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Fragility analysis of flood protection structures in earthquake and flood prone areas around Cologne, Germany for multi-hazard risk assessment

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The work presents a methodology for fragility analyses of fluvial earthen dikes in earthquake and flood prone areas. Fragility estimates are being integrated into the multi-hazard (earthquake-flood) risk analysis being undertaken within the framework of the EU FP7 project MATRIX (New Multi-Hazard and Multi-Risk Assessment Methods for Europe) for the city of Cologne, Germany.
Scenarios of probable cascading events due to the earthquake-triggered failure of flood protection dikes and the subsequent inundation of surroundings are analyzed for the area between the gauges Andernach and Düsseldorf along the Rhine River. Along this river stretch, urban areas are partly protected by earthen dikes, which may be prone to failure during exceptional floods and/or earthquakes. The seismic fragility of the dikes is considered in terms of liquefaction potential (factor of safety), estimated by the use of the simplified procedure of Seed and Idriss. It is assumed that initiation of liquefaction at any point throughout the earthen dikes' body corresponds to the failure of the dike and, therefore, this should be taken into account for the flood risk calculations. The estimated damage potential of such structures is presented as a two-dimensional surface (as a function of seismic hazard and water level). Uncertainties in geometrical and geotechnical dike parameters are considered within the framework of Monte Carlo simulations. Taking into consideration the spatial configuration of the existing flood protection system within the area under consideration, seismic hazard curves (in terms of PGA) are calculated for sites along the river segment of interest at intervals of 1 km. The obtained estimates are used to calculate the flood risk when considering the temporal coincidence of seismic and flood events. Changes in flood risk for the considered hazard cascade scenarios are quantified and compared to the single-hazard scenarios.