THE SIGNIFICANCE OF SEDIMENT STORED BEHIND LOG DAMS TO THE 2005 AWATARARIKI DEBRIS FLOW; IMPLICATIONS FOR RISK MANAGEMENT

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Summary

Based on field information and published data, it is unlikely that debris stored behind log-jam dams in the Awatarariki Stream prior to the 2005 debris flow contributed significantly to the magnitude of the event. Therefore the debris-flow risk on the Awatarariki fan cannot be reduced significantly by keeping the Awatarariki Stream channels free of log-jam dams .

Introduction

The 2005 debris flow in Awatarariki Stream, Matata, Bay of Plenty in 2005 deposited an estimated 300000 – 500000 m^3 of debris (comprising boulders, gravel, sand, silt and organic debris) on the Awatarariki fan, severely damaging many properties (McSaveney et al., 2005). The future risk to dwellings on the fan, made evident by this event, is proposed to be managed by retreat from the area of the fan in which the risk is assessed as unacceptable. This area has been delineated by modelling potential future debris flows, based on the 2005 volume being 300000 m^3, and by mapping of the spatial distribution of boulders on the fan after the event (Tonkin & Taylor, 2015).

The sources of the debris that made up the debris flow are (i) rainfall-induced hillslope debris avalanches that delivered sediment and organic material to the stream-bed (Appendix 1 Fig. A1); (ii) material comprising the stream-bed above bedrock that was eroded, in many places down to the bedrock, by the debris-flow (Appendix 1 Fig. A2); and (iii) material that was stored above the stream-bed in natural log-jam dams (Appendix 1 Fig. A3). While (i) and (ii) cannot be influenced by management, the possibility exists that artificial removal of log-jams, if feasible, could reduce the quantity of material in a future debris-flow and thus reduce the future risk to dwellings on the fan – perhaps to the extent that the current retreat policy can be relaxed.

The purpose of the present work is to estimate the volume of sediment in source (iii) prior to the 2005 debris flow, in order to assess the degree to which future risk can be managed by removal of log-jams, thus allowing the stored sediment to be moved down the stream by minor storms and thus not contribute to the volume of a future debris flow event.

Data

While information on log-jam dams in the Awatarariki stream system is sparse, John Douglas reports that such features were certainly present in the stream during his inspections since 1993. He recalls climbing over debris dams 6-8 m high which retained sediment to form a flat plain upsteam of the dam, upstream of which was usually a lake before the stream-bed appeared again (Fig. 1). He also re-

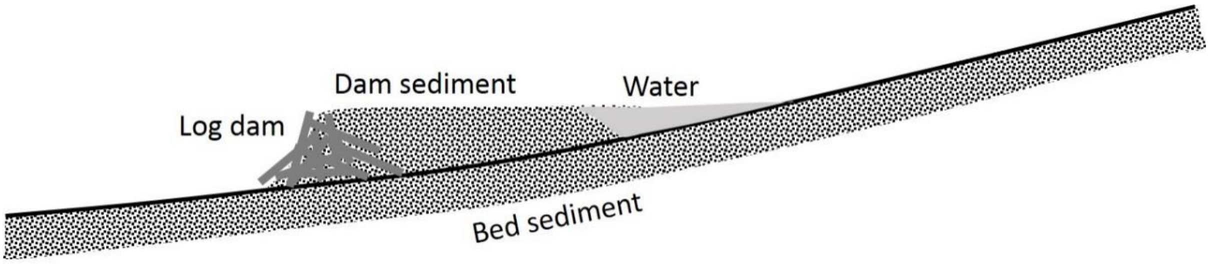

Fig. 1 Schematic diagram of sediment storage by log-jam dam

calls finding about 10-12 such dams in the Awatarariki Stream.

These data can be compared with the only published information on log-jams in NZ streams, and the volume of sediment stored. Pearce and Watson (1983) surveyed six streams in the Notown area of Westland following a series of rainstorms, and documented 35 log-jams up to 8 m high retaining a total of 25200 m^3 of sediment and 4700 m^3 of logs in a total channel length of about 10 km; one longitudinal profile from this study is shown in Fig. 2.

