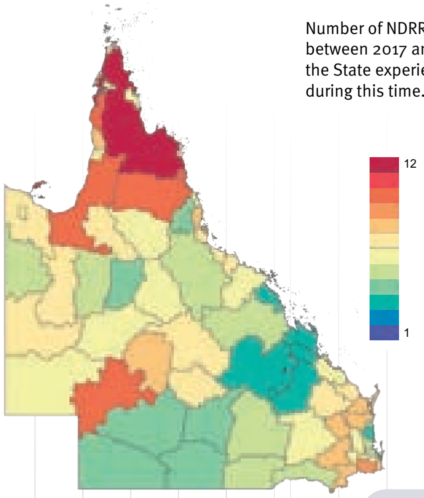
QUEENSLAND

2021/22 STATE DISASTER RISK REPORT

Queensland Government

2017 – 2022 State Disaster Timeline



Number of NDRRA activations per LGA between 2017 and 2022. The majority of the State experienced multiple disasters during this time.

2017

EMERGENCY MANAGEMENT SECTOR ADAPTATION PLAN FOR CLIMATE CHANGE

SNHRA17 PUBLICATION

IGEM REVIEW: CYCLONE DEBBIE

STATE NATURAL HAZARD RISK ASSESSMENT 2017

A report on 7 natural hazards that formed the basis of State-wide hazard prioritisation in the Queensland State Disaster Management Plan.

TC NORA

Tropical Cyclone Nora

Widespread damage and flooding in North Queensland.

SOUTH EAST QUEENSLAND THUNDERSTORMS

South East Queensland Thunderstorms

Over 130,000 homes lose power for >24hours after destructive winds gusting to over 109km/h brings trees and powerlines down across the South East. Energex records 265,000 lightning strikes in 24 hours. Worst affected areas are Kingston, Jimboomba, Crestmead, North Maclean and Beenleigh.

2018

SEVERE THUNDERSTORM EVENT

Severe Thunderstorm Event

- Widespread storms, destructive winds, flash flooding and large hail from the South Burnett to the Sunshine Coast
- A powerful tornado hit Tansey, north-west of Murgon
- 3 injured

2018-2019 BUSHFIRE SEASON

2018-2019 Bushfire Season

- More than 4 million hectares burnt across the State
- Multiple homes lost

2018-2019 QLD BUSHFIRES

TC PENNY

HEATWAVE

Heatwave

Much of the State experienced multiple days with daytime temperatures in excess of 40 degrees and nighttime temperatures above 25 degrees.

TC TREVOR

Tropical Cyclone Trevor

2,100 people evacuated from Borroloola, Numbulwar and Groote Eylandt.

TOWNSVILLE MONSOON & FLOODS

Townsville Monsoon & Floods

- 2 fatalities
- $1.2 billion insurance cost
- 300,000 cattle perished

STATE HEATWAVE RISK ASSESSMENT

State Heatwave Risk Assessment

A comprehensive overview of current and future heatwave risk in Queensland, intended to be utilised by all levels of government in conjunction with the Queensland Emergency Risk Management Framework (QERMF) to better plan for, respond to, and recover from the likely impacts of future severe and extreme heatwave events.

IGEM REVIEW: EFFICACY OF RECOVERY GOVERNANCE

2019

QUEENSLAND STATE EARTHQUAKE RISK ASSESSMENT 2019

TSUNAMI GUIDE FOR QUEENSLAND

IGEM REVIEW: 2019 MONSOON TROUGH RAINFALL AND FLOOD REVIEW

IGEM REVIEW: 2018 QUEENSLAND BUSHFIRES REVIEW

2019-2020 BUSHFIRE SEASON

2019-2020 Bushfire Season

- 7.7 million hectares burnt across the State
- Multiple homes lost

SEVERE THUNDERSTORM EVENT

Severe Thunderstorm Event

A significant thunderstorm outbreal South East Queensland with the Cit hit by a 1 in 50-year storm that left s and thousands of houses without p rain falls in just over an hour, with v as floodwaters rose to a metre high

HEATWAVE

Heatwave

Record-breaking he the Black Summer

IGEM RE BUSHF

IGEM REVIEW: PARADISE DAM PREPAREDNESS

2019 GOLD COAST STORM

2019 Gold Coast Storm

Large hail impacted areas in the Coast, Logan and the northern G

DOCUMENT	ROYAL COMMISSION	COVID-19 PANDEMIC	TROPICAL CYCLONE	RIVERINE FLOODING	HEATWAVE	BUSHFIRE	SEVERE THUNDERSTORM EVENT

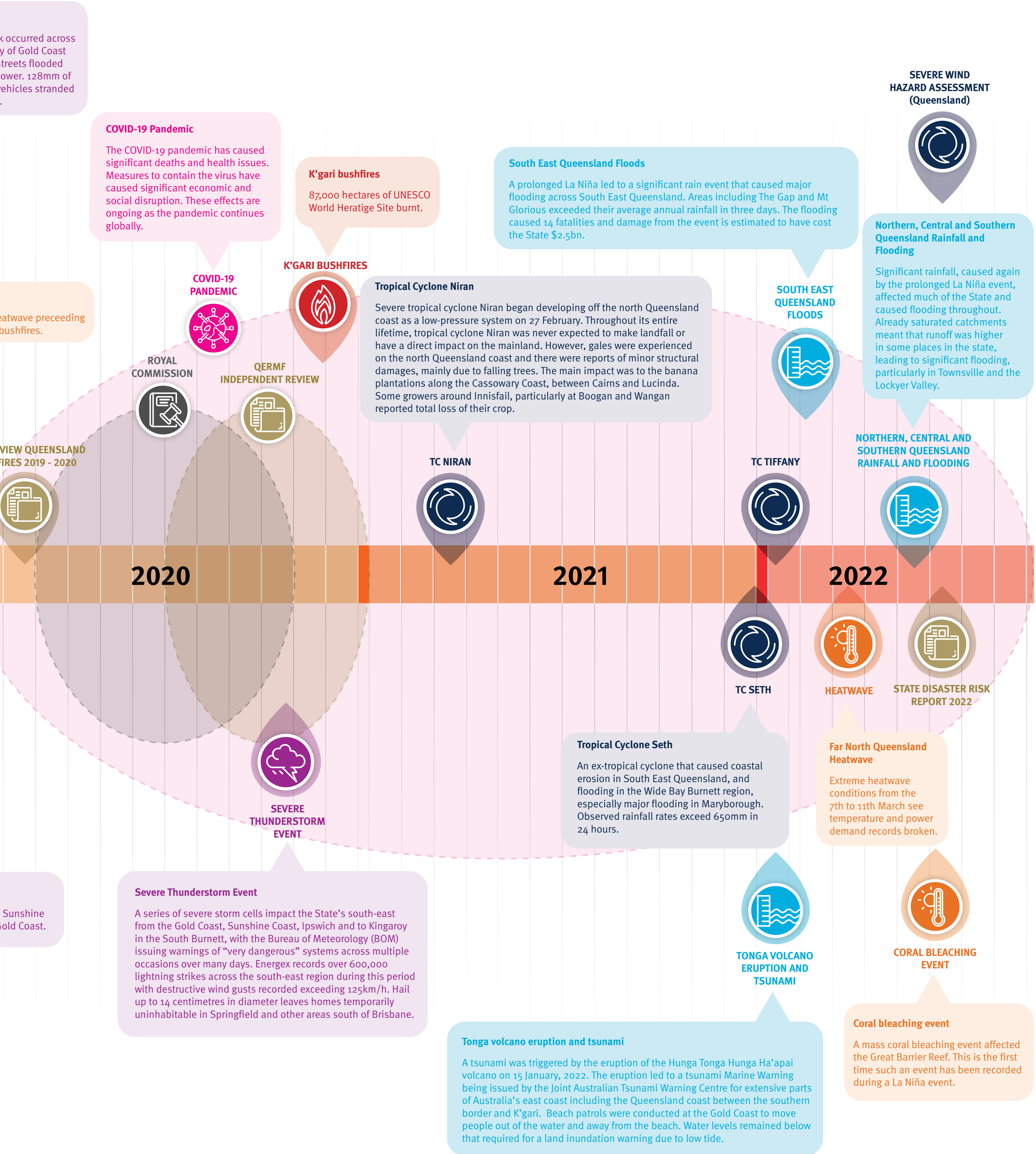


Figure 1: Queensland's disaster timeline since 2017 showing the number, frequency, type and locations of events.

Authors

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Additional contributions acknowledged throughout.

Acknowledgements

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Queensland 2021/22 State Disaster Risk Report. Queensland Fire and Emergency Services, Brisbane.
https://www.disaster.qld.gov.au/qermf/Pages/Assessment-and-plans.aspx

Foreword from Queensland Fire and Emergency Services

Living in Australia's most disaster impacted state means that Queenslanders are no strangers to disaster risk. Our communities, the infrastructure on which they depend and the environment around them are exposed to a range of hazards that can result in potentially devastating impacts.

Since the publication of the 2017 State Natural Hazard Risk Assessment, 64 of Queensland's 77 local governments have been impacted by one or more declared disaster events.

Within recent years we have experienced disasters of a size and scale that are almost unparalleled in our nation's modern history and the landscape of disaster risk is continuously changing. Climate change is contributing to more extreme heatwaves, increasingly severe fire conditions, higher sea levels and worsening floods. As our society grows, so too does our exposure and the value of things that can be at risk.

Our world is more connected than ever, creating complex and wide-ranging interdependencies that are leading to more systemic vulnerability. COVID-19 has exposed many of these vulnerabilities, forcing us to think differently about the world in which we live, the way we work and the lifestyle values we cherish.

These events reinforce the need to understand and share information about disaster risk with the Commonwealth, across jurisdictions and the three tiers of Queensland's disaster management arrangements - local, district and state.

The Honourable Mark Ryan MP
Minister for Police and Corrective Services and Minister for Fire and Emergency Services

Mr Greg Leach, Commissioner
Queensland Fire and Emergency Services

This foundational report is the result of a collaborative effort between stakeholders at all levels of government and other entities working within Queensland's disaster management arrangements. Its scope builds on the 2017 Assessment by assessing a wider range of hazards and risk drivers and provides the results of assessment at a regional planning level. As with the 2017 Assessment, this report was developed using the Queensland Emergency Risk Management Framework to assess those hazards considered within.

The information contained within can help to inform more detailed, place-based local and district risk assessments and disaster management plans. These assessments and plans can guide decision making before, during and after an event to help reduce impacts of disasters on our communities, our infrastructure and environment.

All Queenslanders are affected by disaster risk in some way. We encourage all Queenslanders to consider the valuable information in this report to help them better understand and manage the disaster risks applicable to their interests and responsibilities.

We thank all stakeholders for their ongoing contributions to disaster risk management and for their contributions to this 2021/22 State Disaster Risk Report.

Queensland Government

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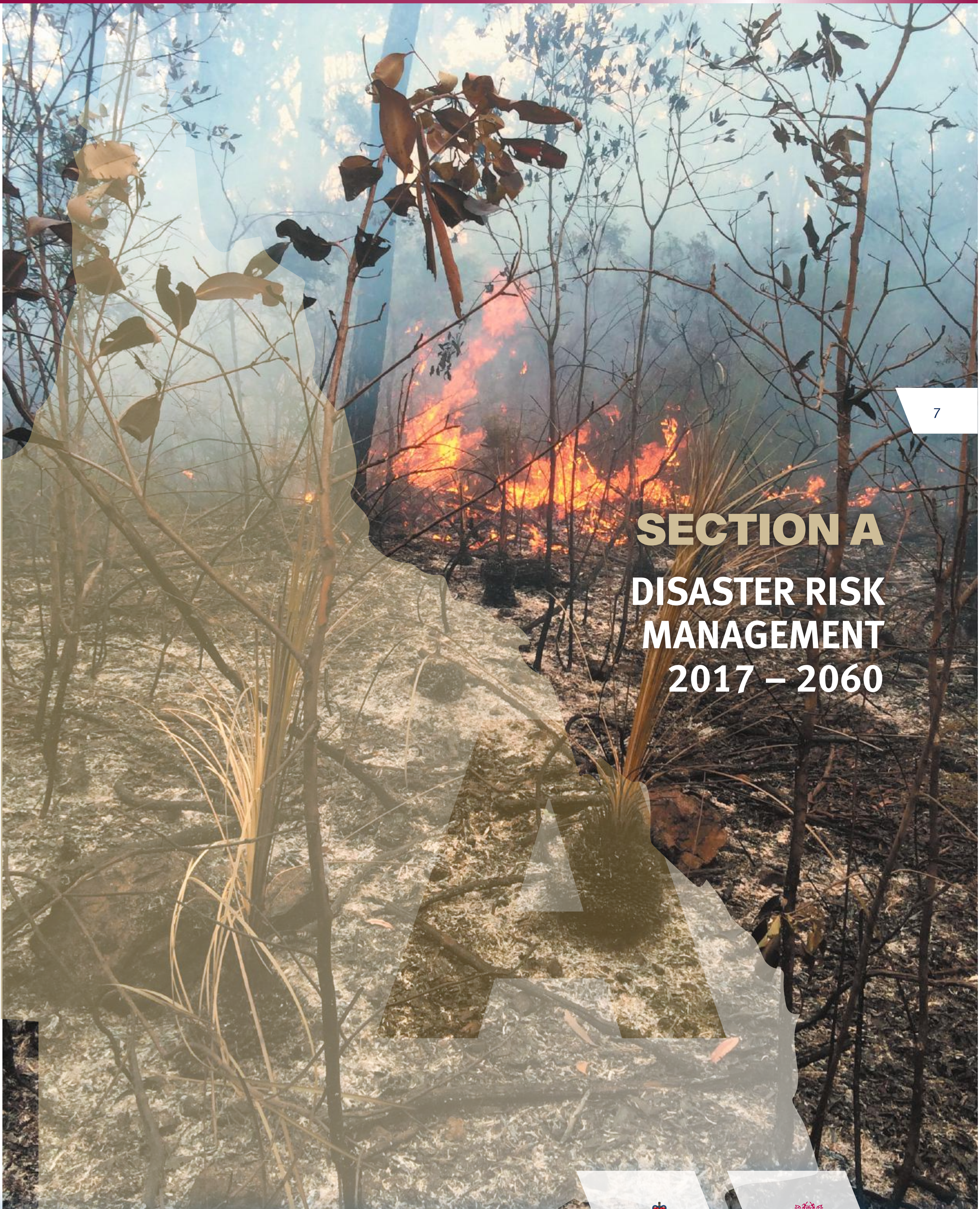


SECTION A

DISASTER RISK MANAGEMENT 2017 – 2060

Queensland Government

Disaster Risk

Introduction

Under the Queensland State Disaster Management Plan (QSDMP), Queensland Fire and Emergency Services (QFES) has responsibility for State-wide assessment of disaster risk.[1]

This 2021/22 State Disaster Risk Report provides an assessment of State-wide risk for ten hazards, two compound or cascading events, and a range of risk drivers. This report builds on the 2017 State Natural Hazard Risk Assessment, which assessed risk for seven in-scope natural hazards, deemed the most significant to Queensland at the time of publication.[2]

This report improves Queensland's understanding of disaster risk and provides information for all entities with disaster management responsibilities to support decision making.

The 2021/22 State Disaster Risk Report uses the Queensland Emergency Risk Management Framework (QERMF) to assess these risks, as did the 2017 State Natural Hazard Risk Assessment. The 2017 State Natural Hazard Risk Assessment was the first report to use the QERMF to conduct risk assessments at the state level, with the aim of providing a baseline for risk assessments compiled at all levels of Queensland's disaster management arrangements.

The 2021/22 State Disaster Risk Report extends the risk analysis of the 2017 State Natural Hazard Risk Assessment by:

- **Updating risk assessments to incorporate insights and knowledge gained from experience in the years since 2017.** In particular, the State Disaster Risk Report builds on the development, implementation, and improvement of the QERMF, the production of Statewide, hazard-specific risk assessments, and the increased availability of relevant data and models.
- **Incorporating more hazards than the 2017 State Natural Hazard Risk Assessment.** The report encompasses both natural and anthropogenic hazards, including a renewed focus on pandemics and epidemics, given the emergences of the COVID-19 pandemic.
- **Including further information on climate change.** Projections from 2021 to 2060 have been included, based on Representative Concentration Pathway 8.5 (see the section on climate change and disaster risk for more information) to understand how disaster risk will change across Queensland over the coming decades.
- **Reflecting the needs and expectations of numerous end-users, experts and disaster management stakeholders.** These stakeholders were consulted with during engagements across the State, undertaken since publication of the 2017 State Natural Hazard Risk Assessment.

The intent of the State Disaster Risk Report is to provide a foundational level of information for risk assessments undertaken by the Local and District Disaster Management Groups (LDMGs/DDMGs) and other entities within Queensland's disaster management arrangements.

These assessments should inform the development of risk-based disaster management plans across all levels of Queensland's disaster management arrangements.

The State Disaster Risk Report also provides authoritative guidance on climate change and its relation to disaster risk in Queensland.

The State Disaster Risk Report is part of a suite of information and evidence that provides support for risk assessments, especially under the QERMF.

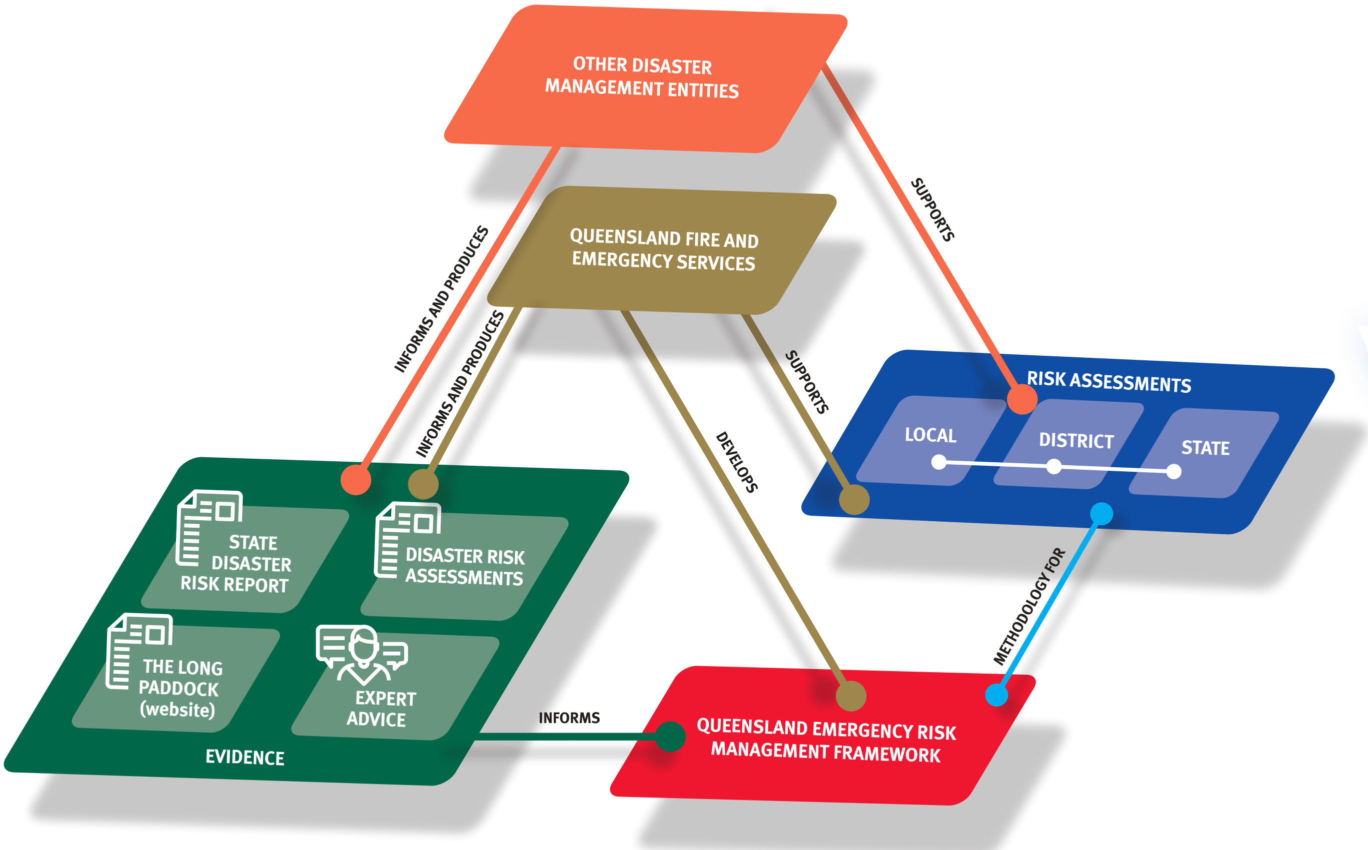


Figure 2: The State Disaster Risk Report is a key component of the integrated information and evidence used for managing Queensland's disaster risk.

The State Disaster Risk Report is published in five parts across two reports:

1. **Executive Summary**, which provides a summary of the report for policy and decision makers.
2. The **2021/22 State Disaster Risk Report**:
    a. **Section A – Disaster risk management in Queensland 2017 – 2060**, details how disaster risk is assessed and managed in Queensland, major events that have occurred since 2017, traditional and longstanding Indigenous applications of disaster risk management, and how climate change will influence disaster risk between now and the later part of the century.
    b. **Section B – State disaster risk assessment,** contains hazard specific risk assessments and risk analysis, and provides an overall view of risk for the State.
    c. **Section C – Risk prioritisation**, provides a prioritisation of hazard risks for Queensland's planning regions and for the State overall.
    d. **Section D – Technical methodologies** contains details of the technical methodologies that underpin the report.

Background

The development of the State Disaster Risk Report is a requirement for QFES under the Queensland State Disaster Management Plan,[1] and is an action of the Inspector-General Emergency Management's (IGEM) 2018 Queensland Bushfire Review,[3] with scope and objectives presented to the State Disaster Coordination Group (SDCG) in October 2019. This report also supports the continuous improvement of the Queensland Emergency Risk Management Framework (QERMF).

This report has been informed by extensive engagement undertaken across Queensland throughout 2020 and early 2021, including stakeholders representing local governments, Local Disaster Management Groups, District Disaster Management Groups, and providers of essential services.

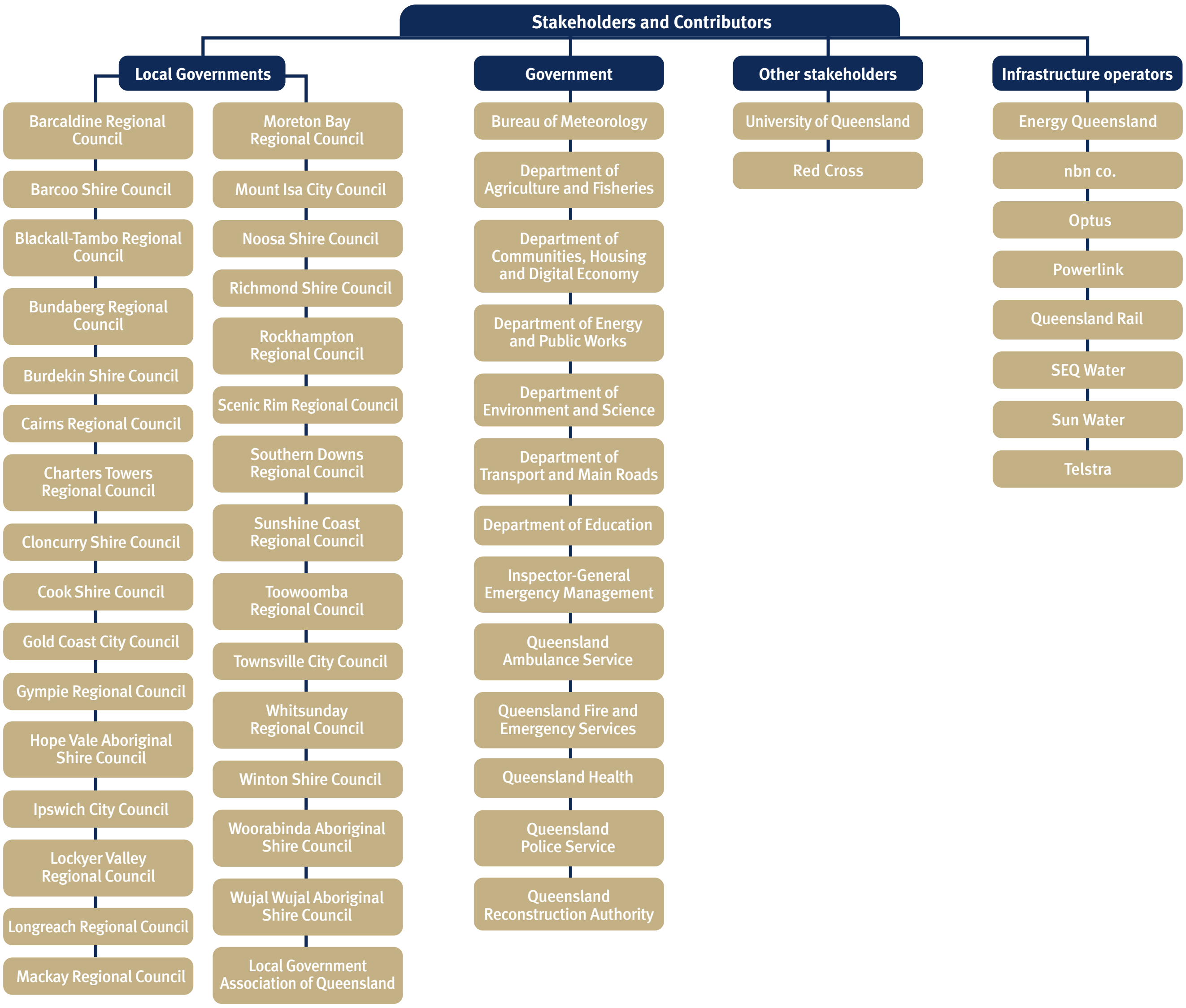


Figure 3: The stakeholders involved in consultation during compilation of the report.

This engagement acknowledged feedback from disaster management practitioners during the 2019 QERMF Local Government Forum, informing the scope and development of risk assessments within this report, and pooling the experience and expertise of stakeholders across the State.

This ensured the State Disaster Risk Report was developed with a user-centred focus to provide information – especially in Section B State disaster risk assessment – that is relevant to the disaster management priorities and requirements of decision makers across all levels of Queensland's disaster management arrangements.

Concepts

Disaster risk

Disaster risk can be a difficult concept to grasp because it deals with potential impacts that have not yet been realised. The United Nations defines disaster risk as:

> "the potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity".[4]

Hazards are just one component of disaster risk. Disaster risk arises when hazards interact with exposed and vulnerable communities, and when the impacts of these interactions exceed the capabilities and capacities available to manage these risks.

A specific hazard – such as an earthquake – poses risks to specific elements because of how the hazard manifests. For example, damage to unreinforced masonry is a risk that is posed by earthquake, because these materials have the potential to be both exposed and vulnerable to the hazard. The earthquake event in itself is not a risk.

This distinction is important because mitigation strategies can be difficult to determine when considering the hazard, but can become clearer when considering the other aspects that combine to create risk. For example, during the COVID-19 pandemic, many local governments closed outdoor gyms and playgrounds to reduce the risk of the virus spreading through contact with these elements. While the hazard itself is difficult to mitigate at a local government level, this strategy reduced exposure to infection, and therefore the risk posed by the hazard.

The endorsed methodology for assessing disaster risk in Queensland is the QERMF.[5] The framework provides a method for managing risks associated with emergency and disaster events in Queensland. It is intended for use by entities working across Queensland's disaster management arrangements, and is designed to provide precise and objective measures of risk and enable continuous improvement, while being easily implemented by disaster management stakeholders across Queensland.

The QERMF has adopted the United Nations Office for Disaster Risk Reduction's (UNDRR) definition of disaster risk,[6] describing disaster risk as a combination of five variables:

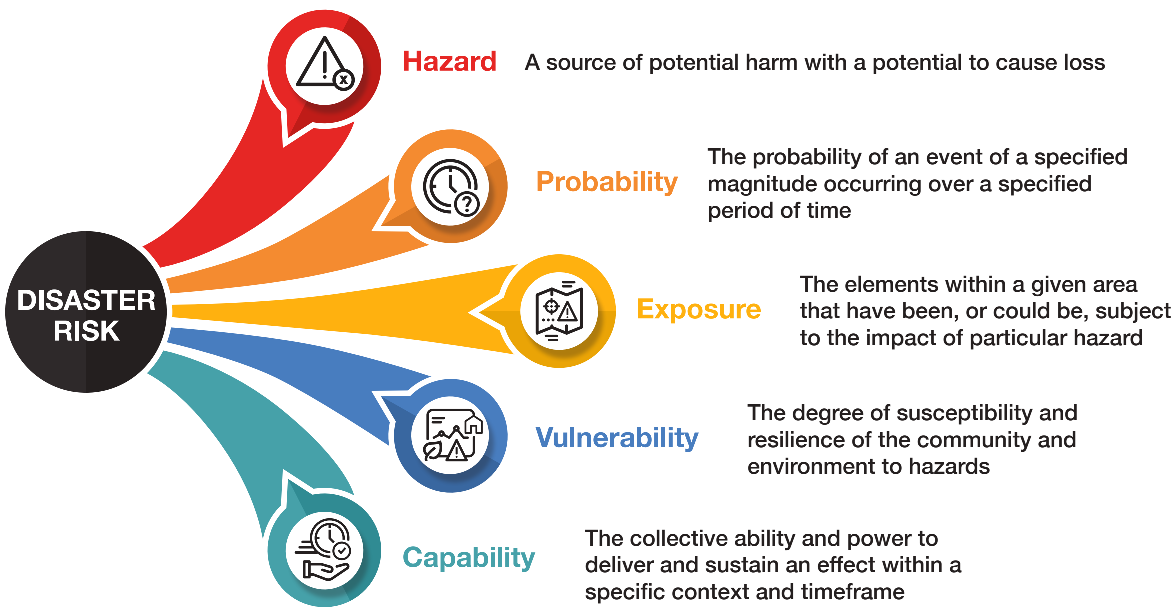


Figure 4: The five components of disaster risk.

This definition of disaster risk has the following components:

1. A **hazard** has certain characteristics that contribute to its potential to cause loss, including location, intensity or magnitude, duration and extent. Hazards can also be single, sequential, or combined in their origin and effects. For example, a tropical cyclone can induce a range of concurrent and cascading hazards including severe winds, flooding, storm surge, tornados, landslips and technological hazards such as hazardous materials spills.
2. Hazard **probability** (or likelihood) varies depending on the frame of reference, or specified period of time. For example, in the State Heatwave Risk Assessment 2019, comparison of hazard scenarios for 2030 and 2090 shows that extreme heatwaves are more likely towards the end of the century than present day.[7] Probability or likelihood is also specific to certain locations – for example, tropical cyclones are more probable in Far North Queensland than in the south west.
3. A hazard interacts with objects that are **exposed** because they are located in hazard-prone areas, or are dependent on other elements in those hazard-prone areas. For example, although a household may not be located in a flood prone area, it may be dependent on elements that are, such as roads, power, communications or medical care.
4. **Vulnerabilities** are the conditions that increase the susceptibility of exposed elements to loss, damage or harm. For example, households become vulnerable when they are no longer able to withstand the effects of the hazards they are exposed to, such as flood or bushfire. Elements may also be vulnerable because of their dependencies on other assets, networks or systems. For instance, the effectiveness of medical services depends on the robustness of supporting infrastructure such as roads and utilities.
5. **Capability** is the collective ability and resources available within the area of assessment to deliver and sustain a desired effect.

Disaster risk assessment

Disaster risk assessment can be undertaken through qualitative and/or quantitative approaches to determine the nature and extent of disaster risk by analysing potential hazards and evaluating existing conditions of exposure and vulnerability that, when combined, could harm people, property, services, livelihoods and the environment upon which they depend.

Disaster risk assessments include:

- identification of hazards and hazardous events (scenarios)
- a review of the technical characteristics of hazards such as their location, intensity, frequency and probability
- analysis of exposure and vulnerability to hazards, including the physical, social, health, environmental and economic dimensions
- evaluation of the effectiveness of existing and alternative coping capacities for a range of scenarios.

When assessing disaster risks, it is best practice to use disaster scenarios.[8–10] Scenarios identify hazard events of a specific severity and locate them in particular places at particular times. They are used to assist those assessing disaster risk in analysing the likely impacts of a hazard event, and then to produce a more realistic and holistic risk assessment. They help to analyse the potential impacts of a hazard event, and the responses to the event, so that planning will better reflect likely occurrences of hazard events. In the State Disaster Risk Report, scenarios are provided for each of the hazards, to provide a basis for risk assessments of these hazards.

Disaster risk management

The UNDRR defines disaster risk management as “the application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses”.[11]

This can be further broken down into three approaches for managing disaster risk:

- prevention of new disaster risks
- reduction of existing disaster risks
- management of residual risks.

The context for managing disaster risk as it applies to Queensland and its many communities is outlined in the next sections.

Context

This report draws on several risk assessments at the international, national and state/territory levels in the context of disaster risk reduction policy, guidance and activities. It also draws on international materials and frameworks.

GOVERNANCE AND POLICY	LEVEL	GUIDANCE MATERIAL
Sendai Framework for Disaster Risk Reduction Global action to reduce disaster risk **Sustainable Development Goals** Blueprint to achieve a better and more sustainable future for all by 2030 **Paris Agreement** Legally binding international treaty on climate change to limit global warming	Global Goals	**Global Risk Assessment Framework (GRAF)** Promotes a better understanding of the dynamic nature of risk and the increasing complexity and interconnectedness of society **Words Into Action** Practical guidance to support implementation of Sendai **WorldRiskIndex 2020** Statistical calculation of risk and consequence for natural disaster events across 181 countries **Global Risks Report 2021** Analysis of disaster risk at the global, regional and industry levels. **Intergovernmental Panel on Climate Change** Links disaster risk management, climate change adaptation and sustainable development
Ulaanbaatar Declaration 2018 Alignment of Sustainable Development Goals & Disaster Risk Reduction	Asia Pacific Alignment	**UNDRR Regional Office for Asia and the Pacific (ROAP)** Supports disaster risk reduction efforts across the Asia-Pacific region
National Disaster Risk Reduction Framework National policy agenda for coordinated action **Australian Disaster Preparedness Framework** Supports development of capability to effectively prepare for and manage severe to catastrophic disasters	National Policy & Support	**Guidance for Strategic Decisions on Climate and Disaster Risk** Guidance on climate and disaster risk for strategic long-term planning and investment decisions. **Australian Disaster Resilience Index** Snapshot of the capacities for disaster resilience in Australian communities
Disaster Management Act 2003 (Qld) Provides for effective disaster management for the State. **Strategic Policy Statement** Informs Queensland's strategic approach to disaster risk. **Queensland Emergency Risk Management Framework** Queensland's approach to disaster risk management **State Disaster Management Plan** Describes the roles and responsibilities of disaster management stakeholders **Queensland Strategy for Disaster Resilience** Builds the state's capacity for resilience against all hazards. **State Planning Policy** Policy framework for state interests and land use planning **Climate Adaptation Strategy** Manages the risks and harnesses the opportunities of a changing climate.	State Direction & Funding	**Queensland Disaster Management Training Framework** Training courses and inductions relevant to key disaster management stakeholders **Queensland Disaster Management Guideline** Provides flexible, good practice advice for implementing disaster management practices **2021/22 State Disaster Risk Report** State level disaster risk assessment to inform disaster risk management activities **Resilient Queensland in Action** Showcases learnings and good practice to improve disaster resilience **Sector Adaptation Plans** Help to prioritise climate change adaptation activities across the key sectors of the community
District Disaster Management Plans Plan for disaster management within a disaster district **Regional Plans** Support growth and development in the regions while protecting resources and state interests.	Regions Districts Coordination	**Queensland Disaster Management Training Framework** Training courses and inductions relevant to key disaster management stakeholders **Queensland Disaster Management Guideline** Provides flexible, good practice advice for implementing disaster management practices
Local Disaster Management Plans Plan for disaster management within a local government area **Local Planning Instruments** Guide growth, development and change taking into account state planning interests	Local Leadership Delivery	**Queensland Disaster Management Training Framework** Training courses and inductions relevant to key disaster management stakeholders **Queensland Disaster Management Guideline** Provides flexible, good practice advice for implementing disaster management practices
	Household	**Get Ready Queensland** Helps all Queenslanders prepare for disasters **Person-Centred Emergency Preparedness Toolkit** Guidance to support emergency preparedness and planning for people with chronic health conditions and disabilities **Australian Red Cross: Help in emergencies** Resources to help households and communities to prepare for, respond to and recover from disasters

Figure 5: Overview of disaster risk reduction policy and guidance.

Global

United Nations Office for Disaster Risk Reduction

The UNDRR, formerly known as the UN International Strategy for Disaster Risk Reduction (UNISDR), is the United Nations focal point for disaster risk reduction. The UNDRR oversees the implementation of the Sendai Framework for Disaster Risk Reduction 2015-2030,[12] supporting countries in its implementation, monitoring and sharing what works in reducing existing risk and preventing the creation of new risk.

Australia contributes to and aligns itself with the UNDRR Sendai Framework and other agreements between UNDRR member states. The governance arrangement prioritises regional-level action, which is a process endorsed by all Australian jurisdictions.

Representing a broad shift in disaster risk management, the Sendai Framework prioritises the reduction of disaster risk as opposed to focusing on responding to disasters. The Sendai Framework provides a global blueprint for disaster management stakeholders to use, aimed at preventing and reducing disaster risks, and promoting community resilience and sustainable development.

WorldRiskIndex 2020

The WorldRiskIndex[13] provides a statistical calculation of the risk and consequence of extreme natural disaster events across 181 countries. It is used to calculate risk for the annual WorldRiskReport.

The methodology for calculating the WorldRiskIndex is complex and calculated on a country-by-country basis through the multiplication of exposure and vulnerability.

Exposure encompasses natural threats to communities – specifically, earthquakes, storms, floods, droughts and rising sea levels.

Vulnerability includes the social sphere and is calculated by analysing the following, equally weighted components:

- The **susceptibility** of a population, including the quality of its public infrastructure and housing, its level of nutrition, poverty, and economic capacity and income distribution.
- **Lack of coping capacity**, which includes strong and stable governmental institutions, disaster preparedness, access to medical services, strength of social networks and distribution of insurance.
- **Lack of adaptive capacity**, which includes education levels, gender equality, environmental and ecosystem protections, adaptation strategies and investment in public good projects.

According to the WorldRiskIndex, Australia rates as ‘low’ on a global scale, despite our reasonably high level of exposure to natural hazards. This is likely due to our relatively high levels of coping and adaptive capacity. This ranking has not changed significantly since the publication of the State Natural Hazard Risk Assessment in 2017.

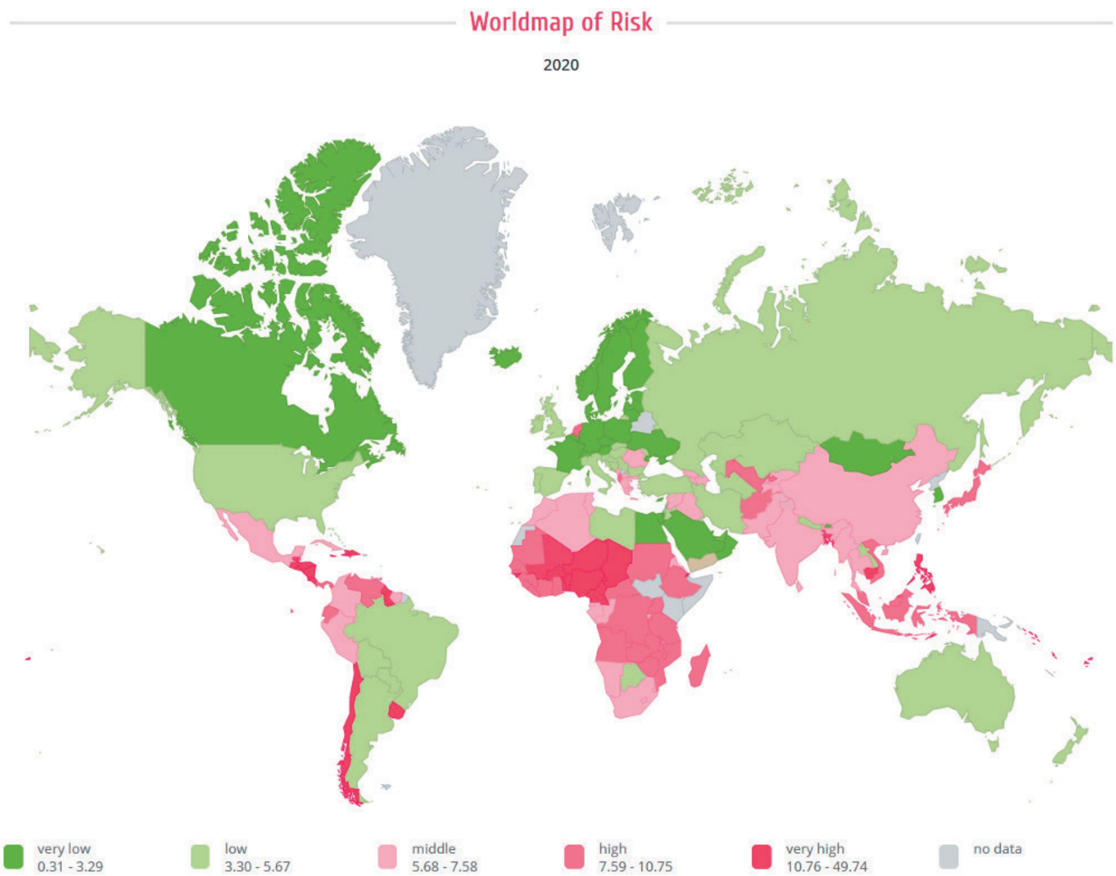


Figure 6: 2020 WorldRiskReport findings.[13]

World Economic Forum – Global Risks Report 2021

In 2021, the World Economic Forum released the Global Risks Report 2021, the sixteenth edition of the report.[14] The report provides an overview of the evolving risk landscape, and identifies the top global risks by both likelihood and impact (Figure 7). One of the key findings of the report is that the perceived likelihood of infectious diseases was much more prevalent in this report than in previous editions. Four of both the seven most likely risks and highest impact risks are environmental.

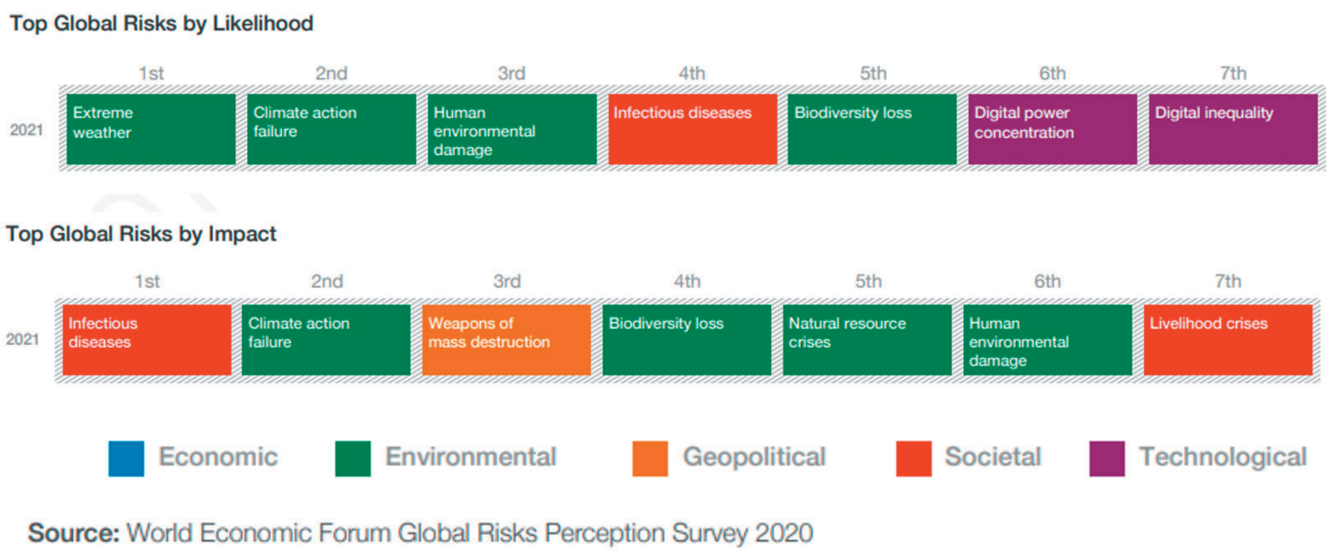


Figure 7: The top global risks by likelihood and impact. Source: World Economic Forum Global Risks Perception Survey 2020

Asia-Pacific

Ulaanbaatar Declaration

Following the adoption of the Sendai Framework by participating governments including Australia, the Ulaanbaatar Declaration was adopted at the 2018 Asian Ministerial Conference on Disaster Risk Reduction. The Ulaanbaatar Declaration outlines a two-year action plan to accelerate implementation of the Sendai Framework in Asia between 2019 and 2020. This Action Plan aligns with the *Asia Regional Plan for Implementation of the Sendai Framework for Disaster Risk Reduction 2015-2030*,[15] adopted at the 2016 Asian Ministerial Conference on Disaster Risk Reduction.

The broad intent of the *Asia Regional Plan* is to provide:

- policy direction to guide the implementation of the Sendai Framework in the context of the 2030 Agenda for Sustainable Development in the Asia region
- a long-term road map, outlining a chronological pathway of the Sendai Framework, structured around key milestones
- continuation of the *Action Plan 2017-2018* with specific activities, prioritised based on the long-term road map and in line with the policy direction.

The UNDRR also convenes the Global Platform for Disaster Risk Reduction, a biennial information and knowledge sharing forum, supporting partnerships across the disaster management sectors. The goal of the forum is to improve implementation of disaster risk reduction through better communication and coordination between stakeholders. Its core function is to enable disaster management stakeholders including national governments, non-government organisations, scientists, practitioners, and UN organisations to share their experience. This shared knowledge can help to formulate strategic guidance for the implementation of global disaster risk reduction agreements.

Australia

National Disaster Risk Reduction Framework

The National Disaster Risk Reduction Framework[2] (NDRRF) was released in April 2019. This framework was developed through an inclusive approach with input provided by all states and territories, as well as representation from local government and key private sector organisations with responsibilities in disaster management.

The NDRRF provides direction for Australia's efforts to reduce disaster risks associated with natural hazards.[2] The Sendai Framework Working Group – a body representing all Australian governments – has developed a national roadmap for implementation and reporting against the NDRRF.[16] This reporting is measured against the UN's 38 global indicators to measure progress against the Sendai Framework's seven global targets – providing Australia with a long-term view on the effectiveness of policy interventions.

The NDRRF states that disaster risk is a product of:

- hazard (a sudden event or shock)
- exposure (the people and things in the path of potential hazards)
- vulnerability (the potential for those people and things to be adversely impacted by a hazard)
- capacity (the ability for those people and assets and systems to survive and adapt).

Structurally, the NDRRF associates the following areas requiring protections as:

- built environment, i.e. physical and social infrastructure assets
- social environment, i.e. socioeconomic and demographic trends
- natural environment, i.e. natural assets such as rivers, land and complex ecosystems
- economic environment, i.e. public and private sector economic factors.

The framework identifies four key priorities and associated actions to reduce disaster risk in Australia, as shown in figure 8 (over).

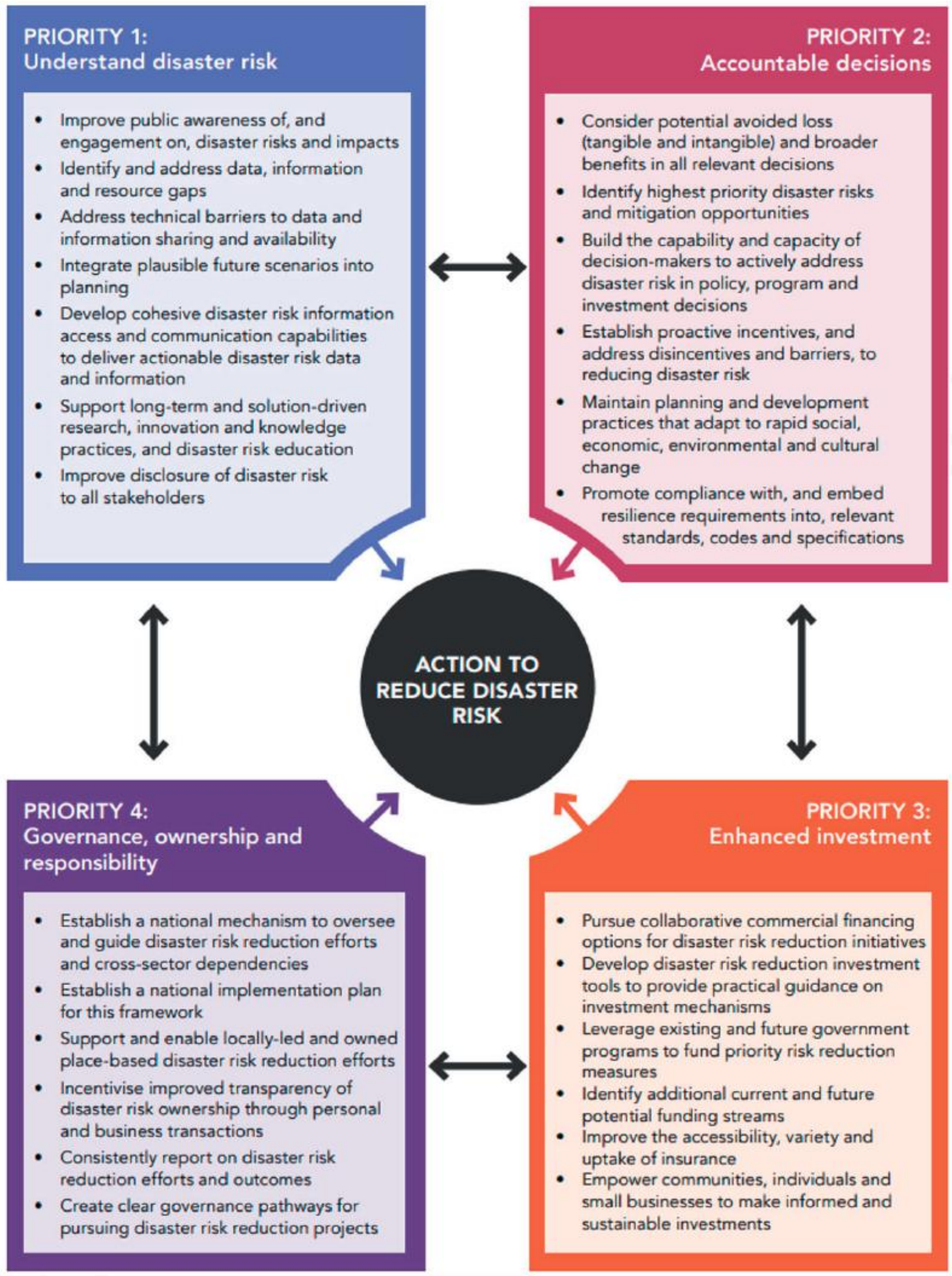


Figure 8: Australia's National Disaster Risk Reduction Framework priorities to reduce disaster risk.[17]

Guidance for Strategic Decisions on Climate and Disaster Risk

This set of guidance documents supports implementation of the NDRRF. The guidance is designed to help all sectors and communities consider climate and disaster risk in strategic planning and investment decisions. The set includes four key guidance documents:

- Guidance on Governance describes systemic risk and systemic risk governance, including how existing governance creates barriers to the diagnosis and treatment of causes and effects of climate and disaster risk.
- Guidance on Vulnerability focuses on ways to understand vulnerabilities to climate impacts, natural hazards and disaster. It also supports growing understandings of the systemic causes and effects of vulnerability, particularly societal values and interdependent systems, for determining possible steps towards reducing them.
- Guidance on Scenarios explains how to develop and use scenarios to consider the potential implications of high-stakes strategic and operational decisions when highly uncertain drivers of climate and disaster risk are present.
- Guidance on Prioritisation encourages users to re-visit investment, program and project objectives by shifting the focus from ‘assets’ to ‘services and communities’. The guidance also enables consideration of the cross-scale and multi-stakeholder nature of climate and disaster risks and offers a prioritisation framework to rapidly assess opportunities and pathways for creating and capturing value from investments in disaster risk reduction.

Australian Disaster Preparedness Framework

The Australian Disaster Preparedness Framework[18] (ADPF) provides guidance on the preparedness phase of the Prevention, Preparedness, Response, Recovery (PPRR) cycle. The ADPF has four aims:

1. To provide Australia with a mechanism to effectively articulate its preparedness and capability requirements to prevent, plan for, respond to and recover from severe to catastrophic disasters.
2. To build an appropriate level of capability to manage severe to catastrophic disasters across Australia by incorporating international best practice approaches.
3. To provide a method by which all jurisdictions across Australia can understand, assess and begin to develop the capabilities required to deal with a severe to catastrophic disaster.
4. To provide a mechanism to determine what capabilities meet national priorities and thresholds, and how they may be developed, accessed, enhanced and sustained when responding to severe to catastrophic disasters.

The ADPF is focussed on building capacity and capability as part of disaster preparedness and includes an extensive list of capabilities that are required to effectively be prepared for disasters. The framework lists key considerations for establishing effective disaster management governance, including understanding different roles that agencies can play and establishing formal agreements between those agencies while fostering partnerships that are effective in managing disasters.

Australian Disaster Resilience Index

The Australian Natural Disaster Resilience Index (ANDRI) is a resource released in 2020, that assesses disaster resilience using factors that encapsulate the resources and abilities to prepare for, absorb and recover from natural hazards (Coping Capacity), or that enable learning, adaptation and problem solving (Adaptive Capacity) at the Statistical Area 2 (SA2) level across Australia. In addition to a method of measuring resilience based on coping capacity and adaptive capacity, the ANDRI identifies possible strengths that contribute to resilience and barriers to building resilience, and identifies five clusters of SA2s that have similar resilience profiles.

The ANDRI uses the following eight factors for assessment as shown in Figure 9: social character, economic capital, emergency services, planning and the built environment, community capital, information access, social and community engagement, governance and leadership.

The ADRI uses the following eight factors for assessment:

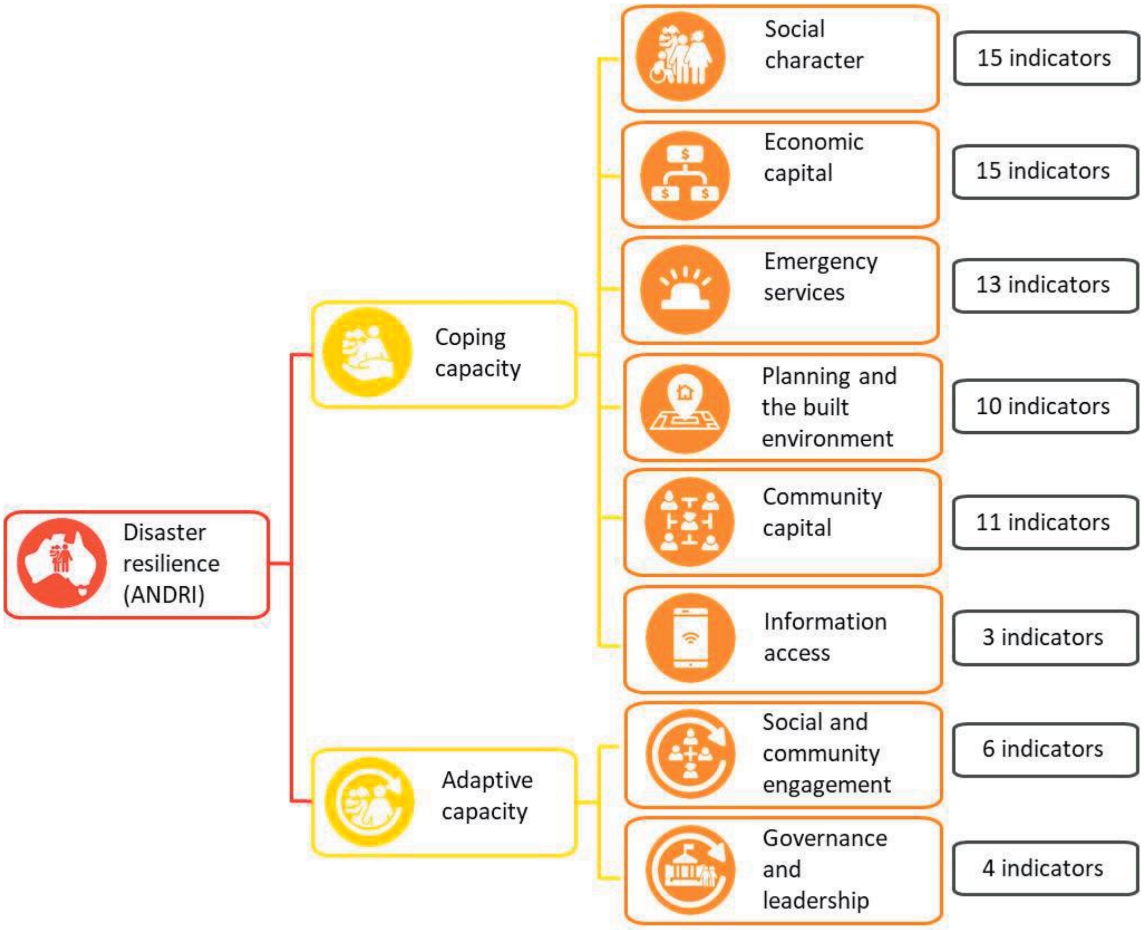


Figure 9: Hierarchy of measurement. Source: Parsons et al., p. 8.[19]

ANDRI finds that disaster resilience depends on multiple interrelated factors, each with its own character that contributes in different ways to disaster resilience.

The ANDRI has undergone uncertainty and sensitivity analysis, which assess the accuracy and reliability of ANDRI's findings. These are outlined in the ANDRI's launch report.[19] These tests provide confidence that the results of the calculation of ANDRI are meaningful and unbiased.

Queensland

Overview

Queensland is the most disaster-prone state in Australia, and the most impacted financially by disasters.

The Climate Council calculates that Queensland has suffered over $30 billion in losses due to disasters between 1970 to 2019.[20] Likewise, the Australian Business Roundtable for Disaster Resilience and Safer Communities (ABR) report *Building resilience to natural disasters in our states and territories*[21] calculates that the total economic cost for Queensland over the 10-year period to 2016 was, on average, $11 billion per year. This equates to 60 per cent of the national cost over this period.

The updated report *Update to the economic costs of natural disasters in Australia,* released in 2021, calculated the increased costs of natural disasters under different emission scenarios. Under a high emissions scenario (RCP8.5), the total economic cost of natural disasters in Queensland between 2020 and 2060 is estimated to reach $530 billion, which is nearly 40% of total national costs. The most economically significant natural disaster events have historically been flood events (66 per cent of the cost), cyclones (25 per cent of the cost), hail and storm (six per cent and four per cent of the cost respectively).[22]

The intangible costs of disasters to Queensland – that is, the costs arising from the impact of disasters on health and wellbeing, education, and employment – are also estimated by ABR to be significant. A case study of the 2010-11 Queensland floods found that the tangible cost was $6.7 billion and the intangible cost was $7.4 billion.

As the severity of disasters increases due to climate change, the costs of disasters will continue to rise.[23]

The ABR report concludes that:

- Further investment in disaster resilience (both physical and community preparedness) is essential to lessen the forecast increase in costs.
- Investment in disaster resilience provides the dual benefits of avoiding the impact of disasters when they occur, while facilitating the flow on benefits when disasters do not occur.

Academic literature and government reports consistently raise the ongoing benefits to investing in disaster risk reduction.[24–28] The precise values for cost-benefit ratios depend on the hazard investigated and the measures in place.[24] Mechler found that, on average, a sample of 39 disaster risk reduction studies identified a cost-benefit ratio of 1:3.7.[26] That is, for every dollar spent, $3.70 was returned in benefits from the risk reduction activities. The full table per hazard is as follows:

Hazard	Cost : benefit ratio ($)
Flood (riverine and coastal)	1:4.6
Wind (tropical and extratropical)	1:2.6
Earthquake	1:3
Drought	1:2.2
Landslide and avalanche	1:1.5
Average	**1:3.7**

Table 1: Cost-benefit ratio of disaster risk reduction for different hazards.[26]

The table shows us that overall, the benefits of investing in disaster risk reduction consistently outweighs the cost of investment.

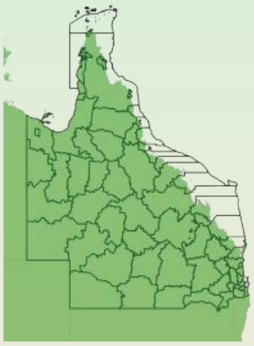
As such, establishing and promoting a robust disaster hazard and risk mitigation model which helps to prevent the effects of disasters is a priority of the Queensland Government and QFES. Two pillars of Queensland's approach to disaster risk management are Queensland's disaster management arrangements, and the Queensland Emergency Risk Management Framework (QERMF). In this section, we provide a detailed description of the arrangements and the framework.

Queensland's Disaster Management Arrangements

For a complete description of Queensland's disaster management arrangements refer to the Queensland State Disaster Management Plan (QSDMP).[1]

Consistent with the governance established at the international and federal level, Queensland's disaster management arrangements acknowledge the three levels of disaster management governance (federal, state and local). Further, Queensland's disaster management arrangements also include an additional tier between local and State governments – disaster districts, which are aggregated from the local government level. This is shown in Figure 10.

[1] https://www.iag.com.au/sites/default/files/Newsroom%20PDFs/Special%20report%20_Update%20to%20the%20economic%20costs%20of%20natural%20disasters%20in%20Australia.pdf



77 Local Disaster Management Groups (LDMGs)

Assess disaster risks and risk management plans for the local government area

Develop and update disaster management plans

LOCAL LENS

Coordinate District/State resources and support services as required/requested

Communicate and escalate residual risk

Inform the district group of residual risk and work together to develop risk management plans

23 District Disaster Management Groups (DDMGs)

Assess disaster risks and risk management plans for the Disaster District

Develop and update disaster management plans

DISTRICT LENS

Provision of State resources and support services as required/requested

Communicate and escalate residual risk

Inform the State group of residual risk and work together to develop risk management plans

Queensland Disaster Management Commitee (QDMC)

State Disaster Coordinator (SDC)

State Disaster Coordination Group (SDCG)

Assess disaster risks and risk management plans for the State

Develop and update disaster management plans

STATE LENS

Provision of Australian Government resources and support services as required/requested

Communicate and escalate residual risk

State requests for Assistance

National Cabinet

National Federation Reform Council (NFRC)

National Emergency Management Ministers' Meeting (NEMMM)

Australia-New Zealand Emergency Management Committee (ANZEMC)

Australian Government capability and support mechanisms

NATIONAL LENS

DISASTER MANAGEMENT ACT 2003

4A Guiding principles

Local governments are primarily responsible for managing events in their area

29 Establishment

A local government must establish a local group

30 Functions

Functions of local groups includes:

(a) ensure disaster management and operations are consistent with the State

(b) regularly review and assess disaster management

(d) identify services required and provide advice to the district group

(g) provide reports and recommendations to the district group

DISASTER MANAGEMENT ACT 2003

4A Guiding principles

District groups and the State group should provide local governments with appropriate resources and support to help them carry out disaster operations

23 Functions

Functions of a district group includes:

(a) ensure disaster management and operations are consistent with the State

(b) egularly review and assess disaster management

(c) provide reports and recommendations to the State group about disaster management

(d) review and assess (i) disaster management of local groups and (ii) local disaster management plans

DISASTER MANAGEMENT ACT 2003

4A Guiding principles

District groups and the State group should provide local governments with appropriate resources and support to help them carry out disaster operations

18 Functions

Functions of the State group includes:

(a) develop strategic framework for disaster management for the State

(c) establish and maintain arrangements between State and Commonwealth

(e) provide reports and make recommendations about disaster management and disaster operations

(g) coordinate State and Commonwealth assistance

Australian Strategy for Disaster Resilience

National Framework for Disaster Risk Reduction

Australian Disaster Preparedness Framework

Figure 10: Application of different disaster management lenses across Queensland's disaster management arrangements.

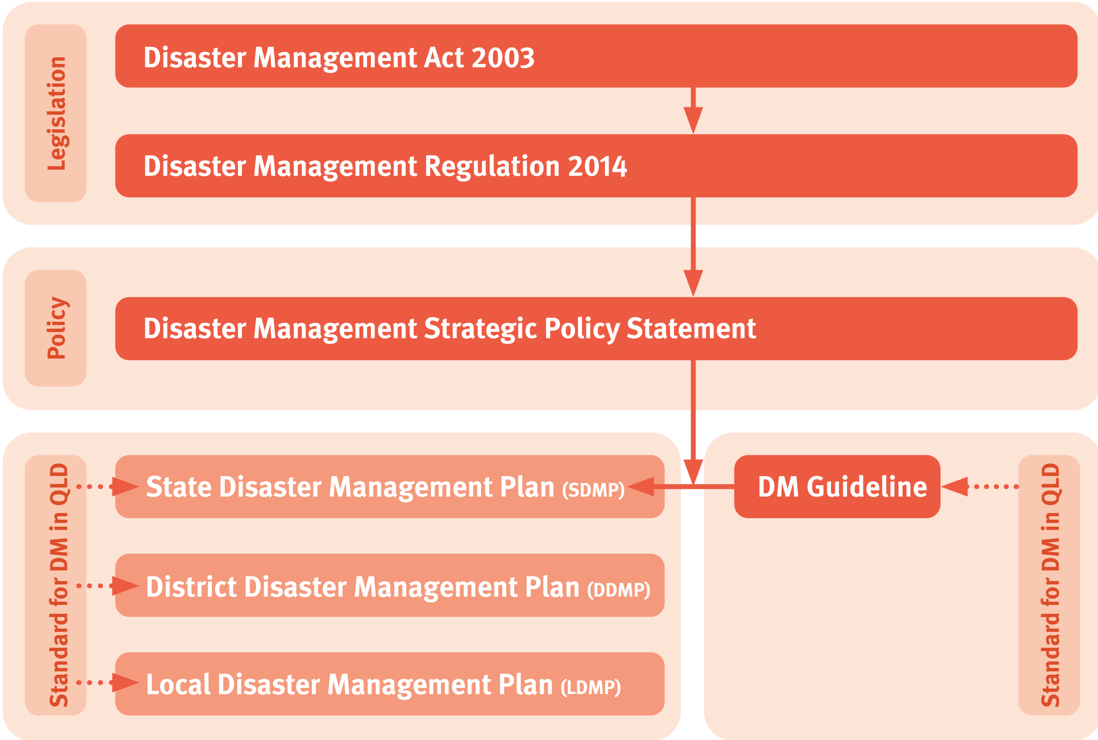


Figure 11: Document map of Queensland Disaster Management Plans.

At the State level, the *Disaster Management Act 2003* (the Act) and the Disaster Management Regulation 2014, which outline the Queensland Government's strategic approach to disaster management. The Queensland Government's requirements under the Act are affirmed in the Queensland Disaster Management 2016 Strategic Policy Statement.

The Act governs:

- How Queensland's local, district and state levels work together to reduce disaster impacts and build the capacity of communities to manage disaster risks.
- How disaster operations are focused on reducing:
  - illness, injury or the loss of human life
  - the loss of or damage to property
  - damage to the environment.
- The functions of the Commissioner of QFES as the Chief Executive, which include:
  - establishing and maintaining relations between the State and the Commonwealth
  - ensuring that disaster management is undertaken in accordance with relevant legislation, policy and standards
  - providing advice and support to disaster management groups.
- The functions of Inspector-General Emergency Management (IGEM), including development of standards and assurance of disaster management performance.

The Act assigns primary responsibility for managing events to local governments, and specifies that each local government must establish a Local Disaster Management Group (LDMG). Part of an LDMG's function is to improve and foster effective disaster management through regular reviews and assessments of disasters which, in turn, enables the local government to develop its Local Disaster Management Plan (LDMP).

At the district level, a District Disaster Management Group (DDMG) is established for each disaster district. Part of a DDMG's function is to develop effective disaster management for the district, including a District Disaster Management Plan (DDMP). This plan is developed through regular review and assessment of local government disaster management arrangements within their district and their LDMPs.

In addition, the State government has the responsibility for:

- coordinating and executing disaster management arrangements in Queensland
- providing strategic direction and coordination of efforts to build resilience across all sectors of the community
- enabling access to up-to-date and reliable risk information
- ensuring all sectors of the community are aware of the options available for effective risk reduction.

To achieve these responsibilities, the State government has established comprehensive governance arrangements. Within these arrangements, the most senior committee is the Queensland Disaster Management Committee (QDMC). Part of the QDMC's function is to ensure effective disaster management is developed and implemented for the State through preparation and regular review of the QSDMP. The QDMC also provides strategic direction during disaster events.

The SDCG and the State Disaster Coordination Centre (SDCC) also sit at the State level. The SDCC is an operational venue for the provision of State-level support to disaster management operations. The SDCG's function is to support the State Disaster Coordinator and provide advice on resources and options for disaster management, ensuring the coordinated and efficient deployment of State government resources.

Queensland State Disaster Management Plan

The QSDMP aims to "enable Queensland to mitigate the effects of, prepare for, respond to, recover from and build resilience to disaster events".[1] The QSDMP identifies both functional and hazard specific responsibilities for key entities across each phase of disaster.

The current QSDMP identifies four priority areas:

- **Risk management**. Queensland uses an evidence-based risk assessment methodology to evaluate the potential impacts of hazards, recognise areas of exposure and their vulnerability, and identify subsequent risks to communities. This is achieved through the QERMF.
- **Planning**. Disaster management plans are informed by risk assessments, and completed for the appropriate level of Queensland's disaster management arrangements (i.e. local, district or state).
- **Local focus**. LDMGs are empowered by legislation to act as the frontline of disaster management in Queensland. This work is undertaken from a perspective of shared responsibility among all stakeholders and is characterised by consultation, collaboration and participation. LDMGs are supported by district- and state-level groups, as well as relevant State departments, statutory bodies, essential service providers and non-government organisations.
- **Resilience**. Queensland aims to be Australia's most resilient state, and disaster management decisions should support this aim at the community level.

This State Disaster Risk Report is a guide for risk management – the first of these four – that provides additional information to stakeholders in local contexts.

Queensland Emergency Risk Management Framework (QERMF)

To ensure actions undertaken through Queensland's disaster management arrangements can have maximum effect in reducing disaster risk, QFES established the QERMF. The QERMF is a framework that can be used to identify disaster risks and develop risk management plans and mitigation strategies.

The QERMF applies a standardised approach to the prioritisation, mitigation and management of risk.

The successful foundation for disaster risk management lies in clearly identifying and understanding the level of exposure and vulnerability to a community and its assets against specific hazards, along with an understanding of the capabilities and capacities available to manage and reduce disaster risk.

Effective risk assessments produce information that is targeted, authoritative, and can be easily understood and used to inform decision making. The QERMF outlines four steps for the identification, analysis and management of risk:

1. Establish the context
2. Analyse hazards
3. Assess risk
4. Risk-based planning.

The QERMF provides a comprehensive and systemic approach to understanding disaster risks for the purpose of risk-based planning, and a mechanism for coordinating planning across all levels of Queensland's disaster management arrangements.

Residual Risk

In addition to preventing new disaster risks and reducing existing disaster risk, effective disaster risk management also includes management of residual risk. The definition of residual risk used by the UNDRR and adopted by Queensland is:[6]

"...the risk that remains in unmanaged form, even when effective disaster risk reduction measures are in place, and for which emergency response and recovery capacities must be maintained".

The presence of residual risk implies a continuing need to develop and support effective capacities for emergency services, preparedness, response and recovery, together with socioeconomic policies such as safety nets and risk transfer mechanisms, as part of a holistic approach.

Within the context of Queensland and Queensland's disaster management arrangements, this includes risk that is beyond the capability and/or capacity of the local or district groups to effectively manage. Depending on the potential impacts, this may include communication and escalation of residual risk for consideration by successively higher levels within Queensland's disaster management arrangements.

