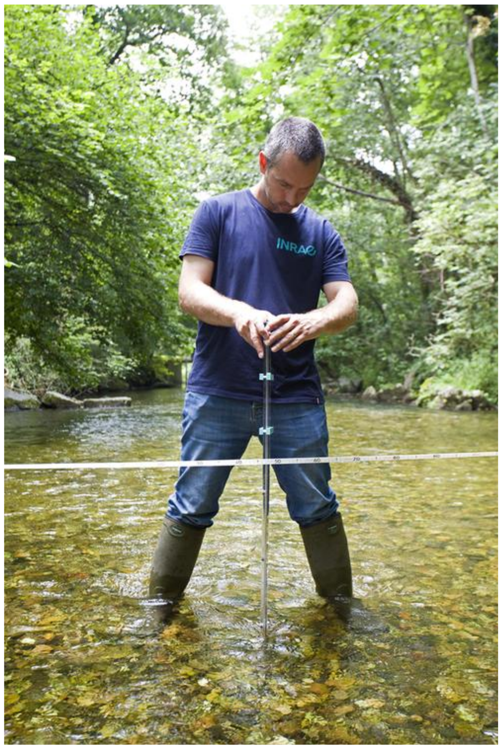
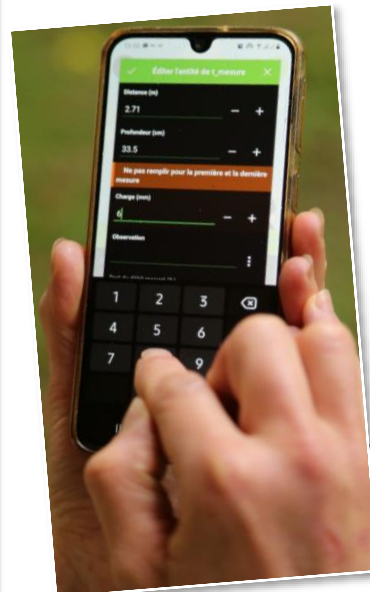
Webinar
28 March 2025

INRAE streamgauging rulers: news and feedback





ràj

Jérôme Le Coz[1], Mickaël Lagouy[1], Cédric Gouineau[2], Adrien Vergne[3]

1 INRAE

2 cater CALVADOS ORNE MANCHE

3 PRÉFET DE LA RÉGION BRETAGNE
Liberté
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DREAL Bretagne
Direction régionale de l'environnement, de l'aménagement et du logement

INRAE streamgauging rulers: news and feedback

INRAE

RiverLy

River hydraulics

RiverLy research unit
River Hydraulics group
INRAE (Lyon, France)

cater CALVADOS ORNE MANCHE

Technical Coordination Unit
for Water and Rivers
Calvados Orne Manche (Normandy, France)

Calvados LE DÉPARTEMENT

Orne LE DÉPARTEMENT

14-50-61 FÉDÉRATIONS DÉPARTEMENTALES PÊCHE

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LA MANCHE LE DÉPARTEMENT

RÉPUBLIQUE FRANÇAISE eau seine NORMANDIE

RÉPUBLIQUE FRANÇAISE agence de l'eau Loire-Bretagne

Regional office (Brittany) of the
national hydrological service
(Rennes, France)

HydroPortail

VIGICRUES

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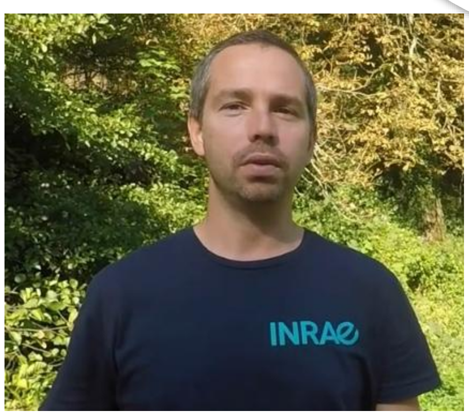
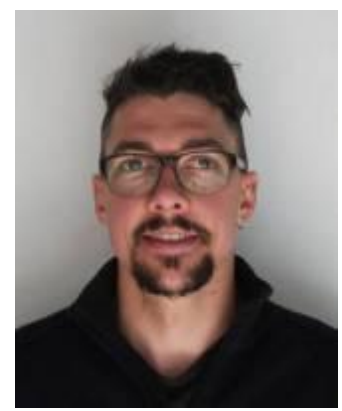
Jérôme Le Coz



Mickaël Lagouy

Cédric Gouineau



Adrien Vergne

Contents of this presentation

1. The INRAE streamgauging ruler
2. Smartphone tool Qràj (CATER COM)
3. Example of a hydrological service / river board partnership

One instrument, different names...

- **règle à jauger**
- réglette
- règle à Jéjé *(INRAE Lyon)*
- **streamgauging ruler**

- transparent rod
- transparent velocity-head rod
- stream velocity board *(Robin Pike, Canada)*

- Le Stick *(University of Dundee, Scotland*)
- bathroom-break rod *(DREAL Nouvelle-Aquitaine, France)*
- plastic-made Bernoulli *(Alex Hauet, France)*

What do we want to measure?

Streamflow, or **discharge**:
the volume of water passing through the cross-section during a unit of time

$$\text{Discharge } Q = \frac{\text{Volume}}{\text{Time}}$$

Units:

- m^3/s
- L/s

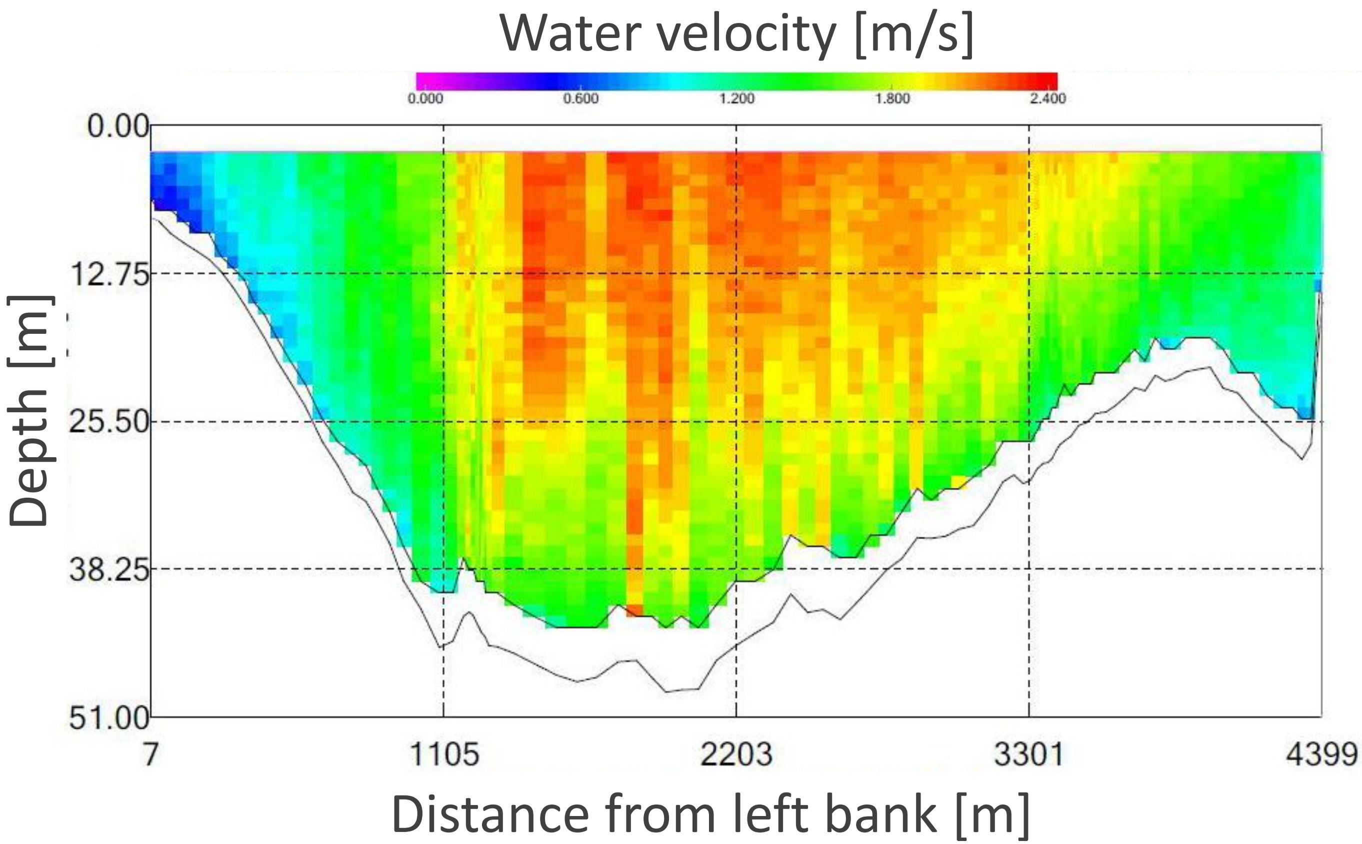
What do we want to measure?

Streamflow, or **discharge**: the volume of water passing through the cross-section during a unit of time

$$Q = \text{Velocity} \times \text{Area}$$

m/s m²

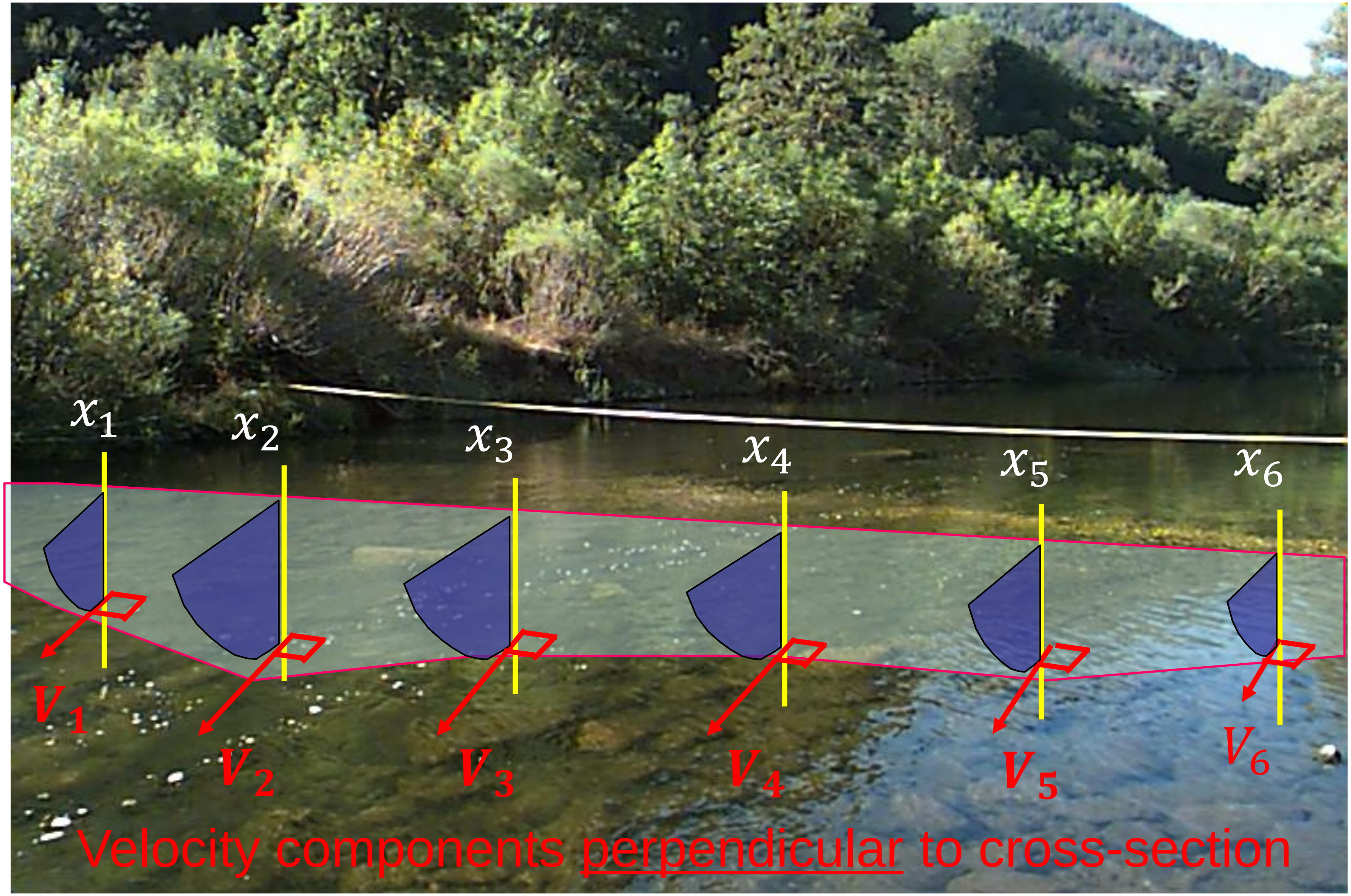
m³/s



Measured cross-section of the Amazon River at Itacoatiara, Brazil (220 000 m^3/s)

