Development of a freshwater lens in a new strip of dunes

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ABSTRACT

Part of the dune area close to Rotterdam was widened into the sea by about 300 meters in 2008. The purpose of the widening was compensation for lost nature area due to an extension of the harbor of Rotterdam. Now that some years have passed, the question arises whether the conditions are fit for the desired biotopes.

Groundwater level measurements show that the initial groundwater level increase due to a rainwater surplus has probably ceased. Groundwater quality and geo-electrical measurements were performed, to determine if the freshwater lens is still changing. A cross sectional groundwater flow and transport model was used to link these measurements to each other, in time and space. The model was calibrated on groundwater heads and the salinity decrease in some of the wells in the new dune strip.

These activities provided the opportunity to investigate the growth of a freshwater lens on a short time scale, and to test our transient models. The model showed that the initial head change took place in about 2 years, while the salinity distribution was still changing significantly.

The research is still going on and will be decisive for future intervention in the dune valley. If the groundwater heads are too low and the amount of surface water in the valley will be insufficient, measures will be taken.

INTRODUCTION

Close to the port of Rotterdam, near Hoek van Holland, the dunes are about 500 meters wide. This dune area was widened into the sea by about 300 meters in 2008 (Figure 1). The new strip of dunes was created on the sea side of the beach, enclosing the old beach as a valley. The purpose of the widening was compensation for lost nature area due to an extension of the harbor of Rotterdam (Figure 2). The geology consists mainly of sand, intersected by a few clay layers, of which the most important one is 1-5 meter thick at about -20 m below sea-level.

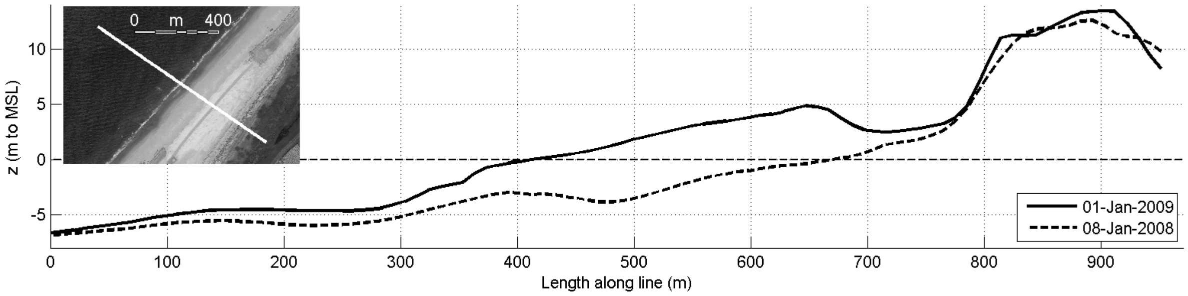

Figure 1. Two altitude profiles: after and before the construction of the new dune strip.

The design challenge was to determine the optimal elevation of the valley floor to meet the desired environment, while the influence of the dynamic dune-forming processes in creating and maintaining the valley was uncertain. Now that some years have passed, the question arises how the morphology and hydrology of the valley has changed and whether the conditions are fit for the desired biotopes.

Figure 2. A photograph from the top of the old dune, showing the harbor of Rotterdam on the left and the new strip of dunes on the right (https://beeldbank.rws.nl, Rijkswaterstaat / Harry van Reeken).

METHODS

Initially the area was monitored by groundwater level and salinity measurements in 8 shallow piezometers, grouped in 2 lines perpendicular on the coast. The filters were placed between 1.5 and 2 m below sea level. The rise in groundwater heads due to the construction of the new dune strip was difficult to separate from the seasonal fluctuations, but seems to have ceases after about 2 years. The water in the inland piezometers was already fresh at the start of the project, and by 2012 all other piezometers had also turned fresh.

To continue the monitoring of the freshwater lens, geo-electrical measurements were performed at the start of 2014. These geo-electrical measurements consisted of 4 CVES profiles. These profiles showed increasing salinity with depth, which was quite constant in the horizontal plane. In the CVES profile perpendicular to the coast, the influence of the sea was noticeable only at the most seaward part. Measuring the conductivity during a drilling by a hand auger to 5 meters depth showed similar resistance values as the CVES-profiles, getting more saline at a the bottom of the auger hole.

A cross sectional groundwater flow and transport model was used to link these measurements to each other, in time and space. The model uses the SEAWAT model code (Langevin, et al., 2007) and consists of a cross-section of a few kilometers perpendicular to the coast, in the same direction as the piezometers and one of the CVES-profiles. The model reaches from the sea to the dunes and the polder behind the dunes, enclosing the entire fresh water lens below the dunes.

