Salinisation and freshening of phreatic groundwater in Zeeland, The Netherlands

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Introduction

Fresh groundwater resources on top of the saline groundwater of the Province of Zeeland are jeopardized by anthropogenic activities such as groundwater exploitation and water level management. In addition, land subsidence, sea level rise and climate change threaten the groundwater system even more (Fig. 1).

Aim of the study

1. To get a better insight in the salinisation and freshening processes in the top of the water system (Fig. 2);
2. To quantify changes in freshwater resources, seepage and salt loads from the groundwater to the surface water system;
3. To analyse what measures are effective to make fresh water supply in this area climate proof;
4. To make a more reliable fresh-brackish-saline distribution;
5. To construct a flexible tool in order to analyse and quantify subareas on different scales.

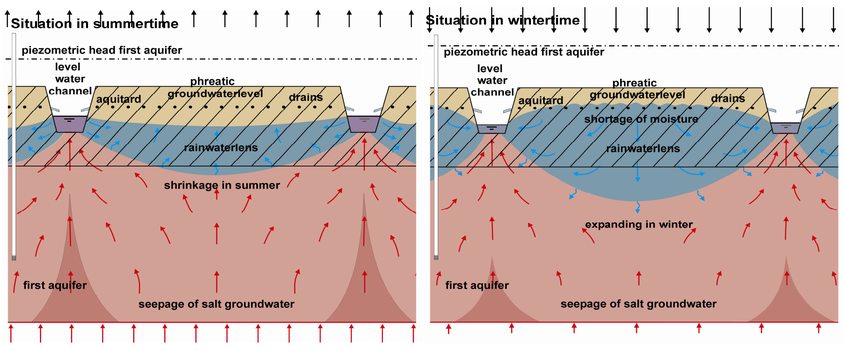

Fig.2: Fresh water lens in summer and winter, along with ditches containing salt water.

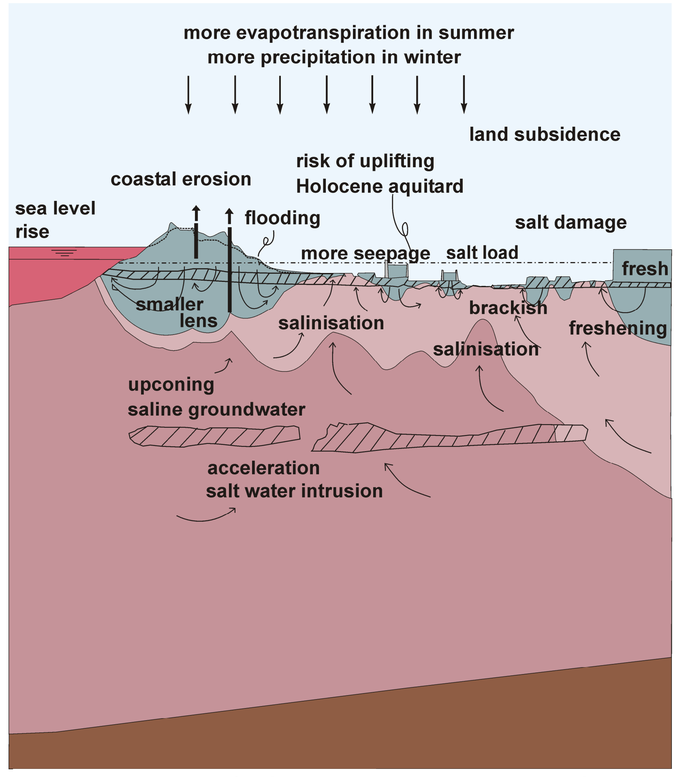

Fig. 1: Concepts of salinisation processes in Dutch coastal areas in case of sea level rise and climate change.

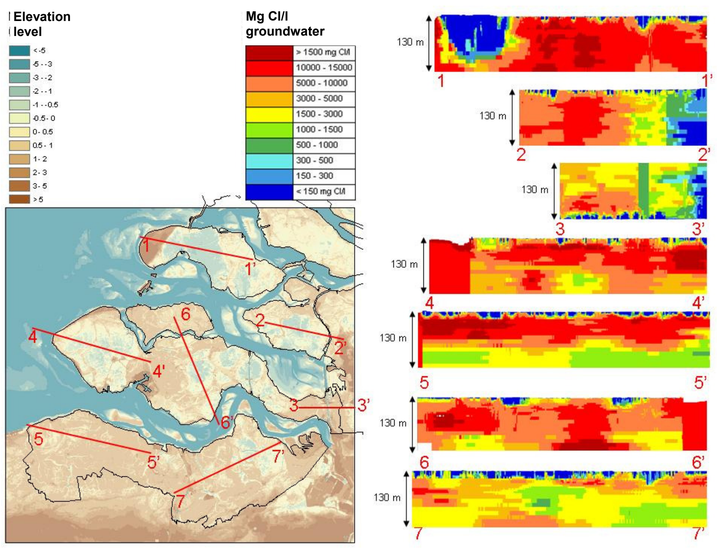

Fig. 4: model result: chloride concentration in 2010.

