EFFECT of an INTENSE RAINFALL EVENT JUNE 2016 on CAVES at MOLE CREEK, TASMANIA

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Genesis 7:11: '...on the same day were all the fountains of the great deep broken up, and the windows of heaven were opened. And the rain was upon the earth...'

The heavy rainfall which affected the east coast of Australia in early June 2016 caused flooding from southern Queensland to Victoria and Tasmania. The weather system responsible, an East Coast Low, formed off the coast of New South Wales due to moist air from the Coral Sea being drawn into an upper level trough. The low was pushed southwards by a north-easterly airstream originating from a near-stationary high pressure system over New Zealand. Other centres of low pressure developed and interacted with the main low, directing a very moist north-easterly airstream over Tasmania from 5-7 June.

Tasmania's northern river basins were particularly affected following falls in excess of 200 mm in the 24 hours to 9 am on the 6 June. Many northern Tasmanian centres posted their wettest days on record. In a number of cases recorded rainfall more than doubled previous maximums. The exceptional nature of this event is the discussed in a special publication by the Bureau of Meteorology (2016).

Parts of Launceston city were inundated by floodwater, as were large tracts of chiefly agricultural land around La Trobe and other rural centres. Show cave operations at Marakoopa Cave, Mole Creek, and Gunns Plains Cave, were severely disrupted.

In the Mole Creek area, private gauges registered 270 mm at Mersey Hill and 430 mm at Liena, while Hydro Tasmania recorded >400 mm not far away at Lake McKenzie on the Central Plateau. These totals represent an essentially continuous downpour during the 36 hours from late on 4 June to early on 6 June. Bureau of Meteorology data for Mole Creek township indicate 24 hour totals above 100 mm on four previous occasions over the last 100 years, the maximum on record being 138.9 mm in February 1956. Other significant rainfall events are recorded over periods of 2-3 days, including a notable fall of 213.4 mm over three days in January 2011.

Unfortunately, the Bureau of Meteorology dataset for Mole Creek appears to have been discontinued in early 2015. There is little doubt however that rainfall at this location in early June 2016 was exceptional and probably unprecedented within living memory.

Liena Bridge on the Mersey River – destroyed during the flood

This article provides a qualitative description of the effects of the flood on caves at Mole Creek, based on an initial assessment conducted a short time after floodwaters receded. Two case studies are provided: a show cave, Marakoopa Cave, and an undeveloped cave, Croesus Cave. Both caves are located in the Mole Creek Karst National Park and Tasmanian Wilderness World Heritage Area; the managing authority is the Tasmanian Parks and Wildlife Service. The scale of flood effect in these caves appears to have been conditioned in part by the role of relictual conduits, which were invaded by floodwater causing otherwise dormant discharge points to be re-activated. This finding highlights the need to consider the potential for cryptic, stage-related thresholds in evaluating flow regimes in complex multi-level karst conduits. The article concludes with a brief discussion of possible linkages with predicted effects of climate change.

Marakoopa Cave

Marakoopa Cave is an extensive network of active and fossil tunnels associated with two underground streams: Long Creek and Short Creek (Figure 1). Under normal flow conditions the two streams occupy discrete eastern and western branches of the cave and only come together after discharging into a surface channel outside the cave. The stream headwaters are located high on Western Bluff (1420 m).

The effects of the flood were most severe on Long Creek, especially the downstream portion developed for cave tours. The following changes were observed: large volumes of gravelly sediment had been displaced, undermining concrete paths and viewing platforms or burying them to a depth of 0.5 m; sediment build-up had displaced the course of Long Creek, re-aligning it onto the tourist path for a distance of 15 m; relictual sediment banks up to 4 m high had been destabilised and in some cases collapsed onto pathways; boulders up to a metre in diameter had moved, impeding access through the cave; flowstone sheets deposited on gravelly fills had been undercut and some had fractured; lights and wiring had been torn away. Lesser effects were observed in the The Railway Tunnel – a fossil conduit used to provide access for tours to a viewing point on Short Creek. Water had evidently ponded up within this passage, bringing with it a flux of mucky silt. The net result of these various effects was not a pretty sight for a cave manager first thing on a Monday!

The scale of flood damage at Marakoopa Cave was potentially compounded by several factors. First, the discharge of Long Creek may have been augmented by water from Short Creek, via a connecting conduit such as The Railway Tunnel. In fact, although ingress of silt indicated that this passage was partially inundated during the flood, the water did not rise high enough to initiate transfer of water between the two creeks via this pathway. However, cross-flow may have occurred via presently un-mapped lower level fossil channels. Assuming such channels exist, flow would most likely be in the direction of Short Creek to Long Creek, due to water backing up on Short Creek above a constriction known as The Fireplace.

