Scoping Studies on the Effect of Quaternary Climate Change on the Hydrogeology in the Sellafield Potential Repository Zone

J A Heathcote
Entec UK Ltd, 160-162 Abbey Foregate, Shrewsbury, SY2 6AL UK

Introduction

The present investigations in the vicinity of the Sellafield potential repository zone (PRZ) have provided data on groundwater pressure (presented as freshwater head) and salinity to a depth of some 2000 m, for a section extending from the hills to the east of the zone, to the coast. As part of the process of demonstrating the suitability of the site for a deep radioactive waste repository, work has been undertaken to reconcile these observations of pressure and salinity with an understanding of the hydrogeology of the site. It is considered possible that the long glacial historyof the site may in part be responsible for present observations. This work documents some preliminary studies to determine the possible magnitude of such glacial effects, using SUTRA (Voss, 1984).

Glacial Effects

Three kinds of effects were considered: land elevation changes, sea level changes, and changes in recharge quantity. Possible effects of glacial loading, other than relative elevation changes, were not investigated.

Because no pre-Devensian sedimentary evidence has yet been found in the area, the parameter history necessary to model the last million years is largely based on assumptions. Oxygen isotope data from Prell et al. (1986) have been used to define three climates: warm (similar to or warmer than today), cold (boreal or periglacial, but no continental ice-sheet in the area), and glacial (area under continental ice-sheet). Nine full glacials are identified.

In a situation where both land surface and sea level are moving absolutely, it is necessary to define a suitable frame of reference. We define as a reference a peg on the present ground surface, at sea level. Using information from Clayton (1994), some 28 m of rock are eroded each glaciation, so the land surface is 252 mAR (above reference peg) at 1 Ma BP. Erosion in the uplands is less extensive, resulting in a net isostatic uplift of 21 m per glaciation, thus the elevation at 1 Ma BP was 411 mAR, to arrive at the present elevation of 600 mAR at the present.

During Warm conditions, sea level is assumed to be at the present elevation (0 mAR). During Cold climates, there is a eustatic fall to -15 mAR. During Glacial climates, eustatic fall is more than compensated by isostatic depression, and sea level rises to +15 mAR.

In the present Warm climate, recharge is around 300-500 mm/a on the lowlands. In the uplands, recharge is limited by rock permeability and the water table is near the surface. In Cold climates, precipitation is less and runoff is increased, reducing recharge. A value of 100 mm/a was used. The upland area is frozen and receives very little recharge. In Glacial conditions, recharge is limited to sub-glacial melting and is set to 20 mm/a, based on Boulton *et al.* (1993). This results in low heads beneath the ice-sheet in this model. Actual boundary conditions are quite uncertain and require further investigation.

Results

The histories of pressure and salinity for Borehole RCF3, located in the centre of the PRZ, calculated by the model are shown in Figures 1 and 2. During Warm periods, heads at shallow depth adjust rapidly to the increased recharge, but that salinity adjusts slowly. Heads may achieve near steady state during interglacials, salinity never does. At the present time, heads at depth are increasing, and salinity is decreasing. The mean positions about which heads and salinities fluctuate is different from the position to which they are trending with present boundary conditions.

More detailed study of the results suggests that of the three influences studied, variation in recharge has the greatest effect. Sea level change produces short term transients at shallow depth, and change in topography produces a steady trend most noticeable in the coastal area.

Conclusions

If the assumptions about cold climate recharge used here are approximately correct, glacial intervals have the ability to cause significant perturbations of deep saline groundwater systems, with salinity at shallow depth increasing during glacial periods. Associated sea level and topographic changes cause smaller effects.

Glacial cycles are sufficiently long that they cannot be considered a rapid process and the average used. They are too short for steady state ever to be reached, especially for the most recent transition, only ~10 ka ago. The system is probably not in equilibrium with the modern climate, and therefore it is not clear that steady state models using boundary conditions based on the present climate are realistic representations of the system.

It should be noted that this initial attempt at modelling the effects of climate change is rather crude and is a poor match to observations of pressure and salinity. No attempt has yet been made to improve this match, nor to consider other geochemical data which may record parts of the history.

Acknowledgements

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References

Boulton G S, Slot T, Blessing K, Glasbergen P, Leijnse T, and van Gijssel K, 1993. Deep circulation of groundwater in overpressured glacial aquifers and its geological consequences. Quat. Sci. Reviews **12** pp 739-745.

Clayton K, 1994. Glaciation of the British Isles: an approach seeking to determine the role of glaciation in landform development over the last million years. Nirex Report NSS/R337.

Prell W L, Imbrie J, Martinson B G, Morley J J, Pisias N G, Shackleton N J, and Steeter H F, 1986. Graphic correlation of oxygen isotope stratigraphy - application to the late Quaternary. Palaeoceanography **1** pp 137-162.

Voss C I, 1984. SUTRA. USGS Water Resouces Investigation Report 84-4369, 409pp.

