

GLASSHOUSE MOUNTAIN SUMMIT ROUTES: BALANCING SAFETY, ACCESSIBILITY, AND TOLERABLE RISK

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ABSTRACT

The Glasshouse Mountains National Park located in Southeast Queensland, Australia is formed around a group of 11 volcanic peaks. The variety of walking tracks within the remarkable natural environment and panoramic views attainable at the peaks mean the national park is increasing in popularity with locals and tourists alike. Two of these peaks, Mount Tibrogargan and Mount Beerwah, include summit routes that have exposed, steep rock sections that are explicitly recommended only for fit, experienced hikers and rock scramblers by Queensland Parks and Wildlife Service (QPWS).

These two noted summit routes present unique challenges for managing slope risk due to their exceptionally steep topography and natural hazards. This paper explores the application of quantitative geotechnical risk assessment processes to reduce risk for track users while maintaining accessibility to these popular natural sites.

The tolerable risk levels for more challenging trails like these are typically aligned with other perceived high-risk recreational activities, such as climbing, scuba-diving and skiing. Assessing what is considered tolerable risk helps strike a balance between public safety and accessibility. This process is a risk-based compromise between maintaining access to the natural landscape, minimising invasive infrastructure, and reducing exposure to hazards.

Ultimately, to allow continued public access, there is a need for regular risk assessments and review of risk management to uphold safety standards while allowing the public to engage with these fulfilling national park experiences.

1 INTRODUCTION

The Glasshouse Mountains National Park encompasses eleven volcanic peaks and is located in Southeast Queensland, Australia. This area is renowned for its beautiful and unique scenery, with the park attracting thousands of visitors annually, including hikers, picnickers, and climbers. Among its many trails, the summit scrambling routes of Mount Tibrogargan and Mount Beerwah are popular with those looking for a challenge, due to their difficult terrain and breathtaking views from the peak. These routes are explicitly recommended for fit, experienced hikers and rock scramblers due to their steep and often rough profile.

As the number of park visitors grows, balancing risk reduction and safe access to the park's summit routes for all users is an increasing challenge. Striking the balance between safety and accessibility is an increasingly complex task for Queensland Parks and Wildlife Service (QPWS), particularly given the abundance of natural hazards and the unique track topography of each route. Effective geotechnical risk management is needed to allow continued public access on these scrambling trails while minimising the likelihood of accidents and injuries for park users.

The objective of this paper is to explore how quantitative geotechnical risk assessment can be used to effectively manage these two summit scrambling routes within the Glasshouse Mountains National Park. As the risk to users cannot be entirely eliminated, QPWS is tasked with the responsibility to reduce exposure and enhance hiker awareness, balancing public safety with the recreational value of the summit routes.

This paper focuses on the geotechnical aspects of risk management, relating to slope stability and rockfall hazards. It does not address access in relation to First Nations cultural and heritage perspectives. Other risk considerations such as an individual's competency are discussed, however this paper is not informed by these aspects.

2 BACKGROUND AND SITE DESCRIPTION

2.1 GEOLOGICAL AND GEOGRAPHICAL OVERVIEW

Mount Beerwah and Mount Tibrogargan are two prominent peaks within the Glass House Mountains, which are a collection of volcanic plugs formed from magma intrusions during the late Oligocene, approximately 27 to 26 million years ago (Willmott, 2007). Mount Tibrogargan is located about 3 km southwest and Mount Beerwah about 6.5 km west of the Glass House Mountains Township. These and other peaks are shown in Figure 1.

