


INTERPRETATION OF A THERMAL RESPONSE TEST IN A BAYESIAN FRAMEWORK TO INFER THE HYDRAULIC PROPERTIES SURROUNDING A STANDING COLUMN WELL

Louis Jacques and Philippe Pasquier

Geothermal Research Chair on the Integration of SCWs in Institutional Buildings
Department of Civil, Geological and Mining Engineering
Polytechnique Montréal

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POLYTECHNIQUE MONTRÉAL
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1. INTRODUCTION

Objective :

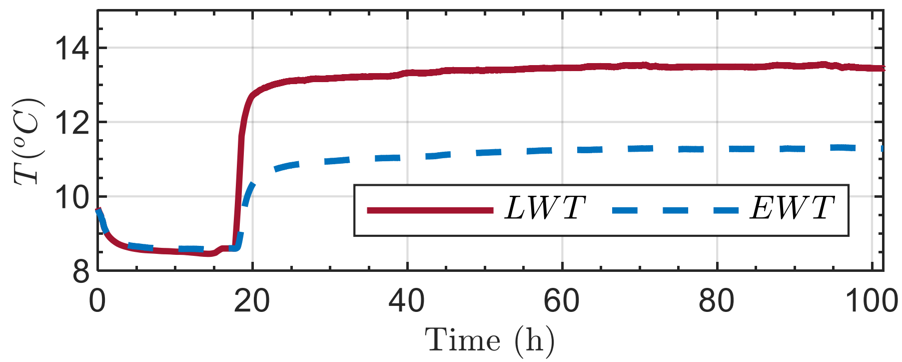
- Infer the hydraulic properties using a temperature response

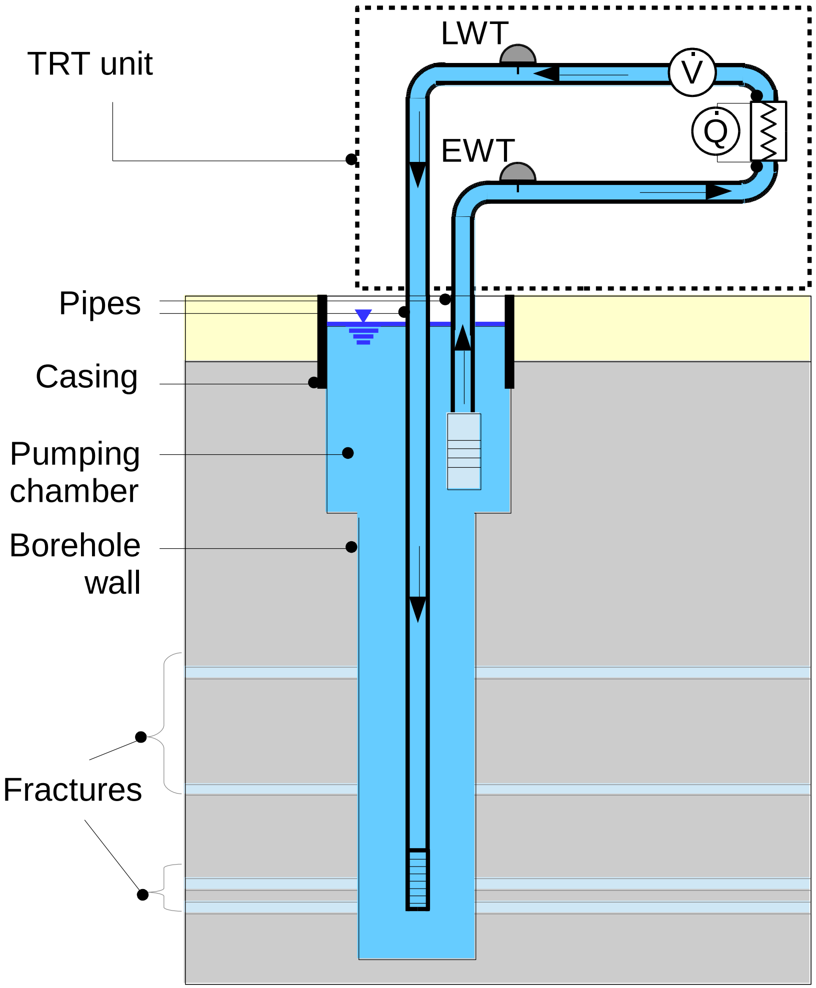
Standing column well (SCW)

