Brackish Groundwater as a New Resource for Drinking Water, Specific Consequences of Density Dependent Flow, and Positive Environmental Consequences

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ABSTRACT

The Netherlands, like other deltaic areas have extended aquifers partly filled with brackish to saline groundwater most probably resulting from previous transgressions. Low-lying areas like previous lakes hat have been pumped dry in the past to allow development. In these so-called polders a dense network of surface canals and ditches maintain the surface water level and discharge the recharge surplus and the intense groundwater seepage. The network effectively creates a fixed-head top boundary condition. To a large extent this seepage, which is driven by the head difference with adjacent areas of mostly several meters, generates saltwater upconing. Much of the water management consists of flushing these polders to get rid of this brackish water, while this water itself poses environmental problems due to its salinity and high concentration of nutrients like phosphates, sulfates and ammonia.

INTRODUCTION

It is not easy to find and develop reliable sources for drinking water in this densely populated country with its intense agriculture and industrialization. But since reverse osmosis technology has developed so much, currently, drinking-water production from anaerobic, particle-free brackish to saline groundwater has become an economically attractive possibility especially due to its technical simplicity as compared to the complicated series of treatment steps necessary when using (polluted) surface water. A perceived major advantage of using brackish groundwater is that it is old and therefore anthropologically unpolluted. Another advantage is its short distance to consumers. A further advantage or opportunity is that extraction of brackish groundwater below deep polders will result in diminishing or even disappearing of saltwater seepage and thus reduction of pollution of fresh surface water. Hence, it would also solve currently persistent environmental problems.

In this presentation we discuss some hydrogeological effects of brackish water extraction. With the term brackish water we have to think of chloride concentrations in the order of 7000 mg/L, about 40% of sea water values. The density of this water is around 1010 kg/m^3 (as was used in the modeling) and cannot be ignored, as we will see. The extraction of this brackish water will take place below the interface with the overlying fresh water.

BRACKISH AND FRESH WATER FLOW

Currently, the brackish water seeps up over a wide area of the polder (fig. 1). Figure 1 shows the result of a 2D steady-state simulation with equilibrium interface. It shows the upconing and upward seeping groundwater. The steam lines are isolines of the stream function with a discharge of 0.25 m^2/d between any two adjacent lines. This works for the fresh as well as for the salt water. The streamline pattern shows that the intensity of the discharge is relatively low in the column of brackish water and high in the adjacent fresh water seepage as indicated by the curved arrows. Also, the zone of brackish seepage can be wide with moderate to low intensity seepage as compared to the intense fresh water seepage near adjacent to the brackish water cone. The picture with density ignored is very different with a much more intense upward seepage in the center of the polder.

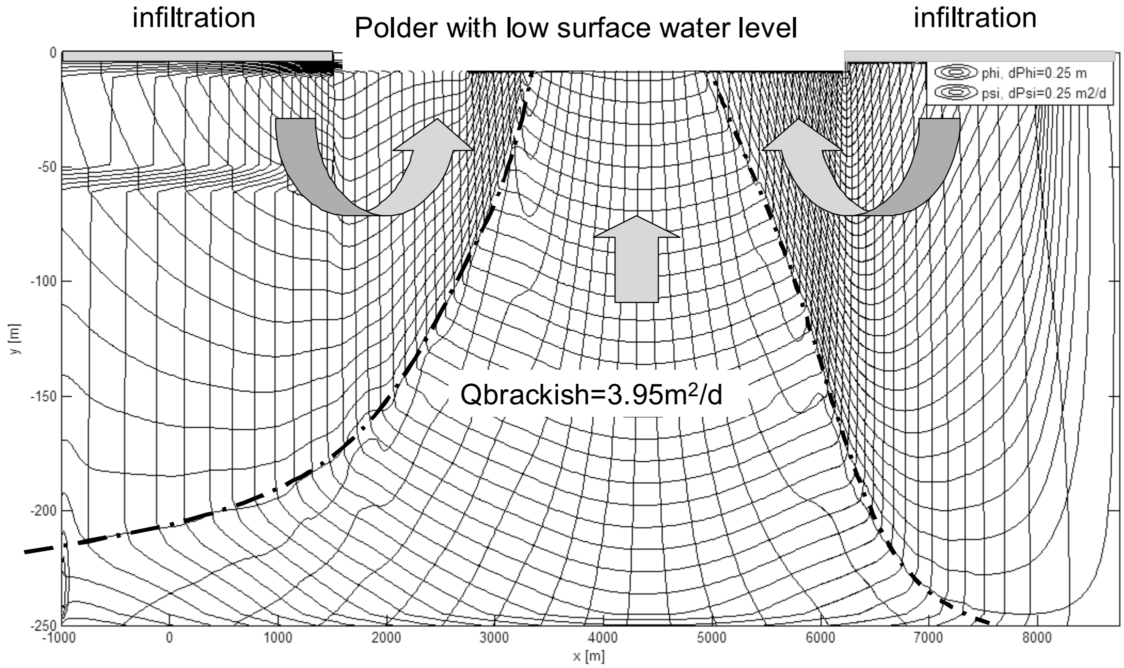

Figure 1. Cross section with brackish water upconing and seepage in the center. Streamlines at 0.25 m^2/d intervals and freshwater heads at 0.25 m intervals are shown. The interface between brackish and fresh water is indicated by the thick line. The brackish water had 1010 kg/m^3 density.

It turns out that even the moderate density of 1010 kg/m^3 that we have here has a large effect on the flow and the seepage. Hence we must include density in much of our modeling, at least more regularly than is customary today.

