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Hydrogeological modelling as a tool for understanding rockslides evolution

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Several case studies of large rockslides have been presented in the literature showing dependence of displacement rate on seasonal and annual changes of external factors (e.g. rainfall, snowmelt, temperature oscillations) or on human actions (e.g. impounding of landslide toe by artificial lakes, toe excavation).
The study of rockslide triggering can focus on either the initial failure or the successive reactivations driven by either meteo-climatic events or other perturbations (e.g. seismic, anthropic). A correlation between groundwater level oscillations and slope movements has been observed at many different sites and in very different materials and slope settings. This seasonal dynamic behavior generally shows a delay between perturbation (e.g., groundwater recharge and increase in water table level) and system reaction (e.g., increase in displacement rate). For this reason, groundwater modeling offers the means for assessing the oscillation of groundwater level which is a major input in rockslide and deep-seated gravitational slope deformation modelling, and that could explain both the initial failure event as well the successive reactivation or the continuous slow motion.
Using a finite element software (FEFLOW, WASY GmbH) we developed 2D saturated/unsaturated and steady-state/transient groundwater flow models for two case studies for which a suitable dataset is available: the Vajont rockslide (from 1960 to October 9th 1963) and the Mt. de La Saxe rockslide (2009-2012, Aosta valley; Italian Western Alps).
The transient models were implemented starting from hydraulic head distributions simulated in the previous steady-state models to investigate the groundwater fluctuation within the two chosen times interval (Vajont: 1960-1963 ; La Saxe: 2009-2012). Time series of infiltration resulting from precipitation, temperature, snowmelt data (La Saxe rockslide) and reservoir level (Vajont rockslide) were applied to the models. The assumptions made during the construction of the models, in particular the partition of the slope in different sectors with different hydraulic conductivities, are coherent with the geological, structural, hydrological and hydrogeological field and laboratory data.
The sensitivity analysis shows that the hydraulic conductivity of some slope sectors (e.g. morphostructures, compressed or relaxed slope-toe, basal shear band) strongly influence the water table position and evolution. In transient models, the values of specific storage coefficient play a major control on the amplitude of groundwater level fluctuations, deriving from snowmelt or induced reservoir level rise. The calibrated groundwater flow-models are consistent with groundwater levels measured in the proximity of the piezometers aligned along the sections.
The two examples can be considered important for a more advanced understanding of the evolution of rockslides and suggest the required set of data and modelling approaches both for seasonal and long term slope stability analyses. The use of the results of such analyses is reported, for both the case studies, in a companion abstract in session 3.7 where elasto-visco-plastic rheologies have been adopted for the shear band materials to replicate the available displacement time-series.