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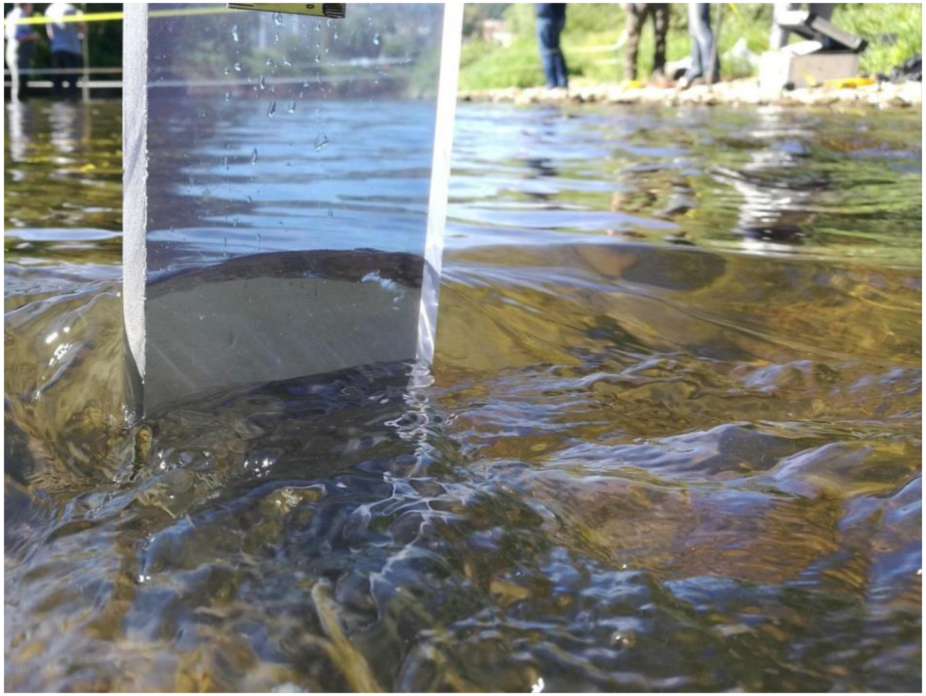
EGU General Assembly 2020

Low-cost river discharge measurements using a transparent velocity-head rod



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INRAE

River hydraulics

Wading streamgauging methods

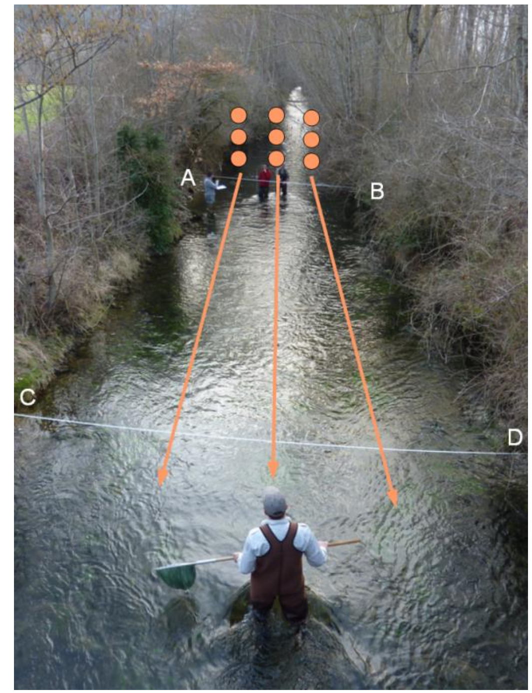
Mechanical currentmeter

Acoustic Doppler Velocimeter

Electromagnetic currentmeter

Acoustic Doppler Current Profiler

5 000 – 30 000 €



Floats

< 50 €

Credits: http://echo2.epfl.ch/e-drologie/chapitres/chapitre7/chapitre7.html
Le Coz et al. (2011), Onema/Irstea.

Evolution of the velocity head rod

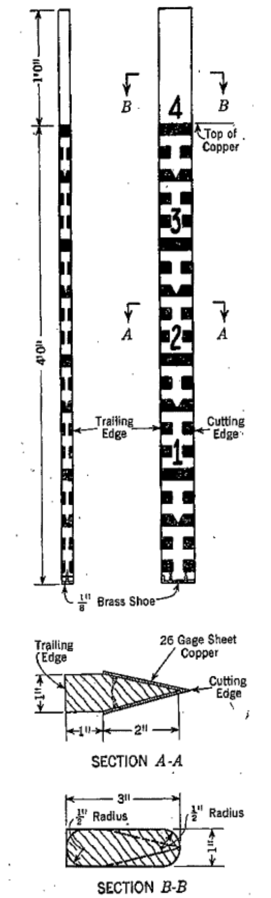
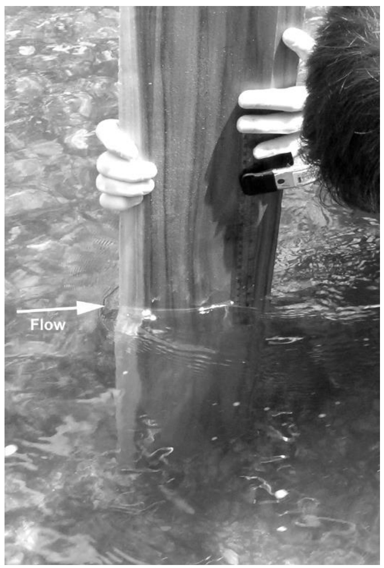
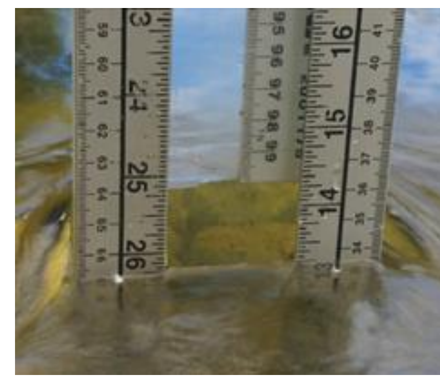


Fig. 1. Velocity-Head Rod Developed at San Dimas Experimental Forest



Wilm and Storey (1944)

