Use of environmental tracers to assess the viability of lake bank filtration

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Introduction

- Evironmental tracers:
- Naturally ocurring in the environment
- Cheap and easy to sample/measure
- Sufficient contrast needed between end-members
- Can be used to trace processes and quantify fluxes

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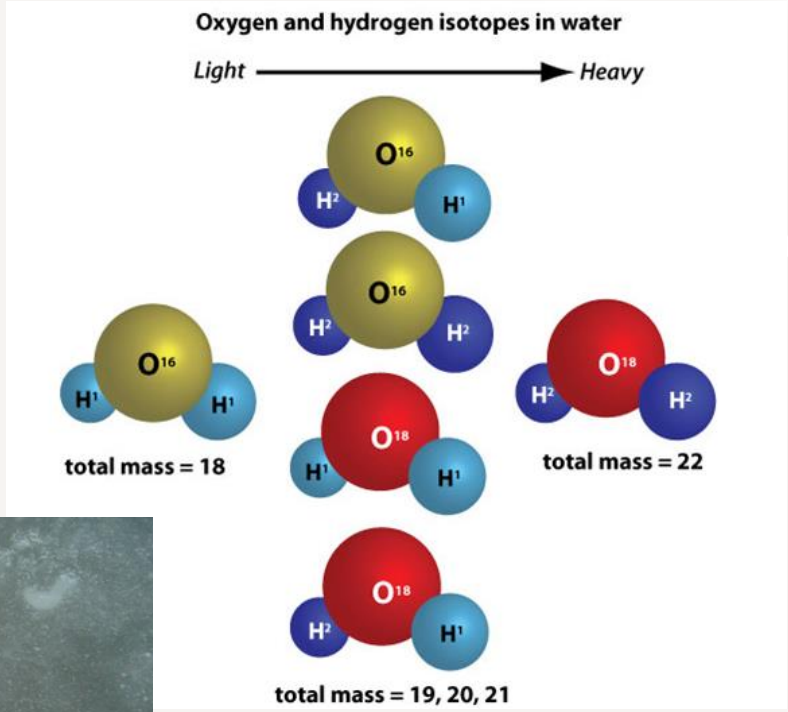
Introduction

- Most common environmental tracers in hydrology:
  - Temperature
  - Water stable isotopes ($\delta^{18}O$, $\delta^{2}H$)
  - Electrical conductivity (EC)
  - Water quality



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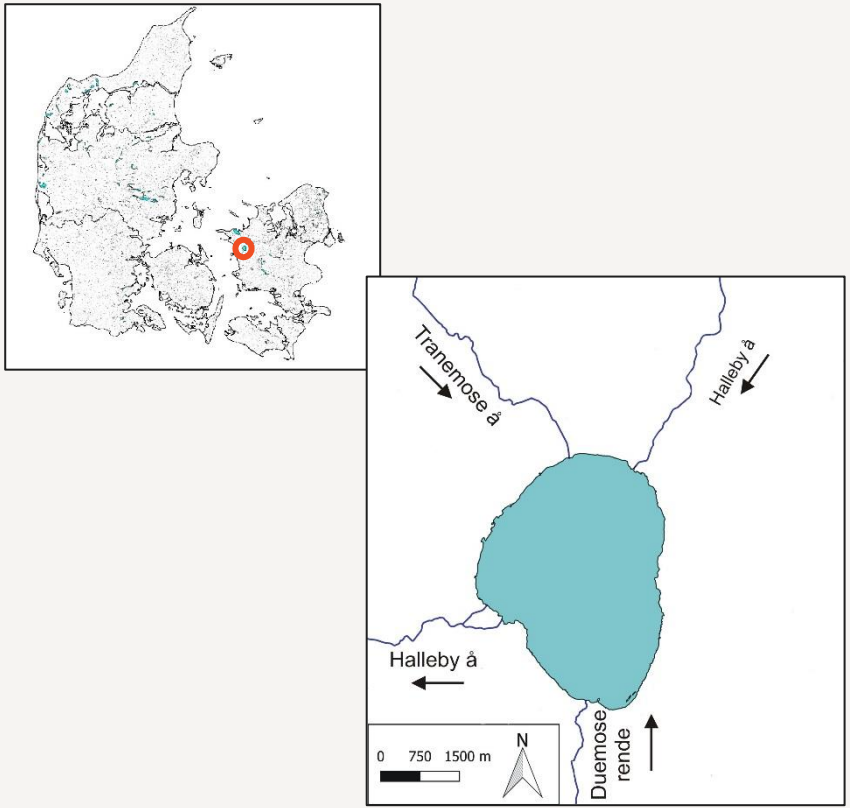
Field site



- Tissø:
- 4th largest lake in Denmark
- Water volume approx. 100 million m³
- Extraction of 5 million m³/yr surface water
- KALFOR would like to increase the extraction by 5-10 million m³/year

- Could lake bank filtration be a viable option?
- How to assess its feasibility?