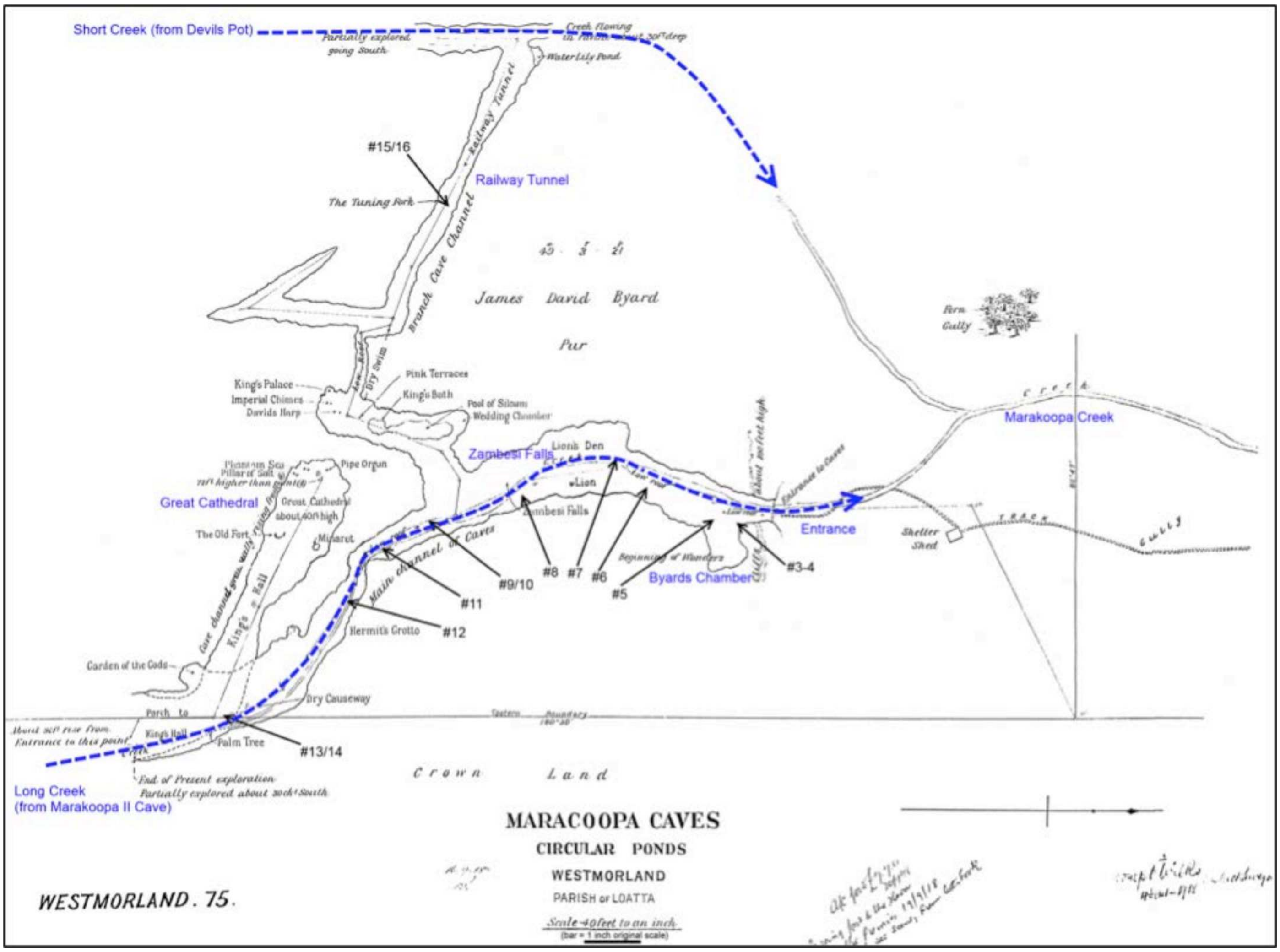

Figure 1: Partial plan of Marakoopa Cave based on a 1918 plan prepared by the surveyor Wilkes.
The Railway Tunnel is a fossil connection between the two active watercourses (blue).
It is inferred that part of the flood peak in Short Creek was diverted to Long Creek.

Cave guide Dave Lee at the Tuning Fork speleothem (The Railway Tunnel, Marakoopa Cave), indicating the level of the June 2016 flood versus a lesser flood in January 2011.