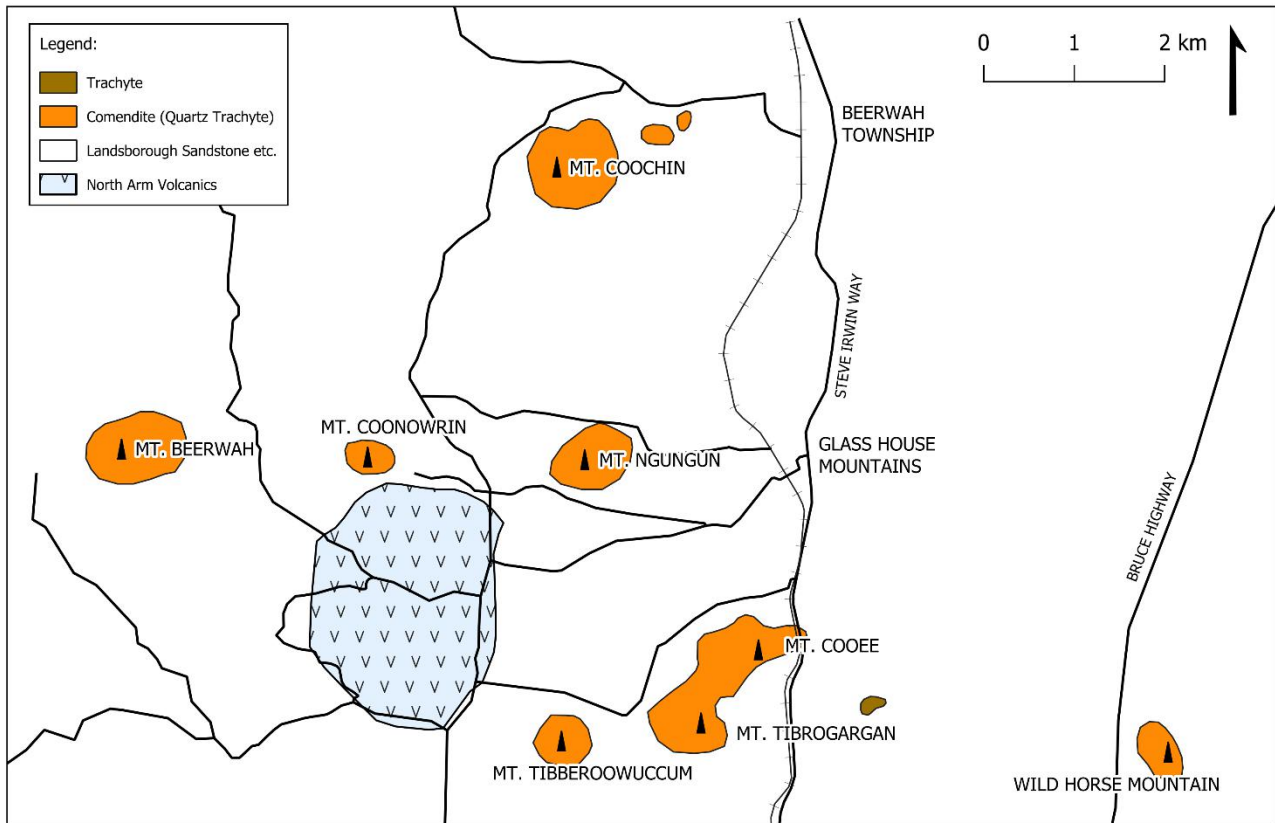


Figure 1: Glasshouse Mountains Geology (Willmott, 2007)

The Glass House Mountain formations are remnants of a volcanic complex which formed when Australian continental crust passed over 'hot spots' in the earth's mantle. They formed as magma intruded into older sedimentary rock layers, solidifying into plugs of alkali rhyolite, trachyte, and related volcanic rocks. Mount Beerwah is composed mainly of alkali trachyte, while Mount Tibrogargan consists of a bluish alkali rhyolite (comendite) (Willmott, 2007). As these volcanic bodies cooled, contraction within the rock led to the formation of vertical columnar joints, visible today in features like the "Organ Pipes" on Mount Beerwah and blocky structure of Mount Tibrogargan (as shown in Figure 2).



Figure 2: Left: Mount Beerwah 'Organ Pipes' Columnar Jointing, Right: Mount Tibrogargan blocky structure

Over millions of years, the basalt flows, and then subsequently the surrounding softer sedimentary rocks, primarily Landsborough Sandstone, eroded away, exposing the harder volcanic plugs. The peaks now stand as isolated remnants of the once majority volcanic landscape due to their greater resistance to weathering. Groundwater has also played a role in shaping the landscape by seeping along defects, weakening the rock, and creating shallow caves on the mountain faces.

2.2 GLASS HOUSE MOUNTAIN TRAILS INFORMATION

The Mount Tibrogargan summit access route follows the mountain's western ridgeline, while Mount Beerwah, the highest peak in the Glass House Mountains National Park, has its summit access route on the northern face. Despite their difficulty, these routes attract hikers of all skill levels. Regular foot traffic has caused significant anthropogenic erosion, making the summit routes visible in aerial photography, as shown in Figure 3.

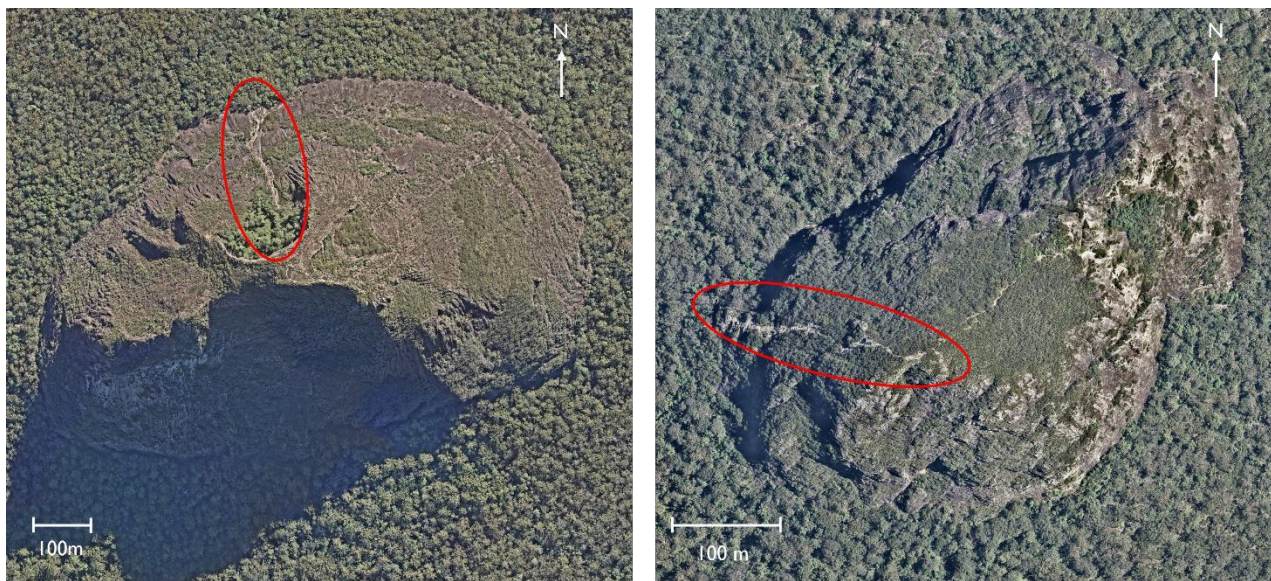


Figure 3: Plan view of Mount Beerwah (L) and Mount Tibrogargan (R) showing the summit access routes clearly eroding the slope faces (© Nearmap, 24 December 2024).

