

ANALYSIS OF MID-NORTH AND NORTH COAST WEATHER EVENTS 2025

FINAL REPORT



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Project Analysis of Mid-North and North Coast Weather Events 2025	Project Number 126008
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EXECUTIVE SUMMARY

WMAwater were engaged by Essential Energy to perform a weather impact assessment between the landfall of Ex-Tropical Cyclone Alfred, which occurred in March 2025, and the floods across the NSW Mid-North Coast during May 2025 event. In particular, it was requested to examine whether the severe impacts from the May 2025 event were influenced by the earlier Ex-Tropical Cyclone Alfred and the rainfall events occurring between the two events. To address this question, this report assessed how rainfall, soil moisture content, and wind conditions changed prior to and during these storm events, comparing them to long term historical records.

This report analyses the severe flooding and widespread damage that occurred on the North Coast and Mid-North Coast in March and May 2025. It then examines whether the catchment conditions prior to the May 2025 event were influenced by the earlier storm events in March 2025. Based on the analysis of the available evidence and data, the March 2025 event resulted in widespread soil saturation across the region. Rainfall between the two events continued to saturate the soil. While the May 2025 event is one of the rarest events on record, particularly on the NSW Mid-North Coast, the catchment conditions prior to this event were far wetter than long-term averages. Therefore, it is highly likely that the March 2025 event (and follow-up rainfall) increased the severity of the May 2025 event. These two events were therefore assessed to be related rather than independent.

The methodology involved analysing soil moisture and rainfall data from March to June 2025 and comparing this against long-term averages. Wind-speed data during the two events were also analysed. In doing so, the following was identified:

- Ex-Tropical Cyclone Alfred made landfall in March 2025, bringing intense rainfall, strong winds, and major flooding in north-east NSW. Prior to this first event, soil moisture conditions were close to the long-term seasonal average; however, the event resulted in extensive wetting of coastal catchments in the Mid-North Coast and North Coast. Maximum wind gusts of up to 120 km/hr were recorded during this first event.
- In the period between the two events, there was persistent and above-average rainfall. While not extreme enough to result in flooding, the frequency of these “top-up” events were sufficient to prevent the catchments from drying and returning to pre-event averages. The period between the two events was near-record wet, being one of the wettest in over 100 years when analysing long-term soil moisture statistics across many catchment basins.
- In some catchments, particularly the Richmond, Clarence, Bellinger, Macleay, Hastings, and Manning, soil moisture was at or near its long-term maximum during this period.
- The May 2025 coastal event produced heavy rainfall across the Mid-North Coast. There was substantial overlap with areas impacted in the March event, particularly in the Mid-North Coast. The inter-event rainfall meant that antecedent conditions were far wetter than before the March 2025 event.

The result of the above was an amplified risk of damage to power infrastructure, particularly through flood risk, meaning that the risk profile for large riverine flooding in May 2025 was higher than it would have been if the March 2025 event (and the wet inter-event period) had not occurred.

In addition to amplifying flood risk, saturated soils also increase the likelihood of trees being

uprooted during strong winds, thereby contributing to power outages. While soil moisture alone cannot predict power outages, it has been shown in previous studies to be a useful covariate in estimating where outages may occur. This means that wet soil conditions do not necessarily cause outages but can be used to estimate where they are more likely to occur. Storm damage to power infrastructure is therefore likely to be significantly higher where pre-event soil moisture is very high.

1. INTRODUCTION

WMAwater were engaged by Essential Energy to investigate if a region-specific link exists between Ex- Tropical Cyclone Alfred (March 2025) and the NSW North Coast Floods (May 2025), and the impacts as they relate to the temporal and geographical coverage of their electricity network. This report investigates if there is a clear link between the events and assess the severity of the impact of the combined events.

According to Essential Energy (2025), almost 100,000 of their customers were without power during the March event because of fallen trees, toppled power poles and damaged powerlines and electrical assets, particularly in northern NSW. Just a few months later in May, over 46,000 customers were without power due to the heavy rain and extensive flooding on the mid-north coast.

Two of the primary storm mechanisms leading to flooding in the East Coast of New South Wales are East Coast Lows and Tropical/Ex-Tropical Cyclones. These events are characterised by their large temporal and spatial footprints, and bring severe rain, wind, coastal erosion, and flooding. While they can occur at any time of the year, they commonly occur in Autumn and Winter and typically occur several times each year off Australia's East Coast.

The severity of catchment flooding is driven by several factors. This includes the duration and intensity of rainfall, as well as catchment soil moisture conditions prior to large rainfall bursts (***antecedent conditions***). As catchments become saturated, infiltration of rainfall into the soil is reduced, resulting in an increase in flood severity.

This report looks to examine any link between Ex-Tropical Cyclone Alfred, which occurred in March 2025, and the flooding and widespread damage caused by an easterly trough in May 2025. This report shows that the March event, and subsequent top-up rainfall between the March and May events resulted in cumulative and explicitly linked impacts. The evidence base in the report is built by looking at rainfall data and soil moisture estimates in 2025 against long term averages on the NSW mid-north and north coast. The basins of interest for this report are shown in blue in Diagram 1.

In the context of power outages, saturated soils also allow trees to uproot more easily during the high winds associated with intense storm events. Past research has used satellite derived soil moisture data to forecast power outages with 91% accuracy during Hurricane Matthew on the East Coast of the USA (Gorder 2016), for example. Along with this, soil moisture estimates allow for quantitative assessment of antecedent conditions. Each of these justify its use in this assessment.

Please note that all diagrams in this report are also included in Appendix A for clarity.

