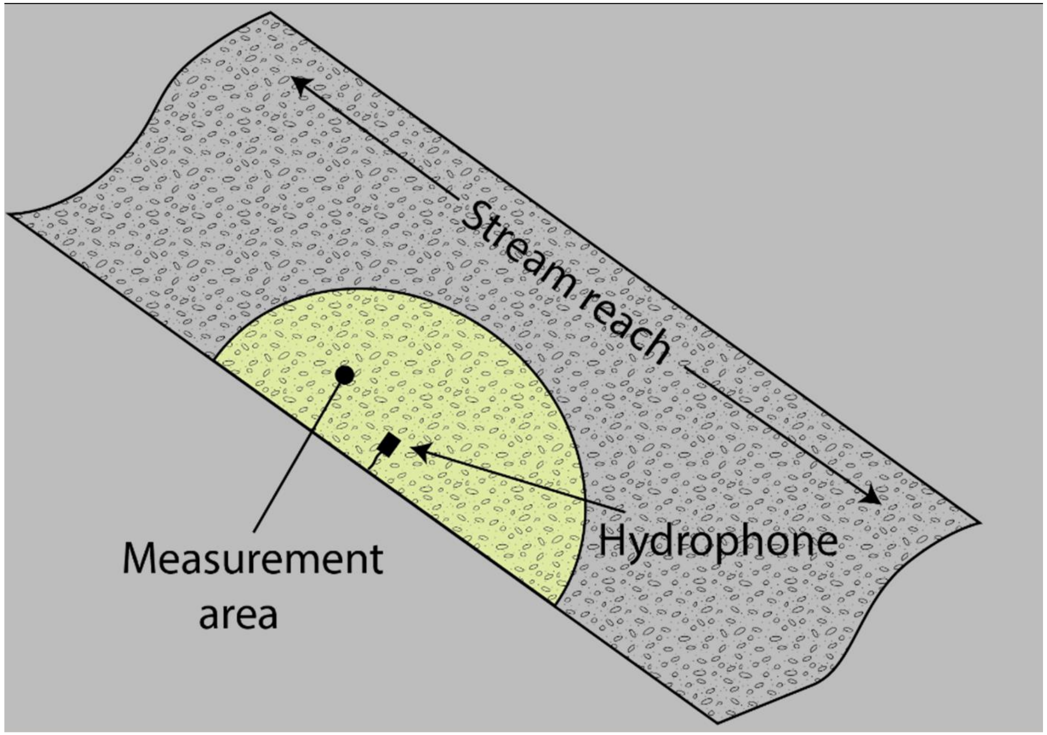


Edwards and Glysson, 1999, TWRI

Surrogate technologies for bedload measurements

Sediment-Generated Noise (SGN)

Principle SGN = The sound a particle emits when it hits another particle while in transport.

