Ruakuri Cave - environmental management & development

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Abstract

Ruakuri is a Waitomo, New Zealand, cave recently re-opened to visitors. The cave has a number of valuable features including significant speleothems, sediment deposits, cave fauna and historic values. It operated as a show cave from 1904 to 1988. The recent re-development (by a major national tourism operator, Tourism Holdings Ltd), included a new tunnel entry, a new internal tunnel, relighting, and new pathways. The cave traverses three tenures of land: private land, road reserve and Scenic Reserve. The development was subject to the conditions of environmental resource consents from two local authorities and the concession process of the Scenic Reserve. The cave is of great significance to the local community, especially to local iwi.

Environmental management and development had to take into account this complex range of tenures, interest groups and statutory requirements, the values of the cave, the effects of tunnelling and other in-cave works, and the potential effects of visitation. Environmental monitoring and management regimes were established to protect the cave through the development stage and into the operational phase. Examples included airflow management, tunnelling monitoring, speleothem protection, sensitive walkway development and lighting systems.

Introduction

Ruakuri Cave lies in the Waitomo Valley, a few kilometres above the well-known Waitomo Glowworm Cave. A flaggy horizontal Oligocene limestone (25Ma) surrounds most of the cave. The cave comprises about 3.88km of passage and is #23 on the New Zealand cave length list (#9 around Waitomo) (NZSS website, 2007). Vertical development is about 60m. A long stream passage (the Okahua Stream, used for Black Water Rafting tours) is found at the base level, with an overlying set of palaeo-stream passages. Some of these are at quite different orientation to the current stream. Progressive retreat of the Huhunui side stream has created a set of incoming passages along one side of the cave, the oldest of which is the dry Drum passage, the youngest is the wet Twin Tomo entrance. The cave has two major shaft entrances. In addition to genesis through stream development and downcutting, there is major rockfall in an old wide part of the cave, the Holden's Cavern – Rockfall passage series. Thick tephra soils and a variety of vegetation types overlie the cave.

The cave has very important connections to the local community. The main entrance was used as a place of shelter (charcoal layers and rat bones (Ritchie, unpublished)) while journeying between the Waipa valley and the coast. That same site is also one the most important publicly known urupa (burial sites) in the local area, and is registered with the Historic Places Trust. The main entrance area is in the process of being returned from Scenic Reserve to the local iwi (local Maori people). For the caving community, Ruakuri was the site of the first serious accurate cave survey in New Zealand, by the Tokoroa Caving Group in the 1960s. One of New Zealand's first computers was used to crunch the data, at night by caving employees of New Zealand Forest Products. The cave was developed and opened for tours in 1904. The history of the cave tours, closure of the cave, and issues around the re-opening are covered in Martin (2003) and elsewhere in these Proceedings.

Values of the cave

Ruakuri Cave was rated in the New Zealand National Geopreservation Inventory (Worthy, 1990) as B3, meaning it is of national significance ("B") and unlikely to be damaged by humans ("3"). It is cited for its geomorphology/length and its significance as a tourist cave.

The values of the cave are summarised in Table 1.

Table 1: Environmental values of Ruakuri Cave

Geomorphology	Cave length of 3.8km. Long and large streamway for Waitomo area.
Geology/lithology	Not unusual for area.
Speleothem deposits	Major collection of calcite speleothems in the Mirror Pool area. The inner end of Holden's Cavern contains one of the more notable assemblages of evaporation-derived speleothems in the Waitomo area.
Sediment deposits	Potentially significant laminated sediment deposits in the lower Drum passage: layers of silt, sand and gravel with flowstone laminates (Williams et al, 1999).
Cave fauna	Site of first discovery of a trogolobitic pseudoscorpion in NZ (Miller pers comm). New species of millipede (Dalodesmidae) found 1998. Significant glowworm display along main stream. Diversity of fish species in cave including long-finned eel, koaro and torrentfish. Good range of habitats and typical Waitomo cave species found including troglobites. New hydrobiid snail species await description (Haase, unpublished).
Flora	No significant values known. Good example of twilight zone flora in original tourist entrance.
Biogenic deposits	A typical range of fossils have been found in the cave (bird, frog, skink). All have been surface rather than stratigraphic deposits.

