# HEAT DISSIPATION TEST WITH FIBER-OPTIC DISTRIBUTED TEMPERATURE SENSING TO ESTIMATE GROUNDWATER FLUX

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# Outline

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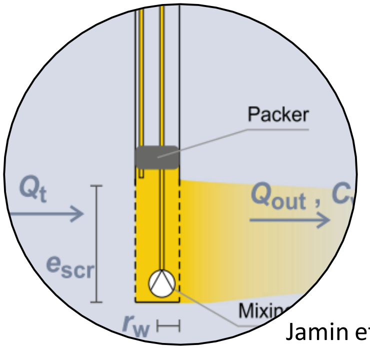
# Motivation

- Quantify groundwater flux
- Water resource management



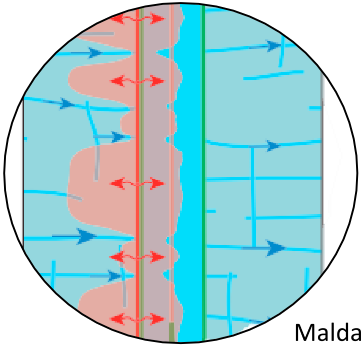

Jamin et al., 2020

**Solute**

- **Several observation wells**
- **Require a long duration**
- **Formal analytical methods(X)**

# A single well method

- **Simplify its implementation in the field**
- **Characterizing time variability**
- **Fiber-optic(FO) cables and DTS technology**



Maldaner et al., 2019

# FO cables and DTS

**Heating curves**

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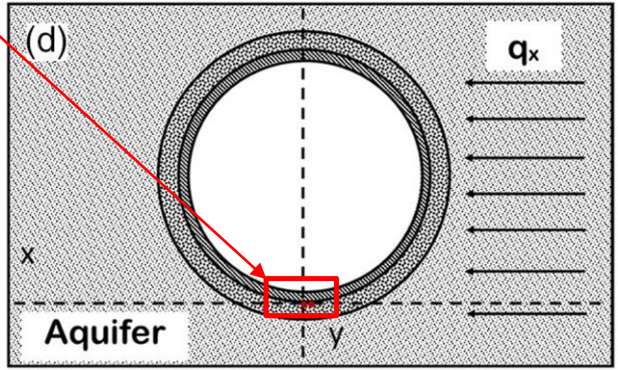
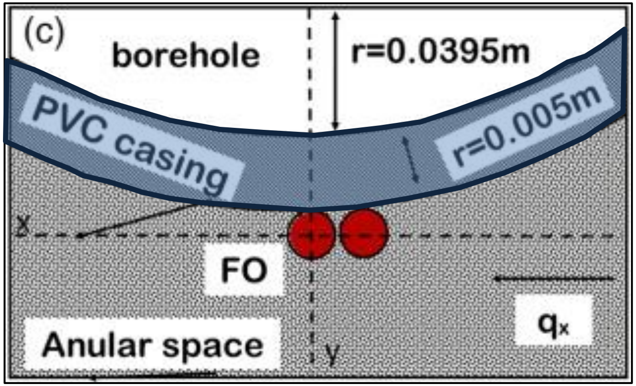
**Quantify groundwater flux**

- **Quantification of groundwater velocity**
- **Interpretation of the heating curves**
- **Cable installation**




Del Val et al., 2021




Del Val et al., 2021

**The installation aims to:**

**(1) At the same time as the borehole installation.**

**(2) Keeping the cable as in close contact.**

**(3) Maintaining of additional monitoring devises.**

# METHODOLOGY

## Methodology

$$T(x,y,t) = \frac{P}{4\pi\lambda} e^{\frac{q_x c_w x}{2\lambda}} W_H(u,v); with\ u = \frac{C_b r^2}{4\lambda t}\ ; and\ v = \frac{q_x C_w r}{2\lambda}$$

