From storm to study: Insights on resilience from Tropical Cyclone Alfred

Understanding damage, vulnerabilities and future risk in south-east Queensland and north-east New South Wales

Dr Geoff Boughton[1], Dr David Henderson[1], Dr Bruce Harper[2]

1. Cyclone Testing Station, James Cook University, Townsville 2. Systems Engineering Australia

Version	Release history	Date
1.0	Initial release of document	06/05/25

Australian Government

Natural Hazards Research Australia receives grant funding from the Australian Government.

We acknowledge the Traditional Custodians across all the lands on which we live and work, and we pay our respects to Elders both past, present and emerging. We recognise that these lands and waters have always been places of teaching, research and learning.

Publisher:
Natural Hazards Research Australia

ISBN: 978-1-923057-24-1

Report number: 45.2025

May 2025

Cover: Cyclone Testing Station, James Cook University

Photo credits: All images in this report are courtesy of the Cyclone Testing Station, James Cook University

Table of contents

Acknowledgements

The authors thank the residents of the affected Southeast Queensland communities who generously assisted with this study by volunteering information and inviting the authors onto their properties, and to the staff of City of Gold Coast, City of Redlands, City of Moreton Bay, staff of Queensland Police Department, Queensland Fire Department, and Suncorp for intelligence and assistance.

The authors also acknowledge the assistance and information from:

- University of Queensland – Dr Matthew Mason
- Bureau of Meteorology – especially Joshua Soderholm for providing data and Joe Courtney and Andrew Burton for providing the Bureau of Meteorology summary information.

The Cyclone Testing Station (CTS) is grateful for the financial support from Natural Hazards Research Australia and CTS sponsors and benefactors.

Executive summary

Tropical Cyclone Alfred (TC Alfred) approached south-east Queensland as a category 2 event with gust wind speeds estimated at 155 kilometres per hour. It stalled on approach and caused strong winds for around three days in southeast Queensland and north-east New South Wales (NSW). It also weakened and eventually crossed the coast in the north of Moreton Bay as an ex-tropical cyclone on the evening of 8 March 2025.

Maximum three second gust wind speeds around 100 kilometres per hour were experienced across the impacted zone from Redcliffe to Cape Byron. These lower than originally forecast wind gusts were not high enough to lift debris off the ground to become wind-borne. Even branches landed close to the tree from which they fell. The lack of wind-borne debris meant that few windows were broken. If the winds were 20 kilometres per hour higher, then the winds would have started to lift more roof tiles, pick up trampolines, garden sheds and rubbish bins and cause fallen branches to fly further. The low wind pressures and the lack of wind-borne debris contributed significantly to the low levels of structural damage in the area.

In these ways, the weakening of TC Alfred just prior to landfall meant that the large population in south-east Queensland and north-east NSW ‘dodged a bullet’. Had the wind been closer to the 140 to 155 kilometres per hour gust wind speed that the Bureau was forecasting for this category 2 system, the level of structural damage could have been very different.

The peak gust measured was 82 per cent of the design serviceability wind speed and 55 per cent of the design ultimate wind speed for importance level two buildings.

Even at the relatively low wind speeds in the event, some buildings in poorer condition were structurally damaged and wind-driven rainwater entered many buildings. The low incidence of structural damage meant that for the majority of buildings, rainwater ingress was through an undamaged building envelope. Water entered through closed windows and masonry blockwork at wind speeds less than the serviceability wind speed. Weatherproofing systems of buildings need to improve to strengthen community resilience.

Some issues associated with tall residential buildings were observed. In addition to the weatherproofing, there were issues with pedestal-mounted pavers on balconies, windows at or near ground level and differential pressures within buildings which prevented occupants from opening their apartment entrance doors. The event also highlighted the dependence of these buildings on power and the need to have reliable backup power sources for essential services such as operation of sump pumps, lifts, fire equipment and emergency lighting. Several aspects for improvement are noted:

- messaging for future tropical cyclones in this area
- selection of corrosion-resistant materials for hidden structural elements
- weatherproofing for buildings
- fastening balcony pavers
- resilience measures for tall buildings.

End-user statements

Commissioner Steve Smith AFSM, Queensland Fire Department
"This recent damage survey by the James Cook University Cyclone Testing Station adds to their significant body of knowledge on the impacts from severe weather events. This body of knowledge has been a fundamental input to the information used by Queensland Government for tropical cyclone preparedness for ex-Tropical Cyclone Alfred; the Severe Wind Hazard Assessment for Queensland and south-east Queensland. These documents have been instrumental in raising awareness in south-east Queensland to the estimated geographical extent and impact from tropical cyclones, and the expected frequency of these impacts.