The Queensland Parks and Wildlife Service (QPWS) provides detailed information on various walking trails within the Glass House Mountains National Park, assigning each a specific grade to indicate its level of difficulty (Queensland Parks and Wildlife Service, 2025). However, the summit routes for Mount Beerwah and Mount Tibrogargan are absent from this grading system due to their unique challenges and higher assessed risk.

Among the graded routes, examples include:

- **Mount Beerburum Summit Walk**
This track is classified as Grade 3, meaning it presents a moderate challenge. It includes a steep 750 m concrete section that can be slippery, requiring reasonable fitness and appropriate footwear. The full return distance is 3.5 km, with an estimated completion time of 1 hour and 30 minutes.
- **Yul-yan-man Track**
Rated as Grade 5, this track is designed for experienced hikers with rock scrambling skills. It offers a challenging adventure with access points from both the Beerburum and Tibrogargan trailheads.

In contrast, QPWS provides information about the summit routes for Mount Beerwah and Mount Tibrogargan at the bottom of the Glass House Mountain Journeys webpage, following all other graded trails, and precedes the section on the webpage with a safety video. The absence of a grading system serves as a subtle warning, reinforcing the challenges and risks involved. QPWS strongly advises that only those with sufficient experience and preparation attempt these climbs. To support this, a comprehensive cautionary information sheet is available on the website, including detailed descriptions and profile maps (see **Figure 4**).

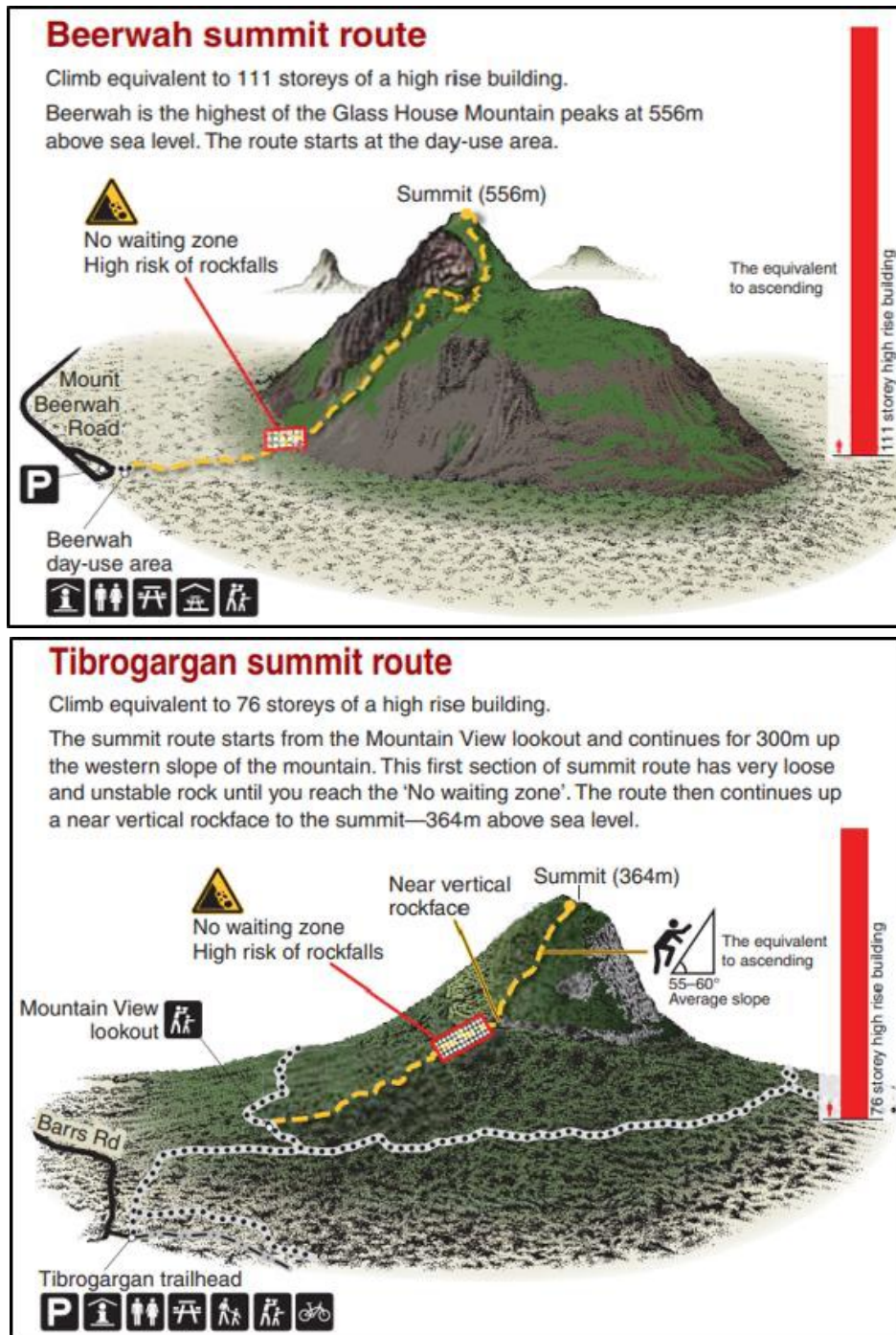


Figure 4: Glass House Mountains summit route profile maps; Top: Mount Beerwah, Bottom: Mount Tibrogargan (© State of Queensland. Queensland Parks and Wildlife Service. MA787 August 2022).

