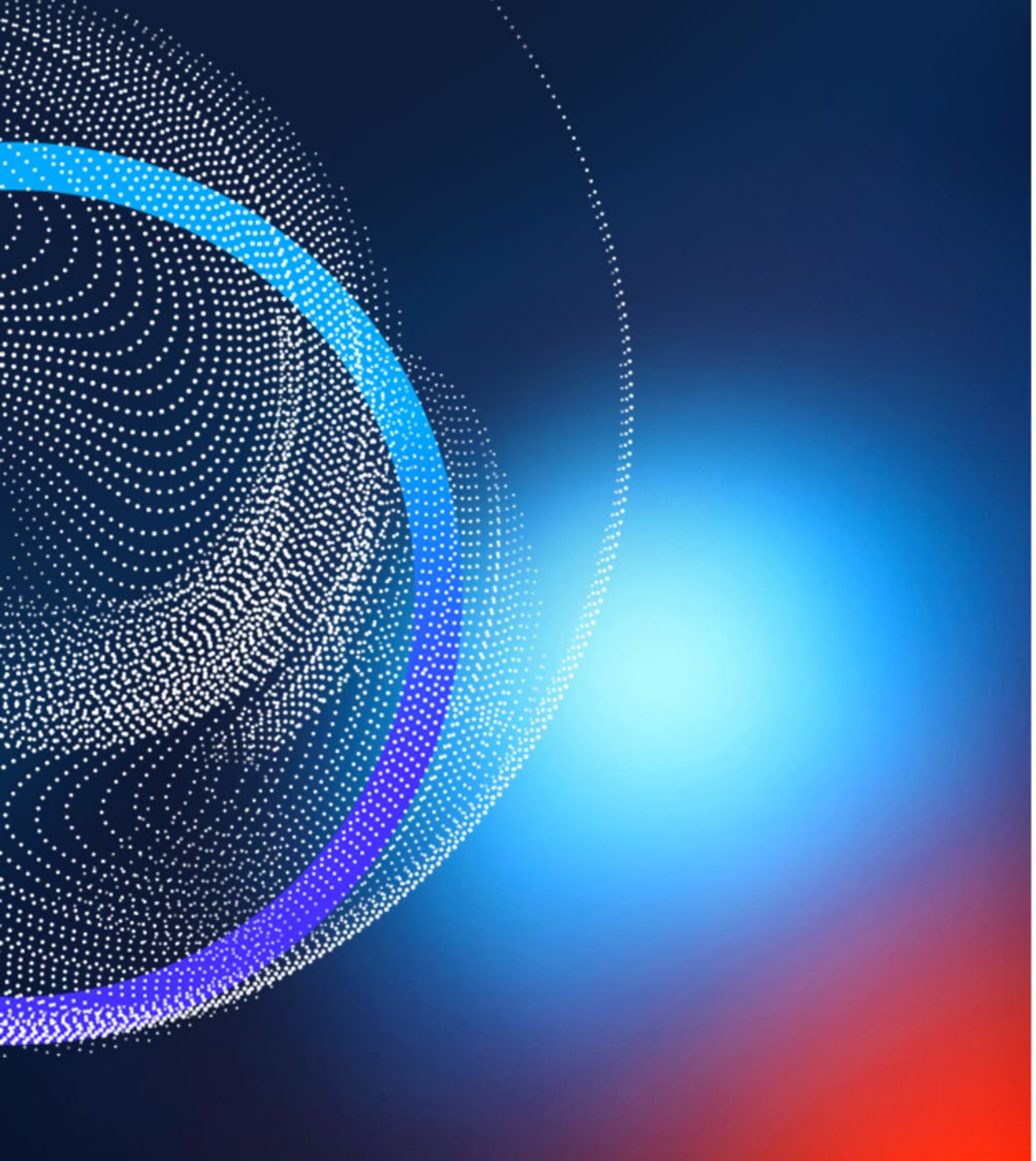


TotalEnergies

ORCAD PROJECT

Innovative Solution for Groundwater Characterization and Monitoring

International Project Team work

Sébastien Dehez
Nathalie Nief
Bertrand Segues
Gilles Pucheu
Anthony Credoz

PhD John Frederick Devlin
PhD Trevor Charles Osorno

Vincent Douard
Mathilde Grandjean
Philippe Monier
Alexia Mary

Salvador Jordana (Spain)

Béatrice Ducastel

TotalEnergies and Water

TotalEnergies

The CEO Water Mandate

January 31, TotalEnergies joined the **CEO Water Mandate**

REDUCTION TARGET FOR WITHDRAWALS FROM AREAS OF WATER STRESS

-20% by 2030

2030 WATER DISCHARGES QUALITY TARGET

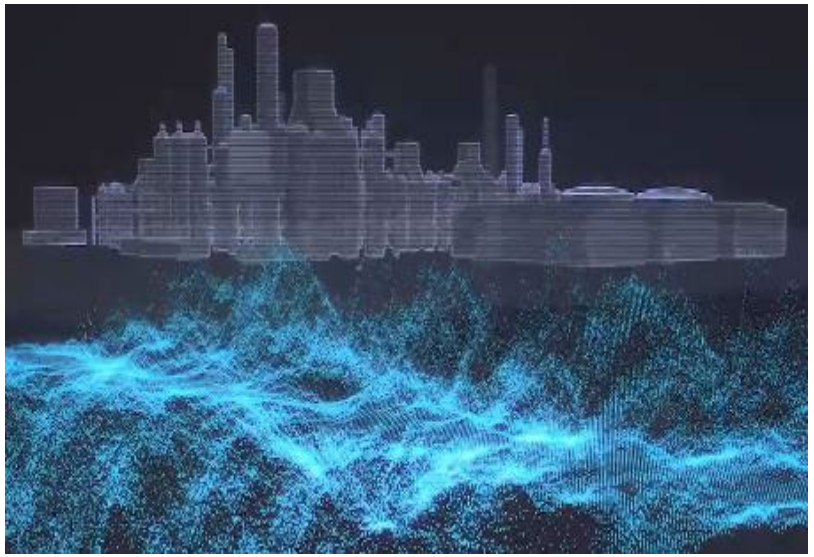
for **offshore** sites	for **onshore** site
<30 mg/l	**<1 mg/l**

Sites currently in line with 2030 target

92%	**80%**

Our R&D vision for GroundWater Monitoring

- ❑ Improve subsurface environmental **diagnostic** and **monitoring**
- ❑ Improve monitoring of environmental **footprint**
- ❑ Better face water **resource scarcity** in quantity and quality
- ❑ Comply with **regulation**
- ❑ **Manage** Subsurface Environmental Risks , on **groundwater resource**