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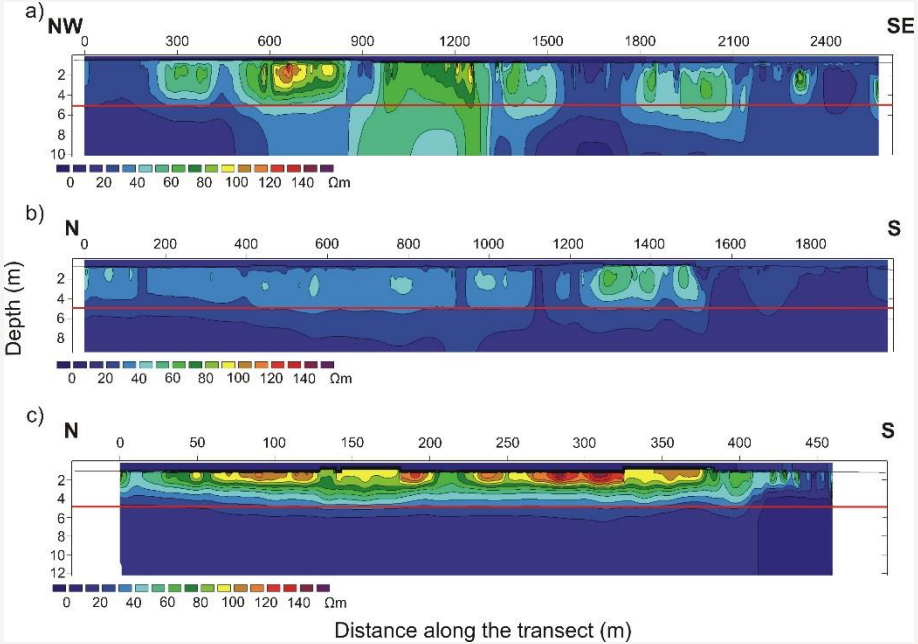
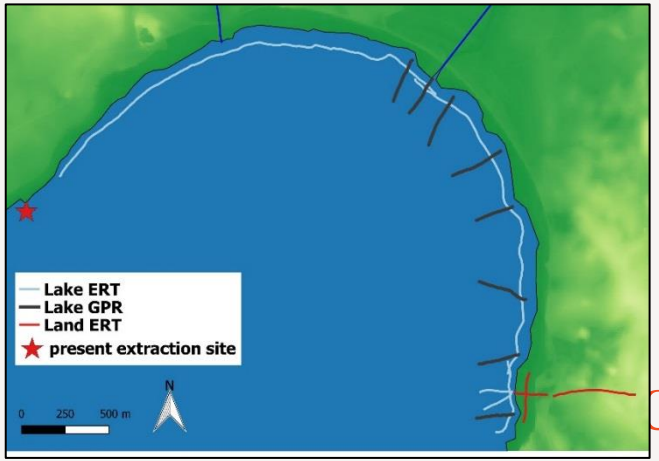
Field site

- Eastern shore of Tissø
  - Field site selected based on waterborne geophysical surveys (floating elecrtode MEP and GPR) showing coarse sediments under the lake extending to the lakeshore
  - Piezometer transect perpendicular to the shore
  - Filter depth between 1,5-8,5 m below ground





Aim of the study

- Test if environmental tracers can be used to characterise and quantify groundwater-lake interaction
  - Direction of groundwater flow
    - water stable isotope samples from piezometers
  - Location of hotspots for groundwater-lake water interaction
    - underwater thermal surveys at the lakebed
    - airborne thermal surveys over large areas
  - Quantification of groundwater fluxes
    - lakebed sediment temperature profiling

- Assess if environmental tracers can be used to monitor the lake bank filtration/ quantify the ratio of lakewater and groundwater