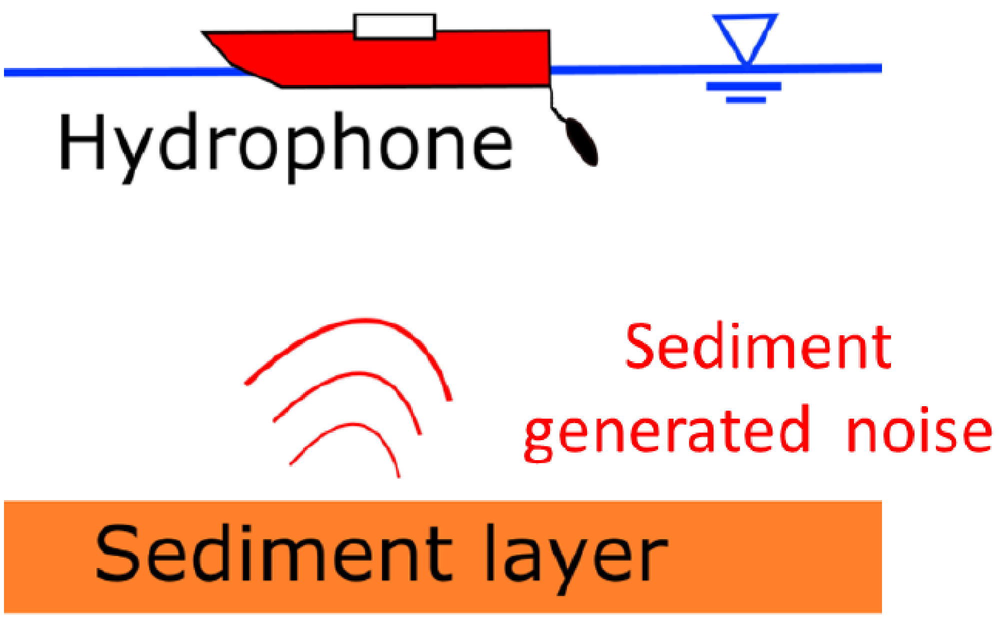


(Wren, Goodwiller, Rigby, from different US agencies, FISP)

Sediment-Generated Noise (SGN) for bedload measurements

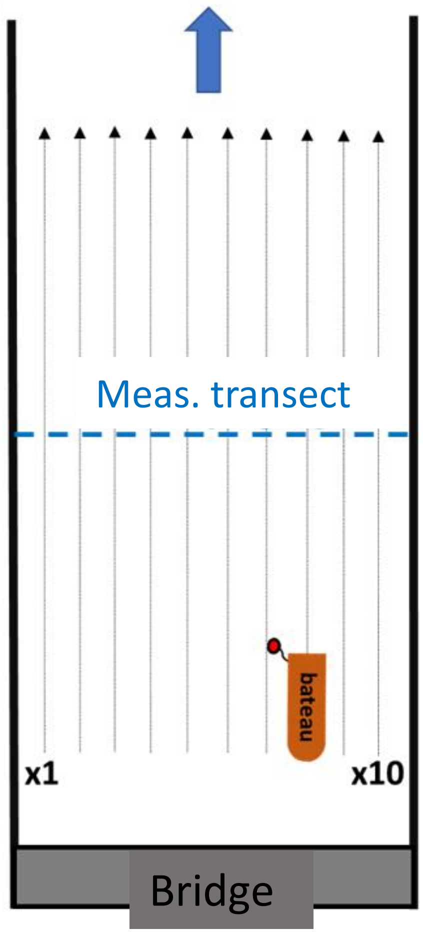
There are different applications such as (Hydrophones, geophones)

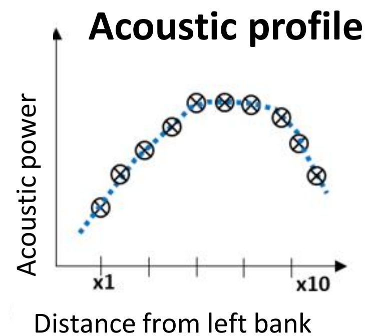
Passive Methods



Nasr, 2023

Hydrophone method (Jules Le Guern et al.)

