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Response to SSM on Hydrogeological conditions during glacial effects

1 Background

SSM has requested a supplementary study where the hydraulic properties of the transmissive sheet joints observed at shallow depth (≥ –150 masl) are affected by forces of a continental ice sheet. The request, stated in SSM2011-2426, is as follows (translated): *SSM requests an additional analysis on the effect on groundwater flux at repository depth of the loads applied from a continental ice sheet due to changes in the hydraulic properties of the very transmissive structures found in the upper 150 m of the bedrock.*

The sheet joints at Forsmark are hydraulically heterogeneous but locally very transmissive (a high specific capacity value). A model variant with enhanced transmissivities is already handled in Vidstrand et al. (2010) and hence not repeated here. Instead, this document focuses on describing the setup and results of a simulation case where the sheet joints are excluded in the model setup.

2 Model setup

The structural-hydraulic model without sheet joints is identical to that used in Vidstrand et al. (2010) except that the additional transmissivity contribution from the three sheet joints is excluded from the model. Groundwater flow through the structural-hydraulic model without sheet joints is simulated using DarcyTools v3.4. Because DarcyTools v3.2 was in use at the time of SR-Site, the case with sheet joints (denoted WSJ below) has been rerun with v3.4 in order to facilitate the comparison with the results obtained from the supplementary case without sheet joints (denoted NSJ below).

The comparison reported here focuses on the calculated Darcy fluxes, in particular on the evolution of the Darcy flux at measurement locality 2 (ML2) in the case of an advancing ice sheet margin without permafrost in the proglacial area, see Chapter 6 of Vidstrand et al. (2010) for details. ML2 is located at repository depth in the centre of the suggested repository volume, i.e. ca. 300-400 m below the sheet joints. ML2 is assigned bedrock properties typical for a deposition hole environment.

3 Results

In Figure 1 below the effect on the permeability field of removing the sheet joints is illustrated in the x-direction (WE-direction). It is clear from the figure that the sheet joints have a significant impact on the permeability field creating a horizontal plane of higher permeability in the shallow bedrock. The removal of these structures lowers the upper bedrock permeability by one to two orders of magnitude in the x-direction. Because the lateral extent of the modelled sheet joints is limited, their exclusion only affects the bedrock permeability directly above the suggested repository volume.

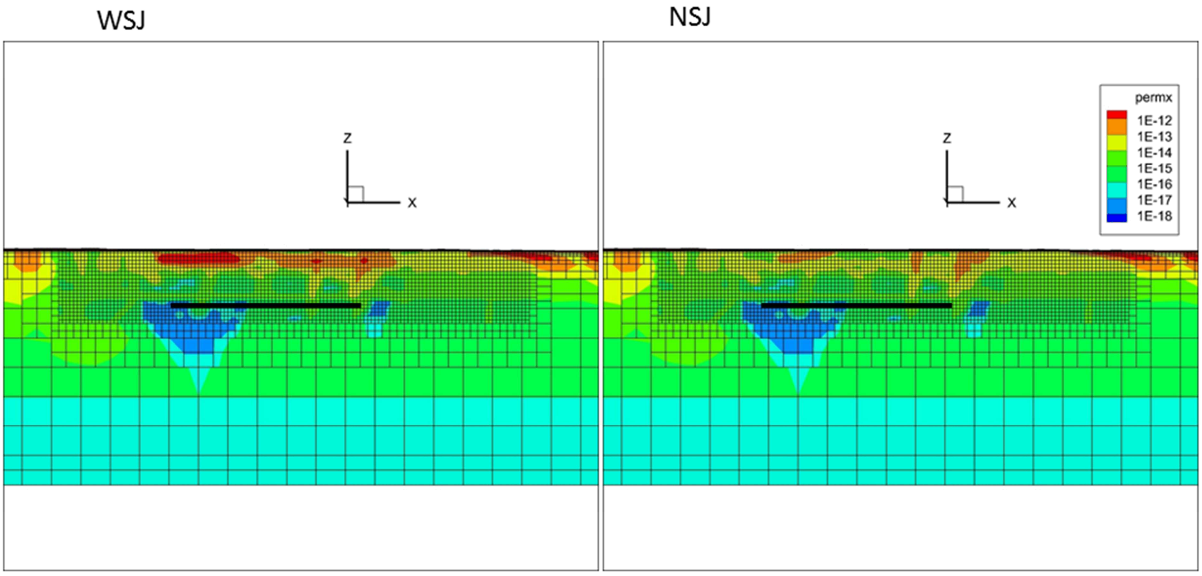

Figure 1. *Illustration of the permeability field in the x-direction along a WE cross-section. Left: With sheet joints (WSJ), Right: No sheet joints (NSJ). The effect on permeability in the y-direction is similar and the z-direction experiences a slightly smaller change.*

The calculated fluxes at ML2 for the two simulation cases are plotted in Figure 2. The exclusion of the transmissivity contribution from the sheet joints plays no significant role on the calculated Darcy fluxes at ML2. It is also noted that the case without sheet joints (NSJ) is similar to the case with sheets joints (WSJ) previously reported in Figure 6-16 in Vidstrand et al. (2010).

