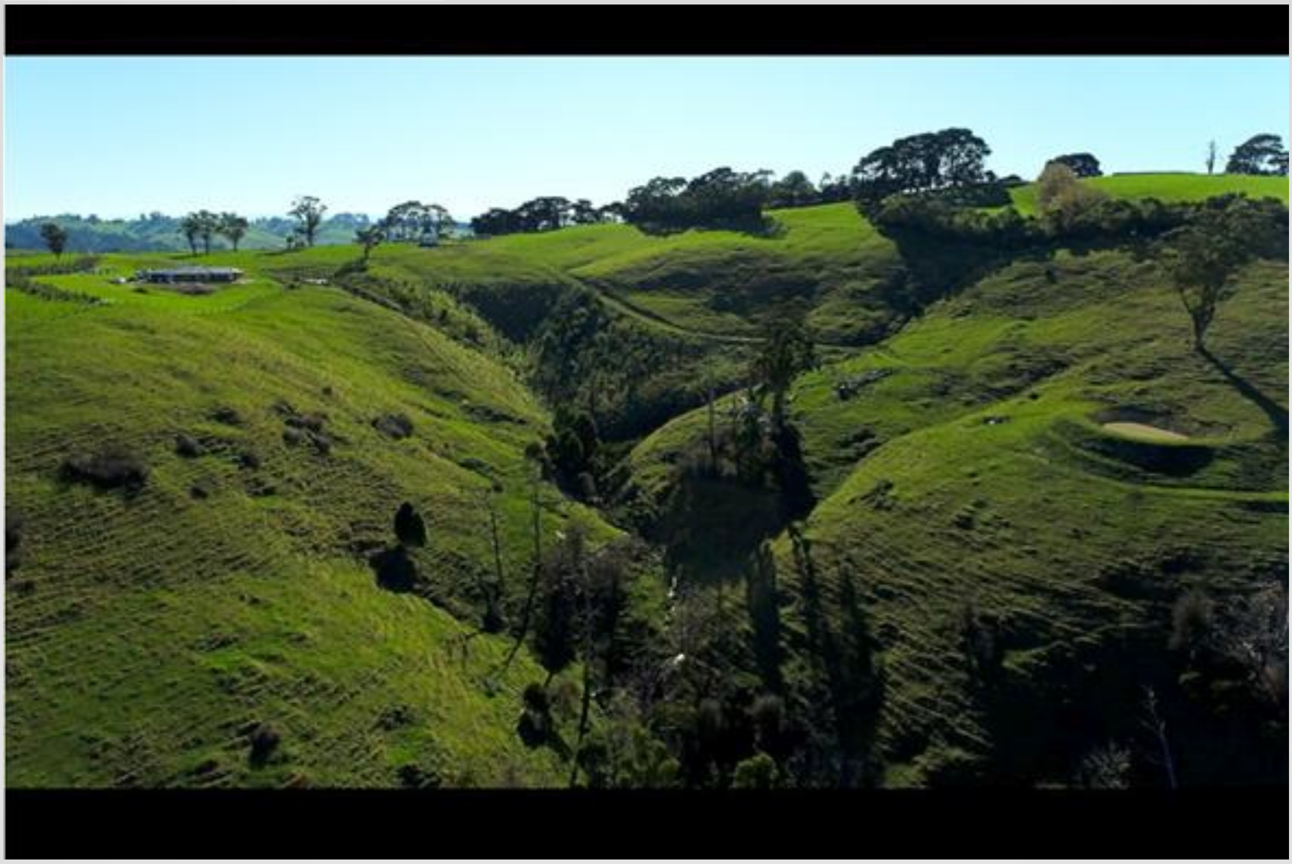

Final Report

Threat Mitigation and Soil Hydrology for the Giant Gippsland Earthworm-Soil Hydrology

Bass Coast Landcare Network

24 April 2026

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ACKNOWLEDGEMENT OF COUNTRY

The Board and employees of Water Technology acknowledge and respect the Aboriginal and Torres Strait Islander Peoples as the Traditional Custodians of Country throughout Australia. We specifically acknowledge the Traditional Custodians of the land the Bunurong Land Council Aboriginal Corporation (BLCAC) who were also involved in revegetation of the project site alongside Water Technology personnel.

We respect the knowledge, skills and lived experiences of Aboriginal and Torres Strait Islander Peoples, who we continue to learn from and collaborate with. We also extend our respect to all First Nations Peoples, their cultures and to their Elders, past and present.

Artwork by Maurice Goolagong 2023. This piece was commissioned by Water Technology and visualises the important connections we have to water, and the cultural significance of journeys taken by traditional custodians of our land to meeting places, where communities connect with each other around waterways.

The symbolism in the artwork includes:

- *Seven circles representing each of the States and Territories in Australia where we do our work*
- *Blue dots between each circle representing the waterways that connect us*
- *The animals that rely on healthy waterways for their home*
- *Black and white dots representing all the different communities that we visit in our work*
- *Hands that are for the people we help on our journey*

EXECUTIVE SUMMARY

The Giant Gippsland Earthworm (*Megascolides australis*) is one of Australia's mega fauna that have survived a decline in habitat since European settlement. The species is Listed as Vulnerable under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) and was selected as part of the Saving Native Species Program. Given that key threats include climate-driven reductions in soil moisture (e.g. reduced rainfall and increased temperatures), as well as activities that alter soil structure and hydrology (such as infrastructure development, planting, and agricultural grazing), there was a clear need to investigate soil parameters.

This project provides a unique 22 month pilot study monitoring soil habitat conditions within a Giant Gippsland Earthworm colony on a private property at Arawata, Gippsland, Victoria. The project compared conditions within a Giant Gippsland Earthworm colony within pasture grasses, adjacent locations outside the colony and a 2 year old revegetated site. Soil moisture and temperature to 80cm depth were recorded with a soil oxygen probe placed at 30cm depth for the majority of probes.

We found the monitoring to be a success with a good suite of results that could be used in analysis. Generally, soil moisture is relatively stable at depths of 80cm whilst fluctuates dramatically closer to the surface with a drying out in hot dry summers when there is infrequent sustained rainfall. Over the monitoring period, the site and nearby surrounds recorded lower than average summer rainfalls, resulting in effectively drought conditions. This resulted in lower soil moisture at shallow (10cm), mid (40cm) and deeper (80cm) soils and in turn resulted a dramatic drop in the number of "gurgles" (the movement of Giant Gippsland Earthworm within moisture filled burrows). This does not mean the species was not present but does indicate movement deeper into the clay-based soil to locate moist conditions. As rainfall increased through the project and soil moisture recharged at depth there was an increase in the number of gurgles with an increase in soil moisture suggesting the optimal soil moisture content is 60-80% for activity "gurgles" to be heard, particularly at depths of 80-40cm.

A comparison of soil moisture between the revegetated probe and pasture grasses sites within the main colony showed a lower percentage moisture at 80cm depth within the revegetated site in summer hot/dry conditions. In addition, the following year of results the soil moisture levels did not appear to recover to the 60-70% at depths of 80cm. This provides some early evidence that the uptake of sapling trees and shrubs through plant transpiration is making the soil dryer compared to sites containing mainly pasture grasses and other graminoids.

Soil temperature fluctuated most near the soil surface (10cm) and closer to the ambient temperatures. At depth (80cm), there was little seasonal fluctuation as the surface soil and pasture grass act as a buffer. Soil temperature is likely to be important for reproduction success in Giant Gippsland Earthworms and given that an egg cocoon was located close the surface (top 5-10cm) mid-way through the project it is likely the conditions were suitable.

The information will provide insight into optimal soil moisture conditions for Giant Gippsland Earthworm colonies and shows fluctuations closer to the surface are observed in both temperature changes and after precipitation. Given that two drought periods occurred within the monitoring period and dramatic declines in soil moisture occurred there is even further evidence that Giant Gippsland Earthworm are susceptible to climate change events of drying, and would be also at risk of excessive rainfall in some areas, particularly if this occurred adjacent to colonies on the streambank. In addition, changes to soil hydrology as a result of earthmoving, water diversion through dams and retarding basins, road works and improper planting of native and exotic tree species pose further risk to this species highlighting the need for threatened species searches for GGE prior to earthworks, appropriate planning mechanisms and conservation of this species.

ACKNOWLEDGEMENTS

Project Partners:

Gippsland Threatened Species Action Group, South Gippsland Landcare Network, Bass Coast Landcare Network, Invert-Eco Terrestrial Invertebrate Consulting, Oates Environmental Consulting, Drift Media, and Water Technology.

Project Funding:

This project received grant funding from the Australian Government Saving Native Species Program', aimed to advance the conservation of the Giant Gippsland Earthworm (*Megascolides australis*) (GGE).

Acknowledgements:

This project would never have occurred without the initial discussion between Bertrand Salmi and GGE expert Beverley Van Praagh who identified a real gap in the relation between GGE presence and the soil hydrology conditions where the species is located. During the installation of the equipment, we had assistance from Fern Aberton on a work experience visit from the UK, the project team and local land manager Dave Crowley who transported equipment and supplies to the site as well as providing a practical solution for setting up the equipment. We are grateful to the landholder Paul Hardy-Smith, who both provided a site for our project and was in every way hospitable and appreciative of the changing nature of the project and equipment. Paul's enthusiasm for conservation, his willingness to participate and the balance of farming needs was of particular importance to the site's success. Other Water Tech personnel Gayani Chandrasena and Adam Buller for analysis and particularly Claire Morgan, Dominique Roche, Elsa Burnell and Bertrand Salmi who all provided analytical support and/or on-ground participation in community days, data collection/analysis and tree-planting activities. Spatial outputs were thanks initially to Emmanuel Bina, Mandy Low and then Kevin Chang and Ruby Carr in the latter stages. Bass Valley Landcare Network members Dave and Marian Crowley also provided a local base and of course, the collaboration with David Sutton, Michael Green, Cassie Wright, Amaryll Perlesz, Allison Oates, David Bateman, Joel Geoghegan (for making this happen) and particularly GGE expert Beverley Van Praagh and her team at Invert-Eco. ICT Environmental assisted with setup of the monitoring and support during the monitoring period. No GGE were harmed during this project.

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1 INTRODUCTION

1.1 The Project

This project under the Saving Native Species (Priority Species) program aimed to advance the knowledge in soil hydrology to aid the conservation of the Giant Gippsland Earthworm (*Megascolides australis*) (herein referred as GGE). It was progressed in partnership with Gippsland Threatened Species Action Group, South Gippsland Landcare Network, Bass Coast Landcare Network, Invert-Eco Terrestrial Invertebrate Consulting, Oates Environmental Consulting, Drift Media and Water Technology. The project was initiated in response to a recognised gap regarding the soil conditions that support this species within its core habitat, and the factors may be threatening the conditions beneath the ground. This part of the project concentrates more on the soil hydrology and should be read in conjunction with Van Praagh (2026) and Oates (2026).

1.2 Background

The Giant Gippsland Earthworm (GGE) is a species recognised as under serious threat from habitat decline within the Gippsland area of Victoria. It requires specific habitat conditions including blue clays, south (and west) facing slopes often on land that has terracettes or is on a higher part of a streambank (Van Praagh *et al.* 2007). The GGE has been subject to serious decline in its habitat, including as a result of changes in soil hydrology brought about by urban development, farm management, changes to waterways and changing global weather patterns resulting from climate change.

The GGE has been identified by the Federal Government as a top priority threatened species in its Saving Native Species (Priority Species) program. It has been recognised that more research is required to enhance opportunities for protection and conservation of the GGE.

Water Technology, in collaboration with project partners, developed a soil monitoring pilot study to better understand the conditions supporting the species over almost a two year monitoring period including adjacent locations where they do not occur.

1.3 Scope

The scope of the project was to monitor the soil moisture conditions of a known habitat location and an adjacent non-habitat within the GGE species distribution within Gippsland, Victoria for a 22 month period (May 2024-October 2025, which was extended to March 2026). The project provided an insight into the soil hydrology to better understand the species' sensitivity to soil moisture, temperature, and oxygen whilst concurrent projects were running (Van Praagh 2026 and Oates 2026). These projects were looking to protect GGE colonies across priority properties through detailed mapping, landholder engagement, and targeted conservation works including fencing, weed control, and revegetation.

1.4 Aims

The aims of the pilot study project were to monitor soil moisture, temperature, and oxygen levels over a 22 month period at multiple key GGE sites. This involved:

- Site selection within a suitable property (identified by Bass Coast Landcare Network, in collaboration with the project partners);
- Development of a soil probe monitoring network, for assessment of parameters to a depth of 0.8m, for known GGE habitat site with an active colony and non-earthworm activity (outside habitat and colony);
- Monitoring soil parameters of soil moisture and temperature (depth at 10cm intervals to 80cm), soil oxygen to 30cm depth;

- Determination of weather conditions, using local weather stations and soil parameters over the monitoring period;
- Comparison of data between GGE habitat within the colony and adjacent non-GGE habitat outside the colony; and
- Analyse the success of probes and determine opportunities for improvements with the equipment.

