2016 Tasmanian State Natural Disaster Risk Assessment

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Disclaimer

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This report contains the views of a wide range of stakeholders engaged as part of the risk assessment process. The views expressed are the responsibility of the University of Tasmania and are not necessarily those of the Australian Government, Tasmanian Government or other organisations that participated in the development of this report.

This is research work, and as such there is potential for uncertainties in what has been presented. While every effort has been made to ensure that the material in the report is accurate, the Contributors provide no warranty, guarantee or representation that the material is accurate, complete, up to date, non-infringing or fit for a particular purpose. The use of this material is at the risk of the user.

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Image: Warren Frey, Tasmania Fire Service

Minister's foreword

Tasmania is exposed to a range of natural hazards, which can lead to significant consequences for the Tasmanian community.

In 2013, Tasmania experienced one of the worst bushfire seasons in almost 50 years with properties, businesses and infrastructure destroyed in several communities.

In 2016, the Tasmania Fire Service and partner agencies undertook a 60 day bushfire campaign involving thousands of emergency services personnel including volunteers, public servants, business employees, and community members. Over 1,000 personnel were deployed from numerous States, Territories, and New Zealand. At the same time, the State Emergency Service also responded to state-wide flash flooding and storm damage events.

These events reinforce the need for a Tasmanian community-based state-level risk assessment, which can inform emergency services and emergency management partners in making decisions to prepare for and mitigate against the impacts of natural disasters and encourage other stakeholders to do the same.

The *National Strategy for Disaster Resilience* promotes the importance of continuing to develop community resilience to better withstand the effects of natural disasters. Under this strategy, it is recognised that a disaster resilient community is one that works together to understand and manage the risks that it confronts, and that disaster resilience is the collective responsibility of all sectors of society, including all levels of government, business, the non-government sector and individuals.

The *2016 Tasmanian State Natural Disaster Risk Assessment* contributes to enabling disaster resilience by providing information on state-level risks posed by a range of priority natural hazards. This revision of the Tasmanian State Natural Disaster Risk Assessment includes emerging risks associated with climate change, such as heatwave and coastal inundation.

The University of Tasmania, Antarctic Climate and Ecosystems Cooperative Research Centre and RMIT University project team facilitated the participation of Tasmanian Government agencies and other organisations including the Australian Red Cross, Engineers Australia, the Bureau of Meteorology, and private businesses in the development of the *2016 Tasmanian State Natural Disaster Risk Assessment*. This approach of working together to understand risk is a positive indicator of the Tasmanian community's disaster resilience.

I thank all stakeholders for their contribution to the *2016 Tasmanian State Natural Disaster Risk Assessment*, and their continued commitment towards improving the Tasmanian community's disaster resilience.

I encourage all organisations with a role in emergency management to consider this valuable report and utilise it to inform the management of risks applicable to their interests and responsibilities.

The Hon Rene Hidding, MP
Minister for Police, Fire and Emergency Management

Executive summary

This report will help the Tasmanian community be better prepared for, respond to and recover from natural disasters through an updated understanding and awareness of the natural hazards that have the most potential to impact the State.

The information contained in this report, including the risk register and risk treatment options together with the accompanying all hazard summary report, can be used by stakeholders and practitioners throughout the emergency management sector to inform emergency management planning.

This report assesses the State level risks posed by Bushfire, Flood, Severe Storm, Landslide, Tsunami, Earthquake, Heatwave, Coastal Inundation and Pandemic Influenza.

Bushfire remains the greatest aggregated risk to Tasmania. It is a 'High' or 'Extreme' risk across all sectors of society, often with catastrophic consequences expected every 30 years (i.e. 'Unlikely' likelihood). This likelihood is expected to become more frequent with climate change.

Land-use planning and building systems are strong and effective controls for each of the hazards apart from Pandemic Influenza. Limiting future development and vulnerability in known 'at risk' areas is considered to be the most effectve way of protecting life and property while limiting future government liability.

A 'multi-hazards' approach to exercises and business continuity planning within government was agreed to be an important treatment option, with hazard-specific training recommended for key incident management personnel (e.g. incident controllers) as well as formalising the arrangements to guide decision-makers in times of crisis to ensure rapid decision.

Contents

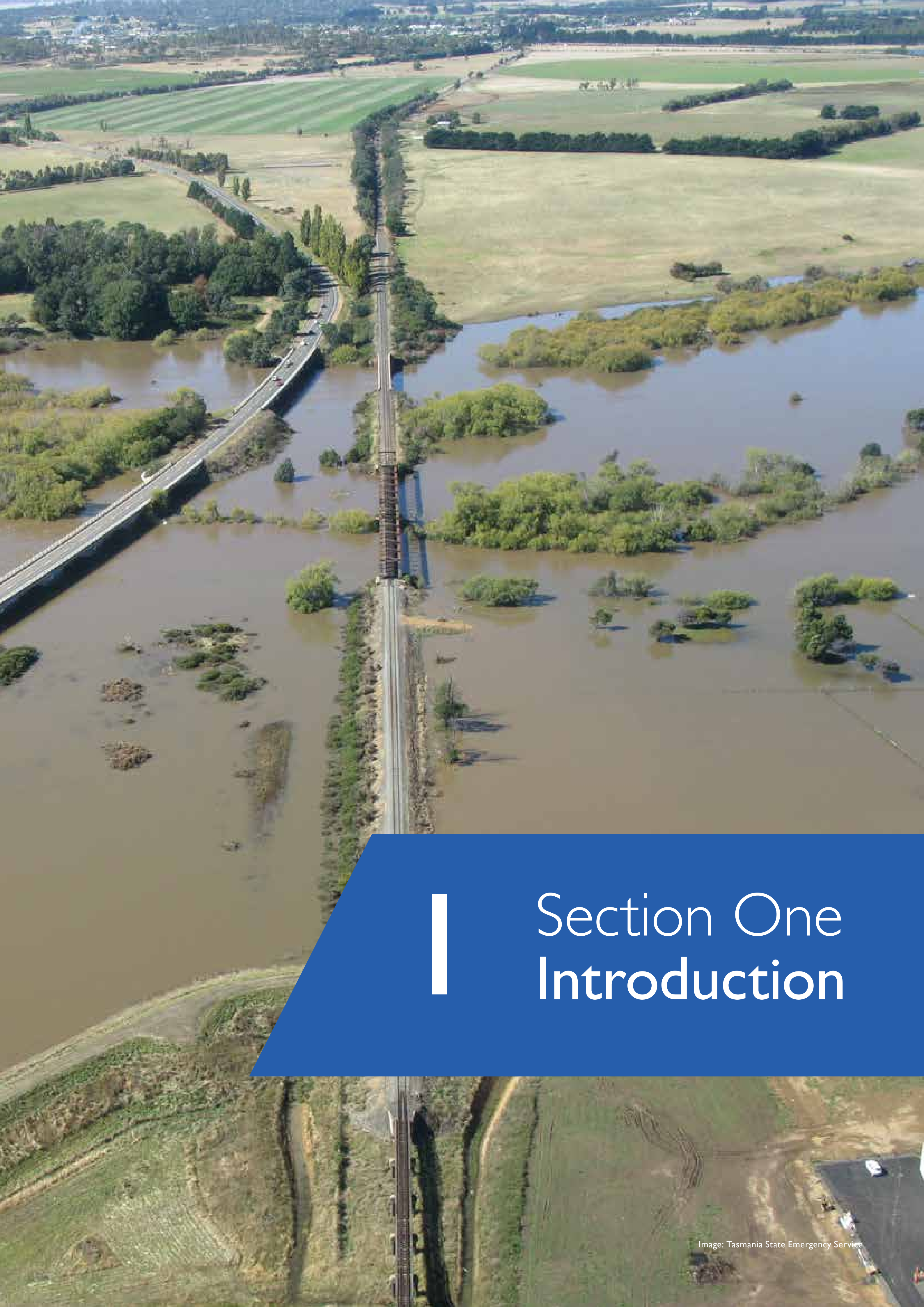
Contents

Contents

Contents

Contents

Contents



1 Section One Introduction

Image: Tasmania State Emergency Service

1 Introduction

1.1 Background: TSNDRA 2012

There is an increasing focus on risk assessment being used to inform emergency management priorities, particularly in the area of natural disasters. The 2004 Council of Australian Governments (COAG) review of mitigation, relief and recovery arrangements identified eight key areas for improvement in current Australian emergency management arrangements:

- a lack of independent and comprehensive systematic natural disaster risk assessments, and natural disaster data and analysis
- a focus on response and reaction at the expense of prevention, mitigation and recovery of affected communities
- a lack of independent and comprehensive post-disaster assessments to identify lessons learnt, and opportunities for improvement
- uneven recognition of the important role local governments have to play in emergency management arrangements
- a lack of preparation for catastrophic disasters
- limited availability of flood insurance
- a tendency on the part of governments to introduce ad hoc special relief schemes which may lead to confusion, inequities and higher costs
- a lack of effective inter-governmental, and in some cases intra-governmental, machinery to support a coordinated national approach to disaster management.

In response to these findings and the report's subsequent recommendations, a suite of national activities were commenced to address the identified issues, improve capability and build resilience to disasters. One of the first outputs relating to risk assessment was the National Risk Assessment Framework for Sudden Onset Hazards (2007), which identified a need to develop a consistent national approach to risk assessment, and consistent baseline information to support hazard risk assessments. This was followed by the development of the National Emergency Risk Assessment Guidelines (NERAG) in 2010, which produced a new methodology designed to improve the consistency and rigour of emergency risk assessments, increase the quality and comparability of information on risk and improve the national evidence base on emergency risks in Australia.

The push for greater collaboration and cooperation led to all states and territories signing the National Partnership Agreement (NPA) on Natural Disaster Resilience (2009)[1]. With the aim of building resilience to withstand natural disasters, under the NPA each Australian state and territory agreed to produce a state/territory-wide prioritised natural disaster risk assessment in accordance with the relevant Australian standards.

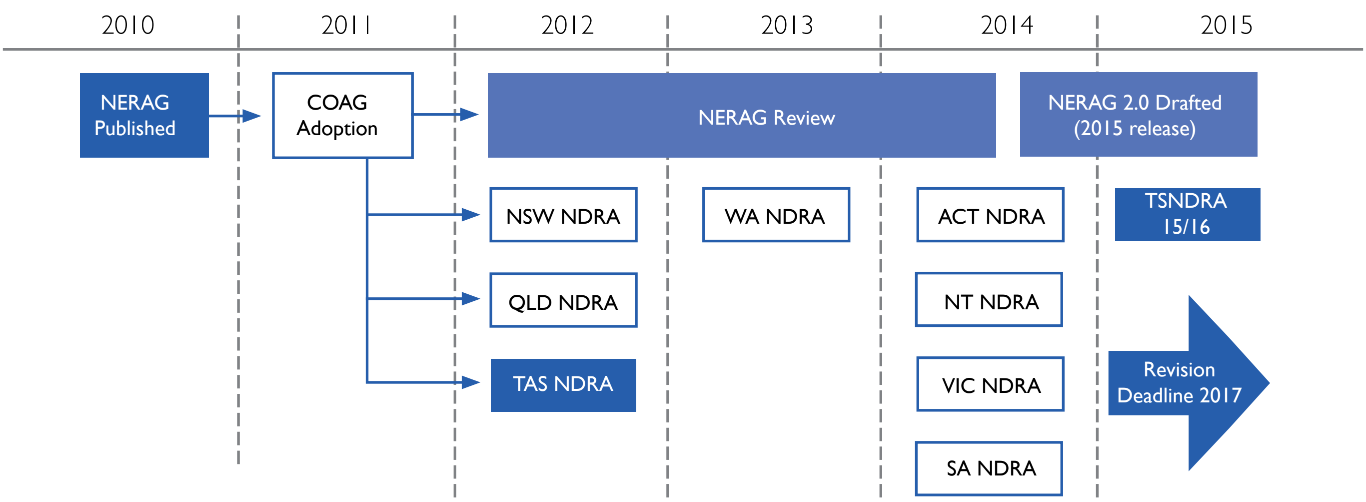
Risk is also a major theme within the National Strategy for Disaster Resilience, which was published in February 2011[2] and promotes a focus on priority outcomes to build disaster-resilient communities across Australia. Warning that communities are becoming increasingly vulnerable in a climate which has the potential for more frequent and severe extreme weather events, the strategy outlines a range of risk-themed activities framed around better understanding and communicating the nature and extent of local disaster risks.

These activities led to the production of the 2012 Tasmanian State Natural Disaster Risk Assessment (TSNDRA)[3], which provided a platform for informing risk reduction and mitigation priorities across the Tasmanian emergency management sector.

1.2 The TSNDRA 2016 project

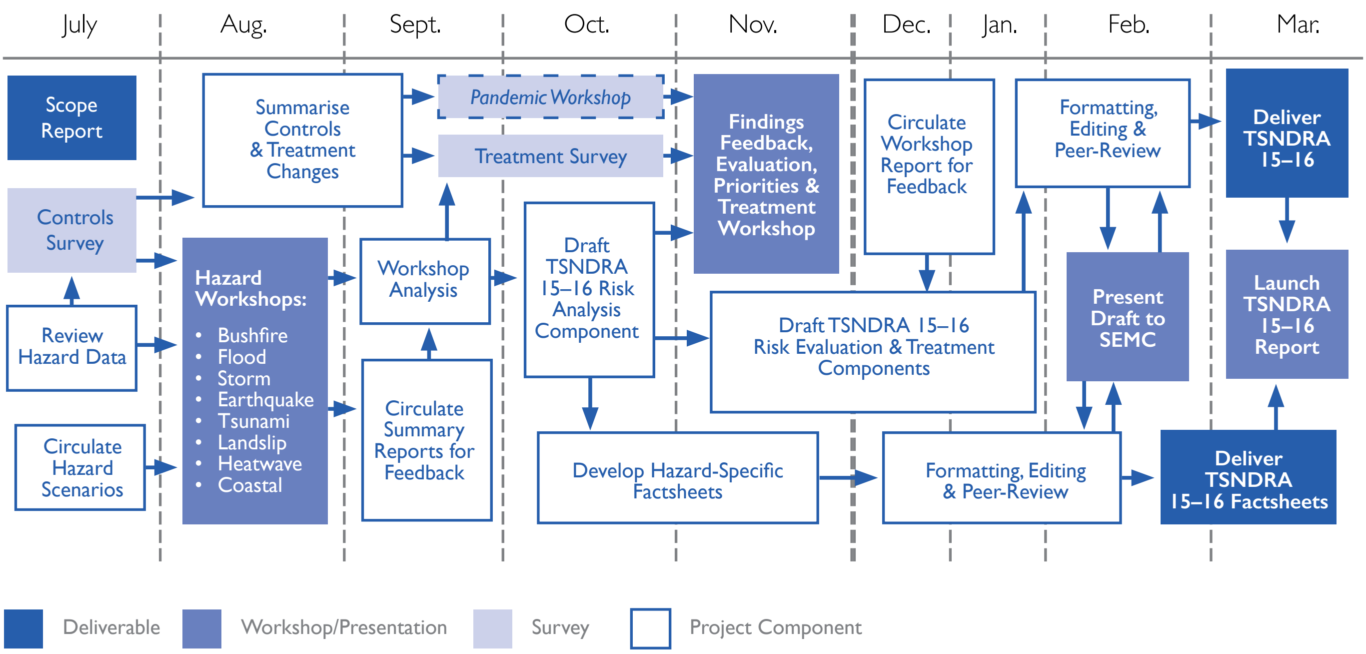
TSNDRA 2012 was one of a series of state/territory-wide assessments conducted following the publication of the first edition of the NERAG in 2010. Development of these risk assessments – as well as the NERAG guidelines that underpinned them – was iterative, with assessments such as TSNDRA 2012 building on the learnings and approaches applied in other states, some of which pre-dated the formalisation of national guidelines (the State of Victoria, for example, developed an emergency risk assessment framework that was applied in 2008, before release of the ISO 31000:2009 standard)[4]. The 2012 Tasmanian assessment process, completed in 2012, was one of the first to fully follow the NERAG guidelines, with others updating earlier approaches to fit the new national framework[5], with variable levels of compliance[6]. A timeline of the national NERAG development process is shown in Figure 1.1, which provides the historical context for the TSNDRA 2016 project.

Figure 1.1 Timeline of the development, implementation and review of the National Emergency Risk Assessment Guidelines.



All Australian states and territories are now required to complete revised assessments under the new NERAG 2015 guidelines before the national deadline of June 2017. The TSNDRA 2016 revision project, funded through the State Emergency Management Program (SEMP) and led by the University of Tasmania in partnership with the Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC) and RMIT University, is one of the first such projects to be initiated. It is expected that all state-level revised assessments will have a much higher level of consistency with the NERAG 2015 methodology (due to an extensive state-level consultation process), allowing greater comparability between state reports, risk matrices and treatment plans. As such, the first stage of this project was to review and re-calibrate the findings of TSNDRA 2012 in order to assess their compatibility with the new national guidelines, as well as their currency in light of changes to the Tasmanian context, before reassessing the priority hazards following NERAG 2015. The project program, designed at the outset of the project, is set out in Figure 1.2.

Figure 1.2 TSNDRA 2016 indicative project structure and timeline.



1.3 Aims and objectives of TSNDRA 2016

TSNDRA 2016 aims to provide a review of TSNDRA 2012 and update the understanding and awareness of natural hazard risks affecting Tasmania.

The purpose of the TSNDRA is to provide a basis to inform decision-making across the Tasmanian emergency management sector, particularly in respect to the prioritisation of risk management activities. Through delivery and use of its outputs, the TSNDRA project aims to achieve the following outcomes:

- a better understanding of the State's emergency risk profile
- improved prioritisation of resources
- improved understanding of emergency risk issues
- improved prioritisation of hazard information collection
- increased transparency and understanding of risk assessment processes
- the ability to undertake a meaningful comparison of risk across different geographical areas and/or hazard classes.

The objective of TSNDRA 2016 is:

> *"To produce a statewide priority natural hazard risk assessment, in accordance with the relevant International and Australian standards"*

In addition to complying with relevant standards, TSNDRA 2016 also adopts the methodology as detailed in the National Emergency Risk Assessment Guidelines 2015 (referred to hereafter as the NERAG 2015)[7]. The relevant risk management standards were identified as:

- AS/NZS ISO 31000:2009 Risk Management – Principles and Guidelines
- ISO 31010:2009 Risk Management – Risk Assessment Techniques
- ISO Guide 73:2009 Risk Management – Vocabulary

1.4 Scope

The TSNDRA 2016 methodology (see Section 2) has been developed using a re-calibration of the TSNDRA 2012 methodology, as well as using the relevant national guidelines and standards, but with appropriate modifications to enable an assessment of emergency risks in a 'state level' context. In light of its national drivers, the TSNDRA has focused on a consideration of risks from disaster events arising from identified priority natural hazards.