"This recent damage survey highlights the growing issue of wind driven water ingress which is leading to further building issues and has the potential to increase risk to life safety. We support the continued efforts of the James Cook University Cyclone Testing Station to advocate for changes in the design and construction of the homes that we live in."

Deputy Commissioner Daniel Austin, NSW State Emergency Service
"Given it has been some 35 years since there was a cyclone that directly impacted New South Wales, this research will support our knowledge and understanding into the future."

Introduction

This report investigates damage to buildings caused by Tropical Cyclone Alfred that crossed the south-east Queensland coast near Bribie Island on Saturday, 8 March 2025 at around 9 pm as a tropical low.

The investigation commenced 5 March 2025 and covered sites in Moreton Bay City Council, Redlands City Council and Gold Coast City Council. It was supported by street-based observations in north-east NSW and Brisbane City Council to establish whether damage patterns in other areas followed those in the investigated areas.

The field deployment aligns with Natural Hazards Research Australia's (the Centre) research priorities focused on improving community resilience to extreme weather events through evidence-based building design and construction practices.

Objective

As Tropical Cyclone Alfred approached landfall near Bribie Island in March 2025, the Cyclone Testing Station deployed a team to south-east Queensland and northern New South Wales to undertake a rapid post-event damage assessment. The team commenced investigations on 5 March 2025 focusing on areas affected by wind, rainfall and coastal processes. The deployment covered sites including the Gold Coast, Redcliffe and Ballina, where storm impacts varied in severity.

Field observations included photographic documentation, inspection of structural elements, and assessments of water ingress, power disruption, and damage to building envelopes. Particular attention was paid to the performance of windows, roofs and building components under sub-design wind conditions. Wind speed data from 34 automatic weather stations were analysed and corrected for terrain and topography to benchmark building performance against relevant standards.

The study aimed to identify recurrent vulnerabilities and contribute to the evidence base supporting improved building codes, construction practice and community preparedness in cyclonic regions.

Wind field

Data from 34 Bureau of Meteorology Automatic Weather Stations was analysed to establish wind speeds and directions for the period in which the study area was affected by TC Alfred. The work involved adjusting wind speeds for terrain and topography so that the output was equivalent to standard conditions – flat land with open terrain. While the gust wind speed records were all 3 second gust wind speeds, the Australian wind loading Standard AS/NZS 1170.2 uses 0.2 second wind gust speeds, so the data was all converted to 0.2 second gusts which are around 12 per cent higher. This enabled it to be compared directly with the design wind speeds tabulated in AS/NZS 1170.2.

Refer to Cyclone Testing Station *Technical Report 70 - TC Alfred, SE Queensland and NE NSW: Damage to Buildings* for detail on the conversion of the wind gust data and development of the wind field map shown in Figure 1.

TC Alfred crossed the Australian coastline at latitude 27^{o} 10’, which is almost in the centre of wind region B1 which is applicable to south-east Queensland and northern NSW. All the discussion relates to the winds compared with those used as the basis of design of buildings in region B1.

- The maximum 0.2 s wind gust of 31 metres per second was 82 per cent of V_{20} for region B1 – usually used as the serviceability design wind speed
- The maximum 0.2 s wind gust of 31 metres per second was 55 per cent of V_{500} for region B1 – usually used as the ultimate design wind speed – appropriate for the strength design of Importance Level 2 Buildings such as houses, small offices, shops and warehouses.