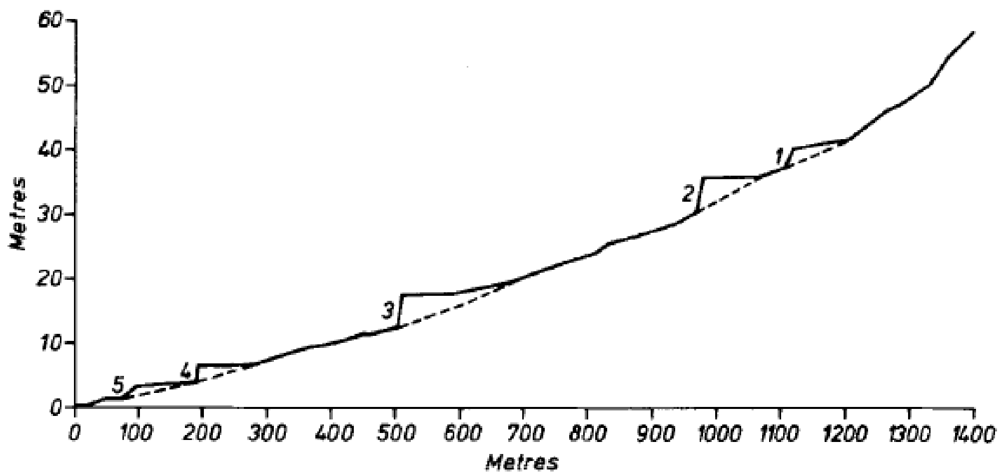

Fig. 2 Ryan's Creek, Notown (Pearce and Watson, 1983); longitudinal profile with debris dams shown. Debris dams contained about 7000 m^3 of sediment in total.

Retained sediment volume

The total channel length of the Awatarariki Stream, including tributaries, is about 7.5 km (Fig. 3). While the gradient of the 2.8 km long main channel is about 5%, that of the tributaries is about 10%. First we estimate the total number of dams in the system; John Douglas found 10-12, presumably in the main channel, which is about one every 250 m. If we assume this spacing applies to the remaining 4.8 km of tributary channels, we would expect about another 20 dams, making about 30 altogether.

In the main channel, with S = 0.05, 12 dams each say 7 m high would each retain $7^2/2 \times 0.05 = 490$ m^2 of sediment longitudinal section area giving a total of about 6000 m^2. To find the volume we need to multiply the longitudinal area by the width; this will obviously vary significantly, and will not be uniform with height, so we estimate an average width of 5 m, giving a volume of the order of 30000 m^3.