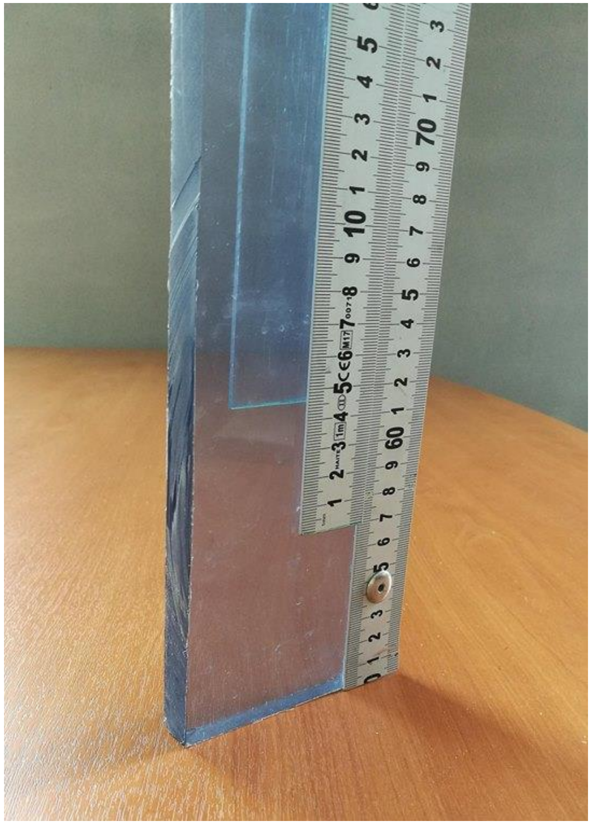
Drost (1963)



Fonstad et al. (2005)

Pike et al. (2016)

The transparent velocity head rod

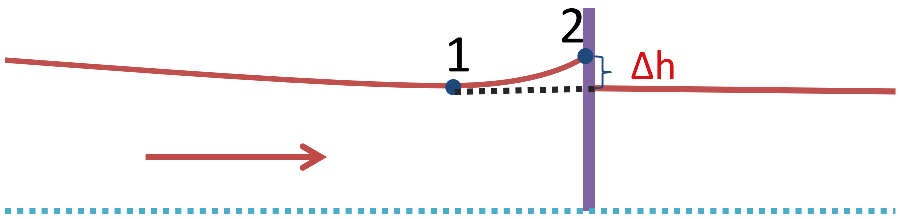


Experimental prototype

- Built after Pike *et al. (2016)*
- *Cost ≈ 40 €*

Photo: Pernot Francis

Operating principles



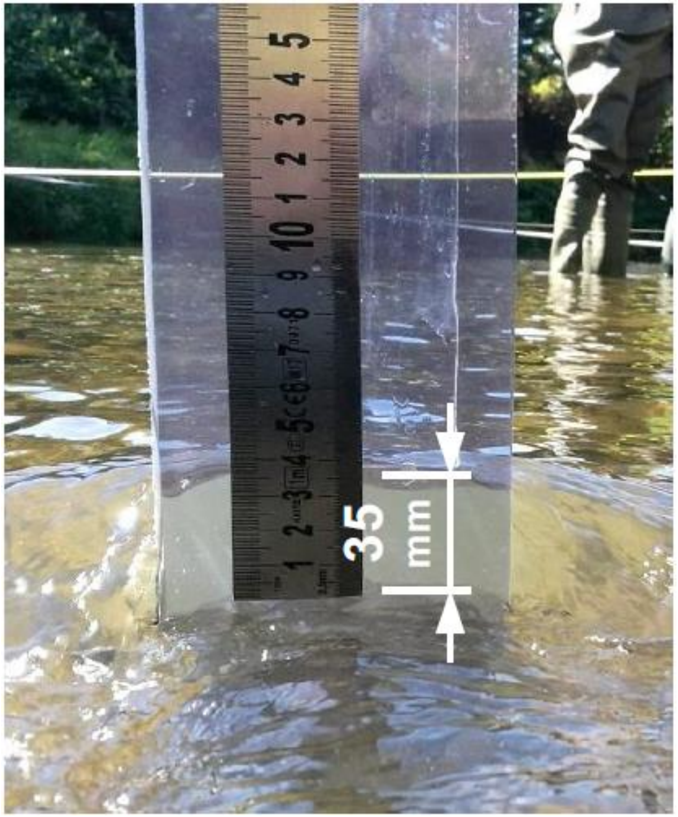
Kinetic energy (velocity head) converts into potential energy (hydrostatic head)

$Ec_1 + Ep_1 = Ec_2 + Ep_2$

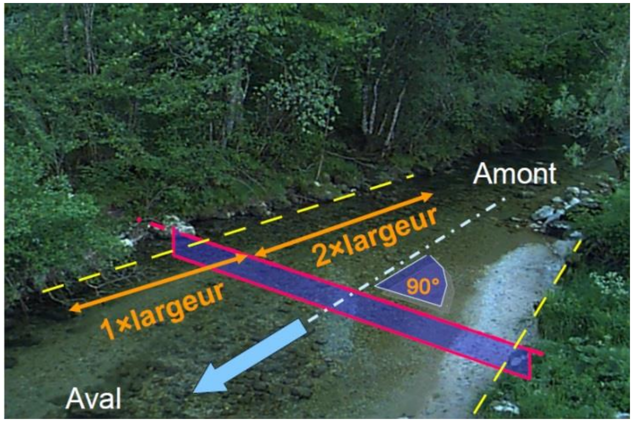
$\frac{1}{2}\, m\, v_1^2 + m\, g\, z_1 = \frac{1}{2}\, m\, v_2^2 + m\, g\, z_2 - \Delta h$
$= (z_2 - z_1)$

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

In theory…



Comparison measurements



Field streamgauging by:

- INRAE
- DREAL Pays de la Loire, DREAL Auvergne-Rhône-Alpes, DREAL Grand Est.