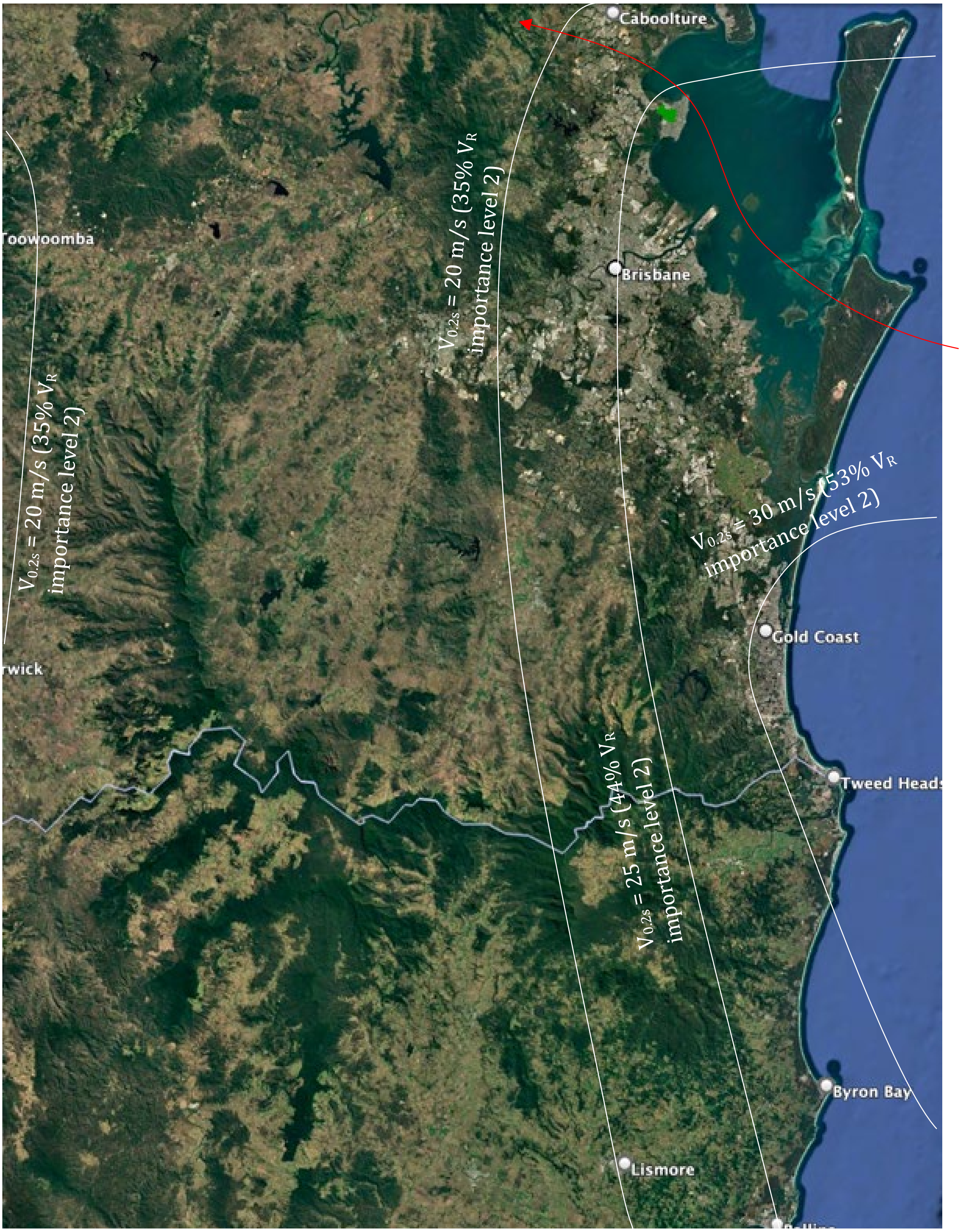

Figure 1: Estimates of wind speed as percentage of design

Storm tide measurements

Data from tide gauges, storm tide gauges and wave buoys in both Queensland and NSW were obtained from the relevant government monitoring bodies and analysed to estimate the maximum height attained by storm tide (shown as the black line Max WL in Figure 2), and the water height above the normal astronomical tides – storm surge (the green line in Figure 2).

For the gauges within Moreton Bay, the measured storm surge was around 0.5 metres, and for tide gauges from Gold Coast to Yamba in NSW which were located on the open coast, the measured storm surge was around 0.8 metres. The difference is attributed to breaking wave setup produced by the large waves that were also measured in south-east Queensland and north-east NSW.

Refer to *Technical Report 70 – TC Alfred, SE Queensland and NE NSW: Damage to* Buildings for more details on the analysis of water height data.

