Geogenic saltwater intrusion into a freshwater aquifer – a case study in northern Germany

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ABSTRACT

Since the beginning of the 2000's, the freshwater demand of the city of Plön, Schleswig-Holstein, northern Germany (population approx. 13,000) has been supplied by just one water plant after a second plant was shut down due to anthropogenic contaminations as well as to saltwater intrusions. Increasing extraction rates in the freshwater wells led to a significant rise in chloride concentrations, and subsequent shutdown of extraction wells on the remaining production site as well. To warrant continuous supply of the city's freshwater demand of about 700,000 m^3/a, the exploitation concept had to be optimized including conceptualization of additional well locations enabling extractions at sufficiently low chloride concentrations.

Saltwater intrusion in the Plön area originates from a salt wall situated directly beneath the extraction area at depths >400 m below surface. Saline waters then rise to near-surface depths through a system of faults associated with salt tectonics. The remaining freshwater reservoir on top of the saltwater surface reaches a thickness of about 70 m at maximum. Underneath this relatively thin freshwater layer, saline waters (electrical conductivity >1,000 µS/cm) are spread throughout the investigation area of more than 30 km^2.

The geology of the area consists of largely Quaternary sediments, mostly glacial outwash with some intercalated till layers. West of the extraction galleries, glacial sediments are thrusted in a Weichselian-age push moraine leading to higher topographic relief than in the rest of the area. In the eastern part of the investigation area, a dome of calcareous sediments of Cretaceous age almost reaches the surface. The area is further covered with many freshwater lakes, equally of glacial origin.

To devise alternative locations for sound freshwater extraction, the following investigations were planned and performed:

- mapping of the saltwater surface by a geoelectrical survey
- mapping of groundwater recharge rates
- construction of a conceptual hydrogeological model
- generation and operation of a numerical groundwater model including transport of chlorides

From the modeling efforts, the following results were produced:

- The saltwater surface reaches its highest levels (i.e., freshwater thickness is lowest) directly beneath the lakes and on top of the Cretaceous dome

- The saltwater surface is steadily held low in areas overlain by sediments of low hydraulic conductivity (mostly tills). This is particularly the case beneath the push moraine where the saltwater table reaches its lowest level at about 70 m below surface.
- Further, areas with prevailingly high hydraulic (freshwater) gradients also contribute to lowering of saltwater levels.
- The freshwater body is generated by groundwater recharge and lakewater infiltration in approximately equal shares.

Under consideration of these results optimized well locations were be determined and successfully tested by test wells. The test results reconfirmed the suitability of the locations with respect to freshwater extractions in high quality as well as sufficient quantity.