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Influence of karst conduits morphology on tracer tests breakthrough curves (Fontaine de Nîmes, France)

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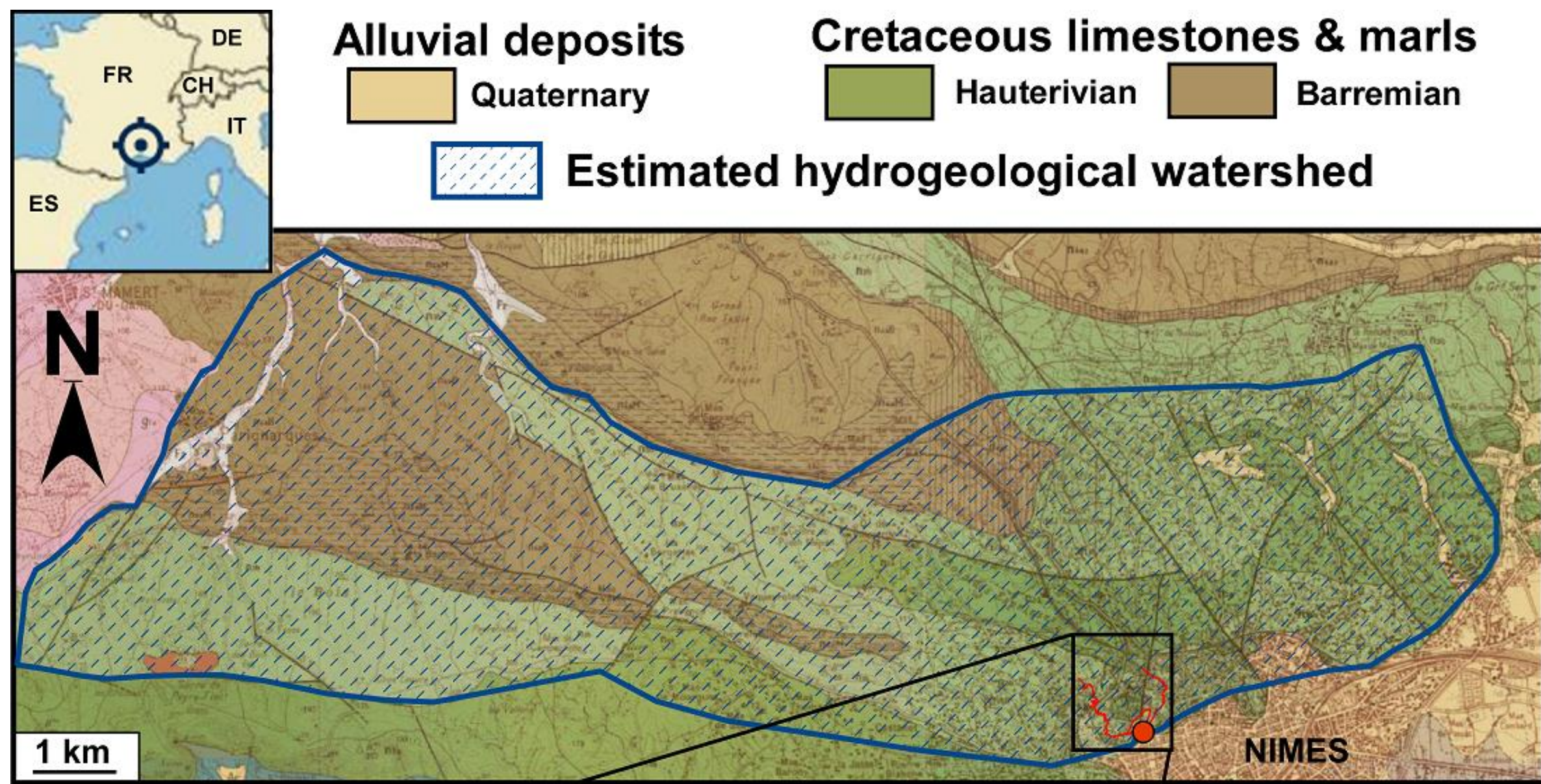
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Influence of karst conduits morphology on tracer tests breakthrough curves (Fontaine de Nîmes, France)