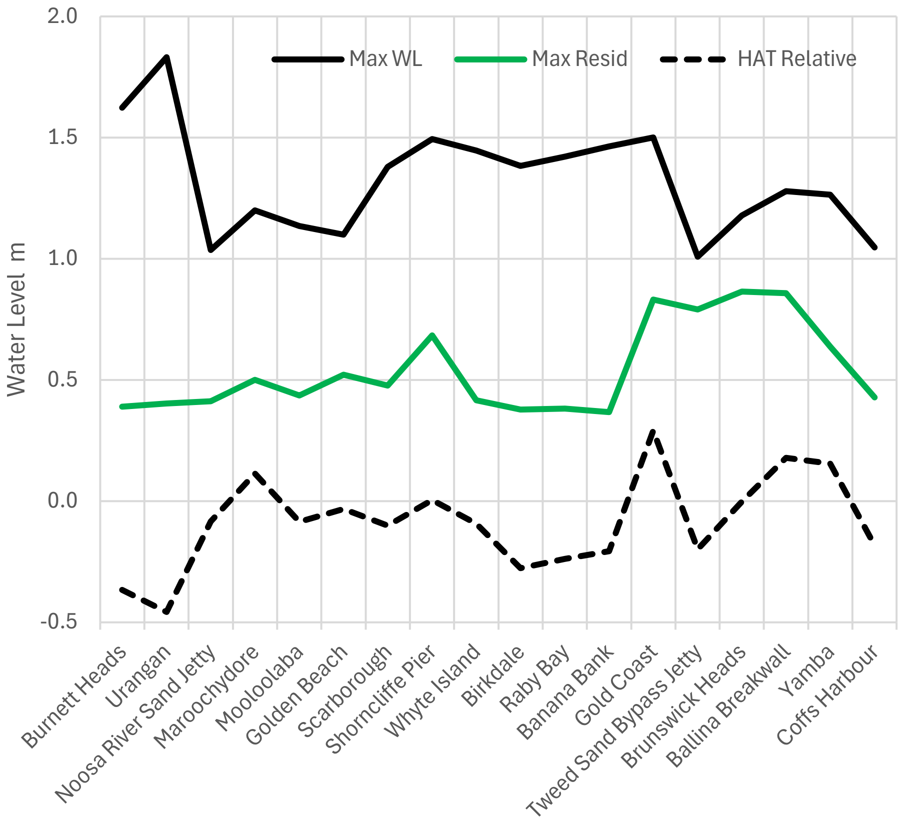

Figure 2: Estimates of water level above highest astronomical tide (HAT)

The storm tide reached around the Highest Astronomical Tide mark since the crossing of TC Alfred occurred during a period between spring tides and neap tides when the high tide level was falling from the spring tides five days prior to the crossing.

Because the built environment has clearance to the Highest Astronomical Tide, there was little effect of storm tide on structures in this event.

The strong winds caused significant waves, though no wave height records were broken. Beach erosion was widely reported along surf beaches in the study area.

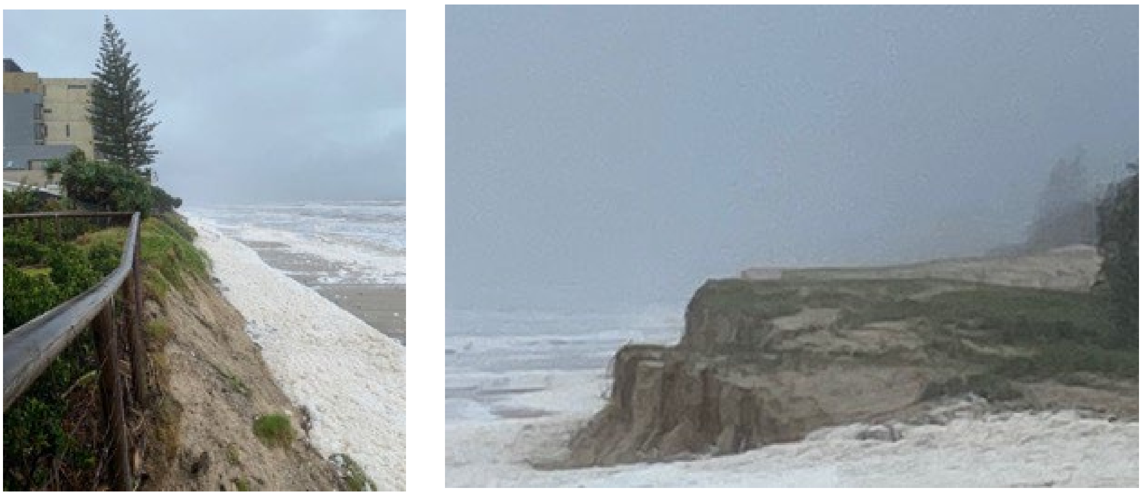

Figure 3 - Coastal erosion from storm tide

Damage from wind effects

The most conspicuous damage was to trees. It ranged from loss of small branches to whole trees falling. The tree damage was similar to other events where recorded 3 sec gust wind speeds were 100 kilometres per hour or less.

- Where trees fell on powerlines, they caused power outages.
- Where trees fell on buildings, they caused damage to the building.
- Where trees fell across roads, they caused disruption to transport.