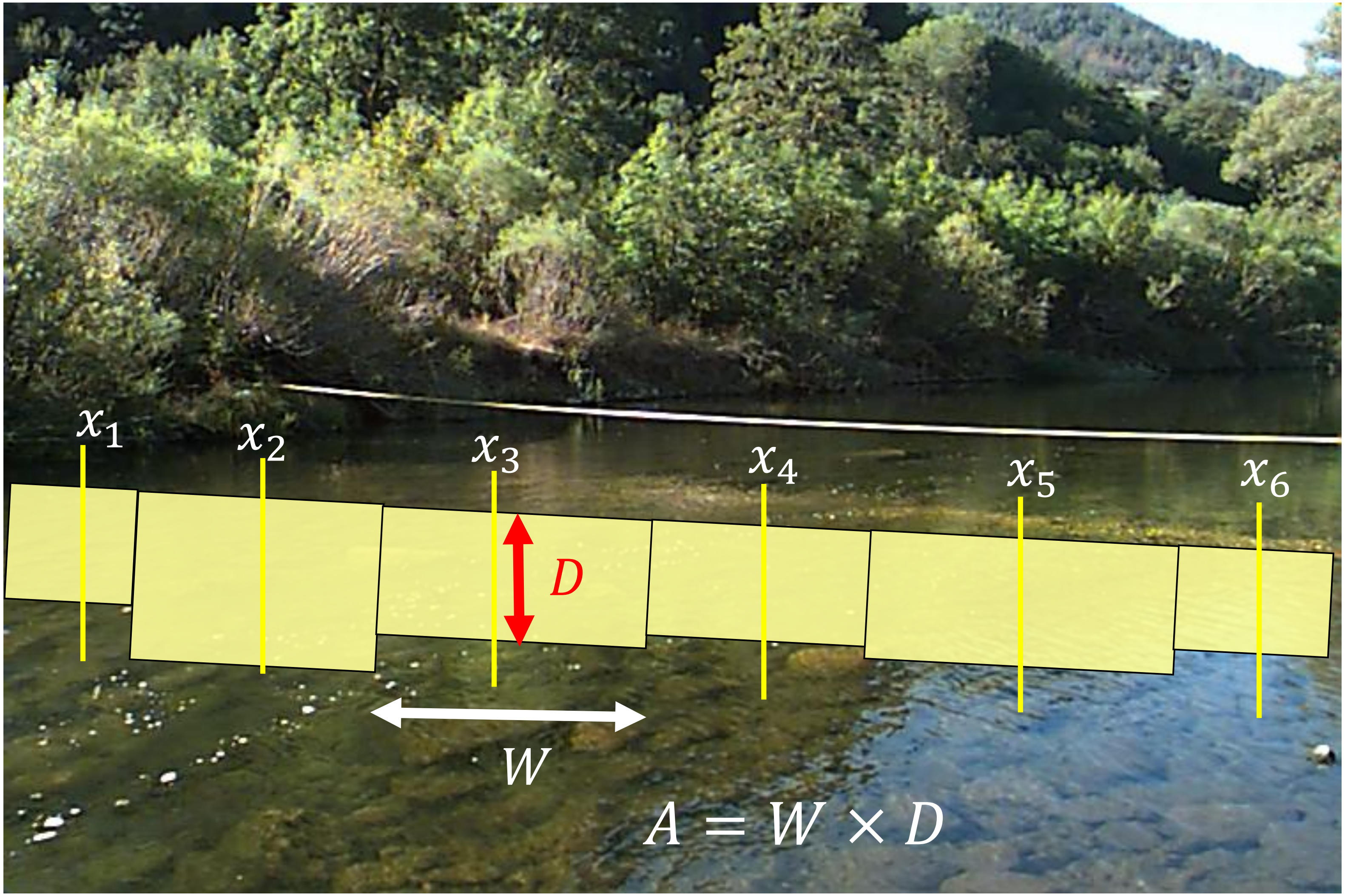
Mid-section discharge measurements

Measuring depth-average velocities on verticals



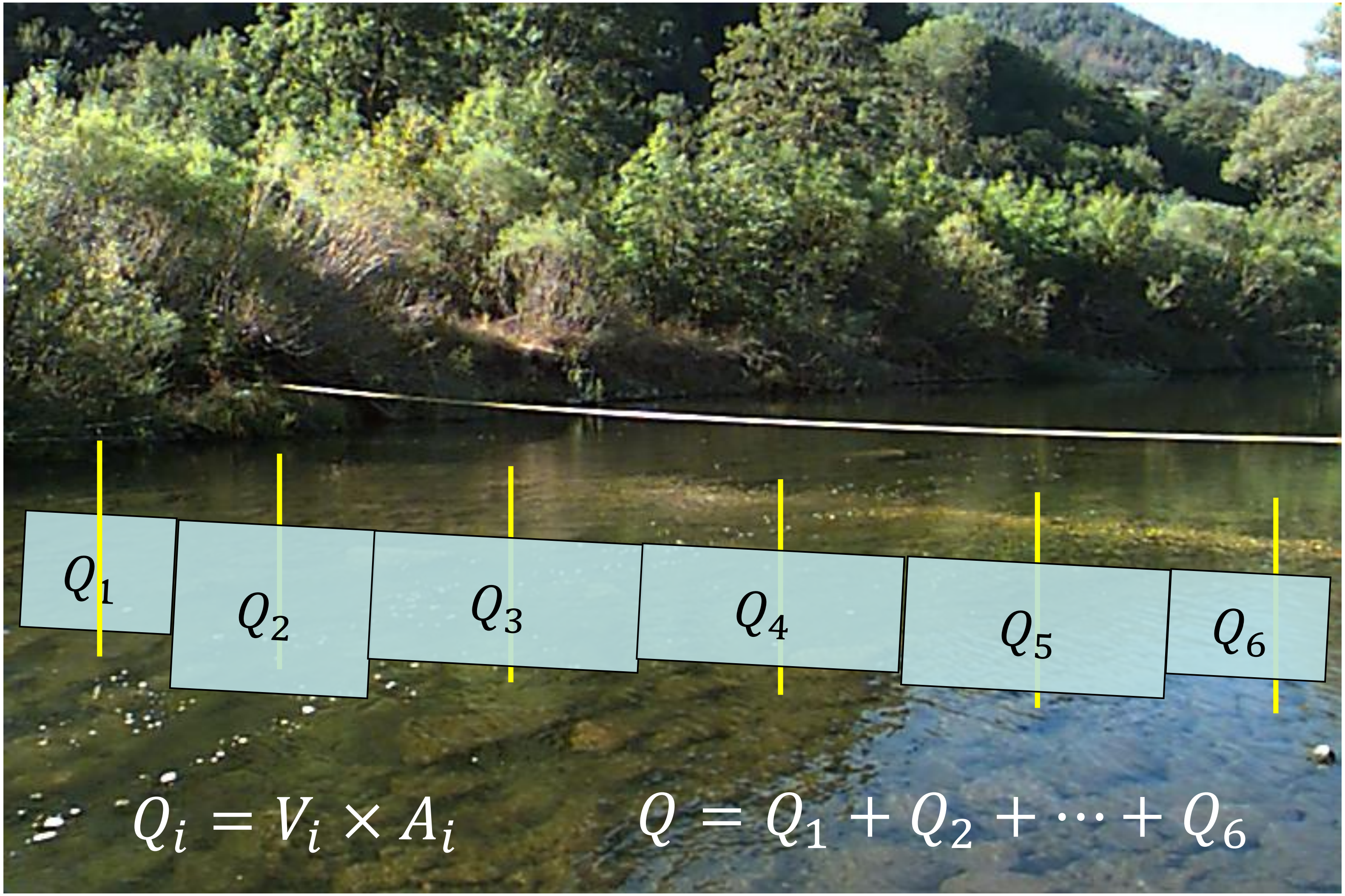
Mid-section discharge measurements

Assign wetted areas (of rectangular panels) to velocities



Mid-section discharge measurements

Compute partial discharges (panels), then take the sum



Mid-section discharge measurements

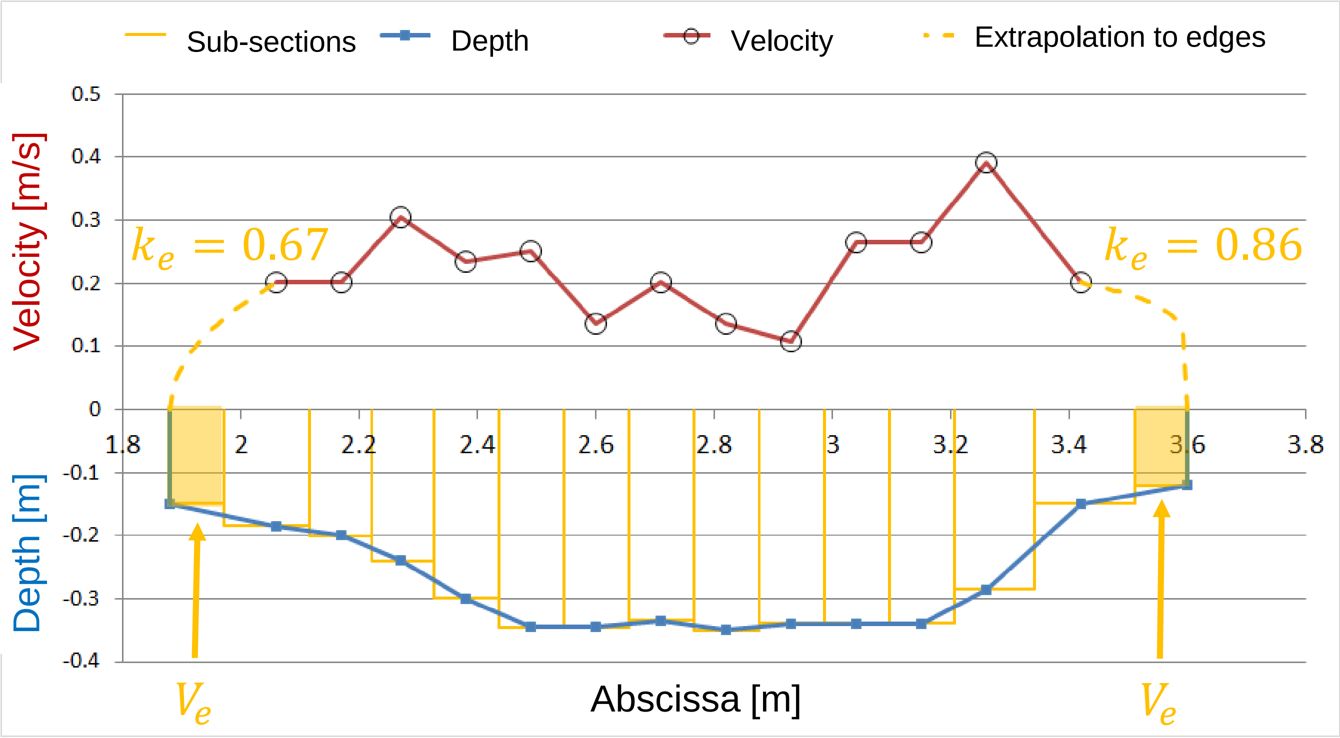
Special case of near-edge panels

The near-edge velocity profile is extrapolated using an **edge coefficient k_e**.

Typical values for k_e:

- 0.67 (natural sloping bank)
- 0.91 (smooth vertical wall, concrete)
- 0.86 (intermediate situations)

No velocity measurement at the edge!
(Abscissa and depth only)



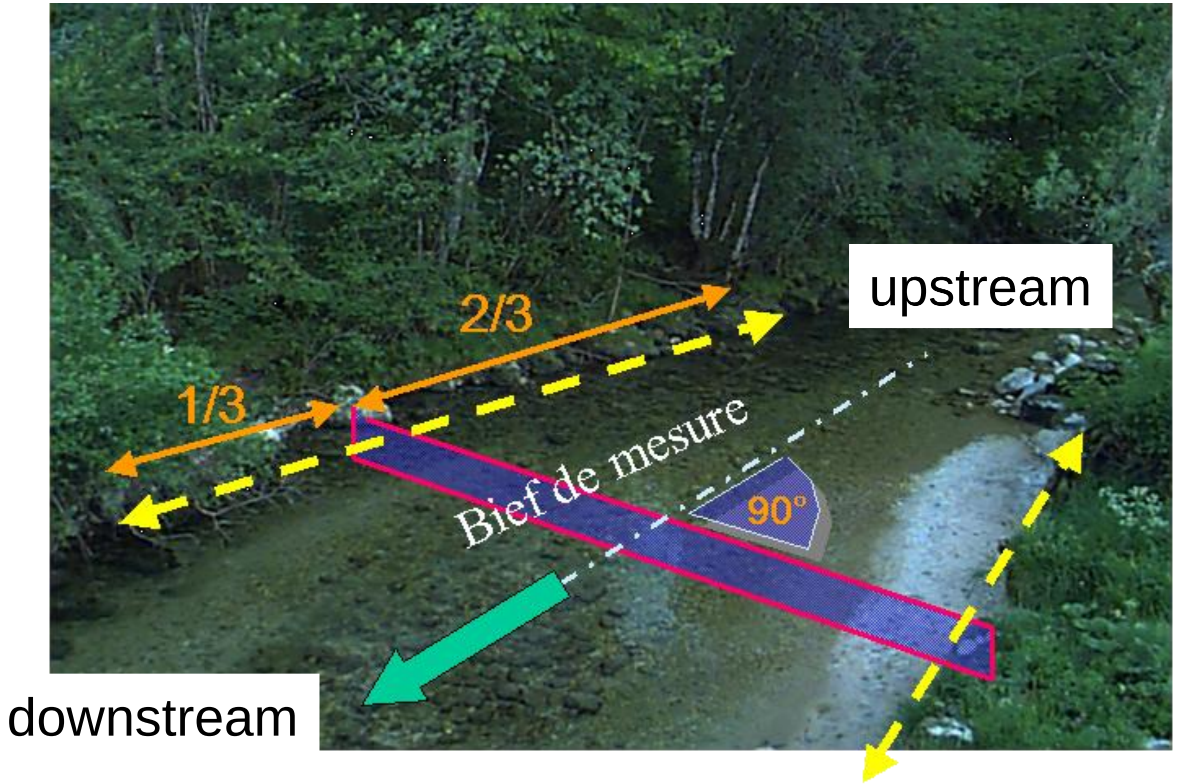
The velocity V_e assigned to the edge sub-section depends on the velocity V_{measured} measured at the nearest vertical:

$$V_e = (2\,k_e - 1)\,V_{\text{measured}}$$

Mid-section discharge measurements

Main steps in the field :

1. Choosing the measurement site, setting it up if necessary



Mid-section discharge measurements

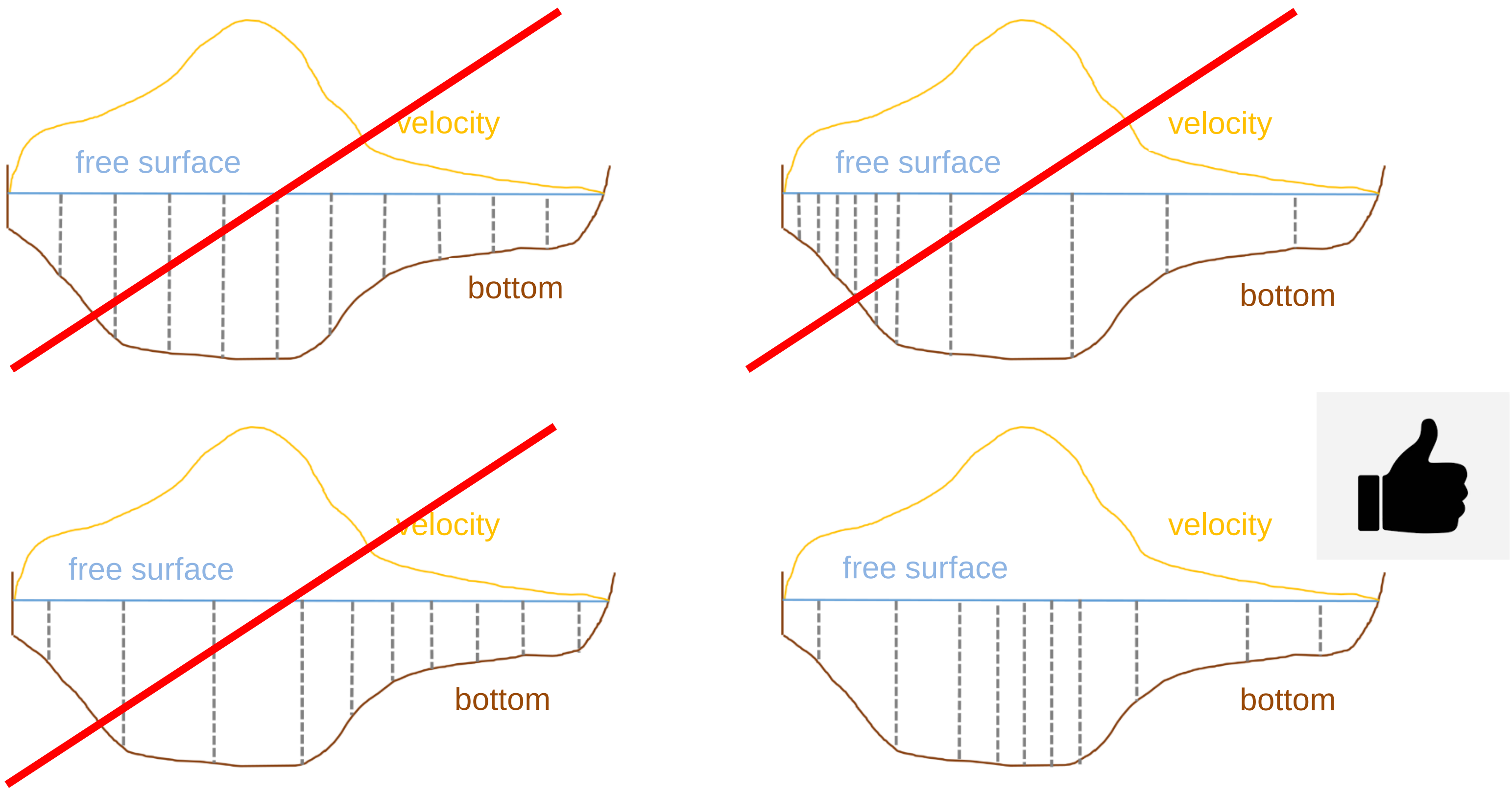
Main steps in the field :

