Springbrook Groundwater Investigation (SGI)
Final Report 2025

Dr Lucy Reading (Assoc. Prof), Jim Stanley, Juliana Albano Reis, Laura Bellis, Kylie van Duyn
Wade Somerville, Callan Howell and Grant Periott

Executive Summary

Springbrook Groundwater Investigation (SGI) – Final Report 2025

The Springbrook Groundwater Investigation (SGI), initiated in July 2021, addressed major gaps in groundwater, surface water, and ecohydrology within one of Australia's most biodiverse World Heritage landscapes. Over four years it established monitoring networks, produced extensive hydrological and geochemical datasets, and developed a conceptual model of aquifers and their ecosystem connections.

As part of the Gondwana Rainforests World Heritage Area (Gondwana Rainforests), Springbrook offers an internationally significant case where aquifers, ecosystems, and cultural values converge, informing national priorities in water security, biodiversity, and heritage stewardship. Supported by the City of Gold Coast, QUT, Seqwater, the Queensland Government, and TERN, the SGI has completed its investigation phase, laying the foundation for a Critical Zone Observatory (CZO) — the first subtropical montane site in Australia to be studied at this scale.

Key Achievements

1. Established operational **monitoring networks for groundwater, surface water, rainfall (temperature, humidity, barometric pressure), soil moisture, and ecohydrology**.
2. Developed **conceptual models** depicting aquifer characteristics, recharge pathways, groundwater–surface water connectivity, and inter-aquifer mixing.
3. Produced a **multi-year dataset** of groundwater chemistry and isotopes, identifying distinct basaltic and rhyolitic sources and rainfall recharge signatures.
4. Confirmed **strong hydrological links between aquifers, streams, and ecosystems**, including groundwater dependence of rainforest species.
5. **Installed ecohydrological monitoring sites** across an altitudinal gradient, including sap-flow meters, soil moisture probes, dendrometers, fog collectors, canopy throughfall gauges, and telemetered weather stations.
6. **Presented findings at national and international scientific forums**, including the 2024 Ecosummit, 2025 TERN Science Symposium and a FluxNet conference field tour on-site at Springbrook.
7. Contributed datasets to State agencies, informing **Water Quality Objectives** and providing expert evidence and advice for groundwater management and policy processes.
8. Engaged stakeholders, including government agencies, scientists, and Indigenous partners in planning the establishment of the **Springbrook Critical Zone Observatory**.

The SGI's outputs extend beyond research, informing policy, water planning, legal processes, and Australia's engagement with UNESCO and IUCN. This demonstrates its dual role as both a scientific study and a decision-support tool for governments and communities.

Recommendations for Future Monitoring and Assessment

1. Maintain and expand long-term **groundwater, surface water, and ecohydrological monitoring networks** to detect system responses to climate variability and extraction pressures.
2. Target extended dry periods to **identify thresholds when aquifer levels** fall to critical points and creek **baseflow ceases**.
3. Continue and extend **data analyses**, **integrating ecohydrology, hydrochemistry, and flora and fauna monitoring** to identify ecological thresholds.
4. Establish **long-term environmental monitoring** using the **Critical Zone Observatory** approach, incorporating existing SGI monitoring with cloud/fog interception and soil water storage quantification, combined with the addition of **eDNA and eco-acoustics** monitoring of significant **flora and fauna relevant to the World Heritage OUV**.
5. Embed **partner, community, and Indigenous engagement** in the governance and co-design of the CZO.
6. Strengthen collaboration between QUT scientists, project partners, and policymakers at all levels of government to inform adaptive **groundwater management strategies**.

Recommendations for Policy and Planning

- **Support long-term monitoring** by securing sustained funding and resources through all levels of government and institutional partnerships, anchored in the Springbrook CZO.
- **Ensure transparency** through public disclosure of commercial water extraction volumes, enabling community oversight and long-term risk assessment.
- **Continue to refine the regulation of commercial groundwater extraction** within the Springbrook Plateau to move towards best practice management of this globally significant World Heritage Area, prioritising protection of sensitive ecosystems.
- **Embed regular reporting in local, state and national obligations**, ensuring monitoring outcomes inform UNESCO/IUCN reporting and adaptive management of World Heritage Outstanding Universal Value.
- **Institutionalise cross-border collaboration**, mirroring models such as the Great Barrier Reef's Reef 2050 Integrated Monitoring & Reporting Program

Conclusion

The Springbrook Groundwater Investigation has achieved its objectives, delivering a substantive evidence base that links the mountain's water cycle to its ecosystems. It has demonstrated that Springbrook's aquifers, streams, and ecosystems are tightly coupled and highly sensitive to hydrological change.

The SGI's legacy is the foundation of the **Springbrook Critical Zone Observatory** — a platform for integrated hydrological, ecological, and cultural monitoring. Investment in the CZO is now essential to ensure continuity of data, safeguard biodiversity and cultural values, and position Springbrook as a **benchmark site for long-term environmental monitoring in Australia and globally**. If sustained, the Springbrook CZO would stand alongside Australia's most significant long-term monitoring investments, such as the TERN Supersites and Great Barrier Reef programs. Stable investment would secure not only world-class science but also community trust, Traditional Owner partnerships, and the long-term resilience of an ancient landscape central to the Gold Coast's ecological and cultural identity.

Acknowledgements

The Springbrook Groundwater Investigation (SGI) team express our heartfelt thanks to the many people who have assisted us in our work towards addressing community concerns about water, developing a deeper understanding of the hydrology at Springbrook.

Traditional Owners – heartfelt thanks to Rose Best and the Kombumerri Rangers for cultural guidance.

Springbrook Landholders – Profound thanks to the many landholders who provided property and bore access for monitoring – without your cooperation the project may not have been possible.

Springbrook Community – Thanks for welcoming the team and for showing such interest at the community information sessions.

QPWS Staff – thanks for your cooperation with site access and assistance with fieldwork.

QUT Undergraduate Students – Without all of you this project would have been much harder.

QUT Postgraduate Students – Your efforts were essential for targeted research outcomes.

CoGC Staff – Thanks for giving up your time to support project fieldwork.

Council of the City of Gold Coast – Thanks to the support of full Council, this project received recognition and sufficient funding.

Seqwater – thanks for the steadfast support in the steering group and through in-kind and funding contributions.

QLD State Agencies – Thanks for listening to local community, thanks also for the equipment, in-kind and direct funding support.

Contents

Table of Figures

1.0 Background and Introduction

Springbrook, the highest region of the Gold Coast, rises to over 1,000 metres at Repeater Station Road. With annual rainfall commonly exceeding 3 metres, the plateau is one of subtropical Australia's wettest landscapes. It is globally recognised for its ecological and cultural significance as part of the Gondwana Rainforests of Australia World Heritage Area, inscribed in 1986 in NSW with QLD additions in 1994, for its Outstanding Universal Value (OUV) (IUCN 2024); UNESCO WHC 2023). The convergence of Bassian and Torresian biogeographic regions, combined with steep altitudinal gradients and high rainfall, produces exceptional biodiversity and supports very high levels of endemism including rare and threatened flora and fauna (Kooyman *et al.* 2013). Many species occur at the margins of their ranges, and the plateau provides critical headwaters for the Hinze Dam and other waterways essential to the Gold Coast.

1.1 Community concerns as a project driver

The initiation of the Springbrook Groundwater Investigation (SGI) was strongly driven by **community concerns about groundwater management**. Residents and conservation groups raised repeated alarms that **commercial groundwater extraction, a relatively unregulated activity, posed risks to groundwater-dependent ecosystems and to the integrity of Springbrook's World Heritage OUV**.

These concerns were especially acute during drought periods, when the extraction of water for bottling was perceived as directly competing with ecosystem needs and potentially reducing flows to the plateau's waterfalls and streams. Groundwater resources are fundamental to maintaining Springbrook's sensitive environment. Globally, groundwater is the primary source of drinking water for nearly two billion people, yet overexploitation has led to declining water levels and degraded ecosystems in many regions (Konikow & Kendy 2005). The SGI was established to provide the robust scientific evidence needed to assess groundwater sustainability, inform regulatory frameworks, and address community expectations for the protection of Springbrook's unique natural values.

1.2 Springbrook's Community Values and UNESCO Outstanding Universal Value

The current conservation outlook for Gondwana Rainforests World Heritage (of which Springbrook is a part), is assessed by IUCN as **Significant Concern** (World Heritage Outlook 2020), reflecting high threats from climate change, fire and invasive species. The 2019–20 bushfires affected ~196,000 ha (≈53%) of the property, and the World Heritage Committee (UNESCO 45 COM 7B.79, 2023) recorded its utmost concern and requested a State Party

*The current IUCN **Conservation Outlook of Gondwana Rainforests** World Heritage Area is listed as of **Significant Concern** - persistence of Paleo-Antarctic Rainforest Lineages, endemic canopy species, and ancient songbird lineages at Springbrook are central to the site's Outstanding Universal Value (OUV) under World Heritage criteria; any degradation of these refugial systems risks diminishing this OUV and, in turn, jeopardising the integrity of the Gondwana Rainforests World Heritage listing.*

https://worldheritageoutlook.iucn.org/explore-sites/gondwana-rainforests-australia update by 1 December 2024, including on the proposed water extraction near Springbrook. Australia has since released an updated climate vulnerability assessment and a climate-change toolkit for World Heritage managers; however, a site-specific Climate Vulnerability Index (CVI) rating for the Gondwana Rainforests has been published in December 2025. The Climate Vulnerability Index assessment rates the Gondwana Rainforests of Australia (Queensland Section) as having High vulnerability of key World Heritage values to climate change, with community vulnerability assessed as Moderate, indicating elevated risk to Outstanding Universal Value despite some adaptive capacity (Day et.al.). Notably, Lamington National Park, a key Queensland component of the property, was admitted to the IUCN Green List in April 2024, recognising strong park-level management even as OUV remains under pressure.

1.2.1 Springbrook as a refugium for Paleo-Antarctic Rainforest Lineages

A defining feature of Springbrook's biodiversity is its role as a refugium for Paleo-Antarctic Rainforest Lineages (PARLs), ancient plant groups that trace their ancestry to Gondwana. These "southern wet forest survivors" include canopy dominants such as *Nothofagus moorei* (Antarctic Beech), *Eucryphia jinksii (isolated single occurrence)*, and *Orites excelsus*, as well as members of *Cunoniaceae, Proteaceae, Lauraceae*, and *Atherospermataceae* families. Their persistence in high-rainfall, high-altitude refugia links the modern forests of Springbrook with fossil floras of Patagonia and Antarctica dating back more than 50 million years (Kooyman *et al*. 2013, Kooyman et.al. 2014).

Springbrook is one of the few places on Earth where paleo-endemic species from multiple Gondwanan families still co-occur, illustrating extraordinary evolutionary heritage. Globally, these lineages are increasingly threatened by land-use change and climate instability (Kooyman *et al.* 2014). The high-altitude cloud forests of Springbrook, dominated by Nothofagus moorei and associated paleo-lineage species, represent unique refugial systems that are critical for both biodiversity conservation and for understanding ecosystem responses to environmental change.

In addition to these ancient Gondwanan lineages, Springbrook continues to reveal newly described Australian endemic canopy species, highlighting its ongoing evolutionary significance. Recent surveys by Lui Weber (Altitude Ecology, Weber 2024) identified Syzygium nebulosum, the "Caldera Cloud Forest Lilly Pilly", as a distinct montane cloud forest species, previously misidentified as other Syzygium taxa. Although not classified as a PARL, its discovery underscores Springbrook's role as both a refugium for ancient lineages and a contemporary centre of rainforest endemism and speciation, with direct implications for conservation and ecohydrological research.

1.2.2 Ancient songbirds in Gondwanan refugia

Springbrook also protects some of the oldest surviving lineages of songbirds (oscine passerines), emphasising Australia's role as the cradle of global songbird evolution. Lyrebirds (*Menura*) and scrub-birds (*Atrichornis*), for example, are among the most ancient extant songbird families. Genetic studies indicate that songbirds originated in Australia ~33 million years ago, dispersing to Asia via island chains around 23 million years ago before radiating worldwide (Norman *et al.* 1998; Jønsson *et al.* 2011; Australian Geographic 2016).

Within the Gondwana Rainforests (previously known as the Central Eastern Rainforests Reserve of Australia - CERRA), of which Springbrook is a core part, deeply divergent bird lineages have persisted since the Miocene, supported by the stable humid refugia of upland rainforest.

Species such as the rufous scrub-bird (*Atrichornis rufescens*) and Albert's lyrebird (*Menura alberti*) are direct descendants of these Gondwanan lineages, confined today to fragmented montane refuges like Springbrook and Lamington (Jønsson *et al*. 2011). Their survival is closely tied to the same refugial conditions that support PARL flora, highlighting an integrated picture of long-term persistence across trophic levels.

1.2.3 Economic and social value of Springbrook

Beyond its ecological and evolutionary importance, Springbrook underpins significant economic, cultural, and social values for the Gold Coast and broader SEQ region.

Tourism and Recreation: Springbrook National Park attracts >500,000 visitors annually (QPWS Visitation Data), making it one of the Gold Coast's top ecotourism destinations. Iconic waterfalls, lookouts, and World Heritage forests drive revenue for local hospitality, accommodation, and ecotourism businesses.

