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Current research in urban hydrogeology: urban underground development confronted by the challenges of groundwater flow, quality and temperature

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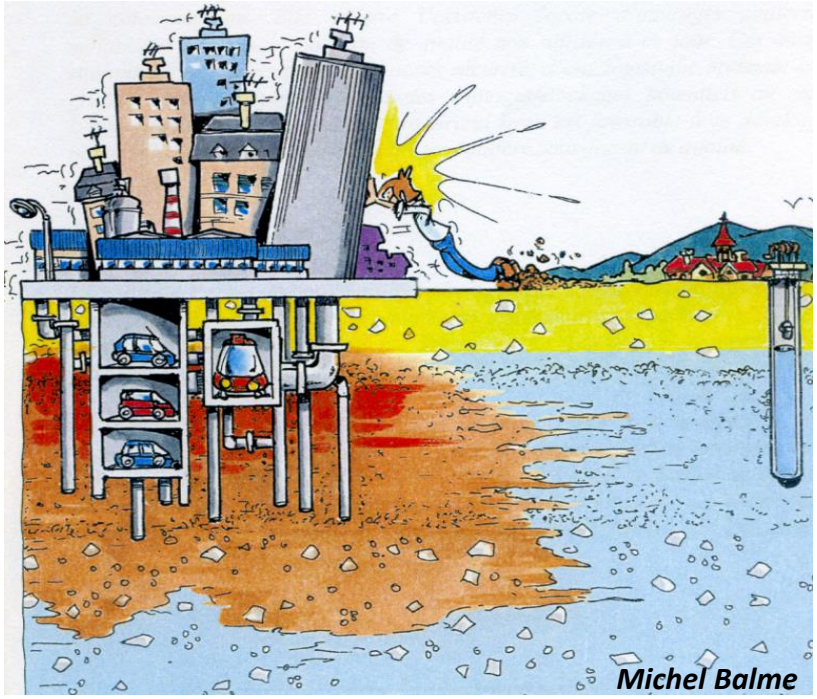
Urban groundwater versus underground develoment

- **Urban groundwater:**
  - 40 % of the **water supply** in Europe *(Eiswirth et al. 2004)*.
  - **Geothermal heat** is a strategic resource *(European Commission, 2009)*.

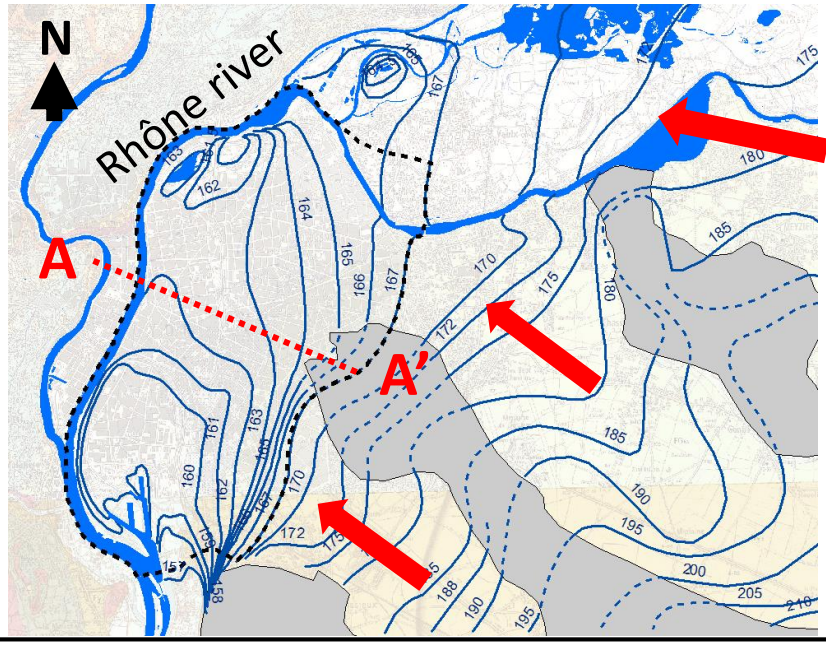
- **Interaction between groundwater and underground structures** can generate risks and disturbances:
  - Rise to **compactions** and **floodings** *(Yoo et al. 2012)*.
  - Impact on groundwater **quality** *(Chae et al. 2008)*.
  - Impact on groundwater **temperature** *(Epting et al. 2013)*.