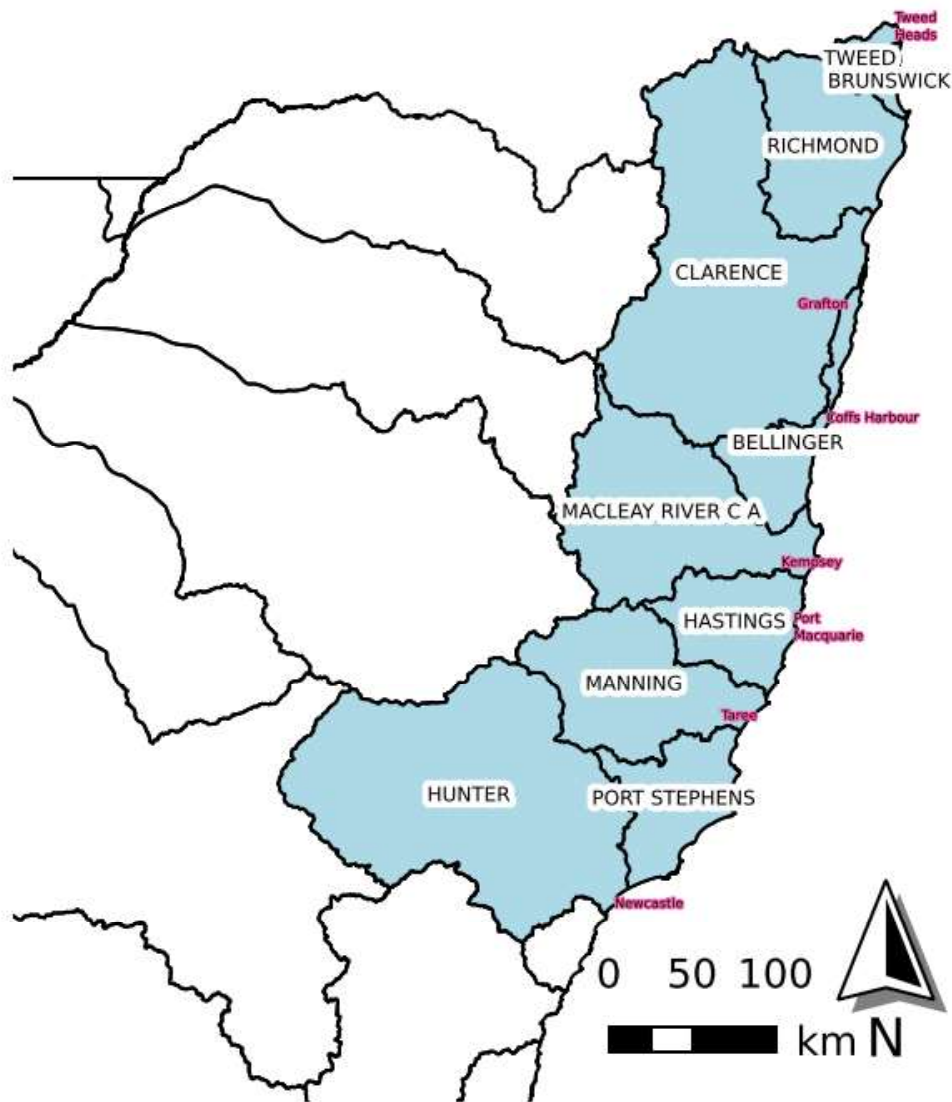


Diagram 1: Basins analysed in this report

2. Data

2.1. Australian Water Availability Project/Australian Gridded Climate Data (AWAP/AGCD)

The Australian Water Availability Project v1/Australian Gridded Climate Data is the Bureau of Meteorology's official dataset for the climate variables of rainfall, temperature (maximum and minimum) as well as vapour pressure at daily timescales. The gridded rainfall dataset is used for this report and is available back to 1900 at a grid resolution of approximately 5x5km, and uses the methodology described in Jones et al. (2009). This study uses the AWAP data from 1920 – 2023 from AGCD v1.0.3. The AGCD/AWAP rainfall data is also used as an input into the AWRA-L model (see below) and can be downloaded directly from the Australian Water Outlook Website.

2.2. Australian Landscape Water Balance Model

The Australian Water Resources Assessment Landscape model (AWRA-L) is the Bureau of Meteorology's operational water balance model. The model underpins water information services for national water resource assessment reporting, water use accounting, and situation monitoring (Frost et al, 2020).

The model is run on a daily timestep on a grid of approximately 5x5km with the water balance simulated on a daily timestep since 1911, providing outputs of surface runoff, soil moisture, evapotranspiration and deep drainage. The outputs from the AWRA-L model have been used for climatological, flood, drought, fire, water and agriculture applications across Australia (Frost et al, 2020). The AWRA-L model is optimised against satellite derived soil moisture, among other inputs. The model is also validated against observational datasets including point soil moisture probe data and flux tower estimates of soil moisture. This makes the modelled output robust.

The key variable assessed in this study was the root zone soil moisture. This is the sum of the Upper (0 – 0.1m) and Lower (0.1 – 1m) soil layers, representing the percentage of available water content in the top 1 m of the soil profile. It should be noted that saturation excess overland flow from the AWRA-L model is governed by the groundwater storage and the ground elevation – despite this, the soil moisture in the upper one metre of soil was used as an indicator of how wet catchments were prior to each event, and in the period between the two events. This is mainly due to the deep layer storage not being well quantified, as per the Australian Water Outlook, and so it was not utilised here.

2.3. Wind Speed Data

The Bureau of Meteorology maintains a network of wind-gauges. The maximum wind gust data is assessed in this report, and this variable is the maximum wind speed measured over a 3 second period from a standard height of 10 metres.

3. Event Description and Analysis

3.1. March 2025

On March 8, 2025, Ex-Tropical Cyclone Alfred made landfall in south-eastern Queensland. The cyclone caused significant damage in South-East Queensland and North-Eastern NSW, including major riverine flooding in the Richmond, Clarence and Bellinger Rivers, and severe flash flooding in the north-eastern NSW (Bureau of Meteorology, 2025a).

The cyclone also caused large-scale power outages, extensive coastal erosion and property damage from wind and falling trees. The Bureau of Meteorology reports 500,000 customers were without power in southeast Queensland and northeastern New South Wales for several days, generally due to windy conditions and fallen trees (Bureau of Meteorology, 2025a). Essential Energy reports that 100,000 of their customers were without power during this event (Essential Energy, 2025).

Diagram 2 plots the daily rainfall totals occurring between 5th March – 11th March 2025. The rainfall data for 2025 was obtained directly the Australian Water Outlook website (Bureau of Meteorology, 2026). The bottom right panel shows the total event rainfall over this period, including 100 and 200mm rainfall depth contours. These show the approximate event footprint, confirming that most of the rainfall occurred in the Richmond, Bellinger and Clarence basins.