Water Security: Springbrook's aquifers and creeks are headwaters for the Hinze Dam, providing drinking water to over 700,000 residents (Seqwater 2023). Protecting recharge processes and streamflow ensures resilience of the regional water supply under drought and climate change.

Property, Lifestyle and Wellbeing: The intact natural setting provides outstanding recreational setting, enhancing property values and underpinning the Gold Coast's identity as a **"city in balance with nature."**

Cultural and Educational Value: The plateau is a living classroom for schools, universities, and research institutions, and a site of deep cultural significance for Traditional Custodians.

Collectively, these values demonstrate that the **economic prosperity of the Gold Coast and SEQ is closely tied to the ecological health of Springbrook**. Any degradation of its hydrological systems, whether through unsustainable extraction, climate-driven stress, or biodiversity loss, would directly threaten regional industries and community wellbeing.

1.3 The Springbrook Groundwater Investigation (SGI)

In response, to a lack of groundwater data, the City of Gold Coast initiated the SGI in collaboration with QUT, Seqwater, and the Queensland Government. Stage 1 (2019–2020) piloted hydrogeochemical and hydrological methods, identifying key knowledge gaps. Stage 2 (2021–2025) expanded this into a multi-year investigation with integrated monitoring networks and ecohydrological studies.

The SGI objectives were to:

- Establish integrated monitoring networks for groundwater, surface water, and vegetation.
- Develop conceptual models of aquifer characteristics, recharge pathways, discharge locations, and groundwater-dependent ecosystems.
- Conduct water balance assessments, including recharge, discharge, extraction, and ecosystem use.
- Develop numerical models to simulate groundwater–surface water and groundwater–vegetation interactions.
- Provide evidence to inform groundwater management strategies and policy.

Between 2021 and 2025, the SGI implemented continuous groundwater and surface water monitoring, on monthly/bimonthly basis (biannual for final year) hydrogeochemical sampling, and pioneering ecohydrological studies on canopy tree species across an altitudinal gradient. The decision to pursue ecohydrological assessment was critical for developing a more complete picture of the water balance and the ecosystem demands on aquifers and soil moisture. This work confirmed distinct basaltic and rhyolitic aquifers, demonstrated inter-aquifer connectivity, and highlighted the role of rainfall while also identifying cloud and fog as additional sources of recharge. Ecohydrological monitoring established new benchmarks for developing a deeper understanding tree water use, soil moisture dynamics, raising questions about the vulnerability of Paleo-Antarctic lineage species such as *Nothofagus moorei* to climate change.

1.4 Legacy: towards a Critical Zone Observatory

The SGI has now completed a four-year investigation, making significant progress towards its original objectives. However, the project has been shaped by one aspect of climate variability, with extremely wet conditions and rainfall well above average across the last five years. This underscores the need for long-term monitoring to capture the full range of system responses to climate variability and human pressures.

Its legacy is the establishment of the **Springbrook Critical Zone Observatory (CZO)**; a long-term, integrated monitoring hub linking hydrology, ecology, and climate. The CZO will employ an altitudinal transect to target *Paleo-Antarctic Rainforest Lineages (PARLs)* and hydrologically sensitive fauna alongside comprehensive monitoring of rainfall, cloud interception, surface water, soil moisture, groundwater, and ecohydrology. By embedding vegetation and fauna observations within this hydrological framework, the CZO will provide globally significant insights into the resilience and vulnerability of relict Gondwanan ecosystems. Just as importantly, it will underpin the economic, cultural, and social values that depend on Springbrook remaining a healthy and iconic landscape.

2.0 Indigenous culture and lore

The First Nations people who lived and continue to live in the Nerang River catchment, including Springbrook are known as the Kombumerri people. The SGI project team acknowledge the traditional owners, the Kombumerri and their deep wisdom and living connection with “country”. In particular, the SGI team would like to thank Roselene Best, a Kombumerri and Ngugi Traditional Owner, and a nominated representative of the Danggan Balun (Fiver Rivers) Native Title Claim group, who speaks for the “lands and waters” at Springbrook (Burrigan Mountain and surrounds). Roselene and her family have strong ancestral connections to Springbrook and the headwaters of Nerang River, where her family lived for generations (Figure 1. Depicts ancestral connections and water lore). She is a keeper of “Women’s Water Lore”, important cultural knowledge that has been handed down an intergenerational matrilineal line. Springbrook and its *living* waters are deeply embedded in the culture and lore of the Kombumerri, there are Dreaming stories, “*Bootherams”*, that speak of ancestral beings who created the landscape and are the spiritual source of the living waters at Springbrook. There are mountain springs, such as, the source of Rush Creek at Springbrook, that are sacred to the Kombumerri people. There are *Bootheram s*tories concerning initiatory men’s business and also women’s business that cannot be shared publicly and can only be transmitted with express permission of tribal elders.

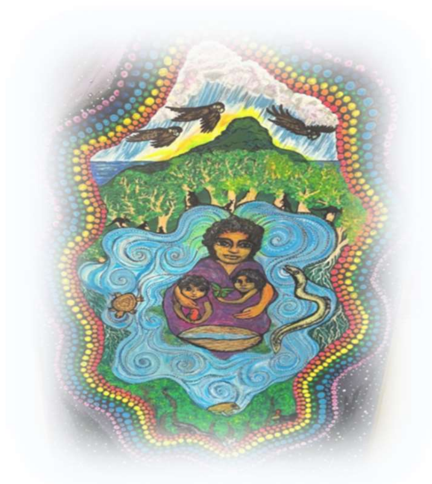

Figure 1. Painting by Roselene Best represents Women's Water Lore, water’s life-giving forces, and the importance of intergenerational equity to water security. Artwork depicts Kombumerri Matriarchal Ancestor, Warri (Sarah Clarke) and her children, Jenny and William, residing on the banks of the Nerang River.

Roselene was able to share some insight into Women’ water lore, a glimpse of the depth of Indigenous understanding about what scientists’ term “the water cycle”:

CLEVER WATER.

In culture we acknowledge five waters – salt/fresh/sky/ground and the biological sea, within all lifeforms. The Elders teach us that we are Clever Water, each of us a part of the biological sea which flows through all lifeforms on this planet. It cycles through all life. For us to survive we need to respect the connection between all forms of life and do everything in our power to protect the purity and life-giving forces of the sacred water.....we are clever water and we must protect it always.

***Roselene Best** - Kombumerri/Ngugi Traditional Owner*

3.0 Rainfall conditions over investigation period

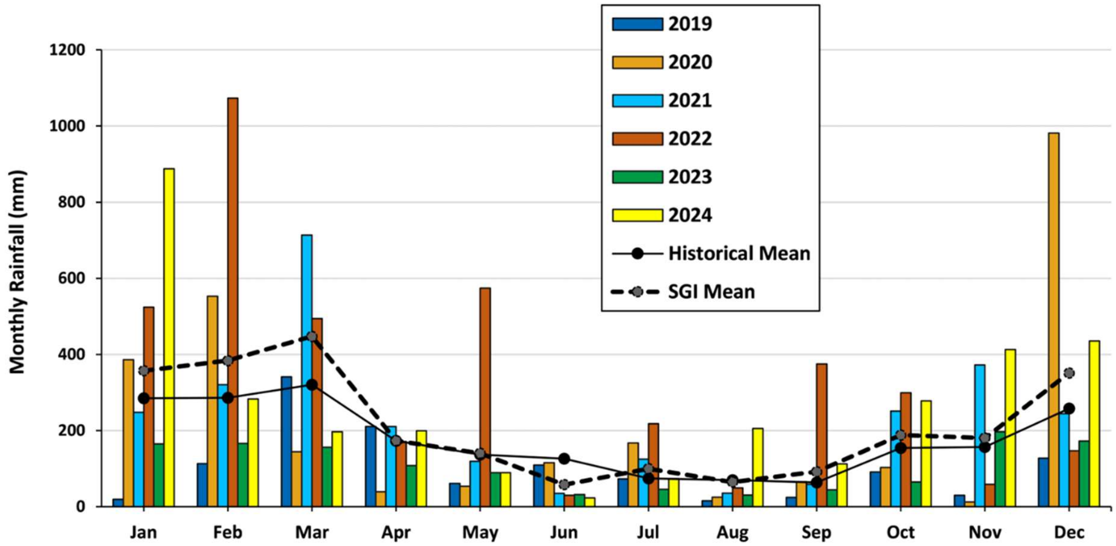

Figure 2- SGI Monthly rainfall data comparison with long-term 44-year average (includes SGI pilot project 2019-2020)

Annual rainfall at Springbrook was above average conditions in multiple years; above-mean rainfall was recorded in 2020, 2021, 2022, 2024 and 2025 (refer to Figure 2.). In March 2025, the plateau received a deluge of approximately 6 months of (average) rainfall. 2019 was almost entirely below-mean.

There are several important implications of above average rainfall levels to the SGI research:

1. Groundwater recharge levels are very likely to be higher than historical rates, for the majority of the monitoring period.

2. It is difficult to assess the behaviour of the hydrological system under stress conditions without a significant period of dry weather (Bruijnzeel 2010).

3. Commercial extraction impacts to groundwater and surface water systems will not be possible to accurately assess with high rainfall data and little to no dry season data.

It is recommended that further monitoring and analysis is conducted over years with lower rainfall rates.

4.0 Establishing a water monitoring network

In July 2021, Phase A of the SGI project commenced to address the first objective of this project, "establish a groundwater, surface water and vegetation monitoring network at Springbrook". Hydrological monitoring at Springbrook involved semi continuous monitoring at measurement intervals of 15-30 minutes, for soil moisture, groundwater levels, surface water levels, evapotranspiration and local climate. Soil moisture content was measured using soil moisture content sensors, groundwater levels were measured using submersible pressure transducers and surface water flows have been measured using pressure transducers coupled with flow measurements and flow rating curves. Groundwater level and surface water flow measurements have taken place across the plateau.

In parallel to the hydrological monitoring, a program of water sampling and geochemical analyses has been conducted, aimed at assessing groundwater flow-paths, inter-aquifer connectivity, groundwater-surface water connectivity and sources for water uptake by deep-rooted vegetation. The sites used for water monitoring throughout the SGI are shown in Figure 3.

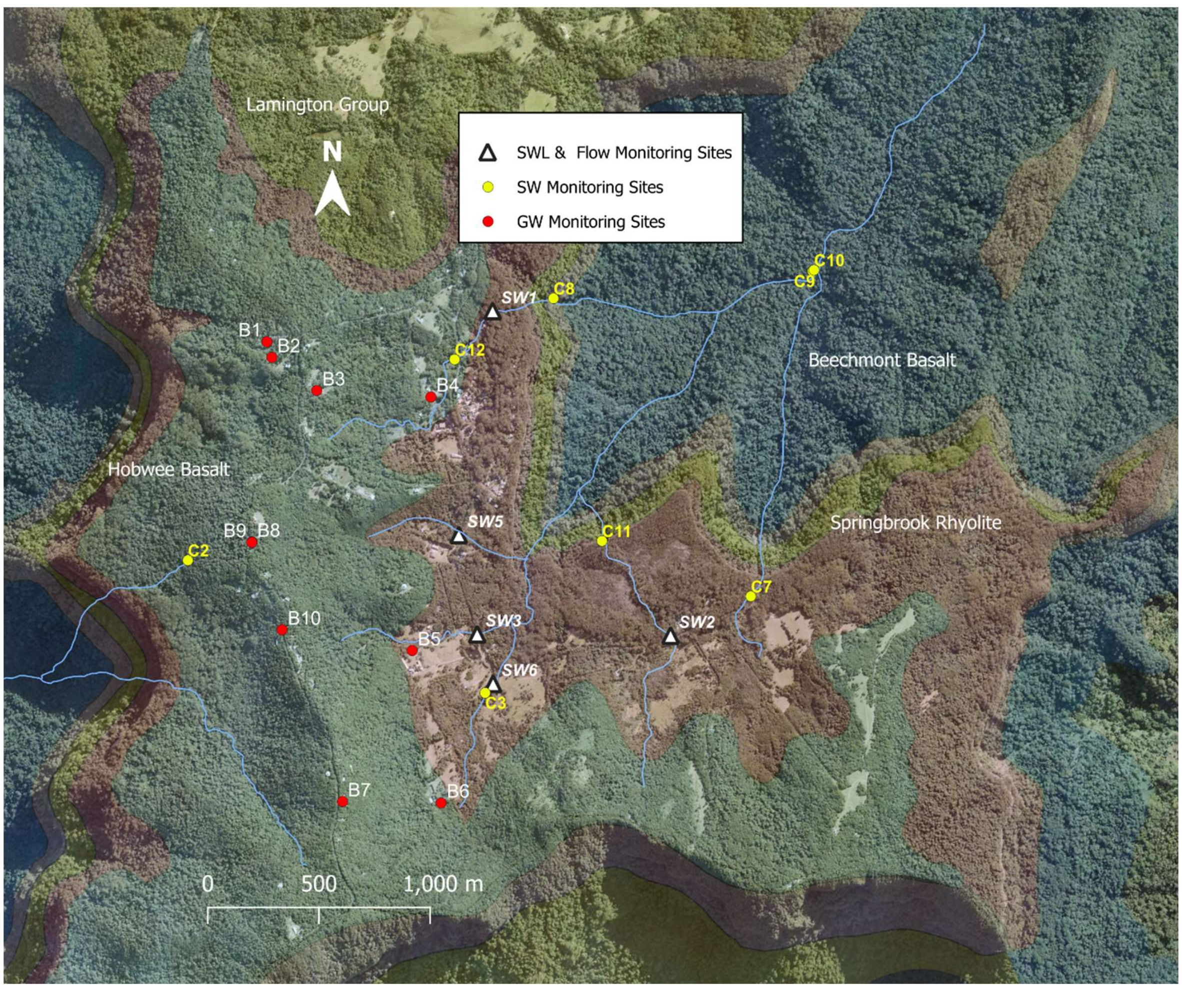

Figure 3- Southern region of Springbrook plateau: groundwater sites (red dots), surface water chemistry (yellow dots), surface water flow sites (white triangles). The Hobwee Basalt formation- blue/green and the Springbrook Rhyolite - pink

5.0 Understanding Springbrook Groundwater

5.1 Groundwater Levels and Spring Occurrence

When the project was initiated, there was no groundwater data and limited bore logs. This necessitated a review of existing privately owned bores within the study area at differing elevations along Repeater Station Rd and Springbrook Rd. Bore logs were mostly absent and limited information about the bores was available. Monitoring sites were selected in consultation with landholders who agreed to ongoing monitoring. In July 2022 three dedicated monitoring bores were installed by the SGI team, enabling full bore logs and lithology to be established.

