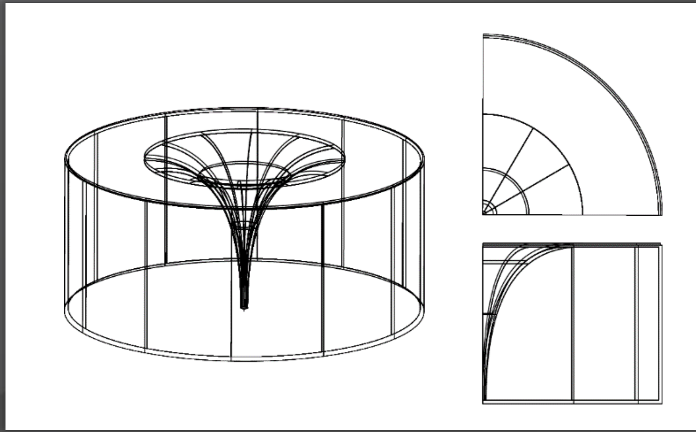

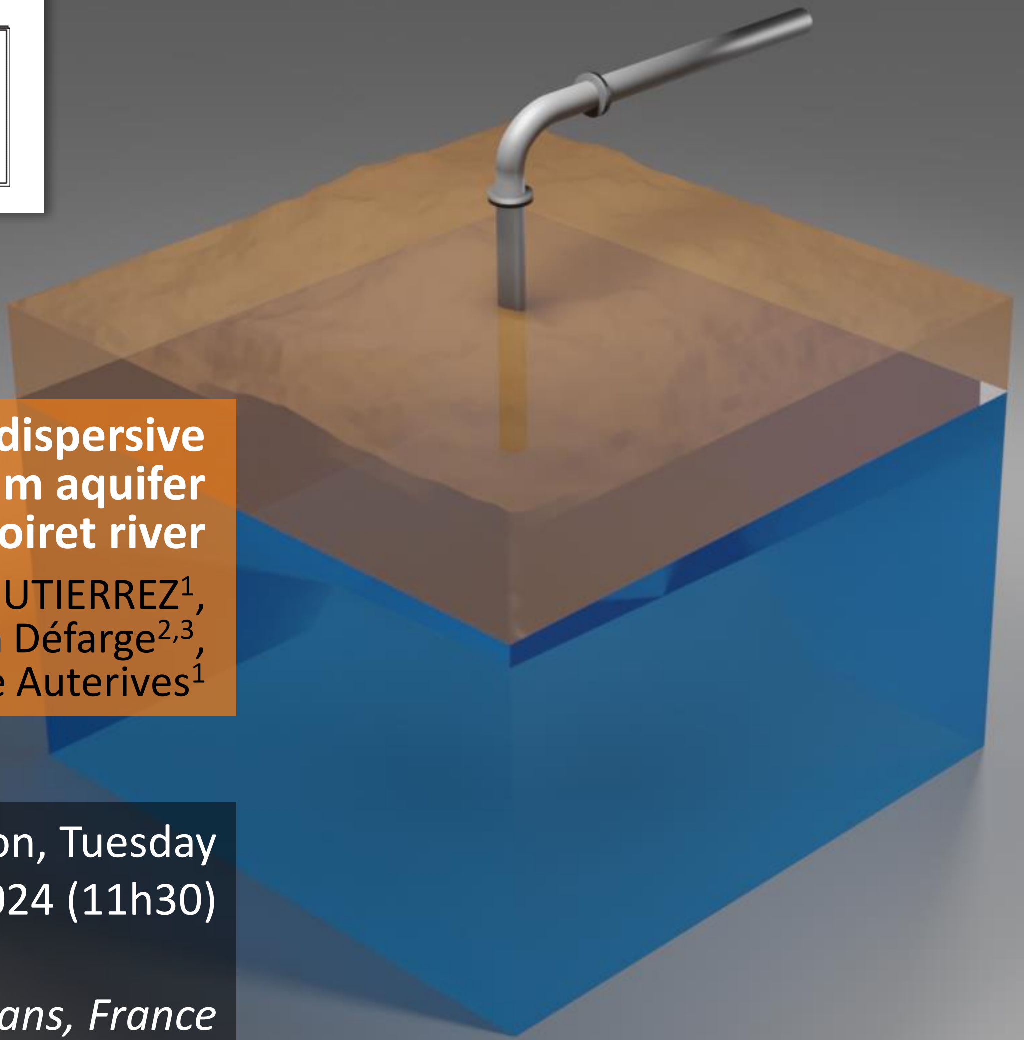

French Geological Survey
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Water Resource Management
3 avenue C. Guillemin BP 36009
45060 **Orléans** Cedex 2 France

Estimation of hydrodispersive characteristics of the alluvium aquifer of the Loiret river

Thomas KLINKA[1], Alexis GUTIERREZ[1], Nevila Jozja[2], Christian Défarge[2,3], Chrystelle Auterives[1]

Oral communication, Tuesday 14/05/2024 (11h30)

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Tracer 9
14-16 May 2024
Benicassim (Spain)

PRESENTATION OUTLINE

CENARI-O project

- ❑ Project's objectives
- ❑ Context
- ❑ Geology
- ❑ Hydrogeology
- ❑ Experiments
  - **Pumping test**
  - **Tracer test**
- ❑ Results
- ❑ Conclusions

Losses of the Loire

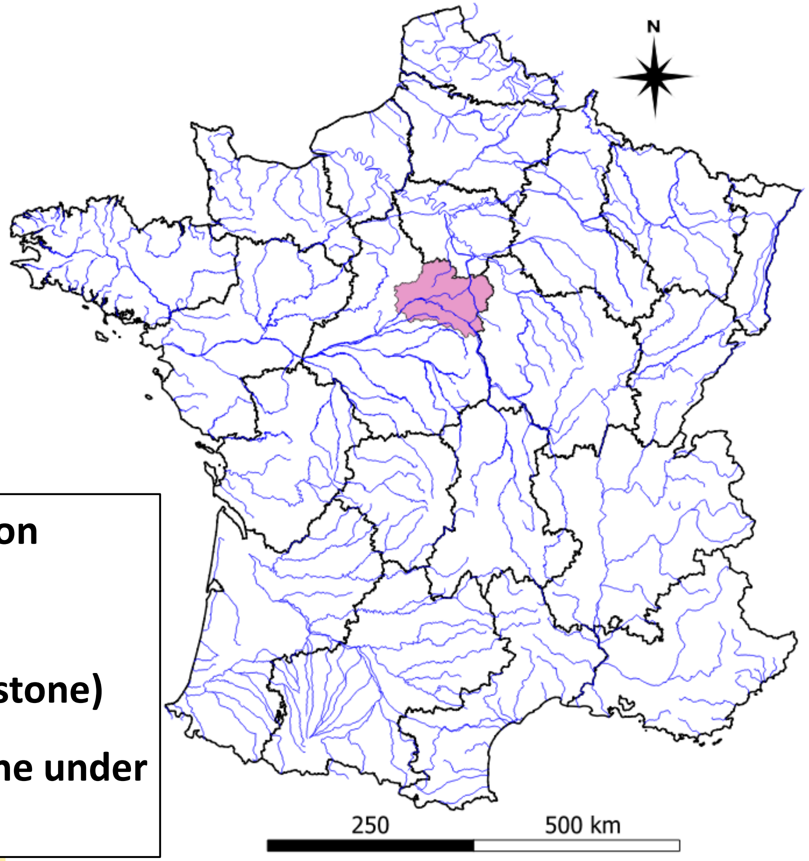
The Bouillon basin seen from the sky during a diving operation.
Photo Denis Chailloux (October 2020)

