

## **Accident study of torrential protective structures based on the French RTM database**

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Torrential protective structures such as dikes, sediment traps, and check dams aim to reduce damage on elements at risk. They are built given a reference scenario. Nevertheless, this scenario can be exceeded or structures can fail because of their design or their ageing. We later talk about "accidents". The 1996 Aras disaster near Biescas (Spain) showed that consequences can be significant: 35 of 40 check dams were destroyed which involved 87 fatalities in a campsite. The accident probability and its consequences must be taken into account to analyze risk. Databases are useful tools to extract needed information.

In France, the Restoration of Mountainous Areas department (RTM) has been public funded to develop a database, specific to mountainous areas (the Alps and the Pyrenees). Almost 12 500 check dams, 80 sediment traps and 600 dikes were registered in public forests in 2011. These samples were assumed significant for check dams and sediment traps but not for dikes because the most part was missing. In parallel, more than 31 000 torrential events were registered. Given these elements, an accident study was developed.

We first extracted 1 925 events with accidents on protective structures: 39 % occurred during the 19th century and 53 % have occurred since 1900. Sediment traps were involved in 37 events, check dams in 336, and dikes in 1488. Then, a detailed analysis was specifically carried out for check dams. Event phenomena were extracted: torrential flood, liquid flood, snow avalanche, rock fall, and landslide. Accident typology was also specified: scouring, breaking of several check dams, total or partial destruction of one structure, overflowing.

Causes of accidents on check dams were first analyzed. Torrential floods were responsible of 85 % of events (284 of 336) even if other phenomena must be also taken into account. Almost 45 % of events (152 of 336) involved total destruction of one or several check dams. Taking into account events for the last 150 years, 30 events were registered with destruction of several check dams: the annual probability of occurrence is 3.10-4. Analyzing consequences, only 11 of previously retained events (1925) were registered with fatalities.

Finally, these quantitative elements were compared to qualitative feedback analysis from field practitioners and were illustrated with the 1987 Saint-Antoine event, in Modane. The total or partial destruction of 25 check dams released between 20 000 and 30 000 m<sup>3</sup>, which was one third of the estimated debris flow volume (85 000 m<sup>3</sup>) which damaged an industrial area. The lack of their maintenance partially explained this accident.

As a conclusion, we must keep in mind that these results are limited to available data (all events have not been necessarily reported). Accidents on check dams are rare according to these data. It can be due to their general maintenance. This first analysis could be improved taking into account expert analysis, completing with information from other countries databases and formalizing the approach through a dependability analysis framework.