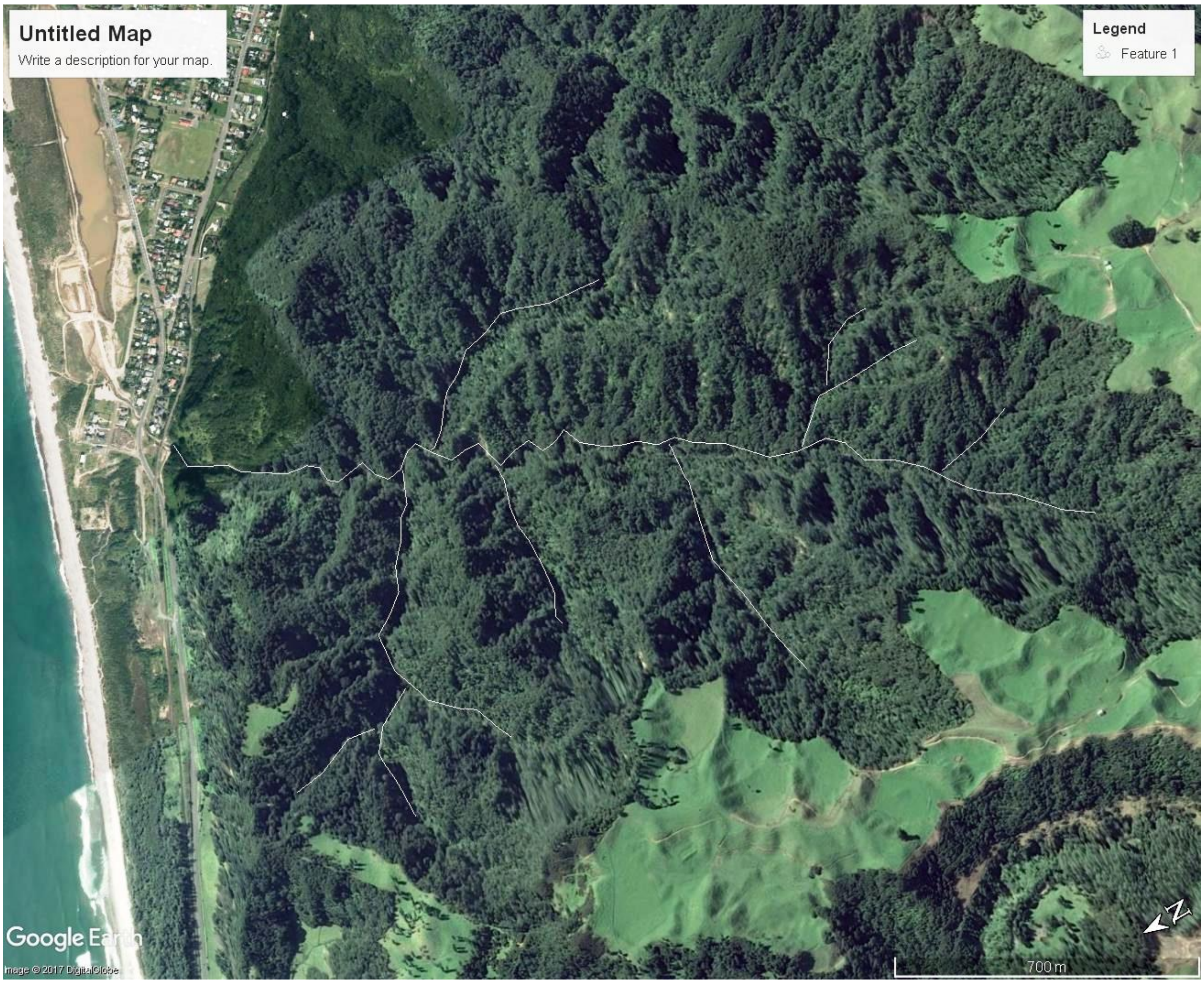

Fig. 3 Google Earth image of Awatararariki Stream with channel network outlined in white.

The volume of sediment retained in a dam depends on the dam height and channel slope (Fig. 4) ; here we ignore the small lake often present (Fig. 2).

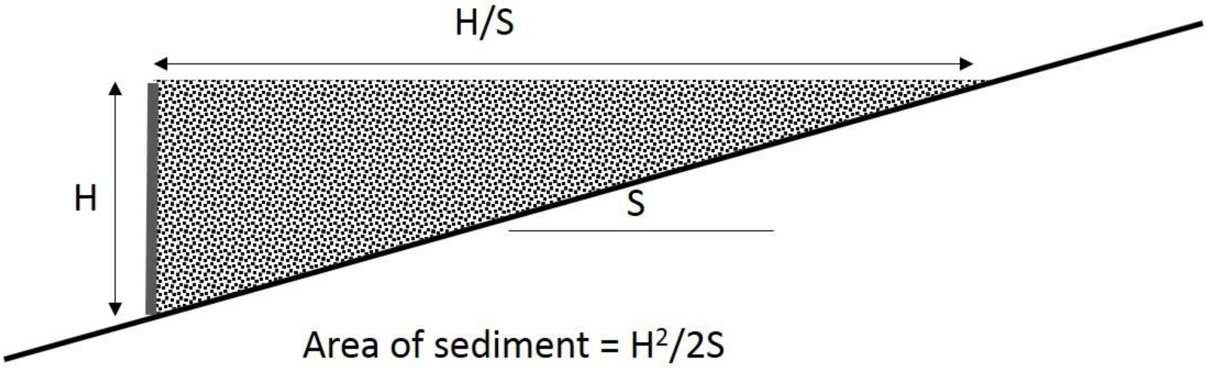

Fig. 4 Sediment area behind a dam; longitudinal section.

In the tributary channels the 20 dams each say 7 m high would each retain $7^2/2 \times 0.1 = 245\ m^2$, giving a total of $4900\ m^2$. The tributary channels will be narrower than the main channel, so if we estimate a width of 3 m this gives a total volume of the order of $14700\ m^3$. The grand total volume of sediment retained in log-jam dams is then 44700 m^3, or, to a realistic degree of precision, 40000 – 50000 m^3. That this is of the same order of magnitude as the Notown figure of Pearce and Watson (1983) encourages some confidence in the estimate.

