Project Summary C3 - Geophysical measurements of the subsoil
Guidance for better mapping the horizontal variability of the subsoil

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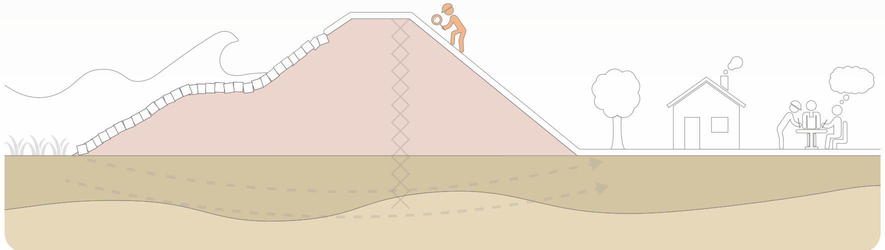
Project Summary

C3 - Geophysical measurements of the subsoil

Guidance for better mapping the horizontal variability of the subsoil



By Juan Chavez Olalla

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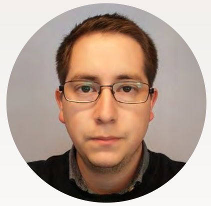

Project start: 09/2017

Project end: 09/2021

Promotors

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Dr. R. Ghose

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Outcome

The goal of this project was to develop statistical methods to incorporate geophysics into the characterisation of subsoil heterogeneity. The aspects of heterogeneity that have been addressed are the geometry of soil layers and the variability of material properties at small and large scale. The outcome of this project is guidance for better mapping the horizontal variability of the subsoil.

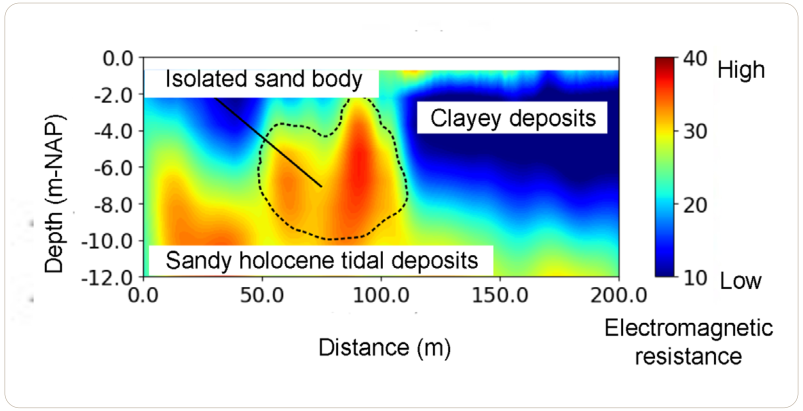

Figure 1: Paleochannel detection with electrical resistivity tomography. Image by Juan Chavez Olalla.

Motivation and practical challenge

Traditional site investigation methods measure the horizontal variability of the subsoil often insufficiently. As a result, geophysical methods are becoming increasingly popular for engineering applications such as dikes and roads because they map the subsoil in a horizontally continuous manner. However, the operational effort required by many geophysical methods does not always pay off. Expectations are, in some cases, beyond the physical limits of the methods. The practical challenge is, therefore, to find the scale of heterogeneity that geophysical methods can resolve which at the same time gives valuable information for geotechnical calculations.

Research challenge

I formulate methods to answer the question: how to incorporate geophysical data for better mapping the subsoil variability? Specifically, I work on uncertainties related to the geometry of soil layers and material properties.

Innovative components

I look at the type of subsoil variability that plays a role in failure mechanisms of dikes (**Figure 3, top-left**). For example, in clay-over-sand dikes, the thickness of the clay layer on the landward side provides resistance against piping (**Figure 3, top-right**). Dikes are longitudinal structures, so it is challenging to map variability with point data, such as cone penetration tests (CPTs). One component of my research is to study the geometrical variability of layers with geophysical methods (**Figure 3, bottom**). I pay special attention to electromagnetic methods that quickly cover large distances such as Electrical Resistivity Tomography (ERT), Frequency Domain Electromagnetics (FDEM), and Ground Penetrating Radar (GPR) data. The innovative aspect is the statistical combination

Figure 2: Geophysical survey in dikes and associated instrumentation. Photos by Juan Chavez Olalla.