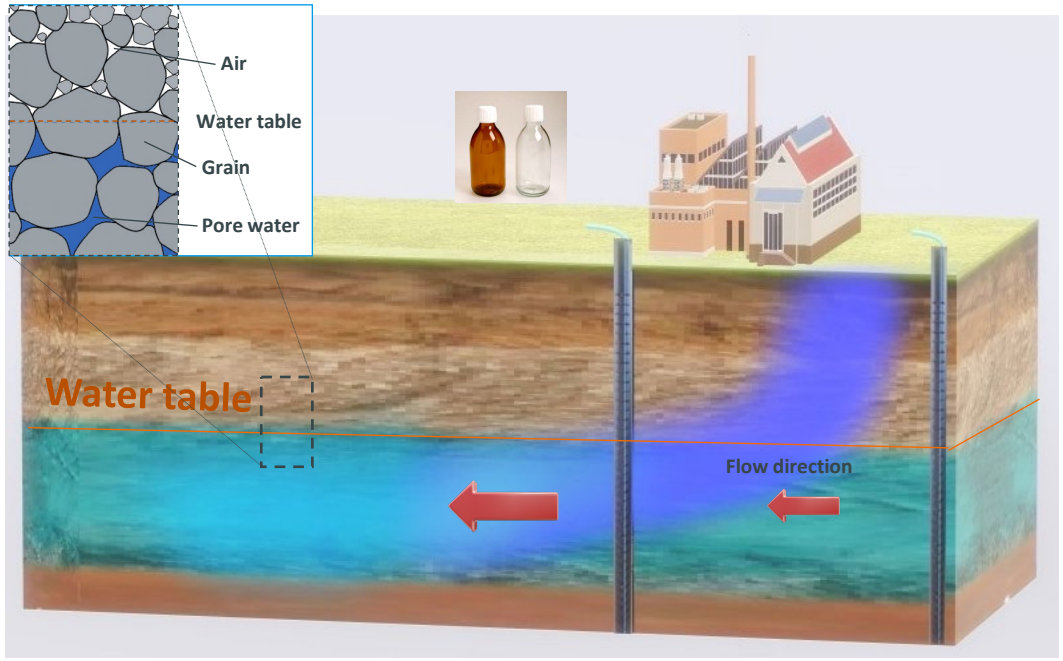
➔ ORCAD Solution: Online & Realtime Characterization of Aquifer Dynamic

In-situ, real-time and remote solution for GW monitoring

ORCAD - A New Approach

Flow velocity	x	Concentration	=	Mass Flux
$[m.s^{-1}]$		$[g.m^{-3}]$		$[g.m^{-2}.s^{-1}]$

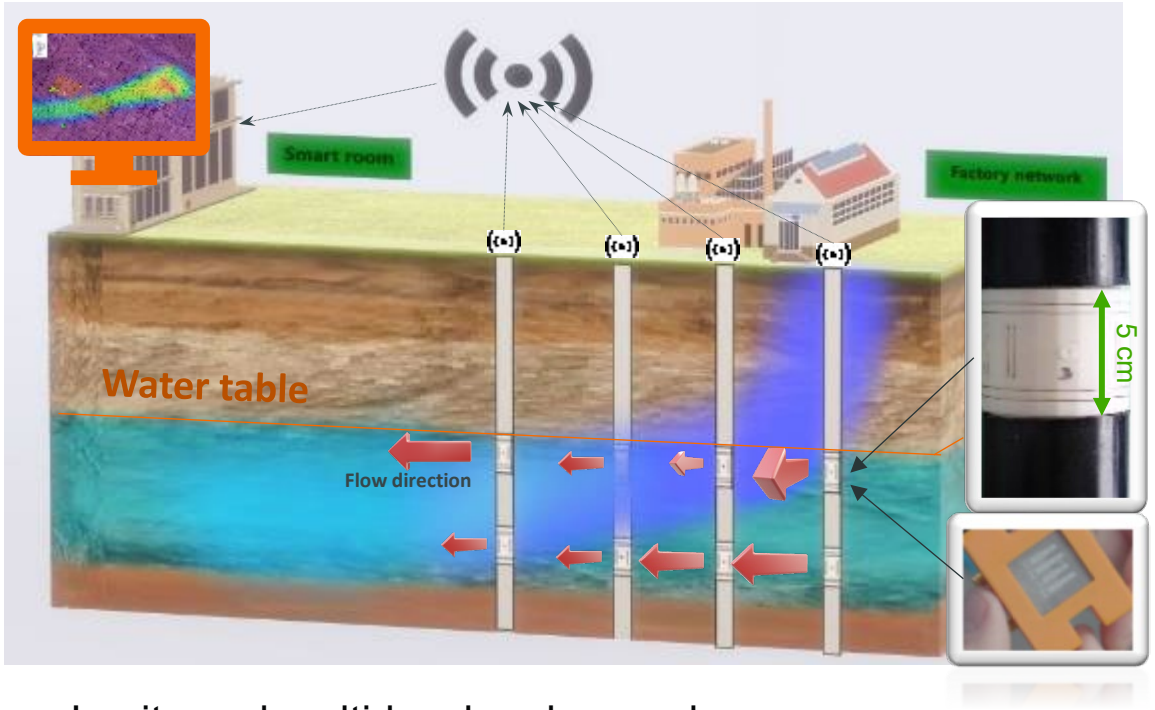
Till now: current "static" approach



- Spot sampling campaigns of monitoring wells
- GW flow velocity estimated from hydraulic gradients
- Chemical analyses on GW samples performed by external laboratory

➔ **Static image of aquifer (2D)**

Tomorrow: "dynamic“ monitoring of GW



- In-situ and multi-level probes and µ-sensors
- Real-time, continuous, remote solution

➔ GW flow direction & velocity measurements

➔ Mass flux assessment of dissolved contaminants

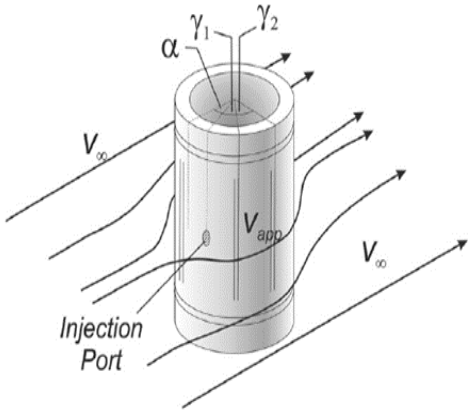
➔ **Dynamic characterization & monitoring of GW (~ 4D)**

