Urban Geophysics

How to combine different geophysical techniques in an urban environment

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Deltares

The urban challenge

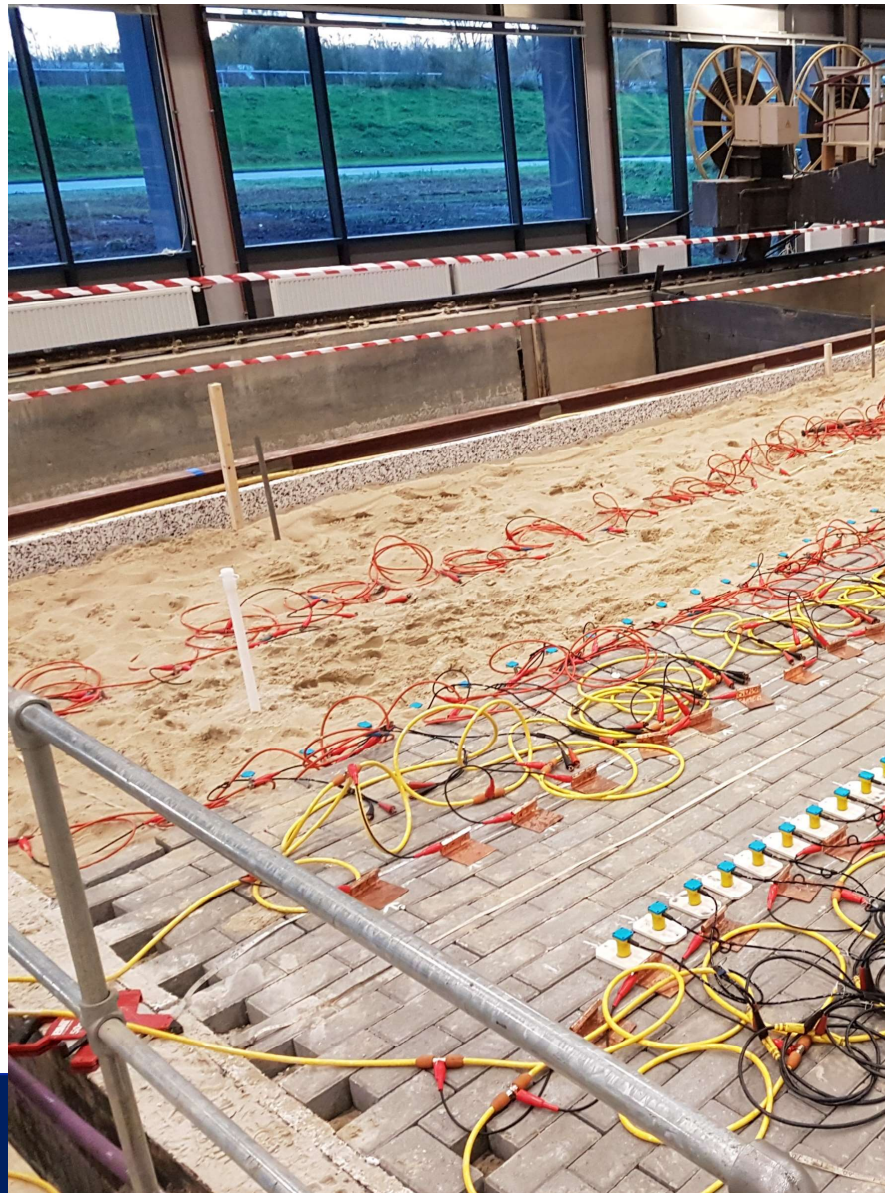
- Settlement of roads, buildings and constructions due to unforeseen consolidation and groundwater variations
- Replacement and maintenance of cables and pipelines
- Collapse of roads due to subsurface cavities
- Environmental contamination

The urban challenge

- Surveying comes with congestion and hindrance
- Due to buildings and structure, not all locations are easily accessible
- Most soil has been reworked, anthropogenic and contains cables and pipeline infrastructure

Geophysical surveying

- Spatially continuous image of the structure and properties, with limited local hindrance.
- Large variation in physical properties makes that not a single technique can offer an adequate image of the underground.



