



QUEENSLAND STATE EARTHQUAKE RISK ASSESSMENT 2019





Foreword

Disaster events affect the lives of all Queenslanders and have a significant impact on the economy and our environment. Whether of natural or human origin, disasters are becoming increasingly extreme and complex, exacerbated by our globally interlinked economies.

We realise, since a significant earthquake has not impacted Queensland in recent memory, that this does not mean it cannot happen. Earthquakes represent a rare but ever-present risk to all communities across Queensland.

Following the release of the State Natural Hazard Risk Assessment in 2017 and through consultation with stakeholders at all levels of Queensland's Disaster Management Arrangements (QDMA), the need for detailed and consistent information regarding Queensland's risk from earthquake was identified.

Our collective ability to assess and more deeply understand disaster risk is the first step towards the development of resilience. This approach is also reflective of the international focus on understanding disaster risk as priority one of the Sendai Framework for Disaster Risk Reduction 2015–2030.

Queensland is exposed to a range of natural hazards which can lead to significant consequences for our communities. Within the last decade we have experienced natural disasters of a size and scale that are almost unprecedented in our Nation's modern history. These events reinforce the need to communicate



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Minister for Fire and Emergency Services



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appropriate risk information across the three tiers of QDMA: Local, District and State.

Starting at the local level, the communication of consistent risk information between each tier of QDMA can support communities and government, emergency services and all emergency management partners in making informed decisions.

This assessment represents a maturing capability for informing the development of risk-based plans across QDMA. Risk-based planning is one of the cornerstone enablers for the Queensland community to be better able to prevent, be prepared for, respond to and recover from natural disasters.

As the Minister for Fire and Emergency Services, and the Commissioner of Queensland Fire and Emergency Services, we thank all stakeholders for their contribution to this assessment and the continued commitment towards creating safer and more resilient communities. We would also like to specifically thank Geoscience Australia and the University of Queensland for partnering with QFES on this initiative, and local governments for their ongoing cooperation.

We encourage all Queenslanders affected by disaster risk to consider the information and strategies within this valuable assessment and use it to inform the management of risks applicable to their interests and responsibilities.

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Thank you

The Queensland State Earthquake Risk Assessment 2019 was a collaborative effort, bringing together the expertise of multiple stakeholders. QFES would like to thank all the organisations and individuals who assisted us in developing this document. Particular thanks to Geoscience Australia, The University of Queensland and Local Government Association of Queensland.





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Introduction

Purpose and intended audience

This high level report along with the companion executive and technical summary are intended as the overarching component of earthquake risk assessments for all levels of Queensland's Disaster Management Arrangements (QDMA) to inform the development of risk-based disaster management and business continuity plans.

This State Earthquake Risk Assessment provides a comprehensive overview of earthquake risk in Queensland, and is intended to be utilised by all levels of government in conjunction with the Queensland Emergency Risk Management Framework (QERMF). The QERMF, as the endorsed methodology for the assessment of disaster related risk, is intended to:

- Provide consistent guidance in understanding disaster risk that acts as a conduit for publicly available risk information. This approach assists in establishing and implementing a framework for collaboration and sharing of information in disaster risk management, including risk-informed disaster risk reduction strategies and plans.
- Encourage holistic risk assessments that provide an understanding of the many different dimensions of disaster risk (hazards, exposures, vulnerabilities, capability and capacities). The assessments include diverse types of direct and indirect impacts of disaster, such as physical, social, economic and environmental.

This risk assessment was developed using the QERMF to undertake a scenario-based analysis of Queensland's earthquake risk.¹ Overall, the assessment and associated report seeks to complement and build upon existing Local and District earthquake risk assessments by providing updated and validated information relating to the changes in understanding of Queensland's earthquake potential.

Context

In 2017 QFES completed the State Natural Hazard Risk Assessment which evaluated the risks presented by seven in-scope natural hazards. The 2017 assessment evaluated the risks presented by earthquakes in broad terms, and highlighted a number of key vulnerabilities and risks requiring further analysis.²

As QFES matures the Queensland Emergency Risk Management Framework (QERMF) by working with Local and District Disaster Management Groups (LDMGs/DDMGs), opportunities have arisen whereby QFES, in collaboration with relevant Federal and State Government and industry partners, QFES is in a position to provide State-level support to LDMGs and DDMGs, through the development of in-depth risk assessments.

The development of the State Earthquake Risk Assessment 2019 was supported by Geoscience Australia (GA) and the University of Queensland through the provision of expert advice, relevant spatial datasets and the development of the scenarios used through this assessment. Input has been sought from GA to help contextualise the findings of the National Seismic Hazard Assessment 2018 for Queensland.

How to use this assessment within the QERMF Risk Assessment Process

Although widespread destruction due to 'great' earthquakes (as observed in plate boundary regions such as New Zealand) is highly unlikely within Queensland, the consequences of these events can be devastating and have significant and prolonged impacts on the community. Advice for the implementation of this assessment at a Local or District level is to distil the information contained within this document by applying the scenario-based approach to evaluate and understand:

1. The probability of occurrence of an earthquake of the magnitude required to deliver potentially destructive ground shaking within the location under assessment. This can be derived from comparing the seismic hazard source zone map (Figure 10) with the source zone occurrence data available in Figure 9.
2. The vulnerability of the location under assessment through analysis of local ground conditions and the topography (with respect to landslides).
Note: This may require specialist capability beyond that inherently available to most Local Governments. Refer to the Summary for further advice.
3. The elements of the community which may be exposed in the location under assessment (against the six QERMF categories of exposed elements) and the vulnerability of these exposed elements, noting that some elements may be exposed through broader social or economic impacts from an earthquake event occurring outside of the region.
4. The existing controls to manage or mitigate this type of event at the respective level of QDMA (such as building codes, community warning strategies and specific agency disruption or continuity plans).
5. The existing capabilities at the respective level of QDMA to respond to this type of event.
6. The capacity of the identified capabilities.
7. The identified gaps in capability or issues of concern (residual risk) and how the management of these will be implemented through the passage of residual risk through QDMA.

Once steps 1 through 7 have been completed, this assessment can then be tabled for acceptance by a disaster management group for incorporation in to their respective disaster management plan. If, through the implementation of this assessment, an LDMG or DDMG wishes to seek further advice or evaluation of their area of responsibility, assistance in accessing relevant expertise can be sought through the contact details provided within this report.





UNDERSTANDING THE HAZARD



General context

What is an earthquake?

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. These are put into a formula which converts them 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 x 30) more energy than a magnitude 5.0, as shown in Figure 1.

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.

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.

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.

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 river banks 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 tsunamis.

Earthquakes in Australia

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.

Earthquake Magnitude

Magnitude – as magnitude increases, the strength of ground shaking, duration, and area impacted increases

Ground shaking
Increases by 10 times for every magnitude unit

Energy released
Increases by 32 times for every magnitude unit

Duration of shaking
From a few seconds (M 4) to several minutes (M 9)

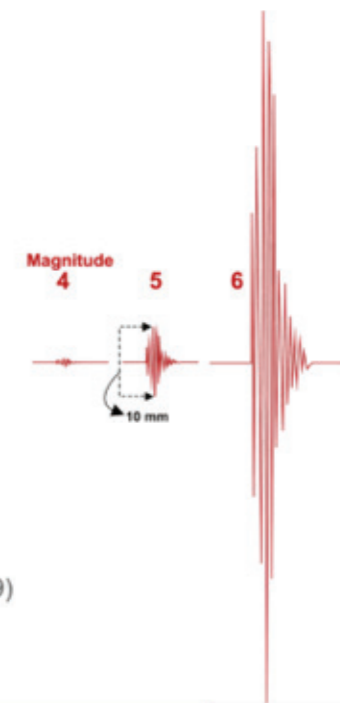


Figure 1: Illustration of earthquake magnitude. Source: Geoscience Australia





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.

Analysis by Geoscience Australia (GA) through the (NSHA18) indicates that across Australia an earthquake of magnitude 6.0 or greater can be expected every 10 to 15 years on average. Along the eastern seaboard of Australia, a magnitude 6.0 earthquake may be expected to occur approximately once every 200 years. Approximately two earthquakes of magnitude 5 or

greater occur within the Australian continent each year.³ Since European settlement, more than 20 earthquakes have caused damage to property or exceeded magnitude 6.⁴

For the very shallow earthquakes common in many parts of Australia, with a focal depth of less than 10 kilometres, people who are near the epicentre and on average density ground will usually experience the maximum MM intensities illustrated in the table presented in Figure 2. If people or buildings are on soft ground, such as old river sediments, the MM intensity experienced may be one to two units higher than if they are on average ground conditions; if on solid rock, it may be one unit

lower. The intensity with which the earthquake is felt may also be higher on hilltops.⁵

Overall, Australia experiences a seismic activity rate:

- among the highest for similar, stable continental regions
- comparable with eastern North America and China
- considerably higher than northern Europe, Africa and much of continental South America.⁶

That said, the rate of seismic activity within Australia is an order of magnitude lower than plate boundary regions, with return periods – or frequencies – of the largest magnitude earthquakes estimated to be in the thousands of years.

The Queensland context

Earthquakes pose a much lower threat to Australian 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.

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.⁷

Figure 4 indicates the locations of all known earthquakes within the State from 1866 to 2018. 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.⁸ A recurrence of this earthquake has the potential to cause significant damage and economic consequences.⁹

Structural damage to buildings and some infrastructure is inevitable for such an event, requiring inspection and potentially repair prior to the re-establishment of normal business. Infrastructure such as refineries, ports, and power and transport networks may experience disruptions ranging from a few

days to weeks depending on the severity of damage. Given the significant contribution of Gladstone to the Queensland economy, the indirect losses from such down-time may far outweigh the direct insured losses incurred.

The region surrounding Gayndah in Central Queensland is of particular note, having experienced damaging earthquakes over magnitude 5.5 in 1883 and 1935 with commensurate aftershocks occurring for many years after.

Central Burnett remains one of the most active regions of the State, with the most recent notable earthquake being the 2015 Eidsvold magnitude 5.2 earthquake. Aftershocks of this event continue to be recorded some four years later.

While infrequent, moderate to large earthquakes present risk to communities and infrastructure within Queensland. Several factors must be considered when estimating the hazard posed by earthquakes, including primary factors such as earthquake magnitude and proximity to the earthquake source, as well as secondary factors such as the local geological conditions and quality of building stock.

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.

It is vital that seismic hazard to Queensland communities is diligently assessed and factored into preparedness activities of governments and emergency services. This assessment is an important component of such preparedness activities, clearly detailing the estimated return periods for potentially damaging earthquakes and providing a factual basis for assessing the seismic hazard to which Queensland communities are exposed.

Notable Queensland earthquakes of magnitude 5.0 or greater have occurred in the locations provided in Figure 3.