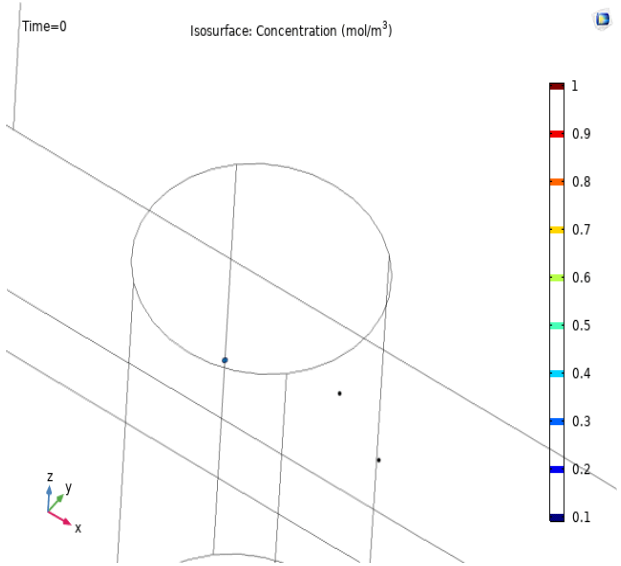
ORCAD – PVP probe

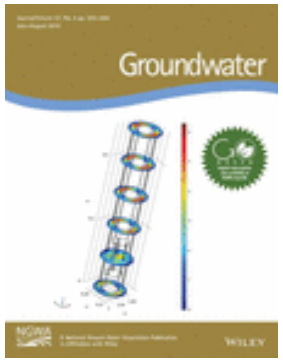
Measure groundwater pore velocity directly via in-situ small-scale tracer tests

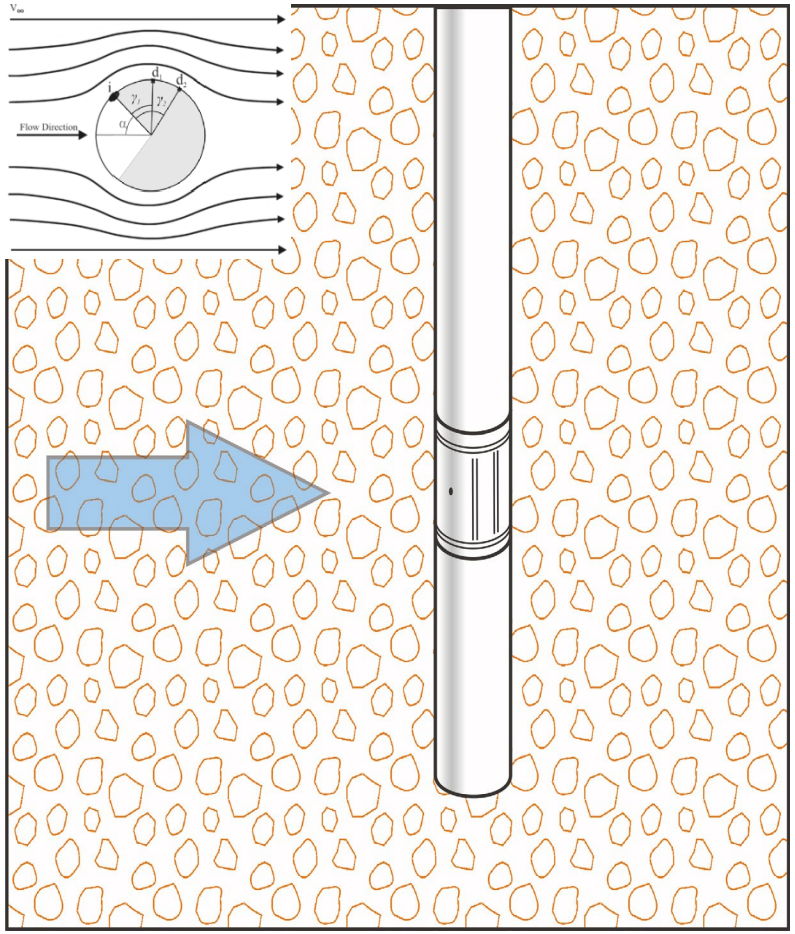
PVP : Point Velocity Probe

- Designed for unconsolidated porous media to measure 3-D velocity vector
- Tracer test along surface of cylinder in contact with porous media
- Including in situ GW sampling points





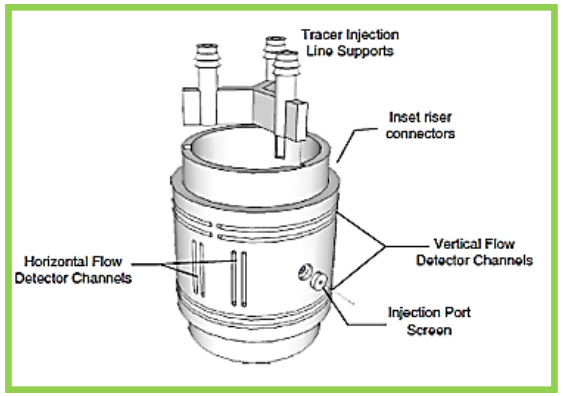


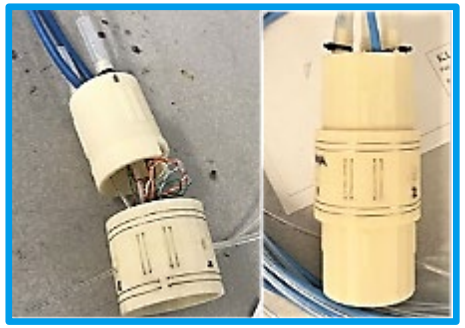


Martí Bayer-Raich, Anthony Credoz, Jordi Guimerà, Salvador Jordana, Diego Sampietro, Jordi Font-Capó, Nathalie Nief, Matthieu Grossemy Estimates of Horizontal Groundwater Flow Velocities in Boreholes, 14 August 2018
Ground water 2019 v.57 no.4 ISSN 0017-467X pp. 525-533 https://doi.org/10.1111/gwat.12820

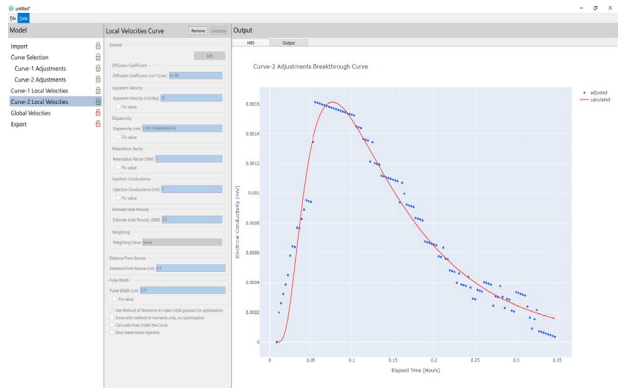
ORCAD – PVP probe

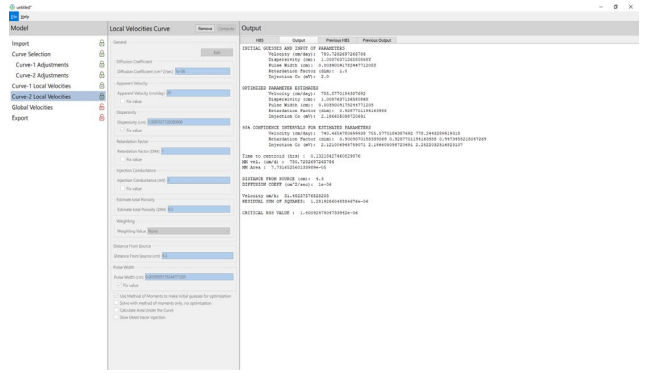
3D printed sensors and hand made assembly ➔ cost-effective device





