Effects of debris-flow magnitude-frequency distribution on avulsions and fan development

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Introduction

Shifts in the active channel on a debris-flow fan, termed avulsions, pose a large threat because new channels can bypass mitigation measures and cause damage to settlements and infrastructure. Recent, but limited, field evidence suggests that avulsion processes and tendency may depend on the flow-size distribution and associated flow-size sequences, which are difficult to constrain in the field.

Objectives

Here, we investigate how flow magnitude-frequency distribution and associated flow sequences affect the spatio-temporal patterns of debris-flow fan development. To do so, we study and compare the evolution and avulsion mechanisms of three experimentally-created debris-flow fans formed by different flow-magnitude distributions.

Methods

A well-defined channel setup through gravel substrates forms the basis of the experiments. Mainly composed of gravel, the fans were created on a gently sloping surface with a mean slope angle of 3°. The fans were exposed to a series of visible and infra-red videos.

Results

Cross-sections

Fig. 7: Cross-sections through the experimental fans at distinct stages of fan development. The channels are filled with a high bedload content. The cross-sections show the development of the channels through time. The fan shows a braided channel structure.

Conclusions

Overall, the three fans formed by similar patterns of development: alternating channelized and unchannelized phases governed by backstepping deposition and avulsion. Volume variations, however, lead to contrasting avulsion mechanisms: (1) Large flows can overtop the channel and carve new flow paths, initiating avulsions within a single event. (2) Series of small-medium flows can block the active channel, leading to avulsion in the next large flow. We infer that there may be an optimal magnitude-frequency distribution that maximizes the avulsion frequency, reflected by the balance of small versus large flows.