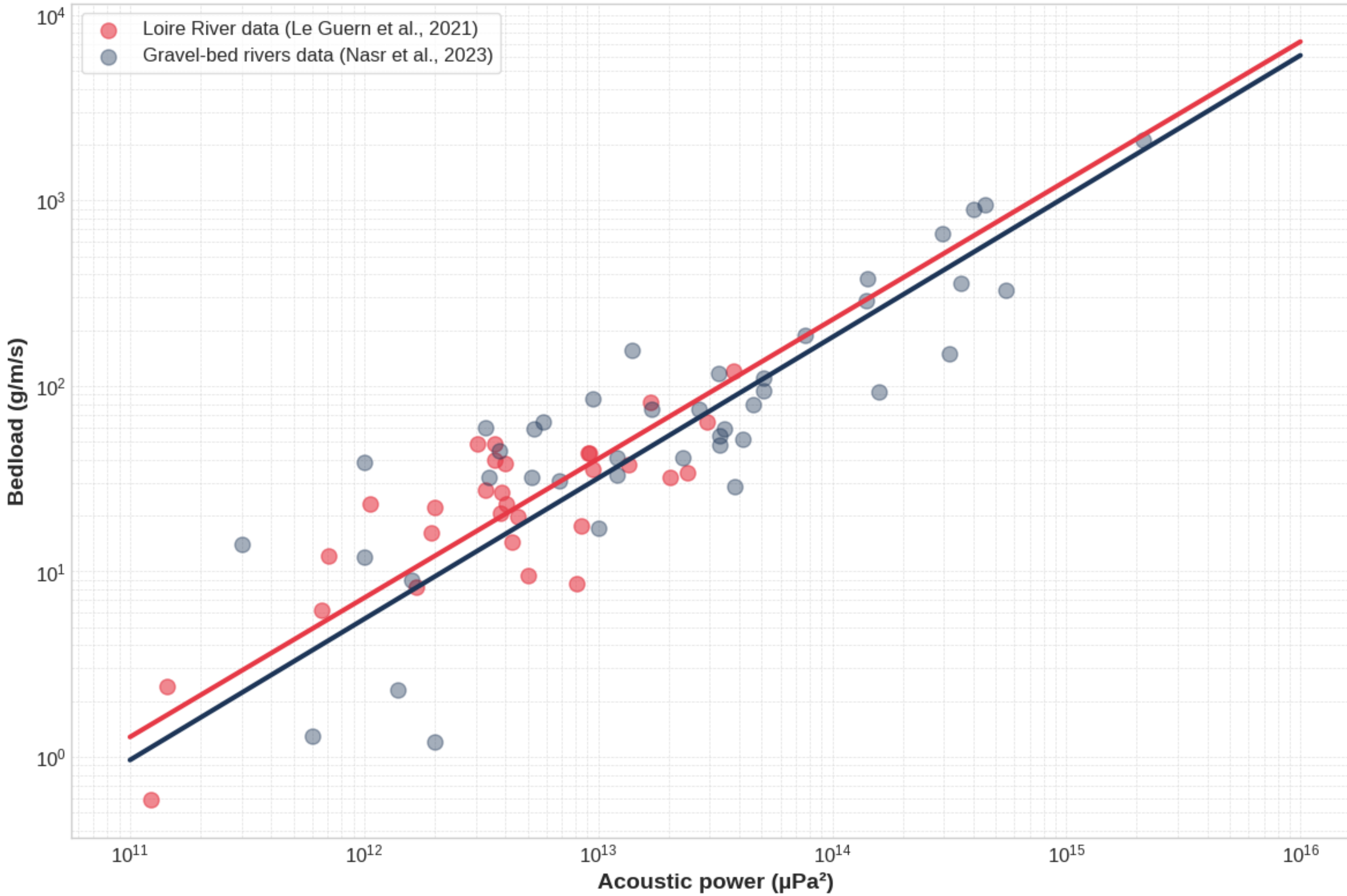




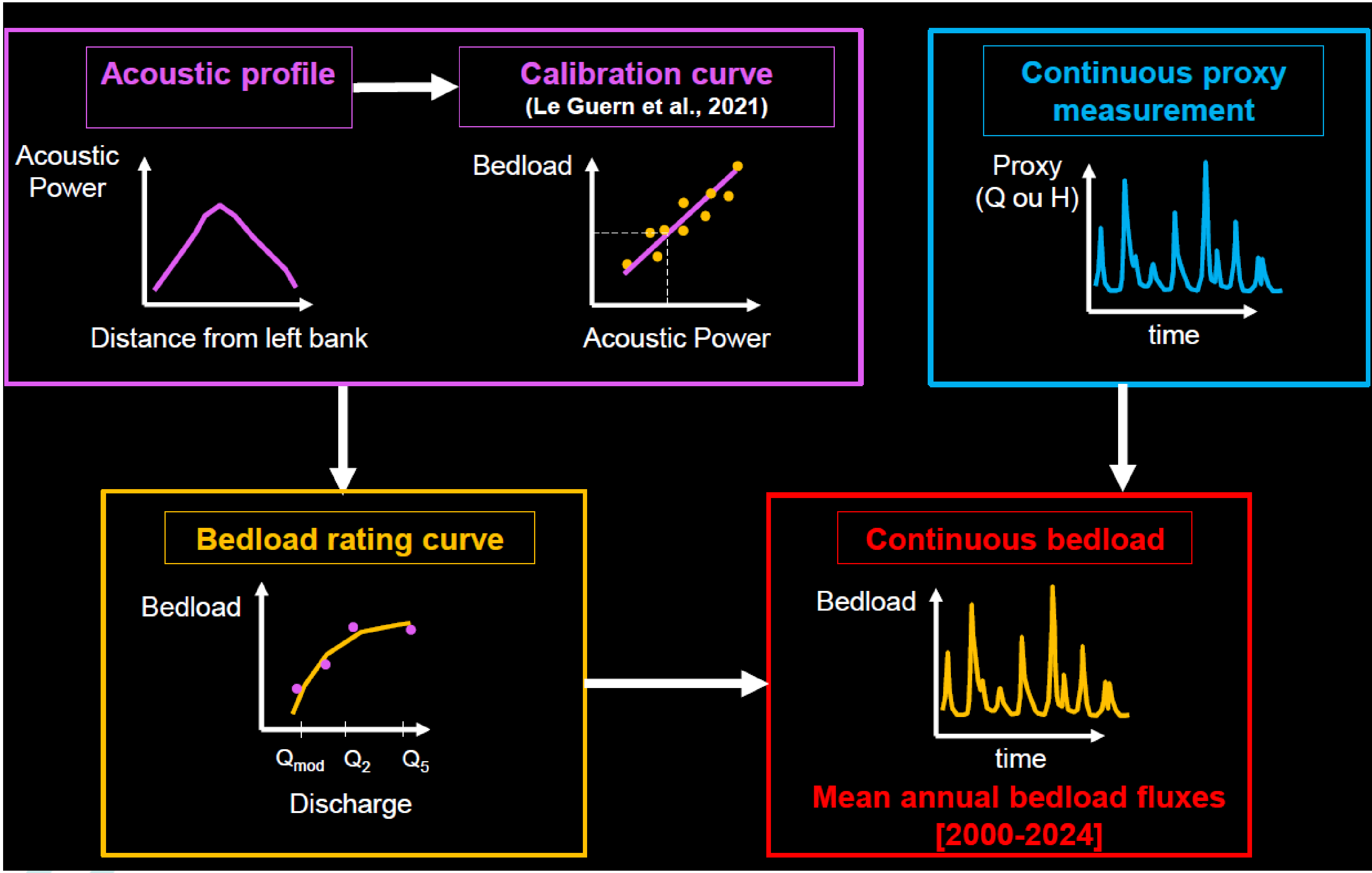
Hydrophones for Bedlooad measurements

Results in different rivers (slopes, d50, width)

Geay et al. (ESD, 2020), Le Guern et al. (ESD, 2021) & Nasr et al. (JHE, 2023)



Hydrophones- Processing the bedload



(Jules Le Guern et al.)

In-situ measurement for sediment transport requires :

- Expensive equipments (samplers, boats, samples storage capacity)
- Trained teams to sample and measure in good safety conditions