2.3 VISITOR DEMOGRAPHICS AND USAGE TRENDS

Usage data provided by QPWS shows approximately 36,000 and 25,000 counts at the Mount Tibrogargan and Mount Beerwah summit routes in 2023, respectively. Data was collected using a variety of installed automated loggers, including motion and heat sensors. It is assumed that an individual hiker triggers the usage monitoring apparatus twice, on ascent and descent, so actual usage figures are half of the above. Usage patterns indicate that most hikers make the ascent during the day at weekends and public holidays. When the 2023 Mount Tibrogargan usage data is compared to data collected in 2016, an increase in usage of approximately 38% is evident. It may be assumed that Mount Beerwah has seen a similar increase. The increasing usage highlights the need for effective risk management strategies.

3 RISK MANAGEMENT FRAMEWORK

3.1 PRINCIPLES OF GEOTECHNICAL RISK ASSESSMENT

Assessing geotechnical risk is critical for understanding and managing hazards in all areas where geotechnical hazards are present. The process follows a structured approach to evaluating potential ground-related risks, ensuring informed decision-making and mitigation strategies (AGS, 2007). The key principles include:

1. Hazard Identification – Recognising potential geotechnical hazards such as rockfalls, landslides, and erosion through geological surveys, historical data, and site investigations.
2. Risk Analysis – Assessing both the likelihood of hazard occurrence and its potential consequences, using qualitative (e.g. risk matrices) or quantitative (e.g. probabilistic models) methods.
3. Risk Evaluation – Comparing assessed risks against regulatory guidelines and acceptable thresholds to determine the need for intervention.
4. Mitigation and Control Measures – Implementing engineering solutions (e.g. slope stabilisation, drainage), monitoring systems (e.g. inclinometers), and administrative controls (e.g. hazard zoning, access restrictions).
5. Uncertainty Management – Accounting for variability in ground conditions, geological processes, and modelling assumptions through conservative design and sensitivity analysis.
6. Continuous Review and Adaptation – Risk assessments should be updated as new data becomes available, environmental conditions change, or unexpected events occur, ensuring ongoing refinement of risk mitigation strategies.

By following these principles, geotechnical risk assessment provides a systematic framework for managing ground hazards, reducing potential impacts on infrastructure and public safety.

3.2 RELEVANT GUIDELINES AND INDUSTRY BEST PRACTICE

For public recreational activity, ideally risk should be eliminated. This is quite often not possible, or eliminating the risk devalues the benefit of the activity. Instead, to allow continued amenity to the public, the risk must be managed in a way that balances the risk and benefit. ISO 4980:2023 provides a framework for regulatory decision-making based on legal, organisational, and societal considerations. The methodology of this standard is outlined in Section 6.1.2.

As stated in the AGS Guidelines (AGS, 2007) defining tolerable risk criteria is the responsibility of the regulator because the implications affect the community at large. For National Parks in Queensland, the regulator is Queensland Government's Department of Environment, Tourism, Science and Innovation (DETSI). QPWS operates within DETSI.

ISO 4980:2023 differentiates between tolerable risk and acceptable risk specific to a recreational activity as follows:

- Tolerable risk: A risk that is deemed manageable under the given circumstances but still requires monitoring and mitigation where possible. It acknowledges that some level of hazard is inherent in recreational activities.
- Acceptable risk: A risk level that does not require further action because it aligns with the expected and reasonable exposure associated with the activity.

According to the standard, risk criteria for a recreational activity should be established based on:

1. External Context – Regulatory requirements, legal frameworks, cultural attitudes, and societal expectations.
2. Internal Context – Organisational policies, facility objectives, and the purpose of the activity.
3. Nature of the Activity – The inherent risks versus the intended benefits (e.g., rock climbing involves unavoidable fall risks but provides significant physical and mental reward to the climber).
4. User Demographics – The abilities, experience, and decision-making capacity of participants (e.g., children's play areas may have lower tolerable risk thresholds than adult adventure activities).
5. Risk Reduction Measures – The effectiveness of interventions such as equipment, training, supervision, and emergency response systems.

An assessment team to define appropriate criteria should comprise at least three members with expertise in the relevant activity. This should include designers, site managers, and activity leaders, with a team leader that has significant experience in risk assessment and facilitation.

3.2.1 Industry Landslide Risk Tolerances

As an example of quantified tolerance levels, there are many differing tolerances for landslide risk used around the world with different regulators citing differing technical guidance for their nominated tolerance. Table 1 shows a multitude of regulators, their nominated risk tolerance for loss of life and cited reference. The variance across multiple industries

highlights the uncertainty inherent in the practice of quantifying risk. For example, three different entities across New South Wales have tolerable limits that differ by more than three orders of magnitude.

