THE SAGA of the PINK TERRACES: A CASE STUDY of CAVE IMPROOOOVEMENT!

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Caterpillar: *Recite.*
Alice: *Oh. Yes sir. How doth the little bumblebee improve each...*
Caterpillar: *Stop. That is not spoken correctically. It goes: How doth the little crocodile improve his shining tail. And pour the waters of the Nile, on every golden scale. How cheerfully he seems to grin, how neatly spreads his claws. And welcomes little fishes in, with gently smiling jaws.*
Alice: *Well, I must say, I've never heard it that way before.*
Caterpillar: *I know. I have improooved it. (Carroll 1865)*

The dictionary doesn't have an entry for improooove. A possible definition would be that an improooovement is an attempt to improve things that doesn't actually bring into being a more desirable or excellent condition (the dictionary tells us this is what defines an improvement). Humans have a strong tendency to want to improve things, though sometimes the outcome is an improooovement. So it is with cave management.

The root of the problem is twofold. First, caves are complex natural systems of which our understanding will always be imperfect. It follows that tampering with them while seeking to improve certain aspects can have unforeseen environmental consequences. Second, show caves have historically been promoted primarily as an aesthetic experience, and often still are. This entails scope for pandering to the faddish and ephemeral.

The pitfalls facing the cave manager are well illustrated with regard to events surrounding the Pink Terraces and certain other features at Marakoopa Cave, Tasmania (Figure 1). The Pink Terraces is a series of large rimstone dams that create an impressive sequence of tiered ponds several metres wide and tens of metres in length (Plate 1). Originally, the ponds took up most or all of the width of the passage at this point, presenting