Laboratory experiments:

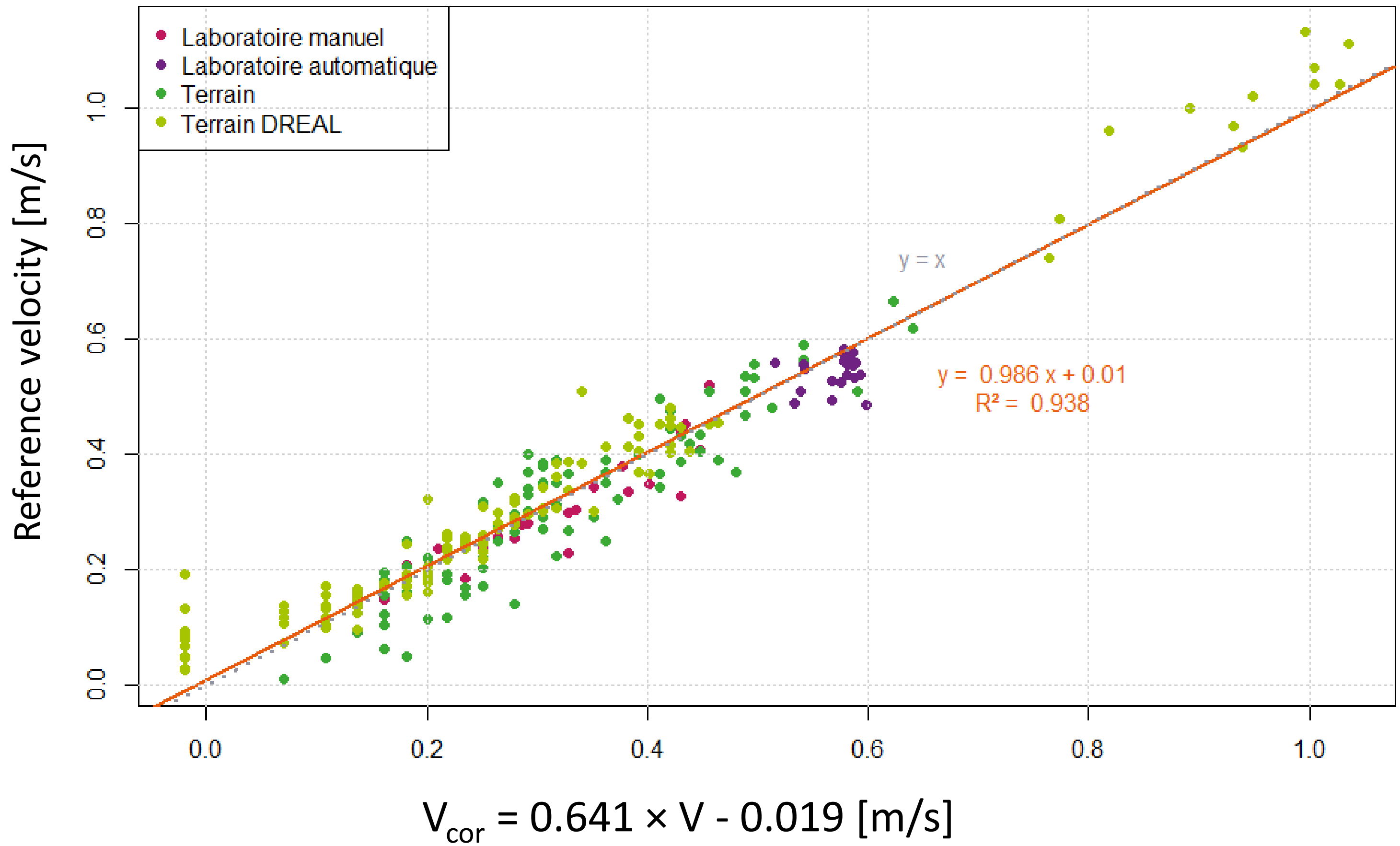
- In the tilting flume of INRAE Lyon (HHLab)
- Automated measurements

Each velocity head rod result is compared with a conventional measurement

Credits: Le Coz *et. al* (2011), ONEMA / IRSTEA, left. F. Pernot, right.

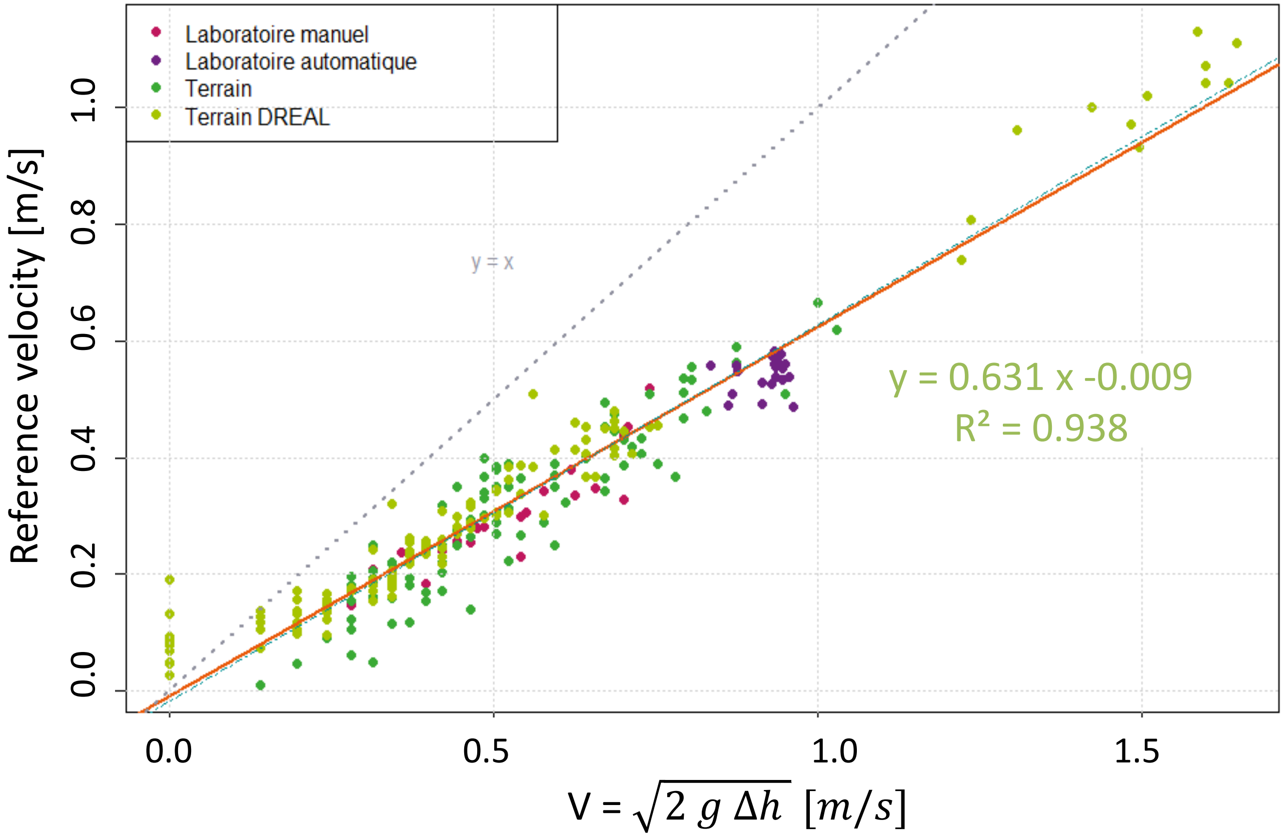
Velocity rating from Pike et al. (2016)