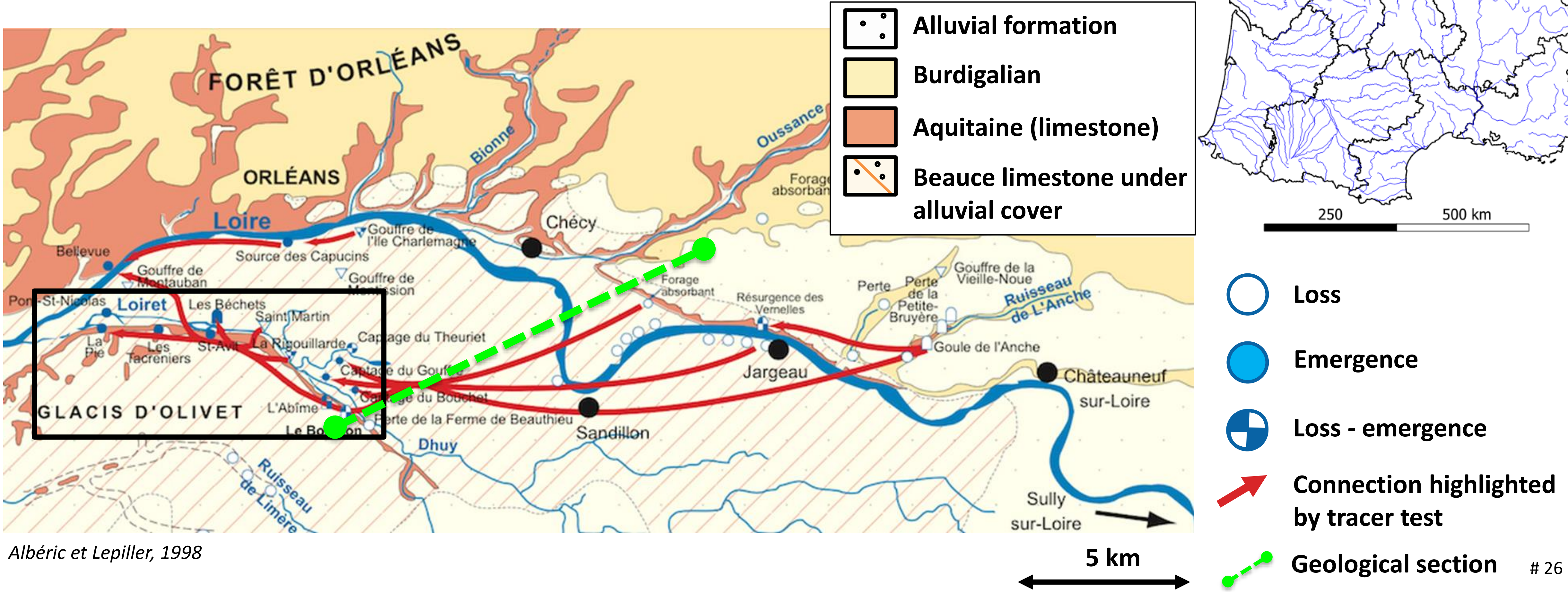
OBJECTIVES OF THE CENARI-O PROJECT

Complex system in Loire-nappe-Loiret interactions

- ❑ Better understand the interactions between groundwater and rivers

- ❑ Map of karst circulations in Val d'Orléans:

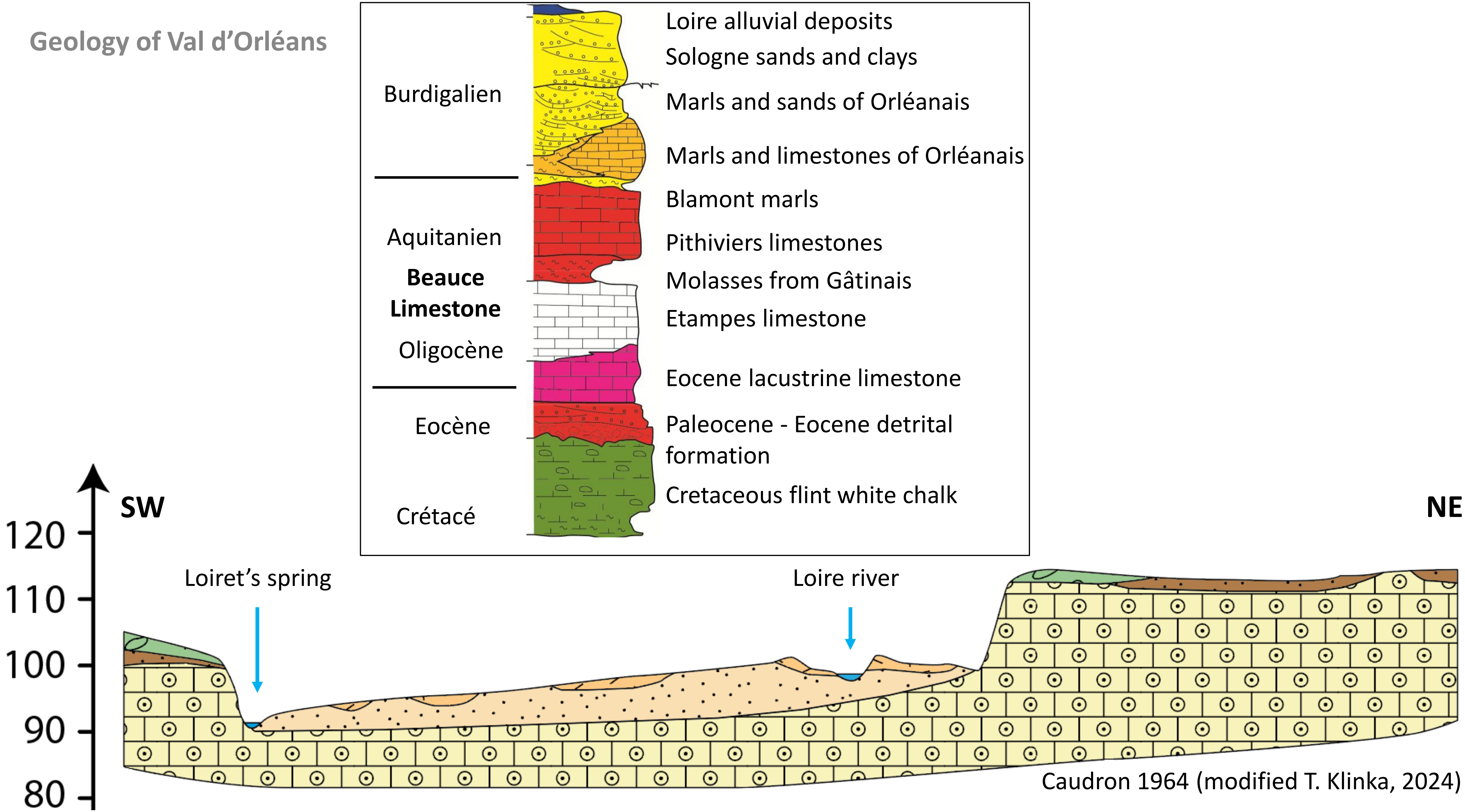




Albéric et Lepiller, 1998

GEOLOGICAL AND HYDROGEOLOGICAL CONTEXT

Geology of Val d'Orléans



Caudron 1964 (modified T. Klinka, 2024)

GEOLOGICAL CONTEXT

A karst system known for a long time…

The losses of the Loire nearby Jargeau

Tracer test in a loss

Entrance to the karst network explorable by speleologists

Karst network

Source of the Loiret (le Bouillon)