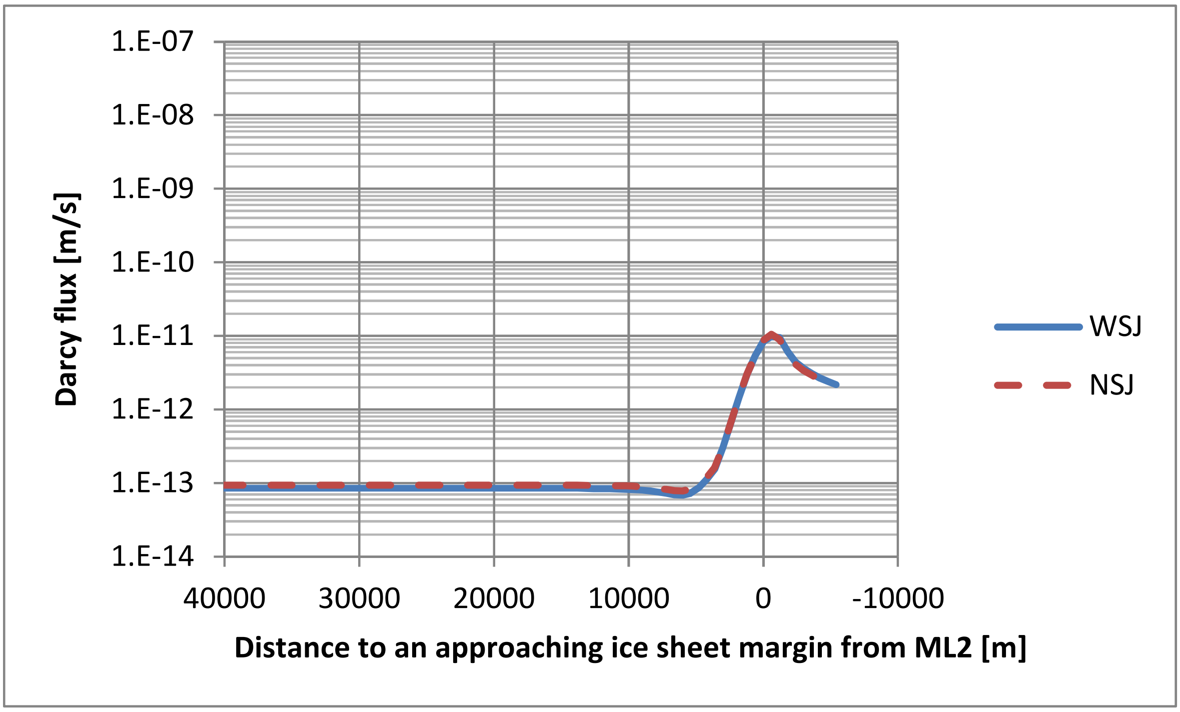

***Figure 2**. The evolution of the Darcy flux at ML2 for an advancing ice sheet margin. The time on the x-axis refers to the time since the simulation started with the ice sheet margin just northwest of the model domain. The Darcy flux is shown on the y-axis (in m/s or m^3/s and m^2).*

Figure 3 illustrates the Darcy flux in the z-direction on a cross-section for the two different cases simulated. No major differences can be distinguished.

