Historic and projected saltwater distribution at the left bank of the river Scheldt near the port of Antwerp, Belgium.

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ABSTRACT

To investigate the influence of the planned changes (e.g. the construction of the Saeftinghedock and the Deurganckdock sluice, the creation of several nature compensation areas, changes in the management of streams, etc.) at the left bank of the Scheldt near the port of Antwerp, a 3D density dependent groundwater model has been developed. The developed model starts in 1976. This date has been chosen as it coincides with the earliest developments at the 'Waasland' harbor. Additionally, it allowed us to use the salinization map of De Breuck et al. (1974) for the initial saltwater distribution. From the situation in 1976, the current situation has been obtained by changing the boundary conditions of the model every few years to the new developments in and around the 'Waasland' harbor. As such, a good fit between the simulated and the observed hydraulic heads and saltwater concentrations for the current situation was obtained. From the current situation on, three development phases have been distinguished. The first one focusses on the development of nature reserves as a compensation for the deepening of the lower sea Scheldt while the second and third phase focus on the expansion of the 'Waasland' harbor as well as on the development of additional (optional) nature reserves. The results of the model indicate that the hydraulic heads and saltwater concentrations in large parts of the left bank of the Scheldt are going to rise due to the creation of new (controlled) tidal areas. This will also induce salinization in some of the neighboring areas as well as in an area that is specially conducted for the creation of salt meadows. In the harbor itself the hydraulic heads will rise in all newly developed areas (sluice, tidal dock and newly heightened areas). The saltwater will raise at the location of the new tidal dock and sluice, while near the newly heightened areas the salt water will significantly lower in only a few years. Additionally the developed 3D density dependent groundwater model revealed the leakage of brackish water from the docks from the 'Waasland' harbor to the largest waterways in the neighborhood of the harbor.

INTRODUCTION

In the next 10 to 15 years the view of the 'Waasland' harbor and the surrounding areas will drastically change due to a series of planned developments. The foreseen developments have two reasons, the first one is the expansion of the port of Antwerp and includes e.g. the construction of the Saeftinghedock, the construction of the Deuckganckdock sluice to connect the Deurganckdock with the 'Waasland' harbor and the heightening of new terrains. The second reason is nature development. As compensation for the loss of valuable nature by dredging parts of the sea Scheldt new nature reserves have to be created. These new nature reserves include two tidal areas, a controlled tidal area, salt meadows and adaptations to the current water management of several waterways in order to optimize the nature along them. To investigate the influence of all the foreseen developments on the hydraulic heads and salt water distribution at the left bank of the Scheldt a 3D density dependent groundwater model has been constructed. For this model the MOCDENS3D code (Lebbe and Oude Essink 1999) was used. Visual MOCDENS3D (Vandenbohede 2007) was used as a postprocessor.

METHOD

The developed model starts in 1976, this coincides with the earliest developments at the left bank of the river Scheldt. Additionally, it allowed us to use the salinization map of De Breuck et al. (1974) for the initial saltwater distribution of the area. From 1976 on, the current situation has been reached by working in 5 discrete time steps. At the end of each time step the boundary conditions of the model were changed according to the planned developments in and around the 'Waasland' harbor. By doing so a good fit between the observed and modeled hydraulic heads and salt water concentrations was possible. For the modeling of the future changes at the left bank of the Scheldt, the foreseen developments have been divided into three development phases each corresponding with a foreseen development horizon (2016, 2020 and 2025). Again, the boundary conditions have been changed at each of these horizons including the new developments in and around the 'Waasland' harbor. After the last horizon the model has been continued for 50 more years to see the evolutions in the long term.

RESULTS

Figure 1 shows some of the results of the conducted 3D density dependent groundwater flow model. On this figure, the saltwater distribution near the water table is given for four periods. The upper left figure, gives the salinity distribution in 1976. This distribution is derived from the salinity map of De Breuck et al. (1974) and was used for the initial concentrations. From this figure it seems that the area closest to the Scheldt (at the right of the figure) is saline with the occurrence of 3 fresh water lenses within the area. Furthermore, brackish water can be observed locally near the largest waterways. The upper right figure shows the salinity distribution in 2013. In the upper part of the figure the draining channels are clearly coming forward as places with higher salinities while the intermediate areas are subject to limited freshening. In the 'Waasland' harbor there is a clear freshening near the heightened terrains while the different docks are clearly visible as places with a higher saltwater concentration. Furthermore, an outflow of brackish water from the most southern docks towards the largest waterways can be observed. The figure in the lower left corner shows the simulated saltwater distribution in 2030. This is 5 years after the last development horizon. On this figure the concentrations in the northern part of the model area are clearly raised due to the construction of new (controlled) tidal areas. In these new areas the water of the Scheldt can again (freely) flow leading to the infiltration of brackish water. Additionally the construction of the Saeftinghedock just south of these new tidal areas also led to the increase of salt concentrations near the dock. For the rest the same elements are visible as in the current situation: a freshening at the heightened terrains, a salinization near the docks and an outflow of brackish water from the southern docks towards the main waterways. The last figure (at the lower right) shows the situation in 2075. This is the situation 50 years after the last changes. This figure shows the evolutions in the long term. As can be seen the earlier discussed processes have continued leading to a complete freshening of the groundwater reservoir under the heightened terrains, while the docks are clearly distinctive due to their higher concentrations. The outflow from the southern docks continued leading to a clear salinization at the most important waterways around the heightened terrains of the 'Waasland' harbor. Furthermore, the salinization in the new tidal areas continued leading to similar saltwater concentrations as in the Scheldt.