- Groundwater recirculates in an open borehole
- Advective and conductive heat transfer, even without net pumping

Thermal response test (TRT)

- Continuous fluid heating
- Temperature evolution leads to thermal conductivity





2. EXPERIMENTAL SITE

Bayesian inference of :

Thermal conductivity of materials

Deduced from cuttings :

- Three (3) materials
  - Loose deposit (Till)
  - Sandy dolomite
  - Quartz arenite

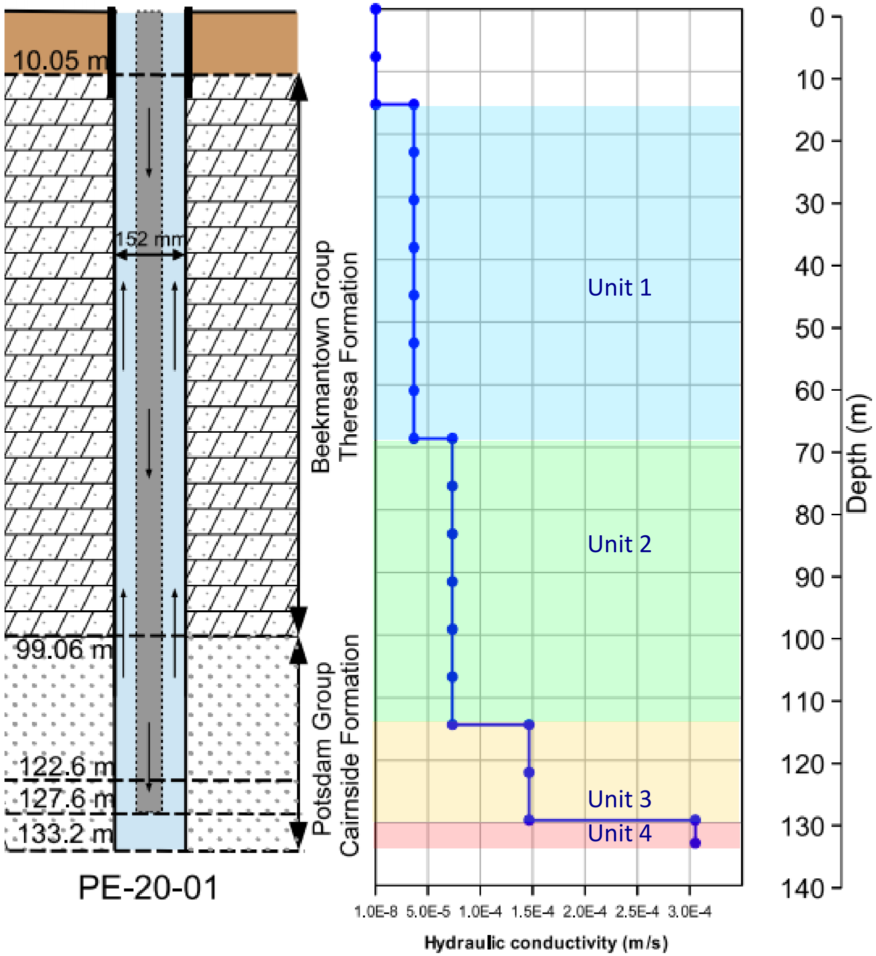
Hydraulic conductivity of units

Deduced from groundwater flow observed during drilling :

- Four (4) units

Subsurface materials

Hydrostratigraphic units



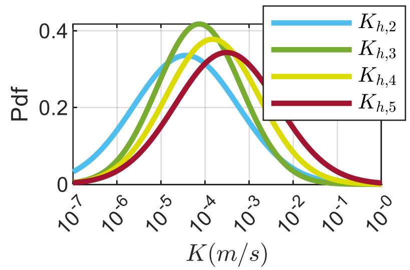
*adapted from Robert *et al.* (2022).