Moment Magnitude (Indicative only)	MM Intensity (Likely maximum)	Definition
1.2	II	MMII - felt by a few persons at rest indoors, especially by those on upper floors or otherwise favorably placed.
2.0	III	MMIII - felt indoors, but not identified as an earthquake by everyone. Vibrations may be likened to the passing of light traffic. It may be possible to estimate the duration, but not the direction. Hanging objects may swing slightly. Standing motorcars may rock slightly.
3.0	IV	MMIV - generally noticed indoors, but not outside. Very light sleepers may be awakened. Vibration may be likened to the passing of heavy traffic, or to the jolt of a heavy object falling or striking the building. Walls and frame of building are heard to creak. Doors and windows rattle. Glassware and crockery rattle. Liquids in open vessels may be slightly disturbed. Standing motorcars may rock, and the shock can be felt by their occupants.
4.0	V-VI	MMV - generally felt outside and by almost everyone indoors. Most sleepers awakened. A few people frightened. Direction of motion can be estimated. Small unstable objects are displaced or upset. Some glassware and crockery may be broken. Some windows crack. A few earthenware toilet fixtures crack. Hanging pictures move. Doors and shutters swing. Pendulum clocks stop, start or change rate. MMVI - felt by all. People and animals alarmed. Many run outside. Difficulty experienced in walking steadily. Slight damage to masonry D. Some plaster cracks or falls. Isolated cases of chimney damage. Windows and crockery broken. Objects fall from shelves and pictures from walls. Heavy furniture moves. Unstable furniture overturns. Small school bells ring. Trees and bushes shake or are heard to rustle. Material may be dislodged from existing slips, talus slopes, or slides.
5.0	VI-VII	MMVII - general alarm. Difficulty experienced in standing. Noticed by drivers of motorcars. Trees and bushes strongly shaken. Large bells ring. Masonry D cracked and damaged. A few instances of damage to Masonry C. Loose brickwork and tiles dislodged. Unbraced parapets and architectural ornaments may fall. Stone walls crack. Weak chimneys break, usually at the roof-line. Domestic water tanks burst. Concrete irrigation ditches damaged. Waves seen on ponds and lakes. Water made turbid by stirred-up mud. Small slips, and caving-in of sand and gravel banks.
6.0	VII-VIII	MMVIII - alarm may approach panic. Steering of motor cars affected. Masonry C damaged, with partial collapse. Masonry B damaged in some cases. Masonry A undamaged. Chimneys, factory stacks, monuments, towers, and elevated tanks twisted or brought down. Panel walls thrown out of frame structures. Some brick veneers damaged. Decayed wooden piles break. Frame houses not secured to the foundation may move. Cracks appear on steep slopes and in wet ground. Landslips in roadside cuttings and unsupported excavations. Some tree branches may be broken off.
7.0	VIII-IX	MMIX - general panic. Masonry D destroyed. Masonry C heavily damaged, sometimes collapsing completely. Masonry B seriously damaged. Frame structures racked and distorted. Damage to foundations general. Frame houses not secured to the foundations shift off. Brick veneers fall and expose frames. Cracking of the ground conspicuous. Minor damage to paths and roadways. Sand and mud ejected in alluviated areas, with the formation of earthquake fountains and sand craters. Underground pipes broken. Serious damage to reservoirs.

Figure 2: Earthquake effects can be rated using the Modified Mercalli (MM) intensity scale. An explanation of masonry categories is available at <http://www.ga.gov.au/scientific-topics/hazards/earthquake> Source: Information from Geoscience Australia, table created by QFES

Date	Location	Magnitude	Depth
August 2016	Offshore north east of Bowen	5.8	7km
August 2015	Offshore east of Fraser Island	5.3	13km
July 2015	Offshore east of Fraser Island	5.4	13km
February 2015	Eidsvold, Bundaberg	5.2	13km
July 2011	Bowen, Mackay	5.3	7km
November 1978	Heron Island, Yeppoon	5.2	12km
December 1974	Offshore of Mackay	5.1	6km
June 1965	Tarewinnabar, Warwick	5.3	28km
June 1918	Lady Elliot Island, Gladstone	6.0	15km

Figure 3: Locations of notable Queensland earthquakes of magnitude 5.0 or greater. Source: State Natural Hazard Risk Assessment 2017



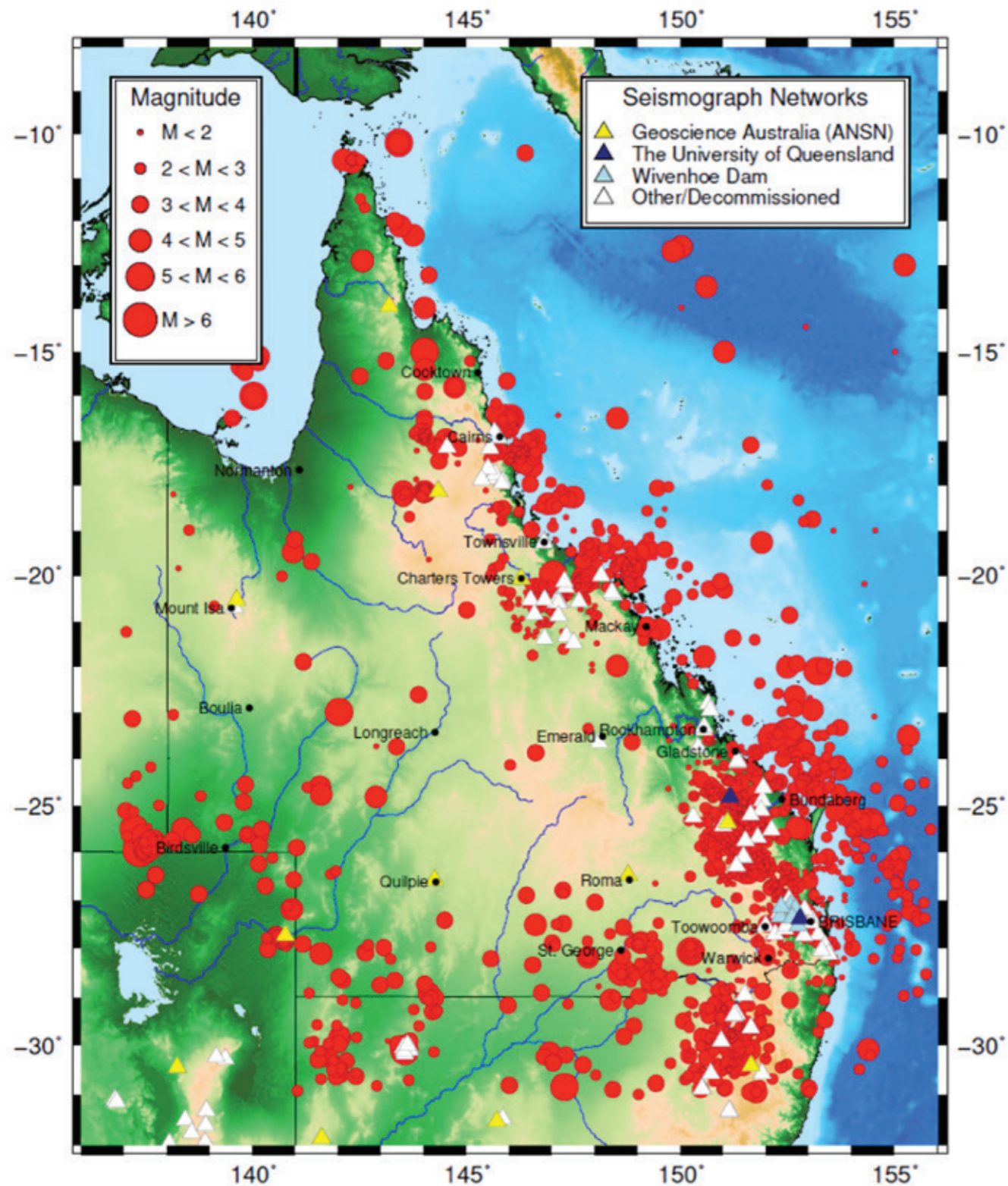


Figure 4: Record of earthquake occurrence within Queensland since 1866. The map highlights a bias in recording associated with the location of settlement activity and the placement of seismographs across Queensland. Thus, it is likely that the map does not truly reflect the record of Queensland's earthquake history, especially in the central and west regions of Queensland. Source: Dr Dion Weatherley, The University of Queensland

The scenario

In consultation with GA and the University of Queensland, this assessment advises that LDMGs and DDMGs focus risk assessments and disaster management planning on a **credible worst-case scenario**¹⁰ which has a higher probability of occurrence than those previously considered catastrophic or extreme events.

Review of previous earthquake risk assessments and subsequent plans have shown a tendency to focus on earthquakes of an extreme magnitude, some of which are not possible given the seismic potential that exists within Australia. In general terms, there are currently no known features within Australia that can deliver beyond a magnitude 7.7 earthquake. Indeed, the NSHA18 does not provide occurrence rates for earthquakes above a magnitude 7.45 for onshore regions within Queensland.

There is geological evidence for the occurrence of earthquakes larger than magnitude 6.5 in Queensland but the probabilities of occurrence of earthquakes of this magnitude exceed one in 100,000 years.

Assessment of extreme magnitude events can lead to biases within the risk assessment process simply because these extreme events could inevitably yield catastrophic consequences across all exposed elements within the communities of Queensland.

As such, this risk assessment was conducted against the known impacts of a major event within the historical record: the 1989 Newcastle earthquake. While this 'known event' occurred in New South Wales, its use in conducting the assessment is relevant due to similarities in earthquake potential for certain regions of Queensland.

Identifying and understanding the potential impacts to Queensland of an unexpected earthquake of even moderate magnitude, as with 1989 Newcastle, is essential. Queensland has not experienced an event of this magnitude within a populated area in modern history. Linking the assessment to the Newcastle event allows for extrapolation of the potential impacts to the communities of Queensland.

Scenario-based analysis such as this is useful for identifying the impacts of potentially 'catastrophic' events, and improves decision-making by allowing deeper consideration of outcomes and their implications. For example, analysis of the possibility of Queensland being struck by a severe earthquake suggests that while the probability is low, the consequences are so high that the event is far more significant than the low probability (in any one year) alone would suggest.

Newcastle, New South Wales, 1989

The earthquake, which struck at 10.27 am 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 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. If constructed to Australian building standards, damage to this building would not have proven fatal for its occupants.



Figure 5: Rescue efforts at the Kent Hotel, Newcastle. Source: Telstra Museum, Newcastle



Figure 6: The impact to the RSL Club building, Newcastle. Source: Telstra Museum, Newcastle



The number of people in the city on the day of the earthquake was lower than usual due to the Christmas 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. (Figures 5 and 6).

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 constructed using unreinforced masonry. 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.

Deloitte Access Economics estimates that if the same event occurred today, total losses would exceed \$18.7 billion in tangible and intangible costs (2016 figure).¹¹

The Great Queensland Quake, Lady Elliot Island, 1918

The magnitude 5.9 to 6.0¹² 'Great Queensland Quake' occurred off Lady Elliot Island (north east of Bundaberg) on 7 June 1918 and was felt as far north as Mackay, as far west as Charleville and as far south as Grafton in New South Wales. This is shown by the isoseismal map in Figure 7. This earthquake was a higher intensity than the 1989 Newcastle earthquake, and demonstrates Queensland's exposure to earthquake. Reports of severe damage to the settlements of Bundaberg, Rockhampton and Gladstone were noted in regional newspapers of the time but little more is known about this event and its overall impacts. A reoccurrence of this event today would likely have catastrophic consequences for the local community, and State-wide economic impacts.

Other major earthquakes within Queensland's historical record include a magnitude 5.7 earthquake impacting Ravenswood, 80 kilometres south of Townsville on 18 December 1913 and the magnitude 5.9 earthquake which devastated the settlement of Gayndah on 28 August 1883.¹³

'ShakeMaps' for both 1918 Gladstone and 1989 Newcastle events show the likely impacts in terms of ground shaking from both events against the cities of Gladstone and Townsville respectively. They are provided in Appendix B on page 36.