Prior to referring residual risk to the next level of the disaster management arrangements for additional advice and/or support (e.g. from local to district levels), reasonable attempts at consultation should first be made with the relevant entities as part of the shared responsibility for managing risk.

This is consistent with the Act, which identifies that local governments are responsible for disaster planning and operations within their area, with support provided from district, State and the Commonwealth as requested.

The process for escalating residual risk in Queensland can be broken down into the following three levels and corresponding actions, in order.

LOCAL LEVEL

1. **Local level:**
   a. An LDMG conducts a risk assessment.
   b. In consultation with the relevant DDMG, residual risk identified through the local risk assessment process is further considered and where appropriate referred to the DDMG for assistance with mitigation or management through the DDMG risk management process.

DISTRICT LEVEL

2. **District level:**
   a. The DDMG conducts a risk assessment that includes evaluating the residual risks referred by the relevant LDMGs. There should be collaboration and consultation with all relevant entities, including within their own departments and organisations.
   b. Any remaining residual risk is referred to the State for further consideration. This is through formal correspondence (District Residual Risk Brief) by the District Disaster Coordinator (as Chair) to the SDCG chair via the secretariat.

STATE LEVEL

3. **State level:**

    a. The SDCG Chair will initiate further consideration of the risk through QFES for quality assurance and general coordination of the residual risk process at the State level. Coordination in this instance refers to the communication of risk across all levels of Queensland's disaster management arrangements, as well as the provision of assistance in the development of resolution strategies where QFES is not the responsible entity for the risk under the QSDMP.

    b. The following broad steps allow for the consideration of residual risk at the State level:

        i. Convening of State representatives from entities relevant to the residual risk, as guided by the QSDMP.

        ii. Evaluation of the residual risk and evidence base that supports the residual risk being referred to the State group, including consultation with the relevant LDMGs and DDMGs.

        iii. Identify suitable mitigation and risk reduction strategies and next steps, which will be formulated in a SDCG Residual Risk Brief.

        iv. The brief must provide a recommendation to the QDMC regarding the management of the residual risk.

        v. As a part of this process, a lead entity or entities will be identified to take the risk forward on behalf of the State as determined by the nature of the risk and appropriate legislation or plans.

    c. Formal presentation of the Residual Risk Brief to the SDCG is carried out by lead entities as defined by the QSDMP (or appropriate legislation).

    d. As a part of this process, a lead entity or entities will be identified to take the risk forward on behalf of the State as determined by the nature of the risk and appropriate legislation or plans. If a lead entity is not clear or risk is not accepted by any entity, development of a presentation of the Residual Risk Brief to the SDCG will be coordinated by QFES, including recommended courses of action.

    e. The SDCG will communicate on behalf of the QDMC, back to the relevant DDMG regarding the outcome of the residual risk consideration and course of action.

Active, clear communication of residual risk is essential when multiple areas are affected by the same or similar risks and/or event and require support in a compressed timeframe. This is because it has implications for the prioritisation and mobilisation of limited resources during the preparedness and response phases of disaster management.

At both local and district levels, the QERMF risk assessment process is supported by QFES, through its Hazard and Risk Unit and regional Emergency Management Coordinators. This support can also include consultation with other entities across local, district and state levels to inform the local and district assessments (i.e. reach back to State agencies for assistance or guidance).

The process for communicating and escalating residual risk is broadly highlighted in Figure 12.

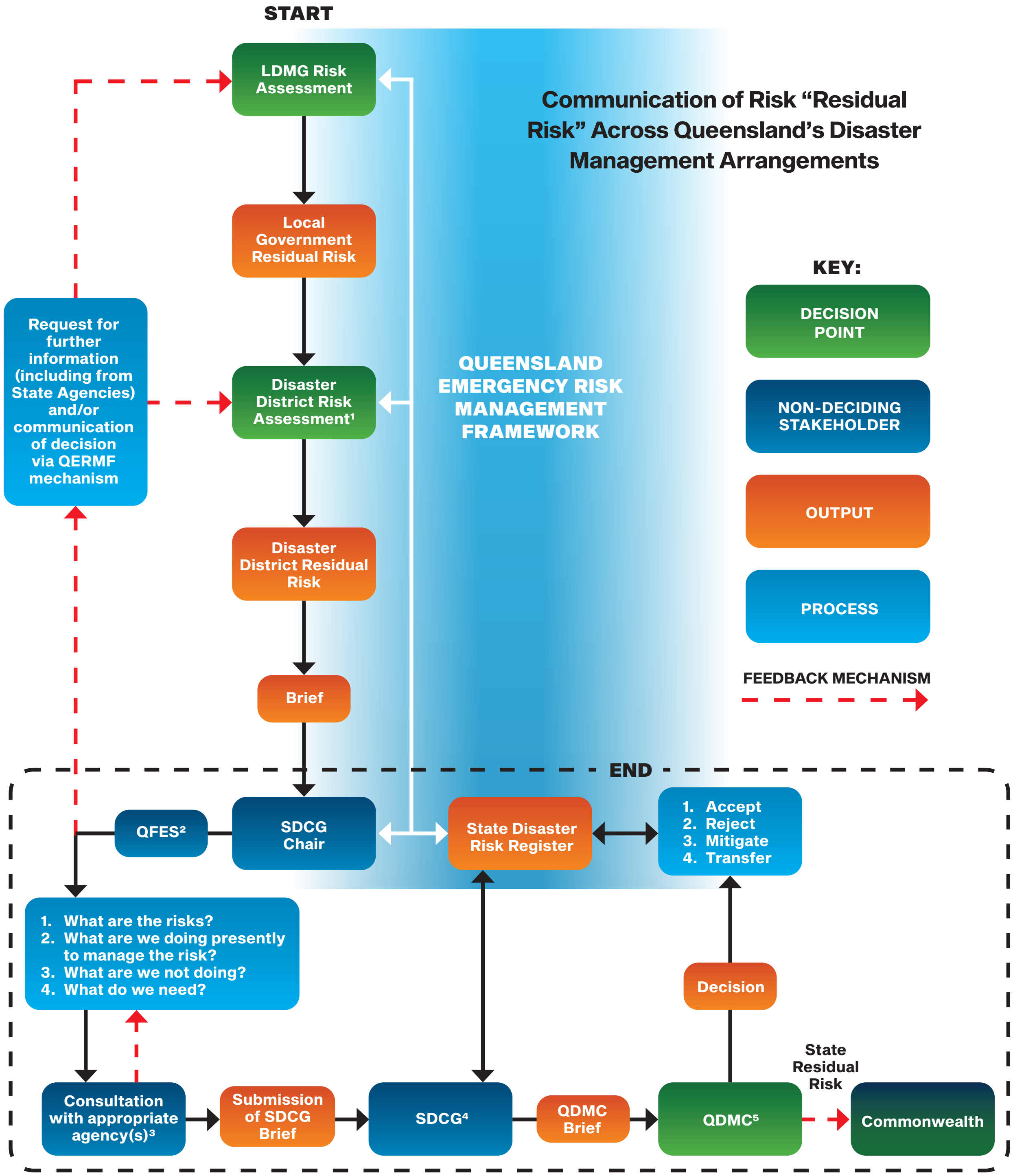


Figure 12: The residual risk process across Queensland's disaster management arrangements.

The identification of residual risk and implementation of strategies to manage the residual risk is a fundamental part of this report. Providing disaster management stakeholders with easy access to lead and functional entity planning and reports increases their ability to actively and effectively engage with residual risk priorities.

Other relevant documents

Disaster risk management is one part of disaster management responsibilities in Queensland. This section outlines some of the other relevant documents that play an important role in disaster management in Queensland, with a particular focus on disaster risk.

Quality assurance

The Standard for Disaster Management in Queensland[29] establishes the performance requirements for all entities involved in disaster management. Applied in conjunction with disaster management doctrine and government policy, the standard is outcomes-focused, and aims at enhancing performance and achieving a shared system-wide goal for the disaster management sector.

The standard acknowledges the shared responsibilities for disaster management. As such, it is designed to be used by all entities across Queensland's disaster management arrangements. Transition to a refreshed standard commenced on 1 July 2021:

Shared responsibility	Outcomes
Managing risk	There is shared understanding of risks for all relevant hazards
	Risk is managed to reduce the impact of disasters on the community
Planning and plans	There is shared understanding of how the impact of disasters will be managed and coordinated
	Plans outline and detail how the impact of disasters on the community will be reduced
Community engagement	Entities proactively and openly engage with communities
	The community makes informed choices about disaster management, and acts on them
Capability integration	Resources are prioritised and shared with those who need them, when they need them
	Entities develop integrated capabilities and shared capacity to reduce the impact of disasters on the community
Operations	Response, relief and recovery operations minimise the negative impacts of an event on the community and provide the support needed for recovery
Collaboration and coordination	Entities proactively work together in a cooperative environment to achieve better results for the community
	A collaborative culture exists within disaster management
Common language	Common language is used by all entities within Queensland's disaster management arrangements

Figure 13: Shared responsibilities under the Standard for Disaster Management in Queensland. The standard identifies that "the management of risk is fundamental to making the community safer".[29]

The standard sits within Queensland's Emergency Management Assurance Framework (EMAF). Developed by IGEM in partnership with disaster management stakeholders, the EMAF promotes an end-to-end approach to the continuous improvement of disaster management and enables a statement of confidence in Queensland's disaster management arrangements.

The application of the framework enables entities and disaster management groups to ensure their responsibilities are being met and to demonstrate that this is the case. This provides support for continuous improvement of entities' programs across all phases of disaster management. The EMAF also provides the structure and mechanism for reviewing and assessing the effectiveness of disaster management arrangements.

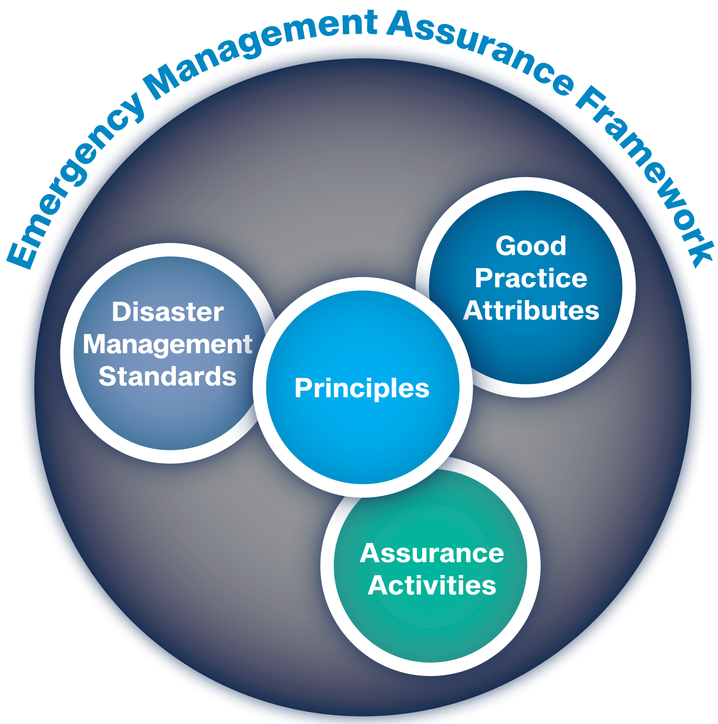


Figure 14: An overview of the interrelated parts of the Emergency Management Assurance Framework for Queensland.

Emergency Management Sector Adaptation Plan for Climate Change

The Emergency Management Sector Adaptation Plan for Climate Change complements the Queensland Climate Adaptation Strategy, providing guidance for the emergency management sector "in managing the risks associated with a changing climate, and to harness the opportunities provided by responding to the challenges".[30]

It identifies actions, outcomes and challenges for each of eight identified priority areas. Of these priority areas, the most relevant to the context of the State Disaster Risk Report are the following:

- Priority 1: Sector-led awareness and engagement about climate change.
- Priority 2: Integration of climate change into sector governance and policy.
- Priority 3: Enhancing the sector's understanding of climate change risk and its ability to adapt.

Some of the data products and methodologies that underpin the findings of this report also address priority 4:

- Priority 4: Research and development of new knowledge and supporting tools.

Queensland Strategy for Disaster Resilience (QSDR)

The Queensland Strategy for Disaster Resilience[31] provides an overarching framework to empower Queenslanders to factor in resilience measures and activities. The guiding principles of the strategy are as follows:

- **Shared responsibility:** Disaster management is a shared responsibility for all Queenslanders.
- **An integrated risk-based approach:** This approach will ensure that initiatives are locally driven and address disaster hazards and associated risks of that community.
- **Evidence-based decision making:** Inform actions to reduce and prevent disasters by recent and reliable data.
- **Continual learning:** Disaster management and community resilience building is an ongoing process with a need to continually learn from our experiences.

The Queensland Reconstruction Authority (QRA) is responsible for delivering on the objectives of the QSDR, doing so in collaboration with a range of disaster management stakeholders.

Queensland Disaster Resilience and Mitigation Investment Framework

The Queensland Disaster Resilience and Mitigation Investment Framework,[32] prepared by the QRA, aims to provide guidance around investment that links to existing frameworks around disaster management, resilience, and disaster risk reduction. It aims to "support decision-makers in the assessment and prioritasation of infrastructure-based resilience and mitigation investments and non-infrastructure or community resilience" and to "facilitate progress of investment in disaster risk reduction, mitigation and adaptation by acting as both a link and enabler between existing Queensland policy documents, funding sources, guidelines, and approaches to investment and procurement".

The framework provides an interface between existing policies, funding sources, and guidelines on funding and procurement, as shown in Figure 15.

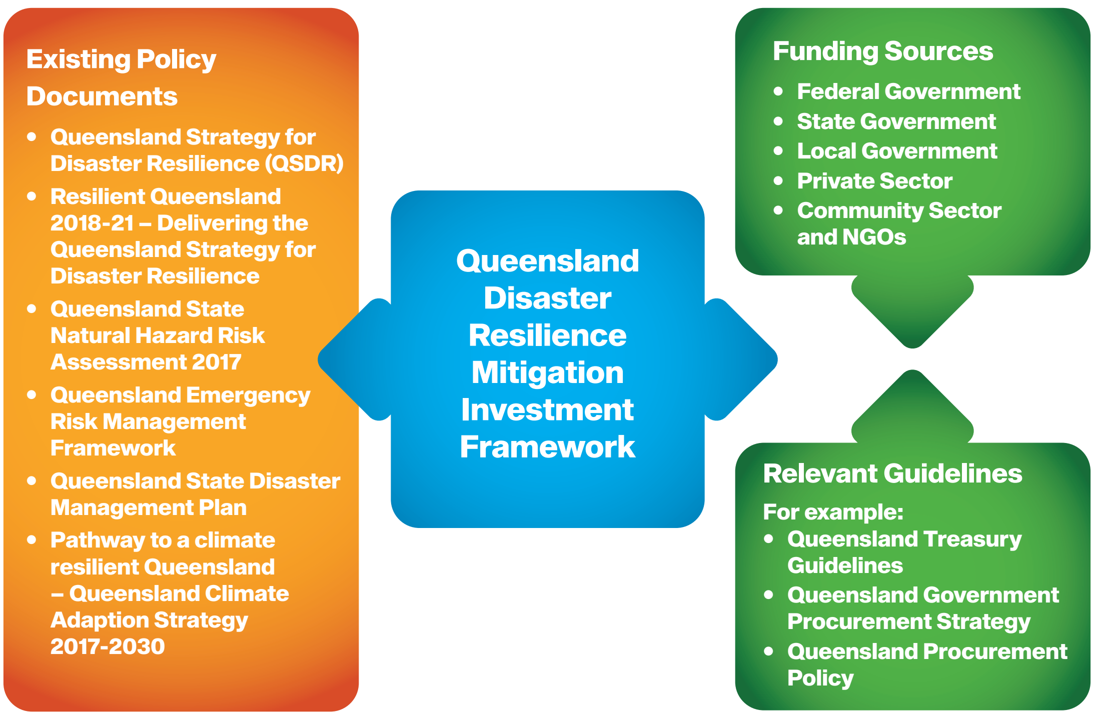


Figure 15: The relationship of the framework to other parts of the disaster resilience system, demonstrating how the framework links disaster resilience mitigation investment to policy and funding sources.

Disaster management since 2017

Since the publication of the State Natural Hazard Risk Assessment in 2017, the understanding and management of disaster risk across Queensland's disaster management arrangements has seen continual improvement. This stems from work undertaken by QFES and a range of other entities on the furtherance of State strategies, as well as new challenges of unprecedented natural disaster events and the impact of climate change.

During the past four years, Queensland has experienced a number of significant disaster events which have resulted in reviews, updates and changes to disaster management planning. The impact of these events has caused significant review, improvements and changes to disaster management plans and procedures. As one example, since 2017, 75 of the 77 LGAs in Queensland have seen NDRRA activations, and the average number of activations across this four-year period is 4.5 (see Figure 16).

Figure 1 (on pp. 2-3) provides an overview of some of the major developments over the past five years.

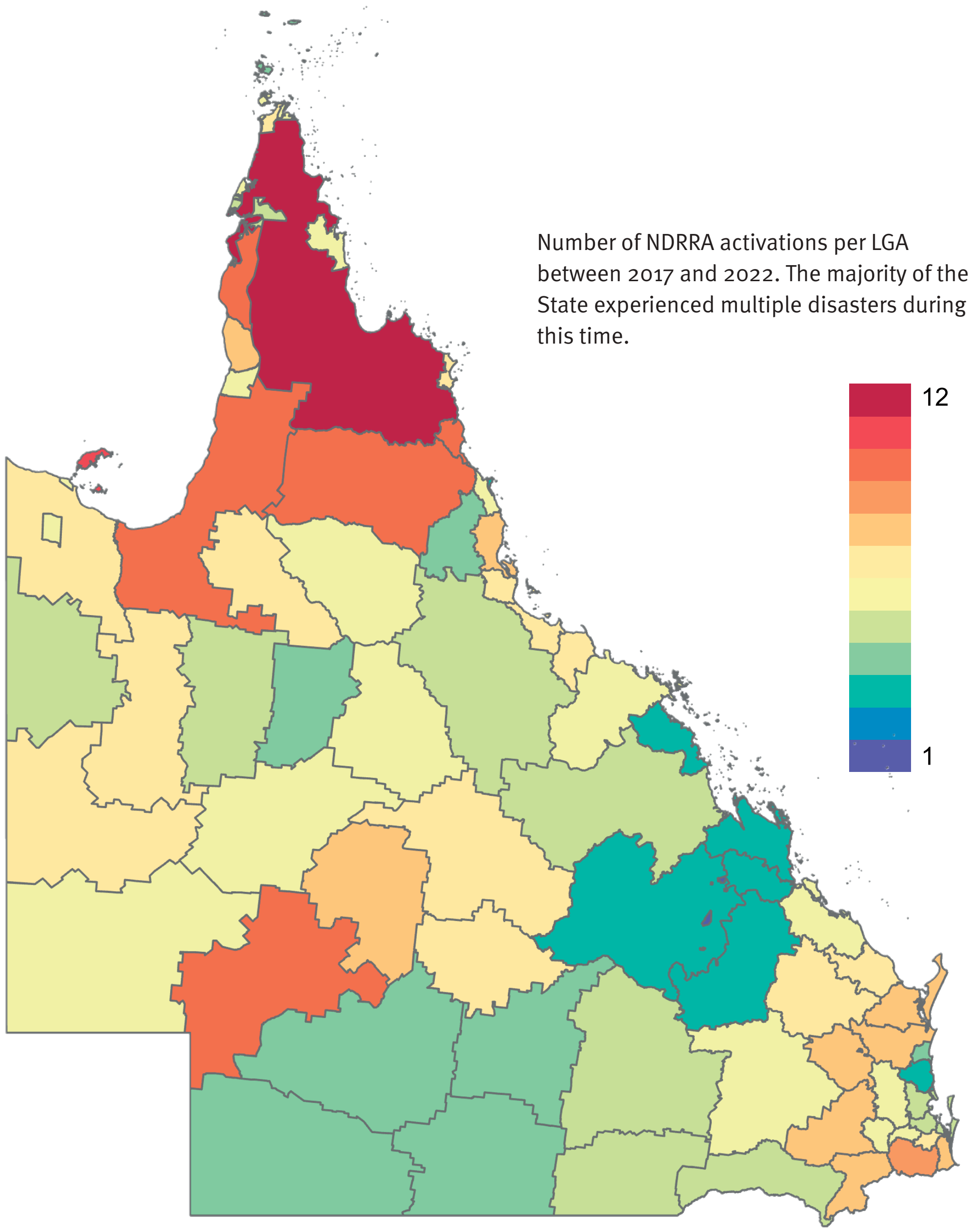


Figure 16: Number of NDRRA activations per LGA between 2017 and 2022.

Royal Commission into National Natural Disaster Arrangements

Following the unprecedented 2019-20 bushfire season, a Royal Commission was established into Australia's National Natural Disaster Arrangements. While the Royal Commission was often called the 'Bushfire Royal Commission' in the media, it examined disaster management arrangements more generally, and how Commonwealth and state and territory disaster management arrangements operate to respond to disaster events.

The final report of the Royal Commission[33] was released on 30 October 2020. Discussions of disaster risk feature prominently in the final report, especially in the context of a changing climate and the changing nature of risk.

At the National Federation Reform Council meeting on 11 December 2020, the Commonwealth, state and territory governments agreed to collaborate to implement the Royal Commission's recommendations and to prioritise a group of recommendations, including the improvement of natural disaster risk information to support decision making such as land-use planning and the sharing of hazard reduction data and information across jurisdictions.

The State Disaster Risk Report and other products developed by QFES allow for up-to-date information on natural hazard risk, particularly in the context of a changing climate, that is designed to give decision makers confidence in making decisions around mitigating and responding to disaster risk.

Figure 17: The intensity, speed of spread and broad geographic impact of the Black Summer bushfires of 2019 – 2020 prompted the establishment of the Royal Commission. The fire in this photo – taken in Pechey, near Toowoomba – burnt through over 20,000 hectares, and destroyed multiple homes. Source: QFES.

Indigenous application of disaster management in Queensland

Contributed by Various QFES employees, who recognise and respect the many different and distinct Aboriginal and Torres Strait Islander groups, each with their own culture, language, beliefs and practices.

Current disaster management practices in use in Queensland have evolved in the context of two centuries of European colonisation.

There are varying estimates for how long the presence of Aboriginal and Torres Strait Islander people extends back to in Queensland, however, current research reveals over 60,000 years.[34]

The emergence of disaster management practices over these millennia – given a much longer and more varied experience of natural hazards – can help to highlight how these risks have been mitigated in the past.

Many First Nation groups' vocabularies did not have a definition, phrase or word for now what is widely called 'disaster management' or 'disaster risk reduction'. This term has only been associated with First Nations practices recently because of the bearing of traditional knowledge on contemporary practices such as land management, coverage of natural disaster events via digital media and the increasing role that Indigenous local governments play in disaster risk management in collaboration with other local and State authorities.

Indigenous management of Country

The ecosystems and landscapes of Queensland and of the rest of Australia have changed substantially since European colonisation. The Traditional Customary Lore followed by Indigenous peoples have played an important role in how people both occupied and used the country. All decisions and interactions with the environment were meticulously managed by Traditional Customary Lore. This lore is passed down from ancestors to each generation, by reciting stories of creation in a multitude of mediums including dance, song, engravings and glyphs, sites of significance and Indigenous technologies.

Effectively, lore has been used to govern land and sea-based resources. The lore has guided people's interaction entirely by

- regulating movement through different parts of Country
- allocating parcels of land, their boundaries, and significant sites according to natural barriers like rivers, creeks and geomorphic formations
- specifying what species of animals and plants could be used by members of tribes/nations, family clans and individuals.

With respect to disaster risk management, Traditional Lore in Queensland included complex land management skills which has been attuned to an in-depth knowledge of weather patterns and cycles dating back to and linked with previous natural occurring events like volcanic activity and major sea level rise tens to hundreds of thousands of years ago.

This understanding of all biota enabled Indigenous peoples' practices overlap and complement Queensland plant and animal species' reproduction, movement and migration. These practices have promoted food security for both Indigenous populations and endemic wildlife.

These skills have enabled Indigenous people to understand what influenced plant and animal behaviour. This allowed people to 'read' nature using what are best described as indicator species, which aided Indigenous people in understanding both extremes and seasonal anomalies in weather patterns.

In 2014, ABC news published a story on how Aboriginal people observed animal behaviour and use it to understand future weather patterns – in particular, to move away from areas that Cyclone Tracy impacted.[35]

[...] the Arnhem Land people she spoke with took her to an area with rock slabs.

At first she could not see anything unusual, but then she saw a sight she has not forgotten in the decades since.

> "I realised there were snakes coiled up and sunning themselves and the goannas lying only a few feet away, a metre or so away from each other," she said.
>
> "Goannas were facing the sun, the morning sun, but there were other goannas with their backs to the sun facing the west."
>
> "I said, 'Ooh that's funny, I've never seen that before."
>
> "They said, 'No, this is why we're telling you - you tell everybody to come back. Everybody you see you tell them to come back to their country because something really bad's going to happen but we don't know what it is. Snakes and goannas - they're natural enemies and here they are sunning themselves on the same slabs of rock.'"

Fire in the landscape

A common Indigenous practice that shaped and renewed the environment has been the contentious use of landscape fires and micro fire management. These fires targeted specific animal and plant species' reproduction, movement and promote resource gathering. This practice commonly named now as cultural burning, firestick farming and cool burning incorporates many reworkings of traditional Indigenous fire usage. This technique mitigated wildfires and importantly abated loss of human life and sustained animals and plant life used for food and shelter.

Weather Cycles

The transfer of information from generation to generation provides high-quality historical knowledge of weather systems that has been used to mitigate present-day risk. This developed a complete understanding of the cycle of life that enabled the continuance of nomadic existence of people in Australia.

To best present holistic knowledge of country, Indigenous seasonal calendars aim to materialise the combination of climatic seasons, weather cycles, ecological knowledge and land management practices.

These calendars have been an intricate component of oral histories and the evidence was the meticulously risk-based management of environment that has allowed the movement of both people and animals through country.

The Bureau of Meteorology has collected the calendars of several Indigenous cultures, showing how these calendars were suited to local environmental and weather conditions.

Figure 18: Yirrganydji calendar. The Yirrganydji traditional lands and waters extend along the coastal plains from Cairns to Port Douglas in Far North Queensland. Source: Bureau of Meteorology.

Indigenous migration

Where many regional towns or centres are located today were once areas of significant occupation. However, most of these areas were not occupied continuously throughout the year, as they are now. Having an in-depth knowledge of locations guided people on how long areas were inhabitable which in-turn lowered exposures to risk.

Indigenous peoples' movement through country has been continuous and complex. The frequency of this location-based migration is linked to many cultural practices such as ceremonies, intra and inter-tribal gatherings, settlements and trade. Previously, some of these journeys would take days and weeks.

Movement of Indigenous groups previous occurred before, during and towards the end of specific weather, plant and animal cycles, as this was most often when species were plentiful, or it was time to move, rest and rejuvenate country.

Other non-culturally specific movements occurred due to areas being impacted by severe weather events. By utilising traditional ecologic knowledge, people were able to understand how weather would impact them and what could be utilised to prevent or mitigate risk to human life. This either involved relocating elsewhere to higher ground or employing strategies close to areas of settlement. For example, some Indigenous groups moved to sand dunes to avoid flooding during periods of significant rainfall.[36]

Indigenous people's nomadic lifestyle formed a complex regime guided by lore that harmonised with the cycles of weather, plants and animals. Although complex, its simplicity in understanding and treating risks enabled a small number of personal items designed to be easily transportable over long distances and the intimate knowledge of the land and sea scapes enabled a population of people to be flexible and agile to maintain existence in what is described as one of the harshest environments on the planet.

Climate change and disaster risk (2020-2060)

Climate change refers to any significant change in climate variables lasting for several decades or longer (such as temperature, rainfall or wind patterns). It is different from weather, which is short-term and variable. Climate change is attributed to several natural and human-induced factors.[37–39] Climate modelling work indicates that climate change is likely to have transformative impacts across Queensland's disaster management arrangements, with impacts relevant across varied industries, demographics and ecosystems.

The Intergovernmental Panel on Climate Change (IPCC) defines climate change as "an alteration in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. […] Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. Anthropogenic climate change is projected to continue during this century and beyond."[37]

The Queensland climate is highly variable and climate change is already impacting the economy, environment, and society. Average temperatures across the State are 1°C higher than they were 100 years ago,[40] with shifts beyond natural variability resulting in exposure to increased disaster risk.

Projected Climate change trends for Queensland

There are many factors that make it difficult to predict the future effects of climate change. Different rates of change identified across a range of scenarios, as well as the number of climate variables, lead to a range of plausible future scenarios. There is no historical data accurately documenting climate change and, on this basis, it is difficult to estimate future impacts.[40] Predicting the impact of climate change in Queensland is also challenging as it is dependent on the mitigation strategies employed by Queensland, Australia and the world.

For this reason, representative concentration pathways (RCPs) have been developed by the IPCC to examine the various possible futures of climate change.[41,42] RCPs are scenarios for the future concentration of atmospheric greenhouse gases. They focus on the 'concentrations' of greenhouse gases that lead directly to a changed climate and include a 'pathway', that is, the trajectory of greenhouse gas concentrations over time.

Four pathways were identified by the IPCC in 2010:[41]

- RCP2.6, a low estimate
- RCP4.5 and RCP6.0, medium estimates, and
- RCP8.5, a high estimate.

Each RCP number represents a measure of average global radiative forcing in the year 2100.[41]

Each of these pathways makes different assumptions about climate change mitigation activities. RCP2.6 assumes strong mitigation efforts, while RCP8.5 assumes weak to no mitigation efforts and minimal reduction in carbon emissions. Likewise, each RCP is associated with differing intensities of the effects of climate change.

The Queensland high-resolution climate projection data have been modelled using both RCP4.5 and RCP8.5 as these are thought to provide realistic upper and lower trajectories that are useful for estimating future climate risks. It has been found that the trend in global emissions has followed RCP8.5 most closely for the past decade, and that it appears to be the most likely scenario until 2050, even given recent efforts at mitigation.[43]

The broad climate change trends projected for Queensland are outlined below. However, it is important to note that these trends represent the projected average trend, meaning that changes to climate over time will be experienced unevenly across the State. For further information about the sources used for these broad trends, refer to the full version of the Emergency Management Sector Adaptation Plan (EM-SAP) found at: www.disaster.qld.gov.au

Figure 19: Future climate projects are available at: www.climatechangeinaustralia.gov.au and https://longpaddock.qld.gov.au/qld-future-climate/.

Climate projections for Queensland's planning regions

Detailed information on Statewide climate projects can be accessed in Climate Change in Queensland[40] and the Queensland Future Climate Dashboard, both produced by the Department of Environment and Science. Major impacts that are expected include:

- higher temperatures
- hotter and more frequent hot days
- harsher fire weather
- significant changes in rainfall including large reductions in rainfall in some parts of the State, and more intense downpours in others
- less frequent but more intense tropical cyclones, that can extend further south than commonly observed in the historical record[44]
- a rising sea level, including more frequent sea extremes
- a warmer and more acidic sea.

These impacts at the state level are described in detail in Climate Change in Queensland. Because the risks that are reported in the State Disaster Risk Report apply to the planning region level, the following table is a regional overview of some of these impacts until 2060, assuming RCP8.5.

Region	Significant impacts
Cape York	• Significant decrease in summer rainfall for 2020-40 and 2040-60, and in autumn for 2040-60 • Increases in temperatures are below State averages for both periods (2020-40 and 2040-60) • Significantly lower than State average Forest Fire Danger Index (FFDI) through to 2056-66, though rising relative to earlier decades • Some impacts of sea level rise on coastal areas
Central Queensland	• Significantly higher than average autumn rainfall in 2040-60 • Lower than average increases in annual temperatures in 2040-60, and higher than average summer maximum temperature increases in 2020-40
Central West	• Significantly higher than average annual temperature increases in both periods (2020-40 and 2040-60) • Significantly higher number of spring hot days for both periods (2020-40 and 2040-60) • Substantial increase in decadal FFDI towards 2056-66, greatly above the State average
Darling Downs	• Lower than average increase in hot days for both periods (2020-40 and 2040-60) • Significantly lower than average increases in summer and autumn temperature, but significantly higher than average temperature increases in winter and spring • Substantial increase in decadal FFDI towards 2056-66, though still slightly below the State average
Far North Queensland	• Significantly lower summer rainfall for both periods (2020-40 and 2040-60) • Lower maximum, minimum, and mean temperature increases than the State average for both periods (2020-40 and 2040-60) • Significant impacts of sea level rise on coastal areas
Gulf of Carpentaria	• Large increase in hot days than average for both periods (2020-40 and 2040-60) • Significantly higher spring rainfall in 2020-40 and 2040-60 and autumn rainfall in 2040-60 • Significantly higher than average spring temperature increases in 2020-40, and significantly lower than average increases in spring and summer temperatures in 2040-60 • Substantial increase in decadal FFDI towards 2056-66, greatly above the State average

Mackay, Isaac and Whitsunday	• Larger decrease than average in spring rainfall for 2040-60 • Lower than average spring and autumn temperature increase for both periods (2020-40 and 2040-60) • Significant impacts of sea level rise on coastal areas
Maranoa-Balonne	• Significantly lower than average autumn and summer temperature increase in 2020-40 • Significantly higher than average winter and spring temperature increases in both periods (2020-40 and 2040-60) • Substantial increase in decadal FFDI towards 2056-66, though still not greatly above the State average
North Queensland	• Highly significant increase in summer and autumn maximum temperatures in 2040-60 • Lower than average increase in winter and spring temperatures for both periods (2020-40 and 2040-60)
North West	• Significantly higher than average increases in average summer and autumn temperatures in 2040-60 • Significant increase in spring rainfall for both periods (2020-40 and 2040-60), and for summer and autumn in 2040-60
South East	• Significant increase in number of hot days for all seasons for both periods (2020-40 and 2040-60) • Lower than average temperature increases for 2020-40 • Significantly lower spring and autumn rainfall for both periods (2020-40 and 2040-60) but significantly higher summer and winter rainfall for both periods (2020-40 and 2040-60) • Significantly lower than average FFDI through to 2056-66 though rising relative to earlier decades • Significant impacts of sea level rise on coastal areas
South West	• Significantly higher increases for temperatures and hot days for all seasons for both periods (2020-40 and 2040-60) • Lower winter rainfall for both periods (2020-40 and 2040-60) • Significantly higher decadal FFDI than the State average, increasing towards 2056-66
Wide Bay Burnett	• Significantly fewer hot days for all seasons and all periods (2020-40 and 2040-60) • Lower than average temperature increases for 2020-40 • Significantly lower than average FFDI through to 2056-66, though rising relative to earlier decades • Significant impacts of sea level rise on coastal areas

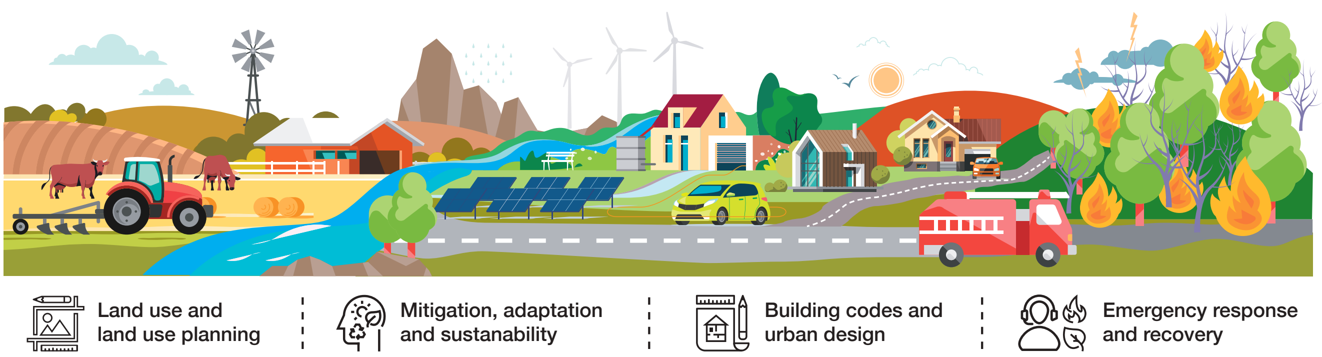
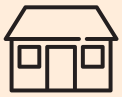
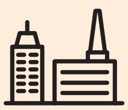
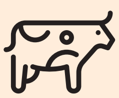
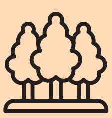


Figure 20: Overview of some risk management practices that contribute to disaster risk reduction. Source: QFES.

Projected industry impacts

Changes in the climate have, and will continue to have, transformative impacts on Queensland's industries. If unmanaged and not prepared for, climate change has the potential to cause catastrophic impacts to multiple industries. The more significant the changes, the larger the impact on resilience. This will contribute to a lower overall disaster resilience for significant industries, as well as local economies and communities.

The following table, adapted from Climate change in Queensland, details the climate risks, impacts and potential responses based on industry sector.[40]

Sector	Climate Risks*	Impacts*	Potential Responses*
	↑ heatwaves ↑ fire weather ↑ inundation and flooding ↑ tropical cyclone intensity ↑ sea level	• Erosion and infrastructure damage along the coastline • Increased maintenance costs • Increased disruption to services • Increased energy and water usage	• Consider future climate and sea-level rise when locating and constructing new developments and infrastructure • Increase road heights • Insure public assets • Design buildings to accommodate changing climate
	↑ temperature ↑ heatwaves ↑ fire weather ↑ tropical cyclone intensity ↑ sea level	• Increased threats to tourism infrastructure • Damage to popular environmental sites • Risks to tourists unfamiliar with conditions	• Consider climate risks in emergency planning for tourist sites • Adopt appropriate cancellation policies for extreme weather • Prepare for changing seasonal demand
	↑ heatwaves ↑ fire weather ↑ rainfall intensity ↑ inundation and flooding ↑ tropical cyclone intensity ↑ sea level ↑ sea temperature	• Disruption to supply chains • Disruption to workplaces and infrastructure • Loss of customers during emergency recovery • Increased flood damage • Increased maintenance costs • Increased disruption to water supplies	• Business continuity planning • Shift critical infrastructure out of hazard zones • Enable flexible working arrangements • Diversify customer base and products • Consider future climate and sea-level rise when locating and constructing new infrastructure • Insure critical assets • Implement water management planning
	↑ heatwaves ↑ fire weather ↑ flooding ↑ sea level	• Damage to cultural sites • Loss of significant ecosystems	• Identify cultural sites at risk and mitigate impacts • Review and document cultural practices • Increase cultural activities and ceremonies to transfer knowledge
	↑ temperature ↑ hot days ↑ heatwaves ↑ fire weather ↑ drought risk ↓ rainfall ↑ tropical cyclone intensity ↑ sea temperature	• Changed distribution of pests and diseases • Heat stress on livestock and crops • Farms affected by bushfire • Reduced water security • Crops destroyed by cyclones • Increased heat stress	• Consider diversifying outputs or business • Employ strategies to minimise heat stress on livestock • Consider different crop varieties and sowing times • Improve water efficiency
	↑ temperature ↑ hot days ↑ fire weather ↑ drought risk ↓ rainfall ↑ tropical cyclone intensity ↑ sea level ↑ sea temperature ↑ ocean acidification	• Changes to habitat • Altered disturbance regimes • Changing dynamics of invasive species • Cyclone and storm tide inundation damage to landscapes and natural systems • Coral bleaching • Existing threats to flora and fauna are exacerbated	• Develop strategies to respond to new and emerging diseases and pests • Increase green urban infrastructure and urban biodiversity • Link habitats to allow species to move • Consider moving selected populations to new areas
	↑ heatwaves ↑ fire weather ↑ flooding ↑ tropical cyclone intensity	• More stress on health and emergency services • More heat-related deaths, particularly among the elderly and disadvantaged • Mental health effects • Changes in disease occurrence	• Use existing social networks to support vulnerable community members • Implement rural mental health care programs • Consider climate risks when developing emergency planning for schools, hospitals, services • Increase green spaces and cool zones for heat stress
	↑ heatwaves ↑ fire weather ↑ rainfall intensity ↑ inundation and flooding ↑ tropical cyclone intensity	• Increased fire season duration and fire intensity will affect urban fringe communities • Increased sea level and storm intensity will affect coastal communities and increase inland flooding risk	• Improve bushfire safety standards for urban development • Increase focus on community preparedness and prevention • Update risk management standards to account for increased risk from climate change

↑ = Increase ↓ = Decrease * As applicable to specific state regions

Table 3: Overview of projected climate risks, impacts and potential responses in Queensland, based on industry sector.

The Queensland economy, and all industries need to plan for the impact of climate change. To summarise, a changing climate could have broad impacts including:

- Disruption and changes to tourism seasons and the accessibility of popular tourist activities (e.g. beaches will have greater prevalence of venomous jellyfish and the Great Barrier Reef will be further impacted by ocean acidification and warming).
- Public perception and reporting of disaster impacts and extents may present reputational risks for many sectors, especially interstate and international tourism.
- Disruption to business operations due to an increase in natural hazards (e.g. flooding and bushfires).
- Decreasing crop production, livestock carrying capacity and animal production, impacting food supply chains and local economies.
- Changes to the biodiversity of natural ecosystems.
- Disruption to business operations due to increased prevalence of hazards which will impact on a person's ability to be able to work, namely:
  - increase in frequency and severity of bushfire and likelihood of infringing on urban areas
  - increased risk of heatwaves and the associated human health impacts
  - increases in tropical cyclone, storm intensity and inundation, riverine flooding and sea level rise.

Climate change adaptation

The Queensland Climate Adaptation Strategy[45] is an important document guiding planning and preparedness in the context of climate change. This strategy builds on the growing momentum and valuable collaborative approaches adopted by stakeholders to plan for current and future climate impacts across different sectors and regions.

Climate adaptation refers to actions taken to reduce the negative impacts of climate change, or to take advantage of emerging opportunities. Adaptation involves going above and beyond traditional preparedness for climate variation, natural hazards and disaster events. It requires developing a comprehensive understanding of how a changing climate will affect Queensland, our regions and our communities, and actively working to reduce our exposure to climate risks while capturing new opportunities. Successful adaptation to climate change is a proactive and long-term process.

To achieve this, the strategy is based around the four clear objectives:

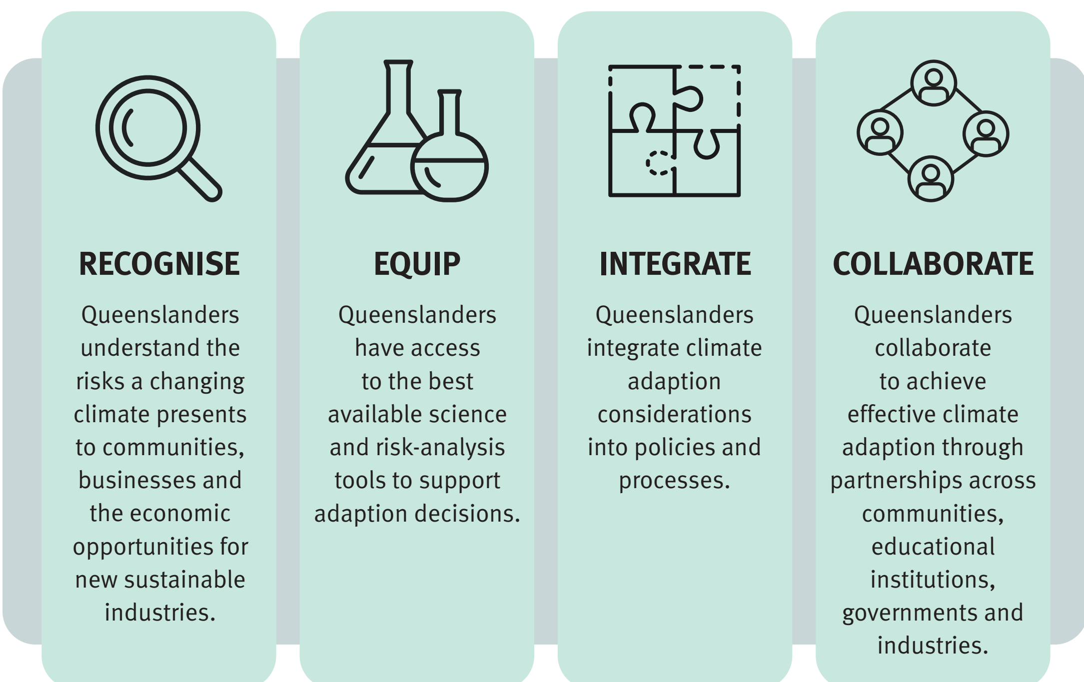


Figure 21: Objectives of the Queensland Climate Adaptation Strategy.

Through actions highlighted in the Queensland Climate Adaptation Strategy, actions can be taken across industries to reduce the impact of climate change on their operations, helping to improve disaster resilience as part of hazard and risk-based planning.

Disaster risk reduction (DRR) activities undertaken at all levels of Queensland's disaster management arrangements can be designed and implemented within a framework of climate change adaptation (CCA).

The objectives and implementation of DRR and CCA are closely aligned.[46] However, a major challenge in combining DRR and CAA is that they occur on different scales.[47–50]

Because effects of disaster events tend to be localised to a particular place, DRR occurs at a local level. CCA is informed by data at the state, national and international levels, and driven by policy direction at higher levels.

Research has shown that greater clarity around governance arrangements and increased resourcing can assist in overcoming these challenges.[51,52]

In Queensland, policies such as the State Planning Policy[53] can provide a practical guide for marrying the two approaches, as well as broader development frameworks such as the Sustainable Development Goals.[54]

Queensland's disaster management arrangements, through disaster management groups at the local and district level, also can act as a mechanism for ensuring that DRR activities to the goals of the Queensland Climate Adaptation Strategy.

Useful information sources

Climate change assessment and projection continues to be a global effort with several domestic and international agencies providing information and guidance on the issue. The Queensland Department of Environment and Science, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and, the Bureau of Meteorology (BoM) continue to lead the provision of data and information for jurisdictions on likely future climate conditions to support decision-making.

When using the information and data from any source for planning or decision-making, it is important to give full consideration to the limitations and assumptions underpinning the models and resolutions. For example, some of the sources below use Global Climate Models at low resolution spatial scales, while others use downscaled high-resolution models.

The Queensland Government acknowledges that "understanding our climate variability and likely future climate change is crucial for adaptation and preparedness". For this reason, the Queensland Government provides community and local government stakeholders access important and accurate data on climate change in Queensland.

For further information on trends by region in Queensland, refer to the Queensland Future Climate Dashboard or the Regional Climate Change Impact Summaries. The regional Climate Change Impact Summaries break down the impact of climate change for each Queensland region and provides targeted information which can help with local and regional based planning decisions.

SECTION B

STATE DISASTER RISK ASSESSMENT

Overview

Scope

This report expands on the 2017 State Natural Hazard Risk Assessment and builds on the comprehensive hazard assessments undertaken since, including the 2019 State Heatwave Risk Assessment, 2019 State Earthquake Risk Assessment and the 2022 Severe Wind Hazard Assessment.

The scope for this assessment has been expanded to include a broader range of natural and non-natural hazards, along with a range of risk drivers. While prioritisation of these hazards is provided as part of the risk evaluation, all hazards assessed have the potential to result in severe or catastrophic impacts and should be given appropriate consideration.

The hazards assessed within this report are not exhaustive - the updated hazard list to support monitoring and reviewing the implementation of the Sendai Framework for Disaster Risk Reduction identifies 302 hazards in total, although not all are relevant to Queensland.[55] Alignment of assessments in this report with the revised Sendai hazard list is outlined in Figure 23.

Figure 22: State-level disaster risk assessments produced by QFES. Source: QFES.

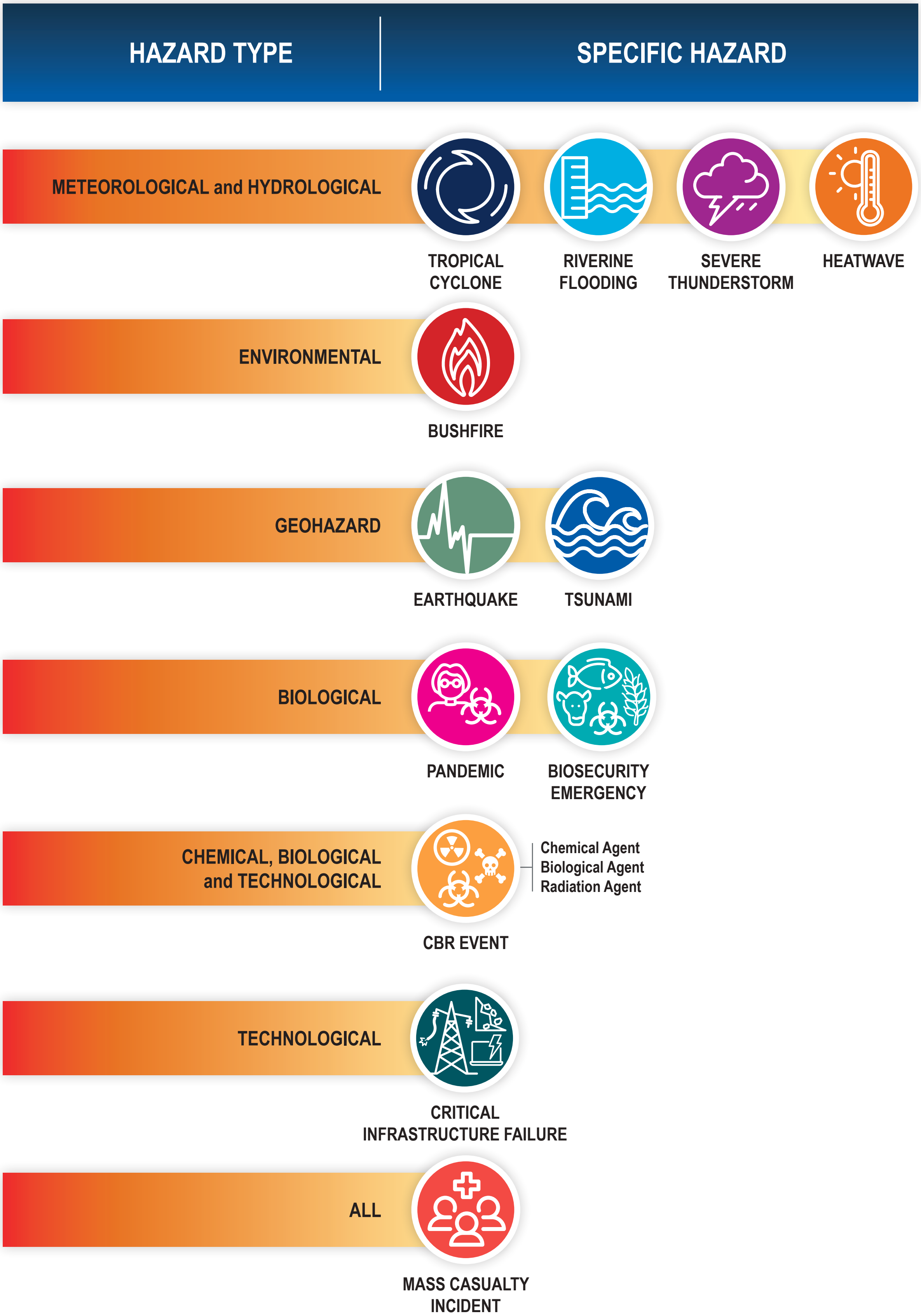


Figure 23: Twelve hazard assessments are included in the scope of this report. Source: QFES (adapted from https://www.undrr.org/publication/hazard-definition-and-classification-review).

How to read the assessments

Each hazard assessment has a consistent format, to maximise their usefulness in preparing risk assessments at the local and district levels. Each assessment has been designed to link to the development of appropriate scenarios and calculation of risk under the Queensland Emergency Risk Management Framework or QERMF (see Section A for more details). The sections of each risk assessment, as well as some guidance about how to interpret their contents, is given below.

1. Understanding the hazard

This section provides a general overview of the hazard and scope of the assessment, contextualising both the history and projections or future occurrence of the hazard.

The **definition** of the hazard used for the assessment draws on definitions used by other Queensland and Commonwealth government agencies. Hazard ratings provide guidance on the scale and severity of hazards to support scenario-based risk assessments. **Hazard ratings** are provided for the ten hazards (tropical cyclones, riverine flooding, thunderstorm, heatwave, bushfire, earthquake, tsunami, pandemic, biosecurity, and chemical, biological and radiological incident) and not the cascading and compounding events (infrastructure failure and mass casualty incident). Cascading and compounding events generally have a broader scope and more varied causes than the other hazards identified here. They arise from systems of interrelated parts, which makes them difficult to assign hazard ratings to reliably.

Where feasible, the Projections section in each assessment provides guidance on **probability** for each hazard at the regional planning level. Probabilities are provided on a scale of 1 to 5, as follows:

Variable	5	4	3	2	1
	Almost certain	Frequent	Likely	Infrequent	Rare and Very Rare
Annual Exceedance Probability (AEP)	63% per year or more	20% to <63% per year	5% to <20% per year	0.5% to >5% per year	Less than 0.5% per year
Average Recurrence Interval (ARI)	1 year	4.5 years to 1 year	20 to 4.5 years	200 to 20 years	More than 200 years
Description	Could happen at least once a year	Could happen several times per decade	Could happen about once a decade	Could happen one or more times within my lifetime, or within the lifetime of my home	Could happen in my lifetime, or in the lifetime of my children or grandchildren

Table 4: Probability variables used within the assessments.

There are a range of ways to express probability. Table 5 provides additional guidance on how to consider the likelihood of an event over a range of time frames. This can help to communicate the risk and potential danger to the community and relevant decision makers, helping them make informed and long-term decisions about risk.

Chance of an event of a given intensity being exceeding in any one year	Probability of experiencing an event in timeframe		
	30 years (mortgage)	70 years (lifetime)	100 years (infrastructure)
10% (1 in 10 odds)	95.76%	99.93%	99.99%
5% (1 in 20 odds)	78.53%	97.24%	99.40%
2% (1 in 50 odds)	45.45%	75.68%	86.73%
1% (1 in 100 odds)	26.03%	50.51%	63.39%
0.5% (1 in 200 odds)	13.96%	29.59%	39.42%

Table 5: Guidance on how to understand and communicate probabilities across different timeframes. Adapted from: Queensland Chief Scientist.[56]

We do not provide probability variables for all hazards, due to inherent difficulties in finding probabilities for some hazards. Because the causes of critical infrastructure failure and mass casualty incident are complex and arise through the interaction of multiple systems, we do not provide probability variables for these events.

The methodologies for deriving probability scores are described in detail in Section D.

2. Management of the hazard

An overview of key hazard management functions and entities. Potential **Triggers** for the activation of response arrangements are identified where practical for each hazard. Identifying these triggers, and linking these to relevant preparation and response activities within disaster management plans can help to ensure timely activation of support and resources across all levels of Queensland's disaster management arrangements, as outlined in the Queensland Disaster Management Guideline.

A high level overview of the roles and responsibilities of primary and supporting entities is provided.

Considerations for disaster management groups

These breakout boxes are provided to prompt discussion within disaster management groups and to help identify considerations for appropriate risk-based planning.

They are not intended to be prescriptive or exhaustive.

3. Scenario

These boxes contain scenario examples that can be tailored for use in hazard assessments at the local and district levels. These scenarios can also provide a basis for an exercise to validate the assessment of risk and local capability. They have been produced in consultation with subject matter experts.

4. Impacts

An overview of potential impacts for each hazard across a range of exposed elements. Impact descriptions are clustered into the following categories, representing aspects of the built, social, economic and natural environments:

- Essential infrastructure
- Transport
- Community
- Health and wellbeing
- Business and economy
- Natural environment

These are high-level, and reflect the experience of LDMGs and DDMGs, the guidance of subject matter experts, and findings of academic research. They are designed to act as a prompt for assessing local and district level exposure and vulnerability. Impacts can also be spatially mapped for communities across Queensland to provide a more explicit overview of hazard exposure and vulnerability.

5. Supporting information

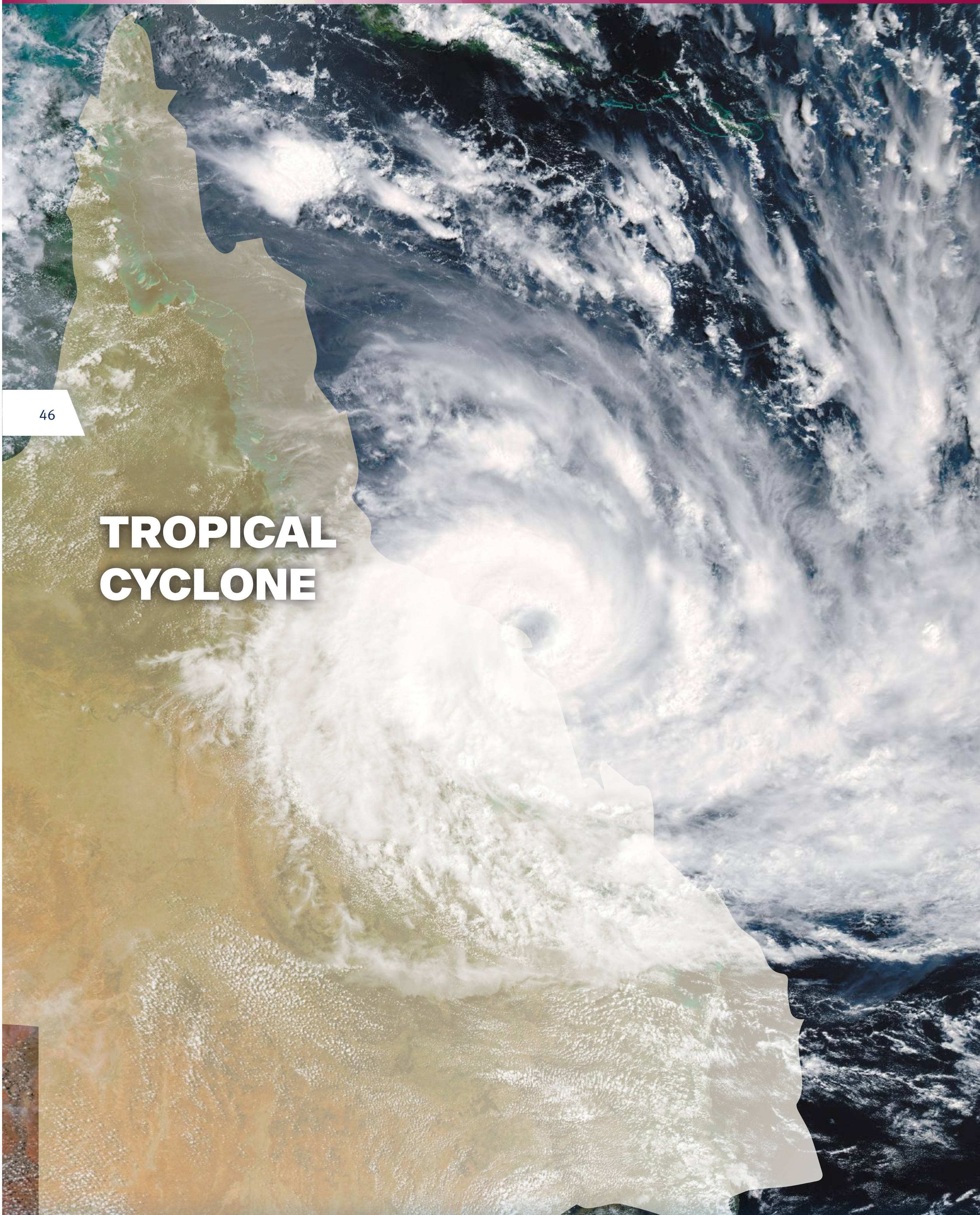
Additional reference information and links for each hazard. This includes the relevant State and Commonwealth plans and procedures for each hazard, as well as technical guidance.

6. Risk summary

A summary of the risks associated with the hazard, including:

- impact, likelihood and forward projections of the risk
- mitigating factors
- potential impacts across the areas of essential infrastructure, transport, community, health, economy and the natural environment.

TROPICAL CYCLONE



Tropical cyclone

Tropical cyclone is the second highest priority hazard for Queensland. This represents a change from the highest priority in the 2017 Queensland State Natural Hazard Risk Assessment.[2] Full details of prioritisation are provided below and in Section C - Risk prioritisation.

Understanding the hazard

The information presented in this risk assessment is a distilled version of the Severe Wind Hazard Assessment (Queensland). Please consult that document for more detailed information on tropical cyclone impacts and probabilities.

Tropical cyclones (cyclones or TCs) are a regular part of Queensland life, particularly in the north of the State. Between 1960 and 2021, an average of seven tropical cyclones have affected Queensland each year – three from the Gulf of Carpentaria and four off the east coast.[57]

Many Central to Far North Queensland communities have experience managing tropical cyclone risk, however direct impact to a major populated centre anywhere in Queensland has not been observed since 1971 with the impact to Townsville by TC Althea.

Recent studies indicate that the communities of South East Queensland are becoming increasingly exposed to tropical cyclone risk. This is not only in terms of the increased potential of severe tropical cyclone impact in the south east region, due to climate change, but also because the underlying drivers of risk (e.g. the built environment and density of population) are conducive to the hazard.

In April 2021, TC Seroja crossed the Western Australia coast as a Category 3 system near Port Gregory, about the same latitude as the Queensland – New South Wales border. TC Seroja caused widespread damage to towns and communities in the mid-west region of Western Australia. Around 10% of buildings in Kalbarri and Northampton had damage classified as ‘severe’ or ‘total’, with many newer houses subjected to structural damage from wind speeds less than their design.[58]

Tropical cyclones can cause widespread damage, significant disruptions to business as usual and can result in injury and death. Queensland’s tropical climate and concentration of population along the coast and rivers makes Queensland particularly susceptible to tropical cyclones compared to other parts of Australia.

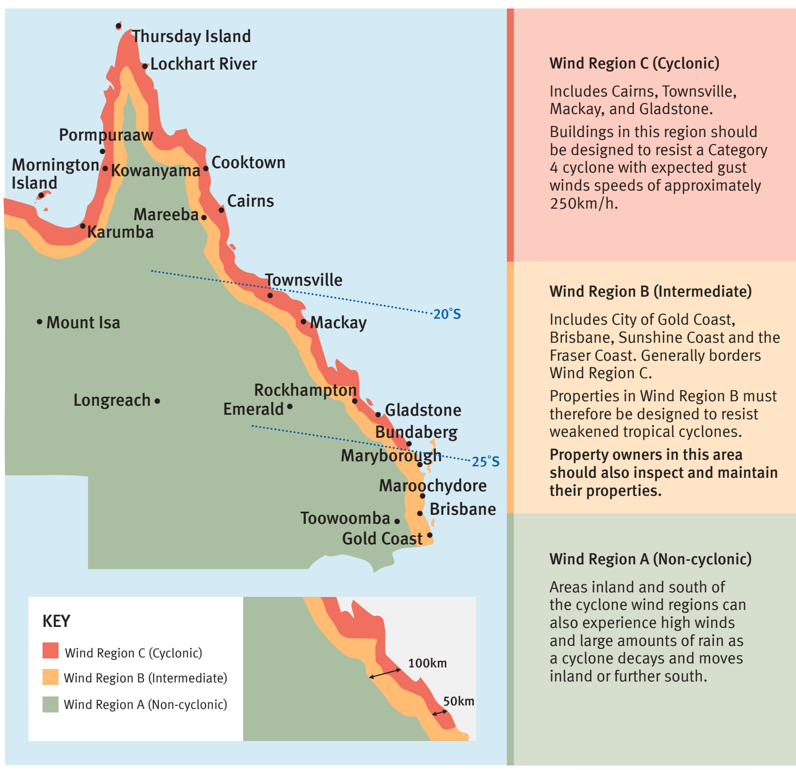


Figure 24: AS/NZS 1170.2 2011 Wind Regions for Queensland, with key locations marked (after AS/NZS 1170.2, 2011).

Definition

Tropical cyclones are low pressure systems that form over warm tropical waters, rotating around a single point or 'eye'. Tropical cyclones can vary considerably in their size and intensity and typically form when the sea-surface temperature is above 26.5°C. Tropical cyclones can persist and change intensity over many days, even weeks, and may follow quite erratic paths.

A cyclone will dissipate once it moves over land or over cooler oceans. However, conditions may be present that allow cyclones to maintain their intensity much further inland then may be expected; as was the case with TC Larry, 2006 and TC Yasi, 2011, as shown in Figure 25. The potential for cyclones to maintain destructive potential far inland, over terrain conducive to the hazard, presents a major challenge for regions not used to their impact.

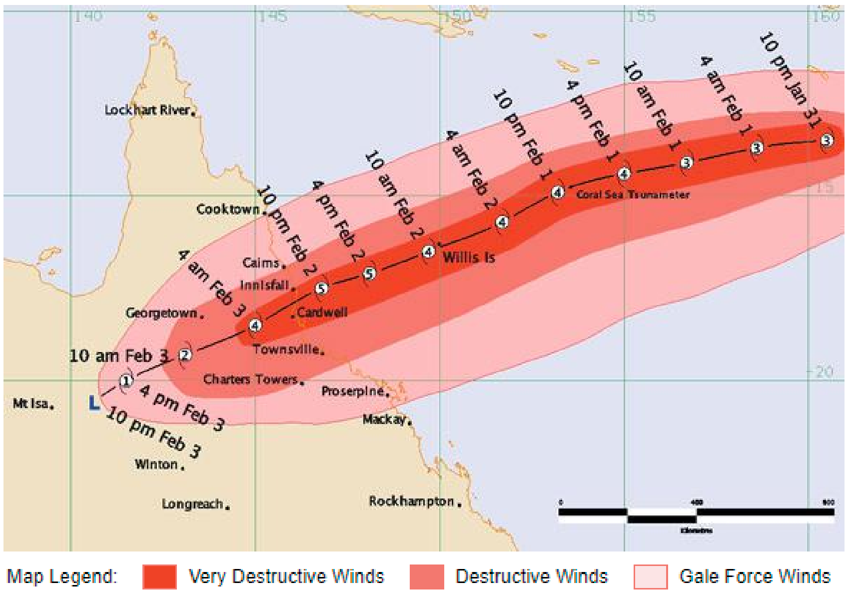


Figure 25: Track and Intensity Information for Tropical Cyclone Yasi.
Source: reproduced with permission from the Bureau of Meteorology.

The technical definition of a cyclone is "A non-frontal low pressure system of synoptic scale developing over warm waters having organised convection and a maximum mean wind speed of 34 knots or greater extending more than half-way around near the centre and persisting for at least six hours".[59]

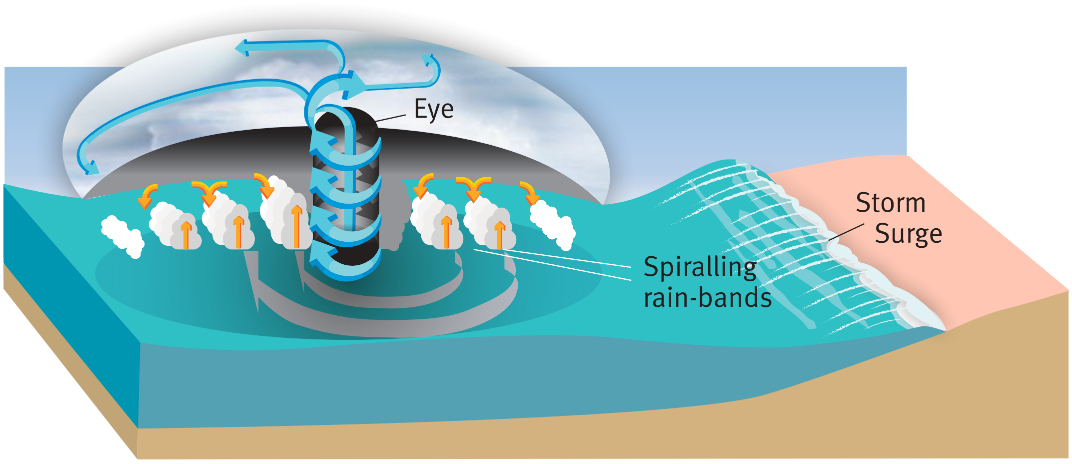


Figure 26: Diagram of a tropical cyclone system.

An additional hazard associated with the passing of a tropical cyclone is storm tide inundation. Storm tide is defined as the "the total water level obtained by adding the storm surge and wave setup to the height of the astronomical tide".[60] Storm tides can inundate low-lying areas causing erosion and significant damage to coastal communities.

The storm surge is a combination of the lower pressure and the strong winds. The height of the surge is dependent on the characteristics of the particular cyclone as well as the shape of the seafloor.

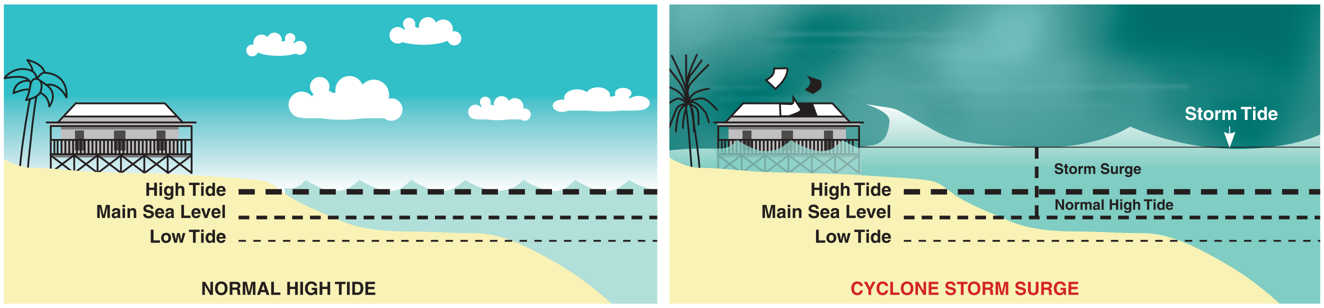


Figure 27: Depiction of 'normal' high tide and storm tide.
Source: Queensland Fire and Emergency Services based on an original illustration by Bureau of Meteorology.[60]

Figure 28: The effects of storm surge at Tully Heads from Tropical Cyclone Yasi in February 2011. Source: ABC News (Kerrin Binnie)

Hazard scale

In Australia tropical cyclones are assigned a category from one to five, depending on maximum mean wind speed and typical strongest gust (see Table 6).[4]

Category	Maximum mean wind (km/h)	Typical strongest gusts (km/h)	Typical effects
1	63 - 88	‹ 125	Damaging winds. Negligible house damage. Damage to some crops, trees and caravans. Boats may drag moorings.
2	89 - 117	125 - 164	Destructive winds. Minor house damage. Significant damage to signs, trees and caravans. Heavy damage to some crops. Risk of power failure. Small craft may break moorings.
3	118 - 159	165 - 224	Very destructive winds. Some roof and structural damage. Some caravans destroyed. Power failures likely.
4	160 - 199	225 - 279	Significant roofing loss and structural damage. Many caravans destoyed and blown away. Dangerous airborne debris. Widespread power failures.
5	› 200	› 280	Extremely dangerous with widespread destruction.

Table 6: The five-category system used to describe the severity of a tropical cyclone. Adapted from the Bureau of Meteorology.

The Queensland context

History

The eastern Australian coastline from Cape York Peninsula to Coolangatta has experienced multiple tropical cyclones over the past 100 years, with many severe tropical cyclones causing major destruction to communities, such as Tropical Cyclone Althea at Townsville in 1971 and Tropical Cyclones Larry and Yasi at Innisfail in 2006 and 2011 respectively.

One of the most intense tropical cyclones ever to occur in the Southern Hemisphere, Tropical Cyclone Mahina, made landfall in Far North Queensland in 1899.[61,62] There are also records of tropical cyclones making landfall in South East Queensland in the 1950s (the Great Gold Coast Cyclone, 1954), and numerous cases of tropical cyclones passing close to South East Queensland but remaining offshore (e.g. tropical cyclones Dinah in 1967 and Oma in 2019), causing significant impacts from wind, rain and waves.