For the purpose of the assessment, an emergency-related risk means:

> *"A risk, which, if realised, would result in an emergency with implications at a state level"*

To this end, the methodology is based on analysis of large-scale event scenarios, with impacts measurable at a state level. The cumulative impact of frequent smaller-scale emergencies is difficult to capture using this definition, but is noted as an emerging issue for the State and may be more appropriately captured with regional or municipality level assessments.

Given the availability of data, the unpredictability of natural disasters and the overall context of the assessment, detailed risk analysis is not feasible. Accordingly, the TSNDRA should be considered a baseline, statewide screening assessment. This method provides an improved understanding of Tasmania's emergency risk profile, i.e. the picture of emergency-related risk that Tasmania faces, including information about the key controls currently in use and guidance for future investment in prevention and mitigation and preparedness. The results are intended to provide valuable information to aid emergency response planning, in a state level context, thus providing a tool for risk-based strategic planning.

1.5 Audience

Given its state-level scope and context, the principal audience for the TSNDRA is the State Emergency Management Committee (SEMC). As the key emergency management decision-making body in Tasmania, with responsibility for determining priorities at the state level, the SEMC is also the nominated business owner of the TSNDRA outputs.

Other key stakeholders include hazard management authorities, agencies, individuals and organisations with defined emergency management responsibilities across Tasmania, and the wider national emergency management community.

In recognition of the important role that risk awareness plays in building disaster-resilient communities, a separate summary TSNDRA document has also been prepared for the purpose of educating the broader Tasmanian community about state-level risks.

1.6 Updating Tasmania's priority hazards

TSNDRA 2012 determined that Bushfire, Flood, Severe Storm, Landslide, Tsunami and Earthquake were natural hazards that posed a threat to Tasmania. TSNDRA 2016 broadened this scope to include the additional priority hazards of Heatwave, Coastal Inundation and Pandemic Influenza.

Of these, Bushfire, Flood and Severe Storm were recognised in TSNDRA 2012 as being the hazards with the greatest economic impact to Tasmania, with agencies specifically dedicated to managing the prevention and mitigation, preparedness, response and recovery (PPRR) activities of these hazards on an operational basis.

Of the geological hazards, while instrumentally recorded seismicity is low in Tasmania, there have been some previous earthquake events that have caused impact, and there are areas of land within the State that have been identified as susceptible to earthquake, such as the Lake Edgar fault in southern Tasmania. Tasmania is also considered prone to landslides, with several active, slow-moving landslides presently being monitored by Department of State Growth's (DSG) Mineral Resources Tasmania (MRT). Records indicate that more than 150 buildings have been destroyed by landslide in Tasmania since the 1950s. Further to this, recent work by MRT has identified many areas across the State at risk from debris flow, including highly frequented, populated centres.

Coastal hazards (referred to hereafter as Coastal Inundation) were considered a secondary priority for assessment in TSNDRA 2012. However, due to the potential implications of future climate change scenarios combined with consensus during the initial stakeholder workshop, Coastal Inundation was included in TSNDRA 2016 assessment to complete the Tasmanian Emergency Management Plan (TEMP)[8] priority list of natural hazards.

While the category of coastal hazards comprises emergencies arising from both Tsunami and Storm Surge, it is noted that while areas of exposure are similar, these events tend to have different sources, triggers, frequencies, magnitudes of consequences and management controls. Thus, Tsunami and Coastal Inundation are assessed separately as distinct priority hazards. As sea levels rise in response to global climate change, coastal inundation will emerge as a natural hazard with greater impact on Tasmanian communities. Therefore, coastal inundation was considered explicitly as a separate hazard in TSNDRA 2016.

Heatwave has been identified as the most dangerous natural hazard in Australia, causing more deaths than all the other natural hazards combined[9]. It was determined during the initial stakeholder workshop that inclusion in TSNDRA 2016 was necessary.

Pandemic influenza was recommended by the 2012 report to be included in future iterations. It is a naturally-occurring hazard with two important differences:

1. Most natural hazards affect a defined, often localised area, whereas a pandemic affects a large area, with global impact.
2. Most natural hazards have relatively short emergency response phases followed by potentially lengthy recovery periods, whereas pandemic influenza may have a protracted response phase, with illness potentially hitting communities in waves for up to four-to-six months until a pandemic vaccine is developed and widely available.

It has been established that pandemic influenza is an ongoing significant risk globally, and represents a significant risk to Australia, including Tasmania. It has the potential to cause high levels of morbidity and mortality and to disrupt our community socially and economically[10]. Therefore, it was deemed important to be included as a hazard within TSNDRA 2016.

A definition of each identified priority hazard is presented in Table 1.1.

Table 1.1 Working definitions of the natural hazards considered during the TSNDRA process.

Priority Hazards	Definition
Bushfire	For the purpose of the TSNDRA, a bushfire includes any fire in 'vegetation', regardless of origin or cause.
Coastal Inundation	A rapid rise in coastal sea level, including: storm surge; abnormally high spring tides; or their co-occurrence.
Earthquake	An earthquake is shaking and vibration at the surface of the Earth caused by underground movement along a fault plane or by volcanic activity[11].
Flood	Flooding is a general and temporary condition of partial or complete inundation of normally dry land area. This inundation is caused by the overflow of inland waters from the unusual and rapid accumulation or runoff of surface waters from any source[12].
Heatwave	A period of unusually high atmospheric temperatures for a region for a period greater than 48 hrs (simplified from Nairn & Fawcett 2013)[13].
Landslide	A movement of rock, debris or earth down a slope. Rapid onset landslide events are the focus of this study.
Pandemic Influenza	A pandemic is a disease outbreak that affects a large proportion of the world. Influenza pandemics are unpredictable but recurring events that occur when an influenza virus emerges with the ability to cause sustained human-to-human transmission, and the human population has little to no immunity against the virus[14].
Severe Storm	A storm is an atmospheric disturbance characterised by strong winds and heavy rain. To fit the criteria of a severe storm (or thunderstorm), a storm must produce either: a tornado; hail of a diameter >2 cm; wind gusts of ≥90 km/h; or very heavy rain that is likely to lead to flash flooding[15].
Tsunami	A tsunami is a series of ocean waves with very long wavelengths caused by large-scale disturbances of the ocean such as: earthquake; landslide; volcanic eruption; explosion or meteorite[16].

1.7 Risk assessment objectives and the organisation

An important step in both ISO 31000:2009 and the NERAG 2015 is the need to define and understand the nature of the 'organisation' – being the entity whose risk is to be managed. In the emergency management context, governments have specific roles, responsibilities and resources that promote the safety of the community and its assets. The external context includes people, industry, the economy and the built and natural environment.

In the TSNDRA methodology, the external context is Tasmania as a part of the Commonwealth of Australia, and the organisation is the public sector operating in Tasmania, including the Commonwealth and state governments, government departments, agencies and local government. The basis for this is that governments have considerable but not total responsibility to manage risks within their jurisdiction.

The definition of risk in the ISO 31000 is the 'effect of uncertainty on objectives'. It is therefore relevant to define the objectives of the organisation, i.e. the public sector in Tasmania. Public sector objectives are not necessarily articulated in a way that can be related directly to an emergency risk assessment; however, some guidance can be provided by the strategic outcomes of the National Strategy for Disaster Resilience 2011 (NSDR 2011)[2]. The NSDR 2011 has four target outcomes:

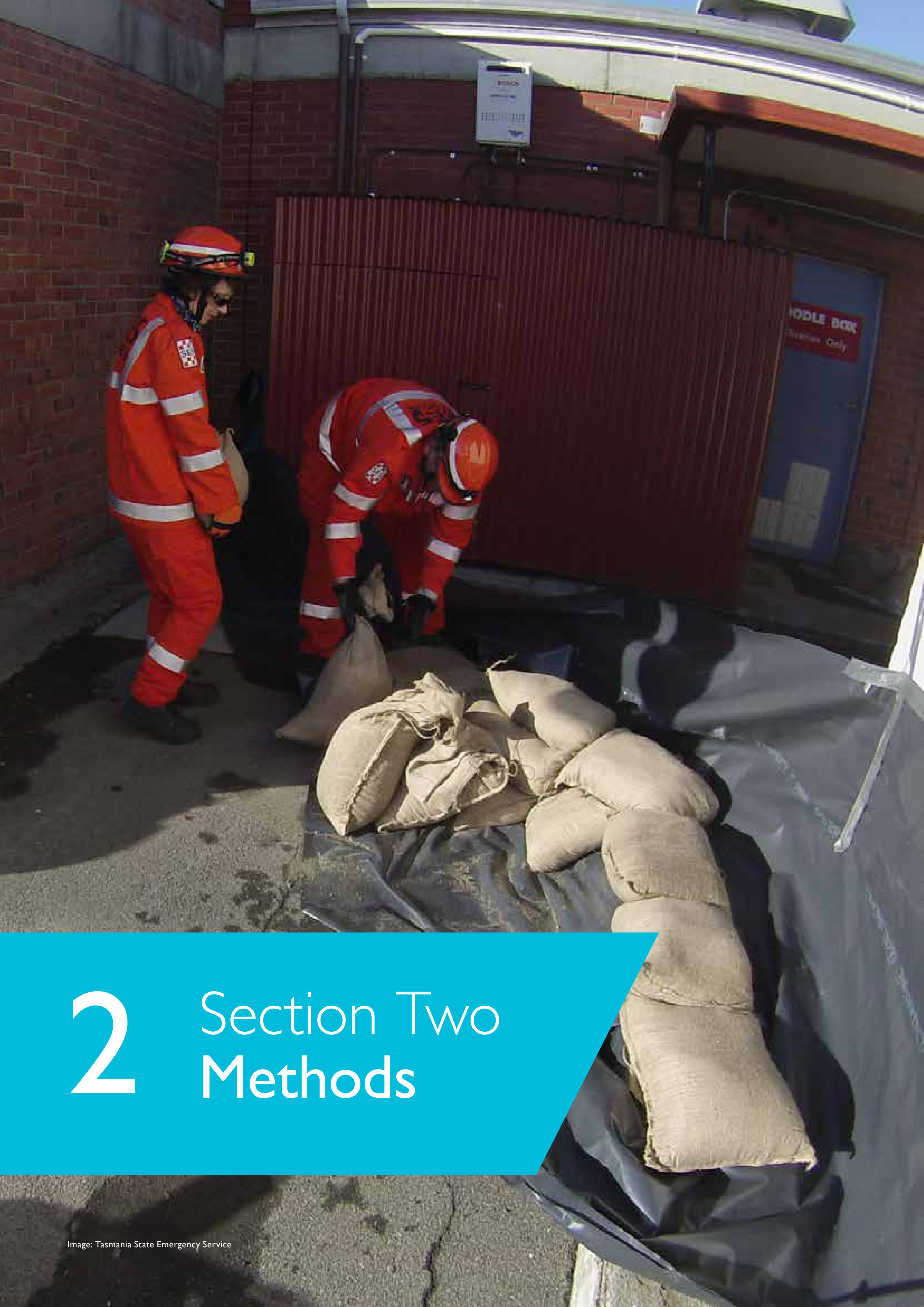
1. Encourage the development of communities that function well under stress.
2. Support communities in efforts for successful adaptation to challenges.
3. Facilitate the progression towards communities that are self-reliant.
4. Ensure communities have the capacity to prevent, prepare, mitigate, respond and recover where appropriate to hazards and risks.

To help provide governance to achieve these outcomes, the Tasmania State Emergency Management Committee has developed four strategic directions, defined in the Strategic Directions Framework[17]. These four strategic directions are:

1. Understanding and managing risks.
2. Recovery and building resilience.
3. Ensuring capability and capacity.
4. Developing collaborative leadership.

TSNDRA 2016 fits with the first strategic direction, Understanding and managing risks, and informs the other three. As such, they provide a logical reference point upon which to frame the risk assessment.

Disasters and emergencies can have an effect on progress towards these goals/objectives. Given the inherent uncertainty in the location, timing, severity and impacts of hazards, the role of risk assessment is to reduce uncertainty through identification of the characteristics of the risk by bringing together the best information and judgement, and using that to design appropriate strategies to lessen the likelihood of the consequences occurring.



2 Section Two Methods

Image: Tasmania State Emergency Service

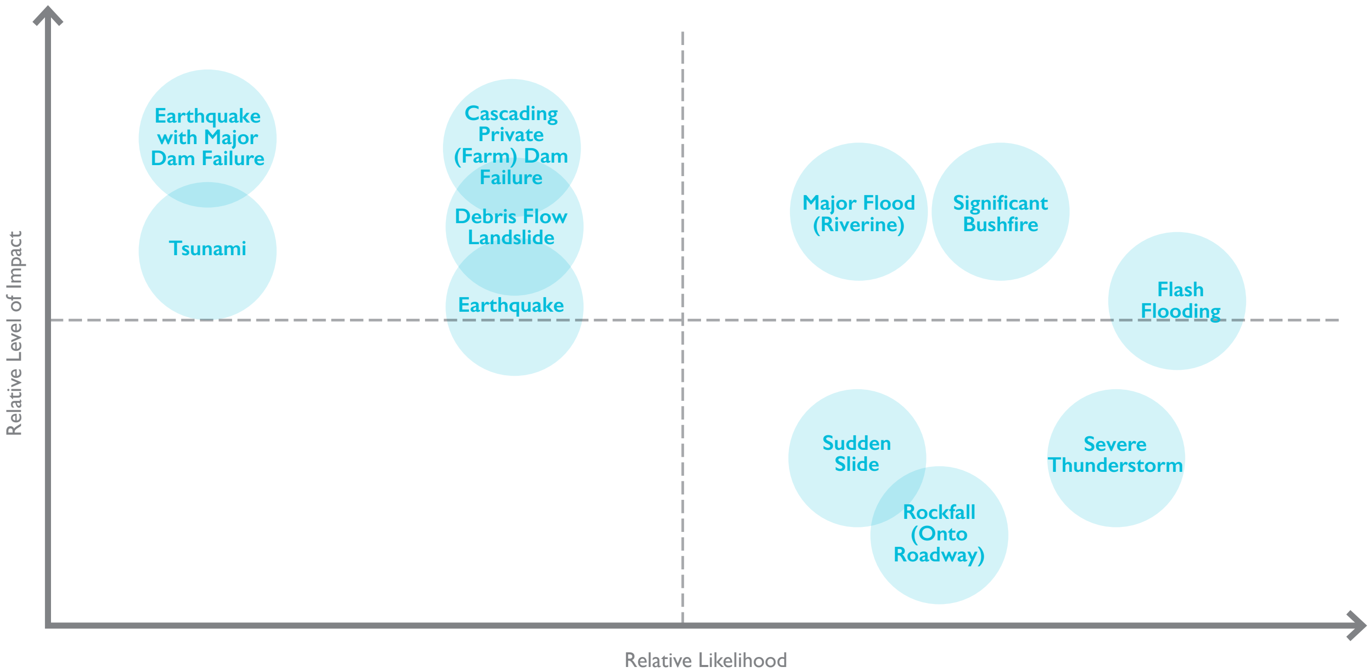
2 Methods

2.1 Re-calibrating the 2012 Risk Assessment

The risks posed by six priority natural hazards: Bushfire, Flood, Storm, Landslide, Tsunami, and Earthquake, were assessed in TSNDRA 2012.

Worst-case scenarios were developed for each of these hazard areas (in some cases split into multiple categories due to divergence in characterisation or location). A visualisation of the TSNDRA 2012 results is reproduced in Figure 2.1.

Figure 2.1 TSNDRA 2012 summary of all hazards across all sectors.



Under the revised NERAG 2016, likelihood levels, consequence levels, and the overall risk matrix classifications have all been modified. A summary of the associated methodological changes is provided below:

- The **likelihood** level of 'Almost Incredible' that was included in the 2010 approach has been removed, with no modification to the frequency of other likelihood classifications. The level of 'Possible' has also been removed, however, meaning that the frequencies associated with 'Possible', 'Unlikely' and 'Rare' are now associated with 'Unlikely', 'Rare' and a new category of 'Extremely Rare' respectively.

- Although the thresholds for **likelihood** classification have not changed, the descriptors for each are now based upon 'Annual Exceedance Probability' (AEP), ranging from a scenario being 'Almost Certain' (AEP of 63% per year or more) to 'Extremely Rare' (AEP of 0.001-0.01% per year).
- The **consequence** levels have not changed; however, the underlying thresholds and sectoral categories have changed significantly with 'Infrastructure' being removed, definitional changes to 'People' in relation to health, and extensive changes to the criteria for Environmental impacts.
- The **risk matrix** categories now include a 'Very Low' classification, with an upgrading of the risk classification of a number of Major/Catastrophic Consequence, Very Rare/Extremely Rare Likelihood events (see Figure 2.2).
- Methods for assessing **confidence** in each scenario's assessment have been modified, with two new levels of confidence classification being added, more extensive descriptors of thresholds being included, and a directive to consider confidence in both scenario likelihood and scenario consequence.
- Assessment of **controls** no longer includes the 'Bow-tie Diagram' assessment method, with a simplified matrix approach being used to qualitatively assess controls or control groups on a risk-by-risk basis.
- Risk **prioritisation** now differentiates priority on the basis of the five confidence levels previously mentioned, with an additional **decision point** included for consideration after the development of a comprehensive risk register with the aim of determining whether research to further improve confidence is needed.
- Risk prioritisation and the decision-tree described above replace the risk **tolerability** section of the 2010 NERAG, as well as any reference to the As Low As Reasonably Practicable (ALARP) principle and associated pyramid diagram.

To ensure the TSNDRA 2016 results are comparable with the findings of the 2012 assessment, the latter had to be re-calibrated to the new classification system (see Figure 2.2) in order that the effects of new controls, risk treatments and environmental/contextual conditions can be observed over the intervening period.