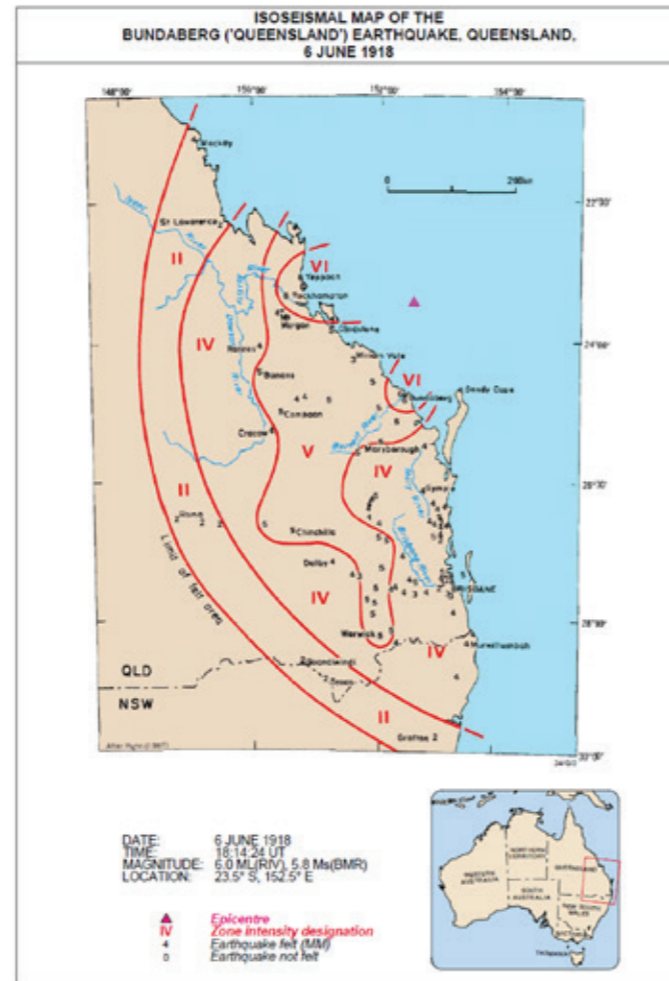


Figure 7: Isoseismal map of the 'Great Queensland Quake of 1918' showing the extent to which the occurrence of the earthquake was felt across Queensland and New South Wales. Note the epicentre of the earthquake occurred a significant distance offshore and yet high levels of associated seismic shaking were felt over a broad area of Queensland. Source: Everingham, McEwin and Denham (1982). Atlas of isoseismal maps of Australian earthquakes, Bureau of Mineral Resources, Geology and Geophysics Bulletin 214



Figure 8: Newspaper extract from 30 August 1883 detailing the impacts from Gayndah earthquake of 1883.

THE ASSESSMENT



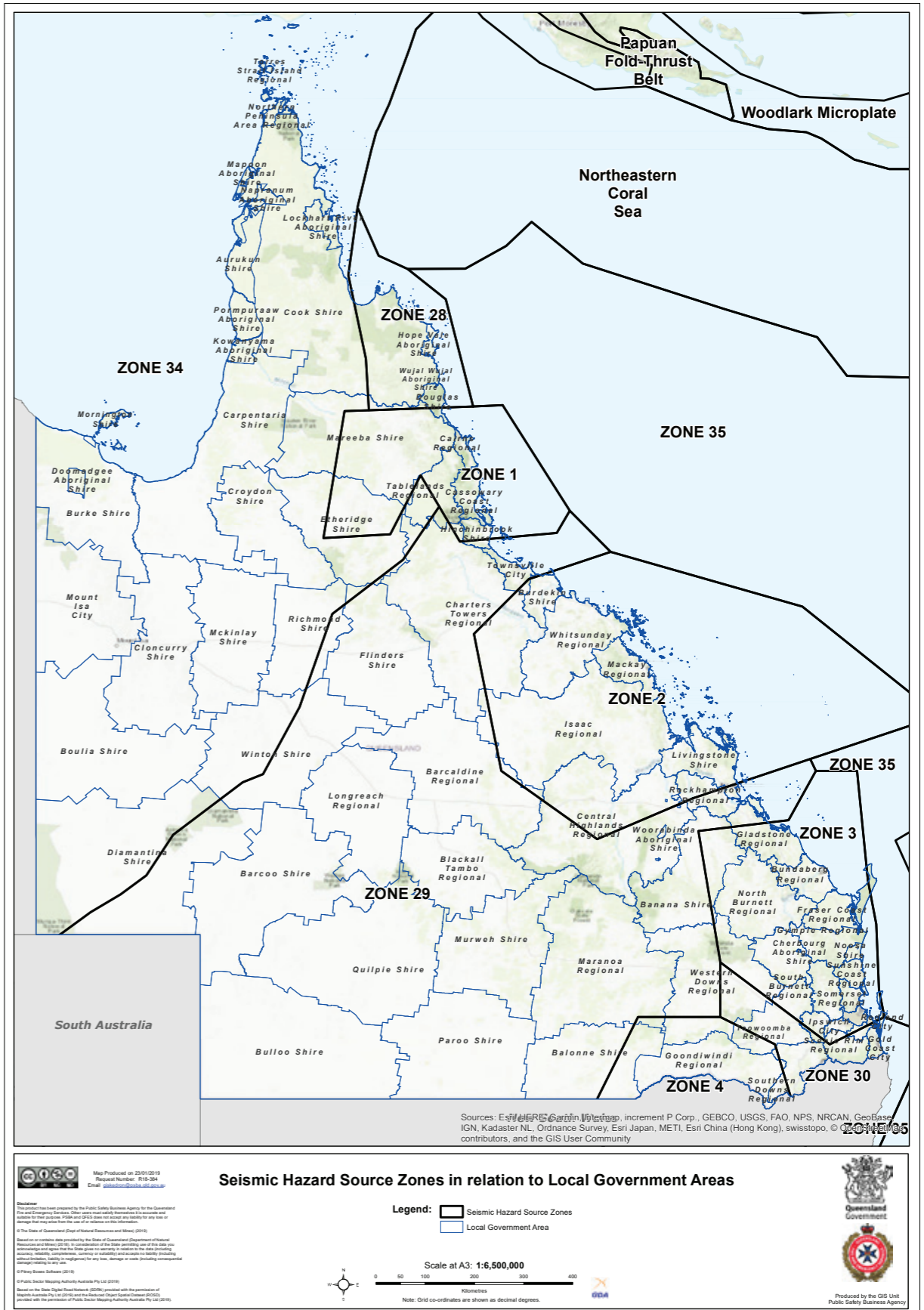


Figure 10: Seismic Hazard Source Zones in relation to Local Government Areas. Source: produced by Public Safety Business Agency using source zones obtained from Geoscience Australia

Probabilistic assessment of Queensland's earthquake risk

This assessment includes the probabilities of occurrence for several time frames, for each source zone within Queensland of a magnitude 5.35 to 6.05 event. This is to highlight the significant difference in occurrence rates between the 1918 Gladstone and 1989 Newcastle events, as well as the increase in impact probability for long-term planning decisions. LDMGs/DDMGs can use these probabilities as part of a scenario-based approach to understand and evaluate the risk of a similar magnitude earthquake occurring in their regions.

Figure 9 details the probability of a magnitude 5.35 (Newcastle 1989 event) and a magnitude 6.05 (Gladstone 1918 event), along with the annual exceedance probability and broader timeframe probabilities for each source zone in Queensland. Figure 10 displays the seismic source zones for Queensland in relation to each Local Government Area.

The probability timeframes were selected by Geoscience Australia to allow understanding of the risk across Queensland to various sectors of society and the economy.

These timeframes are:

- **Annual Exceedance Probability:** the chance of the event occurring on an annualised basis
 - **30 years:** typical length of a mortgage in Queensland
 - **50 years:** land use planning horizon
 - **100 years:** critical infrastructure build horizon.
- Occurrence rates are based on the National Seismic Hazard Map 2012 (NSHM12) regional area source zones¹⁴, as calculated using the National Seismic Hazard Assessment 2018 (NSHA18) earthquake catalogue uniformly expressed in terms of moment magnitude.¹⁵

SOURCE ZONE OCCURRENCE DATA NSHA2018

ZONE	MAGNITUDE		MAGNITUDE		MAGNITUDE		MAGNITUDE	
	5.35	6.05	5.35	6.05	5.35	6.05	5.35	6.05
Z001	0.13%	0.02%	3.38%	0.53%	6.27%	0.88%	12.15%	1.76%
Z002	0.14%	0.02%	4.23%	0.59%	6.96%	0.98%	13.43%	1.96%
Z003	0.35%	0.06%	5.56%	0.78%	9.10%	1.30%	17.37%	2.58%
Z004	0.19%	0.03%	5.64%	0.79%	9.23%	1.32%	17.60%	2.61%
Z028	DATA UNAVAILABLE		DATA UNAVAILABLE		DATA UNAVAILABLE		DATA UNAVAILABLE	
Z029	0.53%	0.07%	14.66%	2.15%	23.21%	3.58%	41.03%	6.99%
Z030	0.03%	0.00%	0.82%	0.11%	1.36%	0.19%	2.70%	0.37%
Z034	2.18%	0.41%	48.36%	11.79%	66.76%	18.86%	88.95%	34.17%
Z035	0.29%	0.06%	8.25%	1.72%	13.36%	2.84%	24.94%	5.60%

Magnitude 5.35 equivalent to Newcastle 1989 Event. Magnitude 6.05 equivalent to Gladstone 1918 Event.
 30 Years – Typical length of a mortgage in Queensland
 50 Years – Land Use Planning Horizon
 100 Years – Critical Infrastructure Build Horizon

Figure 9: The probability of occurrence of a magnitude 5.35 event and a magnitude 6.05 event within each of the dominate source zones in Queensland. Source: produced with assistance from Geoscience Australia





Potential exposures

For the purposes of this report, impact has been assessed against the Newcastle scenario with an MMVI-VIII range of intensity. This assessment is applicable for the whole of Queensland, but must be rationalised against the probabilities of occurrence highlighted in Figures 9 and 10.

Assessing hazard interaction and the impact of hazard characteristics on exposed elements provides a clear understanding of vulnerabilities. This risk assessment highlights those elements susceptible to the characteristics of the hazard.

The key observations for communities across Queensland are presented below according to the six exposed element categories outlined within the QERMF.

This list is not exhaustive and will not be applicable to every Local Government Area within Queensland.

Essential infrastructure

Key points

- Water supply and sewerage systems are highly vulnerable to damage
- Restoration of power and communications following disruption will depend on the level of damage, site accessibility, availability of response personnel and equipment, and identified priorities
- Aged in-ground gas and liquid fuel lines are vulnerable to rupture
- Fuel and water tanks without baffling are vulnerable to damage or failure.

Power and communications

- Significant but short term disruption to the transmission network akin to that experienced in Newcastle, NSW, to be expected in areas of severe shaking (> MMVII-VIII)¹⁶
- In response to the Newcastle event, operational recovery saw high voltage supply restored to major industrial customers 1.5 hours after the incident. Restoration of supply for general distribution began within 30 minutes, with all bulk supply points energised after 2.5 hours. Subsequently, damage then had to be assessed, plant safety assured, and repairs commenced so that normal

levels of reliability could be returned to the community. This phase of restoration took three weeks to repair most major circuits and many months to complete.

- For an event of similar magnitude in Queensland, 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. Powerlink has a service level agreement (SLA) with Energy Queensland in Central and North Queensland to complete emergency and routine work on Powerlink assets. However, 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 Powerlink resources to assist the response) may hamper restoration efforts.
- General availability of spare parts for repairs is also likely to be an issue in the event of significant damage to transmission assets. Transformer trips are likely to be easily rectified, however the primary equipment failures (e.g. porcelain insulator failures) would take longer to rectify.
- Direct effect of intense ground shaking on power distribution network (power plants, generators, switchyards, distribution transformers, poles and lines) is likely to lead to significant disruption across the affected area exacerbated by interdependency of systems and networks on power. Terminal switching and zone substations are highly likely to have damage to vulnerable components including buildings' housing control equipment.
- Power poles may be displaced or toppled by earthquakes and any secondary landslides. If power is lost, the subsequent effect on other lifeline infrastructures, especially water supply, sewerage systems and telecommunications, would be significant.
- Additionally, the interdependency of communications networks and other key community infrastructure (including government services and governance infrastructure) on power may lead to protracted disruption issues.
- Prolonged power outages will lead to the inability to charge mobile communication devices which may compound communication issues.
- 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.¹⁷
- 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.
- Cordless voice over internet protocol (VoIP) phones will cease to work in the event of power outages.
- Microwave dishes and other point to point communications infrastructure are likely to suffer misalignment due to intense ground shaking.
- 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.
- 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.
- 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.
- Disruption and restoration timelines will depend on a variety of factors including:
 - extent of devastation within the affected area
 - access to and from damaged infrastructure
 - availability of requisite components to repair damaged infrastructure
 - capability and capacity of critical infrastructure owners and operators to respond to the event
 - prioritisation of reconnection, with government and industry infrastructure likely to be prioritised over community.

