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Landslide-channel feedbacks amplify flood response and channel erosion

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Flood stream power is amplified in mountainous catchments by channel confinement and steep slopes, generating widespread channel erosion and causing significant challenges for flood risk management. Approaches to predicting flood channel response include identification of stream power thresholds. However, in a mountainous catchment in Colorado, USA, we find that stream power, estimated from the pre-storm DEM, was not a good predictor of channel flood response and that landslide-channel feedbacks better explain the observed pattern of channel erosion.

The North St Vrain is a 250 km^2 catchment in the Colorado Front Range. It was among several catchments impacted by a 1000 yr prolonged rainfall event in September 2013, which generated a 200 yr flood and $>$100 landslides in the catchment. We estimated peak discharge and stream power using radar-based rainfall data, wherein the rainfall was converted to a discharge based on the upstream drainage area and assuming no infiltration (a reasonable assumption after 3 days of heavy rainfall). Measured high water marks in key reaches were used to calculate a field-based estimate of peak discharge. These discharge estimates were compared with spatial erosion estimates, calculated using the differenced pre- and post-flood LiDAR DEMs.

We found that the onset of profound channel erosion was determined by the formation and failure of an in-channel dam. The dam, composed of debris flow and tributary sediment input, was sufficiently large ($\sim$150,000 m^3) to temporarily overwhelm channel transport capacity even during flood. Our field-based estimate of peak discharge downstream of the dam is more than 2 times greater than our rainfall-based estimate, which suggests a dam burst event occurred. Further downstream we observe additional channel reaches in which erosion was amplified by landslide and tributary sediment input, either through the formation and failure of dams or potentially through sediment bulking alone. These findings imply that when estimating flood risks along mountainous channels, model accuracy might be improved if the effects of landsliding are also considered.