The following image (Figure 29) is a heatmap representing a century of cyclone tracks, illustrating where cyclones have historically occurred relative to Queensland's planning regions. The yellow and red areas represent more frequent occurrence.

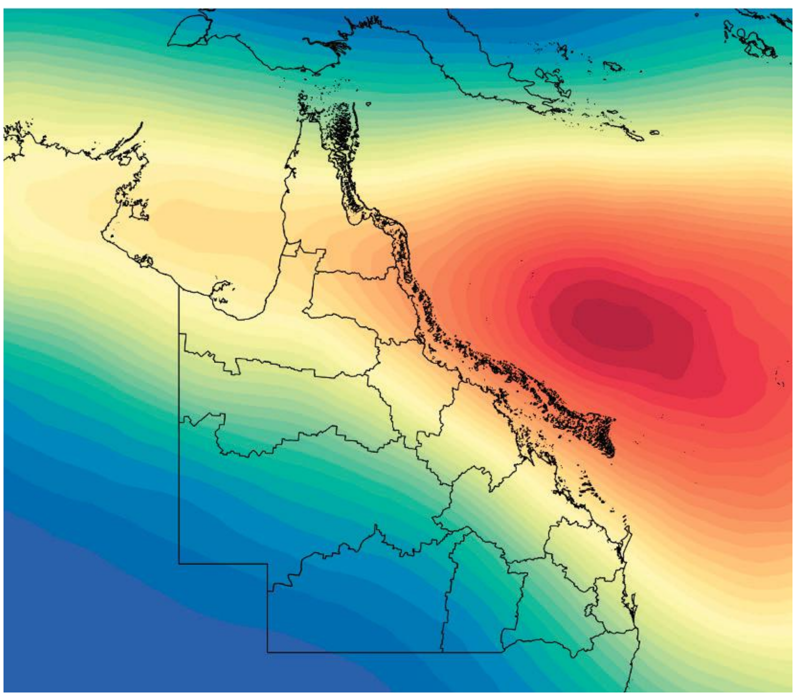


Figure 29: Density of tropical cyclone tracks between 1921 and 2021, with outlines of regional planning areas and the Great Barrier Reef. Data from IBTrACS.[63] Red indicates greater cyclone activity, and blue indicates lesser. Source: QFES.

Cyclone impact across Queensland – 1918 to 2011

Figure 30: *Looking south down Sydney Street post the impact of the 1918 Mackay Cyclone.*

Figure 32: *Roof Loss in Norman Street, 1954 Great Gold Coast Cyclone.*

Figure 34: *Houses and apartment blocks with their roofs blown off in Innisfail after Cyclone Larry struck in March 2006. Source: Mark Baker(AP)*

Figure 36: *The aftermath of Cyclone Yasi as it crossed the Far North Queensland coast. Dozens of luxury boats were smashed together at the Port Hinchinbrook marina in Cardwell. Source: Marc Mccormack*

Figure 31: *Storm surge at Tuesleys Jetty, Southport - 1954 Great Gold Coast Cyclone.*

Figure 33: *The suburb of Pallarenda, Townsville, after Cyclone Althea in December 1971. Source: City Libraries Townsville Local History Collection*

Figure 35: *Cardwell in the aftermath of Cyclone Yasi, 2011. Source: Townsville Bulletin*

Figure 37: *Dunk Island devastation from Cyclone Yasi. Source: HeraldSun (AAP)*

Cyclone impact across Queensland 2015 to 2018

Figure 38: *Damage to buildings in Yeppoon in the aftermath of Cyclone Marcia, 2015. Source: Queensland Fire and Emergency Services*

Figure 39: *Serious damage around Sarina Range due to landslips from Severe Cyclone Debbie. Source: Loretta MacGregor*

Figure 40: *Shute Harbour is littered with debris following Cyclone Debbie. Source: Dan Peled (AAP)*

Figure 41: *Roof damage sustained to holiday accommodation on Hamilton Island from Cyclone Debbie. Source: Dennis Garrett (ABC News)*

Figure 42: *Damage sustained in Pormpuraaw post the transit of Cyclone Nora. Source: Queensland Police Service*

Projections

Recent analysis of the impact of climate change on Queensland tropical cyclones indicates the following key points:

- The declining frequency (~40% by 2100 under RCP8.5) and little shift in the distribution of tropical cyclone intensity suggests that overall, the likelihood of extreme wind speeds (with reference to annual exceedance probability) will be reduced into the future.
- The most extreme events are becoming more intense however, the reduced frequency will largely offset this when viewed in terms of annual exceedance probability.
- There may be some regional variations around this – for example, some models indicate a relative increase in tropical cyclone landfall over the southern half of the Queensland coast.
- There is medium to high confidence of an increase in TC-related precipitation globally of around 14%. This will lead to significant impacts to buildings and communities in future events.
- Storm surge levels are widely projected (with high confidence) to increase in line with projections of sea level rise.[44,64–67]

Modelling performed by Geoscience Australia as part of the Severe Wind Hazard Assessment for Queensland projects that while the overall number of tropical cyclones are expected to decrease through to 2060, the number of more severe tropical cyclones is expected to increase.

Projections for the probability of events of any magnitude are summarised below. The numbers 0 to 5 do not represent the number of potential cyclones, but rather expected frequency of tropical cyclone events, with 0 representing no hazard frequency and 5 representing the highest hazard frequency.

Probability variables for any TC event under RCP8.5			
Region	**1981 – 2010**	**2021 – 2040**	**2041 – 2060**
Cape York	5	4	4
Central Queensland	2	2	2
Central West	0	0	0
Darling Downs	1	1	1
Far North Queensland	3	4	3
Gulf of Carpentaria	2	2	2
Mackay, Isaac and Whitsunday	3	3	3
Maranoa-Balonne	1	1	1
North Queensland	3	3	3
North West	1	1	1
South East	2	1	1
South West	0	0	0
Wide Bay Burnett	2	2	2

Table 7: Projected changes in the probability of tropical cyclones for each Queensland region from 1981-2060.

Landfall patterns are also projected to change under RCP8.5, as illustrated by the following figures below.

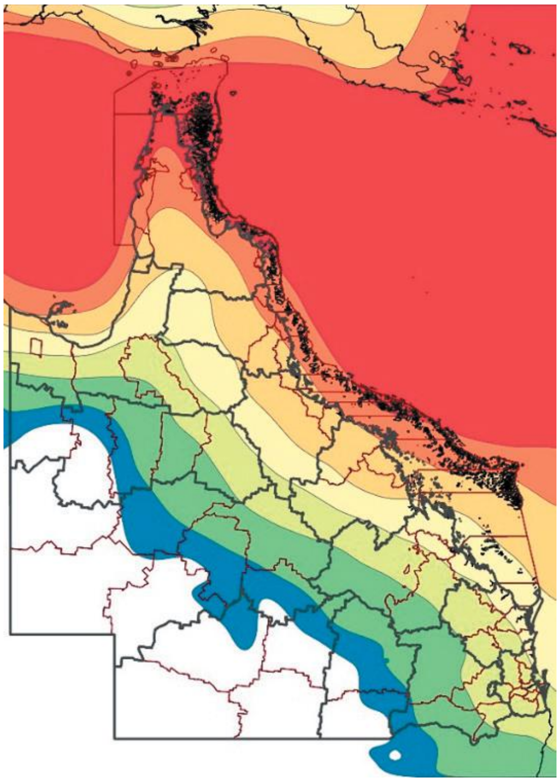


Figure 43: Cyclone events in 1981 - 2010.

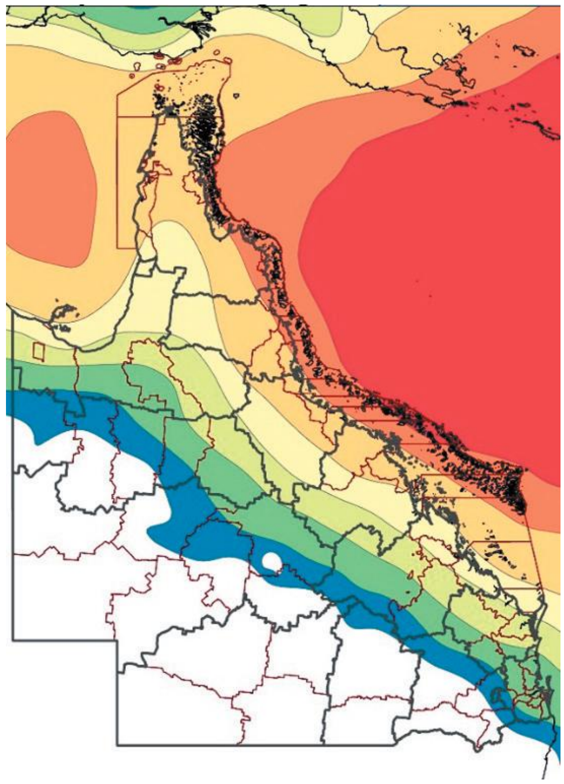


Figure 44: Projected cyclone events from 2021 - 2040.

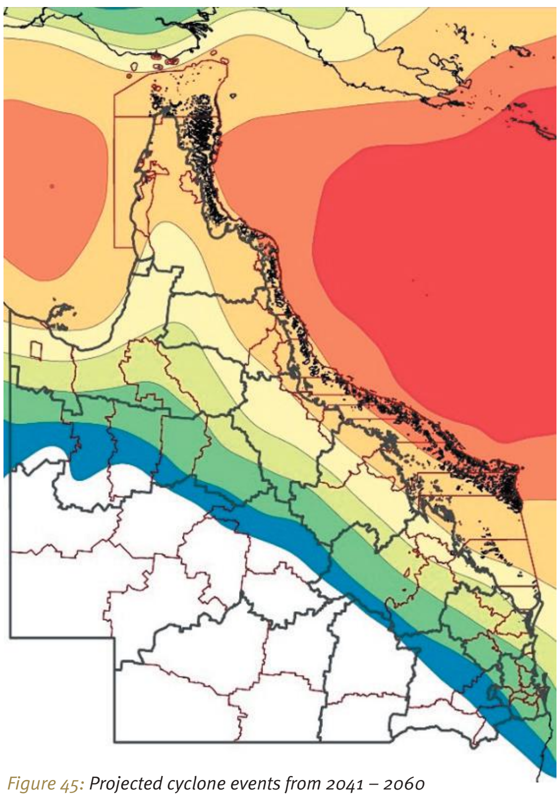


Figure 45: Projected cyclone events from 2041 – 2060

Annual Recurrance Interval

1 in 1 years (annually)

1 in 2 years

1 in 5 years

1 in 10 years

1 in 20 years

1 in 50 years

1 in 100 years

Note that between 2041 and 2060, the landfall rates of lower AEP are projected to drift further south. This means areas that have historically not been exposed to tropical cyclones below a certain AEP threshold will be exposed more frequently in the future.

A limitation of this data analysis is that, because of the relatively short historical record, modelling results for future periods are likely to reflect only a limited understanding of tropical cyclone exposure. South East Queensland has a limited number of cyclone events in the observed records and this influences forward projections. Further investigations beyond observed records indicate the risk may be greater than these projections suggest.[68]

The methodologies for deriving probability scores are described in detail in Section D: Technical methodologies.

Management of the hazard

The Bureau of Meteorology (BoM) provides tropical cyclone forecasts, warnings and expert advice. This includes producing intelligence and warnings for the emergence, evolution, and dispersal of tropical cyclones, including the modelling of cyclone tracks. BoM also provides seasonal climate outlooks that support forward planning.

Queensland Fire and Emergency Services (QFES) undertakes emergency preparedness and response operations, and produces hazard mapping[1] in partnership with Geoscience Australia by using the Tropical Cyclone Impact Model (TCIM) and the Tropical Cyclone Risk Model (TCRM) .

The Department of Environment and Science (DES) provides storm tide and wave information, expertise and advice.

Queensland Police Service (QPS) coordinates and provides support for evacuation operations as required in the lead up to tropical cyclone or storm surge impacts.

Figure 46: Winds and storm surge from Cyclone Debbie washes a yacht ashore at Airlie Beach, March 2017. Source: Mr Privacy/Shutterstock.

Bureau of Meteorology (BoM)

BoM chairs the Australian Tropical Cyclone Advisory Group, which supports tropical cyclone hazard management agencies across northern Australia – primarily the Western Australia Department of Fire and Emergency Services (DFES), Northern Territory Emergency Services (NTES) and Queensland Fire and Emergency Services (QFES) – in mitigating the hazards caused by tropical cyclones.

Department of Environment and Science

The Department of Environment and Science (DES) chairs the Coastal Hazard and Inundation Committee, which reports to the State Disaster Coordination Group (SDCG). Members of the Coastal Hazard and Innundation Committee include QFES, BoM, and the Local Government Association of Queensland (LGAQ).

Considerations for disaster management groups

- Can the group access, interpret and act on tropical cyclone advice, warnings and decision support products?
- Is the group aware of the limitations and uncertainties associated with forecasting tropical cyclone development, intensity and track direction?
- Does the group have the ability to interpret the technical information contained in advice, warnings, and other sources, and develop messaging appropriate for its target audience?
- Has the group discussed its requirements with relevant entities so appropriate preparation and planning are developed to help make informed decisions – for example, the identification of response triggers, limits and escalation of risk between relevant entities?
- Is the group aware of the potential for additional concurrent, compounding and cascading hazards?

Additional hazards relating to tropical cyclone that are assessed within this report include:

- Riverine flooding
- CBR Event
- Critical infrastructure failure
- Mass casualty incident

Figure 47: There can be near complete destruction of coral communities at reefs exposed to the full force of a cyclone as shown in this photo taken on Myrmidon Reef in February 2011, post the impact of TC Yasi.

Scenarios described in this section are selected from 2018 Tropical Cyclone Hazard Assessment.

Far North Queensland

The Category 5 scenario (Figure 48) impacts the coastline around Cairns as well as into the Tablelands. Early advice indicates that the cyclone will drift slowly across the Coral Sea for several days before heading towards Cooktown. Later advice indicates that the system brushes past Cooktown, where maximum winds reach 190km/h and then accelerates towards Cairns, making landfall almost directly over the CBD.

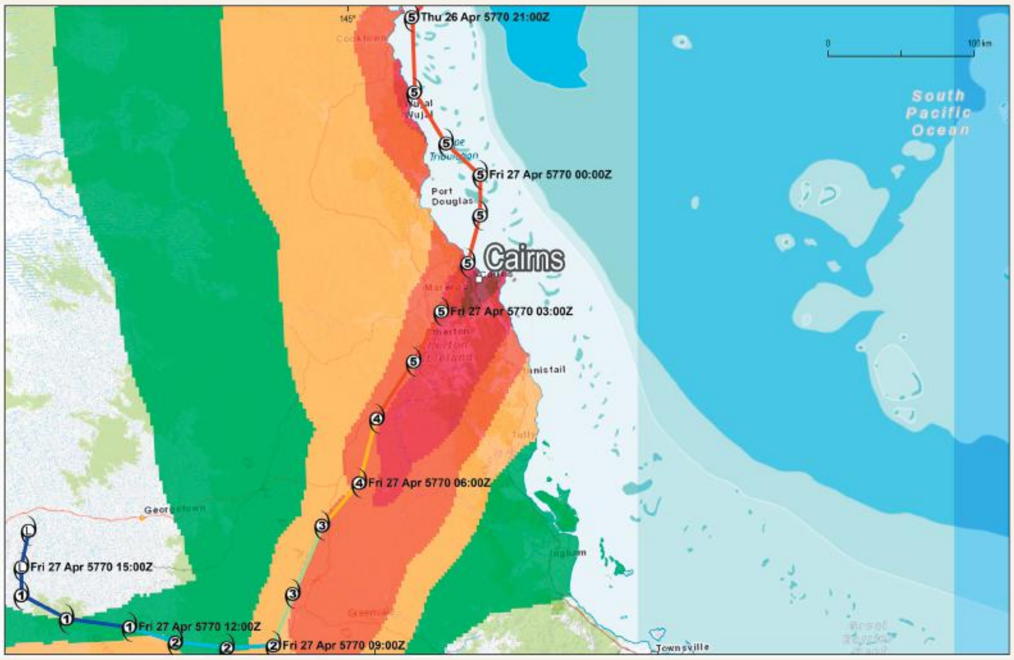


Figure 48: Regional wind field for scenario 013-03564, a Category 5 cyclone impacting Cairns, Qld.

Maximum wind gusts at Cairns Airport are recorded at around 290km/h. As the cyclone moves rapidly inland, Category 3 to Category 4 winds persist several hundred kilometres inland with significant damage to communities in the Atherton Tablelands and as far south as Charters Towers where 108 homes are completely destroyed.

The strongest winds in this scenario are centred around the airport and southwards towards Cairns city. Extreme wind speeds (over 300km/h) occur along the foreshore, as well as eastwards towards Yarrabah. Local wind acceleration occurs due to the steep topography around Mount Whitfield and along the range to Mount Sheridan, seeing wind speeds in these areas exceed 300km/h. Throughout the lower lying areas of Cairns, maximum winds are around 140-180km/h.

Suburbs along the coastline from Trinity Beach to the city sustain the greatest damage, with complete damage of all detached dwellings. Suburbs along the foot of the Whitfield Range, and also around Redlynch, sustain significant damage as well despite homes generally being of modern construction – this is because local wind acceleration exceeds the design wind loads for some sites. Further south, towards Edmonton and Gordonvale where the landscape opens out, some suburbs also sustain major damage as the open terrain does not reduce local winds. There is a significant proportion of older properties (e.g. older rural houses) in these areas which would contribute to the estimated damage.

The Mareeba and Tablelands Shires sustain major damage, especially around Malanda and Yungaburra. The Category 3 regional winds extend well inland over the Tablelands and, with only one third of houses built after the 1980s, this outcome is not surprising. This impact analysis is expanded further on the following pages and highlighted in Figures 49, 50 and Table 8. The community of Yarrabah also suffers major damage, bearing the brunt of the eyewall of the cyclone. Most of the houses are exposed to winds in excess of 280km/h, and nearly 60% of the houses are either extensively damaged or destroyed.

Given that this scenario only models wind impact to residential buildings, it should be noted that there would likely be significant to catastrophic additional impacts from associated debris, wind-driven rain, flash flooding and landslips (due to the complex terrain), riverine flooding and storm surge along the coastal strip and in estuaries (as with TC Yasi, 2011). There is also the consideration of impact to critical infrastructure (e.g. power and telecommunications) that would exacerbate the scale of impact to communities, and the ability to respond and recover in the aftermath.

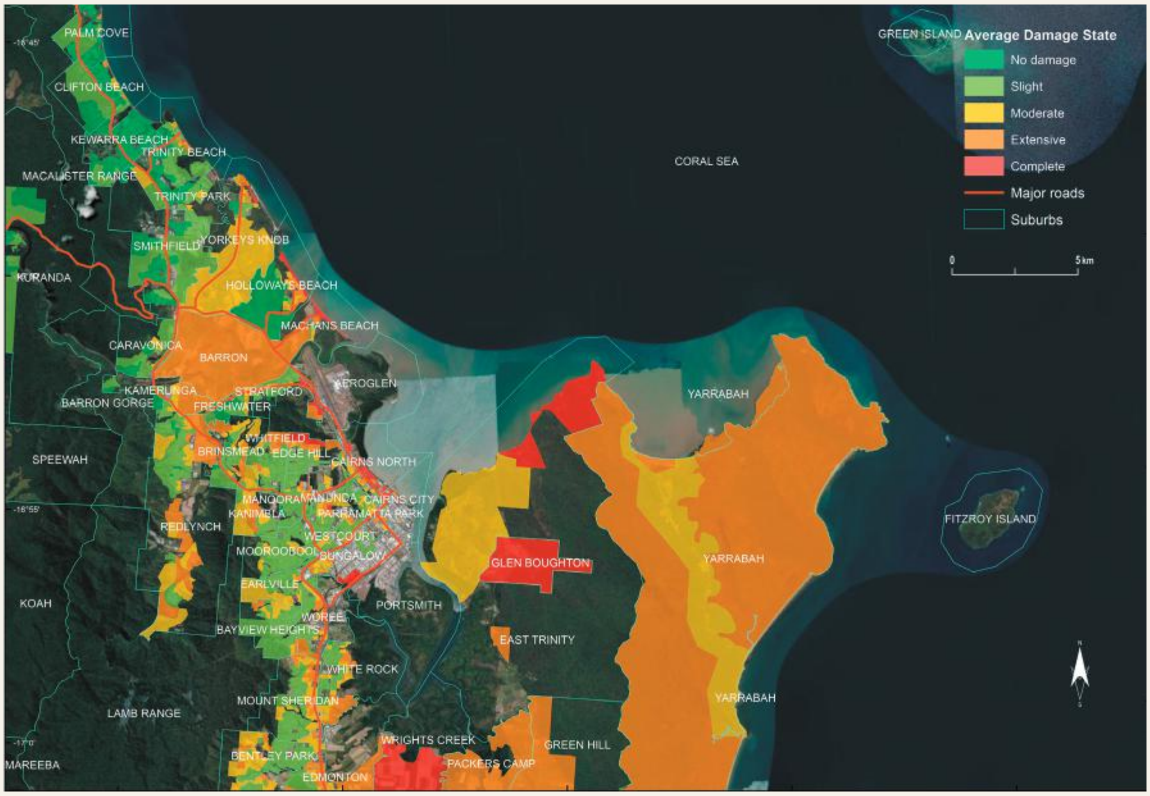


Figure 49: *Aggregated residential building damage states for mesh block areas, for scenario 013-03564, a Category 5 cyclone impacting in Cairns, Qld.*

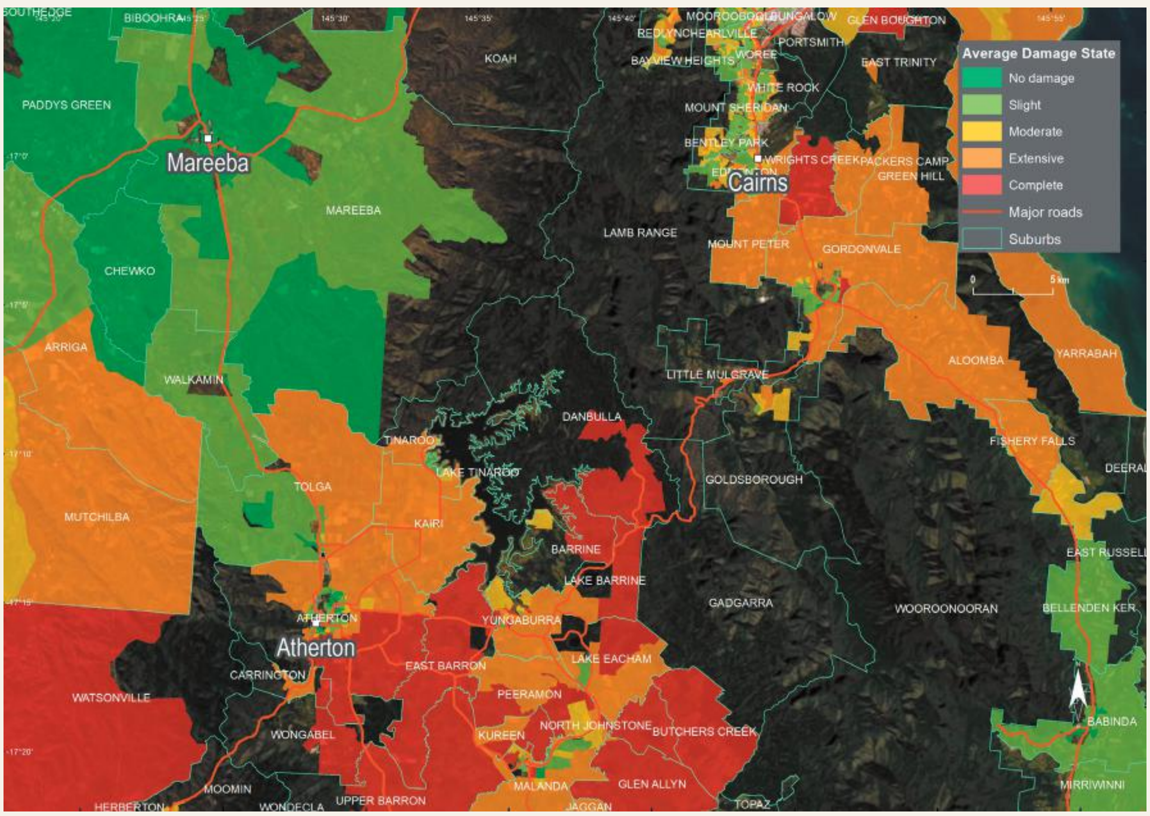


Figure 50: *Aggregated residential building damage states for mesh block areas, for scenario 013-03564, a Category 5 cyclone impacting the Atherton Tablelands, Qld.*

Table 8 presents the distribution of houses in each damage state across the impacted local government areas. Even though Mareeba misses the direct path of the cyclone, there are nearly 700 houses moderately damaged or greater throughout the shire. In the Tablelands Shire, nearly 5,500 houses are Moderately damaged or greater. Such a situation would rule out using the inland region for either evacuation or temporary accommodation in the lead up to or directly after the cyclone for Cairns' impacted population.

Overall, over 20,000 houses would sustain major damage (Moderate, Extensive or Complete) across the Cairns region from wind impact alone. The scale of impact and over such an extensive area would pose an extreme challenge in the emergency management context especially when considered in the wider context of likely additional impacts.

LGA	Negligible	Slight	Moderate	Extensive	Complete
Cairns (R)	11,667	29,769	6,489	6,074	1,369
Cassowary Coast (R)	15,677	147	7	12	2
Charters Towers (R)	1,137	3	1	5	108
Cook (S)	2,211	48	69	43	11
Douglas (S)	4,153	96	1	0	0
Hinchinbrook (S)	5,442	0	0	0	0
Hope Vale (S)	221	0	0	0	0
Lockhart River (S)	159	0	0	0	0
Mapoon (S)	29	0	0	0	0
Mareeba (S)	6,422	1,089	242	225	220
Napranum (S)	179	0	0	0	0
Tablelands (R)	2,611	2,539	1,235	1,867	2,367
Wujal Wujal (S)	48	7	0	0	0
Yarrabah (S)	1	112	60	200	8

Table 8: Distribution of residential houses in each damage state, grouped by local government area for scenario 013-03564, a Category 5 cyclone impacting Cairns, Qld. Note that some local government areas are not fully covered in this analysis, so the total number of houses listed in each LGA may be lower than actual. NB (S) = Shire, (R) = Region.

South East Queensland

In this scenario, the storm initially develops in the Coral Sea, remaining in the area for several days and intensifying to a maximum intensity of Category 5. The storm takes a south-south-westerly track towards the coast, making landfall over the southern portion of Stradbroke Island as a Category 4 storm. This track was selected as it is similar in its progression over time to TC Dinah (1967) but, in this scenario, the cyclone makes landfall.

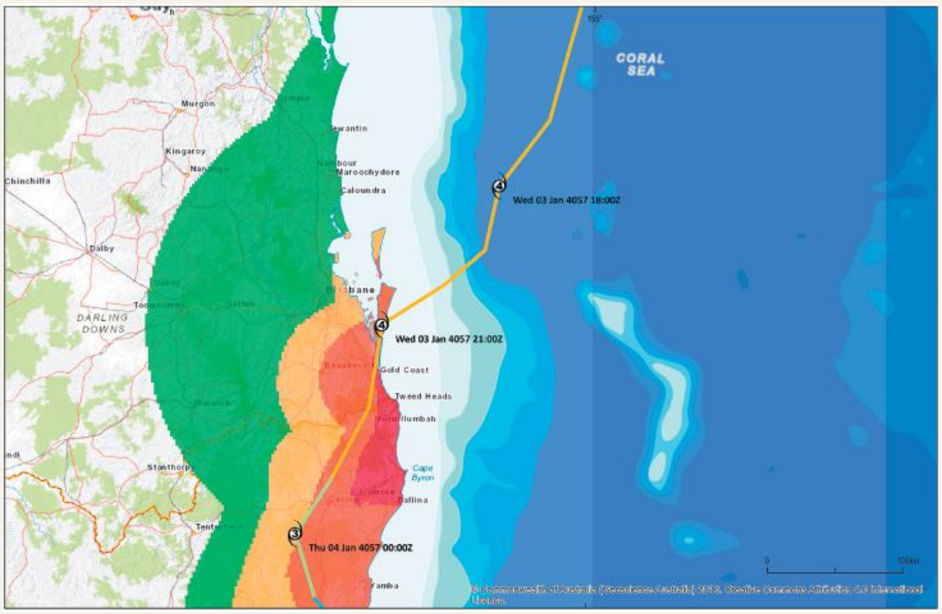


Figure 51: Regional wind field for scenario 001-00406, a Category 3 cyclone impacting Gold Coast, Qld.

Highest winds of around 220km/h are experienced along the coastal strip, where there are minimal obstructions. In comparison, estimated maximum wind gusts in the 1954 Gold Coast cyclone were around 170km/h (~Category 3). There are also areas of high winds well inland, due to local topographic enhancement over the steep topography of the Gold Coast hinterland.

In some areas, the maximum local wind speed may exceed 250km/h. These wind speeds are still sufficient to exceed local design levels in some areas, so a significant amount of damage is sustained (refer Figures 52, 53 and Table 9).

There is a narrow band along the coastal strip that sustains major (Moderate, Extensive or Complete) damage. Behind the coastal strip, damage levels are lower due to the reduced local wind speeds that arise from the change in terrain (from open water to urban areas). Further inland again, around the Gold Coast hinterland, there are pockets of Extensive and Complete damage. These occur because of the local enhancement of wind speeds through the steep topography of the area, leading to areas where winds again exceed the design levels for the site conditions.

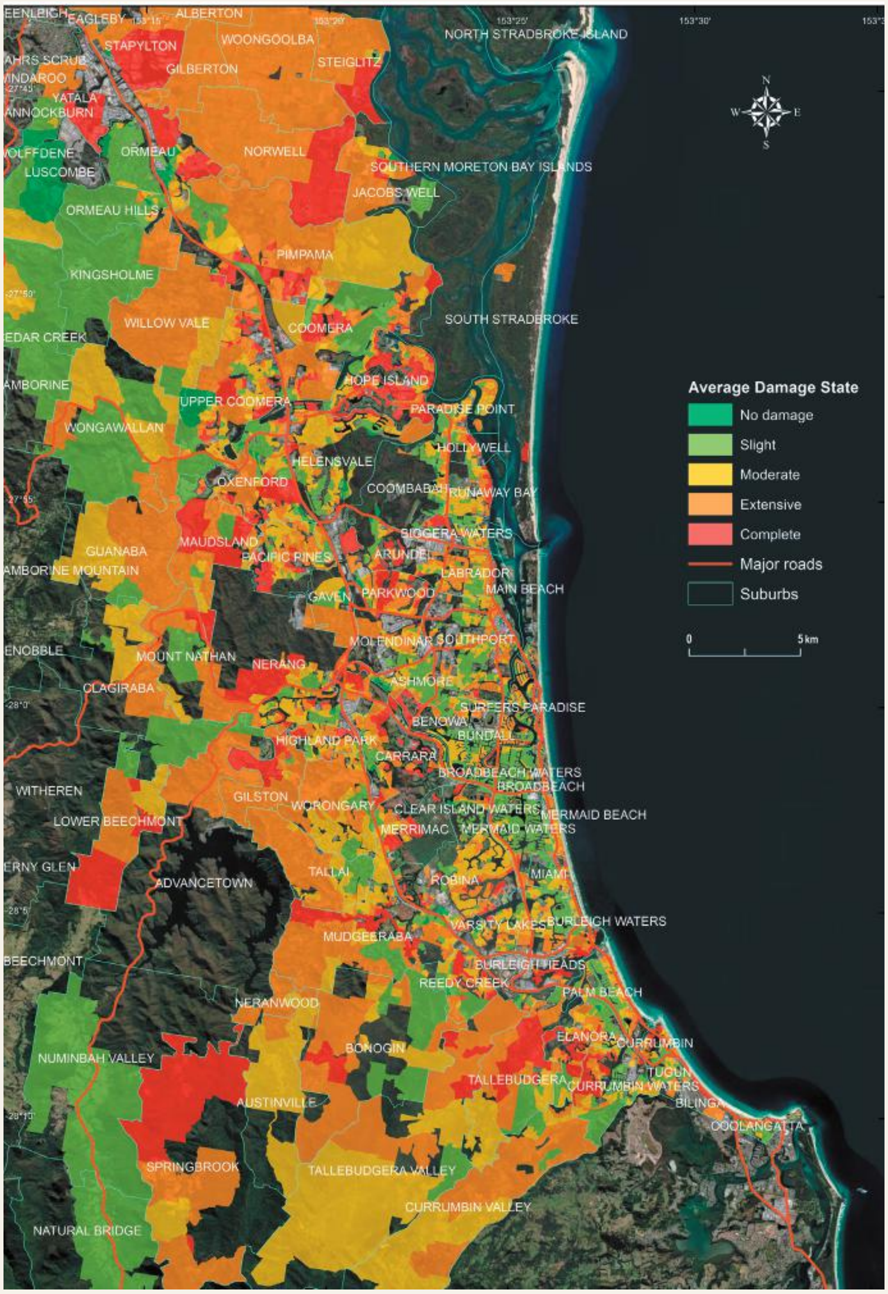


Figure 52: Aggregated residential building damage states for mesh block areas, for scenario 001-00406, a Category 3 cyclone impacting Gold Coast, Qld.

For the residential housing analysed here, the construction standards for modern houses only partly address the threat of cyclones. A severe TC (mid-range Category 3 or higher) would generate wind gusts that exceed the current regional design standards (205km/h), leading to major structural damage, even in well-constructed and maintained houses. Past experience with thunderstorm events (e.g. The Gap Storm, 2008) indicates that wind gusts of 170km/h are sufficient to destroy modern houses in the region as it is a combination of the wind speed and pressure distribution.

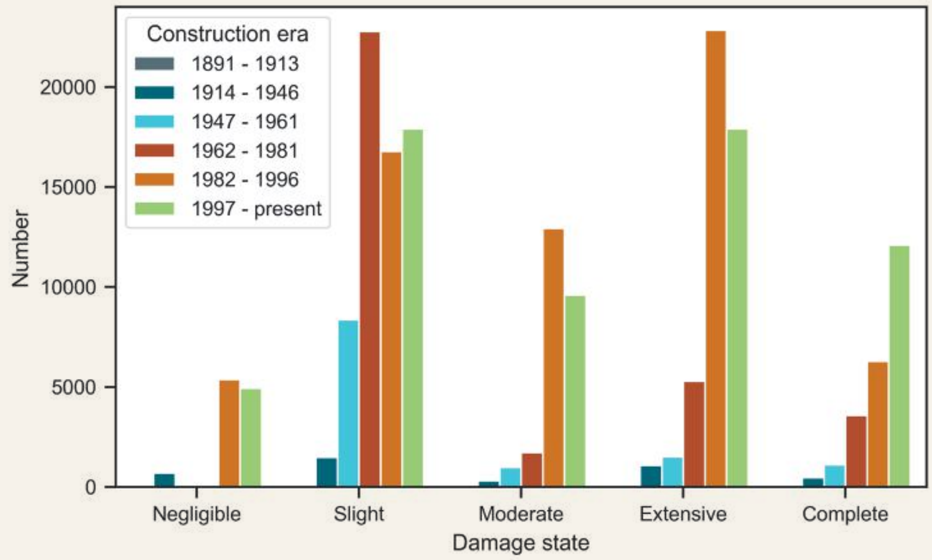


Figure 53: Count of buildings in each damage state, grouped by construction era, for scenario 001-00406, a Category 3 cyclone impacting Gold Coast, Qld.

	Damage state				
Construction era	**Negligible**	**Slight**	**Moderate**	**Extensive**	**Complete**
1840 - 1890	362	305	19	58	34
1891 - 1913	84	48	3	9	4
1914 - 1946	693	1,481	316	1,079	460
1947 - 1961	4	8,359	989	1,515	1,118
1962 - 1981	19	22,786	1,722	5,296	3,588
1982 - 1996	5,363	16,787	12,929	22,858	6,277
1997 - present	4,936	17,904	9,590	17,901	12,097
Total	11,461	67,670	25,568	48,716	23,578

Table 9: Count of residential buildings in each damage state, classified by construction era, for scenario 001-00406, a Category 3 cyclone impacting Gold Coast, Qld.

If this magnitude of cyclone impacted elsewhere in South East Queensland, similar impacts are likely in any of the large metropolitan areas, as the cyclonic Wind Region C, and the higher design wind speeds, starts at (approximately) Bundaberg.

While the likelihood of a Category 3 or 5 cyclone impacting South East Queensland is very low, from an emergency management perspective, the consequences of even a Category 3 event would be extensive and require a far greater response and recovery effort compared to a similar intensity cyclone in northern parts of the State.

It must also be considered that lower intensity cyclones (Category 1 or 2) may present considerable impacts to South East Queensland communities and, as such, increased cyclone preparedness in this region, in line with that of severe storms, would be beneficial.

Impacts

Impacts of tropical cyclones on communities

Figure 54: Diagrammatic representation of the direct and indirect impacts from tropical cyclones and their associated hazards. Source: QFES

Essential infrastructure

- Restoration of critical infrastructure following a broad impact, including both power and telecommunications, will be prioritised based on greatest need and/or criticality of downstream assets, for example the size of a population, or loss of power to a major hospital where redundancy is insufficient to maintain essential services.
- Many individuals and households are underprepared for cascading hazards, including disruption to energy, water and communications following a major event. These disruptions affect the ability to access to information, essential services and conduct basic domestic tasks (e.g. cooking, washing).
- Individual and household preparedness for disruption to essential infrastructure is generally lower where persons or households have moved into a community within the last five years, and when they are not aware of the associated risks. There has also been an observable increase in risk as the digital interdependence of systems continues to grow.[69]
- Low levels of household preparedness can strain local disaster response and recovery as attention and efforts are diverted to aid households that have not adequately prepared themselves for disruptions to essential goods or services.

Communications and energy

Figure 55: Fallen transmission lines as a result of Cyclone Yasi, 2011. Source: Powerlink

- The direct effect of wind on power lines and communications infrastructure coupled with the cumulative effect of flooding on key network nodes has led to prolonged periods of disruption.[70] Additionally, the interdependency of communications networks and other key community infrastructure (including services such as water and governance infrastructure) on power has led to protracted disruption issues.

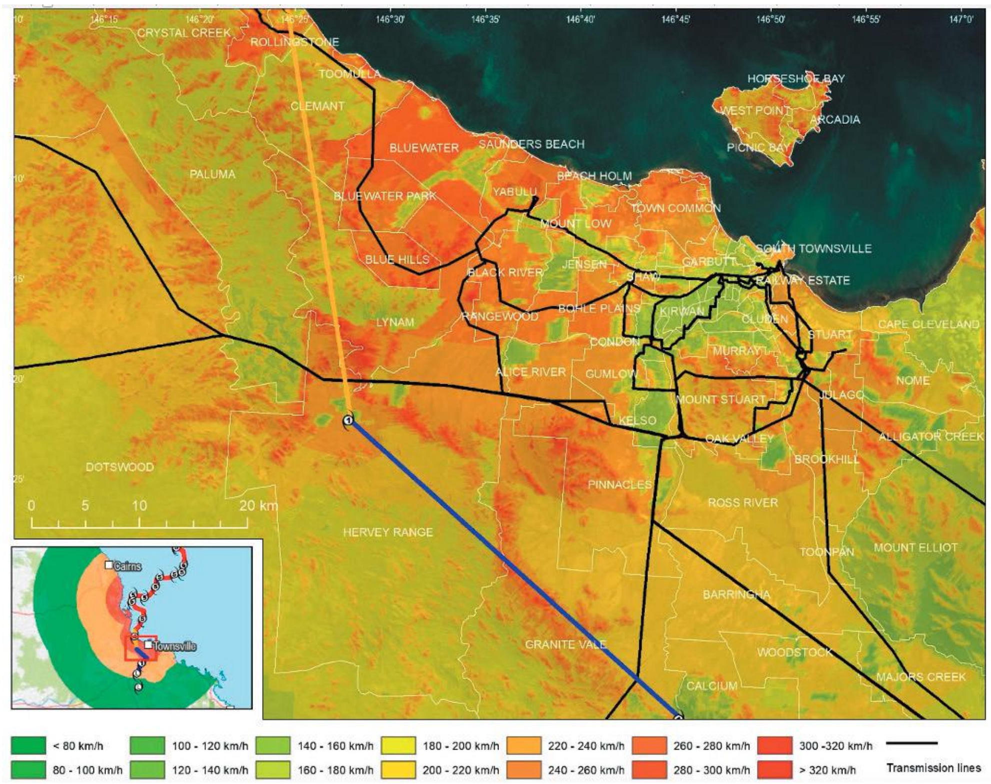


Figure 56: Overview of the transmission and sub-transmission network superimposed over a local wind field for a Category 5 scenario impacting Townsville. Note the position of the network in areas where there is significant acceleration of the cyclonic winds over areas of steep terrain or complex topography.

- Resilience to sustained destructive cyclonic winds is variable across the transmission and sub-transmission network as vulnerability is dependent on various factors, including the design and age of the infrastructure and topographic exposure.
- Given most Queensland's network assets (i.e. transmission and sub-transmission lines) run parallel to the coast, significant portions could be exposed to destructive wind gusts. Sections traversing significant topography (e.g. sections of the Great Dividing Range) may experience higher wind speeds due to multiplying effects.
- Historically, tropical cyclone impacts have resulted in disruptions to the electricity distribution network lasting between seven and 21 days (e.g. Tropical Cyclones Larry 2006, Yasi 2011 and Debbie 2017).
- Variability in energy redundancy to mobile and other communications broadcast towers, along with the possible prolonged disruption period in relation to power, may result in the total loss of communication services in some areas.
- Prolonged power outages can also lead to the inability to charge mobile communication devices which compounds the issue when communities are caught unprepared for such a possibility.
- As with the supply of additional generators, fuel supplies will often be locked down by critical infrastructure owners and operators across the affected regions (especially those areas where mining or heavy industries are located). This may significantly impact the availability of additional redundancy in the event of broad scale power outages.
- Adequacy of fuel reserves during response and recovery phases of an event is often cited as a key issue, with demand outstripping supply.
- A common vulnerability for power distribution and communications broadcast networks is a lack of redundancy on these networks. In areas where a single power line or chain of telecommunications towers serves a community, disruptions along any segment of this line will cause disruptions to all points further down this line. This is a particular issue in regional areas.

Water

- Disruption to water and wastewater services can occur due to flooding and wind. This includes damage to pumps, pipelines, water tanks and water treatment plants, and contamination of water supplies from debris, increased turbidity and sewerage overflows.

- During previous events, key areas of concern have included isolation of treatment plants, access to equipment, and loss of power and communications to plant supervisory control and data acquisition (SCADA) systems to determine the efficacy of schemes during an event. Lightning often directly impacts treatment and pumping SCADA systems and the loss of mains power will have a secondary impact on an inability to operate electrical pumps, electrical dosing and electrically operated instrumentation.[71]
- Wind can damage roofs of drinking water reservoirs resulting in an inability to maintain the water quality to the Australian Drinking Water Guideline (ADWG) standards.[71,72]
- In addition, surface water run-off impacts raw water quality. This results in an inability to treat the available water to the ADWG standards.[71]

Transport

- Highly populated areas and communities with limited access to transport may be more vulnerable to impacts, as their ability to evacuate in a safe and timely manner can be impeded. In some instances, flooding may obstruct evacuation routes well before maximum flood and wind impacts are experienced.

Transport infrastructure

- Along the east coast where Queensland's population density is greater, extreme and prolonged flood events have caused substantial impact to major road and rail networks, airports and maritime infrastructure.
- Physical infrastructure of the transport network (e.g. stations, hubs, depots) will likely suffer a varying level of impact dependent on age, location and type of construction. Non-hardened transport infrastructure such as glass shelters, poles and signage, will likely suffer significant damage and add significantly to the potential for wind-driven debris.

Figure 57: The aftermath of Cyclone Yasi as it crossed the Far North Queensland coast. Dozens of luxury boats were smashed together at the Port Hinchinbrook marina in Cardwell. Source: Marc Mccormack

- Marinas and vessels have historically experienced extensive damage resulting from a combination of severe winds and storm surge wave action.
- Isolation of airports, aerodromes and airfields due to flooding, along with Notices to Airmen (NOTAMs) prohibiting movement of aircraft may impede normal flight schedules, as well as evacuation and resupply operations.

Access and resupply

- At a minimum, short-term disruption to air, road, rail and maritime travel should be expected. Associated flooding (coastal, flash or riverine) across major road and rail networks has historically led to short- to medium-term disruptions.
- Disruption should be expected to last days as a result of impact from flash flooding of creek systems, green debris and landslips, fallen powerlines, and scour damage to roads from fast moving flood waters.
- Road networks near coastal areas are highly vulnerable to scour damage through storm surges impact. Potential to measurably affect access & resupply as well as any potential necessary evacuations.

Figure 58: Serious damage around Sarina Range due to landslips from Ex-Tropical Cyclone Debbie. Source: Loretta MacGregor

- Potential for major riverine flooding and significant debris loads in rivers delivering impacts to State and local bridges. This may result in closure of bridges until inspection can deem the structure safe for use.
- Areas within the Gulf of Carpentaria, the Cape York Peninsula and along the Great Dividing Range have been susceptible to short- to medium-term isolation due to flooding events brought on by the effects of a cyclonic or severe weather event. In most cases there is a reasonable degree of resilience as most people in those areas are accustomed to isolation and have redundancy plans in place.

- In extreme scenarios where building stock is not suited to communities sheltering in place, there may be a requirement to evacuate tens to hundreds of thousands of people away from forecast impact areas. This may include sheltering at locations significantly inland and may require interstate coordination. This is more likely for southern or South East Queensland (i.e. in Wind Region B) where the population is not used to cyclone impact and the building stock is not suited to sheltering in place.
- It is unlikely that the majority of road networks would cope with a sudden or uncontrolled mass egress of communities.
- Restoration of essential services to communities is highly dependent on the level of disruption across the transport network. Restoration and recovery may be complicated depending on the magnitude and duration of the event.
- Inundated roads may impact the ability to resupply treatment plants with chemicals and transport essential staff to sites.[71]

Community

Households

- Where houses are built to modern standards, little damage is expected from events that are below the regional design levels. However, the cities and towns along the east coast of Queensland are an uneven mix of older and newer construction, leading to worse damage outcomes.

Figure 59: Damage to buildings in Yeppoon in the aftermath of Cyclone Marcia, 2015. Source: Queensland Fire and Emergency Services

- Remote and rural properties reliant on news broadcasts, social media and word-of-mouth for emergency alerts are more vulnerable to loss of communications.
- Direct impact from wind and inundation to shelter and housing may lead to widespread displacement across the community.
- Many communities have residents over the age of 65 who are not in aged care facilities but receive care at home via at home service providers. These households may require greater assistance from emergency services.

Community infrastructure

- Community infrastructure (e.g. schools, community centres) may be directly and indirectly affected through infrastructure damage, loss of power, water and communications.
- Many community buildings will not be able to remain fully functional post impact. Elements such as wind-driven rain via aspects of the building envelope (e.g. flashings and windows), and disruption to power, water and telecommunications may result in these buildings being in a non-operational or impaired state.
- Region-wide school closures in the event of a cyclone warning and impact should be expected in the short term. This is likely to extend into the medium- to long-term where school infrastructure has been significantly impacted. The Department of Education must certify that schools are fit to reopen which may delay community recovery efforts if repair and rebuilding activities are delayed or protracted.
- It is worth noting that due to the higher levels of structural resilience, many schools in Queensland have a secondary role as shelters or places of refuge. If mass shelter is required post impact, schools may be delayed in reopening and thereby further protracting community recovery.

Figure 60: Over 700 people shelter in a makeshift evacuation centre in an Innisfail school. People were evacuated ahead of a large storm surge predicted to accompany Cyclone Yasi on February 2, 2011. Source: Lyndon Mechielsen.

Health and wellbeing

Physical and mental health

- Injury due to falling masonry or other building materials, or due to wind driven debris that is picked up and carried by the cyclone, are possible during cyclone events.
- Some medium-term health impacts related to flooding caused by tropical cyclone include infected wounds, complications of injury, poisoning, gastrointestinal illness, poor mental health, communicable and vector-borne diseases, and starvation.[73–75]
- Higher levels of impact to vulnerable persons (e.g. elderly, those with a disability, homeless persons, pregnant women, and those with chronic illnesses or those awaiting urgent treatment) are expected where there is loss of power, communications and isolation.

- Affected people may require a range of support including information, financial or practical assistance to meet their basic needs for immediate food, clothing, medication and shelter, may require personal and crisis support, and assistance to connect with family.
- Vulnerable and critical care patients require specific transport and care arrangements that can be disrupted by tropical cyclone events. Early identification of these patients in the warning phase of an event and proactive management of their evacuation helps to mitigate risks.
- Vulnerability to heatwaves following tropical cyclones is higher.[76] Heatwave impacts can be severe and lead to significant health effects including death.[77,78] For more on the impacts of cyclone related heatwaves, see the Queensland State Heatwave Risk Assessment.[7]
- Exposure to tropical cyclones as well as repetitive events of varying magnitude, duration and impact has led to an increase in mental health issues for people and communities.[79]
- Long-term mental health effects, and effects on social capital and connection to place have been noted for floods[80,81] and significant tropical cyclone events.[79,82]
- Concerns about access to safe places of refuge may cause psychological distress for affected residents. Messaging around places of refuge can allay these concerns.

Health care and infrastructure

- While hospital infrastructure must be built to Importance Level 4 (1:2000 AEP), many hospitals have been built in stages over several decades and resilience to sustained destructive winds, and heavy rainfall will not be uniform.
- Forecast impact from a tropical cyclone would likely trigger evacuations of local hospitals to other regional hospitals outside of the forecast impact area, as occurred during Cyclone Yasi, 2011. Nine hospitals, both private and public, were organised to receive (and did receive) patients from Cairns.

  Queensland Health disaster management guidelines mandate that all health facilities are required to have plans for evacuation of their facility and establishment of alternative care facilities. Under these guidelines, health facilities that are geographically isolated must consider long-distance evacuation in their planning arrangements, while HHSs should have pre-standing arrangements to manage the evacuation of these facilities and reception of patients elsewhere. Hospitals also need to identify facilities that may be used as a temporary medical facility, if the major facility is impacted or closed.
- Aged care facilities and services, and their residents, may experience significant impacts, including poor communications and messaging, issues with consumable supply chains and evacuation of staff and residents.

Figure 61: Hospital patients wait in the international terminal building at Cairns Airport before being loaded onto RAAF C-17 and C-130 aircraft and evacuated to Brisbane ahead of Cyclone Yasi on February 2, 2011. Source: Paul Crock (AFP)

Business, industry and the economy

- Disruption to industry has occurred as a result of direct impact from an event. The dependency on power and communications for industry has also led to a considerable decrease in productivity creating loss of stock, income and employment. In some areas across Queensland, there has been a permanent loss of local business as a result of tropical cyclone events.
- Impacts to the tourism industry can be extensive with some areas unable to recover post impact. For example, the Dunk Island Resort, located off the Cassowary Coast, was devastated in TC Yasi and has not yet been rebuilt. This has had a significant impact on the local economy. Damage to the natural environment such as the Great Barrier Reef, upon which much of Queensland's tourism depends, can be more impactful than damage to physical infrastructure.

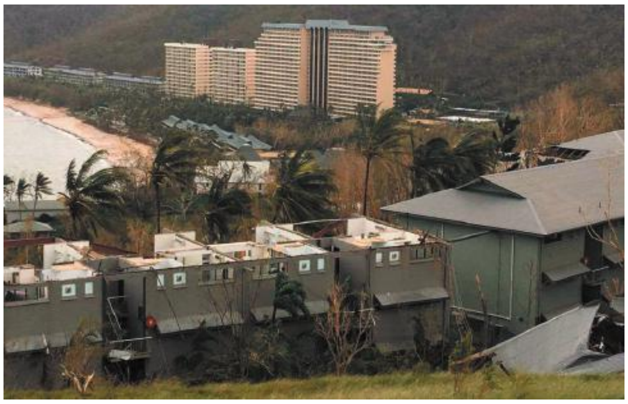


Figure 62: Roof damage sustained to holiday accommodation on Hamilton Island. Source: ABC News (Dennis Garrett)

Figure 63: Dunk Island devastation from Cyclone Yasi. Source: HeraldSun (AAP)

- Considerable increase in stock and crop losses occur regularly as a result of tropical cyclone events. Removal of fertile soil due to flood impact may exacerbate these impacts. Producers may suffer considerable loss of production buildings and equipment.

Figure 64: Damage to banana plantation. Source: Image courtesy of Torsten Blackwood.

- Disruption to financial services such as ATMs/EFTPOS can significantly impact consumers' ability to access basic goods and services.
- Loss of power may result in loss of refrigerated stock. The community may be unable to access essential goods such as food and medicine across.
- Financial hardship following a major event may result from loss of property, employment and support services.

Natural environment

- Due to the nature of a tropical cyclone, environmental impacts can be widespread or concentrated. Potential impacts to the natural environment include:
  - loss of vegetation cover and wildlife habitat[83,84]
  - loss of biodiversity and ecosystem services
  - mud slides, soil erosion and excessive siltation - river bank damage, impacts to fish stocks, dugongs and turtles
  - water and soil contamination - saltwater intrusion, sewage overflow, fertilizer runoff, contaminated mine water discharges
  - damage to offshore coral reefs and natural coastal defence mechanisms[85–87]
  - contamination/pollution from increased wastes (some of which may be hazardous), its biological movements into the environment and debris accumulation
  - damage to waste disposal site infrastructure leading to potential impacts from, for example, leachate collection pond overflow into waterways
  - temporary closure of licenced waste disposal facilities, leading to a build-up of stockpiled waste at temporary sites and management of potential environmental impacts such as odour and leachate
  - impacts associated with human displacement and reconstruction and repair to damaged infrastructure and critical supply chains (e.g. deforestation, industrial and port operations, quarrying, waste pollution)
  - damage to cultural and/or built heritage values and places.

Figure 65: Much of the Caley Valley wetlands was blackened by coal dust laden water released from the nearby Adani Abbot Point Terminal. The occurred after torrential rains from Tropical Cyclone Debbie inundated the coal storage facilities, leading to a controlled release of excess water into the wetlands. The environmental impact has been extensive to local flora and fauna.

Supporting information

Plans

- Local, district and disaster management plans: https://www.disaster.qld.gov.au/cdmp/Pages/default.aspx
- Storm Tide Handbook (QFES): https://www.disaster.qld.gov.au/dmp/Documents/Storm-Tide-Handbook.pdf

Technical guidance

- Severe Wind Hazard Assessment (Queensland)
- The Queensland Tropical Cyclone Preparedness Guide, which provides information on household preparedness for tropical cyclones
- The Tropical Cyclone Storm Tide Warning Response System Handbook
- Cyclone resilient building guidance for Queensland homes, which provides information about designing and building wind resilient homes in cyclone prone areas:
- Get Ready Queensland - Cyclone and Storm Surge
- Tropical Cyclone Hazard Assessment (Geoscience Australia)
- The Biodiversity and Ecosystems Climate Adaptation Plan, which includes information about ecosystems that are exposed to the effects of tropical cyclone88
- Relevant legislation, codes, and standards:
  - Building Act 1975 (Queensland)
  - National Construction Code
  - Australian Standards 1170.2 and 4055.

Risk summary

Development of tropical cyclones in the Coral Sea or Gulf of Carpentaria occurs in the warmer months between November and May, with the potential for significant impacts even if remaining offshore. Historically, the north and north east of the State experiences a higher frequency of impacts from tropical cyclones. The frequency of tropical cyclones is projected to decrease through to 2060, however cyclones are projected to be of significantly higher intensity on average than the historical record. South East Queensland in particular is likely to experience an increase in related wind hazard than other parts of the State.

Any severe cyclone impacting South East Queensland is likely to result in extensive impacts, as the design criteria for houses in this part of the State is lower than those required for moderate Category 3 cyclones.

While the power transmission network is relatively resilient to tropical cyclone impacts, the distribution networks are built to a lower level of resilience and are likely to be subjected to greater levels of damage and longer periods of disruption, extending into weeks for some communities.

Sustained destructive winds will lead to communications outages through direct and indirect impact to telephone lines, mobile communication towers and emergency services radio towers. While mobile towers themselves are unlikely to fail, attached antennae and point to point communication dishes are highly vulnerable.

Water supply services can be disrupted across the short- to medium-term due to isolation of pump stations and treatment plants, green debris and turbidity issues, damaged pipelines and extended power outages.

Infrastructure near the coast and areas susceptible to landslide and flash flooding are highly vulnerable to impact and damage. Disruption to transport networks should be expected to last at least several days as a result of impact from flash flooding of creek systems, green debris and landslips, fallen powerlines, and scour damage to roads from fast moving flood waters.

Marine and coastal infrastructure and vessels are highly likely to be affected. Vessels may break their moorings presenting both navigational and contamination issues. Disruption to air transport will occur, including emergency response and rescue services as well as civil transport.

In extreme scenarios where building stock is not suited to communities sheltering in place, there may be a requirement to evacuate tens to hundreds of thousands of people. It is unlikely that the majority of road networks would cope with an uncontrolled mass egress of communities.

The age profile of suburbs will influence the likelihood of damage from lower intensity events. Little damage is anticipated where houses are built to modern standards, and impacted by tropical cyclone events that are below the regional design rating, however buildings constructed prior to the 1980s (and the implementation of modern wind loading codes) are significantly more vulnerable.

Many community buildings (e.g. schools, community centres) may not be able to remain operational due to direct and indirect impacts including infrastructure damage, and disruption to power, water and communications.

Understanding the context of the community through demography, facilities and resources, attitudes and beliefs, community capacity and community cohesion will assist in identifying vulnerability, likely impacts and capacity to be self-reliant. Impacted people may require a range of support including information, financial or practical assistance to meet their basic needs for immediate food, clothing, medication and shelter, may require personal and crisis support, and assistance to connect with family.

Tourists and people who have recently moved to areas subject to cyclone impacts are at greater risk than the general population, as they may not be familiar with the hazard or well-practiced in their cyclone preparedness.

Higher levels of impact are expected for vulnerable people, especially where there is loss of power, communications and isolation. Exposure to tropical cyclones can also result in short to long-term mental health effects.

Economic impacts and financial hardship may occur as a result of property damage, and disruption to or loss of employment and support services.

Environmental impacts can be widespread or concentrated. Potential impacts include loss of vegetation and wildlife, coastal erosion, environmental contamination, and other impacts associated with human displacement and reconstruction and repair to damaged infrastructure and critical supply chains.

RIVERINE FLOODING

Riverine flooding

Riverine flooding is the highest priority for Queensland. This represents a change from the equal highest priority alongside tropical cyclone in the 2017 State Natural Hazard Risk Assessment.[2] Full details of prioritisation are provided below and in Section C - Risk prioritisation.

Understanding the hazard

Flooding is Queensland's most damaging natural hazard, and is third to heatwave and tropical cyclones in terms of fatalities.[89] Flooding causes significant impacts on people's health and wellbeing, the environment, property and infrastructure, and the State's economic productivity. This is because many Queensland towns and cities, and the transport linkages connecting them, are built on floodplains, usually for historical reasons of access to water for habitation, transportation and agriculture.[89]

Queensland's river basins and catchments cover large geographic areas which may pose challenges in terms of logistics, access and resupply and evacuation.[1] The most devastating disasters in Queensland's recent history have been major riverine floods – in particular, riverine floods resulting from weather patterns including tropical cyclones, decayed tropical cyclones, and monsoon lows or east coast lows – including the 2010-11 floods, floods associated with TCs Oswald (2013), Ita (2014), Marcia (2015), Debbie (2017), the 2019 monsoon trough in North and North west Queensland, ex-TC Seth (2022), and the widespread, major flooding throughout Queensland in the first half of 2022.

Figure 66: Before and After. Flooding in Rockhampton due to rainfall from Severe Tropical Cyclone Debbie in March 2017. Source: Department of Natural Resources and Mines

Riverine flooding is a hazard that is experienced by communities across the State, and disaster management groups are generally well-practised and prepared for the effects of riverine flooding. Furthermore, ongoing investment by state and local governments in flood modelling and hydrological advice means that the appreciation of riverine flooding risk is at an increasingly high level across the State.

Definition

A flood is an overflow of water beyond the normal limits of a watercourse, occurring when water extends over what is usually dry land. This can happen when it escapes from a natural watercourse, such as a lake, river or creek. It can also happen when water is released from a reservoir, canal or dam.[90]

The four main types of flooding experienced in Queensland are shown in Table 10.

Source	General characteristics
Large riverine catchments	Rainfall can build up over hours, days or weeks. The runoff from the rainfall flows across and then down gutters, drains, gullies, creeks and rivers and may create significant floods that inundate large areas of land for varying periods of time. With more time react, flood warning is more effective for these types of floods.
Small river/creek catchments	Heavy, intense rainfall can occur suddenly, and the quickly rising floods caused by this can occur within minutes or hours after the rainfall. Referred to as flash floods, there is often limited time to react, and these vents can be difficult to predict and manage in real time.
Coast	Large tides and storm surges can flood coastal areas. The affected area can be widespread, however there is usually the opportunity for effective flood warning with these events.
Overland flow	In urbanised areas, the formal draining network is usually designed only to manage small, frequent rainfall events. When these are exceeded, water flows along the low points of the topography, often across private property and roads.

Table 10: Types of flooding in Queensland. Source: The Regional Guideline for Flood Awareness Mapping and Communication, QRA (2020)[91]

In this risk assessment, we focus on riverine flooding (i.e. large riverine flooding and small river/creek catchments as described in Table 11). Riverine flooding occurs where rivers break their banks and water covers the surrounding land. In Queensland the most common cause of riverine flooding is heavy rainfall but it can also be caused or exacerbated by king tides, storm surge, and dam releases.[90]

There is also a range of other factors that contribute to riverine flooding. The size, shape and use of catchments, presence of structures and vegetation in and around watercourses, and soil moisture, all influence the ability of waterways to accommodate excess rainfall.

When rain falls over an area of land some is absorbed while the rest drains off downstream. The area that contributes runoff to a particular site is called a catchment. Types of catchment flooding include riverine, local overland and groundwater flooding.[92]

The amount of rainfall, the intensity of the rainfall over time (the temporal pattern) and the distribution of the rainfall over an area of land (the spatial pattern) can all vary widely. The floods that are produced by this rainfall are therefore equally variable, that is, every flood is different. Heavy, intense rainfall can occur suddenly, and the quickly rising floods caused by this in the minutes or hours after the rainfall are known as flash floods.

Flash floods are typically defined as flooding that peaks within six hours of a causative rain event and are associated with relatively small catchment areas where there may be little or no permanent flow of water. As there is little time to react, flash floods are particularly difficult to predict and manage in real time.

Floods can occur more slowly in larger catchment areas. Rainfall can occur over hours, days or weeks. The runoff from this rainfall flows across land and then down gutters, drains, gullies, creeks and rivers and may create significant floods that inundate large areas of land for days, weeks or months.

Hazard ratings

The typical effects of riverine flooding have been categorised into five values of increasing intensity, described below. These have been adapted from various sources[93,94] for this report, primarily to identify and communicate the generalised effects of different flood hazard intensities.

Value	BoM Flood Classification	AIDR Flood Hazard Classification
1	**Minor**. Causes inconvenience. Low-lying areas next to watercourses are inundated. Minor roads may be closed and low-level bridges submerged. In urban areas inundation may affect some backyards and buildings below the floor level as well as bicycle and pedestrian paths. In rural areas removal of stock and equipment may be required.	**H2.** Unsafe for small vehicles
2		**H3.** Unsafe for vehicles, children and the elderly
3	**Moderate**. In addition to the above, the area of inundation is more substantial. Main traffic routes may be affected. Some buildings may be affected above the floor level. Evacuation of flood affected areas may be required. In rural areas removal of stock is required.	**H4.** Unsafe for people and vehicles
4	**Major**. In addition to the above, extensive rural areas and/or urban areas are inundated. Many buildings may be affected above the floor level. Properties and towns are likely to be isolated and major rail and traffic routes closed. Evacuation of flood affected areas may be required. Utility services may be impacted.	**H5.** Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure.
5		**H6.** Unsafe for vehicles and people. All building types considered vulnerable to failure.

Table 11: Flood classifications and assigned values.

The Queensland context

History

The Queensland sub-tropical to tropical climate results in a wet season, which generally extends from October to April. As a result, there is a historical trend for floods to be more likely to occur during this period, however, floods can occur at any time (for example, the August 2007 floods in the Sunshine Coast, June 2005 floods in the Gold Coast).

Queensland has a long history of flooding. In the past 20 years alone, the Bureau of Meteorology (BoM) has reported more than 50 notable floods occurring across the State, including the flood events of 2010-2011 in which 75% of the State was declared a disaster zone.[95]

Queensland flood events occurring in between 2007 and 2016 were estimated to have caused more than $9 billion in damages and represented more than 60% of the State's total disaster-related damages.[22]

Since 2011, and in response to the Queensland Floods Commission of Inquiry, the Queensland Government has supported councils and disaster management entities by delivering flood projects and producing flood maps and information at town and catchment scales. While acknowledging the varying levels of capacity and capability of local governments across the State, ongoing investment by State and local governments into flood modelling and hydrological advice has increased the appreciation of riverine flooding risk. Flood risk includes both the chance of an event taking place and its potential impact.

Land use planning informed by floodplain management plans can reduce risk for new development areas. Flood risk is harder to manage in existing developed areas, however modification measures such as dams or levees can change the behaviour of floodwaters. Property modification measures can help to reduce the level of harm and damage caused by floods, and response modification measures help communities to manage the impact of floods.

Projections

Projections of future climate indicate that the risk of flooding will increase,[96] therefore proactive and constantly improved studies of riverine flooding risk continue to be a priority for State and local governments.

Estimating the influence of climate change on flood risk is complicated. However, there is some agreement that climate change will increase the rate of riverine flooding globally.[96,97] In addition, Queensland's flood records do not extend far into the past, increasing the uncertainty in estimates of future flood probability.[56] For example, a study of the 2011 floods in Lockyer Valley showed that, based on gauge records alone, the 2011 peak was predicted to have an average recurrence interval (ARI) of >2000 years, revised post-2011 to an ARI of 90 years.[98]

Assessment of climate change effects on the Burrum and Cherwell River catchments by Fraser Coast Regional Council showed a 21% increase in peak runoff to creeks and waterways as well as a 0.5m to 1.12m water level increase within the Burrum River system.[99] For the Mary River, assessment of climate change effects showed an 11% increase in peak runoff in the catchment and a 10% increase in the extent of the flood impacted area by 2050.

Ipswich City Council investigated climate change impacts for the Brisbane River under the 2090 RCP8.5 scenario which showed a 2.4m future flood level rise for Ipswich Central for the 1% AEP flood event. More frequent events (such as the 10% AEP) also showed a 1.5m flood level rise, indicating climate change impacts will be felt regularly and with a measurable level of severity.[99,100] Further, recent work undertaken by the State and local governments, showed that, under RCP8.5, the probability of major flood events occurring essentially doubles (that is, a 1% AEP event in 2050 is equivalent to a current day 0.5% AEP event).[100]

While other catchments across Queensland will be less sensitive to these changes and the increased intensity may have no notable effect on the likelihood of flooding, the changing patterns of dry spells and drought will have an influence on the amount of runoff and whether flooding occurs.

Frequency of severe wet periods (24-month Standard Precipitation Index (SPI) between 1.50 to 1.99)			
Region	1986 – 2005	2030	2050
Cape York	5	1	1
Central Queensland	3	2	2
Central West	2	2	2
Darling Downs	4	4	3
Far North Queensland	4	2	2
Gulf of Carpentaria	2	1	3
Mackay, Isaac and Whitsunday	3	1	2
Maranoa-Balonne	3	4	2
North Queensland	4	2	2
North West	2	2	3
South East	2	4	3
South West	2	2	2
Wide Bay Burnett	2	3	3

Table 12: Probability variables for riverine flooding, derived from data included on the Queensland Future Climate Dashboard.

Based on current climate change assessments, increased coastal inundation from sea level rise and increased chance of flash flooding due to an increase in short-term heavy rainfall events are both considered highly likely.[1]

The impacts of flooding will worsen in the future if the urban footprint continues to grow into floodplains and other areas that experience frequent and severe flooding.[97,101] The impacts of coastal inundation on riverine flooding, in places where these intersect, is largely underestimated in existing risk assessment approaches.[102] As the sea level rises due to climate change, this will be an important consideration moving forward.

In Table 12, we use the 12-month Standard Precipitation Index (SPI) data presented on the Queensland Future Climate Dashboard to derive probability scores for each region until 2060.

These results suggest that the probability of flood events will decrease for some parts of the State towards 2030 – with rain shortages expected in this period – before increasing again towards 2060. In many cases, flood risk will be worse in 2060 than in the reference period (1986–2005). Furthermore, rainfall events are expected to be more extreme and erratic so overall risk may remain constant or increase.[103]

These measurements are only indicative of the amount of rain that will fall and do account for geometric features of catchments that contribute to flood risk. These values are intended as a guide for change of probability over time. More detailed modelling as part of a flood study would produce better and more specific estimates of flood risk changes due to climate change.

The methodology for deriving probability scores for this hazard is described in detail in Section D: Technical methodologies.

Management of the hazard

Flood risk management is a partnership between many stakeholders including government, the private sector, non-government organisations and the community. The Strategic Policy Framework for Riverine Flood Risk Management 2017 and Community Resilience guides riverine flood risk management in Queensland and outlines in greater detail the shared responsibilities for management of riverine flood risk.[56,104]

The Queensland Flood Risk Management Framework provides clarity and understanding of expectations and responsibilities to guide and support flood risk management.

State Planning Policy requires development to avoid flood prone areas or mitigate it to a level that is acceptable to the community.[53] Local governments can use local planning instruments to influence the long-term development of an area in consideration of flooding by restricting the location of development and placing conditions on development.

The shared and defined responsibilities for managing floodplains are more complex, and governance of floodplain management in Queensland is also dispersed across various State-level entities.

The QFRM Framework promotes a best-practice approach to managing Queensland's floodplains, based on tailored, proportionate assessment that provides an understanding of flood behaviour so that the full range of flood risk to the community can be understood, and the full range of options to manage unacceptable risk be considered. Such options include:

- land use planning
- emergency management
- community engagement and awareness
- structural / infrastructure
- land management
- built form and property level protection
- insurance.

Flood mitigation measures are generally classified into three categories, as shown in Figure 67 below. Each of these options will have a different influence on the flood impacts.

Figure 67: The three categories of flood mitigation. Source: QRA.

Under State Planning Policy, local governments are required to identify flood hazard areas and include appropriate provisions in their planning schemes to ensure that flood risk is tolerable to their communities.[1,104]

The Queensland Flood Risk Management Framework outlines in detail the shared responsibilities for the management of flood risk in Queensland. Functional responsibilities should also be defined in the disaster management plans of groups and individual entities.

Australia's growing population and changing climate means the characteristics of floods we experience will be different in the future. Better land use planning and floodplain management can mitigate the impacts of flooding. Appropriate urban design can reduce the severity of flood impacts. Catchment and waterway revegetation can reduce the impact of flooding. Emerging technologies can improve our ability to predict and manage floods.

Bureau of Meteorology

BoM operates and maintains the Flood Warning Service for Queensland.[105] Under their Service Level Specification, BoM's responsibilities include:

- collecting and publishing rainfall and river level data
- routine monitoring of flood potential
- flood modelling and prediction
- automated information and alerting
- issuing and communicating flood watches and flood warnings
- maintaining systems to collect data and flood information
- support for emergency management training and training exercises.