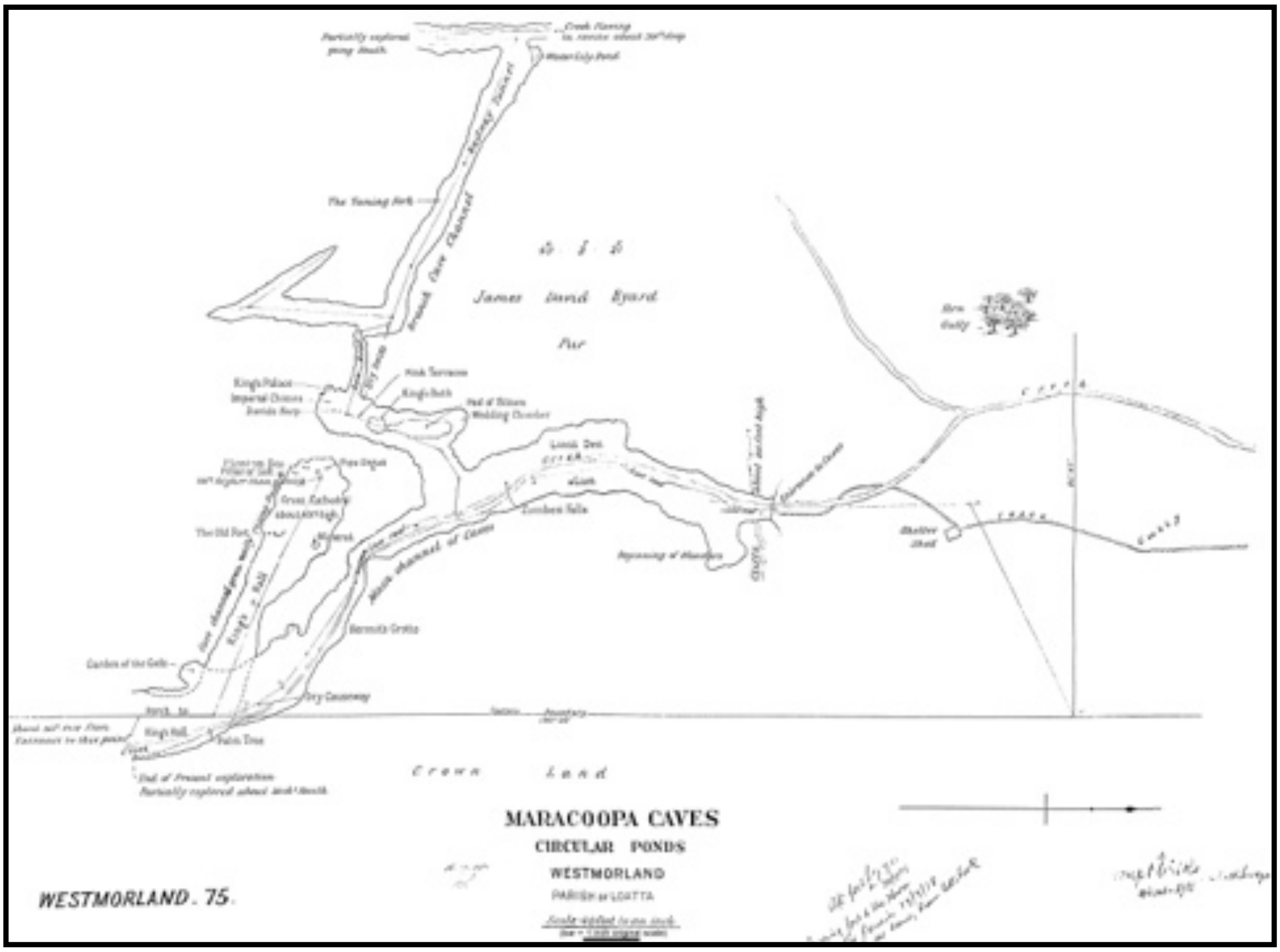

Figure 1: Surveyed plan of Marakoopa Cave dated 1918, by Joseph Wilks, District Surveyor. The feature marked 'WaterLily Pond' is now known as the Lily Pond.

Plate 1: Rimstone barriers towards the upstream end of the Pink Terraces. The pathway on the side was established in the late 1930s; prior to this, parties may have walked directly on the flowstone or the rimstone barriers. Photo: Paul Flood

something of an obstacle for parties proceeding deeper into the cave. In this situation visitors would naturally attempt to stay out of the shin-deep water by stepping on the tops of rimstone barriers or crossing the adjacent flowstone. Some damage may have resulted. 'Spark', who visited Marakoopa around the time of its opening in 1911, had this to say: 'The floor of the cave in many parts is beautiful in the extreme. It seems a sacrilege to walk over it and destroy the artistic patterning of the terra cotta, pink, and white tracing...' (Dyer 1911).

At some stage the rimstone barriers were modified by cutting notches into them, releasing impounded water and reducing their depth, presumably helping tourists keep their feet dry. Improvement or improoooovement? Higher in the same cave, a long flight of steps was chopped into the massive flowstone cascade that extends the length of Kings Hall. By today's standards these actions seem heavy handed if not vandalism. At the time they were evidently regarded as improvements – cost-effective solutions to practical problems in cave presentation.

It is unclear whether breaching the Pink Terraces was entirely effective in achieving dry feet. In any event, by the mid-20th century concrete had become the product of choice and in due course a raised path was constructed along the side of the Pink Terraces. This created a dry, graded access for viewing the terraces and accessing passages beyond. In 1938 David Lowry reported that 'there will be a first class track and step from cave entrance right through to the Lily Pound [sic]' (quotation supplied by Nic Haygarth).

Electric lighting was installed around the same time, replacing earlier hand held acetylene lamps and allowing greater control and flexibility in visual effects. Crystal-lined ponds were obvious targets for creative scene-setting (Plate 2). In this way the Pink Terraces and the Lily Pond came to be regarded as centrepieces of the Marakoopa Cave experience.

In the mid-1980s Chester Shaw (Parks and Wildlife Service) and others made further modifications to the infrastructure. In doing so they attempted to remedy some of the effects of what they considered to be bad past management practices, such as the breaches in the Pink Terraces. They did this by back filling with concrete the sections that had been cut away (Shaw 1991) – one of few Tasmanian examples of repairs to broken speleothems. For similar reasons Chester et al re-aligned

Plate 2: The Lily Pond – looking good following cleaning and restoration of the natural hydrology (cf. Plate 4). Photo: Paul Flood

the route through Kings Hall via a pathway along the side of the passage, off the main part of the flowstone.

Thus resurrected, the Pink Terraces were available to provide pleasing reflections for admiring tourists. That is, until it was noticed that the terraces had a tendency to dry out with increasing frequency and duration, as did the Lily Pond. Some years these features were reported to dry out in summer and not refill until well into winter or spring, if at all. The timeframe over which this occurred is unclear. Such an effect would be consistent with climate change modelling, which predicts that Mole Creek is one of the few Tasmania karsts likely to experience a net annual reduction in precipitation (Sharples 2011); on the other hand, an episodic event such as an extended drought could produce a similar result over a different timescale. For the purpose of this story the important point is that there was a perception that the ponds were behaving differently from the way they had in the past. This was considered to detract from the quality of the cave tours, to the extent that it was feared that visitors would be less inclined to go there.