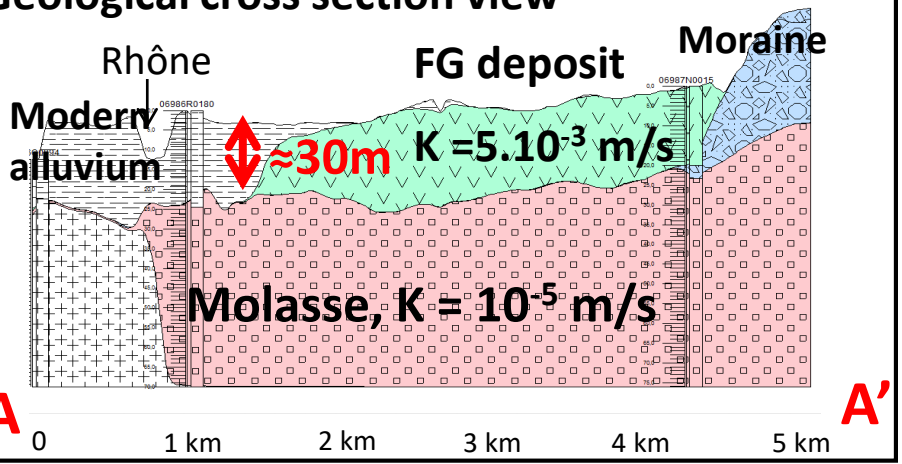
- Aims:
  - Improve the understanding of **the role played by underground structures** at a decision making scale.
  - Provide **guidelines** dedicated to urban planners and project owners.

3D modeling (FEFLOW ©) to assess the impact of underground structures on groundwater flow (Lyon, France)

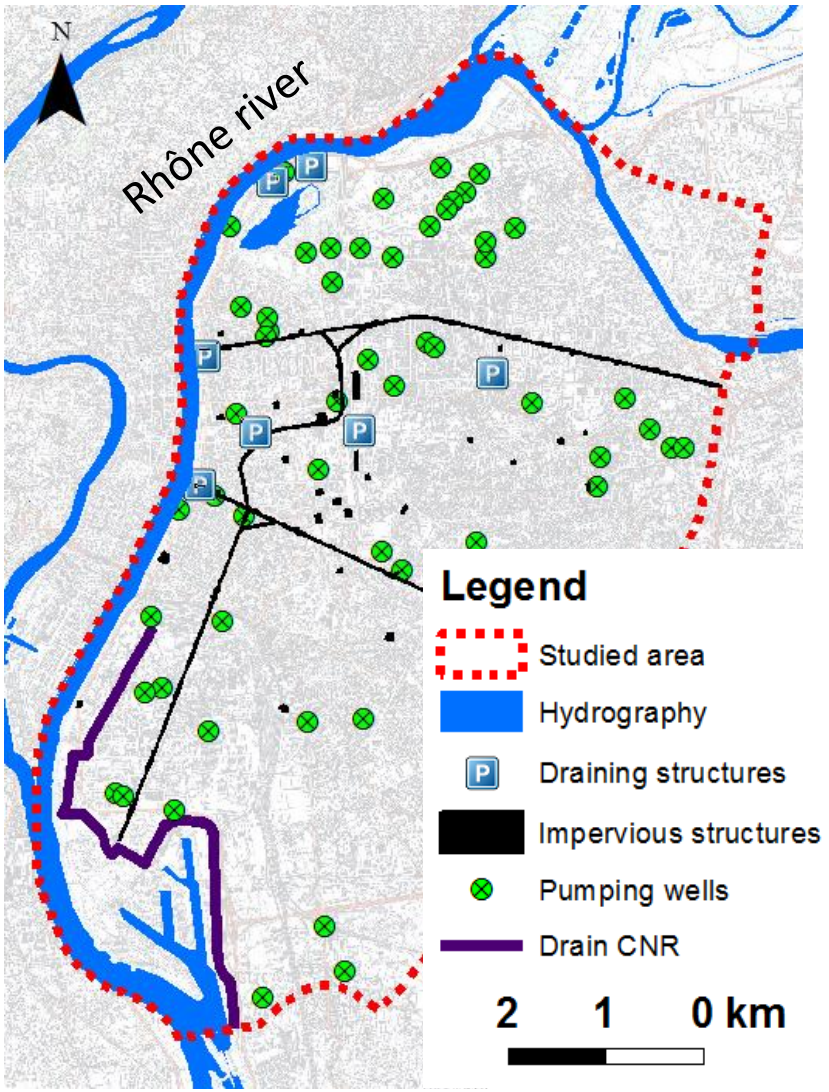
Piezometric map of Lyon area *(Gudefin 1974)*