Figure 4: Fallen tree in Gold Coast

Roof damage

Four buildings were studied where partial roof failure had occurred. In all of these cases, deterioration had caused a loss of performance in some structural elements. This highlighted the critical role played by building maintenance. Because the peak gust wind speeds were less than 60 per cent of the design strength wind speed for the region, the general lack of wind damage was to be expected and these cases highlighted how deterioration can significantly reduce the performance of buildings.

Figure 5: Damage to buildings

Windborne debris

The peak gust wind speeds were slightly less than the wind speed that is typically required to lift potential debris off the ground. This meant that any elements lifted from buildings fell close to the building they came from and other light items on the ground were not lifted. This meant that there were few, if any, cases of buildings being impacted by wind-borne debris.

Glass failure

The absence of wind-borne debris meant that few windows and doors were broken. The wind speeds were also lower than the speeds at which glass should be broken by wind pressures. A few broken windows were due to high pressures at the base of tall buildings that are due to 'downwash' effects.

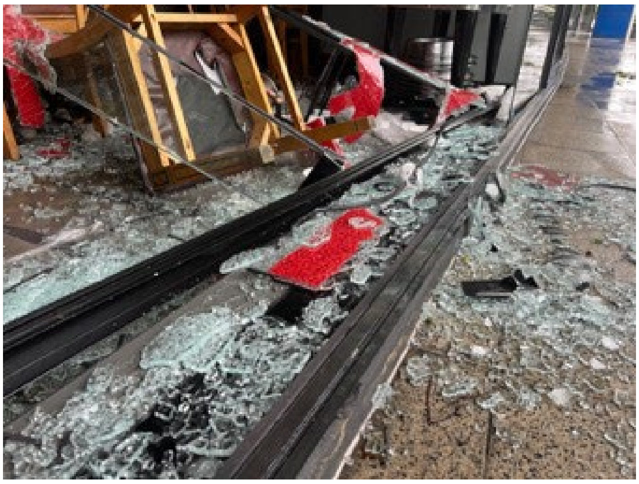

Figure 6: Broken shop front glazing from accelerated winds

Minor structural wind damage

There was minor damage to sunshades on tall buildings and gutters and flashings on lower buildings. Some shade sails were damaged, but many were not damaged because of the low wind speeds experienced. No observations were made of solar panels that had broken or become detached. Significant damage was noted on a retrofitted enclosed veranda that was completely destroyed, while the house it was attached to suffered only minor damage.

Water damage to buildings

The fact that there was so little structural damage to buildings meant that any water ingress occurred through an undamaged building envelope. The study observed the following main entry points for water:

- through the roof
- through closed windows
- through walls
- into basements

The field investigations were based on tens of buildings and were confirmed by anecdotes from other occupants. However, preliminary insurance data indicates that more than one per cent of insured properties in the most significantly affected areas of north-east NSW and south-east Queensland have lodged claims related to rainwater ingress. This will represent a significant cost in an event that had peak gusts that were less than the serviceability design wind speed across the whole area.

Water entering through the roof

Water entered the roof space as wind-driven rain being forced under flashings or through minor gaps in the roof cladding. It was also observed to have come through tile roofs without sarking. Because of the relatively low wind velocities, volumes of water entry were relatively low, but there was still enough to cause mould growth on ceilings or saturate ceiling insulation.

Water entering through walls

There were many instances of water entering directly through concrete block walls. This type of wall relies on weatherproofing using external membranes to stop water from soaking into the porous blocks. These membranes can include washes applied directly to the blocks, render or acrylic paints. Where these had deteriorated, water could find its way into the blocks. Differential pressure between the outside and inside of the building drove the water through the blocks to the inside surface of the blockwork.

Once water was on the inside of the blockwork, it ran down the inside to the concrete slab, where it ponded under the floor coverings.

Figure 7: Water ingress through masonry walls

Water entering through closed windows

There were many social media posts during the event of water entering through closed windows and running down the inside onto floor coverings. Water can enter windows through seals, gaps around moving parts and through weep holes. Under normal operation, any water that gets to the inside of a window drops into the sill where it is drained to the outside through weepholes. Under high winds, there is a strong pressure differential from the outside to the inside across the window. This can prevent water from draining out of the sill and drive water through the weep holes from the outside.

Figure 8: Wind driven rainwater ingress through window systems

Water in basements

There were many cases in which basements flooded. High water tables associated with strong rain and storm surge meant that seepage was much faster than normal. In some cases, rainwater entered basements by running down the inside of walls, seeping through slabs or running through the vehicle entrance.