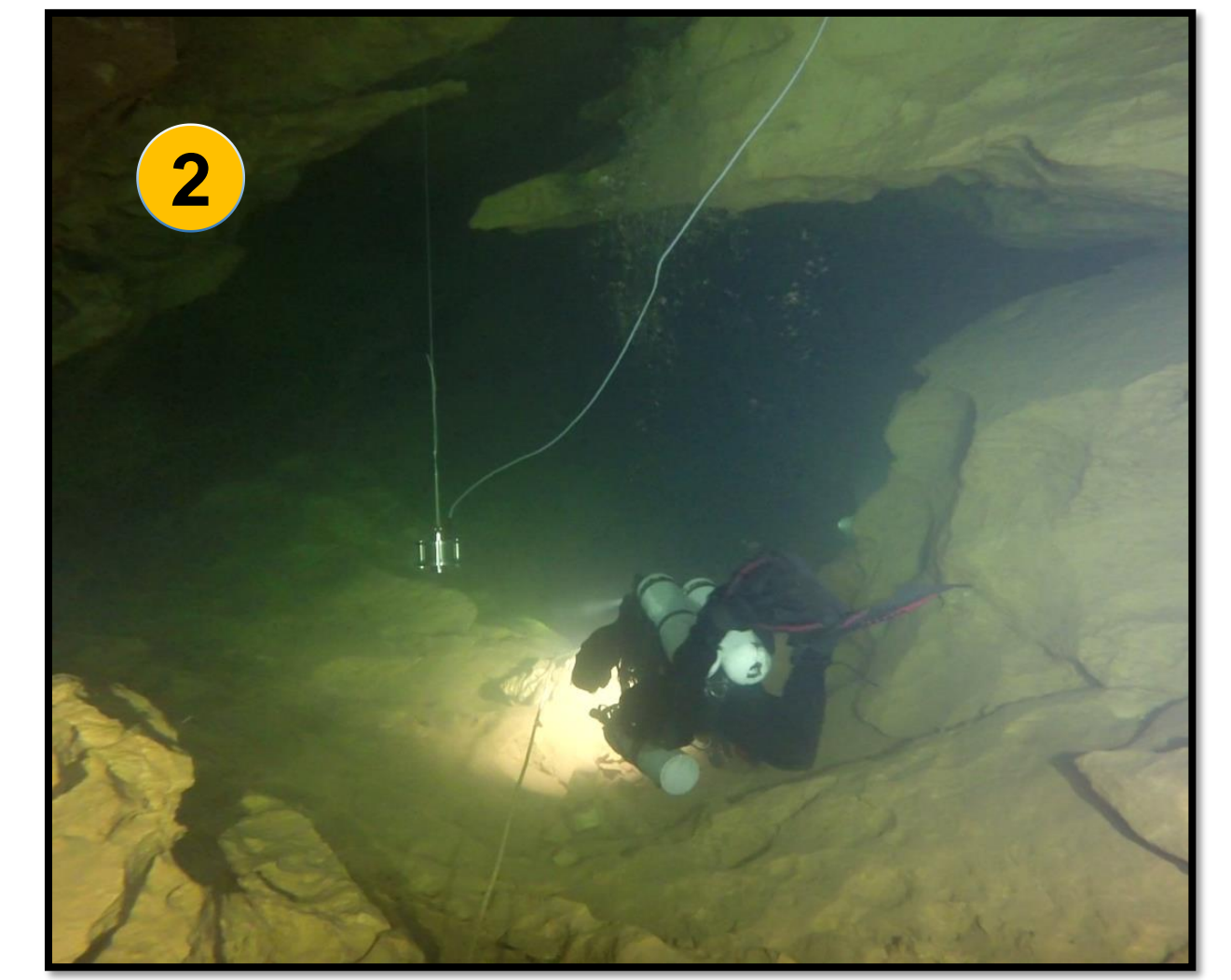
Context, experimentations and measurements