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.

- 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.
- Above ground pipelines may also be affected by intense ground shaking. Vulnerability is greatest at the point of connection due to differential movement.
- Pumping equipment is vulnerable due to dependence on power (where back-up generation is not available).
- 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.
- Asbestos contamination within drinking water (while unlikely to be hazardous to the population through ingestion)¹⁸ would likely attract intense media attention, be of concern at the State level and require immediate action.
- A key vulnerability for all utilities is in the resilience of their supervisory control and data acquisition (SCADA) computer systems. They may fail initially because of the misalignment of their numerous antennae, but such disruption could be quickly rectified if access allows.
- Some referable and tailings dam infrastructure built prior to 1993 (publication of AS1170.4 earthquake loading code) may also be vulnerable to intense ground shaking, although catastrophic collapse is highly unlikely.
- Gravity fed water supply would continue to operate only if the connecting infrastructure is not damaged.
- The vulnerability of water tanks and associated infrastructure is further discussed in the fuel infrastructure section outlined below.

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.





- 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.
- Rail administration buildings, rail yards and depots close to port facilities or built on soft soils may experience extensive damage.
- 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.

Fuel infrastructure

- 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.¹⁹ The probability of rupture and breakage will depend on the precise nature of assets and the earthquake event.
- 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. Aged below ground gas and oil infrastructure such as pipelines (of non-polyethylene construction), wells and other infrastructure may be vulnerable to intense ground shaking leading to ruptures. Such ruptures may lead to disruption to services and/or environmental damage.
- Domestic gas supply is likely to experience medium term disruption in the worst affected areas.
- 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.

Access/resupply

Road and rail

- Major road and rail networks across the State 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.

Key points

- Road and rail networks are vulnerable to considerable protracted damage from earthquake and landslide which may affect response and recovery activities
- Fixed wing aircraft movements may be disrupted due to impacts on associated on-ground infrastructure
- Port facilities, where available, may become the priority route for access and resupply.

- Heavy goods and logistical transport is 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.
- People providing services may be cut off from those with needs (e.g. Meals on Wheels, at home care).
- Some track formations will settle while other rails will buckle laterally as shown in Figure 11 on page 17. As with roads, the most vulnerable points are level crossings, bridges (especially those built prior to publication of AS1170.4- 1993), cuttings, embankments and overpasses.
- 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 as shown in Figure 18 on page 24.
- 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 rare Queensland earthquakes. Vulnerability is greater for shallow cut and cover tunnels than for bored tunnels. For shaking similar to that caused by the 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. Liquefaction of loose granular soils may also cause damage to the approaches to tunnels. For rare but more likely earthquakes, with less severe ground shaking,

structural damage is unlikely though problems may still be encountered with critical mechanical ventilation systems that are poorly restrained and with back-up emergency generation where generation units demount in the shaking. Damage could also be sustained in vertical tunnel access structures such as stations for underground trains where stairways, escalators and suspending ceilings dislodge making them temporarily unusable.



Figure 11: A rail line buckled by the shifting earth is pictured in Christchurch on February 23, 2011. Source: Getty Images

Aerial transport and resupply

- Well maintained and well-constructed airfield pavement is largely resilient to most hazards but may be damaged from the most severe earthquakes as well as debris from damaged buildings. Support facilities such as terminals and fuel systems could be damaged by earthquakes.
- 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.
- Significant demand and dependence on rotary wing aircraft to facilitate access/resupply in the short term is expected.

Maritime transport and resupply

- 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 and social

Key points

- Vulnerability of poorly constructed and maintained buildings presents the most significant risk to public safety during an earthquake
- Secondary (consequential) hazards such as fire, landslides, or infrastructure failure will exacerbate the risk to public safety
- Buildings constructed prior to 1993 are at high risk of damage
- Buildings constructed to comply with wind loading code for cyclonic areas are at least risk due to a high level of structural resilience.

Demographics

- 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. As the engineering adage states: earthquakes do not kill people, poor buildings kill people. Building vulnerability to earthquake shaking is discussed below.
- 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. Where an earthquake is sufficiently severe to cause such damage, it also would have impaired the water supply system and blocked roads with fallen debris, making fires difficult to quickly contain.





- 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 'earthquake induced shock'.

Social infrastructure

- 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, as shown in Figures 13 and 14. 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.

Building stock

- Significant variations in impact between urban and rural centres should be expected.
- Intense ground shaking on soft soils (site class C, D to E)²⁰ 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.

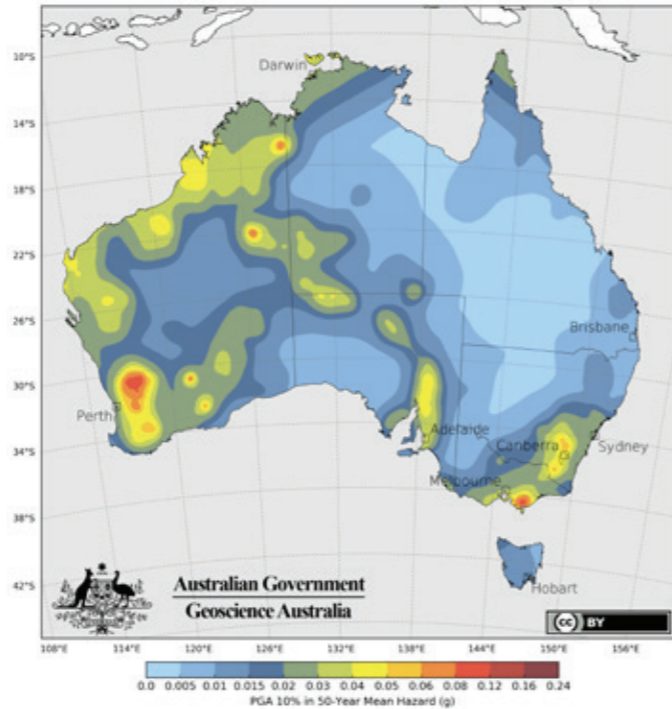


Figure 12: 10%/50 year hazard map based on the NSHA18. Source: Allen, Griffin, Leonard, Clark and Ghasemi (2018). The 2018 National Seismic Hazard Assessment for Australia: model overview, *Geoscience Australia Record 2018/27*, Canberra

- 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.
- Earthquake loads are expressed as an 'acceleration coefficient' which relates to a 10 per cent probability of exceedance in 50 years at 'rock' or 'firm' sites illustrated in the map in Figure 12. This probability corresponds to an annual exceedance probability (the chance of the event occurring once in a year, expressed as a percentage) of approximately 0.02 per cent, or an average recurrence interval, or ARI (the likelihood of occurrence, expressed in terms of the long term average number of years) of approximately 500 years. Following the 1989 Newcastle earthquake, the Australian Standard 3826-1998 was developed to address the upgrade of older buildings to modern earthquake-resistant standards.²¹

Earthquake Building Damage - Examples





MMI V	MMI VI	MMI VII	MMI VIII
Kalgoorlie CBD, 20 April, 2010	Boulder CBD, 20 April, 2010	Greater Newcastle, 27 December, 1989	Central Newcastle and Christchurch, 22 February, 2011
Cracking of vulnerable masonry (e.g. parapets & chimneys with minor falls). Minor cracking to masonry houses.	Collapse of vulnerable masonry and severe cracking to other masonry structures.	Severe damage to unreinforced masonry (URM) buildings, some damage to low ductility framed buildings, particularly irregular buildings.	Heavy damage to URM buildings, severe damage to irregular low ductility buildings.
			

Figure 13: Damage associated with previous known events and certain MM intensity levels of shaking. Source: Geoscience Australia



Figure 14: Damage sustained within the town of Kalgoorlie-Boulder, Western Australia as a result of the magnitude 5.0 earthquake which occurred on 20 April 2010. Source: images courtesy of Department of Fire and Emergency Services, Western Australia



- The NCC has only recently (in 2016) enforced a minimum standard which is outlined in NCC 2016 Vol 1 Part B1.2(c):
 - 1 in 500 year event for small buildings (Class 1)
 - 1 in 1000 year event for large buildings, such as apartments and schools (Class 2 to 9 buildings)
 - 1 in 1500 year event for buildings with a post-disaster function.
- There is no requirement to retrofit a public building that was not originally designed to meet these minimum standards unless new additions to the building increase its footprint by more than 50 per cent.
- 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.²²
- 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.
- 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 Newcastle earthquake. Accordingly, disaster management groups would be prudent to seek structural engineering advice regarding buildings, especially older local government controlled or owned structures. Local government also may wish to advise owners of other critical and sensitive facilities (especially schools and hospitals) of the findings of this assessment.
- The age of construction of all elements of the built environment is a key contributor to their vulnerability. Residential buildings constructed before 1982, for example, will not have been explicitly designed to comply with earthquake loading standards of the NCC.

- Non-residential buildings constructed since 1976 north of Bundaberg and within 50 kilometres of the coastline will have been built to the appropriate wind loading code which will also provide a high degree of resilience to earthquake loads. Similar age thresholds also can be applied to other elements of the built environment including water supply, power supply and sewer infrastructure. Some broad rule-of-thumb characteristics of dwelling structures can be linked to the age of construction as follows:

If built before the early 1950s (see Figure 15 for example):

- exterior and interior walls of timber and/or asbestos
- ceilings are timber or Canite (asbestos) board
- interior cupboards and fittings in solid timber
- high set on stumps two metres or more above ground level
- high pitched hip-ended metal roof
- small windows shaded by verandas or awnings
- brick walls are cavity brick construction.

If built in the 1960s or 1970s:

- greater mix of exterior wall material including brick and timber
- greater proportion of internal walls and ceilings of Masonite, Fibrolite or plasterboard
- large areas of louvers for windows
- windows shaded by small verandas or broad eaves
- increased use of particle board in interior cupboards and fittings
- floor levels above ground on piles up to 0.5 metres above ground
- high pitched metal roofs with an increase in gable ended shape
- brick walls are brick veneer construction.

If built since 1980 (see Figure 16 for example):

- increased use of brick in walls (brick veneer construction)
- interior walls of plasterboard (Gyprock)
- all interior cupboards and fittings of particle board
- large windows and glass sliding doors
- limited shading of windows by narrow eaves
- high pitched metal roofs with a small proportion of tiled roofs
- slab-on-ground construction.



Figure 15: An example of an early post-war house. It has a Fibrolite roof that is susceptible to wind and debris damage, but its small windows make it more resilient to severe wind damage. Its timber frame makes it quite resilient to earthquake shaking. The Fibrolite roof could become a significant environmental hazard if it were damaged in an earthquake. Source: Adobe Images



Figure 16: This is an example of a contemporary house. Their timber frames (under the brick veneer cladding) give them a degree of resilience to earthquake shaking. Source: Adobe Images

- The age-linked structural features described above provide an indication of the potential vulnerability of those buildings. 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 handles 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.

- Consideration also must be given to non-structural components of buildings and the manner in which they have been installed. These include:
 - Architectural: partitions, suspended floors, walls, ceilings, appendages (e.g. awnings, parapets and verandas), masonry, glass and storage racks
 - Electrical: emergency power systems, communications systems, light fittings and switchboards
 - Hydraulic: life safety systems, fire suppression systems (including sprinklers) and hot water heaters



- Mechanical: smoke control systems, boilers, flues, reciprocating and rotating equipment (e.g. chillers, pumps, and fans), ducts and piping systems and their supports
- Transportation: lifts, escalators, conveyors and hoists
- Examples of additional items that would meet this description include shelving, items installed in ceiling voids, cranes, building maintenance units and water storage tanks as shown below in Figure 17.
- Queensland has the lowest level of compliance across Australia with AS1170.4 section 8 which contains specific requirements for non-structural components of buildings. The failure of non-structural architectural and services components to resist seismic forces from earthquakes can result in severe damage to buildings and their contents, and injury or death to occupants.²³



Figure 17: Widespread damage resulting from a ceiling failure after a Canterbury earthquake. Source: Geoscience Australia

Emergency shelters and places of refuge

- Evacuation centres are virtually all public assets, most of them being schools and community centres. It is unlikely that such facilities would be suitable for most, if any, public refuge after the event, especially if they are not constructed to an adequate standard. Very few have adequate air conditioning, toilet facilities or stand-by generators to house displaced or vulnerable persons into the medium term. Restoration of school activities would be a priority in the recovery stage.
- Other designated places of refuge may be impacted and unusable post event.