Water in the basement flooded the sump and, in some cases, overwhelmed the sump pumps. In other cases, power failures meant that sump pumps didn't start and basements flooded. Flooded basements led to loss of cars and items stored in the basement and damage to electrical transformers and switchboards.

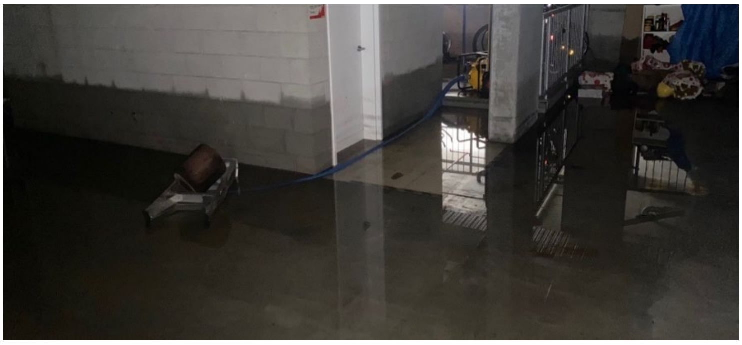

Figure 9: Flooded basement

Consequences of water entry

Water inside the building damages floor coverings, contents and in some cases, can cause damage to wall and ceiling linings.

In addition, water entry to junction boxes can cause short circuits in the short term in electrical or communication circuits. In the longer term, it may cause corrosion that could cause problems in the future. There were increased false alarms in fire systems in the most heavily affected areas.

TC Alfred crossed at a fraction of the forecast strength

Early forecasts had TC Alfred crossing as a category 2 tropical cyclone late on 6 March 2025. The forecast winds had 3 second gusts of 155 kilometres per hour. Fortunately, the cyclone stalled, weakened and crossed as an ex-tropical cyclone on 8 March 2025.

The reduction in strength and delay had the following effects:

- wind speeds were significantly lower than expected
- storm surge could have been higher
- the storm surge would have coincided with higher high tides (closer to spring tides).

The combination of these would have seen more significant damage from wind and from storm surge.

- If the wind had been 155 kilometres per hour rather than 100 kilometres per hour, then the wind pressures would have been 2.5 times the pressures experienced.
- Gust wind speeds of 155 kilometres per hour would have been high enough to lift potential items of debris. This would have broken some windows and this could have compromised the strength of buildings.
- Gust wind speeds of 155 kilometres per hour are similar to those measured in TC Seroja, which affected Kalbarri in Western Australia. Kalbarri has a latitude similar to Brisbane's and has the same design wind speed and design requirements. Kalbarri experienced a significant number of recently built buildings that had severe damage. (Refer to *Technical Report 66 – TC Seroja, Damage to Buildings in the Mid-West Coastal Region of WA)*
- The combination of a higher storm surge and higher high tides will mean that the water level would be well above Highest Astronomical Tide. This would lead to more storm tide damage to structures.