Data collection in situ and realtime, simplified data processing with Velprobe app





➔ GW flow direction & velocity measurements

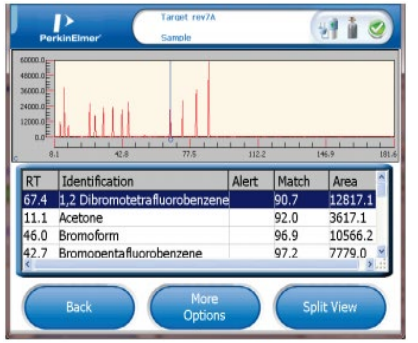
ORCAD Solution for chemical analysis of dissolved species

TotalEnergies

1/ Direct sampling in porous media by PVP Port sampling + Field analyze with Torion T9

- Portable analyzer by gas chromatography /mass spectrometer
- Fast on-site measurements of organic compounds (including VOCs)
- Commercialized by PERKIN ELMER

Torion T9



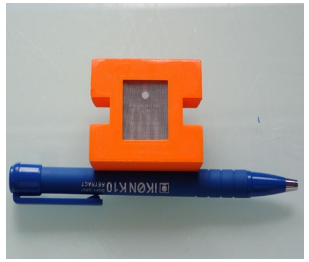
2/ µ-sensors SAW (ANR underground project)

anr agence nationale de la recherche

femto-st SCIENCES & TECHNOLOGIES

https://anr.fr/Project-ANR-17-CE24-0037

- Tested on demonstration pilot site for BTEX detection
- Still in development (Benzene, others chemical species)

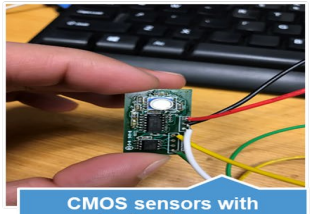


3/ Nano-sensors CMOS in development withTotalEnergies

California Institute of Technology 1891

PH sensors
Range 2 to 12
+/- 0.1

CMOS sensors:
Pression range:
0 to 14 Bars +/- 0.2 mbar
Temperature range
1 to 45°C +/- 0.1°C

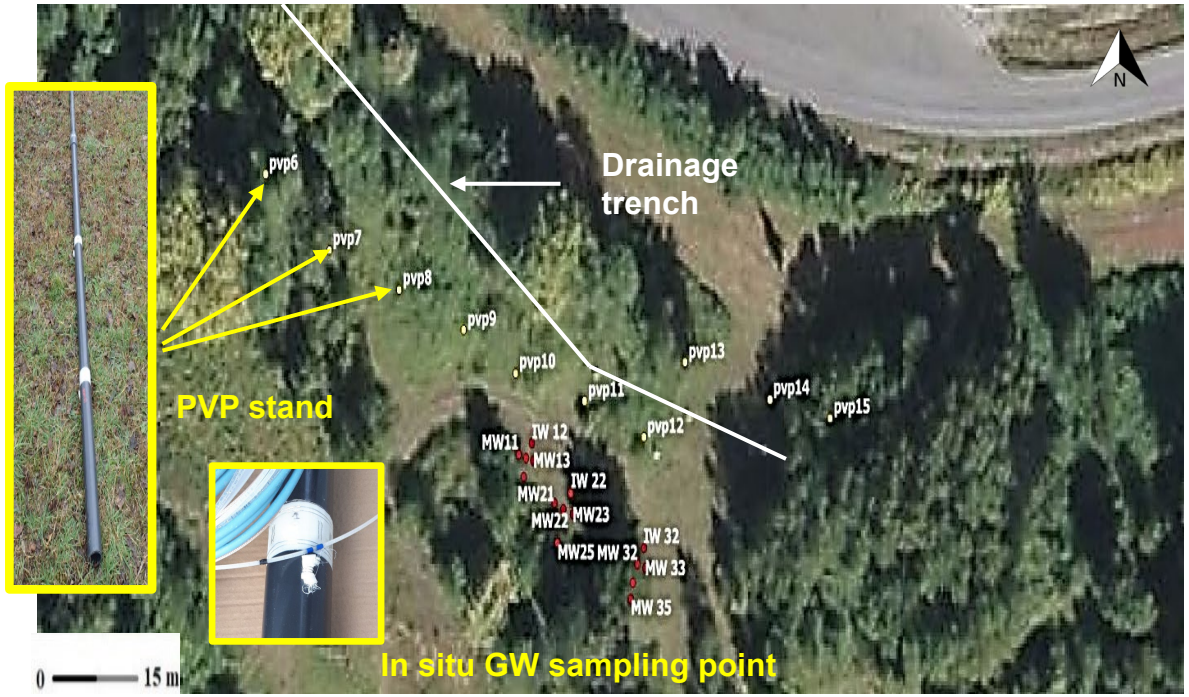


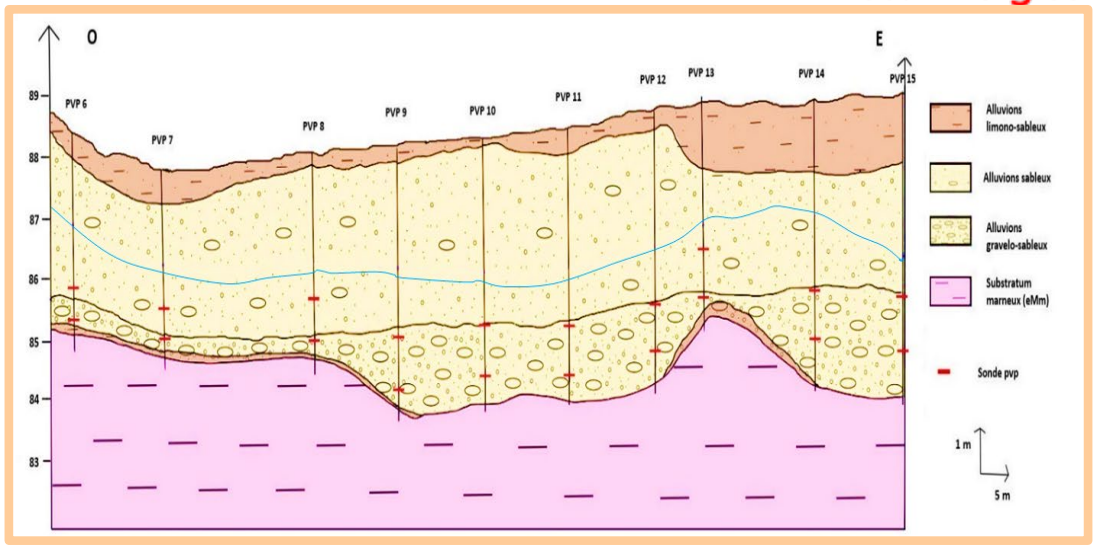
CMOS sensors with electronic nose
BTEX sensors
range 1 to 100000µg/L
+/- 1µg/l