Medical, public and mental health

- 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

Key points

- An earthquake of this magnitude may lead to a mass causality event
- Sole reliance on external supply of utilities (e.g. power, water, fuel and sewerage) increases vulnerability
- Backup equipment may fail if it is damaged during the event or not adequately built and maintained
- Psychological trauma or distress should be expected across large proportions of the population.

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.
- Equally, there is concern about functionality of redundancies in the aftermath of an event. Some emergency generation will be inoperable due to damage or later fail due to a lack of fuel if resupply is hindered.
- Newcastle resulted in 13 fatalities and 162 reported injuries. In complex urban environments, this figure is likely to be much higher. Hospitals and other medical facilities may have to react to a significant influx of casualties while facing a reduction in capability and capacity through direct or indirect impacts.
- Vulnerability of those persons located within these facilities is a concern. 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.²⁴
- Prolonged power failure may cause food spoilage increasing health risks to the community.

Significant industries

Key points

- Heavy industry and manufacturing sites may suffer damage, become unsafe, and/or suffer significant productivity losses
- Disruption to transport and logistics routes will likely have knock-on impacts to regional and State economies
- Coastal tourism hotspots are likely to be vulnerable because of their construction type and location on softer soils. Vulnerability of tourists is also of concern.

Heavy industry and manufacturing

- Wide disruption to industry due to the direct impact from an earthquake with the addition of consequential impact from the dependency on power, communications and water may lead to considerable decrease in productivity.
- Depots of hazardous materials are of a concern at the State level and facilities within individual Districts across the State should be reviewed on a case by case basis.
- Mining and associated infrastructure (such as railways and port facilities) may experience significant impact.
- Mines operating subterranean extraction are at particular risk.
- 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.
- Impacts to any of these industries would result in displacement of workers (local and transient) which is likely to have a significant impact to regional and State economies.

Transport and logistics

- 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.²⁵ Additional information is provided in the previous Heavy industry and manufacturing section.

Agriculture

- 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.

Tourism

- 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.
- Concern around the vulnerability and lack of resilience of tourists, especially those from non-English speaking backgrounds.
- Negative media coverage is likely to have a significant impact on the tourism industry within the affected area over the medium to long term.

Environment

Key points

- Earthquakes and/or landslides can have devastating effects on wildlife and their habitats
- Release of hazardous materials from damaged containers, pipes, or industrial sites is likely to have adverse effects on environmental health.

- 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.²⁶
- 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.²⁷





Secondary hazards

- Earthquakes can instigate multiple secondary hazards of which fires, caused by downed power lines or gas leaks, can be the most dangerous. This is most likely where water supply has been damaged and roads blocked by debris, making it difficult for emergency services to effectively respond.
- There is potential for loss of life and serious injury, especially electrocution, from fallen power lines and exposed electrical circuitry. The demand to 'make safe' may overwhelm local capability and extend the duration of localised power outages.
- Toxic material can leak from ruptured containers or pipes, adversely affecting the health of people, animals and the environment. Health problems also can arise from power outages, leaking sewage, interrupted water supply and from stress-related responses.
- Traffic accidents can be caused by debris on roads and train derailments can occur where the tracks have been distorted by the earthquake or from debris on the lines.
- Large earthquakes can trigger landslides in high to extreme landslide prone areas as shown below in Figure 18.
- The risk of liquefaction in areas dominated by softer soils should be considered and addressed. However, liquefaction generally requires severe to violent levels of shaking (> MMVIII).
- The risk of localised tsunamis (within 500 kilometres of the eastern seaboard) being generated by earthquakes (and the requisite undersea landslide) is low.²⁸



Figure 18: Impact of a landslide triggered by an earthquake in the South Island of New Zealand. Note the impact to the road and rail network. Source: Getty Images

Risk analysis

This section details the consequences of the impact against the five key components of the community:

1. People – injuries sustained and numbers of casualties
2. Financial and economic – impacts to infrastructure, cost of recovery and impacts to the local, regional or State economy
3. Community and social – impacts to the community, the infrastructure on which it depends and the connectedness of those communities
4. Public administration – impacts to and criticism of response
5. Environment – loss of ecosystems and assets of significant environmental value.

The level of consequence is determined through an assessment of the severity of exposure, the level of vulnerability, the coping capabilities and capacities of the communities involved, and the potential consequences.

People

Likely consequence: Catastrophic²⁹

- A considerable number of fatalities (10 or more) and critical injuries are highly likely to occur as a direct result of an event (highly dependent on time of occurrence and location). Modelling suggests that casualty numbers will be markedly higher during daylight hours compared to a night-time event.³⁰
- Experience of the event in the short term followed by possible medium term displacement (evacuations and/or loss of habitable dwellings) may impact on the emotional capacity of individuals. This can lead to an increase in issues associated with mental health (e.g. PTSD) and impacts upon domestic cohesion.
- Increased hardship due to financial impacts felt at a local and regional scale (loss of property, employment and support services) may further affect the mental health of individuals within the affected community.

Financial and economic

Likely consequence: Major to catastrophic

- While highly variable in terms of magnitude and location, an earthquake on the scale of this scenario could lead to severe economic disruption. An event in a complex urban or industrial environment, such as Gladstone or Townsville, is likely to affect industries such as manufacturing, heavy industry, transport and logistics. This may lead to severe disruption within the footprint of the event, with impacts emanating regionally and ultimately significantly affecting the State economy.
- Damage to or loss of residential and essential civic infrastructure (such as hospitals and schools) as well as short to medium term disruption to transport network

infrastructure and services (roads, rail, air and maritime) would be expected. The scenario presented within this assessment would likely see the economic costs associated with the repair and restoration of these services exceed the costs associated with previous major natural disasters experienced in Queensland.

- The risks posed by earthquakes are likely to increase if new construction does not fully adhere to the standards required in the earthquake loading standard of the NCC and if retrofit and maintenance of older buildings to NCC standards is not continued. Fragility of in-ground infrastructure will continue to grow as it ages.

Community and social

Likely consequence: Moderate to major

- Loss of essential services (such as power and water) and government services will significantly affect the community across the short to medium term. Recovery may be protracted depending on the levels of damage and loss.
- There would be a moderate reduction in community wellbeing through activities such as separation, home loss and school closure. Many religious, sporting or social events may be postponed or cancelled due to infrastructure damage and the mobility of the population. Similar parallels can be drawn to recent events across other hazards such as the impact from Severe Tropical Cyclones Debbie, Marcia and Yasi, as well as the statewide floods of 2011 and 2013.
- Damage to elements of cultural and religious significance to the community may intensify the impact to social connectedness.
- The presence of mental health issues may increase markedly within the wider community and would require additional services to identify and manage the impact.
- Recovery efforts within the affected community are likely to require sustainment in to the long term, requiring investment and planning.

Public administration

Likely consequence: Major

- Local and State government functions would be significantly impaired, including the ability to deliver essential services and governance. Vulnerability of buildings and dependency on essential services may cause significant strain (to the point of collapse) on governing bodies and emergency services delivering these core services.
- Business continuity plans are likely to be tested to the extreme. The capacity of governments to deliver services will come under significant pressure because of the response to the event, management of the consequences,





and inevitable depletion of the workforce. It is highly likely that local government services would require significant State support through disruption, recovery and back to business-as-usual.

- There will be increased demand on emergency services requiring specialist emergency capability support to assist frontline officers in restoring basic services and public order while responding to calls for service. The inevitable mass panic that would ensue as a result of the event may quickly overwhelm services without robust business continuity plans to sustain such extreme levels of demand.
- Earthquakes are an ‘Act of God’ hazard. Any perception that the response to earthquake damage and loss is slow or inadequate could, however, generate widespread outrage. It also will be significant where loss, especially in public buildings, is seen as being the result of inadequate quality construction and/or maintenance.

Environmental

Likely consequence: Moderate

- Species and environmental landscapes would be moderately impacted but may be exacerbated if secondary hazards such as landslides occur.
- Ecosystems within the earthquake zone would be expected to encounter localised impacts on species and landscapes however most of these would exist elsewhere within the State. Environmental value would also be impacted with an extended recovery time to be expected.
- Damage to ecosystems of State and national importance such as the Great Barrier Reef would also be devastating to local, regional and State economies.

Risk statement

Damaging earthquakes remain rare across Queensland but such an impact could have very serious consequences both in terms of people killed or injured and economic losses.

The sudden onset of an earthquake, especially an earthquake with an intensity of shaking equivalent to MMVI to MMVIII, 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 severely 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 strain on frontline services across all government sectors would result, due to an increased demand in response to the event with

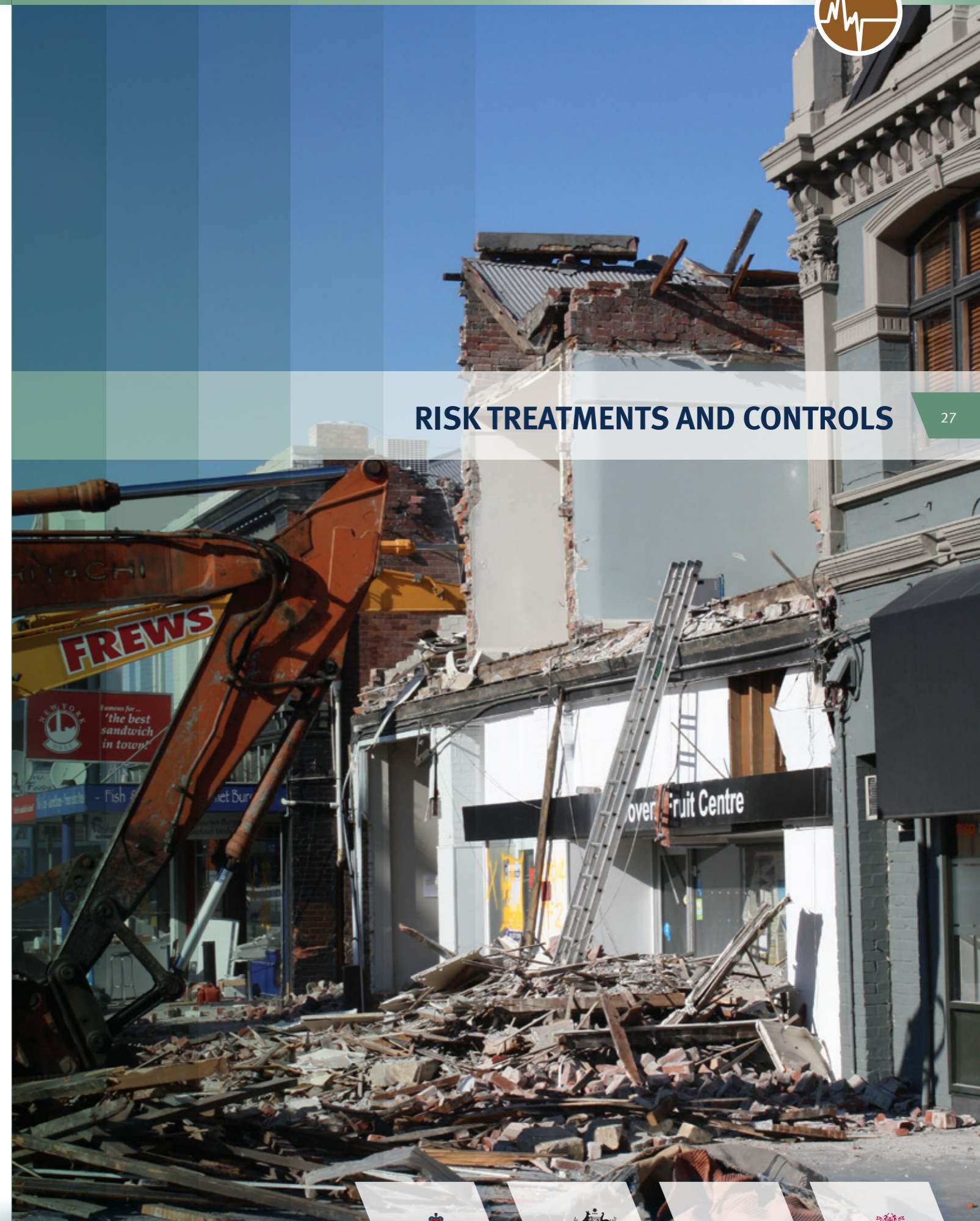
impacts enduring across the wider community while post event recovery efforts continue.