T [°C] : temperature

t [s] : times

**Data set :**

$\lambda$ **(Thermal conductivity)** $= 3\ Wm^{-1}K^{-1}$

$C_w$ **(Water heat capacity)** $= 4.2\ \times 10^6\ Jm^{-3}K^{-1}$

$C_b$ **(Bulk heat capacity)** $= 2.2\ \times 10^6\ Jm^{-3}K^{-1}$

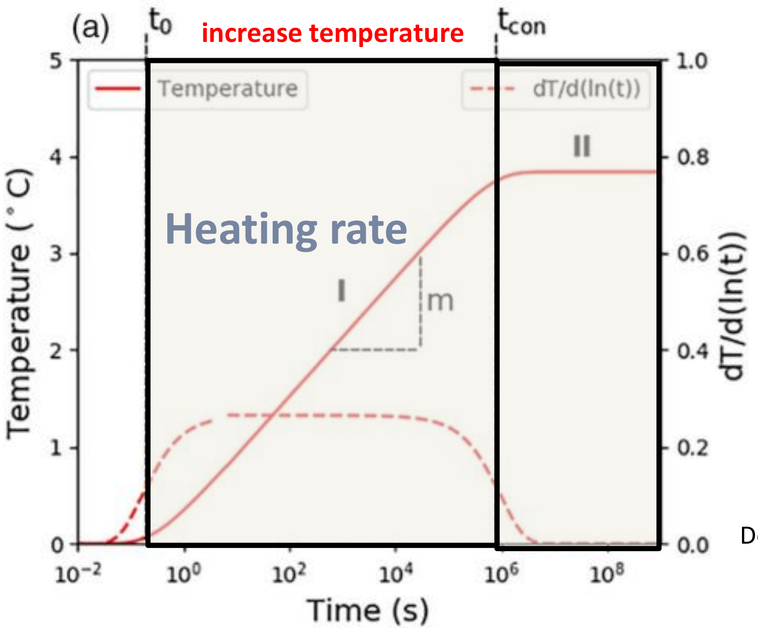
$r$ **(Distance)** $= 0.001m$

$P$ **(Power)** $= 10\ Wm^{-1}$

$q_x$ **(Specific discharge)** $= 1.1 \times 10^{-6}\ m\ \ s^{-1}$

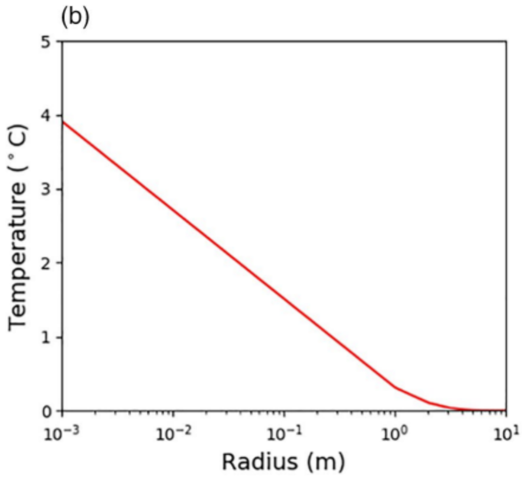
## Methodology

**Conduction** **Advection**



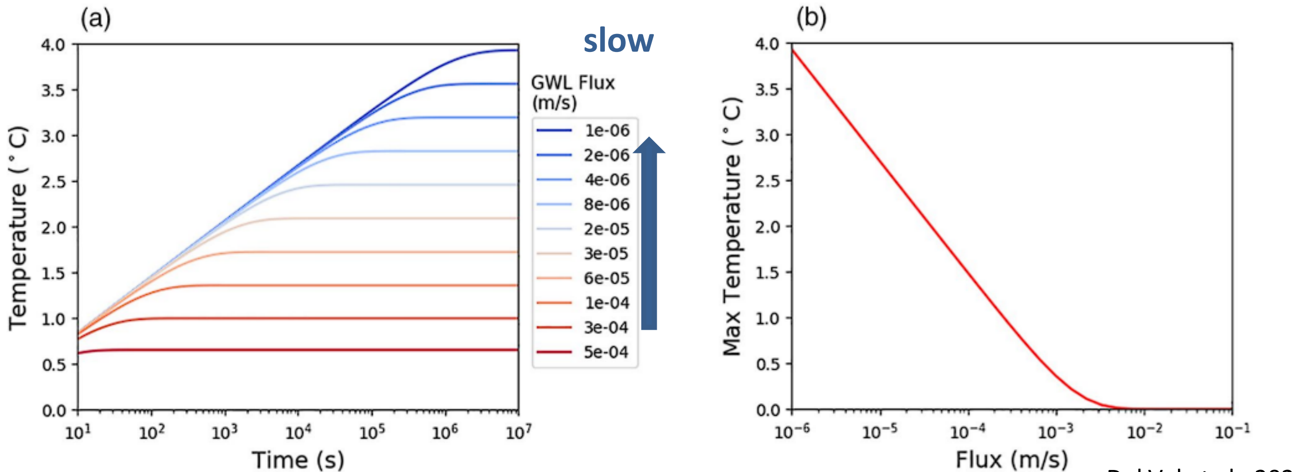

Del Val et al., 2021

- **Radius of influence is dragged by the groundwater flux.**
- **Rinf does not grow anymore and steady state is reached.**




Del Val et al., 2021

# Methodology




Del Val et al., 2021

**(a)Temperature evolution in time under different specific discharge rates.**

**(b)Maximum temperature reach for a wide range of fluxes.**

- The interpretation methodology puts emphasis on the estimation of the cable thermal effects in the heating curves.