Under natural conditions the source water at both sites is derived entirely from percolation flows (i.e. drip water). This could not be controlled; however, it could be supplemented by diverting water from other sources, such as perennial streams elsewhere in the same cave. This was deemed an appropriate thing to do. Accordingly, the following solution was engineered: (1) install inside the cave one 16,000 litre holding tank, comprising a plastic liner supported in a steel frame resting on a treated pine base, (2) pump water from creek into holding tank, regulated by a float valve at the tank, and (3) gravity feed water from the tank to the Pink Terraces and Lily Pond as required, controlled manually via a gate valve. These works were completed and the system operational sometime in the 1990s (Plate 3). The holding tank was located in an undeveloped section of the cave above Short Creek, the source of the water, and was not visible to those participating in tours.

Plate 3: 16,000 litre holding tank in upper level of Short Creek passage.

For a period the new arrangement appeared to be successful – that is, water levels in the ponds could be maintained during dry periods – but new problems became apparent. Short Creek originates from a surface stream rising high on the slopes of Western Bluff. It is derived mainly as runoff from non-carbonate rocks, has a flashy hydrological regime, and carries a variable load of organic material and sediment. It was found that water pumped into the holding tank contained suspended material that settled out in the tank, the Lily Pond and the Pink Terraces. Attempts were made to fix this by periodically vacuuming the base of the tank using a device for cleaning swimming pools. Despite this, sediment continued to accumulate, giving in the Lily Pond and the Pink Terraces a dull sludgy appearance (Plate 4).

Plate 4: The Lily Pond in April 2007. The dark material on the base of the pond is sediment from Short Creek (cf. Plate 2).

I became aware of the water diversion during an assessment of aspects of the environment at Marakoopa Cave in 2004. My first thought was that this practice might be having an adverse effect on the rimstone barriers and associated crystalline deposits. Theoretically, replacing or diluting alkaline percolation water with potentially acidic stream water could slow or reverse the precipitation of carbonate minerals. In other words, the diverted water might be gradually dissolving away the very features it was intended to enhance (improve)! I was also concerned that leachate from the CCA-treated pine base of the holding tank might be contaminating the cave.

Close inspection of the Pink Terraces revealed that although parts of the rimstone barriers were composed of hard crystalline material, as would be expected of actively depositing features, other parts were quite porous and even pitted with fist-sized holes. It was tempting to jump to the conclusion that this was due to solutional attack by aggressive water. In fact it had to be acknowledged that there were other possible explanations, such as physical damage sustained during a century of activity by tourists and cave guides. More compelling evidence was required, as the arrangement had not long been in place, was considered to significantly improve the quality of tours, and would not be a trivial exercise to dismantle. If indeed the hypothesis stood up to further testing.

Cave manager Paul Flood had inherited the set up described above and was supportive of further investigations. Consideration was given to using chemical data to model the state of saturation of the water with regard to carbonate minerals. This was not pursued for a variety of reasons. Instead, an approach was adopted that harks back to 1970s' experiments to quantify rates of erosion in different environments, using standardised blocks of precisely-weighed limestone. At Marakoopa the principal question was whether speleothems in the ponds were being eroded or deposited – quantifying the rate at which this was occurring was not critical. For our experiment we used small pieces of crystalline calcite cut into rectangular tablets weighing 4-5 g each. These were ultrasonically cleaned, dried at low temperature and weighed to four decimal places. The tablets were then encased in plastic mesh envelopes and suspended in the ponds at the Pink Terraces, Lily Pond and a few other places in Marakoopa Cave (Plate 5).

The tablets were retrieved after 12 months, removed from the mesh envelopes, cleaned, dried and weighed. Results are presented at Table 1. A negative change in weight was interpreted as evidence of erosive reduction; a positive change was interpreted as evidence of depositional accretion. Strictly speaking, results cannot be compared quantitatively between tablets, as their dimensions, and hence surface areas available for erosion or accretion, were not strictly standardised. Even so, they can be considered as qualitatively indicative of the relative intensity of erosion or accretion at the different sites.

Five of the tablets showed a reduction in weight. This was most significant in the case of the Short Creek tablet (#2), which lost 7.7% of its original weight. The holding tank (#1) and Lily Pond (#3) tablets lost 2.1% and 1.7% of their original weights respectively, while the most

Plate 5: Calcite tablet in mesh envelope.

upstream of four Pink Terraces tablets (#4) lost 1.1% of its original weight. The Short Creek result may be due to the effects of solution, physical abrasion by water-transported particles (corrasion), or a combination of these processes. The influence of corrasion can be discounted at the other sites.

