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Heterogeneity of groundwater storage properties in the critical zone of Irish metamorphic basement from geophysical surveys and petrographic analyses

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Weathered/fractured bedrock aquifers contain groundwater resources that are crucial in hard rock basement regions for rural water supply and maintaining river flow and ecosystem resilience. Groundwater storage in metamorphic rocks is subject to high spatial variations due to the large degree of heterogeneity in fracture occurrence and weathering patterns. Point measurements such as borehole testing are, in most cases, insufficient to characterise and quantify those storage variations because borehole sampling density is usually much lower than the scale of heterogeneities.

A suite of geophysical and petrographic investigations was implemented in the weathered/fractured micas-chist basement of Donegal, NW Ireland. Electrical Resistivity Tomography provided a high resolution 2D distribution of subsurface resistivities. Resistivity variations were transferred into storage properties (i.e. porosities) in the saturated critical zone of the aquifer through application of a petrophysical model derived from Archie's Law. The petrophysical model was calibrated using complementary borehole gamma logging and clay petrographic analysis at multi-depth well clusters distributed along a hillslope transect at the site. The resulting distribution of porosities shows large spatial variations along the studied transect. With depth, porosities rapidly decrease from about a few % in the uppermost, highly weathered basement to less than 0.5% in the deep unweathered basement, which is encountered at depths of between 10 and 50m below the ground surface. Along the hillslope, porosities decrease with distance from the river in the valley floor, ranging between 5% at the river to less than 1% at the top of the hill. Local traces of regional fault zones that intersect the transect are responsible for local increases in porosity in relation to deeper fracturing and weathering. Such degrees of spatial variation in porosity are expected to have a major impact on the modality of the response of basement catchments to climate change and anthropogenic pressures.