Geological cross section view

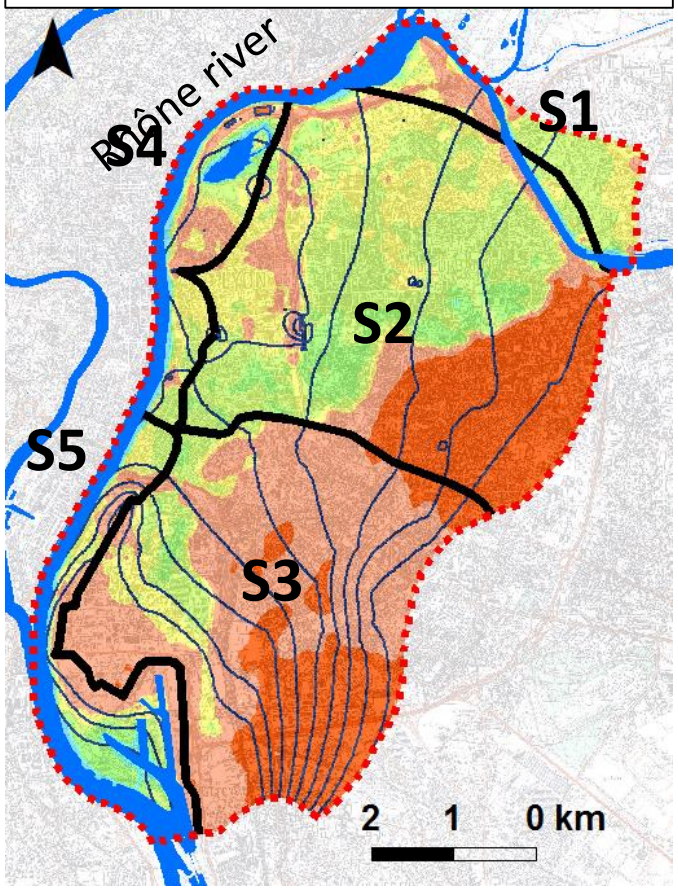


Underground structures in Lyon area

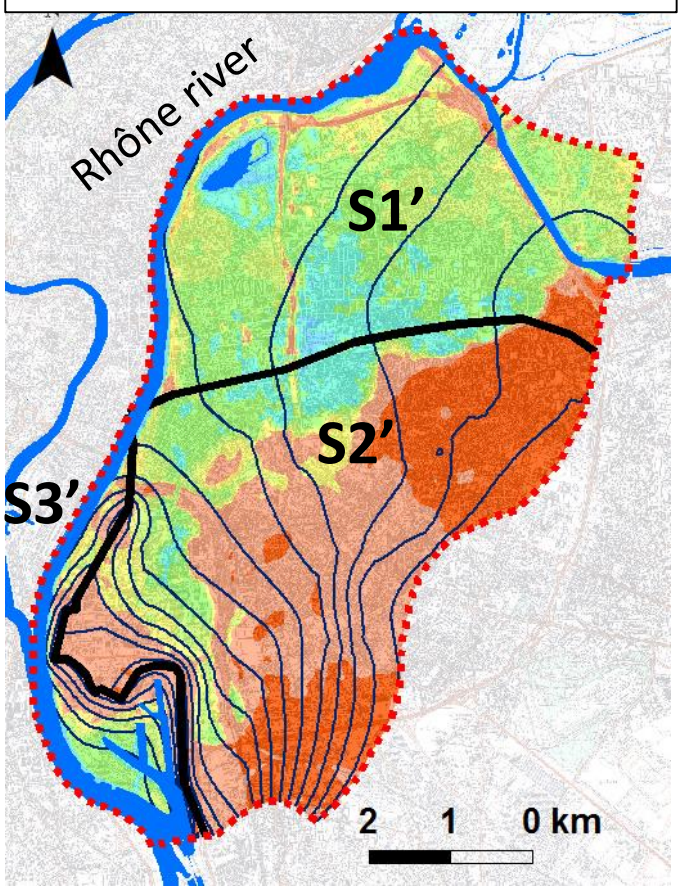


Fragmentation of urban flow systems and drawdown