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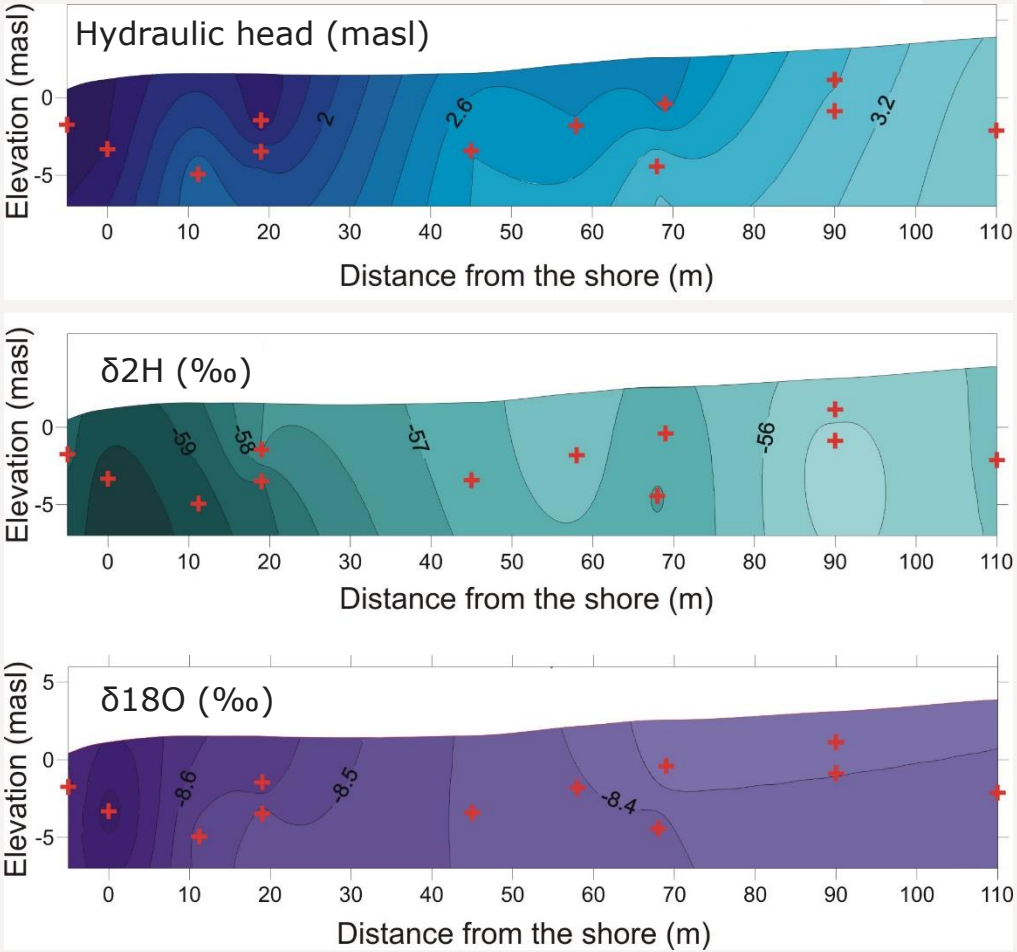
Results

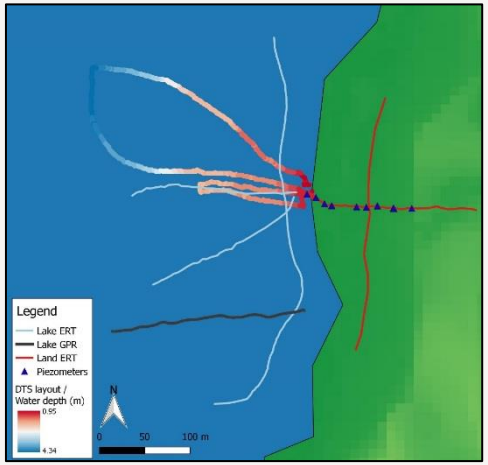
- Direction of groundwater flow at the field site
  - heads and water stable isotope ($\delta^{18}O$, $\delta^{2}H$) samples from piezometers
  - Head data from 18 April 2017
  - Isotope data from 14 February 2017