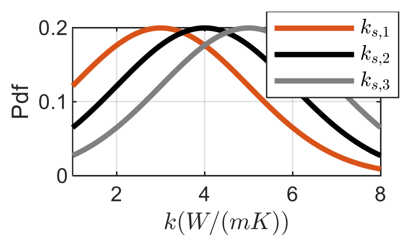
3. BAYESIAN INFERENCE AND SIMULATION

Bayes Theorem

$$P(\theta|x) \propto P(x|\theta) \cdot P(\theta)$$

P(θ) Priors





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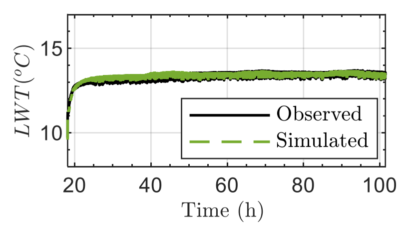
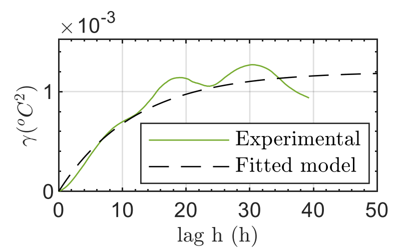
P(x|θ) : Likelihood





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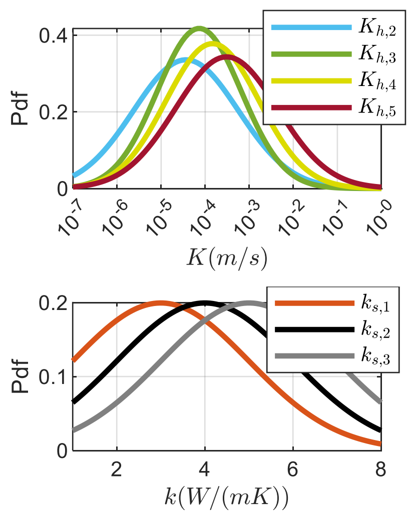

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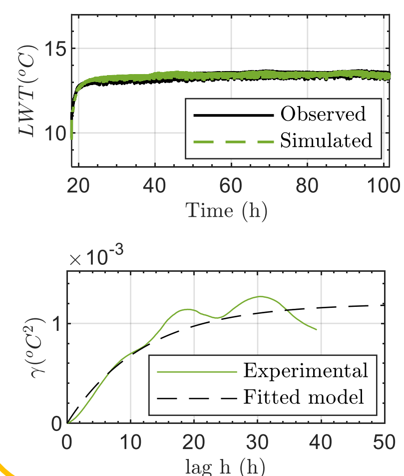
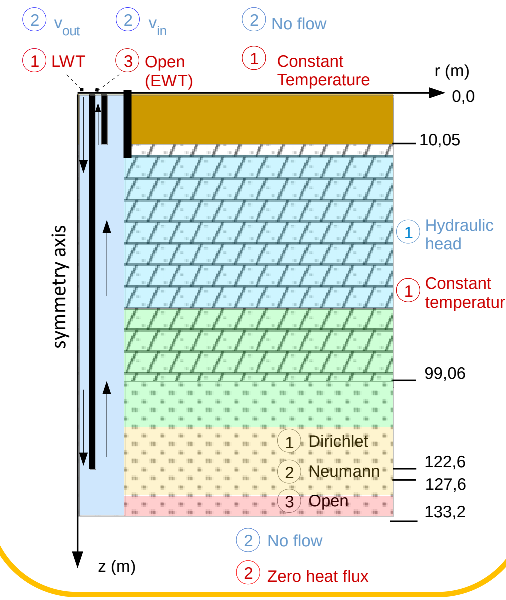
P(x|θ) : Likelihood



Numerical H and T model



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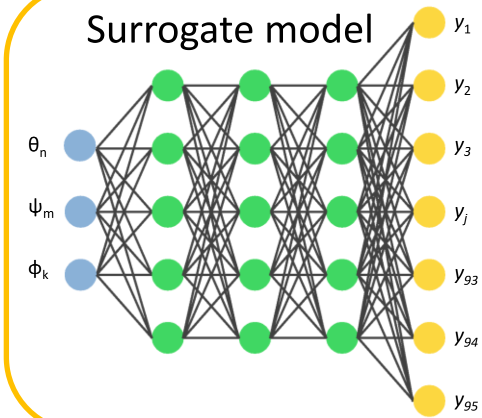
Surrogate model