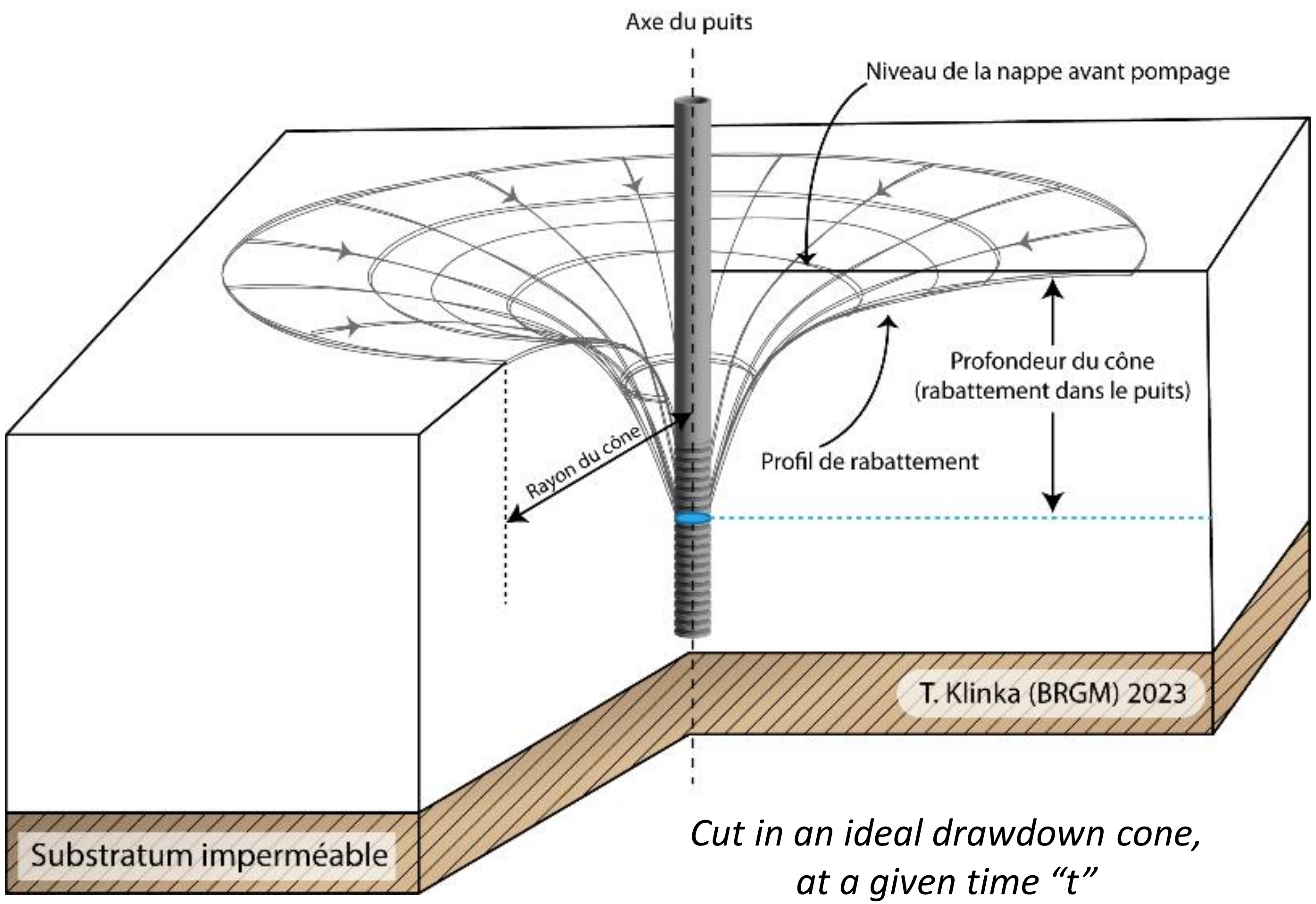
EXPERIMENTS

Coupling test pumping and tracer test

- Observation of the effects of pumping in a well or borehole considered one of the best means of investigation in hydrogeology

- Only with the help of tracing tests can spatial and temporal information on the mixing of substances contained in water (dispersion) and on the effective kinematic porosity in aquifers be obtained.

- Tracer tests make it possible to obtain data on the probable residence times in the aquifer and on the appearance times of substances in a well.



Cut in an ideal drawdown cone, at a given time "t"

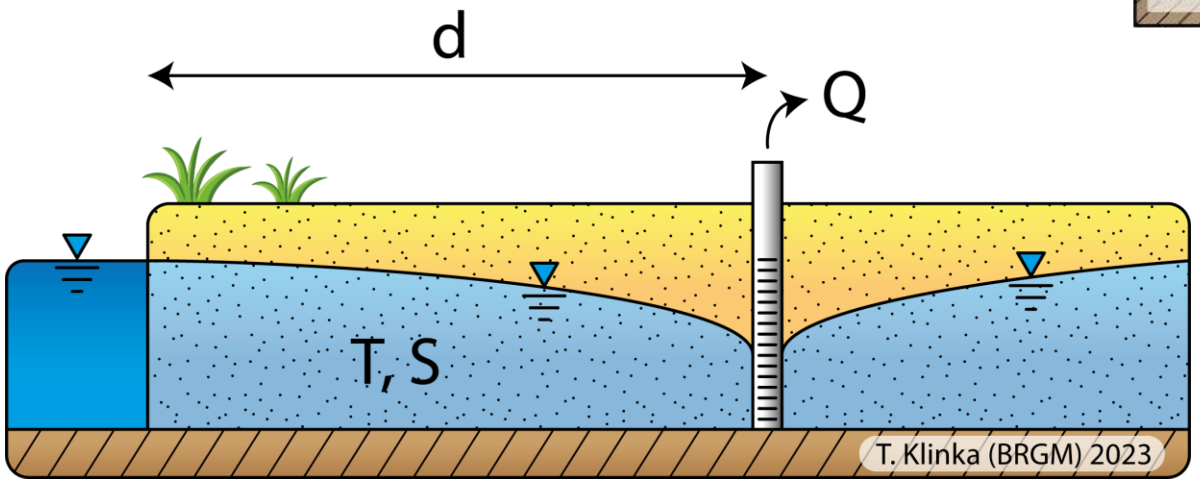
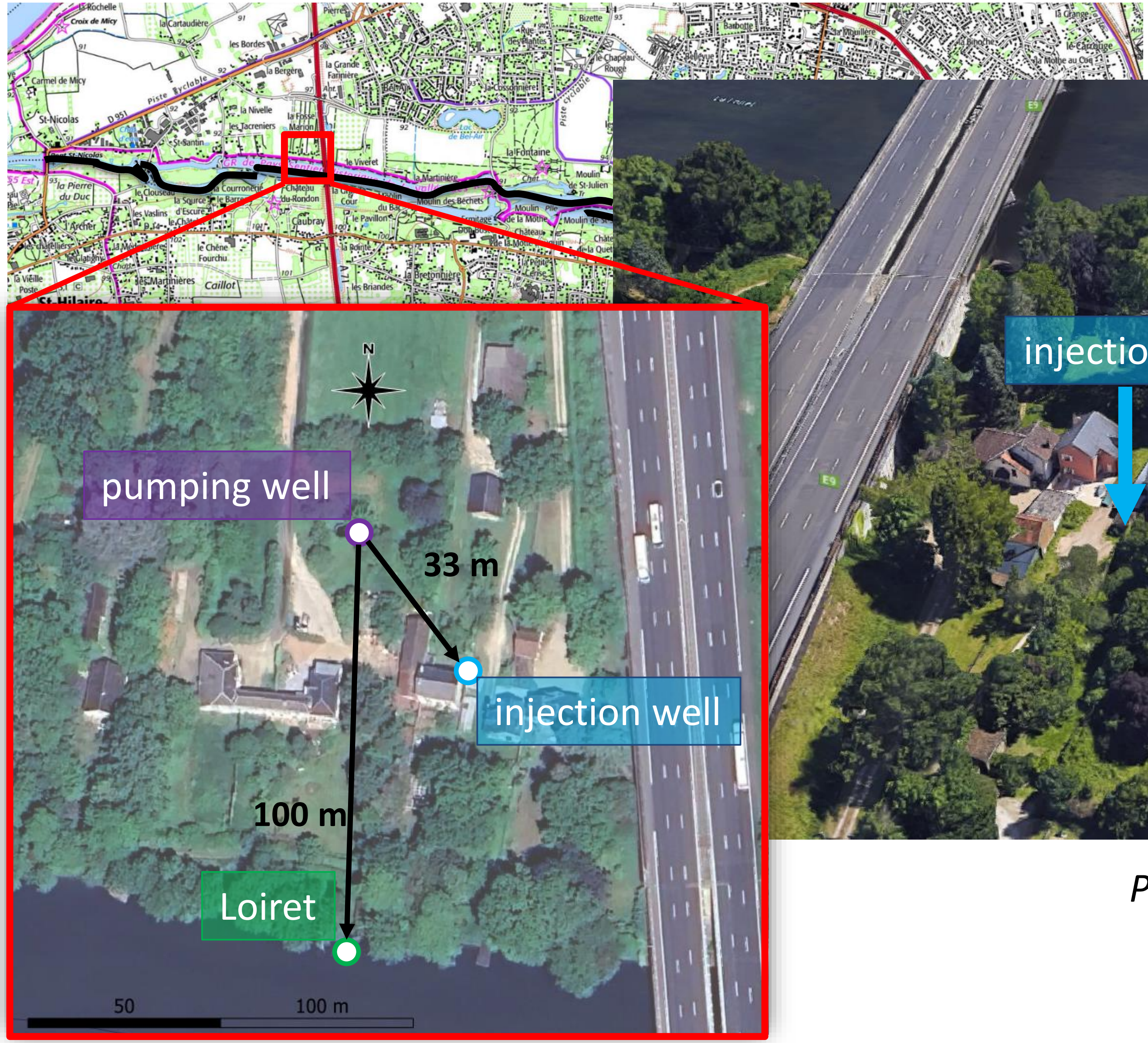
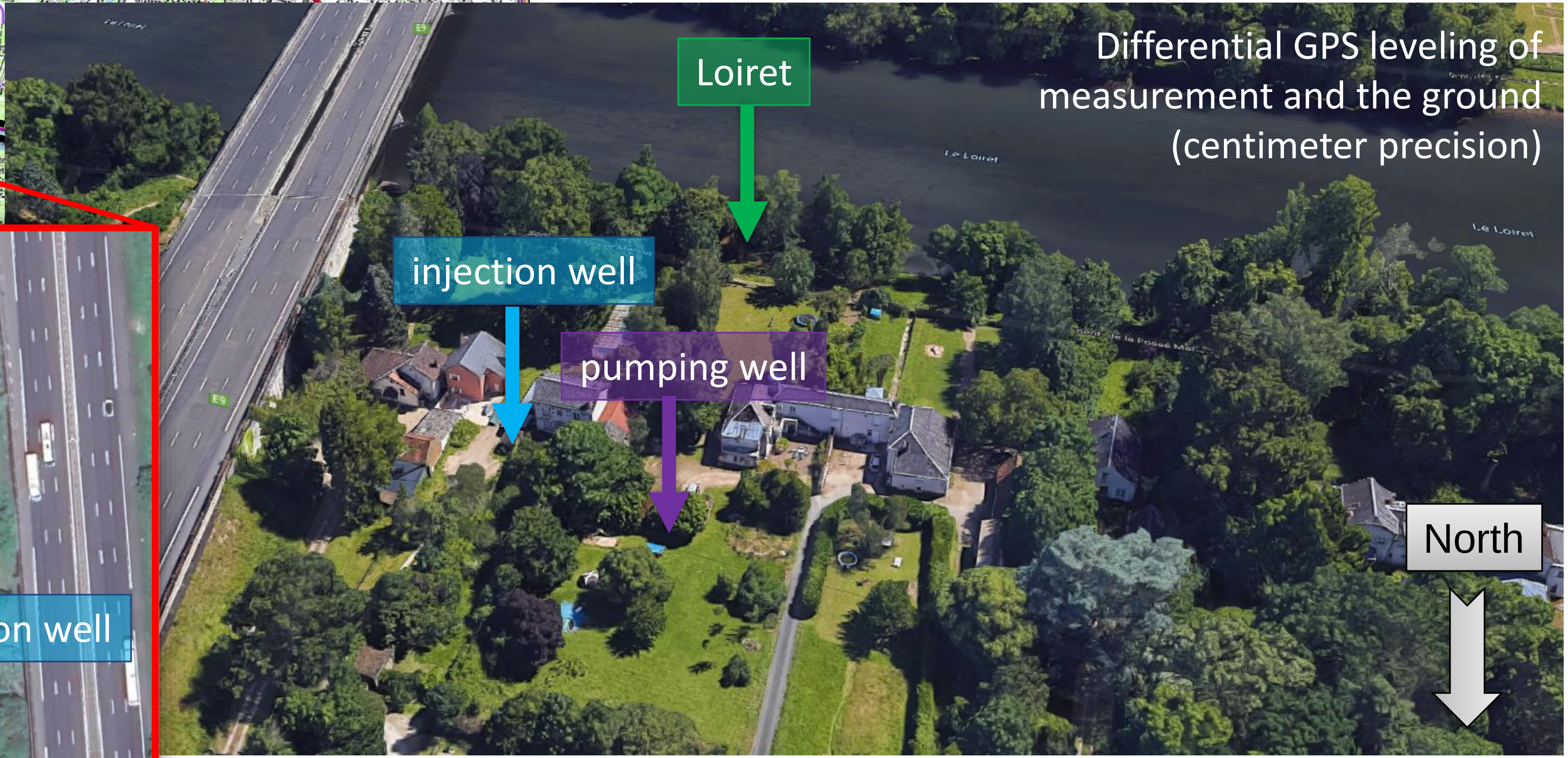


