Controlled level drainage, a feasible measure to increase a fresh water lens in creek deposits

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ABSTRACT

A new artificial recharge measure to expand a fresh water lens in creek ridge deposits is presented. Creek ridges are common in the southwestern part of the Netherlands, and the freshwater lenses are used intensively here for irrigation. The measure is based on a controlled level drainage system, which is used to infiltrate fresh surface water in the creek ridge and at the same time keeping the groundwater level as high as possible. Field measurements in combination with numerical modelling were used to study the feasibility of the measure just north of the village Serooskerke.

INTRODUCTION

The south-western part of the Netherlands is a deltaic area where large areas lie at or below mean sea level. The shallow hydrogeological system in these areas can be characterized by a 1 – 5 m thick semi-confining layer overlying a 10 - 40 m thick aquifer (Goes et al. 2009, De Louw et al. 2011). The semi-confining layer consists of fine sand, clay and peat deposits and is incised by tidal channel and gully deposits (Figure 1). The tidal channel and gully deposits appear as elevated ridges in the landscape, and are referred to as 'creek ridges'.

Beneath the creek ridges, a fresh water lens is present with a maximum thickness between 5 and 30 meters. The lens is important for irrigation in the area, as the majority of the groundwater and the surface waters are saline and there is little transport of fresh water from other areas (De Louw et al. 2011). The amount and rate of fresh water extraction is regulated by the authorities to prevent excessive drawdown and to prevent saltwater upconing. As a consequence, the irrigation demand exceeds the extraction limits in long dry periods, which leads to crop damage. This problem is expected to increase in the future due to the anticipated sea level rise, climate change and land subsidence (Oude Essink et al. 2010). Therefore, countermeasures are likely needed to assure a sustainable and robust fresh water supply.

In this paper, a new measure is presented to expand the fresh water lens in a creek ridge, just north of the village Serooskerke (Figure 1). The measure is based on controlled level drainage, which is used to infiltrate fresh surface water and at the same time keeping the groundwater level as high as possible. The feasibility of the measure is studied using field measurements and numerical modelling.

METHODS

A controlled level drainage system (Figure 1) was installed in April 2013. Various measurement techniques were used to determine the hydraulic head variation and groundwater salinity distribution at site, prior to the installation of the measure. Since April 2013, geophysical measurements and chemical sampling are used to study the effect of the controlled level drainage on the fresh water lens.

In addition to the field measurements, a numerical model was constructed using SEAWAT (Langevin et al., 2008). The purpose of this model was to determine the long-term effects of the measure on the freshwater lens.

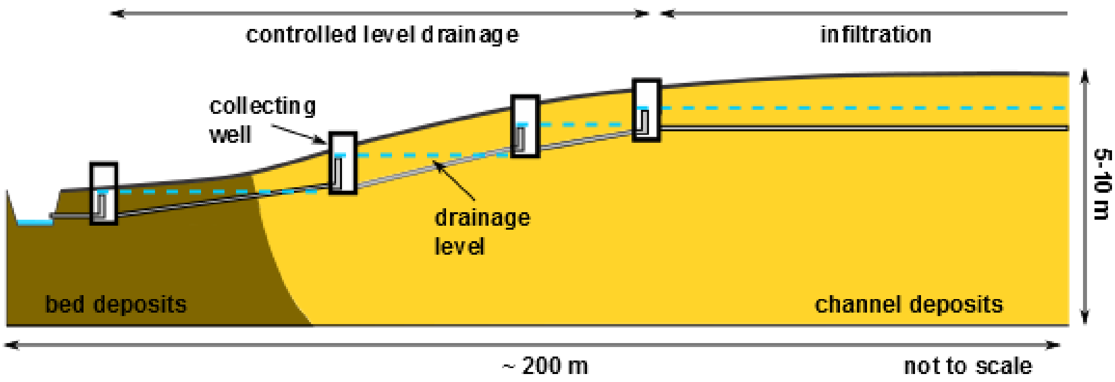

Figure 1: concept of controlled level drainage in a creek ridge.