Methods

Model

A 3D density dependent numerical model with a resolution of 100*100 m^2 is constructed with the code MOCDENS3D to consider fresh, brackish and saline groundwater. The latest results of geological modeling are implemented, using very detailed information of the Holocene lithology. As we are interested in the salinity at the top system, we modeled this top part of the system with thin model cells. The model is calibrated with measured head corrected to freshwater heads (Fig. 3).

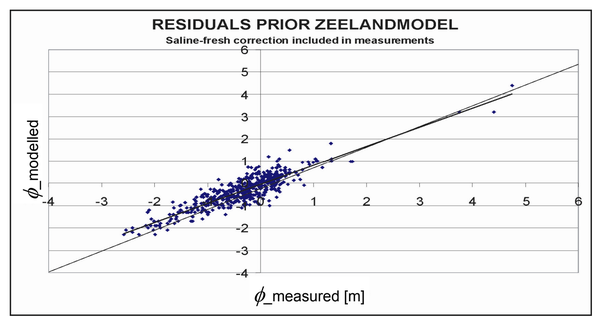

Fig. 3: Modelled versus measured freshwater head.

From chloride measurements to a 3D distribution

We are able to combine various (geophysical) techniques, such as groundwater samples, geo-electrical borehole logs, electrical CPT, Vertical Electrical Soundings (VES), EM31, EM34, groundwater extractions, CVES and TEC probe data, to improve the first estimate of the chloride distribution. In addition we include the mapped fresh-brackish and brackish-saline interfaces and as third step we use the model as a final interpolator (Fig 4 and 5).

Some results

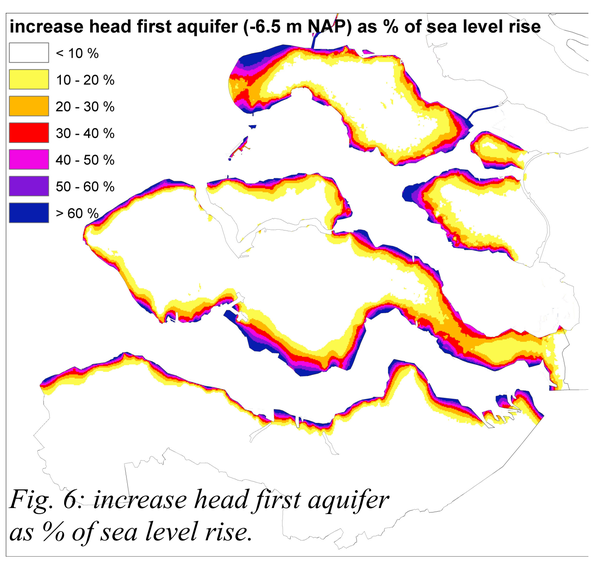

Fig. 6: increase head first aquifer as % of sea level rise.

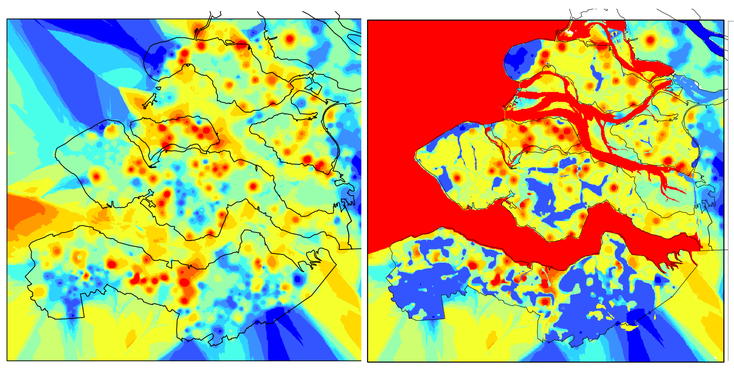

Fig. 5: Chloride concentration groundwater at –6.5 m NAP in three steps: a. interpolating data; b. including interfaces and c. model result 2010.

Applications of the 3D model:

- Future fresh water resources Schouwen-Duiveland (Interreg IV-B Climate Proof Areas);
- Salt load to surface water system of the island Tholen on a decade basis;
- Effects elevation level Grevelingen on groundwater system;
- Physical impacts of climate change on coastal groundwater and surface water systems (Interreg IV-B Cliwat).