General flow direction towards the lake

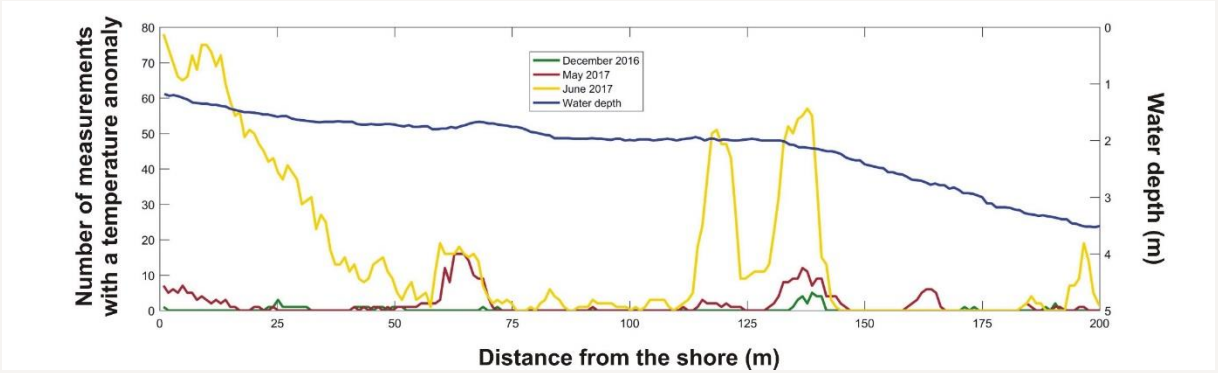


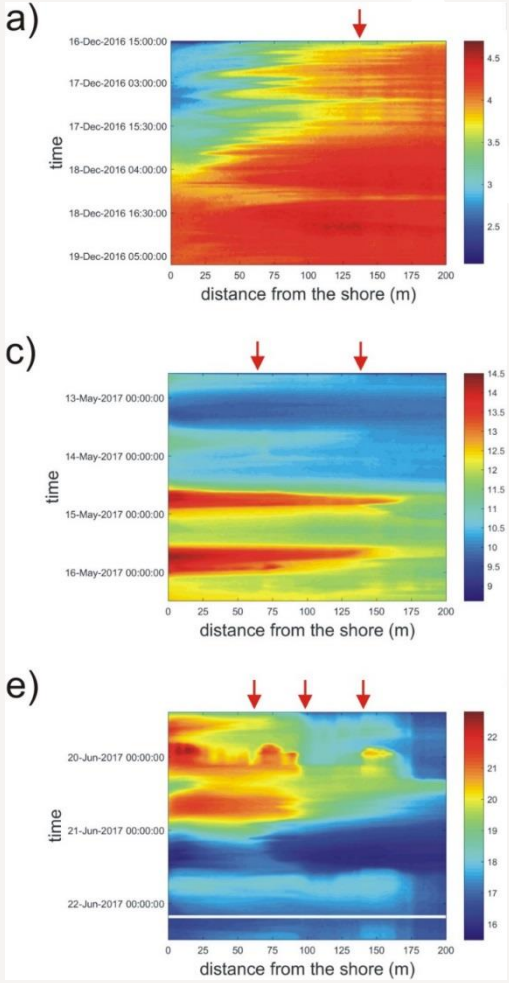
Results

- Location of hotspots for groundwater-lake water interaction
  - underwater thermal surveys during different seasons at the lakebed with fiber optic Distributed Temperature Sensing (DTS) in December 2016, May and June 2017