Validation of the rating proposed by Pike et al. (2016)



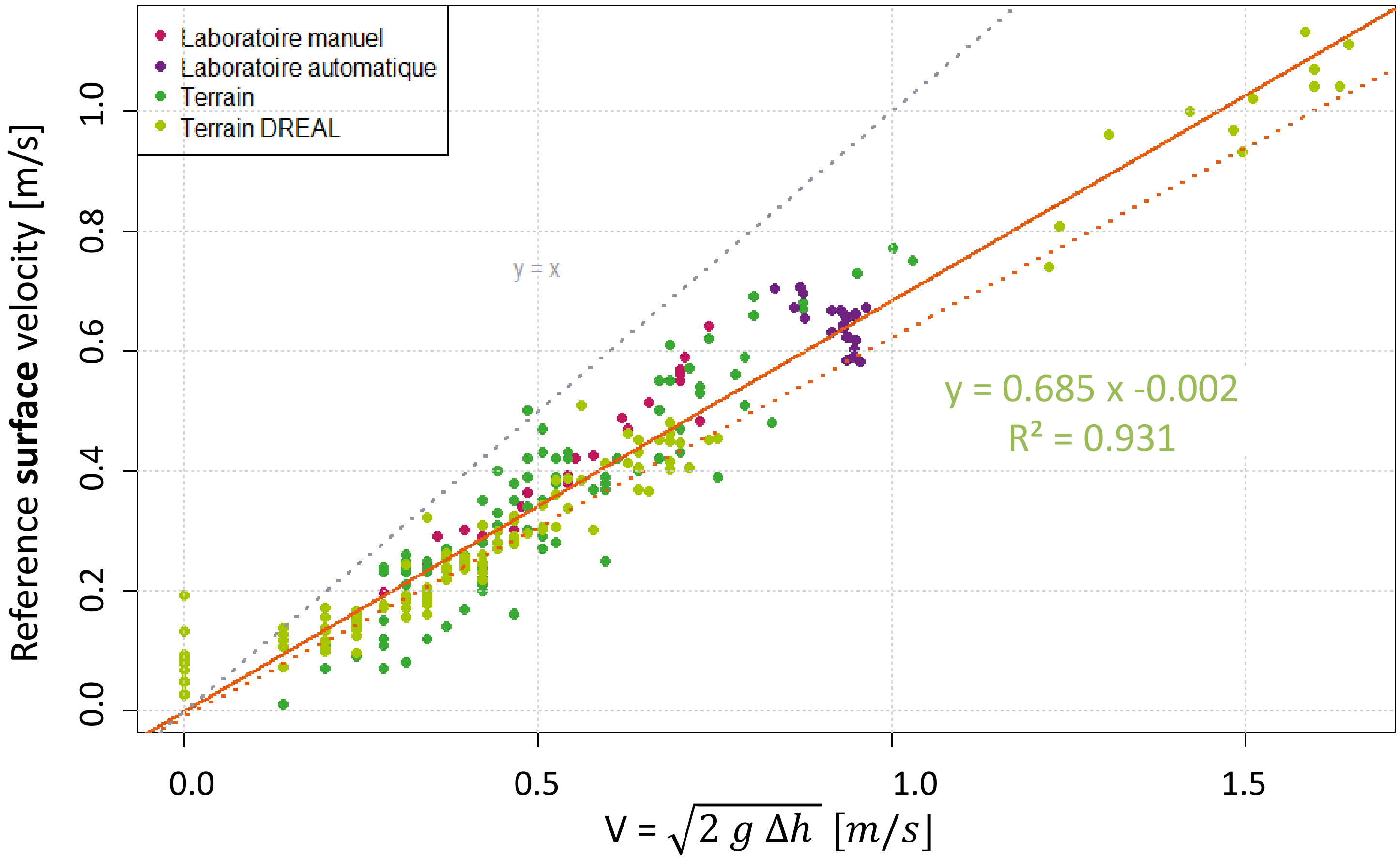
Pike *et al. (*2016) established their velocity rating from 2400 comparisons with SonTek FlowTracker ADV data on 14 sites with 7 operators

Velocity rating calibrated from our data



We found a very similar rating: V_{cor} = 0.631 × V - 0.009 [m/s]
Based on 212 field and laboratory comparisons
Flow depths: 5-55 cm Velocities: 0-75 cm/s