Study Aim

- Optimizing geophysical surveys in an actual urban environment

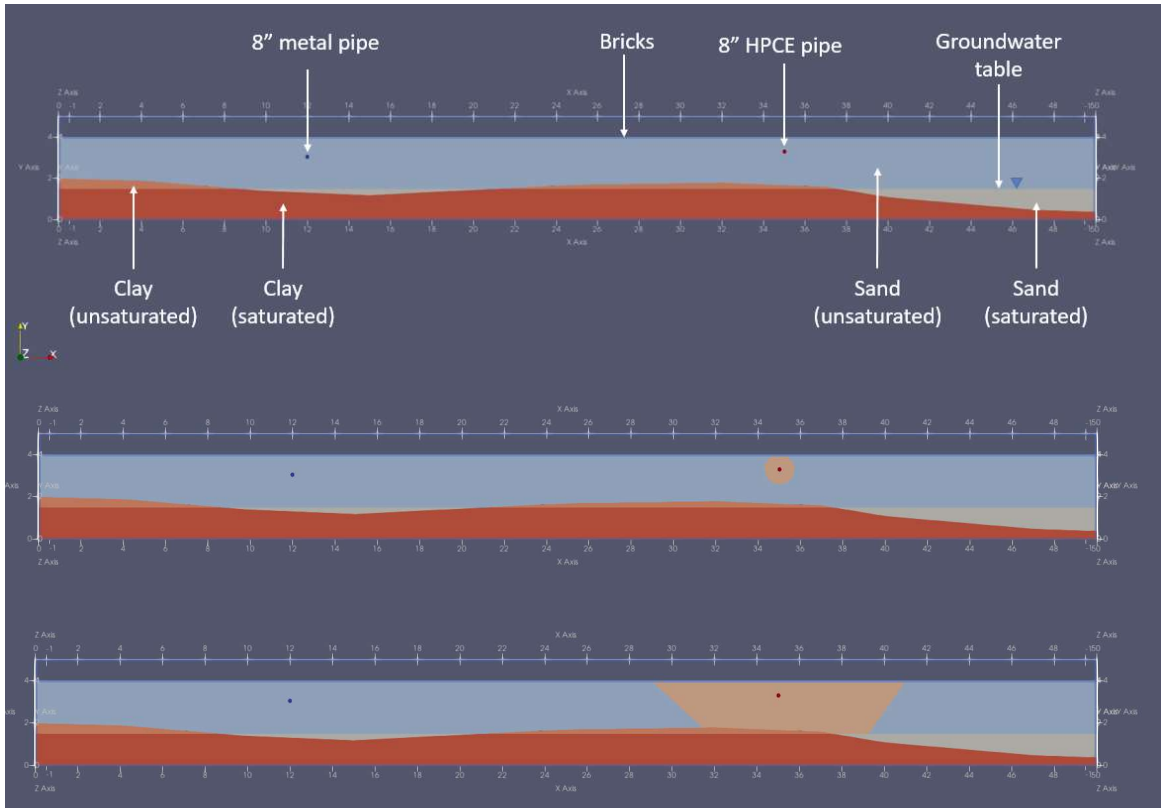
1. Conceptual model
2. Lab experiment
3. Model validation
4. The road ahead – Data fusion

Geophysical methods

- ERT – Electrical Resistivity imaging
- GPR – Ground Penetrating Radar
- Seismic Geophone system – MASW (multichannel analysis of surface waves) and refraction seismic
- DTS - Distributed temperature sensing (using buried fiber optic cables)
- DAS - Distributed acoustic sensing (using buried fibre optic cables)

Conceptual model

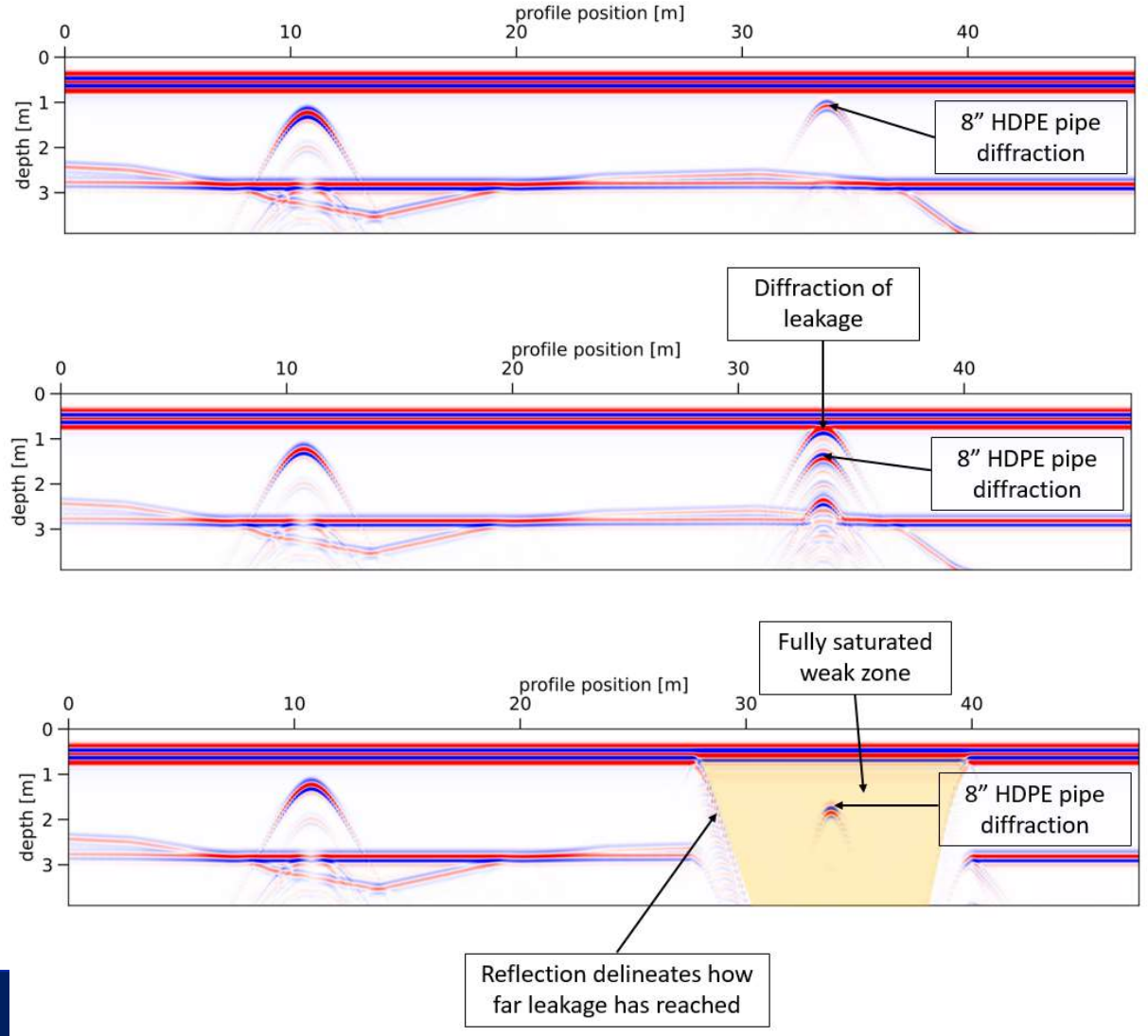
- T0 setting with the presence of two pipes
- Start of leakage in pipe
- Abundant leakage, causing a large saturated weak zone