Current state of GW flow
(with all underground structures)
5 systems



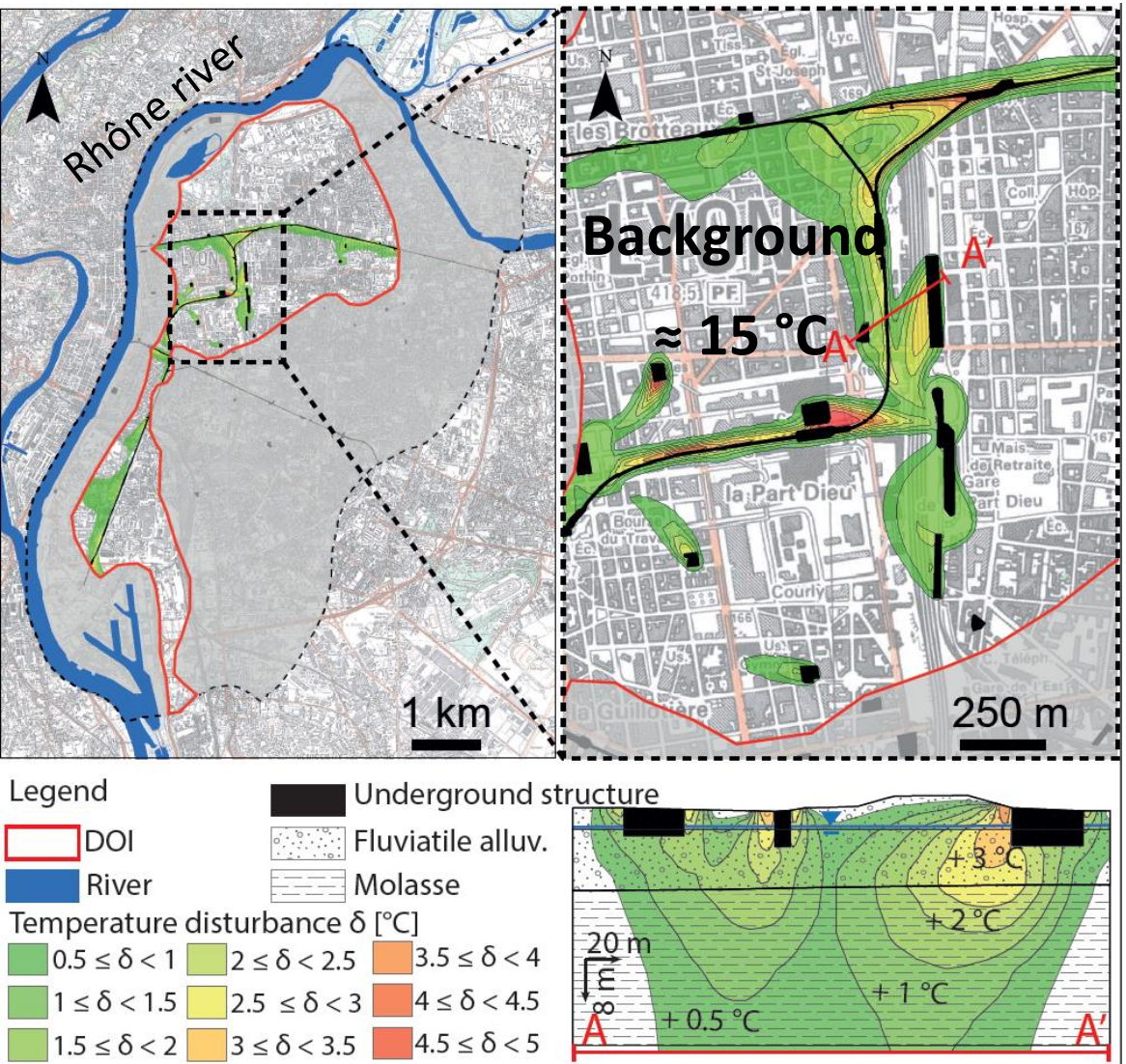
Potential state of GW flow
(without underground structures)
3 systems