Other BoM functions include:

- Actively working with local governments to support the development of systems and procedures, in particular through the provision of advice on the design, implementation and management of flash flood systems through the Flash Flood Advisory Resource (FLARE)
- Communicating supplementary information (to its standard warning products), such as radar and rainfall forecasts, directly through the emergency services mechanism established in each state and territory
- Republishing any state, territory or local government generated flash flooding information on its website if a mechanism for doing so is agreed and arranged prior to the operational event
- Provision of forecasts and warnings for severe weather conditions and potential heavy rainfall conducive to flash flooding and to carry out applied research and development to improve the provision of severe weather information.

Queensland Reconstruction Authority (QRA)

QRA is responsible for rebuilding and recovery of disaster-affected communities. This includes the responsibility to coordinate the development and implementation of comprehensive policies for:

- managing flood risk
- ensuring Queensland and its communities effectively and efficiently recover from the impacts of disasters
- improving the resilience of communities for potential disasters.

QRA's role in relation to recovery from disasters, including riverine flooding, includes:

- leading the coordination and development of disaster recovery, resilience and mitigation policy in Queensland
- when directed by QDMC, leading coordination of recovery planning for specific disaster events
- responsibility for developing the State's strategic disaster recovery plans, as required, to ensure the efficient and effective coordination of recovery and reconstruction across Queensland for disasters
- supporting the delivery of recovery and reconstruction projects
- in consultation with the SDC, coordinating the transition of response coordination to recovery coordination
- supporting local governments and local recovery groups to plan and implement recovery efforts.

Considerations for disaster management groups

- Can the group access, interpret, and act on flood advice, warnings and decision support products?
- Is the group aware of the limitations and uncertainties associated with forecasting rainfall and associated flood heights?
- Does the group have the capability to transform forecast flood height information into meaningful impact-based flood intelligence for the group and the community?
- Does the group have the capability to interpret the technical information contained in advice and warnings, and develop messaging appropriate for their target audience?
- Has the group discussed its requirements with relevant entities so appropriate preparation and planning are developed to help make informed decisions – for example, the identification of response triggers, limits and escalation of risk between relevant entities?
- Is the group aware of the potential for additional concurrent, compounding and cascading hazards?

Additional hazards relating to riverine flooding that are assessed within this report include:

- Tropical cyclone
- Thunderstorm
- Critical infrastructure failure
- Mass casualty event

Scenario

Following a dry winter, a slow-moving system ex-Tropical Cyclone Herman brings significant rainfall to large areas of Queensland. River catchments are quickly saturated and rivers begin swelling. Dam owners at dams along the catchment activate their Emergency Action Plans to ensure the dams can operate safely despite the large inflow of water. In Bundaberg, the Burnett River rises quickly. It breaks its banks and peaks around 7.5m at the Bundaberg City gauge.

Areas south of the river, particularly those adjacent to Saltwater Creek, are impacted by localised flooding. Damage is significant but destruction is not widespread. Areas of North Bundaberg are inundated with swift flowing water, resulting from the shape of the river and from this area laying lower than Bundaberg proper. The foundations of some dwellings in this area are destroyed outright, while many dwellings sustain significant damage. Many transport routes north of the river are rendered inoperative. Communities downstream of Bundaberg are significantly impacted by fast-moving water. Significant ecosystems on the coast are also adversely impacted.

Evacuation proceeds smoothly for the most part, as most residents south of the river are not impeded. Evacuation of residents in North Bundaberg is more difficult due to access being compromised by the flood water. Some residents are evacuated by air, requiring significant coordination efforts.

Some disruptions to business as usual occur. Some schools are closed for days waiting for flood waters to recede. Some electricity infrastructure is damaged, particularly in North Bundaberg, which takes some time to be repaired. Access and resupply to North Bundaberg is a minor issue that is resolved when roads are returned to working order.

Figure 68: Bundaberg flood, 2013. Source: Image courtesy of Torsten Blackwood.

Impacts

Essential infrastructure

Communications and energy

- Flooding may impact power and communications infrastructure including key network nodes, resulting in prolonged periods of disruption. Additionally, the interdependency of communications networks and other critical infrastructure on power can result in prolonged and systemic disruption issues.
- Power assets impacted by recent flood events include bulk and zone substations, C&I substations, overhead lines, pad mount and ground transformers, underground pillars and streetlights.

Water

- Damage has historically occurred to water and sewerage networks, including mains, pumps and electrical assets.[106]
- Water treatment plants and sewerage treatment plants are often located close to waterways and more exposed to flooding.
- Water quality is negatively impacted by increased sediment loads.[106] This may occur more frequently due to climate change.[107]
- Dams and levees can be subject to scouring and damage as a result of flood events, increasing the risk of failure for these structures.[108]
- Lightning often directly impacts treatment and pumping SCADA systems and the loss of mains power will have a secondary impact on an inability to operate electrical pumps, electrical dosing and electrically operated instrumentation.[71]
- Wind can damage roofs of drinking water reservoirs resulting in an inability to maintain the water quality to the Australian Drinking Water Guideline (ADWG) standards.[71,72]
- In addition, surface water run-off impacts raw water quality. This results in an inability to treat the available water to the ADWG standards.[71]

Transport

- Analysis of flood fatalities in Australia shows that nearly half are vehicle related. This is attributed to a combination of driver behaviour and various characteristics of roadways that influence the decisions of drivers such as signage, lighting and barricades.[109]

Transport infrastructure

- Flooding may cause transport-related technological (Natech) disasters. An example of this is flooding which results in train derailment and subsequent release of hazardous materials into the environment.[106,110,111]
- The increasing frequency of extreme rainfall, cyclones and flooding events in recent years has significantly influenced the increasing rate of deterioration of the structural strength and surface conditions (such as roughness and rutting) of road pavements.[112]
- Poorly designed transport infrastructure can increase community vulnerability and impede the ability to safely evacuate.[89]
- Toward the east coast where typically the greater density of Queensland's population inhabits, extreme and prolonged flood events have caused substantial impact to major road and rail networks, airports and maritime infrastructure.
- The cost of reconstruction and restoration of flood affected roads often extends into the billions of dollars following major events,[112,113] and many local governments in regional areas rely heavily on recovery and reconstruction funding to sustain local employment and mitigate population decline.[99]

Access and resupply

- Road inundation and isolation of communities may occur before the flood peak. Local flooding and obstruction of drainage infrastructure can inundate access and egress routes prior to flooding from major creek and river systems.[113]
- There is potential for topography to form high or low flood islands and create an isolation risk. Flood islands, or locations of isolation, are defined as either low or high islands. High islands are those areas which remain flood free, even in extreme events. Isolated properties which become inundated by flood waters as the waters rise are referred to as low islands.[113]

- Inundation of major road and rail networks has historically resulted in short- to medium-term disruption to communities and essential services. Recovery efforts are also likely to be complicated depending on the magnitude and duration of the event.
- Road closures affect community access to homes, schools and places of work. Closure of key transport corridors causes major supply chain disruption for regional trade, including primary producers.[106,114] This can hamper economic recovery post event.
- Areas within the Gulf of Carpentaria, the Cape York Peninsula and west of the Great Dividing Range are susceptible to short to long-term isolation due to flooding events. There is a reasonable degree of household and community resilience in these areas.

Community

Households

- Households situated in flood prone areas are a key driver of disaster risk for communities. Gentrification, new and infill development continues to occur in areas that are susceptible to flooding.[33,115]
- Flooding disproportionately affects socially and economically disadvantaged households, especially those in regional and rural areas.[116,117]

Community infrastructure

- Prolonged disruption and damage of social infrastructure (e.g. schools, hospitals, aged care facilities) is likely to compound response and recovery issues. Damage to elements of cultural, religious and recreational significance to the community can impact on social connectedness.
- Communities often require external assistance with recovery, restoration of functions and to help mitigate permanent dispersal of the population.

Health and wellbeing

Physical and mental health

- Analysis of historical flood fatalities in Australia from 1900-2015 shows that over one-third of all fatalities have occurred in Queensland.[118] The majority of deaths were male and occurred in minor to moderate floods. A significant upturn in the number of flood related deaths was observed from 2010-2015 relative to previous decades (Table 13).
- Intangible costs, including health, wellbeing and community, are estimated at around half of the total costs associated with flood events.[106,119]
- Riverine flooding may increase the risk of vector-borne diseases, like those transmitted by mosquitos, such as Dengue and Ross River virus.[120,121]
- Bacterial infection through interaction with contaminated floodwaters has historically resulted in hospitalisation and fatality.[119]
- Other health impacts include infected wounds, complications of injury, poisoning, gastrointestinal illness, poor mental health, communicable diseases and starvation.[73–75]
- There can be significant demand for psychological first aid immediately preceding flood events, and mental illness following an event can often take 6-12 months to manifest.[119]

YEAR	FATALITIES
1900-1909	32
1910-1919	138
1920-1929	138
1930-1939	76
1940-1949	66
1950-1959	47
1960-1969	9
1970-1979	45
1980-1989	25
1990-1999	34
2000-2009	32
2010-2015	60
Total	702

Table 13: Queensland flood fatalities by decade, 1900-2015. Source: BNHCRC

- Long-term mental health effects, and effects on social capital and connection to place, have been noted, even for small, localised flood events.[80,81]
- Flood events can increase the prevalence of family and gender-based violence, with stress often noted as a key reason and the heightening of existing problems following a disaster event.[119]

Health care and infrastructure

- Major hospitals and facilities may be impacted by flooding events, either directly or due to isolation and inundation of access routes.
- Aged care facilities and services, and their residents, may experience significant impacts, including poor communications and messaging, issues with consumable supply chains and evacuation of staff and residents.

Business and economy

Business and industry

- Considerable increase in agricultural stock and crop losses have historically been observed as a result of riverine flooding events.[122] Removal of fertile soil as a result of flood impact has caused significant impact to the agriculture and horticulture industries which adds to these losses. Integrated catchment management plans can help to alleviate soil loss.[98]
- Floods themselves can also alter the composition of soils, leading to changes in crop productivity.[123,124]

Economy

- Dependency on power and communications can result in a considerable decrease in productivity creating loss of stock, income and employment. Some areas across Queensland have experienced permanent loss of local business and employment as a result of riverine flood events.
- The social and economic costs associated with flood events often extend into the millions and even billions of dollars. For example, the economic and social costs associated with the 2019 North and Far North Queensland Monsoon Trough are estimated to exceed $5.68 billion.[119]

Figure 69: Flooded road in the Herbert River Catchment, North Queensland. Source: CSIRO.

Natural environment

- Environmental impacts can be widespread or concentrated depending on the nature of each event. Severe impacts have occurred upon sections of essential agricultural areas (as noted above), the Great Barrier Reef through sediment transfer and introduction of pollutants,[125] and damage to and loss of Areas of Ecological Significance as a result of habitats experiencing inundation.
- Pollutants and toxic chemicals can pass from urban areas to sensitive ecosystems.[126]
- Weeds can be introduced into an area by flood waters,[106,127,128] potentially posing significant risks to local terrestrial and riparian ecosystems.[129]
- Riparian forests can be damaged and disrupted due to changes in the course of rivers, through damming or straightening or river channels. This has wide-ranging effects, including tree and biodiversity loss,[130] and ultimately reduction of ability of the forests to mitigate future flood risk.[131]
- Removal of upstream riparian vegetation contributes to channel instability, erosion and downstream impacts.[98]
- Retaining sediment and vegetation throughout catchment areas can reduce downstream sediment yields and improve channel-bank stabilisation.[98]
- Floods may have some beneficial consequences, for example replenishing water resources. Most of Australia's unique flora and fauna has adapted to and depend on flood cycles.[56]

Supporting information

Plans

- State Planning Policy – State interest guidance material: natural hazards, risks and resilience - Flood, DILGP, 2017
- Queensland Flood Risk Management Framework, QRA, 2021
- Queensland Recovery Plan, QRA, 2017
- Brisbane River Strategic Floodplain Management Plan, QRA, 2019
- North and Far North Queensland Monsoon Trough – State Recovery Plan 2019–2021, QRA, 2019
- Burnett Catchment Flood Resilience Strategy, QRA, 2018
- Mary River Regional Resilience Strategy, QRA 2020
- Fitzroy Regional Resilience Strategy, QRA 2020
- Central West Regional Resilience Strategy, QRA 2020
- Burdekin and Haughton Catchment Resilience Strategy, QRA 2021

Technical guidance

- Flood classifications in Queensland, QRA
- Understanding floods: Q&A, Queensland Chief Scientist
- Guide for Flood Studies and Mapping in Queensland, DNRME 2017
- Flood Mapping Implementation Kit, DNRME, 2014
- FloodCheck interactive mapping application, DNRME, updated continuously
- Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia, Australian Disaster Resilience Handbook Collection, Handbook 7, 2017 (3rd ed.)
- FLARE – Flash Flood Advisory Resource, BoM
- Flood Resilient Building Guidance for Queensland Homes, QRA, 2019
- Climate Risk Management Guidelines for Small Businesses, DES, 2020

Risk summary

Flooding is Queensland's most damaging natural hazard, and third to tropical cyclones and heatwaves in terms of fatalities. Floods are most likely to occur during the wet season, which extends from October to April. Projections of future climate indicate that the risk of flooding will increase. The southeast of the State displays the greatest potential for increased risk in the medium-term to 2030, with the Gulf, north west and Wide Bay Burnett regions displaying an increase in risk over the long term to 2050.

Effective management of flood risk requires a multi-disciplinary, integrated approach across all sectors and communities. Riverine flooding impacts are varied depending on the size and scale of each event, catchment conditions, and the activities and behaviours of communities, households and individuals.

Flood impacts have historically resulted in systemic disruptions to power and communications, and short to medium disruption to and damage of transport networks. These impacts can result in compounding hazards called Natech disasters ('Natural Hazards Triggering Technological Disasters'), and include events such as the release of hazardous materials and structural failure of dams and levees.

Historically, Queensland has the highest number of flood related fatalities of all jurisdictions in Australia, with an upturn in fatalities occurring within the 2010-2015 period. The costs of social impacts are often intangible but generally represent around half of the overall cost associated with flood events. Health effects during and after floods include injuries, infections, poisoning, mental health problems, family violence and the outbreak and spreading of infectious disease.

Disruption to essential services can result in flow on effects including loss of stock, income and employment. The social and economic costs associated with flood events often extend into the millions and even billions of dollars.

Environmental impacts can be widespread or concentrated depending on the nature of each event. Impacts to agricultural areas can be significant. Damage to and loss of areas of ecological significance can occur as a result inundation and pollution of sensitive ecosystems. This can be compounded by the removal of upstream riparian vegetation, which contributes to channel instability, erosion and downstream impacts.

Figure 70: The extent of rising flood waters from the Fitzroy River can be seen across vast tracts of agricultural and pastoral land near Rockhampton on 5 January 2011. Source: Torsten Blackwood

SEVERE THUNDERSTORM

Queensland Government

Severe thunderstorm

Severe thunderstorms are the fourth highest priority for Queensland. This represents a change from second highest priority in the 2017 State Natural Hazard Risk Assessment.[2] Full details of prioritisation are provided below and in Section C - Risk prioritisation.

Understanding the hazard

Severe thunderstorms are among the costliest hazards that impact Queensland. In the period from 2006 to 2016, flood, hail, and storms – all hazards associated with severe thunderstorm events – cost Queensland $8.25 billion.[22] Severe thunderstorms are so costly because of the concurrent and compounding nature of the impacts that they can exert. For instance, a catastrophic thunderstorm over Sydney in December 2018 caused $1.27 billion in damage from hail and flooding.[132] Similarly, storms between 24 and 31 October 2020 affecting suburbs southwest of Brisbane have been estimated at costing more than $1.23 billion.[133,134]

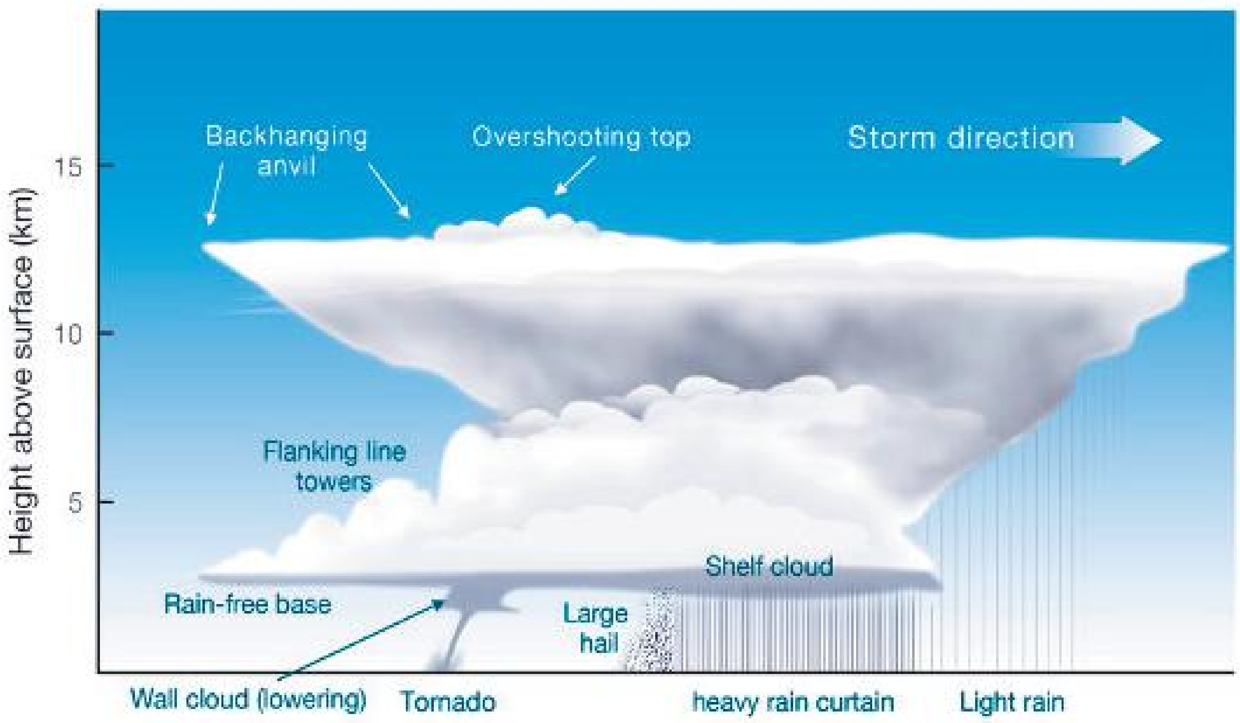


Figure 71: Diagram illustrating some features that may be produced by a severe thunderstorm. Source: BoM.

Storm cells can evolve into ordinary cell (or single-cell), multicell or supercell thunderstorms that are very strong and long-lived. Severe thunderstorms can occur year round but are less prevalent in the dry season of northern Australia. The majority of severe thunderstorms in Queensland occur between September and March, and are most prevalent in the northern and southeast parts of the State.[135]

Definition

Thunderstorms are associated with very tall cumulonimbus clouds that produce turbulence, lightning and thunder.[135,136] Lightning is a spark created when an enormous imbalance of positive and negative charge occurs. It greatly heats the surrounding air to many thousands of degrees, causing the air to expand violently, resulting in the crashing noise known as thunder.

Thunderstorms form when moist air rapidly rises through the atmosphere. For this to occur, three main elements are required:

1. Unstable atmospheric conditions that provide a favourable environment for strong vertical atmospheric motions
2. A lifting mechanism to initiate the rising movement, such as the convergence of airstreams, a frontal system or air movement over rising terrain
3. Sufficient moisture in the low levels of the atmosphere, which condense and release heat as they rise, fuelling further cloud growth.

While Queensland experiences many thunderstorms, more intense thunderstorms are referred to as severe thunderstorms. Thunderstorms are defined as severe when they produce any of the following:

- large hail (2cm in diameter or larger)
- giant hail (5cm in diameter or larger)
- damaging or destructive wind gusts (generally wind gusts exceeding 90 km/h)
- heavy rainfall which may cause flash flooding
- tornadoes.

Hazard ratings

The typical effects of severe thunderstorms and associated phenomena have been categorised into five values of increasing intensity, described in Table 14. These have been adapted from various sources for this report.[137–139] These hazard ratings recognise that – while the effects of thunderstorms are similar to other hazards such as flooding and cyclone – their impacts tend to be more localised.

Value	Precipitation	Wind
1	Potentially damaging hail 5-15mm in diameter. Heavy rain.	Enhanced Fujita Scale (EF) 0-1 tornado (3 second gust between 105-177 km/h).
2	Significant hail 10-20mm in diameter. Heavy rain that may lead to flash flooding.	EF 2 tornado (3 second gust between 178-217 km/h).
3	Severe hail 20-40mm in diameter. Very heavy rain that may lead to flash flooding.	EF 3 tornado (3 second gust between 218-266 km/h). Damaging wind gusts.
4	Destructive hail 40-90mm in diameter. Extremely heavy rain that may lead to flash flooding.	EF 4 tornado (3 second gust between 267-322 km/h) Destructive wind gusts.
5	Giant destructive hail >75mm in diameter. Extremely heavy rain that may lead to flash flooding.	EF 5 tornado (3 second gust >322km/h). Extremely destructive wind gusts.

Table 14: Five categories/values of thunderstorms.

The Queensland context

History

Queensland is highly prone to severe thunderstorms. Severe thunderstorms are less common during winter and the dry season.

Significant examples of severe thunderstorms in recent years include:

- November, 1992 – severe thunderstorms affecting the south of the State, significantly causing a tornado (EF4) in Bucca, near Bundaberg[140]
- November, 2008 – 'The Gap Storm', which resulted in wind gusts of 130km/h, trees uprooted and roofs torn off houses[141]
- March, 2012 – Townsville 'mini-tornado' caused winds of 100km/h, removing roofs and causing flooding[142]
- November, 2014 – the 2014 Brisbane hailstorm, a supercell storm that caused $1.1 billion worth of damage[143]
- October, 2020 – severe storm cells between 24 and 31 October impacted the State's south east from the Gold Coast, Sunshine Coast, Ipswich and to Kingaroy in the South Burnett. Energex recorded over 600,000 lightning strikes across the south-east region during this period with destructive wind gusts recorded exceeding 125km/h. Hail up to 14 centimetres in diameter left some homes temporarily uninhabitable in Springfield and other areas south of Brisbane.

Severe thunderstorms occur across the State. Table 15 summarises all recorded severe local storm events since 1921, from BoM's Severe Storm Archive. A limitation of this data analysis is that not all storms are recorded, and it displays a bias of artificial increase on observed events over time. This is because it can be common for a storm not to be recorded because it impacted an area of low or no community exposure, nobody saw or reported it, or it was not detected by any observation systems. Therefore, expansion of population and weather observations influences the distribution of observed records and also of community exposure to these events.

Planning region	Rain	Hail	Lightning	Tornado	Wind	Total
Cape York	3	0	0	0	0	3
Central Queensland	79	77	2	10	99	267
Central West	20	4	0	4	68	96
Darling Downs	125	222	3	21	189	560
Far North	94	22	0	5	8	129
Gulf Regional	6	0	0	2	9	17
Mackay, Isaac and Whitsunday	77	22	1	3	34	137
Maranoa - Balonne	13	22	1	1	40	77
North Queensland	80	8	1	4	12	105
North West	19	12	0	3	118	152
South East Queensland	618	548	14	41	454	1675
South West	24	7	0	2	34	67
Wide Bay Burnett	127	152	2	25	139	445
Total	1,285	1,096	24	121	1,204	3,730

Table 15: Severe storm events by type from 1 January 1921 to 1 January 2022.

Projections

In general terms, studies have found that thunderstorm increased in Queensland during the period from 2005 to 2016.[144] Other studies have noted that thunderstorms are likely to increase globally due to climate change,[145–149] and that lightning may increase globally due to climate change.[150]

There is some indication that hailstorms may decrease in south-eastern Australia.[151] However, meteorological factors that cause severe thunderstorms to form are likely to become more common in southern and eastern Australia.[148,152] It is unclear at present how these findings will affect Queensland.

In addition to increased exposure, population growth may also affect the probability of severe thunderstorms, as studies indicate that increasing urban footprint and height of buildings may increase the frequency of extreme precipitation on an area.[153–155]

The climatic factors that lead to severe thunderstorms are difficult to project with any degree of confidence.[152] Indeed, even the current distribution of severe thunderstorms is difficult to gauge, because severe thunderstorms are generally only reported when they occur in populated areas or areas with sufficient coverage of measurement instruments.

Management of the hazard

BoM issues warnings and advice for emerging severe thunderstorm and severe weather risk. QFES supports the development and distribution of warnings and advice to stakeholders and communities as required.

QFES undertakes emergency response operations and provides advice and support to disaster management groups for severe thunderstorm risk. QFES also undertakes damage assessments to gather information on the extent and nature of damage to buildings post event and provides this information to other disaster management stakeholders.

Essential service providers will generally undertake damage assessments and restoration for assets under their responsibility.

Figure 72: A super cell hit Brisbane on November 28, 2014, causing widespread destruction in a short period of time. In this photo, a roof has been removed from a block of flats. Source: paintings/Shutterstock.

Queensland Fire and Emergency Services (State Emergency Service)

In managing the impacts of severe weather to the communities of Queensland, QFES works with its partners from State and local government agencies, related industry associations, communities and landowners/occupiers to minimise impacts to communities, infrastructure, the environment and local economies from emerging risks. This seeks to:

- Ensure operations are conducted in accordance with Queensland's disaster management arrangements.
- Leverage off expertise within the State Emergency Service (SES) and emergency management personnel in planning and response operations, and existing local government relationships.
- Collaborate with Local and District Disaster Management Groups, to support coordinated planning, readiness, response and recovery, with an additional focus on concurrent hazard events.
- Use disaster management plans, forecasting and predictive products to anticipate operational demands and scale readiness and weight of response appropriate to risks.
- Conduct risk-based operational planning and ensure that plans incorporate learnings from previous severe weather seasons.
- Respond appropriately to requests for service in impact areas and support communities affected by severe weather events.
- Ensure that all QFES resources are integrated and coordinated through the Local Disaster Coordination Centre (LDCC) and the Emergency Operation Centres (EOC) or Incident Control Centres (ICC) to enable appropriate tasking and management of assets.
- Provide timely and accurate information internally and externally to facilitate shared situational awareness to assist with preparation and enable effective response to threats and community needs.
- Use QFES resources to support the community's timely transition back to normal following disruptive events.

Department of Energy and Public Works

The Department of Energy and Public Works is the functional lead for building recovery in Queensland. The department is also responsible for developing legislation and government policy in relation to building standards which may impact the levels of resilience across the built environment.

Considerations for disaster management groups

- Can the group access, interpret, and act on severe thunderstorm and severe weather advice, warnings, and decision support products?
- Is the group aware of the limitations and uncertainties associated with forecasting thunderstorm and severe weather development, intensification and motion?
- Does the group have the ability to interpret technical information contained in advice and warnings, and develop appropriate messages for its target audience?
- Has the group discussed its requirements with relevant entities so appropriate preparation and planning are developed– for example, the identification of response triggers, limits and escalation points between relevant entities?
- Is the group aware of the potential for additional concurrent, compounding and cascading events?

Additional related hazards to consider that are assessed within this report include:

- Riverine flooding
- Critical infrastructure failure

Scenario

Large, potentially thunderous clouds started forming over northern NSW early in the afternoon of the 16 November, with mature storms soon spilling off the border ranges into South East Queensland. A north-easterly track then carried the storms over Wonglepong, Canungra and Tamborine Mountain, where the first reports of wind and hail damage were reported. The storm subsequently merges with a second cell – also originating from across the border – resulting in a new cell that tracked across Redbank Plains through the western and north-western suburbs of Brisbane, culminating in an extremely intense windstorm over the northern suburbs of Brisbane. After advancing through Caboolture, the storm eventually decayed on the Sunshine Coast.

Damaging hailstones were observed at several locations along the storm's path, including Wonglepong, Yatala, Guanaba, and in the densely populated inner-city suburbs of Paddington, Ashgrove, Enoggera and The Gap, with some as large as golf balls. Intense rainfall and flash flooding also occurred at many locations. Floodwaters cause major disruptions to city traffic and sadly two people drown.

Recorded rainfall intensities included 36mm in 10 minutes at Enoggera and Everton Hills and 60mm in 20 minutes at Ferny Hills. However, the intensity and duration of the destructive winds were the standout feature of the storm with wind speeds exceeding 130kph, particularly in the north-western suburbs of The Gap, Keperra, Arana Hills, Upper Kedron, Ferny Grove and Ferny Hills.

Hail ripped through homes and cars, wind gusts smashed windows, ripped off roofs and branches, and uprooted trees. Damage was also reported from other suburbs including Everton Hills, Albany Creek and Narangba. Numerous additional reports are received, most notably 3-4cm hail at Tamborine Mountain, a possible tornado at Canungra, and a rainfall report of 52mm in just 15 minutes at Morayfield.

State Emergency Services record 4,000 homes damaged and 30 destroyed. Almost one-quarter of a million (230,000) residents are without power for over 24 hours.

Authorities estimate the clean-up bill could cost hundreds of millions of dollars due to the damages from a storm with characteristics equivalent to a Category 2 tropical cyclone.

Figure 73: Damage to houses in Springfield, Queensland following a hailstorm on 31 October 2020, where hail in excess of 100mm in diameter was recorded. The damage caused to tile roofs was far greater than the damage to metal roofs, which experienced negligible damage in comparison. Source: QFES.

Impacts

Essential infrastructure

Communications and energy

- Communication networks are susceptible to disruption through direct and indirect impacts, for example due to the loss of power. While some communications sites have power redundancies such as backup batteries or generators, these redundancies and their limitations are not widely disclosed to disaster management groups and communities.
- Widespread disruption to the power network through direct impact from storm events pose a serious risk across the short- to medium-term.[156,157]
- A common vulnerability for power distribution and communications broadcast networks is a lack of redundancy on these networks. In areas where a single power line or chain of telecommunications towers serves a community, disruptions along any segment of this line will cause disruptions to all points further down this line. This is a particular issue in regional areas.
- Statewide disruption is unlikely in Queensland due to the distributed nature and designed redundancy within our energy grid.[7]
- Increased occurrences of landslips during severe weather events may contribute to disruption across the power network.

Water

- Flooding or hail resulting from severe thunderstorms may impact water treatment and wastewater infrastructure.
- Lightning often directly impacts treatment and pumping SCADA systems and the loss of mains power will have a secondary impact on an inability to operate electrical pumps, electrical dosing and electrically operated instrumentation.[71]
- Wind can damage roofs of drinking water reservoirs resulting in an inability to maintain the water quality to the Australian Drinking Water Guideline (ADWG) standards.[71,72]
- In addition, surface water run-off impacts raw water quality. This results in an inability to treat the available water to the ADWG standards.[71]

Transport

Transport infrastructure

- Major transport infrastructure may be temporarily compromised or damaged due to flooding, or possibly to collapse of power infrastructure over roads.
- Toward the east coast where typically the greater density of Queensland's population inhabits, extreme and prolonged flood events have caused substantial impact to major road and rail networks, airports and maritime infrastructure.
- Severe hail storms causing cars to be unusable may cause those cars to clog roads, shutting them down, possibly for a sustained period. This would require mobilisation of resources to clear the roads.

Access and resupply

- Severe thunderstorm events may cause short-term disruption to air, road, rail and maritime systems due to the impacts of the event (e.g. high winds disrupting air and rail travel).[158]
- Impact from possible associated inundation (flash or riverine) across major road and rail networks have historically led to short- to medium-term disruptions.
- Delays on transport networks caused by a severe thunderstorm event can propagate and cause longer-term delays and slowdowns. This has been observed in rail and road networks,[159] and for aviation.[160]
- Return of essential services to communities and industry are highly dependent on the level of disruption across access and resupply. Recovery efforts also likely to be complicated depending on the magnitude and duration of the event.
- In particular, areas within the Gulf of Carpentaria, the Cape York Peninsula and west of the Great Dividing Range have been susceptible to short to long-term isolation due to flooding events brought on by the effects of a cyclonic or severe weather event. In most cases there is a reasonable degree of resilience as most people in those areas live in isolation generally and have redundancy plans in place.

Community

Households

- Direct impact from wind and inundation to shelter and housing leading to widespread displacement across the community. Places of refuge or evacuation centres may also be impacted by hail damage, reducing their ability to function during severe thunderstorm events.
- Insurance premiums as a result of the increase in intensity of severe thunderstorms may become prohibitive by the end of the century. This may also lead to the spread of 'red zones' – areas that insurers will not insure, as the risk for the insurer is too great. This may have major impacts on the cost of housing, impacting residents' financial stability.[161,162]
- Exposure to repetitive events of varying magnitude, duration, impact and therefore consequence may lead led to a decrease in resilience of individuals and households across Queensland.

Figure 74: Extensive hail damage following the severe thunderstorms that impacted South-East Queensland on 31 October, 2020. Source: QFES.

- Social infrastructure (schools, hospitals and community centres) may be directly and indirectly affected through infrastructure damage, loss of power, water and communications.
- As urban areas grow, community exposure to severe thunderstorm events increases.[163]
- Damage from hail can cause significant and widespread economic loss, particularly when the severe thunderstorm occurs over a large, densely populated area. Widespread hail damage can adversely impact the financial and economic health of the affected communities.

Health and wellbeing

Physical health

- Hail that exceeds 4cm in diameter may directly cause injuries to those who are struck.[164]
- Riverine flooding caused by severe thunderstorms may increase the risk of vector-borne diseases like those transmitted by mosquitos, such as Dengue and Ross River virus.[120,121]
- Some medium-term health impacts include infected wounds, complications of injury, poisoning, communicable diseases and starvation.[73]
- Thunderstorms can cause asthma by the winds associated with thunderstorms transporting large amounts of high respirable allergens.[165,166] A particularly notable case occurred in Melbourne in 2016, which caused over 3,000 excess admissions to emergency departments and 10 deaths.[167] The risk of thunderstorm asthma is at present considered low in Queensland – however, climate change may cause this risk to become more significant.

Mental health

- Exposure to severe weather events can lead to medium- and long-term elevated levels of stress, anxiety, depression and post-traumatic stress disorder (PTSD).[168–170]

Business and economy

- Disruption to various industries has occurred as a result of direct impact from an event. The dependency on power and communications for industries has also led to a considerable decrease in productivity creating loss of stock, income and employment.
- Considerable increase in crop and stock losses have historically been observed due to severe wind gusts, flooding (flash and riverine) and hail.[122]
- Removal of fertile soil as a result of flood damage has caused significant impact to the agriculture industry which adds to the loss of the livestock or crop loss.

Natural environment

- Severe thunderstorms may exert the following impacts on the natural environment:
  - loss of vegetation cover and wildlife habitat[83,84]
  - loss of biodiversity, ecosystems, and associated ecosystem services
  - mud slides, soil erosion and excessive siltation - river bank damage, impacts to fish stocks, dugongs and turtles
  - water and soil contamination - saltwater intrusion, sewage overflow, fertilizer runoff, contaminated mine water discharges
  - damage to offshore coral reefs and natural coastal defence mechanisms[85–87,171,172]
  - contamination/pollution from increased wastes (some of which may be hazardous), its biological movements into the environment and debris accumulation
  - damage to waste disposal site infrastructure leading to potential impacts from, for example, leachate collection pond overflow into waterways
  - temporary closure of licenced waste disposal facilities, leading to a build-up of stockpiled waste at temporary sites and management of potential environmental impacts such as odour and leachate
  - impacts associated with human displacement and reconstruction and repair to damaged infrastructure and critical supply chains (e.g. deforestation, industrial and port operations, quarrying, waste pollution)
  - damage to cultural and/or built heritage values and places.

Supporting information

Plans

- Get Ready materials.

Technical guidance

- SES – StormWise guide
- BOM Severe Weather Knowledge Centre: Severe Thunderstorm Warning Services.

Risk summary

Severe thunderstorms are relatively common across Queensland, particularly in the spring and summer months. However, producing precise estimates of probability is difficult for two reasons. Firstly, the causes of severe thunderstorm events are many and varied and, second, the historical record is focussed on populated areas where they are reported, giving a skewed picture of their geographic distribution.

It is unclear whether severe thunderstorm incidence will increase in Queensland due to climate change. However, factors contributing to severe thunderstorm risk – most notably the spread of urbanisation providing greater exposure to storms – are increasing.

Power and communications infrastructure are susceptible to direct impacts of severe thunderstorm, including wind, localised flash flooding, and hail. Lack of redundancy in these networks may lead to cascading failures that cause longer-term outages. Quality of drinking water may also be impacted.

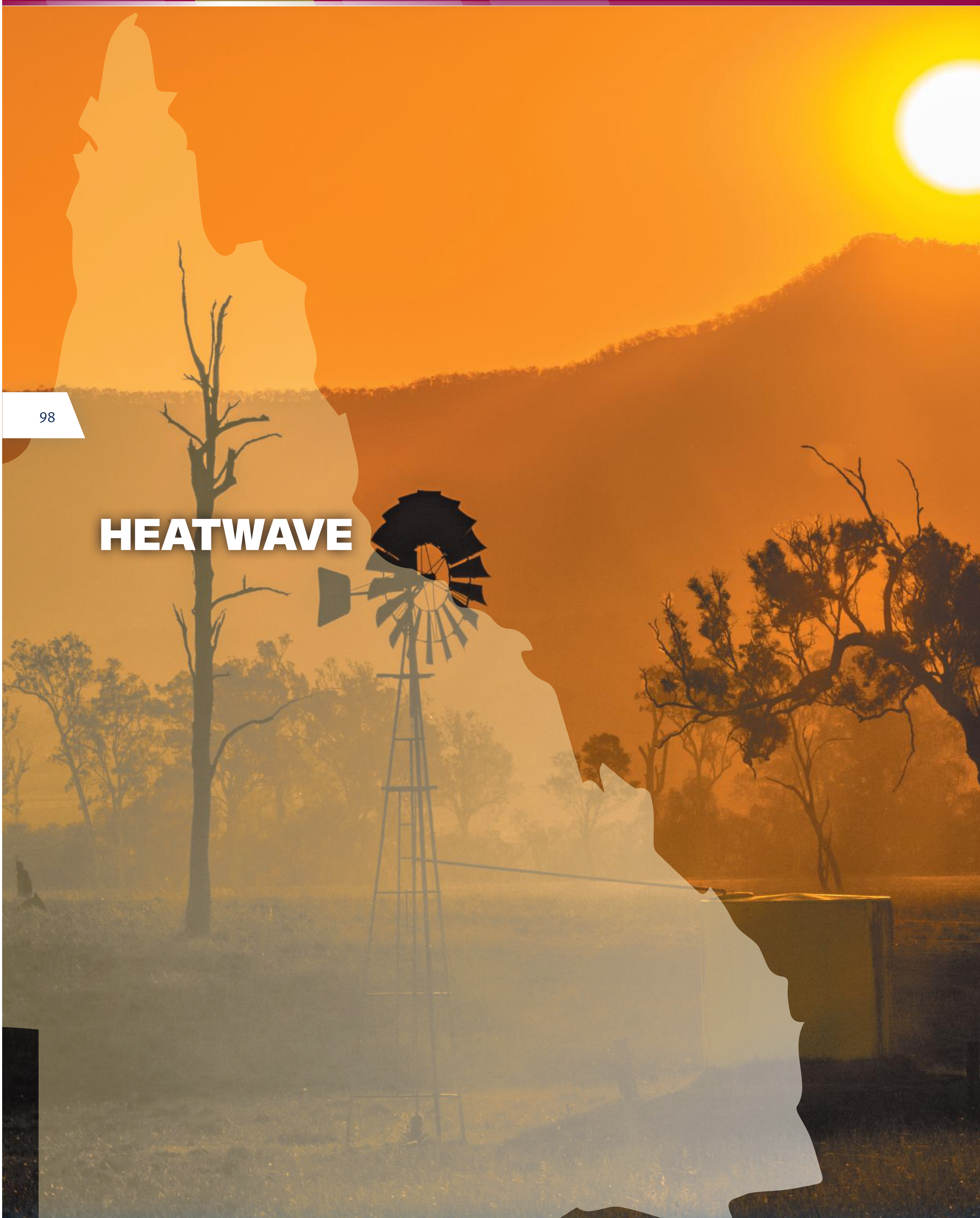
Transport infrastructure can be damaged or destroyed by severe thunderstorms. Damage to vehicles caused by hail may cause clogging of arterial roads or rail lines. Access and resupply can be hampered by these delays. Localised flash flooding may also impact access and resupply.

Damage to the built environment through wind, hail or flooding may be widespread and significant. This is particularly notable in damage to housing which may be financially onerous on homeowners and renters, and may increase future insurance premiums.

Severe hailstorms generally exert a significant cost due to their destructiveness. Industries such as agriculture are also exposed due to damage to livestock and crops.

Environmental impacts of severe thunderstorm may also be widespread, depending on its severity. In particular, contaminants may be introduced to water and soil due to flooding.

HEATWAVE



Heatwave

Heatwave is the fifth highest priority for Queensland. This represents a change from equal third highest (with coastal inundation) in the 2017 State Natural Hazard Risk Assessment.[2] Full details of prioritisation are provided below and in Section C - Risk prioritisation.

Understanding the hazard

This risk assessment is, in part, a summary of the Queensland State Heatwave Risk Assessment 2019,[7] with some additional information from further research and engagement. For more information about the risks posed by heatwaves consult the Queensland State Heatwave Risk Assessment 2019.

Severe and extreme heatwaves have claimed more lives than any other natural hazard in Queensland and Australia.[173] Heatwaves can be dangerous and pose health risks to the most vulnerable such as the elderly, young children, those with chronic health conditions and those from lower socio-economic backgrounds. Heatwaves can also adversely impact the transport, agriculture and energy sectors and associated infrastructure.

Periods of extreme heat can cause or exacerbate health conditions in the population[174–176] and increase mortality rates.[177] Heatwaves can also worsen the effects of other hazards, including air quality[178,179], the number and intensity of bushfires,[180] and the intensity of drought.[181]

An increase in the number and intensity of heatwaves is predicted for Queensland between now and the end of the century.[7] Urban areas tend to be hotter than rural areas,[182] and further urban development across Queensland will mean that heatwaves are felt more acutely within these areas. Since elderly persons tend to be more susceptible to heatwaves,[183–185] Queensland's aging population means that the significance of heatwave risk to Queensland will continue to increase, as will the associated risks.

Definition

The BoM definition for heatwave is "when the maximum and the minimum temperatures are unusually hot over a three-day period at a location".[186] Heatwaves are not like other natural disasters – unlike tropical cyclones or bushfires, there is no well-defined scope or 'epicentre' of the hazard's effect.

Heatwaves are measured relative to the usual weather in the area, and relative to normal temperatures for the season in that area. Therefore, temperatures that people from a hotter climate consider normal can be termed a heatwave in a cooler area if they are outside the normal climate pattern for that area.

The combination of the 'significance index' (how hot the local temperature is compared to normal for that time of year) and the 'acclimatisation index' (comparison of temperatures over the past 30 days to indicate the rate of temperature change) takes into account people's ability to adapt to heat and if a specific heatwave event is more likely to have greater human health impacts.[187]

The minimum (or overnight) temperature is also an extremely important contributor to the calculation. If the minimum remains high, then the subsequent maximum will occur earlier in the day and remain near that high temperature for a longer period. A higher minimum temperature also reduces the period of respite from the heat and provides less opportunity for both people and the environment to discharge heat.

Hazard ratings

The Heatwave Service for Australia, provided by the BoM, categorises heatwaves according to three levels of intensity.[188]

1. Low intensity, where the mean temperature is in the top 10% of temperatures for that location at that time of year.
2. Severe, where the mean temperature is in the top 2%.
3. Extreme, where the mean temperature is in the top 1%.

These are shown in Table 16.

In the Heatwave Response Plan, Queensland Health provides impact statements for these levels of intensity.[189]

Heatwave Type	Colour Code		Temperature	Impact
No heatwave	White		Normal	
Low intensity heatwave	Yellow		Top 10%	Most people expected to have adequate capacity to cope with this level of heat but begin to see health effects.
Severe heatwave	Orange		Top 2%	Increased morbidity and mortality for vulnerable groups, such as those over 65, pregnant women, babies and young children, and those with chronic illness (e.g. renal disease, ischaemic heart disease).
Extreme heatwave	Red		Top1%	Will impact normally reliable infrastructure, such as power and transport and are a risk for anyone who does not take precautions to keep cool, even those who are healthy.

Table 16: Levels of heatwave intensity: Source: Adapted from the Queensland Health Heatwave Management Sub-Plan.

Adding the length of the heatwave to this scale, the hazard ratings below have been developed to assess heatwave hazard for the purposes of this report. Prolonged heatwaves generally exhibit more significant effects than shorter heatwaves, and adding a measure of length captures this information.

Length	Intensity		
	Low intensity	Severe	Extreme
3 – 5 days	1	2	3
5 – 7 days	2	3	4
7 – 10 days	2	4	5
10 – 14 days	3	5	5
› 14 days	4	5	5

Table 17: Hazard ratings for heatwave events.

The Queensland context

History

Since 1958, there has been an observable increase in the occurrence rates of all heatwave severities. Between the 30 years 1986 to 2015, a substantial proportion of the State has experienced an average of three heatwave events per year. This change in heatwave climatology correlates with an increase in demand for heatwave services experienced since the beginning of the 21st century. Queensland Health (QH), as the lead agency for heatwave, has recognised this increased demand and has implemented heatwave planning since the 2004 Brisbane Heatwave.

Queensland's November 2018 heatwave and subsequent bushfires brought into focus the need for greater consideration of heatwave associated risk within the broader disaster management community across the State. Numerous locations reported their highest daily maximum temperature on record during November 2018, or for any month, with some locations breaking their previous record by a large margin.

Projections

In Table 18, we use data representing the heatwave frequency between July to June, as presented on the Queensland Future Climate Dashboard, to derive hazard probability scores for each region until 2090.

Region	1986 – 2005	2030	2050	2070	2090
Cape York	2	2	2	4	5
Central Queensland	2	2	2	3	4
Central West	2	2	2	3	3
Darling Downs	2	2	2	3	4
Far North Queensland	1	2	2	3	5
Gulf of Carpentaria	2	2	2	3	4
Mackay, Isaac and Whitsunday	2	2	2	3	4
Maranoa-Balonne	2	2	2	3	3
North Queensland	2	2	2	3	4
North West	2	2	2	3	4
South East	2	2	2	3	4
South West	2	2	2	3	3
Wide Bay Burnett	2	2	2	3	4

Table 18: Probabilities for heatwave for each region.

Based on these findings, heatwave frequency remains consistent through until 2060, following which it escalates significantly for the entire State.

The methodology for deriving probability scores for this hazard is described in detail in Section D: Technical methodologies.

Management of the hazard

Heatwaves impact many sectors including health, transport, critical infrastructure and essential services, the environment and agriculture, and our economy.

Management of heatwave risk in Queensland is a shared responsibility across all sectors and the community. Queensland Health is the primary agency for heatwave in Queensland.[1] The hazard specific plan for heatwave is the Heatwave Management Sub-Plan, which in conjunction with the State Disaster Management Plan outlines the roles and responsibilities associated with heatwave in greater detail.

Queensland Health

The multi-agency *Heatwave Response Communications Protocol* is a supplementary document to the Heatwave Management Sub-Plan. The Heatwave Response Communications Protocol outlines the multi-agency responsibilities and activities to communicate information and risks to the Queensland community and disaster management stakeholders when a heatwave is imminent in any part of the State. Its aim is to ensure timely and accurate information and advice is provided to assist in mitigating the potential adverse effects of heatwave. The Heatwave Response Communications Protocol can be activated separately to enable effective information and communications in the lead-up to and during an event.

Activation of the Heatwave Management Sub-Plan is based on forecasts from BoM Heatwave Service for Australia (a publicly available service on the BoM website which is monitored daily by Queensland Health's Health Disaster Management Unit (HDMU) when operational). Activation decisions are made using a standard risk assessment of likelihood and impact, with likelihood determined by information received from the Heatwave Service (activation should be considered for severe and is suggested for extreme).

Impact is determined by the size of the area potentially affected by the heatwave, population numbers and vulnerable groups within the potentially affected area and the expected duration of effect. As examples:

- a small, localised extreme heatwave in an unpopulated area would be unlikely to warrant activation
- a widespread, prolonged severe heatwave in a heavily populated area would likely result in activation
- a widespread, prolonged extreme heatwave in a heavily populated area, such as this scenario, would see activation of the Heatwave Management Sub-Plan across all levels of Queensland's disaster management arrangements.

Disaster management groups

Local activation for heatwave may occur without activation of the Heatwave Management Sub-Plan but should involve consultation with QH. Activation decisions by LDMGs should be made on a similar decision matrix as QH's management as outlined in the Heatwave Management Sub-Plan, and follow the same actions relating to the hazard-based exposures, vulnerabilities and likely consequences. Local activation could occur by LDMGs prior to the declaration by QH, although this should not change the LDMG's response strategies – they should be consistent with the Heatwave Management Sub-Plan and with disaster management arrangements as set out in the QSDMP.

This scenario would likely cause activation of the Heatwave Management Sub-Plan in the affected regions, due to the heatwave being measured as severe to extreme, widespread and prolonged. Incident response priorities will be different for each L/DDMG and be based off individual determination of local risk through understanding the hazard, probability, exposure, vulnerability and capability and capacity. As an example, urban L/DDMGs will need to, through preparedness strategies, implement measures to mitigate the urban heat island effect (UHIE), which can increase ambient temperatures by 2 to 12 degrees, to minimise a heatwave's impact on densely populated urban centres. The UHIE occurs due to decreased amounts of vegetation and increased areas of dark surfaces in urban environments, in addition to the heat produced from vehicles and generators.

Queensland Ambulance Service

The Queensland Ambulance Service (QAS) provides specialist logistics support as requested by Queensland Health.

QAS its management of a disaster or emergency incident in the State Major Incident and Disaster Plan and Heatwave Response Plan. These plans inform QAS's disaster managements arrangements alongside the plan. QAS would initiate its disaster management plan for a heatwave.

Bureau of Meteorology

The BoM provides support in forecasting weather patterns that lead to heatwave conditions.

Considerations for disaster management groups

- Has Queensland Health reported to the disaster management group on its prevention and preparedness activities prior to summer?
- Can the group access, interpret, and act on the multi-agency Heatwave Response Communications Protocol, which is a supplementary document to the Heatwave Management Sub-Plan?
- Is the group aware of the limitations and uncertainties associated with forecasting heatwave conditions?
- Does the group have the ability to interpret the information contained in advice and warnings, and develop messaging appropriate for their target audience?
- Has the group discussed its requirements with relevant entities so appropriate preparation and planning are developed to help make informed decisions – for example, the identification of response triggers, limits and escalation of risk between relevant entities?
- Is the group aware of the potential for additional concurrent, compounding and cascading hazards?

Additional related hazards and drivers of risk to consider that are assessed within this report include:

- Tropical cyclone
- Bushfire
- Critical infrastructure failure
- Mass casualty incident
- Biodiversity and ecosystem loss
- Population and demographic change
- Water stress

Scenario

A seven-day severe heatwave occurs in January during school holidays. It impacts approximately half of Queensland, primarily in the Central, South-West and South-East planning regions.

Rural areas, which are already experiencing prolonged drought, see further depletion of their water supplies. In some areas, small amounts of stock death are noted and more heat-sensitive crops have higher rates of failure. Smaller sealed roads in rural areas are damaged by the prolonged heat and in some areas small parts of the electricity transmission networks are disrupted due to damage of the infrastructure. This worsens the impact of the heatwave on affected residents, who cannot operate air conditioning or in some cases pump water.

In urban areas, exposure from the urban heat island effect increases ambient temperatures by two to twelve degrees. A large portion of the population has access to air conditioning, but the use of air conditioning increases demand on the electricity network to near critical levels. While blackouts are not widely experienced, continuity of the power supply is an ongoing concern.

Presentations to emergency departments in the days during and weeks following the heatwave strain these medical services. The elderly and those with pre-existing medical conditions are particularly prevalent. Declines in air quality around the event are noted and may lead to respiratory issues. A number of deaths are directly attributable to the heatwave event.

The heatwave conditions worsen bushfire risk in affected areas across the State and further strain communities already experiencing water stress and drought.

Impacts

Essential infrastructure

Communications and energy

- Rooftop solar panels are helping to mitigate impacts to electricity supply in high demand periods during daylight hours when solar energy is available. Uptake of solar power and decommissioning of non-renewable power stations is creating challenges for existing power generation to meet both minimum and maximum demand limits on a daily basis.
- Peak demand time is shifting towards sunset and minimum demand is decreasing throughout Australia, which may lead to issues with maintaining voltage.[190] Delivered demand during day is now lower in Queensland than the night time for part of the year, and voltage control devices historically installed to manage light load during the night may no longer be sufficient to manage voltages during the day.[191]
- Projected increases in the number of hot nights will likely place a strain on power supply later in the evening.[192]
- There are three main types of power interruptions that can occur during a heatwave:
  - localised outages – impacting a few to several thousand households
  - power system disturbance – a major event disturbs the power system, most frequently caused by a sudden interruption to critical distribution / transmission infrastructure
  - involuntary load shedding – if there is not enough power to meet demand, sections of the grid will be switched off until supply-demand balance is restored.
- Likelihood of involuntary load shedding may increase if impacts to the network have been sustained elsewhere, such as an asset failure or impacts to transmission lines due to a bushfire.[193]
- Transformers are less efficient due to elevated temperatures during extreme events. If cooling systems fail, this may lead to over temperature tripping resulting in localised outages. This represents the biggest risk to modern transmission networks during a heatwave.[193]
- Where backup power generation is available, it may still be vulnerable to failure due to design flaws such as failures in the power computer control network, or through the failure of older individual components linked to modern computer control systems.[194]
- If information and communications technology (ICT) infrastructure loses cooling, it can rapidly fail due to the heat produced from this equipment, particularly as it is often housed in enclosed rooms.
- Heat impact to strategic communications infrastructure is managed by use of air conditioners on larger telecommunications sites. Network failure resulting from heatwave is managed and prioritised through a business as usual restoration process.[195]

Water

- Increasing evapotranspiration rates (>5% increase by 2050) coupled with decreasing annual rainfall (>3% decrease by 2050) may impact reservoir/dam levels across the State increasing the possibility of 'water-stressed' communities.[196]
- Sustained elevated temperatures may damage older elements of the infrastructure, with an increased likelihood of water mains failure during sustained heatwave events.[197]
- There is a higher risk of contamination within infrastructure such as reservoirs and bores through increased rates of bacterial growth, such as blue-green algae. This can pose a risk to human health not only through ingestion but also through direct contact with contaminated water.[198]

Transport

Transport infrastructure

- Passengers at surface transport hubs and nodes (stations and stops) are vulnerable to heatwave due to a general lack of adequate mechanical cooling and ventilation at these facilities.[199]
- Sustained periods of intense heat result in damage to the road and rail network and increasing frequency and duration of heatwaves are expected to exacerbate this damage.[200]
- People are less likely to use active transport during hot weather, increasing reliance on the road and rail network.[201] People walking and using active transport are more likely to be exposed to heat and more vulnerable to heat-related illness.
- Pavement binding begins to fail between 40°C and 45°C. This can result in road closures and affect heavy haulage (especially in western Queensland and the Darling Downs).[200]
- Elevated temperatures and temperature fluctuations can result in premature deterioration or failure of bridges due to stress from thermal expansion and movement.
- Buckling of rail lines can occur in extreme temperatures, resulting in service cancellations or speed reductions for public transport and freight services.[202]
- Disruption to transport services could occur as a result of impacts to power infrastructure.[200]
- High temperatures pose a risk for the loading and unloading of volatile substances such as petroleum and gas products.[202]
- Operation of heavy machinery may damage port yard surfaces, causing surface rutting and heaving.[202]

Access and resupply

- Extreme temperatures affect the capacity of air transport. As air temperature rises, air density decreases, resulting in less lift generation by aircraft wings. This means that aircraft takeoff weight will be restricted, or that greater takeoff speeds and runway lengths are required to reach adequate climb rates. Heavily loaded flights may need to be rescheduled out of the hottest parts of the day.[203]
- Employment arrangements may mean that outdoor workers are entitled to stop work during hot weather, which will affect productivity and delay cargo transfers.[202]

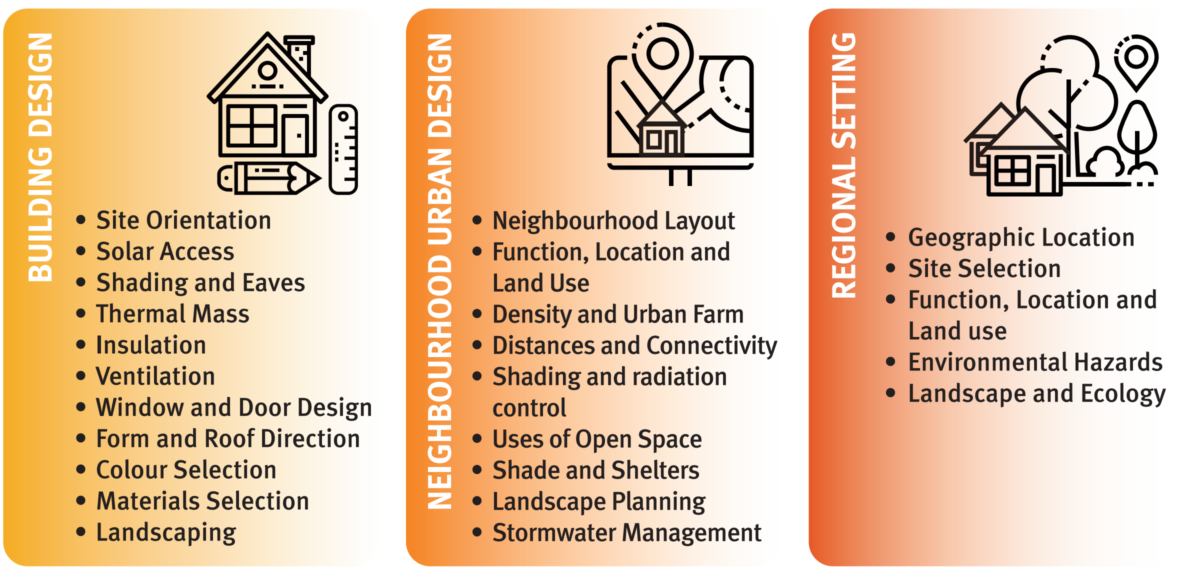


Figure 75: Climatic impacts on building design, neighbourhood urban design and regional settlement patterns. Adapted from: Bitan (1988) and Koppe et al. (2004)

Community

Households

- Australia has seen a trend in increasing housing sizes, with an accompanied increase in air conditioning systems and usage. This leads to high electricity consumption charges and greater potential for overload of the electricity grid during heat events.[204]
- The cost of adapting older buildings by either passive or active means of cooling often restricts implementation, while high electricity costs often mean vulnerable groups may not use air conditioning even if available.
- Rural, regional and remote households and communities are particularly exposed to increasing temperatures and heat events due to the impact of climate change. This will likely result in an increased demand for social support and mental health services, and, at the same time, make it harder to recruit and retain staff in affected areas.[205,206]
- Some vulnerable people may not understand heatwave risk and may not be aware of support services available. Cultural and linguistic barriers can further increase social isolation and vulnerability to heatwaves.[207]
- New residents and visitors from cooler areas are more vulnerable than those acclimatised to warmer temperatures.[208]
- Inconsistent messaging regarding impending heatwaves can cause confusion. Provision of services and advice to people by multiple agencies can result in them being contacted numerous times, sometimes with conflicting information.[209]
- Aboriginal and Torres Strait Islander communities are more vulnerable during heatwaves due to general lower state of health relative to the wider community.[189]
- For some people, leaving their home during a heatwave may not be viable due to mobility or transport issues. This may exacerbate their vulnerability, especially for those with pre-existing morbidities. Financial vulnerability may also influence the choice of people to seek cooler places of refuge during heatwaves (e.g. local pools, shopping centres).[210]

Community services and infrastructure

- The onset of a prolonged or acute heatwave event corresponds to an increase in calls to emergency services, especially Queensland Ambulance Service, as the risks to human health and other societal risks increase.
- Buildings with large volumes of uninsulated thermal mass (e.g. brick, concrete) significantly increase the vulnerability of occupants to heat-related illness. Buildings with large volumes of insulated thermal mass are more resilient to sudden temperature fluctuations but are vulnerable to protracted heatwaves and take longer to cool down compared to lightweight buildings.[211]
- Extreme heat events and/or a lack of air conditioning systems at schools can result in the suspension of the school day if temperatures exceed localised thresholds.[212]
- Some sectors of the community do not currently consider heatwaves as a risk or a natural hazard. This can create barriers to accessing resilience funding streams that may assist in the development of heatwave or heat resistant infrastructure.[31]
- Heatwaves do not currently fall under the definition of an eligible disaster as outlined within the current National Disaster Recovery Funding Arrangements.[213] This may influence the decision of disaster management groups to activate or not during severe and extreme heatwave events.[214]
- Climate change and the increasing frequency of heatwave events is increasing the length of bushfire seasons, which limits the opportunities for prescribed burning.[215]
- During heatwaves, people tend to migrate to beaches, public pools and inland swimming areas as places of refuge. This increases demand on services who monitor these areas, such as lifeguards.

Health and wellbeing

- Heat affects all people differently, and is influenced by:[216]
  - › general health, as a low level of fitness may make people more susceptible to feeling the extremes of heat
  - › age (particularly for people about 45 years and older)[217,218]
  - › body weight (being overweight or obese can make it more difficult to cope with heat)
  - › certain prescription and illicit drug use which can reduce the ability to sweat, reduce plasma volume, change behaviours or directly increase temperature
  - › medical conditions – such as heart disease, high blood pressure, pregnancy, respiratory disease and diabetes, and some types of skin diseases and rashes – can also increase a person's susceptibility and may require special precautions
  - › other factors include circulatory system capacity, sweat production and the ability to regulate electrolyte balance, all of which can be influenced by both acute and chronic medical conditions and medications
  - › their level of heat acclimatisation which generally takes approximately two to three weeks.

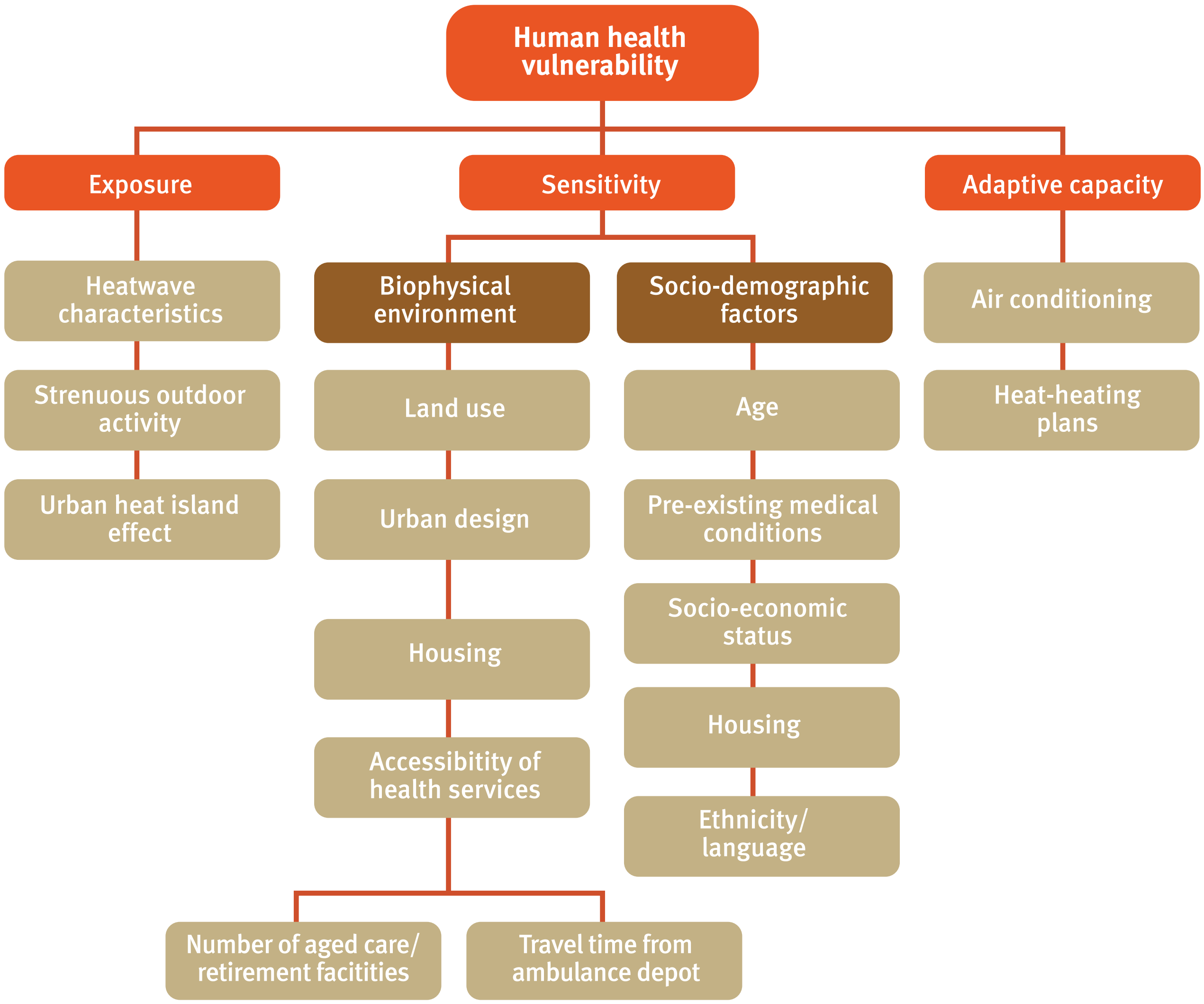


Figure 76: The multitude of factors that create vulnerability to extreme heat events. Source: NCCARF

Physical and mental health

- A clear association between heatwave and mortality has been established, as has the relationship between heat and health over longer periods of time.[219] Heatwave related fatalities usually occur on the same day of exposure or within one to four days after.[220–225]
- Vulnerable groups living in cities are at risk due to the urban heat island effect. This effect continues into the night, increasing the duration of extreme high minimum temperatures, causing heat stress and, under very severe conditions, death from the cumulative heatwave effects.[226]
- Working or being active in hot and/or humid environments can be uncomfortable and lead to heat-related illness which may be fatal.[226]
- Access to air conditioning is a major part of planning for most people and communities. This may occur through individual behaviours such as people going to shopping centres or through community arrangements where places of 'heat refuge', such as air conditioned libraries, are established for people to use during heatwaves. This allows the individual's body temperature to return to normal during heatwave conditions.
- Power failure (and subsequent lack of air conditioning) is often linked to increased heatwave morbidity and mortality.
- Hot weather also increases the risk of food-borne disease due to stresses in food production, particularly for chicken and eggs. Salmonella outbreaks are more common in hot months. These risks can be mitigated through more careful food handling practices. Loss of power also results in a loss of refrigeration of food, increasing risk of food-borne illness if not effectively managed.
- Mental, behavioural and cognitive disorders have been shown to be triggered or exacerbated during heatwaves.[216]
- Fluctuations in weather have been noted to cause an increase in the incidence of mental stress, depression and suicide. As temperatures rise to extreme, the stresses of everyday home, social or work life are likely to be compounded by lethargy, lack of sleep and the inability to function normally during oppressively hot conditions.[79,227]

Health care and infrastructure

- There is an incorrect and potentially harmful perception of 'inherent resilience' within regional Queensland communities, often depicted as 'stoic' and 'well-adapted' to the impacts of natural disasters. While many of these communities have good levels of resilience, this depiction can hinder the development of effective mental health adaptation strategies.
- Loss of refrigeration can also cause damage to certain medicines, such as insulin and vaccines, reducing their efficacy.
- Longer term heatwaves associated with a warming climate have the potential to influence the distribution of vector borne diseases such as Dengue and Ross River fever.

Common clinical effects of a heat illness include:

Heat rash – also known as prickly heat, consists of small, red, itchy or prickly skin lesions due to the plugging of sweat glands.

Heat cramps – painful, often severe, involuntary spasms of the large muscle groups used in strenuous exercise. They tend to occur after intense exertion and often develop during heavy exercise while sweating profusely and replenishing fluid loss with non-electrolyte containing water.

Heat exhaustion – a precursor of heat stroke. It may resemble heat stroke, with the difference being that neurologic function remains intact. Heat exhaustion is marked by excessive dehydration and electrolyte depletion, with symptoms including headache, nausea, and vomiting, dizziness, tachycardia, malaise and myalgia.

Heatstroke – heat illness leading to a change in mental status, which may include an altered level of consciousness or seizures. The presence, or absence, of sweating is a poor guide to diagnosing heatstroke.

Hyperthermia – sweating does not exclude hyperthermia and not all people who present with hyperthermia during a heatwave have heat illness. The most common causes of hyperthermia remain fever due to infection, or associated with other systemic diseases, malignancy or drug reactions.

See Queensland Health's guide for heat-related illnesses for more information.

Business and economy

Business and industries

- Wellbeing and productivity of workers may be impacted across all industries. Heatwaves restrict work capacity and decrease the productivity of exposed workers.[226,228] People who work outdoors or in enclosed indoor spaces without adequate ventilation, even if young, fit and healthy, are highly vulnerable during extreme heat events. This vulnerability extends to a broad range of people including labourers, military personnel, athletes, farmers, emergency and essential service workers, and those working outside in the mining industry.[229]
- Heatwave can have negative effects on staple crop yield following droughts.[230,231] These effects will increase due to climate change.[232]
- As the frequency and intensity of heatwaves increases due to climate change, increased hospitalisations and considerable associated costs due to lost productivity can be expected.[233,234]
- Severe and extreme heatwaves can have significant impacts on agricultural crops and livestock. Sustained elevated temperatures over several days can substantially reduce crop yield and quality, and affect the productivity, health and wellbeing of stock.[226,235,236]
- Livestock will be exposed to a greater risk of heat stress. They are unlikely to travel as far to water which concentrates grazing pressure and increases the risk of adverse pasture composition changes and soil degradation.[237,238]
- Higher temperatures may increase activity of soil-borne diseases and insect infestation, for longer periods during the year.[237]
- Heatwave intensification is anticipated to impact on the forestry industry's resources through increased fire risk, personnel (heat stress and fire response), and plant and equipment (due to overheating).[239]
- Heatwaves are a risk to the tourism sector and can have a significant impact on ecosystems by reducing biodiversity (e.g. Great Barrier Reef and other fragile ecosystems) and, in turn, visitation to Queensland for eco-tourism may be negatively affected.[240]
- Increases in temperatures are a risk to impacts on terrestrial biodiversity that may change or reduce key tourism destination experiences, attractiveness, and participation.[240]
- Enjoyment of Queensland attractions and experiences may be impeded when an extended period of extreme heat impacts outdoor activities or prevents tourists from leaving their accommodation.[240]
- Use of Queensland's hiking trails and many eco-tourism experiences may decline as the capacity for strenuous physical activity drops off rapidly as heat loading increases above a coping threshold.[240]

Economy

- Studies have shown that lost productivity through impacts on heat-affected workers costs Australia more than $8.8 billion dollars annually. This figure is expected to rise due to climate change and in the absence of strong mitigation measures.[228]

Natural environment

- Marine heatwaves can result in mass bleaching of the Great Barrier Reef.[241,242] Branching corals are most vulnerable and bleaching events can significantly impact ecology and biodiversity of the reef as these corals provide habitat for fish and other sea creatures.
- Heatwaves can trigger mass deaths of heat-sensitive species such as flying foxes and birds.226 Plants can also die following extreme heat events, with some species more vulnerable than others.
- Heatwaves and higher temperatures increase the risk of extinction for endangered species such as the Mary River cod and freshwater spiny crayfish.[239]
- Higher temperatures can bring increased occurrence of algal blooms and more instances of fish kill incidents in freshwater ecosystems.[239]
- Mass-death events of species such as flying foxes adversely affects seed dispersal and propagation of native trees, as well as present a human health risk.[243]
- Exacerbation of desertification is likely to occur under the influence of climate change through a repeated cycle of heatwaves, drought, bushfires and dust storms. Notably, the 2018 Queensland bushfires coincided with a series of severe and extreme heatwaves and largescale dust storms that swept across Queensland, which bring with them their own inherent risks to human health and public safety.[244]

Supporting information

Plans

- Heatwave Management Sub-Plan, Queensland Health, 2019
- Heatwave Response Communications Protocol
- State Planning Policy—state interest guideline Natural hazards, risk and resilience, Queensland Government, 2016

Technical guidance

- State Heatwave Risk Assessment, QFES, 2019
- State Heatwave Risk Assessment – Executive Summary, QFES, 2019

Risk summary

Heatwave – or more specifically, extreme temperature – is responsible for more fatalities in Australia than all other natural hazards combined.[173] Heatwaves are more dangerous during warmer months and humid weather. Historical analysis and future projections indicate that heatwaves are becoming more frequent, and will become much more frequent beyond the middle of this century. Heatwave related deaths are also projected to increase significantly, with Queensland and, in particular, Queensland's tropical communities subject to the greatest negative impacts.[245]

Management of heatwave risk includes systemic, integrated and comprehensive approaches to reduce both the impact of heatwave on Queensland communities, as well as action to reduce the emissions that contribute to a warming climate and exacerbate heatwave conditions. The effects of heatwave vary considerably with each event and are compounded by the vulnerabilities and underlying risk drivers of each community, household and person.