Small Spectro FTIR
Acquisition time: ~3 sec
λ range 7.5 to 15 µm

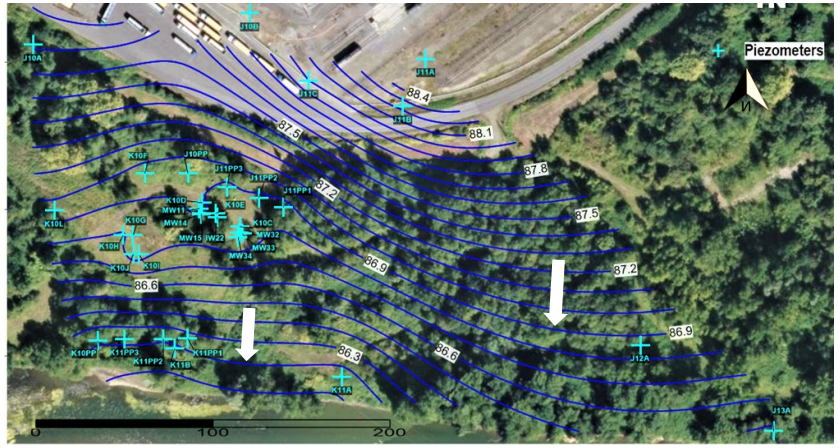
Demonstration pilot site description

- Transect of ten 2-probes PVP stand => **20 PVP**
- 20 in situ **GW sampling points**
- Covered area ~ 100 m
- A paleo-channel suspected in the area
- Crossing of transect through the drainage trench





Homogeneous media: alluvium sandy ; alluvium gravelly sand
=> High velocity expected
Saturated zone = 1.5 to 2 m (substratum between 3,5 to 4.5 m)

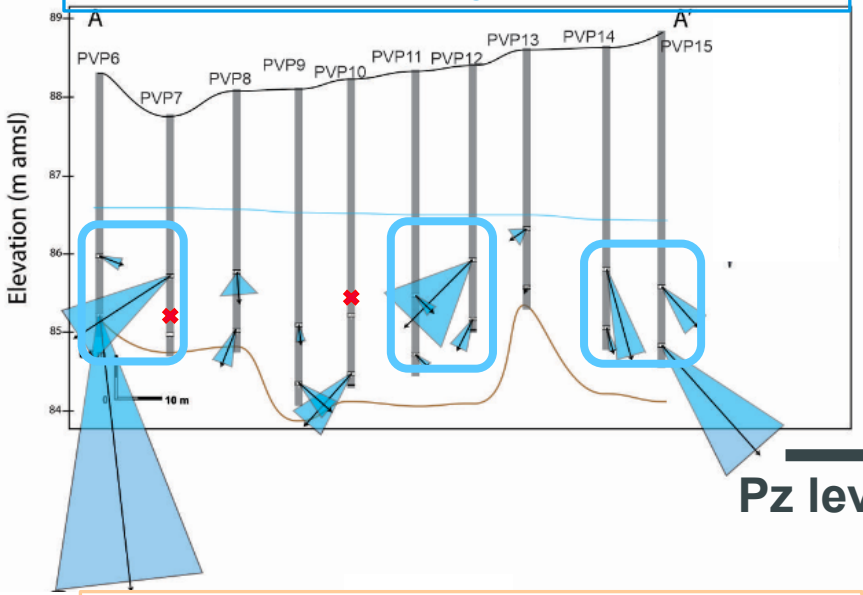


Technical Results : Groundwater FLOW SUMMARY

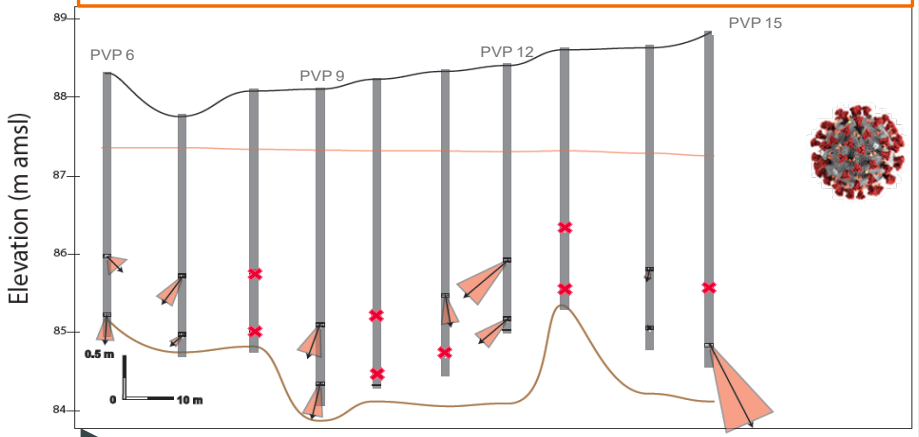
18 PVP tested
(x 3-6 measures)

GW velocity
0.1 m/d
(PVP 13 deeper)
to 12.8 m/d
(PVP 6 deeper)

February 2020



March 2020



12 PVP tested
(x 3 measures)

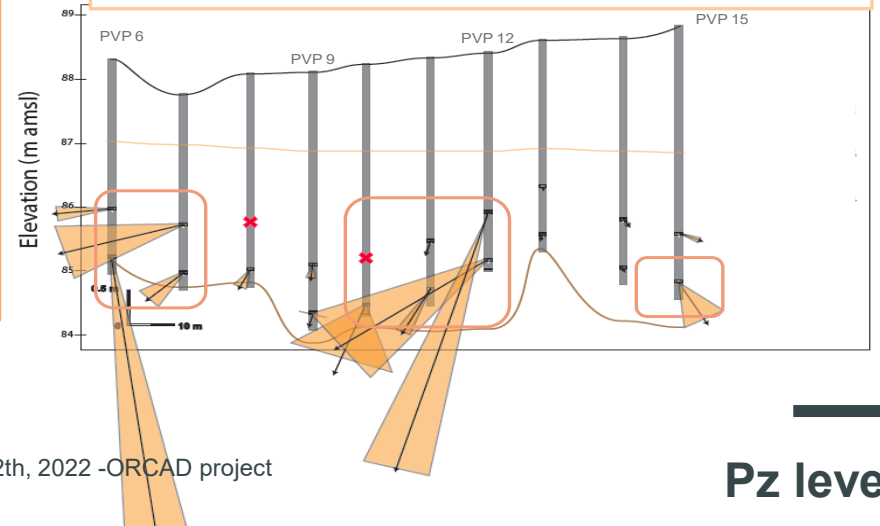
GW velocity
0.1 m/d
(PVP 14 deeper)
to 5.3 m/d
(PVP15 deeper)

