Schweizerische Eidgenossenschaft
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Swiss Federal Office of Energy

Thermo-Hydraulic Well Testing for Characterization and Management for Heat Storage Projects

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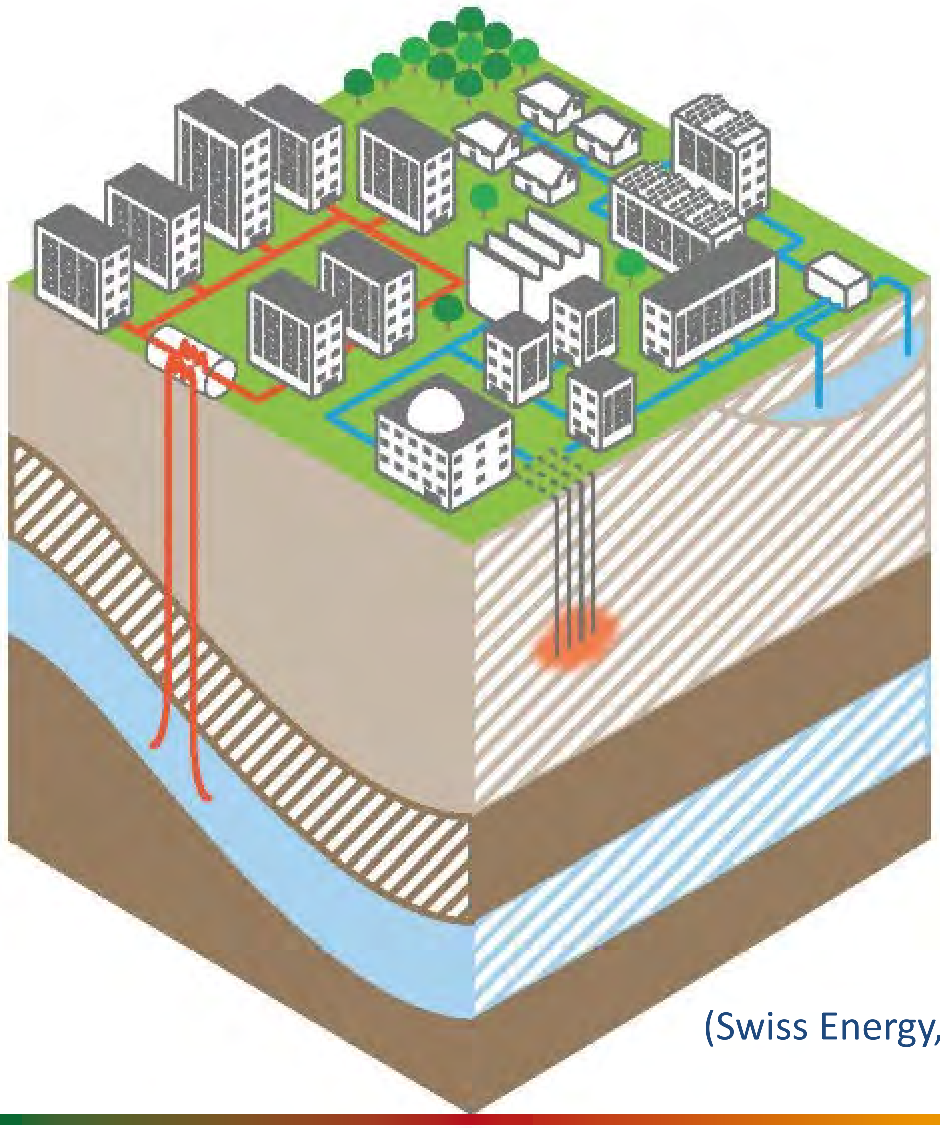
UNIVERSITÉ DE NEUCHÂTEL

GEOTHERMICA



(Swiss Energy, 2017)

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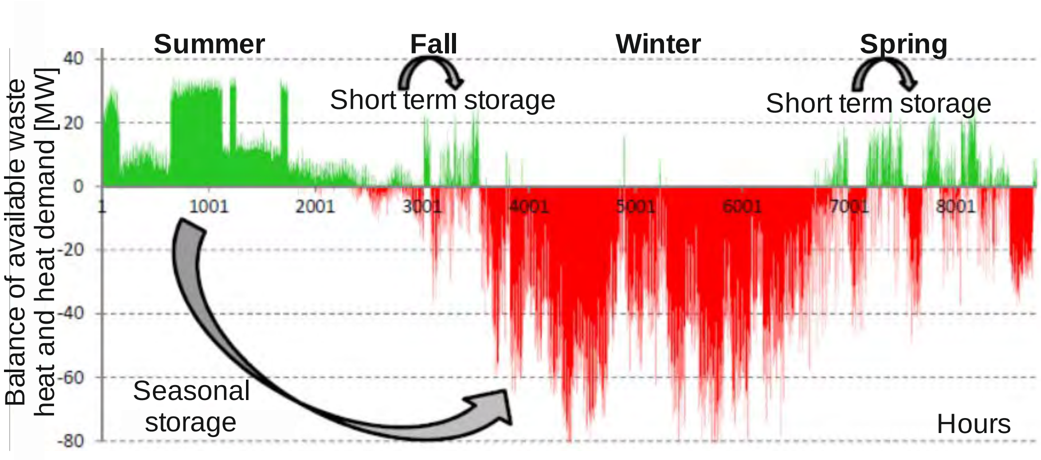
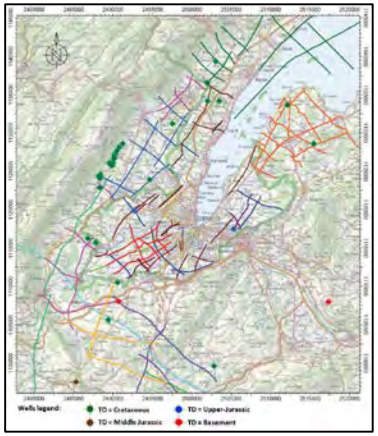


