Probabilistic stability evaluation of submerged slopes in Lake Zurich (Switzerland) and seismic triggering scenarios

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The consequences of subaqueous slope failures both in the marine and the lacustrine realm can be very serious. For hazard assessments, stability analyses of submerged slopes are therefore crucial steps, yet very complex ones, as they require knowledge of several geotechnical and morphological factors.

Traces of subaqueous mass movements are often used to extract paleoseismological information. For Lake Zurich, a perialpine lake in Northern Switzerland, coeval subaqueous landslide occurrences along distinct time-correlative horizons have been previously interpreted as earthquake-triggered. The ‘Oberrieden’ study area (≈2 km²) shows three distinct, dated subaqueous landslides with well-defined headscarp, translation areas and mass-transport deposits. The respective failures have been assigned to different trigger mechanisms ranging from human-induced shore loading to earthquake shaking. However, the local shaking intensities leading to slope failures are unknown.

A 3.5 kHz pinger seismic reflection dataset and a 300 kHz multibeam bathymetric dataset (1 m grid) were used for the detection of landslide features and for the layout of a coring campaign and in situ geotechnical testing. A total of 8 Kullenberg-system piston cores (4 cores/km²) and 22 short gravity cores (11 cores/km²) were taken and 39 in situ Cone Penetration Tests (CPT) (∼20 CPT/km²) were performed. The high density of sediment cores and CPT sites in a well-known area allows us to include the spatial variability in the slope model.

With a probabilistic back analysis of the earthquake-triggered ∼2210 BP subaqueous landslide and an assessment of the actual stability of the neighbouring, unfailed sediment drape, we analyse different scenarios of slope stability under static conditions and under seismic shaking in order to quantitatively constrain failure mechanisms and triggers. We apply a Monte Carlo two-dimensional limit-equilibrium infinite-slope stability model that includes a sediment-mechanical stratigraphy constructed from a high-resolution geotechnical dataset. The results can be used to complement the existing regional paleoseismic analysis and give insight into possible future seismically triggered failure scenarios in the study area. The findings from this lacustrine environment, aiming at establishing subaqueous hazard maps, can also be transferred to applications in the marine realm.