Conceptual model

GPR

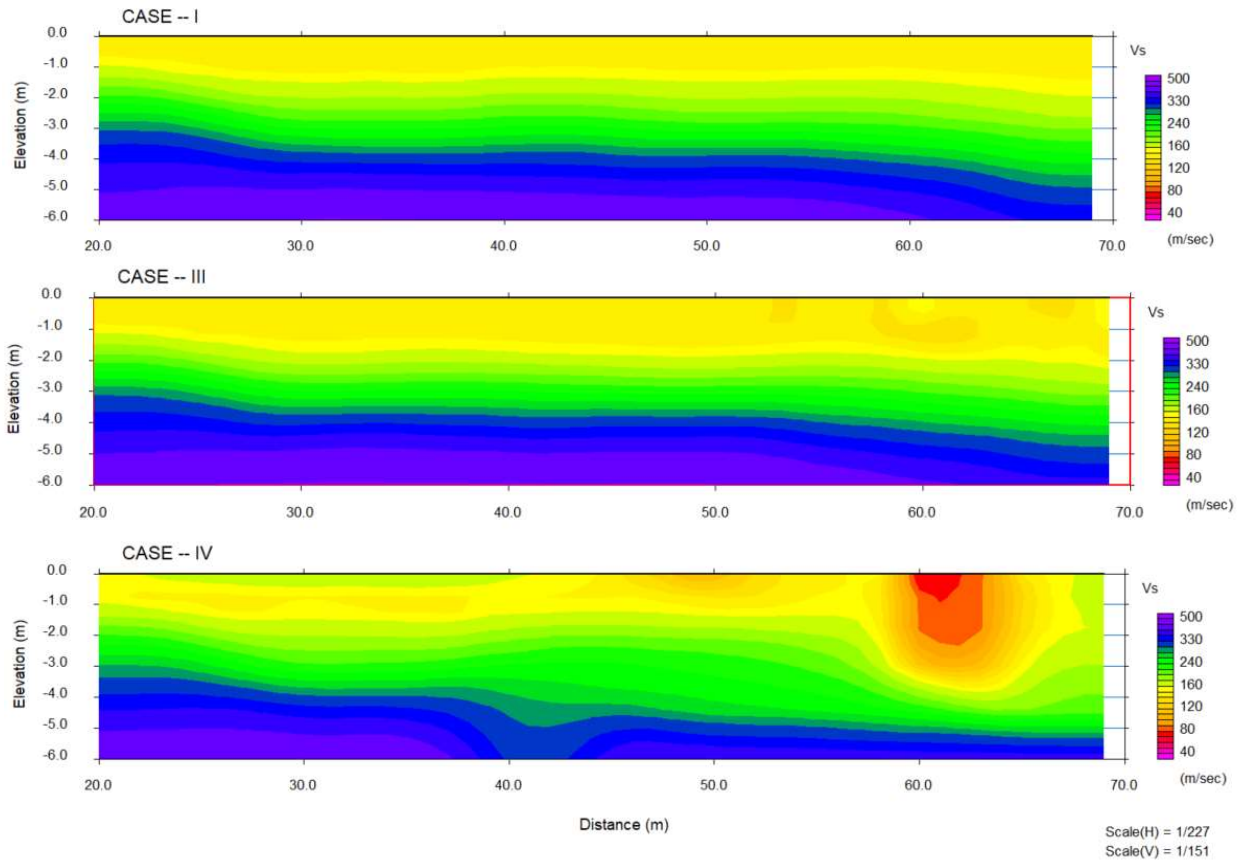
- Pipe shows due to diffraction
- Leakage causes extra diffraction
- When leakage is abundant, the weakend zone due to high saturation is visible as a reflection