Pz level (+ 82 cm)

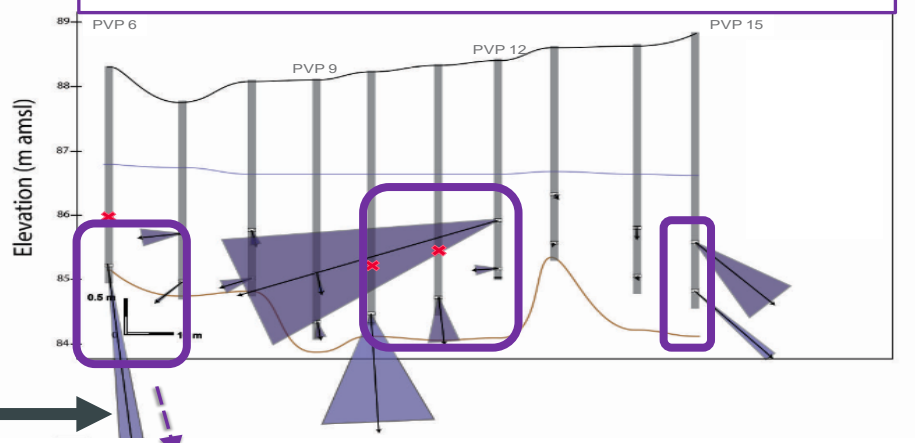
18 PVP tested
(x 3 measures)

GW velocity
0.1 m/d
(PVP 13 shallow)
to 20 m/d
(PVP 6 deeper)

May 2020



June 2020



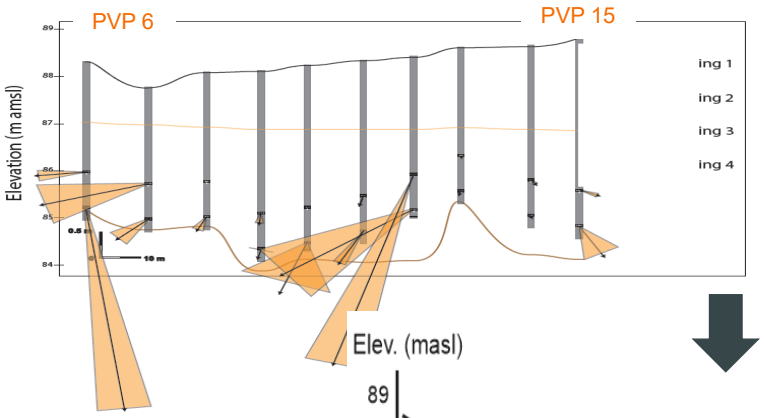
18 PVP tested
(x 3 measures)

GW velocity
0.1 m/d
(PVP 13 shallow)
to 34.1 m/d
(PVP 6 deeper)

Pz level (- 25 cm)

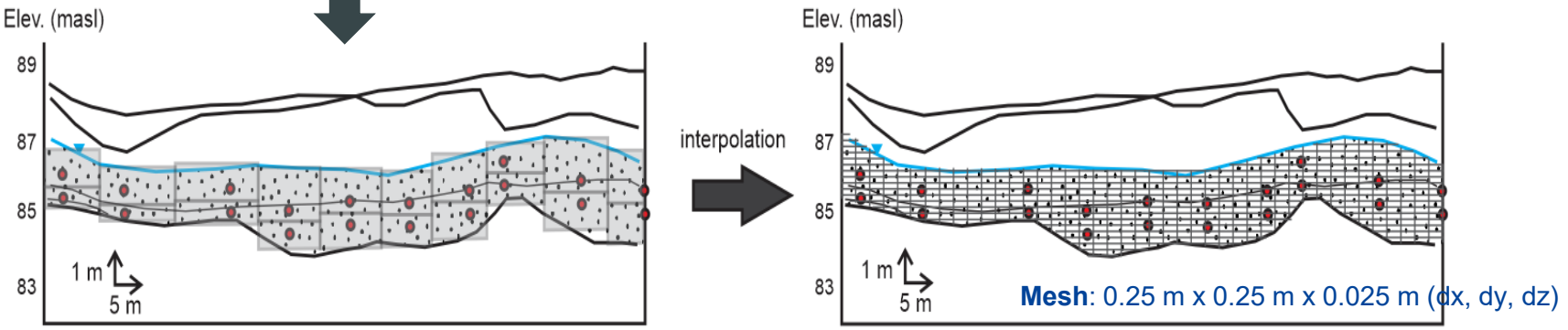
Technical Results: GW Flow Velocity Mapping

Hydrogeological visualization

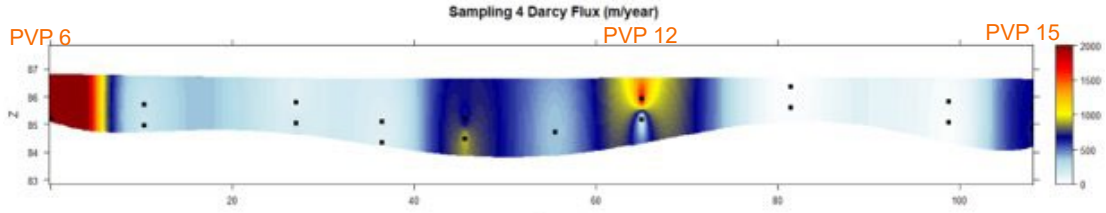


From **discrete** PVP measurement to the **whole** transect

Interpolation : inverse distance weighting



Mesh: 0.25 m x 0.25 m x 0.025 m (dx, dy, dz)

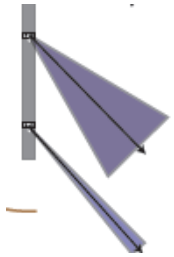


Statistical visualization

Technical Results: Mass Discharge of Dissolved Compounds

$$\sum \text{Darcy Flux} \times \text{Concentration} \times \text{X-Sect Area} = \text{Mass Discharge}$$

[m.year^{-1}] [Kg.m^{-3}] [m^2] [Kg.year^{-1}]