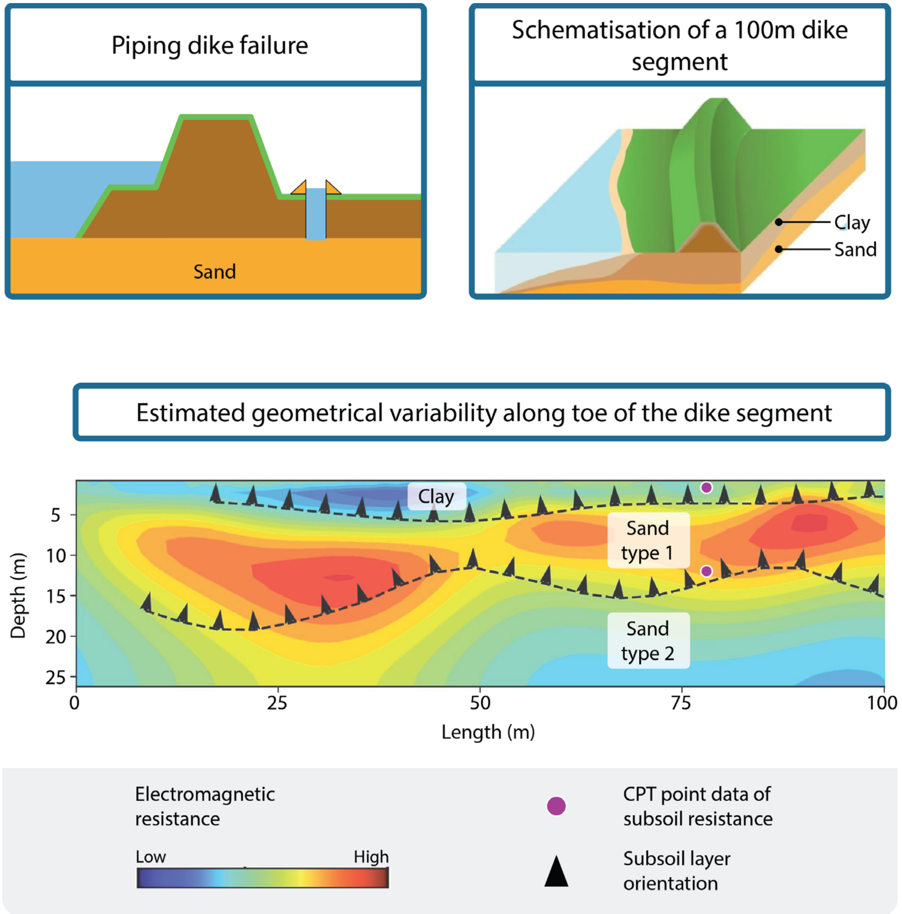

Figure 3: Combination of geophysical data and point data measurements to improve the schematisation of the subsoil below the dikes. Sources: left figure adapted from van Beek (2015), right figure based on scheme from Richard Marijnissen and bottom figure provided by Juan Chavez Olalla.

of geophysical data and point data. Previous approaches use only point data, so they do not explicitly consider the geometrical variability between data points. Another component of this research is related to more elaborate geophysical methods, such as seismic exploration, which require large operational efforts. I study the cases where these methods could bring useful information for geological schematisation.

Relevant for whom and where?

The output of this research is relevant for advisors who assess dike safety where horizontal variability of geological layers is uncertain.

Progress and practical application

Preliminary surveys in test sites show that geological architecture is captured in geophysical data. The level of detail with which it is captured is smaller than that of cone penetration tests. However, the horizontal coverage is larger. By studying the patterns in geophysical data, it is possible to describe more extensively geological architecture. An approach to combine geological knowledge, point data and geophysics is formulated in this research. Part of this approach is aimed at retrieving geometrical variability from tomograms. Another part of this approach is aimed at correlating geophysical and geotechnical properties. For example, electrical resistivity is highly correlated to the cone resistance of a cone penetration test. For details on the results, **see the project outputs on the next page**.

Recommendations for practice

- Use a sequential approach to geophysical investigation from coarse detail (cheap and fast) to fine detail (expensive and slow).
- Interpret geophysical data within a bigger geological context.
- Interpret geophysical data in a consistent and reproducible manner.
- Define the target geological features to be mapped with geophysics before surveying.
- Establish quantitative relationships between geophysical and geotechnical properties.

Montfoort: Testing geophysical methods to map a large paleochannel (with Physical Geography group Utrecht University).
Small paleochannel: map paleochannels that are difficult to map with conventional site investigation methods.
Leendert de Boespolder: Calculating the horizontal correlation structure of geotechnical properties with geophysical tomography.

Image by Juan Chavez Olalla.

Key project outputs

Chavez Olalla, J., Winkels, T.G., Ngan-Tillard, D.J.M. & Heimovaara, T.J. (2021). Geophysical tomography as a tool to estimate the geometry of soil layers: Relevance for the reliability assessment of dikes. Doi: 10.1080/17499518.2021.1971252

Chavez Olalla, J. (2020) Layer interpolation with tomographic aid. Athens, Third European Regional Conference of IAEG, 20-24 September 2020.