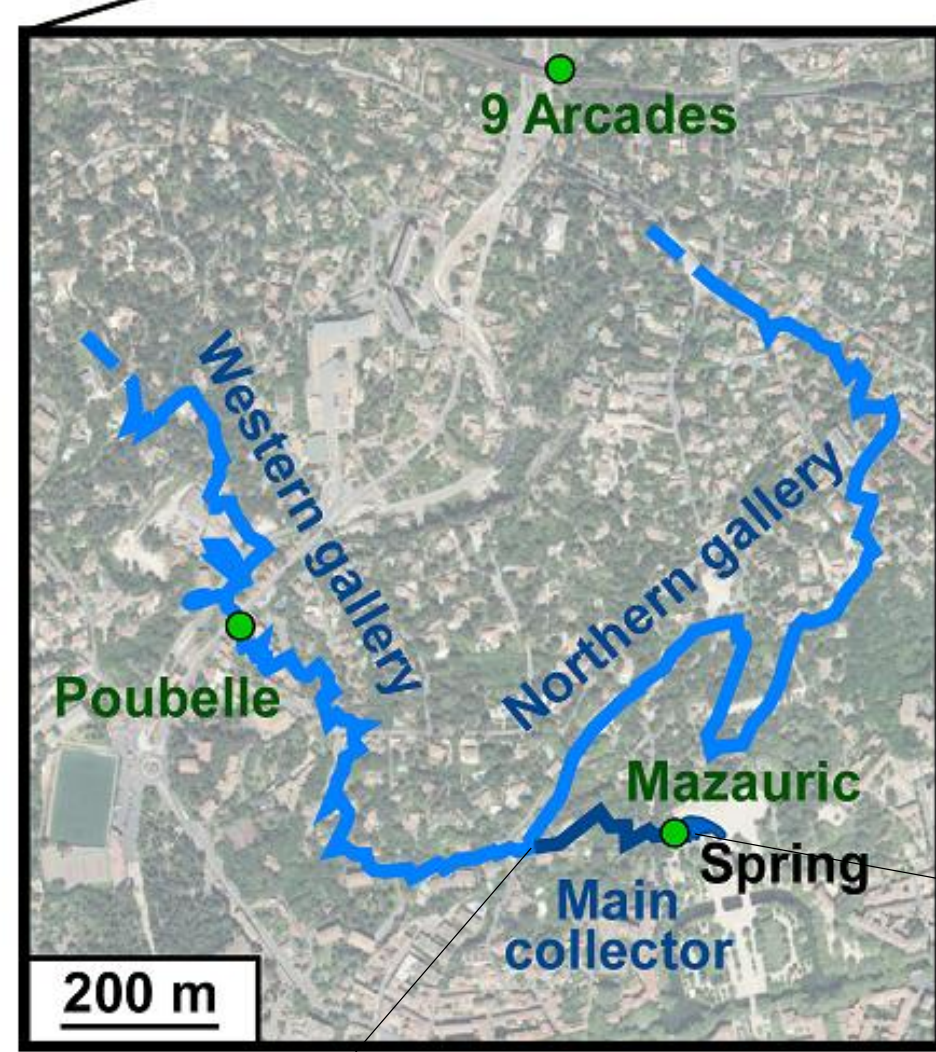
The Lez2020 research program is based on a collaboration between roboticists (LIRMM lab.), hydrogeologists (HSM lab.) and divers in order to develop new devices for karst hydrology.

Within the framework of this project, in-situ experiments have been conducted in the karst conduits upstream Fontaine de Nîmes. This spring is located in the city of Nîmes (Southern France). These experiments consisted in:

- 3D mapping of the main collector:**
Divers visit the main karst conduit with the Navscoot, a device acquiring the geomorphology of the conduit in 3D.
- Hectometer scale tracer tests:**
Tracer is injected in-situ with the Traci, an automated device installed 100 to 200m upstream the spring, in the karst conduit. Restitutions are measured near the spring with GGUN fluorimeters.



▲ GGUN: In-situ fluorimeters monitored from the surface through a natural well (Mazaauric sinkhole)