Seismic lignes localisation



Fractures network interpretation

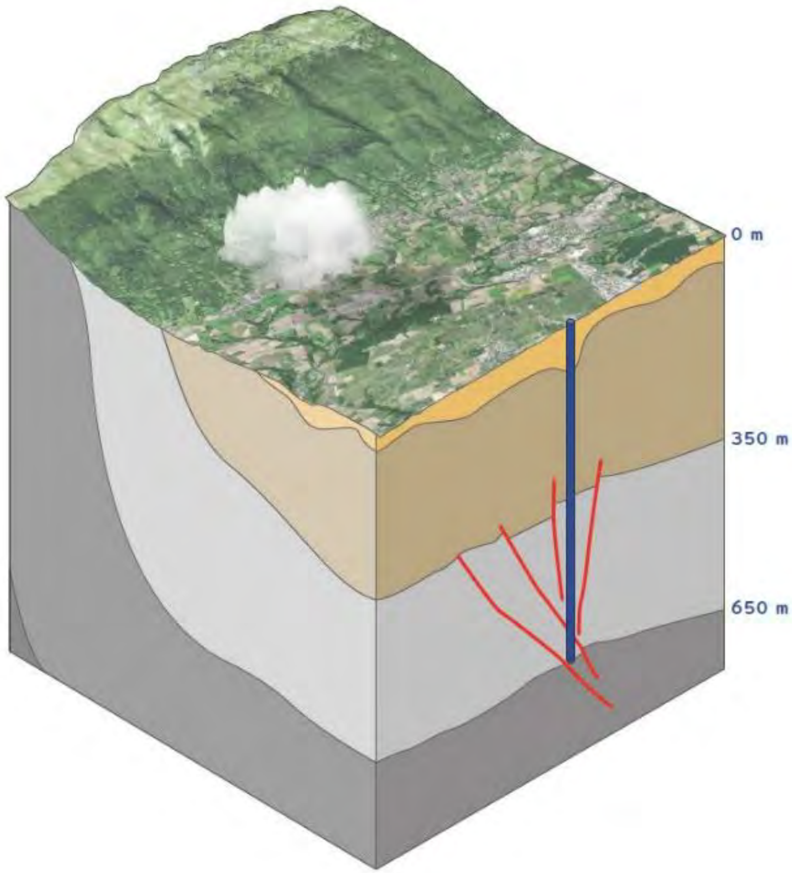
(Clerc, 2016)