Natural values of the cave have been affected by changes in land use and the use of the cave for tourism. Both the autogenic and allogenic catchments have been modified from temperate rainforest to include farmland and plantation forests. Low-intensity stock-grazing occurs in both catchments. A road cut lies across the top of the cave. Show cave tourism from 1904 -1987 left a legacy of corroding fittings, decaying timber and concrete. More recent adventure cave tourism has enhanced weirs, added dams and heavily trafficked the streamways with unknown but probably limited effect on aquatic ecosystems. In recent years some important doline and streamsink areas around the cave have been retired from grazing and re-vegetated.

Major values for protection in cave development

The Ruakuri development proposal incorporated coming in through the Drum Entrance (a closed set of 44 gallon drums placed by cavers through a dig in the 1960s), avoiding the original main entrance. A circular route was sought to link up two dead-end passages in the Holden's Cavern – Rockfall Chamber area. A complete refit of lighting and path structures was required.

Three key environmental issues were of consequence to this proposal.

Firstly the Drum passage appeared to be quite old and had speleothem and sediment values worthy of protection both for their intrinsic value and for potential scientific study. Strong protection from physical damage and climate change was warranted.

Secondly the 'Rockfall Chamber – Mirror Pool' area was a 'deep cave' zone of highly attenuated humidity and temperature range with good speleothem displays and a large fauna habitat area. Protection from climate change was the key requirement here.

Thirdly the evaporite speleothem array at the end of Holden's Cavern needed protection from physical damage by visitors and changes to cave climate.

As well as these key issues other effects, many common to all caves, needed to be considered:

- carbon dioxide and climate effects of visitors
- sediment control associated with the entrance structure
- flows of fauna, air and water at the new entrance and internal tunnel
- vibrational effects of entrance structure construction and other works
- effects of lighting systems
- physical effects of structures through a range of passages

Substantial re-development was in passages that contained little but bedrock, or were previously developed. In these areas the marginal effect of the development was not expected to be great.

Environmental controls

Several major controls were in place to guide development and protect the cave. Foremost was the wish of the development team to work to high standards and use best practice in order to protect the cave. Underlying statutory controls were provided by a set of 'resource consent' conditions for the whole cave, and a set of 'concession' conditions for the Drum passage and entrance structure.

Resource consents are issued by local authorities over public and private land to address resource management issues and the effects of use on soil and water conservation, vegetation, natural features (e.g. caves) and the like. Consents for the Ruakuri development were issued by both the Regional and District Council to an early developer who then moved on. The consents were inherited by the final developer/operator of the Cave. They contained comprehensive conditions around monitoring requirements, retention of expertise, airflow management, sediment control, tunnelling, cave climate management, management plans, bridge construction and toilets.

Table 2: Summary of key resource consent conditions

Regional Council

- Approved development plan describing methods and procedures
- No works in waahi tapu
- Archaeological survey of entrances
- Standard sediment control procedures. No more than 10% increase in stream suspended sediment levels
- Restrictions on disposal of excavated material only at sites approved (by cave experts)
- Removal of remnants of previous tourist operation
- Expert approval for removal or damage to any cave features
- CO_2 limit of 2400ppm
- No more than eight days between tunnel penetration and complete climate control system. Temporary air flow minimisation at all times.
- Humidity to be kept at 92±8% in Holden's Cavern – Rockfall Chamber – Mirror Pool area
- Temperature to be kept at 14.5±3°C in Holden's Cavern – Rockfall Chamber – Mirror Pool area
- Airflow to be managed to prevent adverse changes to speleothems and fauna habitat in the Mirror Pool – Rockfall Chamber area
- Inert materials for structures. No internal combustion engines to be used
- Climate monitoring
  - Drum Passage: CO_2, dry bulb, wet bulb, rock 2cm, rock 8cm
  - Stream passage: Wet bulb, dry bulb
  - Bridal Chamber: CO_2, dry bulb, wet bulb, rock 2cm, rock 8cm
  - Holden's Cavern: Wet bulb, dry bulb
  - Outside: Dry bulb, Soil moisture
- Other monitoring
  - Glowworms: two quadrats at main stream
  - Other fauna/flora: single survey 12 months after tunnel entry