Conceptual model

Acoustics

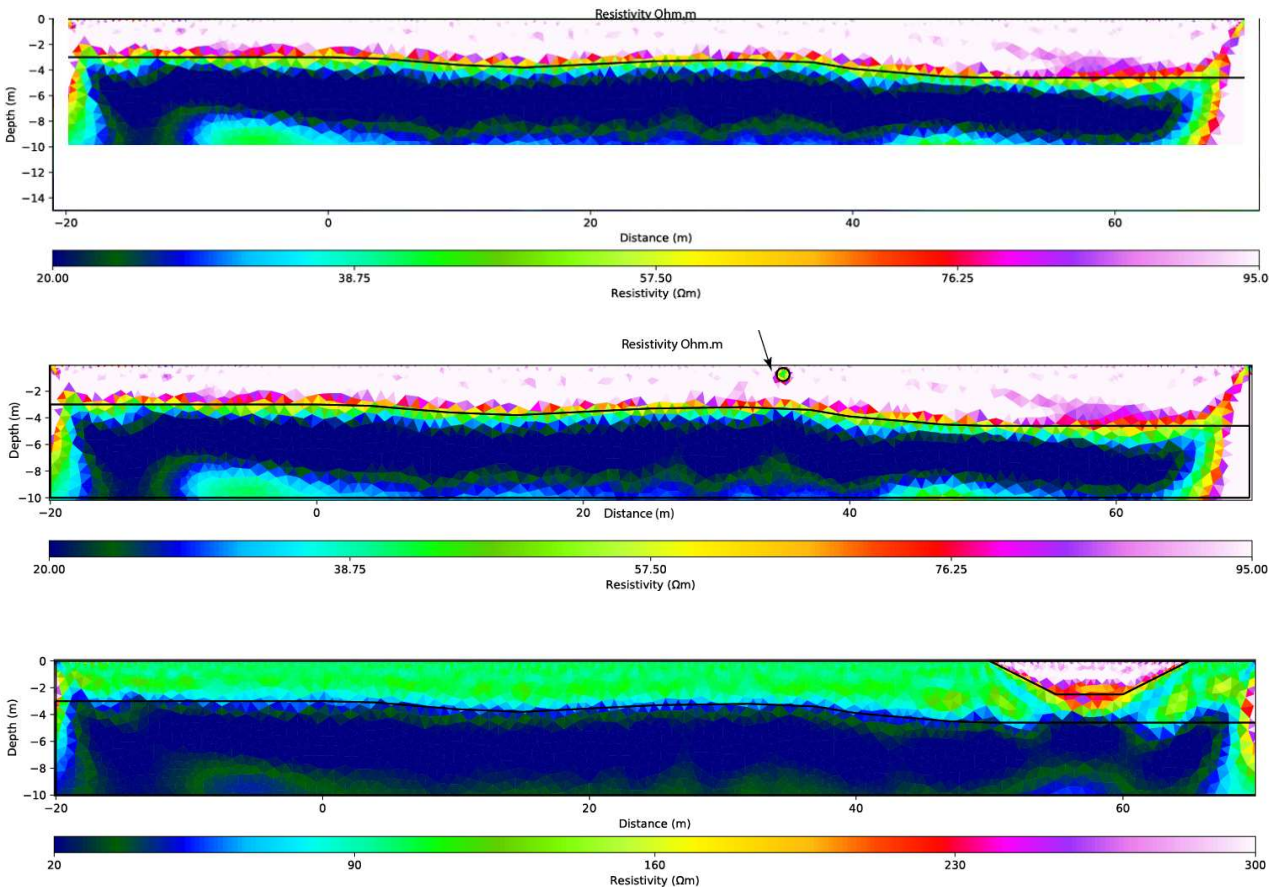
- Higher saturated zone due to leak results in lower shear wave velocity



Conceptual model

ERT

- Leaking pipe is visible as a decrease in resistivity, water is conductive.
- Sink hole (air is not conductive) gives high resistivity response



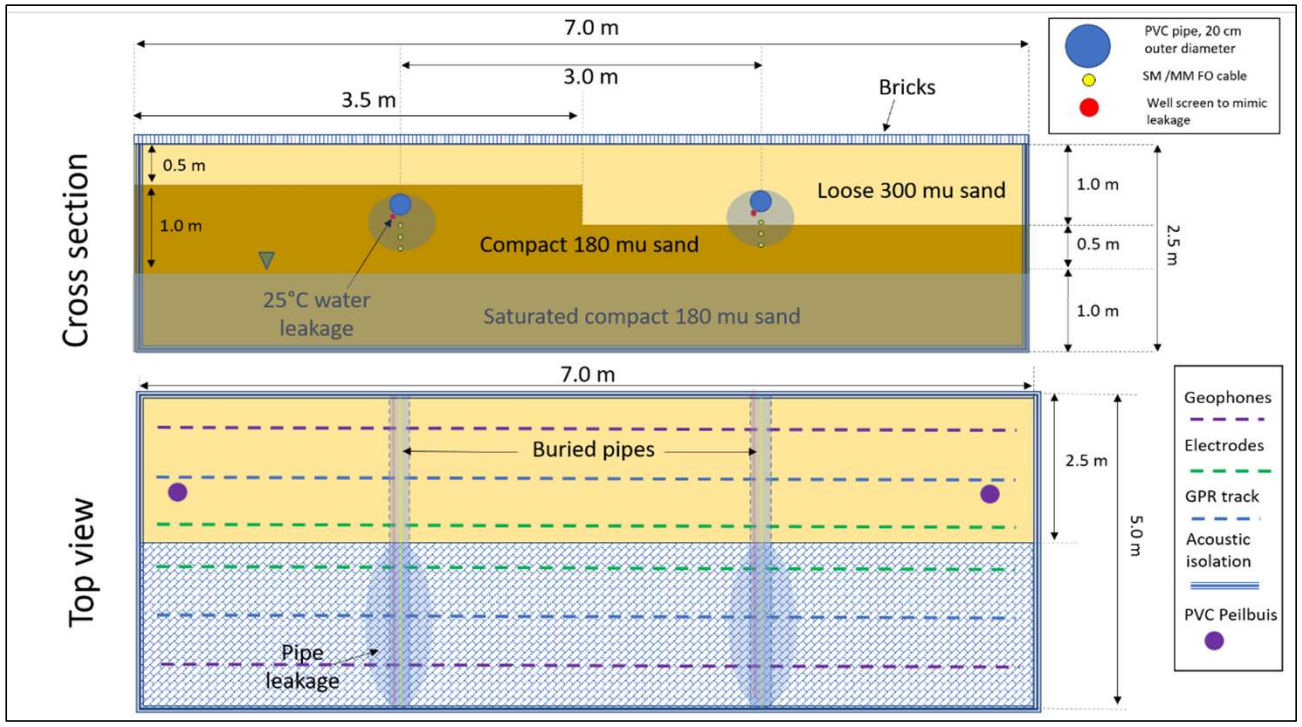
Conceptual model - conclusions

- It is possible to map local changes in resistivity differences with ERT.
- It is possible to map boundaries of saturated zones using GPR.
- It is possible to see an increase in local soil saturation in the shear wave velocity profiles.

