

Influence of long-term climate variations on a freshwater/saltwater system in northern Germany

E. Koesters¹, P. Vogel¹, K. Schelkes¹

¹ Federal Institute for Geosciences and Natural Resources (BGR), Germany

EXTENDED ABSTRACT

The Gorleben site in the northeastern part of Lower Saxony in Germany is on the banks of the River Elbe between the terminal moraines of the late Saalian Warthe stadial and the terminal moraines of the Weichselian glaciation. A regional model was developed to investigate the palaeohydrogeological behaviour of the density-dependent groundwater flow in the area surrounding this site.

The most important aquifers above the Gorleben salt dome consist of Miocene lignite sands and coarse-grained Quaternary glaciofluvial deposits. Intercalated clay layers and thick glacial tills of the Elsterian and Saalian glaciations act as very low-permeability aquitards and low-permeability aquitards, respectively. In general, Palaeogene clays, especially the Rupelian Clay (Oligocene), form the base of the hydrogeological model. In some areas, salt domes are close to the lower boundary of the model, sometimes forming the lower boundary, like the Gorleben salt dome. Salt dissolves in these areas, increasing the groundwater salinity (in some places up to that of saturated brine), and leading to a density-dependent groundwater flow field. A hydrogeological section crossing the Gorleben site (Fig. 1), was used as the basis for the density-dependent groundwater flow modeling (Koesters et al. 2000). The River Elbe and the surrounding lowlands in the centre of the cross section are the main discharge areas. Two major recharge areas in the SSW and in the NNE parts of the cross section are the hills formed by Saalian or Weichselian moraines. Groundwater flow is predominantly from these hills to the River Elbe.

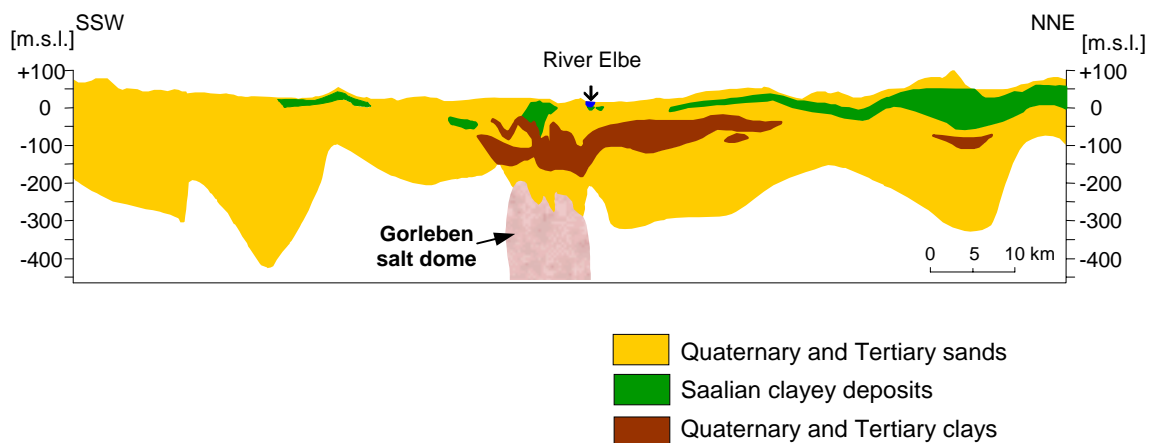


Figure 1: Schematic hydrogeological cross section

Permafrost is one of the most important processes influencing the groundwater flow field and the time-dependent development of the salinity distribution in the aquifer system. The effects were included in the model calculations. Frozen sediments with a time-dependent variable thickness act as a changing upper boundary. The simulation of permafrost development for the cross section was based on a palaeotemperature curve for the Gorleben region (Delisle 1998) and indicate the

different patterns of permafrost distribution (Fig. 2), which were then included in the groundwater model.