# Cable Thermal Effects

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## Skin effect

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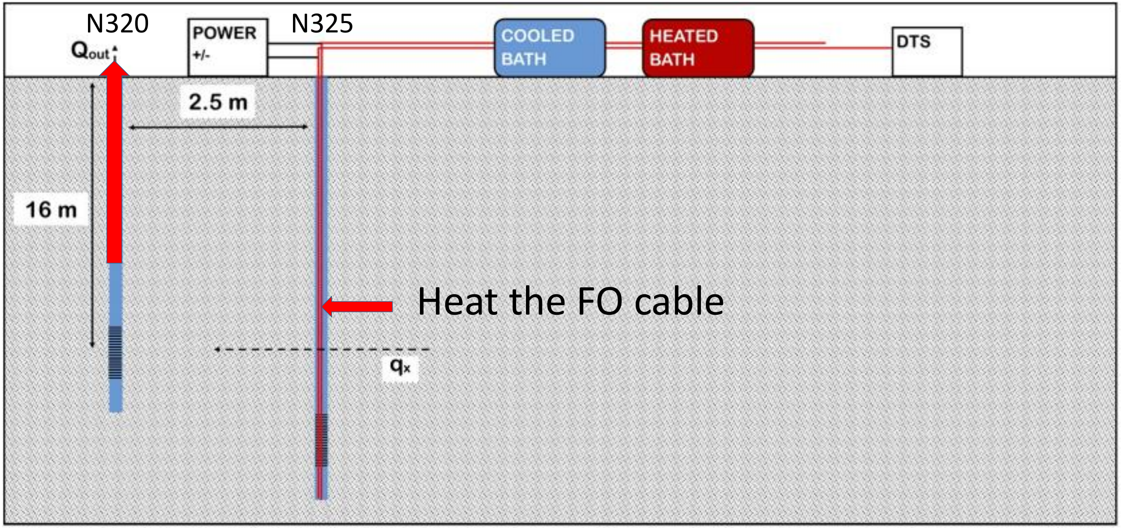
- Cable materials
- Surrounding installation
- Single heating and measuring line

# Heat Dissipation Test

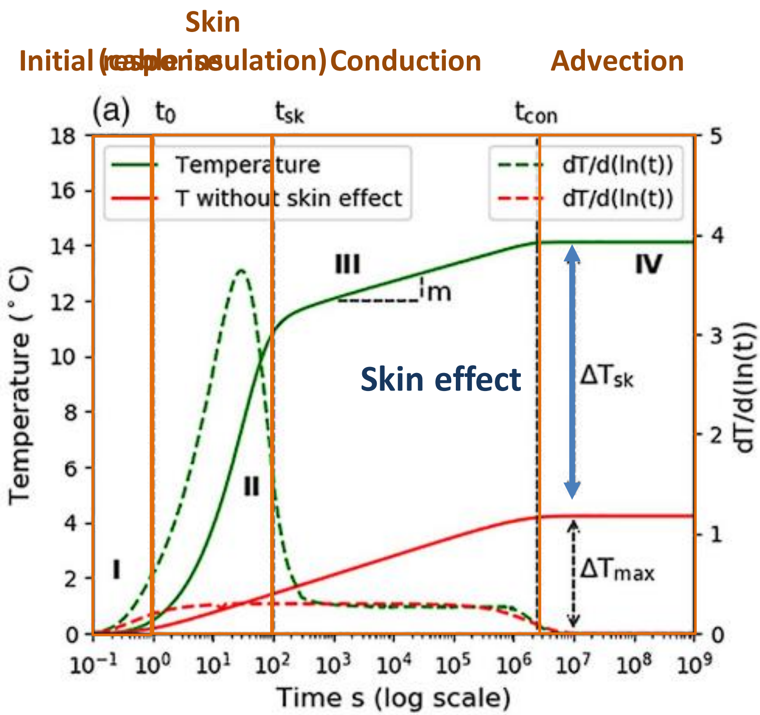
- Heating within the saturated soil.
- Temperature increase reaches steady state.
- Monitoring the temperature development of heating element.