Table 1: Individual Loss of Life Risk Criteria for various Regulatory Bodies (Leroi et al., 2005).

Regulatory Body	Industry	Description	Risk/Annum	Reference
Health and Safety Executive, United Kingdom (HSE)	Land use planning around industries	Broadly acceptable risk.	10^{-6} /annum, public and workers	HSE (2001)
		Tolerable limit	10^{-4} /annum, public	
			10^{-3} /annum, workers	
Department of Urban Affairs and Planning, NSW, Australia	Land use planning for hazardous industries	“Acceptable” (tolerable) limits	5×10^{-7} /annum, hospitals, schools, childcare facilities, old age housing	
			10^{-6} /annum, residential, hotels, motels	
			5×10^{-6} /annum, commercial developments	
			10^{-5} /annum, sporting complexes	
Australian National Committee on Large Dams	Dams	Tolerable limit	10^{-4} /annum, existing dam, public most at risk	ANCOLD (2003)
			10^{-5} /annum, new dam or major augmentation, public most at risk	
Australian Geomechanics Society (AGS) guidelines for landslide risk management	Landslides (from engineered and natural slopes)	Suggested tolerable limit	10^{-4} /annum, public most at risk, existing slope	AGS (2000)
			10^{-5} /annum, public most at risk, new slope	
Hong Kong Special Administrative Region Government	Landslides from natural slopes	Tolerable limit	10^{-4} /annum, public most at risk, existing slope	Ho et al. (2000), ERM (1998), Reeves et al. (1999)
			10^{-5} /annum, public most at risk, new slope	
Iceland Ministry for the Environment Hazard Zoning	Avalanches and landslides	“Acceptable” (tolerable) limit	3×10^{-5} /annum, residential, schools, day care centres, hospitals, community centres	Iceland Ministry for the Environment (2000), Arnalds et al. (2002)
			10^{-4} /annum, commercial buildings	
			5×10^{-5} /annum, recreational homes	
Roads and Traffic Authority, NSW, Australia	Highway landslide risk	Implied tolerable risk	10^{-3} /annum	Stewart et al. (2002), RTA (2001)

4 SITE HAZARD IDENTIFICATION AND RISK ASSESSMENT

4.1 IDENTIFIED HAZARDS

Across the two summit routes there are four significant hazards that were commonly identified, these are all associated with the fall of rock blocks, described in points 1-4 below and shown in Figure 5. Mount Beerwah also has a unique mass flow hazard, described in point 5 below.

1. Large scale rockslide, triggered by erosion and/or heavy rainfall.
 - Defined as multiple rocks with many greater than 0.6 m (average dimension) in size moving as a group, which are likely to disaggregate as they travel and affect the entire width of the track.
 - Will trigger movement of other loose blocks as they travel downhill. The masses are mainly located adjacent to the existing track either as in situ or slightly disturbed rock masses.
2. Release of individual large blocks from the outcropping rock masses defining the upper slopes, triggered mainly by erosion and heavy rainfall, some maybe levered off the slope by the action of roots.
 - Defined as a single rock greater than 0.6 m in size initiating as a singular object but likely to disaggregate into smaller pieces if it travels downslope.
 - The blocks may be funnelled down the summit access route and may trigger other blocks to move as they travel downhill.
3. Release of individual medium blocks, triggered by erosion/rainfall or in some cases, hikers.
 - Single boulder between 0.2 m and 0.6 m in size initiating as a singular object but likely to disaggregate into smaller pieces as it travels and affect a smaller proportion of the track width.
 - Medium blocks are less likely than larger blocks to trigger additional rockfall as they move downhill.
4. Release of individual small blocks, triggered mainly by hikers, with minor releases due to rainfall.
 - Single rock fragment less than 0.2 m in size but typically greater than 60 mm in size initiating as a singular object.
 - The individual small blocks break up with travel but are unlikely to disaggregate to less than 60 mm in size. They will affect a localised section of the track and are unlikely to trigger other hazard detachments.
5. Large scale mass flow of soil and rock, triggered by a bush fire followed by heavy rainfall.
 - This is defined as a semi-liquidised flow of debris from the soil bowl immediately below the columnar cliffs of Mount Beerwah that will move with high velocity and would affect the entire width of the access route.



Figure 5: Examples of hazard types 1 to 4, as shown by photo number.

Whilst this paper explores only the geotechnical risk associated with the Mount Beerwah and Mount Tibrogargan summit hikes, to define a suitable broader risk tolerance for a recreational activity such as hiking, the regulator must consider all possible hazards. These might include:

- Falls from height – Steep terrain and exposed rock faces increase the likelihood of falls.
- Slips and trips – Uneven, loose surfaces, wet conditions, and eroded tracks create hazards.
- Heat exhaustion and dehydration – High temperatures and limited shade can affect hikers.
- Wildlife encounters – Venomous snakes and insects present potential risks.
- Navigation errors – Poor signage or misjudging terrain can lead to getting lost.

4.2 ADOPTED METHODOLOGY FOR ASSESSING RISK

Historically, risk assessments for the summit routes have been conducted using a 'person most at risk' (PMaR) approach, following the AGS 2007 guidelines. This method identifies the individual or group most vulnerable to potential hazards and evaluates the likelihood and consequences of harm specific to them. Societal risk was calculated and found to be little different, due to the frequency of the PMaR visits relative to an average person. Other methods that may be applicable to the summit routes are introduced below, and further discussion is given in Section 6.1.