Groundwater levels between 2 and 55 m below the ground surface were observed during monitoring. Groundwater levels can be seen to respond to rainfall patterns (Figure 4). We observed very responsive groundwater levels throughout most of the monitoring period, however groundwater levels did decline during June 2023 – October 2023.

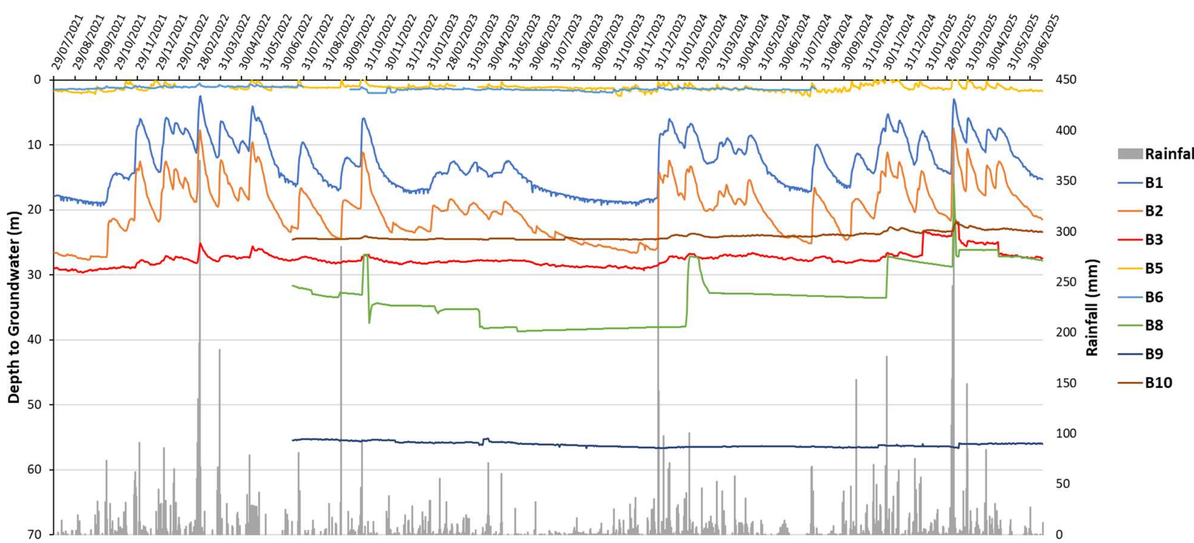

Figure 4 – Daily average groundwater levels vs rainfall from 2021-2025.

Several springs were discovered that directly feed the main creeks on the eastern side of the plateau (e.g. Boy Ull Creek and Ee Jung Creek). Most of these springs emerge at elevations between 820m and 860m above sea level (AHD).

Unfortunately, due to above-average rainfall from 2021 to 2024, the SGI has not had the opportunity to monitor groundwater flow and spring emergence during extended dry periods. Therefore, it is not possible to estimate how much the groundwater levels would decline without regular recharge from rain and whether this would result in some springs completely drying up during periods of low rainfall.

5.2 Groundwater Recharge

Groundwater recharge is the process by which water from precipitation (rainfall) and from atmospheric deposition (cloud moisture, atmospheric condensation and fog), as well as surface sources like streams and rivers, infiltrates the ground to replenish aquifers. Recharge is crucial for sustaining streamflow and groundwater-dependent ecosystems, and understanding it is essential for managing groundwater extraction.

Two methods were used to estimate groundwater recharge rates at Springbrook. The application of the Chloride Mass Balance (CMB) method revealed spatial variations in groundwater recharge, and this was complemented by the application of the Water Table Fluctuation (WTF) method, which indicated differences in seasonal recharge rates at the Plateau. The application of the Chloride Mass Balance method revealed mean recharge to rainfall rates between 38.5% and 55.4% (Albano Reis, J., 2024).

Significant discrepancies were found between the results of applying the Chloride Mass Balance method with rainfall chloride calculated from field sampling and with rainfall chloride extracted from regionalised data. Even though the estimation of chloride concentrations in rainfall is subject to errors, local rainfall sampling is expected to bring lower numerical errors than the regionalisation of chloride concentration in rainfall. The evidence shows that recharge varies seasonally at Springbrook. This is a valuable insight for further water management, as rainfall contributions to groundwater recharge represent the main input to the groundwater system. Multiple years of groundwater level monitoring and surface water level/flow monitoring are required to fully assess recharge processes and groundwater-surface water interactions.

The recharge estimates for the SGI were completed as part of a master's research project (2021-2023) undertaken by a QUT post graduate student; thanks to Juliana Albana Reis for this work (Albano Reis, J., 2024).

5.3 Aquifer Properties

Aquifer properties, such as lithology (the type of rocks and sediments making up the ground), are important for understanding how water moves and is stored at Springbrook. Lithology affects how easily water can flow through the ground and how much can be stored in underground layers. For example, if the rocks are very porous or cracked, like the Hobwee basalt at Springbrook, they can hold more water, but if they are dense, like clay, water will flow slowly or get trapped. Knowing these properties helps us predict water availability, movement, and how quickly rainwater can recharge the aquifers. This understanding is key to managing Springbrook's water resources sustainably.

New knowledge of the lithology was achieved with drilling the three dedicated monitoring bores for the SGI in July 2022. The drilling process used a diamond tipped rock core saw to extract 80m deep rock cores samples preserving the structure of the rock layers. The rock cores extracted from the Hobwee Basalt were used for the definition of hydrostratigraphic units, used to form the physical structure of conceptual and numerical models.

The geology of the Springbrook Plateau can generally be defined as a sequence of weathered basalt from 15 to 35 m thick, underlain by basaltic rocks that are approximately 50 m thick, and further underlain by rhyolitic rocks of an unknown thickness (Somerville, 2023). These results reflect those of Ewart *et al.* (1977) who observed the Hobwee Basalt formation consists of numerous flows generally less than 10 m thick, underlain by two rhyolitic lava horizons, the lower unit (25 m maximum thickness) and the upper unit (70 m thick). The thickness and depth of the Hobwee Basalt layer do not vary considerably (generally 50 to 70 m) within boreholes along the cross-section (Figure 5. Images of Drill rig and rock cores extracted, Figure 6. Cross-section of geological logs at Springbrook). This consistency across the plateau could be attributed to the relatively higher viscosity and lower silica content of basaltic lava flows. From these observations, we can estimate a minimum of 5 lava flow events present in the Hobwee Basalts. The assessment of bore logs at Springbrook revealed the consistent targeting of fractured basalt or rhyolite units in most groundwater bores along the cross-section, indicating their significance as potential aquifer zones.

Figure 5 - Repeater Station Rd drilling rig and extracted rock core sample 2022.

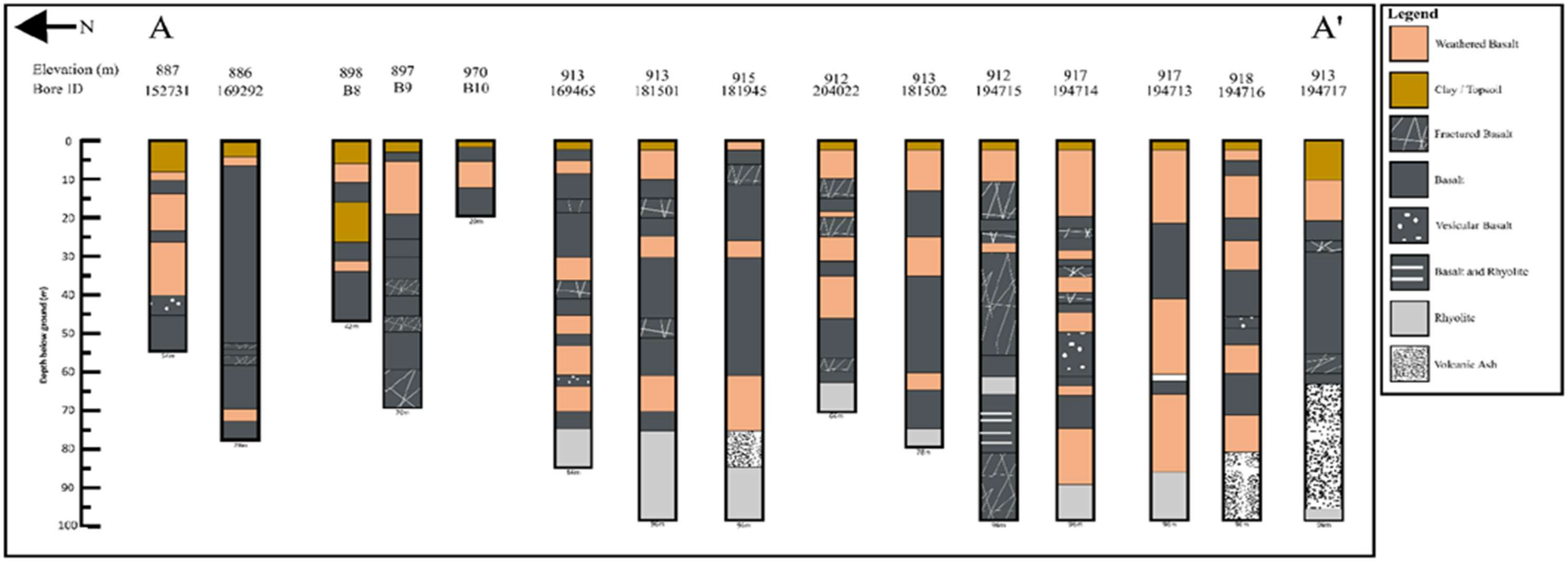

Figure 6 - Cross-section of geological logs at Springbrook. This was created from historical bore logs (when available) and comprehensive bore logs for the 3 dedicated monitoring bores installed during SGI (B8, B9 & B10)

Fractured and glassy basalts were estimated to have the highest hydraulic conductivity due to the joints and open spaces present. Other facies, such as volcaniclastic breccia and massive basalts, were estimated to be less permeable. Fractured basalts were observed throughout the core length, while glassy basalts were encountered at 42 to 46 m depth. These fractures, typically occurring at the top and bottom of lava flows play a crucial role in providing pathways for groundwater flow. The current investigation revealed that several rock types displayed lower estimated hydraulic conductivity. Vesicular basalts in the core lacked interconnected vesicles, rendering them unsuitable as potential aquifers.

The study has also highlighted the heterogeneity of aquifer depth across the plateau, emphasising the need for a more comprehensive investigation of the region's aquifer geology at a larger scale. This stratigraphic correlation raises questions about the lateral variability of the identified fractured and glassy facies, which presents a promising avenue for further research. The in-depth analysis of bore log lithology was completed by Wade Somerville as an Honours Study for the SGI.

5.4 Groundwater Chemistry

Groundwater chemistry analysis is used to identify the sources of water, track the movement of contaminants, and assess water quality because it reveals the interactions between water, rock, and biological processes within an aquifer system.

A large water chemistry data set has been created from monthly to bi-monthly sampling and analysis (Figure 7. Multi-probe used for basic physical chemistry data collection directly from groundwater bores and at surface water sites). The data indicates strong links between groundwater and surface water and evidence of inter-aquifer connectivity (Basalt-Rhyolite connection). The results of the major ions water chemistry analysis shows that the groundwater sites can be categorised into two chemically distinct groups (Figure 8. Trilinear plot). Bores B3, B6, B7, B9 and B10 consistently had higher concentrations of Ca, Mg and HCO_3 than the other bores. This is consistent with fresh groundwater derived from the Hobwee basalt, due to the chemical dissolution of silicate minerals in the aquifers. The other bores were drilled into the Springbrook rhyolite (B1, B2, B3, B4, B5). They consistently displayed lower concentrations of Ca, Mg and HCO_3 but had slightly higher concentrations of Na and K. Their groundwater was usually characterised as either Na-HCO_3 type, Na-Cl type or "mixed" type.

Figure 7 - Multi-probe - water chemistry

Groundwater with higher calcium, magnesium and bicarbonate (Ca–Mg–HCO_3 type) is typically younger water, recently recharged by rainfall moving through basalt rocks. In contrast, sodium- or chloride-dominated water (Na–HCO_3 or Na–Cl types) with associated higher potassium concentrations, reflects water-rock interactions in rhyolitic aquifers. These signatures help trace the 'fingerprints' of where the water has come from and how long it has been underground.

