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Assessing the acceptability of concrete dam submergence considering scour

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Why ?

For many dam operators, their assets are aging in a context that evolves both with new flood assessment methods and new legal or normative frameworks. Building new outlet structures to ensure enough flood release capacity can be expensive and limited. Figure 1 presents the reason for submergence acceptability assessment for a generic case, based on a real dam [1].

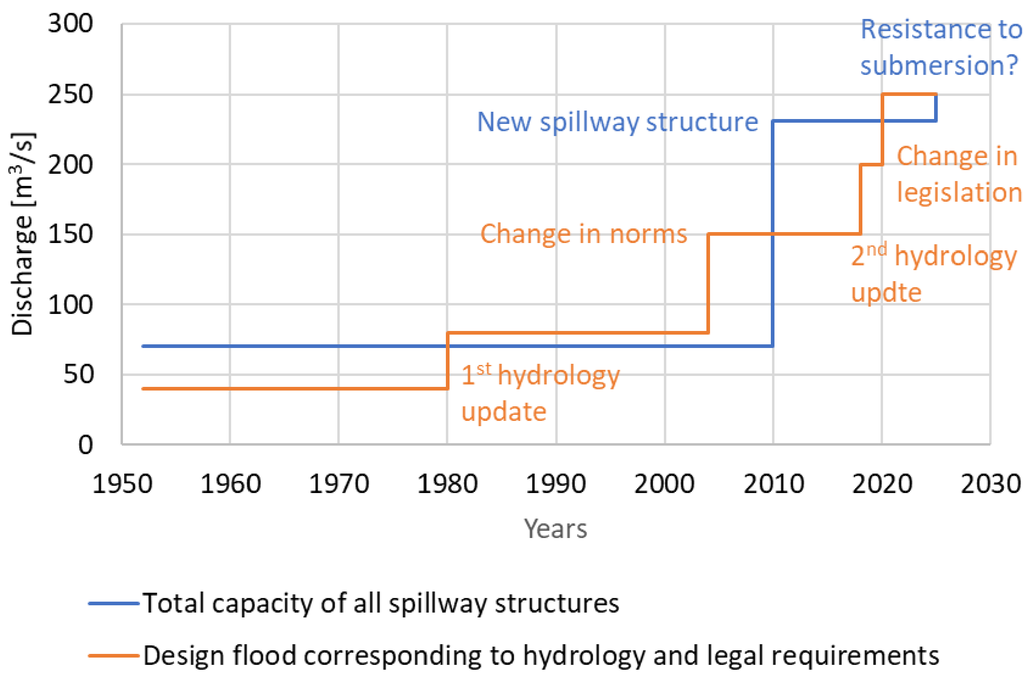

Fig. 1 Hypothetic dam history regarding flood release capacity

Submergence can be an alternative, but the dam stability has to be guaranteed and therefore it raises a few questions:

- Can the dam withstand higher reservoir levels above the crest?
- Which flood events can be accepted?
- What is the acceptable residual risk?
- To which extent is dam toe scour acceptable, considering the dam's or the abutment's instability?

This last question can be the most challenging one.

The proposed method

Divided in four modules, the method offers a framework to consider the different inputs necessary to assess the risk of dam instability due to scour following dam submergence (Fig. 2), due to insufficient conventional spilling capacity. The vulnerability to scour formation is assessed based on the duration of the submergence events, on the geometry of the falling nappes, on the downstream tailwater levels and on dam foundation & riverbed rock conditions. Then, scour evolution is assessed through different methods, considering to some extent the complexity of the processes taking place during scour progress by the interaction of air, water and rock.

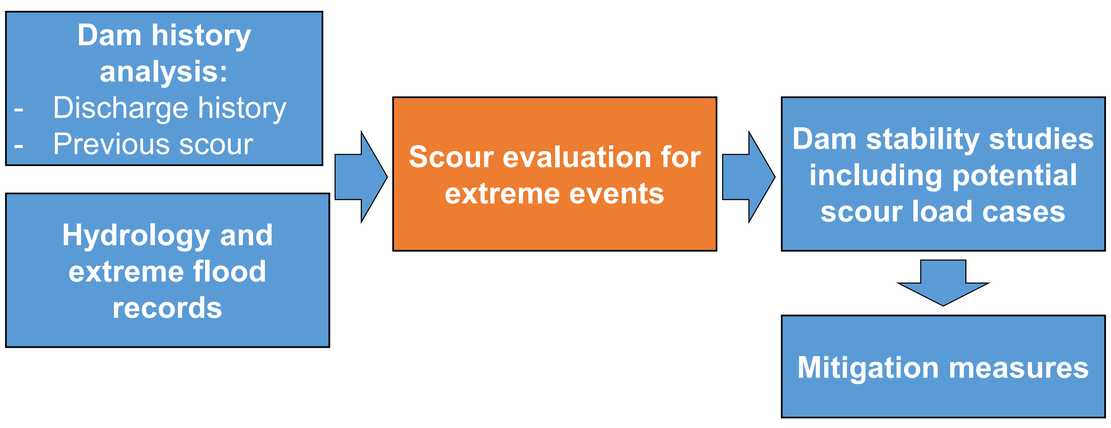

Fig. 2 Simplified chart of the proposed method for risk assessment

One of the most challenging issues in rock scour assessment is to account for the effect of time [1]. **Ultimate scour methods (USM)** allow estimating scour extent for a given discharge assuming it last long enough to reach an equilibrium configuration. **Energy-based methods (EBM)** [7,8] focus on scour progress as function of a chronological sequence of spillage discharges, varying in intensity and duration.

