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Hydrology and Earth System Sciences Discussions

Interactive comment on "Quantifying water and salt fluxes in a lowland polder catchment dominated by boil seepage: a probabilistic end-member mixing approach" *by* P. G. B. de Louw et al.

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Reply to comments of referee Alexander Vandenbohede:

We thank Alexander Vandenbohede for the constructive comments and appreciation of our work. Below we respond to each of the comments raised by the referee.

Comment: P154 – l1-6: Authors speak of spatial variability of fluxes and composition. Seasonal variation at a location is less important (perhaps because of the managed

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Interactive Discussion

Discussion Paper

water levels and drainage)?

Reply: Indeed, in our case the temporal variation of both seepage fluxes and seepage composition is small. The yearly amplitude of the hydraulic head in the upper aquifer below the confining layer is only 15 cm and surface water levels are kept constant throughout the year. This results in relatively constant head differences of around 1.5 meter with the surface water and therefore constant boil seepage fluxes which is explained at P158 -L14-19. The groundwater level shows more fluctuation (yearly amplitude 0.3–0.7 m) resulting in a seepage flux that varies throughout the year. This effect is incorporated in our model (Eq. 3). Because the seepage water comes from the upper aquifer below the confining layer at greater depths than 7 m and groundwater flow is a slow process, the groundwater composition in the upper aquifer will not change significantly due to seasonal variations in precipitation and evapotranspiration. This is confirmed by our monitoring data described in our previous work (De Louw et al., 2010). We analyzed the groundwater composition of the upper aquifer at two moments in the year (April and November) and the differences were less than 5%. In the revised version we will mention this in section 2.2 and refer to our previous work.

Comment: P158: water infiltrated in the Boezem to the groundwater and which is drained in the polder (not the Qa component) is considered in the Qgrw component? Why is Qb considered as a separated component, it is also some kind of seepage from the groundwater? To stress it importance?

Reply: Infiltration of boezem-water takes place but has no significant contribution to the total water balance (« 1%) due to the small area where this takes place compared to the total polder area. Therefore we did not consider it as a separate balance term. It is necessary to consider boil seepage Qb as a separate component because their flux and composition differ significantly from the other seepage types. These choices we will clarify in the manuscript, also following similar comments of reviewer 2.

Comment: P155 – l22 – fig2: the fig gives the location of boils in the polder. On p157, it

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is given that the total number of boils is unknown. How do we have to understand this? Boils are map in the some areas of the polder and other not (for instance southern part of the polder, fig 2).

Reply: The confusion is understandable and we will clarify it in the revised version. We mapped 49 boils but we are sure that we only map a small part of the boils in the polder. As boils are rather small, concentrated and mainly underwater phenomena, they are hard to find. In fact every ditch should be inspected to find all boils. With a total length of more than 400 km of ditches and watercourses this is an enormous task which we couldn't carry out within our research. Besides this, boils in the larger and deeper canals can not be seen directly and other methods should be applied to map them. Currently we are experimenting with different mapping techniques (air borne thermal infra-red, temperature and conductivity measurements of surface water, temperature measurements with DTS fibre optic cable) to improve the boil mapping.

Comment: P156: Water is pumped from the polder in the Boezem which is on a higher level. This means that part of the water in the Boezem reinfiltrates? So why is then the Boezem at a higher level? This is needed to evacuated the water to sea during low tide?

Reply: Because Polder Noordplas is situated at about 6 m below mean sea level (M.S.L.) and the surrounding peat lands at about -2 m M.S.L., the water must be pumped at a higher level to get it transported by gravity to the sea where another pumping station, pumps it into the sea. This surface water system at higher level is called, the 'boezem' (see Fig. 1). Infiltration from the 'boezem' takes place but is of minor importance (see comment and reply P158).

Comment: P156: Did I understood well that during dry periods (when it is said that water is admitted in the polder), groundwater levels are too low (although it is a low-lying polder)?

Reply: At 14 locations (see Fig. 2) we measured surface and groundwater levels

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for a period of 2 years. Only at 5 locations, groundwater levels dropped below the surface water level for a short period during the summer (2 to 6 weeks). In addition, given the low permeability of the clayey soil and the large ditch distances (100 to 200 m), infiltration from the surface water network can be neglected. Boezem water is principally admitted to maintain the surface water level at a constant level (for ditch side stability, ecological and water quality, irrigation and to reduce the salinity of the surface water.

Comment: P156 – l26 – fig 2: Is there a particular reason that there are no observation wells between ditches?

Reply: We installed our observation wells at different distances from the ditch (see Fig. 2), from which some are installed exactly between 2 ditches, to analyze the groundwater-surface water interaction. The monitoring data showed that the ditches do not have a significant effect on the groundwater level. This is caused by the low permeability of the soil and the fact that almost all agricultural fields are drained with subsurface drains with a spacing of 10-20 m. Our sensitivity analysis shows the large impact of subsurface drains on groundwater level and discharge dynamics (Table 5 and Fig. 5).

Comment: P159 – l24: is dn not the distance between the level of HAQ and hgrw,i instead of the thickness?

Reply: The confining layer consists of different layers which differ in lithology (lithological layer n). To obtain the total hydraulic resistance, r, of the (saturated) confining layer, we determined r for every lithological layer n. To do so, the thickness (dn) of lithological layer n must be divided by the vertical hydraulic conductivity kv,n of that layer. So, dn indicates the thickness of a lithological layer within the (saturated) confining layer. We will add some explanation in the revised paper to clarify this.

Comment: P161 – eq 8: There is a winter and summer term of the Boezem water admission. Doesn't that have to be one term which changes according to it?

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Reply: In fact, it is one balance term which change throughout the year but the temporal variation of the admission flux is unknown. However, there is a clear difference between admission during the summer and during the winter period (given by the management of inlets by farmers and the Water Board). As fluxes and composition are thought to be significant different between winter and summer, we separate the admission of 'boezem' water into two end-members. We will describe the arguments for the distinction between winter and summer admission in the revised paper.

Comment: P167 – l13-26: Concentration is related to depth, as is also shown on figure 1. Is this figure one a conceptual drawing or are the isolines drawn on more or less the right (mean) depth? So these boils "extract" water from relatively deep, 20 to 30 m?

Reply: The conceptual isolines of Fig. 1 are based on real measurements as described in De Louw et al., (2010). So the conclusion that boils "extract" groundwater from relatively great depth is right (probably from 30 to 40 m depth, see Fig. 1). This upconing mechanism is mentioned in section 3.2 and explained in more detail in De Louw et al., 2010.

Technical Corrections

Comment: P160 – l1: it would be clearer if qditch and qdr are defined (in words) directly after equation 2 where they are first mentioned.

Reply: We agree and will add this in the revised version.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 8, 151, 2011.