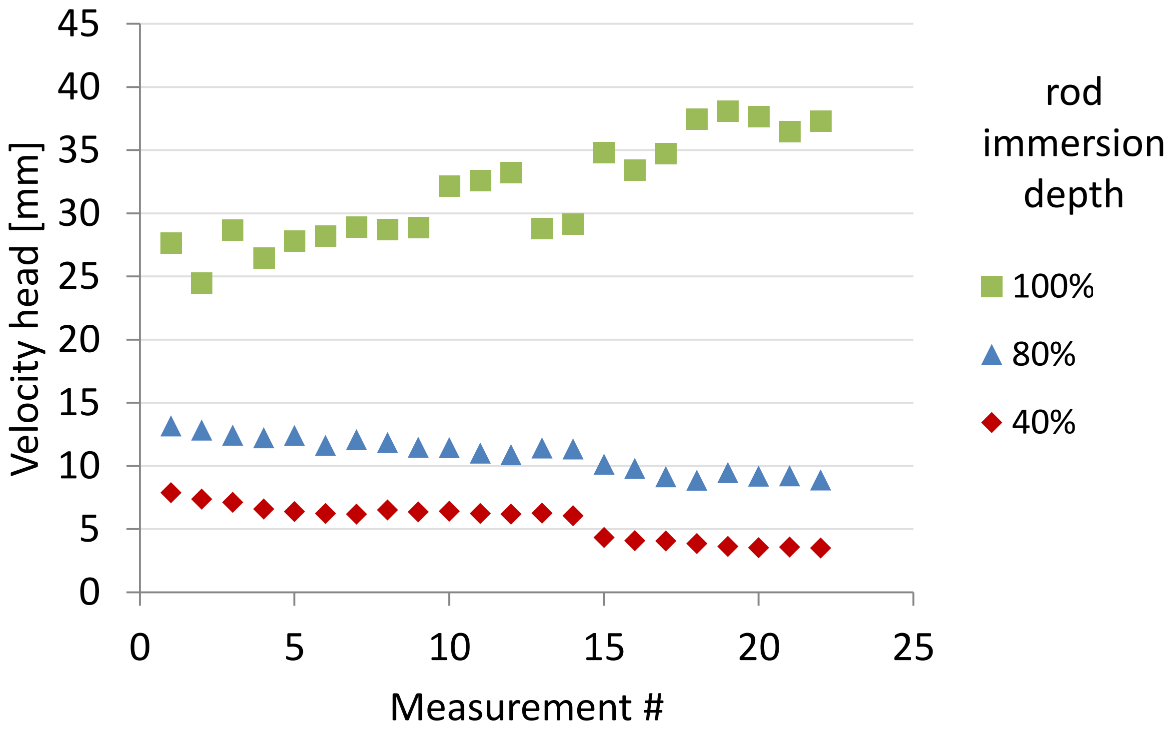
Velocity rating using near-surface velocity



Near-surface velocity (0.2 × depth) is still much lower than the theoretical head rod velocity

Sensitivity to rod immersion depth

Head rod and ADV on automated mount in the tilting flume



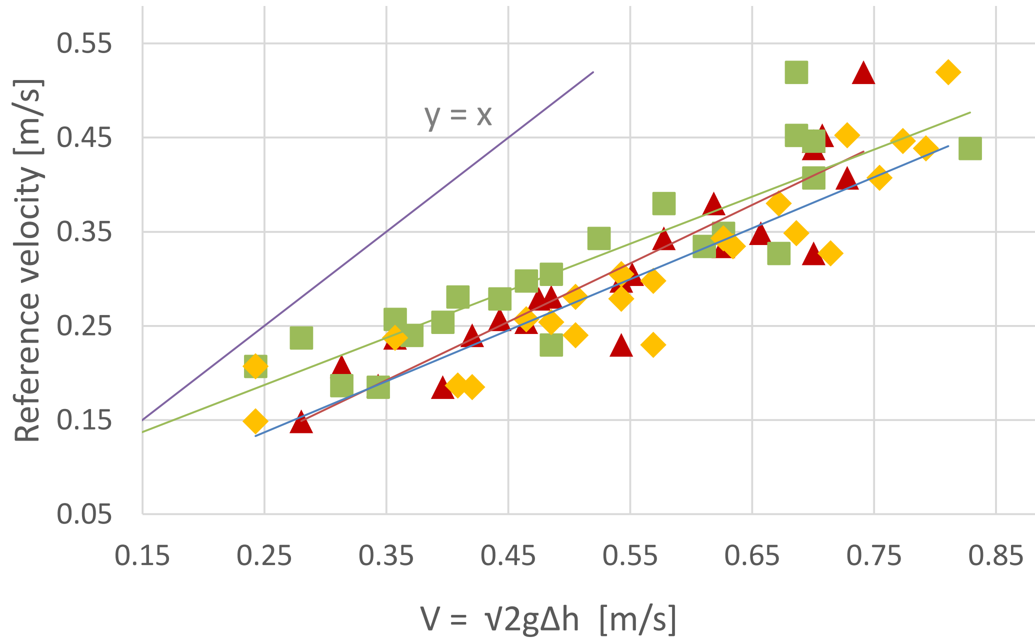
The head rod must be set on the streambed. Significant underflow reduces the observed water level difference and destroys the velocity rating.

Sensitivity to rod width

We were unable to predict the impact of width theoretically.