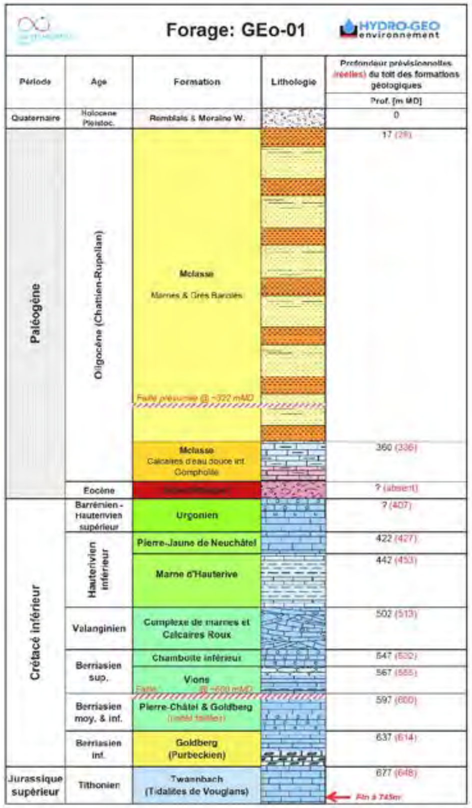
3D Geological Informations

Motivation

3D Geological Informations

Satigny Borhole GEO-1

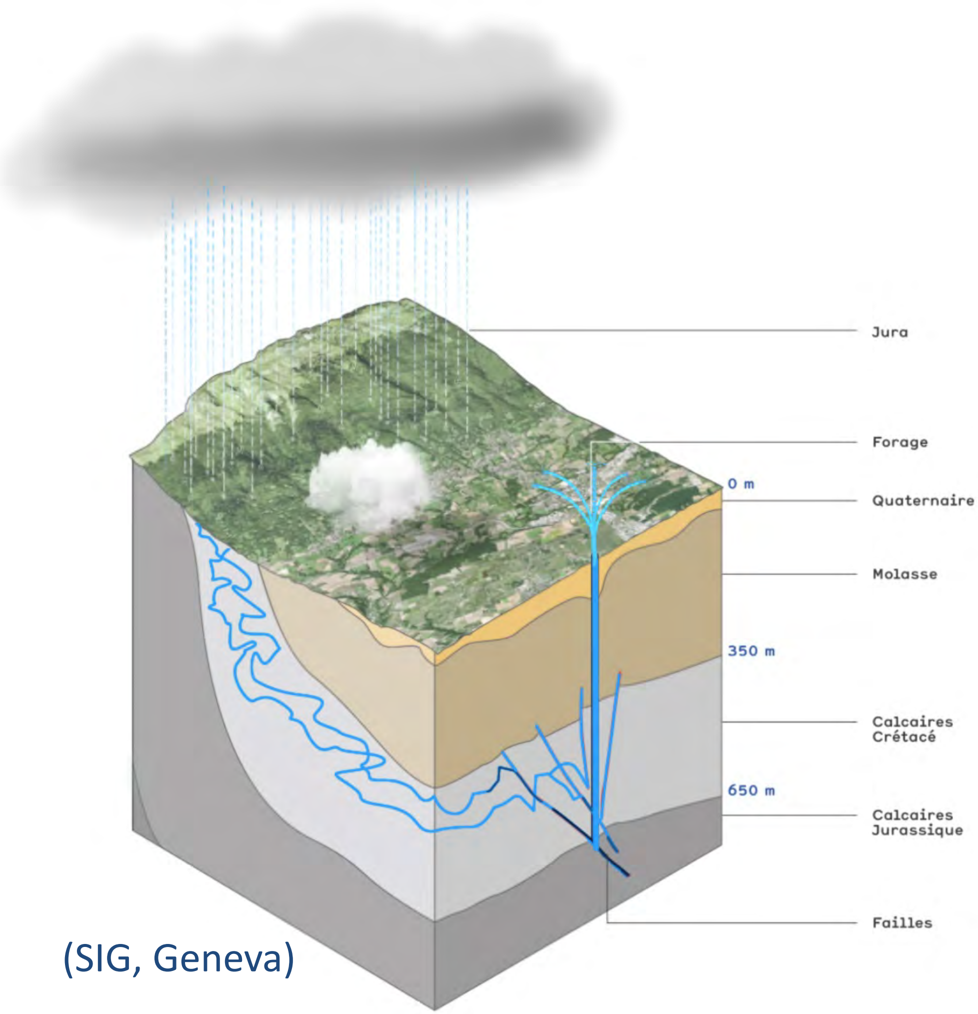




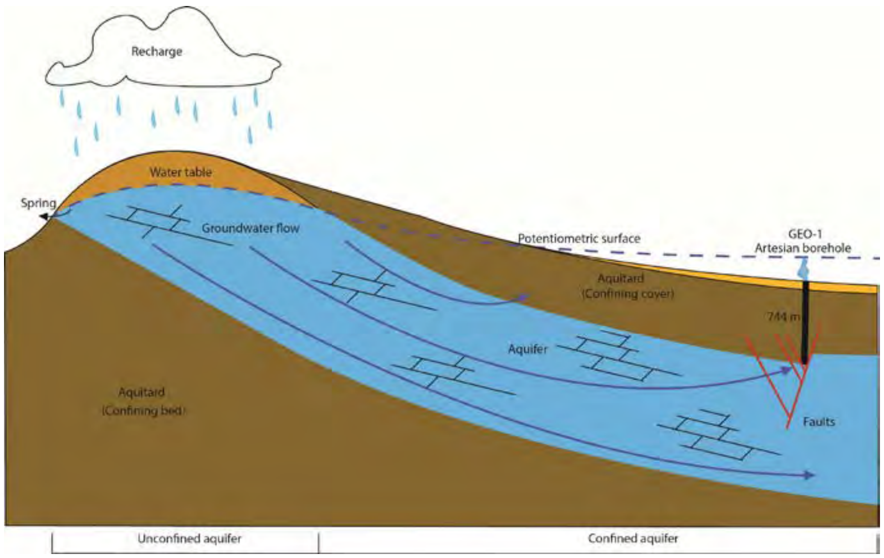
Période	Age	Formation	Profondeur prévisionnelles (réelles) du toit des formations géologiques Prof. [m MD]
Quaternaire	Holocene Pleistoc.	Remblais & Moraine W.	0
Paléogène	Oligocène (Chattien-Rupelian)	Molasse Marnes & Grès Bariolés	17 (26)
		Molasse Calcaires d'eau douce inf. Gompholite	360 (336)
	Eocène		? (absent)
Crétacé inférieur	Barrémien - Hauterivien supérieur	Urgonien	? (407)
	Hauterivien inférieur	Pierre-Jaune de Neuchâtel	422 (427)
		Marne d'Hauterive	442 (453)
	Valanginien	Complexe de marnes et Calcaires Roux	502 (513)
	Berriasien sup.	Chambotte inférieur	547 (532)
		Vions	567 (555)
	Berriasien moy. & inf.	Pierre-Châtel & Goldberg	597 (600)
	Berriasien inf.	Goldberg (Purbeckien)	637 (614)
Jurassique supérieur	Tithonien	Twannbach (Tidalites de Vouglans)	677 (648)

(SIG, Geneva)

Motivation



(SIG, Geneva)



(Sohrabi & Valley, in prep.)

