Universiteit Utrecht
Faculty of Geosciences
Physical Geography Departement

TNO innovation for life

Numerical modelling for the design of a combined pumping and infiltration test to determine the hydraulic resistance of an aquitard in Zeeland

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Introduction

The **Geological Survey of the Netherlands** (TNO-GSN) maintains a **3D voxel model** of the upper 30-50m of the Dutch subsurface: **GeoTOP** (***Fig.1A***).

Rationale

The **hydraulic parameterization** of the voxels is based on the successive **upscaling** of hydraulic conductivities from core-scale laboratory measurements. However, the application of this method is suspected to **lead to biased estimates** of the resulting hydraulic resistances of aquitards.

Strategy

TNO-GSN initiated a Ph.D. project to **improve the upscaling of hydraulic conductivities**.

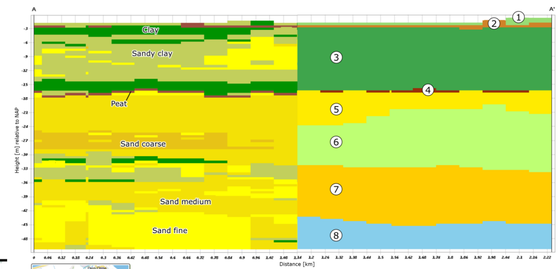
A field experiment will be carried-out on Schouwen-Duiveland (Zeeland; ***Fig.1B***). This site has been selected because of the presence of a **high resistance in the basal Holocene** deposits over a large area, according to the current GeoTOP model.

The hydraulic experiment will consist of a novel combination of **pumping and injection** of groundwater underneath this aquitard with the hypothesis that this will allow for a much better estimate of the **aquitard resistance spatial variability**.

Research question

Can a combination of pumping and infiltration tests bring additional information on the spatial variability of the resistance of the basal Holocene deposits and a better estimation of its value compared to a pumping test alone ?

A.



B.

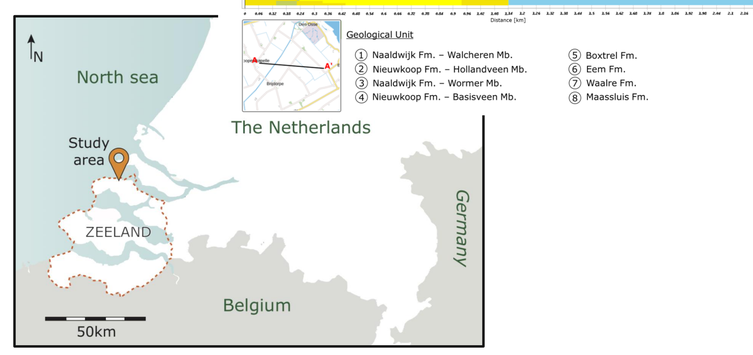
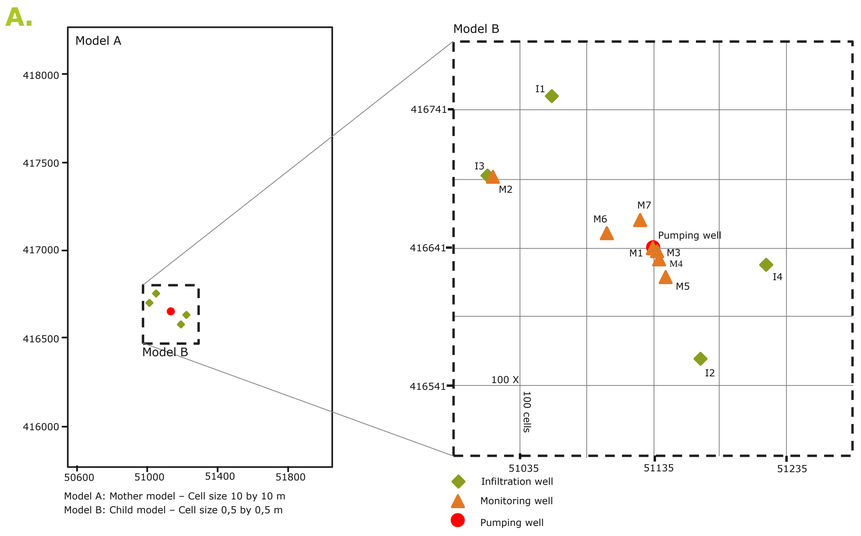


Figure 1: A – Location of the study area on the Schouwen-Duveland island, in Zeeland, **B -** Cross-section of the Geological formations and lithoclasses present in the area (GeoTOP).