Heatwave events are a contributing factor to increased bushfire risk.

Increased mortality rates are to be expected among aged populations and those medically dependent persons with pre-existing conditions. Many within the community may require assistance through a coordinated response.

Disruption to transport and essential services such as power and water may occur as high temperatures increase the risk of failure and damage to these assets. People with limited access to air conditioning or who lack redundancy in supply of power and water are at greater risk.

Heatwave events increase the demand on emergency services and in particular health care. Increased use of cooler places of refuge such as retail shops, swimming areas and public buildings will also increase demand on these services.

Livestock, fish stock and crop losses can occur during extreme conditions. This risk can be further elevated by drought and bushfire.

Many terrestrial and aquatic ecosystems are susceptible to heatwave events. The Great Barrier Reef can suffer significant loss during marine heatwaves. Conservation areas and wildlife populations are highly vulnerable to heatwaves and the associated risk of bushfire.

Heatwaves often occur prior to, during or after the impact of another major disaster such as a bushfire or cyclone, further compounding these risks.

BUSHFIRE

Bushfire

Bushfire is the third highest priority for Queensland. This represents an increase from fourth highest priority in the 2017 State Natural Hazard Risk Assessment.[2] Full details of prioritisation are provided below and in Section C - Risk prioritisation.

Understanding the hazard

Bushfires are a natural part of the Australian environment. The level of bushfire risk and the timing of the bushfire season varies from region to region and from year to year.

The primary drivers of bushfire behaviour are fuel, topography and weather. The topography of the landscape significantly influences bushfire behaviour, particularly where the landscape includes a slope greater than 10 per cent. Bushfires also require a source of ignition – this can occur naturally, such as through a dry lightning strike or can result from human activities, intentionally or otherwise.

Fires can burn more intensely with abundant and drier fuel. Extended hot and dry periods, such as heatwaves and/or droughts, can lead to an increase in dry and highly flammable fuel loads making fires easy to start and harder to control. Bad fire weather days are characterised by strong winds, low relative humidity and high temperatures, often in combination.

Patterns of land use and population growth influence bushfire risk. As the population grows, so does the urban footprint resulting in more people residing in the urban/rural interface zone (I-Zone).

Definition

A bushfire is a fire involving grass, scrub or forest. A bushfire can cause injury, loss of life and/or damage property or the natural environment.

Drivers of bushfire risk

Bushfires are unplanned, and can include grass fires, forest fires and scrub fires.[246] Bushfires occur in both managed and unmanaged areas of vegetation such as reserves, national parks, private property and urban corridors.[247]

Bushfires are a common part of the Australian landscape and frequently occur. Factors that create favourable environments for bushfires include:[248]

- fuel load – the amount fine fuels such as leaves, grass, fallen bark, leaf litter and small branches accumulating in the landscape; fuel which is concentrated but loosely compacted will burn faster than heavily compacted or scattered fuel sources
- fuel moisture
- wind speed
- ambient temperature
- relative humidity
- slope angle – fires accelerate when travelling uphill and decelerate travelling downhill, therefore, the steepness of the slope plays an important role in the rate of fire spread
- ignition source.

Weather conditions that lead to significantly elevated bushfire risk include a combination of high temperatures, low humidity and strong winds. This type of 'fire weather' can be identified and measured using the Fire Behaviour Index (FBI). Heat and dryness are two of the biggest drivers of the weather-related components of bushfire risk. The drier and hotter the weather, the less bushfires require, from a thermodynamic perspective, to spread faster and become increasingly dangerous.

Hazard ratings

Systems for rating fire danger are a key component of proactive fire management. They are also a highly valuable tool in communicating bushfire risk to the community, increasing public awareness and triggering notifications regarding potential threat.

The Australian Fire Danger Ratings System (AFDRS) has been developed by AFAC, in collaboration with participation from all Australian jurisdictions. Fire danger refers to how dangerous a fire could be, if one started. As part of the AFDRS, Fire Danger Ratings are reported in a consistent way across Australia. There are Fire Danger Ratings levels, as outlined in Figure 77.

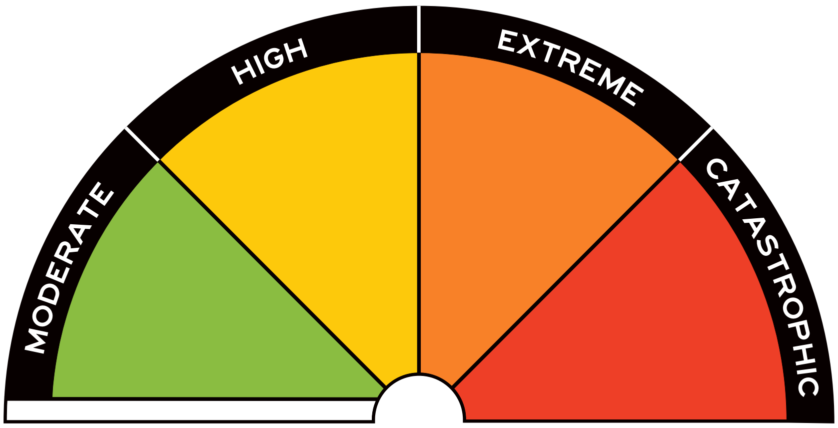


Figure 77: Australian Fire Danger Ratings. Source: AFAC

The four ratings have been adapted into a five-value ranking to assess bushfire hazard for the purposes of this report, shown in Table 19.

Value	Associated fire danger ratings[249]
1	**No Fire Danger Rating (Fire Behaviour Index 0-12)** If a fire starts it can be easily controlled. It poses little or no risk to life or property. People should monitor the situation and stay informed.
2	**Moderate (FBI 12-23)** If a fire starts it can most likely be controlled. Well-prepared and well-constructed homes should be used as a place of safety. Some homes and businesses may be damaged or destroyed.
3	**High (FBI 24-49)** Expect hot, dry and possible windy conditions. If a fire starts and takes hold, it may be difficult to control and move quickly. Well prepared homes that are actively defended can provide safety. People may be injured and homes and businesses may be destroyed. Leaving is the safest option.
4	**Extreme (FBI 50 – 99)** Expect extremely hot, dry and windy conditions. If a fire starts and takes hold, it may be uncontrollable, unpredictable and fast moving. Spot fires will start, move quickly and come from many directions. Homes that are situated and constructed or modified to withstand a bushfire, that are well prepared and well constructed may not be safe. People may be injured and homes and businesses may be destroyed. Leaving is the only option for survival.
5	**Catastrophic (FBI 100+)** These are the worst conditions for a bushfire. If a fire starts it may be uncontrollable, unpredictable and fast moving. Well-prepared and well-constructed homes are not designed or constructed to withstand fires in these conditions. They are not safe. Many people may be injured and many homes and business may be destroyed. The safest place to be is away from bushfire prone areas. Leaving is the only option for survival.

Table 19: Associated fire danger ratings and their five-value rankings.

When implemented, the AFDRS will:

- provide greater scientific accuracy to support government and emergency services decisions and advice
- increase community awareness of their fire risk
- give communities, industry and business clear and timely information in which they can have confidence.[251]

Future iterations of the State Disaster Risk Report will include more information about the AFDRS when it has been implemented by all states and territories.

The Queensland context

History

While Queensland generally sustains more damage from tropical cyclones and thunderstorms, bushfires are a major hazard for the State. Bushfires and grassfires occur annually in Queensland, to differing levels of intensity, based on weather and fuel loads leading up to the period around November and December. Some major events over the past decade include:

- September 2011 fires, which burned across 42 local government areas throughout the State[252]
- November-December bushfires in 2018 across the State, especially around Gladstone, Rockhampton, and Mackay, which caused one fatality and the destruction of 9 homes.[253]
- Black Summer bushfires in 2019, which affected the Sarabah/Scenic Rim area, the Stanthorpe area and Peregian Springs; 29 homes were destroyed, and approximately $69.9m of insurance costs were incurred.[254]

Figure 78: Bushfires burnt through 85,000 hectares of K'gari (Fraser Island) from October to December, 2020. Source: QFES

Projections

For most of the State, fire weather risk until 2060 is stable. However, for Cape York, Wide Bay Burnett and the Gulf, fire danger is projected to increase. For the North West region fire weather will become less prevalent, due primarily to a projected increase in rainfall in that region.

Projecting future bushfire risk is difficult, because the factors that lead to fire – including most importantly fuel load, fuel moisture, wind speed, slope angle and ignition source – are not currently able to be modelled into the future with any degree of confidence.

An alternative approach is to measure fire danger based on weather prediction. Table 20 shows probability scores per region for fire weather risk at twenty-year intervals. The scores capture the risk that weather conditions will be conducive to fire risk in the region during that period. This is not a measure of the annual probability of a bushfire of a certain severity but is instead an indication of how weather conditions will shift in the coming years to be more or less conducive to fire activity.

The weather conditions used in the calculation of fire probability are outputs of the future climate modelling available on the Queensland Future Climate Dashboard. As such, these probabilities represent the probability of bushfire weather conditions according to current climate projections.

Region	1986 – 2005	2030	2050
Cape York	1	2	2
Central Queensland	2	2	2
Central West	5	5	5
Darling Downs	2	2	2
Far North Queensland	2	2	2
Gulf of Carpentaria	2	3	2
Mackay, Isaac and Whitsunday	2	2	2
Maranoa-Balonne	2	2	2
North Queensland	2	2	2
North West	4	3	3
South East	1	1	1
South West	4	4	4
Wide Bay Burnett	1	1	2

Table 20: Probabilities for bushfire for each region.

The methodology for deriving probability scores for this hazard is described in detail in Section D: Technical methodologies.

Management of the hazard

Bushfire risk management is a shared responsibility of all land managers, and all Queenslanders have a responsibility to reduce the potential for and the impact of bushfires.

QFES is the primary agency for bushfire in Queensland. The hazard specific plan for bushfire is the Queensland Bushfire Plan, which outlines in greater detail the shared responsibilities for bushfire management. This includes, vitally, processes for understanding and mitigating risk.

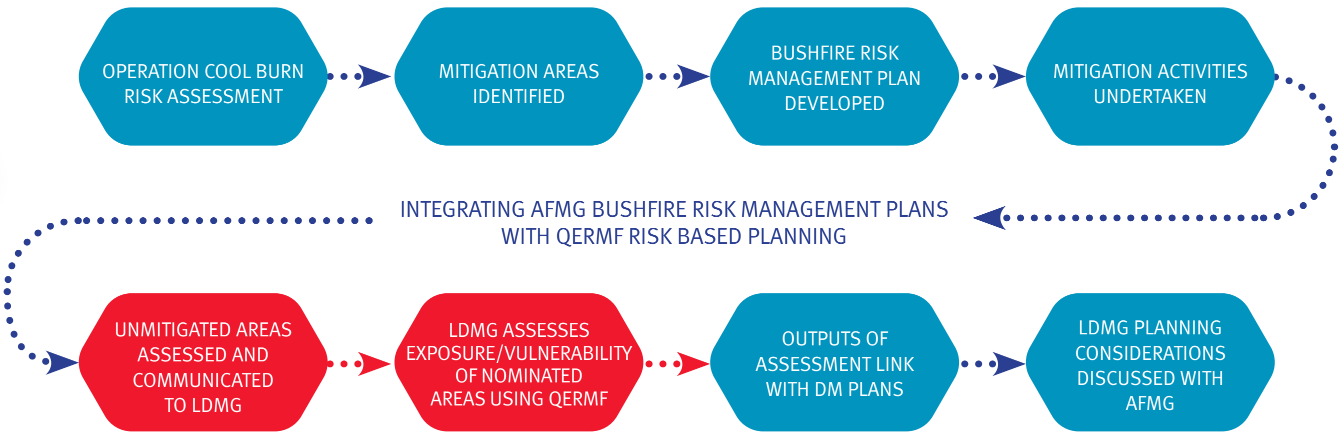


Figure 79: QERMF process for bushfire risk management.[249]

The Department of Environment and Science (DES) through the Queensland Parks and Wildlife Service (QPWS) is responsible for managing fire on protected area and forest estate. QPWS provide a strong support role to QFES in bushfire risk management across the State.

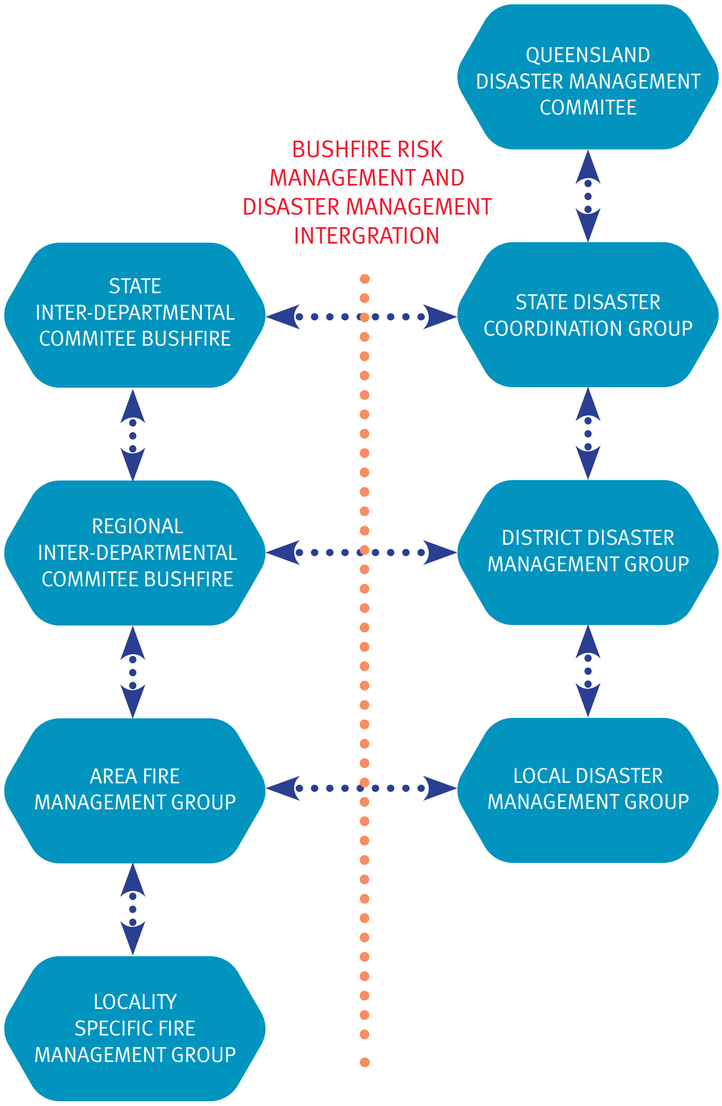


Figure 80: Queensland's Bushfire Management Arrangements. Source: QFES[249]

Queensland Fire and Emergency Services (QFES)

QFES is the primary agency for bushfire in Queensland. The hazard specific plan for bushfire is the Queensland Bushfire Plan, which outlines in greater detail the shared responsibilities for bushfire management.

Queensland's bushfire management arrangements are characterised by partnerships and shared responsibility between land managers, the community, service providers, fire management groups, disaster management groups (DMGs), committees at a regional and state level and government at the local, state and Commonwealth level.

Under the Queensland Bushfire Plan, bushfires are managed in a different way to other hazards. Alongside LDMGs and DDMGs, the plan establishes a structure of Fire Management Groups and Committees, and specifies how these integrate with the LDMGs, DDMGs, and the SDCG. The roles and functions of each of these groups is outlined in the plan. Queensland Bushfire Plan also details responsibilities and best practice throughout each of the phases of Prevention, Preparedness, Response and Recovery.

Department of Environment and Science

As the largest single landowner in the State (over 13 million hectares), the Department of Environment and Science (DES) through the Queensland Parks and Wildlife Service (QPWS), is responsible for managing fire on protected area and forest estate. QPWS provides a strong support role to QFES in bushfire management across the State.

QPWS has two targets for its fire management program:

- ›5% of the QPWS-managed estate has fuel loads reduced by planned burning, to reduce fire risk to life and property and protect key values
- ›90% of the scheduled Protection Zones is treated to protect life and property.

The Queensland Bushfire Plan details the role of QPWS in bushfire response, as well as QFES's role on QPWS-managed land for all Level 2 and 3 bushfire responses where there is a clear threat to life and infrastructure.

The QPWS fire management system includes legislation, policy, strategic direction, planning, operations, assessment and review. It applies to all fire management activity relating to fire planning, planned burning, wildfire preparedness and response, and fire reporting on the QPWS estate where responsibility for managing fire rests primarily with QPWS.

QPWS's primary fire system, FLAME, is a spatially enabled online system that enables the department to carry out integrated fire planning and reporting functions. Information from FLAME is shared with QFES.

QPWS works collaboratively with more than 30 First Nations groups to plan and conduct planned burns on protected area and forest estate, with more than two million hectares of Queensland's protected area estate under formal joint management arrangements between the State and the respective First Nations. QPWS supports First Nations-led fire management on Country through the Land and Sea Ranger Program, which supports communities around Queensland.

Queensland Health

Queensland Health (QH), in consultation and collaboration with other entities, will provide briefings and consistent information to support community warnings.

Surge and continuity arrangements provide additional resources to hospitals as needed to ensure ongoing care of the community.

QH works with other emergency services, disaster management groups, St John Ambulance (Qld), the Pharmacy Guild, the Royal Australian College of General Practitioners, the Commonwealth Department of Health (regarding aged care facilities) and the Australian Red Cross, as well as other non-government organisations with a community care focus.

Through these networks, and through QH's Hospital and Health Services and Primary Health Networks, aged care facilities, private hospitals, community health care providers and pharmacies, QH can ensure identification and distribution of messaging to vulnerable groups across Queensland. QH also monitors and provides advice on the public health risks associated with effects of bushfire, in particular the health effects of poor air quality as a result of smoke from bushfires.

Department of Energy and Public Works

The Department of Energy and Public Works is the functional lead for building recovery in Queensland. The department is also responsible for developing legislation and government policy in relation to building standards which may impact the levels of resilience across the built environment.

Considerations for disaster management groups

- Has the area fire management group reported on mitigation activities undertaken, areas of residual risk, and provided the DMG with a copy of their bushfire risk management plan?
- Can the group access, interpret, and act on seasonal outlooks, fire weather and bushfire advice, warnings, and decision support products?
- Is the group aware of the limitations and uncertainties associated with forecasting fire weather and predicting fire spread?
- Does the group have the ability to interpret the information contained in advice and warnings, and develop messaging appropriate for its target audience?
- Has the group discussed its requirements with relevant entities so appropriate preparation and planning is developed to help make informed decisions – for example, the identification of response triggers, limits and escalation of risk between relevant entities?
- Is the group aware of the potential for additional concurrent, compounding and cascading hazards?

Additional related hazards and drivers of risk to consider that are assessed within this report include:

- Heatwave
- Critical infrastructure failure
- Mass casualty incident
- Biodiversity and ecosystem loss
- Population and demographic change
- Water stress

Scenario

During a strong El Niño–Southern Oscillation year, rainfall across Queensland is much lower than average, ambient temperature is significantly higher and relative humidity much lower. In November, fire weather is slightly more frequent and intense than a normal year. This leads to many smaller fires breaking out in Central, southern and South East Queensland.

Many of these fires in Central and southern Queensland occur in grasslands, significantly impacting the agricultural sector in these areas. Some smaller towns are directly impacted but major centres are not. However, the number of concurrent fires makes it difficult for local RFS crews to coordinate activity and effectively contain some of the fires.

In the south east, fires occur within urban interface zones (I-Zones), threatening residents' properties. Fires are fewer in number in the south east but tend to be larger, and pose a greater threat to life and property. Some communities within I-Zones are evacuated as fires spread rapidly during days of intense wind and heatwave conditions. Some homes and buildings are destroyed.

Residents in south easter urban areas are affected by the smoke of the south east bushfires. This significantly increases the number of presentations to emergency departments, requiring these emergency departments to expend significantly more resources as they deal with presentations due to heatwave conditions.

Impacts

Essential infrastructure

Communications and energy

- Where power infrastructure transects areas of dense bushland or national parks there is increased vulnerability to bushfires. Some areas have seen short-term, localised periods of disruption to the network due to direct impact from fire to power poles, substations, and indirect impact from rising ash and embers causing powerlines to arc and short circuit at key points across the network. This is more likely to be an issue if the powerlines in the area are lower, wooden poles close to vegetation.
- There are three main types of power interruptions that can occur during a bushfire, dependant on location, scale and time of impact:
    1. Localised outages – impacting a few to several thousand households, these occur due to multiple factors and are likely to result in short-term interruption to supply. Single-Wire Earth Return (SWER) lines and older infrastructure across Queensland are more vulnerable due to a lack of resilience against sustained high temperatures and direct attack.
    2. Power system disturbance – occurs when a major bushfire event disturbs the power system, most frequently caused by a sudden interruption to electricity infrastructure. In Queensland, system disturbance can occur from smoke causing short circuiting, or severe wind or bushfire damaging transmission and distribution lines and infrastructure.
    3. Involuntary load shedding – on rare occasions, usually during heatwave conditions, there may not be enough power to meet demand, and sections of the grid may be switched off until the supply/demand balance is restored. The likelihood of involuntary load shedding may increase due to infrastructure damage or failure in other parts of the network, such as damage to transmission lines from a bushfire.

- There are multiple key telecommunication assets (e.g. masts, towers) across Queensland located within elevated areas. These assets act as a "backbone" to the telecommunications network providers, facilitating greater coverage of service for Queensland's communities. However, this leaves the infrastructure vulnerable to exposure from bushfire impact (which is also worsened by the topography) as most of these locations such as natural bushland and national parks.
- Indirect impacts to the communications network may occur if the local power network is impacted with sporadic communication outages likely dependent on the level of redundancy available. It is important to note that the efficiency of battery redundancy reduces – by upwards of 50 per cent in extreme cases – with exposure to severe or extreme heat.

Water

- While most infrastructure operators employ effective mitigation strategies to ensure assets are as safe from general bushfire impact as possible, the scale of the high-intensity bushfires observed in recent years has highlighted significant impact to the water network is highly likely. These risks are managed or mitigated by the local or regional water service provider i.e. Seqwater and Sunwater, or local government.

- Bushfires may degrade water quality and alter the dynamics of river and stream ecosystems in many complex ways. Most critical effects occur if there is heavy rain soon after fire, as loss of vegetation and altered soil structure can make fire-affected soils more erodible. Runoff can carry sediments and pollutants that affect aquatic environments, drinking water quality and agricultural industries. The degree to which water quality is affected by fire depends on factors such as:
  - geographical features and size of the catchment
  - size and extent of the fire
  - time period between the last fire and a significant rainfall event
  - type of surrounding vegetation, soil and erosion.
- High intensity fires can cause enormous damage to water catchments by destroying ground cover and changing hydrology, as well as altering the structure, behaviour and erosion of soil. The loss of riparian vegetation may result in high volumes of sediment (measured as turbidity) entering the stream and may also increase stream temperatures due to a lack of shade.
- Chemical reactions triggered by fire can release nutrients, metals and other toxicants stored in vegetation and soil. Rainfall after a fire washes these contaminants into waterways and reservoirs, which can have substantial implications for agriculture, human safety and amenity. This occurred after the Canberra bushfires in January 2003, for instance.[255] Use of affected water may be unsafe for agriculture or human consumption without additional treatment or alternative water sources may have to be found.
- Indirect disruption has been observed in the short term when power has been affected. Loss of power can result in the shutdown of water treatment plants and, depending on the availability of reserves in the system, may require the issuing of boil water notices. This can potentially cause a cascading critical infrastructure failure: please refer to the Critical Infrastructure Failure risk assessment for more information.
- Water to fight fires may become difficult to access during periods of low rainfall. Planning for access to water for this purpose may be required for drought-affected communities going forward.

Transport

Transport infrastructure

- Transport infrastructure situated in I-Zone locations may be vulnerable to bushfire impact either directly or indirectly. Where infrastructure is exposed to severe bushfire conditions, disruption to roadways and road structures (e.g. bridges, overpasses and signage) is likely.
- Bushfires can also disrupt road and rail networks by causing low visibility due to smoke. Major corridors such as the Bruce Highway and important rail links have been impacted in past events.[256]

Access and resupply

- Short- to medium-term (days to weeks) disruption periods have been observed during bushfire events. Direct and indirect impact to air, road and rail networks (including ember attack and smoke reducing visibility) has led to disruption in access to areas for the general community, emergency services and the supply chain. Disruption can be reduced if alternate routes or traffic management plans are available and enacted. There are significant costs for repair or return of services associated with direct impact.
- During response, understanding the rate of spread and the potential for imminent impact and closure of access corridors is critical when considering or enacting any evacuation of threatened communities. Evacuation from areas likely to be impacted by bushfires is typically highly challenging, with different levels of preparedness and compliance within communities.

Community

Households

- Built up areas established in locations surrounded by national park or bushland (e.g. mountainous suburban areas) also are more exposed and vulnerable to bushfire. This risk will increase as peri-urban areas encroach further into bushfire-prone areas.[257–259]
- These types of I-Zone areas are significant focus areas for key messaging and preparedness activities undertaken by QFES and LDMGs due to their restricted access and egress routes and proximity to high fire risk areas. This is especially important where planned mitigation activities have had limited opportunities to reduce fuel load.
- I-Zone areas within remote Indigenous communities and townships comprised of a mix of ethnically, culturally and socio-economically diverse groups – who at times are reliant on social media and word-of-mouth for emergency alerts rather than official alert channels – are vulnerable to loss of communications across the State which may result from bushfire occurrence.
- Consistent messaging regarding impending bushfire impact is essential. People who are recipients of services and advice from multiple support agencies can at times be contacted numerous times by different organisations, sometimes with inconsistent information. QFES uses standardised information where possible to minimise any confusion.
- Clear, consistent communication of risk information in bushfire-prone areas is highly beneficial. Without this, complexities can arise, particularly with homeowners wishing to protect their homes and communities, from fires.[260–265] Communication strategies that consider – and strive to integrate and align – homeowner and community priorities are a means of mitigating this risk. Pre-identified and agreed triggers for action and contingency plans are also important in mitigating this risk.[266]
- A strong sense of community and sense of attachment to community positively influences preparedness.[258,267,260] Some isolated and therefore vulnerable people do not understand bushfire risk and may not be informed of support services available to increase their individual resilience. Cultural and linguistic barriers can also exist which increases social isolation and vulnerability to bushfires.
- People who have recently moved to Queensland from areas with cooler climates are at greater risk than long-term residents. This increases for new residents and tourists for whom English is not their primary language, and their ability to interpret key messaging is low. These people may not be as well prepared for extreme climatic conditions, including bushfires which have an increased likelihood in peak tourism season. While bushfires may affect all people, residents tend to be more accustomed to and better prepared for bushfires, particularly in terms of taking appropriate action to prepare and respond.

Community services and infrastructure

- Social infrastructure may be impacted directly or indirectly through damage to associated infrastructure and disruption to essential services such as power, water and communications.
- While most communities are unlikely to be directly impacted by anything other than high-intensity, large scale bushfires, as with the 2018 and 2019 fires, there are some rural and remote communities in isolated areas which are highly vulnerable to general bushfire occurrence. These small, populated locations are at times off the grid and located in densely vegetated areas presenting a significant challenge for bushfire risk management.

- During periods of fire danger, severe and beyond, bushfires can become uncontrollable even if fuel levels are minimal. Extremely hot days and heatwaves increase underlying bushfire risk.[268,269] Bushfire occurrence during these periods places additional pressure on local and regional emergency management capability and capacity and increases the risk of impact to the community.
- Climate change and the increasing frequency of heatwave events is increasing the length of fire seasons, which limits the opportunities for prescribed burning.[270] Usual mitigation efforts are less likely to impact bushfires during extreme, and compounding conditions, for example drought, high winds and heatwaves.[269] The risk of heat stress and heat stroke for emergency service personnel is managed under operational health and safety guidelines. However, it has been noted that compound extremes, such as simultaneous bushfires and heatwaves, may result in operating thresholds being exceeded faster than normal.[271]

Health and wellbeing

Physical and mental health

- Exposure to smoke from fires can worsen asthma and other respiratory conditions, cause coughing and shortness of breath and irritate the eyes, nose and throat. Large particles in bushfire smoke also irritate the eyes, nose, throat and lungs. Finer particles can penetrate deep into the lungs and are more harmful. Other health hazards from bushfires include extreme heat and physical injuries such as burns, heat stress and dehydration.[272–274] These indirect effects lead to increased mortality rates among older populations and medically dependent persons with pre-existing conditions.

  Those at greatest risk of harm from bushfire smoke are:[180]

  1. people with respiratory disease, especially asthma, but also emphysema, chronic bronchitis or allergies
  2. smokers
  3. people with heart disease
  4. children
  5. the elderly.

- For some people, leaving their home during a bushfire may not be viable due to mobility or transport issues. This may exacerbate their vulnerability, especially for those with pre-existing morbidities.
- There is also an incorrect and potentially harmful perception of 'inherent resilience' within regional Queensland communities, often depicted as 'stoic' and 'well-adapted' to the impacts of natural disasters. While many of these communities have good levels of resilience, this depiction can hinder the development of effective mental health adaptation strategies.
- The Department of Environment and Science (DES) in collaboration with industry partners operates an air quality monitoring network across the State. Data from the monitoring network is presented online as ambient concentration, air quality index values and health action levels, updated hourly. Health action levels are recommendations that have been developed by Queensland Health to support and inform the community on what actions to take to protect their health during a smoke event. More information is available on air quality monitoring is available at https://www.qld.gov.au/environment/pollution/monitoring/air/air-monitoring.

Health care and infrastructure

- Health assets and infrastructure in built up, remote and rural townships that interact with I-Zone areas have a moderate level of exposure and vulnerability to bushfire hazard. Primary concerns relate to loss of essential services (power, communications and water) as well as smoke impact.
- Aged care facilities and services, together with their residents, have experienced significant impact during large-scale bushfires with incidences of compromised telecommunications and therefore messaging, issues with consumable supply chains and, in extreme situations, full evacuation of sites for the safety of staff and residents. The majority of these issues have resulted from limited business continuity planning with respect to natural hazards and could be resolved through development of enhanced preparation and response measures within the aged care sector.

Business and economy

Figure 81: A tractor impacted by bushfire near Kabra, Queensland. Source: QFES

Business and industry

- Agricultural areas across Queensland have sustained stock and crop losses from direct exposure to significant bushfires. Additionally, associated infrastructure such as stock fencing, bulk storage areas (e.g. grain silos and cotton stores) and, in some locations, cattle yards have and may continue to be significantly impacted. The impacts of bushfire to these locations and industries have had and are likely to continue to deliver medium to long-term disruption and economic impact. Recovery within agricultural sector can be protracted, especially if the area is already experiencing impacts associated with other natural hazards such as drought or floods.
- Queensland's forestry industry is highly vulnerable to exposure from bushfire hazard due to the nature of the industry. Loss of equipment, infrastructure, and timber, at a significant scale can cause long-term disruption to the industry with significant flow on impacts to local and regional economies.
- Underground mining locations across Queensland rely on surface air vents to supply clean air to workers who are at times located at significant depths below-ground. Air intakes are vulnerable to impact from exposure of smoke in air vents produced in a bushfire hazard. This has and can cause short-term disruption to production of those mines due to essential evacuations of the underground workers.
- Tourism, and particularly ecotourism, is vulnerable to the impacts of bushfires, as a result of damage to property, disruption of infrastructure, and ongoing environmental devastation.

Economy

- Direct costs of bushfires can be significant. For example, the total cost of Victoria's Black Saturday bushfires in 2009 is estimated at more than $4.4 billion, with significant impacts on government-owned infrastructure assets.[275]
- Economic impacts of bushfire can be felt by affected communities for years following the event, particularly for destructive events.[276] This can also have impacts on the economic viability of regions more broadly.[277]
- Bushfires have historically not cost the Queensland economy greatly, especially when compared with floods and tropical cyclone.[278] However, due to the projected increase in fire weather due to climate change, it is likely that the cost will increase in the coming years.

Environment

- National parks and areas of dense vegetation have shown consistency in being the high exposure areas across the State to bushfire. Uncontrolled burns in these areas have led to significant natural bushland areas being impacted by bushfire.
- Intense bushfires cause the death, by incineration or smoke suffocation, of large numbers of native animals and insects that are unable to avoid the flames.[279] Microsites (i.e. small areas that are ecologically distinct from their surrounding areas) that do not burn under low intensity burns are incinerated leaving no areas of refuge for fire-sensitive flora or fauna, or for subsequent recolonisation after the fire.
- Any animals that are able to take refuge in holes in the ground or in logs are usually quickly lost after a bushfire as they no longer have any cover from predators. Local food chains can also be affected by loss of riparian vegetation after a fire, which leads to:
  - higher water temperatures
  - increased light availability
  - loss of habitat
  - reduced protection from predators for instream biota.

  Combined with increased contaminant loading, increased water temperature can trigger a greater breakdown of organic matter by bacteria, which may deplete oxygen levels in the water. Fish suffocation is a common result of this sudden depletion of dissolved oxygen.[280,281]
- Other potential impacts include:[197]
  - loss of vegetation cover and wildlife habitat
  - loss of biodiversity and ecosystem services
  - water and soil contamination - sewage overflow, fertilizer runoff
  - contamination/pollution from increased wastes (some of which may be hazardous), its biological movements into the environment and debris accumulation
  - damage to waste disposal site infrastructure leading to potential impacts from, for example, leachate collection pond overflow into waterways
  - temporary closure of licenced waste disposal facilities - build-up of stockpiled waste at temporary sites and management of potential environmental impacts such as odour and leachate
  - impacts associated with human displacement and reconstruction and repair to damaged infrastructure and critical supply chains (e.g. deforestation, industrial and port operations, quarrying, waste pollution)
  - damage and degradation of Indigenous cultural heritage values and built heritage places.

Supporting information

Plans

- Queensland Bushfire Plan
- DES (QPWS) Good Neighbour Policy

Technical guidance

- Bushfire Resilient Guidance for Queensland Homes
- DES (QPWS) Bioregional Planned Burn Guidelines
- Business Continuity Planning Resource for Aged Care Facilities, QUEENSLAND.

Risk summary

For most of the State, fire weather risk until 2060 is stable. However, for Cape York, Wide Bay Burnett and the gulf, fire danger is projected to increase. For the north west region, fire weather will become less prevalent, due primarily to a projected increase in rainfall in that area.

Bushfire risk management requires effective partnerships and shared responsibilities between many stakeholders. In Queensland, bushfire risk is managed through Fire Management Groups and Committees that integrate with the LDMGs, DDMGs and the SDCG.

Generally, risk management and mitigation strategies employed by infrastructure asset owners are effective in mitigating bushfire impacts, however essential services may still be subject to localised, short-term periods of disruption.

Transport may be vulnerable to either direct or indirect bushfire impacts. Disruption to road transport can be anticipated and should be considered in relation to evacuation planning and operations.

The majority of the population will generally not be directly exposed to bushfire. Rural and remote communities in isolated areas and communities in I-Zones are more vulnerable to bushfire impacts.

More vulnerable people include new residents and tourists from backgrounds where English is not their primary language. People at greatest risk of harm from bushfire smoke include those with respiratory disease and heart disease, smokers, children and the elderly. Aged care residents are particularly vulnerable, exacerbated by a lower level of continuity planning and training across aged care facilities and service providers.

Agriculture and forestry areas across Queensland may sustain heavy losses from direct exposure. Associated equipment and infrastructure may also be impacted. The impacts of bushfire to these locations and industries may deliver medium to long-term disruption and economic impact. Short-term disruption to mining and other industries may occur.

Environmental impacts are integrally linked to bushfire. National parks, bushland and areas of dense vegetation are highly exposed to bushfire.

Large numbers of native animals and insects may be killed, and fire sensitive flora or fauna may be lost. Local food chains can also be affected by loss of riparian vegetation after a fire, compounding environmental impacts.

EARTHQUAKE

Earthquake

Earthquake is the ninth highest priority for Queensland. This represents a reduction from fifth in the 2017 State Natural Hazard Risk Assessment. This is due largely to the inclusion of additional hazards (particularly pandemic and infectious plant or animal disease) in this report.[2] Full details of prioritisation are provided below and in Section C - Risk prioritisation.

Understanding the hazard

This risk assessment is, in part, a summary of the Queensland State Earthquake Risk Assessment 2019.[282] For more information about the risks posed by earthquakes consult the Queensland State Earthquake Risk Assessment 2019.

Earthquakes pose a significant risk for Queensland. Between 1886 and 2020, there were 327 known earthquakes above magnitude 3 – that is, with enough force to cause visible damage – at an average of 2.4 earthquakes per year. There are many more of lower magnitudes, and there are likely to be many more outside areas that are presently covered with seismic instruments, and therefore remain undetected.

In Australia, earthquakes with magnitudes of less than 3.5 seldom cause damage and the smallest magnitude earthquake known to have caused fatalities is the magnitude 5.4 Newcastle earthquake in 1989. However, magnitude 4.0 earthquakes occasionally topple chimneys or result in other damage which could potentially cause injuries or fatalities.

Definition

Earthquakes are vibrations within the earth caused by rocks breaking under stress. The underground surface along which the rock breaks and moves is called a fault plane. The focus of an earthquake is the point where it originated within the earth inclusive of depth. The earthquake epicentre is the point on the earth's surface directly above the focus.

The size or magnitude of an earthquake is determined by measuring the amplitude of the seismic waves recorded on one or more seismographs and the distance of the seismographs from the earthquake. The amplitude of the shaking caused by an earthquake depends on many factors such as the magnitude, distance from the epicentre, depth of focus, topography and the local ground conditions.

Measuring earthquakes

Earthquake magnitude is traditionally measured on the Richter scale, however some magnitudes are calculated in terms of moment magnitude, which is proportional to the fault area multiplied by the average displacement on the fault. Using this measure, amplitude of systemic waves are converted to a magnitude, which is a measure of the energy released by the earthquake. For every unit increase in magnitude, there is roughly a thirty-fold increase in the energy released. For instance, a magnitude 6.0 earthquake releases approximately 30 times more energy than a magnitude 5.0 earthquake, while a magnitude 7.0 earthquake releases approximately 900 times (30 × 30) more energy than a magnitude 5.0.

Other effects

In areas underlain by water-saturated loose granular sediments, large earthquakes (usually magnitude 6.0 or greater) may cause liquefaction or other permanent ground deformation e.g. surface rupturing, lateral spreading (often on riverbanks and hill slopes). The shaking causes the wet sediment to lose its strength and stiffness, and begin to flow. Subsidence from liquefaction may cause buildings to topple and the sediment may erupt at the surface from craters and fountains. Large undersea earthquakes that cause permanent displacement on the ocean floor can cause a tsunami, or a series of waves, which can cross an ocean and cause extensive damage to coastal regions. Earthquakes can also create underwater landslides that in turn can trigger more localised tsunami.

Hazard ratings

Earthquake effects are rated using the Modified Mercalli (MM) intensity scale, which ranges from I (imperceptible) up to X (destruction of most masonry structures). The intensity felt at a location depends on many factors such as distance from focus, nature of the local strata overlying bedrock, local topography, physical damage and an observer's level of alertness and activity at the time of an earthquake.

Value	Earthquake
1	Less than Modified Mercalli Intensity (MMI) VI: Light-moderate shaking. Some windows and items broken
2	MMI VI: Strong shaking. Fallen plaster, damage slight
3	MMI VII: Very strong shaking. Slight to moderate damage to ordinary structures
4	MMI VIII: Severe shaking. Considerable damage to ordinary structures
5	MMI IX-X: Violent to extreme shaking. Considerable damage and destruction

Table 21: The Modified Mercalli intensity scale used for rating earthquake effects. Source: Adapted from Geoscience Australia.

The Queensland context

Although the Australian continent is located entirely within the Indo-Australian tectonic plate, it is not devoid of tectonic earthquake activity, which typically occurs where tectonic plates meet. Earthquakes in Australia are usually caused by movements along faults as a result of compression in the earth's crust. The Australian continent is generally in a state of compressive stress, arising largely due to collision of the Indo- Australian tectonic plate with its neighbouring Pacific plate to the north and east of the country.

History

Earthquakes pose a much lower threat to Queensland communities than many other populated regions of the world. The relative youth of our building stock, combined with effective building codes and standards, greatly reduces the likelihood of widespread destruction. However, localised earthquake damage may still be severe or fatal within an affected community. Queensland has vast areas underlain with sedimentary basins such as flood plains and coastal areas, which may suffer ground shaking of increased intensity and duration compared with regions underlain with bedrock closer to the earthquake source. Such local site amplification may increase the shaking intensity by as much as one MM intensity unit compared to adjacent regions underlain by competent rock. This local site amplification of ground shaking may result in quite localised damage within a wider community that is otherwise relatively unaffected.

Written reports of moderate intensity earthquakes have been published in Queensland since the first decades of European settlement. The first known such publication refers to an earthquake occurring in Cape York in 1866. Further anecdotal evidence of Queensland earthquakes also exists in the oral histories of Indigenous inhabitants, demonstrating that seismic events of significance have long been recognised in the State.

Figure 82 shows the locations of all known earthquakes within the State from 1866 to 2020. The largest recorded Queensland earthquake occurred off the shore of Gladstone in 1918 with an estimated magnitude of 6 and a felt area exceeding three million square kilometres. A recurrence of this earthquake has the potential to cause significant damage and economic consequences.

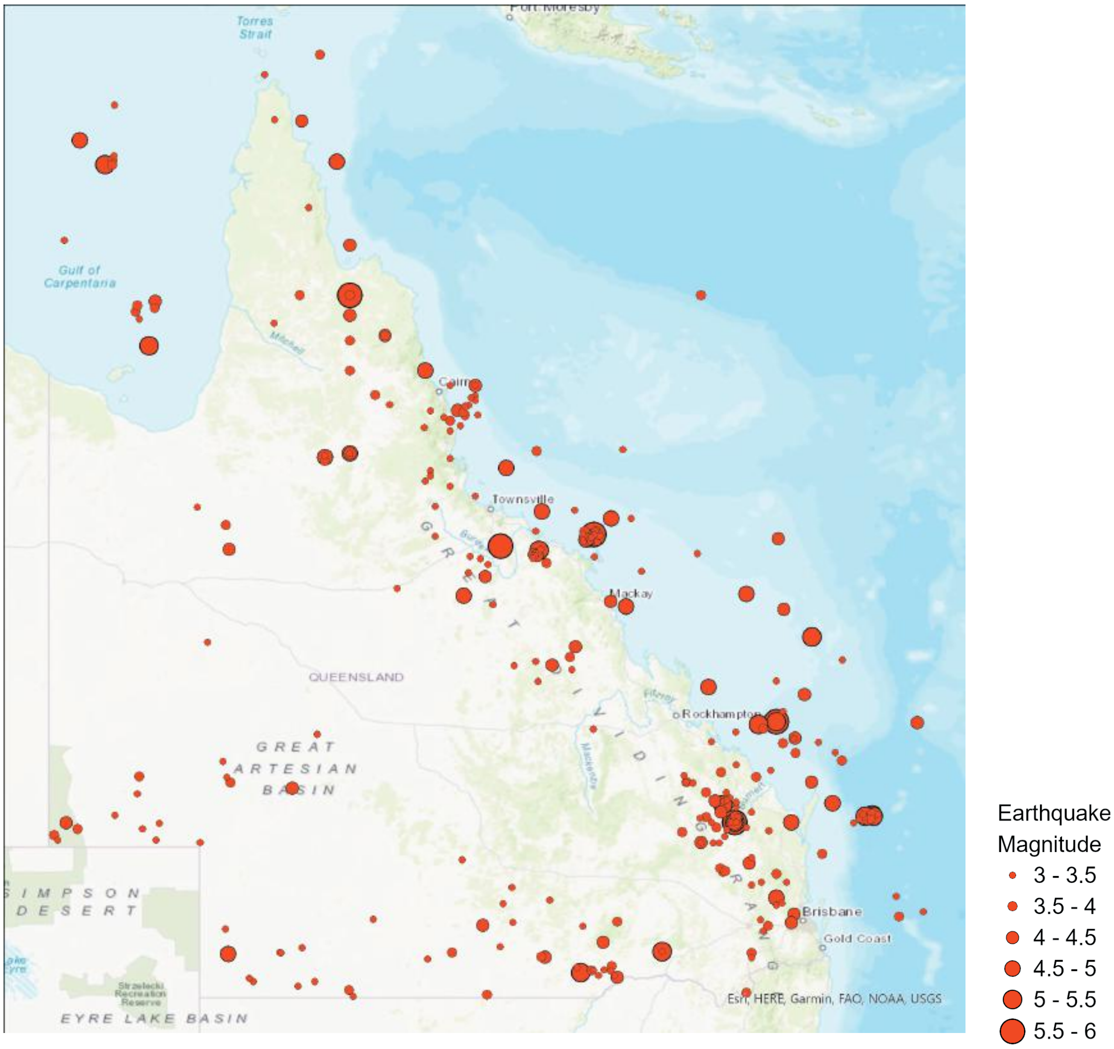


Figure 82: Locations of recorded earthquakes in Queensland, between 1866 and 2020. The size of the points represents the magnitude of the earthquake. Source: Data from Geoscience Australia.

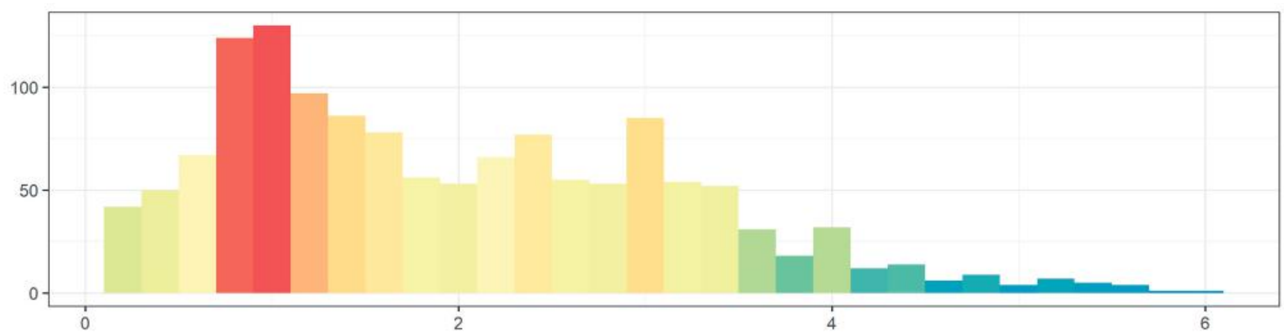


Figure 83: The distribution of the magnitude of recorded earthquakes in Queensland. Earthquake events are common, but are usually very low magnitude and therefore typically not felt.

Projections

While smaller earthquakes occur regularly in Queensland, the probability of a destructive earthquake – an earthquake between MMI V and VII – is very low, compared with the Australia-wide risk. Using data from the National Seismic Hazard Assessment,[283] probabilities for a destructive earthquake occurring in the regions have been identified and are provided in Table 22.

Probability variables for an earthquake exceeding MMI V to VIII over a 50-year period		
Region	**QERMF Scores**	**Annual Exceedance Probability (AEP)**
Cape York	1	0.24%
Central Queensland	1	0.12%
Central West	1	0.14%
Darling Downs	1	0.14%
Far North Queensland	1	0.28%
Gulf of Carpentaria	1	0.21%
Mackay, Isaac and Whitsunday	1	0.11%
Maranoa-Balonne	1	0.11%
North Queensland	1	0.11%
North West	1	0.17%
South East	1	0.22%
South West	1	0.08%
Wide Bay Burnett	1	0.32%

Table 22: Probability variables for a destructive earthquake over a 50-year period.

While the probability is very low across the State, there are still important differences in the regions. Wide Bay Burnett, Far North Queensland and Cape York have a relatively high probability, while the south west has a very low probability.

The methodology for deriving probability scores for this hazard is described in detail in Section D: Technical methodologies.

Management of the hazard

Geoscience Australia

Geoscience Australia provides earthquake risk information to help disaster management stakeholders and communities understand the effects of earthquakes, which contributes to more resilient communities.

Geoscience Australia's risk management and support capabilities include:

- observations through the Australian National Seismograph Network
- 24/7 monitoring and alerting via the National Earthquake Alert Centre
- national hazard through the National Seismic Hazard Assessment
- vulnerability assessment (through earthquake damage models) and development of mitigation strategies.

Through their data products – especially Earthquakes@GA[284] – Geoscience Australia provides a comprehensive understanding of earthquake risk and occurrence across Queensland.

Disaster management groups

The impacts of earthquakes are managed by all of Queensland's public safety agencies – including QFES, QPS and QAS (with Queensland Health). In extreme events, impacts to human health will be managed as per protocols for mass casualty incidents.

Considerations for disaster management groups

- Can the group access, interpret, and act on earthquake advice, impacts, and decision support products?
- Is the group aware of the limitations and uncertainties associated with modelling earthquake intensity?
- Does the group have the ability to interpret the technical information contained in advice and modelling, and develop messaging appropriate for their target audience?
- Has the group discussed its requirements with relevant entities so appropriate preparation and planning is developed to help make informed decisions – for example, the identification of response triggers, limits and escalation of risk between relevant entities?
- Is the group aware of the potential for additional concurrent, compounding and cascading hazards?

Additional related hazards and drivers of risk to consider that are assessed within this report include:

- Tsunami
- Critical infrastructure failure
- Mass casualty event

Scenario

The earthquake, which struck at 10.27am on 28 December 1989, ranks as one of Australia's most costly natural disasters, not only in terms of economic losses but also in regards to fatalities and people displaced. This earthquake, a magnitude 5.4 (maximum observed MMVIII) event, occurred near the town of Boolaroo, 15 kilometres south west of the Newcastle central business district at a relatively shallow depth of 11 kilometres.

The effects of the earthquake were amplified by soft sediments deposited from the Hunter River. This intensified the ground motion, making shaking (or 'seismic loading') experienced by built infrastructure in Newcastle worse. This earthquake resulted in:

- 13 fatalities
- 162 reported injuries
- damage to more than 50,000 buildings (80 per cent of which were residential properties)
- 1000 people made homeless
- structural damage to 47 schools
- demolition of 300 buildings including 100 homes
- loss of power and water reticulation in some areas of the city for more than two weeks
- over $4 billion in insured losses (1989 figure).

Twelve of the 13 fatalities attributed to that earthquake resulted from the collapse of a single building: the Newcastle Workers' Club. The subsequent inquiry concluded that a simple copying error made to plans during the design of that building was responsible for its fatal collapse.

The number of people in the city on the day of the earthquake was lower than usual due to the end of year holidays and a coinciding strike by local bus drivers. Had the event struck at a similar time (10.27am) during a normal business and school day, the effects of this earthquake are likely to have been much more devastating.

In general terms, building vulnerability to the 1989 Newcastle earthquake was due to methods of construction employed, poor maintenance and deterioration with age. Some buildings were made with low-quality unreinforced masonry with little to no reinforcement bars and poor masonry strength to support tension built up by shaking. For some buildings, proximity to the coast made this vulnerability worse due to corrosion of brick ties between brick courses.

The collapse of brick facades remains one of the highest risks to communities during earthquakes. Older school buildings, government and commercial buildings are of the greatest concern to Australian seismologists and earthquake engineers, as many of these buildings are built using unreinforced masonry due to the lower legislated standards at the time of their construction. Evacuation of such buildings after the first phase of ground-shaking may result in occupants suffering significant injuries due to falling debris dislodged during the more violent ground-shaking induced by subsequent surface waves. Whilst surface rupturing in Australia is uncommon and did not occur from the Newcastle 1989 event, it is worth noting that the 2018 magnitude 5.7 earthquake in the Lake Muir region in Western Australia resulted in a three kilometre-long surface rupture.

Impacts

A description of possible impacts resulting from an earthquake with equivalent ground shaking to the 1989 Newcastle event is described below.

Essential infrastructure

Communications and energy

- Significant, short-term disruption to the transmission network akin to that experienced in 1989 Newcastle, NSW, is expected in areas of severe shaking (> MMVII-VIII). Response and restoration of services is dependent on the ability for field crews to safely access sites. Damage to the supply chain and transportation routes (affecting the ability to access damaged sites and other infrastructure as well as hindering opportunities to fly/drive in additional resources to assist the response) may hamper restoration efforts.

- Availability of parts for repairs may be an issue in the event of significant damage. Transformer trips are likely to be easily rectified, however the primary equipment failures (e.g. porcelain insulator failures) would take longer to rectify.
- Direct effects on the power distribution network (power plants, generators, switchyards, distribution transformers, poles and lines) may lead to significant disruption across the affected area, exacerbated by interdependencies of other systems and networks on power.
- Loss of power and communications to electronic funds transfer at point of sale (EFTPOS) terminals would affect the community's ability to access basic goods and services.
- Vulnerability of telecommunication towers is relatively low in terms of direct impact and damage (except in the event of secondary hazards such as liquefaction and landslides). However, performance of the network is likely to suffer due to extreme congestion (volume of people making calls or trying to access the network) for some hours after the event.
- Battery redundancy may also present a significant problem if loss of power is sustained. As an example, post 2011 Christchurch earthquake, battery redundancy designed to last <24 hours ran down within six hours. Further, access to the network may decline because of failure in battery redundancy.
- Network performance will improve to usable, and then to near-normal levels if generators and cell towers on wheels (CoWs) are deployed. Generator re-fuelling may present major logistical challenges due to road conditions and availability of generators and fuel. Diesel is likely to be quarantined for generator and emergency services vehicle use.
- Microwave dishes and other point to point communications infrastructure are likely to suffer misalignment due to intense ground shaking. In-ground cables, including optical fibre cables (such as that of the National Broadband Network) and electricity cables, are susceptible to damage by earth movements experienced in earthquakes and landslides, especially through lateral shear. Any ground movement that exceeds design specifications is likely to require assessment of the cable and potential replacement of cable networks.
- Underground gas and oil pipelines traversing areas with seismic hazards (e.g. faults, steps) have a moderate chance of rupture and low chance of complete breakage. The probability of rupture and breakage will depend on the precise nature of assets and the earthquake event. Domestic gas supply is likely to experience medium-term disruption in the worst affected areas.
- Emergency services and local government UHF and VHF radio infrastructure generally have high levels of resilience across all-hazards inclusive of earthquakes. Where the Government Wireless Network (GWN) is present, loss of power may affect the network. Any disruption of emergency services communication towers would affect the ability for these services to deliver a coordinated response.

Water

- The most significant exposure of infrastructure to earthquake damage is the in-ground infrastructure of water supply and sewerage, particularly where pipes are old and brittle. Above ground pipelines may also be affected by intense ground shaking. Vulnerability is greatest at the point of connection due to differential movement.
- Water supply and sewer systems (to a lesser degree) are vital to community wellbeing. Brittle material, especially unlined asbestos cement (AC) and cast iron, may be particularly susceptible to fracture. A significant amount of such pipe has been used in the water supply reticulation networks in all areas of Queensland. Rupture of significant segments of the pipe network could reduce the availability of potable water to the community and firefighting water to emergency services. Widespread damage to the water reticulation network could take considerable time to resolve and disruptions to mains water supply could be expected across the medium- to long-term where replacement of the pipeline is protracted.
- Pumping equipment is vulnerable due to dependence on power (where back-up generation is not available).
- Some referable and tailings dam infrastructure built prior to 1993 (publication year of AS1170.4 earthquake loading code) may also be vulnerable to intense ground shaking, although catastrophic collapse is highly unlikely.
- Even smaller earthquake events that cause damage to water infrastructure may lead to the issuance of boil water alerts until testing is able to be carried out.[285]
- Where an earthquake is sufficiently severe to cause damage, it may impair the water supply system and blocked roads with fallen debris, making fires challenging to contain.

Transport

Transport infrastructure

- Several regional airports (including terminal buildings) are identified as having been built on reclaimed alluvial (soft) soils. Such areas have a higher probability of liquefaction and subsidence in intense shaking conditions. Localised liquefaction will cause runway pavement damage and 'sand boil' features. Rail administration buildings, rail yards and depots close to port facilities or built on soft soils may experience extensive damage.
- Well maintained and well-constructed airfield pavement is largely resilient to most hazards but may be damaged by severe earthquakes and debris from adjacent buildings. Support facilities such as terminals and fuel systems could be damaged by earthquakes.
- Some industrial and commercial port facilities are located on reclaimed alluvial soils or estuarine deposits which are susceptible to subsidence through liquefaction. Rotation of some wharf retaining structures will also occur. Movement in wharf front rail systems for wharf cranes and other materials-handling equipment will render them unusable. Tall structures such as container cranes are especially vulnerable to being toppled. Disruption to operations may have regional or State financial impacts.
- In-ground infrastructure exposed to earthquake shaking and those elements in the softer soils are more likely to be damaged than those in solid rock. Ruptures may lead to disruption to services and/or environmental damage.
- Large metal fuel tanks are susceptible to damage caused by the liquid inside the tank sloshing from side to side, under action from intense shaking, placing stresses on the tank walls. Damage or failure, often referred to as 'elephant's foot buckling', can occur as a result. Pipe connections to the tank also can suffer damage or be sheared off by differential movement. Domestic water tanks, particularly those traditionally constructed in corrugated iron, also are very susceptible to similar damage.
- Major road and rail networks may be susceptible to shaking induced settlement and lateral spreading, leading to considerable surface damage. The most vulnerable points tend to be bridges and other choke points such as railway crossings. Heavy goods and logistical transport are likely to be affected in the short- to medium-term, leading to difficulty in resupplying essential items such as perishable foodstuffs, fuel and chemicals for water treatment. All tracks and rail bridges will require extensive inspections including the use of a track inspection vehicle before recommissioning.
- Sections of railways may be blocked by landslide debris or affected by embankment fill failures.
- Signalling and control equipment reliant on electricity and telecommunications may fail for the associated disruption period.
- Typically, road and rail tunnels are not highly vulnerable to major Queensland earthquakes. Vulnerability is greater for shallow cut and cover tunnels than for bored tunnels. For shaking similar to that caused by the 1989 Newcastle earthquake, cut and cover structures in soft soil have a significant chance of damage to tunnel linings. Problems may be experienced with tunnel portals and with slope failure adjacent to tunnel approaches.

Access and resupply

- Any surface damage to runway infrastructure or terminal buildings is likely to result in short-term disruption as these are expected to be a priority for repair to facilitate access and resupply where road and rail networks are significantly hindered.
- Access to maritime infrastructure (such as industrial/commercial ports) is likely to be affected resulting in economic disruption due to the issues previously identified. If port facilities are unaffected or services can be restored quickly, major resupply is expected to be facilitated via sea if disruption to the road and rail network is extensive.

Community

Households

- People providing services may be cut off from those with needs (e.g. Meals on Wheels, at home care).

- The earthquake loading code does not apply to single dwellings/residential buildings (Class 1) but all structures containing two or more dwellings. All residential, commercial, public and industrial buildings (building Classes 2 to 9) must conform to the standard enforced by the National Construction Code (NCC) 2016 Volume 1 Part B1 which refers currently to AS 1170.4-2007. Previously, the NCC (and therefore AS1170.4-2007) stated that a building should be designed to the known seismic hazard within the area. However this was not enforced and, subsequently, there will be buildings that have only been designed to the minimum tolerable standard.[286] Even where buildings are constructed to or above NCC standards, it is possible for some building components to fail and cause harm. For example, air-conditioning units and solar panels mounted on the roofs of buildings may be dislodged.
- Many older buildings may not be in optimum condition due to poor maintenance and their resilience to ground shaking may be poor, as occurred in the 1989 Newcastle earthquake. Accordingly, it would be prudent for disaster management groups to seek structural engineering advice regarding buildings, especially older local government controlled or owned structures.
- Most dwellings in Queensland are constructed over a timber frame. Timber frame buildings behave in a ductile manner in earthquakes and can undergo large displacements because of their non-rigid construction. Solid brick or masonry walls are more susceptible to damage because of their rigid construction. Well-built timber buildings perform better than other forms in earthquakes. Poorly maintained buildings of both construction types may also be more susceptible to earthquakes.
- The shape of the building can also affect how it responds to earthquake shaking. While older high-set designs are especially well suited to the State's variable climate, they are likely to be more susceptible to earthquake shaking. Most tall structures that are not engineered to withstand shaking from side to side can be damaged or toppled by the inverted pendulum effect created during an earthquake where the amplitude of the shaking is greater at the top of the structure than at its base. So-called 'six pack' unit blocks which have a 'soft story' (i.e. the garages occupy the first-floor level with no internal walls) also are very susceptible to failure under earthquake loads.

Community services and infrastructure

- Significant variations in impact between urban and rural centres should be expected.
- Intense ground shaking on soft soils (site class C, D to E)287 can cause liquefaction (secondary hazard) which may result in subsidence or collapse of several buildings.
- Public buildings built prior to 1993 are unlikely to have been built to account for any seismic hazard as the earthquake loading code was introduced following the events of Newcastle 1989. Public buildings built in stages require special consideration. Examples of this are schools or hospitals where the central structure is a 19th century to pre-1993 building but subsequent additional structures or extensions are of modern construction.
- Many late 19th and early 20th century masonry buildings exist within the central business districts of regional towns and cities (especially within historical or cultural quarters) which are highly vulnerable to intense shaking. Further, a considerable number of regional schools and hospitals are situated in these buildings.
- Many centres of governance and local and State government agencies are located within buildings built prior to 1993. Potential impacts of an earthquake on these buildings may lead to significant disruption to government and agency services across the medium to long term.
- Essential community, government and IT services are likely to be significantly disrupted across the medium to long term due to damage to buildings that house these services and/or depend on power, communications and other essential infrastructure.
- Landmarks, memorials and cemeteries important to the community at large may be significantly impacted by an earthquake of this magnitude.
- Evacuation centres are virtually all public assets, most of them being schools and community centres. The likelihood that such facilities would be suitable for most, if any, public refuge after the event, especially if they are not constructed to contemporary building standards, is questionable. The capacity of these buildings' amenities, such as air conditioning, toilet facilities or stand-by generators, is unlikely to meet the requirements of displaced or vulnerable persons into the medium term. Restoration of school activities would be a priority in the recovery stage.

Health and wellbeing

Physical and mental health

- The exposure of people to earthquakes is directly related to the vulnerability of the building in which they are located at the time of the event.
- However, damage and loss of life associated with severe earthquakes are typically exacerbated by the impact of secondary hazards, especially fire, landslides, the loss of containment of hazardous materials and (rarely) dam failure. Fires are typically caused by ruptured gas lines and/or electrical short circuits. Low-socio economic areas within vulnerable areas of the State are likely to have a lower level of inherent resilience or means to affect individual recovery in the event of an earthquake.
- As earthquakes occur without warning and are inherently rare, an increase in vulnerability across all sections of the population is expected. Vulnerability will not be limited to those typically regarded as vulnerable (due to geographic location, medical or service needs, cultural background and language skills, age or disability).
- Events such as earthquakes can have devastating physical and psychological impacts on otherwise able-bodied individuals. This can result in fatalities occurring from incapacitation.
- Transport hubs tend to be places of mass gathering and, as such, damage to this infrastructure may result in a corresponding increase in casualty numbers.
- Power outages from earthquakes can lead to loss of air conditioning, possibly resulting in health impacts if there are concurrent heatwave conditions.

Health care and infrastructure

- The supply of medical goods and medications may be impacted by damaged or destroyed logistics infrastructure.[288]
- All hospitals and smaller community medical facilities, except those of recent construction (<5 years ago) are of concern as age and methods of construction are varied across all local government areas. Many older hospital buildings of reinforced concrete frame with infill masonry construction will experience damage from an event of this magnitude and will require structural inspection before further use. Some buildings housing critical care facilities will be rendered unusable.
- Dependency on power and water infrastructure increases vulnerability. Hospitals are generally provisioned with 24 hours of redundant power and water generation but it is not known how resupply would be managed in the event of broad area impacts.
- Vulnerability of people in aged care and health care facilities is an important consideration. Evacuation of vulnerable persons at short notice may lead to significant issues regarding coordination, control, and exacerbation of pre-existing conditions. Fatalities may be expected as a result.
- Earthquakes may intensify pre-existing mental health conditions at an individual level or lead to conditions such as post-traumatic stress disorder (PTSD). Of those directly affected by the events of Newcastle, 1989, 25 per cent experienced moderate to severe psychological distress as a direct result of the disaster.[289]

Business and economy

Business and industries

- Impacts to any major industries would result in displacement of workers (local and transient) which is likely to have a significant impact to regional and State economies.
- Hazardous materials storage facilities are exposed to earthquake. Facilities operated at the State level and those within individual districts across the State should be reviewed on a case-by-case basis.
- The potential for damage to agricultural infrastructure, such as grain handling facilities, cotton gins and saleyards, would have repercussions on local and regional economies and associated/supporting industries.
- Intense ground shaking may lead to significant damage to irrigation channels as agricultural areas of Queensland can be bisected by many hundreds of kilometres of channels and associated infrastructure.

- Direct impact will occur to the operation of fisheries if port facilities and associated infrastructure are affected.
- Resorts across coastal areas are likely to be located on softer soils. Further, the age and varied methods of construction of these facilities is of concern. Resort owners and operators may not have considered catastrophic event occurrence within business continuity planning.
- Tourists, especially those from non-English speaking backgrounds, are likely to be more vulnerable to the ongoing impacts of an earthquake, particularly as they are likely to have less resources and support than residents.
- Media coverage is likely to have a significant impact on the tourism industry within the affected area over the medium- to long-term.
- Mining and associated infrastructure (such as railways and port facilities) may experience significant impact.
- Mines operating subterranean extraction are at particular risk, due to the risk of collapse posed by earthquake.

Economy

- Loss of power to industrial centres such as heavy metal plants (e.g. alumina refineries), bulk fuel and gas depots could have major repercussions in terms of operations and, consequently, regional and State economies.
- Disruption to logistics routes (i.e. road and rail freight network, ports, coal rail network) would likely have significant regional and State economic impacts similar to those felt during previous severe tropical cyclones.

Environment

- Earthquakes which occur in areas of the Great Barrier Reef (for example the 2016 5.8 magnitude earthquake offshore from Bowen, Queensland) may cause considerable damage to the reef's structure.[290]
- Intense shaking may precipitate landslips in prone areas. This may contribute to further effects on power and communications infrastructure, populated areas, and result in the destruction of forestry and native habitat.
- Environmental health impacts arising from the disturbance of particulates, rupturing of hydrocarbon supply lines, and possible asbestos contamination from buildings would likely be of concern at the local, district and state levels.
- This can result in significant losses to biodiversity and environment, impacting animal behaviour and habitats across the medium- to long-term.

Figure 84: Damaged caused by the 1989 Newcastle earthquake was significant and destructive. In this photo, the RSL club is almost completely destroyed. Source: Telstra Museum, Newcastle

Supporting information

Plans

- No hazard-specific plans exist for earthquake.

Technical guidance

- Queensland State Earthquake Risk Assessment 2019, QFES.
- National Seismic Hazard Assessment (NSHA) 2018. Geoscience Australia
- Earthquake [webpage]. Geoscience Australia
- Shakemap. United States Geological Survey

Risk summary

Damaging earthquakes are rare across Queensland however impact could have very serious consequences both in terms of people killed or injured and economic losses, depending on the location.

The area of highest risk in Queensland encompasses a large area in the State's south east, from Gladstone in the north to Logan and Scenic Rim in the south, and from the coast across to the Burnett and Western Downs regions. This considers the probability of earthquake occurrence in these areas, as well as the density of population, infrastructure and economic activity in the area.

Earthquake occurrence may lead to widespread power, water and communication outages, as well as the closure of transport hubs and infrastructure including highways, major roads, local airports and ports through extensive infrastructure damage within the affected area of Queensland.

Such disruptions will impact access and resupply in the affected area across the short term while disruptions to essential services such as mains gas and water may be significant, protracted and require substantial assistance to enable full return of service. Multiple fatalities and critical injuries could be expected depending greatly on the magnitude and intensity, duration, location and time of occurrence of the event.

Short- to medium-term reduction of services, coupled with resourcing challenges for frontline services across all government sectors, would occur, due to an increased demand in response to the event with impacts enduring across the wider community while post event recovery efforts continue.

The presence of any vulnerable persons within the affected area may lead to an increase in the number of injuries sustained and increased pressure on frontline services during response and recovery phases.

Building damage, especially concerning those buildings constructed before 1993, is likely to be extensive and may further impact upon the provision of essential and governance services from those agencies housed within vulnerable buildings across the medium- to long-term. The presence of asbestos within buildings and elements of infrastructure, such as pipelines, may result in contamination across an affected area and may exceed local capacity to manage.

Offshore earthquakes of significant magnitude located near or under the Great Barrier Reef may lead to structural damage of the reef. The potential for localised tsunami as a secondary hazard also exists. Secondary hazards such as liquefaction may occur or be exacerbated by the geomorphology of the affected area and intense shaking may precipitate landslides in prone areas.

TSUNAMI

Tsunami

Tsunami is the tenth highest priority for Queensland. Tsunami was not reported on in 2017 State Natural Hazard Risk Assessment.[2] Full details of prioritisation are provided below and in Section C - Risk prioritisation.

Understanding the hazard

This assessment is in part based on the Tsunami Guide for Queensland 2019, with additional information in this report about potential impacts. For more information on tsunami risk for Queensland consult this guide.

Tsunami (pronounced 'soo-nar-me') is a Japanese word comprising 'tsu' meaning harbour and 'nami' meaning wave.

Until recently, tsunami were often called tidal waves. This term is now generally discouraged because tsunami generation is not caused by tides, which are driven by the gravity of the earth, moon and sun. Although some tsunami may appear like a rapidly rising or falling tide at the coast, in other situations they can also feature one or more turbulent breaking waves.[291,292]

While a major tsunami has not impacted Queensland or Australia in recorded history, the State is exposed to tsunami risk. This is due to its proximity to a number of source zones, the potential for submarine landslides along the continental shelf, and the large proportion of our population living on or near the coast.

Definition

Tsunami are waves caused by the sudden movement of the ocean surface due to earthquakes, sea floor (or 'submarine'), landslides, land slumping into the ocean, large volcanic eruptions or meteorite impacts in the ocean.

Tsunami behave very differently to regular wind waves. While both are influenced by similar processes, tsunami waves occur at a much larger scale than wind waves. The major result of this difference in scale is that, while wind waves will dissipate over significant distances, tsunami do not. Also, islands are typically sheltered from wind waves, whereas tsunami can wrap around the island and increase in size.

Wind waves will tend to break on the beach, whereas tsunami typically do not break (as illustrated in Figure 85). The momentum of a tsunami can push water further inland than wind waves. The water's current will be too strong for a person to stand or remain stable.