An ancillary objective was to share project findings through a public field day, educational video production, and the expansion of resources on www.giantearthworm.org.au, including use of the interactive GGE habitat tool developed in a previous project.

- During the project an additional probe to measure soil moisture and temperature was placed in adjacent fenced land that the landholder had recently revegetated to compare data in that site compared to the remainder of the probes linking the concurrent projects (Van Praagh 2026 and Oates 2026).

2 METHODS

2.1 Site Selection

Site selection for this pilot study was carried out in close consultation with GGE expert Dr. Beverley Van Praagh (Invert-Eco) and the project partners. A single property containing multiple GGE colonies was selected, with the aim of capturing a representative range of habitat conditions required by the species. While the colonies reflected known habitat preferences, it was recognised that variability existed between them. The condition of the areas just outside the mapped colony boundary was also monitored to enable comparison of conditions between known habitat and an area where GGE did not occur.

The site contained areas of steep gullies adjacent to an unnamed creek, all of which are prone to erosion. Cattle were grazing the pasture grasses above GGE colonies prior to installation.

Ecological information previously gathered by Dr. Van Praagh and Gippsland Threatened Species Action Group (GTSAG) played a key role in guiding the selection process.

Key factors that informed site selection included:

- Existing and available ecological data – availability of historical monitoring and colony data.
  - “Gurgles” from the movement of the GGE through moist tunnels was recorded prior to the placement of monitoring probes.
- Soil characteristics – Soil type was manually assessed to confirm suitability.
  - As the species is located in grey and red clay soils it was important that these formed part of the site selection process. Generally the soils are described as deep wet, clay-rich soil on south or southeast-facing slopes of the bank of lower drainage lines, composed mainly of pasture vegetation; and
  - A small exploratory dig by Invert-Eco experts was also made at the site of each probe to ensure that the worms had a chance to leave the direct impact area where the auger was used for probe placement, and also to determine the presence of tunnels.
- Monitoring potential – the site allowed for the installation of environmental probes within and between colonies across a habitat gradient;
- Site accessibility and longevity – the property could be accessed safely and consistently for maintenance and monitoring purposes.
  - In addition the landholder was prepared to provide preventative fencing to exclude cattle;
- Land tenure and management – the landholder granted consent for access, and the site offered potential for long-term protection as he fenced off the probes from cattle.
- Habitat diversity – the site featured a range of microhabitat conditions, including:
  - Blue-grey clay soils in the creek bank
  - Terraced creek banks and soaks
  - South-facing slopes
- Habitat Assessment was performed by Invert-Eco during May and July 2024. Standardised GGE survey techniques were used, including listening for gurgles, digging small quadrats to identify burrows.
  - Most active colonies were found on steep, east to south-east facing slopes or lower benches adjacent to drainage lines in clay-dominated pasture systems. Detailed methods to Giant Gippsland Earthworm Gurgle monitoring are described in Van Praagh (2026) A baseline assessment was undertaken in May 2024 with following assessments involving transects at two colony sites during May and October

2025. Concluding assessments were undertaken during summer of 2026 (January, February and early March 2026).

The chosen site was one where substantial background data on the colonies was already available with numerous “gurgles” recorded. These gurgles are an indication of the presence of the species where standardised GGE survey techniques were used, including listening for gurgles and digging small quadrats to identify burrows. A concurrent project was also carried out on three other priority properties to map GGE colonies (Van Praagh 2026).

The selected property is shown in Figure 2.1 **Error! Reference source not found.**, highlighting the features that aligned with the site selection criteria described above. An aerial image of the site is provided in Figure 2.2, showing known GGE locations across the site, accompanied by photos of the landscape for those areas as well as the specific sites that were selected for monitoring (green polygons). The No Worm Zone is also shown, outside the habitat where no GGE gurgles occurred. The location of probes can be observed in Figure 2.4.

- Land Management Facilitation

The landholder was available and willing to assist and provided rapid fencing to prevent the probes from being interfered with by livestock by installing a fenceline around the two sites. In addition, the landholder assisted by checking on the equipment and/or facilitating the teams access. The landholder also carried out spot weed control practices as part of his maintenance of the property. Large Hawthorn *Crataegus monogyna* plants were treated with weed control by trunk injection but it was requested they not all be removed during the course of the pilot study to ensure sudden changes to shading and soil disturbance were minimised. GGE habitat was fenced off on private land in order to mitigate risks from grazing (pugging, damage to top soil) and disturbance to probes from weight above in addition to data loggers and solar panels which cattle would most likely damage. We also observed weed species including Ragwort (*Senecio jacobaea*), which was actively spot-sprayed by the landholder.

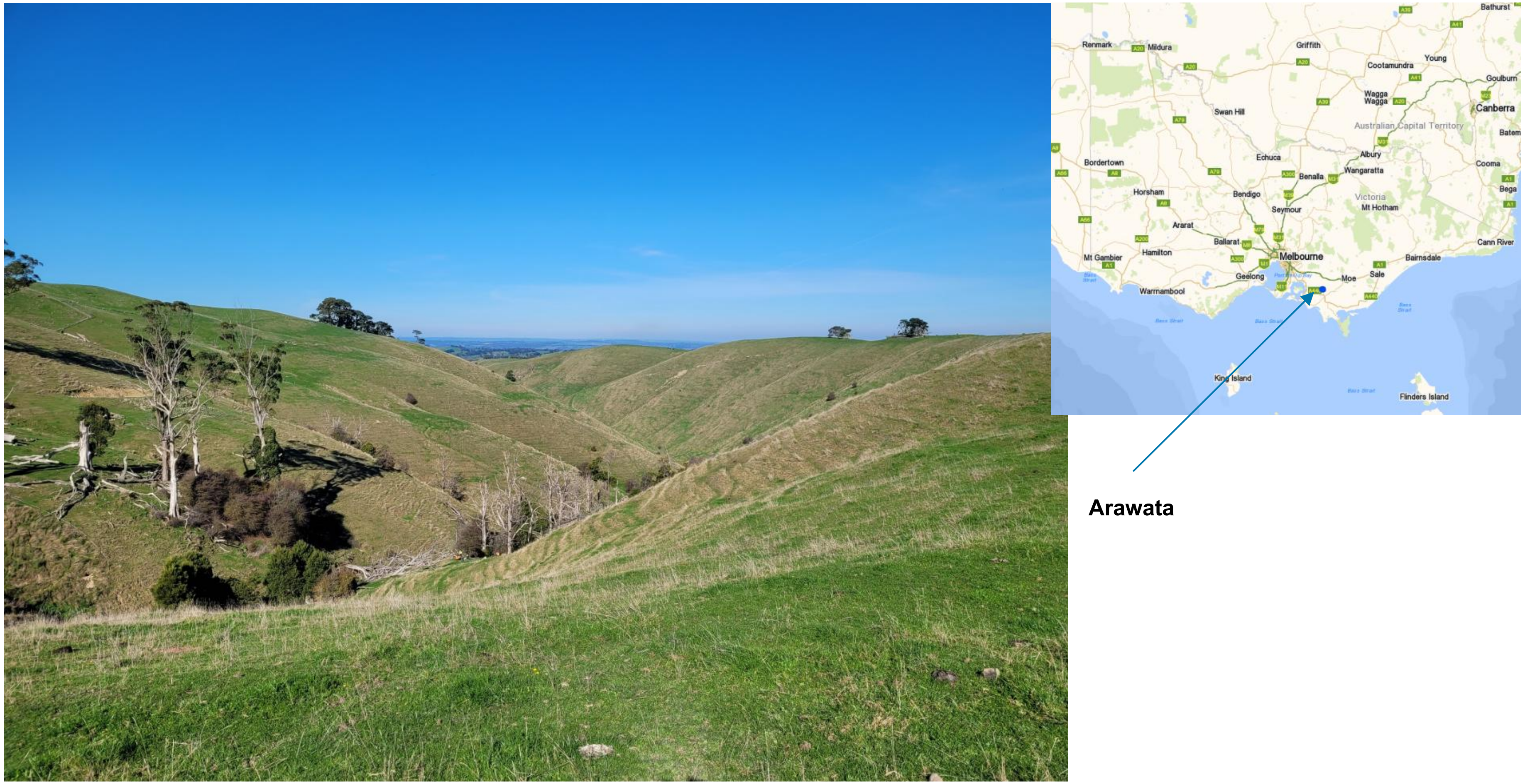

Figure 2.1 Property used for GGE soil hydrology monitoring Arawata, Victoria. Site location insert.

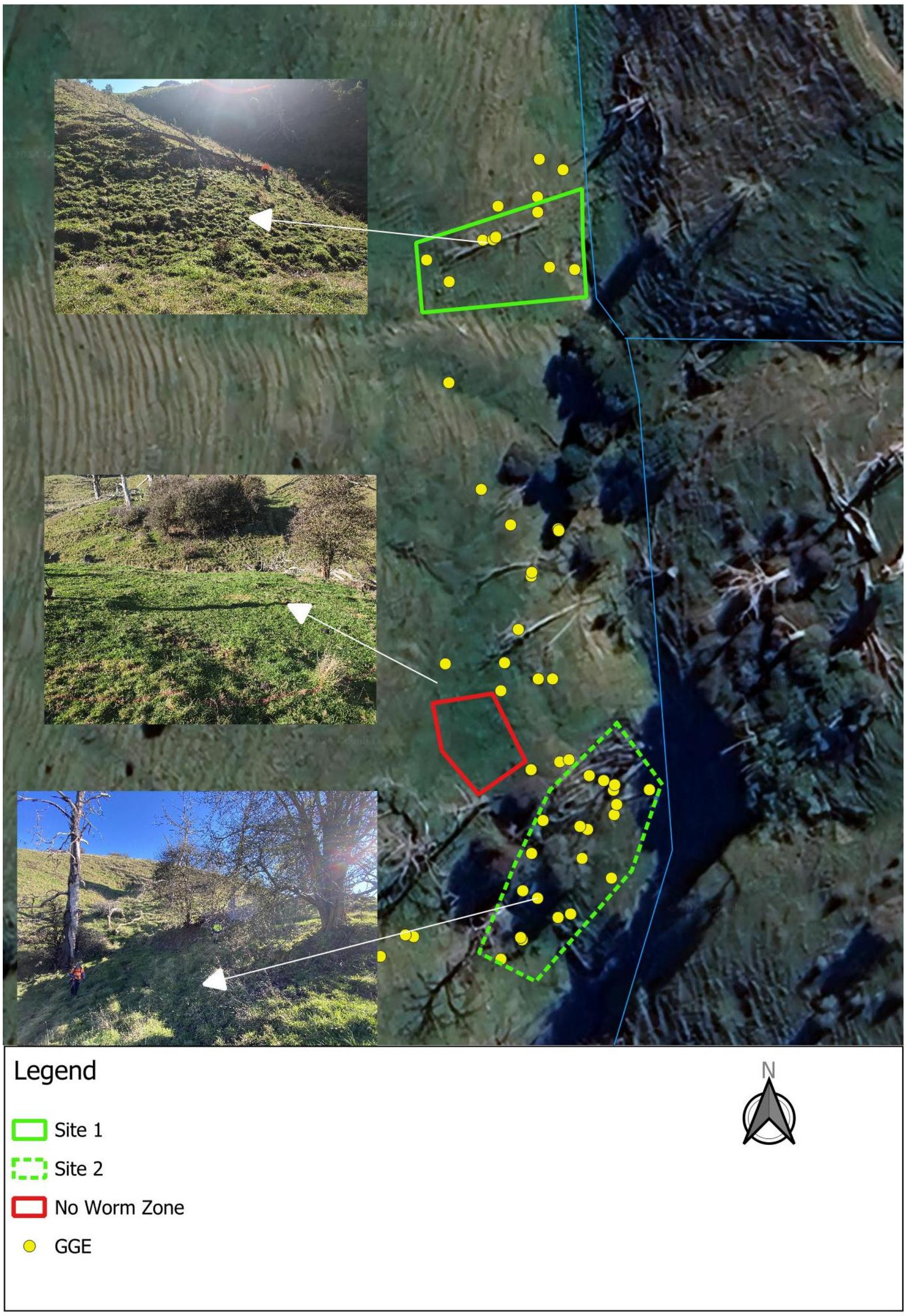

Figure 2.2 Aerial imagery and photos of site selection (Source: Van Praagh)

2.2 Site Condition Monitoring

Site condition monitoring was conducted through the installation of long-term, low-impact soil probes to assess soil parameters within and outside of the selected GGE colony. Seven probes were installed on May 29-30th 2024, while an eighth probe was installed by GTSAG personnel in July 2024, and they have been recording data through to March 2026.

