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On the use of multi-method geophysical investigations for the delineation of hydrogeological connectivity in landslides

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We present a case study where different geophysical methods were conducted along with borehole data for the investigation of a recently developed landslide located in Wolfsegg, an urban settlement in Upper Austria (Austria). The study site is characterized by an intricate lithological setting that features layers of coal/lignite, gravelly sands, sandstones and clays in varying thickness and occurrence. It has been hypothesized that strong and long-lasting precipitation events are the triggering cause of the landslide, due to the build-up of positive pore-water pressures and associated reduction in shear strength, particularly for clayey sediments. Therefore, subsurface investigations are required to delineate the internal structure of the landslide as well as the textural composition of the clay-rich materials, which control the surface-groundwater interaction and groundwater flow. Hence, the geophysical investigations aimed at the subsurface characterization with high spatial resolution as required to define the geometry of the landslide, quantify the volume of mobilized material, and, in particular, delineate the hydrogeological structures. Furthermore, geophysical imaging results are applied to investigate hydrogeological subsurface connectivity, a concept that has not yet been applied in the scope of landslide research. Hydrogeological connectivity describing the connectivity of high hydraulic conductivity paths (e.g. preferential flow paths) is traditionally investigated through hydrological techniques, such as piezometer networks, slug and tracer tests. However, such techniques can only provide point-scale information and thus spatial up-scaling is needed. Hence, we propose here the application of diverse geophysical methods to gain information about subsurface properties across different scales and different depths of investigation to solve for a quasi-continuous 3D subsurface model. Our results are based on the combined application of shallow electromagnetic low-induction number (EMI) mapping and deeper 3D investigations using induced polarization (IP) and ground penetrating radar (GPR) profiles to solve for the spatial variations in the electrical subsurface properties. Moreover, deeper variations in the electrical properties were validated through transient electromagnetic (TEM) 3D surveys. Furthermore, seismic refraction tomography (SRT) datasets were collected along different transects for an improved interpretation of the electrical images. Besides the combined interpretation of the geophysical results including borehole information, in a further step structural information obtained through SRT, TEM and well-bore data were used to constrain the IP imaging results applying a joint-inversion approach. Eventually, we integrate such multi-type (geophysical, wellbore, soil-physical and hydrogeological data) and multi-scale (e.g. EMI and TEM) data into a Bayesian hierarchical model and discuss the model output – the hydrogeological connectivity within the landslide.

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