A second factor is the possibility that landslips on Western Bluff increased the peakiness of tributary streams and released into them quantities of sediment which were washed into the cave. A point of comparison here is a debris avalanche (landslip) on nearby Westmorland Creek. This rapid mass movement of slope materials was initiated following torrential rain in January 2011. It resulted in the blockage of Westmorland Cave by transported debris, which ran out into adjacent farmland, damaging agricultural assets. Despite evidence of new landslips high on Western Bluff above Marakoopa Cave, an inspection of surface tributaries returned no evidence of significant slugs of sediment moving into the cave. It is therefore concluded that landslip activity was not a major contributory factor in the scale of sedimentation on Long Creek, implying that the gravelly sediment mobilised during the flood was sourced from material already stored inside the cave. This is fortunate as it implies a more limited supply of sediment available for reworking by future floods.

The third potential contributory factor is the historical engineering of the natural course of Long Creek inside the cave, to facilitate tourist access and enhance presentation of cave features. The modified channel failed to contain the flood and in places impeded or re-directed its flow in ways that adversely affected natural and built structures. The fact that the show cave infrastructure has been developed incrementally over many years, much of it prior to modern engineering

Bouldery debris deposited by floodwater on tourist path in Marakoopa Cave.

standards, did not help. Built structures at two points on Long Creek were particularly important in conditioning the behaviour of the stream during and to an extent after the flood. First, a culvert at the cave gate was grossly inadequate for the flood discharge and calibre of entrained gravels, causing the stream to back up, flooding Byards Chamber and contributing to the failure of a rock and mortar wall at the cave entrance. Second, a low reach of passage further upstream of the junction with The Railway Tunnel created a bottleneck which trapped gravels moving downstream during the flood. Whilst this section of passage had been artificially enlarged many years ago to increase headroom for tourists, it was also made more constricted at stream level when a path and safety barrier was installed. The resultant build-up of material was responsible for the aforementioned displacement of the watercourse onto the tourist path.

Croesus Cave

Croesus Cave is a spacious pipe-like conduit extending between two upstream entrances (April Fools, Top Hole) and the cave outflow near the Mersey River. The site is managed as a restricted access wild cave i.e. access controlled by permit and limited to experienced avers. All entrances are gated. The cave stream is noteworthy for its steady but typically modest discharge – it rarely flows strongly or floods. Unlike the majority of other stream caves at Mole Creek, Croesus Cave is feed by diffuse sources and has no regular streamsink feeder. It is highly regarded for the scale and quality of its formations, especially large rimstone dams which occur virtually continuously through the main passage.

During the post-flood inspection it was immediately obvious that the cave had experienced very forceful flows. Shrubs and woody debris had been stripped away from around the outflow