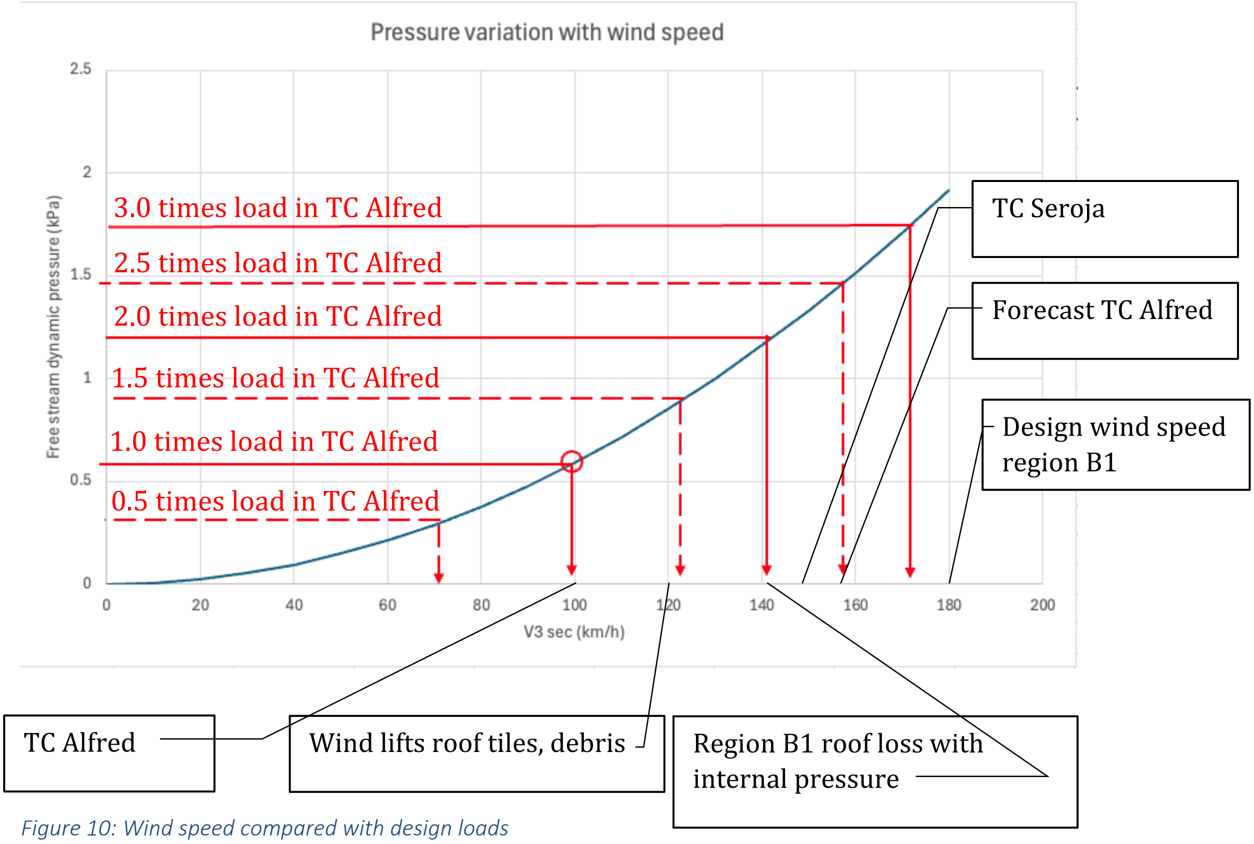

Figure 10: Wind speed compared with design loads

TC Alfred has made the population of this region aware of the chance that cyclones could impact this area in the future. It was fortunate that it crossed with a much lower wind speed than originally forecast and this contributed to the low levels of structural damage observed in the investigation.

However, the investigation observed relatively high levels of rainwater ingress, given the low wind speeds. Higher wind speeds in future events will cause significantly higher levels of rainwater ingress and will increase the level of structural damage for the community. Because of the high population in this area, increasing the damage above the level experienced in TC Alfred will have significant economic and social consequences.

Observations for improvement

Technical Report 70 – TC Alfred, SE Queensland and NE NSW: Damage to Buildings has drawn significant recommendations to make communities in south-east Queensland and north-east NSW safer and to improve the resilience of the community to future tropical cyclones in this area. They are reproduced here as they align with the Centre's objectives increasing community resilience through evidence-based information.

Observations for improvement on issues related to community safety

- TC Alfred demonstrated that storm tides can accompany tropical cyclones in this region. It is recommended that storm tides be included in all plans for community safety in tropical cyclone events.
- Continue to inform property owners of the importance of preparing buildings and yards for predictable high winds such as tropical cyclones and east coast lows. This includes the removal of shade sails and umbrellas prior to the arrival of the event.
- Some windows broke and the pressure across the windows in this event forced glass well into the building. In even stronger events, breaking glass could prove fatal, so it is important to maintain messaging about staying away from windows during strong winds.
- Brick ties in coastal locations should be made from materials that will not corrode, as their continued performance is vital to the safety of masonry walls under lateral loads in high winds or earthquakes.
- Pedestal-mounted pavers on balconies must be fixed down. It is recommended that standards for the installation of pedestal-mounted pavers include a requirement for anchorage of each paver.
- Specification of products used at ground level on or near high-rise buildings should consider the higher loads that occur in these areas due to the local flow patterns around tall buildings. In specific cases, these loads and pressures should be available from wind tunnel studies, but some guidance should be incorporated into AS/NZS 1170.2.
- Temporary or relocatable buildings should be wind-rated appropriately for their exposure.
- An evaluation of the performance of all buildings used as a place of refuge should be undertaken to give feedback on the level of shelter provided, the penetration of rainwater into the building and features of the buildings that either contributed to its role as a place of refuge or detracted from it. This information should be used to update the local list of potential places of refuge and guide the selection of places of refuge in the future.