Potential offshore discharge peaks

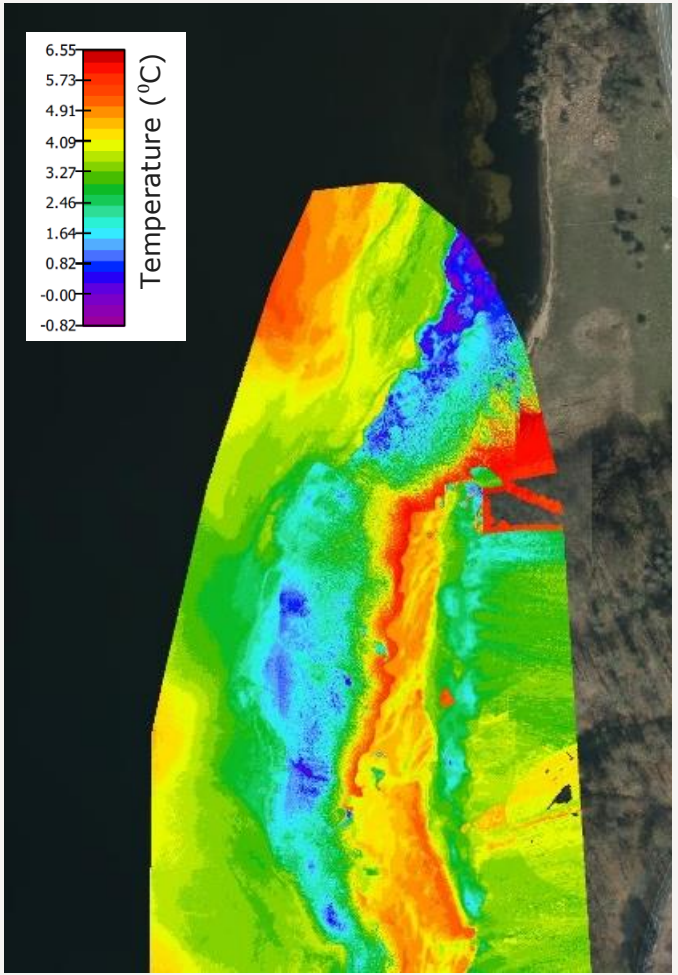




Results

- Location of hotspots for groundwater-lake water interaction
  - airborne thermal surveys over large areas
  - data from 28 November 2016

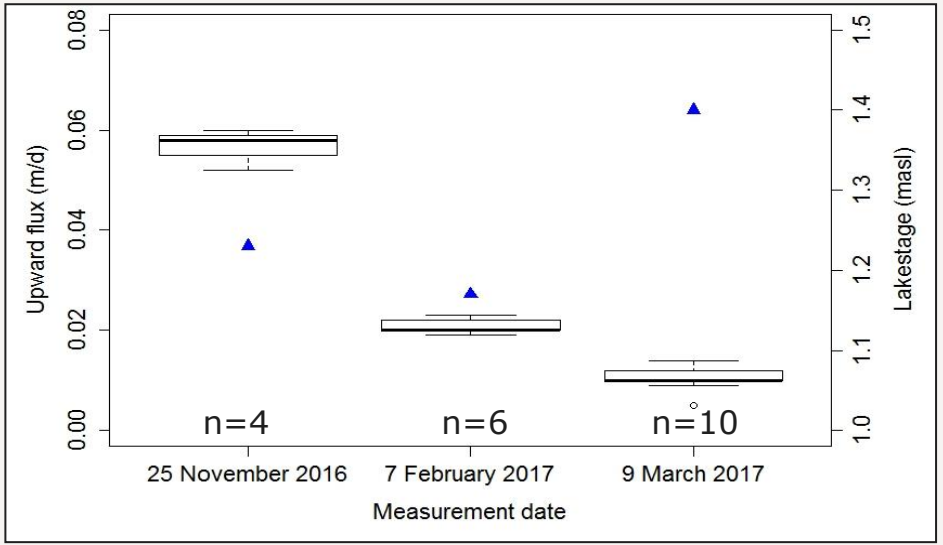
Warm land surface zone along the shore indicating potential groundwater discharge to the wetland bordering the lake



Results

- Quantification of groundwater fluxes
  - Lakebed sediment temperature profiling

Upward groundwater fluxes close to the lakeshore



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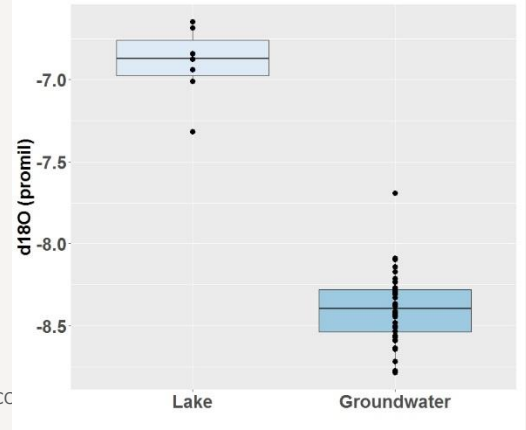
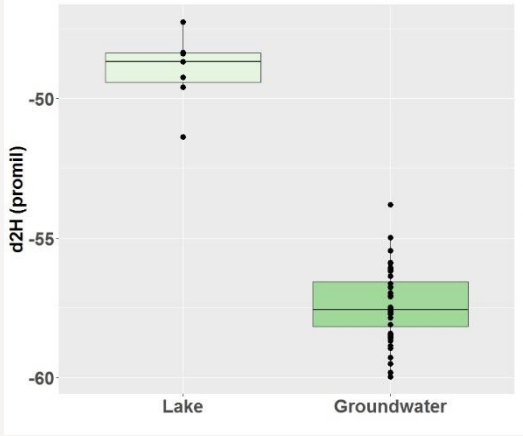
Results

