Freshwater-Saltwater Mixing Zone in Coastal Aquifers: Biased vs. Reliable Monitoring

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ABSTRACT

The installation of monitoring boreholes may cause local vertical flow due to a natural vertical hydraulic gradient at the well location. This causes the borehole to act as a “short circuit” along the gradient, connecting the higher and lower hydraulic head zones. As a result, flow in the borehole (ambient flow) is often large enough to compromise the integrity of water samples and groundwater table measurements. Until the 1980’s, it was still argued that long screen boreholes were more sensitive to the presence of different water bodies than short screen wells because of a better hydrologic connection with the aquifer and the ability to use discrete sampling based on electrical conductivity profiles. Since the late 1980’s, the use of long-screen boreholes for groundwater sampling has been countered in the literature by many studies.

Most of the ~500 monitoring boreholes in the coastal aquifer of Israel are installed with 10-50 m long screens. Our knowledge of the freshwater-saltwater mixing zone is mainly supported by data from hundreds of these long-screened boreholes and from geophysical studies.

In this study we present measurements of groundwater levels and freshwater-saltwater mixing zone fluctuations from a long screened borehole in the coastal aquifer of Israel along with a three dimensional numerical model. The groundwater tidal effects are modeled using FeFlow, a 3D finite element simulator that solves the coupled variable density groundwater flow and solute transport. Although the undisturbed groundwater flow in a coastal aquifer can be simplified into a two dimensional flow on a vertical cross-section, the borehole introduces a radial flow with a component perpendicular to the cross-section; therefore, a 3D model is required for this problem (Figure 1). With this modeling, we are able to describe the biased monitoring of a fully screened observation-well, in which the fluctuation magnitude of the mixing zone is an order of magnitude larger than that in the porous media. The primary parameters that affect the magnitude of this bias in the observations are the anisotropy of the hydraulic conductivity and the differences between the aquifer and borehole hydraulic parameters (borehole hydraulic conductivity depends on its diameter). With no sea-tide, borehole interference is higher for the anisotropic case because the vertical hydraulic gradients are high. When tides are introduced, the amplitude of the mixing zone fluctuation is higher for the isotropic case because the overall effective hydraulic conductivity is greater than the conductivity in the anisotropic case. The large fluctuations of the freshwater-saltwater mixing zone occur only in the borehole and do not occur in the aquifer.

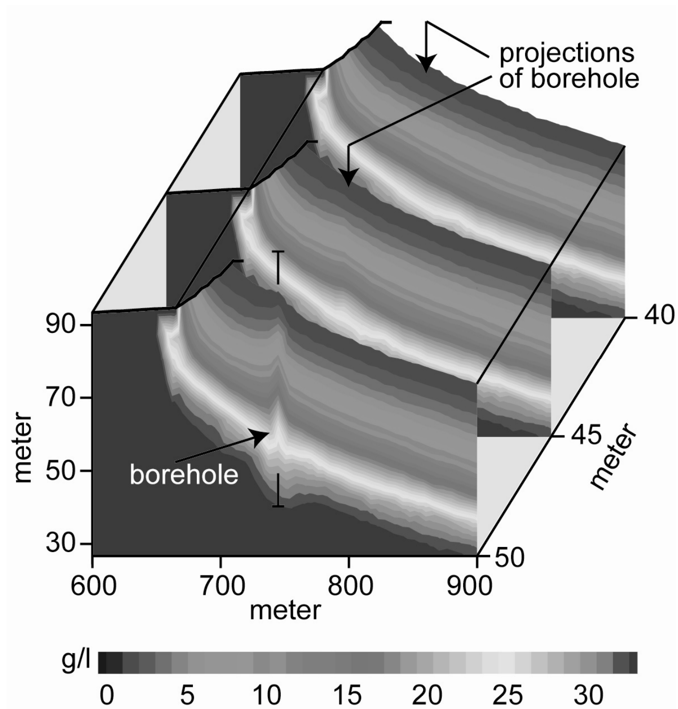

Figure 1. Simulation results showing salinity distribution around the borehole for the anisotropic case. The borehole affects the natural flow and elevates the freshwater-saltwater mixing zone. Away from the borehole the natural flow is undisturbed.

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