- Speleothems: Photomonitoring various sites 12 months after tunnel entry
- Suspended sediment: Daily in local streams during excavation period.
- Reporting – various reports to Regional and District Council required

District Council

- Many of the same conditions as above
- Annual monitoring reports required for first five years then every two years subsequently
- Expert advisory group to be retained with oversight on all technical/analysis/environmental monitoring matters; risk management, environmental effects
- Cave Management Plan to be prepared for approval
- Cessation of tours if climate parameters exceeded for more than four days
- Daily log of visitation, works, maintenance, events etc
- Constraints on parking, vehicle access, nature of external buildings, landscaping, noise limits, and signage

Part of the land was Scenic Reserve administered by the Department of Conservation and thus needing a "concession" or permit over those parts of the Cave. Concession conditions particularly addressed the entrance structure, lighting and feature protection of the upper Drum passage, and airflow management through the Drum passage. Concessions provisions are, as might be expected, generally tougher than resource consent conditions as the latter pursues sustainable management while the former is based on conservation of a Scenic Reserve.

Department of Conservation (Drum passage only)

Entrance development

- Climate monitoring system
- Approved vibration monitoring system
- Sediment control on surface works – cover, diversion, sediment traps
- Pollution intercept measures in place. No use of chemicals, fuels etc in cave without further permission
- Sealed robust impermeable airflow barrier to be in place throughout development until replace by approved airflow control systems
- Surface landscaping plan
- Peer reviewed construction plans

Passage development

- Pathways of inert materials with provision for controlled, contained washdown. Allowance for the natural flow of water through the Drum passage. Barriers to be provided to protect natural features. Detailed plans to be approved.
- All sediment banks etc to only be removed under supervision of person qualified to assess significance of any cave feature. Fossils, speleothems and sediment samples to be retained and provided.

Cave operation

- Drum passage condition targets
  - Air temperature: 12.5±1°C
  - Humidity: 95-100%
  - Carbon dioxide: max 2400ppm
  - VOCs: nil (i.e. no use of combustion engines)
  - Air velocity: minimal
  - Litter, lampenflora: nil
- Monitoring station to be maintained in upper Drum passage
  - Wet and dry bulbs: every 30mins
  - CO_2: every 10mins
- To be reported to Lessor every six months
- Energy inputs (e.g. light, noise, vibration) to be minimum necessary. Lessor may set standards.
- Drum passage cave conditions to be maintained conducive to a troglophile community (upper end) grading down to a mixed troglophile/troglobite community (mid-passage) through minimal but non-zero nutrient input, avoiding compaction of soft sediments,

inflow water free of contaminants, rat control if necessary

- Lighting plan to be approved. Minimum lighting necessary for aesthetics and safety, positioned for minimal lampenflora growth and surface desiccation. Low heat output and only switched on when necessary.
- Annual operation plan including environmental plan

Pre-development studies

In the application process for both consents and concessions, the onus is on developers to study and describe the effects of their developments. To this end Auckland University were contracted to undertake baseline studies, describe the values of the cave. This study (Williams et al, 2004) also made a number of recommendations for cave development, many of which were incorporated in consent conditions.

Managing airflows

Climate is poorly understood in Ruakuri Cave, as befits any cave with 8 entrances, several different streams and several levels of development. The classics appear to be in place: cool air flowing out the bottom entrance on summer days, warm air flowing out the upper entrances on winter days, core areas of highly attenuated temperature and humidity range, and greater variability close to entrances. Circulation patterns in the mid-range entrances and the complex central area around the streamway are yet to be fully understood.

Pre-development data for the Drum passage over six months showed highly attenuated temperature, barely varying from the regional average temperature of about 12-13°C. This suggested little influence from the outside, despite the small holes around the Drum entrance and the high thermal conductivity of the drum covering. Trials showed some stratification of temperature within the passage (of the order of 0.2°C), suggesting that there might be a light circulation cell driven from the lower end of the Drum passage where it emerges high above the main stream passage.