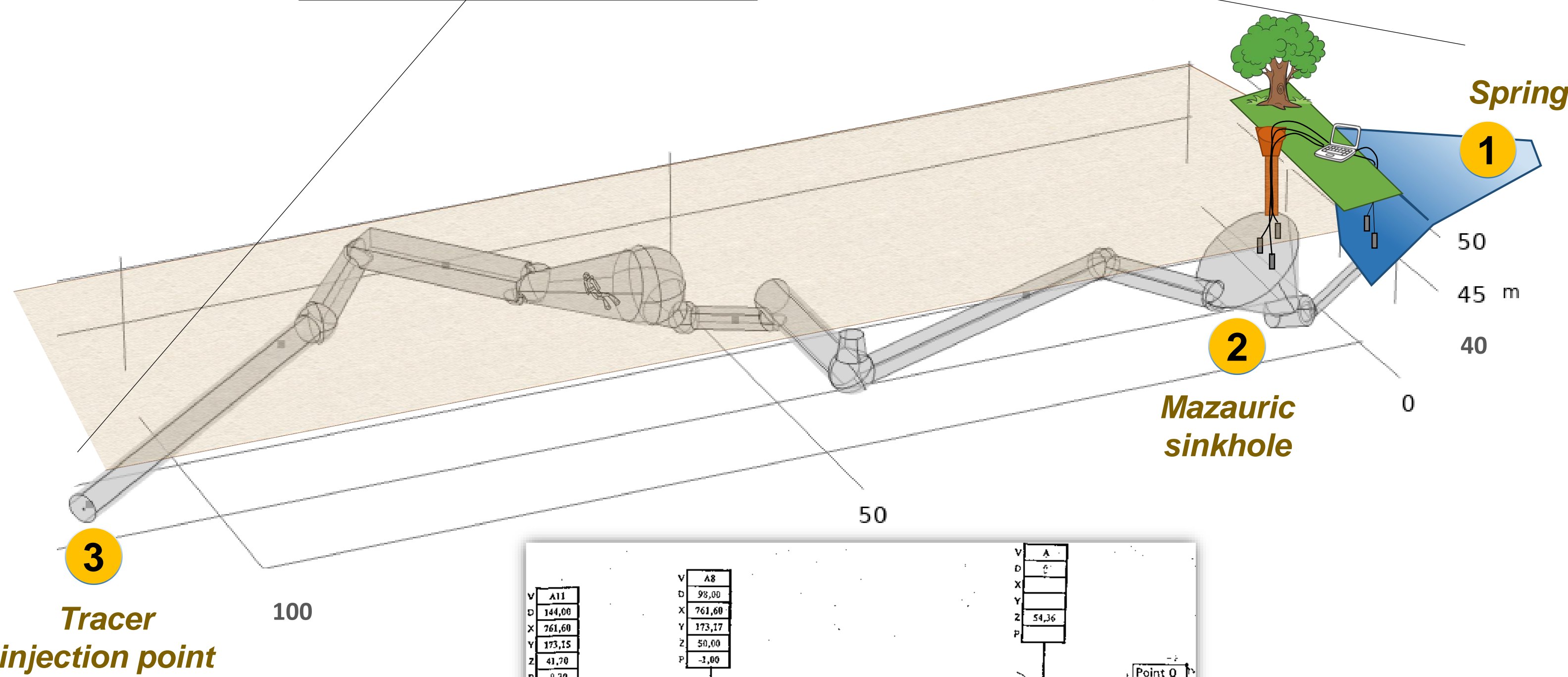


▲ Geological map associated to the karst catchment of the Nîmes spring (Fontaine de Nîmes)

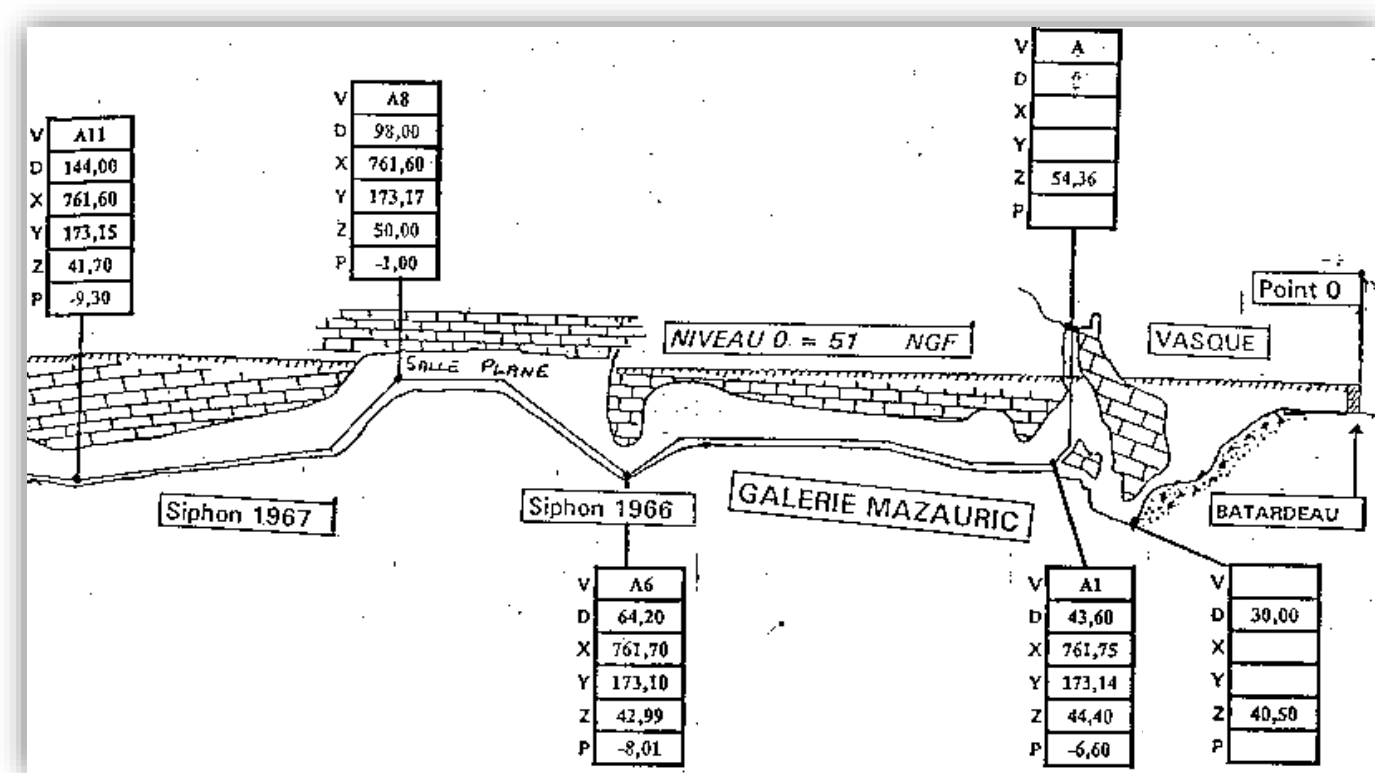
◀ Aerial map highlighting the terminal karst conduits network upstream from the spring (in blue) and wells intersecting these conduits (in green)