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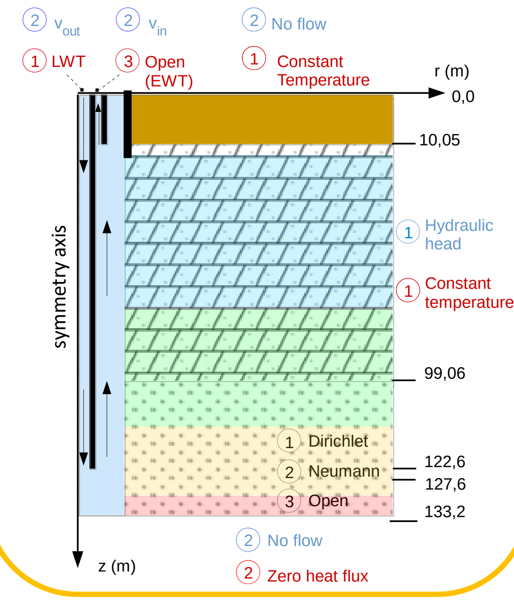
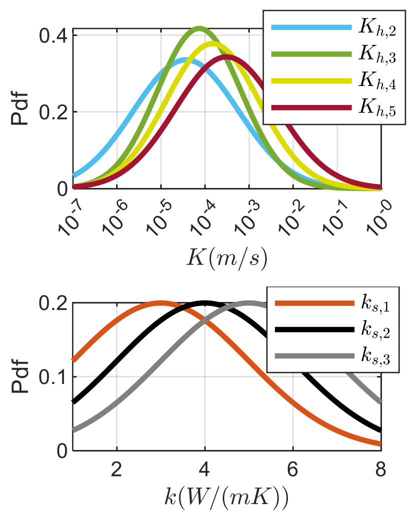


P(θ) Priors



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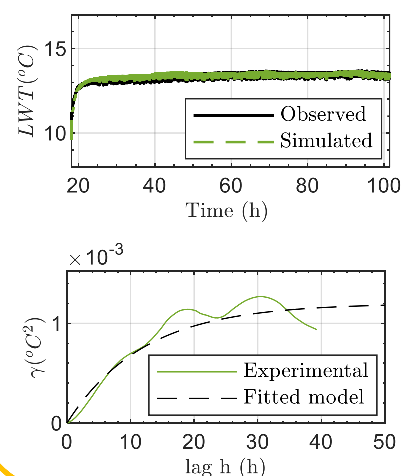
P(x|θ) : Likelihood



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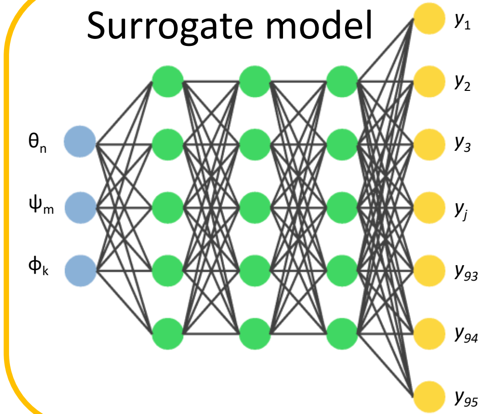
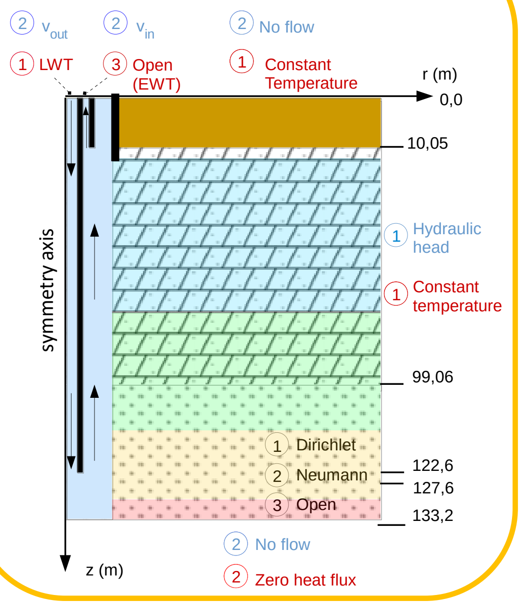
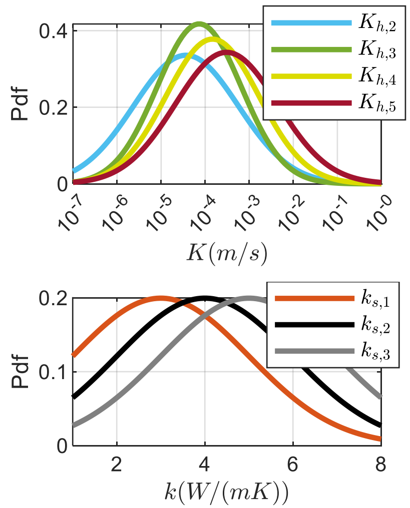


