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Numerical simulations of the impact of hydraulic anisotropy and anthropogenic activities on the complex hydrogeological system of the Lower Yarmouk Gorge

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Transient numerical simulations of coupled fluid flow and heat transport processes were conducted, to investigate (i) the impact of hydraulic anisotropy on a complex hydrogeological system and (ii) the anomalous geothermal gradient in the Upper Cretaceous (A7/B2) aquifer of the Lower Yarmouk Gorge (LYG). The N-S directed geological profile starts on the basalt-covered Golan Heights, crosses the LYG and ends at the Jordanian Ajloun Plateau. Heated fresh groundwaters ascend within the LYG from the confined A7/B2 limestone aquifer through artesian Meizar wells and artesian Muhkeibeh well field.
A hydrogeological study based on high frequency water-table measurements at the Meizar wells suggested strong impact of abstraction at the Mukheibeh wells on the hydraulic head distribution north of the LYG (Shalev et al., 2015). Contrastingly, hydrochemical investigations conducted in the area concluded that recharge areas of the A7/B2 aquifer are: (i) the foothills of Mountain Hermon, (ii) the Ajloun Plateau and (iii) the Syrian Hauran Plateau, indicating the presence of a zone of high-hydraulic anisotropy along the main LYG axis. Due to this still debatable hydraulic feature, flow along the LYG principle axis is enhanced whilst flow perpendicular to it is constrained (Siebert et al., 2014). In agreement, transient simulations based on a NW-SE profile supported further the hypothesis of a structural feature existent (Magri et al., 2015).
The modeled profile cross-cuts the heterogeneous zone and hence the heterogeneity was implemented as an impermeable zone by employing the Equivalent Porous Media approach. Initial 2D models managed to successfully reproduce the natural hydraulic head and temperature distributions. In subsequent simulations, by implementing Meizar abstraction rates, results revealed that mixed convection explains the anomalous temperature gradient in the area as temperature patterns of these simulations are in accordance with a temperature-depth borehole profile. Most significantly, the existence of a zone of anisotropic hydraulic conductivity at the LYG, as suggested above, is supported. Sensitivity analysis of the heterogeneous permeability zone (ranging between 1e-7 m/s and 1e-10 m/s) simultaneously displayed hydraulic connectivity and prevented fluid flux occurrence between the northern and southern LYG flanks. Within the studied aquifer system, aquifer topography directs groundwater flow towards the LYG (N-S and S-N). Once groundwaters reach the zone of hydraulic anisotropy the direction is diverted westwards, towards the Lower Jordan Valley. A final finding pointed to the inadequate size of the A7/B2 drainage basin south of the LYG as the Mukheibeh well field requires a larger drainage area.

References

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