1. Choosing the measurement site, setting it up if necessary
2. Set up the tagline, explore the measurement cross-section

Mid-section discharge measurements

Main steps in the field :

1. Choosing the measurement site, setting it up if necessary
2. Set up the tagline, explore the measurement cross-section
3. Plan the positioning of the verticals



Mid-section discharge measurements

Main steps in the field :

1. Choosing the measurement site, setting it up if necessary
2. Set up the tagline, explore the measurement cross-section
3. Plan the positioning of the verticals
4. Measure the initial water level

Staff gauge (station)
Temporary ruler
Any vertical reference

Date-time and time zone

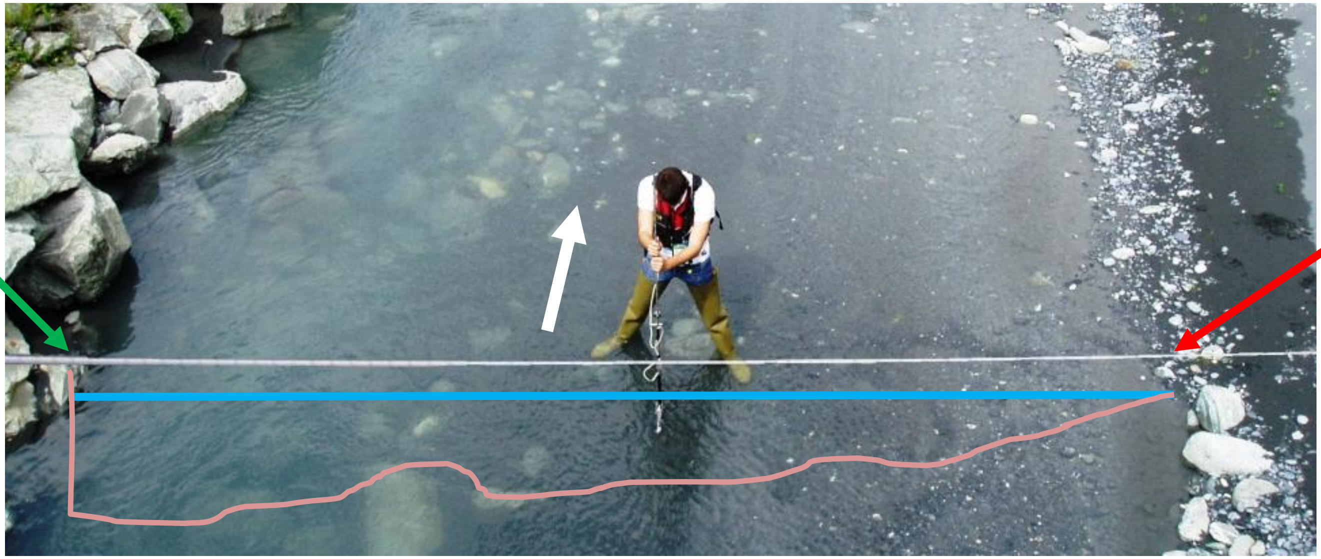
Mid-section discharge measurements

Main steps in the field :

1. Choosing the measurement site, setting it up if necessary
2. Set up the tagline, explore the measurement cross-section
3. Plan the positioning of the verticals
4. Measure the initial water level
5. Measure the starting bank: abscissa, depth, type

x_{left}

x_{right}



$D_{\text{left}} > 0$
vertical, smooth

$D_{\text{right}} = 0$
sloped, natural

Mid-section discharge measurements

Main steps in the field :

1. Choosing the measurement site, setting it up if necessary
2. Set up the tagline, explore the measurement cross-section
3. Plan the positioning of the verticals
4. Measure the initial water level
5. Measure the starting bank: abscissa, depth, type
6. Measure each vertical: abscissa, depth, velocity

Abscissa x (position read on tagline)

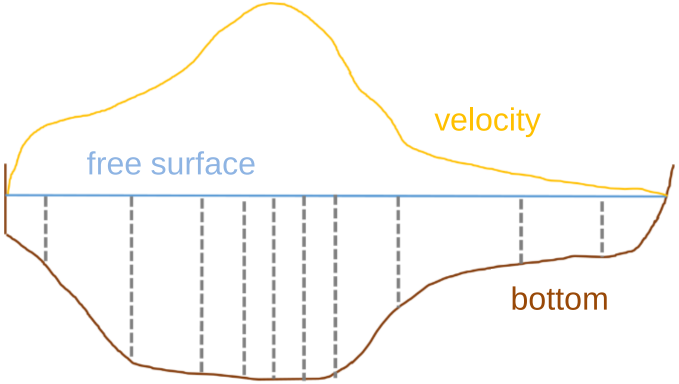
Velocity V (currentmeter aligned perpendicular to the tagline)

Depth P (graduated rod, pressure gauge)

Mid-section discharge measurements

Main steps in the field :

1. Choosing the measurement site, setting it up if necessary
2. Set up the tagline, explore the measurement cross-section
3. Plan the positioning of the verticals
4. Measure the initial water level
5. Measure the starting bank: abscissa, depth, type
6. Measure each vertical: abscissa, depth, velocity
7. Measure the arrival bank: abscissa, depth, type
8. Read the end water level

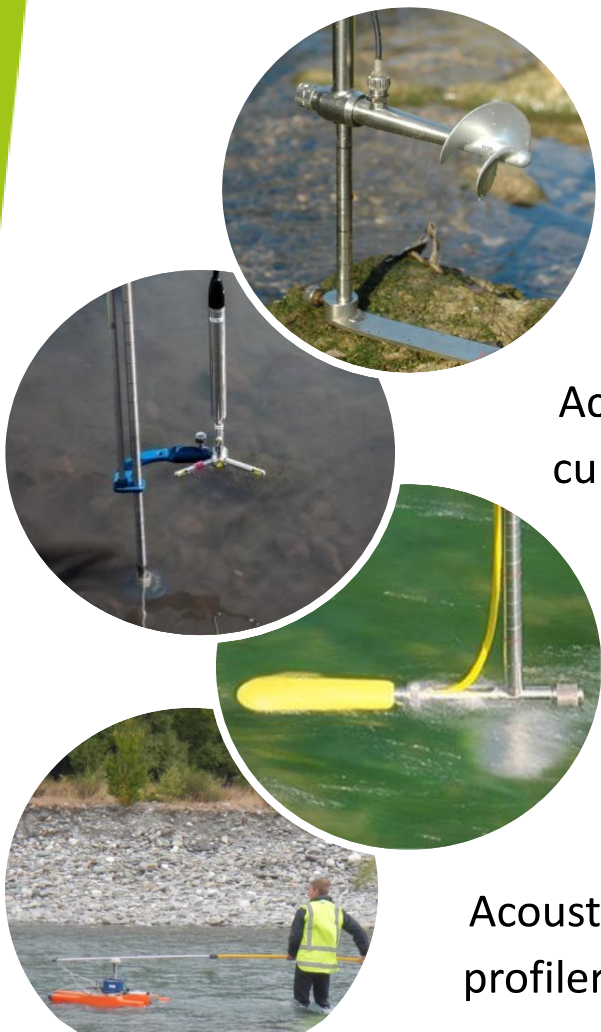


Discharge measurement

Low-cost and low-tech streamgauging

Velocity measuring instruments for wading streamgauging: cost

€5,000 - €30,000

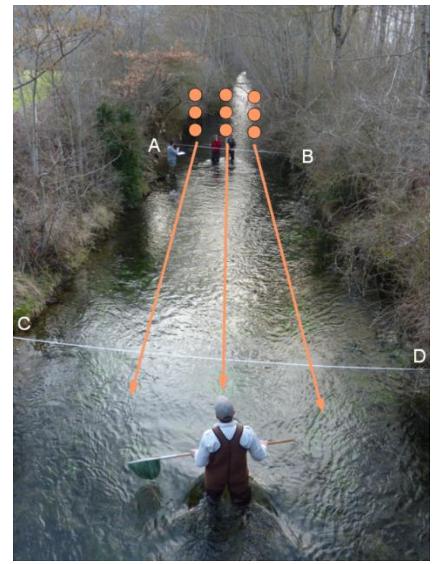


Mechanical currentmeters (propeller)

Acoustic Doppler currentmeters (ADC, ADV)

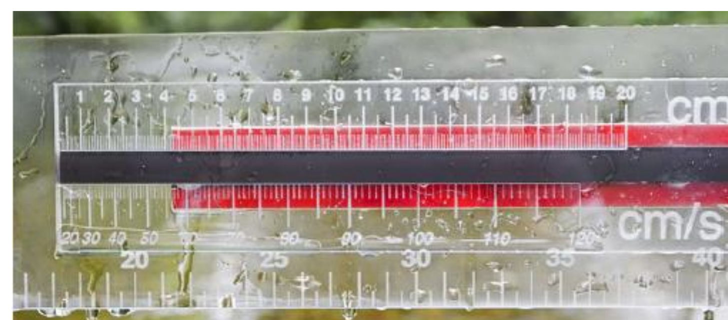
Electromagnetic currentmeters

Acoustic Doppler profilers (ADCP)



Méthode du flotteur

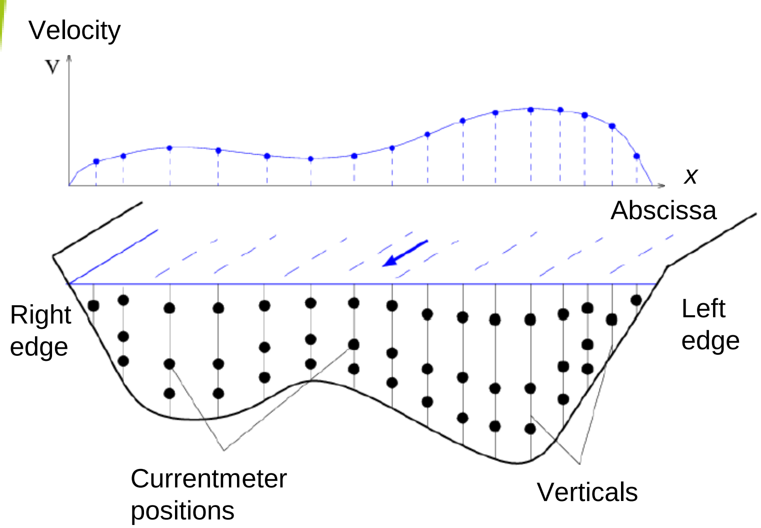
< €50



Streamgauging ruler ~ €200

Low-cost and low-tech streamgauging

Velocity measuring instruments for wading streamgauging: complexity



Currentmeters

- 1 to 3 velocity points per vertical
- 30 to 40 s exposure time per point

Profilers (ADCP)

- Touchy deployment
- Complex measurement process
- Post-processing of results (QRevInt software)

Streamgauging rulers

- Simple deployment
- Direct measurement of the depth-averaged velocity

Velocity-head rods

existed long before us…

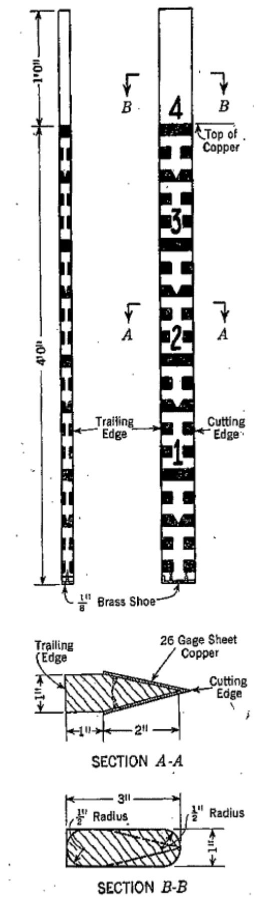
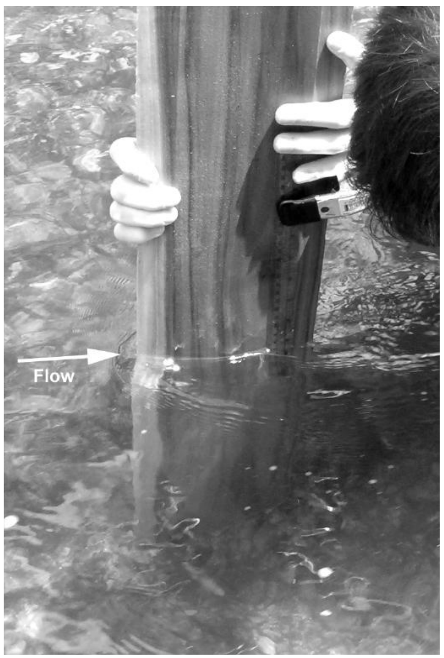
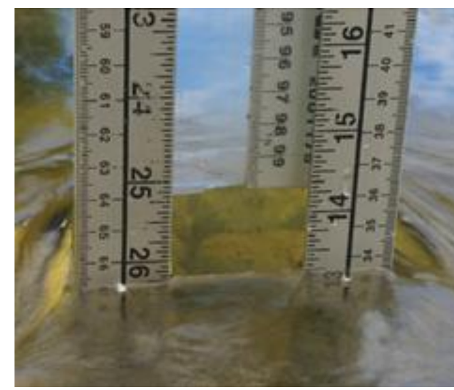


Fig. 1. Velocity-Head Rod Developed at San Dimas Experimental Forest



Wilm and Storey (1944)

Drost (1963)



Fonstad et al. (2005)
1st empirical rating

Pike et al. (2016)
2nd empirical rating

Velocity measurement principle

Against the obstacle, the kinetic energy of the flow is transformed into potential energy.