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.

RISK TREATMENTS AND CONTROLS





What can be done to address the risks from earthquakes in Queensland?

This section highlights a range of mitigation strategies to address earthquake risk across all levels of Queensland's Disaster Management Arrangements. Operational risks and treatment plans are addressed within District and Local level risk registers and disaster management plans. These strategies are not exhaustive as the multifaceted issues arising from a State or macro perspective are at times dealt with in business-as-usual across a range of Commonwealth, State and Local Government fora, systems and processes that are not necessarily bespoke to a single hazard.

Prevention

The risk of earthquakes can be treated to some degree by the application of appropriate building construction and maintenance standards. The large proportion of pre-code residential buildings is of concern. Detailed building construction data and building age data also would greatly improve the vulnerability input to the risk analysis. Future risk can be reduced by designing buildings to withstand a certain level of earthquake motion.

Information available to researchers or disaster management practitioners is highly dependent on output from Commonwealth agencies, with few research opportunities available in Queensland. As shown earlier in Figure 4, Queensland's seismic records show a bias towards areas of settlement activity and the placement of State and national seismic monitoring sites. An increase in the coverage of seismic monitoring sites coupled with research conducted at the State level would provide a more comprehensive understanding of Queensland's earthquake potential and risk.

Further, a more detailed site class study than that available from GA, including a micro-tremor study, would improve the risk analysis in areas of strategic importance to Queensland's economy. Seismo-geological studies, as well as longer monitoring of smaller magnitude earthquakes, would greatly improve estimates of long term return periods of larger earthquakes. They also would provide capacity for intermediate-term forecasting of larger magnitude earthquakes, potentially months or years in advance of the ensuing event.

Preparedness

At present, earthquake occurrence cannot be predicted or forecasted so no warnings are available. Community awareness and education initiatives can improve how earthquakes are recognised, increase understanding of expected impacts, and inform communities on how to respond during an event, leading to a greater understanding of this hazard.

Risk can be reduced by educating the community about what to do in an earthquake – taking shelter under strong pieces of furniture, for example, rather than running outside.

Regular earthquake drills should be conducted in schools, starting at primary or even pre-school level so that people's response in an earthquake becomes rapid and automatic. These drills could be conducted across Queensland schools independently, or as part of the Great ShakeOut drill³¹ that happens in October each year.

Get Ready Queensland³² funding provides an opportunity for targeted community campaigns which can benefit personal earthquake preparedness and community resilience.

The coordination of disaster operations and activities in response to a significant earthquake should be well articulated within Local and District Disaster Management Plans. This will help to improve coordination of relevant information and enable effective decision making.

Response

Acknowledging that Local Governments are primarily responsible for managing events within their Local Government Area, it should be noted that an earthquake equivalent to a Newcastle or Gladstone event would almost certainly exceed Local and District capability to respond. Therefore, it is likely that such an event would trigger a State level response, with the State Disaster Coordination Centre (SDCC) activating within hours of the event to provide support to affected groups as requested. It remains essential that such a response is coordinated at the Local level via Local and District Disaster Management Groups (DDMGs/LDMGs).

It is highly likely that the requirement for comprehensive information at the State level may overwhelm capability and capacity at the Local level. To manage this demand reporting should be timely and accurate, and conducted through coordinated authoritative sources with clearly identified roles and responsibilities as outlined within the State Disaster Management Plan and and State Disaster Management Guideline.

Possible impacts to power and telecommunication networks would likely impact the ability to feed timely and accurate information from Local and District levels to the State. This supports the need for redundancy in communications to address response across all hazards.

During the response phase it is vital the community is kept informed of response activities and provided with advice on how and where to obtain assistance and/or support. The media must be kept fully engaged in this process to ensure they provide positive support rather than become a source of misinformation or ill-informed criticism of response activities.

Recovery

The operation of evacuation centres after an earthquake impact and/or the provision of relief housing may be required for extended periods. After the impact of a destructive earthquake, the restoration of large numbers of damaged homes, businesses and public assets would be likely to take more than 12 months.

The development of strategies to address infrastructure recovery, business recovery and community welfare need to be considered to ensure the impact of an earthquake is not exacerbated by a lack of utilities, economic hardship and social dislocation. Lack of such services would prolong the community recovery process.

People may be required to stay with family, friends, or in temporary public housing for an extended period after the hazard impact when their homes have become uninhabitable or isolated, or the local environment has been rendered unsafe to be reoccupied. This type of accommodation would be required after a destructive earthquake and the subsequent widespread failure of major infrastructure elements such as water and power supply.

A post-event survey of the nature and distribution of damage (such as those conducted by QFES's Rapid Damage Assessment Teams) is an essential step in improving the understanding of earthquake behaviour, and building and infrastructure vulnerability. This should be undertaken as an integral part of the clean-up and recovery process and should be coordinated by the LDMG.

Following significant earthquakes, it is likely considerable interest will be expressed by both national and international academia, the insurance industry and public research agencies (such as GA and CSIRO) in studying the impact. This research activity should be coordinated and resulting outcomes be made available to local governments for planning purposes.

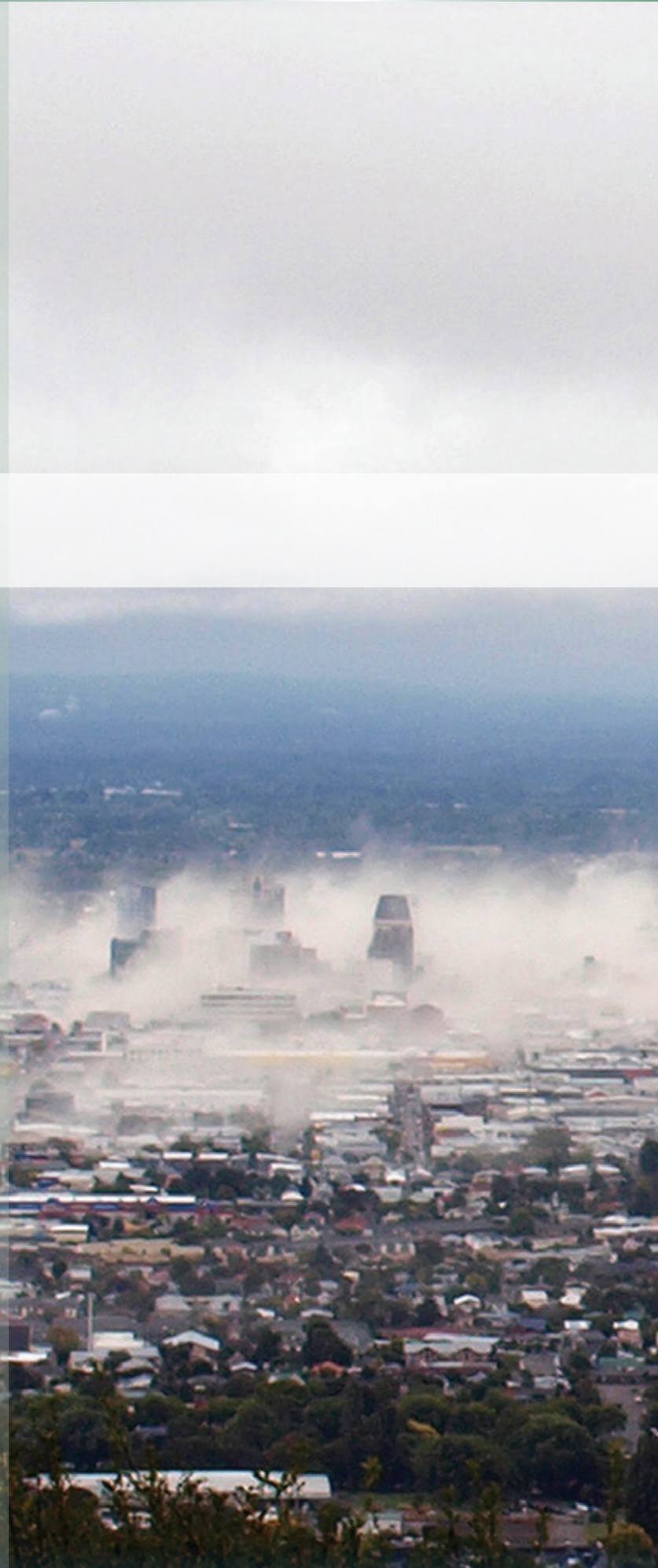
Most comprehensive insurance policies provide cover for earthquake damage. Owners of damaged properties that are uninsured or underinsured would seek external support. The administration of any relief funding needs to be well managed by State Government agencies and coordinated and conform to the relevant Commonwealth Government guidelines.

The demand for repair services for buildings is likely to produce significant delays in work being undertaken, akin to those delays experienced during prior severe tropical cyclone impacts.

Additional PRR treatments and controls

- Recommend land-use controls are in place with regard to landslide prone areas. Use slope, aspect and soil type data to identify high risk areas and map as a development constraint overlay
- Consider or enhance appropriate avenues for the communication of earthquake risks through local media
- Conduct Local and District level exercises that include all stakeholders, inclusive of all Functional Recovery Groups, to gauge capability and capacity to manage the impact of a high demand, sudden onset event
- Encourage the development of business continuity planning, across all sectors of the community, that seeks to address the risks posed from significant earthquake occurrence, and other high consequence, low probability events
- Local evacuation plans have been created, maintained, and exercised
- Evacuation centres are staffed, resourced, and capable of dealing with a high demand, sudden onset event
- Consider whether mutual support arrangements between Local Government Areas and Disaster Districts are capable of dealing with a high demand, sudden onset event
- Local critical infrastructure has adequate redundancy to function during immediate impact period (>72 hours). Consider securing adequate redundancy through MoUs with local suppliers.





As reported in the State Natural Hazard Risk Assessment 2017, the risks associated with earthquake activity remain Queensland's fifth natural hazard risk priority.

However, a key finding of this 2019 updated assessment is that Queensland's exposure to significant earthquake activity may have been underestimated in many previous assessments of the hazard.

Specifically, the area of highest risk from significant earthquake occurrence and impact is those areas of Zone 003 which includes Gladstone in the north, extending south to incorporate the Greater Brisbane area and Ipswich, and west to include areas bordering the Great Dividing Range, as shown in Figure 19. This analysis takes in to consideration several factors which include:

- Density of population within this zone. The population of Local Government Areas (LGAs) within this zone accounts for close to two-thirds of Queensland's total population.³³
- The cross dependency of critical infrastructure within this area. A significant proportion of the State's transport and logistical network, power generation and transmission capability operates within this zone.
- Economic activity. The Gross Regional Product (GRP) of LGAs within this zone accounts for approximately 60% of Queensland's total GRP.³⁴
- The historical record of earthquake activity³⁵ and probability of future occurrence in these zones (refer to Figure 9 on page 12).

As such, Zone 003 (as defined in Figures 10 and 19) is accorded Queensland's highest priority area for significant earthquake risk and should therefore be a priority for any future Queensland based studies or considerations of potential earthquake impact.

Zone 002 (refer to Figure 9 on page 12), encompassing areas of Mackay to Rockhampton in the south and extending to areas surrounding Townsville in the north, is accorded Queensland's second priority area for significant earthquake risk. This is in part due to considerations around economic and industrial activity as well as the probability of future earthquake occurrence.