4.3 RISK ASSESSMENT FACTORS AND OUTCOMES

Quantitative risk assessments for both mountains have provided estimates for the annual risk of loss of life (R(LoL)) for the 'person most at risk'. The PMaR for each summit route is defined as a competent and capable hiker who climbs the mountain almost every day outside of peak hours but occasionally climbs during peak hours due to personal schedule.

They are exposed to the instability hazards for 2 hours during the ascent/descent during daylight hours. The calculated values for these hikers exceed the commonly accepted tolerable risk threshold for the general public (10^{-4} /year) and approach the limit of tolerability for workers (10^{-3} /year). Specifically:

- Mount Tibrogargan: The revised R(LoL) for the PMaR is 9.3×10^{-4} , suggesting a level of risk comparable to high-risk recreational activities such as hang-gliding or scuba diving (refer Section 4.4).
- Mount Beerwah: The R(LoL) for the PMaR is 7.6×10^{-4} , indicating a slightly lower but still significant risk level.

Given these findings, QPWS continues to implement a risk management strategy that adheres to the 'As Low As Reasonably Practicable' (ALARP) principle. Ongoing mitigation measures include track monitoring, controlled scaling, seasonal and event-specific closures, and targeted signage to inform hikers of the inherent risks. While risk cannot be entirely eliminated, these interventions aim to reduce exposure and enhance hiker awareness, balancing public safety with the recreational value of the summit routes. While there are wider assumptions underlying the risk assessments in accordance with AGS 2007 guidelines, these are not discussed here, as they do not directly relate to the paper's focus on balancing risk and accessibility.

4.4 RISK ASSESSMENT METRICS AND TOLERABLE RISK THRESHOLDS

We agree that the adoption of a tolerable risk criterion is appropriate for the Mount Beerwah and Tibrogargan summit access routes. This is based on hikers acknowledging that there is inherent risk in the activity, but they are still willing to tolerate this risk in order to secure the benefits of the experience when undertaking the activity. Health and Safety Executive, United Kingdom (HSE) agree that 10^{-4} per year is the boundary between unacceptable and tolerable for members of the public for a risk that is "in the wider interests of society" (HSE, 2001). HSE also suggests that 10^{-3} lives per year is the upper limit of the tolerable region for workers in industry.

To compare the calculated total risk for the person most at risk of 9.33×10^{-4} per year for Mount Tibrogargan and 7.6×10^{-4} per year for Mount Beerwah, other recreational activities with similarly assessed risk levels are provided in Table 2.

Table 2: Activities corresponding to a 1×10^{-3} risk of fatalities/year (Lee and Jones, 2023)

Activity	Number of times activity is required per year for 10^{-3} risk of fatalities
Hang-gliding	116 flights
Surgical anaesthesia	185 operations
Scuba diving	200 dives
Rock climbing	320 climbs
Mount Tibrogargan Summit Access Route	200 ascents & descents – five during peak traffic ⁽¹⁾
Mount Beerwah Summit Access Route	200 ascents & descents – five during peak traffic ⁽¹⁾

Notes: ⁽¹⁾ Peak traffic times are associated with heightened anthropogenic block dislodgement triggers.

In our opinion, tolerable risk criteria are difficult to quantify for the person most at risk as individual tolerances vary when considering the recreational nature of the activity involved in walking the route. Adoption of residential risk levels may therefore be overly conservative, and adoption of industry worker's risk levels appears the opposite. Therefore, a value between 1×10^{-4} per year and 1×10^{-3} per year for tolerable risk appears appropriate for the two summit routes.

5 RISK MITIGATION AND MONITORING

5.1 CURRENT MITIGATION STRATEGIES

The levels of risk for the summit routes as previously calculated are considered marginally tolerable. Consequently, QPWS takes all practical measures to reduce risk and/or further refine the assessment of risk in accordance with the principle of ALARP. These strategies of ALARP include signage, warnings, removal of routes from walking track maps, seasonal and event-specific closures, additional public information online, and public education. The mitigation strategies are not factored into the risk assessment as the associated behavioural outcomes have not been quantified.

5.1.1 Signage

Signage has been installed at key points along the summit access routes, including the trailhead, the base of the no-stopping zone, and the upper sections of the route. These signs warn hikers of the dangers posed even by smaller dislodged rock fragments, which can become life-threatening projectiles. They also encourage responsible behaviour by advising hikers to watch their footing, stay on the designated path to minimise erosion, and avoid disturbing loose rocks. The signage outlines the risks and challenges of the climb and provides guidance on proper preparation for the ascent (as shown in Figure 6 and Figure 7).



Figure 6: Glass House Mountains summit route information signs, (© Queensland Parks and Wildlife Service).

5.1.2 Public Information

As discussed in Section 2.2, QPWS have implemented a segregated public information management strategy for the summit routes. Information on the summit routes has generally been removed from the standard hiking maps and plans for the Glass House Mountains National Park. Information for these routes is available in a separate section of the QPWS Glass House Mountains webpage, which has been structured so that users must view the warnings and critical skills information before reaching the maps associated with these routes near the base of the webpage. The webpage includes an information video at the top with rangers and local first responders outlining the risks and previous incidents on the summit routes. The summit route information signage, as shown in **Error! Reference source not found.**, has been designed to summarise the hazards and consequences, while providing details on how to reduce personal risk with planning, using appropriate equipment and supplies.