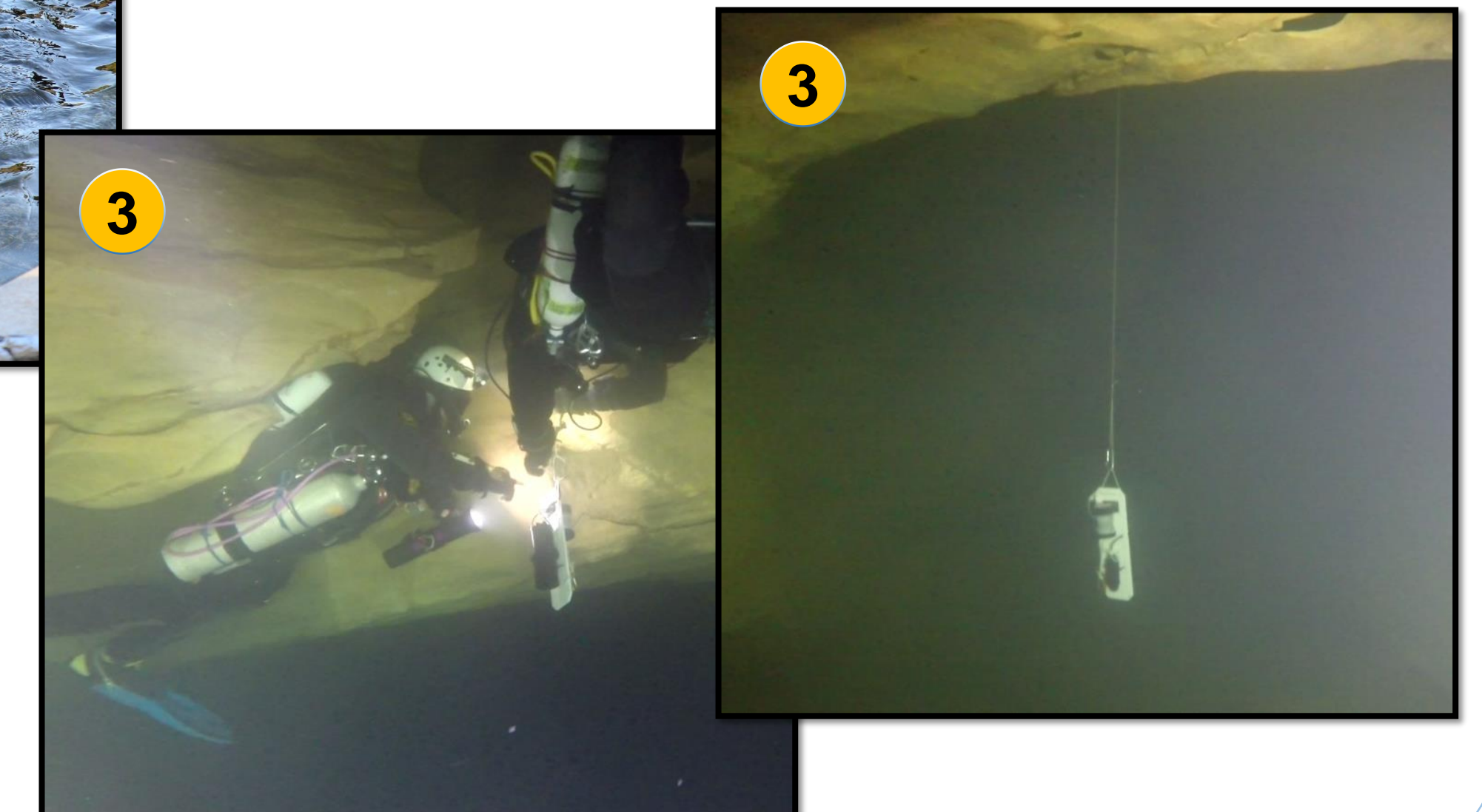
◀ NAVSCOOT: Device acquiring the 3D morphology of the conduits through acoustic resonance and measurements of the direction and velocity of its movements (guided by divers)