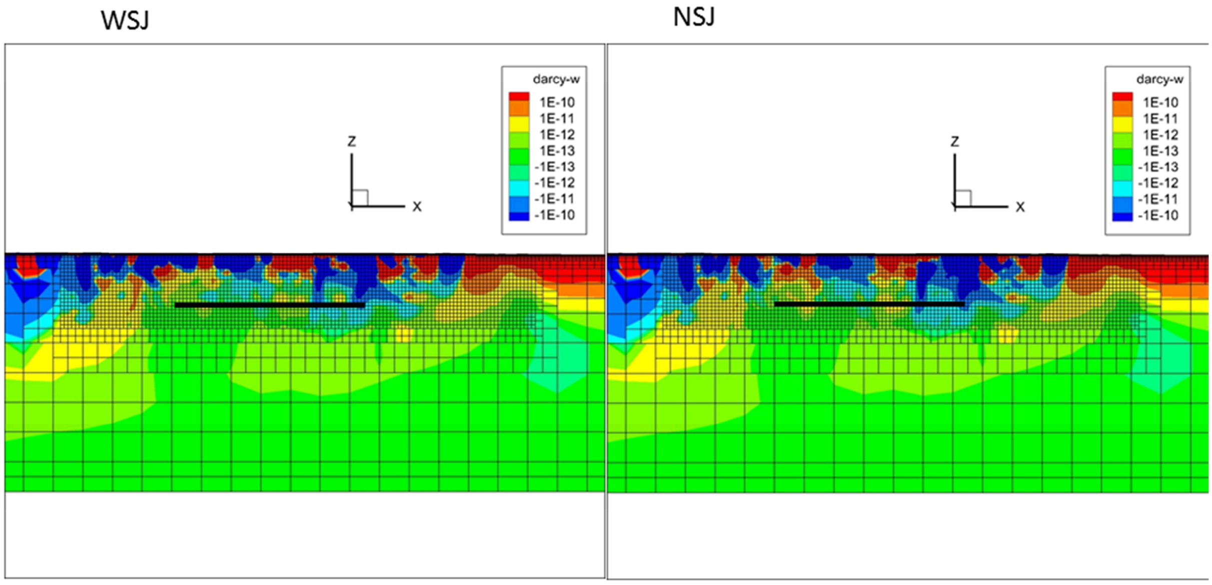

Figure 3. *Comparison of Darcy flux on a cross-section for the two different simulated cases.*

A question that arises is how much the simulation results are affected by the ECPM approach and the relatively coarse grid resolution used in the glacial simulations conducted for SR-Site (the grid resolution of the ECPM grid varies between $(32\ m)^3$ and $(250\ m)^3$). To test this effect the glacial case model of Joyce et al. (2010) was re-run with the sheet joints removed. Figure 4 illustrates that also in a DFN model (ConnectFlow) the removal of the sheet joints has a limited effect on Darcy flux at the suggested repository depth (please refer to section 5.7 and 6.4 of Joyce et al. (2010) for details of the original ConnectFlow model setup and results).

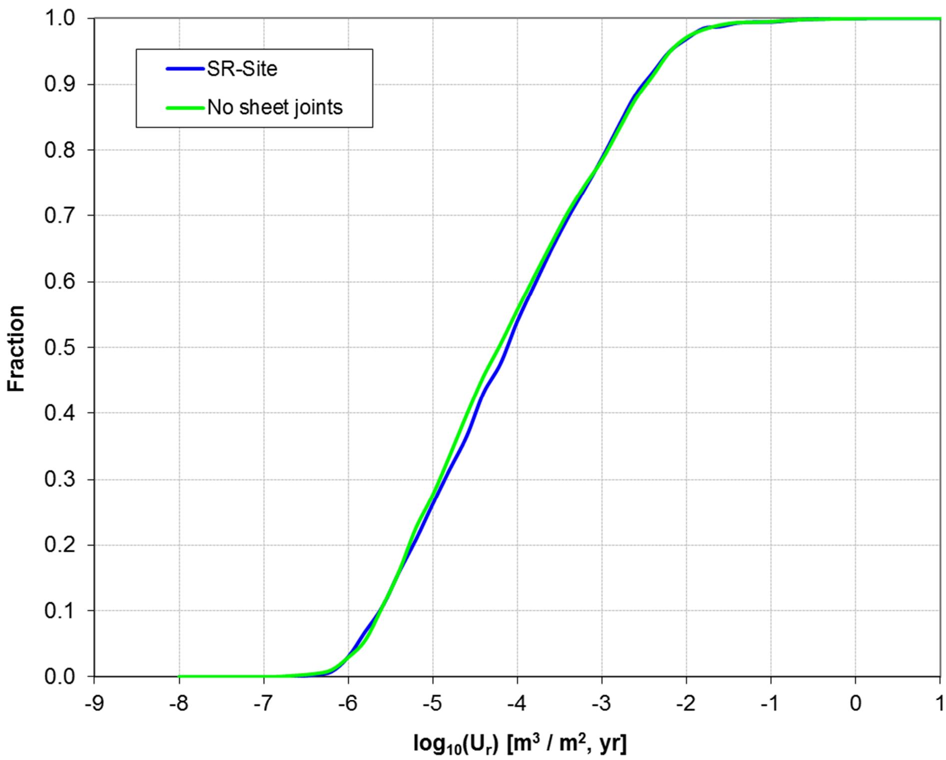

Figure 4. *Cumulative distribution of Darcy flux at the deposition hole locations.*

4 Conclusion

The results indicate that the exclusion of the sheet joints as modelled in SDM-Site has minute effects on the Darcy fluxes at repository depth in general and at ML2 in particular. This interpretation implies that the differences in fracture intensity (and other discrete fracture network characteristics) with depth by itself is enough to result in the observed lack of sensitivity to the sheet joints, cf. Figure 6-65 in the Data Report for the safety assessment SR-Site (SKB 2010).

References

Joyce S, Simpson T, Hartley L, Applegate D, Hoek J, Jackson P, Swan D, Marsic N, Follin S, 2010. Groundwater flow modelling of periods with temperate climate conditions – Forsmark. SKB R-09-20, Svensk Kärnbränslehantering AB.

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