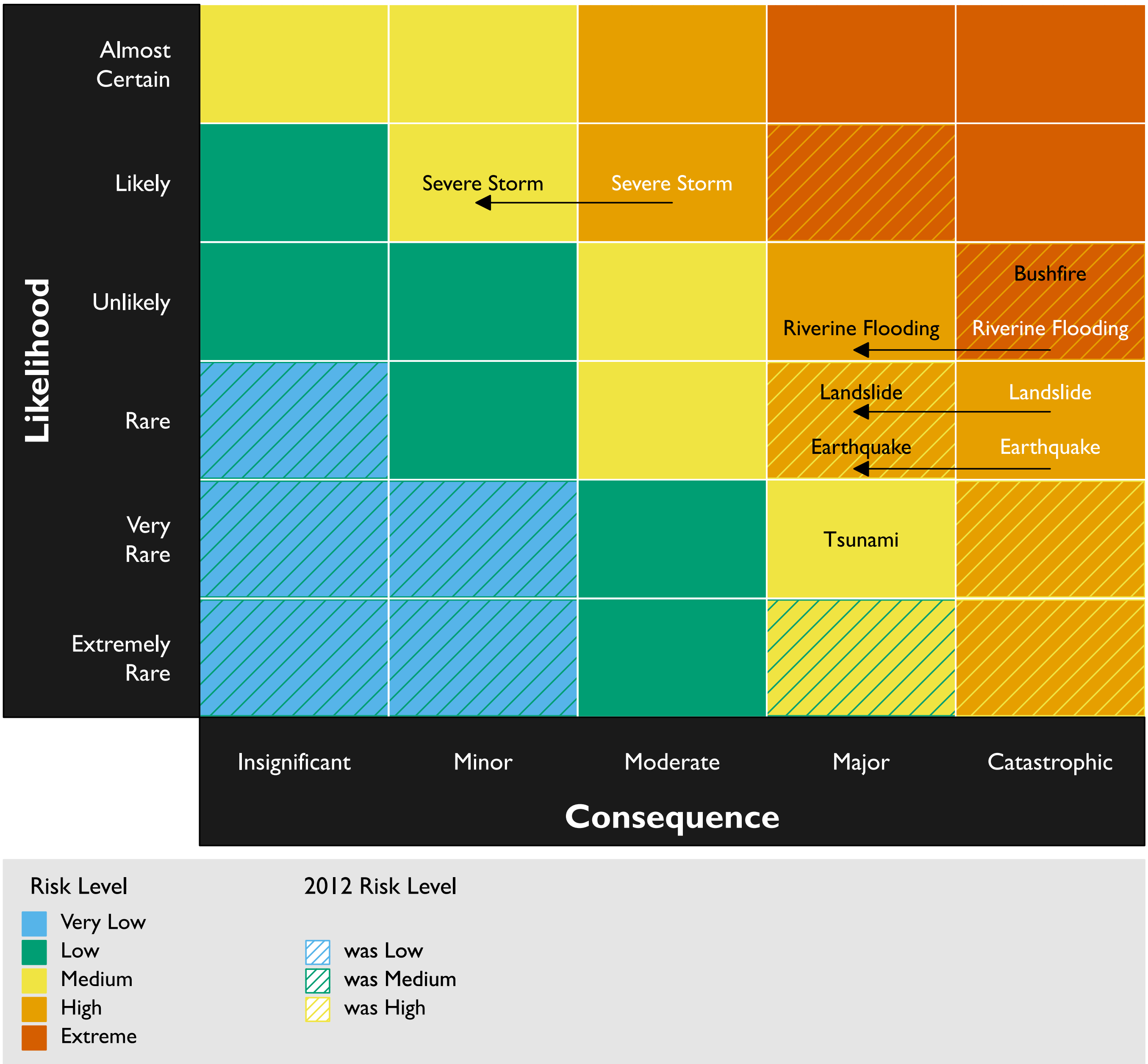
On the basis of the methodological changes above, a re-calibration of TSNDRA 2012 was conducted as part of a cross-jurisdictional exercise by the National Risk Assessment Working Group (the consolidated output from which was submitted to the Australia-New Zealand Emergency Management Committee (ANZEMC) in March 2015, and the Law, Crime and Community Safety Council in May 2015). It is noted that this process was undertaken without stakeholder consultation or consideration of changes to context, controls, improved data, or subsequent risk treatment, and therefore does not constitute a review as set out under the NERAG. Rather, it adjusts the measures that were used to determine risk, under the contextual and control assumptions operating in 2012, allowing dynamic comparison of Tasmanian state-level risk over time under the NERAG 2015 methodology.

Figure 2.2 Demonstration of the changes to the risk matrix as defined in NERAG 2015[7].

Likelihood \ Consequence	Insignificant	Minor	Moderate	Major	Catastrophic
Almost Certain	Medium	Medium	High	Extreme	Extreme
Likely	Low	Medium	High	Extreme (was High)	Extreme
Unlikely	Low	Low	Medium	High	Extreme (was High)
Rare	Very Low (was Low)	Low	Medium	High (was Medium)	High
Very Rare	Very Low (was Low)	Very Low (was Low)	Low	Medium	High (was Medium)
Extremely Rare	Very Low (was Low)	Very Low (was Low)	Low	Medium (was Low)	High (was Medium)

It was also noted that where multiple consequence levels existed for a scenario (for example, with 'People' and 'Public Administration' consequences falling into different categories), this was not expressed in the risk matrix. The project team identified a new, nuanced approach to visualise the range of possible consequences in TSNDRA 2016, including the previous distributions in TSNDRA 2012.

Figure 2.3 Presentation of how the 2012 results have shifted based on changes in methodology under NERAG 2015[7].



The basis of the changes observed in Figure 2.3 are summarised below:

2.1.1 Bushfire: Both the economic and social consequences for the 2012 bushfire scenario increased under the new guidelines; however, this had no impact on the overall consequence assessment ('Catastrophic', on the basis of consequences for people). Likelihoods did not change other than by classification name; however, due to changes in the risk matrix, the bushfire hazard scenario from TSNDRA 2012 is classified as 'Extreme' under NERAG 2015 (an increase from 'High' under NERAG 2010).

2.1.2 Riverine Flooding: Due to changes to the assessment of economic and environmental consequences, as well as the removal of the 'Infrastructure' consequence category, the expected consequence of riverine flooding has decreased, with no change to its likelihood under the new NERAG classifications. Although its position in the risk matrix has changed, due to the altered category ratings (see Figure 2.3), the overall risk level of 'High' remains the same as in 2012.

2.1.3 Severe Storm: Classification of the severe storm scenario in terms of the environmental and social setting categories has decreased from 'Minor' to 'Insignificant', resulting in the hazard's overall classification falling to 'Minor'. With no change to likelihood, this reduced the position of severe storm in the risk matrix to the 'Medium' risk category.

2.1.4 Landslide: Although the individual landslide scenarios shown in Figure 2.1 were not included in the TSNDRA 2012 assessment, the notable changes to the landslide risk profile under the new NERAG system are due to a reduction in the economic consequence classification of a Debris flow scenario from 'Catastrophic' to 'Major'. However, the overall risk classification for landslide as 'High' remains due to modifications to the risk matrix, as shown in Figure 2.3.

2.1.5 Earthquake: Although TSNDRA 2012 states that the overall consequence of a major dam-failure earthquake scenario is 'Moderate', this was believed to be in error (i.e. too low) due to the classification of economic consequences as 'Catastrophic' and associated text (p. 49) to this effect. However, under the new NERAG guidelines, this same consequence category would now be considered to result in 'Major' consequences only, reducing the overall classification of the worst-case earthquake scenario. Due to associated modification to the risk matrix, the overall classification of earthquake risk remains 'High', the same as in 2012.

2.1.6 Tsunami: The only significant change to the tsunami scenario profile is a reduction in environmental consequence categorisation from 'Minor' to 'Insignificant', with no change to the 'Medium' risk classification for the hazard.

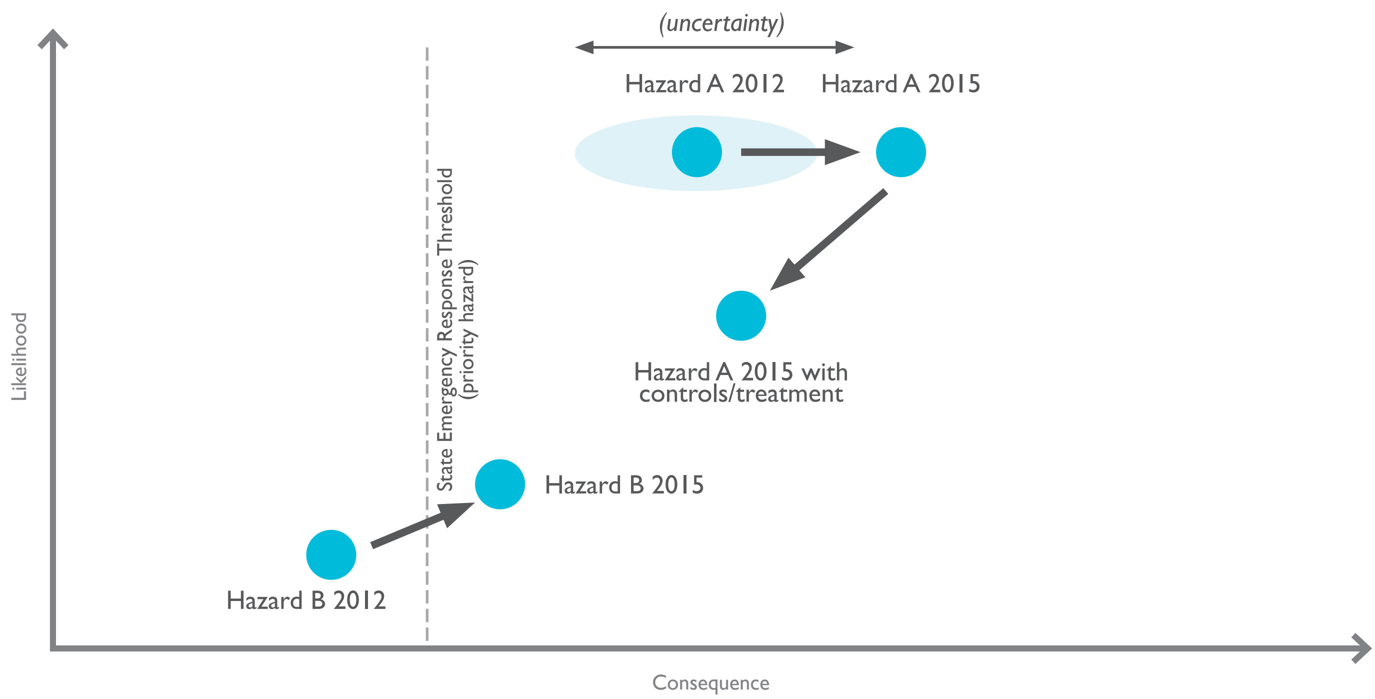
2.2 Updating the Tasmanian risk context

The outcomes of the re-calibration exercise allowed for the analysis of the changes to Tasmania's risk profile over time, which is a product of:

- **improved knowledge** of the likelihood or consequence of a hazard scenario (for example, as shown in Figure 2.4, a reduction in the uncertainty regarding Hazard A could either increase or decrease its expected consequences)
- **changed socio-economic or environmental conditions**, such as the expected increased frequency of extreme heat events due to anthropogenic climate change
- **implementation of risk treatments or controls** that reduce the likelihood or consequence of the hazard scenario occurring.

As shown in Figure 2.4, changes to the local context and hazard profile can also elevate additional hazards to a priority hazard level by increasing their likelihood or consequence such that they justify the implementation of state-level risk management controls. Heatwave is one such hazard, recently recognised as having significant impacts on ambulance call-outs and morbidity in Tasmania, and is discussed further below.

Figure 2.4 Example of how new controls, improved knowledge or changing vulnerability can impact on the position of a hazard in the Consequence-Likelihood space.



The initial workshop had three primary objectives:

1. To establish a representative expert stakeholder group for the project and familiarise them with both TSNDRA 2012, as well as the TSNDRA 2016 process.
2. To confirm the project approach, scope and contextual assessment (in particular, the hazards included for assessment, and the new consequence classification structure).
3. To promote engagement and ownership of the process by end-users.

2.3 Scope: defining natural hazards

As identified in TSNDRA 2012, natural disasters are defined by COAG as being:

> *"...caused by the impact of a naturally-occurring rapid onset event that threatens or causes death, injury or damage to property or the environment and which requires significant and coordinated multi-agency and community response"`*

However, the NERAG guidelines are applicable to both natural and human-induced hazards / disasters, some of which sit across these two categories without clear classification in either academic or emergency management literature. Notably, the Victorian Government State Emergency Risk Assessment Report[5] did not differentiate between natural and human-induced hazard categories, including major incidents such as mine failure, electricity supply disruption and hazardous materials spill in the scope of their state-level risk assessment report. It was also noted during the workshop presentation by the 2012 report's author Doug Rossiter that the 2012 approach was initially intended to cover all emergency management areas, but was subsequently scoped down to priority natural hazards only.

The TEMP sets out 31 state-level priority hazards on the basis of management authority. From this the project team – in consultation with Tasmania State Emergency Service (SES) staff – were able to categorise 20 priority hazards (fires in national parks and state forests, for example, are classified separately under the TEMP due to response requirements), of both natural and human-induced origin. As set out in Figure 2.5, those hazards of natural origin formed the basis of the 2012 report, with the exception of Heatwave and Coastal Erosion/Inundation which are new additions to the TSNDRA.

Figure 2.5 provided the basis for breakout group discussions in the initial workshop, which centred upon the two natural hazards not included in the previous assessment (Coastal Erosion/Inundation and Heatwave), as well as the two 'grey area' hazards: Pandemic and Biosecurity. It was also noted that the project team expertise centred upon natural hazards only (the scope set out in the initial project proposal), with resource implications likely limiting the more extensive analysis of 'new' hazard areas to 1 or 2 of the four identified.

It was agreed by each group that the natural hazards that were included in 2012 remained priorities and should be re-assessed, while heatwaves were also noted to be an emerging risk and high priority for the State, and should be included in TSNDRA 2016. The group rationale for this inclusion can be summarised as:

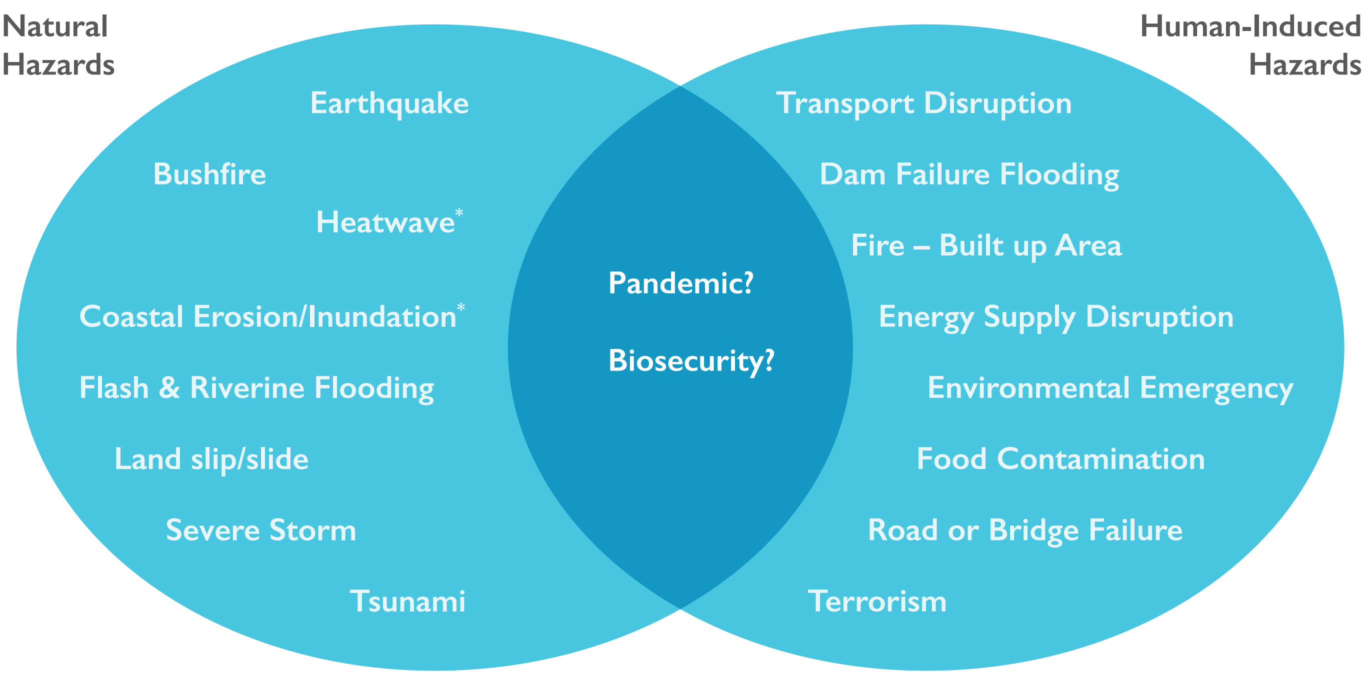
- Recent research (since 2012) has identified heatwave as placing a high load on the health system (as described by the Department of Health and Human Services (DHHS) including Ambulance Tasmania).
- Heatwaves have recently been defined at a Federal level as a rapid onset natural hazard with clear parameters (Extreme Heat Factor Days).
- The current project team has improved capacity and expertise to assess heatwaves as a hazard.

Coastal inundation was agreed to be a better definition than the previously-used separate hazard titles of coastal erosion and tidal surge events. There was consensus that it should be included in TSNDRA 2016 to complete the TEMP priority list of natural hazards, particularly as the project team has internal capacity and expertise in this area.

Pandemic influenza was agreed to be a priority hazard, noting that influenza is the most likely cause of pandemics and the focus of global pandemic preparedness. It was also acknowledged that the range of forms of pandemics would require a variety of different scenarios to properly assess the different controls, consequences and likelihoods of such events occurring. It was flagged that as the TSNDRA project team lacked expertise in this area, assessment would require support, including access to data, from the health sector. DHHS subsequently committed to this arrangement.

Given the very different nature of pandemic influenza to other hazards, assessment was undertaken as a parallel project by DHHS, with coordination and guidance by the TSNDRA project team to ensure consistency with other components of the review and the NERAG.

Figure 2.5 Conceptual diagram of natural and human induced hazards.



* = Natural hazards that were not included in TSNDRA 2012 but have since been identified as within scope.
? = Hazards that are not clearly identified as 'natural hazards' but were flagged as important to address in the future by TSNDRA 2012.

2.4 NERAG 2015 revised state-level consequence scale

Under the NERAG 2015, developing consensus on the thresholds for consequence categories (from catastrophic to insignificant) is a prerequisite step prior to development of hazard scenarios and the conduct of hazard workshops. Although under NERAG 2015 these categories are pre-defined, there is some scope to adjust these to suit individual state contexts, although it was acknowledged that any changes reduce comparability between states. These consequence categories have been defined under the NERAG 2015 and are described in full in Tables 2.1-2.5. Below is a brief description of each category as they are referred to throughout TSNDRA 2016:

1. People
   - 1.1 People – Death: The number of deaths expected as a direct consequence of the hazard.
   - 1.2 People – Injury: The number of injuries or illnesses expected as a direct consequence of the hazard.
2. Economic
   - a. Economic – General: The loss in economic activity and/or asset value as a direct consequence of the hazard.
   - b. Economic – Industry: The economic impact on important industries to the State as a direct consequence of the hazard.
3. Environmental
   - 3.1 Environment – Species: The loss of ecosystems or species from a region as a direct consequence of the hazard.
   - 3.2 Environment – Value: The loss of environmental values of interest as a direct consequence of the hazard.
4. Public Administration
   - 4.1 Public Administration: The decreased capacity of governing bodies and utilities to deliver core functions as a direct consequence of the hazard.
5. Social Setting
   - 5.1 Social – Community Wellbeing: The decreased capacity of a community to function as normal without the need for alternative arrangements as a direct consequence of the hazard.
   - 5.2 Social – Cultural Significance: The loss of culturally significant objects, or the interruption of cultural events as a direct consequence of the hazard.