Nevertheless in my opinion 40000 – 50000 m^3 is probably an upper limit, as the data estimates used have been largely conservative; this applies in particular to dam height, where I have assumed that all dams are 6-8 m (taken as 7 m) high. Since sediment volume is proportional to the square of dam height (Fig. 4), the fact that many dams would probably have been less high would significantly reduce the total sediment storage volume. If an average dam height of 5 m had been used the volumes would have been halved. This is also suggested by comparison with the Pearce and Watson (1983) data, which record about half the volume of sediment in about 30% more channel length.

Discussion

Bull et al. (2016) estimate that 350000 ± 50000 m^3 of material deposited on the Awatariki fan and lagoon in the 2005 debris flow; previously Costello (2005) had estimated 390000 ± 100000 m^3. The up to 40000 – 50000 m^3 of sediment that may have been stored behind log-jam dams is (i) up to 8 - 14% of the total volume material involved and (ii) within the margin of error of the total volume estimates. The risk estimates for the Awatarariki fan are based on assumed volumes of debris involved in the flow (50000, 150000, 300000 and 450000 m^3), so one critical question is, what difference does subtracting up to 50000 m^3 from these scenarios make to the risk assessment? This is best answered by reworking the risk analysis (Tonkin & Taylor, 2013).

However, given that the log-jam sediment storage is within the error of the best volume estimates, then any difference to the risk figures that results from subtracting the log-jam storage volume must also lie within the error of the risk figures. Thus while managing the log-jam storage artificially will in principle reduce the future risk to the fan, *it is not possible to estimate what the degree of risk reduction will be*; and in particular, the risk reduction cannot justify modification to the decisions already made about managing fanhead risk.

Maintaining the Awatarariki stream channel free of log-jams will be difficult logistically. It is not sufficient simply to demolish the log-jam dams, because they will reform in subsequent floods; removal or chopping up of the logs will be needed. The catchment will need to be inspected regularly, and any new dams removed, so the cost will be ongoing. In addition, log-jams are part of the natural ecology of steep wooded streams, so maintaining the stream free of log-jams would alter the natural ecology.

Conclusion

1. It is estimated that a maximum of about 40000 – 50000 m^3 of debris may have been present in Awatarariki stream in storage behind log-jam dams prior to the 2005 debris flow.
2. This is up to 8 – 14% of the estimated total volume of the event, and is less than the margin of error of the total volume estimate.
3. Recalculating the risk assessment for the fan by reducing scenario volume by up to 50000 m^3 (Tonkin & Taylor, 2015) will indicate the reduction in risk that could be achieved by maintaining the stream channel free of log-jams.
4. The fact that the volume change is less than the margin of error in total volume estimates suggests that this recalculation is not necessary.
5. There is no evidence that maintaining the catchment free of log-jams will contribute usefully to reducing debris-flow risk on the Awatarariki fan.

References

Bull, J.M., Miller, H., Gravley, D.M., Costello, D., Hikuroa, D.C.H. and Dix, J.K., 2010. Assessing debris flows using LIDAR differencing: 18 May 2005 Matata event, New Zealand. *Geomorphology*, *124*(1), pp.75-84.

Costello, D.A., 2007. Slope failures and debris flow assessment at Matata, Bay of Plenty, New Zealand. Masters Thesis, Univ. Auckland, New Zealand.

McSaveney, M.J., Beetham, R.D. and Leonard, G.S., 2005. The 18 May 2005 debris flow disaster at Matata: Causes and mitigation suggestions. *Client Report*, *71*. GNS Science Ltd, Lower Hutt, 50p + App.

Tonkin & Taylor, 2013. Supplementary Risk Assessment Debris Flow Hazard Matata, Bay of Plenty. Report 29115.1000 to Whakatane District Council, November 2013, 23p + App.

Tonkin & Taylor, 2015. Letter to Whakatane District Council with attachments, 2 October 2015.

Appendix 1: Illustrations of sediment sources

Fig. A1 Debris avalanche from slope into stream

Fig. A2 Stream bed sediment several meters deep eroded to bedrock by debris flow

Fig. A3 Log-jam in Blackjacks Creek, Notown in 1979. Jam height is 6.4 m (Pearce and Watson, 1983)