Model design (*Fig.2*)

A **MODFLOW-LGR model** of the field site has been set-up to design the field experiment, enabling the preliminary testing of **several pumping and injection set-ups** and their comparisons. It is composed of a mother model (Model A) and a child model (Model B) for refinement of the grid around the wells.

A.



Model A: Mother model – Cell size 10 by 10 m
Model B: Child model – Cell size 0,5 by 0,5 m

B.

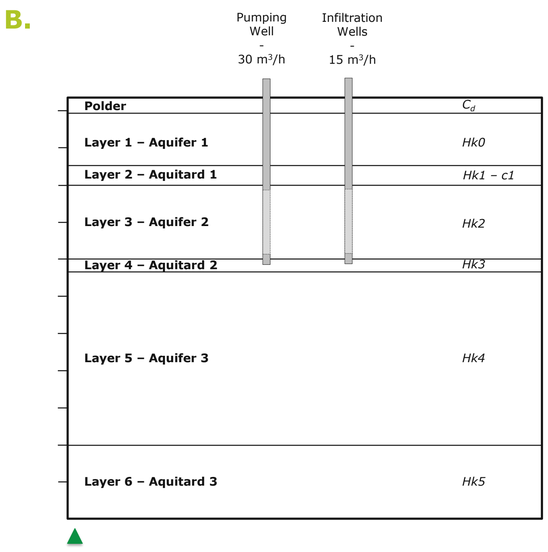
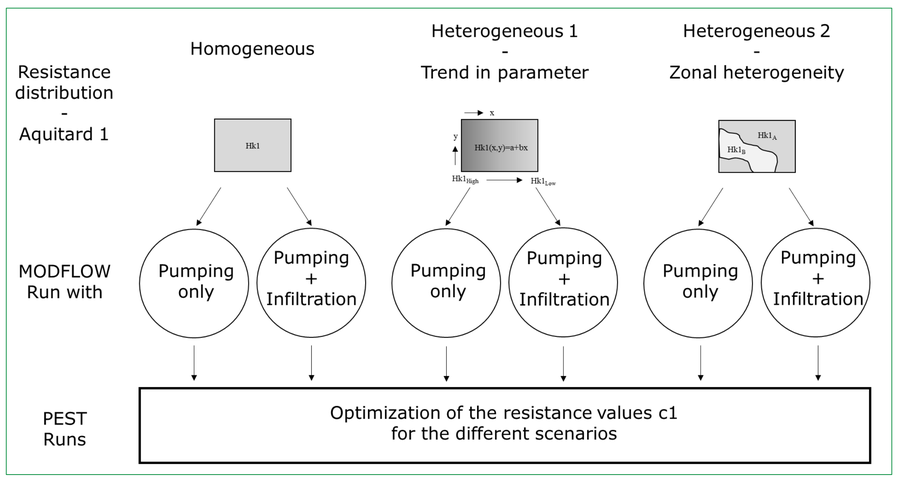


Figure 2: A – Top view of the models. **B –** Cross-section of the models showing the different layers and their thickness as well as the design of the pumping and infiltration wells.

Figure 3: Scenarios used for the optimization of the hydraulic resistance parameter of the basal Holocene aquitard using PEST.

Calibration (*Fig.3*)

- Use of the **PEST** software package for parameter estimation and uncertainty analysis of the MODFLOW models.
- **Optimization of the hydraulic resistance value of the first aquitard (c1) in the model.**
- Optimization performed for different true values and starting values, homogeneous or heterogeneous layer, pumping alone or pumping + infiltration.
- Allows for the comparison of the uncertainty of the hydraulic resistance c1 in the various scenarios.



Model capabilities

The model outputs yield insights into the **response of the aquifers and aquitards** at the planned experiment **site location** (***Fig.4***).

It allows us to **test different experimental** setups, pumping and/or infiltration, flow rates, etc.

The modelling results and their sensitivity analyses showed that, given the low *a priori* estimate of c1, **several weeks** will be needed to determine its value with sufficient accuracy. This is because **drawdown** will **build-up** slowly in the overlying aquifer.

The MODFLOW model will be **used for the interpretation of the actual experiments**, to assess the hydraulic resistance of the basal Holocene deposits and its spatial variation.