Diagram representing a head flow boundary in interaction with the aquifer

EXPERIMENTS

Map of the studied area





Pumping and tracer test device

EXPERIMENTS – PUMPING TEST

Experimental protocol for the long duration pumping test

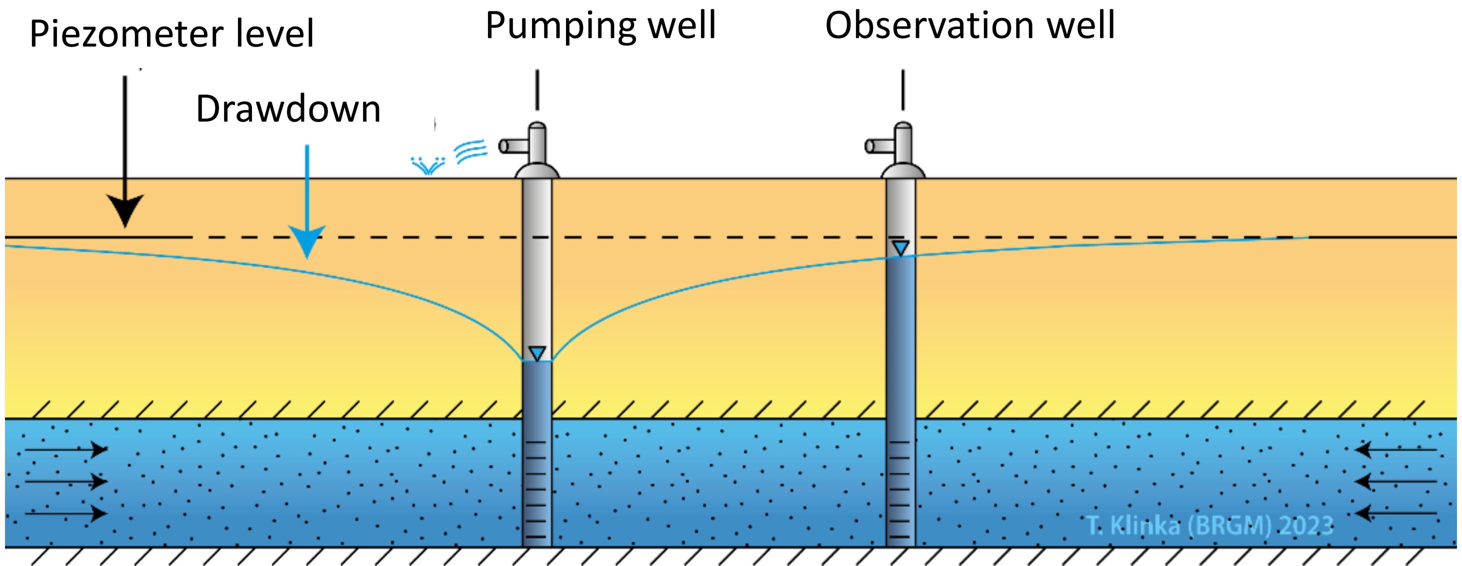
- Objective: characterize the hydrodynamic properties of the aquifer, identify possible boundary effects (relations with the Loiret for example)

- Matériel :
  - Grundfos SQE7-40 pump (10 m3/h)
  - IFM 2000 flow meter
  - Control valve
  - Pressure sensors (Diver, BaroDiver)
  - Rejection of the law of a buried pipe flowing into the Loiret

- Hydrodynamic monotoring:
  - Pumping well (PP)
  - **Observation well (OW) 33 m away**
  - Loiret river (100 m)

- Long duration pumping test
  - From 24/09/2020 to 02/10/2020
  - Pumping rate around 9.5 m3/h then 7 m3/h
  - During around 8 days

Device for pumping and discharging pumped water



EXPERIMENTS – PUMPING TEST

Pumping-test – Pre-test

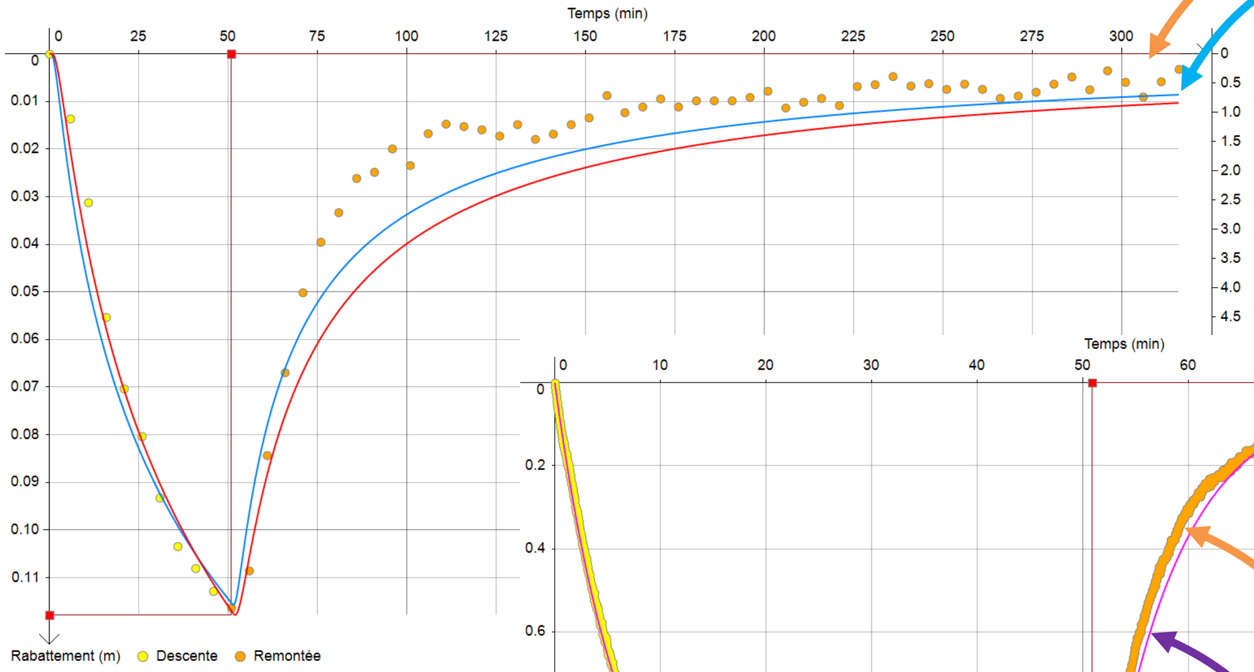
OUAIP Manual, v2 — Tool to assist in pumping tests interpretation