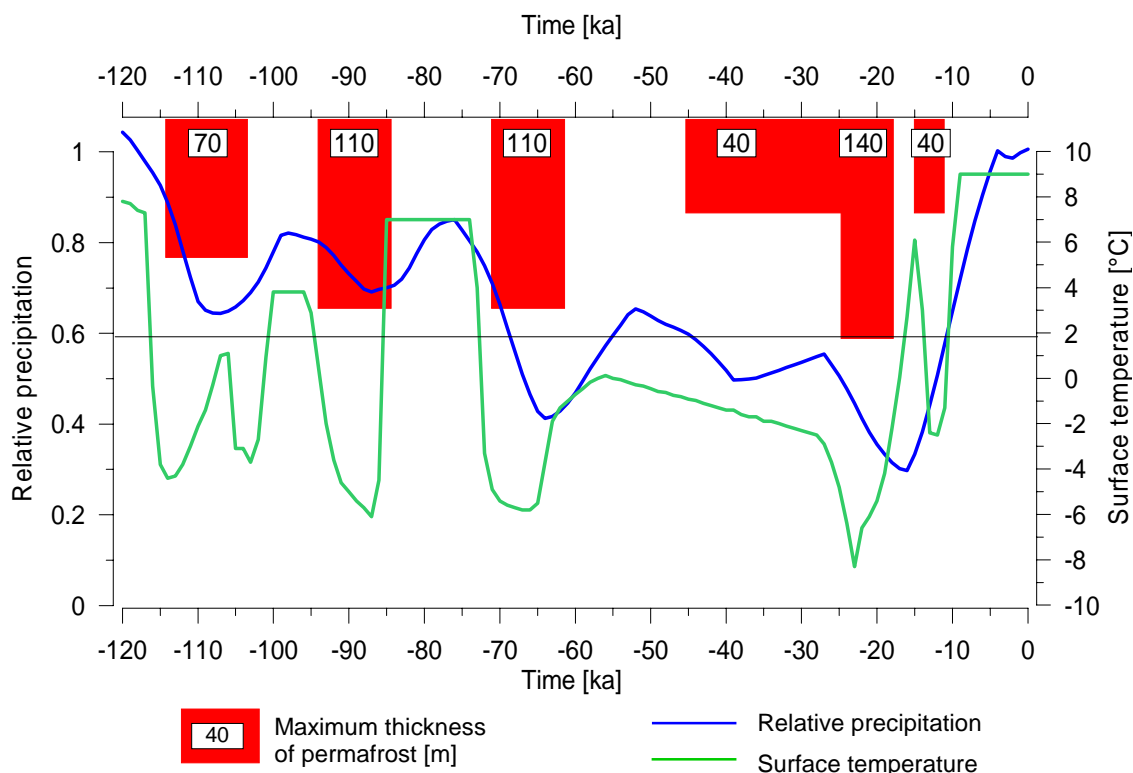


Figure 2: Climatic conditions and thickness of permafrost

The SUTRA code (Voss 1984) was employed for the groundwater simulations. The discretization of the hydrogeological cross section is based mainly on the spatial distribution of the hydrogeological units and the calculated frozen area, which was handled as a very low permeability layer. The hydraulic head at the upper boundary was reconstructed on the basis of the mean precipitation history (Fig. 2). Depending on the presence of an advancing ice sheet inflow of meltwater was specified at the northeast boundary of the model area.

Based on permafrost calculations, the period of 120 000 years from the Eemian interglacial to the present was subdivided into 14 stadial/interstadial intervals, each with a certain annual recharge distribution, mean surface temperature, and permafrost distribution. In addition to the time-varying boundary conditions, several sets of model assumptions were used, forming a series of scenarios. The most important stadial interval is the peak glaciation period about 20,000 years ago. Meltwater flows under high pressure at the bottom of the advancing ice sheet into the aquifer underlying the permafrost.

It can be concluded from the results of these model calculations that long-term climate changes have a significant impact on groundwater flow. The results reveal some of the hydrogeological features and parameters that have a strong effect on groundwater movement and solute transport. Whenever permafrost prevails, the spatial distribution of groundwater discharge is determined by the location of rivers and lakes, where taliks may form. The main groundwater flow direction in the deeper aquifer above the Gorleben salt dome often changes with the transition from stadial to interstadial and vice-versa (Fig. 3). During stadials and glacials the movement of the salt water is northwards and during the interstadials and interglacials it is southwards.

The proximity of a glacier front during the peak period of the last glaciation has a profound influence on groundwater recharge. Recharge with meltwater at the base of the ice sheet affects the magnitude and direction of groundwater flow on a

local or regional scale. Depending on the existence of a lake adjacent to the glacier, complete or partial flushing of saline water from the lower aquifer above the Gorleben salt dome may result. It follows from this study that the hydraulic conditions since the peak period about 20,000 years ago are decisive for the present-day situation in the regional groundwater system and the salinity distribution.

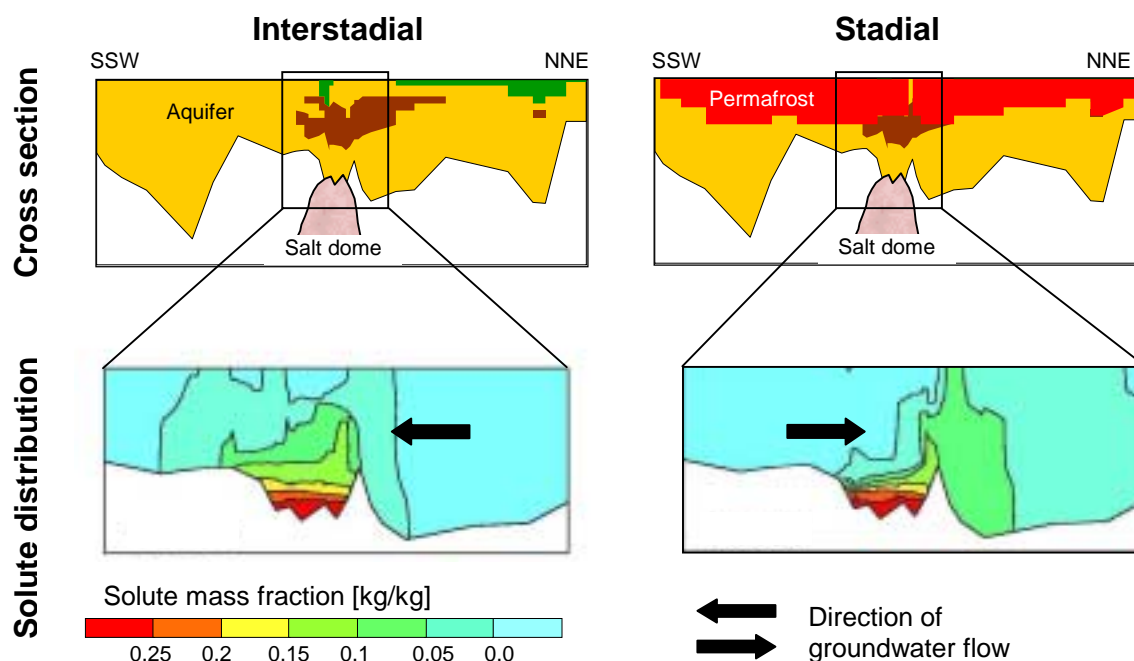


Figure 3: Solute distributions and directions of groundwater flow above the Gorleben salt dome at a typical stadial and interstadial.

References

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Corresponding author: Klaus Schelkes, Federal Institute for Geosciences and Natural Resources (BGR), Stilleweg 2, D-30655 Hannover, Germany
e-mail: k.schelkes@bgr.de