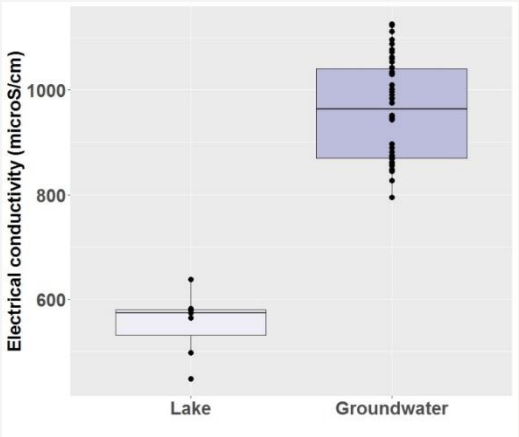
- Assess if environmental tracers can be used to monitor the lake bank filtration/ quantify the ratio of lakewater and groundwater

7 lake water samples from July 2016 - April 2017
44 groundwater samples November 2016 – April 2017

	δ18O (‰)	δ2H (‰)	EC (µS/cm)
Lake average	-6,9	-49	580
Groundwater average	-8,35	-57,2	950





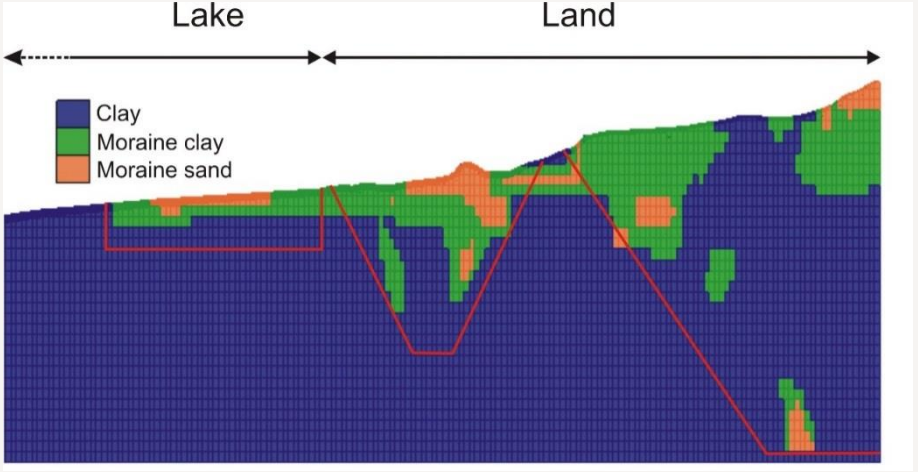


Results

- Assess if environmental tracers can be used to monitor the lake bank filtration/ quantify the ratio of lakewater and groundwater