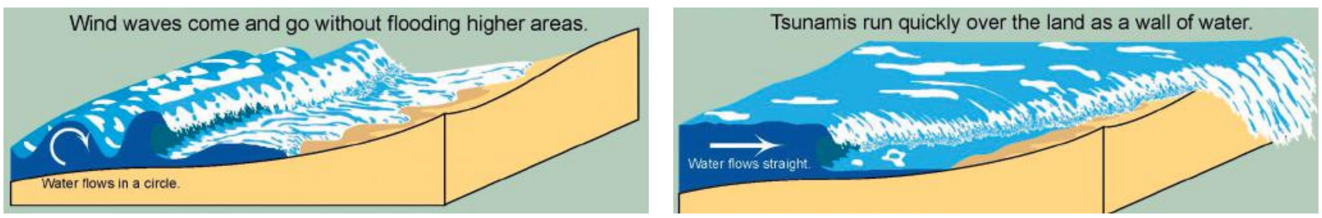
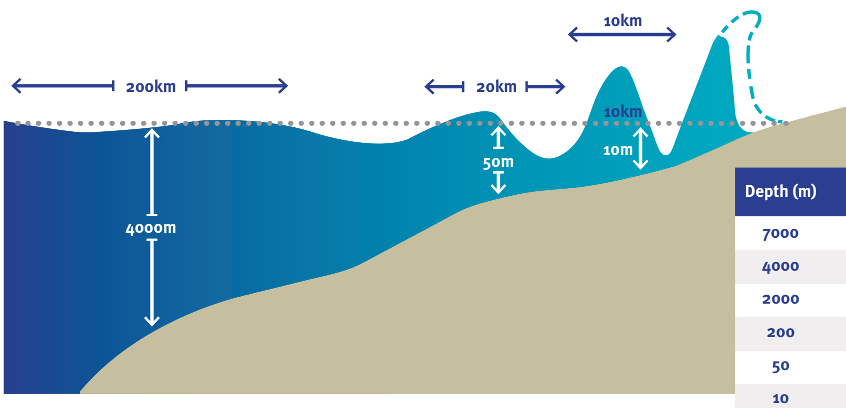


Figure 85: Differences between wind waves and tsunami at the coast. Source: AIDR Tsunami Emergency Planning in Australia Handbook



Depth (m)	Velocity (km/h)	Wavelength (km)
7000	950	300
4000	700	200
2000	500	150
200	150	50
50	80	20
10	40	10

Figure 86: Wave characteristics in the open ocean and near shore.
Sourced and adapted from: AIDR Tsunami Emergency Planning in Australia Handbook

The shape of the sea floor plays a major role in how much the tsunami will grow in height or lose height. This is illustrated in Figure 86. Tsunami slow down and increase in size as they travel over the continental shelf. Low-lying areas are likely to be more vulnerable, but this is also highly dependent on where the tsunami was generated.

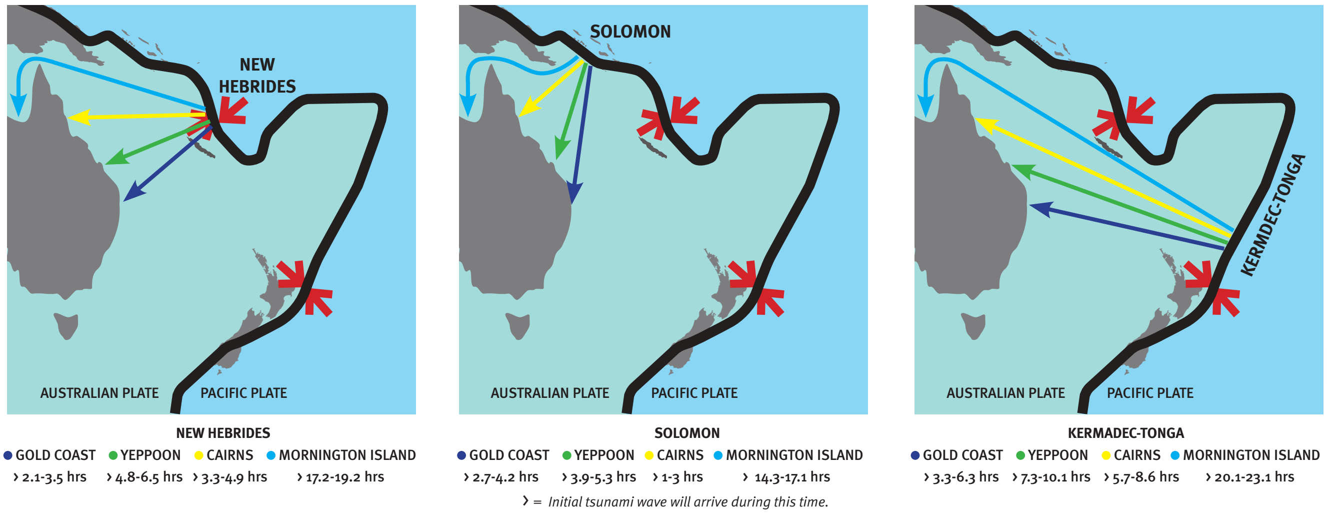


Figure 87: Travel times for regional earthquake-tsunami from the Solomon, New Hebrides and Kermadec-Tonga trenches. Note: *These travel times are derived from models and are based on the initial tsunami arrival offshore. They do not consider the time required for the tsunami to propagate close to shore, or the fact that the tsunami may consist of multiple waves lasting for hours or days. Therefore, these travel times are not suitable for determining when the largest waves will arrive, or when the tsunami risk has passed. In the event of an actual tsunami, the Joint Australian Tsunami Warning Centre will include travel times in their warning products. These should be considered the definitive source in the event of a tsunami. Source: produced by QFES with assistance from Geoscience Australia*

It is important to note that with tsunami, the first wave may not be the largest. A tsunami is comprised of a series of very long waves with each wave lasting between five and 40 minutes. Key sources for earthquake generated tsunami are illustrated in Figure 87.

As the tsunami approaches the coastline, it is influenced by coastal features in the following ways:

- energy can be focussed on particular features, such as prominent headlands
- the shape of the sea floor may cause crossing of waves, generating localised amplification
- the tsunami can also be reflected off the coastline, generating a longer and more complicated wave train.

The primary impact of tsunami occur through inundation, flow depth, broad extent and high velocities. However, major secondary impacts can be caused by debris that is picked up and becomes part of the wall of water as the tsunami proceeds inland. Debris can act as a multiplier of the force of the wave as it impacts physical structures, reducing the ability of that physical structure to remain standing.[293–295]

The concept and quantification of vulnerability is well understood for other water hazards that occur more frequently, such as riverine flooding.[94] However, there are fundamental differences in the physics of these two hazards.

Hazard ratings

Research into hazard vulnerability measures for tsunami has accelerated following the 2004 Indian Ocean Tsunami and 2011 Great East Japan Tsunami. Building vulnerability research has focused on developing models of empirical damage or fragility for a range of structure types and predefined damage states. These were based on actual event assessments and laboratory experiments.

Table 23 is based on data from Sri Lanka and Thailand during the 2004 Indian Ocean tsunami, as well as Samoa during the 2009 South Pacific tsunami. Data from the 2011 Great East Japan tsunami were intentionally omitted as these structures performed better, given they were newly constructed with proper quality controls. It is likely that Australian building codes would also have higher quality controls. As such, the hazard ratings below provide a general guide for onshore tsunami impacts, in the absence of Australia-specific studies.

Hazard Assessment – Hazard ratings Tsunami (Onshore Impacts)				
Value	**Damage State**	**Timber (T)**	**Masonry (M)**	**Reinforced Concrete (RC)**
1	Generally safe for people, vehicles and buildings	<0.3m	<0.3m	<0.3m
2	Non-structural damage. Unsafe for small vehicles	0.3–0.5 m	0.3–0.5 m	0.3–0.5 m
3	Minor structural damage. Unsafe for people and vehicles	~1.2 m	1.3 m	1.4–1.9 m
4	Major structural damage. Unsafe for vehicles and people.	~1.3 m Buildings vulnerable to failure	~1.9 m Buildings vulnerable to structural damage	~3.5 m Buildings vulnerable to structural damage
5	Complete structural failure. Unsafe for vehicles and people.	~1.6 m	2.3–2.5 m	5.4–7.3 m

Table 23: Hazard ratings for tsunami onshore impacts.

The Department of Environment and Science has developed general hazard curves based on the general flood hazard curves, and for the lower limits of timber structures. Complete damage for masonry (M) and reinforced concrete (RC) are also shown as broken lines. The figure also includes the human stability criteria.[296]

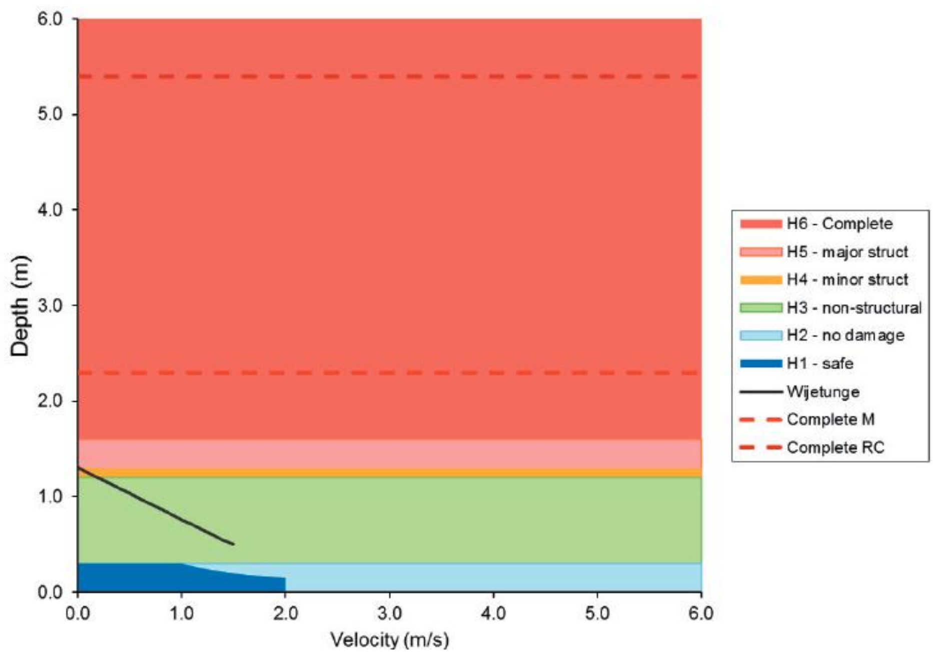


Figure 88: Tsunami hazard curves. Source: DES.

The Queensland context

History

There are large uncertainties in how often tsunami might occur in Queensland because our historical records are short and damaging tsunami are relatively rare in this region. The frequency of key tsunami-generating processes such as large earthquakes and volcanic eruptions is also unclear.

Australia experiences a tsunami once every four years on average. According to the Bureau of Meteorology (BoM), since 1805 the northwest coast of Western Australia has recorded the greatest impacts from tsunamis, including several occurrences of land inundation of up to 300m inland.

Tsunamis have been observed along the Queensland coast, resulting mainly in strong rips, unusual currents and boat damage. This includes a 42cm wave that impacted the Gold Coast in February 2010, as a result of a magnitude 8.8 earthquake off the central coast of Chile 18 hours earlier. Sea level fluctuations outside normal conditions were recorded at many locations around Australia, including Queensland, for more than 12 hours after the initial arrival of the tsunami.

Following the devastating 2004 Indian Ocean tsunami, Geoscience Australia (GA) undertook probabilistic assessments of the Australian coastline at the 100m depth contour and then a further study at 20m. In 2013, Queensland's Department of Science, Information Technology, Innovation and the Arts built on this work by examining the nearshore amplification at a 10m depth along the entire east Queensland coast from Cooktown to the New South Wales border. The report identified the following communities are at the highest risk of tsunami impact (in a decreasing order of magnitude):

1. City of Gold Coast
2. Ocean side of Bribie, Moreton and Stradbroke Islands
3. Sunshine Coast
4. K'gari (Fraser Island)
5. Bundaberg
6. Flying Fish Point (near Innisfail)
7. Capricorn Coast (Livingstone Shire)
8. Agnes Waters (Gladstone)
9. Hervey Bay (Fraser Coast)

Since the 2004 Indian Ocean tsunami, the Department of Environment and Science has upgraded the Statewide storm tide monitoring network to measure water levels at one-minute intervals, capturing multiple tsunami events within Queensland, including those from the Solomon Islands in 2007, South America Chile in 2010 Japan in 2011 and the Hunga Tong Hunga Ha'apai volcanic eruption leading to a tsunami in 2022. To date, the largest tsunami wave captured by the Department of Environment and Science storm tide monitoring network was a 0.5 metre wave detected at Clump Point, Mission Beach during the 2007 Solomon Islands earthquake.

Since 2006, the DES storm tide network has detected several events including:

- 2007 Solomon Island tsunami
- 2010 Chilean tsunami
- 2011 Japan tsunami
- 2021 Loyalty Islands tsunami
- 2021 Kermadec tsunami
- 2022 tsunami triggered by the Hunga Tonga Hunga Ha'apai volcanic eruption

While earthquakes on subduction zones, where the earth's tectonic plates meet, are the leading cause of tsunami hazard, there is also substantial risk from submarine landslides. In this scenario, the time from tsunami generation to impact is drastically reduced from multiple hours as shown in Figure 87 to ~20/30 minutes.

Projections

Historic submarine landslides are clearly evident off the Queensland coast and research has identified areas where future landslides may be possible (as shown in Figure 89). A report from the University of Newcastle suggested estimates of return intervals for submarine landslide generated tsunami are between 1,500 to 15,000 years.[297] It is likely that such an event would be triggered from a large undersea earthquake causing a mass of sediment (deposited on the continental shelf from our major river systems and other coastal processes) to slip. The chance of such a large earthquake occurring within Queensland is very small. For example, there is around a 0.06 per cent chance per year of a magnitude 6.0 earthquake occurring within any 100km × 100km area near the Fraser Coast region. However, other slip processes, such as slumping due to excess load, are also likely causes of submarine landslides.

For more information on the subduction zones most likely to generate an earthquake tsunami affecting given locations in Queensland refer to the Tsunami Guide for Queensland.

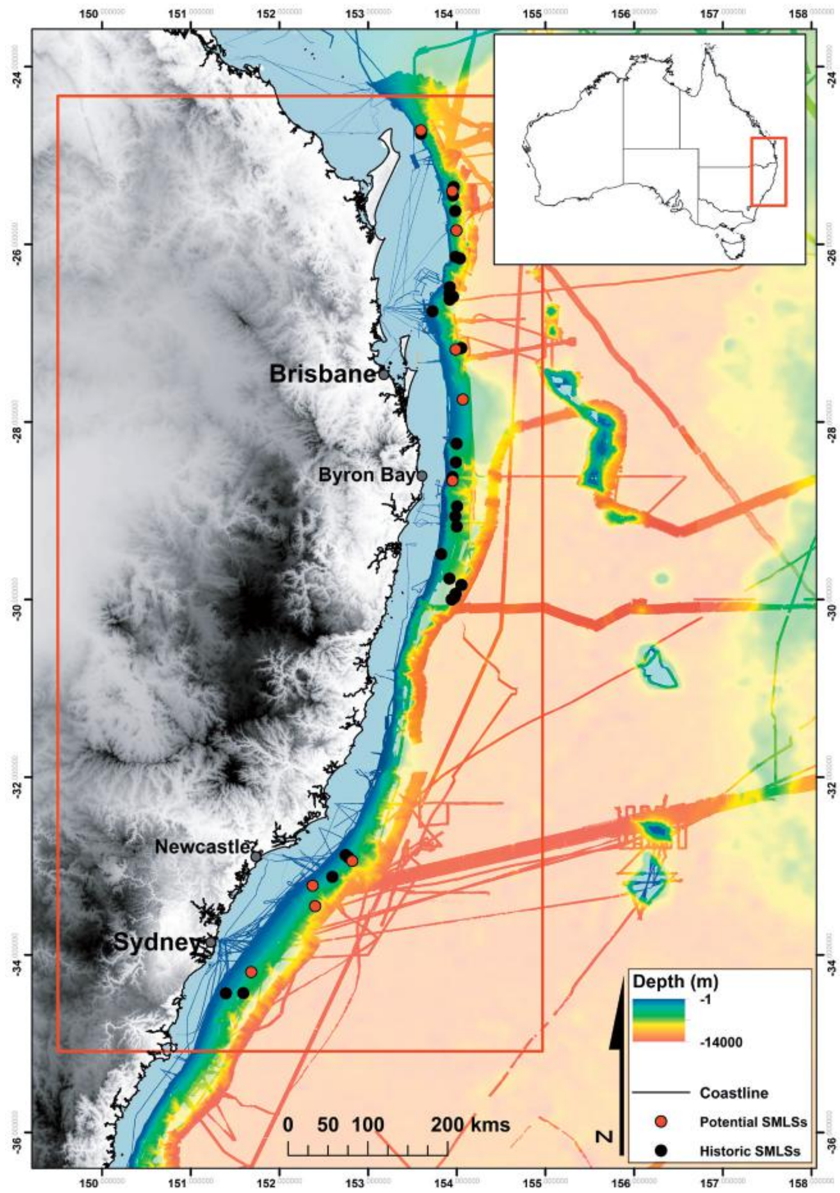


Figure 89: This illustration shows the location of historic submarine landslides with tsunamigenic potential (black dots) and potential future submarine landslides sites (red dots) identified by Clarke (2014) along the east Australian continental margin. The red box outlines the region containing submarine landslides with tsunamigenic potential. Slides with tsunamigenic potential were defined as those with dimensions of 50-250m thick, 1km to >10km wide and in depths of 500-2500m. Source: Clarke et al. (2018)

Management of the hazard

Geoscience Australia and the Bureau of Meteorology

The Australian Tsunami Warning System (operated via the Joint Australian Tsunami Warning Centre – JATWC) is a national collaboration between the BoM, Geoscience Australia (GA) and the Department of Home Affairs through Emergency Management Australia. It provides a comprehensive tsunami warning system to deliver timely and effective tsunami warnings to the Australian population. It is also a key element of the Indian Ocean Tsunami Warning and Mitigation System and contributes to the facilitation of tsunami warnings for the South West Pacific.

GA operates an enhanced network of seismic stations nationally and has access to data from international monitoring networks. It advises BoM of the magnitude, location and characteristics of a seismic event which has the potential to generate a tsunami.

Based on this seismic information from GA, BoM selects appropriate pregenerated tsunami models to generate a first estimate of the tsunami size, arrival time and potential impact locations. BoM verifies the existence of a tsunami using information from an enhanced sea level monitoring network.

The JATWC then disseminates advice and warnings on any possible tsunami threat to state & territory emergency management services (in Queensland, this is via the State Disaster Coordination Centre Watch Desk), media and the public, as shown in Figure 90. JATWC expressly aims that emergency managers and the public are provided with at least 90 minutes warning prior to impact of a tsunami.

Home Affairs, through Emergency Management Australia, liaises with the operations centres of affected state and territory emergency management organisations and coordinates federal assistance as required.

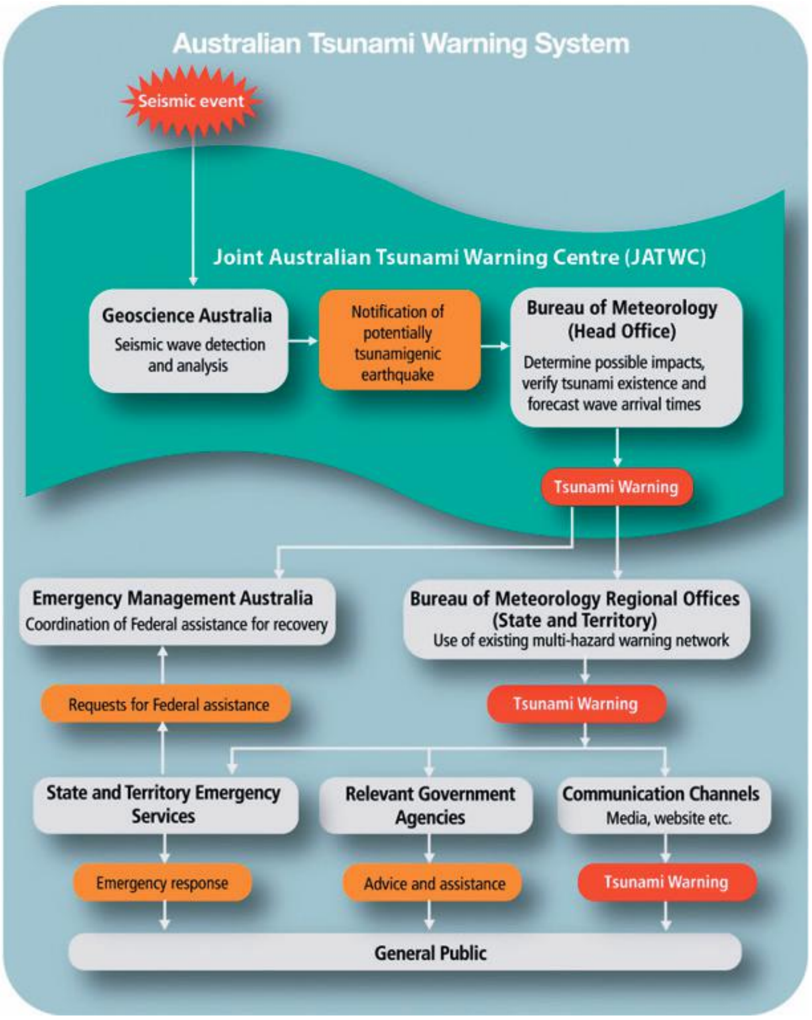


Figure 90: The Australian Tsunami Warning System. Source BoM.

Queensland Health

An adjunct for Queensland is the Tsunami Notification Arrangements which is managed by Queensland Health (QH) for its 16 Hospital and Health Services (HHSs). This arrangement is designed to:

- assist in the protection of life
- minimises the risks posed by tsunami
- contributes to the warning of communities.

QH's response to a tsunami notification will be undertaken in the following steps:

1. notification and dissemination of tsunami warnings to key stakeholders within the Hospital and Health Services.
2. activation of pre-identified roles and responsibilities prescribed in the Queensland Health Disaster Plan (and emergency management arrangements).

At the local level, the critical role is the liaison (by the HHS Chief Executive) with the (to be affected) LDMGs to ensure notification of:

- aged care facilities
- private health services within the HHS operational boundaries if they are considered to be under potential threat.

Local health service Emergency Preparedness Continuity Management plans address pre-impact requirements that will support the community (e.g. preparation of hospitals in 'safe areas' for triage and overflow). For further information on this function, please refer to the Mass casualty incident risk assessment.

Considerations for disaster management groups

- Can the group access, interpret, and act on tsunami advice, warnings, and decision support products?
- Is the group aware of the limitations and uncertainties associated with modelling tsunami development, size and direction?
- Does the group have the ability to interpret the technical information contained in advice and warnings, and develop messaging appropriate for their target audience?
- Has the group discussed its requirements with relevant entities so appropriate preparation and planning are developed to help make informed decisions – for example, the identification of response triggers, limits and escalation of risk between relevant entities?
- Is the group aware of the potential for additional concurrent, compounding and cascading events?

Additional related hazards and drivers of risk to consider that are assessed within this report include:

- Critical infrastructure failure
- Mass casualty incident
- Biodiversity and ecosystem loss

Scenario

At 1100 AEST, a 9.0 magnitude earthquake occurs, emanating from the South Solomon Trench near the Santa Cruz Islands, Solomon Islands. Within 10 minutes (1110 AEST) the JATWC issues a Tsunami Threat to low lying areas and the marine environment across the entire eastern Australian coast.

QFES and NSW SES strongly advise people in affected land threat areas to go to higher ground at least 10 metres above sea level or move to at least one kilometre inland in line with the public tsunami evacuation mapping (refer Tsunami evacuation areas for Queensland https://www.qfes.qld.gov.au/prepare/tsunami/evacuation-areas). Coastal Disaster Districts immediately begin to issue evacuation orders and coordinate the safe movement of people away from the coastline.

Sixty minutes later (1200 AEST) the first waves are observed in the Cairns region with only minor land inundation observed as the wave arrives at low tide. However, marine impacts result in several small and large vessels, which have not had time to seek safe shelter, being forced on to reefs and washed up on shore. This situation is replicated from Cairns to Bundaberg.

Ninety minutes later (at 1230 AEST), the land threat is revised to emphasise that the directionality of the tsunami favours significant impact to coastal communities in South East Queensland (SEQ) and Northern New South Wales (N-NSW), between Noosa River to the Tweed. QFES and NSW SES issue further advice to communities to:

- take only essential items can be carried including important papers, family photographs and medical needs.
- walk to safety, if possible, to avoid traffic jams.
- take shelter in the upper storey of a sturdy brick or concrete multi-storey building if leaving the area is not an option
- boats in harbours, estuaries or shallow coastal water should return to shore, be secured and owner should move away from the waterfront
- vessels already at sea should stay offshore in water at least 25 metres deep until further advised
- do not go to the coast to watch the tsunami
- check that neighbours have received this advice.

Three to four hours later (1400 AEST onwards), the first waves are observed at points along the SEQ and N-NSW coastline. Waves arrive as the afternoon tide is rising all along the coast. On the ocean side of Moreton Bay and North Stradbroke Islands, waves exceed 10m to 14m. All along the Sunshine Coast to Noosa, waves range from 1.8m to 5.4m high. At Rainbow Beach, a 6.1m wave is observed. The dune systems present along the coastline act to dissipate some of the waves, but low-lying areas are inundated with significant impacts to exposed beachfront properties and infrastructure.

Further south, waves surge into Moreton Bay, including through South Passage Bar, causing the water levels to rise 1.5m. Waves of 0.5m to 3.3m are observed all along the Bay from Redcliffe to Cleveland. The Port of Brisbane is severely impacted and a wave 0.6m high surges up the Brisbane River resulting in inundation as far upriver as New Farm.

At the Gold Coast, waves ranging from 4.8m to 6.9m surge up the low-lying coastline and into the inlets and canal systems. Coolangatta observes the highest wave of over 9.4m.

Despite the call to evacuate and move away from the coastline, fatalities number in the thousands with 3,000 dead in the first 48 hours. ~200,000 people are displaced with the worst impacts felt on the island communities and the Gold Coast. The Premier requests activation of the COMDISPLAN with the Australian Defence Force subsequently deployed to help coordinate the rescue and recovery efforts.

Impacts

Essential infrastructure

Communications and energy

- Critical infrastructure near the coast – particularly in low-lying areas – is exposed to tsunami events.[298] These infrastructure may be significantly damaged or destroyed.
- Power generation, distribution and storage facilities may be damaged by a tsunami.[299] This can have significant, protracted consequences on recovery.
- Even if not damaged or destroyed, essential infrastructure can be rendered unusable by large amounts of sand and debris being deposited in and around the infrastructure. The removal of this debris is a major part of recovery efforts and can significantly complicate these efforts.[300]

Water

- Source-water contamination and damage to drinking water infrastructure may occur, leading to an increased number of boiled water alerts in affected regions.
- Saltwater may contaminate drinking water supplies (saline intrusion).
- Sewerage treatment plant and sewerage infrastructure damage/inundation may occur, with overflow and potential land contamination creating public health risk and potentially impacting nearby agricultural (food supplies), creating food safety hazard.

Transport

Transport infrastructure

- Land-based transport infrastructure, such as roads, rail, airports, and ports, are exposed to severe impact and the flow on disruption.[301]
- Scouring and debris from the impact of the tsunami is likely to significantly impact bridge infrastructure, forcing the closure of bridges until they can be inspected and deemed safe.

Access and resupply

- Impacts on infrastructure is likely to hamper efforts at accessing affected communities. Resupply issues may not resolve for weeks or months in remote parts of the State, particularly for communities only accessible by coastal roads or bridges.
- The supply of medical goods and medications may be impacted by damaged or destroyed logistics infrastructure.[288]
- Marine users and marine and beach infrastructure (such as pontoons, jetties, revetment walls along the canals) are highly likely to be affected.
- Failure or loss of canal revetment walls will likely result in significant damage to property – there approximately 700km of canals in the Gold Coast alone.
- Vessels that have broken their moorings may present both navigational and contamination issues, and clean-up of sunken vessels may require significant capacity over a protracted period.
- Debris within the river system is likely to cause additional damage and flooding through narrowing or blockage of channels.
- Resupply efforts by marine vessels would be hampered due the likelihood of waterways being damaged, clogged or inaccessible.
- The risk of major road traffic incidents may increase as residents of impacted areas attempt to evacuate.

Households

- Some vulnerable people may not understand tsunami risk and may not be aware of support services available. Cultural and linguistic barriers can further increase social isolation and vulnerability to tsunamis.
- Cultural and linguistic barriers also can increase social isolation and vulnerability to rare natural disasters such as tsunami (or earthquakes).
- As urban areas adjacent to the coast grow, community exposure to tsunami increases.
- As urban density increases, so does the potential for traffic congestion in response to a tsunami event. Given the limited time available to evacuate from the coastline, it is likely traffic jams and traffic incidents will increase.

Community services and infrastructure

- Social infrastructure (schools, hospitals and community centres) may be directly and indirectly affected through infrastructure damage, loss of power, water and communications.
- Tsunami can result in the destruction or damage of culturally significant sites. This includes significant First Nations sites along the coast, as well as important recreational sites, especially beaches.

Health and wellbeing

Physical and mental health

- The impact of the tsunami itself – especially if coupled with the amplification effect of debris – can cause severe injury and death.[302,303] If widespread, this can cause a cascading mass casualty incident.
- Widespread and significant trauma of local and tourist populations is reported in multiple countries following the 2004 Indian Ocean tsunami.[304,305] Trauma can be a persistent problem for years following the event, and can impact social cohesion.
- Secondary health conditions and diseases can be caused by tsunami. Waterborne diseases can be caused by the overflow sewage and stagnant water.[306] Deaths by pneumonia were reported to have increased in Japan following the 2011 tsunami.[307] Standing water following the event may cause an increase in vector-borne disease.

Health care and infrastructure

- Damage to or destruction of essential infrastructure may include infrastructure that facilitates response and recovery, such as medical facilities.[288] The loss of this infrastructure may hamper the ability of medical facilities to function properly, even if they are not directly impacted.
- Widespread and significant trauma of local and tourist populations [304,305,308] will lead to significant and potentially long-lasting mental health issues.
- Power outages from tsunami can lead to loss of air conditioning, possibly resulting in health impacts if there are concurrent heatwave conditions.

Business and economy

- Trade infrastructure can be damaged or destroyed, including especially ports and vessels berthed in ports, but also airports and major roads adjacent to the coast.[309]
- Strong currents can develop within ports and harbours, even if there is no land risk, damaging vessels, facilities and causing substantial erosion.[291]
- The fishing industry – and especially ocean fisheries – are significantly exposed to impacts of tsunami.[310,311]
- Tourism can be significantly impacted, as tourist sites and infrastructure can be severely damaged or destroyed by tsunami. Even if not directly impacted by tsunami, tourist sites can be impacted by tsunami debris.[312]
- Agriculture in coastal areas can be impacted directly by the tsunami but also in the longer term by soil composition being altered. Silt[313] and in some cases heavy metals[300,314,315] deposited by tsunami can cause issues with viability of soils. Debris from tsunami can also impact agricultural productivity.

Figure 91: Impacts of the 26 December, 2004 Indian Ocean earthquake and tsunami in Banda Aceh City, Indonesia. Hundreds of thousands of people lost their lives as a result of the earthquake and associated tsunami. Source: Shutterstock.

Natural environment

- Tsunami can have major impacts on coral cover in reefs.[316]
- Coastal floodplains can be degraded by the introduction of silt and heavy metals carried by tsunami.[300,313–315] This may have sustained detriments on local ecosystem viability.
- Tsunami can significantly impact environmental features that mitigate disaster risks posed by other hazards.[317] For example, mangrove forests mitigate coastal inundation but they can be destroyed due to tsunami events.[318]
- Ecosystems that are adjacent to the coast – such as forests[301] – can be impacted by tsunami events.
- Erosion of dunes caused by tsunami events can expose coastal communities to subsequent events.

Supporting information

Plans

- Tsunami evacuation areas for Queensland
- AIDR Tsunami Emergency Planning in Australia Handbook and companion documents
- GA jointly operates the Joint Australian Tsunami Warning Centre (JATWC) with the Bureau of Meteorology. Geoscience Australia identifies and characterises potential triggering earthquake sources for a tsunami to initiate the tsunami warning chain. It supports international efforts for the Indian Ocean Tsunami Warning and Mitigation system (IOTWMS). In particular, the JATWC is one of three official Regional Tsunami Service Providers (TSP) for IOTWMS.

Technical guidance

- Tsunami: the Ultimate Guide. Surf Life Saving Australia

Risk summary

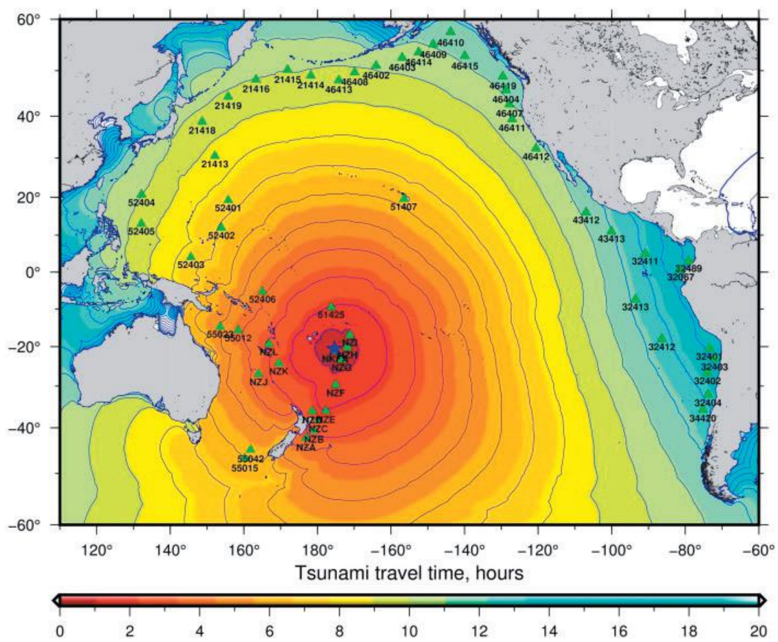
Due to the lack of major tsunami events in the recent historical records, tsunami is not front-of-mind for disaster management in Queensland – the State has recorded 10 minor tsunami since records began. The probability of tsunami across Queensland is low. However, due to the length of Queensland's coast, and the concentration of Queensland's population on or close to the coast, tsunami risk mitigation is still an important consideration.

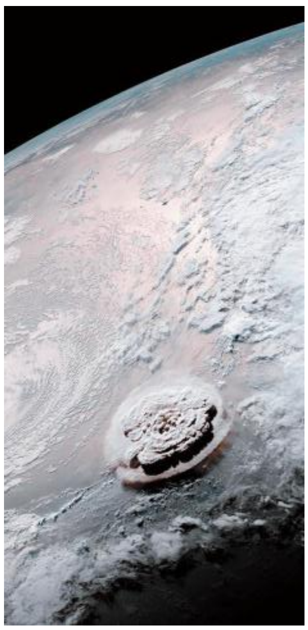
Impacts from tsunami can be significant and severe, as illustrated by the 2004 Indian Ocean tsunami and the 2011 tsunami that impacted the east coast of Japan, with both causing widespread mortality and destruction of the built and natural environment.

Essential infrastructure adjacent to the coast can be damaged or destroyed directly by the force of the tsunami. Tsunami also deposit large amounts of sand, salt water, and debris, which can all have longer-term impacts on essential infrastructure. Transport infrastructure can be compromised by the tsunami which can hamper access and resupply processes.

Significant mortality can occur as a result of tsunami, and secondary health conditions are often prevalent following the event. Significant mental health effects arising from trauma have been reported among surviving populations that have experienced the tsunami. Health care facilities may be damaged or destroyed by the tsunami, which would worsen the impacts through compromising provision of care.

Significant industries can be impacted by tsunami. Tourist sites can be significantly damaged or destroyed, reducing the tourist economy in the area of impact. Tsunami can also degrade soils by carrying silt, debris, and contaminants onto agricultural land. Tsunami can significantly impact important coastal and marine ecosystems, especially reefs.





(Top left) Estimation of the travel time of the tsunami triggered by the Hunga Tonga - Hunga Ha'apai volcano by GNS Science, New Zealand. Green triangles depict location of DART buoys. (top right) Satellite imagery of the eruption courtesy of the National Oceanic and Atmospheric Administration (NOAA). (bottom) Time lapse photography from nearby small boat passengers in the lead up to the eruption two weeks later. Courtesy Smithsonian Institution, Global Volcanism Program.

PANDEMIC


COOLANGATTA RD
Coolangatta
Tweed Hds
SPEED CAMERAS AND
RED LIGHT CAMERAS
40
POLICE
PREPARE
POLICE BORDER
CORONAVIRUS
QUARANTINE

Pandemic

Pandemic is the sixth highest priority for Queensland. Pandemic was not reported on in 2017 State Natural Hazard Risk Assessment.[2] Full details of prioritisation are provided below and in Section C - Risk prioritisation.

Understanding the hazard

Pandemics are occurrences of diseases that are geographically widespread and affect large numbers of people.[319] Epidemics are disease outbreaks similar in character to pandemics but at a more limited geographic scale and affecting fewer people. For instance, an epidemic may be an outbreak of influenza in a particular local government area, affecting a few hundred people, while pandemics generally spread beyond national borders and impact thousands of people and beyond.

Pandemics that have occurred in the past century and have affected Queensland directly include the ongoing HIV/AIDS pandemic, the 2009 H1N1 influenza pandemic ('swine flu') and, most significantly, the ongoing COVID-19 pandemic. Pandemics are primarily a risk to the physical health of Queensland's population. However, as the COVID-19 pandemic has illustrated, they can also have widespread impacts on the economy, quality of life, supply chains and mental health of Queenslanders.

Because the COVID-19 pandemic is ongoing at the time of writing this report, it may be reasonable to assume that it provides the benchmark for all pandemic events. The COVID-19 pandemic however, is a rare, catastrophic event, and most pandemics and epidemics will not result in the same intensity of impact. The primary risks regarding infectious diseases are short-lived spreads of infectious disease that are confined to a limited geographic extent.

Definition

A pandemic is "an epidemic occurring worldwide, or over a very wide area, crossing international boundaries and usually affecting a large number of people".[320] The WHO defines an epidemic as "the occurrence in a community or region of cases of an illness, specific health-related behaviour, or other health-related events clearly in excess of normal expectancy".[321] Because they are defined by an occurrence that is 'clearly in excess of normal expectancy', epidemics are declared events and depend on the specific region and period in which they occur.

Hazard ratings

A scheme for assigning hazard ratings to pandemics – shown in Figure 92 – is the Pandemic Severity Assessment Framework,[322,323] which assigns pandemics a rating of A to D, based on two factors:

1. transmissibility, the rate at which a pathogen can spread in a population
2. clinical severity, how seriously the illness affects people.

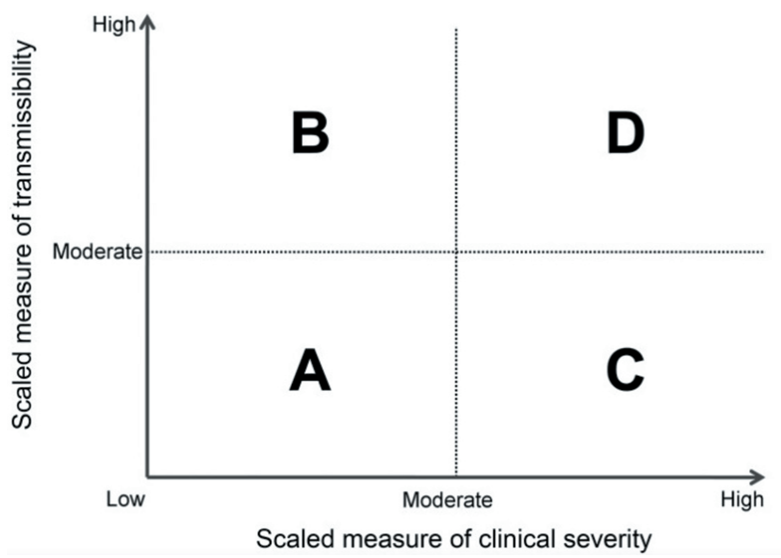


Figure 92: Pandemic hazard scale. Source: Pandemic Severity Assessment Framework [322]

Each of these is associated with several measures, which may be available at early or later stages of the pandemic. Specific limits for each of these measures are provided in the Pandemic Severity Assessment Framework.[322] The calculation of these variables requires specialist advice. While framework provides a generic model for assessing the risk of a pandemic, each disease will present its unique set of risks. Novel viruses may also present additional risks that may not be well understood and will require expert advice from Queensland Health.

For the purpose of pandemic risk assessment under the QERMF, the A to D scale can be reworked as a 1 to 4 scale, where less frequent events that mobilise national or global responses, like COVID-19 and the Spanish Flu pandemics, are assigned a 5 for the purpose of disaster risk management.

Note that the use of this scale is advised in a disaster risk management context. Appropriate medical advice should be sought to ensure the correct understanding of an epidemic or pandemic's danger to communities.

The Queensland context

History

During the past 100 years, not including the current COVID-19 pandemic, Queensland has experienced five epidemic or pandemic outbreaks:

- Influenza, which occurs statewide. Outbreaks that caused fatalities in Queensland include:
  - › H1N1 pandemic, 1918-20 ('Spanish flu')
  - › H1N1 pandemic, 2009 ('Swine flu')324
  - › SARS-CoV-2 (which causes COVID-19) pandemic, 2020 – present.
- Dengue, which occurs mostly in the State's north. The most recent outbreak to have caused fatalities in Queensland was the DENV-3 outbreak in 2008–09.[325]
- Human Immunodeficiency Virus and Acquired Immune Deficiency Syndrome (HIV/AIDS), which occurs statewide. After an initial surge of cases in 1984-85, the rate of notifications for new diagnoses of HIV has remained consistent.[326]

Occurrence of a pandemic may give rise to other hazards as a result of unique risk drivers such as employee absenteeism, decontamination requirements and maintenance of essential assets and services. If a disaster such as a cyclone or a mass casualty incident were to occur concurrently, this could exacerbate capability limitations and present additional challenges for medical care, quarantining and physical distancing requirements. It is widely recognised that this factor now needs to be considered in the planning and management of evacuation centres.

Projections

Defining region-level probabilities for epidemics and pandemics is challenging because the emergence of pathogens that cause these events relies on systems whose operation is difficult to capture in a single metric.

Climate change is predicted[327–332] to cause increases in the distribution of infectious diseases. As places become warmer, pathogens and carriers of pathogens are more likely to enter areas that have not previously experienced them.
For instance, recent studies have shown[333–336] that climate change-induced warming has promoted the spread of Dengue, causing larger outbreaks in areas that have not experienced outbreaks previously.

Ongoing and projected changes to population and demographic characteristics may also result in changes to how pandemics and epidemics are managed in communities – see Other drivers or risk for Queensland: Population and demographic change.

Management of the hazard

Queensland Health

Queensland Health is the functional lead agency for pandemic in Queensland. The Commonwealth Government may also provide strategic direction from the National Incident Room. These can be adapted and used to inform planning at jurisdictional and local levels based on an appropriate risk assessment.

Queensland Health (QH) has a disaster management structure that sits alongside Queensland's disaster management arrangements. At the State level, the State Health Emergency Coordination Centre (SHECC), acts as the coordinating body for responses to health emergencies.

The SHECC also provides a vital reporting function and coordinates communication and media to ensure consistent messaging. At a district level, each Hospital and Health Service (HHS) has a Health Emergency Operations Centre (HEOC). HEOCs may be activated for some disease outbreaks, however in the instance of a pandemic the SHECC would be activated to ensure a coordinated response among HHSs. More information on this structure can be found in the Queensland Health Disaster and Emergency Incident Plan.

Responsibilities of QH during a pandemic includes:

- lead prevention and response activities
- distribute pandemic vaccines and resources to the health sector as directed by the Commonwealth Government
- operational management of the pandemic to reduce the impact on human health
- caring for and treating affected individuals in health services across the State
- coordinating and undertaking pathology services and testing
- provision of health advice and alerts
- epidemiology, modelling and reporting
- guidance in relation to regulation of activities or matters that may impact public health
- coordination and provision of medical supplies
- production and distribution of educational material and research.

Queensland Ambulance Service

Queensland Ambulance Service (QAS) provides specialist logistical support as needed by Queensland Health. Other responsibilities include:

- develop and maintain business continuity plans to manage staff surge capacity and staff absenteeism
- prepare to provide timely and quality ambulance services which meet the needs of the community during a pandemic.
- liaise with HHSs to develop operational plans.

Considerations for disaster management groups

As outlined in the Queensland Health Pandemic Influenza Plan, the respective HHS usually acts as the lead agency for Local and District Disaster Management Groups to provide specialised pandemic response capability. Each HHS is responsible for developing and maintaining operational plans in liaison with local governments and other key stakeholders.

The *Public Health Act 2005* sets out the provisions for public health emergencies. Declaration of a public health emergency may result in the issuing of public health directions and appointment of emergency officers with broad ranging powers.

Figure 93: Variable message sign reminding the community and visitors to maintain social distancing during the COVID-19 pandemic. Source: Shutterstock.

Scenario

The winter influenza season in Cairns peaked in August. The predominant strain that circulated was H3N2 where mainly adults were affected. The greatest burden of disease and highest mortality rates were in those over 70 years of age, with 30 per cent of local nursing homes reporting influenza outbreaks. At the peak of the influenza season, healthcare systems were at risk of becoming overwhelmed as they experienced elevated rates of hospitalisation and mortality, especially in the elderly.

While GPs reported a high uptake of vaccines leading up to and during the season, further analysis shows that the vaccine was not a good match for the circulating strain due to mutations that made it even more highly transmissible.

In December, news from the northern hemisphere is that this new strain of influenza H3N2 is the predominant circulating virus. Unfortunately, the vaccine was not able to be reformulated in time to take into account the mutations seen in Australia earlier that year.

A cruise ship, whose home port is Southampton, UK is currently undertaking a world tour of three months. Passengers have boarded in both the UK and USA, most of whom are retirees. Crew changed over four days ago in Thailand and the vessel is next scheduled to stop in Cairns, where the passengers will spend three days exploring the rainforest and reef. As the vessel enters Australian waters it declares that there is an influenza outbreak on board and requests assistance. Of the 1500 passengers and crew on board, over 200 have reported influenza like symptoms and the medical services onboard are overwhelmed.

Impacts

Essential infrastructure

- It is unlikely that a pandemic will have a direct effect on physical essential infrastructure beyond altering hygiene requirements.[193]
- Depending on the duration and impact of a pandemic and the level of response required, the following alterations to infrastructure may be required:[285]
  - Some essential infrastructure may need to be repurposed and/or physically changed. For example, creating dedicated wards in hospitals to accommodate and treat patients, and establishing purpose built or dedicated quarantine facilities.
  - Established infrastructure may require the addition of CCTV and other technological capability for the purpose of ongoing monitoring throughout the facility.
  - The use of hotels as quarantine sites by government may require physical and technological alteration as well as frequent deep cleaning to ensure compliance and the safety of the public and persons working at those sites.
- The operation of utilities – including power, water and communications – may be impacted by changes in staffing,[337] transport and supply chain disruption and changes in demand patterns. Operators of these utilities should prepare business continuity plans to ensure that operation and maintenance can continue during pandemic.[338]
- Border closures resulting from pandemics may impact business-as-usual operations and can cause service disruptions to telecommunications or electricity infrastructure.[339] This is especially the case if the infrastructure requires critical maintenance to continue operations. Exemptions for the border closures may need to be sought as has occurred during the COVID-19 pandemic.

Transport

- Supply chains – both humanitarian and commercial – can be severely disrupted in the event of a pandemic.[340] This may lead to shortages of everyday goods, medications, and – in the case of particularly severe pandemics – larger items such as medical equipment and vehicles.
- Panic buying occurred globally at the beginning of the COVID-19 pandemic, which led to shortages of everyday goods and rationing.[341] This behaviour may also pose a risk during larger-scale epidemics and pandemics.
- Public transport systems including airlines, road and rail may be suspended or altered during a pandemic resulting in financial losses to operators and impacts on public and private sector workforce movement across the State. The requirement for social distancing and deep cleaning will further impact operators and public transport consumers.[285]

Community

- Widespread pandemics, particularly of highly transmissible diseases, present serious risks for community wellbeing. The introduction of social distancing measures – which involves the suspension of travel, social gatherings including but not limited to funerals, weddings, religious gatherings, community events, concerts and festivals – may erode social cohesion, and may worsen existing social problems such as poverty,[342] and isolation[343] as well as impacting the mental and physical health of individuals.
- Closure of schools as a result of social distancing measures exposes parents or carers of children, who are often required to adjust their work arrangements.[344–346] This leads to an increased financial burden and additional stress.
- Disruption of education in schools can impact the mental health of students.[346–348] Early studies suggest that disruptions to school may have longer-lasting effects on student's content knowledge and level of education.[349,350]
- Culturally and linguistically diverse (CALD) communities are at risk of being isolated from response measures during a pandemic unless messaging and communication is targeted to these communities.[351] Developing relationships with bodies representing these communities is a useful step in ensuring that information is spread to these communities.[352]
- Widespread pandemics strain resources on public administration, particularly if a whole-of-government response is needed. This takes resources away from other priorities that might still be affecting a community, meaning that progress in other areas can stall.
- The effects of pandemic events on wealth and income inequality can be intergenerational, and can exert impacts that outlast the length of the pandemic itself.[353,354] A pandemic may lead to entrenched disadvantage.
- Social isolation measures risk increasing social isolation and loneliness, particularly among the elderly[355] – this risk will grow as the population of Queensland ages.[356]
- Demand for access to social services may increase, risking overburdening the social services system.
- Responding to a pandemic requires a concerted effort by multiple stakeholders in government. This poses a risk to the business of government, since much of its time will be spent responding to the event.
- The costs associated with providing social support and ensuring economic and social recovery are likely to be significant because of the various effects of a pandemic event. This is likely to place strain on future budgets and may result on considerable ongoing debt.[357]
- Absenteeism in the public sector workforce due to illness or the requirement to care for others. This may impact on the quality of services that the State or local governments can deliver.
- Removal of harm caused by natural disasters is a priority, however it is to be noted that the requirement for social distancing measures has the potential to complicate the efficacy of risk management in response to other natural disasters – this has already been noted in the context of COVID-19.[358,359] For instance, fire management can be complicated by enforcing social distancing requrements, and alternative strategies will need to be considered.
- Other hazards and disasters may increase the risk for the spread of pandemics as people are displaced and as response is likely to require contact between potentially infected individuals.[360]

Health and wellbeing

- Pandemics pose the potential to overwhelm hospital and health services administered by Queensland Health and private hospitals. A rapid increase in the number of cases requiring medical attention will require medical services to manage their resources to meet increased demand. This is a particular potential issue for tertiary grade and smaller hospitals, especially in regional and rural areas.[337]
- Community health and wellbeing is the primary exposed element in the case of a pandemic. Depending on the nature of the disease, community health can be exposed to widespread illness or mortality, and potentially to chronic illness caused by the pandemic disease.
- Depending on the nature of the disease, increased mortality rates are to be expected, especially among at-risk populations – such as the very young, the elderly or those with pre-existing conditions.[337]
- An increasing threat of antibiotic resistance created by the normal, widespread use of antibotics may also amplify the mortality during pandemics.[361]
- The increase in demand for medical supplies and personal protective equipment (PPE) may deplete existing stocks with the resulting shortages potentially exacerbating the challenges of providing medical care.[193,362,363]
- A major risk to healthcare providers is the management of staff absenteeism while maintaining sufficient staffing levels to deliver health services which are likely to be experiencing a surge in demand due to the pandemic.[193] Absenteeism may be due to illness or fatigue[364] but may also be due to anxiety of exposure to the pandemic disease.[365]
- Community mental health is exposed, as rates of anxiety and depression increase as a result of the pandemic – due to the general situation, or due to impacts on family members and friends. The exposure of community mental health is made worse by possible social distancing measures to contain the pandemic.[366]
- Studies have indicated that domestic and family violence increases, due to the impact on mental health of pandemics and social distancing measures imposed during pandemics. Additional services may be required to assist those who are impacted.[367–369]
- The mental health of medical professionals may deteriorate due to increased demand for their services, associated professional and personal stressors, fatigue, long working hours, inability to take leave, lack of back up staff and resources, and overarching fear of the pandemic resulting in unwillingness by some to treat people with the disease.[370]

Business and economy

- Industries whose core business cannot be conducted remotely[371] and involve participation of groups of people are most exposed to pandemic events. This includes the tourism, arts, sports, personal services, mining (due to FIFO workers) and transport industries. These industries may severely contract due to extreme disruption of business-as-usual.[372–374]
- As outlined above, the medical industry is exposed by being overwhelmed by increased demand.[337]
- Other industries – including retail and community services – are exposed due to ramifications of the pandemic on the economy and on community and social wellbeing making these services less affordable.[374]
- Agriculture can be directly affected by human pandemics. A large increase of absenteeism precipitated by restrictions on movement of itinerant labour is likely to dramatically affect the amount that can be harvested. Human diseases – for instance, avian influenza – can pass to animal populations, causing loss of livestock.[375,376]
- Social distancing measures imposed to contain the spread of the pandemic may result in the closure of businesses and venues, leading to a loss in consumption and eventually a loss of jobs. Depending on the scale of the measures, economic contraction may occur at a local, regional, state, national or international level. This contraction may be severe and may result in a regional or national recession.[377] Restriction of movement more generally due to local or large-scale lockdowns may exacerbate this effect.
- Effective response measures – including social safety measures – may cause a large increase in debt, both public[357] and private.[378]

Natural environment

- Pandemics do not directly expose the environment, however increased personal protective equipment requirements, improper disposal of medical waste and misuse of disinfectants may result in increased waste and environmental pollution.[379]
- Emergence and spread of viruses can be as a result of the transmission of diseases between humans and animals. This can be driven by human activities such as agricultural intensification, wildlife use and misuse and human-induced landscape changes.[380]
- Pandemics can also provide environmental benefits. Air quality may improve as a result of reduced fuel consumption and industrial activities. Ecological restoration may occur as a result of travel restrictions and reduced pressure on tourist destinations.[379]

Supporting information

Plans

- Queensland Whole-of-Government Pandemic Plan, Queensland Government, 2020
- Pandemic Influenza Plan, Queensland Health, 2018
- Australian Health Management Plan for Pandemic Influenza (AHMPPI), Australian Government Department of Health, 2019
- The Queensland Ambulance Service, as support agency, has the following plans.
  - QAS Pandemic Influenza Response Plan
  - QH Pandemic Influenza Plan
  - QAS SMID Plan
  - QAS Incident Management System (IMS) Framework

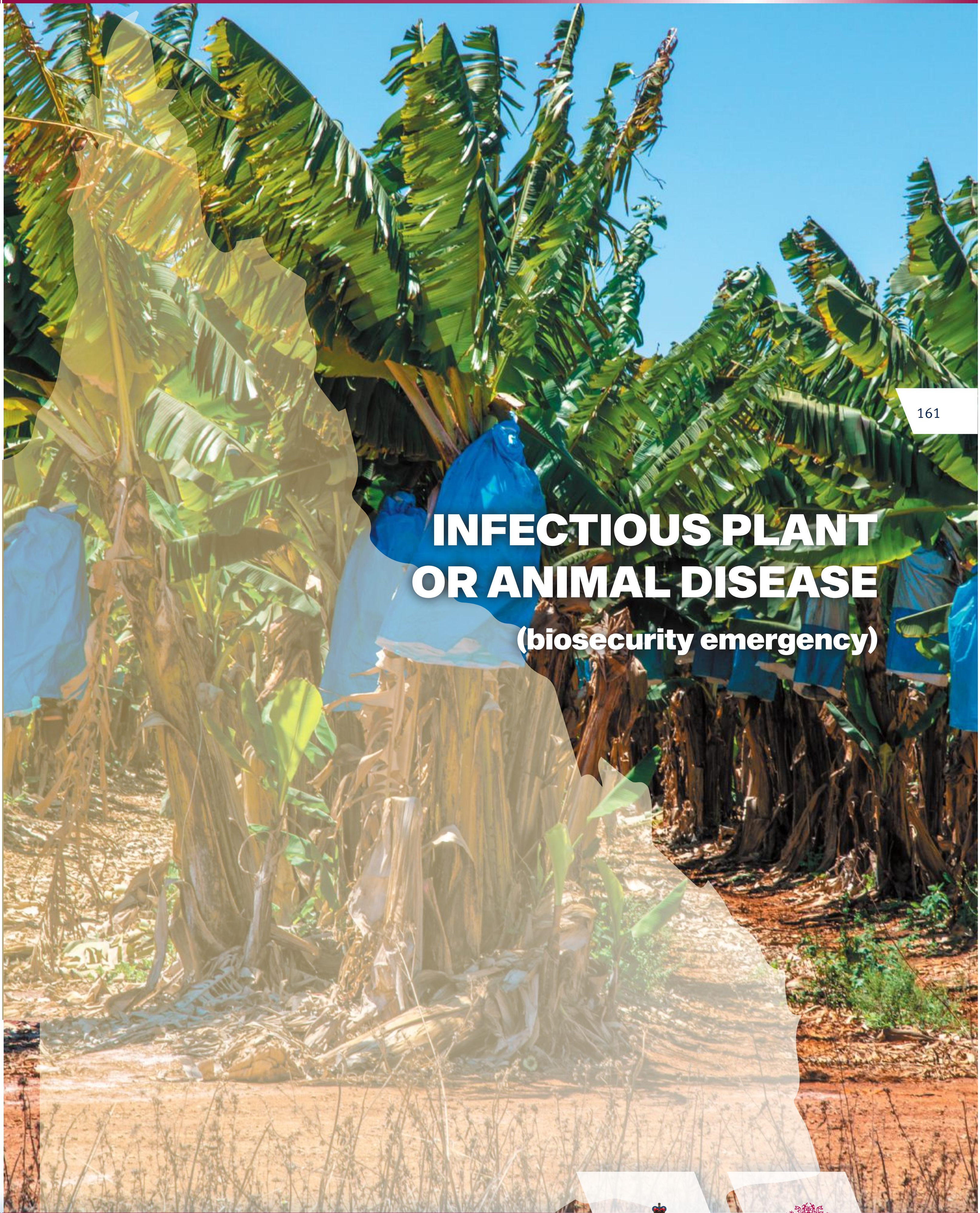
Risk summary

As COVID-19 has illustrated, pandemics and epidemics have the potential to have significant, prolonged and varied impacts for the entire State.

Defining the likelihood of pandemics and epidemics is challenging because the emergence of pathogens that cause these events relies on systems whose operation is difficult to capture in a single metric. For example, increasing global interconnectedness through tourism, logistics and trade, increasing population density, and demographic changes – especially an aging population – all contribute to the risk of epidemics and pandemics. Studies suggest that some infectious diseases may become more widespread and prevalent due to increased range of carriers of pathogens.

Pandemic plans have been updated and are well exercised, meaning that response to pandemics and epidemics will be more effective than in the past. Public awareness of the risk of infectious diseases has also increased, so that hygiene and social distancing measures that mitigate the risk of pathogen spread have become commonplace. This has led to a dramatic decrease in the incidence of influenza throughout Australia,[381] and may provide a mitigating factor for the emergence of future pandemics and epidemics.

The primary impacts of pandemic are to human health. Increased rates of illness or mortality can occur as a result of pandemics. Efforts to restrict the spread of a pandemic or epidemic can have more widespread effects. Measures like border closures, lockdowns, or other restrictions on movement affect business-as-usual in a range of sectors, by disrupting staff movements, supply chains, and transport networks. The efficacy of social and health services can be compromised by increased staff absenteeism due to the pathogen.



INFECTIOUS PLANT OR ANIMAL DISEASE

(biosecurity emergency)

Infectious plant or animal disease (biosecurity emergency)

Biosecurity emergencies are the seventh highest priority for Queensland. Biosecurity emergency was not reported on in 2017 State Natural Hazard Risk Assessment.[2] Full details of prioritisation are provided below and in Section C - Risk prioritisation.

Understanding the hazard

A biosecurity emergency is “a significant problem for human health, social amenity, the economy or the environment” that is “caused by a pest, disease or contaminant”.[382] Examples of biosecurity emergencies that have the potential to impact Queensland include:

- Foot and mouth disease (FMD), which affects livestock including cattle, pigs, goats, sheep, buffalo and deer. A significant outbreak in 2001 in the UK led to the slaughter of 6.5 million animals.[383,384]
- White spot, which affects prawns. An outbreak was discovered in South East Queensland in late 2016.[385,386]

Biosecurity emergencies also occur at smaller scales, such as the incursion of fire ants in South East Queensland.

Definition

Under the Disaster Management Act 2003, ‘infestation’ and ‘plague’ are mentioned in the definition of ‘events’, in reference to biosecurity emergencies. The Biosecurity Act 2014 provides a more detailed definition.

Some key terms under the *Biosecurity Act 2014* include the following.[382]

A *biosecurity matter* is a:

- a living thing, other than a human or part of a human
- a pathogenic agent that can cause disease in:
  - › a living thing, other than a human
  - › a human, by the transmission of the pathogenic agent from the animal to the human
- a disease
- a contaminant.

A *biosecurity event* is an event that is, was or may become a problem for human health, social amenity, the economy or the environment, and is, was or may be caused by a pest, disease or contaminant.

Human health, social amenity, the economy or the environment are defined as *biosecurity considerations*.

A *biosecurity risk* is a risk of any adverse effect on a biosecurity consideration. A risk is or may be caused by:

- biosecurity matter
- dealing with biosecurity matter or a carrier
- carrying out an activity relating to biosecurity matter or a carrier.

A *carrier* is any animal or plant, or part of any animal or plant, or any other thing:

- capable of moving biosecurity matter from a place to another place, or
- containing biosecurity matter that may attach to or enter another animal or plant or part of another animal or plant, or another thing.

A *thing* in this context is alive, dead or inanimate and includes a human.

Hazard ratings

Not all incidents are the same, nor are their responses. However, there is a need to identify and communicate the class or level of incident that is being responded to, to ensure the appropriate level of control, resources and support are provided to achieve a successful resolution.

Broad, nationally agreed criteria are used to classify a biosecurity incident into five levels that enable departmental staff and other jurisdictions to better understand the scale of the incident and therefore the potential resource requirements (see Table 24). For biosecurity emergencies within Queensland, Biosecurity Queensland and the Department of Agriculture and Fisheries are the lead response agencies, and are responsible for managing and coordinating activities.[387]

The levels are as follows:

Incident level	Description
Level one incident	A level one incident is a localised response, being managed by local DAF resources with little or no external support. Facilities for managing the response are small scale.
Level two incident	A level two incident is a local or regional response, being managed primarily at the local level, with some support being coordinated by the State. A dedicated Local Control Centre and perhaps a small scale State Coordination Centre (SCC) may be required to manage the response.
Level three incident	A level three incident is a statewide response, being managed primarily at a state/territory level. This may include the establishment of one or more Local Control Centres and a fully operational State Coordination Centre. Some resource support may be provided from outside the responsible agency or state.
Level four incident	A level four incident is where one or more jurisdictions are involved in managing the response to a biosecurity incident. One or more of the involved jurisdictions' resources or established arrangements are insufficient for the response and the National Coordination Centre (NCC) is required to coordinate nationally available support to the affected jurisdiction/s.
Level five incident	A level five incident is where one or more jurisdictions are involved in managing the response to a biosecurity incident. The national resources are insufficient for the response and the NCC is required to coordinate international support to affected jurisdiction/s.

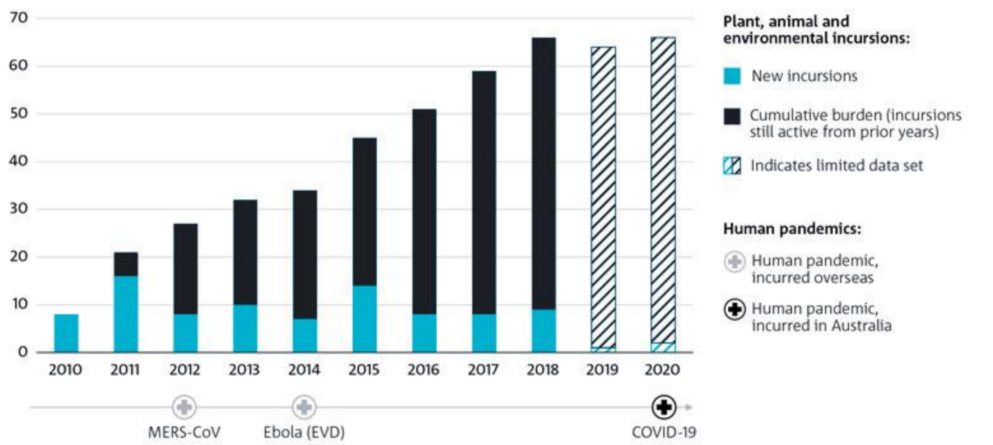
Table 24: Incident levels for assessing biosecurity incidents.

The Queensland context

History

Australia's biosecurity record is, relative to the rest of the world, very strong: "as an island nation with a long-standing commitment to quarantine, Australia remains free from many of the pests and diseases that plague other parts of the world".[388] However, this also means that Australia is particularly vulnerable to biosecurity threats.

Because of increased global interconnectivity, the potential risk of serious biosecurity emergencies has risen in recent years. The CSIRO has found that the number of active plant, animal and environmental incursions has increased year on year since 2010, as shown in Figure 94.



Notes: (1) Incursion and cumulative burden data for years 2019-2020 is limited due to limited data availability (see footnote for sources); expected incursions higher. (2) Animal disease incursion data not included for 2018 due to missing data). (3) Individual incursions differ widely in importance, severity of the issue, and burden of costs and resources. (4) Cumulative burden does not include incursions that initially occurred prior to 2010. (5) Eradicated incursions are not tracked across their active timeframes; cumulative burden is only shown for incursions still active today. (6) 'Transient' marine pest species not listed due to uncertainty of establishment.

Figure 94: Number of incursions (introduction of invasive species) to Australia per year, from CSIRO's 2020 report "Australia's Biosecurity Future: Unlocking the next decade of resilience".[389]

Projections

Defining region-level probabilities for biosecurity emergencies is difficult because the emergence of biosecurity incidents relies on systems whose operation is difficult to capture in a single metric. Further, different biosecurity matters will be likely in certain regions and not others – and, therefore, to ascribe a region-level probability for all possible biosecurity matters is not practicable.

A recent stocktake of megatrends that will impact Australian agriculture has identified population growth in overseas markets and climate change as having potentially significant impacts on this sector.[390] Both of these topics are discussed throughout this report. Population growth will cause larger and more integrated markets, which will increase the risk of a biosecurity emergency occurring. Domestic population growth is discussed as a megatrend affecting Queensland. In general terms, climate change may have a major impact on the likelihood of biosecurity emergencies. Invasive species control methods may become less effective as the climate changes.[391]

Management of the hazard

Queensland's chief biosecurity concerns are the health of its people and its agriculture, horticulture, nursery, marine, aquaculture and livestock industries. Biosecurity emergencies are also of importance to society more broadly, as mentioned above, Biosecurity considerations for Queensland include human health, social amenity, the economy and the environment.

Diseases of animal origin can be highly infectious and, in some cases, fatal – as in the case of Hendra virus or COVID-19. Given Queensland's agriculture sector is estimated to have a gross value of production of $18.78 billion in 2018-19,[392] any wide-ranging impact on the agriculture sector caused by a biosecurity concern would have serious impacts on the Queensland economy, especially in regional and remote areas.

Queensland's primary legislation around biosecurity is the Biosecurity Act 2014, administered by Biosecurity Queensland, within the Department of Agriculture and Fisheries. Under the Biosecurity Act, all Queenslanders have a 'general biosecurity obligation' – this means that everyone must manage biosecurity risks that are under their control, that they know about, or that they should reasonably be expected to know about. Individuals and organisations whose activities pose a biosecurity risk must:

- take all reasonable and practical steps to prevent or minimise each biosecurity risk
- minimise the likelihood of causing a biosecurity event, and limit the consequences if such an event is caused
- prevent or minimise the harmful effects a risk could have, and not do anything that might make any harmful effects worse.[393]

Major factors that introduce biosecurity risks are the movement of people and goods between regions. In particular, international shipping and tourism both act as significant pathways for pests, diseases and contaminants to enter Queensland.[394–396] The increasing connectivity of Queensland to the world – through trade and tourism – means that this risk is likely to continue to increase.

Department of Agriculture and Fisheries (Biosecurity Queensland)

The Department of Agriculture and Fisheries (DAF) is the lead agency for containment and eradication of emergency animal and plant diseases and pests. DAF also provides advice in the areas of agriculture, fisheries and forestry in a disaster event.

As primary agency, DAF's responsibilities include:[397]

- coordinate efforts to prevent, respond to, and recover from plant and animal pests and diseases and invasive plants and animals
- provide advice on animal welfare
- collaborate with stakeholders with shared responsibilities and other organisations to facilitate prevention, preparedness, response and recovery strategies and priorities for animal welfare management within a community
- provide advice in relation to agriculture, fisheries and forestry disaster impacts
- coordinate destruction of stock or crops in an emergency pest / disease situation
- administer Natural Disaster Relief and Recovery Arrangements relief measures including agriculture industry recovery operations as required
- lead the reporting on the disaster impact assessments on the agricultural sector, including economic losses and expected recovery
- report on the possible impact seasonal conditions and climate events will have on the agricultural sector
- coordinate the Agriculture Coordination Group with agricultural industry groups to provide information about the effect that a disaster event has on the agriculture, fisheries and forestry industries and the issues that individuals and businesses are facing in responding to and recovering from a disaster event
- engage with industry on preparedness for climate risks and aid with economic recovery
- assist agriculture and fishery industries in prevention and preparedness through normal business operations and service provision to industry and communities
- participate in District Disaster Management Groups.

During other natural disasters, biosecurity may become a concern. For example, large-scale flooding caused by the 2019 monsoonal trough lead to large numbers of cattle death,[398] creating a significant biosecurity concern.

DAF's role is to manage:

- emergency pests and diseases of animals and plants
- residues and contaminants in agricultural commodities
- invasive plants and animals
- emergency animal welfare incidents, including during natural disaster responses.

DAF also provides guidance on strategic policy and direction, and plans and implements operational activities during disaster events.

Considerations for disaster management groups

Potential requirements from Biosecurity Queensland include:

- capability to provide resources (human and material) during a biosecurity incident response
- road closure and provision of signage for checkpoints, closures, diversions and route control – it is most likely local governments will act in association with the Department of Transport and Main Roads, and the Queensland Police Service.
- general resourcing – portable toilets, catering, shelter, transport, plant and equipment, as examples
- participation in disposal options such as burial pit construction and burning maintenance (in collaboration with the Department of Environment and Science (DES) to consider environmental impacts)
- establishing cleaning and disinfection points
- cleaning and disinfection of vehicles and machinery
- control of decontamination site run off (in collaboration with DES)
- supply of combustible materials for burning of affected / high risk matter (e.g. sleepers and light timber)
- temporary fencing
- temporary road construction/maintenance/ watering of roads for dust control and maintenance
- administrative support or other roles within the DAF coordination centres.

Scenario

Foot-and-mouth disease (FMD) is found on a large cattle property in North Queensland. Movement restrictions are immediately placed on the infected property using powers under the *Biosecurity Act 2014* prohibiting the movement of cattle and other carriers of the disease onto and from the property. All cattle and other susceptible animals on the property are destroyed.

Biosecurity Queensland, as the lead agency for biosecurity responses, stand up a State Control Centre and a Local Control Centre in order to undertake further disease containment and control activities that are in accordance with AUSVETPLAN FMD Disease Strategy.

Further movement controls are implemented across Queensland and tracing activities are undertaken to establish the extent of potential spread off the original infected property (trace forward) and the original source (trace back). Public Information activities are undertaken including engaging industry, community and government departments.

Impacts

The following impacts apply to a range of biosecurity emergencies.

Essential infrastructure

- Essential infrastructure is generally not directly exposed to biosecurity emergencies.[399] However, if located in the area of operations, there may be disruption due to road closures and the potential imposition of decontamination protocols for people and vehicles that exit the property. Vehicles that are used to transport crops or livestock may be impacted.