The main Rockfall-Mirror Pool chamber showed similar temperature attenuation, varying around 12.8 – 13.2°C. Infrared irradiometer (highly accurate) spot readings confirmed this Hobo data. The far end of Holden's Cavern showed more variation, ranging 8-12°C, and particularly showed some response to cold temperatures outside.

Relative humidity was continuously measured in Holden's Cavern using wet and dry bulbs and was continuously around 95-105%. This sort of result (i.e. above 100%) has often been recorded at Waitomo and is an artefact of the difficulty of measuring humidity accurately. Accurate spot measurement with an Assmann psychrometer gave all readings over 95%.

Airflow data through and after the construction period has shown no change i.e. no airflow has been recorded other then when the door was left open for periods during construction. Two ultrasonic anemometers are in use, at the Drum passage and at the end of Holden's Cavern, both continuing to show no airflow. It is possible that these passages within caves have airflow behaviour similar to single entrance caves, with airflows close to the surfaces (as studied by Amar (2005) at Aranui Cave). If this is the case the ultrasonic anemometer may not be picking up such subtle flows due to the size and shape of the instrument.

There were two key requirements – protection of the Rockfall chamber area from 'outer' air through an airlock door system in the excavated internal tunnel, and protection of the Drum passage by installation of airlock doors at the tunnel base. Sonic anemometers are in place next to both the excavated connections and have not shown any significant increase in airflow. This is supported by temperature and humidity data. Short-term elevation was experienced during construction and development however short-term change (an hour or half day here and there) is not thought to be critical in its effects on the cave, it is longer term or cumulative change that seems most important to avoid.

Carbon dioxide

Carbon dioxide management has always featured high on the list of management priorities in the Waitomo Caves area. The well-researched environmental limit of 2400 ppm exists for the nearby Waitomo

Glowworm Cave, and this figure was applied as a limit for Ruakuri Cave. In fact speleothem deposition is far more active in Ruakuri then the Glowworm Cave so the figure is probably a conservative one.

Pre-development CO_2 readings ranged from atmospheric to 900 ppm in core climate areas. The Mirror Pool – Rockfall area was consistently slightly above atmospheric levels. A distinct rising and falling pattern was evident over several days, with some diurnal variation superimposed.. Elevation has been recorded from time to time on the Waitomo Glowworm Cave in the absence of visitors. It is possible that work parties contributed to some elevation but it seems more likely that Waitomo's caves have a natural source of CO_2 not previously described. One possibility is that the elevations may be due to degassing of CO_2 from the extensive water bodies in each cave. This theory is currently being studied in the Glowworm Cave.

All the data collected until recently (using Vaissala detectors logging every 10 mins on a Campbell CRX10 logger) had suggested that carbon dioxide elevation was unlikely to be a significant issue in Ruakuri Cave in the medium term. Visitation rates seemed moderate, while the cave is high volume and seems well ventilated. The highest carbon dioxide level recorded to date until recently had been 1800 ppm, recorded on the opening day when 300 people visited the cave in a few hours. In April 2007 more recent downloads showed several spikes over 2400ppm, including early morning levels above 2000ppm. Clearly the management of the cave will need to be re-assessed in the near future and perhaps become more active.

Entrance caisson and tunnels

The historic state of the Drum Entrance is unknown. A rock and clay blockage was penetrated by cavers and lined by a series of 44-gallon drums, hence the name. But was this debris only emplaced by the cutting of the road (metres above) early last century? This was resolved with an agreed position – that the preferred state for the Drum passage was virtually no airflow, highly attenuated water flows, and limited troglophile access. For engineering reasons the large entrance caisson (vertical drop) and connecting tunnel (horizontal drop) were moved back twenty or so metres from the original entrance. This had the benefit of leaving the original entrance area ostensibly intact. Thus if the artificial entrance was tight in terms of exchanges, the desired conditions would be achieved through the old entrance remaining effectively unmodified nearby. Troglophiles and air still retain their original 'access rights' through the Drum connection (one drum collapsed, which was probably beneficial in terms of cave security).

Silt fences were used during the construction period while PVC strip curtains allowed easy access for workers while providing effective control on airflow. These were later replaced by permanent twin airlock doors which provide airflow control to this day.