- After measurement there are a analysis to do
- Analysis validation
- Flux computing
- …

Laboratory analysis – Concentration

For sediment concentration from a bottle with water and sediment

- Filters preparation
- Sample volume measurement
- Separation of sand and fine by sieving
- Filtration on filters
- Drying in oven (104°C)
- Mass measurement with a laboratory scale

Laboratory analysis – Concentration

Measurement of the volume

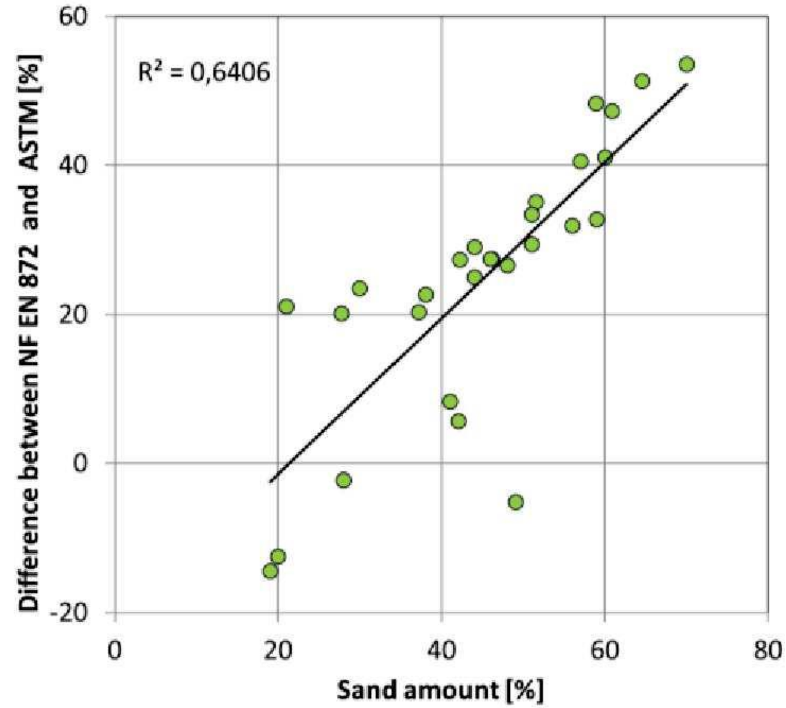
Analysis costs could be important ! (equipments, time)