5.2 TRACK MONITORING AND CLOSURES

A monitoring program for the summit routes helps assess the accumulation of small and medium-sized rock fragments and, where possible, track the movement of larger blocks. While the entire route is reviewed, particular focus is given to areas where debris tends to accumulate. QPWS staff conduct routine inspections, photographing higher-risk areas as needed to track the changes to conditions over time. Additionally, regular track users and local climbing clubs play an active role in reporting any significant changes.

When any new hazards are identified or changes observed by the QPWS team, a professional geotechnical site assessment is recommended. Based on the scale and nature of the geotechnical hazard, the QPWS management team can temporarily close the track until the hazard is assessed and mitigated if required.

Following cyclones, bushfires, or severe wet weather events/storms impacting the mountains, it is recommended that the track is closed. Following these events the routes may require scaling and/or geotechnical assessment and is opportune under the same track closure. Based on previous experience QPWS request a geotechnical assessment if they are concerned about reopening the track. Closure following rain events of 50 mm or more would:

- Allow the track to be assessed to ensure that large scale hazards have not been mobilised.
- Reduce the likelihood of climbers mobilising loose rock because of slippery conditions.
- Potentially have other benefits in injury reduction from slips and falls.

Mount Tibrogargan summit route (allow 3–4hrs return)



Visitors beware!
This summit route is challenging.

- Steep, strenuous climb with sheer rock faces.
- Rocks can be slippery and rockfalls can happen at any time.
- Only fit, prepared climbers should proceed.
- Not recommended for younger children.



Climbers be careful



Less experienced climbers can panic and fall when they encounter steep, almost sheer rock faces. Recognise your limits and avoid tragedy.



Rocks can dislodge and fall at anytime. Wear a helmet.



Stay well back from cliff edges.



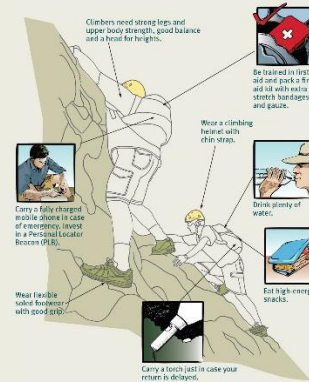
Rain and mist make rocks slippery causing falls. Poor visibility can cause confusion and potentially fatal mistakes. Never climb in mist, after rain or if rain is forecast.



Avoid climbing in extreme temperatures. Stay hydrated and eat to keep your energy levels up.

Rescues are risky and might be postponed in poor conditions.

Be prepared!



Plan ahead

- Check the weather. bom.gov.au
- Allow enough time to complete the climb in daylight.
- Never climb alone.
- Discuss your climbing tactics with others in your group and agree on emergency plans.
- Let someone responsible know your plans and what to do if you don't return when expected.

On the way up

- Wear a helmet for some protection when rocks fall.
- Stay within earshot of your climbing companions.

At the top

- Don't throw stones.
- Stay well back from cliff edges.

On the way down

- Take your time.
- Use the summit route **only**. Side tracks can end in tragedy.

Warn other climbers

Shout loud warnings if you accidentally dislodge rocks. Never climb directly below other climbers who might dislodge rocks.



Figure 7: Glass House Mountains summit route information sign, (© Queensland Parks and Wildlife Service).

6 DISCUSSION

6.1 DIFFERING RISK PERCEPTION AND CULTURE

Perceptions of acceptable and tolerable risk in outdoor activities vary widely across society. The design of infrastructure within national parks can influence how visitors perceive personal responsibility for their safety. A study of three U.S. national parks by Rickard (2014) found that as government agencies construct more paths, signs, and shelters, visitors increasingly transfer the perceived responsibility for their safety to park management. Similarly, research by Gstaettner et al. (2022) in Western Australian national parks found that first-time visitors were the least likely to perceive parks as dangerous, whereas those with repeat visits or previous traumatic experiences in similar environments had heightened risk awareness.

Changing societal expectations, particularly among younger generations, have contributed to a culture where documenting risk-taking through social media is seen as integral to the experience (Palmer, 2004). Activities once considered extreme—such as outdoor bouldering, snowboarding, and standing on precarious ledges—are now embedded in mainstream culture, media, and advertising. This normalisation has shifted these once-thrilling pursuits into common weekend activities, reinforcing the perception that anyone can participate, often without the necessary experience, knowledge, or appreciation of the risks involved (Palmer, 2004).

Unlike many other extreme sports, summitting the Glass House Mountains lacks a tangible "barrier to entry" that might deter inexperienced or unprepared individuals. Comparable activities such as scuba diving or rock climbing typically require specialised equipment, creating an inherent restriction. In contrast, the accessibility of these summit routes allows anyone to attempt them, potentially fostering a false perception of lower risk compared to activities of similar risk levels.

Glass House Mountains National Park offers a variety of trail environments and difficulty levels, but visitor decisions are not always based on trail complexity. Anecdotal observations from QPWS staff and regular park visitors suggest that the summit routes are often attempted by less experienced hikers, drawn more by the challenge and the opportunity for social media content without an understanding of the trail's difficulty. In contrast, other equally complex trails that offer fewer social media-worthy moments tend to attract visitors who are more focused on the challenge itself and have a better grasp of the risks involved.

