Impact of climate change on the phreatic aquifer of the western Belgian coastal plain

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ABSTRACT

Effects of sea level rise and future recharge changes on the coastal aquifer of the western Belgian coastal plain are evaluated with a 3D density dependent groundwater flow model. The area is characterised by a wide dune belt. Sea level rise results in a landward enlargement of the fresh water lens under the dunes and an increase of flow towards the dune-polder transition’s drainage system. Recharge increase results also in an enlargement of the dune’s fresh water lens and an increase of the amount of water which must be evacuated by the polder’s drainage system. Recharge decrease has the reverse effect.

INTRODUCTION

The western Belgian coastal plain is characterised by a relatively wide dune belt (up to 2 km) with an adjacent polder area. The phreatic aquifer consists of quaternary sediments with a mean thickness of 30 m. The lower substratum of the aquifer is formed by the clay of the Kortrijk Formation, Ieper Group (Eocene age). A fresh water lens occurs in the dune area, up to the Tertiary substratum. Water is extracted from this fresh water lens (Vandenbohede et al., 2009). Under the shore, a salt water lens above fresh water flowing from the dunes towards the sea is present (Vandenbohede and Lebbe, 2006). In the polder, a complex fresh-salt water distribution occurs. Fresh water lenses are found at locations of old tidal channels and salt water is found shallow in adjacent less permeable sediments (Vandenbohede and Lebbe, 2002).

This paper focuses on the effects of sea level rise on the fresh-salt water and fresh water head distribution. Therefore, a 3D density dependent groundwater flow model is made to simulate in first instance the current fresh-salt water and fresh water head distribution. Secondly, impact of sea level rise and of two possible scenarios of future recharge changes are simulated and compared with the current situation. This is calculated for the next 200 years.

PROJECTED IMPACT OF CLIMATE CHANGE

Predicted sea-level rise ranges between 0.3 and 0.9 m over the next century with a best estimate of 0.6 m (IPCC, 2007). Here, a relatively conservative sea level rise of 0.4 m per century is used. Können (2001) gives a number of possible climate scenario’s. Each scenario predicts a change in mean temperature, summer and winter precipitation, total precipitation and wind speed. Some scenario’s predict a wetter climate, whereas others predict a colder or a dryer climate. Using daily climatological measurements for the study area, the mean reference evapotranspiration and aquifer recharge is calculated for the 5 scenarios. Current mean aquifer recharge is 219 mm/y. Three of the scenarios result in an increase of the recharge (maximum of
1.26 times) whereas the other two predict a decrease (maximum of 1.19). Therefore, two calculations are made. One with a 1.26 increase and one with a 1.19 decrease of the mean recharge.

DENSITY DEPENDENT GROUNDWATER FLOW MODEL

A 3D density dependent groundwater flow model is made, using the MOCDENS3D code (Oude Essink, 1998) and visual MOCDENS3D (Vandenbohede, 2007) as pre- and postprocessor. The model measures 13.575 times 7.35 km with a resolution of 75 m. The phreatic aquifer is subdivided in 12 layers with a thickness of 2.5 m each. Clay of the Kortrijk Formation is considered as the impermeable lower boundary of the model. The Hydrogeological Code Subsurface Flanders, HCOV is used as geological model. HCOV is a hydrogeological mapping whereby the subsurface is subdivided in permeable and semi-permeable units. Hydraulic parameters (horizontal and vertical hydraulic conductivities) are assigned to the different units. Northern boundary is located in the sea and forms a constant head boundary, equalling the mean sea level. Southern boundary is also a constant head boundary, equalling the drainage level in the polder. East and west boundaries are situated perpendicular to the coastline and are considered as no flow boundaries. Initially, the aquifer is considered to be filled with salt water. This simulates the situation where the coastal plain was still inundated regularly by the sea. This saltwater is then replaced by fresh recharge water and this is compared to the current distribution as mapped by De Breuck et al. (1974). Figure 1 shows in a cross-section situated north-south through the shore, dunes and polders and central through the model domain the simulated current fresh-salt water distribution. As discussed before, a fresh water lens is present in the dunes and a complex distribution occurs in the polder. In the dunes, a water divide is present: water recharging north of the divide flows towards the sea, water recharging south of the divide flows towards the polder.

Sea level rise was simulated by increasing the constant head of the sea boundary with a rate of 0.4 m per century. Figure 1 gives the resulting fresh-salt water distribution 200 years in the future. Because of the sea level rise, the water divide in the dunes will shift towards the sea. This results in less fresh water flowing from the dunes towards the sea and in an increased flow towards the dunes. Therefore, there is a small landwards enlargement of the fresh water lens. Additionally, the drainage system located at the dune-polder boundary will have to drain more water if the current drainage levels should be maintained. By decreasing the recharge, less water recharges the dune area whereby the volume of the fresh water lens decreases. Additionally, less water must be evacuated by the drainage system in the polder. The reverse happens by increasing the recharge rate.
RESULTS

Notice that the fresh-salt water distribution undergoes only very small changes. Because of the wide dune belt, sea level must rise much more than the 0.4 m per century (or longer than 200 years) to have an important impact. This is different for a less wide dune belt. Concerning recharge changes, an increase of recharge is here evacuated by the drainage system and only a small portion of this increase recharges the aquifer, hence the fresh-salt water distribution changes little. In case of a decrease of the recharge rate, less water must be drained but the amount of water recharging the aquifer also changes little.
REFERENCES


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