The hydraulic head is :

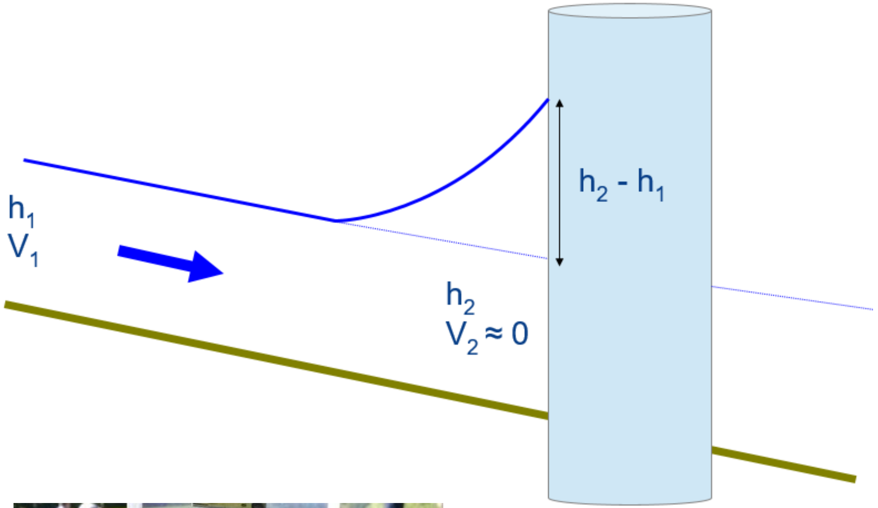
$$H = h_1 + \frac{V_1^2}{2g} = h_2$$

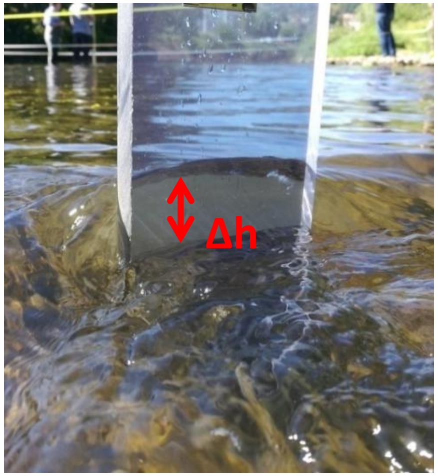
Hence:

$$V_1 = \sqrt{2g\,\Delta h}$$

With $g = 9.81\ \mathrm{m/s^2}$ (gravity)

$$\Delta h = h_2 - h_1$$





In theory…

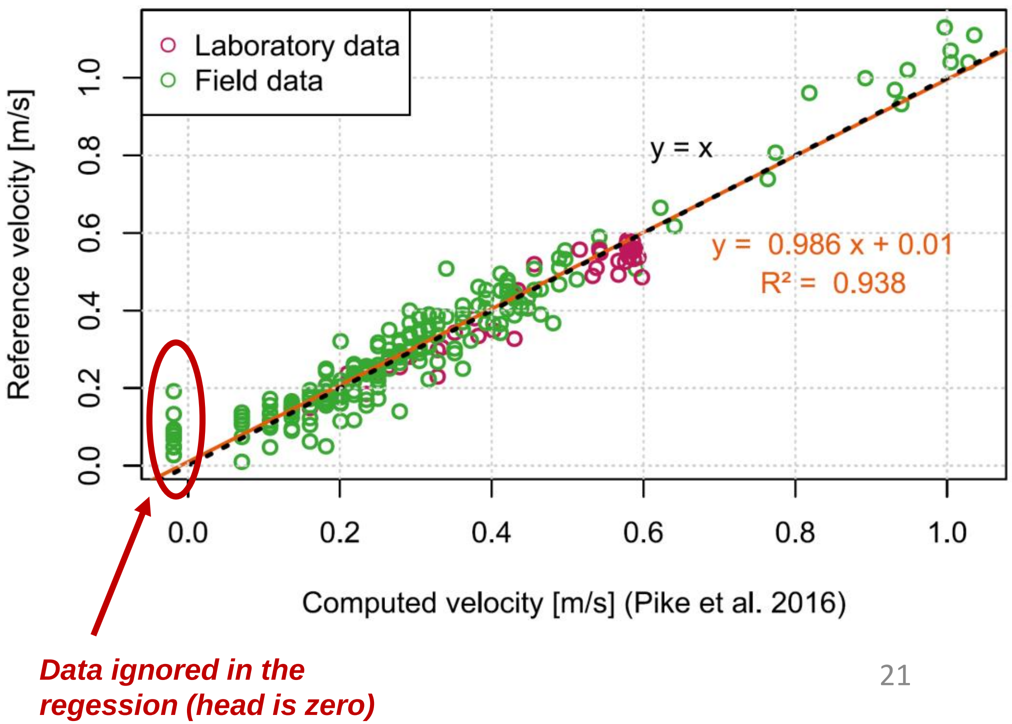
In practice, a correction is necessary

Velocity measurement principle

Depth: 5-70 cm
Velocity: 20-120 cm/s
Ruler set on the bed

Our field and lab data confirm the relation between depth–averaged velocity V and velocity–head Δh proposed by Pike et al. (2016) :

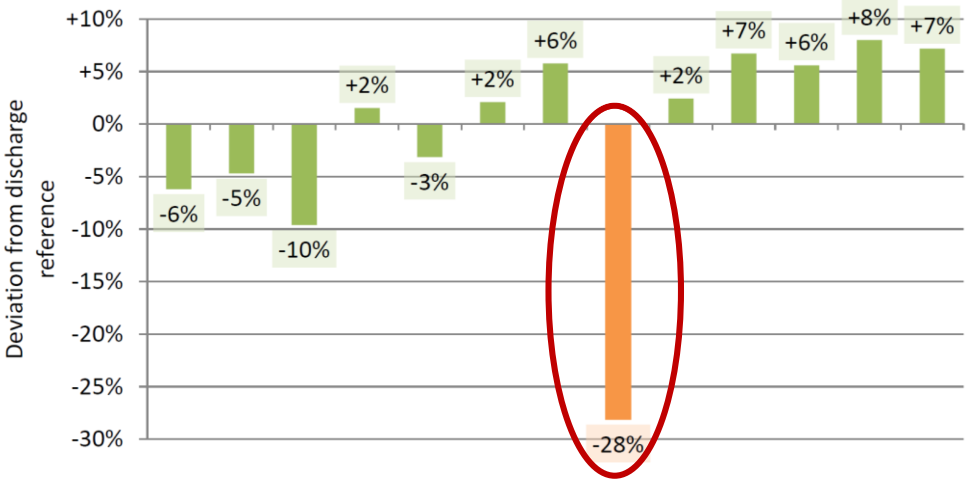
$$V = 0.641\sqrt{2g\,\Delta h} - 0.019$$



Development of the INRAE streamgauging ruler

- Validation of the velocity rating and the discharge measurements
- Practical improvements: spirit level, velocity ruler, magnet mounting, etc.
- Estimation of measurement uncertainties
- Field procedure and calculation sheet for velocity and discharge

The model is open-source. It is produced and marketed by AAIS (Sassenage, France).

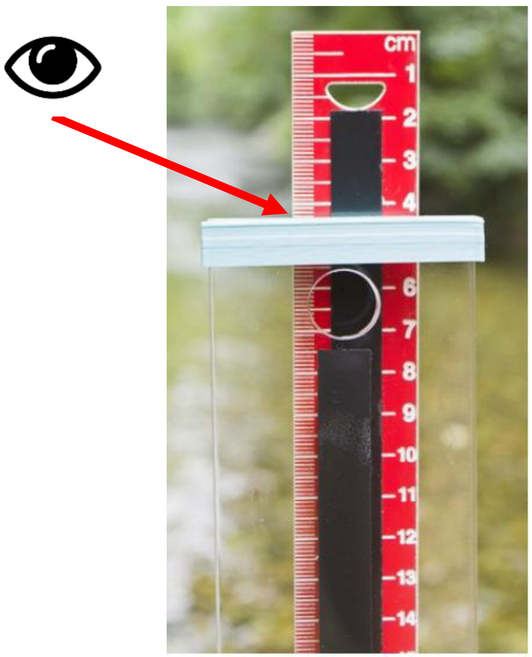


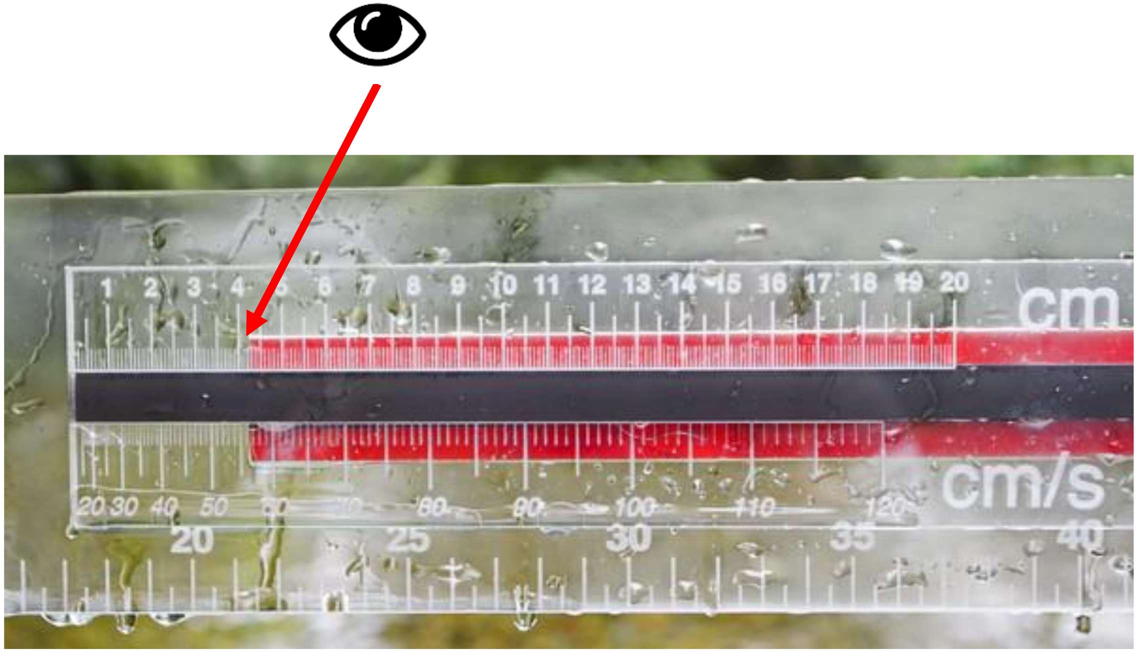
Discharge comparisons gathered during Francis Pernot's internship (2018)

Flow was too slow!
Velocity < 20 cm/s

INRAE streamgauging ruler: recent evolutions

With the new upstream ruler (and a cursor to be inserted on the downstream ruler), it is possible to read the velocity-head, head-up and without parallax.





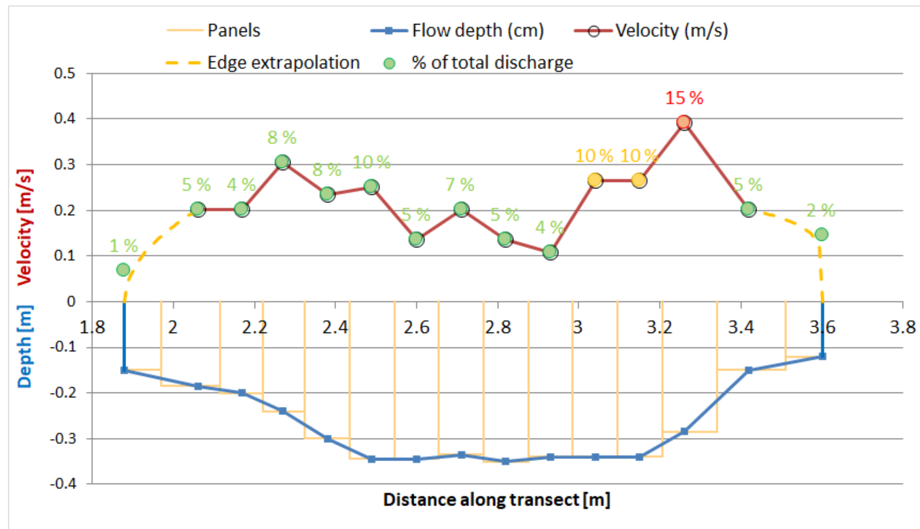
Check the agreement with the velocity-head read at the bottom, and check the precise length of the red ruler (1 m).

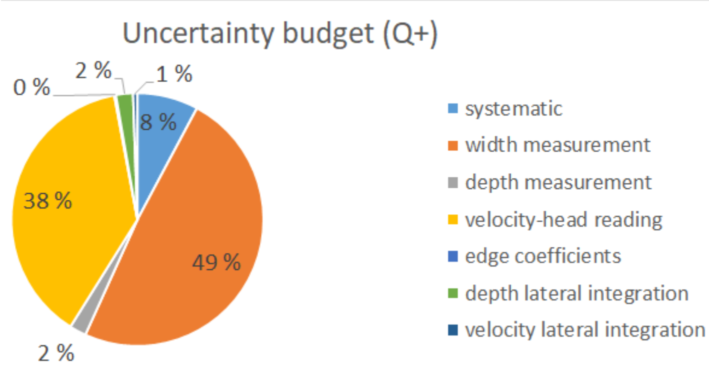
INRAE streamgauging ruler: recent evolutions

Evolutions of the spreadsheet

3 discharge uncertainty methods: ISO748, Q+, Flaure

Streamgauging ruler measurement				Discharge (L/s):	98.9
Operators:	Clément, Maxime		Date:	21/04/2022	
Stream Name:	La Liepvrette		Site Name:	Liepvreville	
Rod ID:	2107		Start Bank (Left/Right):		Right
START Time:	08:20 UTC+2		END Time:	08:30 UTC+2	
START Water Level (cm):	9.5		END Water Level (cm):	9.5	
Vertical	Position (m)	Flow depth (cm)	Velocity head (mm)	Edge coefficient	Observations
1	1.88	15		0.67	
2	2.06	18.5	6		
3	2.17	20	6		
4	2.27	24	13		





Results					
Discharge (m3/s)	Area (m²)	Mean velocity (m/s)		Nb of verticals	
0.099	0.458	0.216		13	
			Discharge uncertainty		
Discharge (L/s)	Measured to Total discharge ratio	ISO748	Q+	Flaure	
98.9	97 %	10 %	7 %	18 %	

INRAE streamgauging ruler: recent evolutions

OFB/INRAE field memento updated

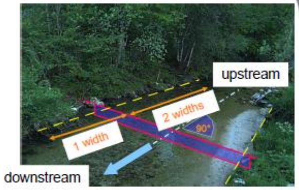
Frequently Asked Questions: Check it out!

Quick field notes
Streamgauging ruler measurements OFB 1/2

I comply with currentmeter gauging instructions

Refer to quick field notes on
Wading rod velocity-area discharge measurements

- Selection of measurement site
- Monitoring the water level
- Deploying the ruler tagline
- Number and position of verticals
- Discharge computation



- *Avoid up/downstream obstructions (boulders, vegetation, etc.)*
- *The flow must be perpendicular to gauging cross-section*
- *Use more verticals where the most flow passes through*

Principle of velocity measurements

Transparent velocity-head rod:

... discharge
... stream

INRAE

Quick field notes
Streamgauging ruler measurements OFB 2/2

I deploy the measuring equipment correctly

- Read and note flow depth downstream of the transparent board aligned with the flow (photo)
- Oppose the flat side to the flow, with ruler in front of you
- Stand downstream, with your legs apart
- Adjust the end of the ruler to the downstream water level
- Adjust the end of the slider to the upstream water level

- *Keep the board vertical using the spirit bubble*
- *Keep the board off a bank or obstacle by 15 cm at least*
- *If water levels fluctuate, average over 40 seconds*

I read the velocity-head and the flow velocity

Two alternative reading methods:

- Reading on top of the red ruler, using the green cap
- Read and note the level difference on the ruler precisely (in mm)

- Board out of the water, horizontal, perpendicular to sight (parallax)
- Read and note the level difference on the ruler precisely (in mm)
- Read the corresponding velocity (optional)
  - *Min velocity-head : Dh > 4 mm (V > 15 cm/s)*
  - *Max velocity-head : Dh < 130 mm (V < 100 cm/s)*

Discharge computation and reporting:
- **Software**: use the INRAE spreadsheet
- **Uncertainty**: no less than 10 %, typically → no more than 3 significant digits!