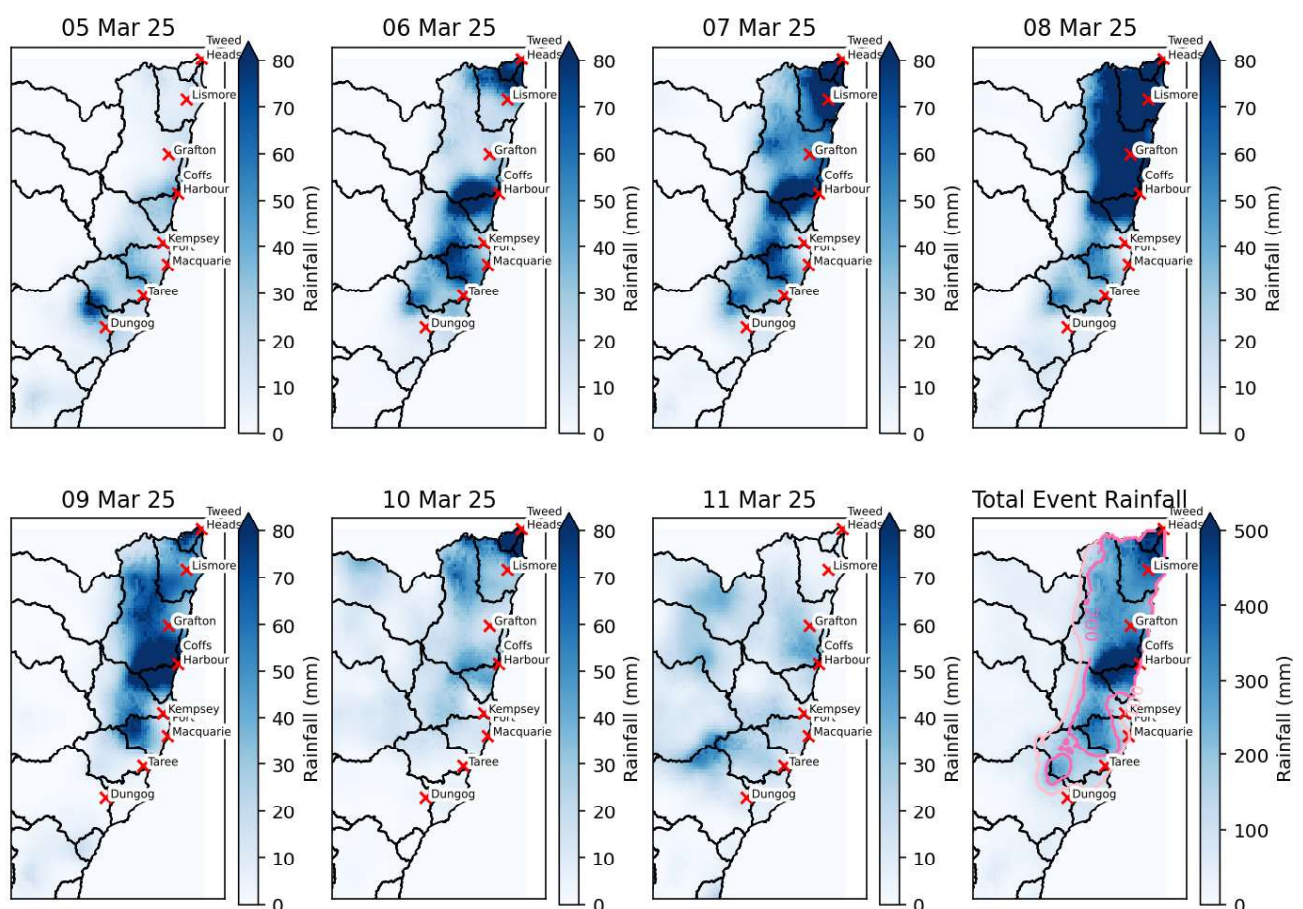


Diagram 2: Rainfall occurring between the 5th – 11th of March over East Coast NSW basins

3.2. May 2025

A low-pressure trough developed off the coast of NSW on May 18th. The low-pressure trough tracked northwards between the 19th and 21st of May, impacting the Mid North Coast, Northern Hunter, and Northern Tablelands.

From May 22nd, rainfall spread across much of Eastern NSW. The rainfall led to flash flooding and minor to major riverine flooding along most of the east coast of New South Wales. The Manning River at Taree exceeded “major” flood levels reaching a new record of 6.45 m on 22 May. There were also reports of rivers reaching Major flood levels in catchments across the Hunter and Mid North Coast districts (Bureau of Meteorology, 2025b). Essential Energy reports that more than 46,000 customers were without power due to the heavy rain and extensive flooding during this event (Essential Energy, 2025).

Diagram 3 shows the rainfall occurring between 18th May – 24th May for NSW. The panel on the bottom right shows an estimate of the total event rainfall. The 100 and 200mm depth contours show the event footprint of this event was further south than the event in March, with most rainfall occurring over the Bellinger, Hasting, Mannings and Port Stephens regions.

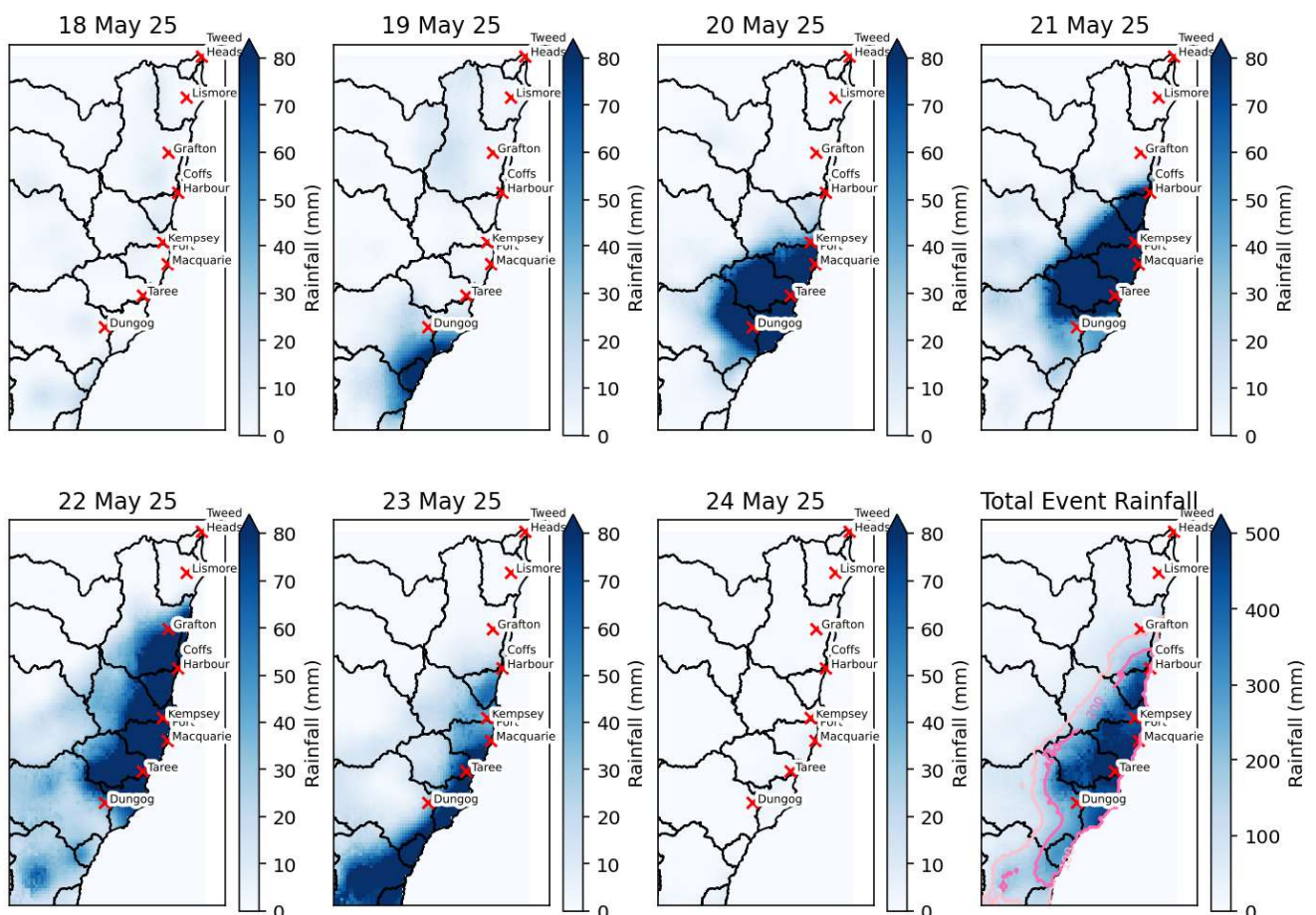


Diagram 3: Rainfall occurring between the 18th – 24th of May in East Coast NSW basins

3.3. Event footprints

Diagram 4 summarises where at least 100mm of rainfall was received in each event. The

Bellinger, Hastings, Manning, Macleay and southern sections of the Clarence basins experienced high event totals in each of the events, and this is the region where it can be reasoned that the impacts of the Cyclone Alfred in March and the Easterly Trough in May are more likely to be linked.