6.1.1 Differing Person Most at Risk

In previous risk assessments of the Mount Beerwah and Mount Tibrogargan summit routes, the Person Most at Risk (PMaR) has been defined by EDG as an individual who summits the respective mountain 200 times per year, with five of those trips occurring during peak traffic periods. This definition assumes that the greatest exposure to hazards comes from sheer frequency of visits. However, past assessments have not accounted for the relative inexperience or unpreparedness of some hikers and the associated risks.

It could be argued that someone trekking the summit routes as frequently as the assessed PMaR is likely to be a competent, fit, and well-equipped individual with an explicit understanding of the safest routes. While they may be more exposed to hazards such as rockfalls, they are also theoretically far less likely to suffer injuries from slips, trips, or falls compared to an inexperienced, unfit tourist during any single outing. Future risk assessments may benefit from considering these additional risk factors to ensure a more comprehensive approach to public safety.

6.1.2 ISO 4980:2023 Framework

As a future alternative, ISO 4980:2023 provides a comprehensive risk assessment framework that may be applicable to the summit routes of Mount Beerwah and Mount Tibrogargan. The methodology evaluates risk based on two key factors: the severity of potential harm and the likelihood of occurrence. Severe injuries require stricter controls, while risk-benefit trade-offs determine whether an activity's value justifies the level of risk due to exposure to the hazards. The process follows the typical risk assessment process of identifying hazards, estimating risk levels, comparing them to predefined criteria, and implementing mitigation strategies where necessary. If risks exceed acceptable thresholds, adjustments must be made. This standard differs to previously undertaken risk assessments as it considers all potential hazards associated with the activity, offering a broader scope of evaluation.

6.1.3 Societal Risk

An alternative risk assessment was undertaken with recent usage data to quantify the societal risk based on the total number of people potentially exposed to the hazards. This approach applied a theoretical average individual's exposure and calculated the cumulative probability of loss of life using F-N criteria in accordance with the New South Wales Parks and Wildlife Service Guideline Document (Golder, 2023). The resulting probabilities were slightly lower than that

estimated using the PMaR method outlined earlier (5.86×10^{-4} and 7.81×10^{-4} for Mount Beerwah and Tibrogargan, respectively) though both remained within the same order of magnitude.

Previous risk assessments have largely focused on risks to individuals. However, societal risk may also need to be considered if an event impacting a large group simultaneously is plausible. At Mount Beerwah and Mount Tibrogargan, this could be relevant in the event of a large debris slide or flow, similar to Hazard 5 identified in Section 4.1, occurring during peak traffic hours when multiple climbers are on the mountain. For societal risk assessments, industry best practices are outlined in ANCOLD (2022).

6.2 BALANCING RISK AND ACCESSIBILITY

Under Queensland and Australian law, QPWS has a duty of care to national park visitors. The visitor safety policy (DETSI, 2001) states that while QPWS must manage and inform visitors of known risks as far as reasonably practicable, it cannot eliminate all risks in natural areas. Visitors are expected to remain vigilant, conduct their own research, and take personal responsibility for their safety.

Balancing legal and ethical responsibilities with societal expectations is key to effective risk management. While national parks inherently involve risks, and while people enjoy the thrill and challenges of nature, effective risk management allows visitors to adapt and respond safely in ever-changing and sometimes unfamiliar conditions. Gstaettner et al. (2022) found that while risk management and control are valued aspects of national park experiences, excessive management can diminish people's awareness of danger and their sense of responsibility in preparing for risks (in line with the observations of Rickard noted in Section 6.1).

In the case of summit routes, adopting a tolerable risk criterion is considered appropriate, as users generally accept a higher level of risk compared to everyday activities—recognising that climbing to the summit carries inherent danger, but that the experience and challenge justify the exposure. However, this level of risk is only considered tolerable when supported by appropriate management strategies, which may include temporary closures during periods of elevated risk.

In line with growing demand for more challenging tracks, QPWS developed the Yul-yan-man Trail in 2019—a Grade 5 track designed to offer a rock scrambling experience while maintaining a lower geotechnical risk profile than the summit routes.

Despite alternative trails, some thrill-seeking visitors will always wish to attempt the higher risk summit routes. To align visitor risk perception with similar extreme sports, QPWS could consider installing an entry barrier, such as a fence with a gated access point. This would not restrict access but encourage hikers to engage with warning signage and create a tactile obstacle similar to equipment requirements in other higher risk activities.

7 CONCLUSIONS

Risk perception varies widely among stakeholders of the Glass House Mountains National Park, shaping both QPWS decisions and visitor behaviour. While some hikers seek to minimise or eliminate risk, others embrace it as an inherent part of the outdoor experience. Societal shifts have led to an increasing number of inexperienced hikers attempting high-risk summit routes without fully understanding the dangers involved. This underscores the need for a nuanced risk management approach that acknowledges these trends while striving to reduce geotechnical risks to levels as low as reasonably practicable.

Balancing risk and accessibility remains a key challenge. While QPWS has a duty of care to manage and communicate risks, it cannot eliminate them without compromising the natural experience visitors seek. The development of trails like Yul-yan-man demonstrates an effort to provide challenging yet lower-risk alternatives. By maintaining this balance, QPWS can preserve accessibility while fostering informed decision-making and personal responsibility among visitors.

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