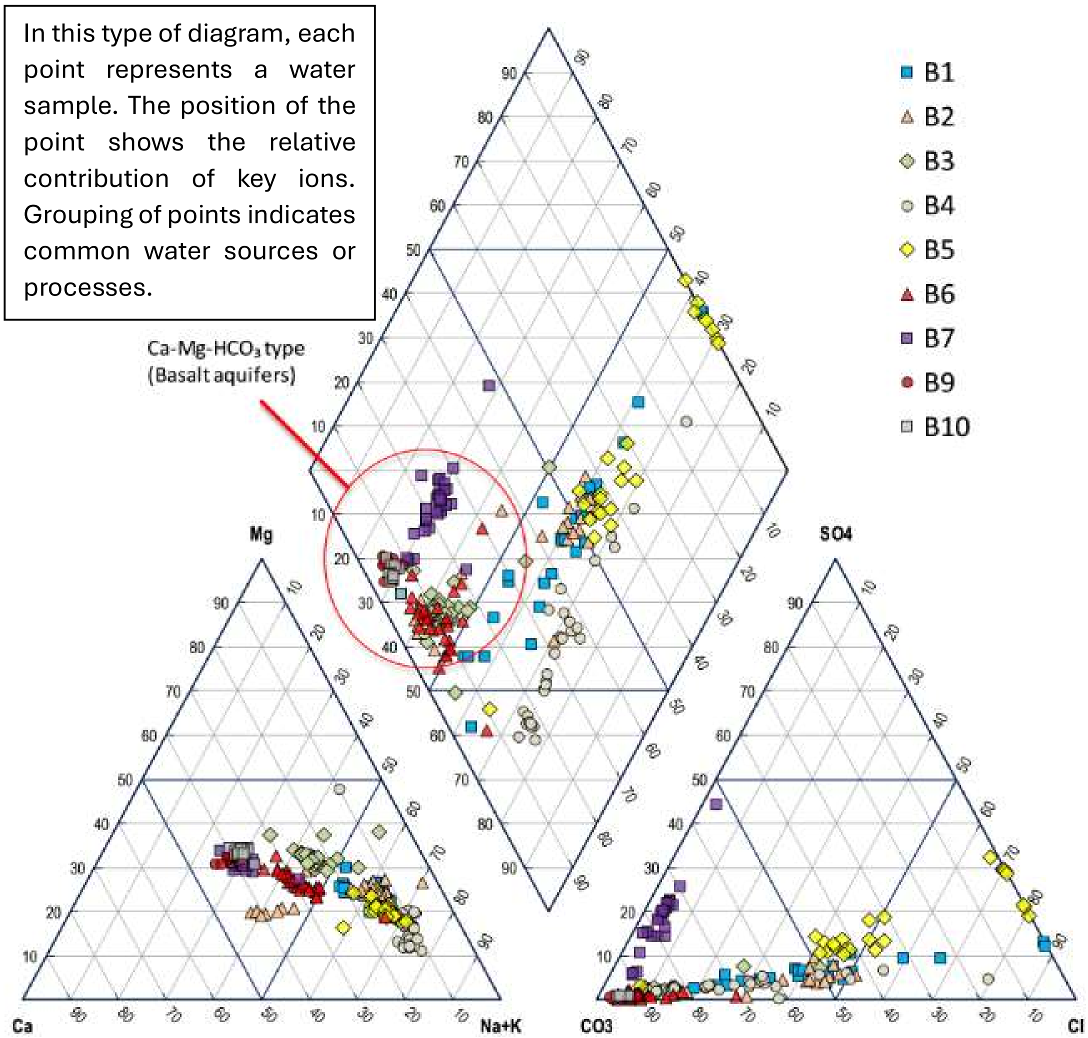

Figure 8 - Trilinear diagram showing groundwater chemistry - all sites

The groundwater at Springbrook had an overall average pH of 5.8, which is mildly acidic. The groundwater sampled from bores in the Hobwee basalt had pH values > 6, but the bores B1, B2, B3, B4 and B5 had pHs lower than 6. The pH values are an indication of groundwater source/aquifer type, with the groundwater from the Springbrook rhyolite producing more acidic groundwater. A decrease in pH was observed to correlate with decreasing surface elevation of groundwater sites, showing that the groundwater is less acidic at higher elevations, within the basalt. Higher pH values were also found to correspond with higher concentration of dissolved solids in the basaltic groundwater.

Overall, Springbrook groundwater has very low Total Dissolved Solids (TDS), placing it in the category of very fresh natural water (< 500 mg/L). This may be influenced by a very low residence time, and comparatively rapid movement of water through the system.

pH and TDS are basic indicators of water quality. Mild acidity (pH ~5.8) is common in high-rainfall forested regions due to natural organic acids and mineral weathering. Very low TDS (<500 mg/L, the 'very fresh' category) indicates exceptionally clean water with short underground residence times, meaning the aquifer system is highly dynamic and responsive to rainfall inputs.

An analysis of rock samples revealed the geochemical signature of each rock type, and the geochemical signatures were observed in the chemical analysis of groundwater samples. Radon has been found to be derived primarily from the chemical dissolution of silicate minerals in the Springbrook rhyolite. The lesser amounts of U and Th present in the Hobwee basalt do not significantly contribute radon to the groundwater.

Radon is a naturally occurring radioactive gas that dissolves in groundwater as rocks weather. Because radon levels change rapidly with recharge, it is a powerful natural tracer for detecting short-term groundwater movements and connections between aquifers. At Springbrook, radon spikes after rainfall provide clear evidence of rapid recharge pathways between rhyolite and basalt aquifers.

The groundwater sites chemically characterised as basaltic aquifers all showed an increase in radon concentrations following rainfall, as the underlying rhyolite becomes saturated, promoting radon movement (Figure 9. Radon fluctuation). Conversely, the other groundwater sites characterised by higher Na-K and Cl displayed a decrease in radon concentrations in response to rainfall, as they were recharged with low-radon groundwater from the overlying basaltic aquifers. Hence, the relationship between rainfall events and radon concentrations is indicative of seasonal groundwater movements (Stanley and Reading 2025).

With no lithological data available for many of the private bores where groundwater was sampled, there exists a knowledge gap in the interpreted internal structure of the geological formations, particularly in relation to the location of contact zones between the rhyolite and basalt. However, combining the observed geochemical and hydro-chemical data with the known depths and screen locations of each bore allowed a more confident identification of the dominant groundwater source and aquifer type at each bore site (SGI Progress Report 2024).

Without detailed borehole geological logs, it is difficult to match chemistry to aquifer layers. This makes it harder to define where and how groundwater mixing occurs.

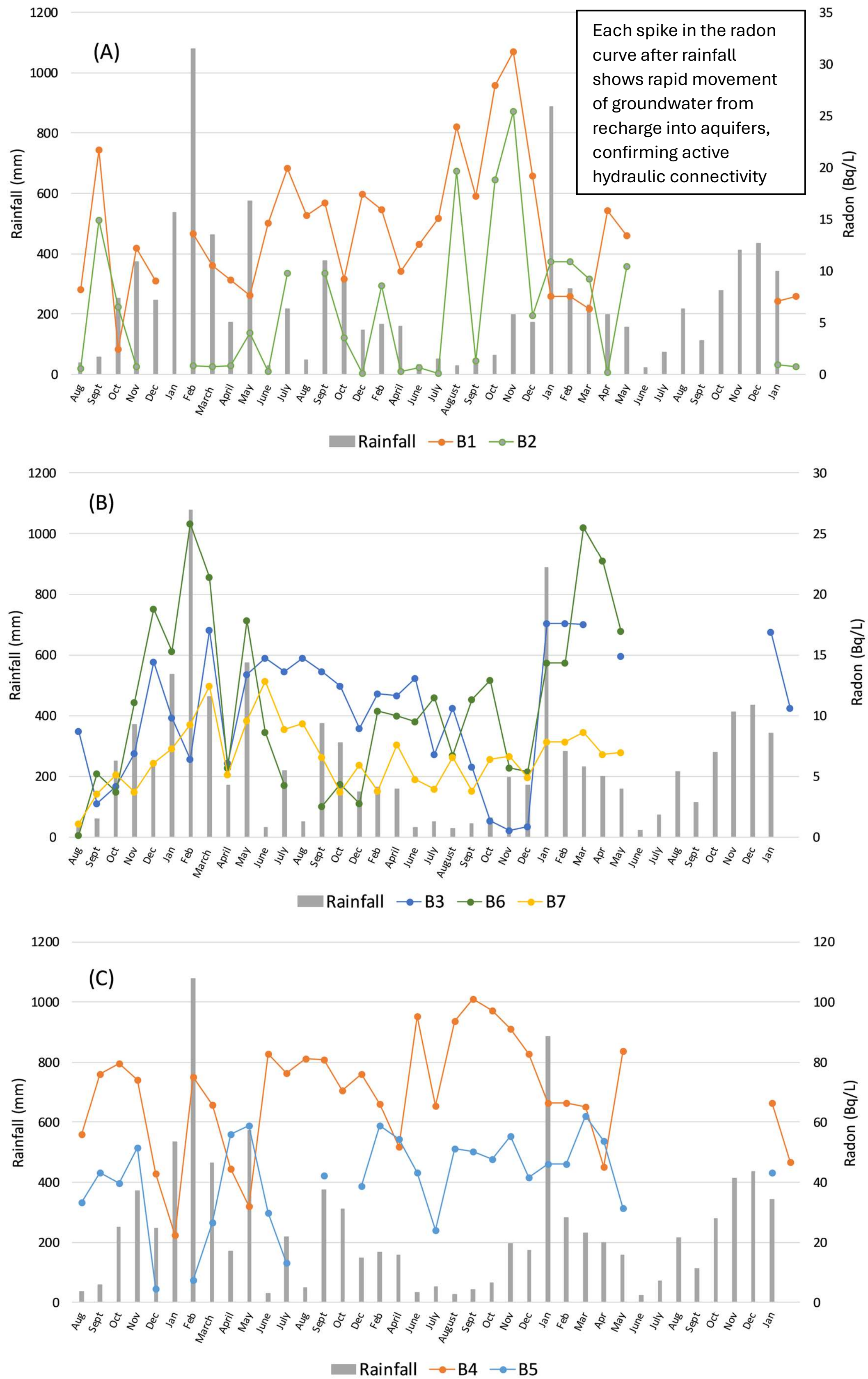

Figure 9 - Radon flux in groundwater as a response to rainfall, August 2022 - May 2024

6. Understanding Springbrook Surface Water

The creeks monitored at Springbrook flowed continuously between 2021 and 2024. Surface water levels while being more directly responsive to rainfall than groundwater, also exhibit a relationship with the groundwater levels (Figure 10), demonstrating a closely aligned rapid decrease in level after rainfall events have ceased. These results provide supporting evidence of strong interactions between surface water and groundwater during this period of above-average rainfall.

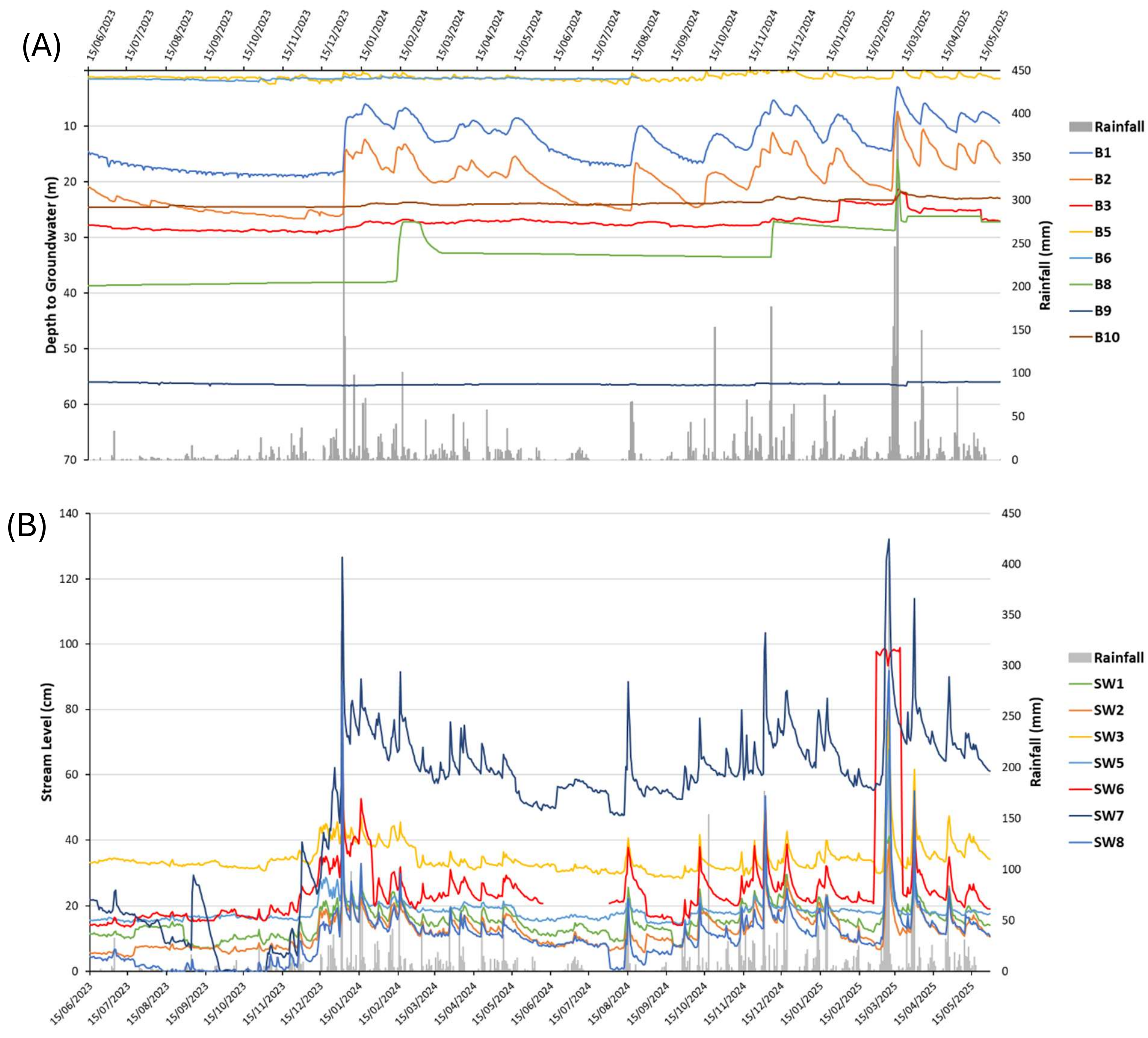

Figure 10 - (A) Daily average groundwater levels vs rainfall & (B) surface water vs rainfall demonstrating inter-relationships, from 2023-2025.