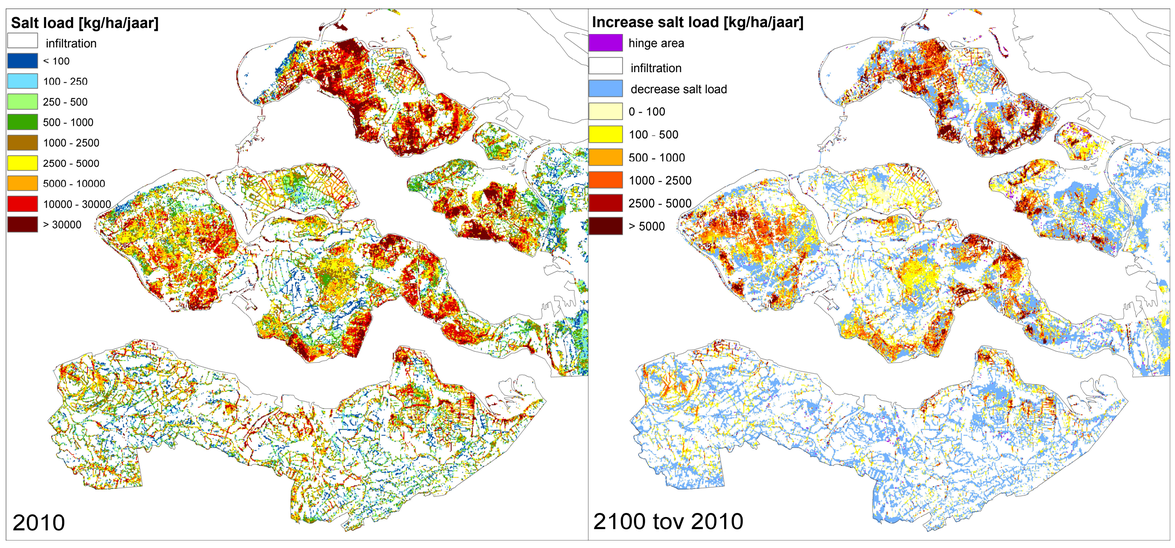

Fig. 7: salt load from the groundwater to the surface water a. yearly mean 2010 and b. 2100 compared to 2010 (without climate change).

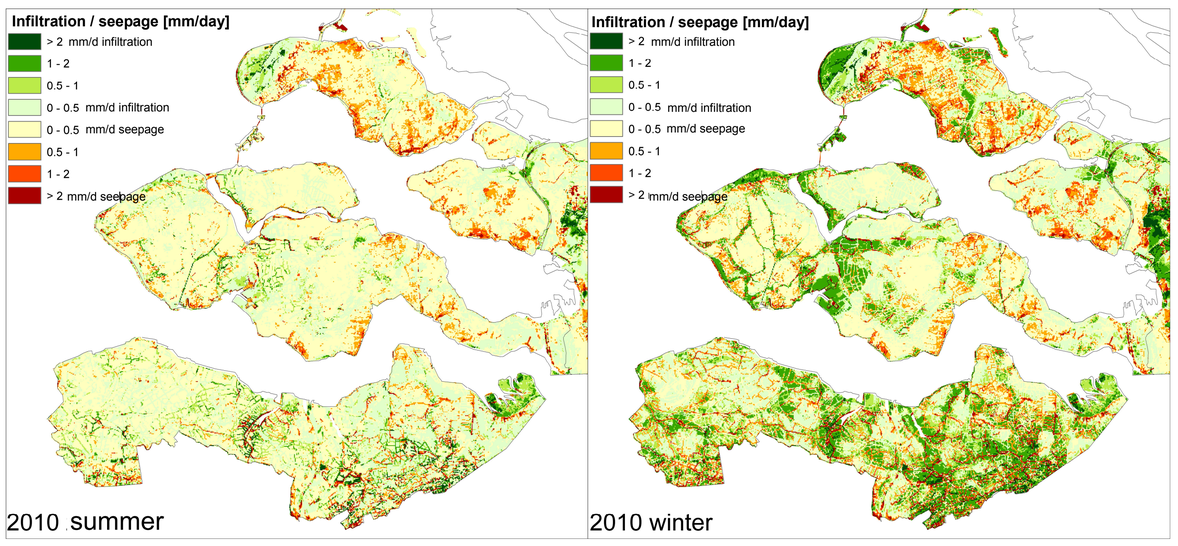

Fig. 8: seepage and infiltration [mm/day] a. summer 2010 and b. winter 2010

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