www.ouaip.brgm.fr

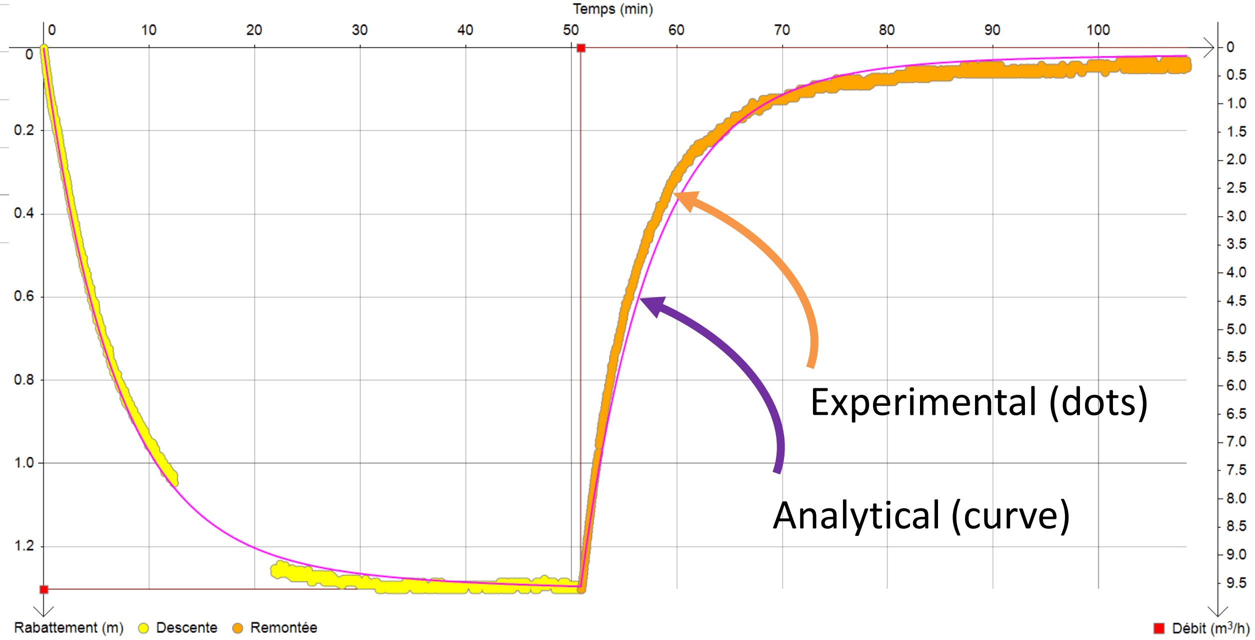
- Pumping pre-test on 09/17/2020:
  - Pumping at approximately 9.5 m3/h
  - For 50 minutes
  - Monitoring at the pumping well and on an observation well

Experimental (dots)

Analytical (curve)

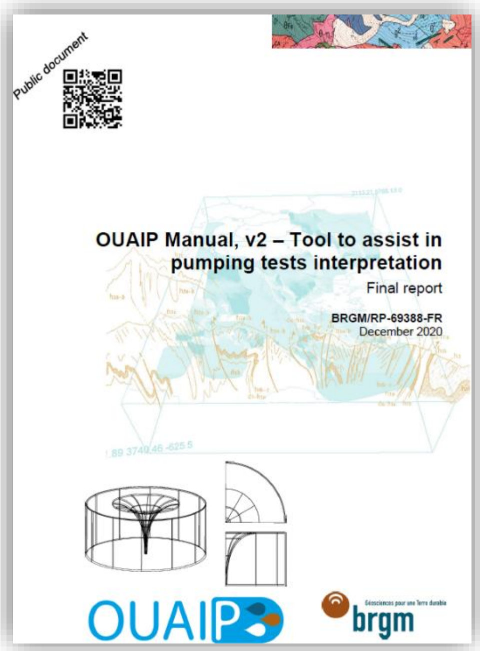


	m^2/s	-	m	m
	T	S	r	rc
Pumping well	5.1E-03	*NA*	0.50	0.52
Obs. well	4.0E-03	2.9E-03	33.00	-



Experimental (dots)

Analytical (curve)


Public document

OUAIP Manual, v2 – Tool to assist in pumping tests interpretation

Final report

BRGM/RP-69388-FR

December 2020

EXPERIMENTS – PUMPING TEST

Interpretations : observation well

- Interpretations with OUAIP software : ouaip.brgm.fr

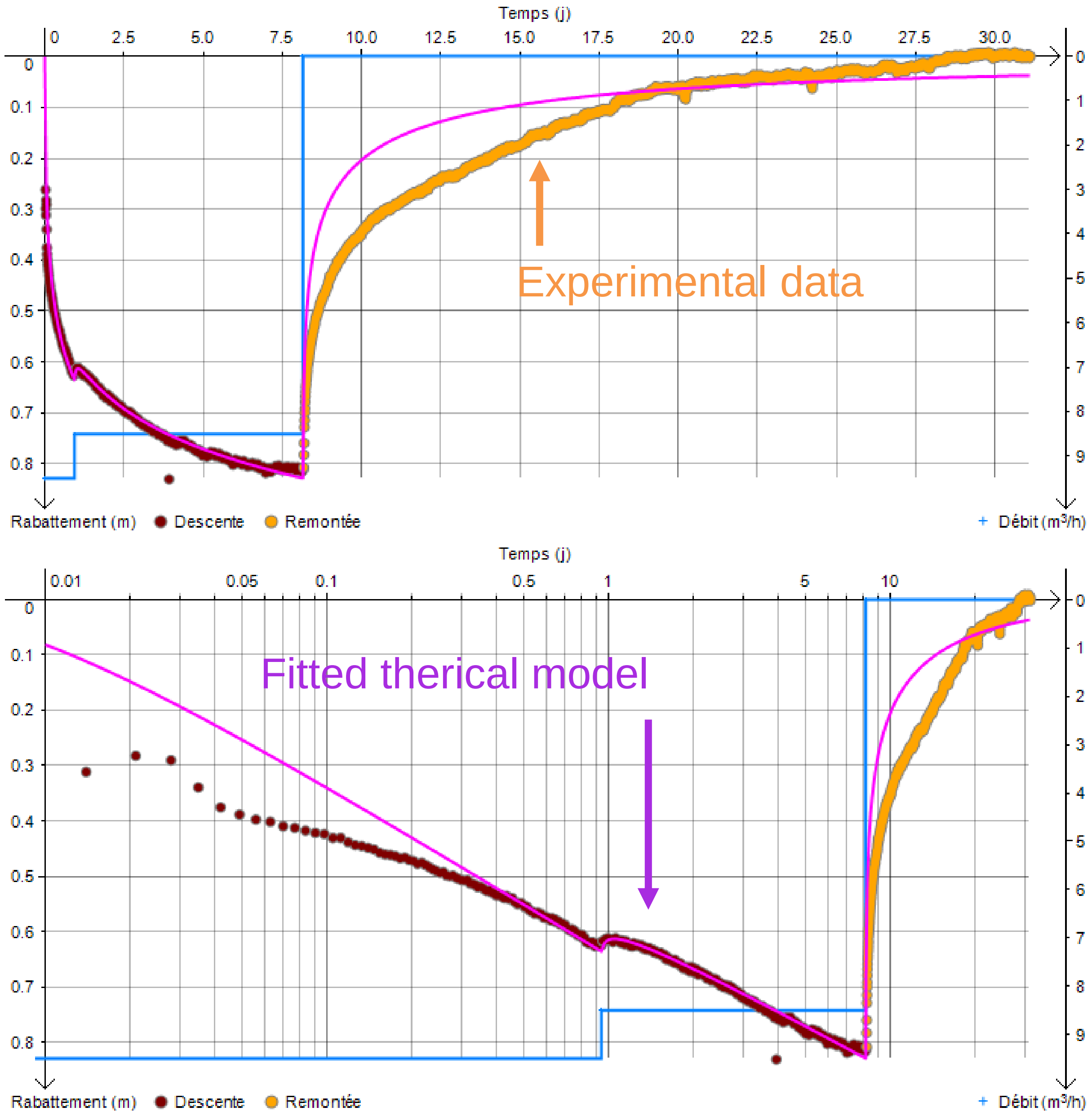
- Observation well

- Simplification of the flow chronicle (in blue)

