Climate change enhanced risk for mass failure of sediment into rivers – how do we manage such events?

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Introduction: In this presentation emphasis is given to the awareness of extreme events, partly dependent on climate changes, and the impact on the risk for mass failure and how prepared we are to meet such events.

Periods with heavy rain, long lasting rain and flooding of rivers increases the risk for mass failure of land into the water because of an increase in soil pore pressure or groundwater level these events causes, and the reduce in resisting forces that occur when surface water level falls back to normal while soil pore pressure still remain high. And, an increased erosion due to flow change. A mass failure of soil into rivers may cause severe consequences both near and far field. Damming effects, destroyed infrastructure, closure of waterways, and transport of huge amounts of sediments to downstream areas, disturbance of bank and bottom sediments due to changes in flow, just to mention some. For the Göta Älv river in Sweden we know that these scenarios may come true. The largest threat that is seriously discussed within the communities concerned is the risk for a giant landslide and how that may affect the downstream areas and the city and harbour of Göteborg at the river mouth. The Göta Älv river is an important waterway linked to the harbour and it is the drinking water supply for 700 000 inhabitants. Historically, large and small landslides have shaped the river and there are still several areas that constitute a risk for sliding out into the river. In addition, some of these instable areas contain soil and groundwater that are heavily contaminated [1].

Methods: In 2005 the Swedish Geotechnical Institute (SGI), commissioned by the Swedish government and based on the climate change scenarios, presented an action plan on how the SGI intend to manage an increased risk for landslide due to climate changes [2]. In 2007 a simplified analytical analyse was made on the contaminant transport from a theoretical landslide of an old contaminated shipyard along the Göta Älv river with the purpose to roughly estimate possible concentrations in the water body [3].

Results: Theoretical computation on shallow slopes of cohesive soils in varying geology showed that the slope stability decreased by 2% to as much as 30% depending on geological stratification and the impact from yearly precipitation, increase in surface water level and increase in pore pressure [2]. For steep sandy and silty slopes the slope stability decreased about 15% [2]. The changes in pore pressure and groundwater that may be a result from the climate changes leads to a lowering of slope stability compared to the situation of today. Especially rapid and short changes, as intense rain, will have a large impact, together with increased erosion of the river. The simplified analytical analyse on the contaminant transport indicate that the concentration of, in this example Zn, probably would exceed general background level by more than a 100 times when the Zn pulse passes the fresh water intake and the city of Göteborg.

Discussion: Based on the climate change scenarios for the west coast of Sweden the calculations clearly indicate an increase in the risk for mass failure of land (sediment). It also reveals that contamination of the water body and the sediment may be severe. We do not know for sure which consequences follow a giant landslide, we can only speculate based on history and expert knowledge. Questions that arise are: how dammed the river will become, followed by flooding of upstream areas; what hydraulic effects will follow and giving which consequences; how much soil will get released from the slided mass and how far will it travel; how will communities, industries, infrastructure, harbour and the estuary get affected? The impact on the quality of the water body as well as the sediment must also not be neglected, both during the event it self but also during the dredging activity to clear the waterway. Even though the probability for a giant landslide is assumed low the possible consequences makes it a risk we are not willing to take and that is why large efforts now are being made for preventative actions for the Göta Älv river. Nevertheless, we need tools to manage such "low frequency but high magnitude" events since the economical resources for prevention and measures are strongly limited.

References: [1] Göransson et al. (2009) *J Soils Sediments* **9**:33-45; [2] Hultén et al. (2005) SGI Varia 560-1; [3] Göransson (2007) unpublished;