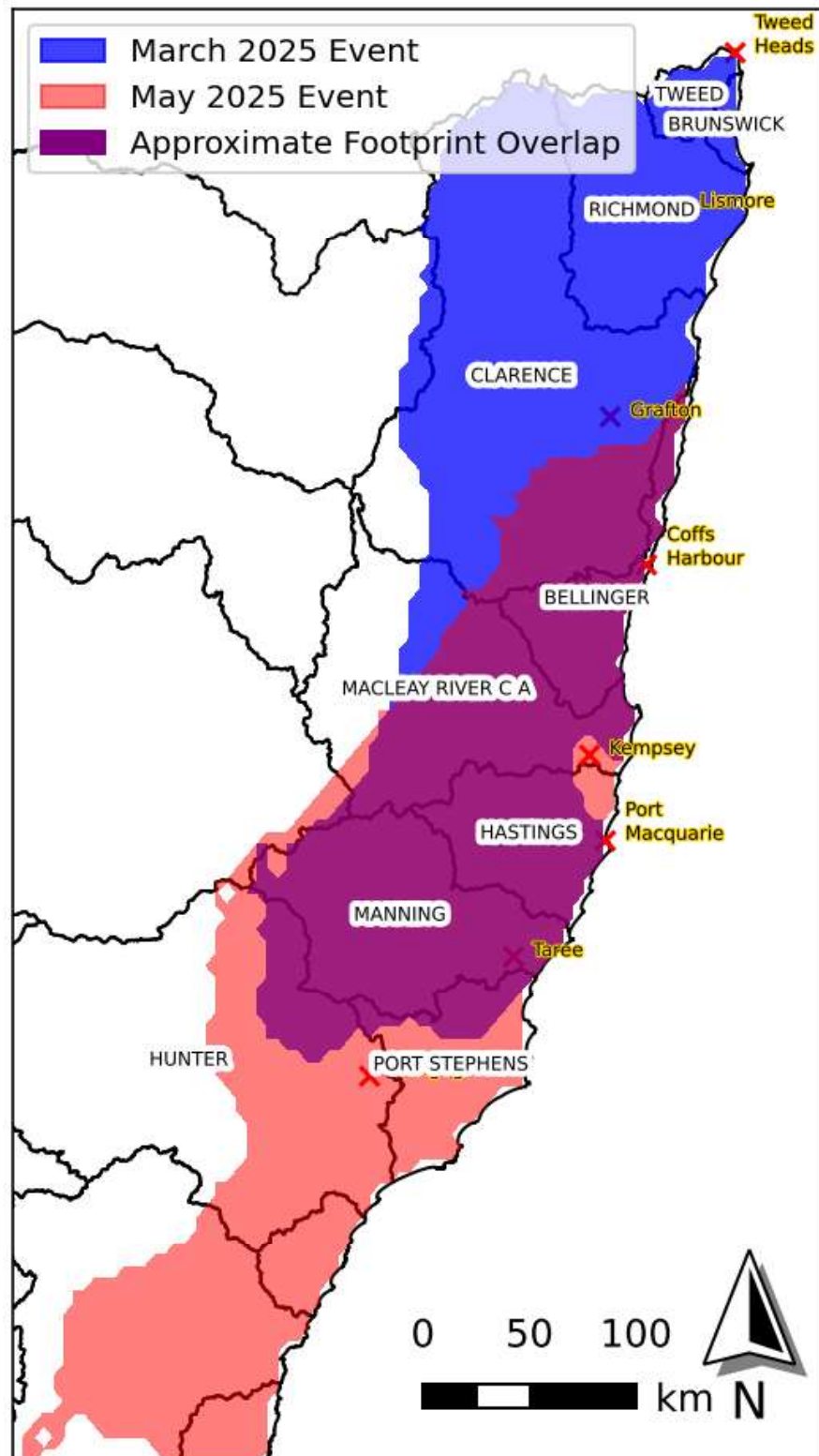


Diagram 4: Footprint overlap from each event where at least 100mm of rainfall was received in each event.

3.4. Inter-event period

3.4.1. Rainfall

In the period between the two events (inter-event period; 12 March – 17 May), the NSW East Coast experienced persistent rainfall that was far higher than the seasonal average. Rainfall data for the same inter-event period was acquired for each year since 1920. This data was available from AGCD.

Rainfall depths in the inter-event period were assessed for each of the catchments shown in Diagram 1. Diagram 5 plots the cumulative rainfall between the 12th of March and 17th of May for all basins, and plots three recent events (2015, 2022, 2025) against long term percentiles. For example, in the Tweed, this interevent period had approximately 500mm of rainfall in 2025. By the end of the period, this plots just above the lightest blue region. This means the interevent rainfall is just above the 75th percentile, and approximately 25% of years have had more rainfall over this same period.

While there was not as much rainfall in this period as some recent wet years (such as 2022), there are apparent ‘top-up’ events in the inter-event period. Across most basins in the mid-north and north coast, this period was in the wettest 10% – 25% of years. This is particularly important, because many of the years exceeding it would have been accompanied by widespread riverine flooding – in 2025 the inter-event period was very wet without any major flooding.