Water table depth

- 0 m ≤ WT < 1 m
- 1 m ≤ WT < 2 m
- 2 m ≤ WT < 3 m
- 3 m ≤ WT < 4 m
- 4 m ≤ WT < 5 m
- 5 m ≤ WT < 10 m
- 10 m ≤ WT

Impact of underground structures on groundwater temperature



- Flow:

steady

- Heat transport:

transient

- Temperature range inside structures:

16 to 27 °C (Dirichlet BC)

- Enclosure thickness:

1 m

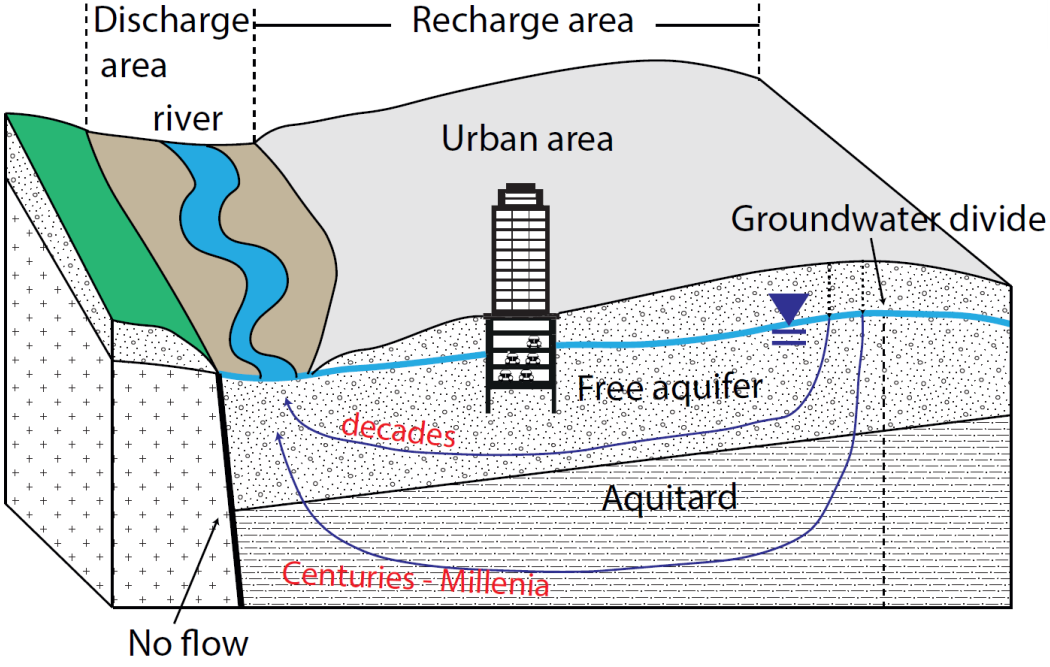
- Heat flow from underground structures:

4.5 GW.h/year

Impact of underground structures on groundwater quality

*The role played by underground structures in **spreading urban contaminations?***