Darcy Flux
[m.year^{-1}]

x

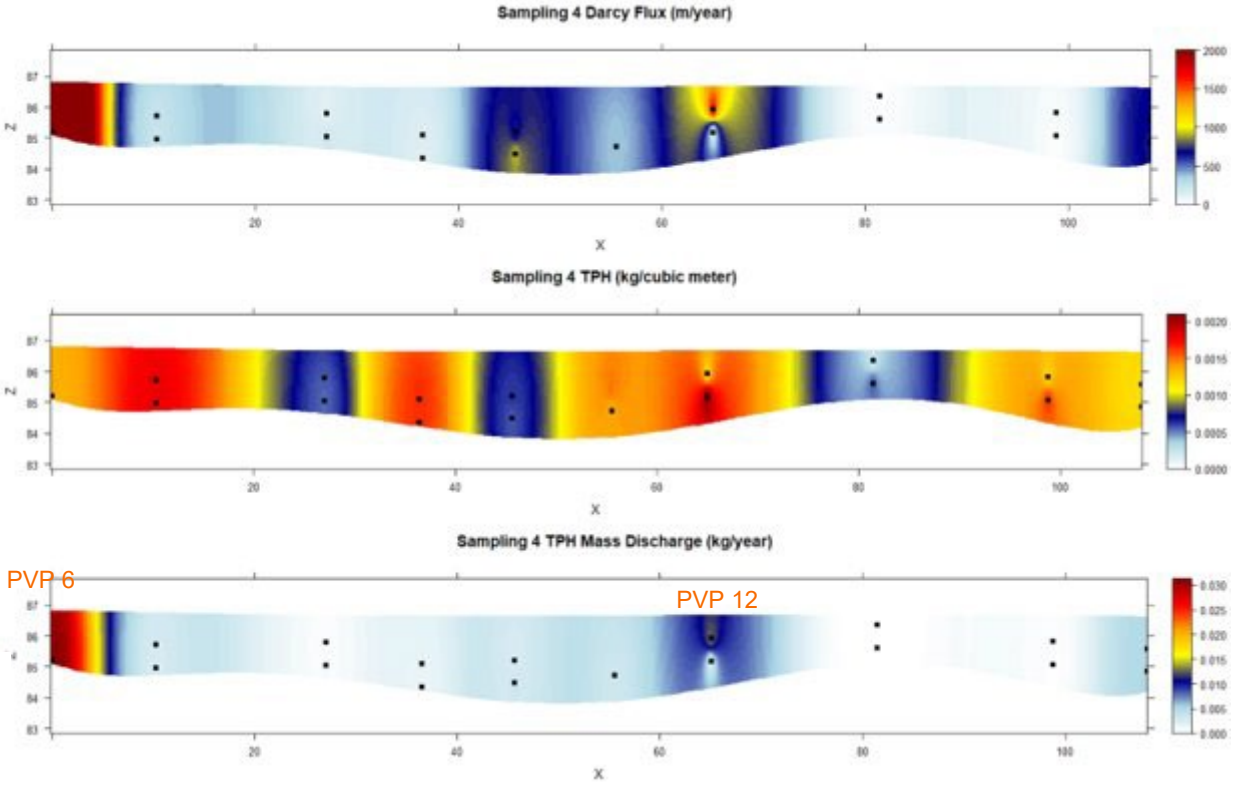
Concentration
[Kg.m^{-3}]

x

Section Area

=

Mass Discharge
[Kg.year^{-1}]

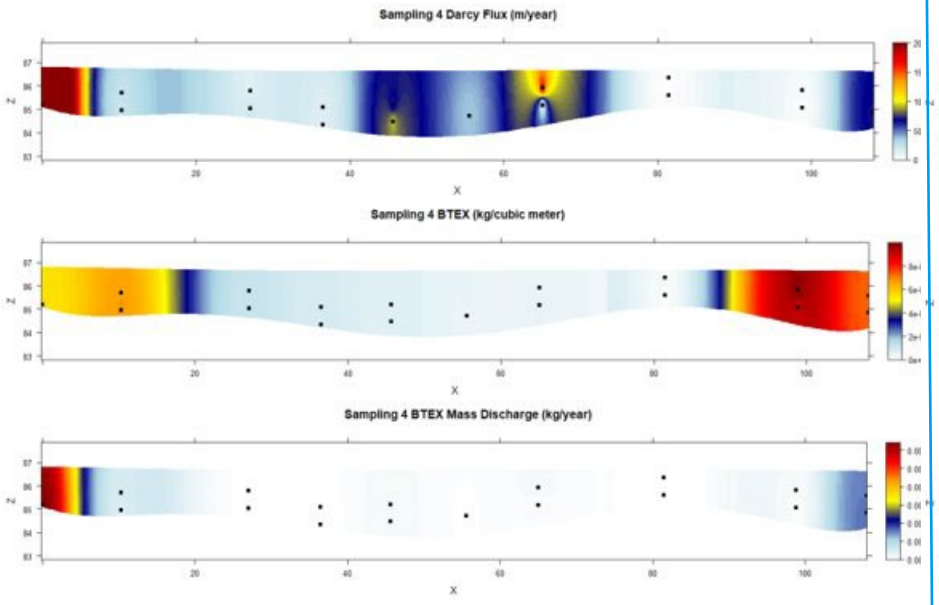


June campaign for Total Petroleum Hydrocarbons

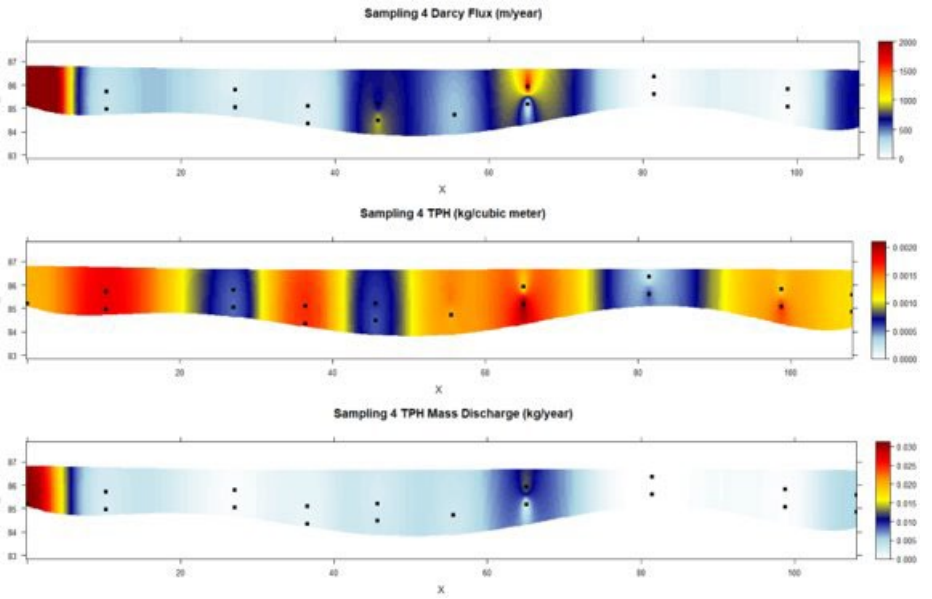
Technical Results: Mass Discharge of BTEX and TPH

2020 June campaign

Benzene, Toluene, Ethylbenzene, Xylenes (BTEX)



Total Petroleum Hydrocarbons (TPH)



Mass discharge dominated by distribution of flow not distribution of concentration