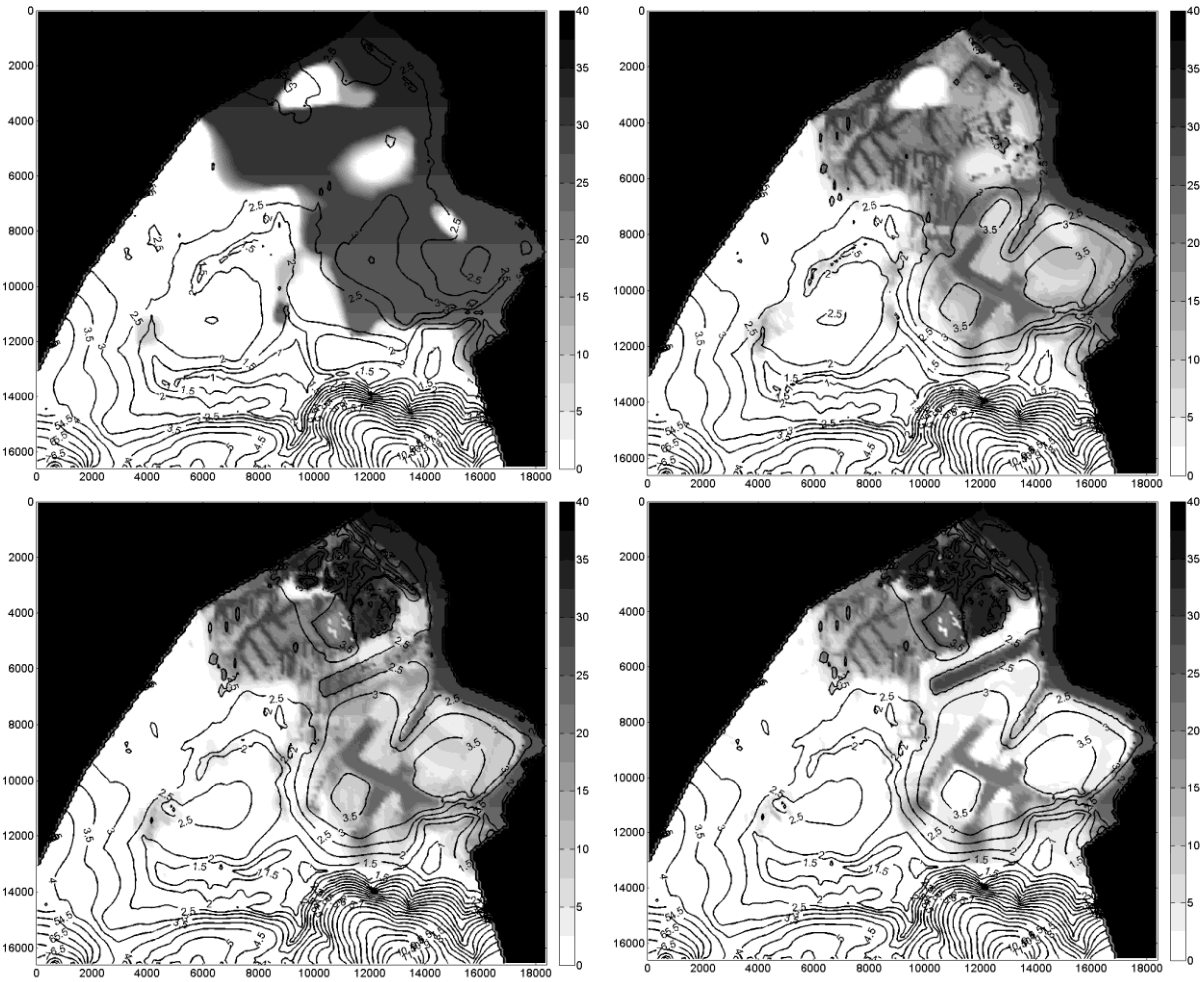

Figure 1. Saltwater distribution near the water table (upper left: 1976, upper right: 2013, lower left: 2030 and lower right: 2075). (Colour scale gives the saltwater percentages, black: 40% salt relative to North Sea water, white: 0% salt relative to North Sea water; black lines give the contourlines of the hydraulic heads.)

CONCLUSIONS

The historic, current and projected saltwater distributions and hydraulic heads at the left bank of the river Scheldt in and around the 'Waasland' harbor are modeled well by changing the reigning boundary conditions every few years according to the planned changes in and around the 'Waasland' harbor. The results show a clear increase in the saltwater concentrations at the newly constructed tidal docks and (controlled) tidal areas, whereas there is a clear freshening at the newly heightened terrains. Furthermore the currently present higher saltwater concentrations near the draining channels remain just as the lower concentrations in the intermediate areas between the draining channels. At last the model showed the outflow of brackish water from the southern docks in the direction of the largest waterways around the heightened terrains of the 'Waasland' harbor.

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