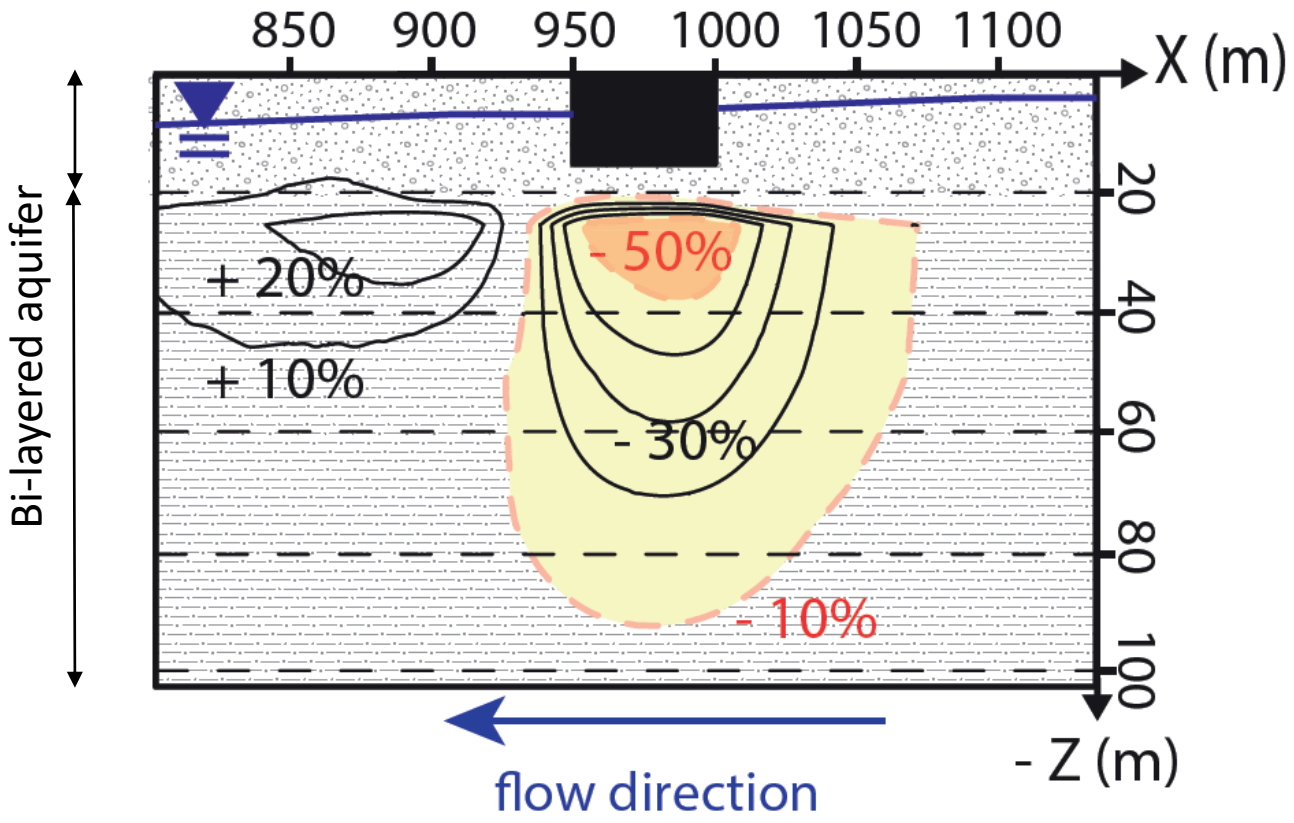
- 3D deterministic modeling approach based on the reservoir theory generalized to hydrodispersive systems *(Cornaton and Perrochet, 2006a,b)*



Bi-layered generic model
4 km²
150 m depth

Dispersive piston effect under structures

- Relative mean age reduction (cross section view)



Summary

- Draining structures have a severe impact on the shape of urban flow systems.
- Under unconfined condition, impervious structures have a non-significant impact on the water table elevation.
- Underground structures generate a heat island effect in the urban groundwater body.
- The heat flow from underground structures should be taken into account in the assessment of the geothermal potential of urban aquifers.
- A *dispersive piston effect* occurs under structures resulting in a mix between shallow and deep groundwater.

Thank you for your attention…

This talk was based on:

Review: Impact of underground structures on the flow of urban groundwater

G. Attard, T. Winiarski, Y. Rossier, L. Eisenlohr
(2016) **Hydrogeology Journal**, 24 (1), 5-19

Deterministic modelling of the cumulative impacts of underground structures on urban groundwater flow and the definition of a potential state of urban groundwater flow: example of Lyon, France

G. Attard, Y. Rossier, T. Winiarski, L. Cuvillier, L. Eisenlohr
(2016) **Hydrogeology Journal**, 24 (5), 1213-1229

Urban groundwater age modeling under unconfined condition–Impact of underground structures on groundwater age: Evidence of a piston effect

G. Attard, Y. Rossier, L. Eisenlohr
(2016) **Journal of Hydrology** 535, 652-661

Deterministic modeling of the impact of underground structures on urban groundwater temperature

G. Attard, Y. Rossier, T. Winiarski, L. Eisenlohr
(in press) **Science of The Total Environment**

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