EPFL's **Comprehensive Scour Model** (CSM) [1] illustrates a possible way to sequentially link several physical processes, one of them being time-dependent. Rock fracture propagation under hydrodynamic loads is modelled using the Paris-Erdogan fatigue law and hydrodynamic loads defined according [2,3,4,6]. Recently, a novel EBM model was proposed by [5] considering only the E**xcess Energy** [EEBM] available for scour at each given moment. The four previous methods allow having multiple truncated entries to inform decisions and risk assessment. Figure 3 graphically shows the required data to properly calibrate such methods.

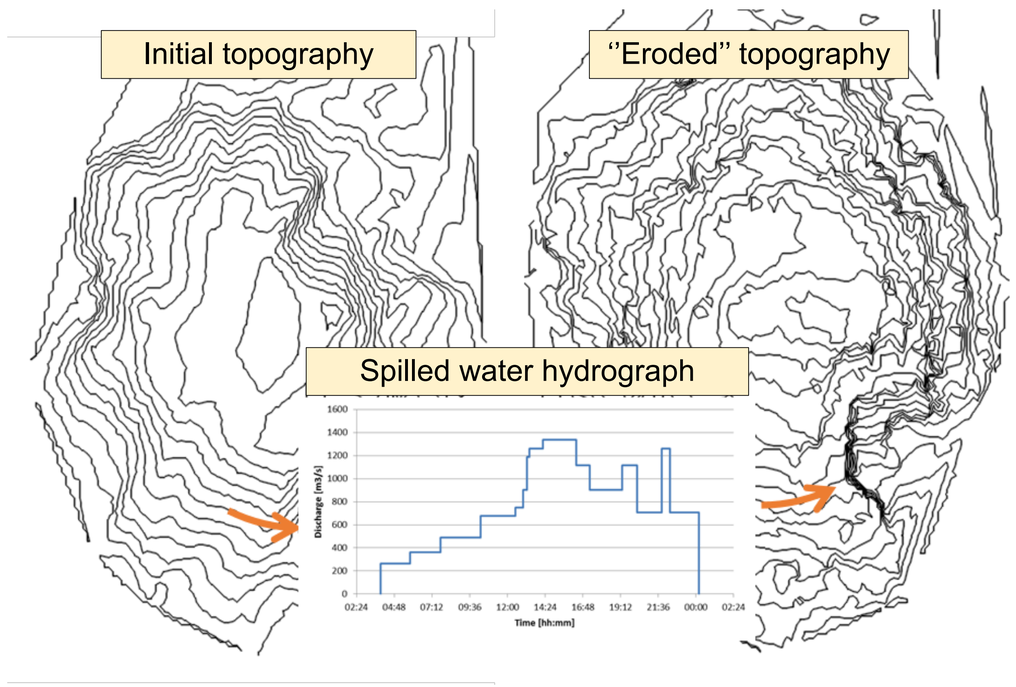

Fig. 3 Calibrating scour computation with passed spill events

Results

The general method was applied to two different dams. The first one is a dam located at a high altitudes with a fairly small reservoir and ungated crest overflow spillway. A Piano Key Weir spillway was added recently to ensure enough capacity for the revised millennial flood. The second dam is quite different, situated at intermediate altitudes and equipped with a three-bay gated spillway with ski-jumps for a total capacity of 5800 m^3/s. The study of the first dam revealed that no scour had occurred yet in over 50 years. The scour analysis with USM methods showed that some erosion could occur for extreme flood events with a return period of 5000 years or more. However, the EEBM time-accounting method [5], based on the potentially available energy for scour, showed that the flood event duration was too short for any serious erosion to occur. For the second case study, with gated spillways, the available plunge pool bathymetries and spillage records allowed obtained site constants of scour progression (according [8]) and estimating scour from extreme events. The application of the EEBM showed interesting results as well, indicating that instead of using site constants to calibrate Spurr's scour evolution function, one should rather use event-related constant for calibration of such function (i.e. the same event might not produce the same scour increase if occurring at different chronological moments in the spillage records).

Further application of these methods could help to better assess how rock quality, discharge intensity and duration are linked to the equilibrium state of a scour pool. Indeed, better knowledge of possible scour evolution can help with assessing the acceptability of dam submergence.

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