It is important to mention that secondary impacts of an event were explicitly excluded from the assessment process (e.g. a death due to complications after a victim's initial admission to hospital; deaths due to contaminated water following a flood). This is especially important in relation to the interpretation of results for heatwave and pandemic influenza.

Tables 2.1-2.5 summarise the new consequence categories by impact sector as defined by NERAG 2015[i], with the value used in practice throughout the process in parentheses where applicable.

i. *AS/NZS ISO 31000:2009 – Reproduced under SAI Global copyright Licence 1411-c083*

Table 2.1 Consequence categories for 'People' sector as defined by NERAG 2015[7].

	People – Death	People – Injury or illness
Catastrophic	Deaths directly from emergency > 1 in 10,000 people (>50 people)	Critical injuries with long-term or permanent incapacitation > 1 in 10,000 people (>50 people)
Major	Deaths directly from emergency > 1 in 100,000 people (>5 people)	Critical injuries with long-term or permanent incapacitation > 1 in 100,000 people (>5 people) – OR – Serious injuries > 1 in 10,000 people (>50 people)
Moderate	Deaths directly from emergency > 1 in 1,000,000 people (>0.5 people)	Critical injuries with long-term or permanent incapacitation > 1 in 1,00,000 people (>0.5 people) – OR – Serious injuries > 1 in 10,000 people (>5 people)
Minor	Deaths directly from emergency > 1 in 10,000,000 people (>0.05 people)	Critical injuries with long-term or permanent incapacitation > 1 in 100,000 people (>0.05 people) – OR – Serious injuries > 1 in 10,000 people (>0.5 people)
Insignificant	Deaths directly from emergency > 1 in 100,000,000 people (>0.005 people)	Critical injuries with long-term or permanent incapacitation > 1 in 100,000 people (>0.005 people) – OR – Serious injuries > 1 in 10,000 people (>0.5 people)

Table 2.2 Consequence categories for the 'Economic' sector as defined by NERAG 2015[7].

	Economic activity/value	Economic impact on an important industry
Catastrophic	Economic decline and/or loss of asset value greater than 4% GSP (~$1b)	Failure of a significant industry or sector as a direct result of the emergency event
Major	Economic decline and/or loss of asset value greater than 4% GSP (~$100m)	Significant structure adjustment required by an identified industry to respond and recover from the emergency event
Moderate	Economic decline and/or loss of asset value greater than 4% GSP (~$10m)	Significant industry or business sector impacts resulting in medium term (>1 year), directly attributable profit reductions
Minor	Economic decline and/or loss of asset value greater than 4% GSP (~$1m)	Significant industry or business sector impacts resulting in medium term (<1 year), directly attributable profit reductions
Insignificant	Economic decline and/or loss of asset value greater than 4% GSP (~$100k)	Inconsequential business sector disruption due to emergency event

Table 2.3 Consequence categories for the 'Environment' sector as defined by NERAG 2015[7].

	Loss of species/landscape	Loss of value
Catastrophic	Permanent destruction of nationally-significant and recognised ecosystems or species	Permanent destruction of environmental values of interest
Major	Severe damage/loss of nationally-significant and recognised ecosystems or species – OR – state-level permanent destruction	Severe damage to environmental values of interest
Moderate	Significant loss/impairment of nationally-significant and recognised ecosystems or species – OR – state-level severe damage – OR – regional-level permanent destruction	Significant damage to environmental values of interest
Minor	Significant loss/impairment of significant state-level ecosystems or species – OR – regional-level minor damage	Minor damage to environmental values of interest
Insignificant	Minor damage to an ecosystem or species recognised at the local or regional scale	Inconsequential impact on environmental values of interest

Table 2.4 Consequence categories for the 'Public Administration' sector as defined by NERAG 2015[7].

	Public Administration (one category only)
Catastrophic	Governing bodies are unable to deliver their core functions
Major	Governing bodies encounter severe reduction in the delivery of core functions – OR – Governing bodies are required to divert a significant amount of available resources to deliver core functions or seek external assistance to deliver the majority of core functions
Moderate	Governing bodies encounter significant reduction in the delivery of core functions – OR – Governing bodies are required to divert some available resources to deliver core functions or seek external assistance to deliver some core functions
Minor	Governing bodies encounter limited reduction in delivery of core functions
Insignificant	Governing bodies' delivery of core functions is unaffected or within normal parameters

Table 2.5 Consequence categories for the 'Social Setting' sector as defined by NERAG 2015[7].

	Loss of community wellbeing	Loss of cultural significance
Catastrophic	Community connectedness is irreparably broken, community function is lost and/or disperses	Widespread permanent loss of culturally significant objects – OR – Permanent cancellation of a major culturally important activity or event
Major	Community connectedness is significantly broken, extraordinary external resourcing required, significant permanent dispersal	Widespread damage or localised permanent loss of culturally significant objects – OR – Temporary cancellation/significant-delay of a major culturally important activity or event
Moderate	Community connectedness is broken, significant external resourcing required, some permanent dispersal	Some damage or localised widespread damage to culturally significant objects – OR – Some delay or reduced scope of a major culturally important activity or event
Minor	Community connectedness is damaged, some external resourcing required, no permanent dispersal	Damage to culturally significant objects – OR – Delay of a major culturally important activity or event
Insignificant	The community of interest's social connectedness is disrupted such that the re-prioritisation of existing resources is required, no dispersal	Minor damage to culturally significant objects – OR – Minor delay of a major culturally important activity or event

In general, it was agreed that modification of the consequence scale to suit Tasmanian conditions would not be justified given the reduction in comparability with other states. However, the following issues were raised:

- The number of deaths per event was questioned due to Tasmania's small population, i.e. minor events that result in deaths of 1-2 people can result in a moderate rating, which was questioned by some as too high.
- The economic metric recommended in NERAG (gross state product; GSP) was questioned as a possibly inappropriate metric to use. Due to the small size of the Tasmanian economy, the trend of the GSP is quite erratic and the impact of a natural hazard on GSP may be indistinguishable from this noise. However, in order to maintain consistency between the states, these metrics were deemed adequate. It was decided that actual numbers would be used alongside the percentage values to allow conversion between different metrics in the future if required.
- It was not clear how socio-psychological impacts were considered under the framework, and what datasets could be used to define community cohesion under Social Setting. In practice this was guided by expert anecdotal evidence.

Subsequently, participants agreed that the NERAG consequence scale would not be modified in order to maximise the comparability of TSNDRA 2016 with other jurisdiction's risk assessments, the previous TSNDRA 2012 report, and any future revisions.

2.5 Hazard-specific experts and stakeholder groups

Following on from the breakout discussions of both hazards and consequences, each group was also asked to identify who would be best suited as expert representatives for assessing each hazard's probable consequences and the likelihood of these consequences occurring, beyond those immediately present in the room. This included: 1) the key experts or expert organisations that related to each priority natural hazard (including the three 'new' priority hazard areas: heatwave, coastal inundation and pandemic influenza), and 2) organisations or individuals that would be familiar with or able to qualitatively consider the consequence categories in relation to these hazards.

2.6 NERAG 2015 revised state-level likelihood scale

The NERAG process is designed to compare vastly different risks, with different triggers and spatial and temporal scales. The likelihood scale defined in NERAG 2015 is presented in Table 2.6[ii].

Given that natural hazards are generally considered to be unpreventable, this is effectively an assessment of the effectiveness of the controls to reduce the consequences once an event has occurred. As such, likelihood is dependent on: 1) the likelihood that an event will occur, and 2) the likelihood those consequences will occur considering the strength/expediency of current controls. Such a system makes sense when investigating risks that are 'Almost Certain' (every year) or 'Likely' (every decade); however, given the logarithmic nature of the likelihood scales, a control needs to practically remove the consequences altogether to influence the magnitude of consequences of natural hazards with likelihoods less than once every 100 years. For example: if tsunamis are ranked as 'Very Rare', it is not possible for consequences to be 'Rare' and would need to reduce the likelihood from once every 1,000 years to once every 10,000 years to be effective and thus reduce the likelihood to 'Extremely Rare' (an unreasonable assumption in most cases); if bushfires are 'Likely', consequences cannot be 'Almost Certain', but they can be 'Unlikely' if controls are strong enough to reduce the likelihood of those expected consequences tenfold (which is reasonable). In many cases this made the assessment of likelihood straightforward.

ii. *AS/NZS ISO 31000:2009 – Reproduced under SAI Global copyright Licence 1411-c083*

Table 2.6 Likelihood scale as defined in NERAG 2015[7].

Likelihood Level	Comparable likelihood measures		
	Annual Exceedance Probability (AEP)	Average Recurrence Interval (ARI)	Frequency
Almost Certain	>63% per year	≤ 1 year	Once or more per year
Likely	10-63% per year	1-10 years	Once per 10 years
Unlikely	1-10% per year	11-100 years	Once per 100 years
Rare	0.1-1% per year	100-1,000 years	Once per 1,000 years
Very Rare	0.01-0.1% per year	1,000-10,000 years	Once per 10,000 years
Extremely Rare	0.001-0.01% per year	>10,000 years	Once per 100,000 years

2.7 NERAG 2015 revised state-level controls assessment matrix

As set out in NERAG 2015, controls include any process, policy, device or action that modifies risk. However, to ensure consistency with 2012, the same three control 'categories' were used: 1) Material/Physical Controls, 2) Procedural Controls, and 3) Behavioural Controls. Although some controls sit across multiple categories, it was explained to participants in each workshop that the objective was to use the categories to ensure a comprehensive consideration of control types, rather than allocate controls to a particular control group.

Methods for assessing the impact – or level – of existing controls, however, have been modified significantly under NERAG 2015, with the 'Bow-Tie' approach from the previous NERAG no longer included within the guidelines. The controls assessment approach (NERAG 2012:30) has also been replaced by a multi-criteria analysis method as shown in Table 2.7[iii] (adapted from NERAG 2015:53). The two new criteria used for control assessment were:

- **Control Strength:** referring to the ability of the control, or group of controls, to achieve its objective if it operates as intended and when required; and
- **Control Expediency:** referring to the ability of the control to be used/deployed readily and the control's acceptability to stakeholders.

Table 2.7 Controls assessment matrix as defined by NERAG 2015[7].

Control Strength	Control Expediency			
	Very Low	Low	Medium	High
High	Low	Medium	Medium	High
Medium	Low	Medium	Medium	Medium
Low	Very Low	Low	Medium	Medium
Very Low	Very Low	Very Low	Low	Medium

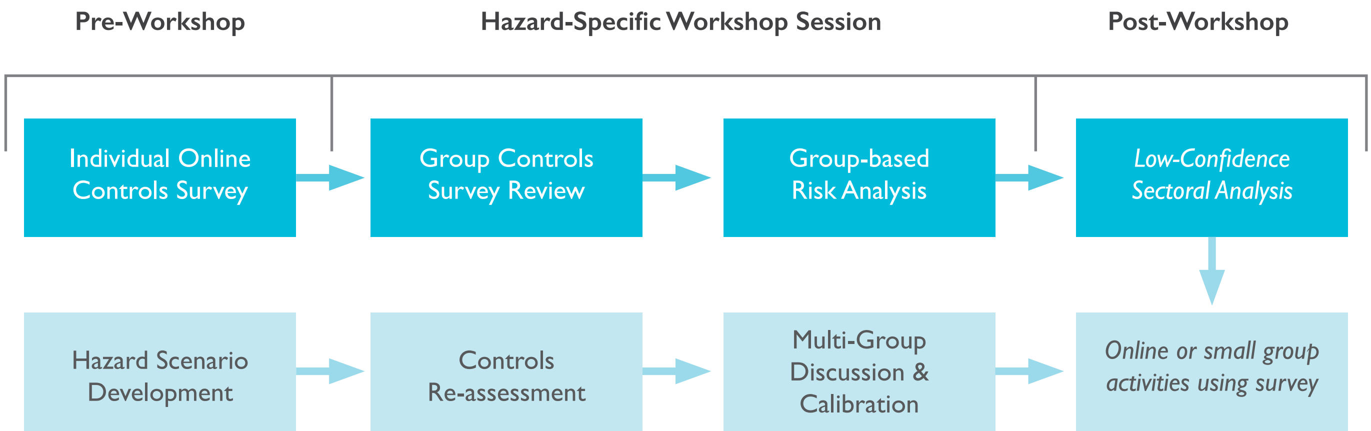
iii. *AS/NZS ISO 31000:2009 – Reproduced under SAI Global copyright Licence 1411-c083*

2.8 Hazard specific workshops

The hazard specific workshops were held as mostly half-day workshops within a two week period. Two full-day workshops were dedicated to bushfire and heatwave. Bushfire was allocated more time as it was the highest priority hazard identified in the 2012 report. Heatwave – a new hazard to be assessed at part of the TSNDRA process – was expected to require more time to describe, identify and assess controls and consequences, as little research or information was available regarding heatwave impacts on Tasmania. The other seven hazards were held in half-day, related workshops (e.g. Landslide in the morning, Earthquake in the afternoon), to allow experts to dedicate the entire day if possible, while also providing flexibility to operational personnel.

Each workshop consisted of four key stages: 1) initial collation of current controls; 2) confirmation and assessment of current controls; 3) scenario consequence rating; and 4) subsequent likelihood rating of those consequences on any given day (not in the instance of an event, i.e. residual risk). This process is represented in Figure 2.6, with further details presented in Appendix A: Methods.

Figure 2.6 Flow diagram of the data collection process employed during the TSNDRA 2016 process.



2.9 Averaging categorical values across multiple breakout groups

With multiple breakout groups, the potential to have differing results was introduced. Therefore, an average value for each 'Consequence', 'Likelihood' and 'Confidence' rating of each sub-sector was required from the values provided by the different working groups.

To achieve this, as the NERAG categories are simplifications of a logarithmic continuous scale, it is still sensible to find an average between two different values of the same type. Therefore, the categorical values were converted to integers (1-5 or 1-6 where appropriate). It was quickly realised that different working groups had differing levels of expertise, so a straight average between groups would be inappropriate to reflect the quality of the information collected by participants. Within the NERAG process, the 'Confidence' value is used to reflect either the level of knowledge about a hazard, or the level of expertise participants believe they have about a hazard. As such, each group's 'Confidence' rating was applied as a weighting factor to achieve a weighted-average[iv]. This vastly improved the overall ratings to better reflect the inputs provided by participants.

However, this created another problem: how to ensure the weighted-average value is correctly interpreted back into the category rating? This may seem a simple problem but it requires specific attention to handle correctly, described in detail within Appendix A: Methods.

2.10 Comparison between 2012 results and 2016 results

The TSNDRA 2012 results were only reported as true categorical values for each sector (rather than sub-sectors) so, where applicable, the maximum risk level sub-sector for TSNDRA 2016 was used. As these values are all perfect categorical values, when added to a figure, many values directly overlay each other, impeding interpretation. For visualisation purposes, the exact locations of each symbol were slightly adjusted to improve user interpretation. As such, symbols inside the same matrix cell (e.g. 'Major' consequence, 'Unlikely' likelihood) should be interpreted as having exactly the same value (e.g. risk level of 'High'). The 2012 values that cross the boundary between cells were rated as halfway between two categories (e.g. 'Minor/Moderate') and should still be interpreted as such.

2.11 Development of the risk register

After summarising the results from the multiple work groups, the TSNDRA review team followed the process as described in NERAG 2015 to produce the TSNDRA 2016 risk register(s).

2.12 Development of risk treatment options

With the risk registers for each hazard in hand, the risk treatment options were developed during a separate workshop. This workshop was held on a single day with a large number of participants, in three major sessions, namely two treatment-option development sessions and an overall feedback session.

During the two breakout sessions, each breakout group developed treatment options based on the controls survey, comments and rationale (from controls, consequence and likelihood analysis stages) collected throughout the previous workshops. The priority ratings from the target hazard's risk register were used to focus development of treatment options for the most at-risk sectors. A casual format allowed individuals to move between groups as required.

iv. *It was recognised that this may be flawed, as some experts were aware of low confidence due to a lack of evidence, or because the mechanisms surrounding the hazard are highly complex introducing uncertainty, rather than a lack of personal knowledge. This was identified as a major limitation of the NERAG process in its current form.*

3 Section Three
All hazards summary

Image: Chris White, University of Tasmania

3 All hazards summary

	2016	2012
Maximum Risk Level:	Extreme	Extreme*
Maximum Consequence:	Catastrophic	Catastrophic*
Maximum Likelihood:	Almost Certain	Likely*
Average Confidence:	High	N/A^

* The 2012 values have been re-calibrated following changes in methodology under NERAG 2015 (see Section 2.1)
^ No average confidence values were provided in TSNDRA 2012

3.1 Summary of Tasmania's natural disaster risks

TSNDRA 2016 reassessed the risk of bushfire, earthquake, flood, landslide, severe storm and tsunami and incorporated the first assessments of coastal inundation, heatwave and pandemic influenza. The relative likelihood and consequence each of these hazards would have on various sectors of society in a worst-case scenario were assessed. The sectors (and sub-sectors) were: People (Death; Injury); Economy (General; Industry); Environment (Species; Value); Public Administration; Social (Community Wellbeing; Cultural Significance). The overall findings of the risk assessment process and the regular themes identified across all hazards are summarised below.