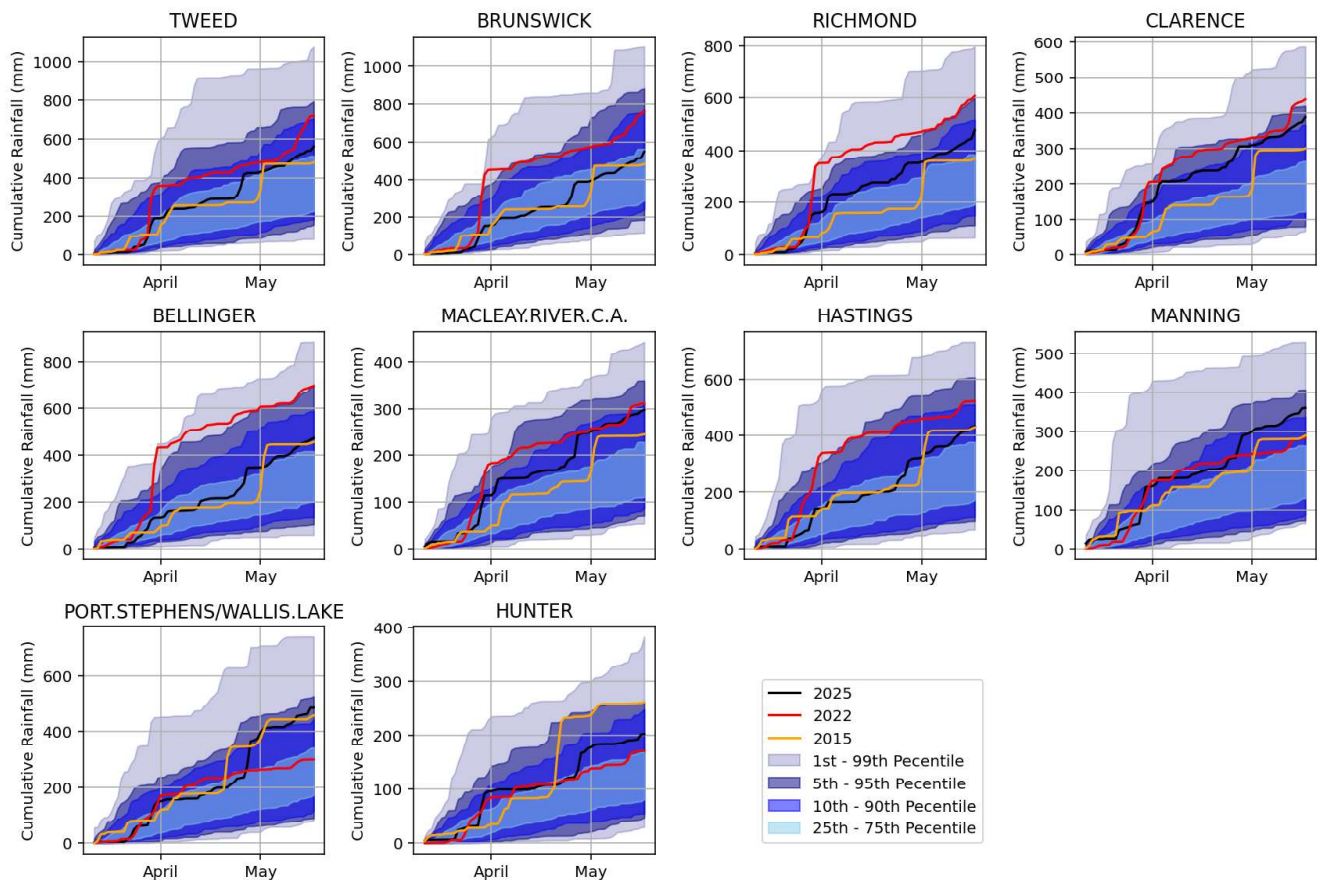


Diagram 5: Cumulative rainfall in the inter-event period since 1920.

Assessing cumulative rainfall totals over the last 100 years between March 1st and June 30th builds on the above. This is shown in

Diagram 6. The total rainfall across this entire period in coastal basins north of the Hunter far exceeded the 95th percentile. This is particularly the case for the Clarence, Bellinger, Macleay, Hastings, Mannings and Port Stephens.

Therefore, when both the March and May events are considered, 2025 was one of the wettest years on record, particularly for the mid-north coast. Even before the main burst of the May 2025 event, most basins were experiencing total rainfall which was in the wettest 5% of years. This shows how the March and May events were linked – the catchment conditions prior to the May 2025 event would have been far wetter than average, amplifying the risk of flooding and damage.

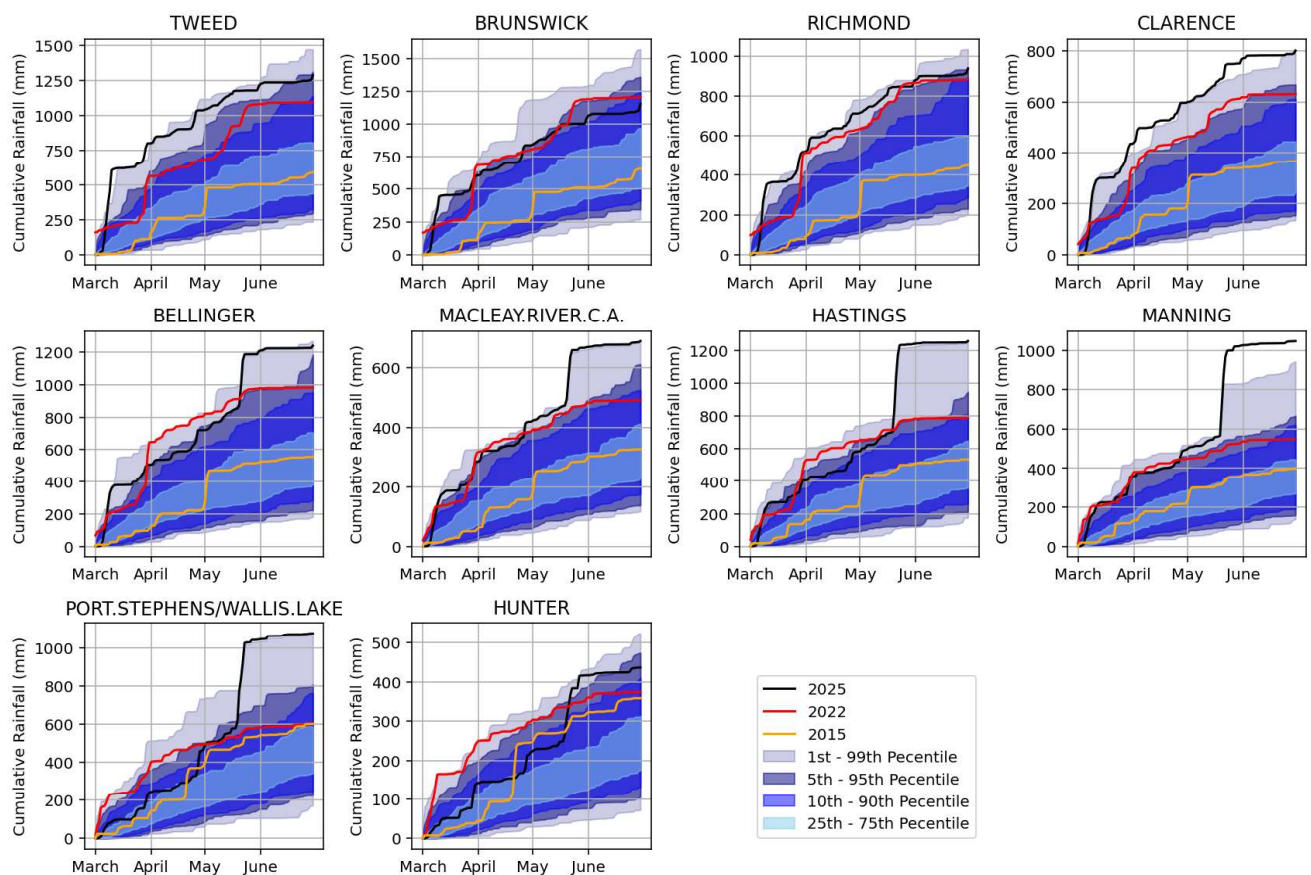


Diagram 6: Cumulative rainfall between 1st March - 30th June since 1920.