Transport

- Disruption to associated sectors of the road and rail transport may occur where the routes enter affected areas.[399]
- In very severe cases, biosecurity emergencies can lead to a shortage of individual crops or products. In the Queensland context, this is unlikely to be a significant issue – but global movement of crops poses a risk.[400,401]

Community

- Biosecurity emergencies that affect the significant industries of an area (for instance, Panama disease on banana crops, or foot-and-mouth disease on livestock) have the potential to have significant impact on the community's social wellbeing.[402–404] This would be a particular issue for smaller regional and remote communities, where the greatest risk to these sectors exists.

Health and wellbeing

- Biosecurity emergencies can include diseases that are dangerous or fatal to humans. For instance, Hendra virus – which originally passed from fruit bats to horses and then to humans[405] – is attributed with four deaths in Queensland.[406]
- Diseases that are zoonotic – that is, whose source is an animal – can cause widespread epidemics or pandemics. For example, COVID-19 is hypothesised to have passed from a bat to a human.[407,408] For more information on epidemic and pandemic risk assessment, see the Pandemic risk assessment.

Business and economy

- Agriculture is exposed to biosecurity emergencies, as contaminants, pests and disease can compromise or destroy crops and livestock. This poses a significant risk to the agriculture and related industry.
- A 2013 report by the Commonwealth Department of Agriculture estimated that the direct cost for a small outbreak in North Queensland totalled $5.96 billion over ten years.[403] The impacts of this cost would not only impact the agriculture sector, but also significantly impact the local and State economy.
- Tourism – particularly ecotourism – can be impacted by measures that restrict access to tourist areas.[394] Tourism is also a vector for the spread of biosecurity risks across the State.[409]

Figure 95: Source: Biosecurity Queensland.

- Backpackers who rely on fruit picking work may be unable to access this work due to a biosecurity emergency, resulting in adverse impacts on the farmers, backpackers and potentially on local economies.[399]
- In rural communities and larger service towns and cities (to a lesser extent), the integration of investment and servicing from the agricultural economy can mean that all commercial activity is impacted by a major disruption in the agricultural sector. Major biosecurity incidents can be ongoing, or impact markets for a number of years, impacting population movement and unemployment in communities.[399]

Natural environment

- Invasive species can have severe impacts on the viability of native species410,411 and lead to loss of biodiversity.[412–415]
- Invasive plant species can impact viability of native plant species and crop plants by altering the moisture composition of soil.[416]
- Invasive species can cause cascading impacts that extend beyond the immediate impacts of the species themselves. For example, freshwater crocodile population density has decreased dramatically due to the spread of cane toads in some places in the Northern Territory.[417] Because the freshwater crocodile is an apex predator, its decline means that prey species can thrive, causing an altered composition of the ecosystem, which may have dramatic and long-lasting effects.
- Proactive surveillance programs at sites that are likely to be impacted by invasive species can reduce the likelihood of species becoming well-established.[418]

Supporting information

Plans

- Queensland Biosecurity Manual. The manual incorporates the strategies and arrangements based on national response deeds, agreements and plans, and incident and emergency management concepts.

Current national plans are:

- The Australian Veterinary Emergency Plan (AUSVETPLAN) outlines a nationally consistent plan for handling animal diseases.
- The Australian Aquatic Veterinary Emergency Plan (AQUAVETPLAN) provides nationally consistent manuals for use during aquatic biosecurity incidents. Like the AUSVETPLAN, these manuals address specific diseases, general operational procedures and management of disease outbreak response.
- The Australian Emergency Plant Pest Response Plan provides nationally consistent guidelines for managing a response to plant pest incident at national, state/territory and local levels, describing the national procedures, management structures and information flow systems.
- The Australian Emergency Marine Pest Plan is an emergency response document that describes the intended response to a marine pest emergency event within Australia.
- The National Environmental Biosecurity Response Agreement establishes national response arrangements to reduce the impacts of pests and diseases on Australia's environment and social amenity.
- Where a national plan does not exist for a particular response, then AUSVETPLAN is used.

Technical guidance

The Commonwealth Government's website – www.outbreak.gov.au/ – provides information about emergency responses to animal and plant pest and disease incursions that affect Australia's agriculture industries and environment.

Risk summary

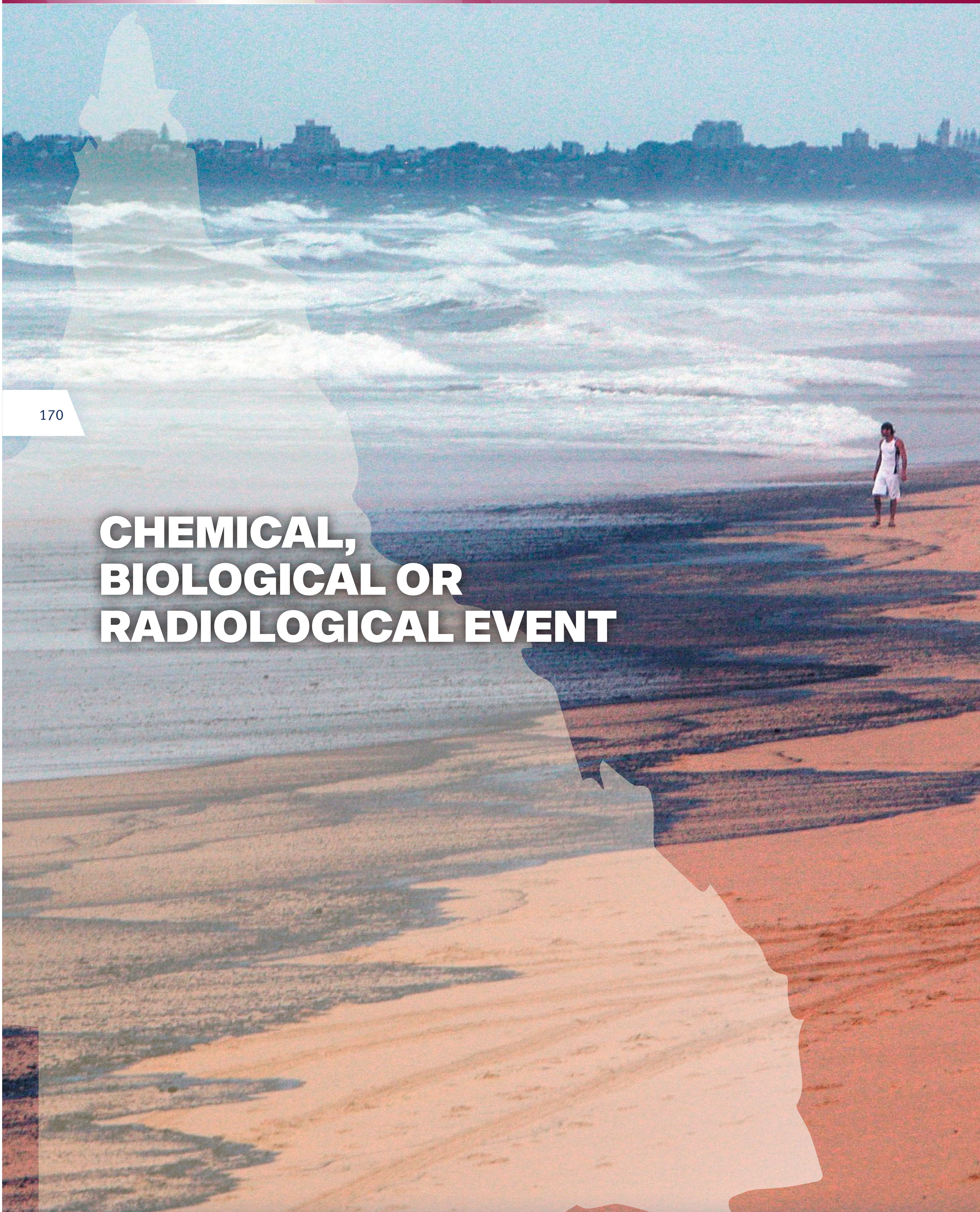
The impacts of biosecurity emergencies can be widespread but most biosecurity emergencies are able to be contained to a specified location. The agriculture industry is most exposed to the impacts of a biosecurity emergency but biosecurity emergencies can also impact communities that rely on agriculture, and – in some cases –the business-as-usual status in other areas of the State.

Defining region-level probabilities for biosecurity emergencies is challenging because the emergence of biosecurity incidents relies on systems whose operation is difficult to capture in a single metric. Further, different biosecurity matters will be likely in certain regions and not others and, therefore, to assign a region-level probability for all possible biosecurity matters is not practicable.

Drivers of risk including populating growth and increased interconnectedness of global agricultural sectors contribute to future biosecurity emergency risk.

Due to Australia's being an island nation with a longstanding commitment to biosecurity, the risk of a biosecurity emergency is uniformly low across the State. Biosecurity Queensland manages biosecurity risk through a range of activities and plans. Due to the organisation's distribution throughout Queensland and its relationship with primary producers, the risk of biosecurity is low across the State.

Biosecurity emergencies are most likely to impact plants and animals, and this impact is most significant when these plants or animals are agricultural commodities or interact with agricultural commodities. The economic impacts of biosecurity emergencies can be significant and can affect sectors beyond just agriculture, including tourism, and local economies of regional centres. The natural environment can also be significantly impacted by the spread of biosecurity matter, especially if the biosecurity matter is an invasive plant or animal.



CHEMICAL, BIOLOGICAL OR RADIOLOGICAL EVENT

Chemical, biological or radiological event

CBR events are the eighth highest priority for Queensland. CBR was not reported on in 2017 State Natural Hazard Risk Assessment.[2] Full details of prioritisation are provided below and in Section C - Risk prioritisation.

Understanding the hazard

Chemical, biological or radiological incidents (CBR incidents) are events in which a harmful chemical, biological or radiological material is released as the result of an accident or deliberate criminal act. Exposure to some CBR materials can result in injury, illness and in some instances may be fatal.

The Chemical Biological Radiological Annex,[419] prepared by Queensland Health, informs Table 25, which gives examples of past chemical, biological and radiological incidents.

Agent	Accidental	Deliberate
Chemical	Accidental methyl isocyanate release – Bhopal, India, 1984. 2,500 deaths	Deliberate release of Sarin nerve agent into subway – Tokyo, Japan, 1995. 12 deaths
Biological	Accidental smallpox infection in hospital worker, East Birmingham Medical School – Birmingham, UK, 1978. 1 death	Deliberate release of Anthrax into postal system – USA, 2001 5 deaths.
Radiological	Accidental dispersal of Caesium-137 radiotherapy source by scrap metal dealers – Goiânia, Brazil, 1987 4 deaths	Landmine with attached payload of radioactive material defused by security forces – Argun, Chechnya 1998 No casualties

Table 25: Past chemical, biological and radiological incidents. Source: Queensland Health.

CBR materials – particularly hazardous chemicals – are common in a wide variety of workplaces and businesses are required to manage the associated risks. Under transport, hazardous materials are subject to state and national standards and requirements. According to the Model Work Health and Safety Regulations 2011, individuals and firms that handle these materials are responsible for managing risks associated with handling them.[420] They are required to have plans and procedures for mitigating the risks posed by CBR materials.

Definition

The Queensland Government defines hazardous materials as "substances that can cause adverse health effects such as poisoning, breathing problems, skin rashes, allergic reactions, allergic sensitisation, cancer and other health problems from exposure".[421] Hazardous chemicals may also be classified as dangerous goods under the Australian Dangerous Goods Code.[422] At the Commonwealth level, Safe Work Australia defines hazardous chemicals as "substances, mixtures and articles that can pose a health or physical hazard to humans".[423]

Hazardous chemicals are assigned hazard categories that describe the hazard the chemicals pose to humans. These categories are derived from the Globally Harmonized System of Classification and Labelling of Chemicals (GHS). Categories include a description of the hazard and a ranking from 1 to 5 for the severity of the hazard posed, with 1 being the most hazardous. Some categories are further classified into more specific subcategories based on different factors, including exposure time needed for the hazard to take effect and concentration cut offs.

Categories are also associated with a set of standardised hazard statements (descriptions of the hazard) and pictograms. Hazard statements "may contain information such as relevant routes of exposure, specific organs that may be damaged and the severity of the hazard".[424] There are nine pictograms that represent physical, health and environmental hazards posed by chemicals, shown in Figure 96.

Figure 96: GHS pictograms provide a global language for associated hazards.[424]

For example, sulphuric acid has the hazard category: Skin corrosion – Category 1A. Category 1 is the highest for all hazard categories, and for skin corrosion it is associated with the hazard statement "Causes severe skin burns and eye damage". Category 1A for skin corrosion refers to a concentration of the hazardous material above 5%, and an exposure time of less than or equal to three minutes to experience the effects of the hazard. The pictogram for this hazard is GHS07 – Corrosion.

The Work Health and Safety Regulations 2011 define a hazardous chemical as "any substance, mixture or article that satisfies the criteria for a hazard class in the Globally Harmonized System of Classification and Labelling of Chemicals but not a substance, mixture or article that satisfies the criteria solely for one or more of the following hazard classes:

a) acute toxicity—oral—category 5
b) acute toxicity—dermal—category 5
c) acute toxicity—inhalation—category 5
d) skin corrosion/irritation—category 3
e) serious eye damage/eye irritation— category 2B
f) aspiration hazard—category 2
g) flammable gas—category 2
h) acute hazard to the aquatic environment—category 1, 2 or 3
i) chronic hazard to the aquatic environment—category 1, 2, 3 or 4
j) hazardous to the ozone layer."

For a chemical to be defined as hazardous in the Australian context, it must reach a certain level of hazard to humans, and low-category materials are not included in the definition.

Hazard ratings

Determining hazard ratings for hazmat incidents is difficult, because the effect of a given hazardous material on its environment depends on what hazard the material poses, and what the material comes into contact with. HazMat risks must be assessed according to the risk that they pose, and the hazard values in Table 26 are appropriate if the chemical has a hazard profile that is relevant to where the spill occurs. For example, a release of zinc oxide – a chemical that has hazard statement "Very toxic to aquatic life with long-lasting effects" – should only be assessed according to the risk of it being released in an aquatic environment. If it cannot spread to an aquatic environment, no risk is posed by the hazard.

Some indicative hazard scores are presented in Table 26, based on three variables:

1. The **highest relevant hazard category** of the material, as listed on the Hazardous Chemical Information System. 'Relevance' refers to whether the material is released in a context that makes it likely that the hazards posed by the material will pose a risk, as described above. For example, ammonium biflouride has hazard categories "Acute toxicity – category 3" and "Skin corrosion – category 1B". The highest hazard category is 1B, and therefore a release of the material should be assessed at 1 rather than 3 *if contact with skin is a risk posed by the release of the material*. Otherwise, it should be assessed at 3.
2. The **amount** of the material that is released. 'Small' and 'large' thresholds are based on advice given in the 2018 Australian Emergency Response Guide Book, prepared by the National Transport Commission.[425] Small spills involve releases of less than 208L for liquids and 300kg for solids; greater than these levels are considered large.[1]
3. The **location** of the release. This is divided into four categories:
   a. on-site – in an industrial area or premises that has plans and protocols for handling releases, such as mines, ports, airports, business premises;
   b. off-site, no/low population – not at a location with plans and protocols, but away from population centres, such as rail lines or roads in remote areas;
   c. population centres, low density – in a population centre, but in an area that is more sparsely distributed, meaning that few people are directly affected by the release initially and that exclusion areas are more easily established; and
   d. population centres, high density – in a population area with large population, meaning that larger numbers of people are directly affected by the initial release, and that exclusion areas are more difficult to establish.

		Location							
		On-site		Off-site		Population centre, low density		Population centre, high density	
Amount released		Small	Large	Small	Large	Small	Large	Small	Large
Highest hazard category	5-3	1	1	1	2	2	3	3	4
	2	1	2	2	3	3	4	4	5
	1	2	3	3	4	4	5	5	5

Table 26: Hazard scores for HazMat incidents.

[1]Exceptions to this are certain chemical warfare agents where small spills are releases up to 2kg, and large spills are between 2kg and 25kg. Such releases are, however, extremely unlikely, and therefore 'small' and 'large' is measured according to the general definition. See the Handbook for more information.

The Queensland context

History

Serious hazardous materials (or HazMat) incidents are rare in Queensland, given strict protocols and regulation. Natural hazards such as floods, severe storms or earthquakes can cause the release of hazardous materials – these cascading events are called "Natech" hazards and are common in the wake of natural disasters.[426] Historical examples of major Natech HazMat events in Queensland include the following:

- On 27 December, 2015, a train carrying 200,000 litres of sulphuric acid derailed in floodwaters near Julia Creek.[427,428] Police declared a two kilometre exclusion zone around the scene. Due to floodwaters, sulphuric acid and diesel flowed into a nearby creek. Flooding also significantly impacted access and resupply to the site, as the only alternate route was by road which was also affected.
- On 11 March 2009, the cargo ship Pacific Adventurer spilled 270 tonnes of oil and 31 containers (around 620 tonnes) of ammonium nitrate into Moreton Bay as a result of rough seas produced by Cyclone Hamish.[429,430] The oil slick impacted beaches across the Sunshine Coast, Bribie Island, Moreton Island, and parts of the Brisbane River. About 2,500 workers were deployed for clean-up operations, which continued for around two months.[431]

Projections

The probability of a CBR incident in Queensland is very low across planning regions because of strong regulation and compliance. However, certain areas are more susceptible to CBR incidents than others. In particular, transport corridors and facilities where chemicals are stored and/or manufactured – including at ports, airports, and mines – are particularly at risk. The heatmap in Figure 97 shows the distribution of these higher-probability places across the State.

Future risk factors for CBR risk include:

- the growth of industry requiring hazardous materials.
- the development of population centres near industries and storage facilities – see Other drivers or risk for Queensland: Population and demographic change
- the spread of other freeways, highways, linking roads, and rail infrastructure used to carry the materials
- ongoing efficacy and currency of regulation and compliance.

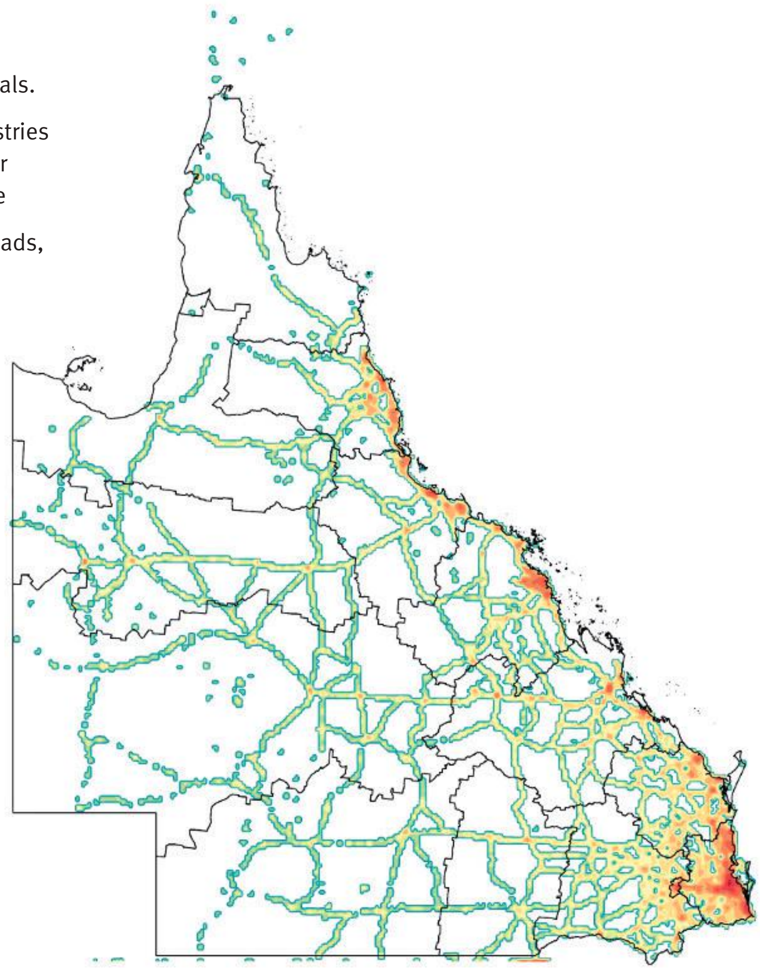


Figure 97: A heatmap of CBR incident risk hotspots across the State. Risk hotspots arise from areas that are involved in the transport of hazardous materials: highways, airports, ports, and rail lines and stations. Source: QFES, data from Queensland Government.

Management of the hazard

Queensland Fire and Emergency Services

Queensland Fire and Emergency Services is the primary response agency for HazMat incidents, and is responsible for operations management and maintenance of the Chemical/HazMat Plan.[432]

Other supporting agencies

- During response, the Queensland Police Service is responsible for coordination and overall control of a HazMat incident.[432]
- Queensland Ambulance Service is responsible for HazMat, biological and radiological operations support, with specialist logistics and specialist paramedics.[1] Queensland Health provides medical and logistical support through medical facilities.[419]
- The Departments of Environment and Science, Agriculture and Fisheries, and Resources provide specific support functions, outlined in the Chemical/Hazmat Plan.[432] These agencies provide advice on methods of prevention and preparedness, and assist with waste management and advice where relevant.[197]

Considerations for disaster management groups

- Is the group aware of the relevant lead and functional agencies, and their associated responsibilities across chemical, biological and radiological events?
- Has the group consulted with these agencies to identify what assistance or support might be expected from them?
- Can the group access, interpret, and act on CBR advice and warnings, and develop messaging appropriate for their communities?
- Is the group aware of the potential for additional concurrent, compounding and cascading hazards?

Additional related hazards and drivers of risk to consider that are assessed within this report include:

If multiple casualties are caused by a CBR event, risks posed by mass casualty incident will coincide with those listed below. Please see the Mass Casualty Incident risk assessment.

HazMat events may also damage or destroy elements of critical infrastructure, causing a critical infrastructure failure.[432]

Natural hazards can also trigger technological disasters, including CBR events. Natural hazards assessed in this report to consider include:

- Tropical cyclone
- Riverine flooding
- Severe thunderstorm
- Bushfire
- Heatwave
- Earthquake
- Tsunami

Scenario

A train carrying large quantities of sulphuric acid derails 10km outside of Julia Creek. The derailment happens in a sparsely populated area. There is a risk that the acid may enter a nearby stream if there is significant rainfall at the site.

Emergency services immediately establish an exclusion zone around the site of the crash. Residents of Julia Creek are told to shelter in their showers until the extent of the spill is known. Fortunately, the risk to local populations is not significant.

Use of the railway is significantly impacted while the hazard is cleaned up and the debris cleared away. The Flinders Highway falls within the exclusion zone, and therefore disruptions to the highway are also experienced. This has significant impacts on the logistics, mining and agricultural sectors, as delays are experienced on the highway, or alternative routes needing to be sought.

The spill is cleaned up in a matter of days and normal operations are resumed. Environmental impacts to the affected area are observed for a long period after the event, and surveillance for potential spread of contaminants following the event is undertaken after the event.

Impacts

Figure 98: Derailment of freight train near Julia Creek, 27 December 2015. Source: Queensland Police Service.

Essential infrastructure

Communications and energy

- Electricity assets in the vicinity of HazMat incidents – especially those that involve fires and/or explosions – may be damaged or destroyed during the incident. This may lead to issues with the electricity network more broadly, depending on the asset in question.
- Restoration of supply times is challenging to evaluate, with the response to the event dependent on the ability for field crews to safely access sites. Damage to the supply chain and transportation routes can hinder opportunities to fly/drive in additional resources to assist and may hamper restoration efforts.

Water

- Contamination of drinking water supply is a particular concern for HazMat incidents.[433,434] Contamination may be caused by contaminants being directly introduced into the water, by hazardous materials contaminating surrounding soil or sand,[435] or by contaminants seeping into the water table e.g. from abandoned mining sites.[436] Even small amounts of hazardous materials in the water supply can have severe adverse effects on public health and on the water infrastructure itself.
- The presence of hazardous materials in waste water – particularly heavy metals in industrial waste water[437,438] – poses a risk to water security overall as it hampers the ability to recycle this water.

Transport

Transport infrastructure

- The greatest risk for HazMat incidents is during the transport of the hazardous materials.[439,440] This means that the transport infrastructure on which the hazardous materials are carried are at risk of damage from incidents involving these materials.
- Infrastructure may be damaged directly by explosions or conflagration caused by collisions of transport vehicles carrying hazardous materials. For example, the derailment of a train in Viareggio, Italy, in 2009, caused a gas leak that lead to successive explosions and destruction of a major railway line, and a road adjacent to the line.[441]
- In Queensland, many of the major routes for the transport of hazardous materials – particularly regional and remote rail lines – do not have redundancies. As such, these routes are particularly at risk from the impacts of a HazMat incident, and if a HazMat incident destroys these parts of the transport network, this will have long-lasting and potentially severe consequences for the State.
- Risks of hazardous materials to airports and airport infrastructure are managed by the airports themselves. The Civil Aviation Safety Regulations 1998 outline safe practices for handling hazardous materials at airports.[442]
- Like airports, risks posed by hazardous materials are managed by the ports themselves, under the direction of the Australian Maritime Safety Authority (AMSA). Under the AMSA's Marine order 41—Carriage of dangerous goods, Australian ports are bound by the International Maritime Dangerous Goods (IMDG) Code, which provides procedures for safe handling and transport of hazardous materials.

Access and resupply

- As noted above, HazMat incidents may damage or destroy parts of the transport network, hampering access and resupply arrangements. This is particularly an issue in regional Queensland, and particularly where there is little or no redundancy in the transport network.
- Damage to or destruction of the transport network may also disrupt access and resupply more broadly, if key transportation routes linking the north and south of the State are affected.
- Highways that act as major supply routes for hazardous materials are at risk of damage or destruction from a HazMat incident. This may disrupt access and resupply during or following another disaster, or may cause shortages of vital goods (e.g. medications, fuel) outside of disaster time.
- Evacuation routes may be impacted by closure of, damage to, or destruction of major roads caused by a HazMat incident. This may significantly impact mass evacuation procedures.
- Railways in Queensland are prone to be impacted by HazMat incidents, as hazardous materials are frequently transported by rail, particularly to major industrial and mining, and train derailments are likely to release hazardous materials that are being transported.[443] Like road infrastructure, rail infrastructure can be taken out of operation, damaged or destroyed during a HazMat incident, hampering access and resupply by rail to regional and rural centres.
- Hazardous materials are stored at and transported through airports, posing a risk of a HazMat incident at airports. Risks to air access and resupply are similar to road and rail: damage or destruction of airport infrastructure can lead to disruptions of normal operations, potentially hampering access and resupply projects.
- Hazardous materials are transported through ports, which makes them prone to incidents, particularly, spills. For example, in December 2020, a spill of two tonnes of sodium cyanide at the Port of Brisbane caused an exclusion zone to be established and a berth to be closed.[444]
- In minor or moderate cases, this can result in reduced capacity as exclusion zones need to be established to contain the incident. In major or severe cases, this can damage or destroy part of the port's infrastructure. Leakage of hazardous materials into water is a particular risk at ports.

Community

- Hazmat incidents in areas where transport of hazardous materials passes through population centres can have medical impacts on local populations.
- Severe incidents involving many injuries or fatalities can seriously impact the social wellbeing of affected communities.

Health and wellbeing

- Chemicals can cause thermal harm, either burns from high temperature if the chemical combusts or frostbite from contact with low-temperature materials.[445] High temperatures can cause external injury from contact or internal injury from inhaling fumes or heated air.
- Certain chemicals – such as hydrogen cyanide and carbon monoxide – reduce the amount of ambient oxygen in an environment. In a confined space, these chemicals can lead to rapid asphyxiation.
- Explosions caused by combustible agents, sudden pressure release or boiling liquid expanding vapour can cause injury or death from direct exposure to the explosion, from shrapnel, or from other causes related to the explosion.
- A wide variety of chemicals themselves can have medical impacts that vary according to the specific material and method of contact. For an extensive list of hazardous chemicals and their effects, see Safe Work Australia's Hazards Chemical Information System.
- Long-term effects of hazardous materials can include chronic illness, such as "progressive organ dysfunction, infertility, birth defects, and cancer".[446] This presents the risk of future costs and burden on the health system if the CBR event is widespread and affects many people.
- In events with multiple casualties, mental health of first responders, friends and family of those affected and community members may be an ongoing issue that requires social support to be provided.[447–449]

Figure 99: A beach closed sign is seen as a result of the oil slick on Kawana Beach which escaped from the container ship 'Pacific Adventurer' during Cyclone Hamish off the coast of Queensland, on March 12, 2009 on the Sunshine Coast, Australia. 650 tonnes of fuel and ammonium nitrate escaped the vessel and affected a 30km area of Moreton Island beaches, as well as the Sunshine Coast. Source: Bradley Kanaris, Getty Images.

Business and economy

- Industries that rely on the hazardous materials – manufacturing and especially mining – may be impacted from a disruption of the supply of these materials. Alternative resupply arrangements may need to be made to ensure these industries can operate at capacity.

- The viability of agricultural land impacted by or adjacent to a HazMat incident can be severely impacted by significant HazMat incidents.
- Fisheries and seafood farms are at risk from oil spills, and chemical contamination which can damage the farm itself and introduce hazardous materials into their produce.[450]
- Tourism, and particularly tourism that relies on access to a natural site, can be impacted by that site being damaged or rendered inaccessible due to a CBR incident.

Natural environment

- Hazardous and toxic materials may spill into bodies of water, causing widespread contamination and severely impacting ecosystems. This is a serious concern for hazards that are identified as toxic for aquatic ecosystems. Further risks are posed for rivers, lakes, dams and reservoirs that are used for drinking and irrigation water.[451]
- Coastal environments are susceptible to HazMat spills and are at greatest risk of oil spills. Oil spills can cause acute effects, such as widespread fatalities among marine life, and chronic effects, such as habitat and species loss, and dramatic changes to the functioning of marine ecosystems.[452]
- Marine ecosystems can be affected long-term by hazardous materials spilled and used in the shipping industry – particularly through the presence of ports and shipyards.[453]

Supporting information

Plans

- According to the Model Work Health and Safety Regulations 2011, individuals and firms that handle hazardous materials are responsible for managing the risks associated with handling them.[420]
- The State Chemical/HazMat Plan[432] specifies the responsibilities of agencies, how to establish operational site control, procedures for securing and controlling HazMat release, and guides the decontamination process.
- The State Biological Disaster Plan[454] details arrangements for the mobilisation and deployment of all the necessary resources to respond to a deliberate biological release affecting human health in Queensland.
- The State Radiological Disaster Plan[455] was developed by Queensland Health to facilitate effective and systematic control of radiological incidents both deliberate and accidental.
- The 2015 Chemical Biological Radiological Annex[419] provides a consistent response framework for planning and management of CBR events. The plan specifies that relevant Queensland Health facilities should have a local CBR sub-plan or procedure which is appropriate, scalable and proportionate to their likely risk of being involved in the response to a CBR type incident. It also provides a list of treatments and controls for local CBR plans.

Technical guidance

- Classifying hazardous chemicals - national guide

Risk summary

CBR incidents are unlikely in Queensland, especially in populated areas. Drivers of risk such as a growing population and growing urban footprint may contribute to increasing risk of HazMat incidents.

National standards for managing CBR events are comprehensive and contribute to the risk of a significant CBR incident being low. Management of the risk of CBR materials is the responsibility of the parties handling these materials. This includes labelling the materials correctly, identifying risks posed by chemical reactions, and providing safety equipment under the *Model Work Health and Safety Regulations 2011* (Commonwealth).[420] These requirements and others decrease the risk posed by the hazardous materials stored at any location, and therefore the overall risk posed by these materials.

CBR incidents can have serious impacts on the community, directly through damage to or destruction of critical infrastructure or injury and death, and indirectly through disrupted supply chains and community mental health. The exposure of CBR materials to the natural environment can have serious and long-lasting effects on the viability of these environments and require clean-up and rehabilitation efforts that last for a sustained period following the incident.

CRITICAL INFRASTRUCTURE FAILURE

Critical infrastructure failure

Due to the complex and wide ranging sources of critical infrastructure failure, critical infrastructure failure has not been prioritised in this report.

Understanding the hazard

Critical infrastructure failure (CIF) refers to a major disruption to a piece of critical infrastructure (CI). 'Critical infrastructure' is an expansive term that covers a range of assets and systems whose failure has a significant impact on security, the economy and basic human needs.[456] These include electricity, telecommunications and ICT networks, but also food systems (supply chains), emergency services systems, and other essential logistical infrastructure.

CI failure is classified as a hazard,[55] and also amplifies the effects of other hazards, by hindering response and recovery to those hazards.[457,458] According to one study, "interdependencies among [critical infrastructure systems] increase the potential for cascading failures and amplify the impact of both large and small scale initial failures into events of catastrophic proportions".[459] CI failure can reveal vulnerabilities in other systems that rely on the infrastructure and can worsen existing weaknesses in these systems.

Impacts of CI failure must be understood within a system. Impacts of CI failure can spread across a system so that distantly related parts of the system are affected. For example, studies have shown that disruption in electricity supply can disrupt availability of water which disrupts the cooling systems of other pieces of infrastructure, restricting their ability to function effectively, resulting in further impacts in other parts of the system.[460] Indeed, CI failure can also cause other CI assets to fail. In a study of flood risk in Cologne, Germany, cascading failure of different CI assets was mapped, as shown in Figure 100.

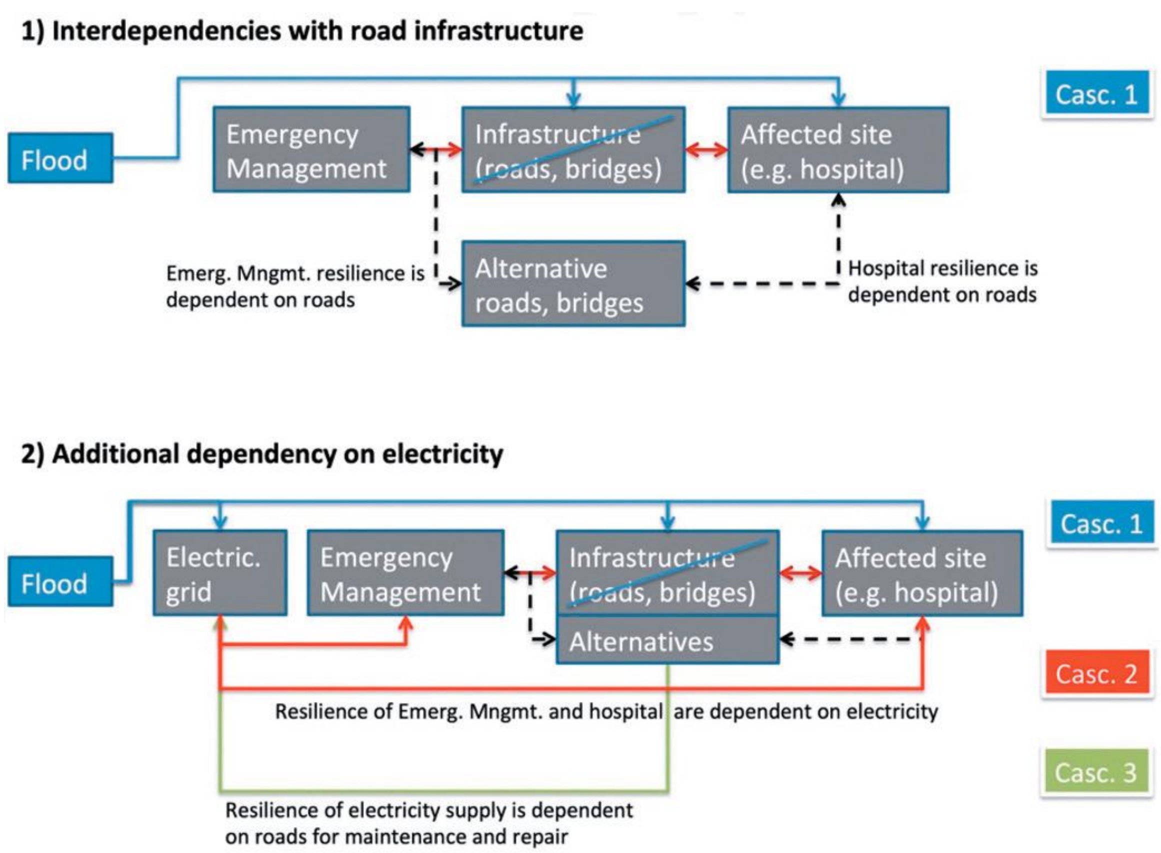


Figure 100: Cascading effects of road infrastructure failure. The direct impact on the road network causes emergency management and other sites to be impacted. In the event of other CI failures, these impacts are amplified. Source: Fekete (2020).[461]

Assessing the risk of CIF, then, can be a challenging exercise, because the causes can be numerous, and the effects can be cascading, as shown in Figure 101. CI failure can result from physical causes – such as tropical cyclones, floods, bushfire and space weather – but it can also be caused by large-scale societal disruptions, such as pandemics, cyber-attacks, terrorist attacks or operator error.

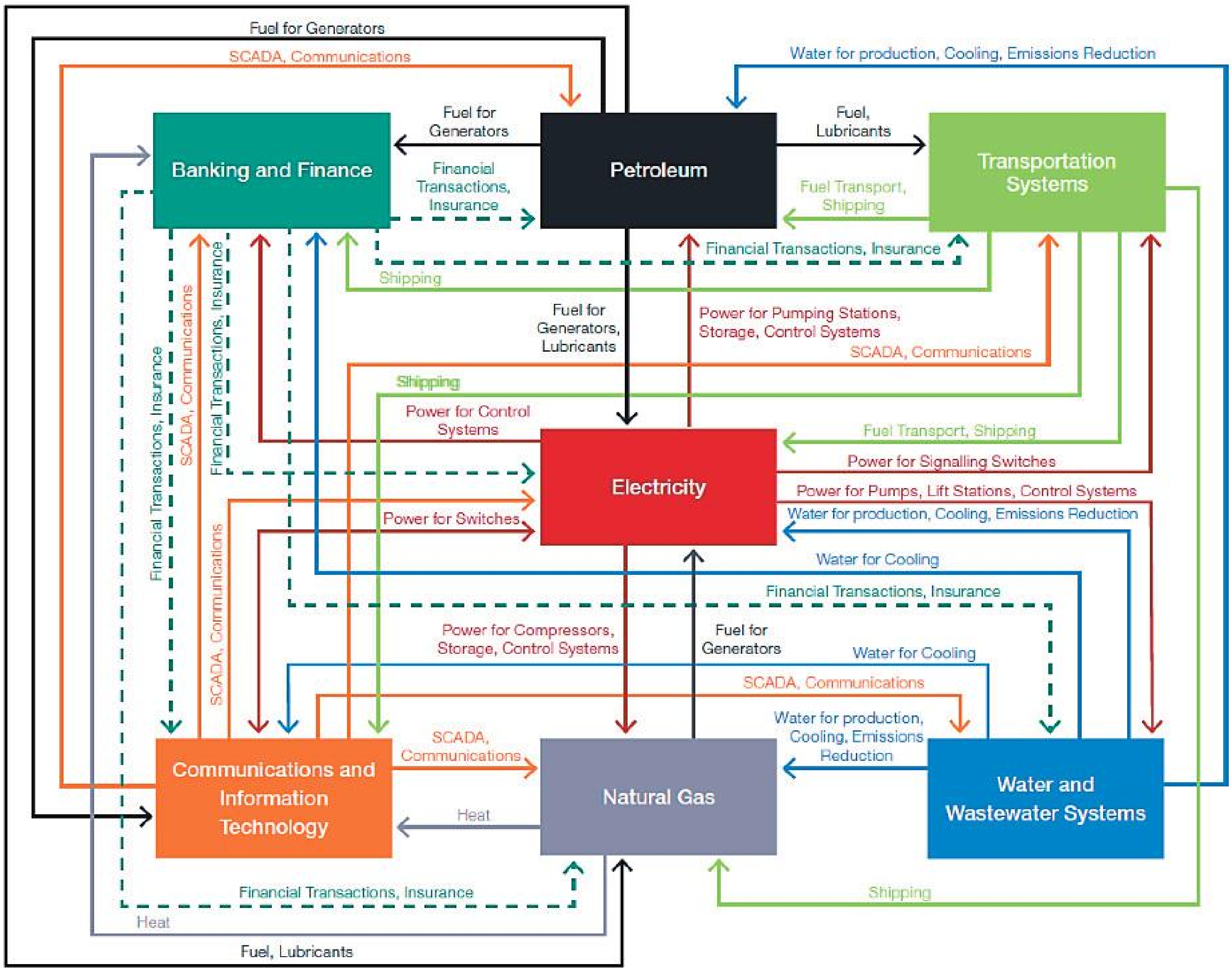


Figure 101: Complex diagram showing an example of interdependencies between infrastructure systems. In particular, it shows the connections between and dependencies across the following sectors: electricity, natural gas, communication and information technology, banking and finance, petroleum, transportation systems, and waste and wastewater systems.[462]

Definition

State, territory and Commonwealth governments share the following understanding of critical infrastructure: "those physical facilities, supply chains, information technologies and communication networks which, if destroyed, degraded or rendered unavailable for an extended period, would significantly impact the social or economic wellbeing of the nation or affect Australia's ability to conduct national defence and ensure national security".[463]

CI may also include intangible assets that are required for the effective functioning of these systems, such as databases and software.

The Commonwealth Security of Critical Infrastructure Act 2018 identifies eleven sectors of critical infrastructure assets:

- Communications
- Data storage or processing
- Financial services and markets
- Water and sewerage
- Energy
- Health care and medical
- Higher education and research
- Food and grocery
- Transport
- Space technology
- Defence industry

The meanings of each of these are provided in the Act. Other assets can be declared critical by the Minister for Home Affairs, in consultation with state and territory governments.

The Queensland context

History

In Queensland, there is an official definition of critical infrastructure. That is, a project may be declared a 'critical infrastructure project' under the Queensland *State Development and Public Works Organisation Act 1971* by the relevant minister. The minister may, by gazette notice, declare a project to be a 'critical infrastructure project', at the same time as declaring it a prescribed project, if the minister considers the project is critical or essential for the State for economic, environmental or social reasons. Critical infrastructure projects are gazetted for a specified timeframe. A list of current critical infrastructure projects is available at the Department of State Development, Infrastructure, Local Government and Planning website.

While the State Development and Public Works Organisation Act 1971 provides a legal basis for the identification of critical infrastructure projects, the legal status of a project does not necessarily impact whether a piece of infrastructure is seen as 'critical' for the purposes of disaster risk management. This determination can be made by Local and District Disaster Management Groups for the purpose of disaster risk assessment and reduction, and management.

In general, for the purposes of disaster risk assessment, critical infrastructure failure will generally apply to:

- electricity production and distribution assets
- water distribution and storage, including dams
- telecommunications assets
- broadcasting assets for television and radio
- major roads, especially where there is no redundancy
- fuel distribution and storage assets
- cyber infrastructure assets, especially those that control physical assets
- loss or corruption of data assets, on which most services and industries rely to operate effectively.

A summary of selected case studies of significant incidents of infrastructure failure – both within and outside of Australia – has been provided in Table 27.

Event	Date	Impact	Cause	Narrative
Texas State power crisis	10-20 February 2021	At the peak of the crisis, over five million people in Texas were without power, some for more than three days. These outages were felt disproportionately in lower-income and minority ethnic areas of the state. By February 21, 70 people had died, with deaths linked to carbon monoxide poisoning, car crashes, drownings, house fires and hypothermia.	Severe winter storms resulting in temperatures as low as -19 °C impacted on inadequately winterised power (natural gas) equipment	In February 2021, the state of Texas suffered a major power crisis, as a result of three severe winter storms sweeping across the United States on 10-11, 13-17 and 15-20 February, a massive electricity generation failure in the state of Texas, and resultant shortages of water, food, and heat. More than 4.5 million homes and businesses were left without power, some for several days. The crisis drew much attention to the state's lack of preparedness for such storms and to a report from US Federal regulators 10 years earlier that had warned Texas its power plants would fail in sufficiently cold conditions. Damages from the blackouts were estimated at $195 billion, making them the costliest disaster in Texas history. According to the Electric Reliability Council of Texas (ERCOT), the Texas power grid was "seconds or minutes away from" complete failure when partial grid shutdowns were implemented.
South Australia blackout	28 September 2016	Almost total loss of electricity to entire state affecting 1.67 million people	Significant storm damage	Gale and storm force winds across wide areas of the state, including at least two tornadoes, damaged multiple elements of critical infrastructure. The state was hit by at least 80,000 lightning strikes. The wind damaged a total of 23 pylons on electricity transmission lines, including damage on three of the four interconnectors connecting the Adelaide area to the north and west of the state.
Warrnambool Exchange fire	22 November 2012	Loss of telecommunications for 20 days, affecting about 100,000 people and 15,000km2 of south west Victoria	Electrical fault causing fire	A fire occurred in the vicinity of the maintenance control room at Telstra's Warrnambool Exchange. The exchange acts as a transmission hub and suffered significant damage to essential telecommunications and broadband equipment.
India blackouts	30-31 July 2012	Two blackouts: the first, affected 300 million people; the second, occurring the next day, affected 600 million people	Over drawing allocated power, increased demand	The detailed cause of the blackouts is still unknown. However, the main reason given is that the power grid is unstable and when overloaded is likely to fail. Numerous commentators have also noted other contributors such poor maintenance, lack of upgrades, lack of investment and a delay in the monsoon season.
Esso Longford gas explosion	25 September 1998	Two people killed, a number of people injured, and all gas supply from the Longford facilities ceased	Equipment failure resulting in a gas explosion and subsequent fires	An explosion took place at the Esso natural gas plant at Longford in Victoria. The fire at the plant was not extinguished until two days later. The Longford plant was shut down immediately. Within days, the Victorian Energy Network Corporation shut down the state's entire gas supply. The resulting gas supply shortage was damaging to Victoria's economy, greatly affecting industry and the commercial sector. Gas supplies to Victoria were severely affected for two weeks.
Quebec blackout	13 March 1989	Total shut down of Hydro-Quebec, the power grid servicing Canada's Quebec province	Solar induced magnetic storm that played havoc with the ionosphere and the Earth's magnetic field	The space weather storm, which resulted from a solar flare, tripped five lines from James Bay and caused a generation loss of 9,450 MW. With a load of some 21,350 MW at that moment, the system was unable to withstand this sudden loss and collapsed within seconds, thereby causing further loss of generation from Churchill Falls and Mania-Outardes. The blackout closed schools and businesses, kept the Montreal Metro shut down during the morning rush hour and disrupted Dorval Airport, delaying flights.

Table 27: Notable infrastructure failure events within and outside of Australia. Source: QFES.

Management of the hazard

Key functions

While critical infrastructure operators have a lead role in managing and maintaining their infrastructure assets and networks, critical infrastructure resilience to natural disasters is a shared responsibility. The preceding hazard assessments illustrates a continuing need to promote this shared responsibility and encourage disaster-resilient communities.

A disaster-resilient community, according to the Queensland Strategy for Disaster Resilience, is one where people in that community have (among other elements):[31]

- an awareness of the hazards and risks that affect them in their local area, including an awareness of who and what is most vulnerable, and understand what actions they need to take in order to prepare for and mitigate these risks
- taken action to anticipate disasters and protect themselves, their assets and to commit the necessary resources to organise themselves before, during and after a disaster.

Recent events – such as the 2021 Texas power crisis, in which a series of winter storms caused power outages that led to shortages of water, food and heat – have highlighted that communities and individuals can be significantly underprepared for the consequential impacts (e.g. loss of power, water and telecommunications) on their ability to maintain access to information technology, essential services and conduct basic domestic tasks, such as cooking and washing.

A lack of sufficient preparedness within individuals and communities has the potential to significantly constrain local disaster response and recovery as attention and efforts are diverted to aid households with no redundancy in power, water or essential goods.

Roles and responsibilities

Critical infrastructure can span many sectors. For the purposes of this assessment, the roles and responsibilities will focus on three key areas. They are:

- energy
- telecommunications
- supply chain (food and fuel).

The key organisations which hold key responsibilities in energy emergency management are detailed in Table 28.

Figure 102: Callide coal fired power station. Source: Alamy

Figure 103: Damage to Unit C4 at Callide Power Station following the plant fire on 25 May, 2021. Source: CS Energy.

<table>
<tr><th>Agency</th><th>Roles and responsibilities</th></tr>
<tr><td>Powerlink</td><td>Advisor to the State Disaster Coordination Group
Holds the lead roles of Qld Responsible Officer and Qld Jurisdictional System Security Coordinator, and potentially the NEM response lead (if event is rated at Level 3 or below), throughout the likely activation of NEMEMF's PSEMP
A Level 3 event is an event that impacts a single jurisdiction, and does not impact multiple NEM participants</td></tr>
<tr><td>Energy Queensland</td><td>As a response agency, Energy Queensland works to restore any supply interruptions to the electricity distribution network
Responsible for the development of an 'Electricity Restoration Plan' based upon impact assessments in affected locations that align with business operational plans
Provides advice and support to state, district and local disaster management groups where required to manage the consequences of disruption</td></tr>
<tr><td>Australian Energy Market Operator (AEMO)</td><td>In the event of an energy emergency such as a black system event, AEMO is responsible for identifying and implementing actions to restore the power system to a secure operating state under the National Electricity Rules.
AEMO carries out this responsibility in accordance with its Power System Emergency Management Plan prepared with reference to jurisdictional energy emergency arrangements
As such, AEMO coordinates and manages emergency arrangements across the NEM, collaborating with jurisdictions, emergency services and industry participants to ensure that planning and preparedness arrangements are in place and able to respond to a major disruption of energy supply
The National Electricity Market (NEM) Responsible Officer (RO): is the emergency contact point at AEMO during an electricity emergency</td></tr>
<tr><td>Department of Energy and Public Works</td><td>Ensures integration with the Queensland Disaster Management Arrangements
Holds the role of Jurisdictional Designated Officer and advising the Minister of the event and keeping the Minister informed (as per the PSEMP)
Minister is responsible for administering the Electricity Act 1994, including the emergency powers instrument (Emergency Rationing Order – restricting use of electricity by customers)

The Queensland Jurisdictional Relevant Official: is the Minister administering the energy portfolio in Queensland, holding powers under the Electricity Act 1994 and the Gas Supply Act 2003 to ration or restrict supply of electricity to customers in the unlikely event of an energy emergency such as a black system event.
These powers are enacted by the Minister and would only be used when AEMO and Powerlink advise DEPW that rationing is required to maintain system security and reliability. The powers are rarely used as there are other tools government can use in response, such as voluntary restrictions or public messaging.
The Queensland Jurisdictional Designated Officer (JDO): is a senior executive of the Energy Division of the DEPW. During an emergency, the JDO is responsible for all communications to the Relevant Official (Minister) and senior staff. The JDO provides briefings, advice and support to the Minister to inform of key events, issues and risks. If required, the JDO facilitates the process for the Minister to exercise electricity specific emergency powers.
The DEPW JDO works closely with Powerlink, AEMO and Energy Queensland Limited to understand energy emergency events and is responsible for advising the Minister on potential response mechanisms and use of emergency powers if required (e.g. voluntary or mandatory restrictions, emergency rationing orders).
Queensland's Disaster Management Arrangements may be stood up in the event of an emergency. The Energy Division has an emergency and disaster management coordination team, which includes departmental communications, operations and liaison with the Queensland State Disaster Coordination Centre. This team is convened by the JCO/JDO and will provide advice and support to the JCO/JDO in response to any declared energy emergency.
The Responsible Officer (RO): Acts as the liaison and emergency contact point between Queensland, AEMO and if relevant, other state ROs.
The Jurisdictional System Security Coordinator (JSSC): The JSSC specifies Sensitive Loads and load shedding priorities in advance of an emergency.
They are responsible for working with AEMO during forecast Lack of Reserve conditions, load shedding, restoration of loads and other operational actions.
Currently, Powerlink representatives hold the JRO and JSSC roles within Qld, and these officers are the primary emergency contact point for AEMO, and provide critical advice and information to the Queensland Jurisdictional Designated Officer (JDO) within the Department of Energy and Public Works (DEPW) and Minister as required.
</td></tr>
</table>

Table 28: Key Energy emergency management organisations and their role and responsibilities.

Considerations for disaster management groups

- How would the group manage the following to minimise impacts to the community:
  - › unexpected loss of mains electricity?
  - › temporary disruption to the availability of gas, oil and fuel?
  - › loss of telecommunications?
  - › loss of, disruption to, or compromise of IT systems?
  - › disruption to the supply of mains water and sewerage?
  - › disruption affecting key suppliers or partners?
  - › significant disruption to transport?
- Has the group considered critical infrastructure failure within its assessment of other hazard events?
- What critical community infrastructure is not currently fitted for or with redundancy?
- Are there gaps in the resupply or maintenance plan for this redundancy during the event?
- Are there agreements with local fuel suppliers (e.g. service stations) to provide fuel for council/emergency services?
- What contingencies are available if restoration activities and supply chains continue are disrupted for longer than five days?

The following hazards assessed within this report can contribute to the risk of critical infrastructure failure. The concurrent occurrence multiple hazards increase the likelihood of critical infrastructure failure:

- Tropical cyclone
- Riverine flooding
- Severe thunderstorm
- Heatwave
- Bushfire
- Pandemic
- Earthquake
- Tsunami
- CBR incident.

Scenario

Refer to other assessments within this report, which may include a critical infrastructure component, for a relevant scenario.

Impacts

It is important to consider that restoration of critical infrastructure following broad scale impact, including both power and telecommunications, will be prioritised based on greatest need and/or criticality of downstream assets (i.e. size of population affected or if impact includes loss of power to a major hospital where redundancy is insufficient to maintain services).

"We should not expect critical infrastructure to be completely resistant to damage, or for essential services to be immune to disruption. Individuals and communities should be aware that they may lose power, water and electricity (including information-technology services) and may be unable to access essential goods such as food at critical moments."[33]

Essential infrastructure

Communications and energy

- Disruption to electricity infrastructure is perhaps the most significant risk of critical infrastructure failure. Failure of electricity infrastructure leads to cascading failures of other systems that depend on electricity. Loss of electricity can affect lighting, heating, air conditioning and electronic equipment, and could result in data loss or corruption. If the electricity outage is widespread, secondary effects can impact all other critical infrastructure systems including:
  - loss of mains water and sewerage
  - loss of mobile communications
  - disruption to financial transactions
  - closure of petrol stations.
- Electricity generation from other sources – particularly oil and gas infrastructure – can be impacted by hazards that cause critical infrastructure failure.[464] This further worsens the impacts of critical infrastructure failure by weakening possible energy generation.
- While exposure of electricity and communications infrastructure to space weather may be rare, the potential impacts can be significant and wide reaching.[465,466] Space weather is “a collective term for different solar or space phenomena that can detrimentally affect technology”, such solar flares or coronial mass ejections. These events can create current within electricity networks, which can lead to those electricity networks tripping automatic shutdown protocols or, in extreme events, cause widespread damage to electricity infrastructure.[466]
- Much of the critical infrastructure operated by council and State government (e.g. hospitals) is fitted with or for generator back-up in the event of power outages. However, levels of fuel reserves, resupply arrangements and operational maintenance available before, during and after impact is highly variable across Queensland. The current standard of back-up generation may be insufficient to maintain services greater than the recommended 72 hours.
- Australia’s and therefore Queensland’s fuel security is highly dependent on global maritime transport. As of December 2018, Australia holds 18, 22 and 23 days of consumption cover for petrol, diesel and jet fuel respectively.[467]
- Fuel disruption events are most likely to occur from unforeseen failures in the supply and distribution network, for example, fires at refineries or terminals, the grounding of a trucking fleet, commercial contractual disputes or extreme weather events. Threats may include malicious attacks on infrastructure, either from physical interference or from cyber events.[467]

Water

- Water supply can be impacted by critical infrastructure failure, especially when water supply is dependent on electricity to be delivered effectively.[468]
- System status monitoring systems can be disrupted, making management of essential and largescale infrastructure (e.g. dams, water treatment) challenging.[460] The impacts of this failure may be significant if CIF occurs concurrently with other hazards, such as flooding.
- During previous events, key areas of concern have included isolation of treatment plants, access to equipment, and loss of power and communications to plant supervisory control and data acquisition (SCADA) systems to determine the efficacy of schemes during an event. Lightning often directly impacts treatment and pumping SCADA systems and the loss of mains power will have a secondary impact on an inability to operate electrical pumps, electrical dosing and electrically operated instrumentation.[71]

Transport

Transport infrastructure

- Transport infrastructure itself may be the affected element of a CIF, through being rendered inoperable damage or disruption. This can cause other parts of the critical infrastructure network to be inoperative.[461]

Access and resupply

- Disruptions to critical infrastructure can impact the ability to resupply communities in response to other disasters.[469]
- Financial infrastructure – especially EFTPOS and ATMs – can be impacted by the failure of electricity infrastructure, resulting in residents being unable to purchase essential items.
- Food security and safety can be impacted by long-term electricity disruption (i.e. disruption of refrigeration supply) or by disruption of food supply networks.
- Fuel supplies and stockpiles may be depleted due to long-term power outages.[470] This may lead to fuel rationing in extreme circumstances.

Community

Households

- Disruption of communications infrastructure can lead to communities and individuals being isolated or uncontactable. This poses a risk particularly for people with higher care needs.
- People within affected areas may have difficulty contacting family members or loved ones during a CIF event, which may alter their behaviour.

Community services and infrastructure

- Business-as-usual delivery of social services can be disrupted by CIF.[469] This may have significant impacts on community wellbeing and mental health.
- Social infrastructure may be impacted by disruption to essential services such as power, water and communications.
- Effective response by emergency services to other hazards can be hampered by critical infrastructure failure, particularly of electricity and telecommunications networks.[470]
- The ability for the dissemination of true and correct information can be hampered by CIF. Disruption of these dissemination networks can lead to further CI failures – such as congestion on critical transport infrastructure.

Health and wellbeing

Physical and mental health

- The hazards that have the potential to cause CIF – such as bushfire or tropical cyclone – may also have direct impacts on patient physical or mental health. If CIF has occurred, these patients may be unable to access timely care, especially for physical injury.

Health care and infrastructure

- Provision of medical care can be severely impacted by long-term power disruptions. For example, an ice storm in Canada in 1998 caused long-term power outages, which resulted in 30 deaths.[471]
- If the CIF occurs concurrently with another hazard that causes significant numbers of casualties, medical care may be overwhelmed by demand.[472] The availability of staff and beds to care for patients may be insufficient to meet demand.[473] This may cause resourcing issues on the other services provided by the facilities, reducing the overall availability of care.

Business and economy

- Because of the widespread economic reliance on critical infrastructure, serious disruptions to or failures of critical infrastructure can result in widespread economic losses.[474–477] The 2016 blackout in South Australia is estimated to have cost the State $367 million.[478] These economic impacts can be felt long after the event.
- Physical infrastructure failure disrupts logistic networks that many regional economies rely on.
- Failure of digital infrastructure, particularly protracted failure, can have a significant impact on businesses. For larger, service-based businesses, this would be hamper their ability to operate successfully. But this is likely to also be the case for everyday operations of small businesses – such as financial reporting, stock and inventory, and booking management.

Natural environment

- Critical infrastructure failure can lead to a disruption in environmental monitoring equipment, which may hamper environmental management efforts.

Supporting information

Plans and procedures

Australian Energy Market Operator

- Power System Emergency Management Plan

Australian Government, Department of Home Affairs

- Critical infrastructure resilience strategy: Plan
- Critical infrastructure resilience strategy: Policy statement.

Australian Government, Department of Industry, Science, Energy and Resources

- National Liquid Fuel Emergency Response Plan.

Powerlink

Powerlink has several plans to respond to a critical infrastructure incident. These include:

- Network Incident Management Plans
- Crisis and Emergency Management Plans
- Hazard-specific Plans.

Energy Queensland

Energy Queensland has several plans which support preparedness activities and response. These include:

- Fault Response Escalation Framework
- Emergency Management Distribution Plan
- Flood Risk Management Plan.

The Fault Response Escalation Framework dictates the business response structure whether it is a local, regional or whole of business response. The Emergency Management Distribution Plan includes requirements to liaise with the relevant and affected disaster management groups.

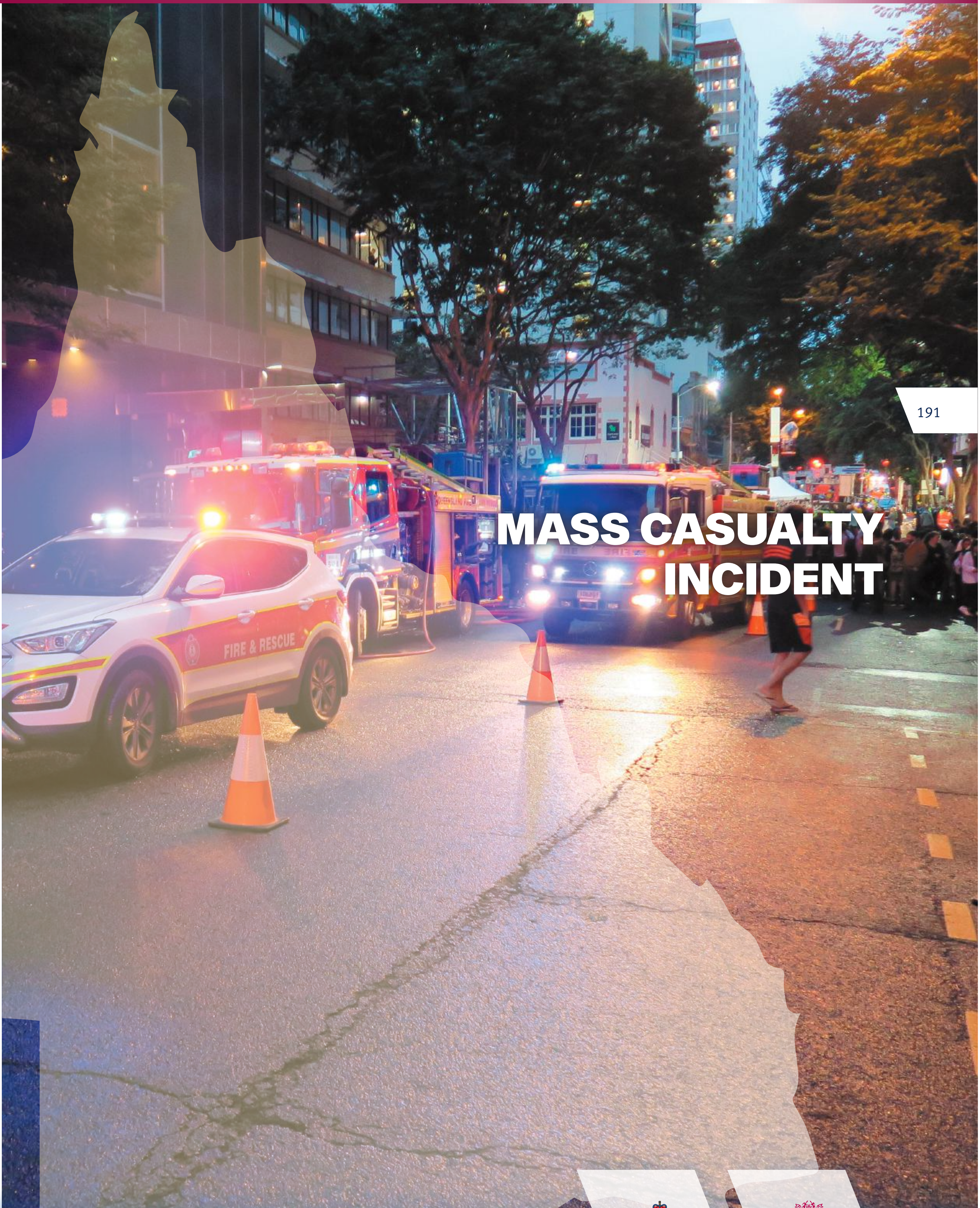
Risk summary

Critical infrastructure failure can arise from a range of sources, including natural hazards as well as human acts or errors. Critical infrastructure failure itself can cascade and compound to cause failures to other parts of the infrastructure system. Particualrly severe critical infrastructure failures can last on the order of days or weeks, and may cause widespread shortages in essential goods and services.

While critical infrastructure is generally of higher resilience than other infrastructure, it is not completely resistant to damage or disruption. Critical infrastructure assets can be damaged or destroyed by severe natural hazards, but can supply of services by critical infrastructure providers can also be significantly impacted by delibrate actions, such as explosives or attacks through computer networks. Where impacted, restoration of critical infrastructure following broad scale impact is generally prioritised according to greatest need and/or criticality of downstream assets.

Households and communities may lose power, water and electricity (including communications services) and may be unable to access essential goods and services. In particular, the delivery of health services can be significantly disrupted, particularly for more vulnerable populations. The economic impacts of a critical infrastructure failure event can be significant and long-lasting, and businesses of all sizes can be seriously disrupted due to these events.

MASS CASUALTY INCIDENT



Mass casualty incident

Due to the complex and wide ranging sources of mass casualty incidents, mass casualty incidents have not been prioritised in this report.

Understanding the hazard

Mass casualty incidents (MCI) are not classified as a hazard. Rather, the occurrence of a mass casualty incident can be caused by a diverse range of events. The principles and management of an MCI typically do not change significantly regardless of the initial cause. While specific incidents will require industries and departments to be involved (such as aviation during an event at an airport), plans could be applied consistently across the field of possibilities, if they are robust in nature.

Therefore, the information presented below will be targeted not only at the specific scenario but also at the management priorities generally of State entities. Within this analysis will be a communication of the roles and responsibilities of disaster management groups (DMGs) which will highlight potential 'best practice' collaborative incident management and mid- to long-term management.

Definition

A mass casualty incident (MCI) is defined in the State Disaster Management Plan as "an incident or event where the location, number, severity or type of live casualties requires extraordinary resources".[1,479]

MCIs may be the result of:

- man-made disasters or emergency events such as transport accidents, industrial incidents or terrorism
- natural disasters such as earthquakes and bushfires or anticipated events such as cyclones or floods where warning may be available
- epidemics/pandemics and the care of evacuated populations.

According to the Queensland Ambulance Service, "an MCI occurs when the initial response is overwhelmed – that is, when the number of casualties and/or the severity of their injuries exceed the capacity of first responders, preventing effective management and transport. The successful management of an MCI requires the effective use of resources to create balance between the available supply of health personnel and equipment, and the demands posed by the multi-casualty incident."[480]

Examples of chief causes for MCIs include transport accidents (road, rail, aircraft, watercraft), terrorist attacks (especially bombings, shootings, and chemical attacks), industrial incidents (chemical explosions, HazMat spills), fires in confined spaces or other catastrophic natural hazards.

The Queensland context

History

Mass casualty incidents are rare in Queensland, due to high safety standards and regulations. Some historical examples in Australia include:

- In June 2015, a gas bottle attached to a café in Ravenshoe was struck and exploded, killing two and leaving 19 with significant injuries, especially burns.[481]
- The Victorian Black Saturday bushfires in 2009 saw 173 people killed in the fires with 414 people presenting to emergency departments.[482]
- Gillies Range Bus Crash, Cairns in 1987 where a bus carrying high school children ran off a cliff due to faulty brakes; eight people died.[483,484]

Management of the event

Queensland Health

Queensland Health is the responsible agency for the provision of an integrated response to mass casualty management. Health and Hospital Services (HHSs) have local responsibility for management of MCIs occurring in Queensland, within their own DDMG frameworks.

Queensland Health has a disaster management structure that sits alongside QMDA. At the State level is the State Health Emergency Coordination Centre (SHECC), which acts as the coordinating body for responses to health emergencies. The SHECC also provides a vital reporting function, and coordinates communication and media to ensure consistent messaging. At a district level, each Hospital and Health Service (HHS) has a Health Emergency Operations Centre (HEOC). The SHECC interfaces with HEOCS, which may be stood up by any HHS across the State. HEOCs can be activated without a SHECC being stood up, if the health emergency is of a smaller scale. More information on this structure can be found in the Queensland Health Disaster and Emergency Incident Plan.

Queensland Ambulance Service

Supporting Queensland Health, the Queensland Ambulance Service has primary medical responsibility for the scene of the mass casualty incident and provides road transport capability. Site Health Commander (SiteHC) works with the QAS leads the Site Health Team (SiteHT). Retrieval Services Queensland (RSQ) coordinates aeromedical transport.

Queensland Police Service

The Queensland Police Service maintains control of the MCI site (outer cordon and inner cordon). The QPS will also assist with investigating the causes of MCIs. Queensland Fire and Emergency Services (QFES) provides scene safety advice when it is the lead combat agency.

Other disaster management stakeholders

Depending on the type of event, other stakeholders may include:

- Airservices Australia
- Civil Aviation Safety Authority
- Department of Transport and Main Roads
- Queensland Rail
- Public transport providers.

Considerations for disaster management groups

- Can the group identify housing, community facilities and other buildings to provide safe refuge from natural hazards?
- Are road safety measures in place to reduce the likelihood of transport related mass casualty incident?
- Is the community able to receive and respond to warnings and directions for evacuation?
- Is there sufficient first aid and search and rescue capabilities available to respond to mass casualty incident?
- Are pre-hospital and hospital care (including essential surgery and emergency care) capabilities able to provide surge capacity to manage mass casualty incident?
- Is psychosocial support available for the affected community to manage mental health effects?

The following hazards are more likely lead to a mass casualty incident:

- Earthquake
- Tsunami
- Pandemic
- Biosecurity
- CBR event

Scenario

Refer to Tsunami scenario.

Impacts

Essential infrastructure

- Depending on the nature of the cause, an MCI may have significant effects on essential infrastructure. MCIs that are caused by or include explosions or conflagrations – such as bomb blasts, aircraft crashes or train derailments – may damage or destroy parts of the infrastructure network.
- The need to move significant numbers of patients may congest the road network, making patient transport more difficult, and also impacting the delivery of other vital services.
- Aerial transport may be required to transport patients if the road network is compromised. This provides an additional logistical challenge to complex situations.[485]

Transport

- Access and resupply will be affected by the impacts on infrastructure noted above, particularly in the case of a large explosion. Depending on the scope of the event, access and resupply may be disrupted for a significant length of time.
- Evacuation of affected persons must occur in a timely and efficient manner to maximise survival rates following the MCI.[486–488] Evacuation of affected persons may be hampered by damaged or destroyed infrastructure, or – if the scale of the event is large – by limited emergency service capacity.
- Evacuations following MCIs require the appropriate triage of patients to balance patient need, local medical capacity and capacity of local infrastructure. This can be particularly challenging in regional and rural areas where resources are typically more limited.
- If the MCI occurs at a major transport hub – such as an airport or a port – then the damage caused to the hub can impact on the resupply of everyday consumer goods for an extended period. In this case, alternative resupply arrangements would need to be found.

Community

Households

- Social cohesion can be impacted by MCIs, particularly following terrorist incidents.[489,490] This may impact preparedness to other disasters by impacted community trust and resilience.