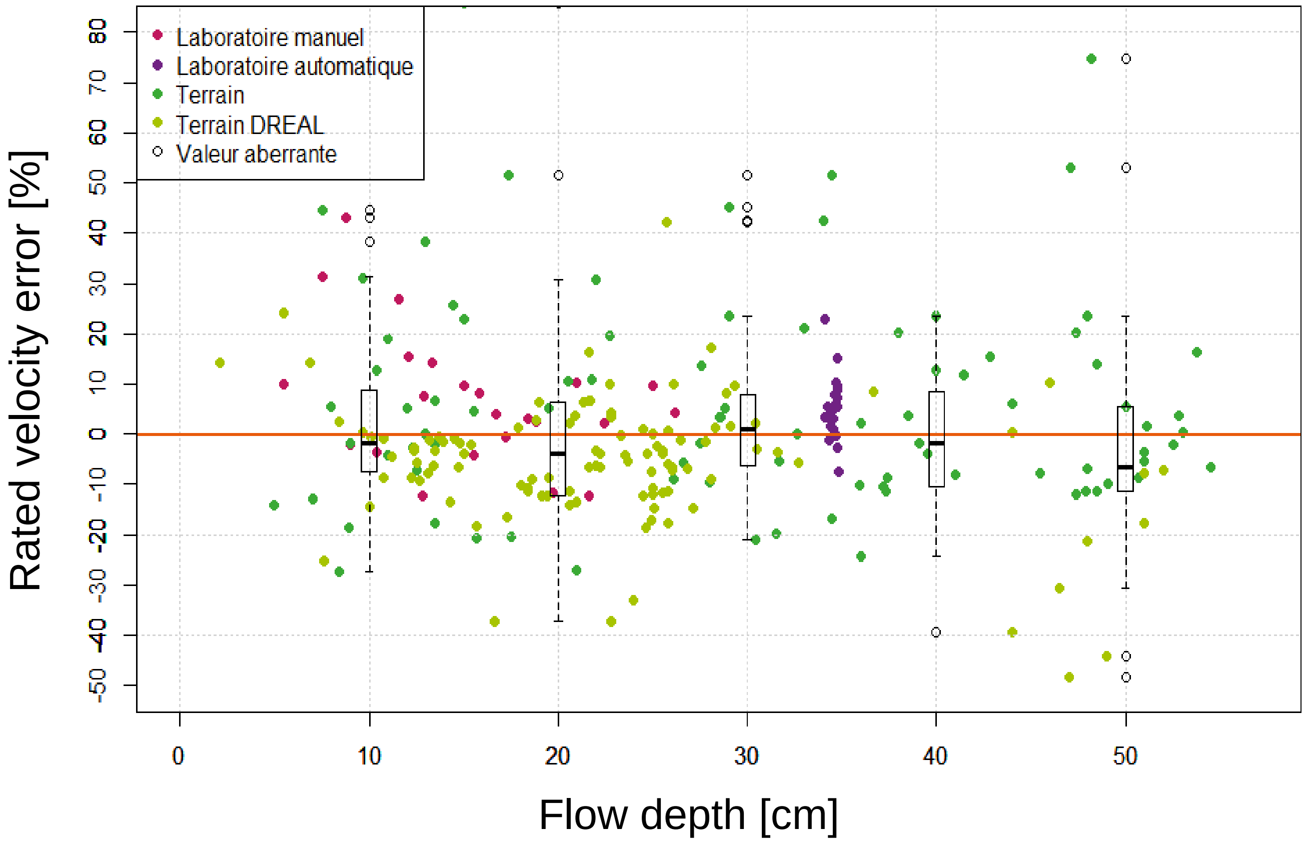
Rods with various widths were tested in the lab.

Rod widths:
5 cm, 9.85 cm and 15 cm



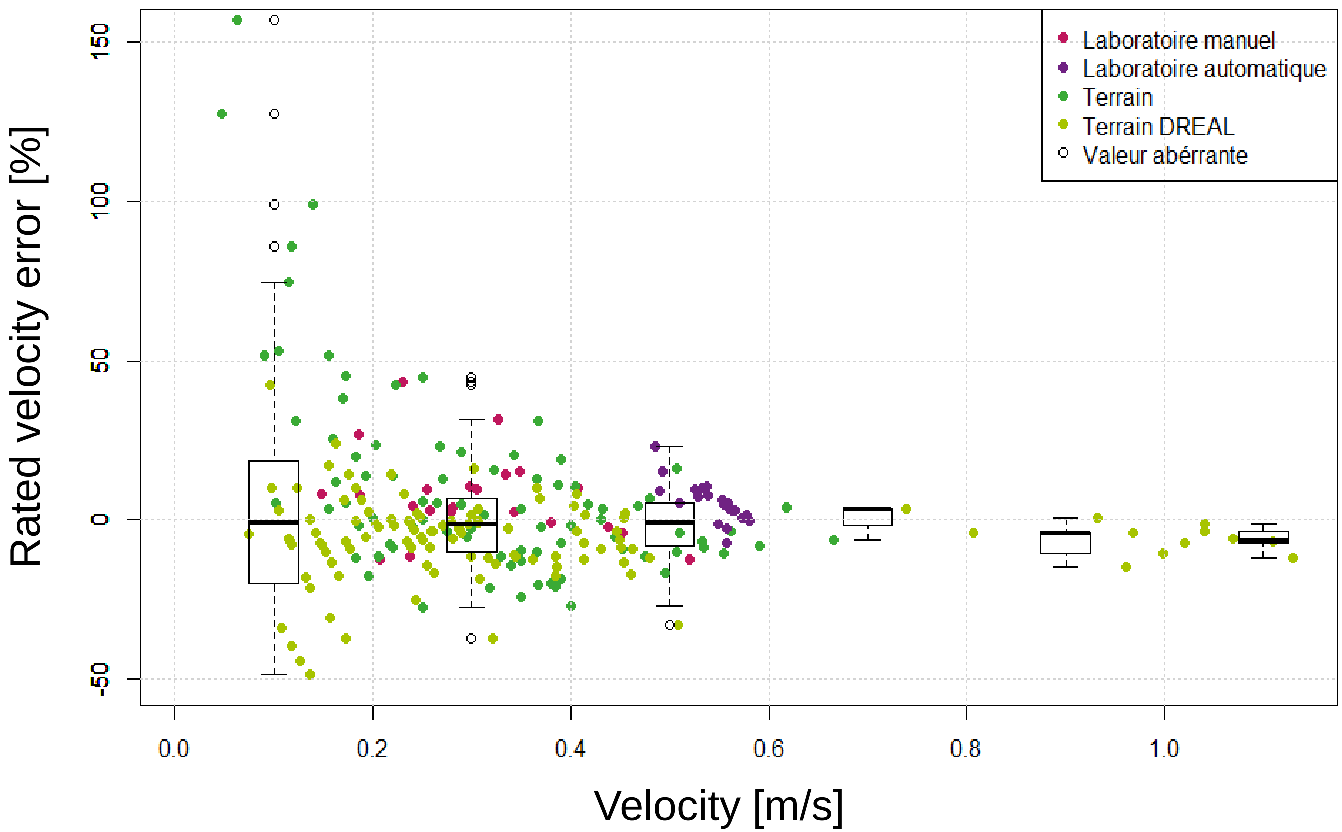
No clear impact of width from our results (too much scatter)