3.4.2. Soil Moisture

The average soil moisture fraction in the top 1m of soil was extracted from AWRA-L for each basin between 1911 – 2025. For each day of the year, the soil moisture in 2025 was compared against all years in the long-term record and the relative quantile was extracted. This was computed on a one-week rolling average through the data to remove noise in the output. The results of this analysis are shown in Diagram 7.

If the catchment average soil moisture value on a certain day, say the 1st of May, is exceeded in half of the years between 1911 to 2025 (i.e. exceeded in approximately 57 years), it will plot at 'AVERAGE' in Diagram 7. If the soil moisture were exceeded in only 10% of years (i.e. exceeded

in approximately 11 years), it would plot at 'TOP 10%' in the diagram. This analysis is shown for each catchment basin in the recent years of 2015, 2021, 2022 and 2025. The inter-event period is the region between the two vertical dashed black lines.

The following summarises the key findings from the Diagram:

- Before Ex-Tropical Cyclone Alfred in early March, soil moisture conditions were approximately average or less than average for this time of year. This is true for all catchment basins analysed.
- In the inter-event period, there were several top up events. These occurred at the end of March and end of April. This is clear looking at the Mid-North Coast catchment basins in the second row of figures.
- Prior to the coastal low in May, all basins had a soil moisture fraction which exceeded their 90th percentile, except for the Hunter. This shows that the inter-event rainfall created antecedent conditions for the May event that were far wetter than the March event.
- Compared to years such as 2015 and 2021, the soil moisture remained high over a longer period. The soil moisture behaviour was similar to 2022 in some basins, staying relatively high over a prolonged period.

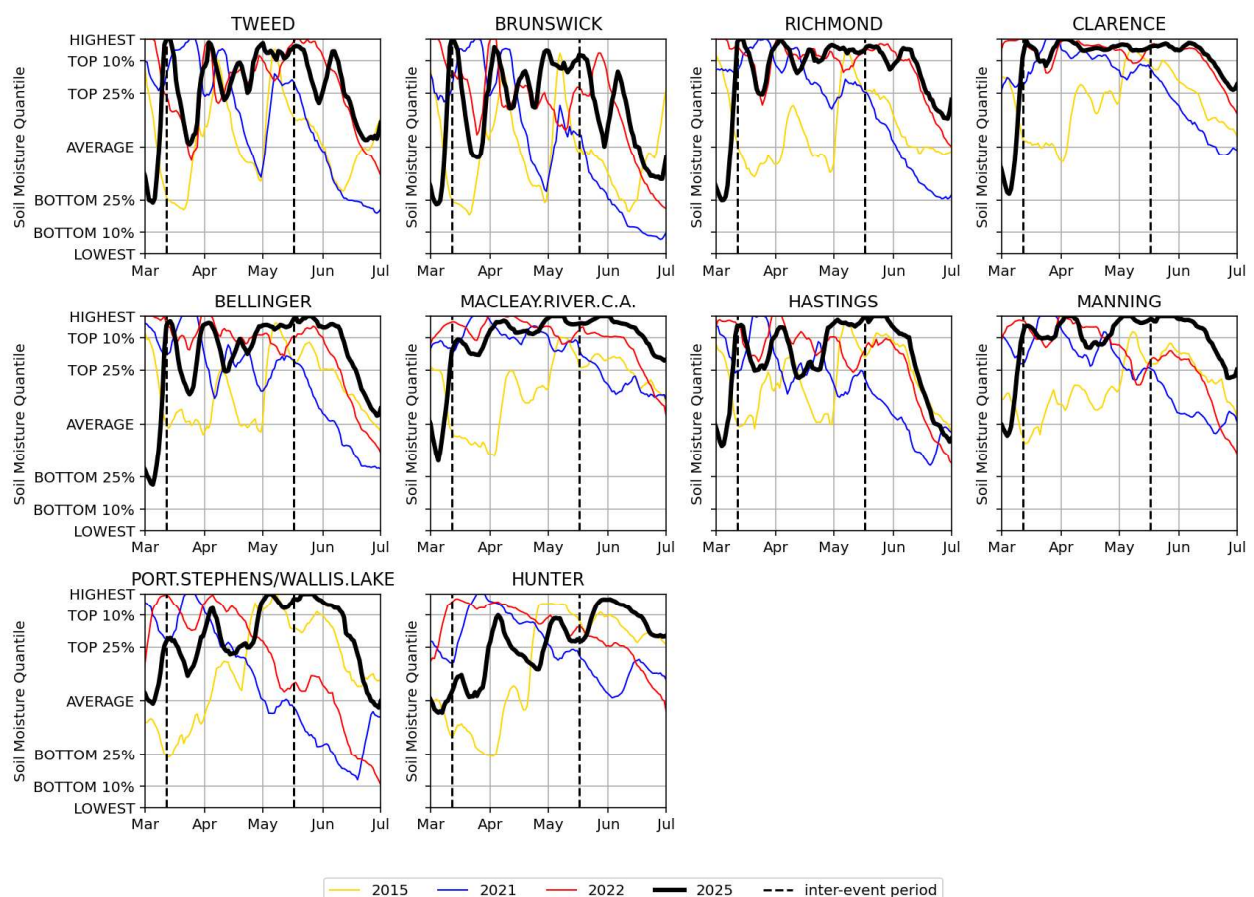


Diagram 7: Comparison of the 1-week rolling average soil moisture quantiles for 2015, 2021, 2022 and 2025.

Next, the average soil moisture across the entire inter-event period was calculated and compared to all years in the record over the same period. This was done for each catchment basin. The average soil moisture over the inter-event period is above the 95th percentile in all basins north of the Hunter. In some catchments, such as the Richmond, Clarence, Bellinger, Macleay, Hastings

and Manning, the soil wetness, as estimated by AWRA-L, is at or near its maximum.