Further monitoring under drier conditions is needed to understand how aquifers and connected creeks respond to extended dry periods. Although creek flows dropped in 2023, water levels quickly recovered with rainfall in early 2024 (Figure 10B). Rainfall events typically produced rapid rises and falls in creek levels. Low flow velocities were common, which made discharge measurements difficult. Field observations also suggest that saturated soils act as a third, episodic water reservoir: they store rainfall and then rapidly release it to creeks. This process has not yet been quantified and represents an important research gap. While water level monitoring is now well established, the dataset needed to produce accurate rating curves is still being built. In parallel, numerical modelling of Springbrook's surface water has commenced using TUFLOW (Gao *et al.*, 2024).

The pH of surface water at Springbrook ranged from very mildly acidic to neutral. Nitrate concentrations were typically around 1 mg/L at the surface water sites. Most of the surface water samples analysed have are dominated by Na and HCO_3. However, the water chemistry at the creek sites was found to vary during the monitoring period. The project has also identified geochemical tracers that can now be used to assess seasonal and interannual variations in groundwater discharge to surface water at Springbrook.

7. Springbrook hydrogeological conceptual model

A hydrogeological conceptual model is a simplified representation of how groundwater systems work in a specific area. It shows the relationships between various features, such as the types of rocks and soil (geology), how water moves through them, and where water is stored underground (aquifers). The model includes details like how water enters (recharge) and leaves (discharge) the system, interactions with surface water (springs, soaks and streams), and the influence of human activities. This model contributes towards understanding and predicting groundwater behaviour, managing water resources, and assessing the impact of activities like drilling or pumping.

The combined data from field observations, water chemistry analysis, historic bore logs and new bore data acquired during the SGI, allowed us to create a basic hydrogeological conceptual model for the upper Springbrook plateau (Figure 11). This conceptual model is useful as an overall guide on a large, formation-wide scale but detailed aquifer properties over small distances are more difficult to quantify. The conceptual model depicts the general evolution of groundwater from recharge (rain, fog/cloud) to discharge (creeks, waterfalls, groundwater abstraction and export from catchment).

Various semi-permanent groundwater aquifers appear in the upper Hobwee basalt, and where the water is stored in clay layers, the gradual gravity-driven percolation of groundwater to the lower layers is slower. These shallow aquifers are likely to be important for sustaining mature rainforest trees in the cloud-forest zone. In the lower layers of the basalt, there appears to be a significant aquifer zone which traverses the geological contact zone. These layers are likely to be very fractured and coincide with the surface expression of many freshwater springs and seeps occurring within the same elevation range (approximately 820m AHD – 850m AHD). These springs are the source of the main creeks which are in turn the source of the plateau's waterfalls. The springs which emerge within this specific elevation range are sustained principally by groundwater from the Hobwee basalt.

Groundwater level data collected during the SGI has shown that the Springbrook rhyolite provides a reliable and permanent source of groundwater. Water chemistry and groundwater level responses indicate that the rhyolite aquifers receive recharge both from direct rainfall and from hydraulic connectivity with the Hobwee basalt aquifers.

It is important that future observations of groundwater and surface water levels are conducted during drier periods, both to reveal aquifer–surface water connections more clearly and to identify threshold groundwater levels at which baseflow ceases and creeks stop flowing. The above-average rainfall during the SGI has so far prevented these conditions from being observed.

Observations during drier conditions are not only about confirming connectivity, they're also essential for identifying **critical thresholds**:

- the groundwater levels below which baseflow is no longer sustained,
- and the points at which creeks transition from perennial to intermittent or cease to flow altogether.

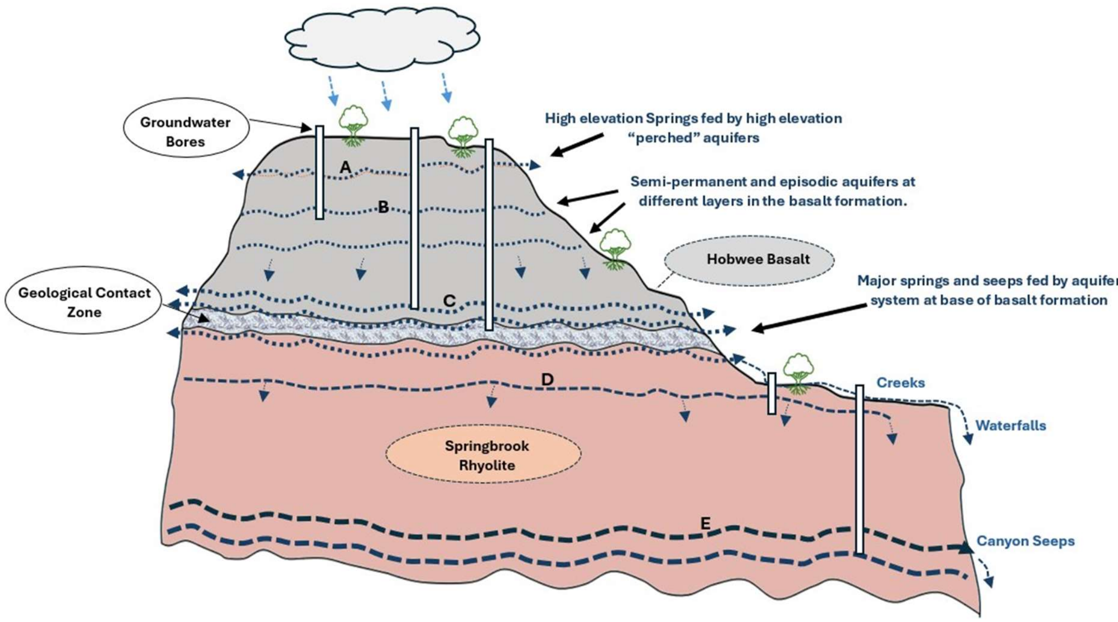

Figure 11 - Springbrook hydrogeological conceptual model.

A: (Basalt) Semi-permanent shallow (<30m depth) aquifers, discharging to high elevation springs. Hosted by very clay-rich layers of weathered basalt in upper formation.
B: (Basalt) Semi-permanent – episodic aquifers (30-50m depth).
C: (Basalt) Deep (70-90m depth) high-storage aquifers situated above and across geological contact zone, discharging to network of springs and seeps which form the headwaters of main creeks and waterfalls.
D: (Rhyolite) Permanent shallow (<30m depth) aquifers.
E: (Rhyolite) Permanent deep (65-80m) high-storage aquifers, discharging to slow seeps in canyon walls.

8. Developing ecohydrology monitoring at Springbrook

Ecohydrology is the study of how water interacts with living things like plants, animals, and ecosystems. It looks at how water availability affects the environment and, in turn, how ecosystems influence the water cycle. Changes in water flow or availability, due to climate or human activity, can impact plants and animals. By studying ecohydrology, we can better understand and protect both the ecosystems and the water systems at Springbrook.

Ecohydrology monitoring was conducted at one site at Springbrook from 2020 to 2024. During this period, rainfall was consistently above average and soil moisture remained unusually high. These wet conditions suggest that vegetation across the monitoring clusters experienced consistently low water stress (Bellis, 2024). However, this raises an important research question: how might the ecohydrological relationships observed under these wet conditions differ during extended dry periods, when water stress is likely to be higher?

Ecohydrological monitoring of trees showed daily and multi-day variations in sap flow. Sap velocity was similar in all but one tree monitored, with no apparent differences between cluster locations or tree size. Both qualitative and quantitative analyses indicated that sap flow was well correlated with hydrometeorological variables, including solar radiation, vapour pressure deficit (VPD), evapotranspiration (EVT), and humidity. At Springbrook, no strong correlations with subsurface water availability were detected during the monitoring period, likely because consistently high rainfall-maintained soil moisture at elevated levels. Despite seasonal variations in climate, there were no clear seasonal differences in sap flow, which may reflect the influence of persistent low cloud cover blanketing the plateau in summer months. Transpiration rates were highest during fine weather (high solar radiation and no rainfall), reaching up to ~150 L/day in larger trees. Importantly, the above-average rainfall throughout the study period means that potential thresholds—where reduced inputs from rainfall and cloud interception, coupled with increased transpiration demand on sunny, low-cloud days, begin to deplete soil moisture and create a dependence on groundwater seepage to sustain vegetation—have not yet been observed. These thresholds are expected to emerge only during extended dry periods, highlighting a key research gap for future monitoring.

The ecohydrology research outlined above was made possible through a QUT PhD, supported by the Queensland Water Modelling Network and the Queensland Department of Environment and Science, ecohydrological monitoring was established by Laura Bellis at Springbrook in 2020.

8.1 Review of the Relationship Between Hydrology and Ecology at Springbrook

Springbrook's sensitive ecology and high biodiversity is intricately tied to its hydrological systems, with numerous vulnerable, endangered, and critically endangered species relying on the abundance of water at Springbrook. As the Springbrook Gondwana Rainforest World Heritage Area and National Park spans across the NSW/QLD State border, both State governments have an interest and respective legislation applies. The flora and fauna of this Gondwana Rainforest and the mosaic of connected ecosystems depend upon a delicate balance of rainfall, cloud water, groundwater/soil moisture, and surface waters.

This study did not assess or monitor the cloud moisture component of Springbrook's water cycle. Cloud moisture input to the forest hydrology at Springbrook remains an area lacking in data, requiring further monitoring and investigation.

The 2020 IUCN Conservation Outlook assessment places the Gondwana Rainforests in the "Significant Concern" category (IUCN, 2024). Risks contributing to this declining outlook include incompatible land use on adjoining properties, groundwater extraction, fire, and climate change. Springbrook was specifically cited in decisions adopted by the extended 45th session of the UNESCO World Heritage Committee that met in 2023 in Saudi Arabia relating to State Party updates on the State of Conservation. The mentions were due to "the granting of a water mining license to extract water from the vicinity of Springbrook National Park." The committee requested that the Australian Government report back on the proposed activity and potential impacts by 1 December 2024 (UNESCO, 2023).

The Queensland Planning and Environment Court has recently approved a new commercial water extraction activity on Repeater Station Road, Springbrook. This matter has not been referred to the Federal Government, although there are multiple potential EPBC Act 1999 triggers (listed species and World Heritage Area impacts). Proposed changes to the EPBC Act will potentially tighten loopholes and lead to an increased focus on matters of national environmental significance (MNES) with legally enforceable national standards (Independent Review of the EPBC Act – Final Report 2020; Commonwealth Government Response 2023-24).

According to the City of Gold Coast's Flora and Fauna database (see Figure 10), a detailed polygon for the study area reveals a significant concentration of threatened species. The database identifies all historic data with a precision of up to 2,000 metres, accounting for multiple threatened species listed under the City Wide Significant (CWS) framework, the Nature Conservation Act 1992 (NCA, QLD), and the Environment Protection and Biodiversity Conservation Act 1999 (EPBC, Federal). This includes 3,602 flora records representing 214 unique threatened species, and 4,212 fauna records covering 62 unique threatened species. The overlap in listings for some species demonstrates the urgent need for integrated management strategies across State boundaries and all levels of government.