Impact of flow depth on velocity errors



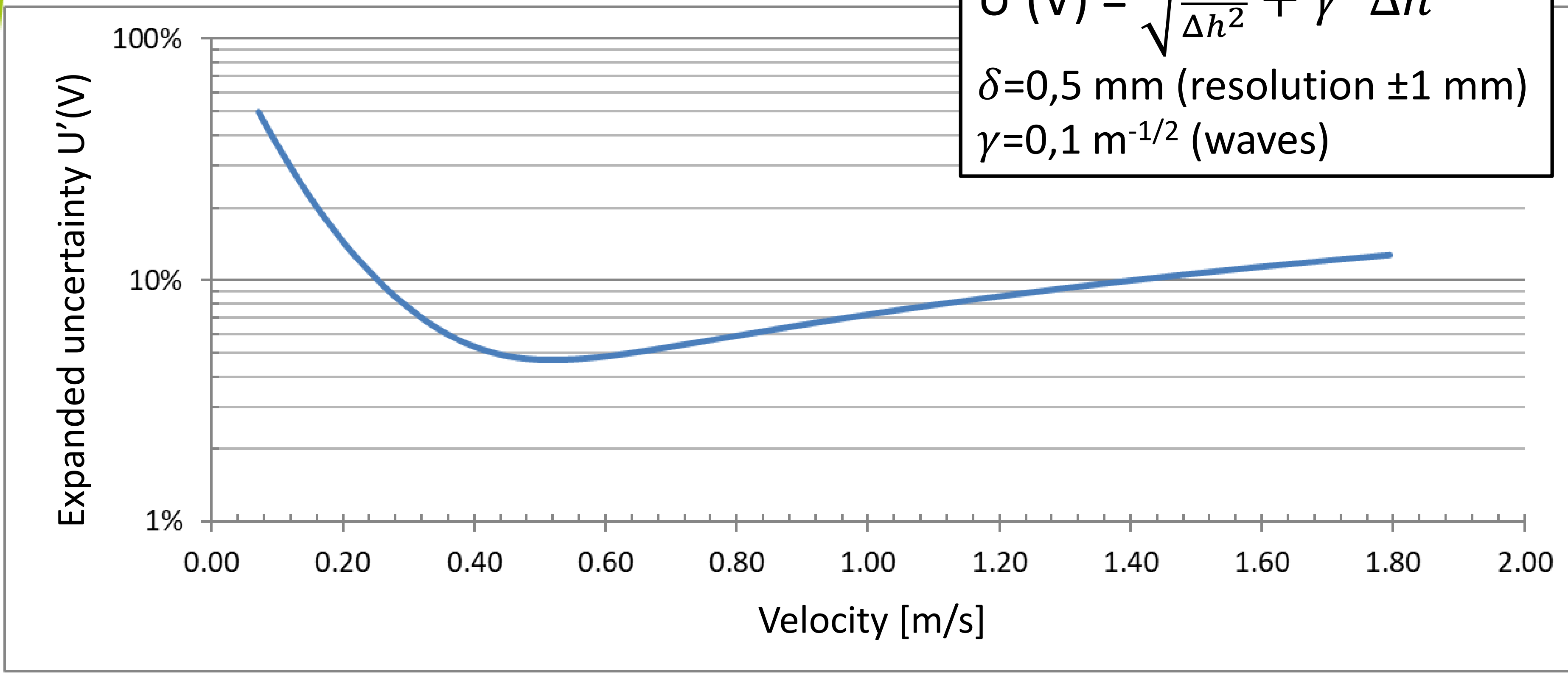
No obvious impact of flow depth on relative velocity uncertainty (in %)

Impact of flow velocity on velocity errors



Relative uncertainty (in %) increases exponentially with decreasing velocity

Velocity uncertainty due to head readings



$$U'(V) = \sqrt{\frac{\delta^2}{\Delta h^2} + \gamma^2 \Delta h}$$

δ=0,5 mm (resolution ±1 mm)

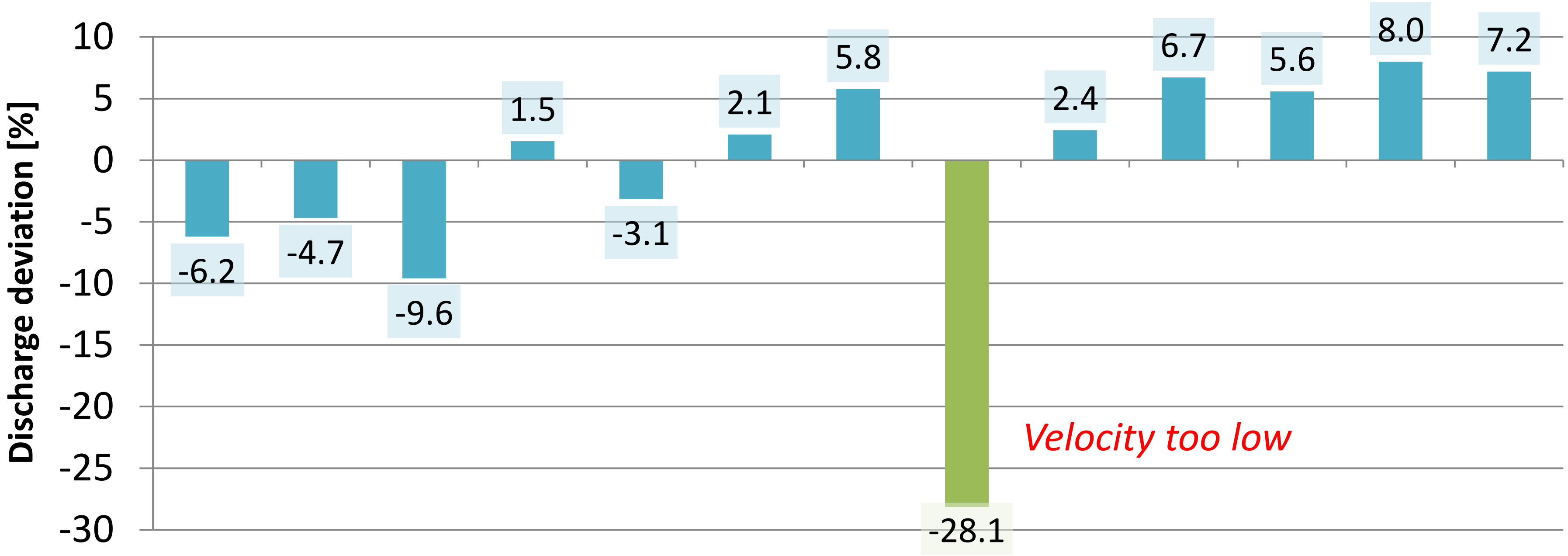
γ=0,1 $m^{-1/2}$ (waves)

Estimation of the expanded (95%) velocity uncertainty due to errors in water level difference reading

Other sources of error include: velocity rating, rod position, operator…

Discharge comparisons (in situ)

Comparison with discharges measured using conventional streamgauging techniques



Mean of absolute values: **5.2%**

Quite acceptable for the price!