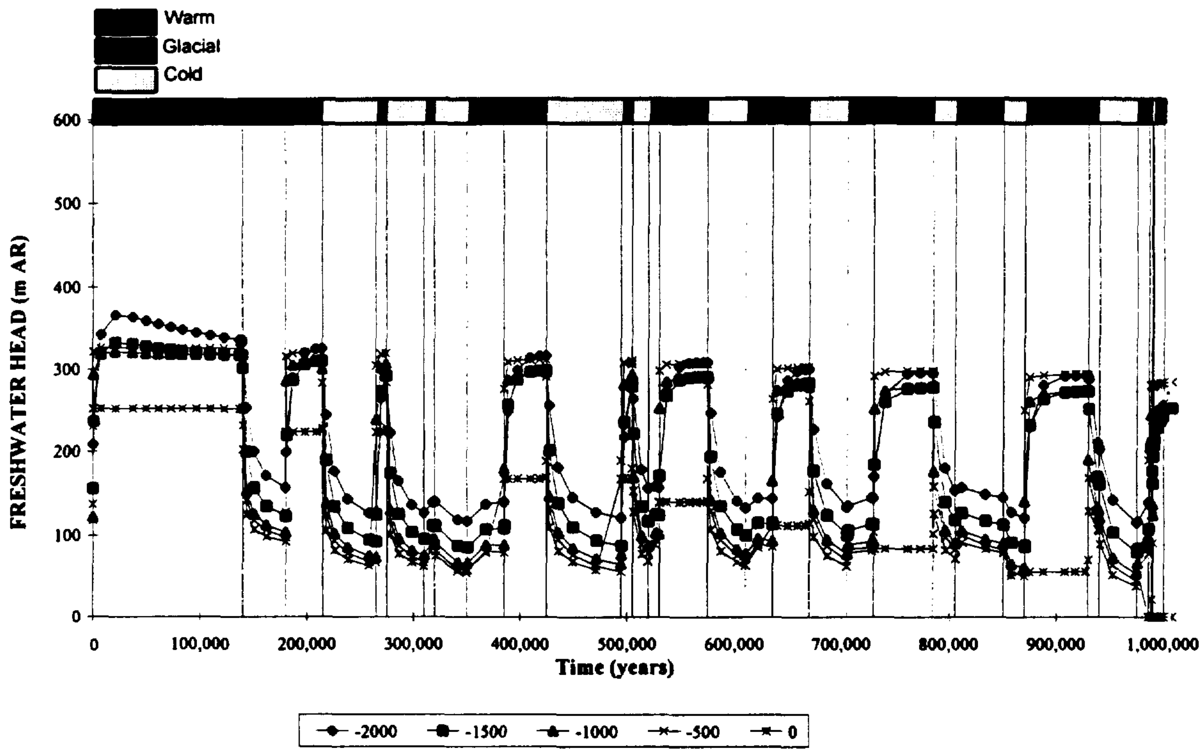

Figure 1 Computed Freshwater Head at Centre of PRZ

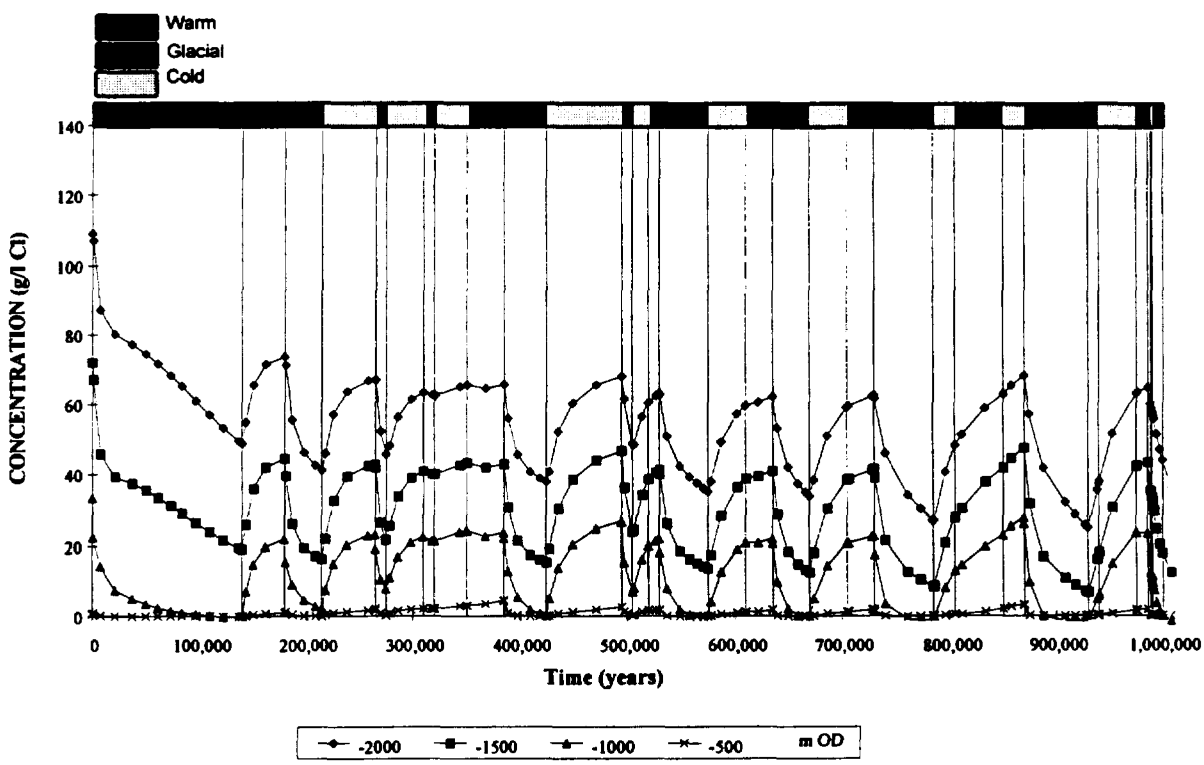

Figure 2 Computed Salinity at Centre of PRZ