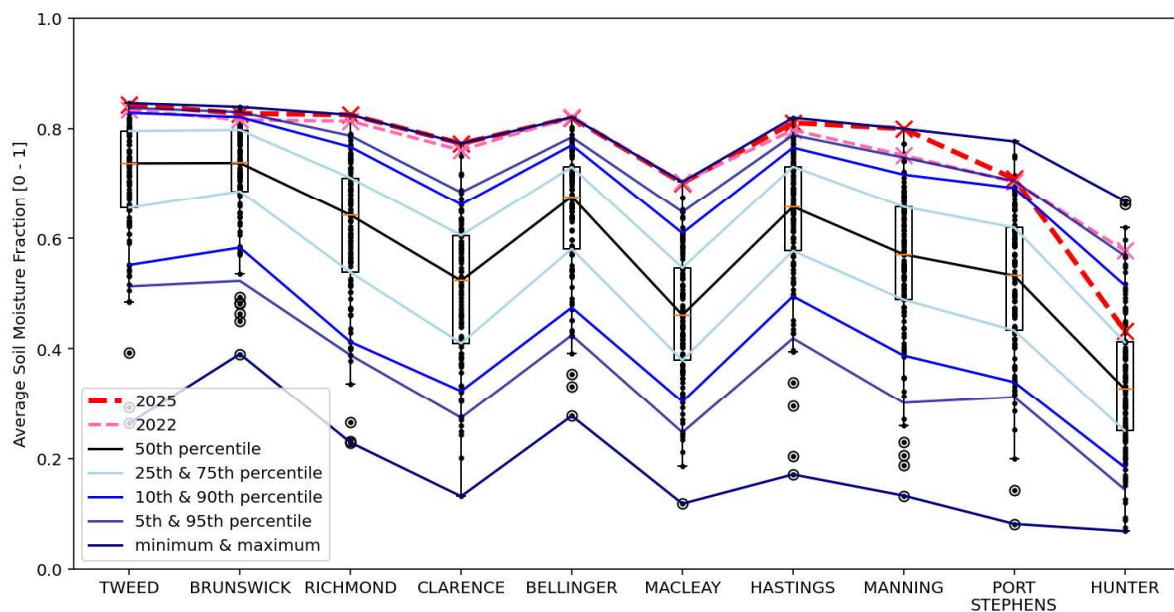


Diagram 8: Average soil moisture fraction in the inter-event period since 1911.

3.5. Wind speed

Between the 3rd and 8th of March, the North Coast and Northern Rivers in particular experienced high peak wind speeds, as measured by the Bureau of Meteorology. Maximum wind gusts of between 50 – 120km/hr were recorded in this part of the state over these days. The maximum recorded wind gust was 120km/hr at Byron Bay on the 7th of March, as per the Bureau of Meteorology climate statement (Bureau of Meteorology, 2025a). This is shown in Diagram 9. High wind speeds and power outages are highly correlated, as trees may be uprooted or power poles may be toppled by wind. This was observed during the event, as per the annual statement from Essential Energy (2025).

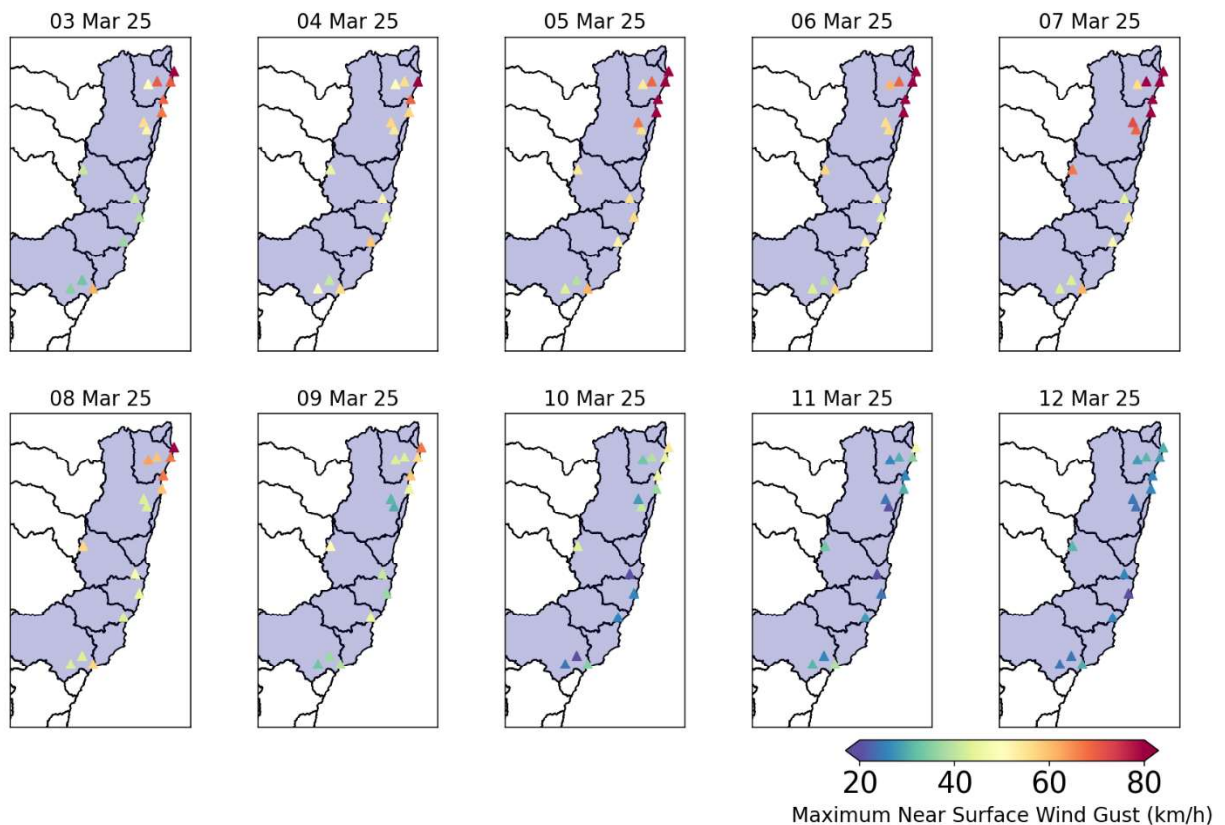


Diagram 9: Peak wind gusts between the 3rd-12th of March

During the second event in May, wind-speeds were lower. This is expected due to the difference in storm mechanism between the two events – tropical/ex-tropical cyclones are typically accompanied by very strong winds. In this event, the mid-north coast received maximum recorded wind gusts in the order of 40-50km/hr between 19th – 21st of May, including 74km/h at Taree Airport on the 19th of May. While the wind-speeds were lower than the first event, it has been shown this event was preceded by a very wet inter-event period. These factors would have contributed to an increased risk of power-outage, despite the lower recorded wind speeds.

