Rainfall Analysis and Thresholds at the Rest and Be Thankful

R Bainbridge[1], M G Winter[2], S Dunning[1] and M Lim[3]

[1] Department of Geography, Newcastle University, Newcastle, NE1 7RU, UK.

[2] Winter Associates, Kirknewton, Midlothian, EH27 8AF, UK.

[3] Faculty of Engineering and Environment, Northumbria University, Newcastle, NE1 8ST, UK.

EXECUTIVE SUMMARY

The link between rainfall and shallow landslides (e.g. debris flows, creep, collapses) is well-established and formed an integral part of the Scottish Road Network Landslides Study, with efforts to establish robust rainfall thresholds for landslide initiation continuing since 2006. While the early work was in a pan-Scotland context, since 2008 these efforts have focussed on the A83 Rest and be Thankful (RabT) site where debris flows and intense rainfall events are both common and significant. The frequency of debris flows events at this site appears to have increased over the last 15 years and there are some strong indicators that this is in direct response to increased intense rainfall events.

Rainfall is generally a good proxy for increased landslide hazard and is well-suited to forming the lowest level of a multi-tiered landslide warning system. However, it is not rainfall that causes landslides but the secondary effects of increased streamflow and infiltration or, more pointedly, the tertiary effects of erosion and lower material strength that lead to landslides.

We have reviewed the published rainfall intensity-duration thresholds for debris flow initiation at the A83 RabT site. These date over a period of fifteen years and in general terms each successive threshold has improved on the last, not just as we have a stronger knowledge base to work from but also because of significant changes and improvements to the rain gauge network, a longer time-series of rainfall data and a longer and more complete landslide inventory at the site. Notwithstanding this, even the earliest developed threshold has successfully been used to trigger a low-level warning since early-2011 in the form of wig-wag flashing lights that are switched on at times of higher rainfall and hence higher inferred debris flow hazard.

A comparison of the data from the different gauges suggests that the SEPA RabT gauge that is specified, maintained and calibrated to national standards is not subject to orographic effects that impact other gauges in the area.

Both deterministic and probabilistic approaches have been used and each has delivered significant insight to the understanding of mass movement processes at the site. Here we present both types of analysis, having used the same rainfall gauge data in their construction. The results indicate that an approach based on the use of a deterministic threshold backed up by an Antecedent Precipitation Index to filter out those rainstorms that cross the intensity-duration threshold but do not lead to debris flows, is the most promising approach for the first tier of an operational warning system.

Accordingly, We have produced a multi-parameter, deterministic intensity-duration rainfall threshold for debris flow initiation. This is based on the SEPA RabT rainfall gauge, the longest running record at the site and uses a newly available debris flow inventory. This uses the same rainfall data and debris flow inputs as a recent probabilistic threshold for the RabT, meaning these two are the only comparable thresholds, making them ideal candidates for trialling. Efforts to continue the population of a reliable and accurate debris flow inventory, containing all events and timings regardless of their impact to the A83 road, should continue to ensure the improvement of thresholds with future event data.

The available data suggest that approximately 1 in 5 (20%) rainstorms that exceed the deterministic intensity-duration and the API rainfall thresholds will generate debris flows. In addition, 1 in 10 debris flow events will be associated with precursor rainfall that exceeds the intensity-duration threshold but not the API threshold, potentially indicating a false negative in any warning system based on both metrics (I-D and API) as a warning would not be issued unless both thresholds were breached. This, in turn, corresponds to an approximately 1 in 80 chance of a rainstorm that crosses the threshold leading to a debris flow but not leading to a warning (as the API is not exceeded).

While these correspond to 80% false positive and 10% false negative rate and reflect the secondary and/or tertiary nature of the relation between rainfall and debris flows; it should be noted that reducing the false positive rate will increase the false negative rate, the latter of which is of greater concern operationally and therefore needs to be minimised.

The system as proposed is intended to operate as the first level of a tiered warning system. The associated warnings are likely to implement relatively low-level actions such as the turning on of warning signs and implementing procedures that cause greater attention to be paid to the emerging conditions. This will need to work within the current operational system used to manage events with or without appropriate modification as agreed with Transport Scotland and the Operating Company. Subsequent warning levels are likely to take actions such as moving traffic to the Old Military Road. In this context fewer false positives, and thus more false negatives, is considered to be undesirable while the existing number of false negatives can be managed through the alerting from higher levels within the tiered warning system.

We make recommendations for the implementation of the thresholds through an online portal which can be used as a shadow trial to the current management system. For this to be effective, the SEPA RabT data will need to be near real-time, or a comparable system which can produce this data needs to be installed within or next to the existing SEPA RabT compound. The recommendations centre on:

1. Establishing an effective means of deriving near real-time data from the existing SEPA gauge(s) and assessing the need for any new gauges.
2. Developing and implementing a shadow trial, as part of multi-tiered warning system, in which near-real-time data is used to suggest 'dummy' decisions alongside the existing system.
3. Determine clear success criteria, organisational responsibilities for operation and warning, and a decision-making framework that includes positive feedback.
4. Continue strategic monitoring at the site to further develop both the landslide inventory and the process and detailed knowledge mechanisms in-paly on the site.
5. Determine costs and programme for consideration by decision-makers.

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