Observations for improvement on issues related to resilience

- Water entry through closed windows was a problem in this event, even though the gust wind speeds were less than the serviceability wind speed for region B1 (wind region B1 applies to south-east Queensland and northern NSW). The glazing industry should be encouraged to incorporate simple features in the window design that control air movement through weep holes under differential pressures across windows. A method of evaluating the impact of these measures should be developed to inform purchasers of windows of the effectiveness of the windows at keeping out water at pressures above the water penetration test pressure.
- Effective sealing is vital to the watertightness of single skin structural systems such as reinforced concrete block walls. The sealing materials must be properly applied and the effectiveness of the weatherproofing maintained throughout the life of the building.

- Subterranean basements have the potential to accumulate water in extreme storms and sufficient backup power should be available to provide pump capacity even if mains power has failed during the event.
- All basements should be effectively sealed to reduce water seepage at all times and reduce the chance of corrosion of reinforcement in basement concrete. Effective sealing will also reduce inflow to basements when high rainfall has contributed to a high-water table.
- The walls behind electrical switchboards and fire control panels should be well sealed and drained to minimise the chance of water ingress compromising the function of electrical or fire panels.
- Provision of automatically activated emergency generators that are sized for pumps, a lift, and emergency lighting will improve the resilience of a building and enable occupants to 'camp' in the building until power is restored. The emergency generator should be located above flood levels, in a protected environment so it can be tended and refuelled even in strong winds and appropriately sized for all the circuits it is connected to. It should have appropriate access to fuel storage for a couple of days of operation and be easily refuelled from a truck. It should be regularly maintained and tested.
- Important buildings and those used as places of refuge should be designed using high internal pressure to minimise damage that follows the failure of elements on the windward wall.

Further reading

Boughton, G., Henderson, D., and Harper, B. (2025) "TC Alfred, southeast Queensland and northeast NSW – Damage to Buildings", Technical Report 70, Cyclone Testing Station, James Cook University. https://www.jcu.edu.au/__data/assets/pdf_file/0003/2246754/TR70-Final-TC-Alfred-report-.pdf

Cyclone Testing Station (2018) "Guide to reduce wind driven rainwater ingress entering through sliding windows and doors", https://www.jcu.edu.au/__data/assets/pdf_file/0004/1175107/Guide-to-protect-window_20181029.pdf viewed 17/3/2025, Cyclone Testing Station, James Cook University.

Cyclone Testing Station (2025) "Weather the storm website" https://weatherthestorm.com.au/#/, viewed 17/3/2025, Bushfire and Natural Hazards CRC.

Queensland Government (2023a) "Places of refuge: Cyclones – guidance on the site selection of buildings", August 2023, Queensland Government Department of Energy and Public Works

Queensland Government (2023b) "Technical guidance document – Assessment of buildings as a Place of Refuge", 2023, Queensland Government Department of Energy and Public Works

Queensland Reconstruction Authority (2025) "Resilient homes building guidance" https://www.qra.qld.gov.au/resilient-homes, viewed 8/4/2025.

Sexton, J., Tait, M., Turner, H., Arthur, C., Henderson, D., Edwards, M., (2023), "Preparing for the expected: tropical cyclones in South East Queensland", Aust. Journal of Emergency Management. Vol 38:4

Team members

David Henderson, Chief Engineer of Cyclone Testing Station

Geoff Boughton, Senior Research Engineer, Cyclone Testing Station

The authors particularly acknowledge the field assistance of:

- Risk Frontiers – Mark Leplastrier
- B3creative – Rob Cowle
- Australian Building Codes Board – Phil Finnimore

References

Boughton, G., Henderson, D., and Harper, B. (2025) "TC Alfred, southeast Queensland and northeast NSW – Damage to Buildings", Technical Report 70, Cyclone Testing Station, James Cook University. https://www.jcu.edu.au/__data/assets/pdf_file/0003/2246754/TR70-Final-TC-Alfred-report-.pdf

Boughton, G. Falck D., Parackal K., Henderson D. and Bodhinayake G (2021) "Tropical Cyclone Seroja Damage to buildings in the Mid-West Coastal Region of Western Australia", Technical Report 66, Cyclone Testing Station, James Cook University.https://www.jcu.edu.au/__data/assets/pdf_file/0004/1801606//Technical-Report-66-TC-Seroja-2021.pdf/__noproxycache

Standards Australia (2021) "AS/NZS 1170.2: 2021 Structural design actions – Part 2: Wind actions", Standards Australia, Sydney NSW