A METHOD FOR ASSESSING THE RESILIENCE OF LEAKY DAM NETWORKS

{ Z. VAN LEEUWEN, L. BROWN, M. KLAAR, M. SMITH, R. LAMB } UNIVERSITY OF LEEDS, JBA TRUST

OBJECTIVES

The objective of the study is to increase understanding of leaky dam network resilience and failure probability to inform inspection and maintenance, assess downstream risk and aid in design decisions in large systems of dams.

INTRODUCTION

In-stream wood is increasingly being used to restore hydrogeomorphological processes in upland rivers for the purpose of managing downstream flood risk. Whilst the longevity of natural wood accumulations has been extensively studied there is little research to quantify resilience of the types of structures now being installed in UK watercourses.

At a strategic planning level in the UK resilience of flood risk management assets is assessed in a risk based framework using fragility curves [1]. A fragility curve quantifies the probability of failure of an asset conditional on a loading condition. Fragility curves can be estimated based on statistical analysis of observations of failure when failure modes are not well understood or consist of complex interactions. This is a commonly used approach in earthquake engineering [2].

One of the advantages of this method is that the analysis can be ran with little data input which makes it possible to obtain an estimate of the failure probability, or conversely, the resilience of leaky dam networks based on the experience of practitioners in the UK.

Increased understanding of leaky dam network resilience and failure probability can inform inspection and maintenance, assess downstream risk and aid in design decisions in large systems of dams.

METHODOLOGY

A fragility analysis was carried out based on observations of leaky dam failure, partial failure and resilience from UK Natural Flood Management projects.

Information from a closely monitored leaky dam study site in North Yorkshire was combined with responses to an informal survey of practitioners. The survey was widely distributed to practitioners through a number of channels including social media, practitioner networks and blogs (RRC, Scottish NFM Network) and was sent out to all projects which benefited from the Environment Agency's £15 Million Natural Flood Defence budget announced in the 2016 Autumn Statement.

The loading condition to which leaky dams were subjected was defined as the event return period which was calculated from the nearest downstream EA operated gauging station. Estimates of the fragility function were made based on pooled information from the sites using a two-stage optimisation procedure of the log normal fragility distribution as described in Lamb et al., 2019 [3].

Figure 1: Failed leaky dam, North Yorkshire

RESULTS

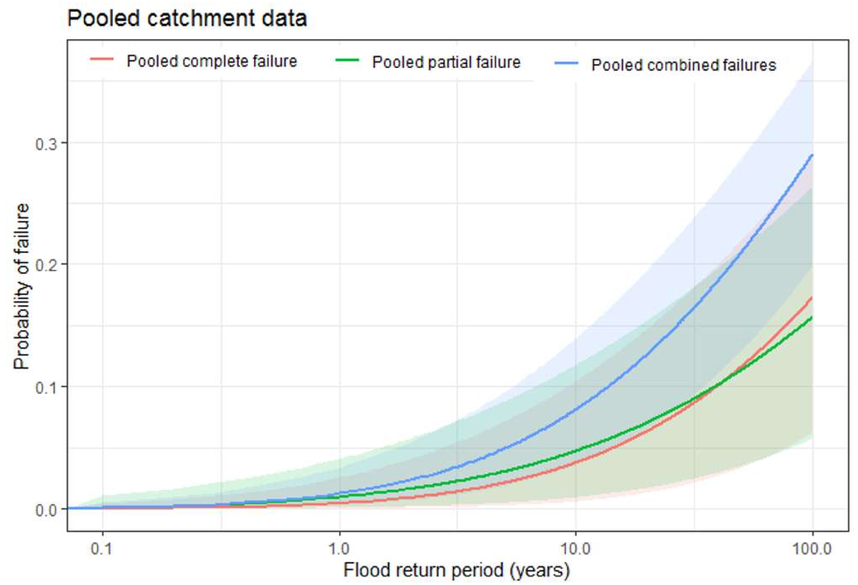

Figure 2: Pooled site fragility curve

- Fifteen projects in which leaky dams were installed provided information in response to the survey. A total of 1500 dams were reported on with the number of leaky dams installed in each project ranging from 8 to 400 dams.
- Four of the projects reported one or more complete or partial failures of leaky dams. In total 13 dams were observed to have failed, and 15 dams partially failed.
- Both complete and partial failures occurred during storms with return periods ranging from <1 year to 13 years.
- In each project the majority of dams were resilient to the event peaks they were exposed to. The most extreme events which affected the sites ranged from 4 to 39 year return period events.
- Pooling information from the four sites on which dam failures were observed shows that the probability of failure or partial of dams is below 0.1 for events with a return period below 10 years.
- During a 1 in 100 year event the probability of observing either a failure or partial failure rises to around 0.16, and the probability of either occurring rises to just below 0.3.
- The pooled fragility curves currently do not incorporate data from the 11 sites which did not observe any dam failures, and is therefore likely to overestimate the probability of dam failure

REFERENCES

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[2] Keith Porter, Robert Kennedy, and Robert Bachman. Creating fragility functions for performance-based earthquake engineering. *Earthquake Spectra*, 23(2):471–489, 2007.

[3] Rob Lamb, Paige Garside, Raghav Pant, and Jim W. Hall. A Probabilistic Model of the Economic Risk to Britain's Railway Network from Bridge Scour During Floods. *Risk Analysis*, 39(11):2457–2478, 2019.

CONCLUSION AND FUTURE RESEARCH

To be able to design inspection and maintenance regimes a greater understanding of resilience of systems of leaky dams at the network scale is required. A fragility curve analysis was applied to observations of leaky dam failures to quantify the probability of failure in UK leaky dam networks.

To give a more nuanced view of resilience at the network scale fragility curves can be estimated for a range of leaky dam designs, site conditions and asset age as more data becomes available in the future.

Contact: gyzrvl@leeds.ac.uk