The simulation time consists of 2 periods: the original situation is simulated for 1000 years to calculate the equilibrium between fresh and saline groundwater. A shorter time period is modeled hereafter in which the new dune strip is present. The model was calibrated on groundwater heads and the salinity decrease in some of the wells in the new dune strip.

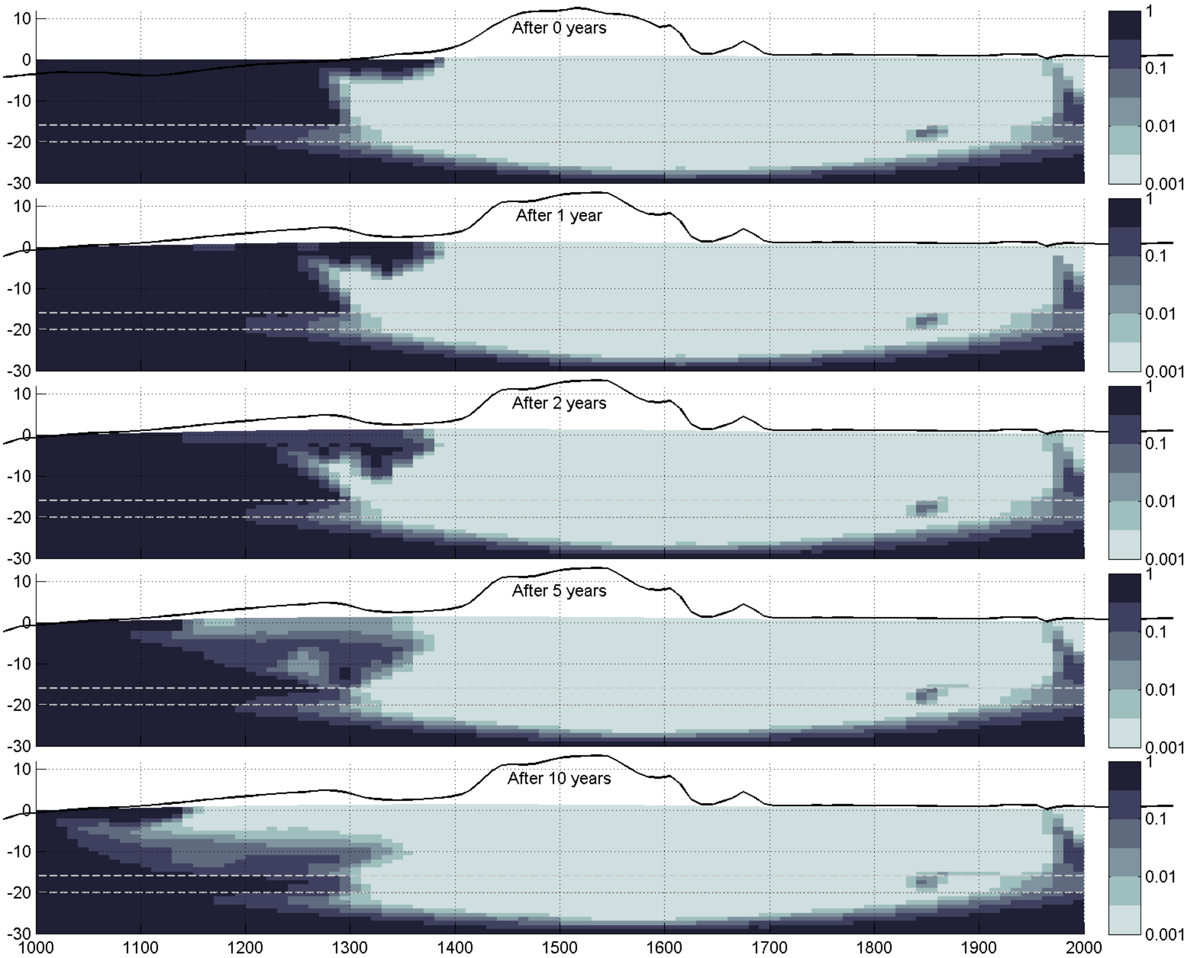

Figure 3. The salinity distribution of the model, at several moments in time.