Numerical H and T model



P(θ) Priors



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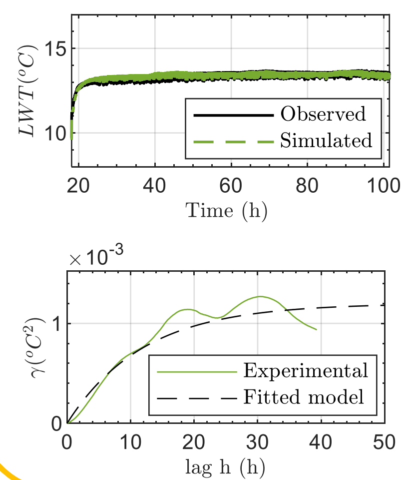
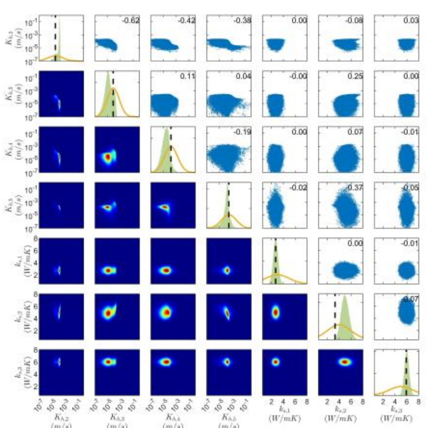
P(x|θ) : Likelihood