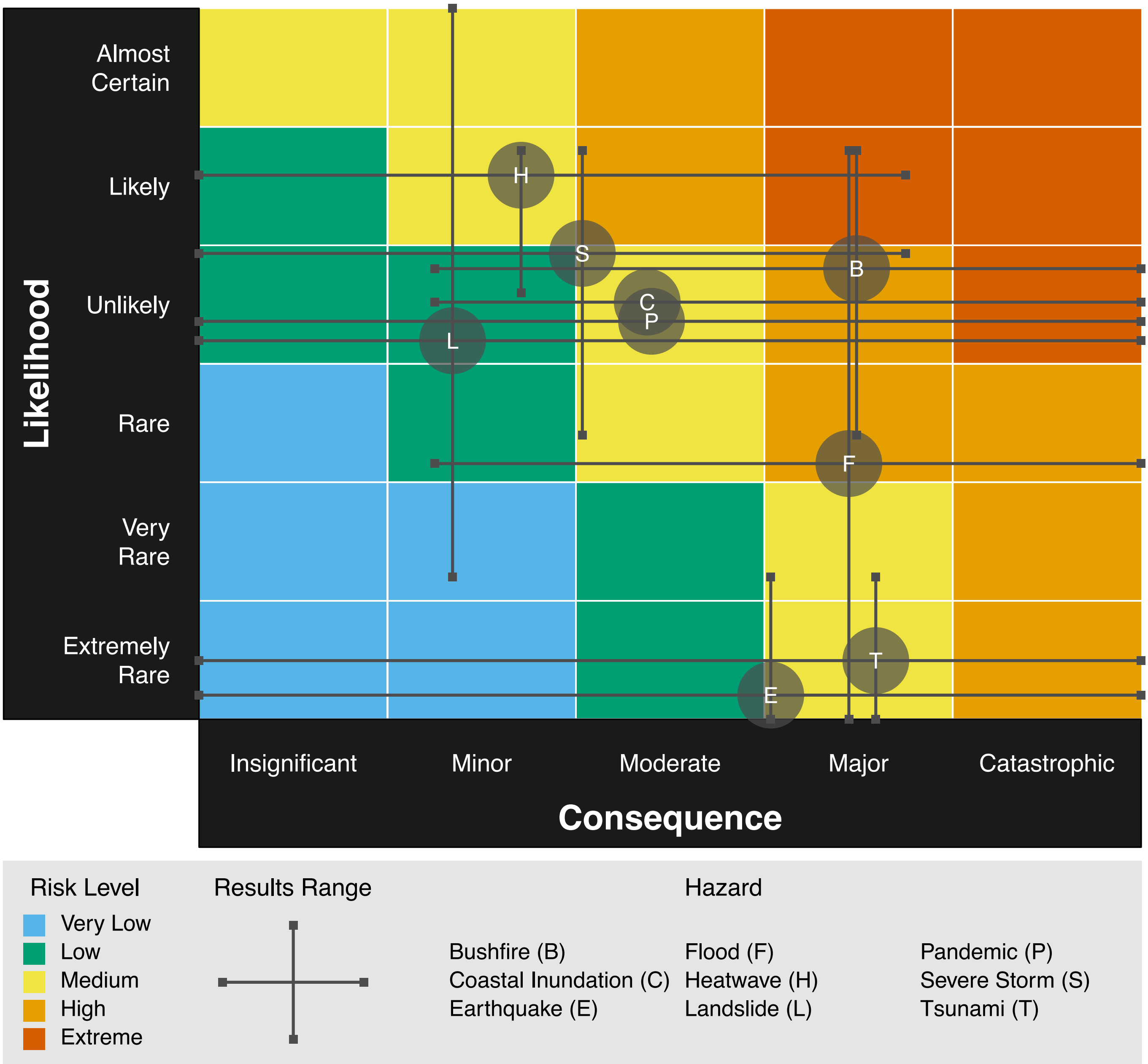
3.2 All hazard comparison

Although each hazard presents its own unique profile of risks to the State, an overall assessment and comparison of the total perceived risk from each hazard was requested from the stakeholders and practitioners throughout the emergency management sector.

It is clear that bushfire remains the greatest aggregated risk to Tasmania. It is a 'High' or 'Extreme' risk across all sectors of society, often with catastrophic consequences expected every 30 years (i.e. 'Unlikely' likelihood). This likelihood is expected to become more frequent with climate change, based on anecdotal evidence from experts and the most recent climate projections[18 19], transitioning at least into the 'Likely' category by 2100 (and possibly into 'Almost Certain').

In contrast, it is also evident that earthquake is the lowest risk hazard due to the 'Extremely Rare' likelihood and the moderate level consequences across the sectors, given the anticipated magnitude of an event. The major/catastrophic impacts are dependent on an earthquake-induced major dam failure that was deemed by experts even less likely than the earthquake itself. Interestingly, participants perceived that if the seismic monitoring system throughout Tasmania were decommissioned, all consequence and likelihood estimates would be substantially increased. It was identified that the seismic monitoring system is in urgent need of review and management, as it is mostly operated by the private sector with no obligation to continue and was almost decommissioned in 2015. This system ensures high confidence surrounding the likelihood of geological events, and the absence of this system would increase the risk level and priority of treatments for these hazards in future risk assessments.

Figure 3.1 Summary of the risk posed by each hazard as assessed in TSNDRA 2016. The central position is the average across sectors for both consequence and likelihood. The whiskers represent the minimum and maximum ratings across all sectors for each hazard.



An overall summary of the risk estimated for each hazard was requested and is presented in Figure 3.1. The overall average positions within the risk matrix do not reflect the most operationally important components of the risk profile across the hazards and within each sector. The range of risk – as presented in this aggregated way – is often so wide it is no longer useful for decision-making; overall 'all-hazards' assessments require reference to a particular sector to provide context. These 'by sector' results are presented in the companion document, the *2016 Tasmania Natural Disaster Risk Assessment – All Hazard Summary*.

3.3 Additional findings

3.3.1 Common issues and themes

During data collection, the integration of expertise and confidence into a single value of 'Confidence' was limiting. In some cases, experts in the field can be certain of a 'Very Low Confidence' rating due to either a lack of knowledge, or an understanding of complexities. Similarly, those with limited knowledge can be unaware of complexities and overestimate their confidence. This was identified as a limitation of the NERAG process. It is recommended future iterations explicitly rate the expertise of different working groups separate to confidence.

With respect to controls, land-use planning, building codes/controls and settlement planning schemes/codes were identified as strong and effective controls for each of the hazards apart from pandemic influenza. Limiting future development and vulnerable uses in known at-risk areas was concluded to be the most effective way of protecting life and assets and limiting future government liability at least cost.

With respect to treatments, a 'multi-hazards' approach to exercises and business continuity planning within government was agreed to be important, with hazard-specific training recommended for key incident management personnel (e.g. incident controllers) as well as formalising the arrangements to guide decision-makers in times of crisis to ensure rapid decision. Governments typically make decisions slowly, following lots of expert advice. During times of crisis, decisions need to be made quickly and decision-makers may struggle to commit to a decision. Programs that may encourage or support similar activities within the private sector were also mentioned.

A multi-hazards approach to household Prevention and mitigation, Preparedness, Response and Recovery (PPRR) was also identified as a potential new treatment, such as a 'hazard response plan' rather than a specific household plan for each kind of hazard.

Complementary to the multi-hazards approach, the frequency and severity of coincident events were identified as a knowledge gap, with broad support for further research in this area across all hazards. It was identified that hazards do sometimes co-occur, stretching emergency response capacity statewide. Some hazards, such as heatwave and bushfire, are likely to co-occur, but this is not incorporated into the exercise scenarios. However, others such as bushfire and flood (as experienced in January 2016) are less obvious, with the expected likelihood of such an occurrence poorly understood, especially under the influence of climate change. It was recognised coincident events should be incorporated into the cross-agency exercise regime to ensure statewide capacity is regularly assessed under different situations to identify areas for improvement.

It was noted that environmental damage from natural hazards can be substantial and control activities should consider the opportunities for maintaining a robust ecosystem, spatially distributed, which is capable of withstanding shocks. This may involve improved protection of existing forest, or active regeneration of targeted areas to improve spatial coverage of a particular kind of habitat.

3.3.2 A note on vulnerable populations

The emergency risk management sector has traditionally approached the identification of population vulnerability from a demographic perspective, using data that reveal those most likely to suffer poorer health outcomes relative to other population groups in the wake of a disaster.

These data suggest groups such as the elderly, young people, those from low socio-economic backgrounds and those with chronic health conditions are more likely to be over-represented in mortality rates and experience greater negative impact as a result of a natural disaster.

While this definition is simple in approach and based on evidence, it does not necessarily capture the full picture of population vulnerability. Everyone has the potential to be vulnerable in particular circumstances and, conversely, individuals from identified vulnerable population groups can be particularly resilient. For example, an otherwise healthy individual may become vulnerable in a bushfire as they remain in danger to protect livestock and infrastructure, while an elderly individual may use their strong existing networks within the community to assist them.

Alongside the recognition of identified vulnerable groups, an individual's adaptive capacities also need to be considered. Overall health and wellbeing, the strength of connections and networks, the ability to recover with financial security, and the knowledge of how to make informed decisions all contribute to an individual's vulnerability in preparedness (as well as recovery) from a disaster.

Vulnerability and resilience are driven by context rather than definition, and are fluid and complex concepts. Agencies working in emergency management need to be aware of these issues and adapt strategies accordingly.

4 Section Four Bushfire risk assessment

Image: Department of Police, Fire and Emergency Management

4 Bushfire risk assessment

	2016	2012
Maximum Risk Level:	Extreme	Extreme*
Maximum Consequence:	Catastrophic	Catastrophic*
Maximum Likelihood:	Likely	Likely*
Average Confidence:	High	N/A^

* The 2012 values have been re-calibrated following changes in methodology under NERAG 2015 (see Section 2.1)
^ No average confidence values were provided in TSNDRA 2012

4.1 Context and definition

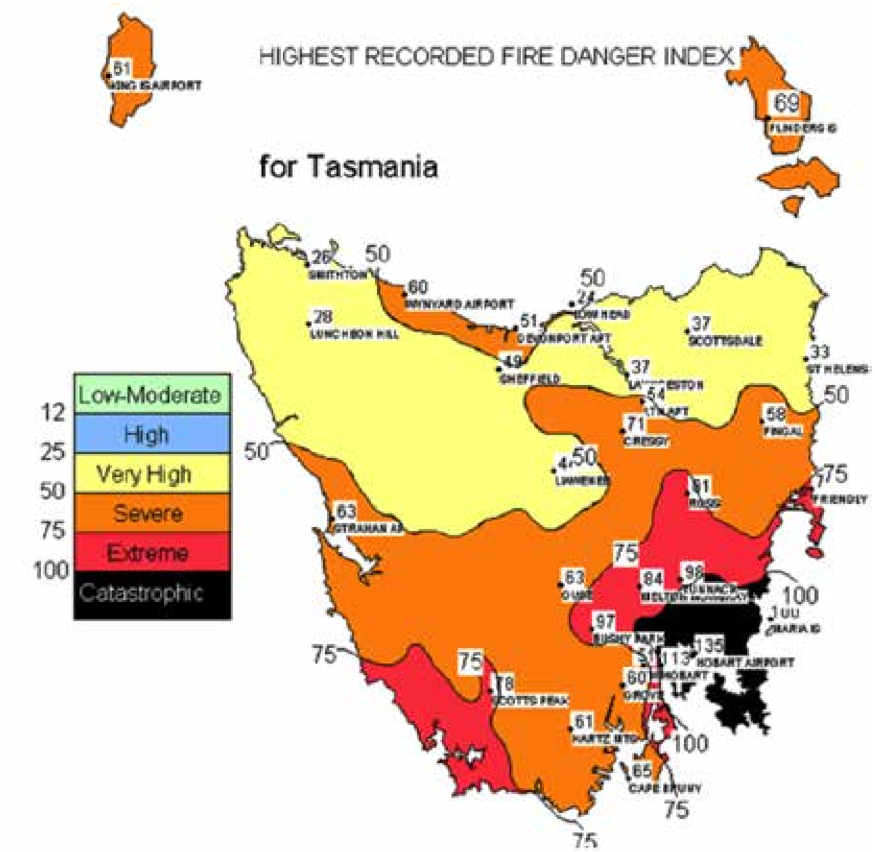
For the purpose of the TSNDRA, a working definition of bushfire was agreed to include any fire in vegetation – irrespective of origin or cause – on the basis that bushfire can occur anywhere in Tasmania where there is vegetation, although its impacts are generally only significant when the fire occurs near populated or settled areas. It was felt important not to exclude bushfires of human origin from the study due to the high number of fires caused as a result of human interaction.

Bushfire has been the most costly natural disaster hazard in Tasmania's history, in both economic and human terms. Bushfire has directly claimed the most lives of any natural hazard in Tasmania (noting that it is difficult to directly associate deaths with Heatwave and Pandemic), and is said to carry an average annual cost of at least $15 million[20].

Bushfires in Tasmania are most commonly associated with dry conditions during summer and autumn. Peak bushfire danger periods vary between years according to the rainfall distribution over spring to autumn. Large differences in rainfall distribution across the State affect when and where bushfires occur, and also the susceptibility of vegetation to fire. Tasmania is considered periodically vulnerable to bushfire due to the level of vegetation cover across the State, the unique population spread and the relationship between high rainfall/low evaporation on fuel loads[21].

The south-eastern part of Tasmania is considered more exposed to bushfire hazard than other parts of the State[18 19]. This region generally experiences less rainfall and drier conditions. As Figure 4.1 illustrates, Forest Fire Danger Index (FFDI) ratings of over 100 (Catastrophic) have been recorded in the south-east. As the chart shows, the north and north-west parts of the State generally experience lower FFDI ratings.

Figure 4.1 Maximum fire danger recorded in Tasmania 2000-2010[22].



4.2 Previous significant events

The south-eastern corner of the State has also experienced the most significant bushfires in the past. In particular the fires of 1967 represent the most catastrophic natural hazard event to have impacted Tasmania. On 'Black Tuesday', 7 February 1967, the FFDI peaked at 128, over 110 fires swept through Hobart and surrounding areas and killed 62 people. More recently, the 2013 bushfires that burned across the State significantly impacted the Dunalley township. This event prompted the 2013 Tasmanian Bushfire Inquiry[23] that included more than 100 recommendations, most of which have been, or are being, adopted by the appropriate agencies.

As part of the workshop process, an analysis of previous significant fire events was undertaken. The major bushfire events from the state-level perspective are presented in the Table 4.1, with a map describing the known 'fire history' over the last 40 years presented in Figure 4.2.

Table 4.1 Major fire events in the Tasmanian historical record.

Event	Date	Area Burnt (ha)	Mortality Rate	People Injured	Estimated Cost
January Lightning Storms 2016	Jan–Feb 2016	125,000			(Not assessed at time of publication)
Dunalley Bushfires and 'The Angry Summer'	Jan 2013	20,000			$90m (2013)
Dolphin Sands	Nov 2009				3 homes destroyed
Lohreys Rd, St Marys and Kellivie	Dec 2006	30,925	0.02 deaths per 10,000 people; 1 dead (Pop: ~500,000)		26 homes destroyed; $50m loss in FT timber assets
Hobart	17 Jan 1998			~50	6 homes destroyed in Hobart's southern suburbs
Pelverata and Bonnet Hill	25 Feb 1991				6 homes destroyed
Kempton	1982		1 fatality		State of Emergency Declared for the region
Zeehan	3 Feb 1981				40 homes destroyed
Black Tuesday, Hobart and Surrounding Area Fires	Feb 1967	264,270	1.7 deaths per 10,000 people; 62 dead (Pop: ~380,000)	900	$45m (1967) ($485m in 2010 with inflation)
16 January and Black Friday 9 February 1934	Jan-Feb 1934	Unknown	At least one fatality		Homes destroyed and some loss of life
Mt Wellington and Hobart Region Fires	Dec 1897	Unknown	0.4 deaths per 10,000 people; 6 dead (Pop: ~160,000)	Unknown	Likely to have been $47m-$142m in today's terms
Huon – Port Cygnet Fires	1854–Jan	Unknown	1.6 deaths per 10,000 people; 14 dead (Pop: ~90,000)	10	Likely to have been $14-$47m in today's terms

It was also noted that south-east Tasmania frequently experiences fire weather conditions similar to those experienced in 1967, with >100 Forest Fire Danger Index (Catastrophic Forest Fire Danger Rating) ratings recorded on "several occasions in the last ten years"[22]. Many recent fire events were identified that had the potential to cause significant impact on the Tasmanian community. These fires may have been more damaging were it not for favourable weather changes and/or the effectiveness of the response to the event.

The environmental impact of past fires was also considered, with significant events including the King Island fire of 2007 that significantly changed an ecosystem at Lavinia State Reserve. It must be noted the environmentally catastrophic bushfires of January 2016 are currently burning within the west coast and central plateau regions as this report is being finalised. They were not directly considered during this process as they occurred after the data collection and evaluation stages. However, those with relevant expertise considered the impact of such an event during the workshop process and categorised bushfire with a catastrophic consequence to the environment sector.

4.3 Climate change implications

Climate change projections were considered by the working groups when determining likely consequences arising from a major bushfire event. While bushfire weather projections conducted for south-eastern Australia do not include significant change for Hobart and Launceston, data published by the Climate Futures for Tasmania project[18 19 24 25] suggest that changes likely to be experienced over the course of the next century may include:

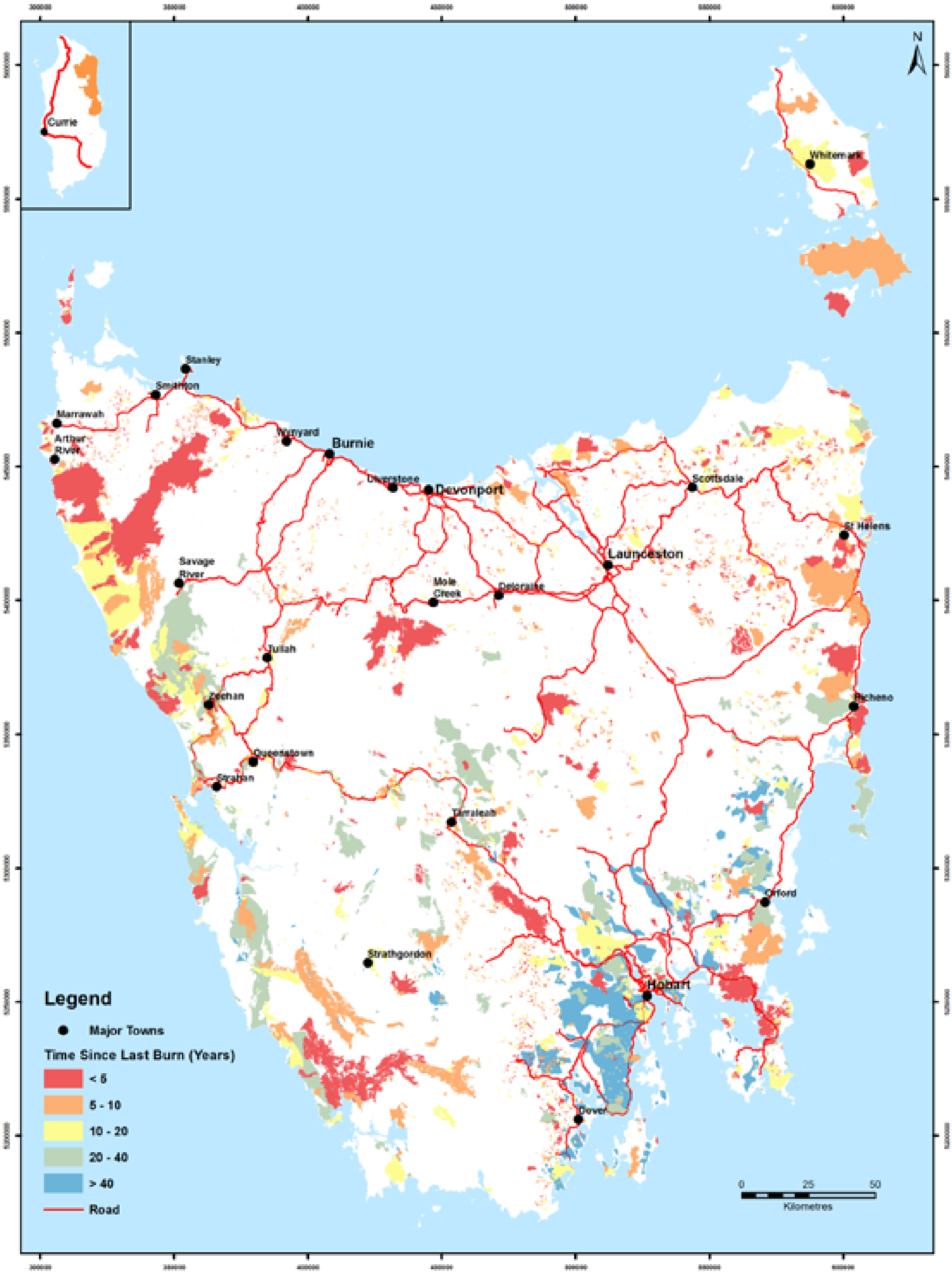
- more hot days and warm nights, dry days and longer dry spells
- more warm spells and heat waves
- more wet days, but fewer cold spells and cold waves
- an earlier start to high-risk conditions in spring.