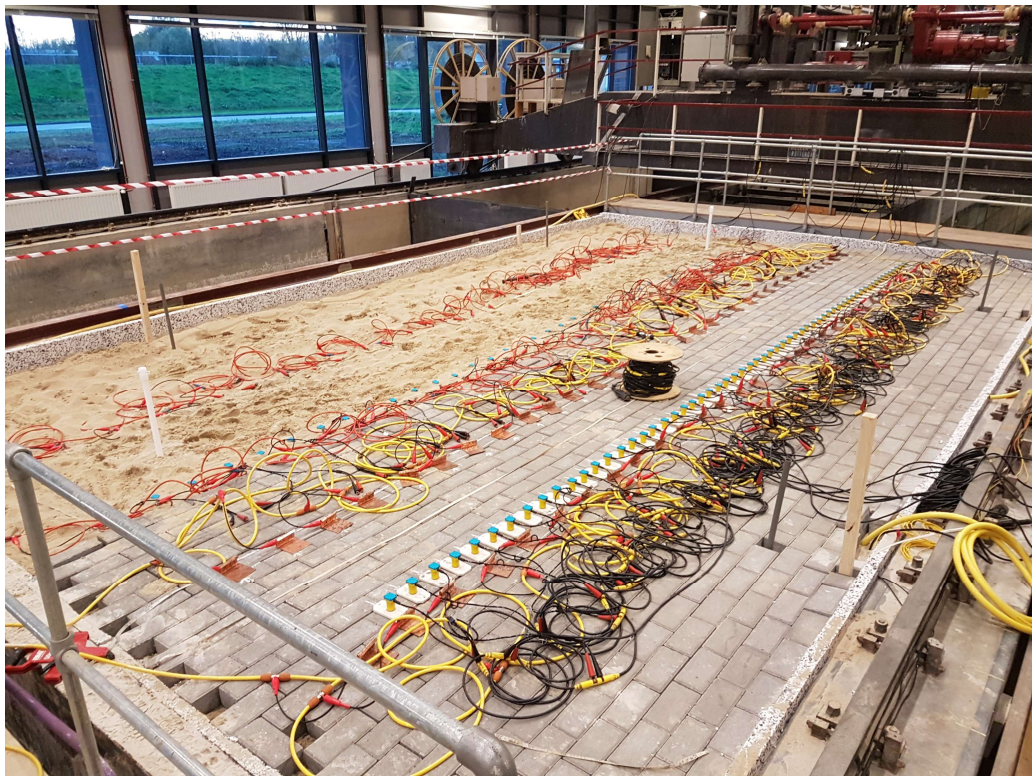
- Based on the results of the computer model, mapping of pipe leakages, its location and size, can be obtained by using (and combining) ERT, GPR, MASW, DTS and DAS.