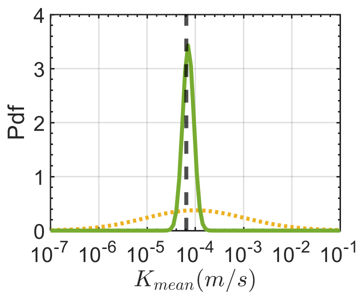
Inferred distributions



4. RESULTS

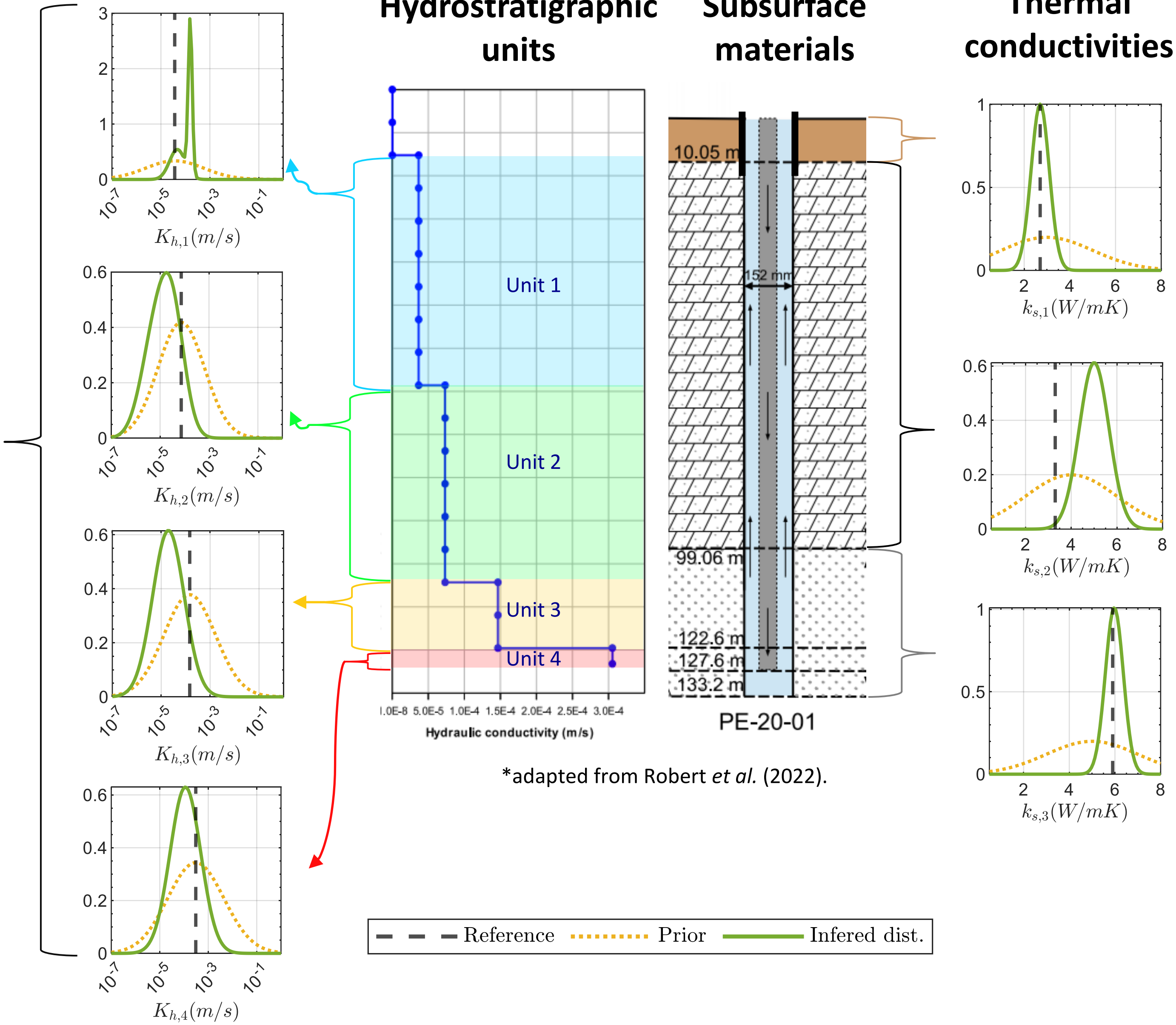
Hydraulic conductivities with TRT

Weighted average :



similar to pumping test with a difference of <u>1.5%</u>

Hydrostratigraphic units **Subsurface materials** **Thermal conductivities**



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5. CONCLUSION

Objective

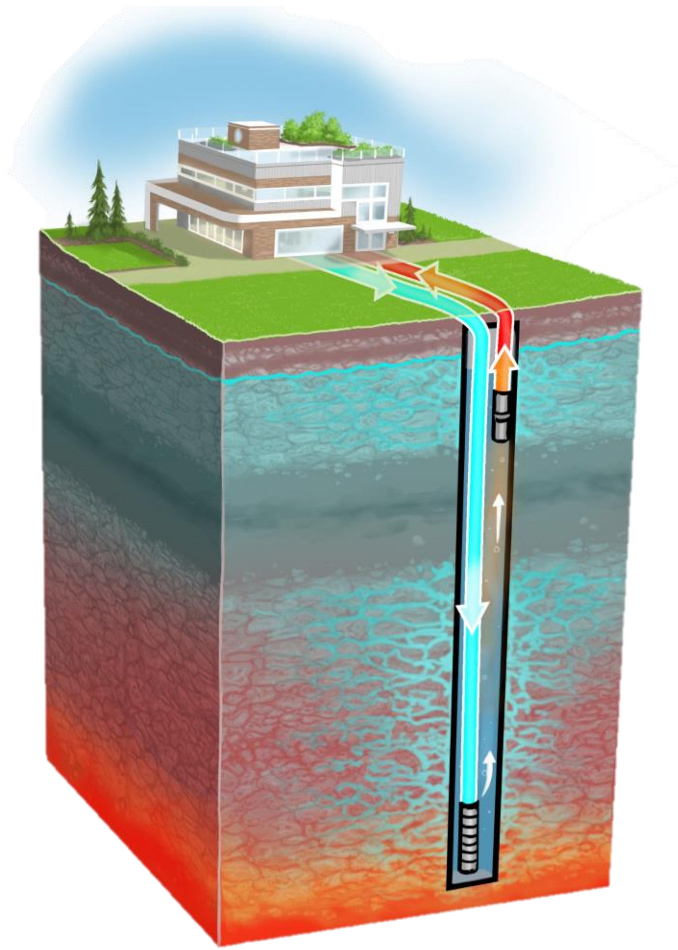
- Infer the hydraulic properties using a temperature response