The monitoring setup included two types of probes installed at each site:

- Soil probes measured moisture content and temperature at 10 cm intervals from 10 cm to 80 cm depth.
- Oxygen sensors measured soil oxygen concentration at 30 cm below the surface.

Measurements were taken every 15 minutes and transmitted to Eratos* database, where it was automatically graphed and made accessible to the project team. Support was provided by ICT International, who supplied the monitoring equipment and managed data storage.

2.2.1 Installation

Each probe was installed using an auger kit supplied with mechanism and set up with a 20W solar panel, data logger, SD card, and antenna for wireless data transmission using Optus signal (Figure 2.3). Solar panel, data logger and antenna were attached to a metal pole and sat approximately ~1.5m-1.8 above the ground level. These were installed using a steel post hole driver and were pushed ~0.5-0.8m beneath the ground surface (refer Figure 2.3).

The installation involved the following technique:

Above ground monitoring and data logging mechanism

- Stainless steel poles (80mm diameter) were cut to 2.5m lengths with a grinded entry point to assist with ground penetration;
- Poles were driven with hand-held post driver to 0.7m below ground and leaving 1.8m above ground. A level was used to have the poles at 90° to ground;
- Solar panel attached with screws and plate to the pole, above top of pole height hole;
- Data logger attached to pole and antenna screwed below data logger;
- Once all attached, data logger switched on (as per instructions);
- Wi-Fi connection checked using Eratos and conforming to support provided by ICT International; and
- All cables were tied together and later covered with plastic pipe to provide some protection from weather and/or damage from animals.

Soil Moisture/temperature Probe

- Exploratory dig to determine presence of GGE holes within soil and encourage movement away from the immediate location with digging noise.
- Dig to shovel depth (30cm) to assist with installation of oxygen probe.
- Auger to a depth of 80cm, careful to set aside augured clay for backfill
- Placement of probe to a depth of 80cm with light covering of clay over top
- Gently press in clay to backfill to eliminate gaps

Oxygen probe

- Dig to shovel depth (30cm) to assist with installation of oxygen probe (this was part of the original exploratory dig. (Appendix A Figure A-9)
- Backfill clay back into hole ensuring no air pockets around the probe
- To prevent disturbance to probes and or solar panels from livestock, fencing was installed around the monitoring area by the landholder to eliminate their access. Ongoing maintenance and data oversight

were supported by GTSAG to help manage operational costs and issues. A map of all the probe locations is shown in Figure 2.4.

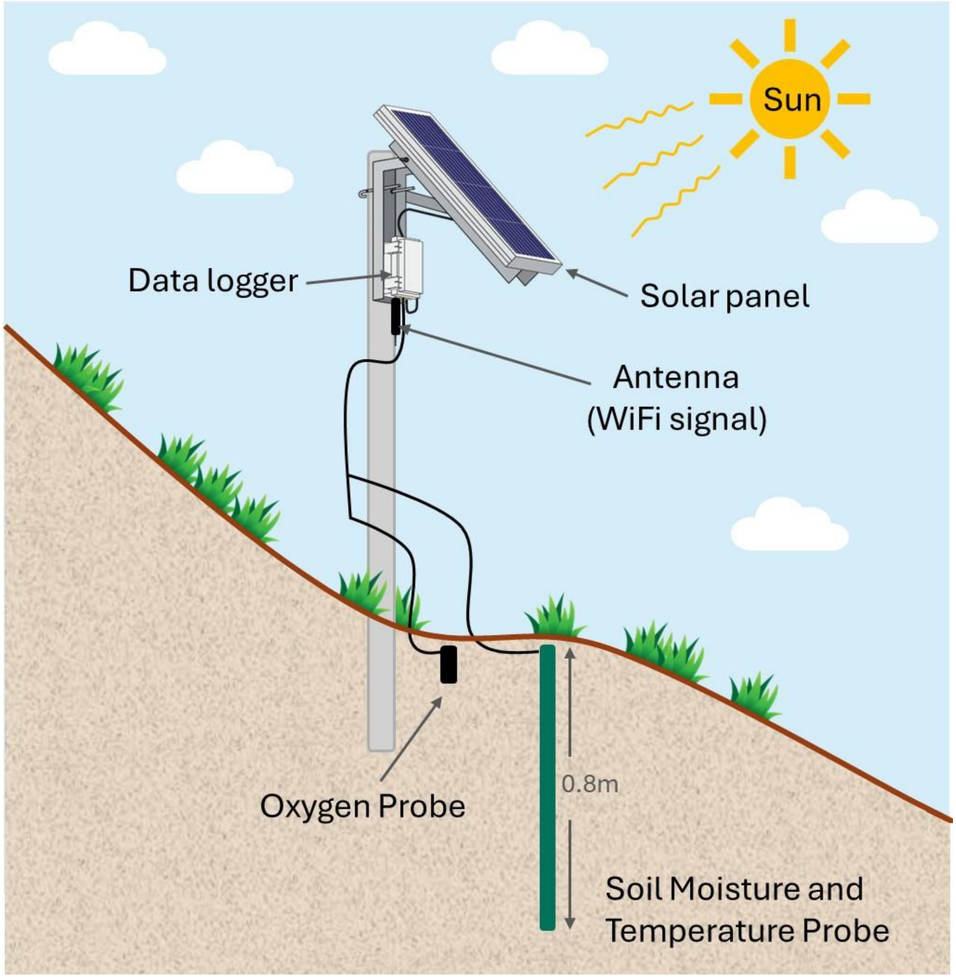

Figure 2.3 Diagram of probe set up, including all components

In addition to in-ground measurement, daily and monthly rainfall data were taken from SILO data collected using SILO, which uses multiple local BOM data sets and then interpolated the results for that lat/long position in Arawata. This provided context for interpreting soil moisture trends over time.

Eight probes were established, as shown in Figure 2.4.

2.2.2 Probe installation description:

- Site 1 – Probe 1: within GGE colony

  This probe was located on a moderately steep, south-east facing slope 1m from the creek on a higher part of the bank. The vegetation consisted of a cover of pasture grasses, with no overhanging vegetation. Native species consisted of Tender Brake (*Pteris tremula*) and Hairy Pennywort (*Hydrocotyle hirta*). Blue-grey clay based soils were dominant and worm burrows were observed during an exploratory dig. Refer to Appendix Figure A-1 for photograph.

- Site 1 – Probe 2: within GGE colony

  This probe was located on a steep, south-east facing slope 5m from the creek on a moist partially terraced slope below a fallen tree. The vegetation consisted of a grassy cover of pasture grasses, with no overhanging vegetation. Blue-grey clay based soils with worm burrows were observed during an exploratory dig and gurgling of GGE movement through burrows beneath were heard during installation. Refer to Appendix A Figure A-2 for photograph.

- Site 1 – Probe 3: within GGE colony

  This probe was located on a steep, south-east facing slope approximately 12m upslope from the creek on a moist, terraced slope above a fallen tree. The vegetation consisted of a grassy cover of pasture grasses and moist exotic herbaceous species, with no overhanging vegetation. Blue- grey clay based soils with worm burrows were observed during an exploratory dig and gurgling of GGE movement through burrows beneath were heard during installation. Refer to Appendix A Figure A-3 for photograph.

- Site 2 – Probe 4, located above a colony, outside known GGE zone.

  This probe was located above a steep, terracette slope on flat ground assumed to be previously compacted and receiving full sun exposure. The vegetation consisted of pasture grasses, with overhanging Hawthorn which was poisoned. Soils were a brown loam with little clay content and without worm burrows observed during an exploratory dig. This and a lack of gurgling indicated a lack of use and a No-worm Zone was determined. Refer to Appendix A Figure A-4 for photograph.

  Probe 4 was installed between active colonies to monitor conditions in potential transition zones and assess whether environmental limitations may be preventing movement between colonies.

- Site 2 – Probe 5: within GGE colony

  This probe was located on a steep, south-facing teracetted slope on a moist surface with a combination of pasture grasses and rush species. Overhanging vegetation consisted of Hawthorn, which was poisoned by the landholder, but retained to ensure some shade effect would occur in summer. Blue-Grey clay based soils with worm burrows were observed during an exploratory dig and gurgling of GGE movement through burrows beneath were heard during installation. Refer to Appendix A Figure A-5 for photograph. This site was at a lower elevation to the other colony probes 1-3. Evidence of cattle slips and minor pugging was observed. The landholder agreed to fencing off the site to exclude cattle and any damage.

- Site 2 – Probe 6: within GGE colony

  This probe was located on a steep, south-facing teracetted slope on a moist surface with a combination of pasture grasses and rush species. No overhanging vegetation was present but shade was cast from Hawthorne nearby. Grey-blue clay-based soils with worm burrows were observed during an exploratory dig and gurgling of GGE movement through burrows beneath were heard during installation. Refer to Appendix A Figure A-6 for photograph. This site was at a lower elevation to the other colony probes 1-3. Evidence of cattle slips and minor pugging was observed.

- Site 2 – Probe 7, located downslope, below a colony:
  - This probe was located on a gentle slope beneath the GGE colony, somewhat in the area of a drain coming from the western hillside. Vegetation consisted of pasture grasses and a healthy population of rush species. Blue-grey clay based soils without worm burrows were observed during an exploratory dig and gurgling of GGE was not heard. Some evidence of sub-surface water was observed. Refer to Appendix A Figure A-7 for photograph.

- Site 1b revegetation area – Probe 8:

  This probe was installed after the others and located in an area that was planted with indigenous trees and shrubs 2 years prior by the landholder (revegetated area). Trees were between 1-2m tall and consisted of Messmate (*Eucalyptus obliqua*), Blue Gum (*Eucalyptus globulus*) and Strzelecki Gum (*Eucalyptus strzeleckii*). Shrubs 0.5-2m formed the lower layer planting including Musk Daisy-bush *(Olearia argophylla*), Prickly Moses (*Acacia verticillata*), Hemp Bush (*Gynatrix pulchella*) and Common Cassinia (*Cassinia aculeata*). This probe was about the same distance from the creek as Probe 2, some 10m north.

  Installed (July 2024) 3 months after initial set up of probes 1-7

2.2.3 Site Management and Monitoring

The landholder provided fencing construction and weed control of Ragwort and Hawthorn trees. Van Praagh (2026) monitored GGE gurgles during the project to compare data to the soil parameters on multiple occasions while Oates (2026) assessed the vegetation of the site in detail.

The GGE monitoring methodology and results are detailed in attached report *GGE Habitat Assessments Veg Monitoring and Landcare Actions Report* (Van Praagh, 2026). Specific monitoring events included:

- Initial baseline site selection: May 2024, numerous GGE located to determine site selection
- Monitoring 1: 15 May 2025 (Autumn)
- Monitoring 2: 16 October 2025 (Spring), followed by incidental surveys 19th November 2025
- Monitoring 3: 15 January 2026
- Monitoring 4: 23 February 2026
- Monitoring 5: 4 March 2026