Despite according these two zones first and second priority, the risk to other zones within Queensland should not be discounted. It is hoped that further future studies will explore this risk in greater detail and as a result, better define Queensland's risk from significant earthquakes.

If further research, analysis or assessment are required after reviewing this document to understand the earthquake risk for a particular area, a collaborative approach with the stakeholders listed below is recommended to ensure consistency in evaluating the hazard in line with State and national assessments.

Key agencies:

- Queensland Fire and Emergency Services (Hazard and Risk Unit)
- University of Queensland
- Geoscience Australia.

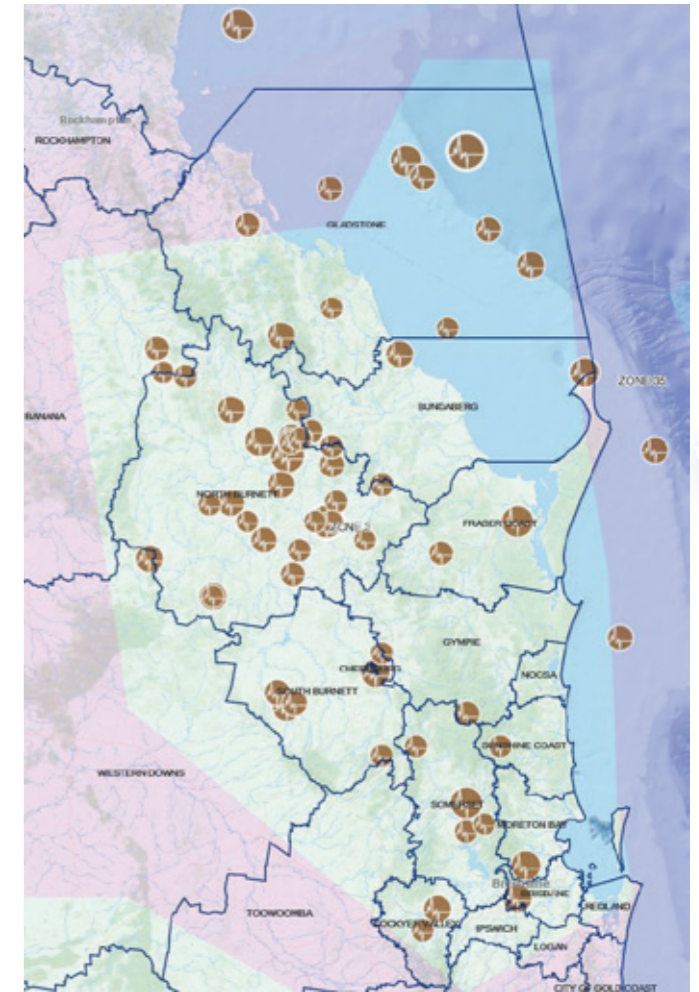


Figure 19: Historical record of earthquakes (>M 3.0) within Zone 003 from 1872 to the present day. Source: Map created utilising the QERMF Risk Assessment Tool. Data supplied by Geoscience Australia.





Technical definitions

Amplitude

The amplitude is the size of the 'wiggles' on an earthquake recording.

Bedrock

Relatively hard, solid rock that commonly underlies softer rock, sediment, or soil.

Geomorphology

Geomorphology is the study of the character and origin of landforms, such as mountains and valleys.

Intensity

The intensity is a number (written as a Roman numeral) describing the severity of an earthquake in terms of its effects on the earth's surface and on humans and their structures. Several scales exist, but the ones most commonly used are the Modified Mercalli scale and the Rossi-Forel scale. There are many intensities for an earthquake, depending on where you are, unlike the magnitude, which is one number for each earthquake.

Lateral spread

Lateral spread or flow are terms referring to landslides that commonly form on gentle slopes and that have rapid fluid-like flow movement, like water.

Liquefaction

A process by which water-saturated sediment temporarily loses strength and acts as a fluid, like when you wiggle your toes in the wet sand near the water at the beach. This effect can be caused by earthquake shaking.

Magnitude

The magnitude is a number that characterizes the relative size of an earthquake. Magnitude is based on measurement of the maximum motion recorded by a seismograph. Several scales have been defined, but the most commonly used are (1) local magnitude (ML), commonly referred to as "Richter magnitude", (2) surface-wave magnitude (Ms), (3) body-wave magnitude (Mb), and (4) moment magnitude (Mw). Scales 1-3 have limited range and applicability and do not satisfactorily measure the size of the largest earthquakes. The moment magnitude (Mw) scale, based on the concept of seismic moment, is uniformly applicable to all sizes of earthquakes but is more difficult to compute than the other types. All magnitude scales should yield approximately the same value for any given earthquake.

Moment magnitude

Moment magnitude refers to the size of an earthquake in terms of how much energy is released. Specifically, moment magnitude relates to the amount of movement by rock (i.e. the distance of movement along a fault or fracture) and the area of the fault or fracture surface. Since magnitude scales are logarithmic, an increase of one unit of magnitude on the moment magnitude scale is equivalent to an increase of 10 times the amplitude recorded by a seismograph and approximately 30 times the energy.

Seismic moment

The seismic moment is a measure of the size of an earthquake based on the area of fault rupture, the average amount of slip, and the force that was required to overcome the friction sticking the rocks together that were offset by faulting. Seismic moment can also be calculated from the amplitude spectra of seismic waves.

Seismic wave

A seismic wave is an elastic wave generated by an impulse such as an earthquake or an explosion.

Seismograph

A seismograph, or seismometer, is an instrument used to detect and record earthquakes.

ShakeMap

ShakeMap is a product of the USGS Earthquake Hazards Program in conjunction with the regional seismic networks. ShakeMaps can provide scenario and near-real-time maps of ground motion and shaking intensity following significant earthquakes. These maps are used by federal, state, and local organisations, both public and private, for post-earthquake response and recovery, public and scientific information, as well as for preparedness exercises and disaster planning.

Tectonic plates (Plate tectonics)

Plate tectonics is the theory supported by a wide range of evidence that considers the earth's crust and upper mantle to be composed of several large, thin, relatively rigid plates that move relative to one another. Slip on faults that define the plate boundaries commonly results in earthquakes. Several styles of faults bound the plates, including thrust faults along which plate material is subducted or consumed in the mantle, oceanic spreading ridges along which new crustal material is produced, and transform faults that accommodate horizontal slip (strike slip) between adjoining plates.

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- Australian Earthquake Engineering Society – www.aees.org.au
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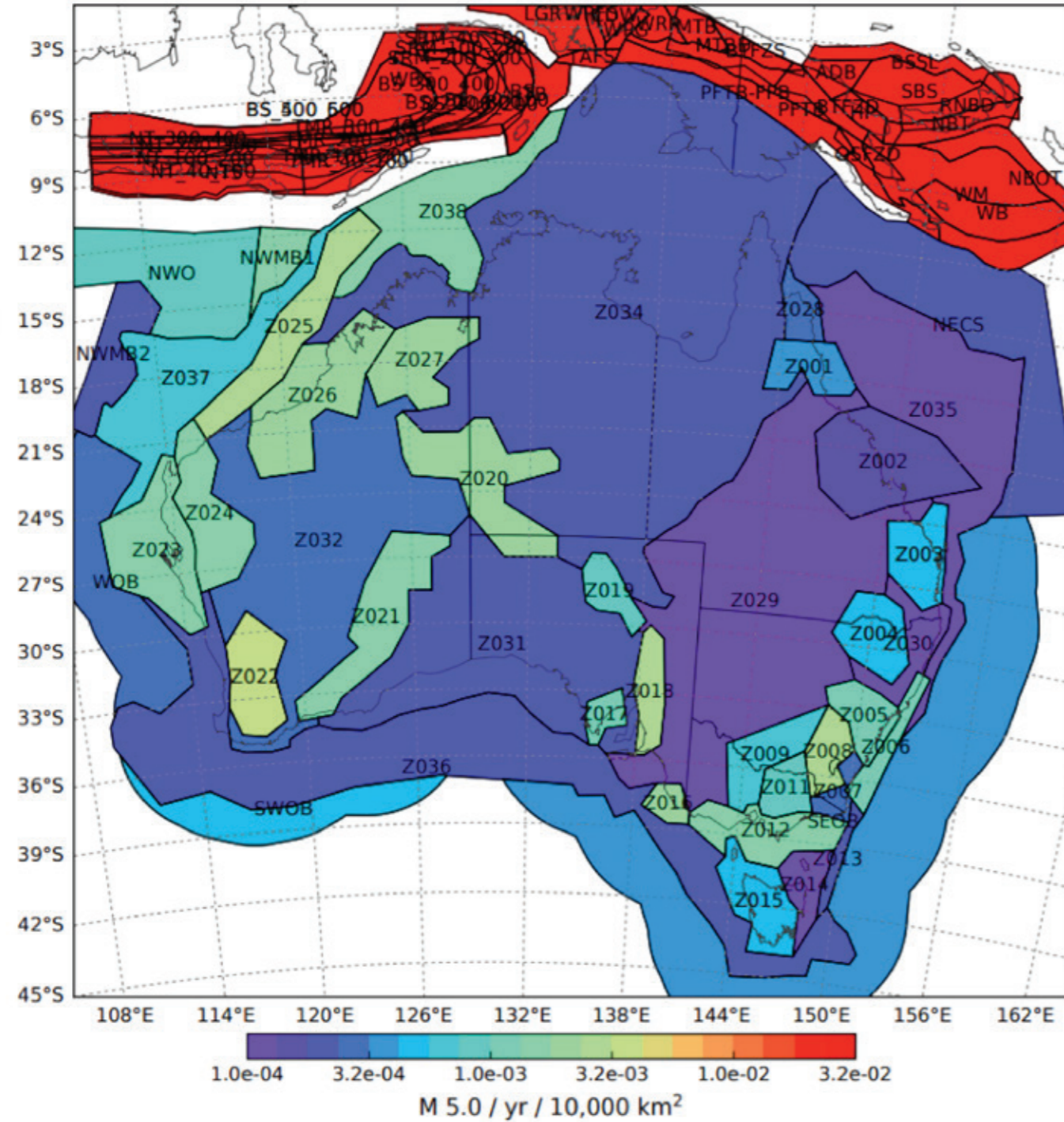
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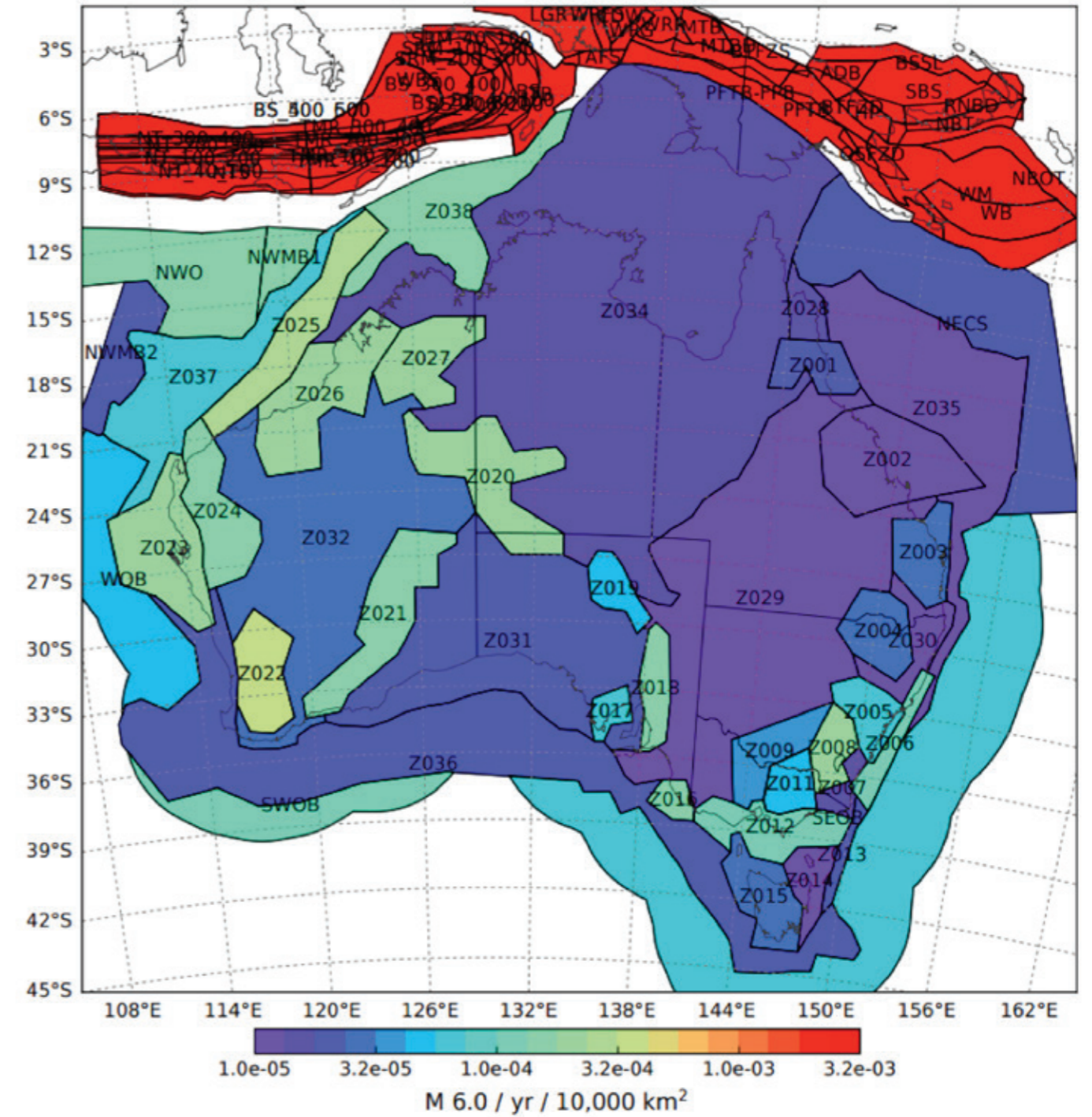