Controlled lab-scale experiment

- ERT
- GPR
- MASW
- DTS
- DAS

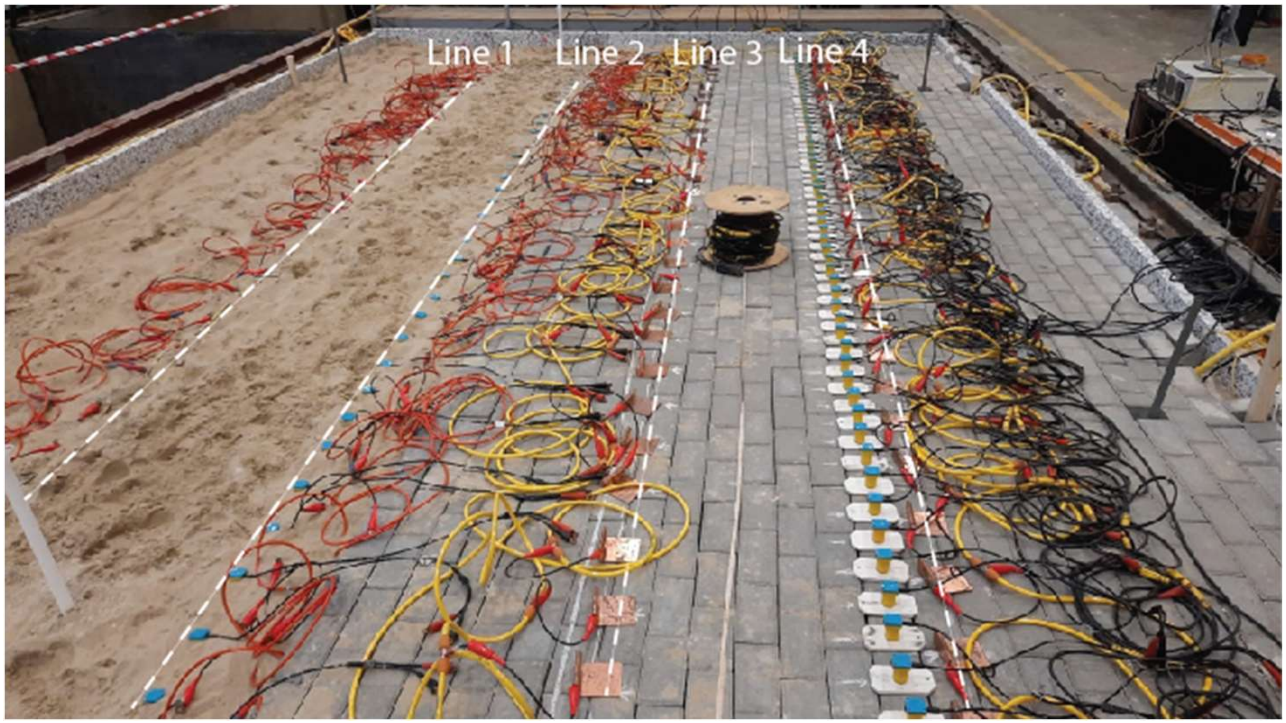


Controlled lab-scale experiment



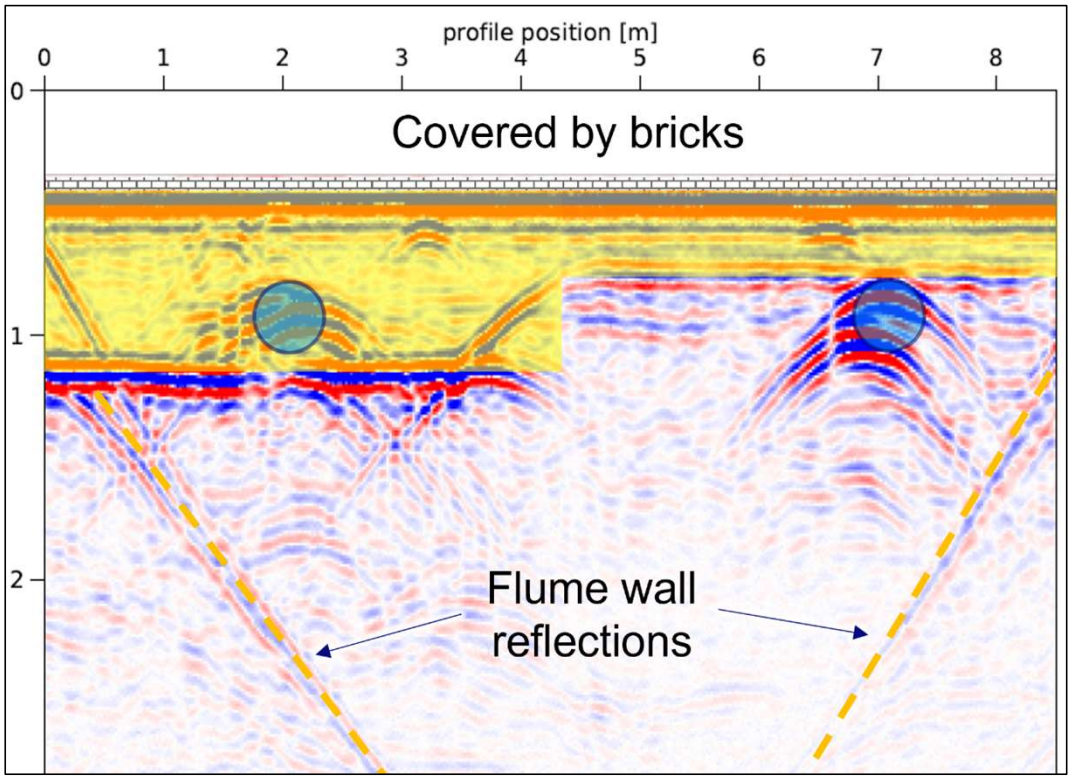
Controlled lab-scale experiment

- GW 1m deep with dry top
- Fully saturated
- GW 1m deep with partly saturated top
- Leaking pipe, hot water (55 C)
- Leaking pipe, cold water (20 C)
- Leaking pipe, cold water (20 C) with active heating DTS/DAS