These climatic changes may result in an increase in the number of high fire-danger days, which has the potential to increase the State's overall bushfire risk.

4.4 Current arrangements

Three major agencies provide fire services in Tasmania. They are the Tasmania Fire Service (TFS), Parks and Wildlife Service (PWS) and Forestry Tasmania (FT). Processes for managing significant bushfires in Tasmania are well-developed, with strong liaison between the three fire agencies and cooperative arrangements in place for multi-agency response. The TFS is the designated SEMC Advisory Agency under the Tasmanian Emergency Management Plan. The roles for the partner agencies are presented in Table 4.2.

Figure 4.2 Representation of past known fire history across Tasmania.



Source: J Richley, Fuel Reduction Unit, Tasmania Fire Service.

Table 4.2 Current arrangements for the emergency management of bushfire in Tasmania.

Hazard	SEMC Advisory Agency	Management Authority		
		Prevention and Mitigation	Preparedness	Response
Fire – national parks and other reserves	TFS	Parks	Parks	Parks
Fire – declared forest land/state forest	TFS	Forestry Tasmania	Forestry Tasmania	Forestry Tasmania
Fire – urban and privately managed rural land	TFS	TFS	TFS	TFS

While these are the general arrangements, it should be noted that in a response situation where a fire has the real potential to impact on lives within the community, TFS assumes responsibility regardless of the land tenure. In such cases the TFS Chief Officer would appoint a qualified Incident Controller and appropriately resourced Incident Management Team to manage the incident.

4.5 Worst-case scenario

Bushfire was rated an 'Extreme' risk in TSNDRA 2012, a classification that was confirmed by a series of severe bushfires that impacted across the south-east of the State in 2013. However, the scenario used for bushfire in 2012 was determined to be consistent, due to the 1967 'Black Tuesday' fires having a more significant impact than the 2013 event, under equally severe weather conditions. For consistency, it was decided to follow the same scenario used in TSNDRA 2012 for TSNDRA 2016. The worst-case scenario for bushfire was:

- Based on the most significant bushfire event in Tasmania's history: Black Tuesday fires, 7 February 1967. Key characteristics associated with this reference event are:
    - a two-day event with a Severe fire danger on Day 1 increasing to Catastrophic on Day 2 (FDI – 75-100+)
    - a Soil Dryness Index (SDI) of 150+, and a Drought Factor Index of 10
    - multiple fires already burning, including at least two large-scale fires that are beyond suppression capability
    - fires burning across all three regions
    - one fire impacting a major population area, the other an isolated community
    - fires impacting a national park area as well as Forestry assets
    - strong winds pushing fire into highly populated area
    - remote critical infrastructure is threatened, inoperative or damaged.*

* This was additional to the 2012 scenario following the experience of the Dunalley Bushfires where emergency communications were interrupted.

Workshop participants were presented with additional information relating to the potential distribution and severity of bushfire in Tasmania, based on historical records and analysis of the extreme weather pattern associated with the 4 January 2013 event. Recent trends, as well as sub-annual distribution and potential shifts of these trends due to climate change, were also considered (in particular the impact on the frequency of dangerous Forest Fire Danger Index days).

4.6 Existing controls

The outcome of the break-out group review of the bushfire controls survey is shown in Table 4.3. It was noted by all groups that there was some difficulty assessing the strength of many of the controls from a 'whole-of-state' perspective; for example, reasonably new programs have not had the test of time to determine their strength. Weaknesses in other programs in remote areas were also observed, e.g. the brigade network was seen to reduce in effectiveness relative to the proximity to infrastructure and population centres. Other controls were observed to be critical in terms of response – for example, the fire trail/break network – however, this could not be accounted for in the strength/expediency assessment framework (i.e. a very strong and expedient control could have little effect on reducing the likelihood of a worst-case consequence scenario).

Table 4.3 Bushfire controls (Str. = control strength, Exp. = control expediency).

Bushfire Controls								
Material/Physical	**Str.**	**Exp.**	**Procedural**	**Str.**	**Exp.**	**Behavioural**	**Str.**	**Exp.**
Fuel Reduction Program	M	L	Community alerts	M	M	Media liaison	M	H
Brigade Network	M	M	Fire permit system	M	M	School fire education programs	VL	VL
State Fire Operations Centre	M	H	Household/property insurance	M	L	Bushfire survival plans	M	L
Community Protection Plans	H	H	Bushfire response plans	M	M	Community development strategies	H	L
Regional Fire Operation Centres	M	L	Bushfire mitigation plans	M	L	Fire-ready schools and sites	M	L
Incident Management Teams	M	H	Community education	L	L	Weather warning system	L	L
NAFC and contract aircraft	M	H	Community protection plans	M	L	Fire-ready neighbourhood program	H	L
LMA resources	M	M	Land-use planning	M	L	Forced evacuation	L	VL

Bushfire Controls								
Material/Physical	**Str.**	**Exp.**	**Procedural**	**Str.**	**Exp.**	**Behavioural**	**Str.**	**Exp.**
Fire Management Area Committees	M	L	Building and development controls	M	L	Community education	L	M
Fire Trails/breaks/ and maintenance	M	L	Total fire bans	M	M	Recovery advice	M	L
Seasonal firefighters	H	H	Per-incident planning/ exercises	M	L	Community engagement in fuel reduction burning	M	L
Additional PWS tankers	M	H	Closing parks/reserves	L	M	Public behaviour change	M	VL
			Prepositioning staff/ resources	M	M	External training programs	M	L
			Hot day response systems	M	M	TFS website	L	H
			Media and website use	L	H	Seasonal forecast system	M	M
			Clean-up procedures	L	VL			
			Fuel stove only areas	H	H			

Tasmania's historical under-insurance, infrequent application of clean-up/decontamination processes, and the limited legislative capacity for enforcing evacuations during emergency response were areas of critical control weakness that were noted for potential integration with risk-treatment planning. Strengths included community protection planning, seasonal firefighter procurement systems (including links with mainland fire services), and media liaison with public health.

Key opportunities for improvement in bushfire controls were also identified. Improved engagement through social media was an example of a strategy that had the potential to improve a number of areas such as awareness of community alerts, fire permit embargos and implementation/use of bushfire response plans. Points of broader integration with government, such as better land-use planning, were also seen as having potential; however, these are difficult to implement in the short to medium term. Opportunities were identified to increase funding in a number of areas including: bushfire mitigation planning; school fire education programs; bushfire ready sites, schools and neighbourhoods. It was also recognised that existing programs need to have their funding requirements sustained.

4.7 Bushfire risk analysis

The risk assessment results for bushfire from TSNDRA 2016 are presented in Figure 4.3.

The 'likely', 'major' consequences in the People sector, as well as 'unlikely' but potentially 'catastrophic' economic impact resulting from a bushfire disaster, resulted in bushfire being assessed as an 'extreme' risk at a state level. Participants expressed a high level of confidence in their analysis of the consequence and subsequent likelihood levels determined across these two sectors, with slightly lower confidence in their ability to assess the impacts as a percentage of gross state product and the resulting injuries and illnesses than the likely number of deaths and impacts on critical industries. It was also noted that long-term impacts on affected populations, both physically and mentally, were not well understood.

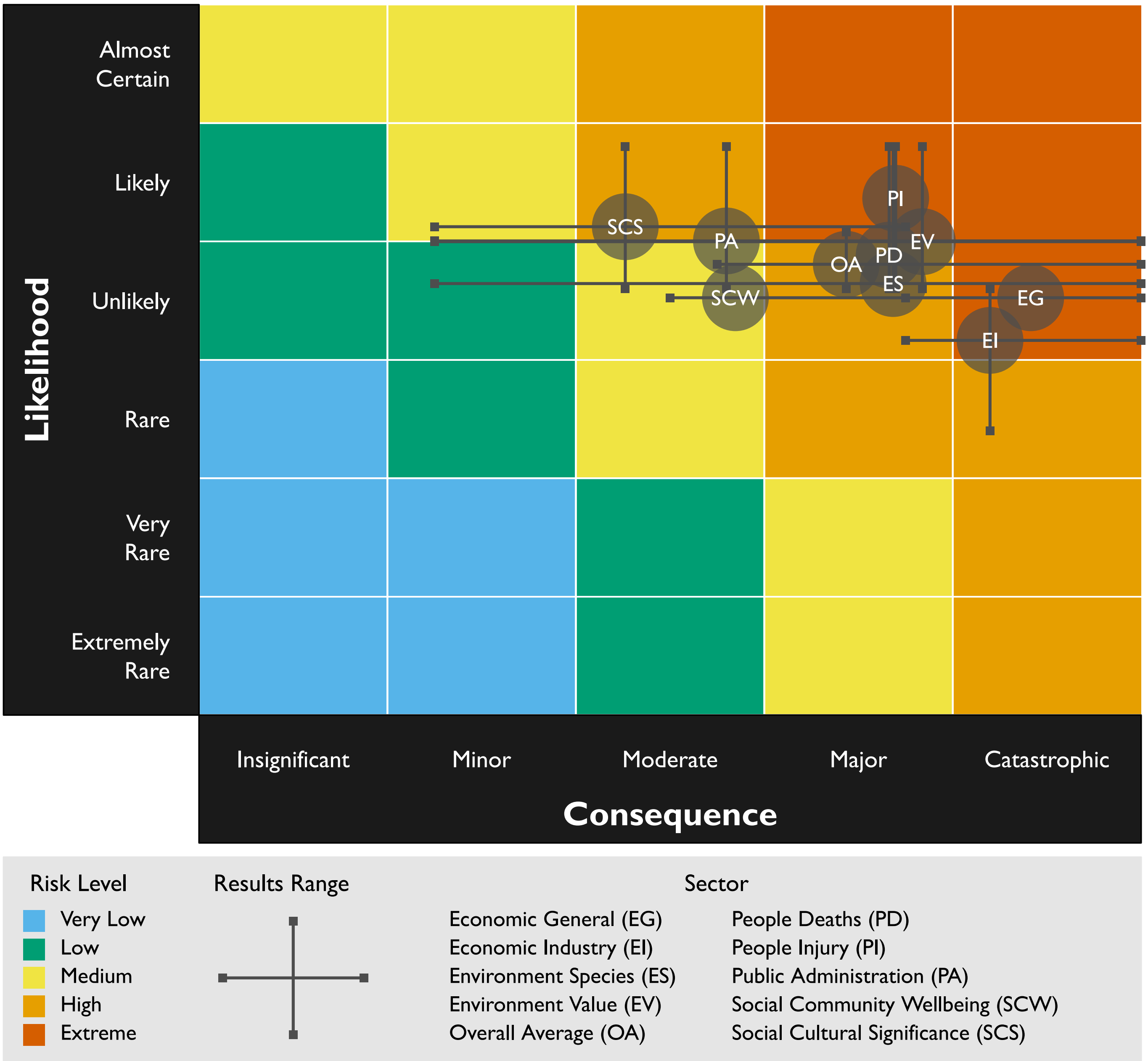
Group members commented that the decision to limit the worst-case consequence below a 'Catastrophic' number of deaths (50 or more), as experienced in 1967, was due to stronger controls being in place in relation to this hazard. Group members noted the number of deaths in a worst-case scenario would be expected to be "many more than six (the cut-off for 'moderate' consequence classification), but less than 50 (the cut-off for 'catastrophic' consequence)". It was also noted that the scenario did not outline the likely impact on vulnerable people, with pre-formed plans and personal relationships playing an important role on the ground. The relatively small geographic spread of key industries, specifically the mining sector and Norske Skog, were observed as reducing the likelihood of the worst-case economic scenarios for industry-specific consequences.

Impacts on Public Administration were expected to fall within the moderate consequence classification; however, there was only moderate confidence in the assessment of whether core government functions would be disrupted due to a limited understanding of the level of redundancy in the system.

The three groups assessed the level of environmental impacts (both in terms of species/landscape loss and loss of value) very differently, ranging from catastrophic to minor. The group with environmental expertise were extremely confident in their assessment of a worst-case scenario resulting in catastrophic environmental damage (specifically, significant loss/impairment of nationally-significant ecosystems) to organo-soils (peats), rainforest and alpine ecosystems. However, this was tempered by a belief that the majority of the Tasmanian environment is resilient or adapted to fire. Assessment of likelihood had a similarly wide spread, ranging from 'not very confident' to 'very confident' across the groups, aligning with the level of expertise. The cyclical nature of ecosystem succession in the light of fire regimes was noted as complicating the assessment of environmental impacts relating to this hazard, with certain species being adapted to, or dependent on, burning cycles.

Social impacts under a worst-case bushfire scenario were considered to be moderate in consequence, with higher confidence in this assessment across the groups in terms of community wellbeing than cultural significance, which was observed to be problematic in terms of defining a "major culturally important activity or event". The high rebuild rate at Dunalley following the 2013 fires was used as evidence of a reasonably short recovery period for affected communities, while the possible impacts on sporting events during the summer period and festivals (such as Taste of Tasmania and Falls Festival) were also noted. The possibility of the catastrophic loss of an entire town was mentioned and deemed plausible, although not expected.

Figure 4.3 The risk of bushfire to each subsector of society as determined by TSNDRA 2016. The central position is the confidence-weighted-average across working groups for both consequence and likelihood (confidence implied the expertise of the group). The whiskers represent the minimum and maximum ratings across groups.



4.8 Bushfire – differences between 2012 and 2016

The change in the risk of bushfire to each sector between TSNDRA 2012 and TSNDRA 2016 is presented in Figure 4.4.

4.8.1 Participants

Following a recommendation from the author of TSNDRA 2012, the TSNDRA 2016 process made a deliberate effort to engage a larger number of experts, with a broader range of expertise than was possible during the 2012 process. This results in some large changes in the economic and social setting sectors.

4.8.2 People

A risk of bushfire to people remained unchanged at 'Extreme'. In TSNDRA 2016, experts agreed the scenario considered would result in 'Major' (<50 deaths) consequences, which is a reduction from catastrophic (>50 deaths) in 2012. Experts believed the general public are more aware of the risk and are also more contactable than ever before, reducing the number of people expected to be exposed. However, the likelihood of a catastrophic event is increasing, changing from 'Unlikely' in 2012 to 'Likely' in TSNDRA 2016. This was believed to be driven by broad scale climate change.

4.8.3 Economic

The risk of bushfire to the economy was increased from 'High/Extreme' in 2012 to 'Extreme' in TSNDRA 2016. In TSNDRA 2012, the economic consequences of the scenario were expected to be 'Moderate/Major'. This was upgraded to 'Catastrophic' consequences in TSNDRA 2016, with the inclusion of potential loss of an entire industry, mostly attributed to an improvement in the expertise engaged. Lower resource (e.g. minerals, timber, woodchips) prices in TSNDRA 2016 relative to those in 2012 have affected the profitability of Tasmanian primary industries, making many of them vulnerable to operational interruptions of any kind. Experts had an appreciation of private assets at risk from bushfire, or protocols that force operational shutdowns during bushfire, that if experienced could force the cessation of Tasmanian operations. However, as particular conditions are required, these were considered less likely, hence the reduction from 'Likely' to 'Unlikely' likelihood.

4.8.4 Environment

The risk of bushfire to the environment remain unchanged at 'High'. It must be noted, the possibility of the loss of habitat/ecosystems/species was considered by TSNDRA 2016. A 'Catastrophic' rating was recommended by one of the groups, who explicitly considered it 'Likely' the irreversible loss of alpine habitat, or a species, would occur within the scenario. Unfortunately this was somewhat prescient of the event that occurred in January 2016, which resulted in devastating losses within the higher elevations of the Tasmanian World Heritage Area. However, averaging across the TSNDRA 2016 groups resulted in a 'Major' rating (even after weighting by confidence, in the absence of a recorded expertise level). This highlights a limitation within this process when using multiple working groups. It is a recommendation that expertise be explicitly recorded by each group for future assessments to ensure appropriate weighting of ratings.

Figure 4.4 Change in bushfire risk level to each sector of society between TSNDRA 2012 and TSNDRA 2016 as rated by the NERAG process.

4.8.5 Public administration

The risk of bushfire to public administration increased from 'Medium' in TSNDRA 2012 to 'High' in TSNDRA 2016, driven by an increase in likelihood as a result of climate change. Experts in the TSNDRA 2016 assessment believe the public administration consequences remain 'Moderate', although the likelihood of the scenario increases from 'Unlikely' in TSNDRA 2012, to 'Likely' in TSNDRA 2016.