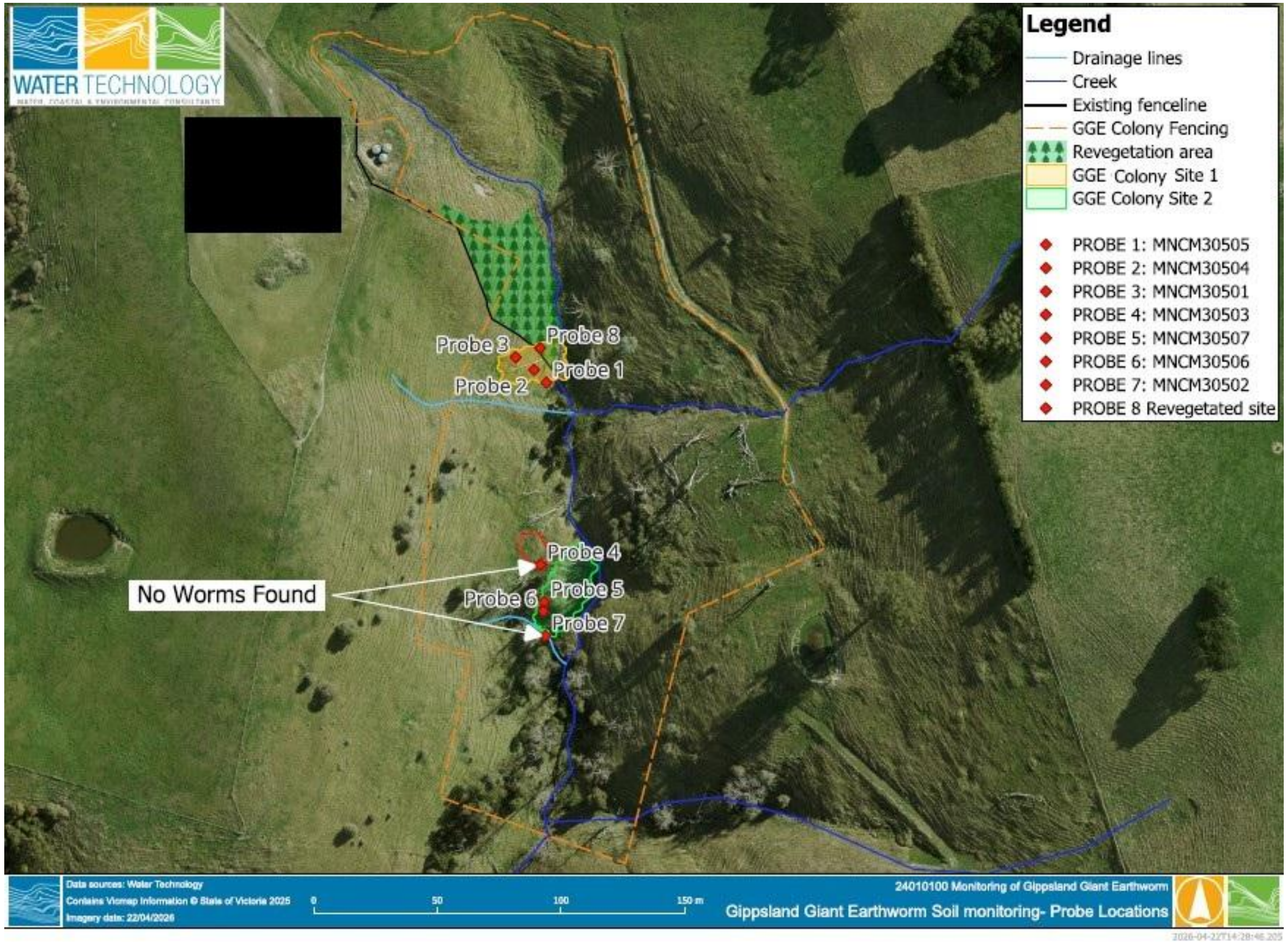

Figure 2.4 Aerial map of probe locations and site

2.3 Community Consultation and Engagement

Community and stakeholder engagement formed an important part of the project. As outlined in the proposal, a series of presentations and meetings were planned to share findings and promote the conservation of the GGE. Throughout the trial, efforts were made to ensure findings were shared with those invested in the conservation of the GGE, and to build broader understanding of the species and its habitat requirements.

A dedicated GGE stakeholder workshop was held on 23 June 2025, followed by a site walkover on 24 June 2025 with representatives from the Federal Government's Saving Native Species (Priority Species) program. These events focused on the monitoring program and showcased preliminary data from the installed probes, supporting a deeper understanding of GGE habitat needs and the technical considerations of long-term monitoring.

Live data feeds from the soil monitoring network were made available through the ERATOS* platform, with access provided to key stakeholders including the South Gippsland Landcare Network, Bass Coast Landcare Network and GTSAG. These live feeds offered ongoing insights into soil moisture conditions in known and potential GGE habitats. In addition, SD cards inside the probe device were accessed until November 2025 when Eratos became insolvent.

To further engage the local community, a planting day was organised in collaboration with the South Gippsland Landcare Network, GTSAG, and Water Technology. Community members participated in revegetation activities. The event supported habitat enhancement and encouraged local involvement in the conservation initiative including Bunurong Land Council Aboriginal Corporations Balirt Biik (Strong Country) Eastern Team.

3 RESULTS

This section presents the findings from the pilot study conducted between May 2024 and March 2026, examining soil conditions within and around GGE colonies. The monitoring program achieved varying levels of success, as outlined in the results that follow. This section focuses on the data that were successfully recorded, while issues related to device performance and data gaps are addressed separately in Section 4 and 5.

The following table provides an overview of the performance of the monitoring devices used throughout the pilot study. It summarises the operational success of each probe or monitoring mechanism and highlights the consistency and reliability of data collection across the project period (Table 3-1).

The hydrological results varied between probes and in general clay-based substrates within GGE colonies were able to be broadly consolidated with the use of several probes. As eight depths were utilised, we looked at general depths of shallow (10cm), mid (40cm) and deep (80cm) to ensure a more digestible comparison.

Table 3-1 Probe records and comments

Probe	Number of days installed at site	Percentage of days **without recorded data**	Percentage of days **with faulty recorded data** ("0" or "not a number")	Percentage of days recorded with usable data
1	664	24.3%	0.1%	75.6%
2	323	50.1%	0.0%	49.9%
3	664	1.0%	71.0%	28.0%
4	664	1.1%	0.1%	98.8%
5	664	21.4%	0.1%	78.5%
6	664	1.1%	0.1%	98.8%
7	664	1.1%	0.1%	98.8%
8	622	49.9%	2.8%	47.3%

3.1 Rainfall Data During the Project Duration

The monthly rainfall over the duration of the project was compared to mean monthly rainfall from BOM for the area using SILO data (creates an average of all close weather stations). Figure 3.1 shows fluctuations from the normal that occurred throughout the project using SILO data (average of local weather stations nearest the site at Arawata).

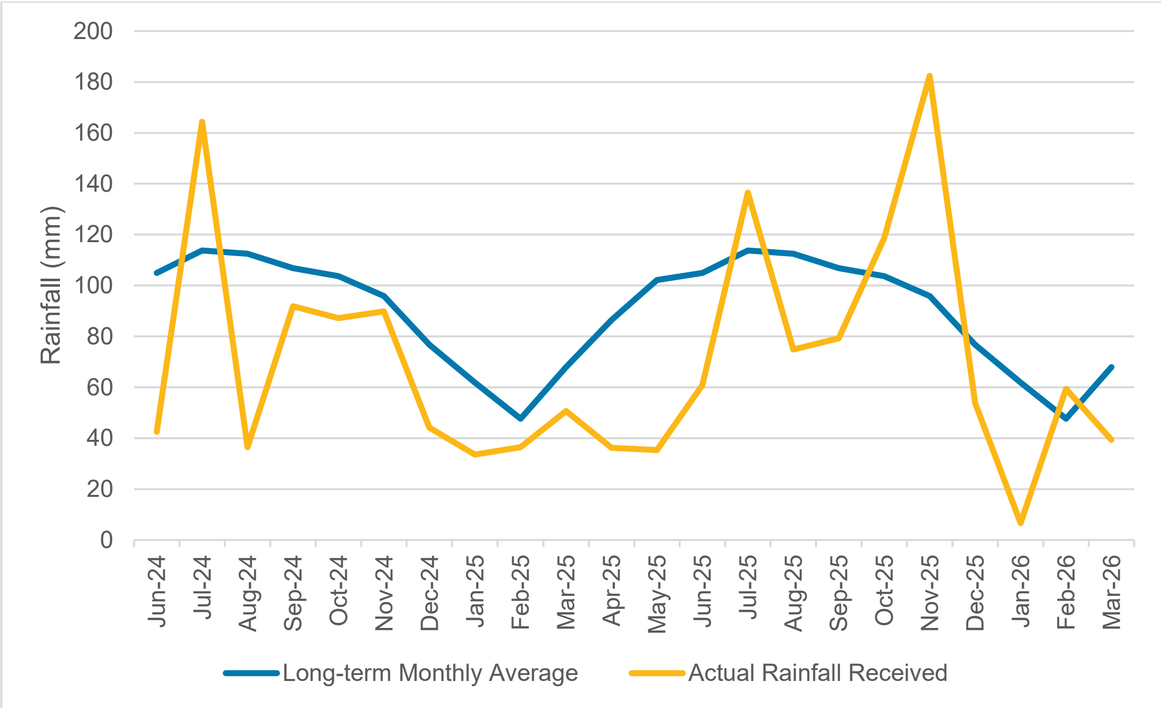

Figure 3.1 Graph comparing the average rainfall vs the actual monthly rainfall between May 2024 and to mid-March 2026

Overall, rainfall during the study period (June 2024 – mid March 2026) deviated substantially from the long-term average pattern for the area. While the region typically receives relatively evenly distributed rainfall throughout the year (approximately 60–95 mm per month, with the most in spring), observed rainfall during the monitoring period was characterised by pronounced variability from the average between months. Extended periods of below-average rainfall for six months (December 2024-June 2025) were interspersed with isolated high-intensity rainfall months (e.g., July 2024, July 2025, and October–November 2025). In January 2026 much lower than average rainfall occurred exacerbating the dry conditions shortly after higher than normal rainfall events. This rainfall fluctuation provides important context for interpreting the observed soil moisture and soil temperature dynamics.

3.2 Soil Moisture Monitoring

The original graphs contain eight monitoring points, which made them visually complex. To improve readability and allow meaningful comparison, three representative depths were selected for all figures: shallow (10 cm), mid-depth (40 cm), and deep (80 cm) (example shown in Figure 3.2).

During periods of dry or drought conditions, soil-moisture levels were consistently lower across all monitoring locations. Correspondingly, little to no GGE activity (gurgles) was detected during these drought periods, aligning with the reduced soil moisture (refer Section 3.5).

3.2.1 Annual Trends

Figure 3.2 shows a graph of the annual trend and consistency between seasons at the same time each year vs the daily rainfall. Probe 6 site 2 within the colony had the most consistent and long-lasting data without failure so was used for illustration in this report. It was used to demonstrate the trends throughout the duration of the project from 30 May 2024, until 18th March 2026, almost 22 months.

The data shows:

- Strong episodic spikes following rainfall events.
- Surface soil moisture at 10 cm responds immediately after rainfall events. The soil moisture data shows:
  - High variability
  - Sharp increases after rainfall
  - Rapid decline during dry periods
- Soil moisture at 40 cm responds more slowly. Soil moisture data shows:
  - Moderate variability
  - Delayed recharge
  - Slower drying
- Soil moisture at 80 cm shows delayed and reduced response. Soil moisture data shows:
  - Most stability
  - Slow recharge
  - Slow decline
  - Longer-term water balance rather than event-driven changes

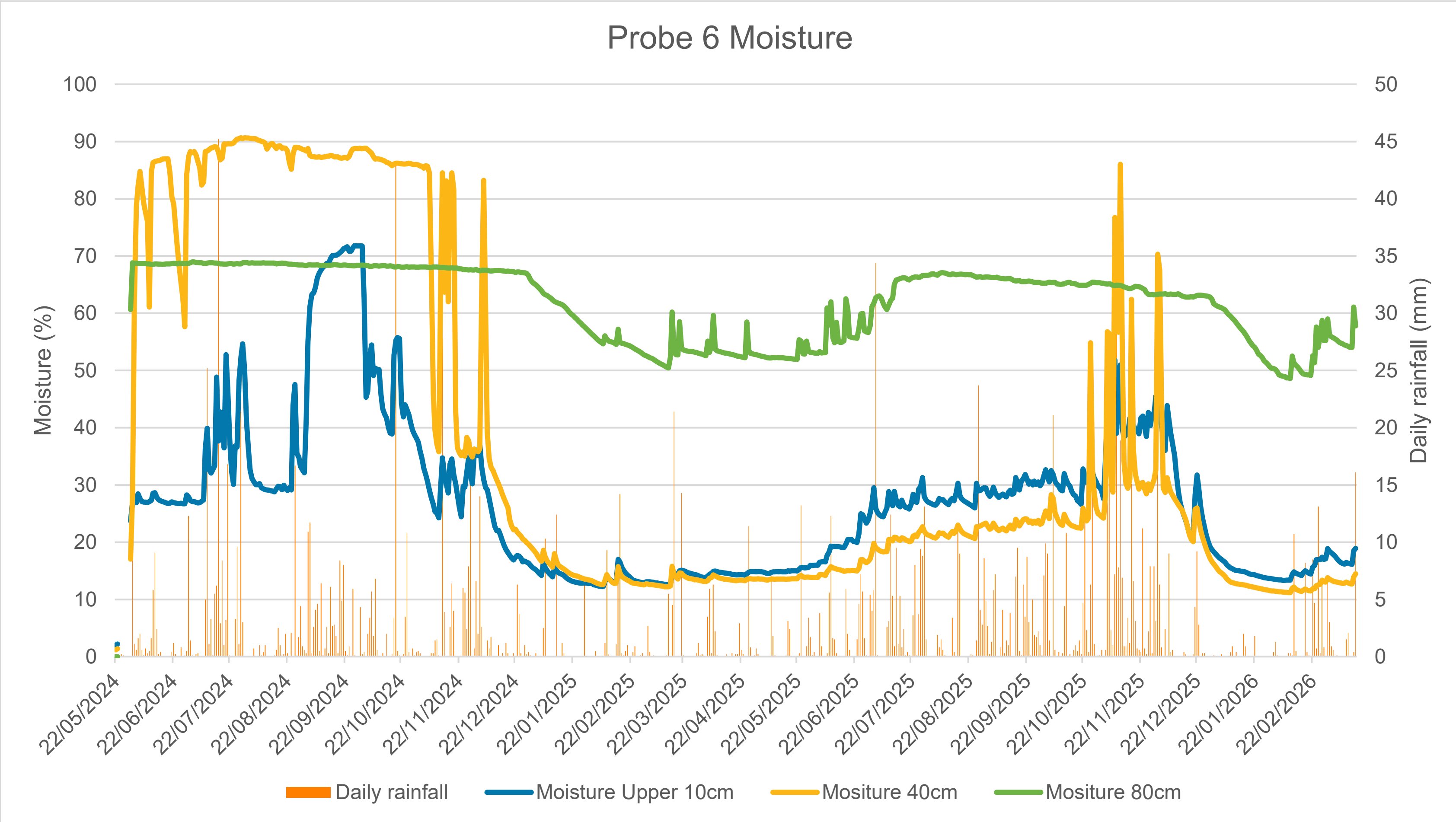

Figure 3.2 Graph showing the data from May 2024 –March 2026 of moisture for probe 6 at three depths v rainfall

3.2.2 After Daily Rainfall Events

Rainfall events produce depth-dependent soil moisture responses at 10 cm, 40 cm and 80 cm.