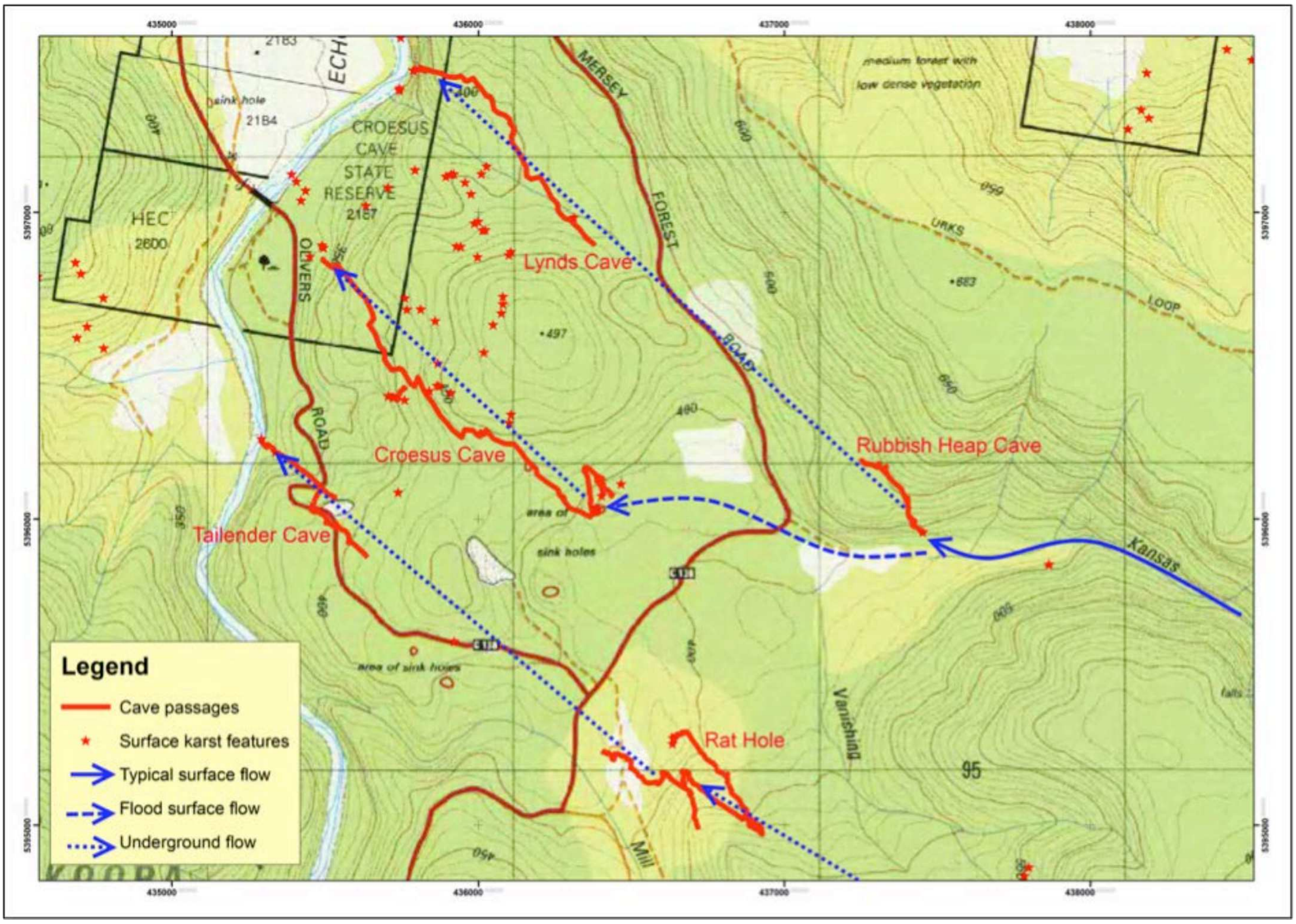

Figure 2: Surface and underground landforms and watercourses in the Croesus Cave area. Note altered flow path of Kansas Creek in flood, redirecting a portion of the flood peak from Lynds Cave to Croesus Cave.

Ranger Dan Bowden inspecting the cave gate at Croesus Cave. Note boulders lifted by floodwater and pinned between the gate and cave entrance.

entrance and along the surface watercourse below it. The outward force of water on the cave gate – a seemingly robust structure of 20 x 20mm steel bar welded into a rectangular mesh anchored to a concrete base and ring bolts drilled into the rock – had been sufficient to bend the steel bars and deform the overall structure. Rocks weighing tens of kilograms were found suspended at various points around the margins of the gate on the inside, having been lifted by the force of water and wedged in gaps between the steel frame of the gate and the adjacent rock. Entry to the cave had to be delayed until assistance had arrived in the form of a team with cutting tools.

The cave generally had experienced water levels 3-4 m above normal. A considerable volume of sandy to granular sediment had been reworked by the flood and deposited on the base and sides of the main passage. At one point a deep hole had formed, making it necessary to swim across what had previously been waded. Quantities of broken cave straws were seen amongst fresh sediment on the cave floor. Some of these may have been broken by caving parties over the years but the majority are interpreted as flood damage; however, many straws survived the flood and it is yet to be determined which sections of passage suffered loss of straws. A form of unusual rounded subaqueous concretion formerly common throughout the lower part of the cave was noted as much depleted, probably because many were buried under sediment or flushed away. Pieces of metal rubbish (e.g. tins, wire) had been unearthed by the flood, including a 3 m long section of concrete, rock and steel, part of an earlier gate structure. This unwieldy object had been exhumed and shifted several metres downstream, obstructing access at the outflow entrance. Despite these changes, larger speleothems including the iconic rimstone dams escaped obvious damage. Also on a positive note, virtually all sediment banks had been 'refreshed' by the flood, erasing the cumulative effect of many year of trampling disturbance.

Karstic effects were critically influenced the scale of flooding at Croesus Cave. This is because the flood re-activated a relictual surface drainage channel and associated former inflow points on Kansas Creek, below the point on the channel where the flow would normally be captured and diverted elsewhere. This watercourse normally sinks underground at Rubbish Heap Cave and then flows underground to Lynds Cave, 'sister' cave to Croesus Cave on the Mersey River (Figure 2). During the flood, Kansas Creek overtopped its normal sinking point and flowed overland to a complex of depressions above the upstream end of Croesus Cave, massively boosting the discharge within that cave. Fluvial scouring and flood debris on the surface in line between Rubbish Heap Cave and upper Croesus Cave provide strong evidence for overtopping on this occasion. A similar event may have occurred in August 1970 when an earlier gate to the cave was damaged, as discussed by Kiernan et al. (1994). In effect, Lynds Cave was deprived of a portion of the flood peak on Kansas Creek, which was re-directed it to Croesus Cave. Lynds Cave was included in the post-flood inspection – the cave experienced some significant effects but less obviously so than Croesus Cave.