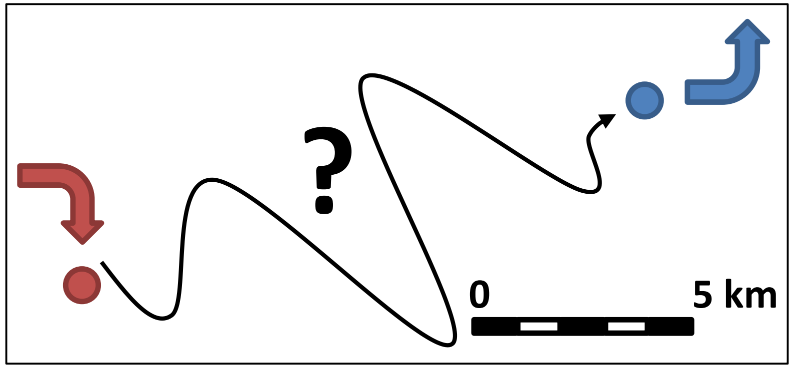
- **Adjustment retained:**
  - Concept of aquifer flow
    - T = 1.6x10^{-3} m²/s
  - Concept of aquifer stock
    - S = 2.3x10^{-3}

- Storage coefficient : low S # 0.23 %

Long duration pumping test –
Fit retained with the Theis
method (purple curve) :
Top - arithmetic scale
Bottom - semi-logarithmic scale

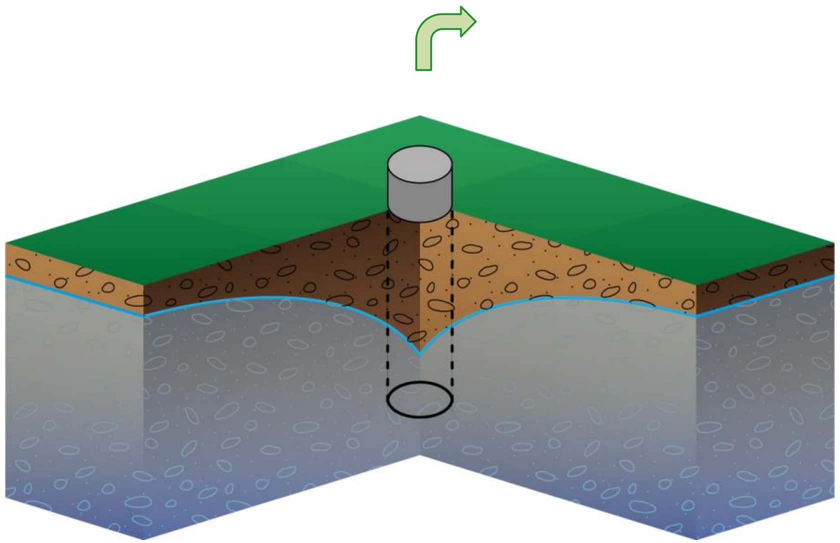


EXPERIMENTS – TRACER TEST



Experimental conditions

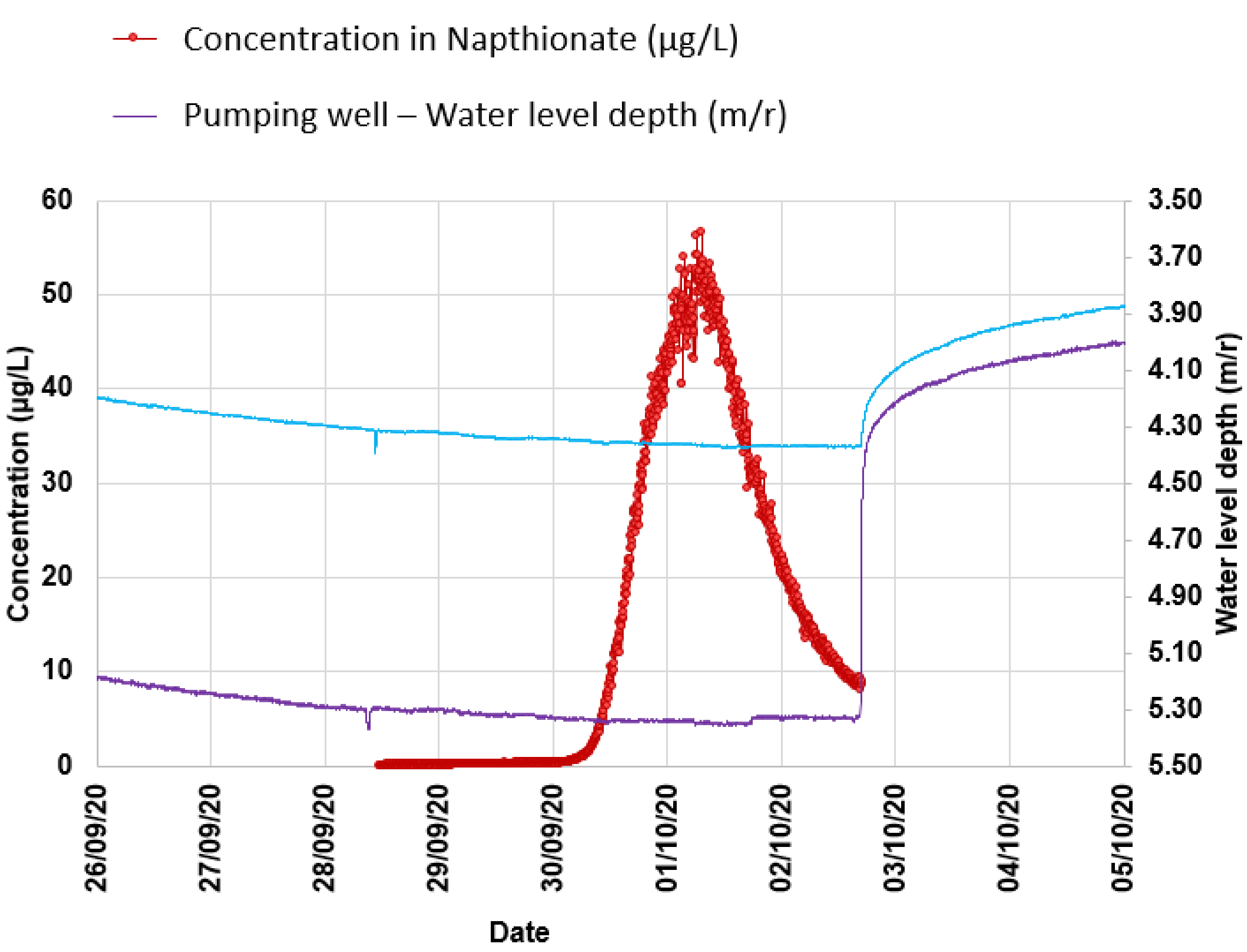
- Pumping well
  - Continuous pumping at # 7 m3/h since 09/24/2020 1:00 p.m.
  - Total depth = 6.26 m
  - NS = 3.96 m/reference and ND = 5.33 m/reference
  - Fluorimeter installed at 5.65 m depth (suspended)
  - Time step acquisition: 5 minutes
  - No automatic sampling possible for spectrofluorimetric analysis (depth of the WL)
- Injection well
  - After about 4 days of pumping
  - Injection of 18 g of Naphtionate (invisible to the eye)
  - Distance between the injection point and the pumping well # **33 m**
- Tracer injection method:
  - Solution volume 1.5 L
  - Flush: approximately 20 L
  - Rigid tube lowered into the well
- Flow configuration: **radial convergent**