Table 1 Listed Flora & Fauna within study area (CoGC, 2024)

Springbrook Significant & Unique Flora & Fauna Records– Listed in Local, State and Federal Policy			
	City Wide Significance	Nature Conservation Act	EPBC Act
Flora			
Critically Endangered		6	3
Endangered		7	5
Vulnerable		26	18
Near Threatened		9	
Total listed flora Species	209	48	26
Total individual records	2430		
Fauna			
Citically Endangered		2	2
Endangered		5	7
Vulnerable		15	11
Near Threatened		1	
Special Least Concern		6	
Total listed fauna Species	51	29	20
Total indiviual records	4212		

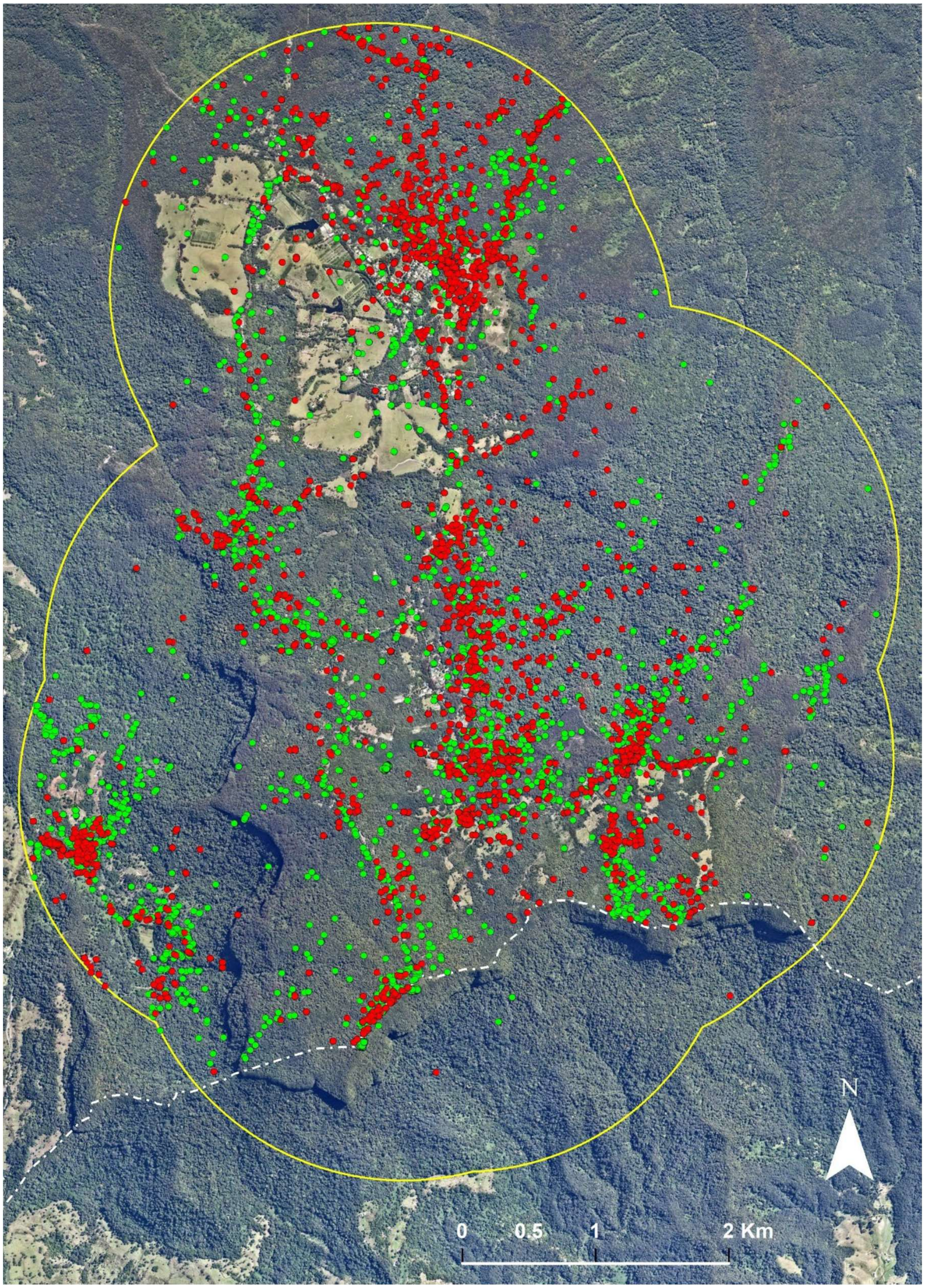

Figure 12 - Location of Listed Flora & Fauna at Springbrook.

8.1.1 Flora

Research has shown that montane cloud forests, such as those found in the Gondwana Rainforests, are particularly reliant on moisture from rainfall, cloud interception, and groundwater to sustain their unique ecosystems (Giambelluca and Gerold, 2011, Narsey et.al. 2020). Cloud forests such as those along Repeater Station Road are known to receive significant water input from fog drip and horizontal precipitation. Intercepted cloud and fog water has been shown to contribute the equivalent of approximately 40% of measured rainfall to high-altitude subtropical rainforest systems (Hutley et al., 1997). Cloud moisture helps sustain not only the epiphytes and ferns but also larger species like the newly described *Syzygium nebulosum* (Cloud Forest Lily Pilly), described from Springbrook specimen in August 2024, and *Nothofagus moorei (*Antarctic Beech - a renown cool temperate species of Gondwana Rainforest). Both large trees exhibit adaptations such as adventitious roots that grow on the trunk and in association with epiphytic mosses to collect cloud moisture. Consistent moisture availability is crucial, especially during dry periods when groundwater becomes the primary water source for many species (Bruijnzeel, 2010).

Figure 13 - Complex structure and diversity of Gondwana Rainforests vegetation.

The complex layering of vegetation in rainforest ecosystems is an expression of niche optimisation for water, sunlight and nutrients. This is a process that can drive evolution through diversification (Weber et.al. 2013). Figure 13 is an image that shows the multiple layers of vegetation from canopy, the mid and under story and shrub layers with profuse epiphytic growth on trees and rocks.

Comparative studies have shown that Springbrook holds the highest level of rainforest plant endemism in subtropical Australia, acting as a triple centre of endemism for subtropical, warm temperate, and cool temperate rainforest types (Weber *et al.* 2013). This makes Springbrook a critical area for conservation, as changes in climate and hydrology—such as decreased rainfall, cloud cover, and groundwater availability— pose a serious threats to these ecosystems.

Paleo-Antarctic Rainforest Lineages (PARLs). *Nothofagus moorei* is a living representative of the Paleo-Antarctic Rainforest Lineages (PARLs), taxa with fossil records in Gondwanan rainforests of Antarctica, Patagonia, and Australia that persist today in ever-wet refugia. Figure 14 – shows *N. moorei* at Springbrook, a PARL species of Outstanding Universal Value (OUV). This image illustrates the living presence of an ancient Gondwanan lineage in situ, demonstrating the ecological and cultural significance of these trees and reinforcing the importance of hydrological stability for their survival. Kooyman *et al.* (2014) define PARLs as woody taxa whose distribution and fossil evidence demonstrate persistence from ancient Gondwanan rainforests into modern ecosystems. Their survival in Australia highlights both evolutionary continuity and vulnerability under climate change. The presence of PARLs like *N. moorei* contributes directly to the Outstanding Universal Value (OUV) of the Gondwana Rainforests World Heritage Area by embodying ancient biogeographic linkages and resilience across geological time.

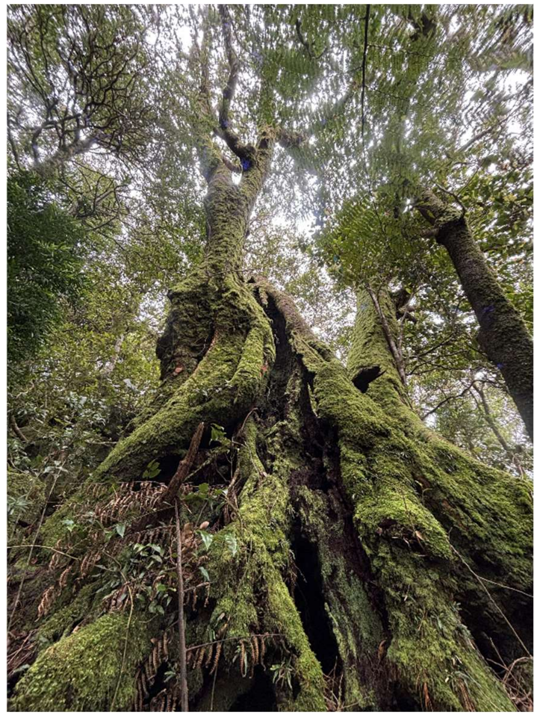

Figure 14 - Nothofagus morei - Antarctic Beech - OUV PARL species

Notably, among the flora, 209 species are listed as CWS, 48 under the *NCA* 1992, and 26 under the *EPBC Act* 1999 , with 3 species classified as Critically Endangered and 5 as Endangered under state and federal criteria. These species, many of which are endemic to the Gondwana Rainforests, rely heavily on hydrological stability. This region's rainforest ecosystems are sustained by abundant water sources, including an average of 3m of rainfall, cloud water inputs are yet to be quantified, and groundwater that maintains a relatively short residence time. Numerous species have evolved to depend on persistent moisture from cloud cover and fog drip, which researchers have identified as vital for sustaining epiphytes, ferns, and canopy trees. "Cloud forests depend significantly on horizontal precipitation (cloud water interception) and fog drip for moisture,"(Narsey *et al.*., 2020) making these ecosystems particularly sensitive to changes in climate and water availability.

Groundwater plays a critical role in maintaining the health of flora during dry periods (Glanville et.al. 2023). A potentially critical resource for species like *Eucryphia jinksii* and *Nothofagus moorei*, which are classified as endangered (*E.jinksii*) or like the Antarctic Beech (Vulnerable NSW) (DESI, 2024) are considered vulnerable to local extinction due to the isolation of populations, potentially high levels of clonality and low-potential for successful sexual regeneration in long-lived individuals (Schultz 2008). The SGI has emphasized the importance of groundwater and surface water interactions, noting that fluctuations in these resources could directly impact local biodiversity. This sensitivity is further demonstrated in the fauna records, where 45 species are listed as CWS, 23 under the *NCA 1992*, and 12 under the *EPBC Act* 1999. The database reveals that 1 Critically Endangered, 4 Endangered, and 11 Vulnerable species rely on Springbrook's hydrological systems for survival.

8.1.2 Fauna

Among the fauna, three species of freshwater crayfish stand out as flagship indicators of Springbrook's ecological integrity: the Federally listed Critically Endangered endemic *Euastacus binzayedi*, *Euastacus maidae* (both endemic to Springbrook) and the State-listed Critically Endangered *Euastacus sulcatus*. All three are highly restricted to montane rainforest streams with habitat that includes saturated groundwater soaks. These crayfish are extremely sensitive to alterations in hydrology. Figures 15 (2023) and 16 (2025**)** illustrate these species in situ (DESI, 2024a), providing visual evidence of their continued presence within the study area.

Figure 15 - Euastacus binzayedi - Springbrook 2023

Other threatened fauna also depend on the stability of Springbrook's ecohydrological systems, including the Endangered Dusky Tailed Antechinus (*Antechinus arktos*) and Albert's Lyrebird (*Menura alberti*) (OEH, 2024). Amphibians such as the Cascade Treefrog (*Litoria pearsoniana*), along with species like the Spotted-tailed Quoll (*Dasyurus maculatus*) (DESI, 2024b, 2024c) and the Richmond Birdwing Butterfly (*Ornithoptera richmondia*) (Sands & New, 2002; QLD Government, 2024), rely directly on stable groundwater seepage, moist soils, and seasonal surface flows for habitat viability.

These species represent part of a broader ecological web that is fundamentally tied to groundwater discharge and rainfall-driven water inputs. Special fauna records also include migratory species, underscoring the importance of maintaining water quality and availability for both resident and transient fauna.

Figure 16. Critically Endangered - Euastacus sulcatus – juvenile specimen *(2025) also found at Springbrook*

The interconnectedness of hydrology with biodiversity highlights the necessity of continued groundwater monitoring and sustainable water management. Any reduction in water availability, whether from extraction, declining rainfall, or reduced cloud interception under climate change, poses a direct threat to these species. Without careful regulation of groundwater extraction and protection of aquifer-dependent ecosystems, the future of Springbrook's unique fauna, together with its rich flora, remains at significant risk.

9. Conclusions & Recommendations

9.1 Monitoring and Literature Review Conclusions

1. Groundwater discharge drives surface water flows at Springbrook (particularly during dry weather).

- strong **links found between groundwater and surface water** and evidence of **inter-aquifer connectivity** (Basalt-Rhyolite connection),
- strong evidence of **seasonal movement of groundwater between rhyolite and basalt aquifers** (wet season can drive water from deeper rhyolite aquifers upwards to mix with basalt aquifers),
- water on the Springbrook plateau has a **low residence time**, and there is comparatively **rapid movement of water through the system**.
- **Above-average rainfall during the SGI** meant that critical thresholds, such as the groundwater levels at which baseflow ceases and creeks stop flowing, were not reached. Ongoing monitoring under extended dry periods is essential to identify these thresholds.

2. Groundwater **recharge rates are highly variable** – spatially and temporally (indicating a complex system).

- Recharge processes are likely to include episodic soil water storage and release, and cloud/fog interception, both of which have been observed but remain unquantified and require further study.

3. Springbrook is home to many **endemic, endangered and vulnerable flora and fauna** species that have evolved in a wet hydrological regime, a hydrological regime that is likely **dependent on groundwater released via springs during dry periods** of low rainfall.

- Flagship species such as *Euastacus binzayedi* (Springbrook endemic), *E. maidae*, *E. sulcatus*, and Paleo-Antarctic Rainforest Lineages including *Nothofagus moorei*, are directly dependent on stable hydrology, including groundwater discharge. Their persistence underpins the Outstanding Universal Value (OUV) of the Gondwana Rainforests World Heritage Area.