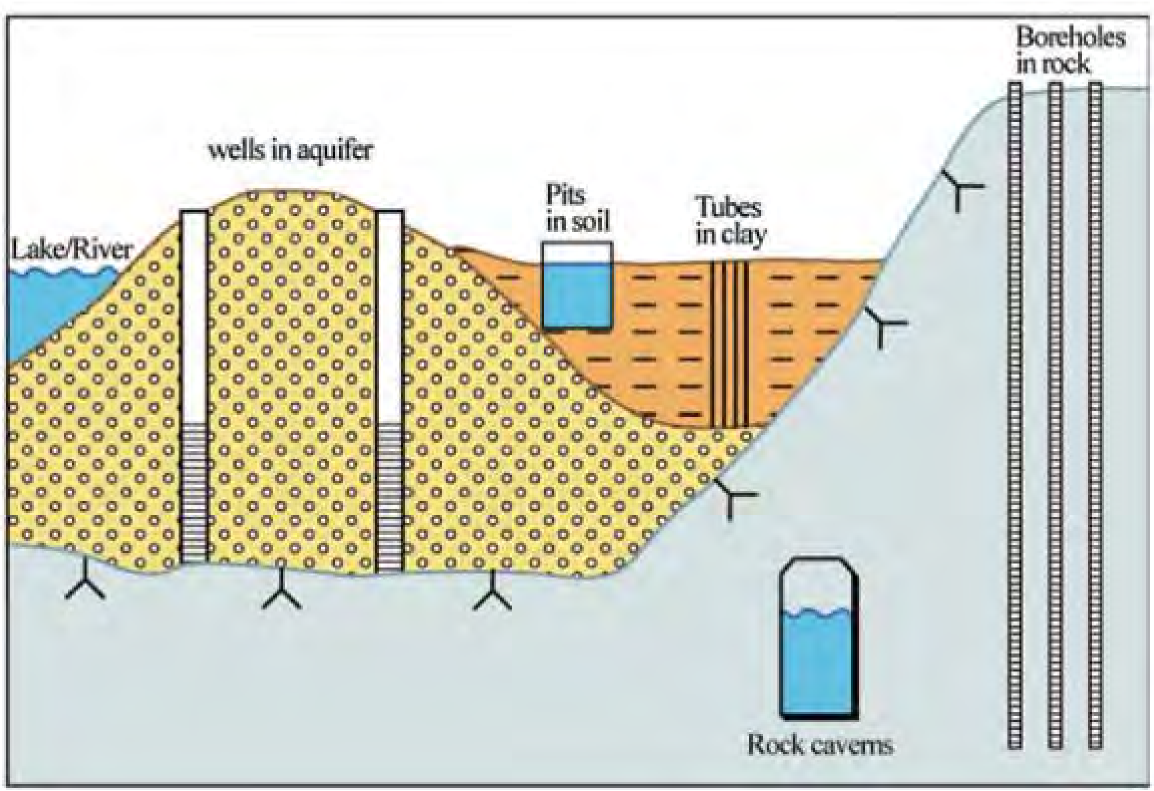
Water Temperature in the reservoir: **33°**