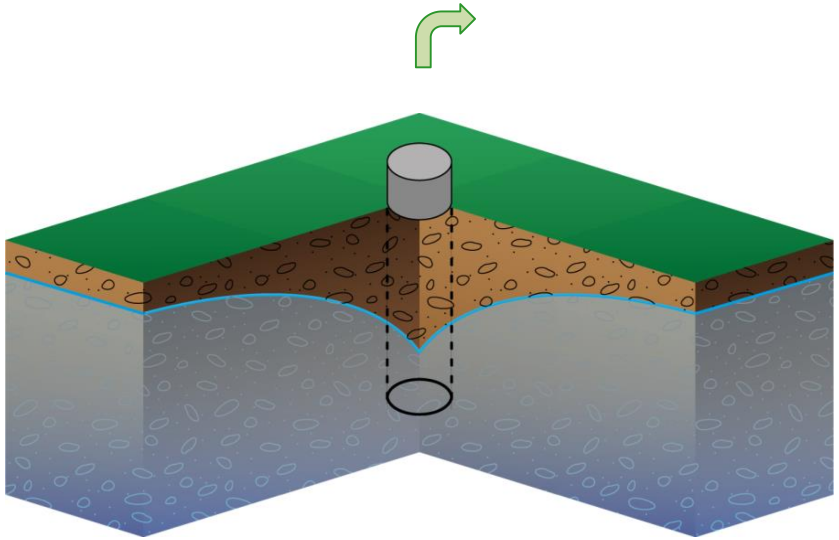


EXPERIMENTS – TRACER TEST

Results

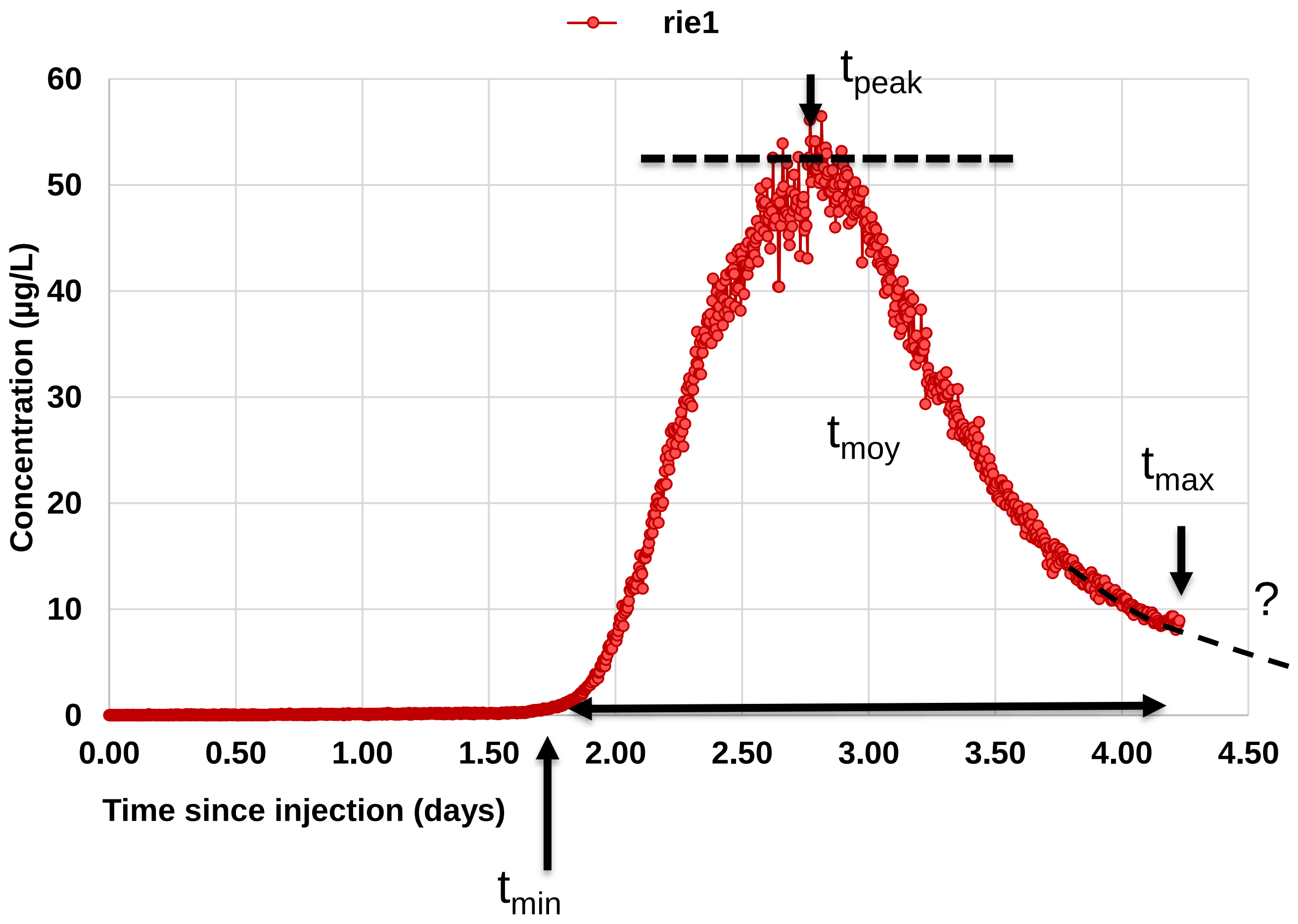
❑ Dynamic level and restitution curve





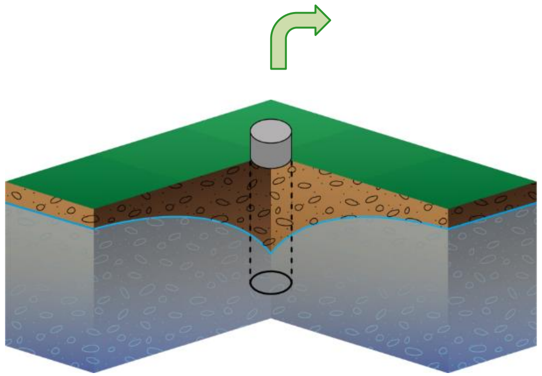
EXPERIMENTS – TRACER TEST

Results



- Maximum velocity : 22 m/j (t_{min})
- Mean velocity : 11 m/j (t_{moy})

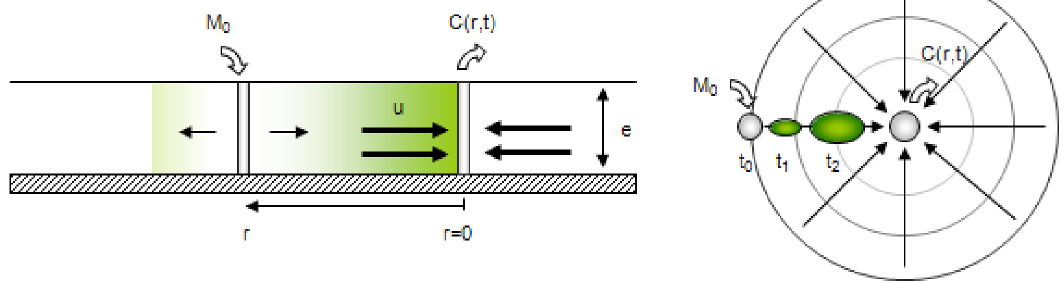
- Recovered mass :
  - 10.84 g
- Recovery rate
- (up to t # 4.2 days) :
  - 60.2 %
- Tailing
- First appearance # 1.5 days
- Restitution duration # 3.4 days
- Peak: 2.8 days
- Maximum concentration: 52 µg/L
- Average time # 2.9 days
- Average stay time # 2.9 days
- Disappearance time > 4.9 days

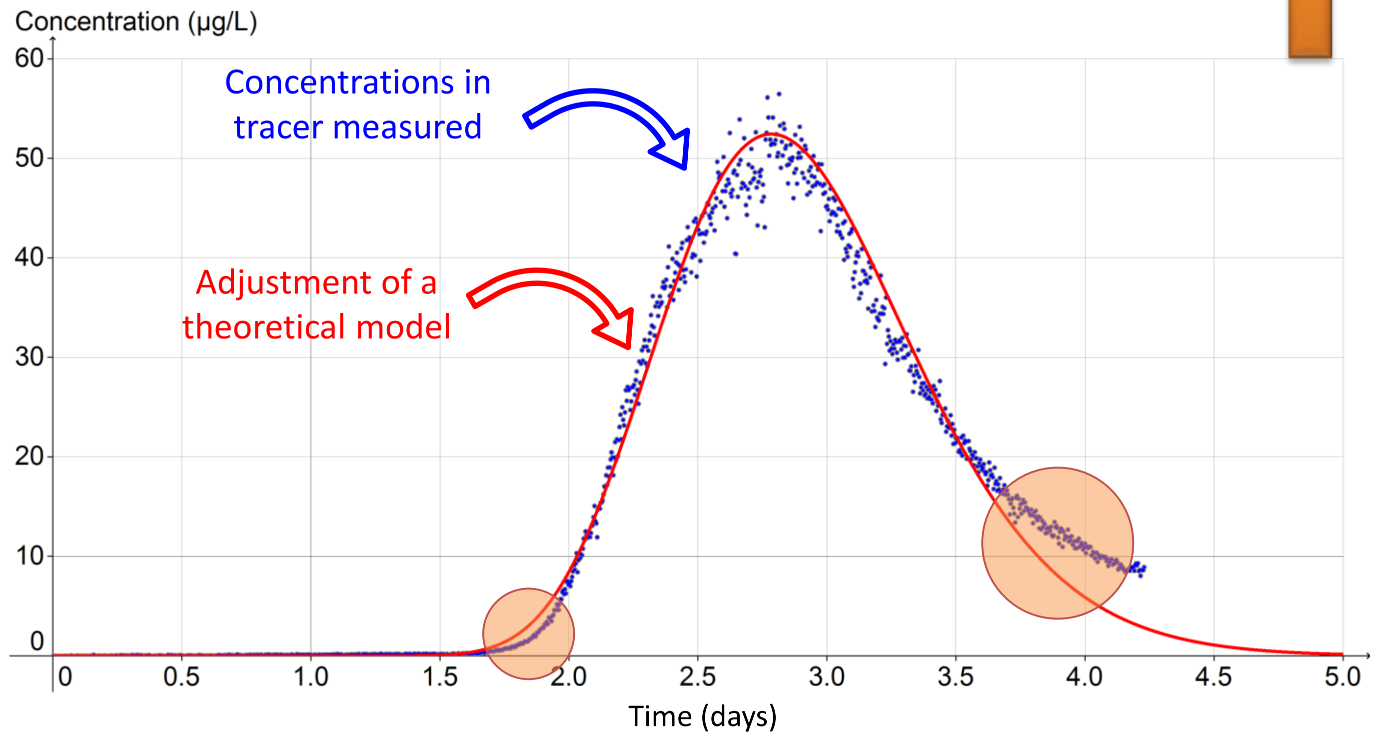


EXPERIMENTS – TRACER TEST

Interpretation

- Interpretation of background-corrected data with **TRAC** (trac.brgm.fr)
- Semi-analytical solution: convergent radial flow model (**red curve**)



