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A century-long landslide history in Norway

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The main railway line between Oslo and Trondheim (2nd and 3rd largest cities of Norway) passes through many landslide-prone areas. Natural slopes in Quaternary deposits at the large glaciofluvial deposit Hagamælen, situated at Støren in Gauldalen valley, have caused landslide problems with historical records dating back to year 1345. The collapse of a landslide dam caused a catastrophic flood wave which covered the rural areas downstream of the landslide. Since construction of the railway line in the 19th century, landslides have hit the railway line with irregular intervals. Natural slopes are steep, with inclination up to 45 deg. High ground-water level results in theoretically unstable slopes for normal friction angles in sand, silt and clay; however, geotechnical data is scarce. On average, the return period of landslides was evaluated to approx. 10 years. Many events have reached and blocked the railway line.
The deposit consists of thick layers of stone and gravel, gradually changing towards finer sediment at depth. At level with the slope's foot, marine clay is encountered. Quick-clay probably played a role in triggering of the large landslide in 1345, but does not seem to be involved in recent landslide processes.
Rainwater and meltwater on the terrace on top of the more than 100 m thick deposit immediately infiltrates into the course-grained ground. At increasing depth, gradually finer soils are encountered. Groundwater daybreaks at a layer boundary between sand and silt, 20-30 m above the railway line. Surface water concentrates in ravines shaped by earlier landslides. Further landslide activity increases the relief of the slopes by deepening the ravines. Seasonal variation in pore-water pressure and probably also soil suction is relevant for landslide release at the site. In spite of a conceptual understanding of the landslide process in the slopes, the knowledge of geotechnical and hydrogeological factors needs to be expanded. Laboratory testing for estimation of retention properties of local soils was performed, in addition to in situ instrumentation with temperature and moisture sensors. Further instrumentation should include an increased number of sensors and locations, and measurement of pore-water pressure with piezometers. The aim of this work is to reach an increased understanding of the slope response, coupling landslide release to rainfall events, and also facilitating local landslide warning. The work is performed within the Centre for Research-based Innovation Klima 2050 (www.klima2050.no).
Slope stabilization measures in active ravines performed around year 2000 was inspected in 2016, and seemed effective. Slope stabilization was continued in 2017. Stabilizing measures consist of a combination of drainage ditches and stone cover on the slope, supplemented by reinforcement of the slope's toe.