4. The groundwater aquifers at Springbrook are:

- overlain by "protected areas" including **National Park utilising the aquifer waters**,
- of **deep cultural significance to First Nations People**, consequently a **thorough indigenous engagement and consultation process should be undertaken to determine appropriate cultural flows** in the Revision of the Water Plan (Gold Coast) 2006.

5. The discrete mountain top **aquifers at Springbrook are relied upon by World Heritage forests**. Therefore, any **extractions from these aquifers pose a potential risk** to these hydrologically sensitive, internationally recognised ecosystems.

- Protecting these aquifers, safeguards not only ecological integrity, but also Australia's ability to meet its UNESCO/IUCN World Heritage obligations.

9.2 Policy and planning recommendations: Springbrook and the Gondwana Rainforests

The following recommendations are proposed to guide policy and planning decisions for land use and land management in Springbrook, which is part of the World Heritage-listed Gondwana Rainforests of Australia. These recommendations align with the ecological significance and cultural values of the region, as well as the need for sustainable resource management. The SGI has demonstrated that these systems are highly sensitive to hydrological variability. Incorporating findings on thresholds, into policy will strengthen adaptive management frameworks.

9.2.1. Inter-government support for long-term environmental monitoring

The Springbrook Groundwater Investigation (SGI), a multi-year study of groundwater, surface water, and ecohydrology, has demonstrated the complexity and sensitivity of the plateau's interconnected hydrological and ecological systems. These systems face increasing risks from human activity, invasive species, and climate change.

Given Springbrook's UNESCO-recognised Outstanding Universal Value, its sensitive ecosystems, and its Indigenous cultural heritage — as well as its social and economic significance as a centre for wellbeing and ecotourism on the Gold Coast — there is a clear need for **long-term, coordinated environmental monitoring and reporting**.

Unlike single-jurisdiction monitoring programs, Springbrook lies within the Gondwana Rainforests of Australia World Heritage Area (GRWHA), which spans the Queensland–New South Wales border. Effective monitoring therefore requires **cross-border collaboration** and resourcing by both State Governments, supported by local government and embedded within a national framework for World Heritage stewardship.

Long-term monitoring should mirror the **integrated, multi-jurisdictional model** applied to the Great Barrier Reef World Heritage Area (GBRWHA). Under the Reef 2050 Plan, the **Reef 2050 Integrated Monitoring & Reporting Program (RIMReP)** coordinates contributions from the Australian Government, Queensland Government, GBRMPA, AIMS, CSIRO, IMOS, and Traditional Owners. This program, alongside AIMS's **35+ year Long-Term Monitoring Program**, demonstrates how sustained, government-backed monitoring enables evidence-based management of Outstanding Universal Value. A recent joint **$63.2 million federal–Queensland investment** reinforces this commitment to long-term monitoring.

A **parallel approach for the Gondwana Rainforests**—with **Springbrook as the focal starting point**—would institutionalise cross-border and multi-level government support, creating a coordinated rainforest monitoring framework that safeguards OUV, strengthens cultural partnerships, and informs adaptive management.

Monitoring should encompass floristics, species diversity, biomass, canopy cover, ecohydrology, and climate factors. It would benefit from adopting methodologies from the Robson Creek TERN SuperSite in the Wet Tropics World Heritage Area (TERN, 2024), extending to both flora and fauna monitoring, incorporating advanced techniques such as eco-acoustics and eDNA analysis.

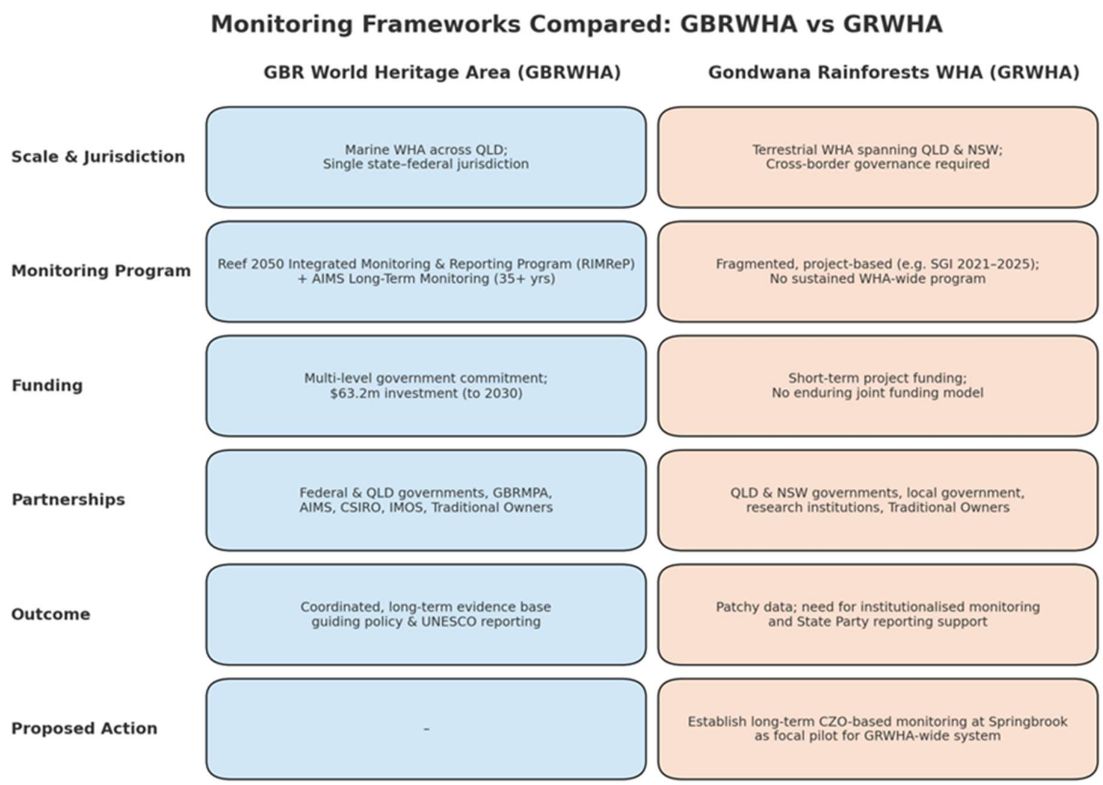

Figure 17 - Comparison of Great Barrier Reef and Gondwana Rainforests monitoring frameworks.

9.2.2. Transparency and Sustainability of Groundwater Extraction

The sustainability of current groundwater extraction activities remains uncertain, particularly in the context of extended dry periods, future climate variability, and the lack of comprehensive monitoring of extraction volumes. To address these concerns, existing commercial groundwater extraction operations should be required by the Department of Local Government, Water and Volunteers to publicly disclose (publish) their water extraction volumes and related data in a manner suitable for assessing impacts.

Such transparency is essential for assessing the long-term impacts on both the groundwater system and the associated critical zone. Given the shared value around Springbrook's environment, disclosure of commercial water extraction data from this public resource is clearly in the public interest.

This data should feed into broader environmental and hydrological monitoring programs to ensure the protection of the sensitive ecosystems in and around Springbrook.

9.2.3. Groundwater Regulation at Springbrook

9.2.3 Groundwater Regulation at Springbrook

A State Government moratorium on new commercial water extraction at Springbrook has been in place since March 2020. While this has prevented further expansion, longer-term groundwater regulation is urgently required. The potential impacts of extraction on the Outstanding Universal Value of the Gondwana Rainforest World Heritage Area, the associated

National Park, and the cultural significance of groundwater and surface water to the Kombumerri Traditional Owners necessitate a stronger regulatory framework.

It is recommended that the **precautionary principle** guide groundwater management at Springbrook, with regulation formally integrated into the upcoming **Gold Coast Water Plan** through establishment of an **Groundwater Management Area (GWMA)**. The moratorium should remain in place until the Plan is finalised (expected by December 2026).

Key regulatory measures could include:

1. **Licensing and Caps** – all extraction subject to licensing, with strict caps, conditions, and sunset clauses tied to environmental limits and groundwater recharge.
2. **Environmental Flow Reserves** – adoption of benchmarks similar to NSW basalt aquifer plans, reserving 82–96% of recharge for the environment.
3. **Comprehensive EIAs** – all new applications must assess hydrological, ecological, and cumulative impacts.
4. **Domestic Bore Oversight** – domestic bores to remain limited to domestic use, with their impacts included in monitoring and cumulative impact assessment.
5. **Transparency** – all commercial extraction data publicly disclosed to support accountability and community trust.
6. **Economic Tools** – tiered pricing systems linked to extraction volumes and ecosystem sensitivity, with revenues directed to Springbrook environmental conservation and/or Kombumerri cultural conservation.
7. **Phased Reduction and Exit Strategies** – allowing existing extractors to transition away from unsustainable use.
8. **Adaptive Management** – regulations updated in response to new monitoring data.
9. **Integrated Cultural Water Management** – decision-making to directly include Kombumerri Traditional Owners as co-governance partners.
10. **Community Partnering and Collaboration** – establishment of a multi-stakeholder advisory group to ensure transparent, inclusive governance.

This suite of measures will provide the robust framework needed to protect Springbrook's sensitive groundwater-dependent ecosystems, cultural values, and community wellbeing in the face of climate change and growing extraction pressures.

9.3 Recommendations for monitoring and research at Springbrook

The review of environmental factors and the model development that has taken place during the SGI has highlighted the key data gaps that will need to be filled to inform future modelling. Specific recommendations include:

- Further investigation on the history of the groundwater extraction at Springbrook, to define baseline conditions for steady-state calibration.
- Retrieval of groundwater extraction rates from properties on Springbrook Plateau, particularly commercial extraction operators.

- Undertaking pumping tests to define local hydraulic conductivity across the Plateau, in the Hobwee Basalt and Springbrook Rhyolite.
- Field tests, using geophysics, to define contact zones between the Hobwee Basalt and Rhyolite layers, and the thickness of this layers with more confidence.
- Investigations into the spatial variability of groundwater recharge and the potential contribution of fog water to groundwater recharge. This should be complemented by investigating episodic soil water storage and rapid release events.
- Monitor the transpiration of the forest ecosystems at Springbrook to assess the ecohydrological demands on the water cycle. This should include targeted monitoring during extended dry periods to detect ecological thresholds in vegetation water use.
- Establish presence/absence and distribution baseline data for fauna in terms of ecological guilds sensitive to hydrology such as crayfish and frogs. Many of these taxa are not only ecological indicators but also central to the OUV of the World Heritage Area.
- Develop long term monitoring for changing climatic conditions and the impact on Springbrook's hydrology and ecology.
- Monitor cloud moisture input as a component of the water cycle at Springbrook.

9.3.1 Establishing a Critical Zone Observatory

The "Critical Zone" is defined as the near-surface layer of the Earth that extends from the top of the vegetation canopy through the soil and aquifers to the bedrock below. It is the zone where rock, soil, water, air, and living organisms interact and where essential ecosystem services including clean water, carbon storage, and biodiversity support, are generated.

Critical Zone Observatories (CZOs) are long-term environmental monitoring hubs established to study these processes holistically. They provide **decade-scale datasets** that underpin climate resilience, water security, and ecosystem health. Internationally, CZOs form a global research network, with established sites across the United States, Europe, China, and other regions (Brantley *et al.*, 2017). In Australia, the Terrestrial Ecosystem Research Network (TERN) hosts complementary "Supersites" in tropical and temperate biomes. A Springbrook CZO would fill a critical gap by establishing the nation's first **subtropical montane CZO**, directly linking into this global scientific infrastructure.

Support from the current project partners (Department of Environment, Heritage and Resilience – City of Gold Coast, QUT, Seqwater, and the Queensland State Government) has enabled monitoring at Springbrook to continue until the end of the 2024/2025 financial year. Funding is now required for the 2025/2026 financial year and beyond to maintain the existing monitoring network and secure the continuity of this nationally significant dataset.

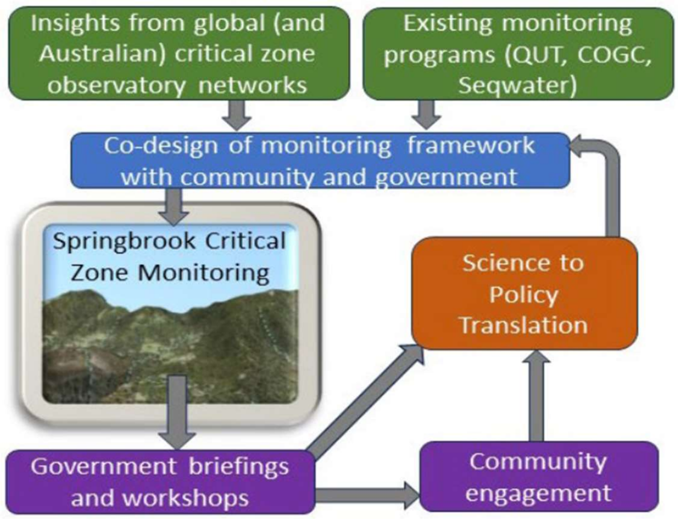

Figure 18 - Springbrook ARC Linkage project proposal overview

This project has five objectives:

1. To incorporate First Nations knowledge in targeting environmental monitoring and reporting.

2. To assess temporal and spatial trends in ecohydrology and determine the impacts of climate and anthropogenic activities on soil moisture, groundwater, and tree water uptake.