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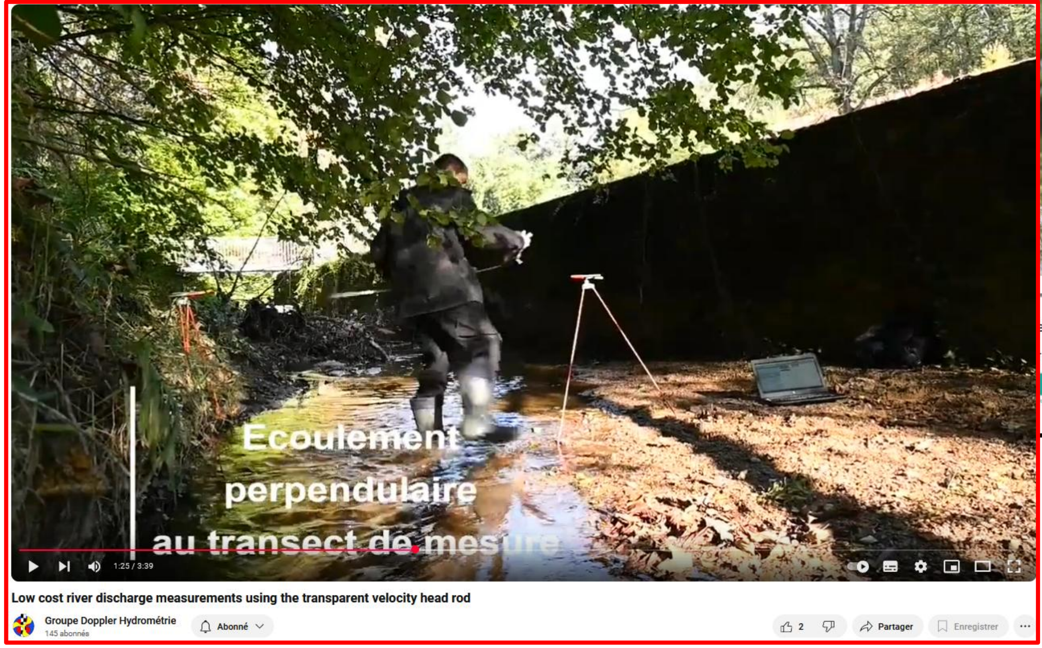


Video tutorial (new version planned for 2025)

Diffusion around the world

In March 2025, 370 rulers used in 21 countries, including:

- Haiti (3 + 10 ordered, University of Louvain-la-Neuve project in Belgium)
- Laos (14, IRD Toulouse project)
- Canada (11, via Robin Pike, one of the inventors of the transparent velocity-head rod)

Web page: https://riverhydraulics.riverly.inrae.fr/eng/tools/instrumentation/streamgauging-rulers
Assistance / infos: contact-raj@listes.inrae.fr (+400 registrees including collective addresses)

The biggest cluster is France, so far

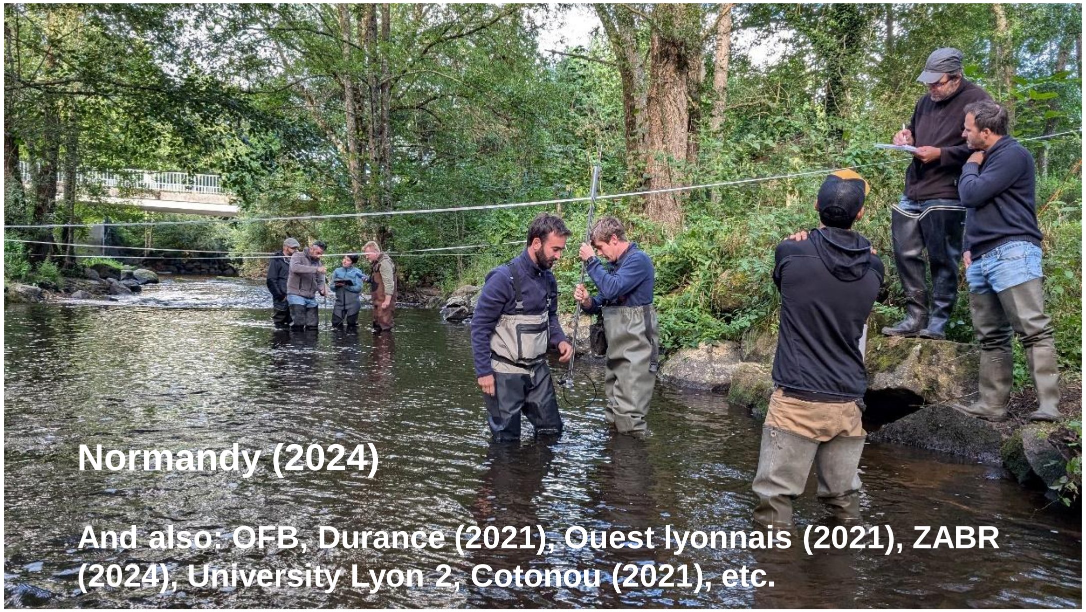
INRAE streamgauging rulers in France (European and overseas territories):

- Guadeloupe, Martinique, French Guyana, Réunion, Mayotte
- New Caledonia, French Polynesia, Wallis-and-Futuna

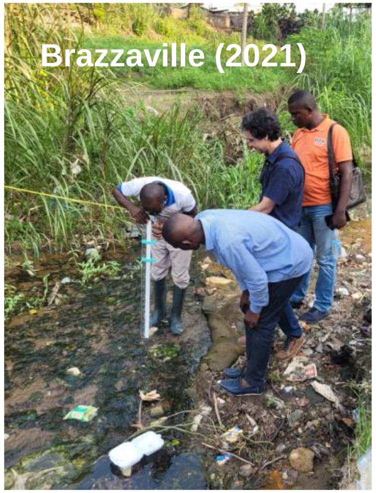
It is possible to gauge on broad-crested weirs, where the depth would be too shallow for usual currentmeters

Web page: https://riverhydraulics.riverly.inrae.fr/eng/tools/instrumentation/streamgauging-rulers
Assistance / infos: contact-raj@listes.inrae.fr (+400 registrees including collective addresses)

Training sessions


Normandy (2024)

And also: OFB, Durance (2021), Ouest lyonnais (2021), ZABR (2024), University Lyon 2, Cotonou (2021), etc.


Brazzaville (2021)

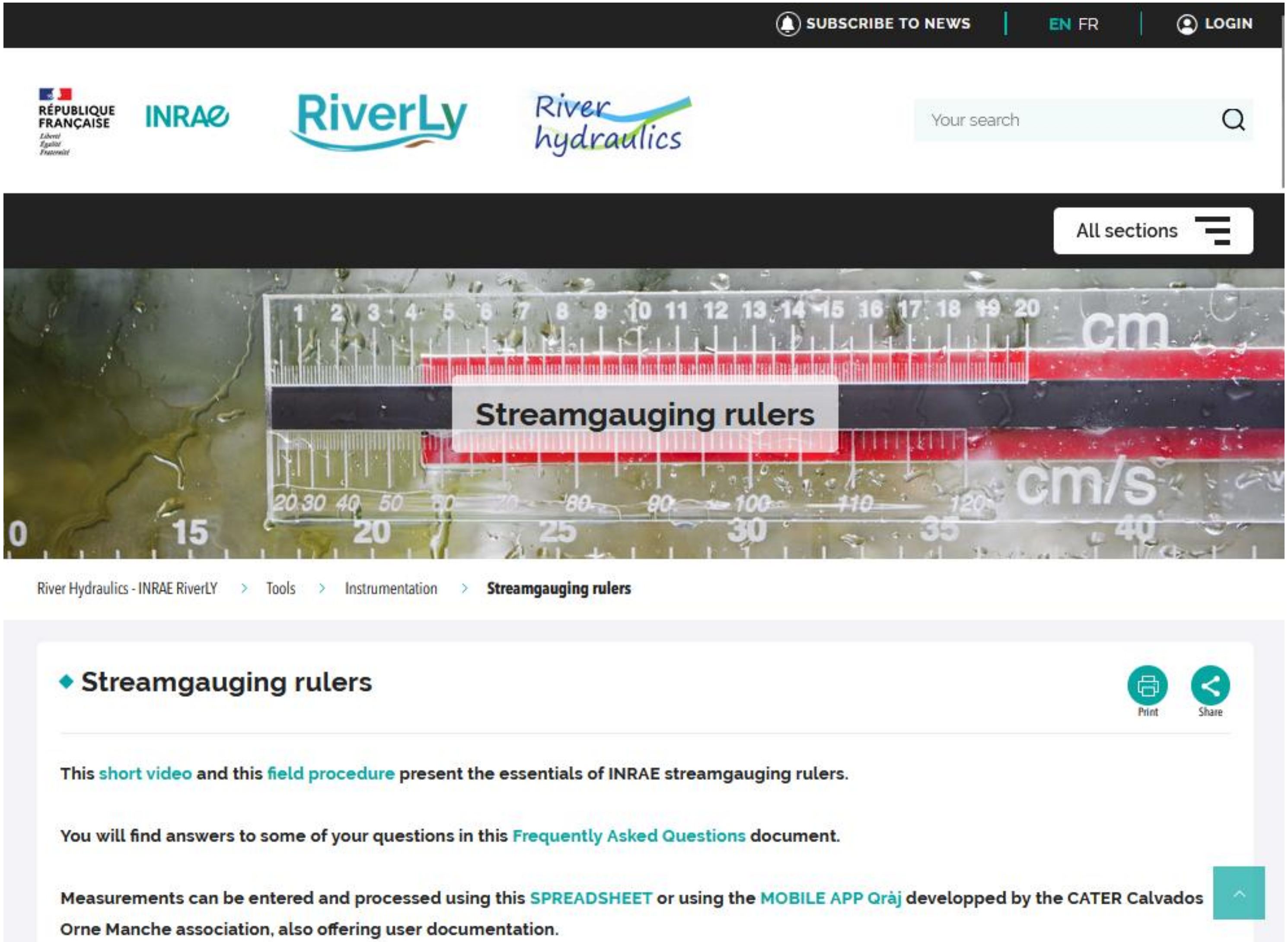

Mayotte (2022)


Pyrénées-Orientales (2021)

Dakar (2023)


Liverpool (2024)

Web page and resources



https://riverhydraulics.riverly.inrae.fr/eng/tools/instrumentation/streamgauging-rulers

References

Scientific article published in open access in Journal of Hydrology (2024) https://doi.org/10.1016/j.jhydrol.2024.131887

Introduces the instrument, the associated tools and the method for calculating uncertainties (adapted from Q+)


Journal of Hydrology 642 (2024) 131887

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Research papers

The streamgauging ruler: A low-cost, low-tech, alternative discharge measurement technique

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ARTICLE INFO

This manuscript was handled by Marco Borga, Editor-in-Chief, with the assistance of George Constantinescu, Associate Editor.

Keywords:
Velocity-head rod
Low-cost
Hydrometry
Streamgauging
Uncertainty

ABSTRACT

The streamgauging ruler, a.k.a. transparent velocity-head rod, is an inexpensive, easy, and quick tool for conducting wading discharge measurements in open-channel flows. It provides reliable velocity and discharge measurements when the right measuring conditions, especially minimum flow velocity, are met. The principle is simple: depth-averaged velocity can be computed from the water level difference between the upstream and downstream sides of a plastic board placed into the flow perpendicular to the flow direction. The model developed by INRAE (commercially available for €210) is a little more expensive than previously published models but it significantly improves the ease-of-use and measurement quality. Comparison experiments with reference measurements performed in a laboratory flume and at various field sites confirm the accuracy of the semi-empirical velocity rating established by Pike et al. (2016). Over most of the investigated cross-sections, the discharge measurements are generally within 10% of the reference discharge, when the velocity is greater than 0.2 m/s. However, operator-related effects (site selection, number and distribution of verticals, adjustment and reading of the sliding rulers) can lead to larger errors, hence operator training and care are essential.

A first evaluation of the velocity uncertainty related to the velocity-head reading is proposed in the form of an equation that can be used in existing methods for calculating discharge measurement uncertainty. As the method is extremely simple and quick, it is well suited for rapid discharge estimates, training or demonstration, citizen science programmes, or cooperation with services with limited resources and/or lacking specialized expertise in hydrometry. As of July 2024, 304 instruments had been built and released to diverse users around the world, along with a simple discharge computing spreadsheet, a video tutorial, and a field memo.

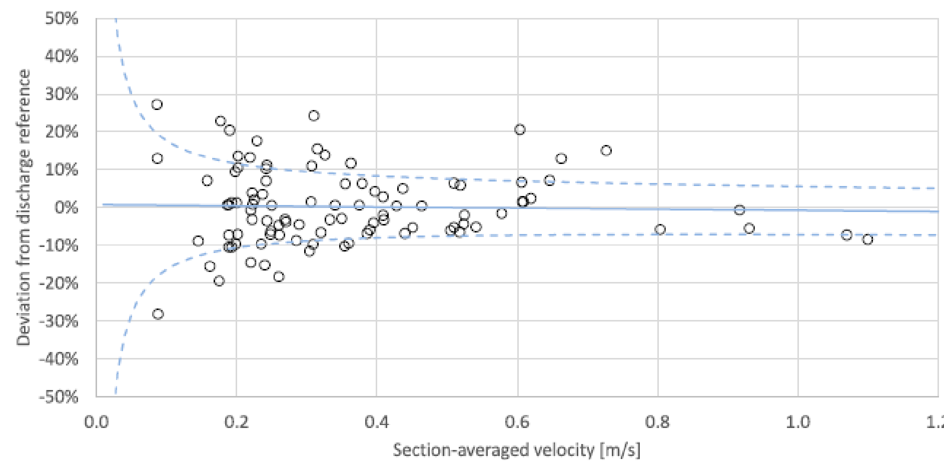
1. Introduction

Research, management, and decision making relating to water resources and water-related hazards are based on hydrological data, notably streamflow measurements and time series (McMillan et al., 2017). Most often, streamflow time series are derived from water level records using stage-discharge models (rating curves) which are established using streamgaugings, i.e. occasional measurements of stage and

It is therefore useful to develop and validate alternative streamgauging systems that are inexpensive, easy to deploy and build, and sufficiently reliable and accurate for the intended purpose of the data. Alternative low-cost techniques may improve discharge measurements in specific site conditions and/or would be more affordable for training purposes and/or use in developing countries or remote regions. Innovative low-cost solutions are often revisited, modernized versions of old and sometimes forgotten instruments and techniques. For in-

~100 discharge comparisons with conventional gauging methods:

discharge differences generally <10% if the average velocity is greater than 20 cm/s

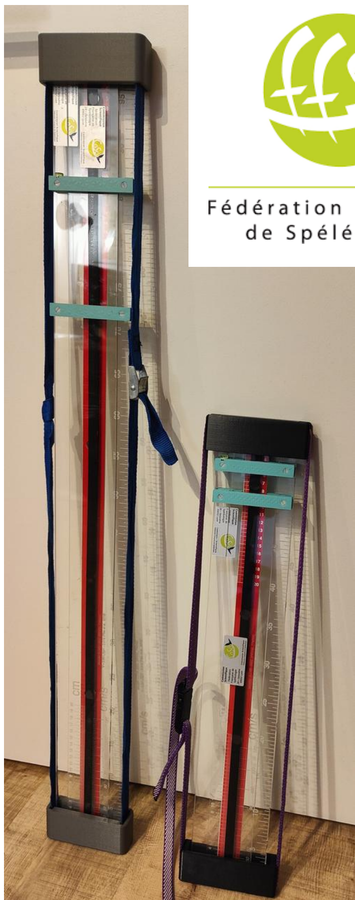


Other references:

- *ISO 748 standard (velocity-area gaugings)*
- *Quality assurance/guidance documents: WMO streamgauging manual, etc.*

Some original projects using the ruler

Shortened model, and protection and carrying system (Scientific Committee of the **French Caving Federation**, Vincent Schneider)