At the soil surface (10 cm), all rainfall events result in a relatively immediate increase in soil moisture due to direct infiltration into the upper soil layer. Small rainfall events (<20 mm) generate short-lived and moderate moisture increases, while larger rainfall events (>20-40 mm) produce stronger and more sustained surface spikes. Some very high short-term values following heavy rainfall may reflect:

- Temporary surface ponding and potential sensor saturation
- Rapid infiltration pulses, particularly where water concentrates down hill

At mid-depth (40 cm), the response to rainfall is delayed relative to the surface. Larger rainfall events result in measurable increases at this depth as moisture moves downward through the soil profile. In contrast, small rainfall events generally produce limited or negligible change at 40 cm, suggesting insufficient infiltration beyond the upper soil layers.

Where the soil is deep (80 cm), soil moisture response is typically minimal following all isolated rainfall events (small or large). Noticeable increases generally occur only after sustained or cumulative rainfall, indicating that deep infiltration requires either high-intensity or prolonged rainfall conditions. These deeper moisture responses may reflect:

- Flow of water down existing worm tunnels
- A result of cracking clays where pore surfaces have opened
- Steady soil moisture during consistently wetter periods

Overall, data indicates:

- Surface soils (10 cm) respond to all rainfall events, with magnitude related to rainfall level
- Mid-depth (40 cm) responds primarily to larger rainfall events
- Deep soils (80 cm) are influenced by sustained or cumulative rainfall rather than isolated events.

3.2.3 Decrease in Soil Moisture

Rapid declines in surface soil moisture (10cm) were observed following rainfall events. These decreases are likely due to:

- High evapotranspiration, particularly during warmer months
- Wind exposure
- Drainage and drying in clay-based soils on a steep aspect

Soil at surface level responded quickly to rainfall but also dried rapidly, particularly during summer. In contrast, deeper soil layers (40 cm and 80 cm) retained moisture for longer periods, reflecting reduced exposure to environmental conditions.

Drier summer conditions may influence both the movement and detectability of GGE within the colony. The absence of GGE detection during dry periods may be attributed to:

- Insufficient soil moisture for the gurgle to be heard;
- Reduced movement in drier soils; or
- GGE going further down, deeper into the clay for more favourable moist soil conditions
  - This is considered the most likely contributing factor

3.3 Soil Temperature

The soil temperature results varied mostly near the surface of the soil. At all of the probes the temperature was highest in summer and autumn months, and lowest in winter. Understandably, the more consistent and stable temperatures with little variance across seasons occurred the deeper the probe measurement was taken.

All air and soil temperatures were warmer in summer and autumn compared to winter and spring as expected. Air temperatures fluctuated most which is typical of the Gippsland seasonal weather temperatures.

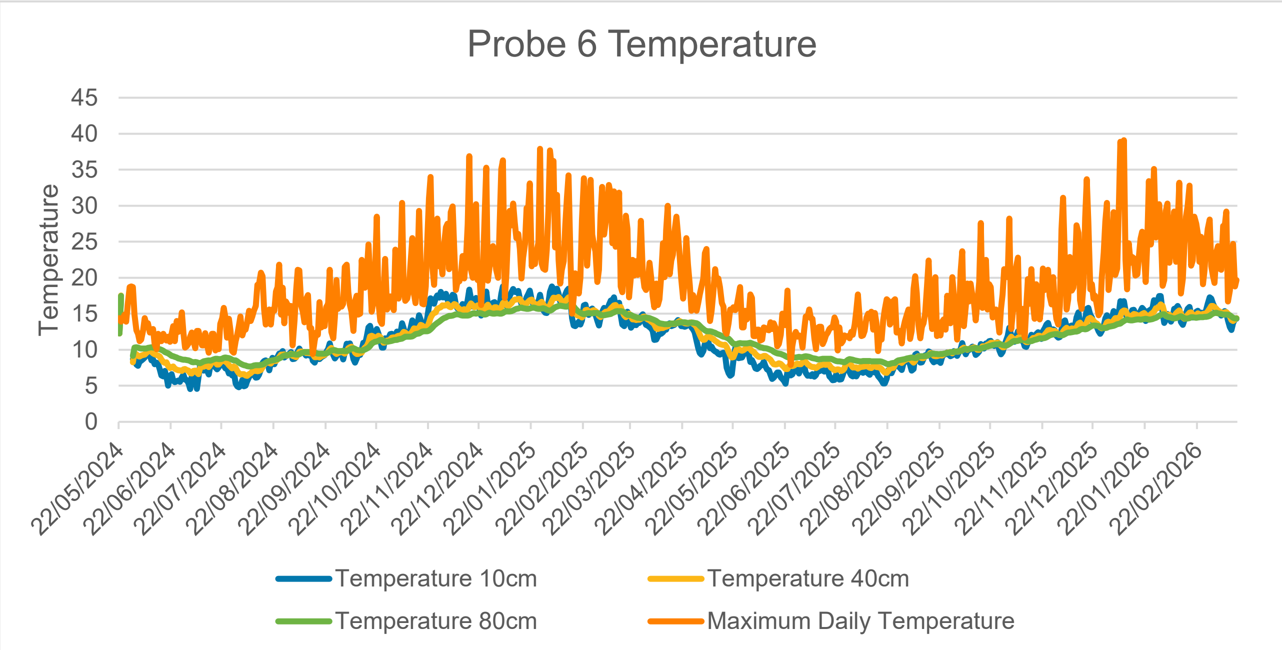

Figure 3.3 Graph showing daily temperature fluctuations from May 2024 – March 2026 for probe 6, against maximum daily temperature

3.3.1 Soil Temperature by Depth of Sensor

10 cm (Surface) Temperature

- Shows the most short-term variability.
- Responds fastest to seasonal warming and cooling.
- Exhibits sharper declines in winter and faster warming in spring.

40 cm (Mid Depth) Temperature

- Slightly dampened variability compared to 10 cm.
- Tracks seasonal trends closely but more smoothly.

80 cm (Deep) Temperature

- Most stable profile.
- Smallest fluctuations.
- Slight lag behind shallower layers in both warming and cooling phases.
- Rarely shows sharp spikes.

This pattern reflects classic thermal damping with depth: the deeper the soil, the more buffered it is from rapid atmospheric changes. As a result, temperature amplitude decreases with depth and seasonal transitions occur more gradually at deeper levels of the soil.

3.3.2 Temperature Comparisons Between Air and Soils

The maximum daily air temperature shows:

- Large daily variability.
- Strong summer spikes between (30–40°C).
- High short-term fluctuations year-round.

In contrast:

- Soil temperatures show similar curve trends for highs and lows but do not fluctuate as much as air temperature demonstrating soil's strong thermal buffering capacity.
- Soil temperatures remain comparatively moderate, even during extreme air temperature spikes,
- Soil temperature at greater depth has lowest fluctuations while when shallow the temperature more closely resembles air temperature due to its closer proximity to the surface.

3.3.3 Overall Findings

- Summer 2024/25 shows a sustained warm period with elevated soil temperatures across all depths.
- Winter 2025 shows the lowest soil temperatures in the dataset.
- Late 2025 into early 2026 shows rising air temperature spikes again, with soil gradually responding.
- The lag between air temperature peaks and soil warming is visible, particularly at 80 cm

3.3.4 Comparing Revegetated Site (Probe 8) Behaviour with other Probe Locations

The soil moisture monitoring probe (probe 8) located within the revegetation site in the Site 1 colony showed prolonged periods of being out of action. This loss of data can only be explained by some malfunction (Figure 3.4). However, as a time window allowed for both graphs with data collected, we compared data during the August to December 2024 time period.

The behaviour of the probe in comparison to rainfall (Figure 3.5) showed a significant drop in soil moisture during summer dry periods of 2024-2025. Baseline soil moisture appeared much lower (20%) 12 months after setup, even following above-average rainfall events, with a sudden drop-off at all depths in conjuncture with a drier-than-usual summer. These changes may be explained by an increase in evapotranspiration as the higher-density planted trees mature. As their root systems extend deeper into the soil, they draw more moisture from multiple depths, reducing the overall soil water availability during dry periods.

In contrast, the soil moisture percentage was similar at both surface and 40cm depth, potentially because localised grasses provide a buffering effect on the soil moisture closer to the surface. This phenomenon may provide a microclimate trapping dews in late spring and early summer.

Comparison of the revegetation site and the closest non-revegetated probe (Site 1 probe 1) (Figure 3.6) over a short duration (6 months) showed the following differences and similarities:

- A different response to dry weather with a sudden decline at depths of 80cm and less response to rainfall events.
- After initial large peaks and flows response to rainfall events was not as dramatic in the revegetated location compared to non-revegetated site.

- Similar long term trends occurred to surface (10cm depth) throughout the comparative period suggesting conditions are similar at both probes with a grassy surface, noting both are fenced from grazing animals.
- Probe 8 has a lower baseline soil moisture and fluctuates less in the revegetated site at mid depths after rainfall events compared to the nearby probe (probe 1).

It was noted in the conclusion of the project timeline that recruitment was beginning to occur at site 1 as a result of the cattle being fenced out. Individuals of Blackwood (*Acacia melanoxylon*) had recruited but in much lower densities as planting where probe 8 was located.

