



## Scaling the piping process

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Seepage underneath river embankments during high water events can lead to erosion by piping. Elevated hydraulic gradients will drive groundwater flow, which when large enough, may breach the confining layer by bursting and wash out finer non-cohesive sediments, especially if the outflow is concentrated in a single point. As material is removed, a pipe may form and continue to progress upstream eventually undermining the embankment. Although often approached as a geotechnical or engineering problem in terms of embankment failure, the process can also be approached from different scales as a geohydrological problem. On the scale of an entire delta there are multiple channel belts that define the regional groundwater flow patterns. On the scale of a single stretch of river embankment the interaction between the river, present channel belts, their orientation, and channel belt architectural elements dominate the exact location of bursting and associated discharge. From there on the process scale becomes important, where the grain size distribution within the facies where the piping is taking place. And the process is dominated by regional bulk hydraulic conductivity in terms of discharge magnitude and grain size distribution at the tip of the pipe in terms of erodibility. In this study, a set of embedded models for the various scales is developed and tested that simulates the formation of a single pipe at these various scales in a holistic approach. Geohydrological conditions are linked to a representation of saturated hydraulic conductivity based on the local grain size distribution to model the feedback between groundwater flow, subsurface conditions and piping at these various scales. Thus, the model

assesses the influence of subsurface heterogeneity on piping and its performance was assessed on the basis of field observations and laboratory experiments. Our results show the validity of the model and stress the need to treat piping as a three-dimensional geohydrological problem.