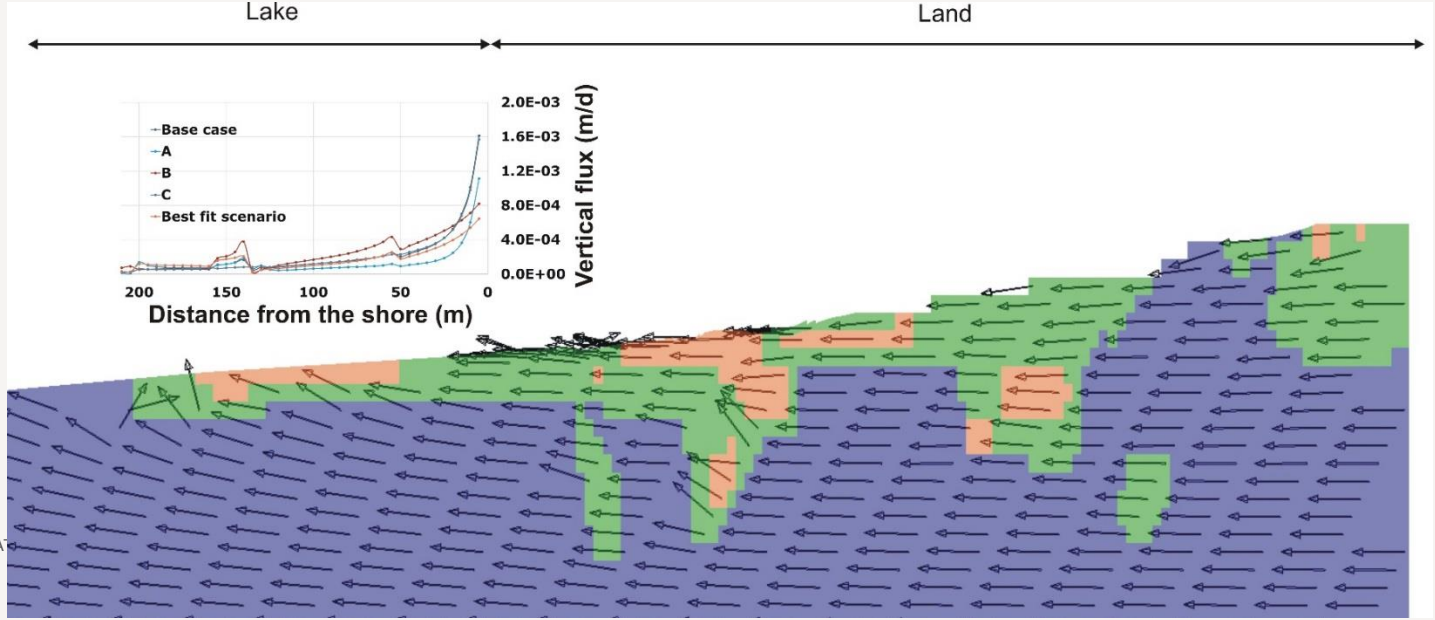
  - 2D groundwater flow model calibrated against head measurements from April 2018
  - Geology in the 2D model based on waterborne and on-land geophysical measurements, K values assigned based on slugtest data

    resistivities of 0-40 Ωm → clay, K= 0.1 m/d
    40-80 Ωm → moraine clay, K= 0.5 m/d
    80 Ωm < → moraine sand, K= 6.7 m/d



Results

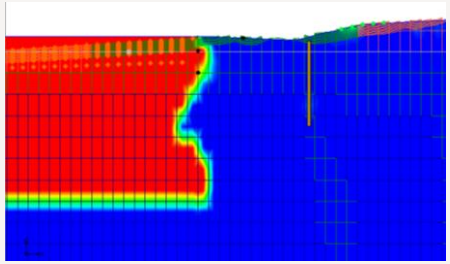
- Assess if environmental tracers can be used to monitor the lake bank filtration/ quantify the ratio of lakewater and groundwater
  - Two offshore discharge peaks at approx. 55 and 140 m offshore
  - The discharge peaks mark the boundaries of the high resistivity zone found by the waterborne ERT survey
  - Upward fluxes in the lake are generally small, most of the upwelling occurs at the wetland bordering the lake on-land



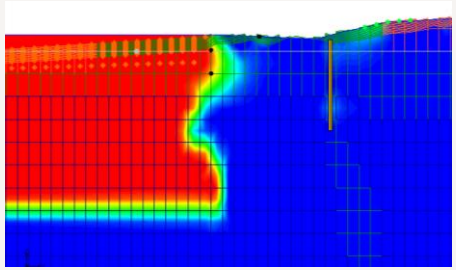
Results

- Assess if environmental tracers can be used to monitor the lake bank filtration/ quantify the ratio of lakewater and groundwater