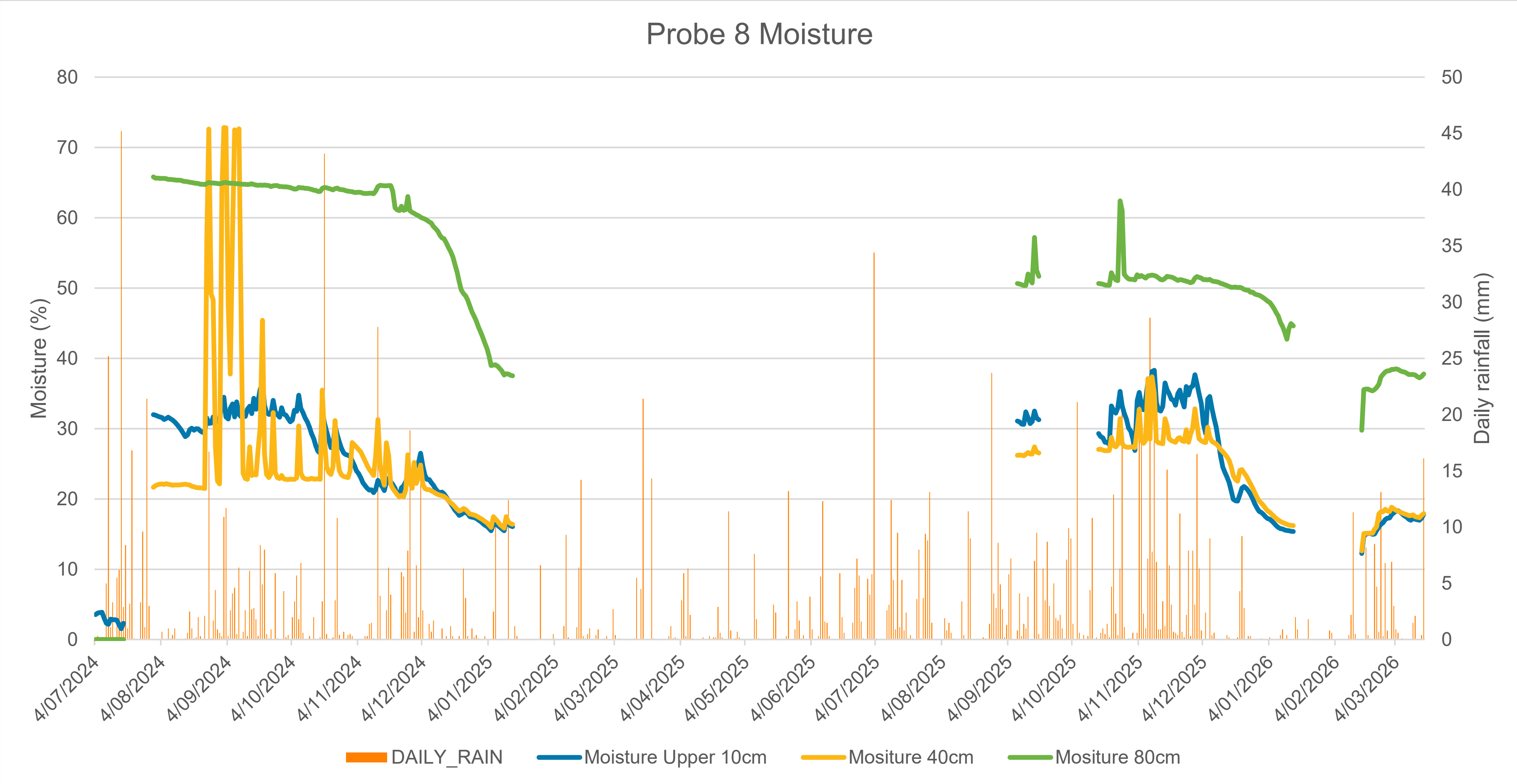

Figure 3.4 **Data capture for probe 8, revegetation site**

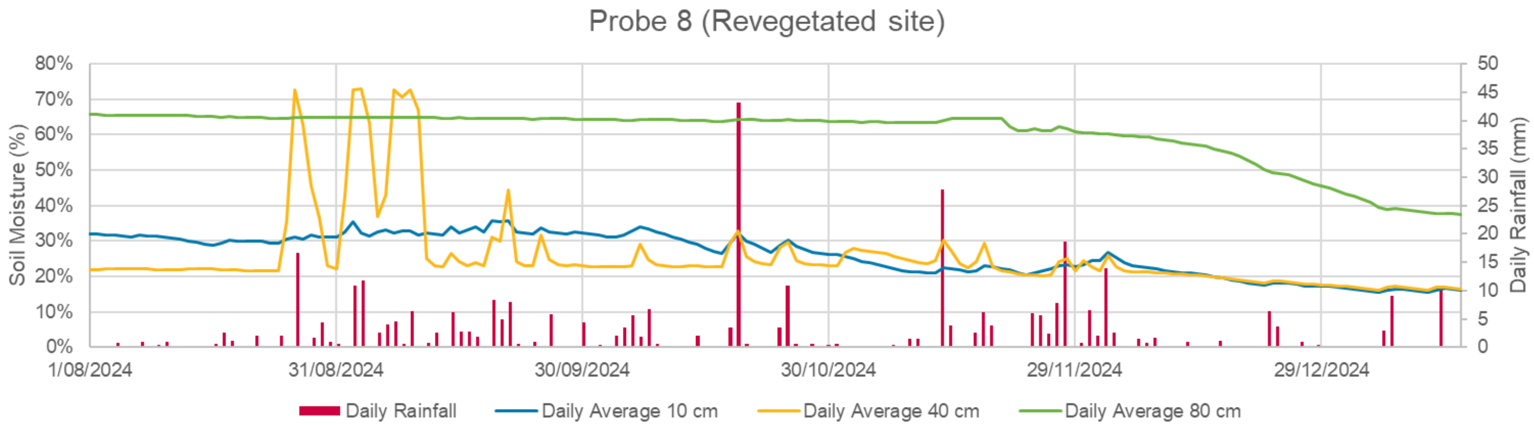

Figure 3.5 Percentage of soil moisture at probe 8 between August 2024 – January 2025 against daily rainfall

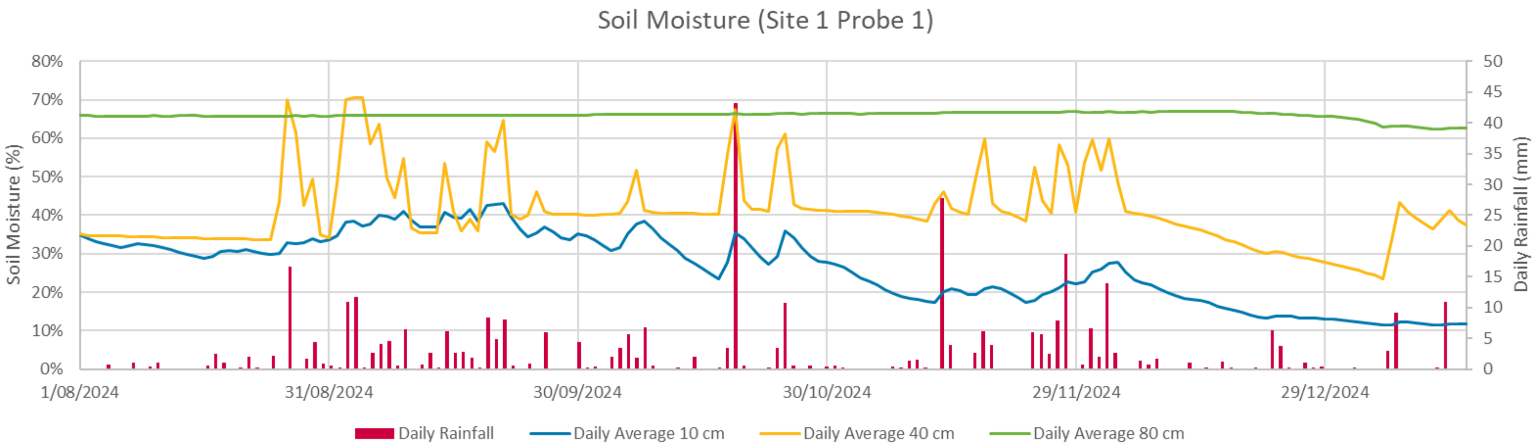

Figure 3.6 Percentage of soil moisture at probe 1 between August 2024 – January 2025 against daily rainfall

3.4 Soil Oxygen

Figure 3.7 provides a snapshot of soil oxygen levels across a selection of sites over one year. NB: Soil oxygen levels were not assessed at the revegetation probe location.

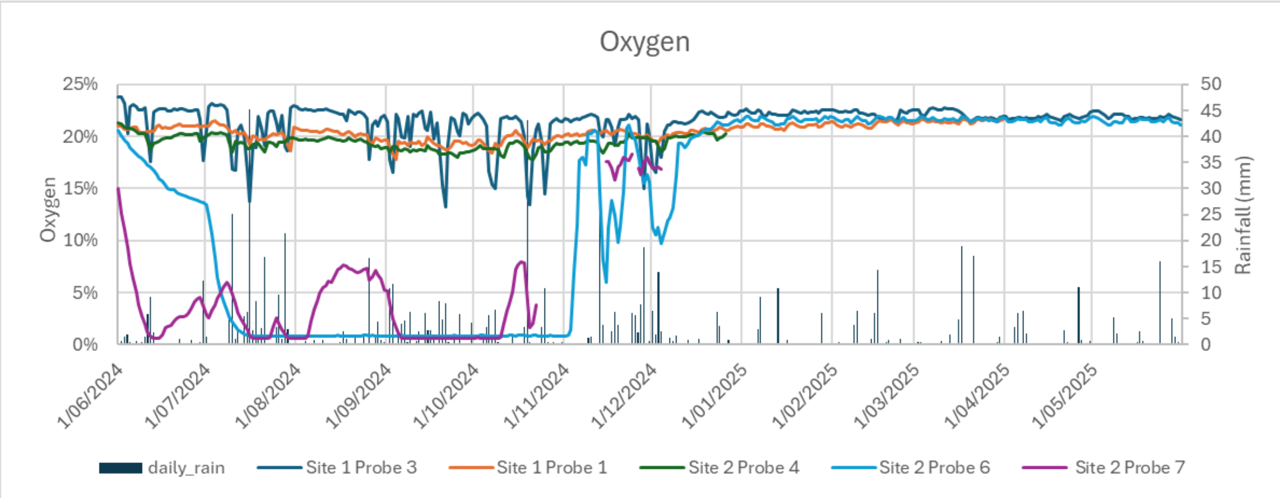

Figure 3.7 Graph showing the percentage of soil oxygen levels against daily rainfall from May 2024 – June 2025

Despite inconsistencies and several data gaps in the soil oxygen records, a number of clear trends could still be interpreted. The following sub-sections summarise the main findings for each probe.

3.4.1 Within Colony and Habitat (Probe 6)

Probe 6 was chosen as this was the best data to compare against soil moisture, within colony and with records of GGE data.

- Soil oxygen declines sharply from ~20% in June 2024 to near 0% by late July 2024.
- Soil oxygen remains near 0% for an extended period (Aug–Nov 2024).
- Exhibits a recovery in November–December 2024.
- Stabilises near atmospheric levels (~21–22%) from January 2025 onward.

3.4.2 Below Colony and Habitat (Probe 7)

The greatest variance of data and fluctuations from low levels Oxygen saturation in probe 7 (beneath colony) where a drainage line is present. The following point summarises the oxygen levels at this probe.

- Oxygen drops rapidly early in June 2024.
- Shows repeated oscillations between ~0–8% through mid-2024.
- Remains low and highly variable through late 2024.
- Gradually stabilises to ~20–21% by early 2025.

3.5 Comparing Soil Moisture and Oxygen Levels

3.5.1 During June – November 2024 when Soil-Oxygen Suppression Occurred

The data from both probes highlights several patterns:

- Both probes show extended periods of very low oxygen.
- Probe 6 drops close to 0% and remains suppressed.
- Probe 7 fluctuates but repeatedly approaches near-zero.

This coincides with:

- High rainfall months (e.g., July 2024).
- Elevated soil moisture following rainfall spikes.
- Reduced aeration due to water-filled pore space and being lower sites in the colony and below the colony.

Probe 6

- Oxygen remains consistently near zero for longer duration.
- Suggests more sustained saturation or reduced drainage.
- Stronger moisture–oxygen coupling.

Probe 7

- Oxygen shows repeated oscillations.
- Suggests cycles of wetting and partial drying.
- Indicates intermittent aeration recovery.

The difference between probe 6 (in colony) and probe 7 (outside colony) is that probe 7 likely experienced more frequent wet–dry cycling, while Probe 6 may have experienced more prolonged saturation. Due to probe 7 being closer to drainage line this makes sense.

3.5.2 November – December 2025 Re-calibration of Soil-Oxygen

During late 2024:

- Probe 6 oxygen shows a sharp recovery spike.
- Probe 7 also increases toward atmospheric levels.
- This corresponds with reduced sustained soil moisture following the major wetting phase.

This marks a shift from:

- Water-filled pore space dominance to
- Improved gas exchange and aeration.

3.5.3 2025 Oxygen Stabilisation Phase (Low Rainfall and Reduced Soil Moisture)

From January 2025 onward:

- Both probes stabilise near ~21–22% or atmospheric pressure.

- Soil moisture during this period was more variable and often below average, in close relation to lower monthly rainfalls.
- No prolonged oxygen suppression is observed.

This indicates:

- Reduced sustained saturation.
- Improved drainage.
- Lower overall soil moisture during early–mid 2025

3.6 GGE Gurgle Counts

In formal counts of GGE Van Praagh (2026) found that a higher number of gurgles occurred at the start of the project during site selection in May 2024 (55 which were located both across (27) and between (28) the two sites) and during probe installation (multiple were heard) in late May 2024. In an assessment on 15th May 2025 just three gurgles, one at site 1 and two at site 2 were heard. While on 16th October 2025 six gurgles were detected, one within site 1 and 4 within site 2. An opportunistic observation of 16 gurgles was observed in wet ter condition s in November 2025 (Oates *pers comm.* 2025).Two assessments in January and February 2026 did not detect any GGE at either of the sites using the same method. However, on March 4th 2026 one gurgle was located and opportunistic observations located 2 gurgles on March 18th during data retrieval.

The impact on GGE colonies as a result of the seasonal changes in weather and soil moisture content:

- GGE near the soil surface would experience high variability in conditions.
- GGE at depths likely benefited from more stable conditions and would have potentially buried themselves deeper within the soil in drier times whilst in sustained moist times were likely to be near the surface.

From a soil/GGE interaction perspective:

- Temperature stability increases with depth.
- Deeper placed GGE experience less thermal stress.
- Surface layers are more vulnerable to rapid temperature swings, suggesting GGE may move deeper to avoid desiccation.

Extreme heat events influence shallow soil most strongly but are moderated quickly with depth which may be avoided by GGE and explain their capacity to live in the Gippsland soils for as long as they have.