## Heat Dissipation Test




Del Val et al., 2021

# RESULT




Del Val et al., 2021

# Interpret the heat curves

- Temperature data
- Computation of temperature
- Skin effect correction
- Estimation of thermal properties

# CONCLUSION

## Conclusion

- **Quantify groundwater fluxes and thermal properties..**
- **Improving quantification of the “skin effect”.**

# FUTURE WORK

## Future Work

- The field set-up and Heat Dissipation Test implementation.
- Find thermal parameter for my Case.
- Plot spatial distribution of temperature and interpret the heat curves to quantify groundwater fluxes.
- Evaluate groundwater quantity for water resource management.

# THANK YOU FOR YOUR ATTENTION

$$T(x,y,t) = \frac{P}{4\pi\lambda} e^{\frac{q_x c_w x}{2\lambda}} W_H(u,v)\ ; with\ u = \frac{C_b r^2}{4\lambda t}\ ; and\ v = \frac{q_x C_w r}{2\lambda}$$

**Hantush well function collected water-level drawdown data during a pumping test (aquifer test).**

$$W_H(a,b) = \int_a^\infty \frac{1}{s} exp\left[-s - \frac{b^2}{4s}\right] ds$$

$$T(x,y,t) = \frac{P}{4\pi\lambda} e^{\frac{q_x c_w x}{2\lambda}} W_H(u,v)\;; with\; u = \frac{C_b r^2}{4\lambda t}\;;\; and\; v = \frac{q_x C_w r}{2\lambda}$$

**(data: λb = 3 Wm−1K−1; Cw = 4.2 × 106 Jm−3K−1;**

**Cb = 2.2 × 106 Jm−3K−1; r = 0.001 m, P = 10 Wm−1;**

**qx = 1.1 × 10−6 m s−1).**

$$T(x,y,t) = \frac{P}{4\pi\lambda} e^{\frac{q_x c_w x}{2\lambda}} W_H(u,v); with\ u = \frac{C_b r^2}{4\lambda t}\ ; and\ v = \frac{q_x C_w r}{2\lambda}$$

$P\ \left[\frac{W}{m}\right]$: **Power released per unit length of cable.**

$\lambda\ \left[\frac{J}{mK}\right]$ : **Thermal conductivity.**

$q\ \left[\frac{m}{s}\right]$: **Specific discharge.**

$Cw\ \left[\frac{J}{m^3K}\right]$: **Water heat capacity.**

$W_H(u,v)$ : **Hantush Well function.**

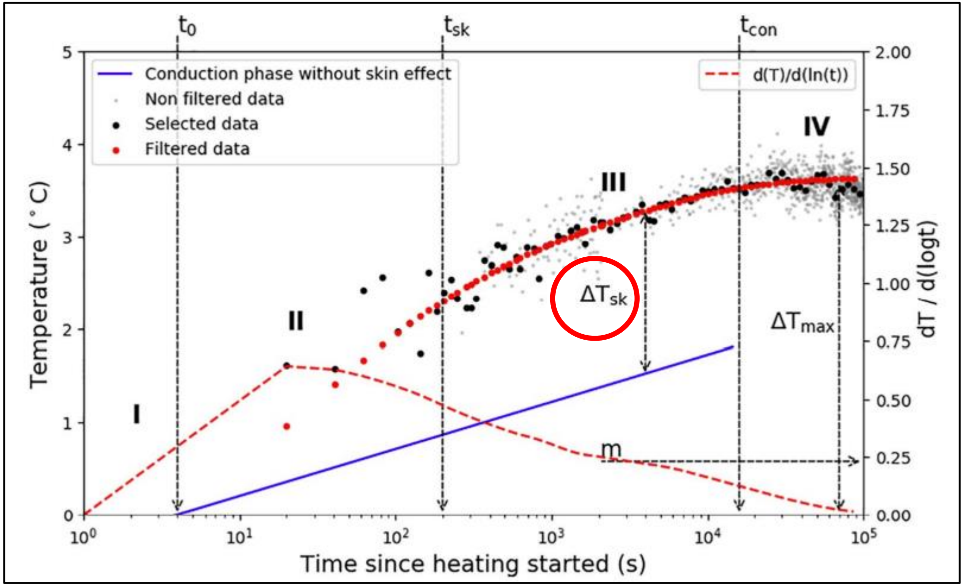
**Modeling groundwater system conditions by existing software.**

**Ex: Yong-an station we can try to estimate groundwater flux,**

**because that place is coastal station so we want to mention**

**about water intrusion problem**

# Result




Val et al, 2021