Analysis of brackish water behavior at an ASTR deepwell infiltration site after 20 years of monitoring

Harry L. M. Rolf[1], Frans W. Schaars[2] and J. J. Lebbink[3]

[1] PWN, North Holland Water Supply, Velserbroek, The Netherlands
[2] Artesia Water Research, Schoonhoven, The Netherlands
[3] PWN, North Holland Water Supply, Velserbroek, The Netherlands
currently: Municipality Hilversum, The Netherlands

ABSTRACT

PWN, Water Supply Company of North Holland has been operating a deep well infiltration- and recovery system since the beginning of 1990. The project, ‘deep well infiltration Watervlak, DWAT’ is located in the Dutch North Sea coastal area, in the dunes opposite Castricum. The infiltration is carried out by means of 20 infiltration wells into an aquifer 50 to 100 meters below sea level. Abstraction takes place by 12 wells in the same deep aquifer. The aquifer is bounded at the lower side by a thin silty layer, under which the groundwater is brackish. In fact, the site can be considered as an ASTR system: pre-purified river water is stored in the aquifer (Aquifer Storage), treated and disinfected (T) by groundwater flow through the aquifer sands and recovered (R) by deep pumping wells. The recovered water is clean and safe drinking water; it just needs some final tuning to remove iron and manganese.

The abstraction rate is kept 10% lower than the infiltration rate. During the design of the site in the late 80’s, the 10% fresh water over-infiltration was taken as a required precaution to prevent up-coning of brackish water under the abstraction wells.

To determine the actual up-coning risk, a comprehensive monitoring network has been installed. This includes Electrical Conductivity (EC) measurements mounted on vertical ‘salt watcher’ cables at 13 depths for 25 locations under pumping and infiltration wells, and also in monitoring wells at a certain distance from the site. The variable abstraction and infiltration rates are registered, as well as the head in relevant monitoring wells.

These measurements have been taken for a period of twenty years, in which several tests were done with different abstraction and infiltration rates. Because of the high monitoring frequency that is used, we can see a clear relation between the over-infiltration and the movement of the brackish groundwater. The length of the monitoring period and the variability of the recharge and discharge fluxes provide a unique data-set that can be used for understanding processes that take place in an aquifer with fresh and salt water. PWN Water Supply is interested determining the over-infiltration rate required to prevent up-coning. Measurements show that the 10% rate is probably enough. Clearly the system is rather robust, leading to opportunities to improve the economics of the site, e.g. by operating it more dynamically or by reducing the amount of over-infiltration. Further analysis will include numerical modeling to get more understanding of the conditions that determine the actual behavior of the underlying interface.

