Modelling landslide-flood interactions: an example from Colorado

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Landslides and debris flows represent natural phenomenon with high geomorphic impact and of significant cascading hazards to human lives and built environment. Intense rainfall events are key triggers of landslides and, as a result, landslides end up interacting with river channels during floods. Large masses of sediment can overwhelm the sediment transport capacity of a river channel and result in the formation of a dam. Nevertheless, this build-up process is not always evident in the aftermath of the event: when a dam burst occurs, a surge of mixed solid and fluid material is produced resulting in significant erosion in the downstream channel. Eventually, the blockage is removed, leaving the process of dam build-up and bursting undocumented. Due to the abrupt nature of this phenomenon, field observations are difficult to obtain.

In this study, we carried out a preliminary analysis by using a computational model to replicate the formation of a channel blockage downstream of a series of landslides during an event that occurred in the North St Vrain Creek in Colorado, USA, during the Great Colorado Storm in September 2013 (estimated to be a 1 in 1000 years event). In this case, there is limited documented evidence of a blockage, but a dam and its bursting were hypothesised by analysing very large erosional patterns in a downstream reach that could not be explained by typical erosive processes (e.g. stream power). We employed the free source code r.avaflow, which is a two-phase model. This code can simulate complex chain phenomena, rapid routing mass flows, and entrainment-deposition processes. Topography of the area was obtained by using high resolution LiDAR DEM before and after the flood event in 2013 and was used as basal topography for simulations, as well as to estimate the amount of sediment released by the landslides. The flood flow employed for the simulation was based on estimated rainfall-runoff and kept constant, since the total simulation time was small compared to the actual flood curve duration. We also tested a limited range of parameters to account for the inherent uncertainties in the variables used.

The model was able to represent the erosion from the landslides and on the river channel, but also displayed the formation of a dam downstream of the landslides across all simulations. Although the topographic change and volume of mobilised sediments were affected by the variation of the model parameters, the formation of the channel blockage was always observed. This modelling will provide the basis for further modelling on landslide-channel interactions and will explain those phenomena that have only been postulated but not directly observed.