Results – T0 measurement

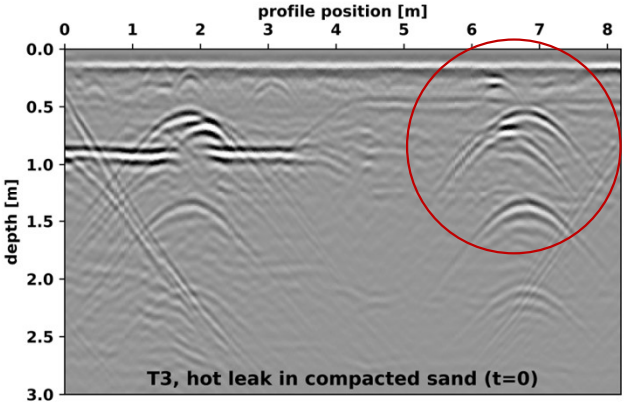
GPR

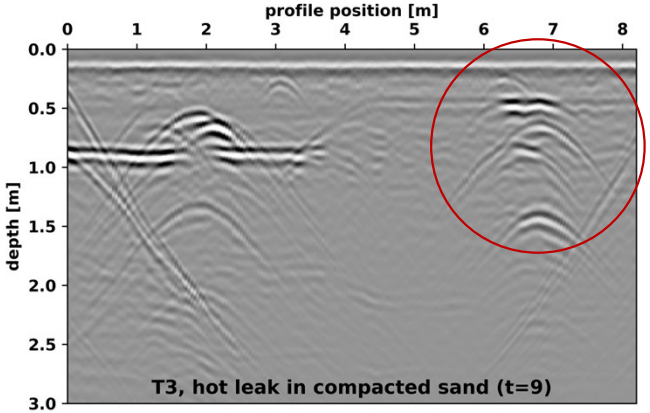


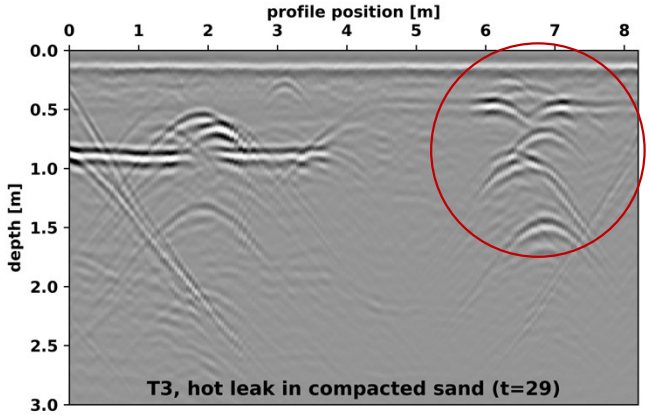
Results – hot leak detection

GPR

- In compact sand: Leak first spread laterally under the sediment interface and at around (t=8) seems to break through and penetrate the overlying drainage sand. The leakage comes close to the surface. Locally a clear ‘dent’ can be observed in the sediment interface which is caused by ‘velocity sag’.



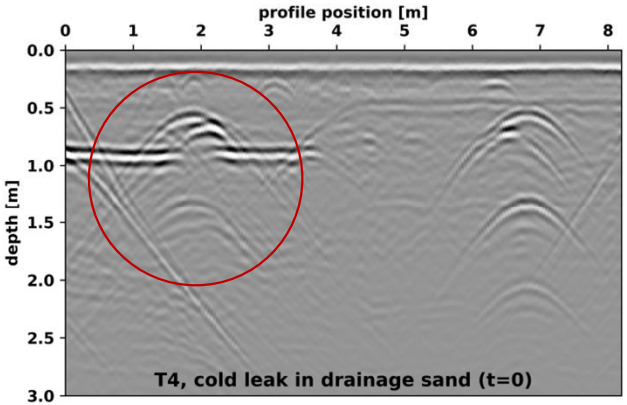


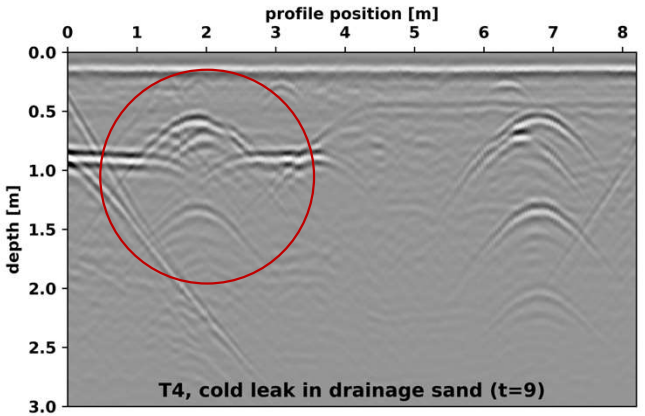


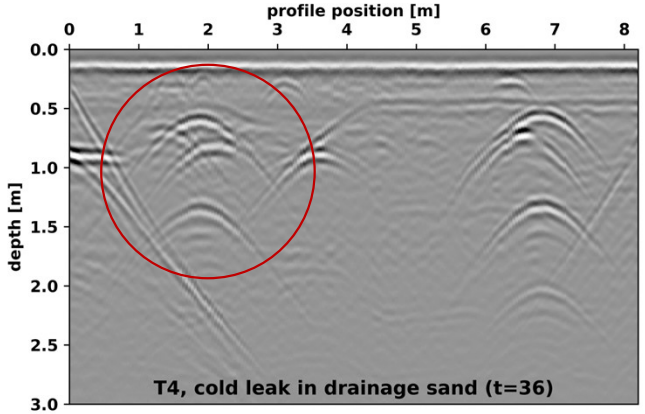
Results – hot leak detection

GPR

- In drainage sand: where the leakage reaches the groundwater reflection, the latter disappears locally. The spreaing of the leak upwards and sideways is clearly visible as it creates its own reflection surface as a halo around the pipe diffraction