Filtration on filters

Mass measurement with a laboratory scale

Laboratory analysis – Concentration

The separation of sand and fine by sieving is mandatory for good analysis



If we don't do the sieving, the error in conc. Is increasing with the amount of suspended sand

Comparison of standardized methods for suspended solid concentration measurements in river samples (Dramais et al. 2018, River Flow)

Laboratory analysis – Grain size distribution

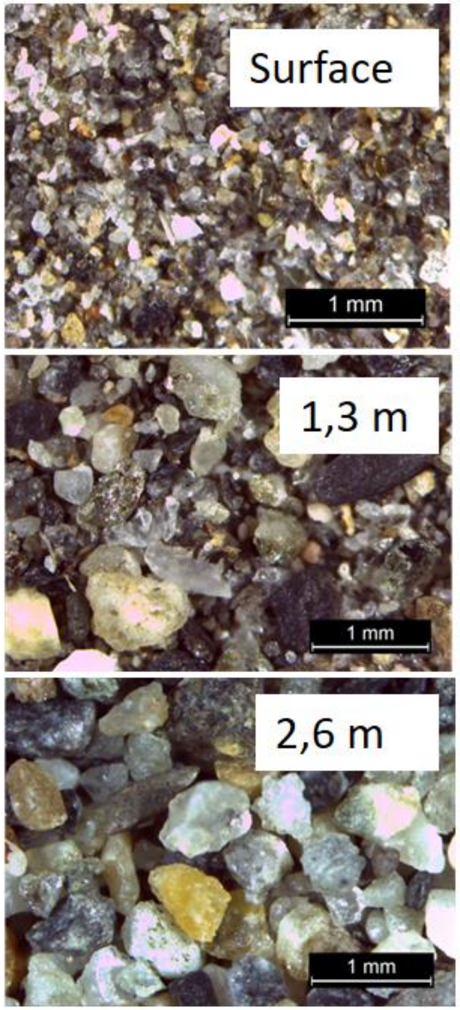
Lazer grainsizer for small fine samples (particles < 2mm) (Malvern Mastersizer 3000)