Concluding remarks

The 'fountains of the great deep' envisaged by Genesis is an apt metaphor for torrential flows of groundwater surging through the caves at Mole Creek. An Old Testament reference seems doubly appropriate, given biblical plagues and the fact that the June 2016 flood followed on the tails of an El Nino drought accompanied by destructive wildfires. These fires attracted international attention when they burned large tracts of land including sensitive alpine areas in the Tasmanian Wilderness World Heritage Area (TWWHA). Whereas the biblical events are accounted for within that text by the hubris of man, we must look to climate science for explanations.

Modelling results predict reductions in winter rainfall over south-eastern Australia over coming decades, continuing a trend already apparent in the data. One of the factors responsible for this is a predicted reduction in East Coast Lows – these weather systems are considered likely to diminish in frequency around Tasmania but their intensity in this region may increase (CSIRO & BoM 2015). The June 2016 flood appears consistent with this prediction of increased intensity.

The consequences for karst and other classes of geodiversity in the Tasmanian Wilderness World Heritage Area, including Mole Creek Karst National Park, of increased frequency in extreme weather events, and other climate change effects, has been reviewed by Sharples (2011). Sharples identifies the following as probable outcomes for karst systems as climate change intensifies:

Increased flash-flooding of caves with increased sediment deposition or reworking: More frequent flooding of caves in high rainfall events is likely. If fluvial catchment erosion increases (due to increased catchment firing as well as more frequent intense rainfall events) then more sediment may be transported into caves and deposited, but if not then existing cave sediments may be scoured by flood waters and reworked or lost. Increased potential for landslips in karst catchments may have significant impacts on caves, resulting in diverted watercourses, increased sediment carried into caves by flood waters, and in some cases slumping of colluvial materials directly into caves. All of these impacts have already been observed in Tasmanian karst systems, and are likely to become more frequent and intense events as a result of climate change.

The above is a prescient summary of the observed effects at Mole Creek of the June 2016 rainfall event and flood.

Sharples characterizes his principal recommendation on climate change effects on geodiversity values as 'triage'. That is, of the very large range of possible effects and potential management responses, resources should be prioritised based on the following considerations (re-worded slightly from Sharples 2011):

1. Feasibility and benefits of limited interventions to mitigate climate change impacts (on geodiversity and/or on other dependant values such as habitat);
2. Value and feasibility of recording, sampling and archiving features and embodied information likely to be irreversibly lost (to preserve scientific information for future reference that would otherwise be largely lost);
3. Usefulness of monitoring and/or undertaking research on the nature and rates of changes to geodiversity occurring in response to climate change (to enable better

understanding of change processes and better management of responses to changes in geodiversity or dependent values, within the TWWHA or elsewhere); and:

4. Doing nothing (where no response is practically achievable, or feasible responses are of little benefit or would conflict with TWWHA management objectives).

The management response the Tasmanian Parks and Wildlife Service to the June 2016 event at Mole Creek will likely involve elements of each of the above options. Interventions to mitigate impacts will be directed at increasing the resilience of tourism and management infrastructure to future floods. Recording, sampling and archiving activities will probably focus on relictual sediments depleted by erosion during the flood – investigation of these will capitalise on freshly exposed sections and respond to the risk of loss if important examples ultimately disappear through natural events. These activities overlap with possible research and monitoring directions. 'Do nothing' is probably a reasonable default response, for example where wild caves are affected by fluxes of sediment and/or woody debris – the basic structure of these caves is resilient to flood effects and not much is to be gained by interfering.

References

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Sharples, C. (2011). *Potential Climate Change Impacts on the Geodiversity of the Tasmanian Wilderness World Heritage Area: A Management Response Position Paper.* Report to the Department of Primary Industries, Parks, Water and Environment, Tasmania (http://dpipwe.tas.gov.au/conservation/publications-forms-and-permits/publications/potential-climate-change-impacts-in-the-

What a contrast! Images of the landscape at Lake McKenzie above Mole Creek burnt in summer 2016 and photographed in April 2016, when regeneration was just starting. The floods occurred 2 months after these photos were take with Lake McKenzie recording >400mm of rain in 24 hours.
Photos: Steve Bourne