Fédération Française de Spéléologie

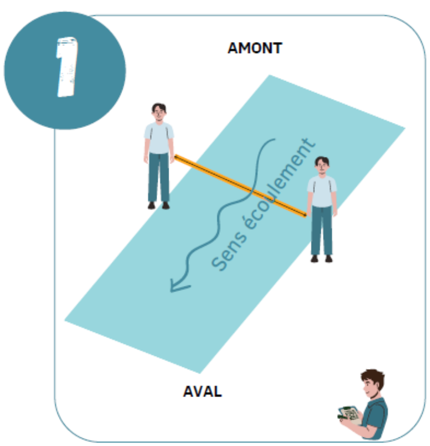
Sophie measuring flow depth with the TVHR

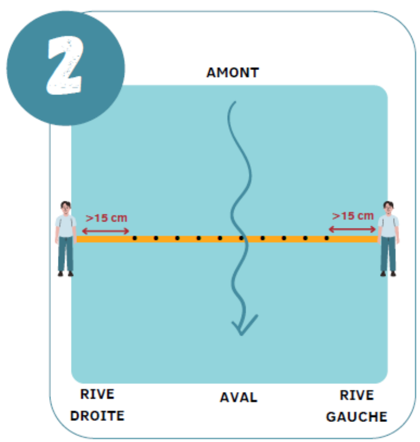
The Oxus expedition: 3 female explorers in search of the sources of the Amou Darya, in the Wakhan corridor (Afghanistan). Mission 2024 postponed to summer 2025

Some original projects using the ruler

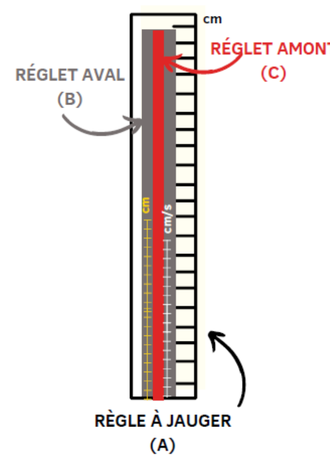
Citizen science project in schools, inspired by the Canadian project ***Adopte un cours d'eau***, with two demonstration sites:

- Lycée polyvalent de Muret (la Lèze, 31)
- Collège de Puygrellier (les Eaux claires, 16)





Extracts from the protocol adapted for students



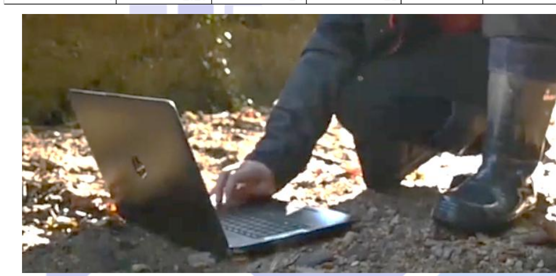
Fiche terrain

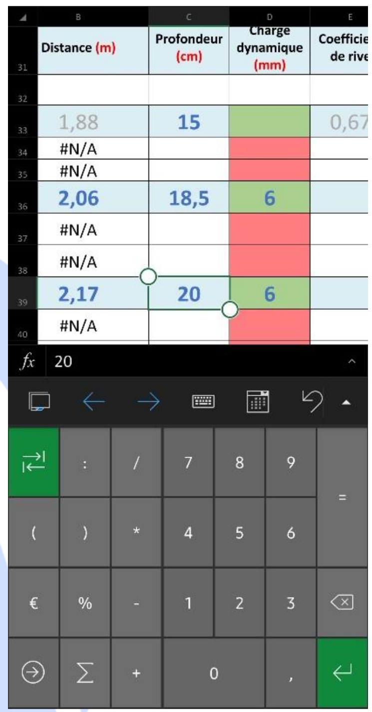
Charge dynamique (mm) (3)	Coefficient de rive (4)	Observations
Ne pas remplir		
	Ne pas remplir	
	Ne pas remplir	
	Ne pas remplir	
	Ne pas remplir	
	Ne pas remplir	
	Ne pas remplir	
	Ne pas remplir	
	Ne pas remplir	
Ne pas remplir		

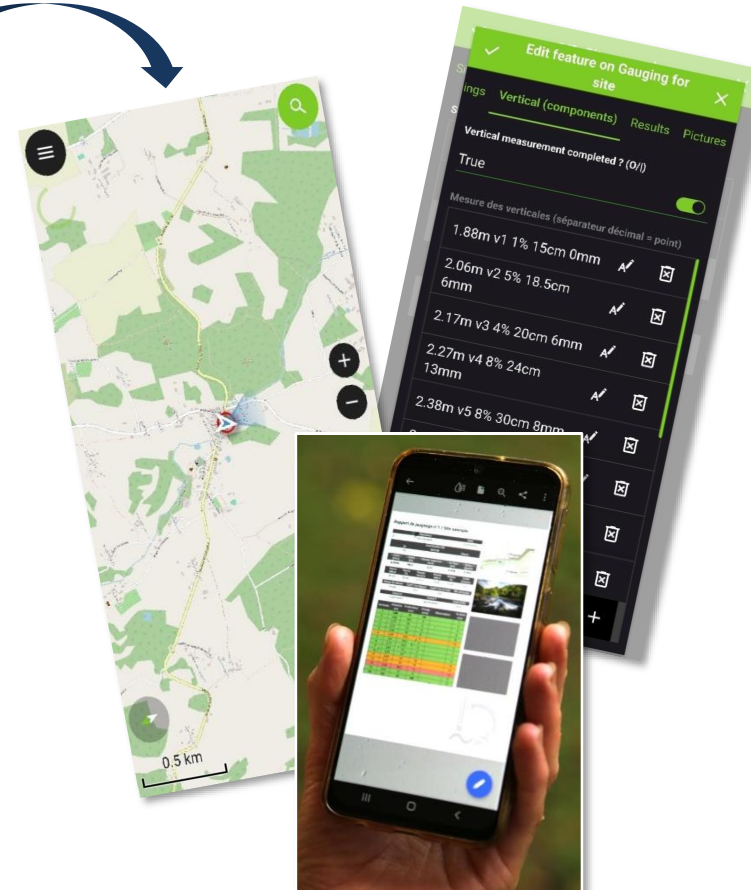
Context of the smartphone tool project

In the beginning was Excel...

Streamgauging ruler measurement			Discharge (L/s):	98.9	
Operators:	Clément, Maxime		Date:	21/04/2022	
Stream Name:	La Liepvrette		Site Name:	Liepvreville	
Rod ID:	2107		Start Bank (Left/Right):	Right	
START Time:	08:20 UTC+2		END Time:	08:30 UTC+2	
START Water Level (cm):	9.5		END Water Level (cm):	9.5	
Vertical	Position (m)	Flow depth (cm)	Velocity head (mm)	Edge coefficient	Observations
1	1.88	15		0.67	
2	2.06	18.5	6		
3	2.17	20	6		
4	2.27	24	13		







Project components

- Qgis, opensource, cross platform, extensible, dynamic evolution, free. Widely used by local authorities and government departments, at least in France 😊.

- QField, smartphone/tablet counterpart to Qgis, cross platform, active development, documented, easy to learn, free.

- SQLite, stand-alone database, simple and lightweight crossplatform, free, proven, supported by Qgis and QField. Spatialite module provide gives it spatial processing capabilities... It's within the database that the magic happens ✨ via SQL processing.

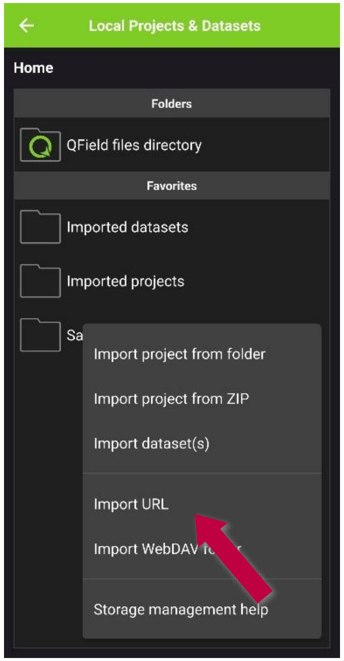
Installation

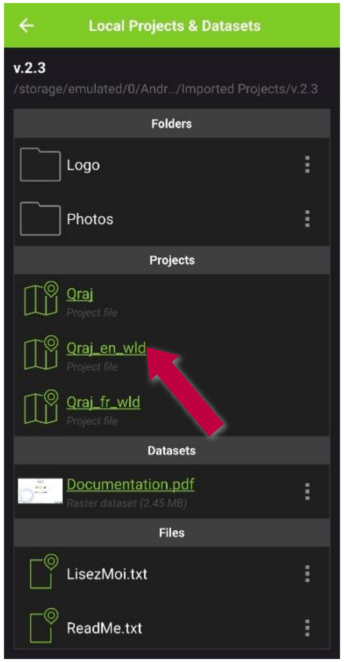
Install (or update) Qfield from your AppStore and download the Qràj zip via the URL

GET IN ON Google Play

Download on the App Store

Download for Windows





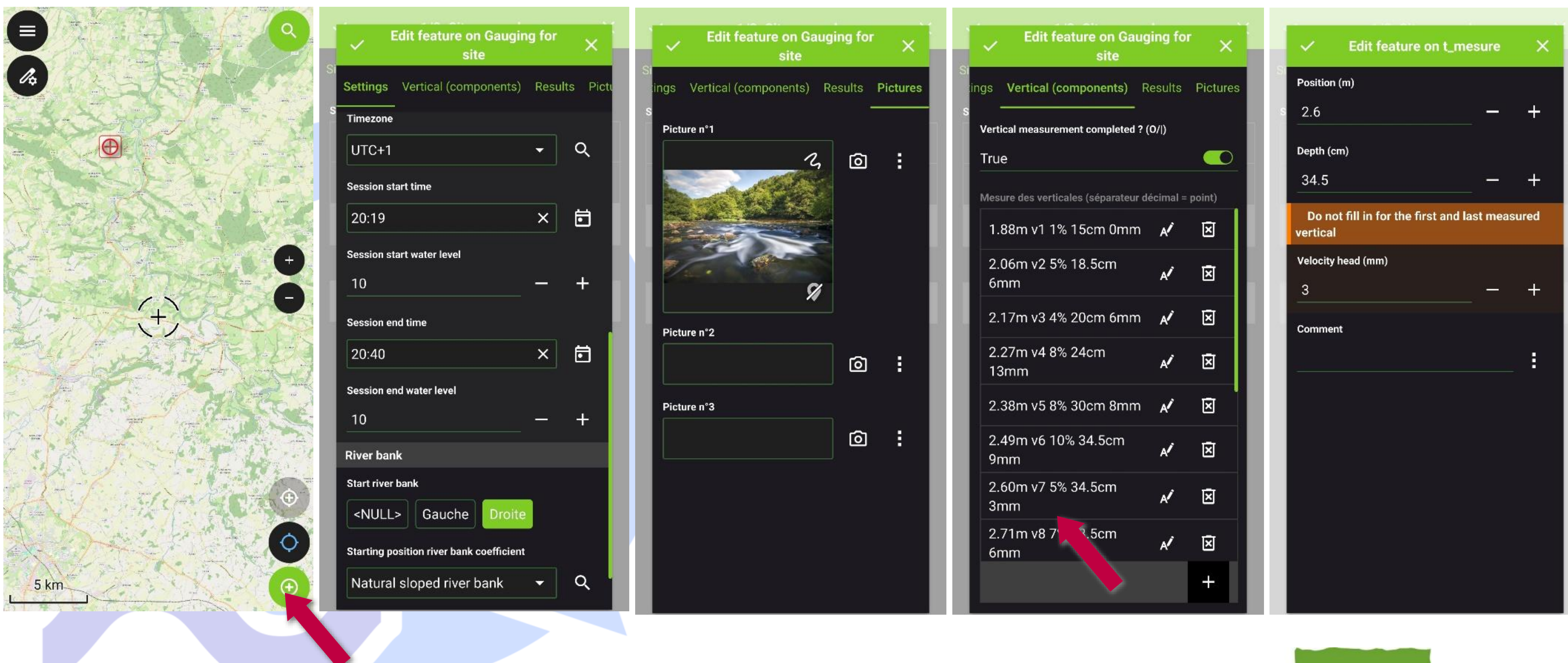
Install it via the 'Import a URL' option using the URL below

https://www.cater-com.fr/fichiers/mediatheque/documents/Qraj.zip

CATER CALVADOS ORNE MANCHE

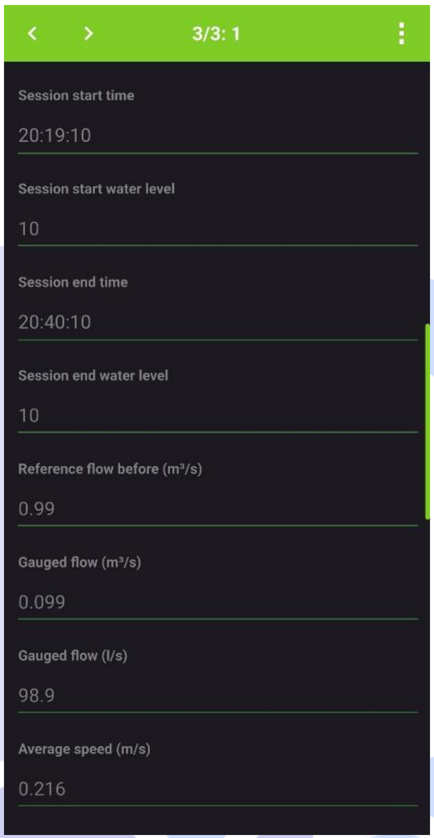
User interface

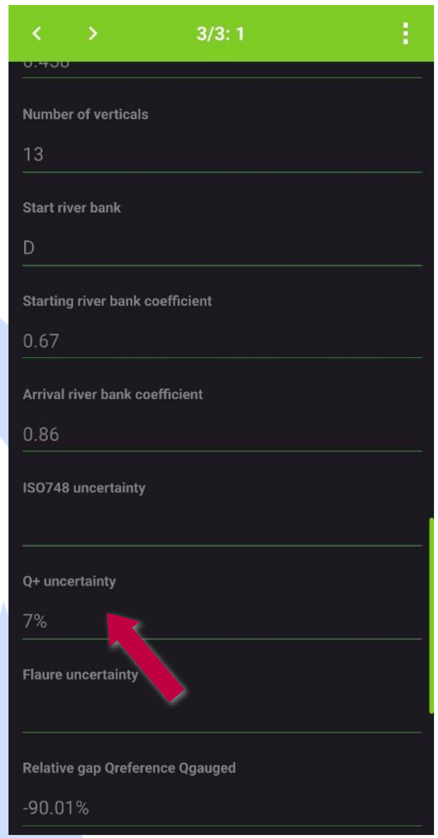
Map, input forms fitting smartphone screen size. **In-situ computation of the discharge share of each vertical.**



Outputs

Discharge, wetted area, mean velocity, discharge uncertainty (Q+), measurement report.





Add your own logo

Three flavours

Qraj > French version projected in Lambert 93 (EPSG 2154) with the ‘IGN Plan v2’ layer activated by default, for use in mainland France.

Qraj_fr_wld > French version projected in WGS84/Pseudo Mercator (EPSG 3857) with the ‘OpenStreetMap’ layer activated by default, for French-speaking users outside mainland France.

Qraj_en_wld > English version projected in WGS84/Pseudo Mercator (EPSG 3857) with the ‘OpenStreetMap’ layer activated by default, intended for worldwide use.