Flow rate at the surface: **50 l/s**

Borehole depth: **744 m**

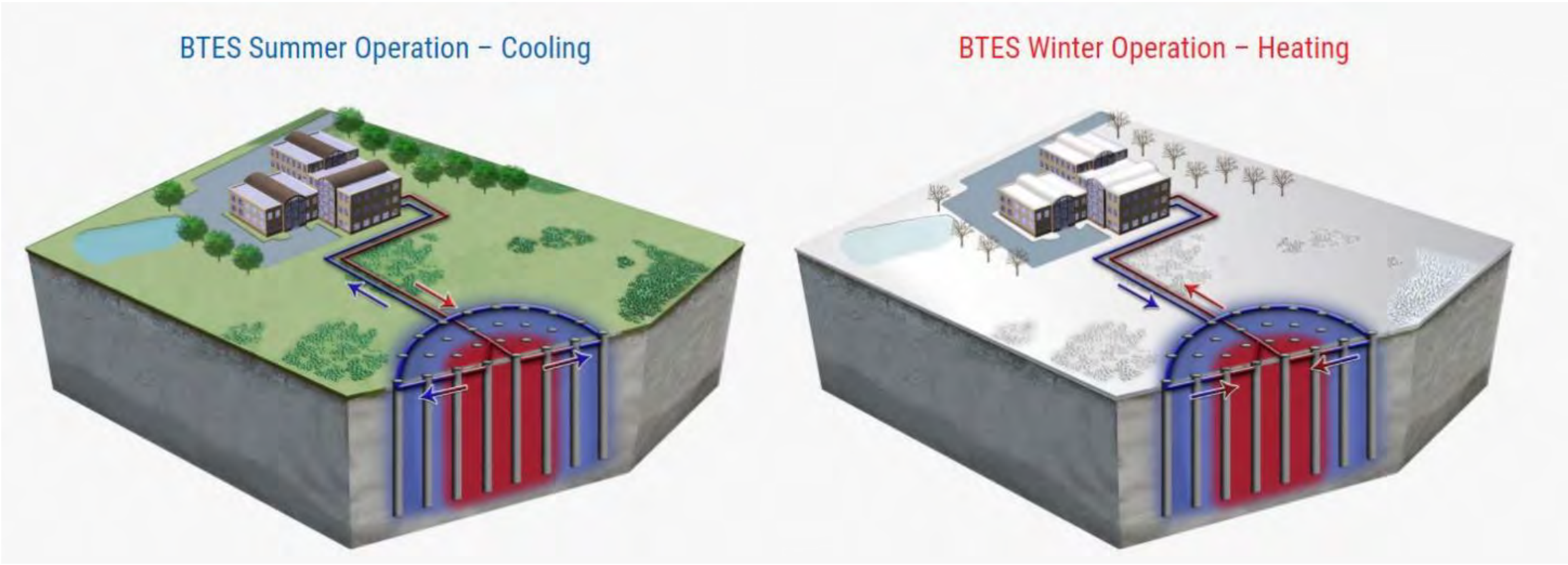
Motivation

Schematic representation of the most common UTES systems



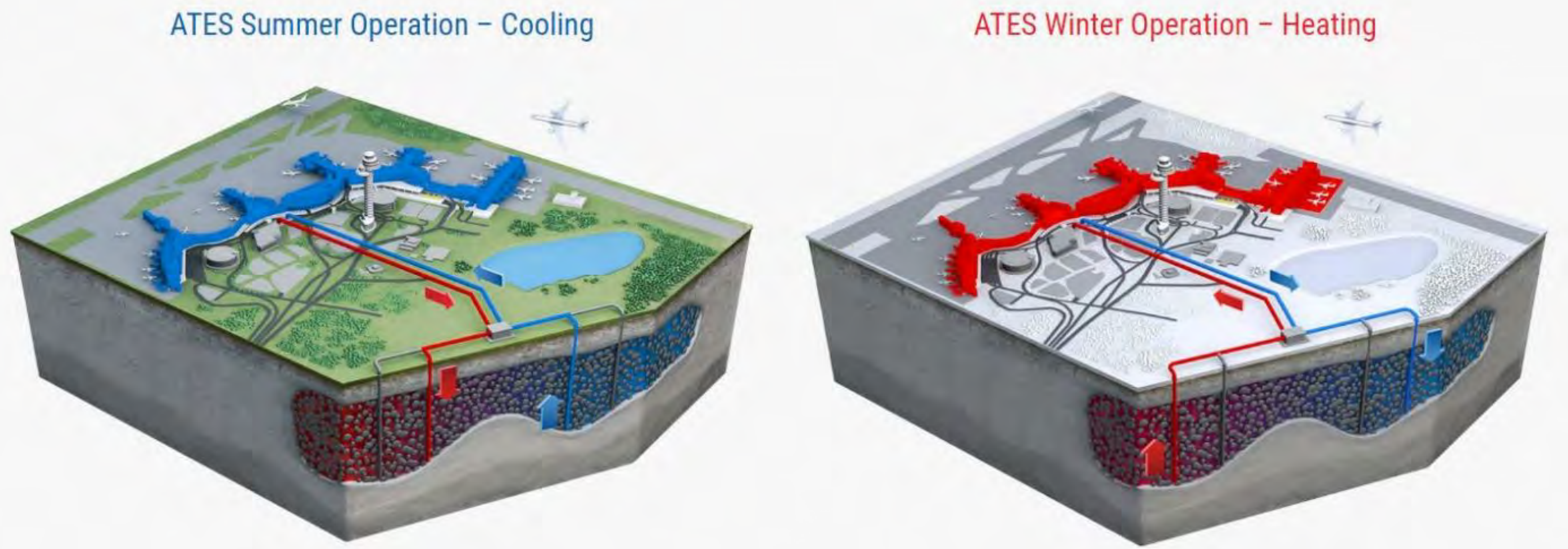
(Nordell at al. 2007)

BTES - Borehole Thermal Energy Storage



(Underground ENERGY)