Sediment from the excavation was disposed of outside the Ruakuri Cave catchment. Dumped household rubbish was removed from one part of the doline and replantings are underway. Shot rock and an upstand pipe were installed in the base of the original drum entrance to preclude silt entering the streamway. With these water flow barriers, replanting of the doline area, and redirection of the runoff from the road above, the water discharge curve is probably closer to its natural state than pre-development.

Vibration control

The effect of vibration on caves, and speleothems in particular, seems variable and difficult to predict. No doubt lithology, tectonic structure, passage layout, speleothem structure, distance and vibration source combine in many ways. For the Ruakuri development, two methods were used to look at vibration, a set of drop sheets under speleothems, and a vibration detection machine. Monitoring in itself is not management, and the detection of any adverse effects would trigger a cessation of whatever vibration was taking place pending re-assessment. After setting the conditions for construction, the excavation method was changed away from piling, reducing the risk of vibration effects. The detection methods were kept in place and throughout the course of the construction period no adverse effects were observed: no bits of stal appeared on the drop sheets and the vibration machine did not register any events above the 0.5mm threshold (theoretically capable of detecting a person walking past).

At one point a large rock needed to be blown during tunnel thrusting. A sediment bank was observed to move as a result, but there was no motion detected on the bedrock or attached speleothems. An earthquake well down the North Island was detected.

Lighting systems

Much of the previous lighting infrastructure was removed or overhauled as part of the development. Low voltage (12V) lighting was used through most of the cave, with LEDs in the upper part of the Drum passage. After a year and a half of operation the first shades of lampenflora have just started appearing in two locations.

Protecting physical features of the cave

A diversity of physical features was conserved through the Ruakuri development. During entrance construction protocols were in place for discovery of bones and laminated sediments; while any speleothems encountered were put aside. In the Drum passage channel samples of sediment banks were kept. Representative areas of sediment bank were retained and again sediment removed was searched for bones and any other significant features.

Sediment and speleothem samples have been provided to the University of Waikato to reconstruct some of the history of the Drum passage.

The protection of floors during cave development and in management has a less than stellar history around the world. So much of our cave heritage lies underfoot, from bone deposits to rimstones, from fauna habitat to sediment layers. Airflows and water flows move across floor surfaces yet they have been routinely constructed upon with little allowance for their features and processes. One of the foci for the Ruakuri development was to place greater value in this area. To that end suspended walkways have been used extensively in new passage development. As well as protecting cave floors, such walkways also reduce the uncertainty (and risk) where the substrate is suspect or unknown. Wire hangings do compromise the aesthetic outlook from the walkways but the overall benefit to cave feature protection is clear. Acrylic shielding has been used to prevent visitors accessing a number of speleothems. During construction, financial penalties were promoted to contractors for breakage of speleothems, to the point of having price tags hanging on some speleothems. As amusing as this seemed to the caving people involved, it certainly seemed to speak the language of the contractors and was quite effective in sharpening their attitudes to the cave.

Two speleothems were accidentally broken by contractors, and a large flowstone-stalactite shield cracked as the interconnecting tunnel head broke through nearby. The latter was bolted back onto the wall. Two area of passage, each a few metres were long, were deliberately removed to facilitate access to the required width specification for the cave.

The Drum passage became a major commuter route before its walkways were installed, so temporary protective measures were used. Specially sourced large semi-airfilled rubber rings protected surfaces while supporting scaffolding planks, grating and the like that then took the traffic. During the construction of walkways, walls were cordoned off to preclude damage. Any angle grinding or steel drilling was done over a collector, while plastic cutting and grating used hose and a carpet runout to collect offcut and shavings.

Summary

Ruakuri Cave was re-developed for tourism in the last few years. The cave is a valuable one and has many features deserving of a high level of protection through development and operation of the cave. A comprehensive set of monitoring and reporting conditions have been set for the cave and are in the process of being implemented. Effective air control has been achieved in important areas and direct damage to physical features of the cave has been minimal. In particular, careful work practices and the use of suspended walkways in the narrow Drum passage has helped protect numerous fine scale and under foot values.

This has been the most significant infrastructural development in a New Zealand cave since the 1920s.

References

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