Social infrastructure

- Patronage of services and infrastructure associated with the MCI may decline, and disruption to services may occur for some time following an MCI. For instance, in the months after the 2005 London Tube bombings, ridership of the network fell by 8.5%.[491]

Health and wellbeing

- Medical facilities may be overwhelmed with the large influx of patients.[472] The availability of staff and beds to care for patients may be insufficient to meet demand. This may cause resourcing issues on the other services provided by the facilities, reducing the overall availability of care.[473]
- Severe burns may be sustained by a large number of patients during the MCI, either as a result of fire[492] or chemicals.[493,494] Severe burns require specific treatment strategies that are not generally possible outside of a major hospital.[495] Demand for these services beyond usual capacity requires additional planning and procedures.[492,493,496]

- Widespread smoke inhalation may also arise as the result of an MCI.[497–499] Like burns, smoke inhalation requires specific treatment plans, and triage strategies to mitigate lack of capacity at hospitals would be beneficial.
- Concurrent transportation of many patients by ambulance is likely to require resources beyond the local ambulance network. Local Ambulance Service Networks (LASNs) are required to plan and activate escalation plans to ensure the needs of the community are met in times of surge.[472]
- The capacity of hospital morgues may be impacted. Deceased patients at the MCI would stay in situ for some time due to initial investigations and would be dealt with separately to transported patients deceased after treatment and transport. Mobile arrangements would be made by the QPS to collect and hold deceased patients in stasis.[472]
- The mental health impacts on medical and clinical staff after an MCI can be significant due to long work hours and the nature of managing and responding to an influx of patients presenting with a wide range of injuries in varying degrees of severity.[447]
- Members of the public may also experience negative mental health consequences after an MCI. Survivors who experienced the MCI first-hand are likely to require mental health support following the incident.[500] General members of the public may also experience distress and increased anxiety following the event.[491,501]

Business and economy

- If the cause of the MCI is transport-related, industries that rely on the infrastructure may be impacted. For instance, airports and airline assets may be damaged, which will impact on the airport's continued operation[472] – this is similar for rail infrastructure and ports and harbours for MCIs that result from respective incidents.
- Studies have suggested that businesses near the site of MCIs can suffer economically, even if not directly impacted by the event. Analysis also showed a fall in house prices around transit hubs following the London Tube bombings.[502]

Natural environment

- Hazards that cause or coincide with MCIs may damage the environment, through spillage of fuels or other hazardous materials, or explosions and fires that spread to wild areas.

Supporting information

Plans and procedures

The plans for a mass casualty incident, in order of hierarchy are as follows:

- AUSTRAUMAPLAN – the federal government response plan for Mass Casualty Incidents of National Consequence
- QHDISPLAN, the Queensland Health Disaster and Emergency Incident Plan, of which the Mass Casualty Sub-plan (QH-MCI) is annexed
- Hospital and Health Service (HHS) Mass Casualty Incident Plans
- Code Brown Plan & Internal Mass Casualty Plans

Other plans include:

- Queensland Ambulance Service State Major Incident and Disaster Plan
- QAS Clinical Practice Guideline – Multi Casualty Incidents
- Technical guidance

Risk summary

Mass casualty incidents may result from technological disasters or emergency events such as transport accidents, industrial incidents or terrorism, natural hazards such as earthquakes, bushfires, cyclones or floods and epidemics/pandemics. Mass casualty incidents are characterised by a large quantity, severity or diversity of injuries – or all of these occurring simultaneously – that can rapidly overwhelm the capacity of local medical resources to deliver comprehensive and definitive medical care. Whether an incdent is a mass casualty incident, then, does not depend on the number of casualties in absolute terms, but on whether the capacity of local medical resources.

Casualties associated with natural disasters, particularly rapid-onset disasters, are overwhelmingly due to blunt trauma, crush-related injuries, drowning and mental health issues. Many deaths following disasters are preventable with rapid medical care. Severe trauma and wounds may occur as a result of collapsing infrastructure and transport related injury. During flooding and tsunami, drowning is a major cause of death. Burns and smoke inhalation are a major cause of death and injury during bushfires. Bushfires and other disaster events may also contribute to transport related injuries and other forms of injury or trauma as people seek safety and refuge. Defined pre-hospital search and rescue and triage are essential to determine patient treatment and transport priorities to save lives and optimise resources.

Figure 104: Recovery efforts underway after the 1997 Thredbo landslide. Source: Obtained from the Australian Institute for Disaster Resilience, Commonwealth of Australia 2021.

ADDITIONAL DRIVERS OF RISK FOR QUEENSLAND

Biodiversity and ecosystem loss

A major driver of disaster risk, particularly in the face of climate change, is the loss of biodiversity and associated ecosystems. Globally, the rate of ecosystem loss and species extinction has rapidly increased in recent decades.[503–506] These trends have been observed in Queensland, and are projected to continue.[507,508]

The loss of these ecosystems appears to worsen the impacts climate change.88 The Biodiversity and Ecosystems Climate Adaptation Plan[88] (BCE-CAP) notes that:

> "Queensland is facing a future of increasing biodiversity loss and ongoing declines in ecosystem integrity and function, in part due to human-induced changes in our climate such as increasing temperature, changed rainfall patterns and more intense heatwaves, droughts, fires, cyclones and floods. As well as the direct impacts of these climatic changes, climate change will compound the effects of habitat loss, pollution and invasive species."

The loss of ecosystems can have serious implications for disaster risk reduction. Outside of their intrinsic value, ecosystems provide important 'services' that have measurable economic benefits.[509–513] This is clear in industries such as tourism and agriculture, which both rely heavily on the viability of local ecosystems to function. However, environmental economists have also observed that certain ecosystems have benefits beyond these examples.

For instance, mangrove forests provide "raw materials and food, coastal protection, erosion control, water purification, maintenance of fisheries, [and] carbon sequestration".[514] The estimated value of mangrove forest preventing coastal erosion alone is estimated to be US$3,679 (AU$4,740) per hectare, per year in Thailand.[515] This method shows the value these ecosystems provide and illustrate what is lost when these ecosystems are impacted.

A 1997 estimate[516] of the average value-add globally of ecosystem services is US$33 trillion (AU$42.5 trillion) per year, with a revised estimate in 2014 of US$125 trillion (AU$161.04 trillion) per year.[517] It is estimated that between US$4.3 and US$20.2 trillion (AU$5.5 and AU$26 trillion) per year is lost due to land use change,[517] and estimated that the cost-benefit ratio of destroying productive ecosystems is 100:1.[509]

These ecosystem services play an important role in mitigating and reducing disaster and climate risk.[37,518–521] For example:

- foliage and patches of vegetation substantially reduce the severity of summer heatwaves[7,522]
- healthy soil microbiomes can mitigate the effects of climate change by increasing water retention and sequestrating carbon[523]
- loss of biodiversity may lead to increases in fuel weight in bushfire-prone areas[524]
- intertidal wetlands and reefs protect coasts from erosion by reducing wave energy and increasing sedimentation.[525]

A loss of ecosystems and biodiversity within these ecosystems may seriously amplify the impacts of disasters under climate change, as these important mitigating systems are removed.

Queensland bio-regions that are particularly exposed to disruption due to climate change are western Queensland, the Wet Tropics, the Great Barrier Reef (GBR) in general and marine regions in the southern part of the GBR in particular, the Gulf of Carpentaria and South East Queensland.[88,526] Ecosystems that are exposed include tropical savanna woodlands, drier rainforest types, coastal floodplains and wetlands, ecosystems at high altitudes, and ecosystems with significant biodiversity (e.g. the Wet Tropics).[526]

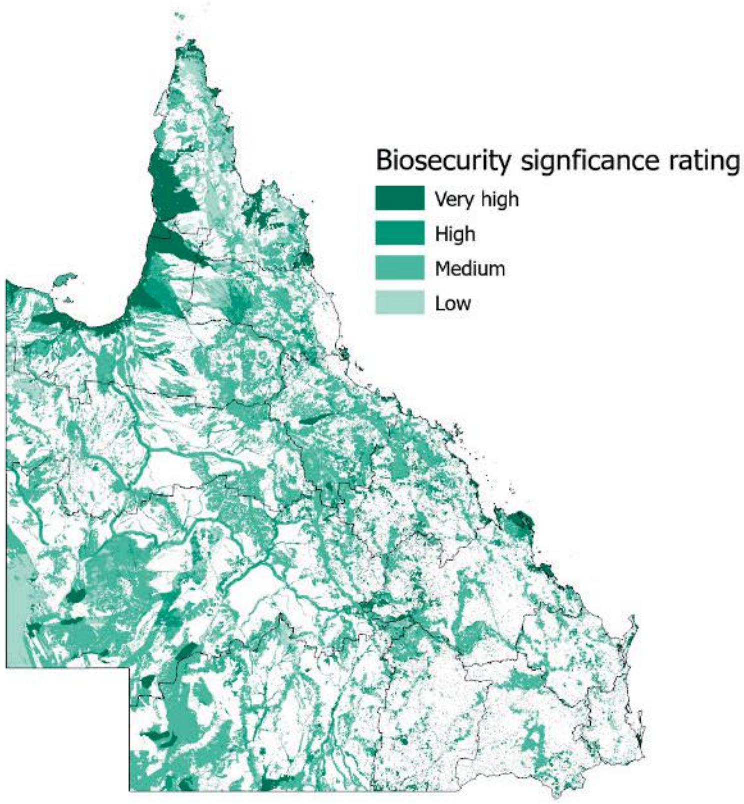


Figure 105: Areas of State biodiversity significance. Source: QFES, data from DES.

Population and demographic change

A key driver of risk for many of the hazards analysed in this report in the Queensland context is a large-scale change in population and demographics. As populations grow and age, and as urban footprints expand, the risk profile of these communities changes. An aging population is more vulnerable to many hazards – particularly heatwave,[527] pandemic, and the health-related impacts of the other hazards. A growing population, a growing number of dwellings, and an increase in the amount of infrastructure all increase exposure to disasters. Finally, even the likelihood and severity of certain hazards – such as thunderstorm[154] and flooding[107] – may be impacted by increased urban footprint, particularly into high-risk areas such as floodplains or dry bush.

Figure 106: Flooded street on 28 February, 2022 in West End, Brisbane, Queensland, Australia. Source: Shutterstock.

Queensland Government

Population

The population in most regions will continue to grow through to 2041 as shown in Table 29.

Region	Estimated resident population (000s)				
	2021	2026	2031	2036	2041
Cape York	40.45	41.71	43.15	44.42	45.60
Central Queensland	288.58	299.76	314.36	328.78	342.31
Central West	38.04	37.24	36.85	36.51	36.18
Darling Downs	387.16	402.13	418.05	433.85	448.46
Far North Queensland	293.90	312.35	332.30	351.84	370.93
Gulf of Carpentaria	38.02	38.18	38.56	38.81	39.00
Mackay, Isaac and Whitsunday	215.72	225.20	237.24	249.64	262.46
Maranoa-Balonne	52.40	51.57	51.05	50.51	49.90
North Queensland	279.11	297.15	317.23	337.41	357.54
North West	40.51	39.86	39.75	39.57	39.29
South East	3,901.65	4,291.36	4,694.72	5,096.04	5,494.36
South West	34.45	33.35	32.53	31.74	30.93
Wide Bay Burnett	403.98	423.34	442.26	459.11	473.92

Table 29: Estimated population trends until 2041 in Queensland regions. Source:Queensland Government Statisitican's Office, QFES.

Region	Population per region			
	% change from 2021			
	2026	2031	2036	2041
Cape York	3.1	6.68	9.8	12.72
Central Queensland	3.88	8.93	13.93	18.62
Central West	-2.11	-3.15	-4.03	-4.9
Darling Downs	3.87	7.98	12.06	15.83
Far North Queensland	6.28	13.07	19.72	26.21
Gulf of Carpentaria	0.43	1.43	2.09	2.59
Mackay, Isaac and Whitsunday	4.39	9.98	15.72	21.67
Maranoa-Balonne	-1.59	-2.58	-3.6	-4.77
North Queensland	6.46	13.66	20.89	28.1
North West	-1.61	-1.89	-2.34	-3.02
South East	9.99	20.33	30.61	40.82
South West	-3.2	-5.59	-7.87	-10.22
Wide Bay Burnett	4.79	9.48	13.65	17.31

Table 30: Population %change per Queensland regional until 2014. Source: Queensland Government Statisitican's Office, QFES.

The largest population growth will be in the south east, but North Queensland, the Far North, and Mackay, Isaac and Whitsunday regions will also see growth of over 20 per cent, relative to their 2021 population. Agricultural areas, particularly in the west of the State, will see declines in population: south west by 10 per cent, and central west, Maranoa-Balonne and north west by approximately five per cent each.

Demographics

Population ages will also have an impact on population vulnerability, as Queensland's population is set to age. The proportion of the population not of working age – that is, younger than 15 or older than 65 – increases across the State, as shown in Table 31.

Region	Number of people not of working age (younger than 15, older than 65)			
	% change from 2021			
	2026	2031	2036	2041
Cape York	2.6%	4.9%	6.8%	8.1%
Central Queensland	3.6%	7.4%	10.2%	12.0%
Central West	3.9%	7.1%	8.9%	10.1%
Darling Downs	2.6%	5.3%	7.6%	9.0%
Far North Queensland	3.2%	6.3%	8.3%	9.6%
Gulf of Carpentaria	2.9%	4.7%	6.4%	7.2%
Mackay, Isaac and Whitsunday	3.3%	6.1%	8.0%	9.0%
Maranoa-Balonne	3.4%	6.7%	9.0%	10.2%
North Queensland	3.5%	6.4%	8.5%	9.6%
North West	1.2%	1.9%	2.5%	2.9%
South East	2.4%	4.8%	7.0%	8.5%
South West	3.6%	7.4%	9.7%	11.2%
Wide Bay Burnett	3.2%	6.4%	8.7%	10.1%

Table 31: Trends in the number of people not of working age. Source: Queensland Government Statisitican's Office, QFES.

Changing age demographics will have complex effects. For instance, due to increasing house prices, an aging population may be pushed to areas that are prone to impacts of natural disasters.[528] The changing demographics of Queensland will result in a need for a different approach to disaster risk reduction going into the future.

Urban footprint

As the following tables show, the Queensland Government Statistician's Office's (QGSO) projections show the number of dwellings increases in every region through to 2041, with major increases in South East Queensland, Central Queensland, Darling Downs, Far North, Mackay, Isaac and Whitsunday, North Queensland and Wide Bay Burnett.

Region	Dwellings (10,000s) % change from 2021								
	2021	2026		2031		2036		2041	
Cape York	2.28	2.38	(4.09%)	2.49	(8.88%)	2.58	(13.07%)	2.69	(17.72%)
Central Queensland	18.61	19.61	(5.41%)	20.69	(11.2%)	21.67	(16.48%)	22.54	(21.12%)
Central West	4.74	4.90	(3.36%)	5.07	(7.06%)	5.24	(10.67%)	5.42	(14.38%)
Darling Downs	20.28	21.45	(5.78%)	22.65	(11.66%)	23.75	(17.07%)	24.69	(21.71%)
Far North Queensland	12.60	13.42	(6.47%)	14.31	(13.53%)	15.15	(20.23%)	15.98	(26.79%)
Gulf of Carpentaria	4.01	4.12	(2.87%)	4.25	(6.21%)	4.38	(9.31%)	4.51	(12.6%)
Mackay, Isaac and Whitsunday	12.13	12.72	(4.89%)	13.48	(11.1%)	14.25	(17.46%)	14.97	(23.42%)
Maranoa-Balonne	5.11	5.28	(3.45%)	5.46	(6.97%)	5.62	(10.1%)	5.76	(12.88%)
North Queensland	15.58	16.58	(6.43%)	17.66	(13.34%)	18.73	(20.2%)	19.82	(27.23%)
North West	1.98	2.01	(1.28%)	2.03	(2.73%)	2.06	(3.89%)	2.09	(5.32%)
South East	156.64	172.91	(10.38%)	189.84	(21.19%)	206.61	(31.9%)	222.87	(42.28%)
South West	2.75	2.85	(3.55%)	2.95	(7.31%)	3.05	(10.81%)	3.14	(14.14%)
Wide Bay Burnett	44.16	47.64	(7.88%)	51.08	(15.67%)	54.24	(22.83%)	57.15	(29.42%)

Table 32: Number of dwellings in each region to 2014 and percentages change in each region until 2040. Source: Queensland Government Statisitican's Office, QFES.

Water stress

Changes in rainfall patterns in Queensland will cause changes in the areas that are affected by water stress. Water stress occurs when available water cannot meet normal use.

Whether a place is experiencing water stress is dependent on local climate, industry, and community water usage. For example, the conditions for water stress will be different in the Wet Tropics than in the dry southwest of the State, because more rainfall is expected in the former than the latter, and smaller changes in rainfall pattern will have a larger effect on the former. Water stress can occur in high- and low-rainfall areas.[529] In defining drought, the Bureau of Meteorology states that[530]

> "... drought is not simply low rainfall; if it was, much of inland Australia would be in almost perpetual drought. To understand when droughts are occurring it's necessary to know how much water is around and how that compares to normal conditions."

Water stress can have significant impacts on quality of life across the State. Significant impacts may include:

- Dust storms, which are worsened by long dry periods, may compromise the safety of transport infrastructure.[531]
- Severe water stress can have long-term impacts on the local economies of affected communities that can persist after the drought has ended.[532] Food prices – particularly for fresh fruits and vegetables – increase significantly during periods of water stress.[533]
- The population density of native wildlife can be significantly decreased by prolonged dry periods.[534] Prolonged dry periods can also lead to desertification – where arable land is converted to unusable desert.[535]
- A community's water supply may be interrupted due to a lack of rainfall. This may lead to water restrictions – or in the most severe cases – water being shut off and water trucked in, as happened in Stanthorpe and Clifton in January 2020.[536]

Water stress may also in turn worsen the effects of other hazards.

Studies have shown that climate change is already increasing dry period length and severity, as rainfall patterns change.[537]

Under RCP8.5, annual dry months are projected to be more frequent by 2070, particularly in areas closer to the coast. Table 33 provides a summary of dry period probability under RCP8.5, using Standard Precipitation Index.[538,539]

Region	Probability variables for severe dry periods under RCP8.5		
	1986 – 2005	2030	2050
Cape York	1	5	5
Central Queensland	5	4	5
Central West	3	3	3
Darling Downs	1	2	3
Far North Queensland	1	4	3
Gulf of Carpentaria	3	4	1
Mackay, Isaac and Whitsunday	3	5	5
Maranoa-Balonne	3	3	3
North Queensland	1	5	5
North West	3	4	2
South East	1	1	3
South West	3	2	3
Wide Bay Burnett	1	1	4

Table 33: Dry period probability under RCP8.5 for Queensland regions until 2050. Source: QFES, data from DES.

Importantly, tropical areas which have historically not been so greatly impacted by drought will see a considerable increase in the number of severe drought months by 2050 – see for example Cape York and North Queensland.

The effects of climate change on rainfall patterns are complex, and some counterintuitive results are also projected. Some areas that are currently prone to dry periods are projected to experience fewer severe dry periods, especially Carpentaria, while others like Darling Downs, Far North Queensland, South East and Wide Bay Burnett show a marked increase in dry period probability. In the data that are used in this risk assessment, the averages are calculated for 24-month periods within the reference period in the period from 1986 to 2005. Future projections are the average of 11 models for periods 2020-2039 (referred to as '2030' in the data and on the Future Climate Dashboard) and 2040-2059 (referred to as '2050').

SECTION C
RISK PRIORITISATION

Risk analysis and prioritisation of hazards

In this section we detail how the hazards analysed in Section B – State disaster risk assessment were prioritised. These hazards are:

- Tropical cyclone
- Riverine flooding
- Severe thunderstorm
- Bushfire
- Heatwave
- Earthquake
- Tsunami
- Pandemic
- Biosecurity
- Chemical, biological and radiological (CBR)

The hazards critical infrastructure failure and mass casualty incident, also identified in Section B, were not prioritised for this report due to the complex and wide-ranging issues that can lead to these events. Also, typically, these hazards arise as a consequence of the 10 hazards listed prior.

For those hazards first assessed in the 2017 State Natural Hazard Risk Assessment, we have seen shifts in their prioritisation. During the subsequent four years, new hazards also have emerged.

The prioritisation resulted from a mixed methods approach that used quantitative and qualitative understandings of disaster risk across the State to rank them in their importance to each of the Queensland regions, and then to the State as a whole.

Qualitative and quantitative analysis in risk prioritisation was appropriate for two key reasons:

1. Successful disaster risk management relies on not just a technical understanding of hazards but also practice-based knowledge that arises from past experiences and shared learnings. Hazard prioritisation, then, should use both kinds of knowledge.
2. Reliable quantitative information, such as data, was available for some hazards but not all. Where reliable data was not available – for example, the severe thunderstorm hazard – this was supplemented by quantitative information.

The resulting method had a two-staged approach: hazard prioritisations per region were derived and then aggregated to the State level and applied to the local level. This means that the State priorities are based on local priorities, reflecting local leadership in Queensland's disaster management arrangements. The methodology for prioritisation is detailed in Section D – Technical methodologies.

While these priorities represent the relative importance of hazards for each region, the prioritisations do not imply that any hazard is unimportant. The hazards detailed in this report are all significant to disaster risk in the State: they represent the most prominent hazards in the Queensland context.

In 2020, the United Nations Office for Disaster Risk Reduction compiled a globally representative list of potential hazards that contains 302 hazards.[55] This demonstrates that even hazards that are relatively low in this prioritisation are extremely important to the Queensland context, and the risks they pose require assessment and subsequent management.

Hazard prioritisation is an important aspect in climate change-related disaster risk reduction. As climate change alters normal weather patterns, the risk posed by each hazard to a given area will change. This change is unlikely to be significant year-on-year, or between each five-year period, but over the decades and towards the end of this century, the likelihood of a given hazard it likely to substantially change.

In some cases, the risk of certain hazards is forecast to decrease – for instance, modelling on the Future Climate Dashboard suggests that drought risk decreases in the North West, Central West and South West regions towards the end of the century, as precipitation is predicted to rise. In other cases, the risk of certain hazards is predicted to significantly worsen – such as drought in the Cape York region.

Because disaster risk assessments address risk over a short period – less than five years – the risk assessment process itself does not directly capture how disaster risk will change towards 2100. Therefore, disaster risk reduction through risk management requires an 'orientational' approach that assesses mitigation activities according to their ability to achieve desired results for shorter-term risk reduction, but also keeps in mind the effects that these strategies will have on disaster risk in the long term.

Mitigation strategies that address a short-term risk but amplify potential future risks are best avoided while strategies that balance long-term, emerging risks with present risk reduction needs are most beneficial.

The Intergovernmental Panel on Climate Change, in their report Climate change: new dimensions in disaster risk, exposure, vulnerability, and resilience,[37] specifically links development to both disaster risk management and climate change adaptation. This is visually represented in Figure 107.

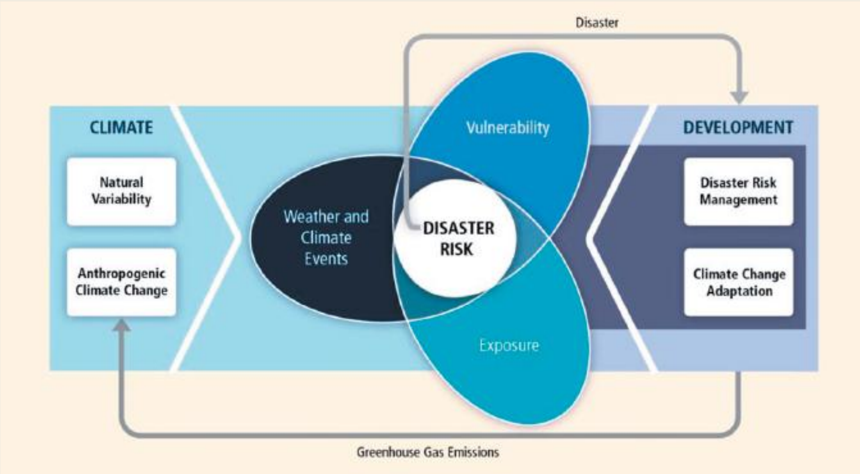


Figure 107: The relation of disaster risk, development, and climate change. Source: IPCC.[37]

Sustainable development reduces both the risk posed by disasters and the impacts of climate change. It is important, then, to consider mitigation activities in a broader and future-focussed context.

There are two key policy documents in Queensland that provide guidance on achieving climate change adaptation through the adoption of strategies for mitigation: the Emergency Management Sector Adaptation Plan[30] (EM-SAP) and the State Planning Policy[53] (SPP).

The EM-SAP is an emergency management sector-specific plan for addressing the risks posed by climate change. It identifies:

- adaptation should address the comprehensive approach to disaster management - prevention, preparedness, response and recovery
- adaptation should be considered using a systems approach, ensuring that it is responsive to local conditions and the needs of the entire community
- adaptation should address both acute major events and continuous incremental change.

Land-use management has been identified as a key lever for climate change adaptation and disaster risk reduction.[540–542] One of the State interests identified by the SPP is that "the risks associated with natural hazards, including the projected impacts of climate change, are avoided or mitigated to protect people and property and enhance the community's resilience to natural hazards".[53] It does so by specifying benchmarks that relate specifically to disaster risk. For example, assessment benchmark 5 states that:

"Development directly, indirectly and cumulatively avoids an increase in the severity of the natural hazard and the potential for damage on the site or to other properties." [53]

Table 34 provides the rankings per hazard for each Queensland region.

Regional ranking	Hazard									
	Tropical cyclone	Riverine Flooding	Severe thunderstorm	Bushfire	Heatwave	Earthquake	Tsunami	Pandemic	Biosecurity	Chemical, biological, radiological
Cape York	1	3	6	2	4	9	8	7	5	10
Central Queensland	4	1	3	2	5	8	10	7	6	9
Central West	9	1	5	2	3	8	10	7	6	4
Darling Downs	9	1	3	2	4	8	10	5	6	7
Far North Queensland	1	2	3	4	7	10	9	5	6	8
Gulf of Carpentaria	1	2	4	3	6	9	10	8	7	5
Mackay, Isaac and Whitsunday	1	3	4	2	5	8	10	6	7	9
Maranoa-Balonne	8	1	3	2	4	7	10	5	6	9
North Queensland	1	2	4	3	5	10	9	7	6	8
North West	5	2	3	1	4	8	10	7	6	9
South East	6	1	2	3	4	9	10	5	7	8
South West	8	1	3	2	4	9	10	6	5	7
Wide Bay Burnett	6	1	2	3	4	9	10	5	7	8

Table 34: Prioritisation of hazard according to Queensland's planning regions.

From these region-level prioritisations, the following LGA-level risk prioritisations have been derived for use in local disaster manage planning.

The justification and methodology for calculating these scores is described in Section D

LGA name	Hazard									
	Tropical cyclone	Riverine Flooding	Severe thunderstorm	Bushfire	Heatwave	Earthquake	Tsunami	Pandemic	Biosecurity	Chemical, biological, radiological
Aurukun	1	3	6	2	4	8	7	9	5	10
Balonne	9	1	3	2	4	8	10	5	7	6
Banana	4	1	3	2	5	7	10	9	6	8
Barcaldine	8	1	5	2	3	7	10	9	6	4
Barcoo	8	1	5	2	3	7	10	9	6	4
Blackall Tambo	8	1	5	2	3	7	10	9	6	4
Boulia	8	2	5	1	3	7	10	9	6	4
Brisbane	6	1	2	3	4	8	10	5	9	7
Bundaberg	4	1	2	3	5	8	10	6	9	7
Burdekin	1	3	4	2	5	10	8	9	6	7
Burke	1	3	4	2	6	7	9	10	8	5
Cairns	1	2	3	4	6	10	9	5	7	8
Carpentaria	1	3	4	2	6	7	9	10	8	5
Cassowary Coast	1	2	3	4	6	10	9	5	7	8

LGA name	Hazard									
	Tropical cyclone	Riverine Flooding	Severe thunderstorm	Bushfire	Heatwave	Earthquake	Tsunami	Pandemic	Biosecurity	Chemical, biological, radiological
Central Highlands	4	1	3	2	5	7	10	9	6	8
Charters Towers	1	2	4	3	5	9	10	8	6	7
Cherbourg	6	1	2	3	4	8	10	5	9	7
Cloncurry	5	2	3	1	4	7	10	9	6	8
Cook	1	3	6	2	4	8	7	9	5	10
Croydon	1	2	4	3	6	7	10	9	8	5
Diamantina	8	2	5	1	3	7	10	9	6	4
Doomadgee	1	3	4	2	6	7	9	10	8	5
Douglas	1	2	3	4	6	10	9	5	7	8
Etheridge	1	2	4	3	6	7	10	9	8	5
Flinders	5	2	3	1	4	7	10	9	6	8
Fraser Coast	4	1	2	3	5	8	10	6	9	7
Gladstone	4	1	2	3	5	7	10	9	6	8
Gold Coast	6	1	2	3	4	8	10	5	9	7
Goondiwindi	9	1	2	3	4	8	10	5	7	6
Gympie	6	1	2	3	4	8	10	5	9	7
Hinchinbrook	1	2	4	3	5	10	8	9	6	7
Hope Vale	1	2	6	3	4	8	7	9	5	10
Ipswich	6	1	2	3	4	8	10	5	9	7
Isaac	1	3	4	2	5	7	10	6	9	8
Kowanyama	1	3	4	2	6	7	9	10	8	5
Livingstone	3	1	4	2	5	7	10	9	6	8
Lockhart River	1	2	6	3	4	8	7	9	5	10
Lockyer Valley	6	1	2	3	4	8	10	5	9	7
Logan	6	1	2	3	4	8	10	5	9	7
Longreach	8	1	5	2	3	7	10	9	6	4
Mackay	1	3	4	2	5	7	10	6	9	8
Mapoon	1	3	6	2	4	8	7	9	5	10
Maranoa	9	1	3	2	4	8	10	5	7	6
Mareeba	1	2	3	4	6	9	10	5	7	8
McKinlay	5	2	3	1	4	7	10	9	6	8
Moreton Bay	6	1	2	3	4	8	10	5	9	7
Mornington	1	3	4	2	6	7	9	10	8	5
Mount Isa	5	2	3	1	4	7	10	9	6	8
Murweh	8	1	3	2	4	9	10	7	5	6
Napranum	1	3	6	2	4	8	7	9	5	10
Noosa	6	1	2	3	4	8	10	5	9	7
North Burnett	6	1	2	3	4	8	10	5	9	7
Northern Peninsula	1	3	6	2	4	8	7	9	5	10
Palm Island	1	2	5	3	4	10	8	9	6	7
Paroo	8	1	3	2	4	9	10	7	5	6

LGA name	Hazard									
	Tropical cyclone	Riverine Flooding	Severe thunderstorm	Bushfire	Heatwave	Earthquake	Tsunami	Pandemic	Biosecurity	Chemical, biological, radiological
Pormpuraaw	1	3	6	2	4	8	7	9	5	10
Quilpie	8	1	3	2	4	9	10	7	5	6
Redland	6	1	2	3	4	8	10	5	9	7
Richmond	5	2	3	1	4	7	10	9	6	8
Rockhampton	4	1	2	3	5	7	10	9	6	8
Scenic Rim	6	1	2	3	4	8	10	5	9	7
Somerset	6	1	2	3	4	8	10	5	9	7
South Burnett	6	1	2	3	4	8	10	5	9	7
Southern Downs	9	1	2	3	4	8	10	5	7	6
Sunshine Coast	6	1	2	3	4	8	10	5	9	7
Tablelands	1	2	3	4	6	9	10	5	7	8
Toowoomba	9	1	2	3	4	8	10	5	7	6
Torres	1	2	6	3	4	8	7	9	5	10
Torres Strait Island	1	2	6	3	4	8	7	9	5	10
Townsville	1	2	4	3	5	10	8	9	6	7
Weipa	1	3	6	2	4	8	7	9	5	10
Western Downs	9	1	3	2	4	8	10	5	7	6
Whitsunday	1	3	4	2	5	7	10	6	9	8
Winton	8	1	5	2	3	7	10	9	6	4
Woorabinda	4	1	3	2	5	7	10	9	6	8
Wujal Wujal	1	2	3	4	6	9	10	5	7	8
Yarrabah	1	2	3	4	6	10	9	5	7	8

Table 35: Local Government Area hazard prioritisations.

These local and regional prioritisations aggregate to the following State-level prioritisation.

Hazard	Overall Rank (State)	Previous ranking (2017)
Riverine flooding	1	= 1
Tropical cyclone	2	= 1
Bushfire	3	4
Severe thunderstorm	4	2
Heatwave	5	= 3
Pandemic	6	n/a
Biosecurity	7	n/a
Chemical, biological, radiological	8	n/a
Earthquake	9	5
Tsunami	10	n/a

Table 36: State-level prioritisation of hazards.

Risk summary

1

Riverine flooding

The 2021/22 State Disaster Risk Report has identified managing the risks associated with riverine flooding as the highest priority for Queensland, particularly over the coming decade. Climate projections present a varied picture for the State for flood risk. However, given the proximity of population centres to rivers or creeks, riverine flooding poses a serious risk to the State. The river basins and catchments of Queensland cover large geographic areas and pose many challenges with regards to logistics, access/resupply and evacuation if required.

Significant work has been and continues to be undertaken in the identification and management of flood risk by both the Queensland and Federal Governments. Previous risk assessments have nominated riverine flooding as the most destructive natural hazard in Queensland with very significant disruption to business and damage to property and the environment, such as the recorded impacts during the flooding events of 2010/11 and 2022.

2

Tropical cyclone

This report has identified managing the risks associated with tropical cyclone as Queensland's second highest priority. This is a relative reduction from equal first in the 2017 State Natural Hazard Risk Assessment, due to a reduction in the frequency of TC events. TC is the most disruptive and damaging natural hazard for Queensland, with the potential to pose the most risk to life due to limitations to disaster operations during impact. Further, tropical cyclones have claimed the most lives in Queensland although not in recent years.

The cascading and coincident effects of a tropical cyclone described in the risk profile can pose complex issues such as:

- damage from sustained high wind speeds
- rapid delivery of concentrated rainfall leading to flash flooding
- increased risk of storm surge creating higher risk of coastal inundation
- onset of riverine flooding due to prolonged and sustained deluges.

While Queensland is very well placed with regard to mitigation efforts, including the capability to prepare for, respond to and recover from tropical cyclones, the reasonably rapid onset and violence of tropical cyclones – over broad scale geography involving numerous local government areas and multiple disaster districts – can make the management of disaster operations challenging. This is particularly the case with large severe tropical cyclones such as Tropical Cyclone Yasi in 2011 and Tropical Cyclone Debbie in 2017. The impacts to Queensland's and indeed the national economy can be very significant, with long term recovery efforts required.

3

Bushfire

Bushfire is a frequently occurring event in Queensland generally well managed and often occurring in areas less densely populated. While this can reduce the risk to life there is still the potential for a range of significant economic impacts to Queensland agriculture, industry and tourism. Bushfire Prone Area mapping is used within land use planning and mitigation operations along with predictive analytics and fire weather forecasts to proactively manage this hazard before risks manifest. **This report identifies managing bushfire risk as Queensland's third priority.** This is an increase from the 2017 State Natural Hazard Risk Assessment, which assessed bushfire as the fourth priority. This is due to a projected overall increase in fire weather conditions throughout the State.

Severe thunderstorm

4

Severe thunderstorms have historically been one of Queensland's most damaging natural hazards. The cascading and coincident effects of severe weather can pose complex issues such as:

- lightning strikes leading to bushfires
- rapid delivery of concentrated rainfall leading to flash flooding and riverine flooding
- damaging wind gusts and hail leading to significant damage to infrastructure
- storm surge causing erosion and localised flooding through coastal inundation.

The Australian Bureau of Meteorology provides weather forecast services and warning advice to Queensland. However, the unpredictable nature of the phenomenon can lead to short time frames for identifying and providing warnings of impact location and intensity or severity across multiple, dispersed communities.

As a result, when conditions are conducive to severe weather events, rapid onset can pose risk to life such as hazardous road conditions. Further, significant economic impacts can result from severe weather events destroying agriculture and damaging built up areas. **This report identifies managing the risks associated with severe thunderstorm events as the fourth highest priority for Queensland.**

Heatwave

5

Heatwaves, arguably due to their less violent, slower onset and less publicised nature, have only more recently begun to be recognised at a true level of risk. Climate projections indicate generally hotter conditions, with the Australian Bureau of Meteorology and Queensland Health working collaboratively on a Heatwave Service to align service response with weather forecasts.

Heatwaves have a broad range of potential health effects impacting mortality rates for vulnerable persons as well as potential impacts on essential services. Heatwaves are also one contributing factor, from a multi-hazard perspective, in the increased hazard of bushfire. **This report identifies managing the risks associated with heatwaves as the fifth highest priority for Queensland.**

Pandemic

6

Until the emergence of the COVID-19 Pandemic in 2020, epidemic and pandemic diseases were not considered high priority in Queensland. The severe impacts of COVID-19 have illustrated that pandemic preparedness is an important aspect of disaster risk reduction in Queensland. At the time of publication, COVID-19 is an ongoing health emergency and continues to have significant impacts on the Queensland economy – especially the tourism and tertiary education sectors. With greater global interconnectedness, and the importance of globally dependant industries to Queensland's economy, future pandemics will pose a significant risk for Queensland, and lessons from the present pandemic will assist in ensuring that Queensland is prepared. **Managing the risks associated with pandemics and epidemics is Queensland's sixth priority.**

Biosecurity emergency

7

Infectious plant or animal disease can have significant economic impacts, especially for parts of the State that have important agriculture industries. Like pandemics, the risk of biosecurity incursions increases as Queensland is more connected to global markets, which sees greater movement of products and people. **Managing the risks associated with infectious plant or animal diseases is Queensland's seventh priority.**

8

CBR incident

Chemical, biological and radiological events can have potentially catastrophic consequences but the risk in general of these events is uniformly low across Queensland. Strong regulations and obligations of companies to manage their own risk with respect to materials that can lead to CBR events means that the risk of an event is not considered significant. However, given that CBR materials are found throughout the State – particularly hazardous materials in urban areas – this poses a greater risk than rare natural hazards. **Therefore, managing the risks associated with CBR incidents is Queensland's eighth priority.**

9

Earthquake

Earthquakes are a frequently occurring phenomenon in Queensland with some geographic areas registering the strongest events to occur on the eastern seaboard in the past 150 years, most notably the Great Queensland Quake of 1918 at a magnitude of 6.05. However, the magnitude of most events is often less than 3.5 with the effects seldom felt. While not relevant to all of Queensland, some areas regularly experience onshore and near shore earthquakes with a magnitude greater than 5. The strongest earthquake to occur most recently was the offshore earthquake, north east of Bowen in August 2016, with a magnitude of 5.8.

An earthquake of this magnitude occurring within the vicinity of a built environment is likely to cause significant damage to structures, underground services and piping, with potential risk to life due to the collapse of structures. The accurate assessment of earthquake susceptibility is a highly specialised discipline with this assessment team referring areas with potential susceptibility to Geoscience Australia. **Managing the risks associated with earthquakes is Queensland's ninth priority.**

10

Tsunami

Due to the low likelihood of tsunamigenic earthquakes around the Solomon Islands and New Zealand, the likelihood of an tsunami impacting Queensland is correspondingly low. However, because the coast is more densely populated than the State's interior – thereby exposing some larger population centres to risks posed by tsunami – the consequences of impact would be significant. There remains substantial uncertainty regarding submarine landslide tsunami potential in Queensland, with recent studies demonstrating a number of potential areas of concern in South East Queensland. **Managing the risks associated with tsunami is Queensland's tenth priority.**

Overall risk by planning area

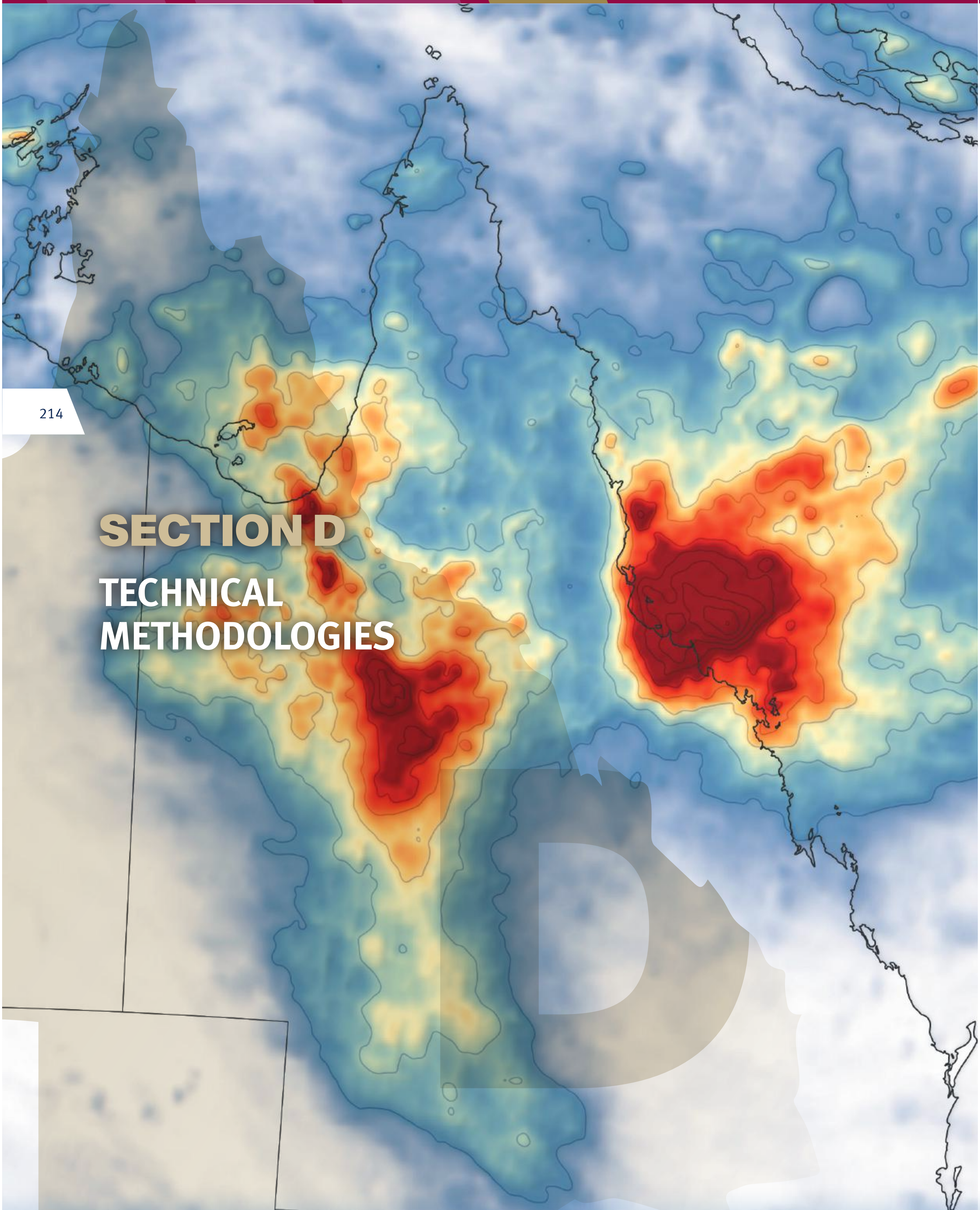
On the basis of the individual risk assessments and additional analysis, the following scores have been derived for exposure, vulnerability, probability and overall risk at the regional level.

The method for calculating these scores is based on two analytic products developed by QFES: the Risk Exposure Index and the Risk Vulnerability Index. These products allow for an analysis of the geographic distribution of exposure and vulnerability by using spatial data of physical assets, and regional economics and demographics. The inclusion of probability – based on the probability information provided in the risk assessments in this report – allows for an overall risk score to be provided for each of the planning regions.

The methodology for calculating these scores is described in Section D.

Region	Overall exposure	Vulnerability			Probability	Risk
		Social	Economic	Overall		
Cape York	1	1	5	3	1.83	2
Central Queensland	3	4	3	4	1.66	3
Central West	3	3	4	4	1.83	3
Darling Downs	4	4	4	4	1.83	3
Far North Queensland	1	3	3	4	1.99	2
Gulf of Carpentaria	1	2	1	1	1.66	1
Mackay, Isaac and Whitsunday	3	1	3	2	1.66	2
Maranoa-Balonne	5	5	3	5	1.83	4
North Queensland	2	5	4	5	1.83	3
North West	2	2	4	3	1.66	2
South East	3	1	3	3	1.66	2
South West	4	4	5	5	1.67	3
Wide Bay Burnett	2	3	5	4	1.66	2

Table 37: Overall risk score for each planning region.



SECTION D

TECHNICAL METHODOLOGIES

This section contains technical details of how some of the quantitative results were obtained in this report. In particular, it contains explanations of the methodologies that are used for

1. Forecasting Queensland Emergency Risk Management Framework (QERMF) variables (Vulnerability, Exposure, Probability, and overall risk)
2. Informing the report's hazard prioritisation findings
3. Identification of significant effects of climate change.

These methodologies were largely developed specifically for this report.

Forecasting Queensland Emergency Risk Management Framework (QERMF) variables

Vulnerability

Vulnerability is the measure of the susceptibility of an asset or community to the impacts of a hazard. To capture community vulnerability for hazards, we chose two major areas: social and economic vulnerability. The calculation of vulnerability scores involves two steps:

1. calculation of indicator scores based on statistics
2. calculation of vulnerability scores based on indicator scores.

Since most data pertaining to communities are available most reliably at the Australian Bureau of Statistics' (ABS) Statistical Area Level 2 (SA2), analysis was conducted at this granularity. Further, data at the SA2 level is considered reliable because, at the SA1 level, data is randomised by the ABS to lower the risk of identification based on the data.

To capture community vulnerability, several statistics were identified as risk factors for susceptibility to the effects of a range of hazards. These statistics represent the latest-available data for each variable.

Social vulnerability				
Indicator	**Statistic**	**Year**	**+/–**	**Data source and custodian**
Health and wellbeing	Risk factors: obesity, excessive alcohol consumption, smoking, low exercise (per cent)	2019-20	+	Queensland Health
	Immunisation at one year and five years (per capita)	2017	–	Public Health Information Development Unit (PHIDU)
	Youth and infant mortality (per capita)	2017	+	PHIDU
	Medical facilities (per capita)	2019	–	Australian Institute of Health and Welfare (AIHW)
Social cohesion and engagement	Informal votes (percent of all votes cast at booths in LGA at 2019 federal election)	2019	+	Australian Electoral Commission
	Volunteering (per cent)	2016	–	Australian Bureau of Statistics (ABS)
	Spread of volunteer ages (standard deviation)	2016	–	ABS
	Homelessness rate	2018	+	ABS
	Net internal migration (per capita)	2018	+	ABS
Skills and education	Children in preschool (per capita)	2017	–	ABS
	Median teacher–student ratio*	2019	–	Australian Curriculum and Reporting Authority
	Median childcare quality*	2019	–	Australian Children's Education & Care Quality Authority
	Continuing education – people studying after high school (per cent)	2017	–	ABS
	Post-school qualification (per cent)	2017	–	ABS
*Imputed variables.				

Table 38: Social vulnerability indicators, statistics and data sources. Year indicates the year for the data and +/- indicates whether this statistic increases or decreases vulnerability, respectively.

Economic vulnerability				
Indicator	**Statistic**	**Year**	**+/–**	**Data source and custodian**
Wealth and income	Median annual personal income	2018	+	ABS
	Vehicles < 5 years old (percent)	2018	+	ABS
	Housing stress	2016	–	PHIDU
	Ratio of rent or mortgage payments to median income*	2018	+	ABS
Workforce	Concentration of workforce in industries	2018	-	ABS
	Diversity of ages in workforce	2016	-	ABS
	Gini coefficient (a measure of wealth inequality)	2018	+	ABS
Low productivity	Participation rate	2018	–	ABS
	Unemployment rate	2018	–	ABS
	Newstart/Jobseeker payees (per capita)	2019-20	–	Department of Human Services
	Number of businesses (per capita)	2016	–	ABS
*Imputed variables.				

Table 39: Economic vulnerability indicators, statistics, and data sources. Year indicates the year for the data and +/- indicates whether this statistic increases or decreases vulnerability, respectively.

These variables were selected based on academic research[543–546] and insights gained through practical experience in measuring risk for local governments. The data associated with each variable were selected on the basis of their consistency (i.e. available for all of the State) and quality (i.e. from a reputable, preferably primary, source). The methodology is robust enough that, in future iterations, additional data can be added, or existing data deleted, without compromising the approach.

These statistics were used to calculate a vulnerability score for each SA2. The resulting score is a number between 1 and 5, where higher scores represent higher vulnerability. In effect, the methodology ranks and assigns a relative value to every SA2 in the State.

The methodology for calculating the vulnerability scores is the following:

1. Scale the data so that each observation x in column X (where each column is a variable) is found by solving x/σ_X, where σ_X is the standard deviation of X. Scaling allows different variables of greatly different magnitudes to be compared, since it transforms the columns so that they are in a similar range while retaining the structure of the data (i.e. the relative distances between the values). In the current data, it allows for the comparison of large differences in, for example, percentages (between 0 and 1) and median house prices (between $20,000 and $5.2 million).
2. Perform Principal Components Analysis (PCA), which reduces the number of variables in a data set into a smaller set of components. These components are uncorrelated and are ordered so that the first component explains the largest possible amount of variance in the original data. The first component summarises several variables into a single index.

   Technically, PCA transforms n variables into an n-vector of scores $X_i=(x_1,\ldots,x_n)$. It does so by using a vector of weights $W_j=(w_1,\ldots,w_m)$, such that a given score is $x_{ij}=X_i\times W_j$ for $i=1,\ldots,n$ and $j=1,\ldots,m$. To find the indicators, we only use the first principal component, Y_1, is found by solving

$$Y_1 = \arg\max_{\|Y\|=1}\left(\sum_{i}^{X}(X_iY_j)^2\right).$$

3. Normalise the indicators again to return meaningful results between 1 and 100 using the following function:

$$\text{normalise}(y) = \left(1 + \frac{99(y - \min(Y))}{\max(Y) - \min(Y)}\right).$$

4. Find the social and economic vulnerability scores. Social vulnerability is the mean of the normalised indicator scores for health and wellbeing, social cohesion and engagement, and skills and education; economic vulnerability is the mean of wealth and income, workforce, and low productivity.
5. The overall vulnerability is the geometric mean of social and economic vulnerability scores – that is,

$$\sqrt{\text{social vulnerability} \times \text{economic vulnerability}}.$$

The geometric mean is preferable to the arithmetic mean in this instance because the distributions tend to be flatter, meaning there is more discrimination in the scores.

PCA-based methodologies are frequently used for socioeconomic indices,[547,548] because PCA is able to reduce a number of variables into a meaningful set of indicators while preserving the structure and characteristics of the variables.

Exposure

Exposure refers to the extent to which an asset is likely to be impacted by a hazard. Exposure is hazard specific. For instance, if a house rests on a hill, it is more likely to be exposed to severe winds but, because of its position, is less likely be exposed to flooding.

To measure exposure, we count the physical assets that are often exposed to the hazards examined in this report. Note that we counted all applicable assets, even though many of these assets would not be exposed. However, automated analysis cannot achieve the same level of detail and fidelity that an in-depth exposure study can. Instead, the results of this analysis should be seen as a prompt for decision-making – as a guide to which Queensland regions have a higher level of general exposure than others.

We have chosen to analyse exposure geographically, at a fidelity of 10km^2. There are three reasons for this:

1. In all regions, there will be an unequal distribution of exposure. Areas of dense population tend to have greater exposure than those that are sparsely populated. Further, disasters are spatial phenomena that affect particular geographic areas within regions. On this basis, it is appropriate to specify where within a region the greater exposure exists, particularly in regions with large, unpopulated areas.
2. The data for exposure are more amenable to this kind of analysis. Exposed assets are generally much more specific – the geographic locations of the electricity networks or roads are reported precisely – as opposed to data relating to vulnerable communities, which are reported at an aggregated geographic level.
3. It captures meaningful population centres in regional areas without the areas being too small to capture overall trends of the region. It also aligns to other government initiatives around risk – including the downscaled climate projections provided on the Queensland Future Climate Dashboard.

The methodology for calculating exposure scores is much simpler than for vulnerability scores and represents an intuitive measure of exposure density within a region:

1. Divide the State into a 10km^2 grid. The same grid used for the Queensland Future Climate Dashboard was used for the SDRR study.
2. For line data (electricity transmission lines, roads), count the length of lines in kilometres within each grid cell. For point data (everything else), count the number of points within each grid cell.
3. To calculate the element category score, add the total amount of the relevant count for each cell – that is, add the total length of line data to the number of points within each cell. This provides exposure density per grid cell, per exposure category.
4. To calculate the overall exposure score for each grid cell, find the mean of the element category scores.
5. Normalise the data using the same equation as in the vulnerability score analysis, except between 1 and 5:

$$\text{normalise}(y) = \left(1 + \frac{4(y - \min(Y))}{\max(Y) - \min(Y)}\right).$$

The elements that were included in the analysis are listed in Table 40.

Element category	Element	Data source and custodian
Essential infrastructure	Electricity network – transmission lines ‹ 66kV	Ergon and Energex
	Telephone exchanges	Geoscience Australia
	Wastewater treatment plants	Geoscience Australia
Access and resupply	Major roads – freeways, highways, local connecting roads	Queensland Government – Baseline roads and tracks dataset (categories 1 – 4)
	Airports	Queensland Government – Built environment series: landmark areas
	Rail network – operational only	Queensland Government – Rail network
Community and social	Public administration buildings – public halls, community centres, and local government chambers	Queensland Government – Built environment series: landmark areas
	Tourist areas	Queensland Government – Built environment series: landmark areas, tourist areas
	Schools	Queensland Government – Built environment series: schools
Emergency management	Emergency services facilities – Fire services, police, ambulance, and SES	Queensland Government – Built environment series: emergency management
Public health	Hospitals – Public and private, excluding clinics etc.	Queensland Government – Built environment series: Hospitals
	Aged care centres	Queensland Health

Table 40: Element categories, elements, and data used in determining exposure.

The variables for exposure were selected based on the QERMF's exposure categories. Data, like the data selected to calculated vulnerability scores, were selected based on consistency and quality.

Probability

The probability scores given for each of the hazards are an estimate based on the best available data on the risk factors that contribute to the occurrence of these hazards. We illustrate the technical detail behind these estimates below.

Tropical cyclone

Estimates of tropical cyclone probability for the reference period (1981-2010) and for two future periods (2021-2040 and 2041-2060) are calculated using modelling performed as part of the Severe Wind Hazard Assessment (Queensland).[44] The models were grouped based on the frequency of events that they found in the reference period and by other metrics such as trends in landfall distribution.[44]

Group 1	Group 2
ACCESS 1.3	ACCESS 1.0
CSIRO Mk 3.6.0	CCSM4
GDFL ESM2M	CNRM CM5
HadGEM2	GFDL CM3
MIROC5	MPI ESM LR
	NorESM1 M

The data output in each of these groups is a grid for each period of interest, where the value of the cells for each group corresponds to the average annual frequency of a cyclone track crossing that grid cell.

To convert this to an annual exceedance probability, expressed as the annual odds of an event over a specified time frame, the cell frequency is converted to the annual exceedance probability for each cell. This conversion is found by solving

$$\left\lfloor \frac{1}{1-(1-p)^y} \right\rfloor,$$

where p is the frequency of the individual grid cell, and y is the number of years in the periods: 30 for reference and 20 for the two future periods. This gives a year value x that corresponds to a '1 in x' event; the floor function converts the output to a whole number. These year values were then used to derive contours using ArcGIS Pro.

The raw frequencies are used to find probability scores. The mean frequency of the grid cells that intersect the region is the identified. These means are scaled using a normalisation function, to return values between 1 and 5. The normalisation function is a simple min-max normalisation function which scales values between 1 and 5 and then rounds them to the nearest integer:

$$\text{normalise}(x) = \text{round}\left(1 + \frac{4(x - \min(X))}{\max(X) - \min(X)}\right).$$

Riverine flooding and heatwave

The methodologies for riverine flooding and heatwave are similar and differ only in the variables used:

- riverine flooding uses the number of consecutive months in a year with a 24-month standard precipitation index (SPI) between 1.50 and 1.99, inclusive
- heatwave uses heatwave frequency statistics, which represents the number of heatwave days relative to number of days in a year.

These variables are available on the Queensland Future Climate Dashboard, and on the Terrestrial Ecosystem Research Network (TERN) websites.

SPI is a measure of average precipitation over a specified length of time that takes into account normal, seasonal variations in precipitation amount. It is computed by "dividing the difference between the normalised seasonal precipitation and its long-term seasonal mean by the standard deviation".[539] The SPI for a given season is found by solving

$$\text{SPI} = \frac{x_{ij} - x_{im}}{\sigma},$$

where x_{ij} is observation j of precipitation at rain gauge i, x_{im} is the seasonal mean at rain gauge i, and σ is the standard deviation of seasonal observations at rain gauge i. The 'season' is determined according to the needs of the analysis. For measuring long-term trends such as drought and riverine flooding, a 24-month season is most appropriate, as it relates to "stream flows, reservoir levels, and even groundwater levels".[539]

Measuring flood probability is a complex and nuanced science. Flooding depends on local geographic, geological, hydrological and climatic conditions, as well as the built environment. Using SPI to measure flood probability measures the conduciveness of climatic factors to flooding but does not take into account the other factors that lead to flooding. Because we are interested in an indicative measure at a broad geographic and temporal scale, this is more appropriate than using other, more specific flood intensity measures such as through the Australian Rainfall and Runoff.

In general, the methodology for calculating hazard probabilities is the following:

1. Extract and calculate reference period data for each variable. Because the data on the Queensland Future Climate Dashboard only references differences of the future period and the reference period (1985-2005), it is necessary to calculate the reference period data for the grid. The values presented on the dashboard are averages of the 11 models used to derive the climate data. As such, the mean of the 11 models for each statistic at each grid cell is calculated.
2. Find the mean reference period and future values for each variable for each region. Aggregating to the region prior to adding the reference period and future data is preferable to the opposite order of operations, as this avoids possible mismatches between the reference period and future period grids.

3. Add reference period averages to future data for each planning region. This makes the future data comparable to the reference period.
4. Scale the data using a normalisation function, to return values between 1 and 5. This uses the same normalisation function as in the tropical cyclone probability assessment above:

$$\text{normalise}(x) = \text{round}\left(1 + \frac{4(x - \min(X))}{\max(X) - \min(X)}\right)$$

where x is a score in X. This function has the helpful property that it preserves the shape of the scores' distribution. It is good practice to scale as many values as possible, even if they are not used, as this gives a truer result for scaling than looking just at the period of interest. For the State Disaster Risk Report, this involves scaling values that represent periods that we are not interested in generally for the hazard assessments – that is, 2060-2080 and 2080-2100 – and SPI values for different-length seasons – that is, 12- and 36-month values.

Bushfire

Calculation of bushfire probabilities is more involved than calculation of probabilities for the hazards discussed prior, because the conditions for bushfire risk rely on the interaction of multiple climatic and physical factors, most importantly fuel load, fuel moisture, wind speed, slope angle and ignition source. The presence and characteristics of these factors is particularly difficult to forecast.

The Australian standard for measuring fire risk are the McArthur Mark 5 Forest Fire Danger Index (FFDI)[549–551] and the Grassland Fire Danger Index (GFDI),[552] which both rely on weather conditions. The GFDI also requires information about the dryness of the vegetation within an area. Due to limitations in the capacity to forecast vegetation with any degree of confidence, the analysis of bushfire probability was restricted to FFDI in the present report.

FFDI is calculated by solving the following equation[552]

$$FFDI = 2e^{-0.45+0.9871 \ln DF - 0.0345h + 0.0338t + 0.0234v},$$

where $0<DF\leq10$ is a drought factor (discussed below), h is relative humidity as a percent, t is the daily maximum temperature in degrees Celsius, and v is average wind speed expressed in meters/second, measured at a height of 10 meters. This produces a score between 1 and 100, where at 1, fires will not burn, and at 100, it will be impossible to contain fires that are burning.[553]

The methodology for calculating the drought factor depends on the context. Two frequently used methodologies are the Keetch-Byram drought index and the Mount drought index, which are both of measures of soil dryness that rely on calculating the time since the last significant precipitation event.[549–551] Indeed, the equation for calculation of a drought factor relies on the drought factor score of the previous day. Calculation of a drought factor, then, requires measurements at the daily level to be consistently applied.

It was intended that FFDI be calculated for each day in the periods of interest – that is, for the reference period 1985-2005, and the future periods 2020-2040, 2040-2060. However, there are several difficulties with this approach, chiefly that the computation of drought factor scores for every day in these periods, for a 10km^2 grid for the State is computationally intensive, and verification and testing of the results would be challenging. But more importantly, analysis at this scale of analysis would be too fine-grained for the purposes of the State Disaster Risk Report, which presents a generalised probability of fire danger for twenty-year periods, at the geographic scale of a planning region.

Instead, periods data from TERN and the Future Climate Dashboard – which includes all variables used in calculation of the FFDI except for a drought factor – were used.

To replace the drought factor, the same SPI measurements were used as for drought above: the average number of consecutive months in a year with a 12-month SPI between -1.50 and -1.99, inclusive for the periods. The 12-month timescale was applied because studies have suggested that short-term measures of soil dryness are more strongly correlated with bushfire frequency than longer-term.[554,555] Since the drought factor needs to be between 1 and 10, the following scaling equation was applied to these values:

$$\text{normalise}(x) = 1 + \frac{9(x - \min(X))}{\max(X) - \min(X)}$$

The range of scores was, therefore, restricted to the scores normally expected from an FFDI calculation.

While the SPI is not directly equivalent to the drought indices above, it suits the calculation of probability scores at the high level. Studies have investigated the SPI as an indicator of forest fire risk,[556,557] and others have examined replacement values for soil moisture.[551] The 12-month SPI, then, can function as an estimator of soil moisture at the periods and geographic scale of these risk assessments.

The inclusion of SPI in the equation itself may be problematic, given that the original equation was designed with specific drought factors in mind. The exponent of e in the FFDI equation

$$-0.45 + 0.9871 \ln DF - 0.0345h + 0.0338t + 0.0234v$$

appears to be a multiple regression equation, which are of the form

$$t = \beta_0 + \beta_1 X_1 + \cdots + \beta_n X_n + \epsilon.$$

The weights applied to each of the variables determine the magnitude of that variable's impact on the overall score. However, fortunately this does not appear to be particularly problematic with the DF term, as its weight is almost 1 – that is, the relationship between drought factor and FFDI is almost linear.[552,558] Indeed, Sharples *et al*. have pointed out that – because DF the FFDI equation can be rewritten as

$$\text{FFDI} = 2DF^{0.987} e^{-0.45-0.0345h+0.0338t+0.0234v}$$

such that the drought factor effectively becomes a multiplicative factor.[552]

Provided the replacement measure represents a similar range to normal measures for the drought factor, and provided that the distribution of the replacement does not differ drastically from the distribution of normal measures, the replacement of the drought factor is possible at the broad geographic and temporal scales here.

Regarding the scale, the SPI scores are scaled to be between 1 and 10. This represents the same scale as other measures used in the drought factor.[549,551]

The resulting scores are not, strictly speaking, FFDIs, but they are good approximations for the purposes of a high-level risk assessment. Since the geographic and temporal scales are broad – being at the planning region level, over periods of twenty years – the main purpose and function of these scores is to illustrate how conducive weather conditions for bushfires are projected to change towards the end of the century.

Earthquake

Earthquake probabilities are derived from the National Seismic Hazard Assessment.[283] As part of the outputs of the project, a 15km² gridded dataset representing the probability of 10% annual exceedance of earthquakes of different intensities, measured by mean peak ground acceleration (PGA) was used. The mean PGA of an earthquake is the average taken of the largest increase in velocity recorded by stations during an earthquake.[559]

The process for determining probability scores per region is as follows:

1. Filter values below the PGA threshold. Modified Mercalli Intensity values of V to VIII were selected as these are the lower and upper bounds for destructive earthquakes in Australia. Using a table proposed by Wald *et al*., upper and lower bounds for PGA of 0.65g and 0.039g, respectively, were chosen.[560]
2. Calculate the mean probability of cells that fall within each of the planning regions.

Overall regional probability

The overall probability of experiencing any hazard for a specific region – which provides a measure of that region's proneness to the impacts of hazards – is found by finding the joint probability for the quantified probabilities. The general equation for finding the probability of two events that may be mutually inclusive is

$$P_{A \text{ or } B} = P_A + P_B - P_A P_B.$$

To find the probabilities with QERMF scores – that is, integers from 1 to 5 – solve

$$P_{\text{overall}} = 5\left(\frac{\sum_{i=1}^{n} P_i}{5n} - \frac{\prod_{i=1}^{n} P_i}{5^n}\right),$$

where n is the length of a tuple containing all hazard probabilities, and P_i is the ith value in the tuple. The probability scores are all represented on a scale of 1 to 5, as per the QERMF. To convert them to probabilities between 0 and 1, they are each divided by 5. The above equation uses a short cut in its representation, in having the left and right denominators be the maximum for the sum and product of the probability scores, respectively. The resulting value is multiplied by 5 to return it to a QERMF-compatible score.

The quantified hazard probabilities in the SDRR are:

1. Tropical cyclone, P_t
2. Riverine flooding, P_r
3. Bushfire, P_b
4. Heatwave, P_h
5. Earthquake, P_e
6. CBR incident, P_c

There are six hazard probabilities, and therefore $n = 6$. The combined probability for a given region is found by solving

$$P_{\text{overall}} = 5\left(\frac{P_t + P_r + P_b + P_h + P_e + P_c}{5 \times 6} - \frac{P_t P_r P_b P_h P_e P_c}{5^6}\right)$$

Overall risk

The overall risk scores for the planning regions are the geometric mean of the three components enumerated above: vulnerability, exposure, and probability:

$$\text{overall risk} = \sqrt[3]{\text{vulnerability} \times \text{exposure} \times \text{probability}}.$$

As with vulnerability scores above, the geometric mean is used to flatten the distribution and have more discrimination in the results.

Hazard prioritisation

The methodology for prioritising hazards relies on a combination of quantitative and qualitative analysis of the relative risk posed by different hazards. Both of these were necessary as the probabilities for some hazards – most significantly, severe thunderstorm event – were not able to be derived using quantitative methods.

For hazards that do have quantitative probability scores, the methodology is as follows:

1. Calculate vulnerability, exposure and probability scores per Local Government Area. The methodologies for each of these is effectively the same as those articulated above, except that the scores are aggregated to the LGA geography rather than the planning region.
2. Calculate an 'impact weight' that measures the population and number of dwellings in an LGA. The impact weight is the mean of the z-scores of estimated resident population (ERP) and number of dwellings. A z-score is a measure of the distance from a variable from that variable's mean, expressed as the standard deviation. The z-score of an observation x with mean $\bar{x}$ and standard deviation σ is found by solving

   $$z = \frac{x - \bar{x}}{\sigma}.$$

   The impact weight for LGA i is found by solving

   $$w_i = 2 + \frac{((e_i - \bar{e}) / \sigma_{e_i}) + ((d_i - \bar{d}) / \sigma_{d_i})}{2},$$

   where e_i and d_i are the ERP and number of dwellings of i, respectively. The addition of 2 to the mean ensures that there are no negative terms in the data.
3. Combine impact weights with vulnerability and exposure for each LGA to find an impact multiplier, by solving

   $$m_i = \text{exposure}_i \times \text{vulnerability}_i \times w_i.$$

   To normalise the multiplier, divide each m_i by the overall mean value for m. This expresses each m_i as a percentage of the mean.
4. Multiply the probability of each hazard for each LGA with that LGA's impact multiplier to derive the LGA's hazard priority rating (HPR). The overall region hazard priority rating is the mean of the relevant LGA scores. That is, the overall HPR for hazard h in region r is found by solving

   $$\text{HPR}(r, h) = \frac{\sum_{i \in r} P_h^i m_i}{n},$$

   where P_h^i is the probability of h for LGA i, and n is the number of LGAs in that region.

This gives an ordering of hazards that have a probability score but does not account for hazards that do not. For this reason, the quantitative methodology acts as a guide for the final prioritisation, which was performed based on previous prioritisations (in the 2017 State Natural Hazard Risk Assessment and State Disaster Management Plan) and recent experience in disaster management.

This produces a rank for each hazard in each reason. Once the hazards were ranked for each region, an overall State HPR was derived by solving

$$\text{HPR}(s, h) = \sum_{r \in s;\, h \in H} \frac{1}{\text{rank}(r, h)},$$

where rank(r;h) is the rank of hazard h in region r, and where H is the set of hazards. This equation works by finding the inverse of the ranks, so that higher ranks – which are smaller numbers – produce a higher score than lower ranks. When these HPRs are found, they are ranked to produce state-level HPRs.

Identifying significant effects of climate change per region

In the 'Climate projections for Queensland's planning regions' segment within Section A of this report, an illustration of the significant effects of climate change per planning region is provided. To determine the significant effects of climate change, two major datasets were used:

1. Gridded climate data by season for four periods of interest: 2020-40, 2040-60, 2060-80, and 2080-2100. These data were presented at a $10km^2$ grid and were taken from the Future Climate Dashboard. The statistics that were used to find significant impacts were, which all represent the change of the periods, relative to the reference period 1985-2006:
    - maximum temperature
    - minimum temperature
    - mean temperature
    - precipitation (annual average mm/day)
    - hot days (days/year).

2. CSIRO decadal maximum forest fire danger index data for decades between 2006 and 2066.[561] This data is presented at 0.75° × 0.75° resolution – roughly $83.25km^2$.

These variables were aggregated from the respective grids to the planning region by finding the mean for each variable per season or decade. To find the significant effects, the z-score of the variables was found. For a variable x, the z-score is found by solving

$$z = \frac{x - \bar{x}}{\sigma},$$

where $\bar{x}$ is the mean value of x, and σ is the standard deviation of x.

Finding the z-score of an observation shows how statistically significant that observation is. Comparing the variables' z-scores highlights trends that deviate significantly from the average effects across regions.

Calculating local government area hazard prioritisations

To derive prioritisations for each local government area (LGA), a similar methodology as the region-level prioritisations is used, with two key differences in the LGA hazard prioritisation methodology.

1. In the absence of probability scores, the hazard priorities of the regions are used in the calculation of LGA hazard priorities – that is, the outputs of the region-level methodology are used as inputs in the LGA-level methodology. Each region's probability, exposure and vulnerability scores, and each region's hazard priorities, are applied to its LGAs.

   This methodology was chosen over calculating these each individually for the LGAs to ensure consistency with the findings of the SDRR; and particularly to retain consistency with the region-level prioritisation, which was conducted in consultation with relevant stakeholders.

2. Because this results in all LGAs within a given region having the same probability, exposure and vulnerability scores, each LGA is assigned a weight based on its estimated resident population (ERP) and the number of dwellings in the LGA.

The methodology for calculating LGA-level prioritisations is as follows:

1. Calculate the per-region probability, exposure and vulnerability scores.
2. Assign weights to each LGA. The weights are calculated by:
   a) Finding modified z-score for each LGA's ERP and number of dwellings.

      An observation's z-score is the distance of that observation from the mean, expressed in units of the standard deviation. As such, a z-score of 1 means that an observation is one standard deviation above the mean; a z-score of -1 means that the observation is one standard deviation below.

      To find the weight, we use a modified z-score, which only returns values above 1 – because the weight will be used as a multiplier of the LGA's probability, vulnerability and exposure scores, the weight must be above 1 so that the resulting scores are not negative.

      Each LGA, then, has a modified z-score for its ERP and its number of dwellings. Each of these is calculated by solving

      $$z = 2 + \frac{x - \bar{x}}{\sigma},$$

      where x is the value of the variable in question for the LGA of concern, $\bar{x}$ is the mean of that variable across all LGAs, and σ is the standard deviation of that variable across all LGAs.

   b) When the two z-score are calculated, the overall weight for each LGA, w_i, is the mean of its modified z-scores.
3. Calculate each LGA's overall susceptibility. This is found by solving

   $$s_i = e_i v_i w_i,$$

   where e_i is LGA i's exposure, v_i its vulnerability, and w_i its weight.
4. Calculate the probability of an event.

   If a probability score is available – see page 233 of the State Disaster Risk Report for cases in which they are not available – then assign the probability of the hazard to the LGA.

   If a probability score is not available, then use the inverse of the priority directly; that is,

   $$\Pr(h, i) = \frac{1}{p_{hi}},$$

   where h is the hazard of concern, and p_{hi} is the priority of h in LGA i.
5. Find the hazard score for each hazard and each LGA. This is found by solving

   $$s_i - \Pr(h, i)\frac{1}{p_{hi}}.$$

   These scores are then ranked to find the overall ranking of the hazard per LGA. In the case that there are tied hazards in an LGA – if the scores are equivalent, for instance – then the ranking reverts to the ranking of its parent region. For example, if bushfire and cyclone are tied in a given LGA, but the parent region has bushfire ahead of cyclone, then the LGA's ranking will also have bushfire ahead of cyclone.

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