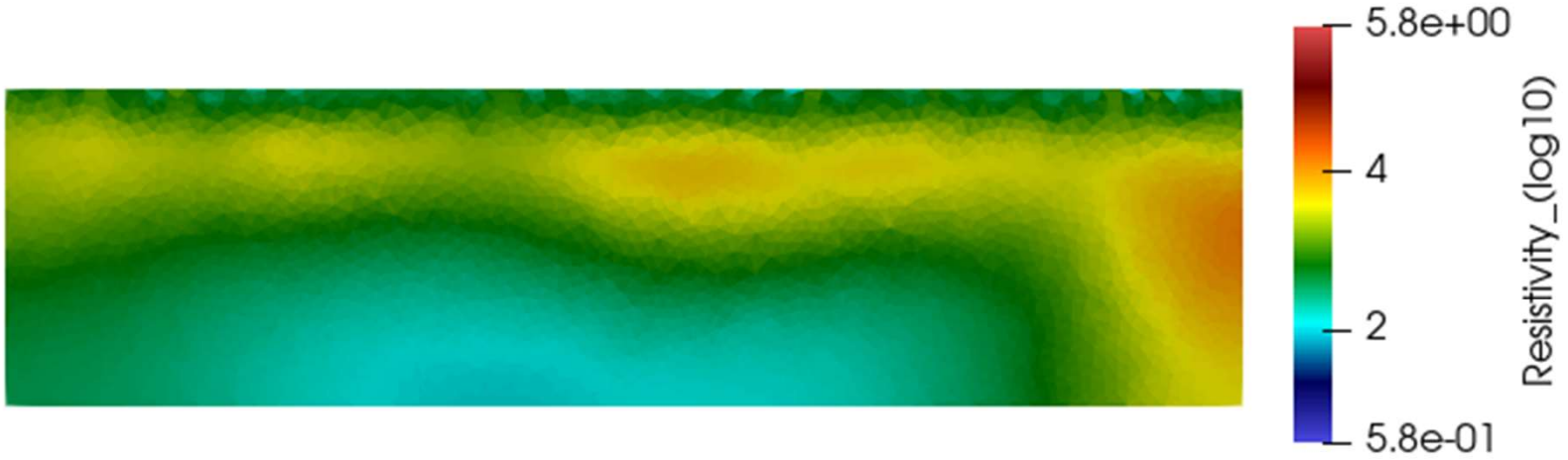




Results T0 measurements

ERT

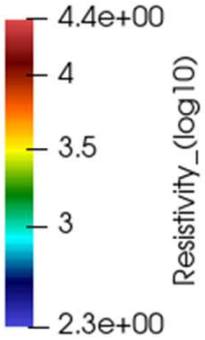
- Brick layer: low resistivity due to use of conductive gel
- Boundary effect

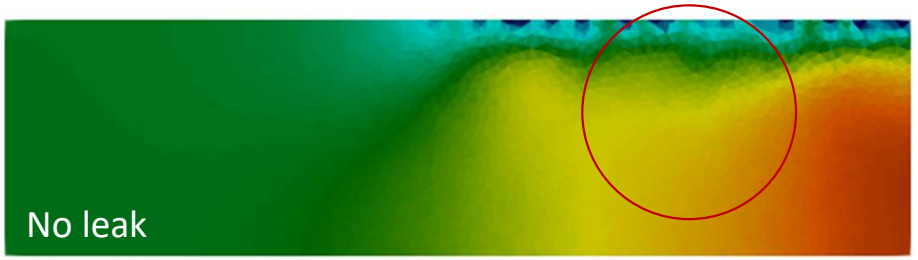


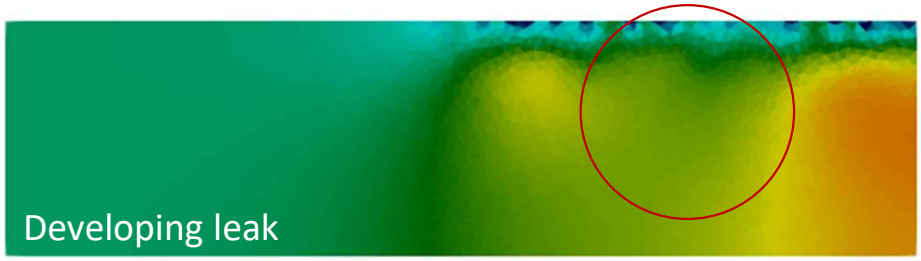
Results hot leak detection

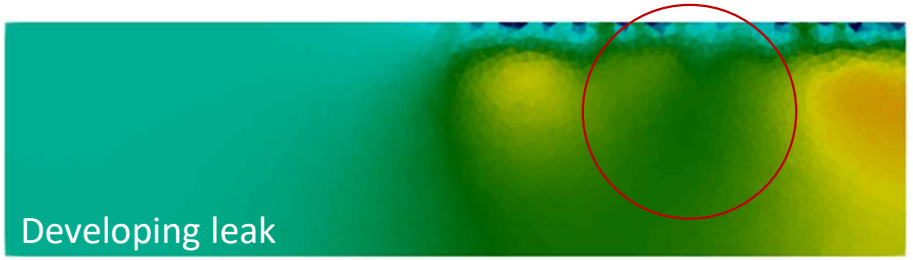
ERT

- Water is conductive
- Conductivity = 1/Resistivity
- Water leak results in higher saturation of area close to the leak
- Higher saturation results in lower resistivities, measurable with ERT









Lab experiments - conclusions

- It is possible to map local changes in resistivity differences , caused by a water leak, with ERT.
- It is possible to map boundaries of saturated zones, caused by a water leak, using GPR.

- Processing of seismic data, DTS data and DAS data is still work in progress.

The Road Ahead

- Advanced Processing
  - Reflection seismics
  - AVO analysis
  - More…
- Data Fusion
  - Joint or constrained inversion of electrical resistivity tomography and ground penetrating radar
  - Joint inversion of reflection seismic and ground penetrating radar data
  - More…

Thanks for your attention!

Questions?

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Foto’s

- kabels en leidingen nederland - Google Zoeken
- urban infrastructure - Google Zoeken
- urban subsurface infrastructure - Google Zoeken