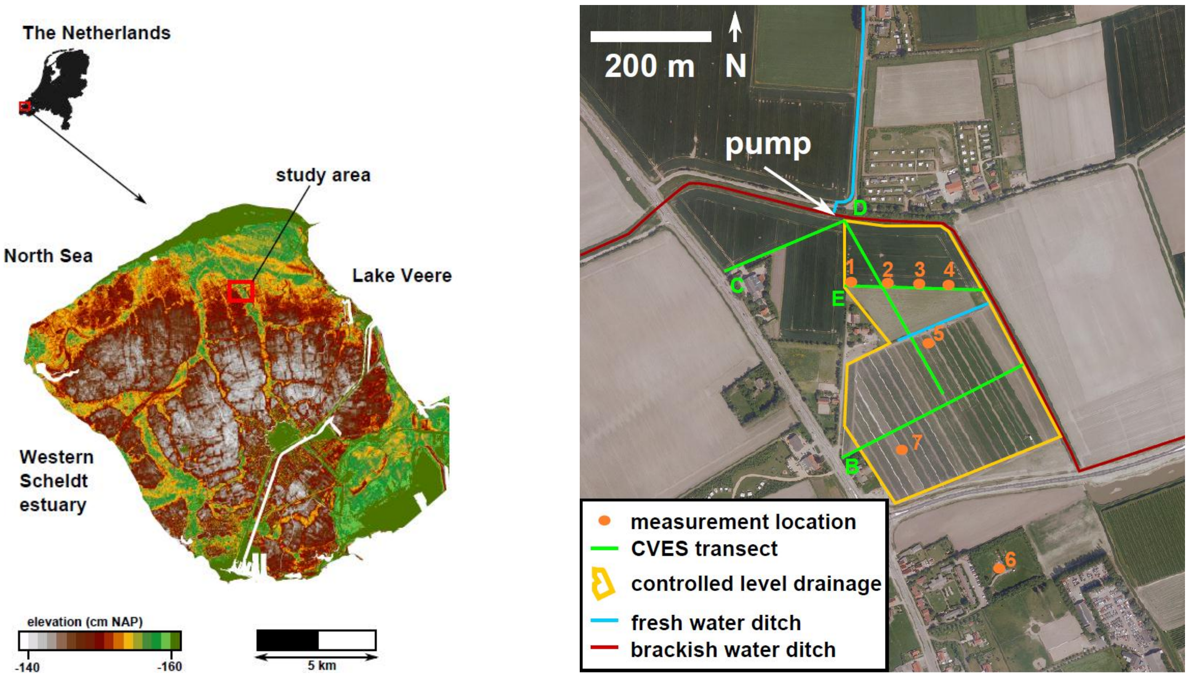

Figure 2: Left: Study area where the controlled level drainage has been installed. Right: Overview of the controlled level drainage area, the most relevant brackish and fresh water ditches and the measurement locations.

RESULTS

For brevity of this paper, only the results of the sampling are given here. Six piezometers using 40 cm screens at several depths were used to sample the groundwater at measurement location 1 (Figure 2). Figure 3 shows the electrical conductivity (EC) of the groundwater in September 2013 (prior to the infiltration) and Februari 2014 (during the infiltration). The data shows a decrease of the fresh-saline transition zone of about 1.5 m. A reference measurement at a location where the controlled level drainage was not installed, showed a decrease of the fresh water lens of about 0.1 m during this period.

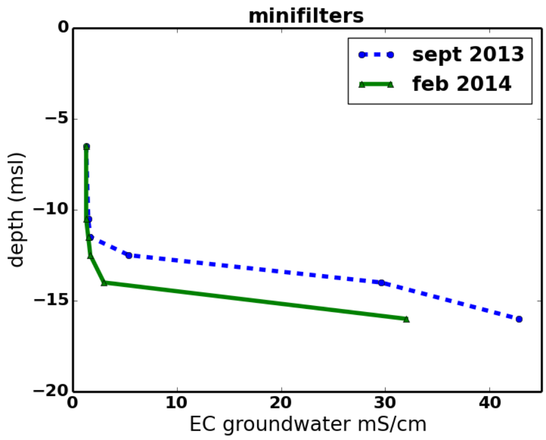

Figure 3: Results of the groundwater sampling at measurement location 1 (Figure 2).

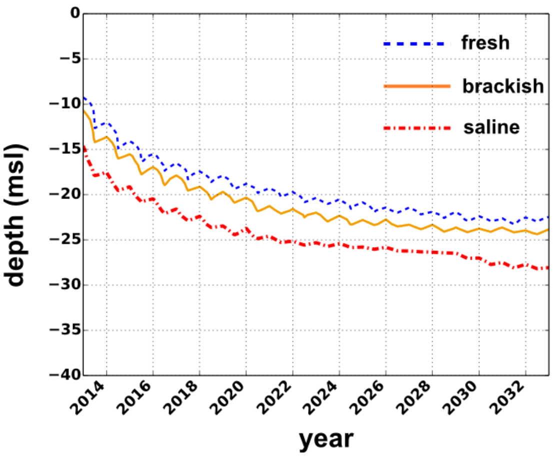

Figure 4: Result of the numerical model which was used to estimate the long-term effect of the measure. The blue, orange and red lines indicate the 1000, 5000 and 10000 mg l^{-1} Chloride contour. Chloride is used as a representative proxy and varies between 0 (fresh water) and 18630 mg l^{-1} (sea water).

The numerical model indicates that the measure leads to a significant expansion of the fresh water lens in the creek ridge on the long term. During the infiltration period (half a year) the transition zone lowers. During the following dry period, the transition zone depth recovers only a slightly. The net result over the year is an expansion of the fresh water lens.

DISCUSSION AND CONCLUSIONS

The controlled level drainage system is intended to be used as a relatively easy and cheap measure to increase the fresh water lens in creek ridge deposits. The advantage of the method is that the expansion of the lens does not occur locally, but along the total area where the groundwater level is increased by controlled level drainage. The disadvantage is that it takes a relatively long time before the expansion of the lens is realized. The expansion of the fresh water lens contributes to a larger freshwater (safe) yield from the lens, but this was not further quantified.

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