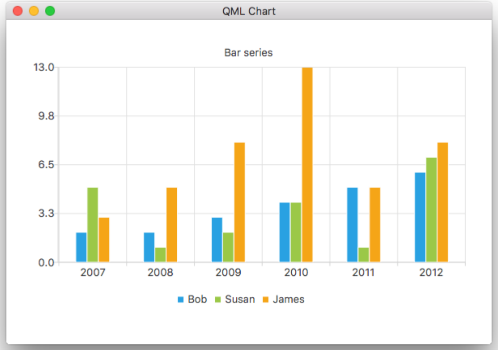
Next...

- We're already working on improvements for the next version.

- QField is evolving and will no doubt bring new features that could be used by Qràj.

- Qfield has released a plugin based on the QML language (Qt + Javascript). QML can handle graphics, so... and Javascript could probably export CSV files...

- Qgis and QField > external sensors > interfaces for viewing, collecting and processing other hydrometric data?



Example of a partnership application

More and more requests for low-water flow measurements

(from river boards, watershed associations, city councils, etc.)

- Awareness after severe drought 2022
- Water volumes that can be abstracted?
- Wastewater treatment plant discharges?
- Pollutant flows?...

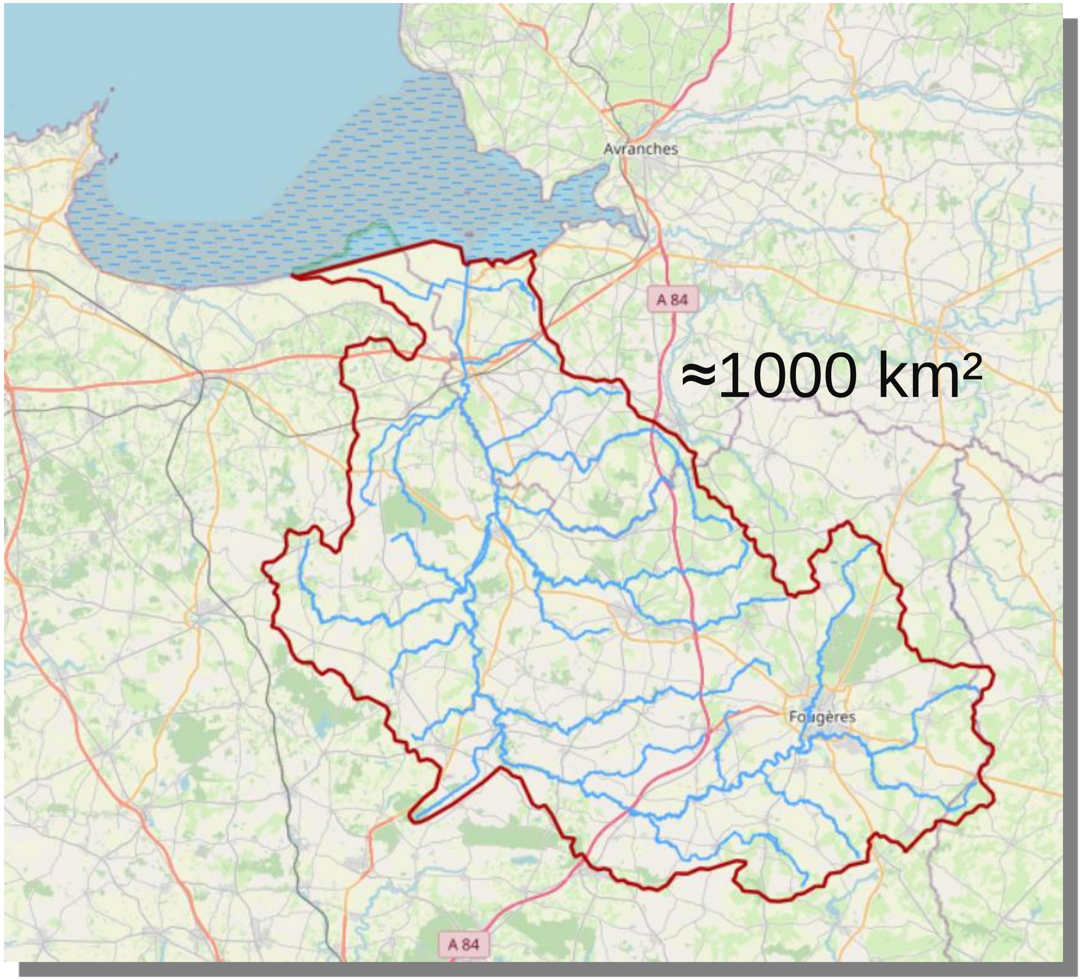
The governmental (DREAL Bretagne) hydrometric network **does not cover** all local issues.

PRÉFET
DE LA RÉGION
BRETAGNE
Liberté
Égalité
Fraternité

DREAL Bretagne
Direction régionale de l'environnement,
de l'aménagement et du logement

Example of a partnership application

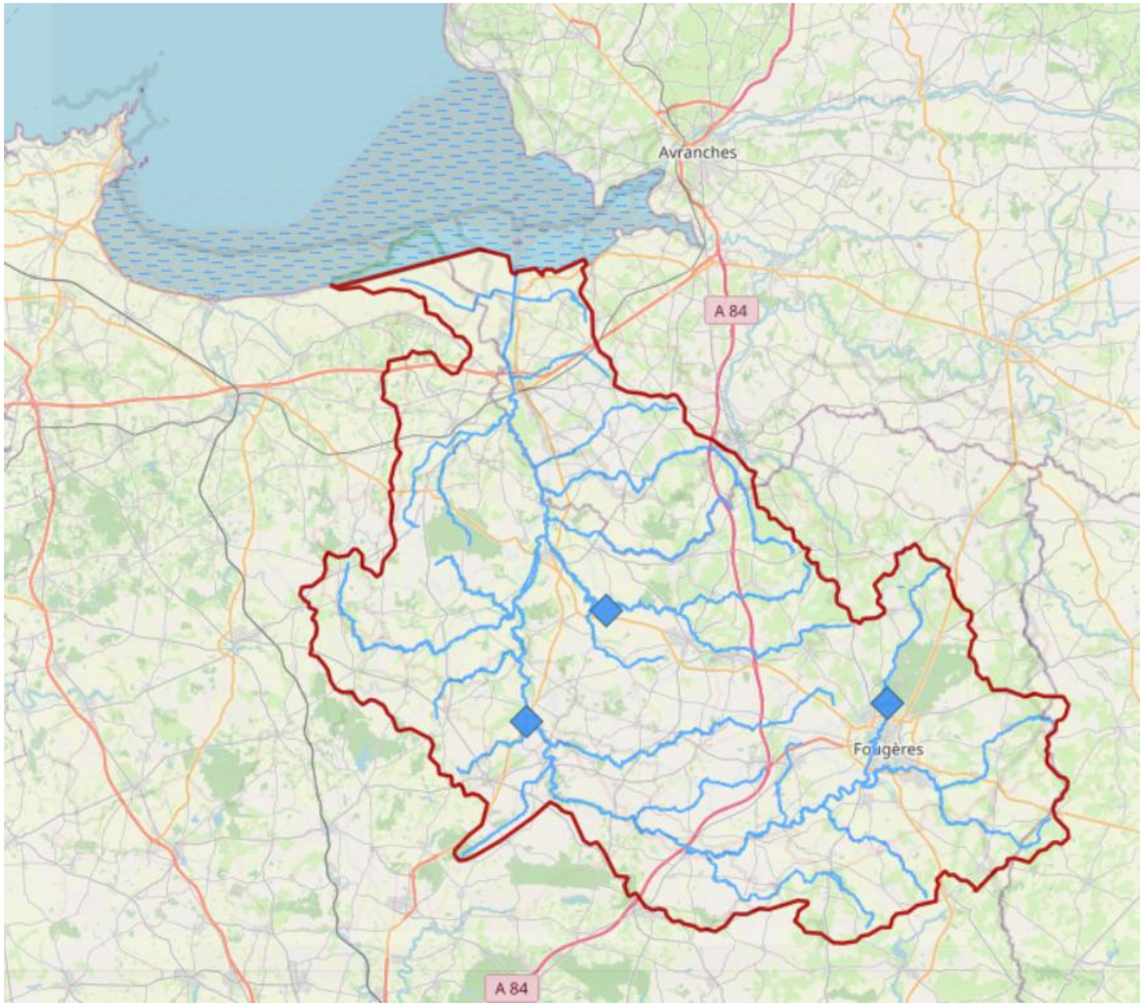
Experimentation on the **Couesnon River**



The **Mont-Saint-Michel** island lies at the mouth of the Couesnon River, at the border between Normandy and Brittany.

Example of a partnership application

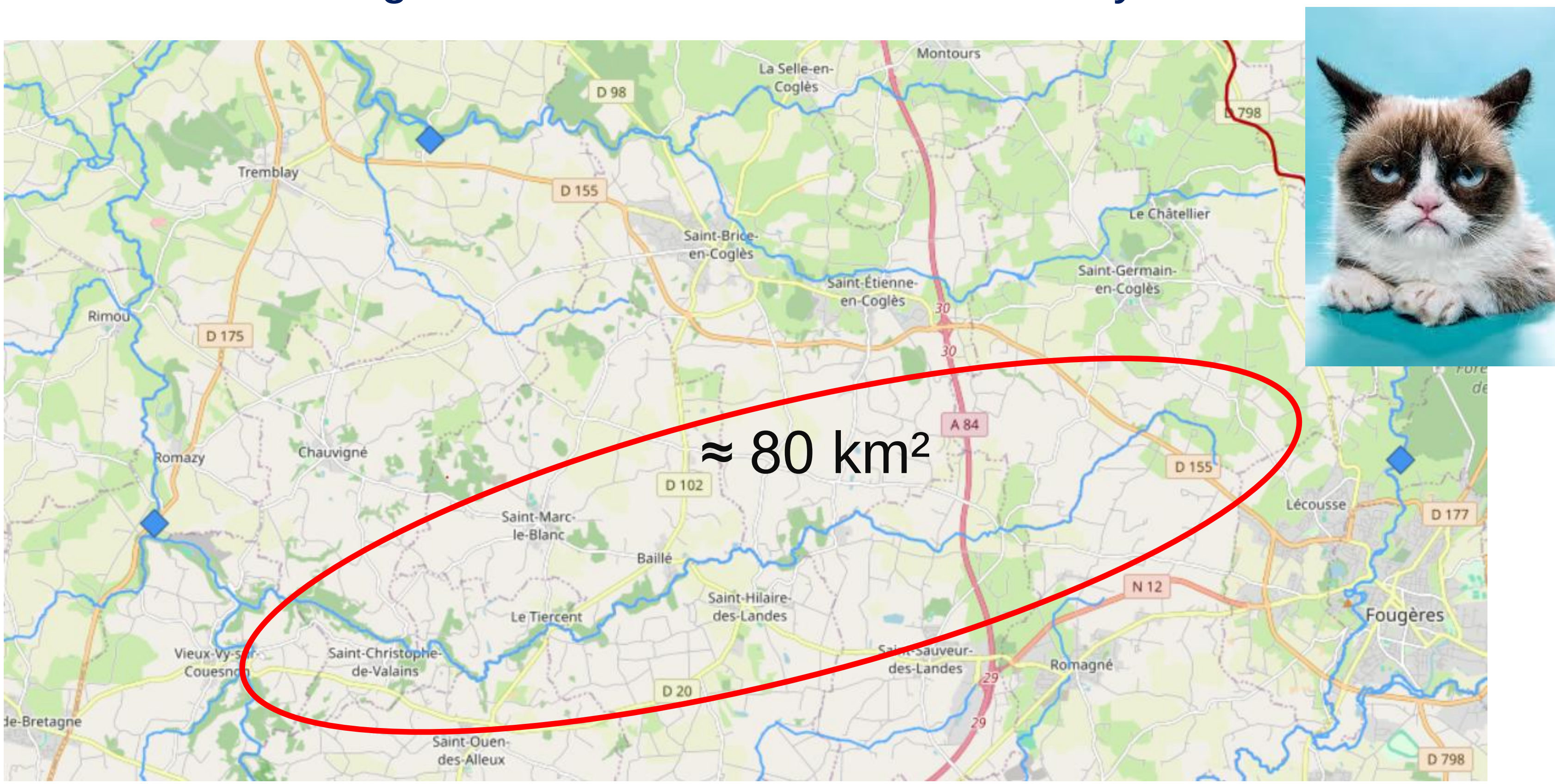
Though in Normandy, the catchment has been well instrumented by the Bretons with 3 hydrometric stations!



Example of a partnership application

Insufficient for local stakeholders:

What is the discharge of the Minette* River, a tributary of the Couesnon?



*French for Pussycat…

Example of a partnership application

A **half-day** in the field together to...