The remainder of the Pink Terraces tablets experienced negligible or slightly positive weight changes. Of these, the most significant change was recorded at the middle to lower end of the Pink Terraces (#6), where the tablet increased in weight by 0.3%. A similar result was obtained from a tablet immersed in a nearby pool fed entirely by dripwater (#8). The weight of this tablet increased by 0.5%. These changes are consistent with accretion due to deposition of carbonate minerals, as would be expected under natural conditions in pools fed by water percolating through limestone. Interestingly, the weight of the most downstream tablet (#7) remained virtually stable. A transition from conditions of net annual erosion at the upstream end of the Pink Terraces, to one of stability or net annual deposition in the downstream direction, is implied.

Sample Id.	Location	Initial weight (g) 17/3/2005	Final weight (g)7/4/2006	Difference (g)
1	Holding tank	4.6541	4.5556	-0.0985
2	Short Creek	4.7440	4.3783	-0.3657
3	Lily Pond	4.8279	4.7441	-0.0837
4	Pink Terraces	5.0935	5.0345	-0.0590
5	Pink Terraces	5.9641	5.9619	-0.0022
6	Pink Terraces	5.1567	5.1707	+0.0140
7	Pink Terraces	5.8026	5.8027	+0.0001
8	Dripwater pool	4.6410	4.6659	+0.0249
9	Long Creek	5.5221	-	-
10 (control)	(not deployed)	4.4841	4.4819	-0.0022

Table 1: Results of calcite tablet immersion experiment. Tablet 9 was swept away in a flood.

Lab. No.	Date	Arsenic (µg/L)	Chromium (µg/L)	Copper (µg/L)
68165	22/12/2004	69	18	9
80566	04/10/2005	96	54	23
84728	15/12/2005	26	14	7
88559	23/03/2006	32	3	11.9

Table 2: Dissolved metals in standing water under the holding tank (analysis by Analytical Services Tasmania).

We interpreted the above results as evidence that the practice of diverting water from Short Creek into the Pink Terraces and Lily Pond was affecting chemical processes within the ponds. Specifically, the results suggested that deposition of subaqueous crystalline deposits had been impeded and in places reversed. We did not have any data from prior to the diversion; nor have we continued the experiment after the diversion ceased. We also acknowledge that our results do not imply a necessary connection between the stream diversion and the observed pitting at Pink Terraces, although we suspect that these things may be related. Despite these limitations, a prima facie case that the diversion was probably harming the cave had been established.

For reasons not fully understood at present, rimstone barriers at another Mole Creek Cave – the iconic Croesus Cave – do show evidence of advanced erosion in places. Unlike the Pink Terraces, there is no obvious cause for this, beyond the rather nebulous one of disturbance due to forest operations within the catchment. Eroding rimstone barriers at Croesus Cave exhibit characteristics ranging from subtle muting of forms compared to 'healthy' barriers, to more substantial signs of erosional reduction, such as crater-like holes and entrenched channels cutting into their surfaces. The rimstone barriers in Marakoopa do not show a comparable degree of modification, presumably because of the short duration of their exposure to the allogenic water.

Regarding the possibility of contamination due to leachate from the CCA-treated pine base of the tank, water samples were collected from a shallow pool of standing water beneath it. These were analysed for dissolved arsenic, chromium and copper – active ingredients in CCA-treated pine (Table 2). All samples showed elevated results for these metals compared to other sites around Mole Creek, where earlier sampling had returned results mostly below detection limits (Eberhard & Houshold 2002). Leachate from the pine beams was clearly implicated.

The results of these investigations, and a recommendation that 'the appropriate response is to cease diverting water into the [Pink Terraces and Lily Pond] and to remove the associated infrastructure', provided the ammunition Paul Flood needed to obtain support for shutting down the diversion. Removing the tank itself was no trivial task, as the structure had first to be dismantled and then ferried piecemeal across a 10 m deep canyon above Short Creek. This task was coordinated by Parks and Reserves Manager Chris Emms and completed in July 2010 (Plate 6).

The moral of this story could be that despite best intentions, some improvements turn out to be improoooovements. How can cave managers minimise their legacy in this regard? Using the Pink Terraces as a case study, the following may be useful starters: rigorously question the basis for actions that may result in permanent changes to natural features and processes; be sceptical of assumptions or untested predictions about how the environment will respond when component variables are manipulated; and, be mindful that the sensibilities of generations to come will differ from those of today – they may judge us harshly if our decisions restrict their choices in matters of aesthetics and the environment. In this way we can strive to do things correctically (with apologies to The Caterpillar).

References

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Plate 6: Dismantling and removing the holding tank, June 2010. Photos: Rolan Eberhard

Marakoopa Cave. Photo: Paul Flood