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Anatomy of a sudden onset flood: The 18 March 2007 Crater Lake break-out lahar, Mt. Ruapehu, New Zealand

Vern Manville (1,*) and the Crater Lake lahar research Team

(1) School of Earth and Environment, University of Leeds, Leeds LS2 9 JT, UK (v.r.manville@leeds.ac.uk), (*) formerly at GNS Science, Wairakei Research Centre, Taupo, New Zealand, (2) S.J. Cronin, G. Lube, E.E. Doyle, S.E. Cole, J. Procter: Institute of Natural Resources, Massey University, Palmerston North, New Zealand, (3) J.L. Carrivick: School of Geography, University of Leeds, UK, (4) A. Graettinger: Department of Geology & Planetary Science, University of Pittsburgh, USA, (5) C. Massey, R. Jongens: GNS Science, Avalon and Dunedin Research Centres, Lower Hutt and Dunedin, New Zealand, (6) J. Watson, J. Halstead: Horizons Regional Council, Palmerston North, New Zealand, (7) B. Waugh: NIWA, Tokaanu, New Zealand, (8) H.J.R. Keys, C. Lawrence: Department of Conservation, Turanga Place, Turangi, New Zealand, (9) T. Marutani, T. Yamada: Hokkaido and Kyoto Universities, Sapporo and Kyoto, Japan

Sudden onset floods are significant hazards in many environments and regions around the world, resulting in loss of life, damage to infrastructure, and dramatic geomorphic changes due to the very high rate of energy expenditure associated with high flow velocities and depths. In these transient, highly dynamic phenomena, the evolving floodwave typically undergoes a complex series of interactions with the flowpath, involving multiple feedback loops, to produce spatially and temporarily varying sediment loads that affect their density, viscosity, mobility, peak discharge and absolute volume, and hence their hazardousness. However, due to their unpredictability, ephemeral nature, and high energy they are challenging to characterise adequately, making mitigation difficult.
At Mt. Ruapehu, New Zealand, an outburst flood caused by collapse of a tephra barrier impounding a summit Crater Lake generated an opportunity to characterise the downstream evolution of a single discrete floodwave through: (i) multi-parameter measurement of time-series hydraulic parameters at key locations along the channel; (ii) visual observations at manual sampling and gauging sites; (iii) capture of geomorphic changes using pre- and post-event high resolution topographic surveys and vertical aerial and oblique imagery; (iv) stratigraphic logging and granulometric analyses of the flood deposits; and (v) testing and calibration of numerical models using the newly acquired data.
On 18 March 2007, the natural dam failed, releasing c. 1 Mm3 of warm, highly mineralised water in less than two hours. The flood rapidly bulked by entraining debris along the steep gorge of the upper Whangaehu valley, more than tripling in size, before debouching onto the Whangaehu Fan where it braided into multiple distributary channels. The flood recollected into a single channel to continue downstream to the coast 215 km from source.
Stage, discharge, frontal and flow velocity, sediment-load, and geochemical data show that the flood progressed as a series of variably overlapping kinematic waveforms composed of ambient river water, Crater Lake water, and entrained sediment, each with differing wave celerity. Complex interactions with the channel resulted in proximal-distal changes in peak discharge, the volume and velocity of each waveform, and both the quantity of the sediment-load and its grain-size distribution. Airborne LiDAR data indicate 4.5 and 1.4 Mm3 of net erosion and deposition respectively along the first 47 km of channel. Patterns of geomorphic change are complex, being related to a combination of channel gradient, width and expansion ratio. Further analysis indicates that calculated mean sediment content in the lahar peaked early and was then maintained for at least 50 km, suggesting that feedbacks between the evolving lahar wave and the flowpath stabilised key flow parameters at the rheological transition between hyperconcentrated and debris flow behaviour. This maximised sediment transport capacity, despite downstream changes in channel geometry and physical properties that resulted in lowering flow competence and distal fining of the load.