HAZARD ASSESSMENT AND RISK MANAGEMENT IN CASE OF UNSTABLE SLOPES ALONG RIVERS

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INTRODUCTION

A natural dam formed by landslide deposits in a river channel creates a backwater. Upstream areas are threatened by flooding. Especially in low-gradient rivers, a relatively small volume of deposits can impound large water volumes. If the natural dam formed by the landslide deposits is overtopped, its erosion starts. Depending on the dam geometry this erosion may be limited or progressive. The consequence of such progressive erosion is a relatively sudden release of the impounded water and thus the formation of a flood wave threatening downstream areas. The assessment of hazards and the analysis of risks related to unstable slopes along rivers, therefore, have to include the following aspects:

- Extent of the backwater created by the slide deposits
- Assessment of the erosion processes once the deposits are overtopped and of their local consequences at the dam site
- Probability of a progressive erosion of the deposits and assessment of its consequences for the downstream areas

The main problems in such analyses are the uncertainties related to decisive parameters, e.g. the geometry of the deposits, the characteristics of the material deposited or the river discharge. Therefore, an assessment will usually base on scenarios. The uncertainties and the use of scenarios usually do not justify the use of complex tools. Furthermore, a first assessment is often required within relatively short time.

THE CASE STUDY OF BERNHARDZELL

In the canton of St. Gallen, several unstable slopes are located along the Sitter River between St. Gallen and Bischofzell. For one of these unstable slopes, located near Bernhardzell on the outer bend of a meander of the Sitter River (Fig. 1), the possible consequences of a potential slide damming up the river were investigated. Due to the uncertainties mentioned before, the study relied on a relatively simple and pragmatic approach. The main aim was to determine the critical scenarios and intensities of the processes and thus to provide a base for the assessment of the hazards and of the risks as well as for the planning of measures.
From a geotechnical study, different scenarios for the geometry of the potential slide deposits in the Sitter River were known. The maximum volume of deposits is 60’000 m^3, whereas the maximum volume of the lake forming upstream of the deposits may reach 300’000 m^3. Even the mean annual discharge would fill the potential lake volume within only few hours.

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A relatively simple numerical model was used in the present study that accounts for the retention in the lake and bases on a rotational erosion of the downstream part of the slide deposits in case of overtopping. This simple model allowed the simulation of a large number of scenarios within reasonable time. Main parameters to vary were the inflow hydrograph, the dam geometry, the dam material characteristics and the potential breach width. The outflow hydrographs resulting from these simulations were subsequently introduced as upper boundary condition to a 1D numerical model of the downstream river reach. This second model bases on the explicit solution of the Saint-Venant equations.

The analysis for the present case showed that the extent of the area influenced by the backwater upstream the dam will not represent any danger for settled zones or infrastructure. Also the local consequences at the dam site will be limited. However, there is a pronounced probability of progressive erosion of the potential natural dam. This is mainly due to the relatively small volume of the potential dam compared to the potential volume of impounded water. The peak discharge resulting from progressive dam erosion is relatively independent from the inflow discharge. Hence, the inflow determines primarily the time until the water starts overtopping the dam. The peak discharges resulting from progressive erosion are comparable to natural discharges during rare flood events. Hence, if the slide occurs during a flood in the Sitter River, the situation for the downstream reach will not drastically change. A major danger, however, results if the slide occurs when the discharge in the Sitter River is small, e.g. during the summer. In this case, the resulting flood wave could endanger a larger number of persons, because the downstream river reach is an favored recreation area.

CONCLUSIONS

The use of simple models to simulate the retention, erosion and flood wave propagation for the case of natural dam formation by a slide into a river allows the investigation of a large number of scenarios within short time. Determining scenarios can thus quickly be identified. Thus, the resulting risks can be quantified and appropriate measures can be planned. In the present case, the most important danger results from the fact that a slide resulting from the unstable slope could trigger a flood wave comparable to natural flood when nobody would expect it, i.e. when the weather is fine. A continued survey of the slope and in case of accelerated slope movements the installation of water gauges up- and downstream the potential dam site are proposed to early detect the formation of the potential lake. Thus, the required advanced warning time can be gained to evacuate the downstream river reach.

Fig. 1: The Sitter River at the toe of the unstable slope near Bernahrdzell (seen against the flow direction).

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