SEPARATION OF FRESH AND BRACKISH WATER BODIES

Fig.2 shows the situation with extraction of brackish water below the interface. The well screens have been placed between a depth of 150 and 200 m. The extraction is such that the interface does no longer reach the top of the aquifer. The extraction needed for this is about the same as the previous saltwater seepage into the polder. The shown situation is valid once the interface has reached equilibrium. There are several interesting points to be considered next.

In this situation the brackish and fresh groundwater remain separated by the interface as two distinct water bodies. Due to this, there can be no pollution of the brackish water from agriculture or any other uses of ground surface. This way it does not seem to be a problem to use brackish groundwater from urban areas as a resource.

A second point to be considered is that the brackish water extraction does not cause drawdowns in the fresh water system; the two water bodies are separated by their interface. This may be an advantage as this does not induce further subsidence of shallow Holocene peat layers. Such subsidence is a general problem in the Netherlands.

A last point to be considered is that the extraction of brackish water increases the overall seepage of fresh groundwater into the polder. This seemingly counter intuitive effect is due to the increase of the effective transmissivity of the layer of fresh water as a consequence of the lowering of the interface caused by the drawdown due to pumping in the brackish zone.

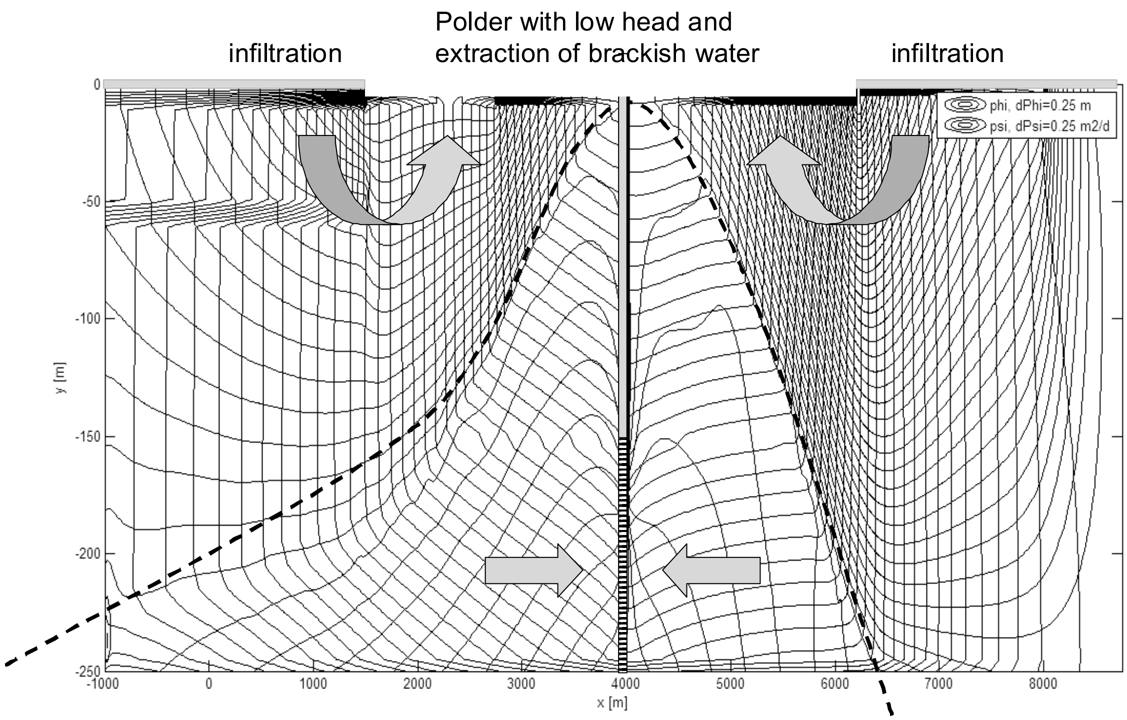

Figure 2. Cross section now including recovery of brackish water with a line of wells screened between 150 and 200 below ground surface. The equilibrium interface is indicated by the thick dashed lines. Interval between streamlines is 0.25 m^2/d, between fresh water head lines it is 0.25 m.

OTHER ASPECTS

Clearly, there are more effects to be dealt with. For instance, the desalination by reversed osmosis (membranes) generates a concentrate containing the removed salts. Effects of injection have to be carefully studied in the framework of an environmental assessment.
Another problem to be considered is the origin of the brackish water, which is still largely unresolved. Isotopic studies have revealed that the brackish water is of Holocene origin (Van der Linden & Appelo, 1988, Van der Molen, 1988, Post, 2004). This water likely results from downward percolation of one or more previous transgressions. It may well mean that the total amount of brackish water is limited, which would also limit the feasible life expectancy of its recovery. This life expectancy has to be investigated as well. One of the issues in such as study will be the distribution of salinities inside the brackish water zone and its consequences for variations of salt concentrations over time and the extent of the movement of the interface. Finally, transients in flow are of concern as well as the way in which such systems should be monitored and mentioned to guarantee protection from pollution.

CONCLUSION

Nevertheless, we have a number of such systems in the Netherlands which would provide opportunity for brackish water extraction for drinking water usage on a larger scale. This use would at the same time help solve various environmental problems due to upward seepage of nutrient-rich brackish groundwater that mixes with the surface water systems currently mainly concerned with flushing this water towards the sea along the shortest possible route.

A final conclusion is that analyzing such systems requires the use of density dependent modeling codes, even if we only deal with brackish water having moderate salinities such as the 40% of seawater used here. Hitherto density-dependent flow has only scarcely been used in regional modeling (except by a few pioneers like Oude Essink (1996). Happily we have seen more and more use of Seawat and SWI in the last couple of years.

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