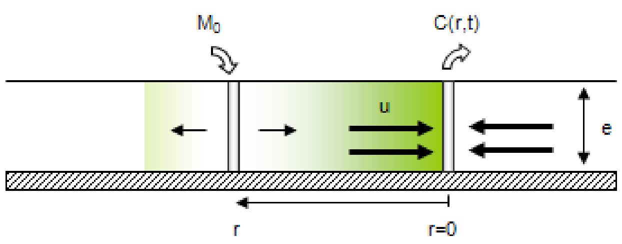


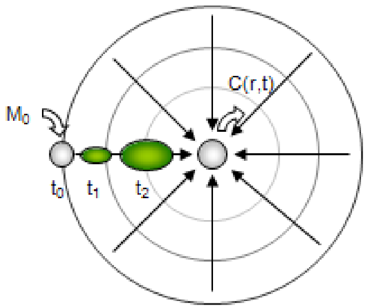
Parameter	Symbol	Value	Unit
Injected mass	m_0	18.0	g
Recovered mass	m_r	10.8	g
% of mass recovered		60.0	%
Kinematic porosity	n_e	2.30	%
Real velocity	u	1.35E-04	m/s
"		0.49	m/h
"		11.66	m/d
Aqifer thickness	e	6.15	m
Longitudinal dispersivity	α	0.38	m
Distance well - piezometer	x	33	m
Pumping rate	Q	7	m3/h
"		1.94E-03	m3/s
Nash	E	0.982	-

- Successful completion and interpretation of tracing
  - **Restitution** of the tracer **# 60%**
  - Estimated **porosity** of around **2.3%**
  - Estimated **dispersivity** of around **0.38 m** (i.e. 1/86 of the transport distance)

  - Maximum **velocity**: 22 m/d
  - **Average velocity: 11 m/d**

EXPERIMENTS – TRACER TEST

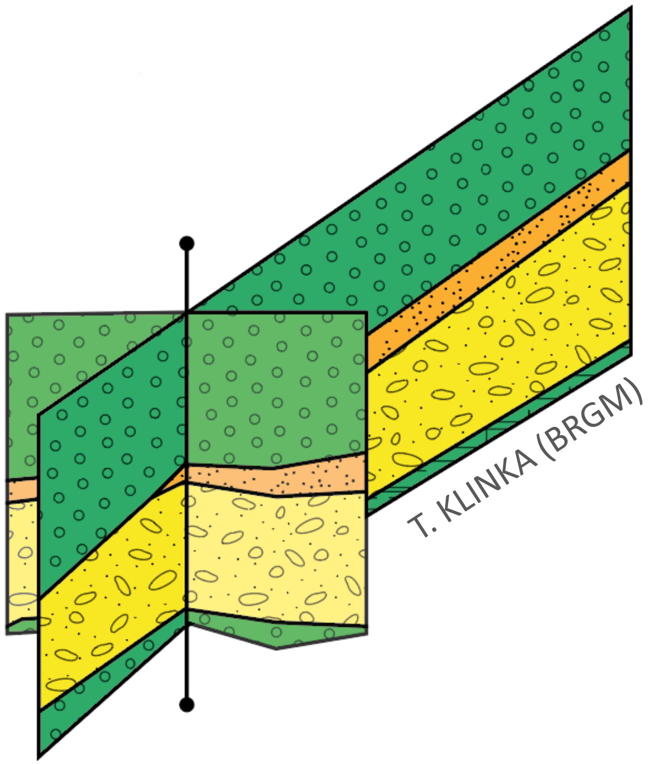




Conclusion

- Characterization of the properties of aquifer:
  - Hydrodynamics: transmissivity and storage coefficient
  - Hydrodispersion: effective porosity and dispersivity, connectivity
  - Relationship between alluvium and the Loiret?

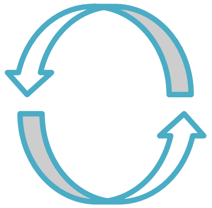
Transmissivity	**T # 2.5x10^{-3} m²/s**
Storage coefficient	**S # 2.5x10^{-3}**
Kinematic porosity	**n_e # 2.3 %**
Max velocity	**22 m/d** (u_{mean} = is 11 m/day)
Dispersivity	**α_L # 0.38 m (1/86 of x)**
Restitution	**R > 60%**

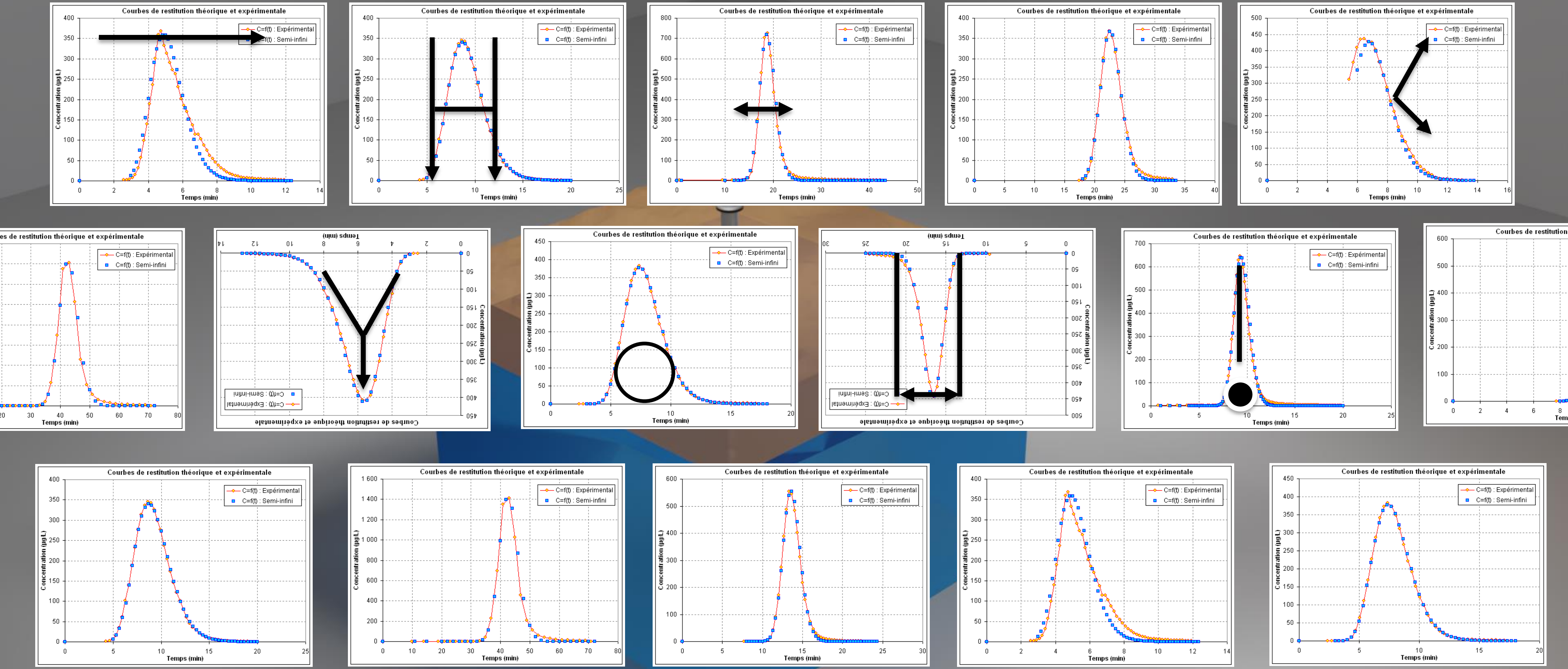


- There are questions about the pumping well, the well could capture alluvium as well as limestone, which would explain **a rapid pressure transfer during the long duration pumping test** (storage coefficient of 2.8x10^{-3}) and a **transfer of material in the unconfined part** of the aquifer (storage coefficient of 2.3 %).

- **Take home message :**

- Modeling allows you to gain experience more quickly than real life …
- … But field experience allows us to understand what the models do not show





Interpreted tracer test in 1-dimension aquifer column

TRACER 9
TRACERS AND TRACING METHODS
Spain 2024