▼ TRACI: Device injecting a given volume of solution of tracer after a 30min timer (installed and activated by divers)



▲ Simplified 3D geometry of the main karst conduit arriving in the Nîmes spring, built based on plans and cross-sections produced by speleologists



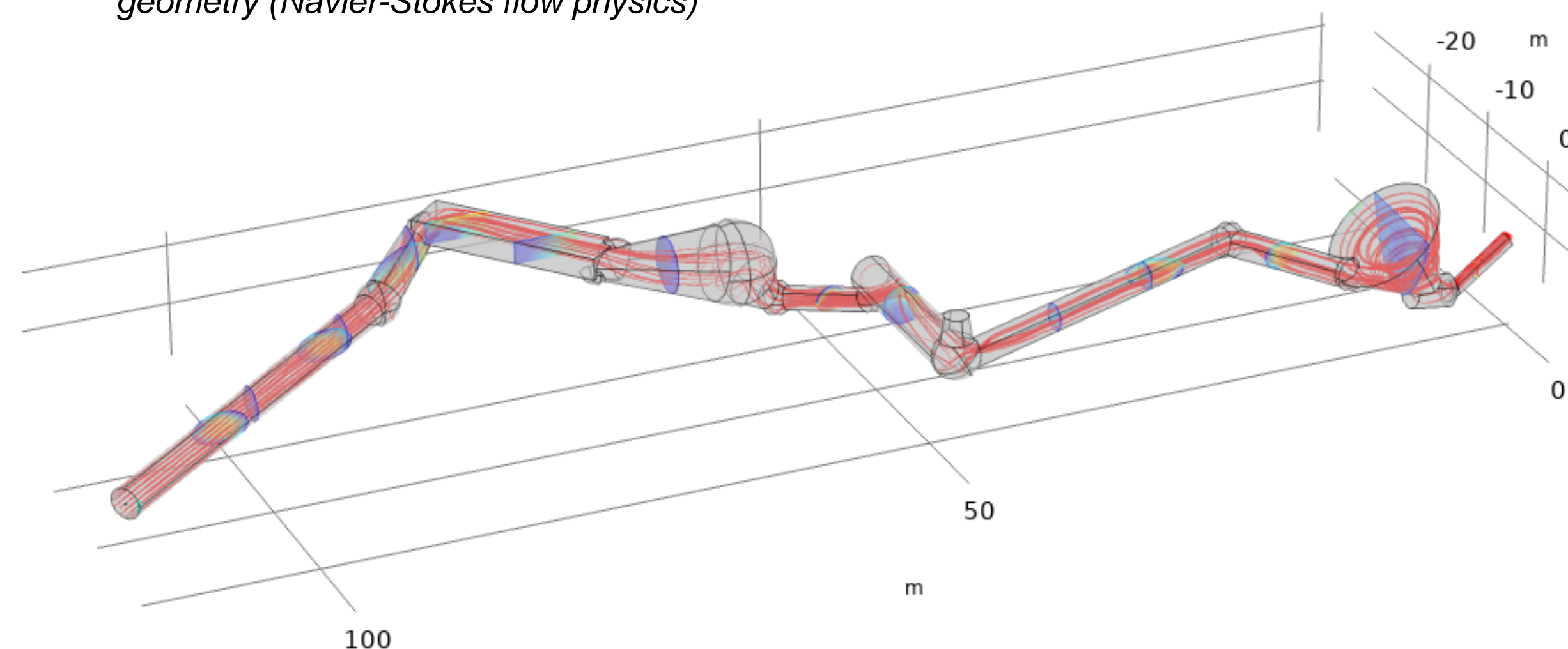
Numerical modeling

A 3D numerical model is built to simulate with accuracy the tracer tests experiments within the karst conduit.