Conclusions

An affordable and reliable tool

- Relatively easy to build
- Quick and easy use
- Direct measurement of the depth-average velocity using Pike et al. (2016) rating

Quality control and uncertainty analysis

- Confirmation of correct operating conditions (V > 20 cm/s)
- Reliable under normal conditions of use (ΔQ < 10%)
- Estimation of the uncertainty due to velocity head reading

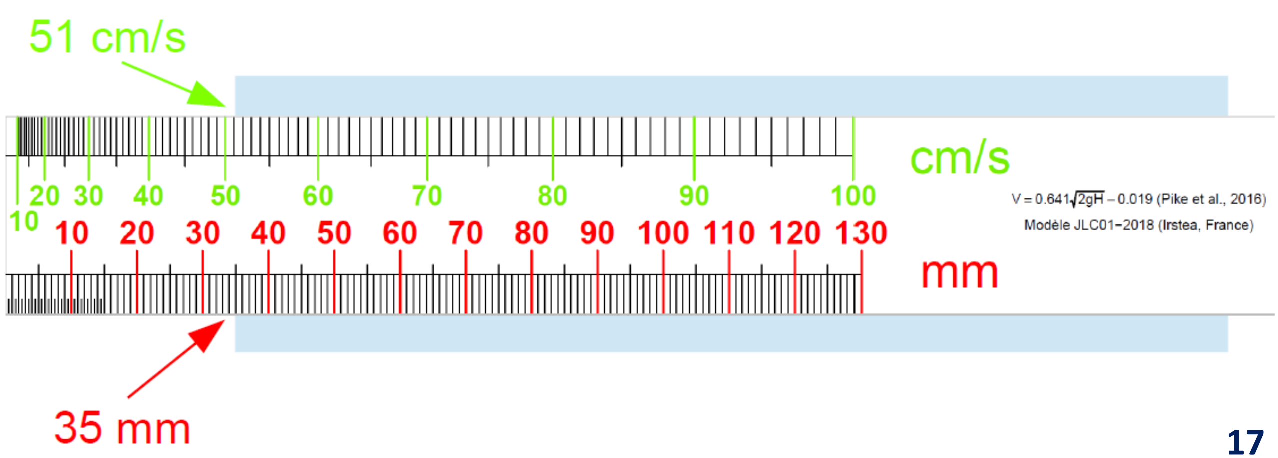
To be recommended for

- Quick flow estimates (instead of floats)
- Students, training
- Crowdsourced hydrology, partner organizations
- Developing countries

Perspectives

Attempts of improving the design

- Magnets instead of o-rings
- Plastic ruler with mm and cm/s graduations
- Spirit level
- Another ruler for depth measurements



Perspectives

- Field procedure and user guide
- Spreadsheet for easy discharge computation

Mémo terrain – Jaugeages Police de l'Eau **1/2**
Jaugeage par perche transparente

AGENCE FRANÇAISE POUR LA BIODIVERSITÉ
ÉTABLISSEMENT PUBLIC DE L'ÉTAT

Je respecte les consignes des jaugeages au courantomètre

Voir le Mémo terrain – Jaugeages Police de l'Eau
Exploration des vitesses sur perche

- Choix du site de mesure
- Surveiller le niveau d'eau
- Déploiement du décamètre
- Nombre et position des verticales
- Dépouillement du débit

- *L'écoulement doit être perpendiculaire à la section de jaugeage*
- *Resserrer les verticales sur les variations de profondeur et vitesse*
- *Resserrer les verticales là où passe le plus de débit*

Principe de la mesure des vitesses

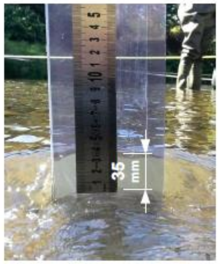
Perche transparente à charge dynamique :

- La différence de niveau d'eau amont/aval *Dh* augmente avec la charge dynamique liée à la vitesse moyenne *V* de l'écoulement
- Dimensions : 9,85 x 100 x 1,5 cm
- Relation d'étalonnage (Pike et al. 2016) :

$$V = 0{,}641\sqrt{2g\,Dh} - 0{,}019$$

[m/s] [m]

- *Profondeurs min/max : 5 à 75 cm*
- *Charges min/max : 2 à 100 mm*
- *Vitesses min/max : 10 à 90 cm/s*



Documents de référence :

- **Pike et al. (2016)** Development and testing of a modified transparent velocity-head rod for stream discharge measurements. Canadian Water Resources Journal, 41(3), 372-384
- **Pernot, F. (2018)** Elaboration de systèmes de jaugeage à bas coût, Mémoire de stage de fin d'études, Irstea / Université Nice Sophia Antipolis, 48 p.

irstea

	A	B	C	D	E	F
1	Stream Gauging using a Transparent Velocity Head Rod (TVHR)					
2						
3	Operators:			Date:		
4						
5	Stream Name:			Site Name:		
6						
7	Rod ID:			Start Bank (Left/Right):		
8						
9	START Time:			END Time:		
10						
11						
12	START Water Level (m):			END Water Level (m):		
13						
14	Vertical	Position (m)	Flow depth (cm)	Velocity head (cm)	Edge coefficien	Observations
15						
16	start	0	0		0.67	
17	1	1	10	1		
18	2	2	15	2		
19	3	3.5	20	3		
20	4	4	22	4		
21	5	5	35	7		
22	end	6	21		0.67	
23	7					
24	8					
25	9					
26	10					
27	11					
28	12					
29	13					
30	14					
31	15					
32	16					
33	17					
34	18					

Perspectives

- Bending in shallow flows may induce back pain
- Attempts of electrical contacts for adjusting rulers

Cheap electric head rod prototype