Manual sorting by size

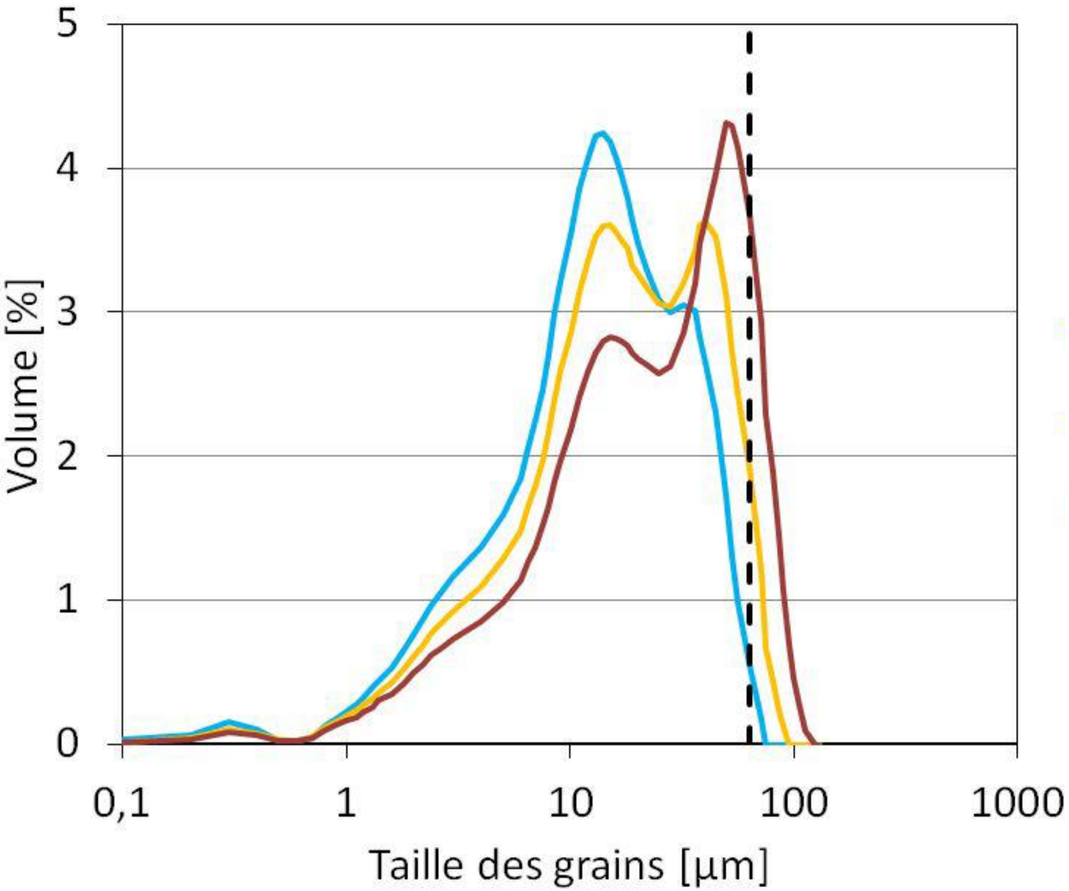
Laible, J., Camenen, B., Le Coz, J. *et al.* Comparison of grain size distributic of sand-silt mixtures using laser diffraction systems. *J Soils Sediments* **23**, 2310–2325 (2023).

Mixing effect

One example of grain size distribution on the vertical



Suspended sand from the Rhône (2016)



Grain size distribution from a laser diffraction system

Data Base example – OSR Data base

https://bdoh.inrae.fr/

INRAE

English

Observatories

“ Base de Données des Observatoires en Hydrologie ”

- Presentation
- Arc-Isère
- Draix
- Guyane
- Haute Loire
- Lônes de l'Ain
- Observatoire des Sédiments du Rhône
- OHM-CV
- Oracle
- Real Collobrier
- Site Atelier Ardières-Morcille
- TPG
- Yzeron

Observatoire des Sédiments du Rhône

The Rhône Sediment Observatory (OSR) was established in 2009 to address issues that had emerged in the integrated project Plan Rhône. Over the 500 km-long Rhône river from Lake Geneva to the Mediterranean Sea, the Observatory aims at producing, collecting and managing data for documenting stocks and fluxes of sediments and the associated contamination.

OSR is a project funded by the Plan Rhône and several partners, and supported by the European Fund for Regional Development research program. It is a research platform that combines scientists (CNRS, Irstea, ENTPE, IRSN, Ifremer) and the main managers of the river (governmental authorities, water agency, CNR, EDF and the regional councils of Auvergne Rhône-Alpes, Provence-Alpes-Côte d'Azur and Occitanie). It is one of the observatories of the Rhône catchment research community (ZABR).

To cite these data you may refer to the following DOIs:

- Thollet, F.; Le Bescond, C.; Lagouy, M.; Gruat A.; Grisot, G.; Le Coz, J.; Coquery, M.; Lepage, H.; Gairoard, S.; Gattacceca, J.C.; Ambrosi, J.-P.; Radakovitch, O., Dur, G., Richard, L., Giner, F., Eyrolle, F., Angot, H., Mourier, D., Bonnefoy, A., Dugué, V., Launay, M., Troudet, L., Labille, J., Kieffer, L. (2021): Rhône Sediment Observatory (OSR); INRAE. https://dx.doi.org/10.17180/OBS.OSR
- Lepage, H.; Gruat, A.; Thollet F.; Le Coz, J.; Coquery, M.; Masson, M.; Dabrin, A.; Radakovitch, O.; Eyrolle, F.; Labille, J.; Ambrosi J.P.; Delanghe, D.; Raimbault, P., 2021. Concentrations and fluxes of suspended particulate matters and associated contaminants in the Rhône River from Lake Geneva to the Mediterranean Sea" https://dx.doi.org/https://doi.org/10.15454/RJCQZ7