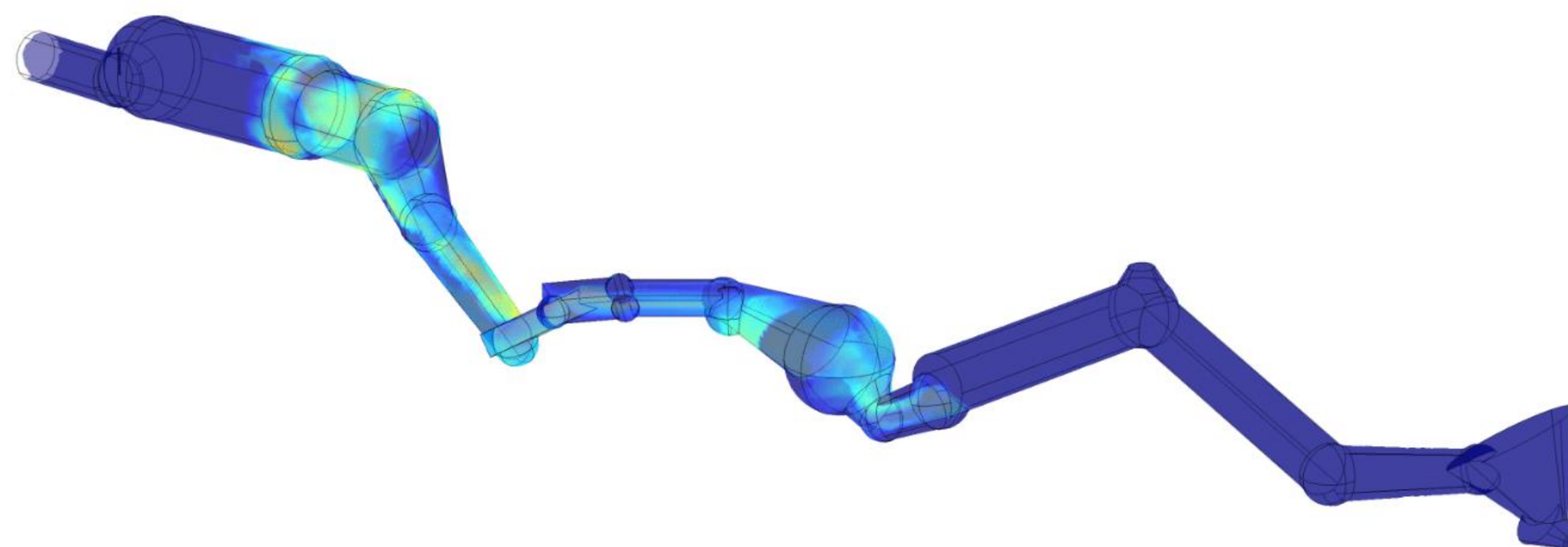
The aim of this model is to study the effects of the conduits morphology on both the tracer plume propagation and the breakthrough curves at the spring, by comparing the results obtained with either a simplified or precise geometry to a controlled tracer experiment.

- Inputs:**
 - As a first step, a simplified geometry of the main collector is built based on cross-section maps.
 - In a second step, the precise geometry acquired with the Navscoot will be used in the model.
 - Experimental conditions (flowrate, quantity of tracer).
- Physics:**
 - Flows are simulated in steady state based on Navier-Stokes physics.
 - Tracer concentrations are simulated in time domain with the diluted transport physics.