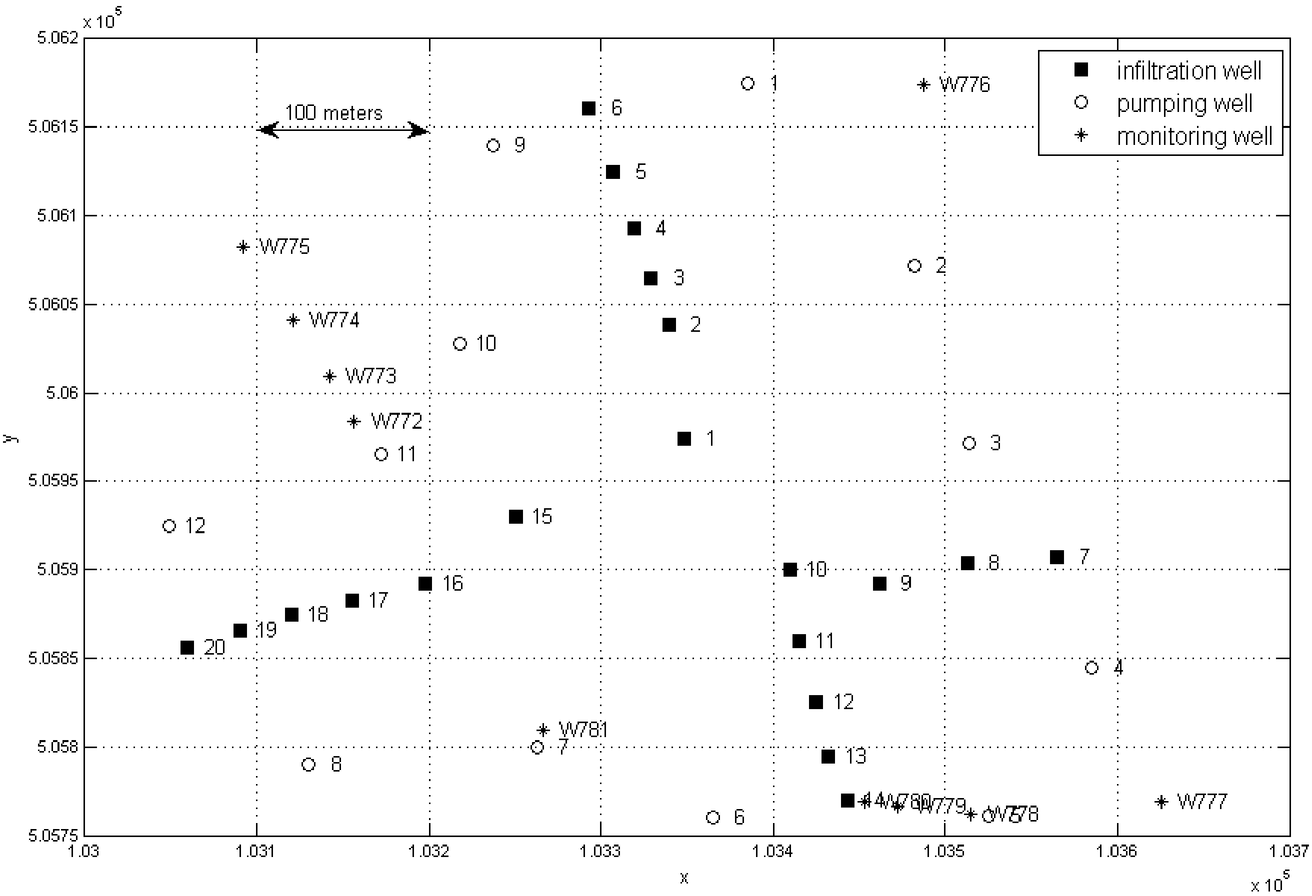

Figure 1. Layout of the ASR system

RESULTS

In figure 1 the layout of the infiltration and abstraction system is shown. Figure 2 shows some typical results for four EC cables. The first graph shows the total infiltration and abstraction rate, for the last 20 years. The other graphs give an impression of the measured electric conductivity, as a function of depth and time. It can clearly be seen that near the infiltration well (I8 and W779) the interface between fresh water (low conductivity, light colors) and salt water (high conductivity, dark colors) travels downwards. There is also seasonal fluctuation. This is probably caused by temperature fluctuations in the infiltration water. This fluctuation serves as a tracer that tells us that the water is moving downwards.

In monitoring wells that are further away from the site (W774) the fresh salt interface moves upwards. This is probably caused by the over-infiltration, that is pushing the salt water towards the edge of the site. The fourth location (W772) lies close to a pumping well (P11). Here we can see the upconing effect of the infiltration stop in 1993. It is also clear that the interface goes down again when the flow is reversed.

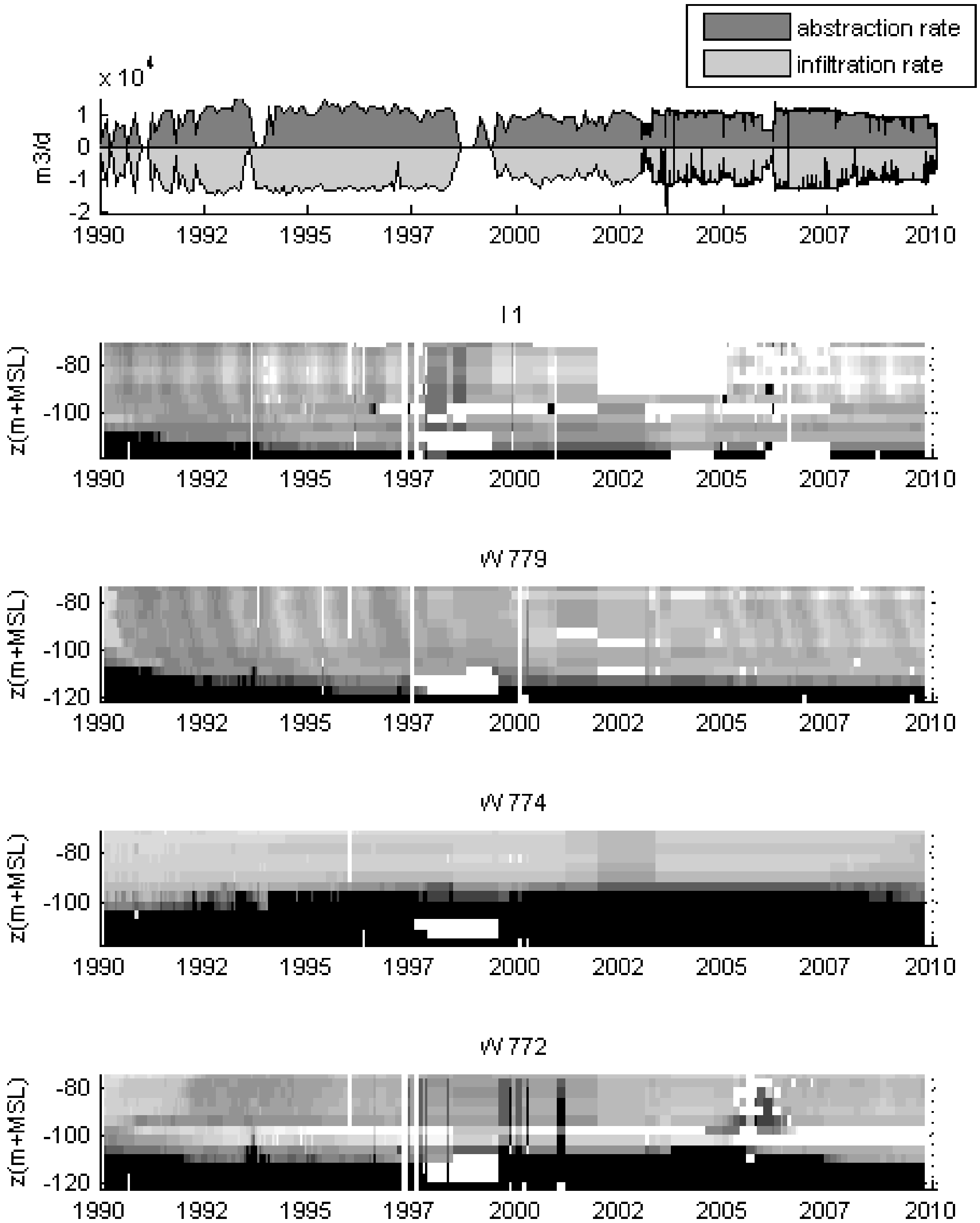

Figure 2. Some EC measurement results. The first graph shows the total infiltration and abstraction rate, for the last 20 years. The other graphs give an impression of the measured electric conductivity.