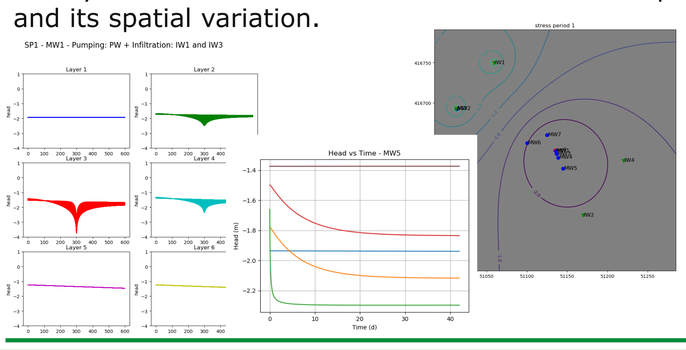


Figure 4: Example of outputs from the MODFLOW Model B. Pumping + Infiltration for 42 days, c1=5000 days.

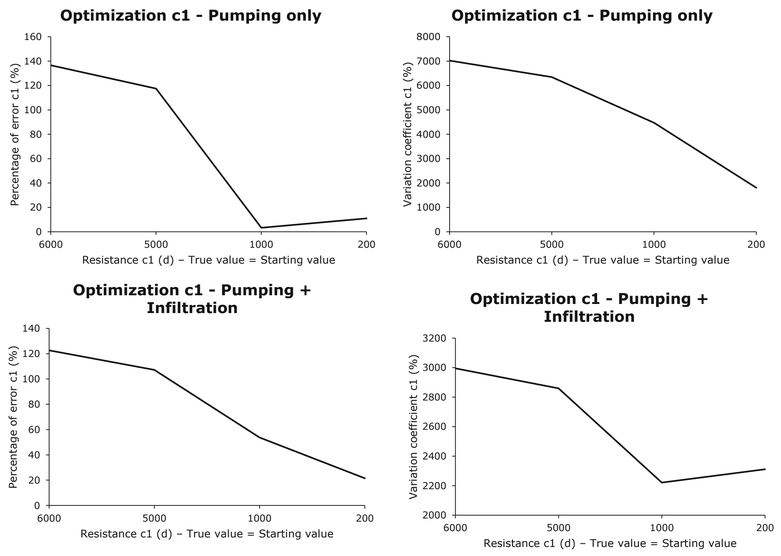


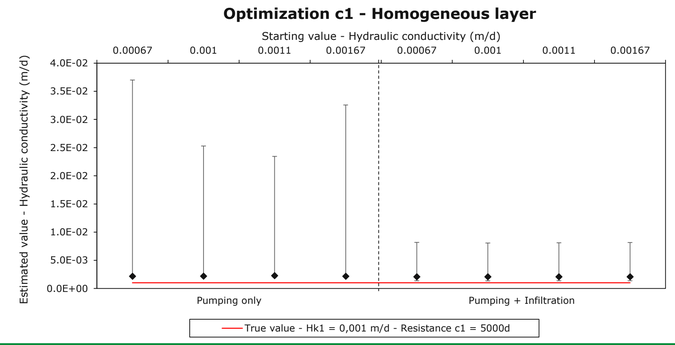
Figure 5: Optimization of c1 with and without infiltration using different starting/true values.

Figure 6: Comparison of c1 optimization results using different starting values for the same true value, with and without infiltration.

Results

The PEST results shown in ***Figure 5*** and ***Figure 6*** are from the optimization of the **resistance value** parameter of the studied aquitard. This parameter has been **optimized** for different parameters values and setups (pumping only or pumping and infiltration).

- ***Figure 5*** shows the results of the c1 optimization for an **homogeneous layer**, with or without infiltration, with a true value equal to the starting value in a range of 6000 days to 200 days.
- ***Figure 6*** shows a comparison of the c1 estimated values and their confidence intervals for different starting values with a true value of 5000 days, and with and without infiltration.



Preliminary answer

In the case of an **homogeneous distribution of c1**, the results show that its optimization will give similar estimated values, regardless if infiltration is happening. However, the **confidence intervals** of those estimated values are **significative smaller** for the scenario **pumping + infiltration** than pumping only and more consistent regarding the starting values.

Outlook

The calibration of the model and the interpretation of the results have been done for an homogeneous distribution of c1 in the aquitard. **The next step is to use spatial variation of the hydraulic resistance c1 in the model.**

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