3. To assess the spatial and temporal trends in the hydrochemistry at Springbrook.

4. To combine environmental DNA (eDNA) with traditional aquatic ecosystem health monitoring to investigate the presence and distribution of indicator species – those that are threatened or are sensitive to ecosystem change.

5. To develop ecohydrological report cards and 3D visualisations for community education and science to policy translation.

Despite multiple strong proposals, applications to the **Australian Research Council (ARC) Linkage Program** (a competitive research funding scheme designed to support collaborative research projects, typically over 3-year cycles) were unsuccessful. The short-term funding model of the scheme is poorly matched to the **long-term objectives of a CZO**, which require decade-scale investment. Importantly, this outcome reflects limitations of the funding program, not of the proposal itself: the innovative monitoring design and interdisciplinary approach of the CZO concept have been consistently recognised by partners and reviewers.

Unlike the ARC Linkage scheme, which is structured around short-term research projects, the Critical Zone Observatory model requires **long-term, stable investment comparable to the funding that underpins the TERN Supersites**. These Supersites are nationally supported because of the enduring value of continuous datasets for science, policy, and ecosystem management. A Springbrook CZO would operate in the same way, providing essential baseline and trend data over decades rather than years.

The case for ongoing investment remains compelling. A Springbrook CZO would:

- **Safeguard Outstanding Universal Value (OUV):** Provide robust evidence to protect the Gondwana Rainforests World Heritage Area and its sensitive groundwater-dependent ecosystems.
- **Detect and define hydrological and ecological thresholds** under extended drought conditions, providing early warning of ecosystem stress.
- **Support State Party Reporting:** Provide long-term data on the conservation status of the Gondwana Rainforests World Heritage Area, directly assisting the Australian Government to meet its UNESCO State Party reporting obligations (UNESCO WHC, 2023).
- **Advance Climate Resilience Science:** Generate long-term ecohydrological datasets critical for understanding climate change impacts on headwater catchments, cloud forests, and biodiversity refugia.
- **Guide Policy and Planning:** Deliver a decision-support framework for government and water utilities, integrating hydrological, chemical, and biological indicators into adaptive management.
- **Strengthen Cultural and Community Partnerships:** Embed Kombumerri Traditional Owners, local community, and ecotourism stakeholders in monitoring, co-design, and governance.
- **Position the Gold Coast as a Leader:** Establish Australia's first subtropical montane CZO, building on international CZO networks and showcasing the region's leadership in science-based water and biodiversity management.

The CZO is not just a monitoring network — it is a **living observatory** that can deliver:

- Early warning of ecological change.
- Measurable evidence of ecosystem health.
- Practical tools such as ecohydrological report cards, eDNA biodiversity baselines, and 3D visualisations for communication with policymakers, Traditional Owners, and the community.

This initiative requires a **long-term funding partnership**, spanning local, state, and federal governments, utilities, and philanthropic or corporate contributors. Investment in the Springbrook CZO will secure world-class science, protect one of Australia's most important ecological and cultural landscapes, and provide a replicable model for other high-value ecosystems nationally and globally.

10. References

Albano Reis, J. (2024) *Conceptual Groundwater Model and Recharge Assessment for Water Management in Springbrook, QLD, Australia*. QUT Masters thesis.

Australian Government (2023–2024) *Reforming Australia's national environmental law: Response to the Samuel Review.* Department of Climate Change, Energy, the Environment and Water (overview resources). See also Parliamentary Library Research Paper (2023–24). DCCEEWAustralian Parliament House

Australian Museum (2024) 'The Eocene Epoch (56–33.9 Ma)'. Available at: https://australian.museum/learn/australia-over-time/evolving-landscape/the-eocene-epoch/ (accessed 3 September 2025).

Bellis, L. (2024) *Exploring Ecohydrology in a Subtropical Montane Forest using Multiple Techniques.* QUT PhD thesis.

Brantley, S.L., McDowell, W.H., Dietrich, W.E., White, T.S., Kumar, P., Anderson, S.P., Chorover, J., Gaillardet, J., Lin, H., Lohse, K.A. and Sullivan, P.L. (2017) 'Designing a network of Critical Zone Observatories to explore the living skin of the terrestrial Earth', *Earth Surface Dynamics*, 5(4), 841–860. https://doi.org/10.5194/esurf-5-841-2017. ESurf

Bruijnzeel, L.A. (2010) 'Hydrology of tropical montane cloud forests: a reassessment', in Bonell, M. and Bruijnzeel, L.A. (eds) *Forests, Water and People in the Humid Tropics*. Cambridge: Cambridge University Press, 462–484. https://doi.org/10.1017/CBO9780511535666.024. Cambridge University Press & Assessment

City of Gold Coast (2024) 'City of Gold Coast Flora & Fauna Database (as of Oct 2024)'. Available at: https://florafauna.goldcoast.qld.gov.au/ (accessed 3 September 2025).

Day, J.C., Weber, E., Doyle, T., Round, V., Heron, K., & Heron, S.F. (2025). Application of the Climate Vulnerability Index: Gondwana Rainforests of Australia (Queensland Section). *State of Queensland (Department of the Environment, Tourism, Science and Innovation) and Climate Vulnerability Index, Brisbane & Townsville, Australia*. ISBN 978-1-923389-10-6.

Department of Environment, Science and Innovation (DESI) (2024) 'Species profile search (Queensland)'. Available at: https://apps.des.qld.gov.au/species-search/ (accessed 3 September 2025). apps.des.qld.gov.au

DESI (2024a) 'Species profile: *Euastacus binzayedi*'. Queensland Government. Available at: https://apps.des.qld.gov.au/species-search/details/?id=36167 (accessed 3 September 2025). apps.des.qld.gov.au

DESI (2024b) 'Species profile: *Litoria pearsoniana* (Cascade Treefrog)'. Queensland Government. Available via species search (WildNet taxon ID 595): https://apps.des.qld.gov.au/species-search/ (accessed 3 September 2025). apps.des.qld.gov.au

DESI (2024c) 'Species profile: *Dasyurus maculatus* (Spotted-tailed Quoll)'. Queensland Government. Available via species search: https://apps.des.qld.gov.au/species-search/ (accessed 3 September 2025). apps.des.qld.gov.au

Ewart, A., Oversby, V.M. and Mateen, A. (1977) 'Petrology and isotope geochemistry of Tertiary lavas from the northern flank of the Tweed Volcano, southeastern Queensland', *Journal of Petrology*, 18(1), 73–113. https://doi.org/10.1093/petrology/18.1.73. Binna Burra Lodge

Gao, S., Reading, L., Lowry, J., Collecutt, G., Ryan, P. and Syme, B. (2024) 'Enhancing catchment runoff simulations using soil-moisture-dependent hydraulic conductivity', *Hydrology & Water Resources Symposium* (accepted paper). [Conference abstract; add DOI/link when available.]

Giambelluca, T.W. and Gerold, G. (2011) 'Hydrology and biogeochemistry of tropical montane cloud forests', in Levia, D., Carlyle-Moses, D. and Tanaka, T. (eds) *Forest Hydrology and Biogeochemistry*. Ecological Studies 216. Dordrecht: Springer. https://doi.org/10.1007/978-94-007-1363-5_11. WetlandInfo

Glanville, K., *et al*. (2023) 'Effects and significance of groundwater for vegetation: A systematic review', *Science of The Total Environment*, 875, 162577. https://doi.org/10.1016/j.scitotenv.2023.162577. IUCN Red List

Gleeson, T., VanderSteen, J., Sophocleous, M.A., *et al*. (2010) 'Groundwater sustainability strategies', *Nature Geoscience*, 3(6), 378–379. https://doi.org/10.1038/ngeo881. IUCN Portals

Hutley, L. B., Doley, D., Yates, D. J., & Boonsaner, A. (1997). Water balance of an Australian subtropical rainforest at altitude: The ecological and physiological significance of intercepted cloud and fog. *Australian Journal of Botany*, 45(2), 311–329. https://doi.org/10.1071/BT96014

IUCN (2024) 'Gondwana Rainforests of Australia – World Heritage Outlook'. International Union for Conservation of Nature. Available at: https://worldheritageoutlook.iucn.org/explore-sites/wdpaid/12202 (accessed 3 September 2025). Queensland Museum Collections

IUCN (2024a) 'Lamington National Park (Australia) – IUCN Green List'. Available at: https://iucngreenlist.org/sites/lamington-national-park-gold-coast/ (accessed 3 September 2025).

Kooyman, R., Rossetto, M., Sauquet, H., Laffan, S., (2013) 'Landscape Patterns in Rainforest Phylogenetic Signal: Isolated Islands of Refugia or Structured Continental Distributions?', *PLoS ONE*, 8(12): e80685. https://doi.org/10.1371/journal.pone.0080685.

Kooyman RM, Wilf P, Barreda VD, Carpenter RJ, Jordan GJ, Sniderman JM, Allen A, Brodribb TJ, Crayn D, Feild TS, Laffan SW, Lusk CH, Rossetto M, Weston PH. (2014) 'Paleo-Antarctic rainforest into the modern Old World tropics: the rich past and threatened future of the "southern wet forest survivors"'. Am J Bot. 2014 Dec;101(12):2121-35. doi: 10.3732/ajb.1400340. Epub 2014 Nov 21. PMID: 25480709.

Konikow, L.F. and Kendy, E. (2005) 'Groundwater depletion: A global problem', *Hydrogeology Journal*, 13(1), 317–320. https://doi.org/10.1007/s10040-004-0411-8. OzCamel

Narsey, S., Laidlaw, M., Colman, R., Pearce, K., Hopkins, M. and Dowdy, A. (2020) *Impact of climate change on cloud forests in the Gondwana Rainforests of Australia World Heritage Area*. Earth Systems and Climate Change Hub Report No. 20. NESP ESCC Hub.

Norman, J.A., Christidis, L. and Westerman, M. (1998) 'Molecular evidence for the phylogenetic relationships of lyrebirds (Passeriformes: Menuridae)', *Molecular Phylogenetics and Evolution*, 9(3), 333–342. https://doi.org/10.1006/mpev.1998.0496. UNESCO World Heritage Centre

NSW Government (2024) 'Saving our Species: *Menura alberti* (Albert's lyrebird) — conservation project'. Department of Climate Change, Energy, the Environment and Water (NSW). Available at: https://www.environment.nsw.gov.au/ (accessed 3 September 2025). [Use project PDF if preferred.] Environment and Heritage

Queensland Government (2024) 'Richmond birdwing butterfly (*Ornithoptera richmondia*) — program page'. Available at: https://www.qld.gov.au/environment/plants-animals/conservation/threatened-species/featured-projects/richmond-birdwing-butterfly (accessed 3 September 2025). Queensland Government

Sands, D.P.A. and New, T.R. (2002) *The Action Plan for Australian Butterflies.* Environment Australia, Canberra. (See also NLA catalogue and archived PDF.) National Library of Australia CatalogueLibrary DBCA

Seqwater (2025) 'Hinze'. Available at: https://www.seqwater.com.au/dams/hinze (accessed 3 September 2025). seqwater.com.au

Somerville, W. (2023) *Lithostratigraphy and Hydrostratigraphy of the Springbrook Plateau: Insights from New Core and Bore Logs*. QUT Honours thesis.

Stanley, J. and Reading, L. (2025). *Determination of Radon Source in Basaltic Aquifers, using Geochemical Tracers and Chemometric Statistical Analysis*; Heliyon (Accepted Journal Article)

TERN (2025) 'Robson Creek Rainforest SuperSite'. Terrestrial Ecosystem Research Network. Available at: https://www.tern.org.au/tern-ecosystem-processes/robson-creek-rainforest-supersite/ (accessed 3 September 2025). TERN Australia

Tourism and Events Queensland (2025) 'Tourism Data Explorer'. Available at: https://teq.queensland.com/industry/research-and-insights/tourism-data-explorer (accessed 3 September 2025). TEQ Corporate

UNESCO World Heritage Centre (2025) 'Gondwana Rainforests of Australia (Property ID 368)'. Available at: https://whc.unesco.org/en/list/368 (accessed 3 September 2025). Road Genius

UNESCO World Heritage Committee (2023) 'Decision 45 COM 7B.79 – Gondwana Rainforests of Australia', in *Decisions adopted during the 45th session*. Available at: https://whc.unesco.org (accessed 3 September 2025).

Wallace, I. and Samuel, G. (2020) *Independent Review of the EPBC Act – Final Report (the Samuel Review)*. Department of Agriculture, Water and the Environment, Canberra. See also Australian Parliamentary Library overview (2023–24). Australian Parliament House

Weber, L., Shoo, L.P., Rossetto, M., *et al.* (2013) 'Plant endemism in subtropical Australian rainforests: centres and patterns of diversity', *Biodiversity and Conservation*, 22(7), 1503–1519. https://doi.org/10.1007/s10531-013-0481-6.

Weber, L. (2024) *Altitude Ecology survey report: Syzygium nebulosum (Caldera Cloud Forest Lilly Pilly).* Altitude Ecology consultancy report. [Grey literature.]

Appendices

2021 – 2025 Springbrook Groundwater Investigation Bi-Annual Progress Reports

2024 Milestone Report

#A115720133 OBJECTIVE DOCUMENT LINK – SGI 2025 Compiled Appendices