The following Figure 3.8 shows the number of GGE “gurgles” at the project site vs Probe 6 as an indicator of soil moisture.

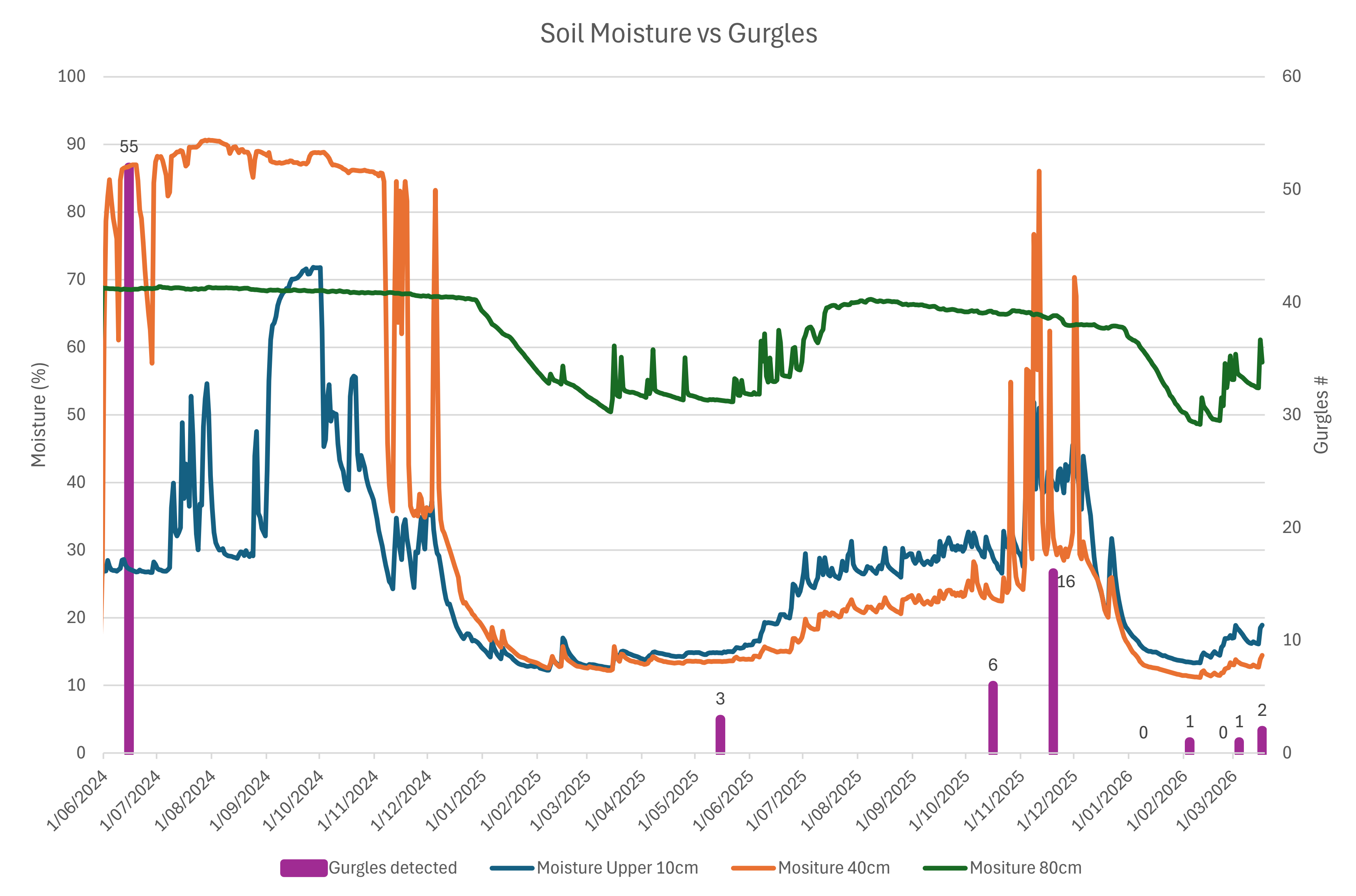

Figure 3.8 **Graph showing the soil moisture at one probe (probe 6) compared to Gurgles across site May 2024 – March 2026**

The following table shows soil moisture at three depths and gurgle numbers as collected by Van Praagh (2026) showing a trend of increased activity (gurgles) as soil moisture levels rise.

Monitoring Event	Date	Season	Number of Gurgles Detected	Reading of soil moisture for that time at depths (cm)		
				10	40	80
Baseline survey (pre installation)	May 2024	Autumn	55*	27.2	86.8#	68.6
Monitoring 1	15 May 2025	Autumn	3	14.8	13.5	52.2
Monitoring 2	16 Oct 2025	Spring	6	28.8	22.8	55.2
Incidental observations	19 Nov 2025	Spring	16*	39.7	31.9	64.7
Monitoring 3	15 Jan 2026	Mid-Summer	0	15.5	13.0	59.5
Monitoring 4	23 Feb 2026	Late Summer	0	15.9	11.9	51.4
Monitoring 5	4 Mar 2026	Early Autumn	1	18.2	13.4	55.9
Incidental observations	17 Mar 2026	Early Autumn	2*	18.9	14.4	57.8

* these were either non-targeted searches (baseline) when selecting sites or opportunistic during other site visits in vegetation assessment or data collection (Oates and Burnell *pers comm.).* However, they are indicative numbers and can be compared to standardized Monitoring. # At the time of probe installation and there may have been a settling period as water may have been accumulating.

Gurgle counts (Baseline and Monitoring) from Van Praagh (2026).

3.7 Other Observations

During the project (in a site visit with the project team in June 2025) we made a small exploratory dig into the earth within site 2, close to probe 5 and 6. At 5cm depth located a cocoon (Appendix Figure A-10) with a juvenile worm inside. As development takes 12 months, the conditions must have been suitable for reproduction during the course of the monitoring.

When taking final recording from the SDD card on 18th March 2026, field ecologist Elsa Burnell from Water Technology heard two GGE gurgles, one from the colony and one below probe 7, outside the original colony boundary. Further investigation is required to determine whether this “Gurgle” shows an increase in the colonies movement that was as a result of the drier conditions upslope.

4 DISCUSSION

4.1 Soil moisture in response to weather

From the results we have determined that soil moisture fluctuates considerably near the soil surface as a result of the change in weather conditions and seasonal patterns. Throughout the monitoring, there were dry, hot summers with below average rainfall whilst occasional months had more than double the average rainfall events. These weather patterns correlated with very varying soil moisture content nearer the soil surface while fluctuations generally were buffered at greater depths with constant and stabler conditions, as depths provided additional protection from atmospheric elements. Soil moisture closer the surface showed high variability with more pronounced responses to weather, e.g. sharp increases after rain and rapid decreases during dry periods. Variability of soil moisture and temperature was more stable in deeper soils compared to surface soils.

4.2 Response of GGE to moisture conditions

The data shows that there is a potential correlation between drying of the clay-based soils where soil moisture declined and a reduction in the number of "gurgles" heard. This may suggest GGE activity reduces or is absent near the surface as the soil moisture declines and soil hydrology is therefore a likely significant factor influencing GGE behaviour. As earthworms do not regulate their body temperature themselves some smaller species are able to aestivate (hibernate). However, in the case of GGE and other giant earthworms, it's likely that they avoid drier conditions and find soil moisture in greater depths than our probes could detect. When it is very dry and hot, or too cold many common earthworms retreat to deeper soil layers. Earthworms are intolerant to drought. They are active only when the soil is moist, and are inactive when it is dry. As earthworms can lose up to 20 % of their body weight each day in mucus and castings, they need moisture to stay alive. We understand that GGE do not aestivate and therefore, retreat is their likely (only) adaptive strategy to reduced soil moisture.

As habitat dries out, clay-based soil conditions become less favourable to aqueous movement of this species that is dependent on soil moisture for both movement and oxygen diffusion. This likely contributes to the observed reduction in gurgles. Importantly, a decline in gurgles does not mean that the GGE have declined in numbers from the colony, the reduced "gurgle count" could be explained by the following:

- that there is insufficient soil moisture in the soil for GGE to be heard moving about "gurgles"; and/or
- that GGE's have migrated towards deeper soil habitat where moist conditions are suitable, with upwards movement to occur when conditions become more suitable again.

The threshold for change in the number of "gurgles" is not easily determined and would likely require a longer monitoring timeframe to establish. Available data, however, suggests that if soil moisture is approximately 60-70% at depths of 80cm, the gurgles are more commonly heard. These results are important as they provide an insight into GGE that if soils dry out for whatever reason, the mobility of GGE declines and the species may become at risk. Long-term drying of habitat, or changes to soil hydrology as a result of land management, diversion from developments and climate change place a threat to the survival of this species.

4.3 GGE Adaptive Strategy to changes in soil conditions

The moisture provides an aqueous environment that lubricates free movement and water movement within burrows. Literature suggests soil moisture is required for the movement of (common) earthworms within the clay soils making them intolerant to drought conditions.

In a review of climate change effects on common earthworms by Singh *et al.* (2020) climatic factors like temperature, precipitation, soil moisture, as well as extreme climate events like drought and flood have been shown to alter the composition and functioning of communities in the soil. They find that highly species- and ecological group-specific responses to climate change, are likely to result in altered earthworm community composition in future ecosystems. Earthworm activity, abundance, and biomass tend to increase with increasing temperature at sufficiently high soil water content, while climate extremes like drought and flooding have deleterious effects. The impact of climate change on large invertebrate species is insufficiently studied Veresoglou *et al.* (2015) and underappreciated Eisenhauer *et al.* (2017; 2019).

Though not demonstrated within the current monitoring, an excess of soil moisture poses a problem to GGE colonies also. When soils become waterlogged' often demonstrated by flooding of their creek-side habitat after excessive rainfall, the GGE are forced to the surface where they are susceptible to injuries and predation. These GGE, if not relocated have little or no chance of survival (Van Praagh *pers comm.*).

In smaller species, earthworms cannot regulate the body temperature themselves. Therefore, when it is very dry and hot, many earthworms retreat to deeper soil layers and/or aestivate. Without the ability to aestivate, we understand that retreating to deeper soil is the only mechanism GGE (and other large species) have to avoid dry/hot soil conditions. In contrast, soil conditions just below the surface are inhabited when suitably moist and warm when humidity is desirable. Exploratory "digs" to determine the use of the colony (GGE tunnels) prior to the insertion of probes and at the location of the probes uncovered evidence of use in the top 30-40cm of the soil. In addition, the surface must be advantageous for cocoon deposits as during the project (in June 2025) we made a small dig into the earth and at 5cm depth located a cocoon with juvenile worm inside. It's likely that conditions here are mitigated by the protective cocoon, but that it may be a requirement of juvenile GGE to have warmer conditions to aid in their development.

There have been considerable studies on common earthworm species in relation to cocoon development and soil temperatures. Bostrom and Lofs-Holmin (1996) provided an account of one species *Aporrectodea caliginosa* in loam soils in Sweden favouring temperatures of 15°C while cocoon production was three times lower at 10°C and almost zero at 5°C. The temperatures during our current study indicated fluctuations between 5-8°C (in winter)-13-18°C (in summer) at 10cm depth, while at 40cm depth these fluctuations ranged between 7-10°C (in winter) while summer saw 15-17°C. At much deeper 80cm depth temperatures were more stable and did not fluctuate as much being around 8-9°C in winter and 15-16°C in summer. Lofs-Holmin (1996) found the majority of the Northern Hemisphere population aestivated in August, when the soil temperature was high and the humidity low. Though aestivation does not occur in giant earthworms (van Praagh 2026), the GGE community was not observed moving in warmer and drier months of this pilot study between December to April as indicated by a lower number of gurgles heard. Daugbjerg (1988) compared three earthworm species in the laboratory indicating them to have similar temperature and moisture preferences to each other. Generally, low soil moisture levels (<10%) and low temperatures (<5°C) limited activities in the upper soil layers in adults and juveniles with the latter also having preference for temperatures up to15°C for development. Soil moisture content is considered to be of major importance in regulating earthworm activity patterns in the northern temperate zone during summer periods. The same could apply to Gippsland and that, if consistent wet, warm conditions were observed there would have likely been more activity through "gurgles".

As a summary, (common) earthworms retreat and their metabolism slows down to the minimum in dormancy, with low winter temperatures. They are active only when the soil is moist, and are inactive when it is dry. As regular-sized earthworms can lose up to 20 % of their body weight each day in mucus and castings, they need moisture to stay alive (Fibl, 2022).

The effect of precipitation on earthworms is a positive response and humid conditions are favourable to activity, reproduction and enhanced growth. Earthworm communities gradually decrease in abundance as the annual rainfall decreases and the dry season becomes longer (Singh *et al.* 2020) and extended dry seasons often lead to a drastic decrease in the density of earthworms (Lavelle 1971).