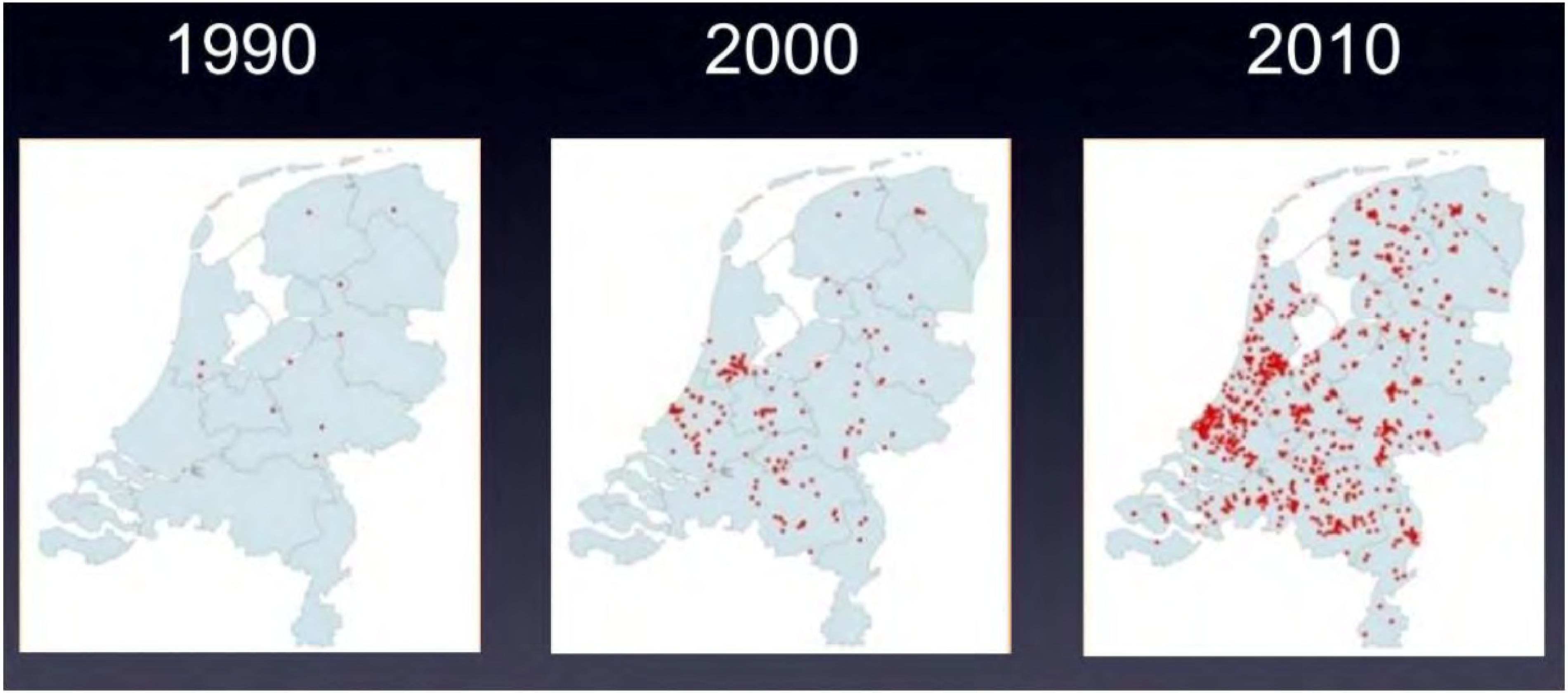
ATES - Aquifer Thermal Energy Storage



Stockholm-Arlanda Airport

(Underground ENERGY)

ATES systems installed in the Netherlands



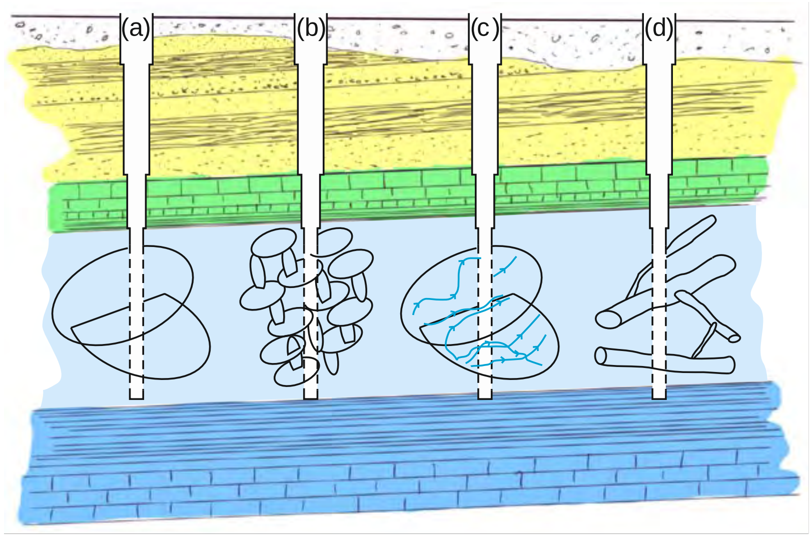
(Worthington, 2012)

ATES - Aquifer Properties

Any ATES application will require a good knowledge of the aquifer being the target to use.

The most important properties are:

- ❑ Geometry (surface area and thickness)
- ❑ Stratigraphy (different layers of strata)
- ❑ Static heat (groundwater or pressure level)
- ❑ Groundwater table gradient (natural flow direction)



Topographical, geological and hydrogeological descriptions

- ❑ Hydraulic conductivity (permeability)
- ❑ Transmissivity (hydraulic conductivity x thickness)
- ❑ Storage coefficient (yield as a function of volume)
- ❑ Leakage factor (vertical leakage to the aquifer)
- ❑ Boundary conditions (surrounding limits)

Geomechanical and geophyiscal data, well test characterization, pumping test

ATES – Determination of the Thermo-Hydrogeological Properties

Hydraulic well tests:

- ❑ Step-Drawdown Test
- ❑ Anisotropy Test
- ❑ Dispersivity Testing => Conservative tracer test

Thermo-Hydraulic well tests:

- ❑ Thermal Push-Pull Test
- ❑ Chemical Push-Pull Test

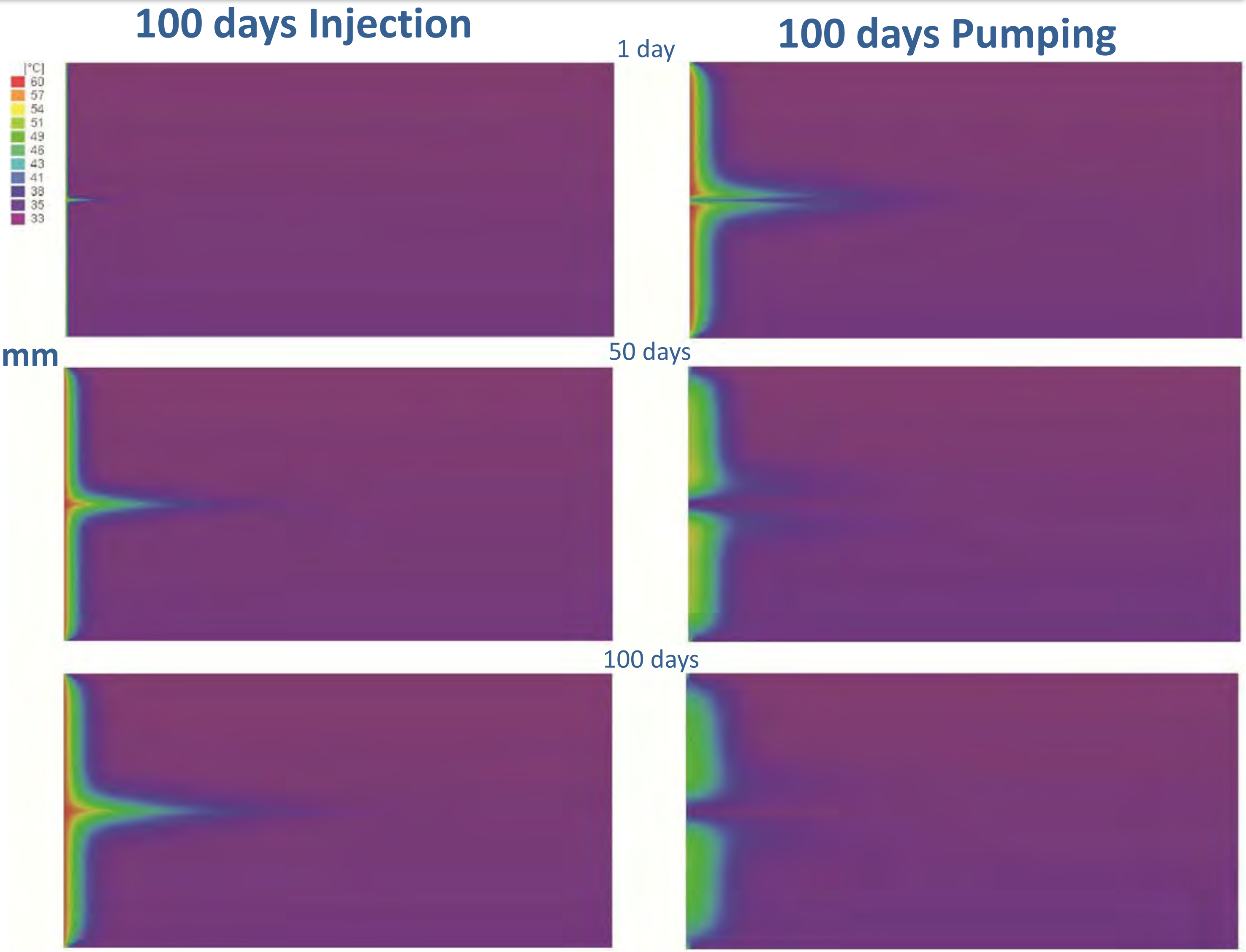
⇒ Quantify the exchange capacity of the reservoir, which reflect the heat exchanger geometry