OSR
Observatoire des Sédiments du Rhône

Go to the observatory

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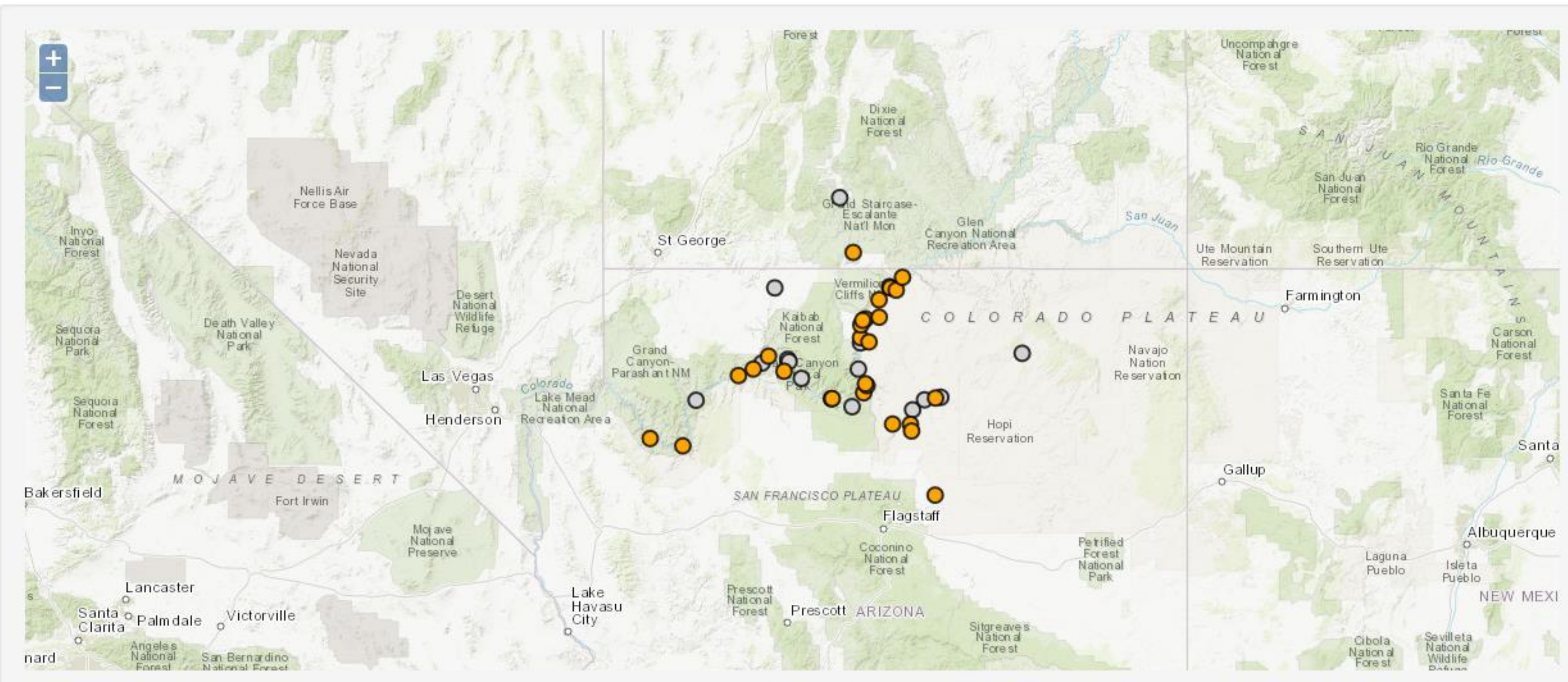
Data Base example – GCMRC Data base

https://www.gcmrc.gov/discharge_qw_sediment/stations/GCDAMP

Grand Canyon Monitoring and Research Center

Grand Canyon Stations

Home > Discharge, Sediment and Water Quality > Grand Canyon Stations



Questions ?

- You have already some good instruments