4.4 Soil Moisture and revegetation

Revegetation appeared to have a rapid decrease of soil moisture at depth in summer at probe 8, presumably as a result of drawdown from juvenile trees and shrubs. When trees were first planted by the landowner to assist the stabilisation of the hillside above the creek which was prone to land slips, he was unaware of the cause of the "gurgles" as he was planting the vegetation. Soil moisture uptake by juvenile trees as part of the revegetation became an important component of the project. The planting of small trees and shrub in zones near colonies may negatively impact soil moisture content, drying out the habitat for the colony present. Conversely, some trees planted near natural springs have not been able to establish due to an excess of water and this is also where GGE have been able to survive (Van Praagh *pers comm.*). We suggest further studies are required over a longer time period and with varying vegetation structure. It is difficult to draw conclusions from the soil probe readings in the short time frame of this project.

Soil uptake by juvenile trees as part of the revegetation is an important component of the project. Van Praagh (2026) and Oates (2026) indicated that the juvenile trees in the vicinity of Probe 8 consisted of Messmate (*Eucalyptus obliqua*), Blue Gum (*Eucalyptus globulus*) and Strzelecki Gum (*Eucalyptus strzeleckii*). Shrubs formed the lower layer planting including Musk Daisy-bush *(Olearia argophylla*), Prickly Moses (*Acacia verticillata*), Hemp Bush (*Gynatrix pulchella*) and Common Cassinia (*Cassinia aculeata*). The ground layer was dominated by pasture grasses. In areas where plants are impacted by drought and a loss of plant diversity this may affect common earthworm communities (Marriotte *et al.* 2016). As plant-soil interactions are expected to play an important role in mediating climate change effects on soil decomposers they replicated drought conditions using subordinate species (grasses). They found that subordinate species, when present, increased in biomass after drought and induced an increase in total earthworm biomass. They found a positive correlation between the abundance of juvenile earthworms and plant community biomass. Anecic earthworms were the main beneficiaries of the presence of subordinate species under drought. Anecic earthworms are a functional group of deep-vertical burrowing worms that preferentially feed at the surface on litter (Lavelle 1988) but of which GGE belongs (Van Praagh 2026).

4.5 Future revegetation methods as a result of these findings

Substantial work has been carried out to assist with planting design around GGE colonies. The Giant Gippsland Earthworm Protecting GGE Habitat Fact Sheet No. 2 (GGE 2023) describes the need to plant in zones with varied planting at distances from the colony. Our data supports the guideline development suggesting planting of trees too close to colonies would likely reduce soil moisture levels and be detrimental to GGE. Further studies are required in a variety of revegetation sites with different ages of revegetation from new revegetation areas to very old revegetation/remnant areas where colonies prevail.

4.6 Soil type and drying

In clay soils, the absorption of water is impeded by a low soil moisture content, a small root system, poor soil aeration, low soil temperature, or a high concentration of the soil solution (Kozlowski 1987).

Recent research in Soil Water Repellency (SWR) was carried out by Then *et al.* (2025) in many sites across south west Western Australia. SWR is most severe in clay soils (similar to those in the current project) when soils are dry and disappears when soils become moist (Doerr and Thomas 2000). Then *et al.* (2025) found that clay content was the most influential factor of soil variables, in that the incidence and severity of SWR decreases with increasing clay content but that greater soil organic carbon content is required where clay content increases.

It has been documented that both grey and red clay based soils are important in GGE habitats and were located where the colony was present in this and other sites (Van Praagh 2026). Areas outside the main colony (such as probe 4) were located on a level, possibly compacted site. Van Praagh (2026) indicated soils were a brown loam with little clay content. The quadrat contained weedy pasture grasses and herbs with the only indigenous plant present being the herb, Native Flax (*Linum marginale*).

4.7 Waterlogging Risk

Conversely, too much precipitation and water logging of heavy clay soils that may be prone to anaerobic conditions (Curry and Schmidt, 2007) unfavourable for earthworms. As earthworms breathe through their skin, they are highly dependent on soil aeration, when soil pores fill with water, oxygen levels drop, preventing easy oxygen diffusion. GGE have adapted to their preferred blue grey clays at Gippsland. The GGE are sensitive to excessive soil moisture conditions, which can force them to leave their burrows and move to the surface where they are prone to injury and predation (Van Praaagh pers comm.). In addition, it has been observed that GGE's prefer the bank above the high water zone of creeks where flooding is less likely.

The importance of Earthworms (the ecosystem engineers (Jones *et al.* 1994)) is that they influence ecosystem functions through litter fragmentation, burrowing, and casting activities, and thereby drive nutrient cycling, soil aggregate stability, water infiltration, plant growth, and soil carbon storage (Coleman *et al.* 2004).

Australian "grey clays" are particularly susceptible to forming a surface seal or "crust" when rained on, which significantly slows the movement of air and water into the soil. In higher rainfall environments, sodic clay soils are highly prone to waterlogging due to poor drainage.

5 LIMITATIONS TO THE PROJECT

The project was the first of its kind to monitor hydrological parameters for a colony of Commonwealth EPBC Listed Vulnerable Giant Gippsland Earthworm. When installing probes augers were required to dig a hole of sufficient size for installation to occur. To ensure earthworms were not in the topsoil, we made noise and expert field technicians from Invert-Eco provided an exploratory dig with a shovel to both encourage GGE to leave the immediate area and also ensure that the burrows were present confirming localised activity. This shovel sized hole was used to place the oxygen probe and may have formed localised pooling in initial stages though to reduce that we backfilled with the same soil-clay that came from the hole.

The absence of detectable gurgling does not necessarily indicate the absence of worms or movement within the burrows. The worms may still be present but due to a lack of water cannot be heard gurgling due to burrows low moisture content. However, it is believed the GGE goes further underground in drier conditions to locate a more suitable moisture content (Van Praagh pers comm). Budget constraints meant that gurgles couldn't be recorded more than a few times during the project timeframe.

Probes were only able to be inserted to 0.8m as this was the size of the probes. It's believed the GGEs could have been anywhere between 0-3m deep but conditions >0.8m depth were not practical to measure nor installation.

The exploratory dig and subsequent placement of the Oxygen probe was at spade depth only. By inserting to 80cm depth there may have been more valuable insights to soil moisture conditions. However at the time of installation we did what was practical and comparable between probe locations.

Rainfall data was collected using the Queensland Government SILO database which contains two major classes of data: point (station) time series and spatial grids, both based on observed data from the Bureau of Meteorology ADAM (Australian Data Archive for Meteorology) database. For point data, interpolated or derived values are used where observations are missing.

As the “real time” data was removed when Eratos went insolvent we were unable to regularly monitor the graphs. There appears to be some anomalies with data starting and stopping and perhaps this was a result of the resetting of the loggers that Eratos was unable to cope with. Therefore, Data cleaning was required to eliminate data that was not compatible as a result of resetting of the datalogger as it changed back to a system setup date.

6 RECOMMENDATIONS AND FURTHER RESEARCH

As stated, this project was a pilot study over short duration with limitations and some malfunctions of equipment. We knew there would be challenges with solar batteries and connection to Wi-Fi but could not predict the unexplainable faults in equipment. It is recommended that the equipment be retained in the field for long-term analysis with upgrades to suit better data collection. Long-term monitoring of the climatic conditions, soil moisture and gurgles would provide a more conclusive study and be more beneficial to the future planning and management for this species. It would be beneficial to determine whether the recent dry conditions have a long term impact on the species or whether they are able to rebound when conditions are conducive to movement and therefore increased “gurgles”.

We suggest that planting of revegetation be continued in the zoning described in GGE (2023) with soil moisture monitored at each planting zone to determine differences in the soil moisture through uptake and providing further knowledge to best fit GGE colonies. Long-term monitoring of the colonies would also provide insight to the conditions as revegetation evolves. In addition, there would be advantages in monitoring soil-moisture in remnant old growth forest where colonies are present to determine such soil conditions.

Further assessment at greater depths would be beneficial to determine soil moisture conditions throughout the full soil profile. This would provide insight into optimal conditions and the depths to which GGE retreat.

In addition, we recommend that further monitoring of colonies in other known locations where colonies occur be performed using a hand-held soil moisture monitoring device. Providing measurement depths are kept consistent this device would contribute to knowledge of soil moisture conditions required to determine activity (gurgling) of GGE at varying habitats.

We suggest a long term-monitoring project be established that has earthen sound recorders that can determine gurgles in all conditions vs soil moisture.

7 CONCLUSIONS

The monitoring of soil parameters at two sites of a GGE colony in Arawata, Victoria was a success albeit with several technical issues hampering the data collection. Sufficient data was collected to conclude that:

Soil moisture percentage is highly variable at 10cm depth near the surface, moderately variable at 40cm and most stable at 80cm depth within the clay soils of the GGE habitat.

After rainfall there are rapid spikes to the soil moisture at shallow depths, which is delayed and slow recharge in 40 and 80cm depths respectively. Conversely, soils dry more rapidly when shallow, while at 40cm soils dry slower and at 80cm there is a slow decline in soil moisture during dryer events which reflects longer-term water balance rather than event-driven changes. From this, we deduce that limited deep infiltration occurs from small rainfall events and that soil moisture is driven by cumulative rainfall rather than isolated events.

Similar trends occur with temperature in these soils with most variability at the surface, a lessened variability at 40cm and stable conditions at 80cm depth. This suggests that the deeper the soil the more buffered it is from rapid atmospheric changes, that temperature changes decrease with depth and that seasonal transitions occur more gradually at depth due to the soil buffer.

With the reduced soil moisture came a decline in the number of gurgles (activity) of GGE from the start to the end of the project. We do not lay claim that this is a reduction in colony but merely a result of the unusually drier soil conditions that are not conducive to the recording of "gurgles".

Although the reduced number of gurgles does not mean a decline in the colony population, long lasting and extreme events are more likely to occur through one or more of the following reasons:

- Abrupt changes to soil hydrology as a result of land management, development or both; and
- More gradual change as a result of revegetation or climate change with the latter resulting in extreme conditions of drought and floods likely to occur more often.

The findings of this study have direct implications for the management of soil hydrology during disturbance activities, including the need to maintain appropriate soil moisture regimes and avoid alterations to subsurface hydrological processes within GGE habitat.

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APPENDIX A
SITE PHOTOGRAPHS

A-1 Site 1

Installation – adjacent to creek

Figure A-1 Dr. Mick Aberton augering hole to install soil moisture probe 1

Figure A-2 Stephanie Phillips augering a hole to install soil moisture probe 2

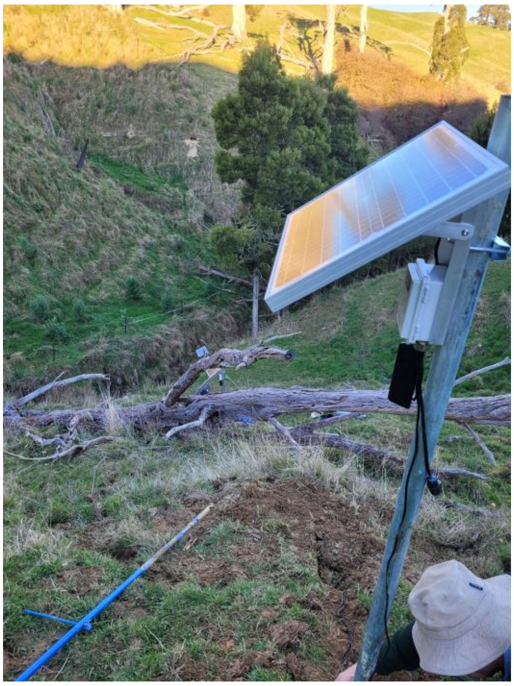

Figure A-3 Installation of soil moisture probe 3 with Solar array, datalogger and Wi-Fi aerial

Site 2

Figure A-4 Site 2, soil moisture probe 4, above and outside colony

Figure A-5 Soil moisture probe 5, mid colony on steep slope

Figure A-6 Soil moisture probe 6, mid colony on steep slope

Figure A-7 Installation of soil moisture probe 7adjacent to drainage line looking downslope from colony

Figure A-8 Soil moisture probe 8 in revegetation area in colony (2 years post planting)

Figure A-9 Exploratory dig to both determine the presence of burrows and discourage worms away from augering site

Figure A-10 Assistance from GTSAG and Bass Coast Landcare Network during installation May 2024

Figure A-11 Project team during project setup May 2024

Figure A-12 Project team during site day June 2025

Figure A-13 Project site in May 2024 (normal rainfall) compared to February 2025 (drought) Supplied: Drift Media

Figure A-14 GGE cocoon held by Dr Beverley Van Praagh adjacent to Probe 5 site 2, (inset closeup of cocoon)

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