Bayesian inference

- Assess joint and marginal probability distributions
- Update prior knowledge conditionally to observations

Contribution

- Robust inference of hydraulic properties with a thermal response test
- <u>Thermal test for hydraulic assessments</u>



QUESTIONS ?

CSSMI

Commission scolaire des Samares

Commission scolaire de Montréal

Éducation et Enseignement supérieur Québec

POLYTECHNIQUE MONTRÉAL UNIVERSITÉ D'INGÉNIERIE

Chaire de recherche en géothermie sur l'intégration des PCP dans les bâtiments institutionnels

Marmott Énergies

Hydro Québec

VERSAPROFILES

Natural Resources Canada Ressources naturelles Canada

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REFERENCES

Beaudry, G., Pasquier, P., & Marcotte, D. (2019). The impact of rock fracturing and pump intake location on the thermal recovery of a standing column well: Model development, experimental validation, and numerical analysis. Science and Technology for the Built Environment, 25(8), 1052–1068. https://doi.org/10.1080/23744731.2019.1648133

Choi, W., Kikumoto, H., Choudhary, R., & Ooka, R. (2018). Bayesian inference for thermal response test parameter estimation and uncertainty assessment. Applied Energy, 209, 306–321. https://doi.org/10.1016/j.apenergy.2017.10.034

Choi, W., Menberg, K., Kikumoto, H., Heo, Y., Choudhary, R., & Ooka, R. (2018). Bayesian inference of structural error in inverse models of thermal response tests. Applied Energy, 228, 1473–1485. https://doi.org/10.1016/j.apenergy.2018.06.147

Comsol A.B. (2022). COMSOL Multiphysics v. 6.0. Stockholm, Sweden

Jeon, J.-S., Lee, S.-R., & Kim, W.-J. (2016). Applicability of thermal response tests in designing standing column well system: A numerical study. Energy, 109, 679–693. https://doi.org/10.1016/j.energy.2016.05.023

Karamanis, M., & Beutler, F. (2021). Ensemble Slice Sampling: Parallel, black-box and gradient-free inference for correlated & multimodal distributions. ArXiv:2002.06212 [Astro-Ph, Stat]. https://doi.org/10.1007/s11222-021-10038-2

Laroche, V., Pasquier, P., & Courcelles, B. (2022). Integration of standing column wells in urban context: A numerical investigation-case in the City of Montreal. Sustainable Cities and Society, 78, 103513. https://doi.org/10.1016/j.scs.2021.103513

Marcotte, D. & Pasquier, P. (2008). Fast fluid and ground temperature computation for geothermal ground-loop heat exchanger systems, Geothermics, vol. 37, no. 6, p. 651–665. https://doi.org/10.1016/j.geothermics.2008.08.003

Pasquier, P., Zarrella, A. & Labib, R. (2018). Application of artificial neural networks to near-instant construction of short-term g-functions, Applied Thermal Engineering, vol. 143, p. 910–921. https://doi.org/10.1016/j.applthermaleng.2018.07.137

Pasquier, P. & Marcotte, D. (2020). Robust identification of volumetric heat capacity and analysis of thermal response tests by Bayesian inference with correlated residuals, Applied Energy, vol. 261, p. 114 394 ; 1–18. https://doi.org/10.1016/j.apenergy.2019.114394

Robert, S., Pasquier, P., & Nguyen, A. (2022). Impact of layered heterogeneity on thermal response test interpretation performed on a standing column well operated without bleed. Geothermics, 101, 102353. https://doi.org/10.1016/j.geothermics.2022.102353