ORCAD Solution - Performances

TotalEnergies

- ✓ Direct **Groundwater pore velocity** magnitude ± *10 %* ***m.day^{-1}*** / angle ± *15°*
- ✓ Groundwater **Dissolved organic species** including volatile compounds: ± 20 % **g.m^{-3}**
- ✓ **Mass flux** calculation (Groundwater flow velocity x concentration): ***g.m^{-2}.day^{-1}***
- ✓ **Mass discharge** assessment (integrated along the transect surface in m^2): ***g.day^{-1}***

Direct, 3-D, real-time and multi-level measurement of pore velocity and flow direction

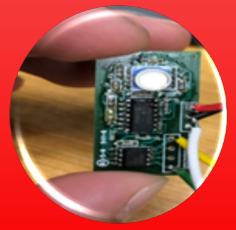
- Better assessment of groundwater dynamic behavior and optimization of further
- Strong reduction of uncertainties comparing to previous approaches for **mass discharge** assessment
- Several acquisitions per month versus quarterly field campaigns: optimized crisis management

onsite analysis

- Increasing analyses representativity
- Decreasing carbon emissions (transport samples + plastic containers)

Progress & Developpement

Miniaturizing & Digitalization & Operation

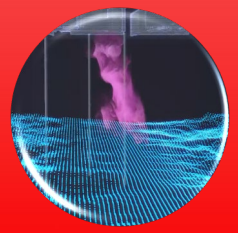


Improve and develop **In-situ microsensors** for chemical analyses and physical-chemical parameters

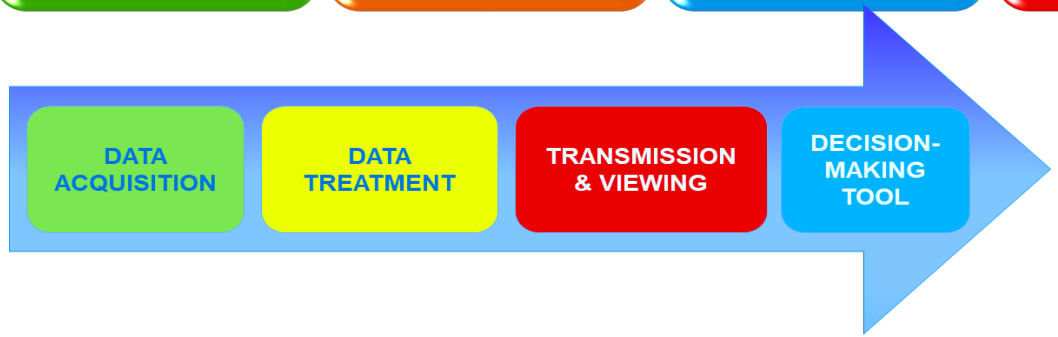
Improve real-time **acquisition** & **data treatment**

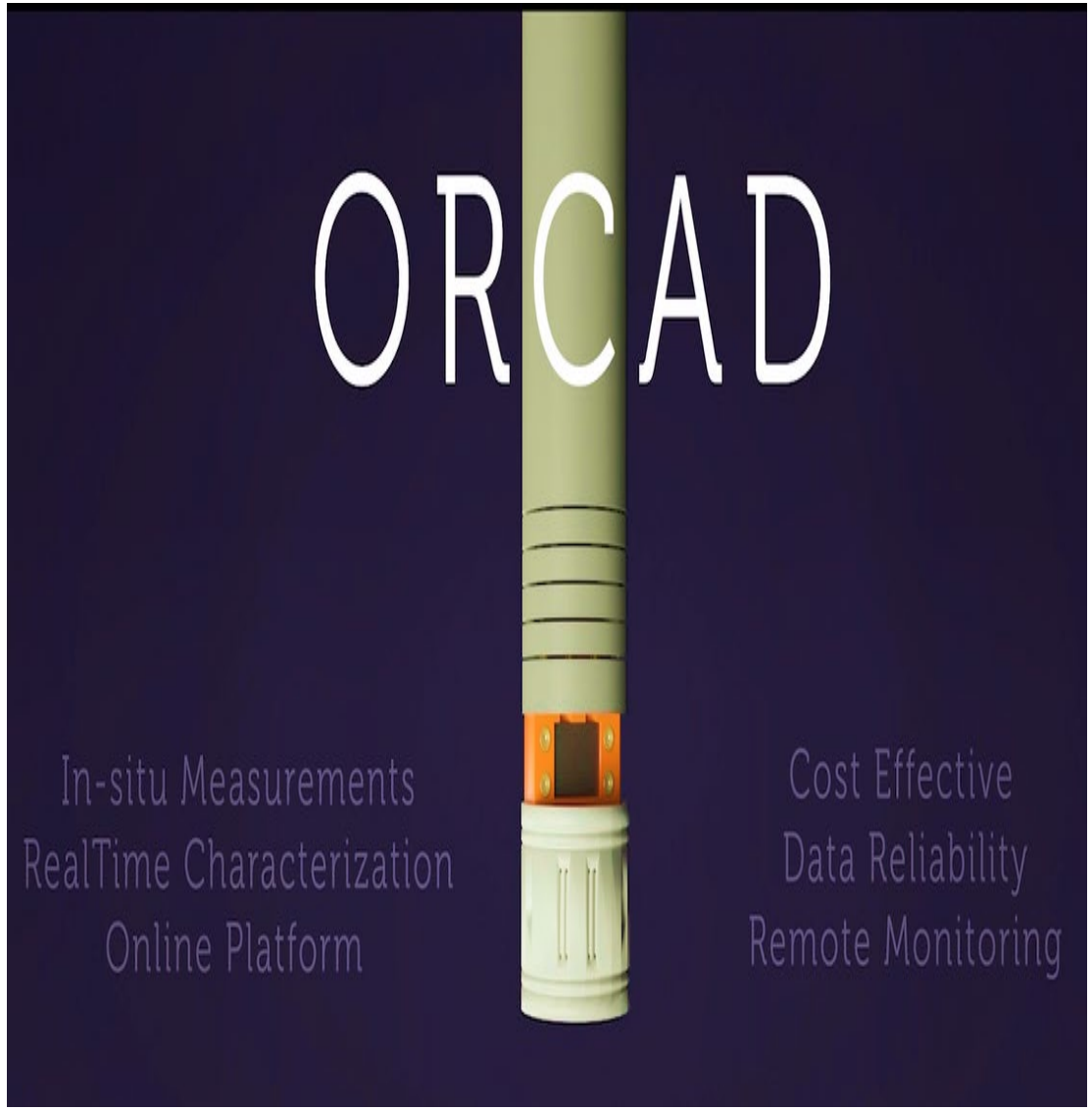
Automatization data transmission to Total Cloud Azure & data base.

Visualization in Remote Operation Lab (application dedicated)



Decision-making tool: respond to local asset manager expectations





TotalEnergies

Merci.

Thank you.