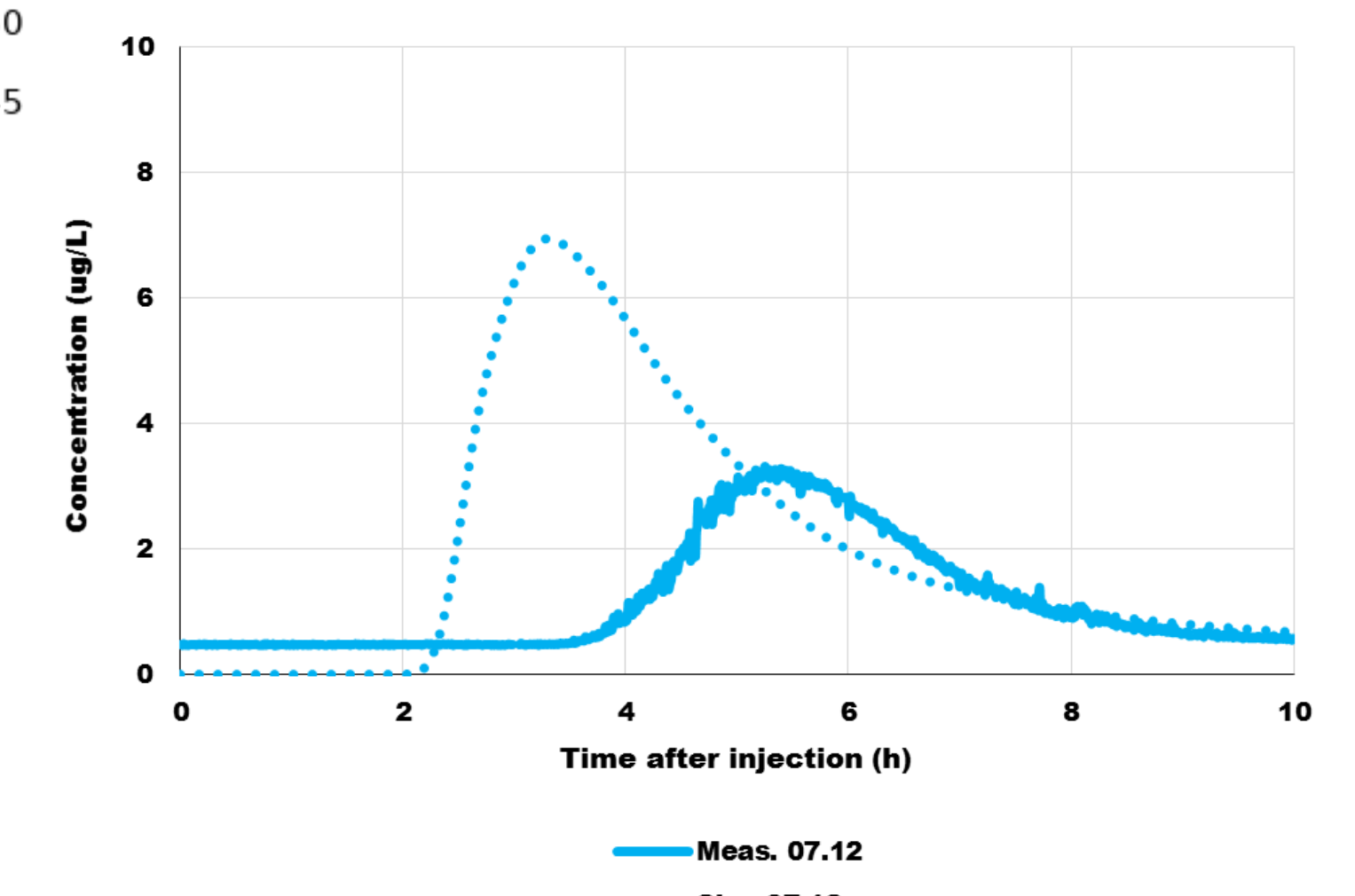
▼ Simulated stream lines (in red) in a steady state regime for a flow rate of 250L/s with the simplified geometry (Navier-Stokes flow physics)



▼ Simulated tracer concentration in time domain in the simplified geometry of the main collector of the Nîmes spring (diluted species transport physics)



▼ Measured versus simulated breakthrough curve (tracer restitution) at the spring. Measurements from the 07.12.2021 experiment. Simulations with the simplified geometry



Aims of the project

- Develop devices able to acquire 3D precise geometry and morphology of flooded karst conduits
- Study the effects of conduits morphology on both the tracer plume propagation and tracer restitutions based on an accurate physic-based numerical model and hundred meter scales fully controlled field experiments

Next steps

- Accurate acoustic imagery of the karst conduit
- Simulations of the experiments with the precise karst conduit's morphology
- Same application at the Lez spring, providing water supply for the city of Montpellier