ATES – Seasonal cold injection and withdrawal

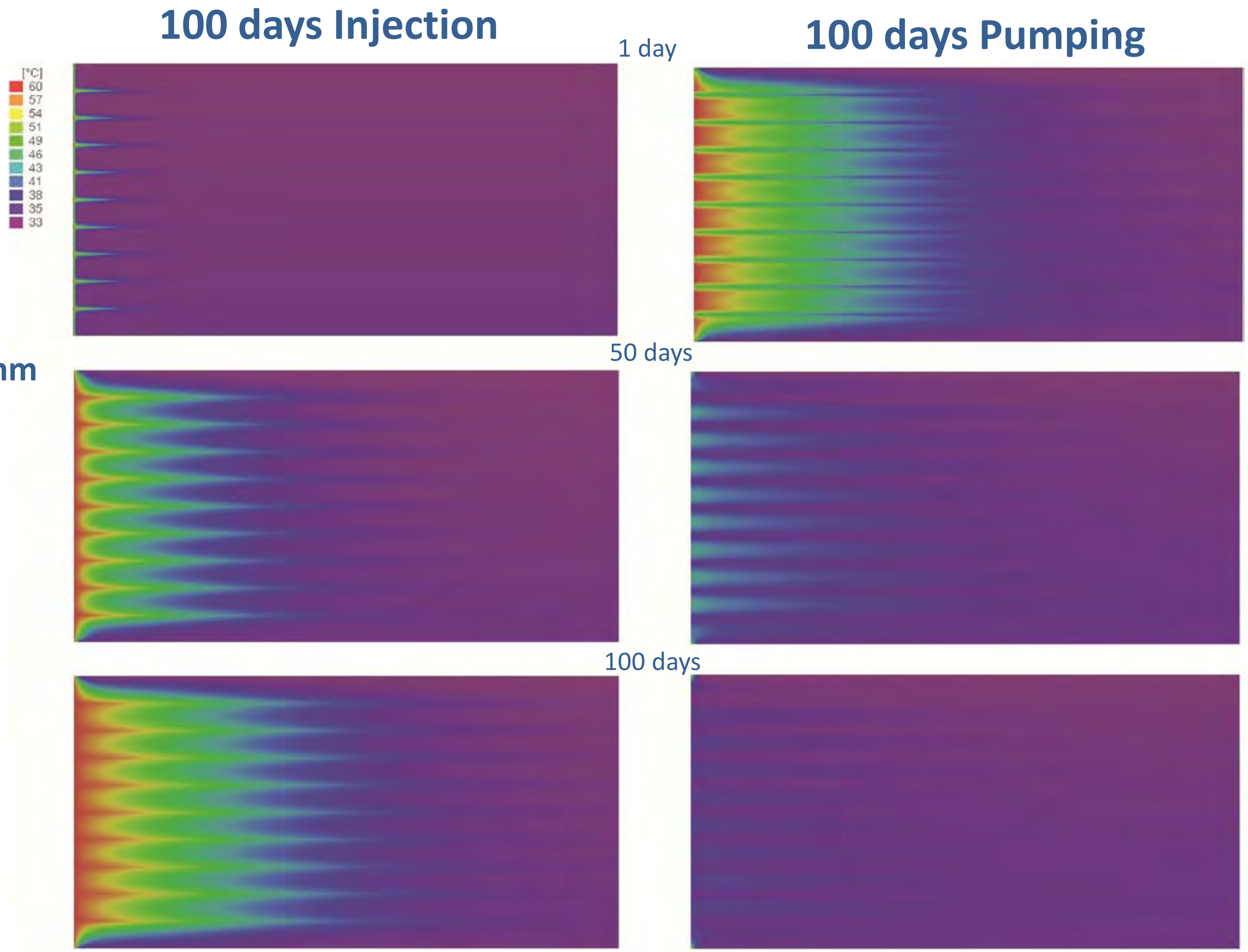
(General case from Underground ENERGY)

ATES – Borehole thermo-hydraulic simulations

- 1 fracture
- Frac. aperture = 1mm
- Kf = 1e -7m^2
- Km = 1e -15m^2



ATES – Borehole thermo-hydraulic simulations



- 9 fractures
- Frac. aperture = 1mm
- Kf = 1e -7m^2
- Km = 1e -15m^2

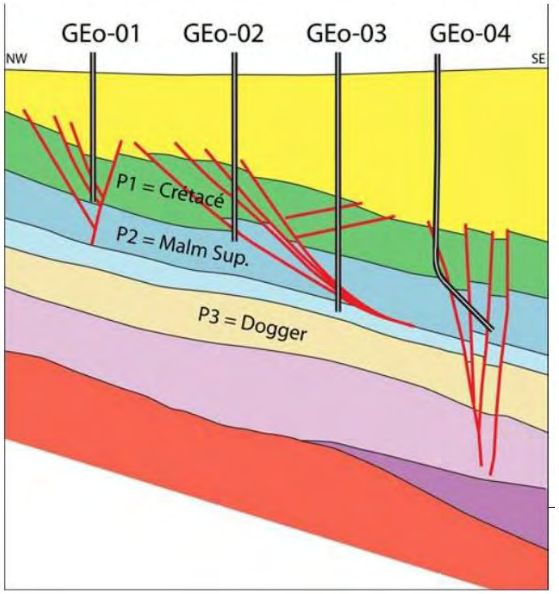
Outlooks

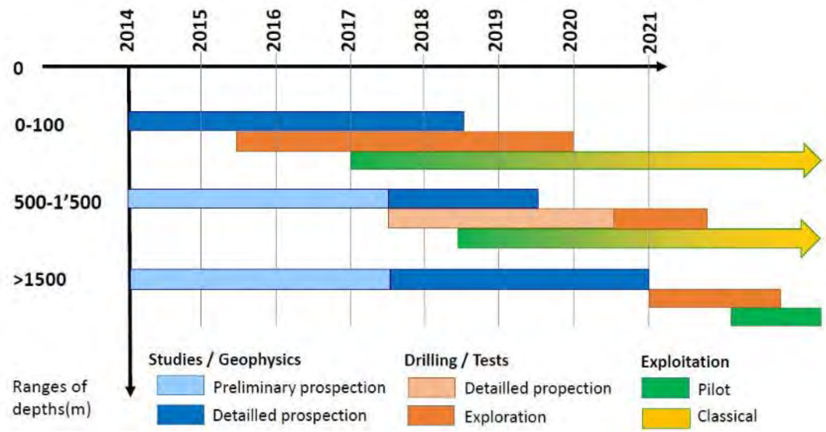
1) Define the relevant key aquifer parameters that must be determined to provide reliable heat storage design in fractured aquifers;

2) Propose well testing approaches (single well configuration) that can be deployed to estimate these key aquifers parameters;

3) Assess the feasibility of these testing approaches through numerical simulations and field tests;

4) Provide testing protocols, simplified test design guidelines and application examples in order to support the acceptance of these testing approaches as an industry standard for heat storage project development in fractured aquifers.





(SIG, Geneva)