Appendices

Appendix A: National Seismic Hazard Assessment 2018: Source Zones



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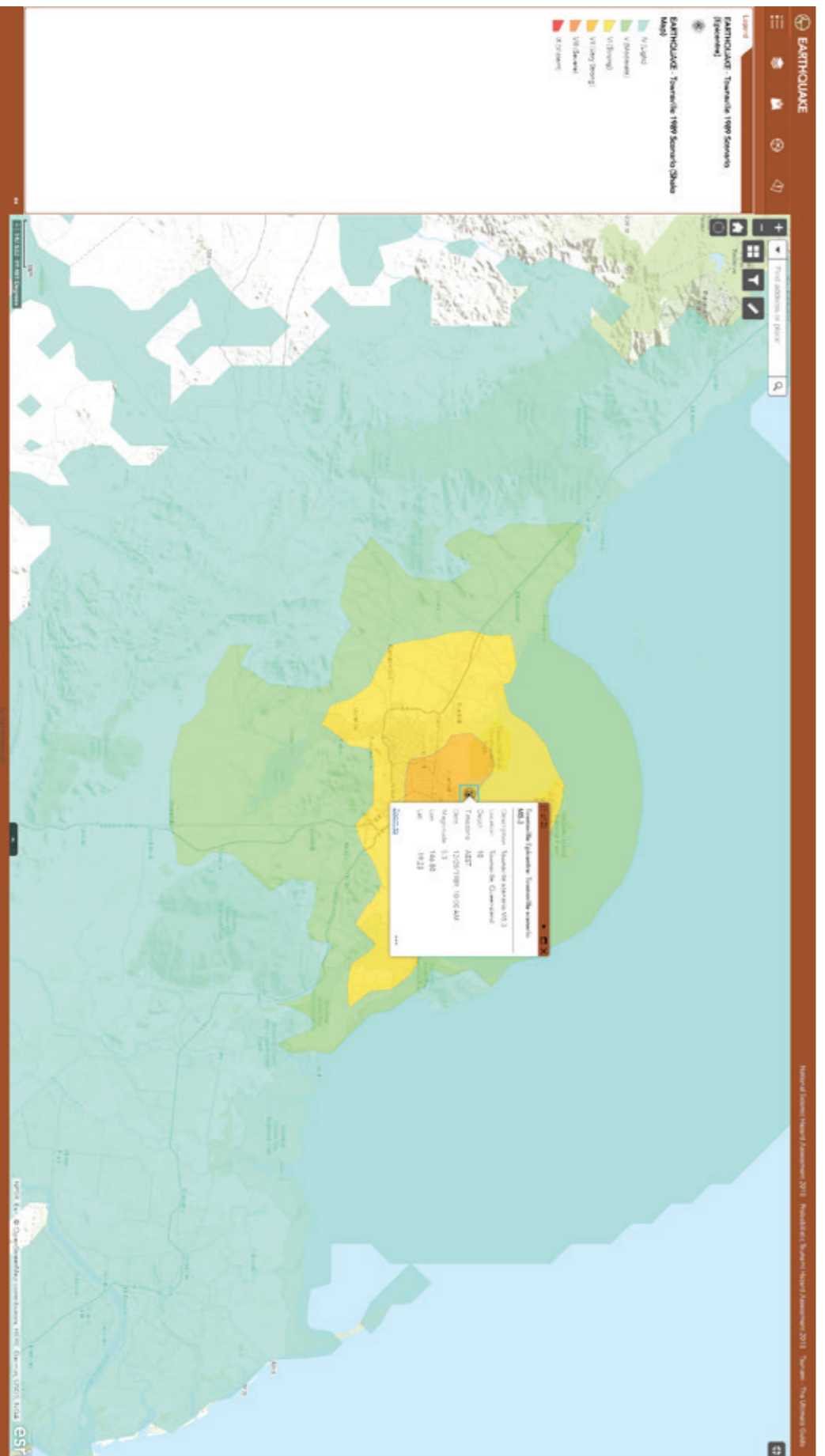
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ShakeMap, rendered within the QERM Risk Assessment Tool, highlighting levels of seismic shaking resulting from a similar magnitude earthquake to that of the M5.3 1989 Newcastle Earthquake occurring within the City of Townsville.

Please Note: This scenario is indicative only and has been created by Geoscience Australia using the USGS ShakeMap software to underpin this risk assessment. It does not reflect an actual event or hazard extent and cannot be relied upon to inform planning considerations. Specific advice or guidance should be referred to Geoscience Australia.

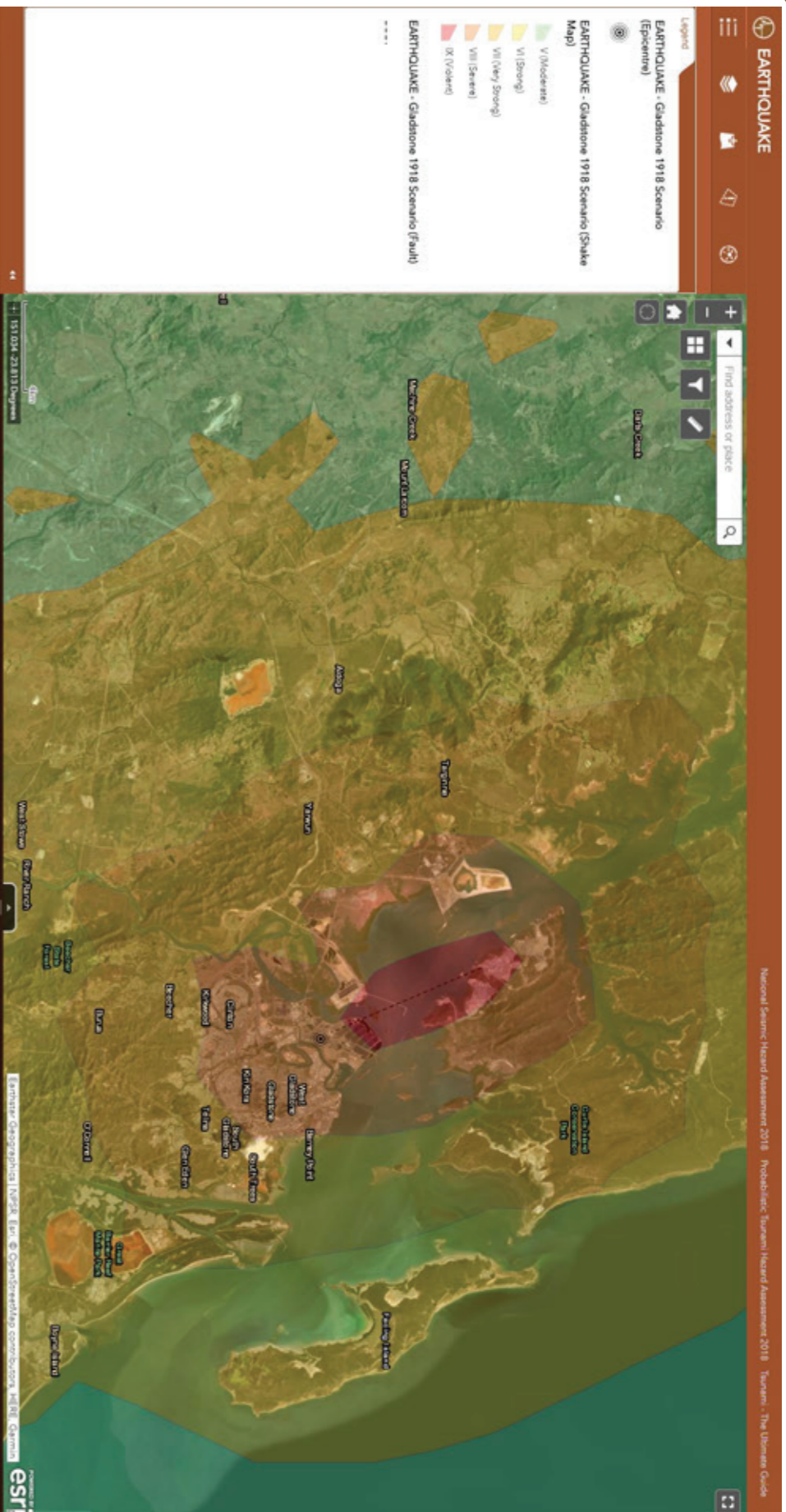
Appendix B: ShakeMap for Newcastle Scenario within Townsville



ShakeMap, rendered within the QERM Risk Assessment Tool, highlighting levels of seismic shaking resulting from a similar magnitude earthquake to that of the M5.3 1989 Newcastle Earthquake occurring within Townsville region.

Please Note: This scenario is indicative only and has been created by Geoscience Australia using the USGS ShakeMap software to underpin this risk assessment. It does not reflect an actual event or hazard extent and cannot be relied upon to inform planning considerations. Specific advice or guidance should be referred to Geoscience Australia.





ShakeMap, rendered within the QERMF Risk Assessment Tool, highlighting levels of seismic shaking resulting from a similar magnitude earthquake to that of the M_s9 – 6.05 1918 “Great Queensland Quake” occurring within the City of Gladstone.

Please Note: This scenario is indicative only and has been created by Geoscience Australia using the USGS ShakeMap software to underpin this risk assessment. It does not reflect an actual event or hazard extent and cannot be relied upon to inform planning considerations. Specific advice or guidance should be referred to Geoscience Australia.

Appendix B: ShakeMap for Gladstone Scenario



ShakeMap, rendered within the QERMF Risk Assessment Tool, highlighting levels of seismic shaking resulting from a similar magnitude earthquake to that of the M_s9 – 6.05 1918 “Great Queensland Quake” occurring within Gladstone region.

Please Note: This scenario is indicative only and has been created by Geoscience Australia using the USGS ShakeMap software to underpin this risk assessment. It does not reflect an actual event or hazard extent and cannot be relied upon to inform planning considerations. Specific advice or guidance should be referred to Geoscience Australia.



