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First results of a large-scale multi-tracer test within an unstable rockslide area (Åknes, Norway)

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As part of the Åknes/Tafjord project in Norway (Blikra 2008) a multi-tracer test with six fluorescent dyes and Bromide was performed in the rockslide area of the Åknes slope. A 500-600 m long tension fracture, the main scarp, marks the upper boundary of the unstable slope at around 800 m asl. According to (Blikra et al. 2007) the unstable rockslope can be divided into a western flank and an eastern block. The western flank is max. 650 m long (as measured downslope) and 400 m wide (as measured in the horizontal direction), has a volume of 10-14 million m^3 and a sliding rate of 8-10 cm/year. The eastern block is up to 500 m wide, 900 m long and slides with 2-4 cm/year. The depth and therefore the volume of this block are still unclear. The most probable scenario estimates a rockslide of about 30-40 million m^3 and a maximum one of about 70-90 million m^3. The rock mass consists of massive gneiss with mica layers. Below around 600 m asl the foliation is gently dipping with 30-35° towards southeast and is oriented parallel to the slope (Ganerød et al. 2007). Three drilling platforms have been installed in the steep unstable slope: The upper borehole locality is standing on the western flank at an elevation of 661 m asl, the middle (563 m asl) and lower (242 m asl) one on the eastern block.

Extensometers measuring the opening of the tension fracture at the upper boundary react strongly to precipitation. Therefore the hydrogeological situation is important for the understanding of rockslide processes. Five springs were detected at a middle spring horizon (370-460 m asl) and eleven were found at a lower one (90-120 m asl), which is located at the foot of the unstable area. All together showed a total discharge rate of 9 l/s after a periode of 5 days with 8 mm of rain followed by three sunny days in August 2007. Although the variability of the flowrate has to be estimated, the value could be compared with the annual precipitation for a water balancing in the future. The springs of the lower horizon can be grouped based on chemical composition and electrical conductivity. Significant differences between the groups lie in the range of 20-30 μS/cm.

In order to develop an understanding of the groundwater flow paths, four fluorescent dyes were injected along the main scarp, Eosin above the western flank, Amino-G above the boundary of the western flank and the eastern block and Uranine and Pyranine above the eastern block. Sulphorhodamine-B was released in the upper borehole in a depth of 120 m below surface, Sodium-Naphthionate 40 m deep in the middle borehole and Bromide in the surface runoff of the large trench at the western boundary of the rockslide. Daily samples were taken during one month from five individual springs, the middle and lower borehole, along the two spring horizons (7 sampled springs) as well as from surface runoffs at the western and eastern side of the rockslide area. Some of them were sampled up to three months.

First results of Sulphorhodamine-B and Eosin can now be presented. Pyranine was also analysed but wasn't recovered in any of the springs. Sulphorhodamine-B was injected where the largest outflow of a borehole of the 661 m drilling platform was observed (Thoeny et al. 2008). After 19 hours the tracer appeared at one of the lower springs 420 m below (altitude) and 920 m in line of sight with respect to the injection point in the borehole. The maximum tracer concentration was already measured 67 hours after injection. This results in a dominant flow velocity of 13.7 m/hour. At one spring of the middle horizon the first signs of the same tracer were observed 11 hours after the injection. The maximum concentration arrived after 28.75 hours, leading to a dominant flow velocity of 13.9 m/hour. This spring is located in a distance of 400 m with 135 m of altitude difference.

Eosin was released on the western side of the scarp and appeared again in all springs of the middle and lower horizon after 15-20 days. This tracer was injected into the unsaturated zone. On the eastern side a streamlet flows directly into the main scarp, where Pyranine was used. Until now, this tracer could not be observed at any spring. It is assumed that this streamlet flows along a deeper groundwater pathway and eventually discharges directly into the fjord at the slope bottom.

The first results show that not all water infiltrating into the main scarp reappears at the two main spring horizons at 90-120 m and 370-460 m asl. Tracers injected on the west side, in the scarp or deep in the upper borehole appeared again and spread over the whole length of the middle and lower spring horizon. Pyranine released on the eastern side couldn't be recovered anywhere.

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