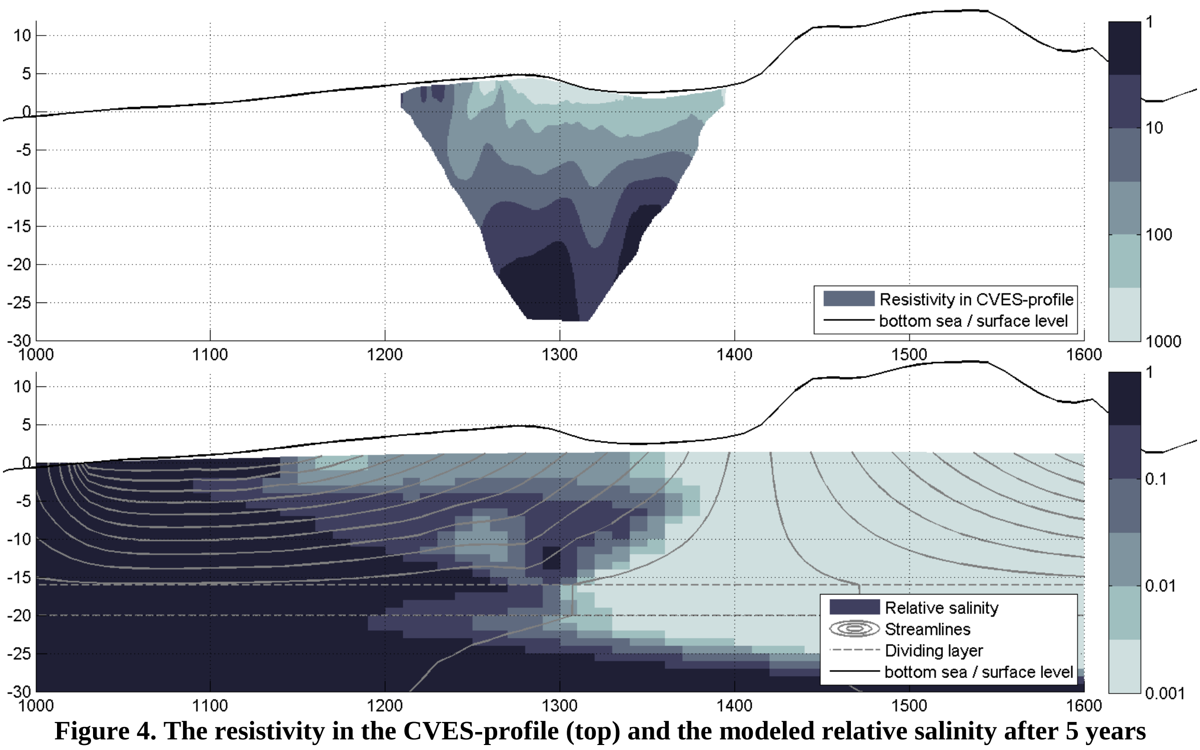

Figure 4. The resistivity in the CVES-profile (top) and the modeled relative salinity after 5 years (bottom).

RESULTS

The model shows that in the first 2 years after the construction of the new dune strip the groundwater levels are increasing fast due to a rainfall surplus. After this period the groundwater level increases only marginally, caused by the gradually changing salinity distribution (Figure 3).

Because of the nature of a cross-sectional model it was not possible to fully match the measured groundwater heads and salinity or the CVES-profiles. However, the model is able to simulate the mayor process: the fresh water lens is formed by new rainfall, mostly horizontal. This will continue in the coming years, until a new equilibrium is reached between rainfall and fresh water flowing to the sea and the polder. The model does not incorporate the tide at the seaward boundary. While the tide does not seem to influence the salinity distribution below the dunes, it can account for the differences between the model and the CVES-profile near the beach (Figure 4).

The CVES-profile shows an increasing salinity distribution with depth, with no inversions. The model however does show an inversion, caused by the fact that salt groundwater at the former location of the beach gets trapped between older and newer fresh water. Another difference between model and measurements is the speed in which the water in the piezometers gets fresh: in the model it takes a few years, while in reality it only takes a few months.

It turns out that the salinity distribution is quite sensitive to the manner in which sand was supplied along the coast. Part of the sand displacement was performed in dry conditions by excavator trucks, while other parts were supplied by rainbowing of sand with salt water. This salt water infiltrated during the construction, constituting an additional salt load. The model showed that this salt load has a mayor influence on the salinity distribution during the first few years of simulation. Another aspect which was examined with the model was the occurrence of surface water at the landward side of the dunes, causing an extra in- or outflow of fresh water to or from the freshwater lens.

DISCUSSION AND CONCLUSIONS

These activities provided the opportunity to investigate the growth of a freshwater lens on a short time scale. The research is still going on and will be decisive for future intervention in the dune valley. If the groundwater heads are too low and the amount of surface water in the valley will be insufficient, measures will be taken. These measures will probably consist of the lowering of the surface level of the dune valley, towards the groundwater level. This will however imply that the ecological development of the valley has to start all over again.

REFERENCES

Langevin, C., Thorne, D. J., Dausman, A., Sukop, M., & Guo, W. 2007. SEAWAT Version 4: A Computer Program for Simulation of Multi-Species Solute and Heat Transport. USGS Techniques and Methods Book 6, Chapter A22.

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