Install the staff gauge + pressure gauge

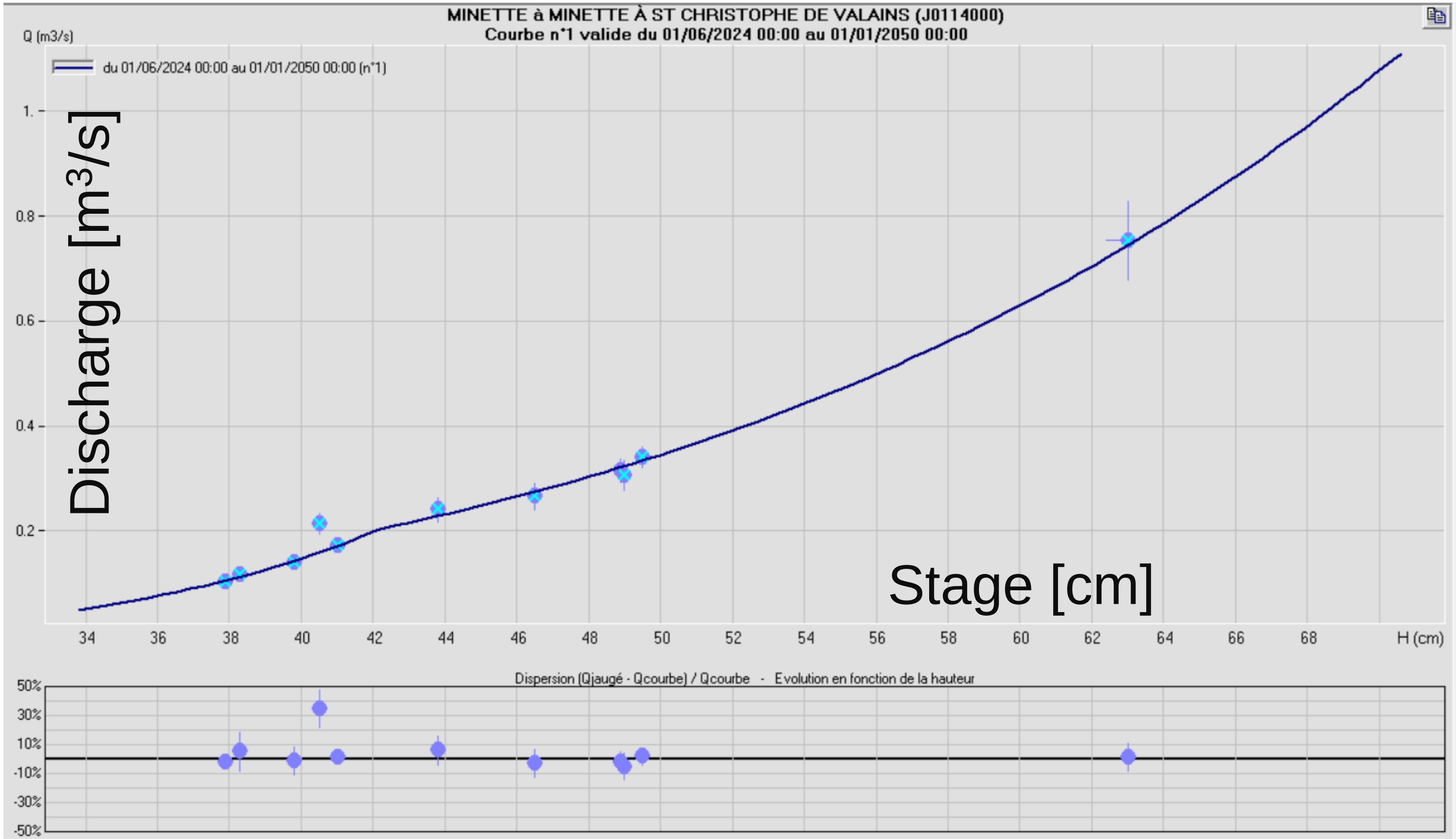
+

Identify the gauging cross-section and train to the use of the ruler

Objective: **a discharge measurement every 10 days**

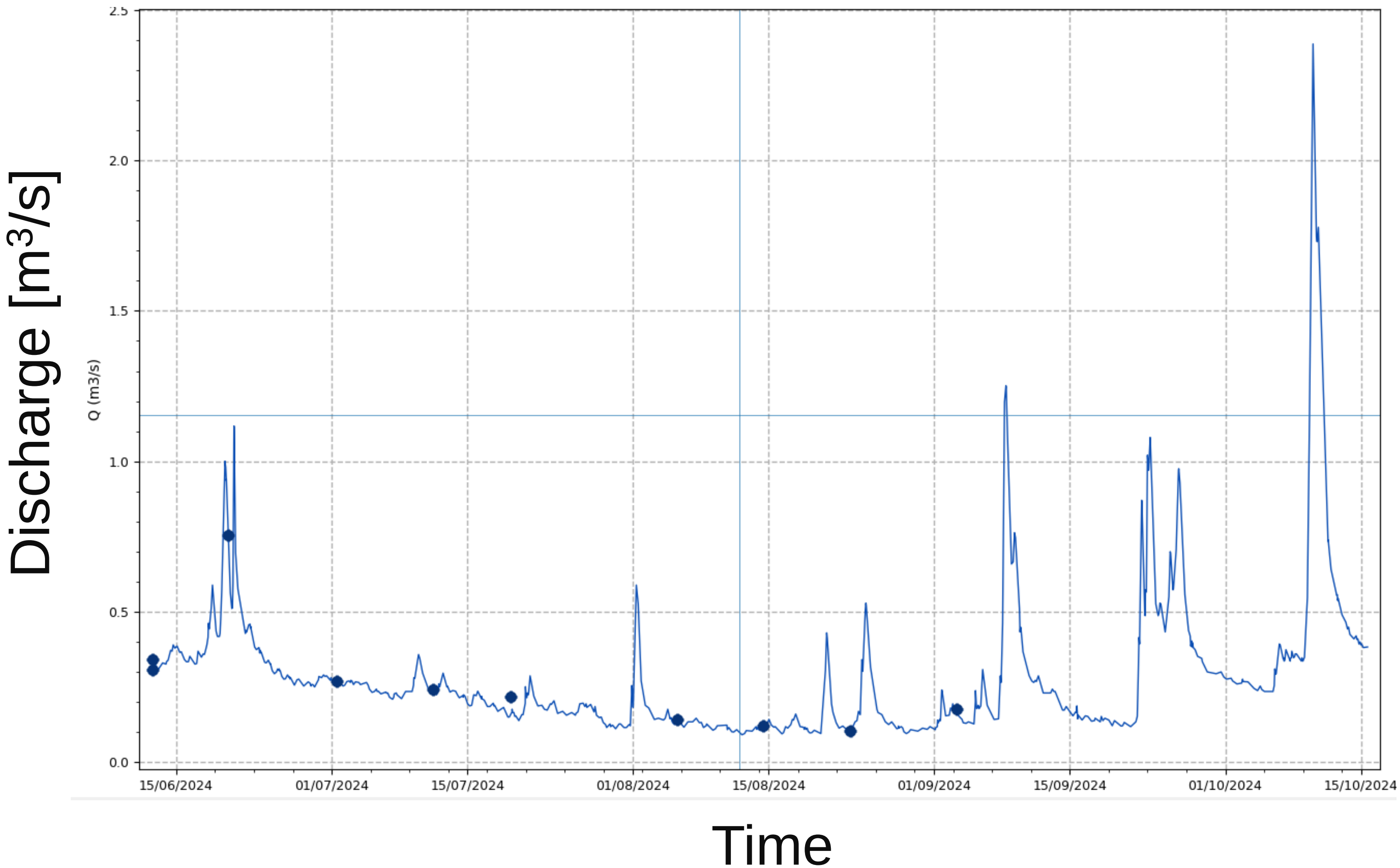
Example of a partnership application

At the end of summer 2024 → a first **low-flow rating curve**



Example of a partnership application

→ **discharge hydrograph** for Summer 2024
(saved in the national PhyC database, accessible via Hydroportail website)



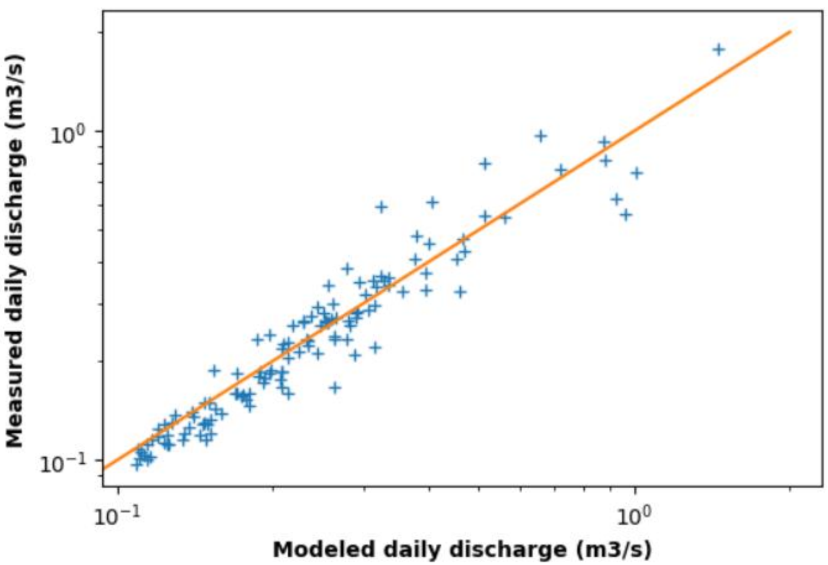
Example of a partnership application

Next: do the same thing over 3 to 5 summers

→ set a **regression** against DREAL gauging stations

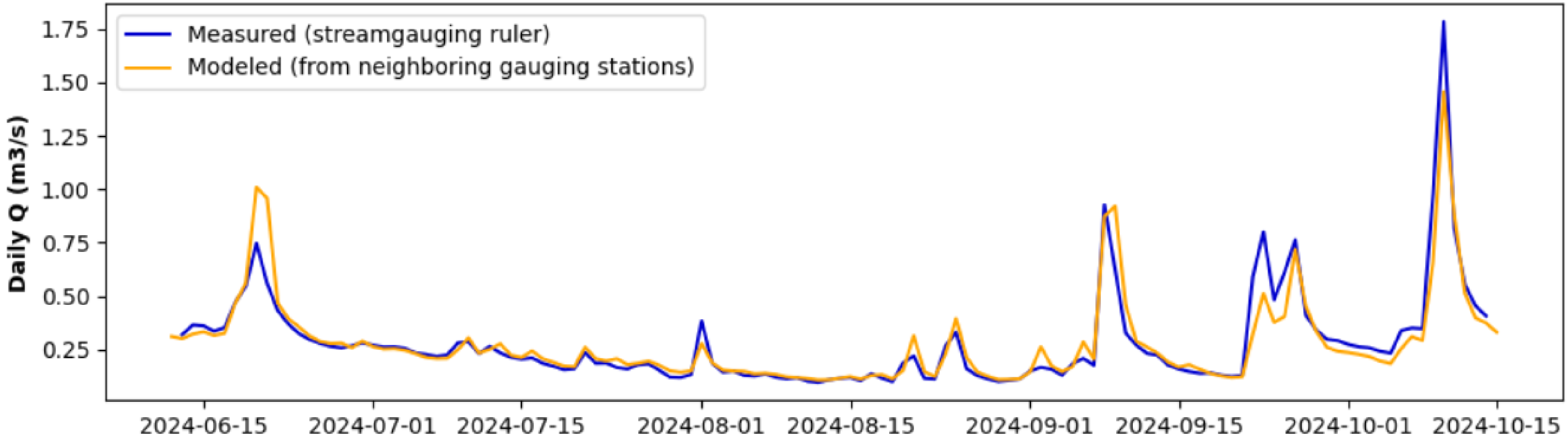
→ extrapolate over the period covered by DREAL records to establish **low-flow statistics** (QMNA5, VCN3 10 years, etc.)

```
                            OLS Regression Results
==============================================================================
Dep. Variable:                Minette   R-squared:                       0.859
Model:                            OLS   Adj. R-squared:                  0.857
Method:                 Least Squares   F-statistic:                     368.6
Date:                Mon, 17 Mar 2025   Prob (F-statistic):           3.35e-52
Time:                        17:38:10   Log-Likelihood:                 675.34
No. Observations:                 124   AIC:                            -1345.
Df Residuals:                     121   BIC:                            -1336.
Df Model:                           2
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const         -0.0003      0.000     -1.023      0.308      -0.001       0.000
Couesnon       0.7599      0.046     16.408      0.000       0.668       0.852
Nançon         0.0421      0.052      0.812      0.418      -0.061       0.145
==============================================================================
Omnibus:                       33.058   Durbin-Watson:                   1.011
Prob(Omnibus):                  0.000   Jarque-Bera (JB):              445.263
Skew:                           0.123   Prob(JB):                     2.05e-97
Kurtosis:                      12.280   Cond. No.                         692.
==============================================================================
```



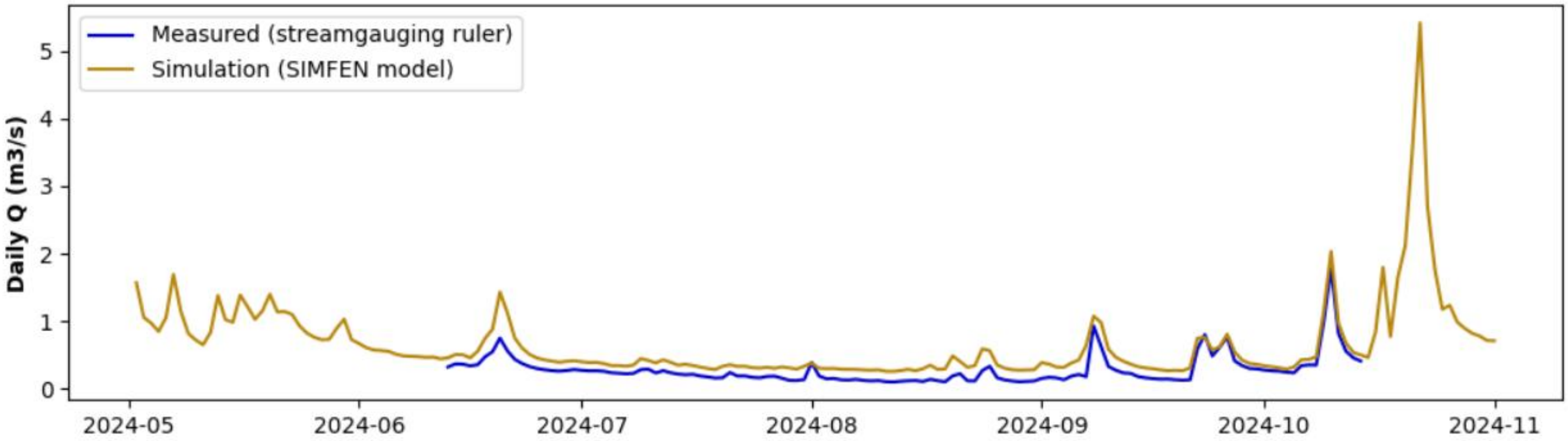
Example of a partnership application

<u>Example over one year:</u> measured discharge vs. linear model



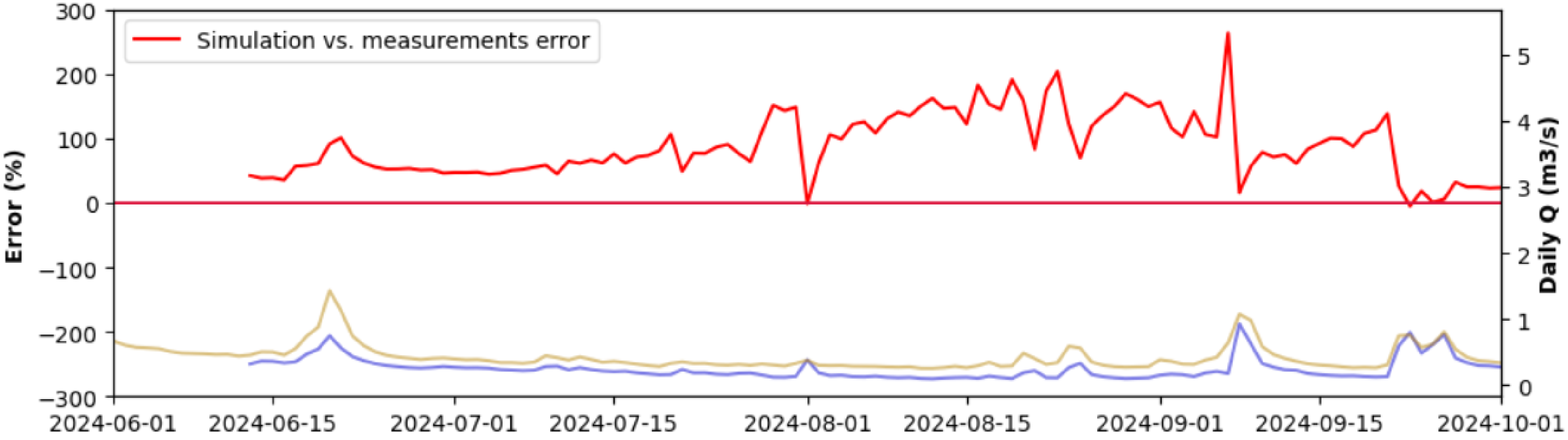
Example of a partnership application

Comparison of **linear model** (derived from streamgauging ruler measurements) vs. SIMFEN **hydrological model** (modelling based on similar gauged basins)



Example of a partnership application

→ for low flows, up to 200% difference in discharge



Example of a partnership application

Conclusion / perspectives

- A promising solution (among others) for obtaining low-flow discharge records with controlled uncertainty (unlike modelling)
- Low investment: approx. €2,500 - €3,000 (sensor + ruler + staff gauge + tagline + waders)
- Suitable for players close to the measurement site
- Not suitable everywhere (sufficient flow velocity required)
- Necessary: do a gauging with exploration of the velocity field on the identified section to use the RàJ.

Thank you for your attention !

Acknowledgements

Since 2018, the development of the INRAE streamgauging ruler has been supported by the French Office for Biodiversity (**OFB**), and by the **Vigicrues** central service.

Numerous users from hydrometric services have provided valuable comparative measurements and feedback.

The **AAIS** company (Sassenage, France) manufactures and distributes (on their own account) INRAE streamgauging rulers.

Many thanks to all!

William Ewart Gladstone (1809-1898)

Four times prime minister under the reign of Victoria, and a big fan of the streamgauging ruler*!*

Seen in St. George's Hall (Liverpool, UK)