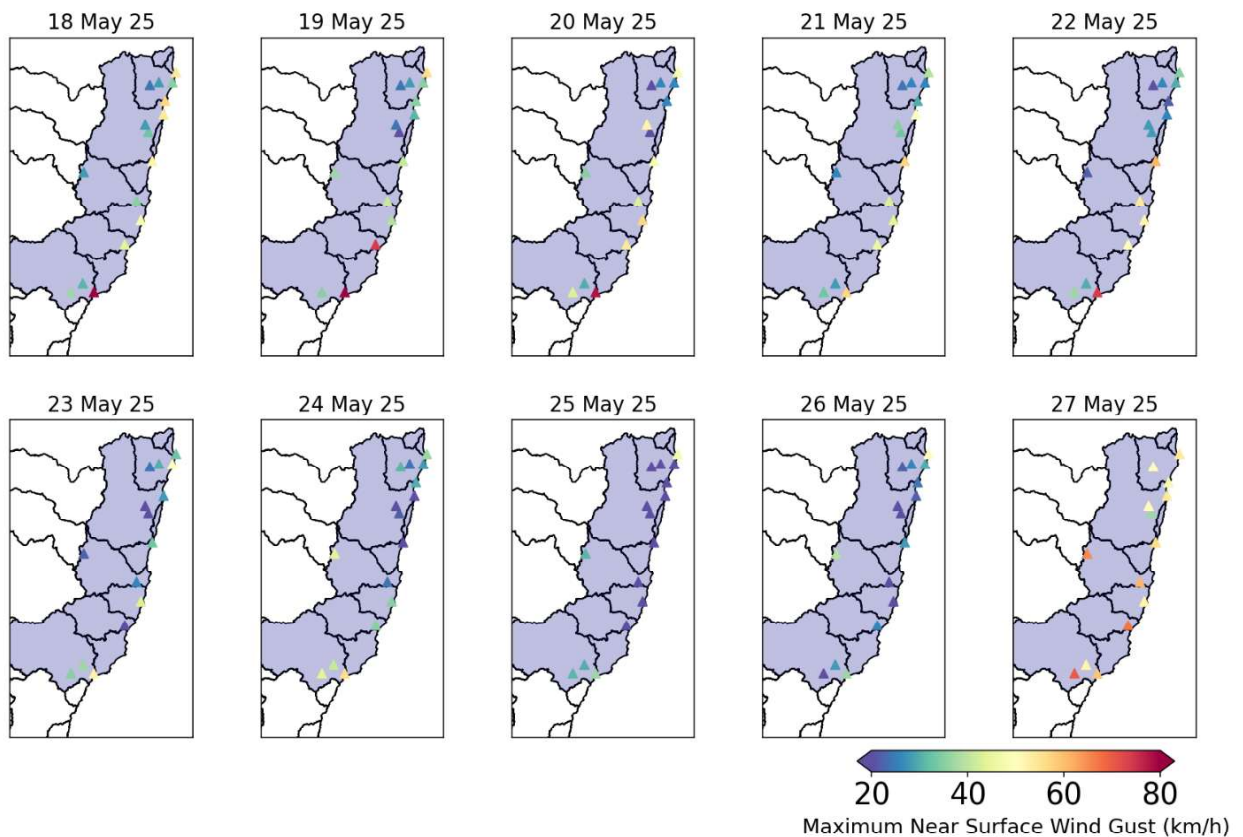


Diagram 10: Maximum wind gusts recorded between the 18th-27th of May

3.6. Mid-North Coast Flooding (May 2025)

According to Essential Energy (2025), “floodwaters had washed away power poles and electrical equipment, including streetlights, while the weather brought down trees over powerlines and equipment”. During the event, the worst flooding occurred on the Manning River at Taree which reached 6.45m at the gauge - a new annual record since recording began. The Mid-Coast council estimate the event was in the order of a 1 in 500 AEP event (MidCoast Council, 2025).

Rivers reaching major flood levels include the “Nambucca River at Macksville, the Macleay River at Kempsey, the Hastings River at Wauchope Railway Bridge and Settlement Point, and the Manning River at Wingham, Taree and Croki” (Risk Frontiers, 2025a). This led to the following towns being severely impacted by flooding (as per Risk Frontiers, 2025b):

- Taree, Glenthorne, Wingham, Croki (Manning)
- Port Macquarie and Wauchope (Hastings)
- Kempsey, West Kempsey, Smithtown, Sherwood Bridge (Macleay)

It is apparent that the Mid-North Coast was significantly impacted by the extreme weather occurring in May 2025. The analysis of antecedent conditions in the inter-event period showed soil conditions were far wetter than average across the Macleay, Hastings, Manning and Port Stephens catchments. These conditions, as has been described, would have likely exacerbated the flooding which occurred during the event.

3.7. Soil Moisture and Power Outages

Numerous studies have examined the link between antecedent soil moisture, rainfall, and other climatic variables to the prediction of power outages during high wind events. The reasoning behind this is that saturated soils increase the likelihood of trees being uprooted or poles being blown over when subjected to strong winds (Quiring et al., 2011). Examples of this include Han et al. (2009) who included soil moisture and other variables in a generalised linear model, improving the accuracy of outage prediction compared to previous models.

The importance of soil moisture as a covariate was also shown by work done by McRoberts et al. (2018). Other research has used satellite derived soil moisture data to forecast power outages with 91% accuracy during Hurricane Matthew on the East Coast of the USA (Gorder, 2016). This is not to say that soil moisture alone can be used to determine outages but can likely be used as a covariate with other climatic variables (such as wind speed, precipitation, elevation, soil class, tree cover) to help predict the vulnerability to damage.

4. CONCLUSIONS

This report examined the link between Ex-Tropical Cyclone Alfred, which occurred in March 2025, and the flooding and widespread damage caused by an easterly trough in May 2025.

Key Conclusion

It has been shown that Ex-Tropical Cyclone Alfred (March) and the widespread riverine flooding in the Mid-North Coast (May) were linked, both temporally and geographically. It can be reasoned that the impacts experienced from the May event, particularly on the Mid-North Coast, were related rather than independent. That is to say, the riverine flooding and extensive damage to power infrastructure in May 2025 was amplified by the earlier Ex-Tropical Cyclone Alfred and the subsequent top- up rainfall prior to the May 2025 event. The following is a summary of the findings:

Event Footprint(s)

- There is significant overlap between the footprint of the two events. Diagram 4 shows where there is a strong case that storm related damages in May 2025 were linked to Ex-Tropical cyclone Alfred and wet conditions in the inter-event period.
- The catchment basins where both events had high rainfall totals include the Bellinger, Hastings, Manning, Macleay and the upper catchments of Port Stephens (Williams and Paterson Rivers).

Antecedent Conditions

- Before Ex-Tropical Cyclone Alfred in March, soil moisture conditions were average or less than average for this time of year.
- Prior to the coastal trough in May, all basins assessed had an average soil moisture fraction which exceeded their 90th percentile, except for the Hunter. This shows that the frequency and intensity of Ex-Tropical Cyclone and the subsequent inter-event rainfall created very wet antecedent catchment conditions.

Inter-event period

- As discussed, there were frequent ‘top-up’ rainfall events in the inter-event period. These occurred at the end of March and end of April. While not particularly rare, these smaller events prevented the catchment from drying out.
- Over the entire inter-event period, the average soil moisture fraction across all basins North of the Hunter were at or above the 95th percentile and some basins experienced their maximum average modelled soil moisture comparing against the same period in 100+ years.
- Compared to recent historically wet years such as 2015 and 2021, the soil moisture remained high over a longer period in 2025.

Wind Speed

- Very high wind-speeds were experienced during Ex-Tropical Cyclone Alfred, particularly in the North Coast.
- During the easterly trough in May, maximum wind speeds were high on the mid-north Coast, but not in the order of magnitude observed in the March event.

Damages-Incurred

- Numerous studies have examined the link between antecedent soil moisture, rainfall, and other climatic variables to the prediction of power outages during high wind speed storm events.
- Soil moisture alone does not predict or determine outage locations but is likely a useful covariate with other climatic variables (such as wind speed, precipitation, elevation, soil class, tree cover) to help predict outage locations.
- The damage due to riverine flooding in the Manning, Hastings and Macleay Rivers for the May event is more direct, and the severity of the flooding and associated damages were influenced the high rainfall experienced in the months prior to the event.

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