4.8.6 Social setting

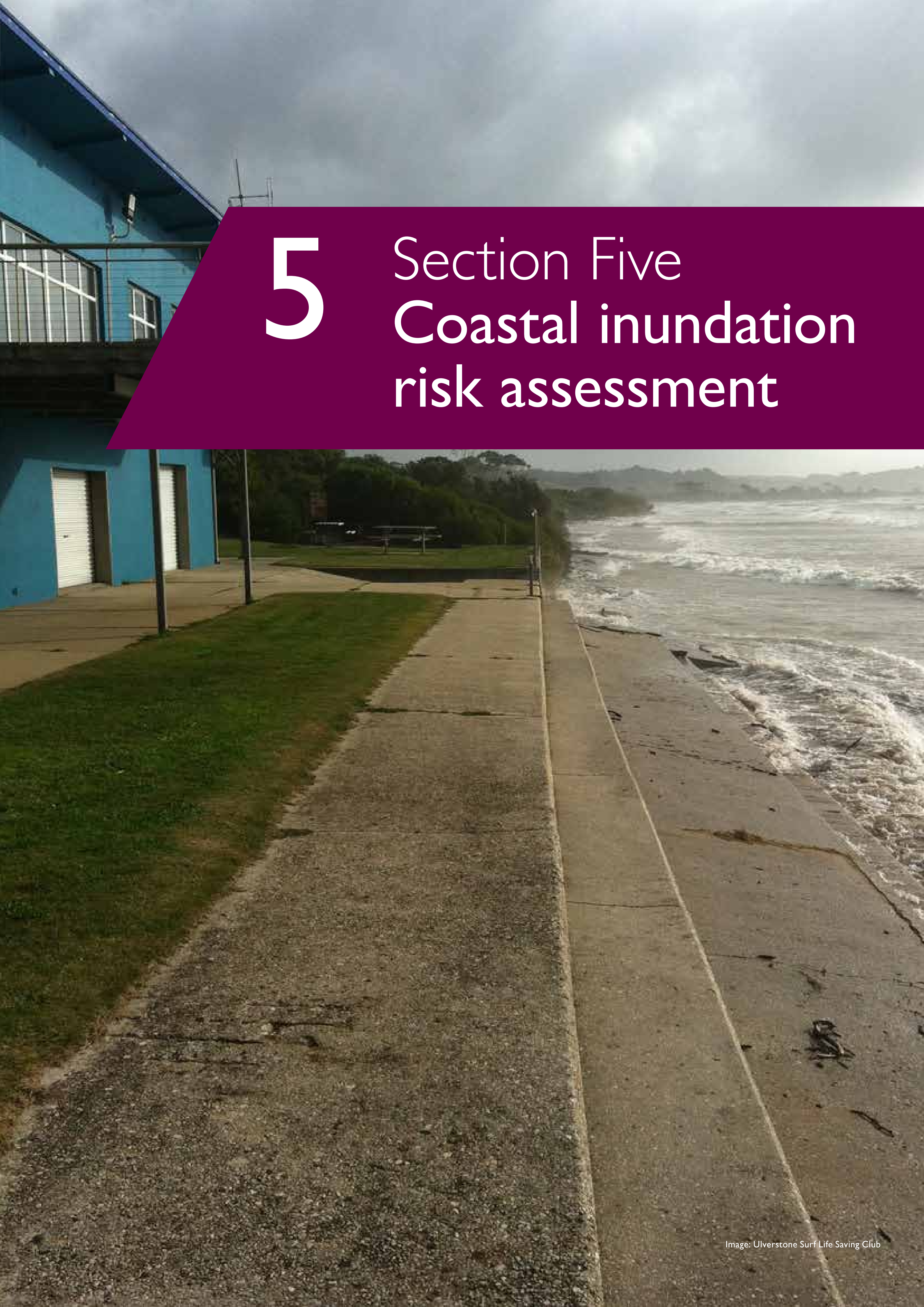
The risk of bushfire to social setting increased from 'Low/Medium' in TSNDRA 2012 to 'Medium' in TSNDRA 2016. The social setting in TSNDRA 2016 was informed by the 2013 bushfires that impacted on the Dunalley township. This event, being fresh in the minds of participants, improved their ability to rate the social consequences, especially with regard to the longer-term impacts. Coupled with this, social setting expertise was engaged and in attendance. As such, consequences increased from 'Insignificant/Minor' to 'Moderate', although the likelihood was reduced from 'Likely' to 'Unlikely'.

4.9 Bushfire risk register

The bushfire risk register, presented in Appendix B: Risk Register, was created by the project team following the process described in the NERAG 2015.

4.10 Proposed bushfire risk treatment options

It is important to note that the proposed risk treatment options, presented in Appendix C: Proposed Treatment Options, have been developed for the purpose of informing further discussion at SEMC/Management Authority level. It is appropriate that these options be reviewed by the management authorities and referred to SEMC for further decision.



5 Section Five
Coastal inundation risk assessment

Image: Ulverstone Surf Life Saving Club

5 Coastal inundation risk assessment

	2016	2012
Maximum Risk Level:	Extreme	N/A*
Maximum Consequence:	Catastrophic	N/A*
Maximum Likelihood:	Unlikely	N/A*
Average Confidence:	High	N/A*

* Coastal Inundation was not assessed in TSNDRA 2012

5.1 Context and definition

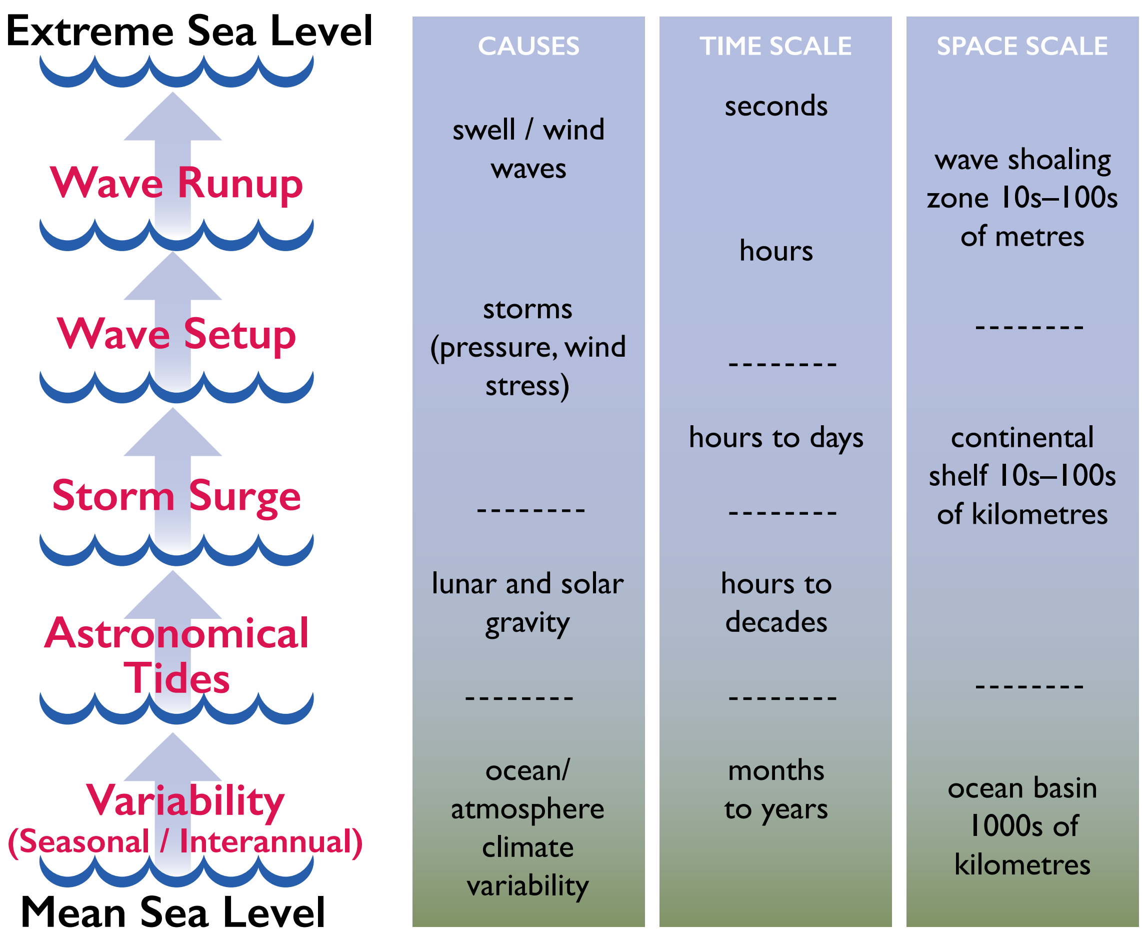
Coastal inundation was not assessed in TSNDRA 2012. However, as it is one of the most visible natural hazards linked to climate change – and there is mounting evidence that a treatment plan is required – participants of the scoping workshop chose to include it in the TSNDRA 2015/16 state risk assessment process.

Coastal inundation is defined as the temporary and permanent flooding of a portion of land within the coastal zone not caused by a geological event (e.g. a tsunami). Temporary inundation is a storm tide event that, similar to inland flooding, is caused by a complex interaction of riverine, coastal and oceanic factors on a range of timescales (see Figure 5.1). These factors may include any one or combination of: tides; storm surge, waves (wind waves and swell); large-scale climate modes; coastline geometry (e.g. bathymetry); rainfall; sea level rise; and coastal geomorphology/ erosion. Permanent inundation is the permanent loss of land to the sea due to erosion of the land either by continuous processes, or a rapid onset event. Only rapid onset events are considered an emergency hazard within the context of TSNDRA.

Annual tidal cycles ebb and flow in response to the phase of the solar, lunar and longer-term ocean cycles (such as the El Niño-Southern Oscillation). Each location has a somewhat unique tidal range, depending on local and regional bathymetry. The bathymetry of the area also influences the way oceanic waves disperse energy on meeting the coastline, where regions with shallow coastal waters reduce the magnitude of energy that reaches the high-tide mark, protecting the coastline.

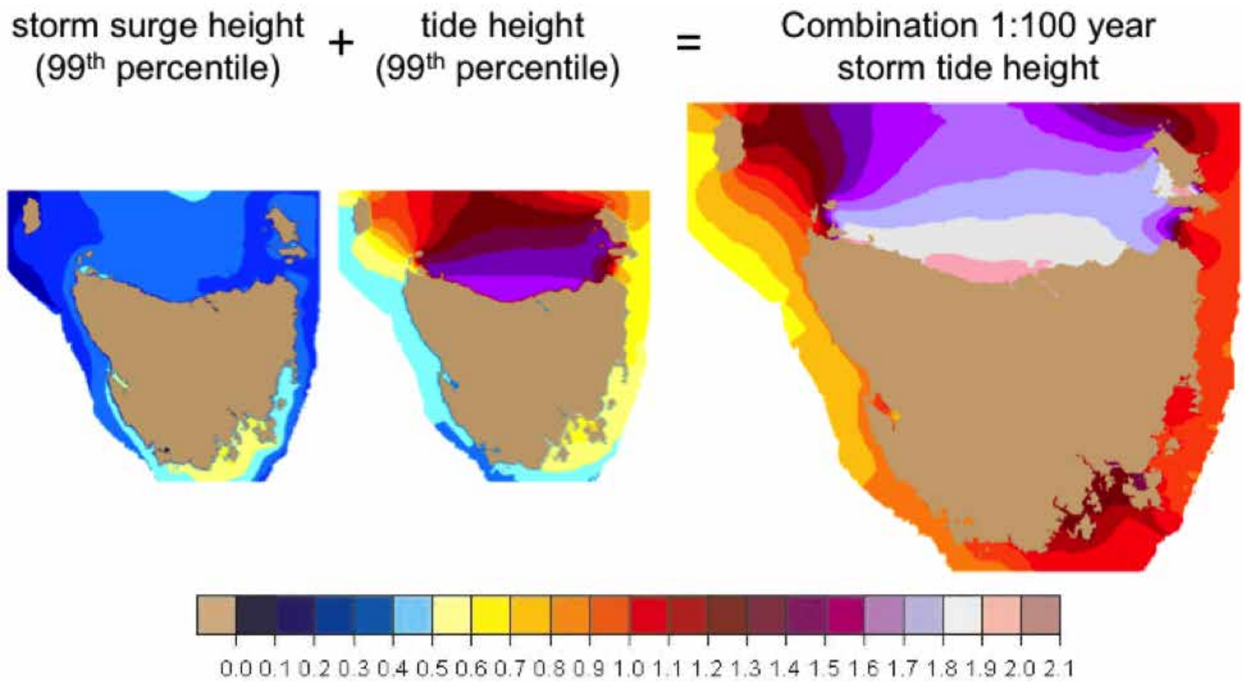
Large low pressure systems (i.e. storms) also have a positive influence on the observed sea level, temporarily raising local conditions by tens of centimetre (the inverse barometer effect: a fall in surface pressure of 1 hPa = 1 cm rise in sea level). As storms are often associated with high rainfall, low-lying areas around rivers are particularly susceptible to storm-surge inundation, as river levels rise from out-flowing and in-flowing waters. High winds during these storms can also push the water against the coast as well as generate or amplify swell and wave action. The most destructive coastal inundation event is a storm tide, which is when the highest spring tides coincide with severe storm surges. These events bring about abnormally high sea level, resulting in significant inundation of low-lying areas. Recent modelling suggests the north coast of Tasmania is the most susceptible to storm tide (see Figure 5.2).

Figure 5.1 Oceanic phenomena that contribute to the total water levels at the coast during an extreme sea level event, their causes and the time and space scales over which they operate.



Source: McInnes et al. 2016[26].

Figure 5.2 Storm tides around Tasmania, formed by the highest spring tides occurring coincidentally with severe storm surges.



Source: figure adapted from McInnes et al. 2011[27].

5.2 Previous significant events

As part of the TSNDRA 2016 project, a limited sourcing of historical coastal inundation events impacting Tasmania was undertaken. Historical information, taken from Sharples 2006[28], is presented in Table 5.1. While storm surges have flooded many low-lying coastal areas in Tasmania during the 20th century, in some cases closing roads and causing property damage, the records of such events are mostly anecdotal and there has been no systematic analysis of historical storm-surge flood records for Tasmania.

No further assessment was undertaken of these events for TSNDRA 2016, however, and it is noted that this remains a notable gap in knowledge.

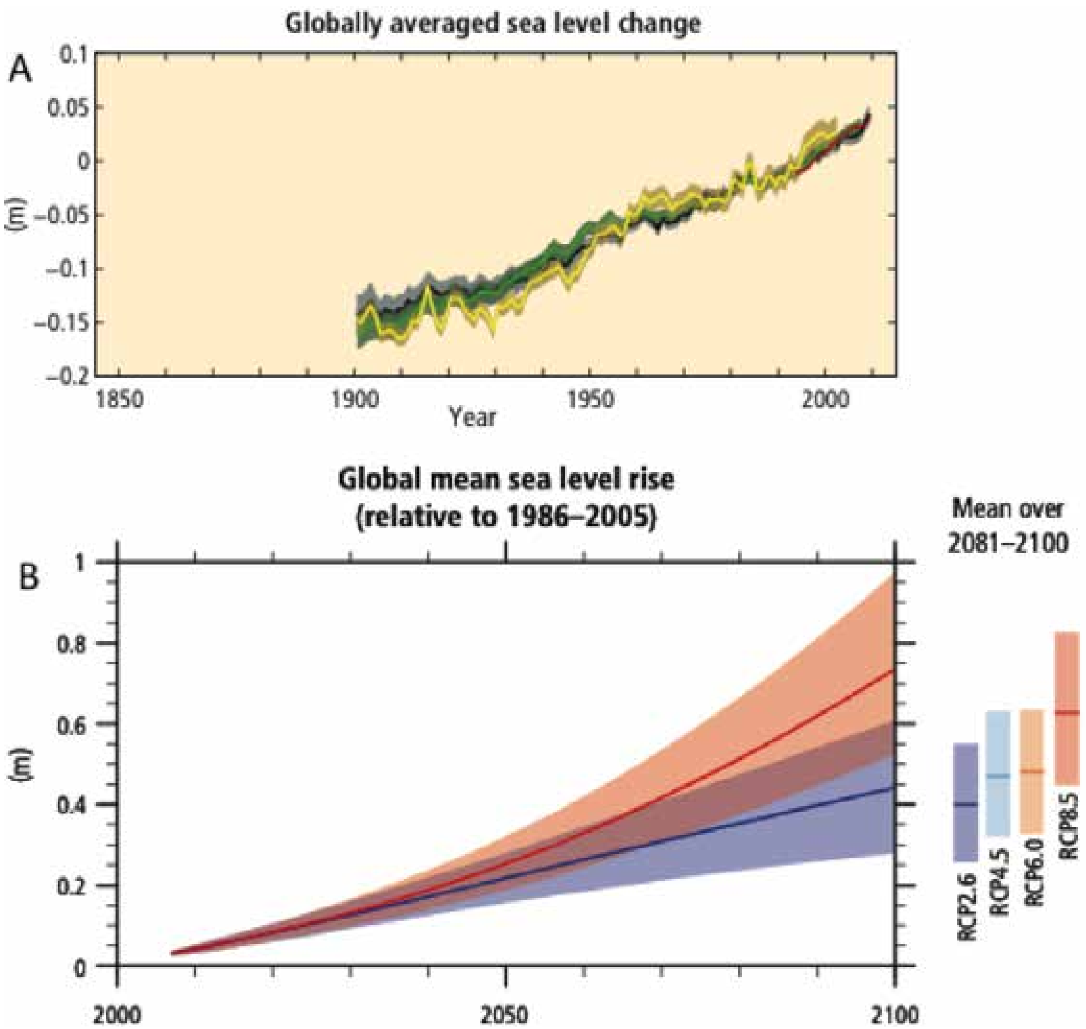
Table 5.1 Notable coastal inundation events in the Tasmanian historical record (summary information taken from Sharples 2006)[28].

Event Type	Year/Date	Impact Summary
Storm surge	Late 1980s and early 1990s	Several storms during the late 1980s and early 1990s caused flooding at Lauderdale, with a 1994 storm closing the main South Arm road at Lauderdale, and another in 1991 washing debris across the road. During the 1991 storm, wind-driven waves were reported breaking on the driveway of the Lauderdale BP Service Station – on the landward side of the main South Arm Road – but the wind abated prior to high tide, resulting in less flooding than would otherwise have occurred (The Mercury, 7 August 1991, pp. 1-2).
Storm surge	25 July 1988	The highest recorded tide at Hobart – caused by a deep low pressure system passing south of Tasmania – reached 1.32m above AHD on 25 July 1988, causing flooding at both Lauderdale and further south at Bicheno Street on the south side of Pipe Clay Lagoon. At Bicheno Street, some residential properties lie 0.8m – 0.9m above AHD, and are thus vulnerable to flooding. Elsewhere in Tasmania, the same storm surge event flooded several homes at West Strahan to above floor level, pushed water to the doorsteps of homes at Kingston Beach, covered waterfront reserves in Sandy Bay (including Marieville Esplanade), flooded a house at Old Beach, covered part of the Huonville to Cygnet Road, submerged some Battery Point streets in Hobart, and flooded several basements on Hobart's waterfront (The Mercury, 26 July 1988, p. 1).
Storm surge	1967 and 1970	Flooding in Lauderdale during 1967 and 1970 resulted in properties and buildings on South Terrace and Bayview Road (south side of the canal) being flooded to depths of "over a foot" in some places, and caused local residents to demand that the local government "solve" the problem (The Mercury "Eastside News" 2 November 1967 (p. 4), 29 October 1970 (p. 1), 5 November 1970 (p. 2)).