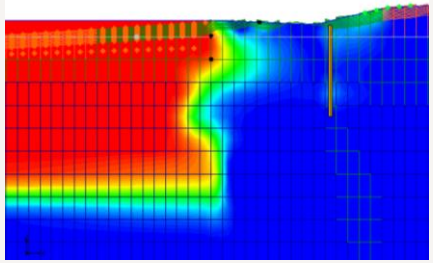
Day 10
EC: 950, GW: 100%



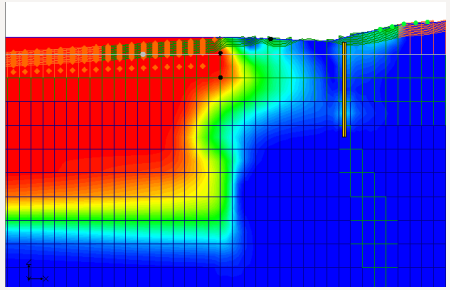
Day 100
EC: 941, GW: 97%



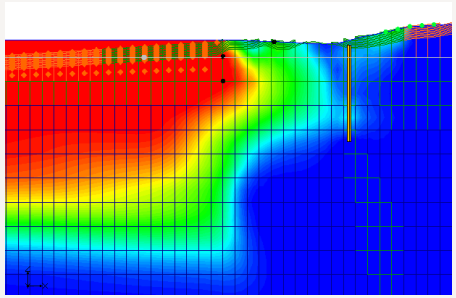
Day 365
EC: 933, GW: 95%



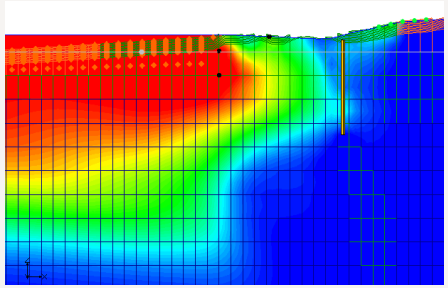
2 years
EC: 915, GW: 90%

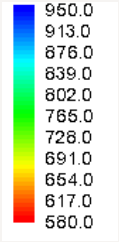


5 years
EC: 879, GW: 80%



10 years
EC: 855, GW: 74%





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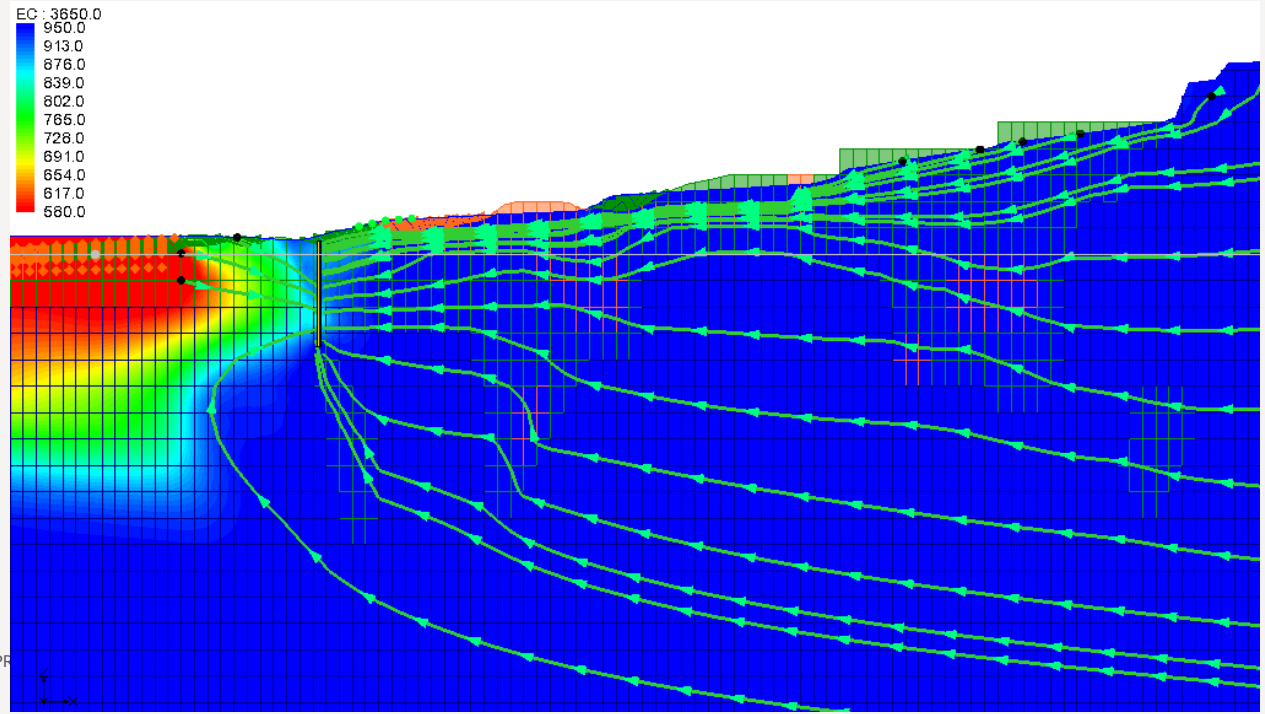

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Conclusions

- Samples for environmental tracers are generally easy and cheap to collect
- Can provide qualitative and quantitative information about groundwater flow
- In the study field site no overlap between groundwater and surface water samples
- Tracers could be used to quantify the ratio of groundwater and lakewater
- Lake bank filtration is not possible at the site

Thank you for your attention!