Geophysical Research Abstracts,
Vol. 11, EGU2009-11450-2, 2009
EGU General Assembly 2009

Water related triggering mechanisms of shallow landslides: Numerical modelling of hydraulic flows in slopes verified with field experiments

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To assess hill slope stability and landslide triggering mechanisms, it is essential to understand the hydrogeological regime in slopes. In this work finite element models are elaborated and field experiments are carried out to study particularly shallow landslides with thickness of a few meters. The basis hypothesis of the presented research assumes that even for shallow landslides the hydrogeological role of the substratum, mostly bedrock, is determinant for the slopes behaviour, either it is draining or feeding the overlaying unstable mass.

The investigated area of about 1 square kilometre is situated next to the villages Buchberg and Rüdlingen (canton Schaffhausen, Switzerland) at the border of the river Rhine. The lithology in this region is characterized mainly by horizontally layered sandstones intersected by marls from the upper seawater and the lower freshwater molasse, overlaid by soil and weathered bedrock of about 1 to 4 m thickness, both classified as silty sands. With a slope inclination of locally up to 40° the area is rather steep and characterized by continuous regressive erosion processes. During heavy rainfall events, such as the one from May 2002, shallow landslides occurred in the area affecting afforested soils as well as woodless areas. Geological field observations, infiltration and tracer tests show a fairly complicated hydrogeological character of the region. Along the slope, in the first few meters of depth, no groundwater table was found. However, seasonally controlled sources can be observed in-between outcropping bedrock. Within the sandstone, vertical faults in decametre scale oriented parallel to the Rhine that most likely opened during decompression due to the cutting of the river affect locally the hydrogeological regime by draining the slope. This implies a high grade of heterogeneity in the water flows in a local scale.

Based on these conceptual hydrological and geological models, a numerical flow model was obtained using finite element software. Different scenarios of groundwater flow pattern and hydraulic head distribution in the saturated and unsaturated zones were modelled considering transient hydraulic conditions. The hydraulic pressure boundary conditions can then be introduced in a geomechanical model in order to evaluate mass movements and to estimate the soil stability. In a next step, a 10 x 30 m large test side situated inside the above mentioned study area was chosen to investigate the slopes behaviour during a triggering field experiment carried out in October 2008. With the aim to provoke a shallow landslide the test site with a mean inclination of 35° was intensely irrigated with sprinklers during 5 days (20 – 30 mm/hr). Transient soil parameters such as suction, pore water pressure and saturation at different depth, water infiltration rate, ground water table and soil movements in a mm-scale were measured.

During this first field experiment, the slope remained stable. At this state the results of experiment and models suggest that:
- At the experiment scale, heavy rainfall is not sufficient to trigger a mass movement if the hydrogeological conditions inside the substratum (bedrock) are not in a critical state as well. During the experiment, the bedrock was not saturated and played a draining role.
- The behaviour of the local area, at the experiment scale, must be modelled within a regional scale (e.g. kilometric) to consider the role of hydraulic pressures inside the bedrock.

The results obtained from the experiment will be used to refine the numeric models and to design future field experiments.