5.3 Climate change implications

There is a growing understanding of coastal extremes, especially in the face of climate change and sea level rise. Climate change projections were considered by the risk study team when determining the likely consequences arising from a coastal inundation event (Figure 5.3). Data published by Climate Futures for Tasmania[27] suggest that by 2030 a 1% AEP event based on late 20th century conditions will occur around twice to 10 times more often (i.e. between 2% to 10% AEP) if sea level rise follows the upper end of the projected range[29]. By 2090, a 1% AEP event based on late 20th century conditions could become a 20% AEP event and up to several times a year if the high-end projections for sea level rise eventuate. As a proactive response to this, Tasmania has adopted a Sea Level Rise Planning Allowance[27].

Figure 5.3 A) Annually and globally averaged sea level change observed compared to average over the period 1986-2005. B) Future range in sea level rise as projected by IPCC CMIP5 AR5 models.



Source: For more details refer to the IPCC source document[29].

5.4 Current arrangements

The State Emergency Service (SES) provides the main coastal inundation response capability in Tasmania, primarily through its volunteer workforce. This response is delivered in conjunction with local council arrangements.

For coastal inundation, the Department of Primary Industries, Parks, Water and Environment (DPIPWE) is the designated SEMC Advisory Agency under the TEMP. Local councils are inherently responsible for prevention and mitigation activities, guided by state-level frameworks. However, the Department of Police, Fire and Emergency Management (DPFEM)/SES often take a leadership role in respect to coordinating effort in coastal inundation risk mitigation. The arrangements as described in the TEMP are presented in Table 5.2.

Table 5.2 Current arrangements for the emergency management of coastal inundation in Tasmania.

Hazard	SEMC Advisory Agency	Management Authority		
		Prevention and Mitigation	Preparedness	Response
Coastal Inundation	DPIPWE	DPIPWE – Resource Management and Conservation Division	DPFEM	DPFEM

5.5 Worst-case scenario

- The scenario is a hypothetical storm-tide event resulting in a localised temporary sea level anomaly of ~2 m along the northern Tasmanian coast. Key characteristics associated with this reference event are:
  - Most of the northern coastline as well as Flinders Island are significantly affected (as well as parts of Victoria), with additional inundation along the eastern and south-eastern coastlines.
  - There is widespread damage to low-lying areas that are inundated, with some buildings destroyed.
  - Some areas are inaccessible for 12-24 hours.
  - The event occurs during a spring 'king tide' and is associated with moderate to severe storm damage.
  - This event has an Annual Exceedance Probability (AEP) of 1% (1:100 ARI).
  - Following the current projected pathway, this scenario is expected to become sub-annual by 2100.

Workshop participants were presented with additional information relating to the nature of coastal inundation including specifics concerning a storm-tide event versus a storm surge or an unusually high tide, the projected impacts of climate change, and the complex interaction of these events with coastlines.

5.6 Existing controls

The outcomes of the expert review of the coastal inundation controls survey are shown in Table 5.3. In general, behavioural controls were generally considered well developed, with political will, public awareness and education and community engagement all well developed or expedient in implementation. Political will was an interesting control that catalysed much discussion.

Government has a broad awareness of the risk from natural hazards and is seeking to address the consequences in a proportional manner. It should be noted, however, that this is a sensitive area where the action of Government may be percieved to be impacting property rights or the liability to Government.

Areas for improvement include the development of evacuation plans by at-risk households and implementation of the prevention, preparation, response and recovery strategies at a household level. Weather forecasting and warnings systems were identified as well-developed, well-tested, strong and effective controls.

Few physical controls were considered effective, as they are expensive and politically difficult to build and once built are only effective to a finite extent. One physical control that was identified as strong and relatively easy to implement was "keeping drainage channels clear". This is labour intensive with ongoing maintenance, but would help the recession of the inundation, thus limiting the impact.

Table 5.3 Coastal inundation controls (Str. = control strength, Exp. = control expediency).

Coastal Inundation Controls								
Material /Physical	**Str.**	**Exp.**	**Procedural**	**Str.**	**Exp.**	**Behavioural**	**Str.**	**Exp.**
Building codes / Standards	L	L	Coastal erosion / Hazard maps	M	H	Community observations of shoreline shifts	H	H
Sea wall	L	VL	Coastal development limit legislation	-	-	Resident coast shift awareness	H	L
Erosion protection	M	VL	Management plans	VL	VL	Evacuation plans	L	L
Relocation / Buy out	M	L	BoM early warning system	H	H	Household preparation / maintenance	VL	VL
Raised access routes	M	VL	Evacuation plans	L	L	Political will	H	H
Modifying infrastructure	M	L	Statewide coastal policy	M	L	Public awareness	H	H

Coastal Inundation Controls								
Material /Physical	**Str.**	**Exp.**	**Procedural**	**Str.**	**Exp.**	**Behavioural**	**Str.**	**Exp.**
Planning standards	M	VL	Evacuation zones and safe havens	H	H	Public education resources	H	H
Temporary defences	H	M	Coastal inundation mapping	H	H			
Weather forecasting / warnings	H	H	Recovery centres	M	H			
Coastal levees	L	H	Community evacuation plans	L	-			
Keeping drainage lines clear	H	M						
Tide flaps	L	L						
Early warning system	H	H						
Floating infrastructure (future)	M	L						

5.7 Coastal inundation risk analysis

Few of the consequences of coastal inundation were considered greater than 'Major', and the likelihood of this worst case scenario was defined as 1:100 years, or 'Unlikely'. As these events can be predicted with some accuracy with approximately 24-36 hours warning, and they occur gradually (therefore, people can safely evacuate), it was estimated there could be about five deaths ('Major'), mostly due to vehicles attempting to negotiate flooded areas. A similar number of injuries to the base levels experienced in bad weather were expected ('Moderate').

Minimal loss of livestock was expected as farmers would have adequate warning to relocate stock to higher ground. Fixed assets at risk of such hazards, such as low-lying crops, infrastructure (e.g. bridges, roads, buildings) and soils could be substantial, especially within the ports or along coastal roads. There was some disagreement within the groups as to whether the economic impact would be 'Moderate' (<$100 million), 'Major' (<1$ billion) or 'Catastrophic' '(>$1 billion). Ultimately it was agreed the event would be of 'Major' consequence, but with high uncertainty due to a lack of evidence. It was noted that many insurance companies explicitly exclude coastal inundation from their policies, so those households that are impacted would probably have limited support, even if they were insured.

Environmental impacts were focused on ecosystems, with sand dunes and kelp forests most at risk. Sand dunes are constantly undergoing the process of construction and destruction. In areas where this process is not impeded it is expected to continue. However, human development has, in some places, halted this process and, as such, in those regions the sand dunes would not recover, resulting in a 'Major' to 'Catastrophic' impact on environmental value.

Kelp forests again are adapted to such extreme events; however, invasive species (such as sea-urchins) can severely reduce the capacity of a kelp forest to regenerate, ultimately resulting in a transition into a bare rock ecosystem, again resulting in significant loss of environmental value. Such a process is highly speculative but was considered worth mentioning in the risk assessment process.

Public administration was expected to be able to manage this event and continue with day-to-day business, as it was expected to be well within the capabilities of existing staff and infrastructure. Power and water supplies were not expected to be broadly affected, although in some regions all utilities would be disrupted for at least a short period (some possibly for an extended time). Impact on communities was considered minimal, even in those coastal villages / centres that will be completely inundated.

Although not necessarily the case, there was a general belief that these areas predominantly consisted of holiday homes (shacks), with communities linked to nearby towns. Some land may be washed away, resulting in permanent dispersal; however, it was thought residents would choose to move into nearby towns, or invest in a different site, therefore, consequences are limited at a state level. It was mentioned by some of the workshop participants that, in some cases, it would be cheaper to relocate these communities than attempt to protect/rebuild them with physical infrastructure. Culturally significant impacts include the loss of Aboriginal middens along the coast. Some may be lost completely, some partially damaged, but given the number of sites it was not expected to be of high significance at the State level.

5.8 Coastal inundation comparison between 2012 and 2016

Coastal inundation was not considered in TSNDRA 2012. As such, a comparison between 2012 and 2016 was not possible.

5.9 Coastal inundation risk register

The coastal inundation risk register, presented in Appendix B: Risk Register, was created by the project team following the process described in the NERAG 2015.

5.10 Proposed coastal inundation risk treatment options

It is important to note that the proposed risk treatment options, presented in Appendix C: Proposed Treatment Options, have been developed for the purpose of informing further discussion at SEMC/Management Authority level. It is appropriate that these options be reviewed by the management authorities and referred to SEMC for further decision.

Figure 5.4 The risk of coastal inundation to each subsector of society as determined by TSNDRA 2016. The central position is the confidence-weighted-average across working groups for both consequence and likelihood (confidence implied the expertise of the group). The whiskers represent the minimum and maximum ratings across groups.

6 Section Six
Earthquake risk assessment

6 Earthquake risk assessment

	2016	2012
Maximum Risk Level:	High	High*
Maximum Consequence:	Major	Major*
Maximum Likelihood:	Very Rare	Very Rare*
Average Confidence:	High	N/A^

* The 2012 values have been re-calibrated following changes in methodology under NERAG 2015 (see Section 2.1)
^ No average confidence values were provided in TSNDRA 2012

6.1 Context and definition

Earthquakes in Australia are usually caused by movements along fault lines that occur as a result of compression in the Earth's crust[30]. Earthquakes are most common at plate margins. Australia does not sit on a plate margin; however, it remains vulnerable to intra-plate earthquakes. While not as common, major earthquakes with magnitudes of 7.0 or more are known to occur in intra-plate regions. Lower magnitude earthquakes can also have significant impacts, for instance the 5.6 magnitude earthquake that struck Newcastle in 1989 and resulted in the loss of 13 lives.

The significance of an earthquake is generally considered according to its magnitude or size. Magnitude is a measure of the energy released by the earthquake, and is calculated using a measurement of the amplitude of seismic waves recorded on a seismograph and the distance of the seismograph from 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 (30x30) more energy than a magnitude 5.0.

The magnitude of an earthquake is not the only measure of its significance. The impact of an earthquake is usually determined by the level of shaking, or the 'felt intensity' experienced at different distances from the epicentre of the quake. Since the early 20th century, the Modified Mercalli (MM) intensity scale has been used to rate the level of effects felt by people from an earthquake (see Figure 6.1).

While there are several factors that influence the amplitude of shaking felt at a location, the below table depicts the usual relationship between the magnitude of an earthquake and the intensity of it as likely to be experienced by people near its epicentre. The descriptors associated with the MM intensity scale are also shown below (see Figure 6.2). The scale highlights that earthquakes of a magnitude of less than 4.0 are considered unlikely to cause damage.

Figure 6.1 Approximate relationship between Modified Mercalli (MM) and magnitude.

Moment Magnitude	Typical Maximum Modified Mercalli Intensity
1.0 – 3.0	I
3.0 – 3.9	II – III
4.0 – 4.9	IV – V
5.0 – 5.9	VI – VII
6.0 – 6.9	VII – VIII
7.0+	IX or higher

Source: Geoscience Australia[30].

Figure 6.2 Modified Mercalli (MM) intensity scale descriptors used to describe the magnitude of an earthquake.

L. Instrumental	Generally not felt by people unless in favorable conditions.
II. Weak	Felt only by a few people at best, especially on the upper floors of buildings. Delicately suspended objects may swing.
III. Slight	Felt quite noticeably by people indoors, especially on the upper floors of buildings. Many do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration similar to the passing of a truck. Duration estimated.
IV. Moderate	Felt indoors by many people, outdoors by few people during the day. At night, some awaken. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rock noticeably. Dishes and windows rattle alarmingly.
V. Rather Strong	Felt inside by most, may not be felt by some outside in non-favorable conditions. Dishes and windows may break and large bells will ring. Vibrations like large train passing close to house.
VI. Strong	Felt by all; many frightened and run outdoors, walk unsteadily. Windows, dishes, glassware broken' books fall off shelves' some heavy furniture moved or overturned; a few instances of fallen plaster. Damage slight.
VII. Very Strong	Difficult to stand' furniture broken; damage negligible in building of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken. Noticed by people driving motor cars.
VIII. Destructive	Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture moved.
IX. Violent	General panic; damage considerable in specially designed structures, well designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X. Intense	Some well built wooden structures destroyed; most masonry and frame structures destroyed with foundation. Rails bent. Large landslides.
XI. Extreme	Few, if any masonry structures remain standing. Bridges destroyed. Rails bent greatly. Numerous landslides, cracks and deformation of the ground.
XII. Cataclysmic	Total destruction – Everything is destroyed. Lines of sight and level distorted. Objects thrown into the air. The ground moves in waves or ripples. Large amounts of rock move position. Landscape altered, or levelled by several meters. In some cases, even the routes of rivers are changed..

Source: Geoscience Australia[31].

While the scale reflects the expected intensity of an earthquake, it is important to note that small earthquakes can still have an impact.

Earthquakes have not caused significant damage in Tasmania in recent history. There are only a few identified faults in Tasmania. While some faults appear to have been active in recent history, they have not been studied in detail. Several geological studies of the Lake Edgar Fault have been undertaken. This fault is located 80 km west of Hobart and has been shown to have moved at least three times in the last 60,000 years with the last movement around 18,000 years ago, causing earthquakes with a magnitude of around 7.0 on each occasion. A very small earthquake also occurred in that location in 2000.

The current Australian design standard for buildings is based on an earthquake hazard map produced by Geoscience Australia (GA). This map[32] shows Tasmania to have a relatively low exposure to earthquake when compared to other parts of Australia. While instrumentally recorded seismicity is low, there is evidence that Tasmania has previously experienced earthquakes up to 7.0 in magnitude. Records held by Geoscience Australia show 46 Tasmanian earthquakes above magnitude 3.0 since 1900. There have also been earthquakes in the late 19th century that caused building damage in Launceston along with other smaller earthquakes felt in populated areas. Other previous Tasmanian earthquake events are summarised in the next section.

6.2 Previous significant events

The most significant events from a state-level perspective are reproduced in Table 6.1 below.

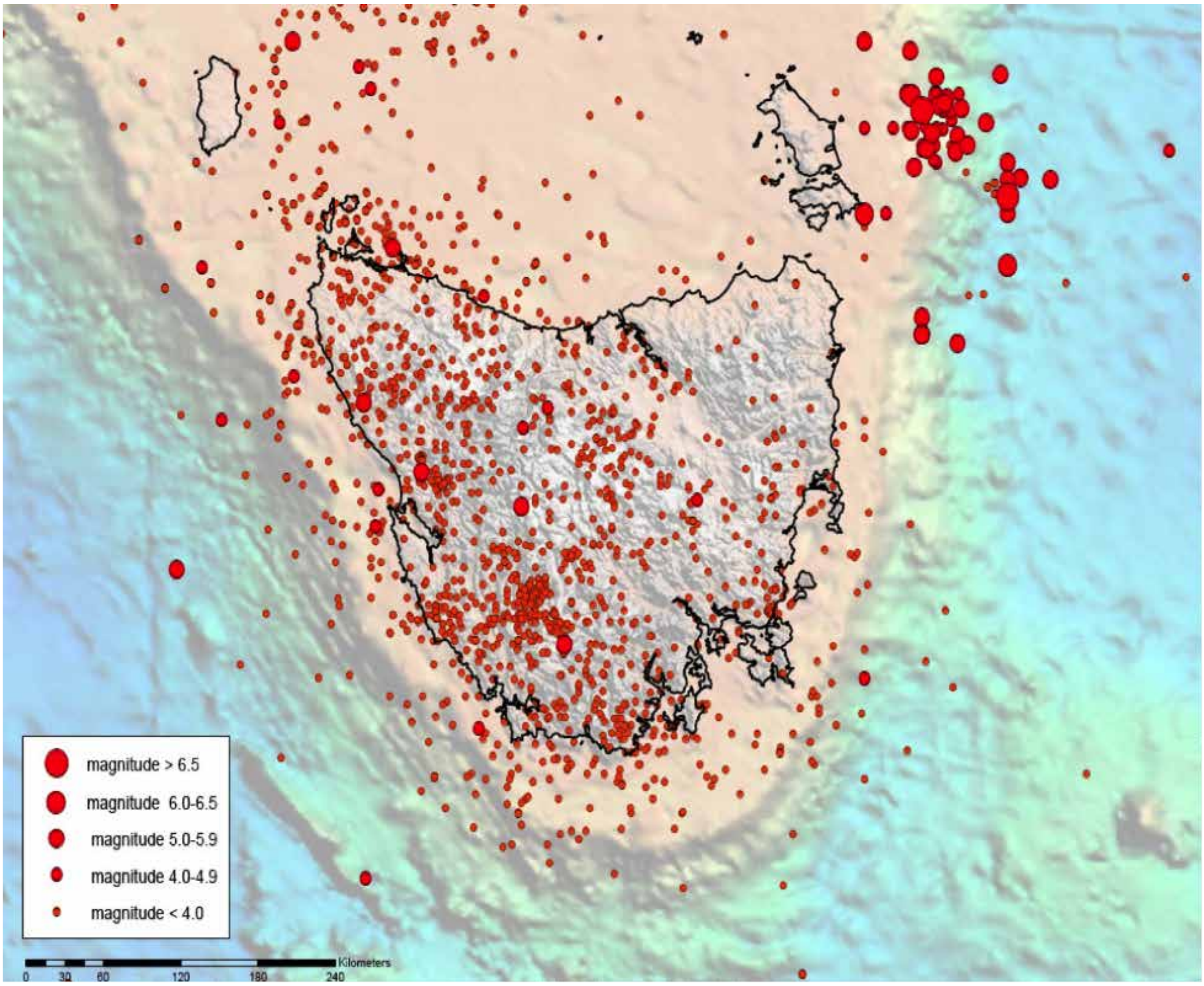
While very few structures are capable of withstanding shaking at an intensity of VIII (MM) or above, older buildings that do not comply with current standards are more susceptible to earthquake damage than newer buildings. Tasmania has a large number of older buildings constructed using unreinforced masonry. Buildings of this type were over-represented in the damage statistics arising from the 1989 Newcastle earthquake[33], and more recently the 2010 Kalgoorlie/Boulder event[34].

The figure below (Figure 6.3) highlights the spread of all historical earthquakes recorded across Tasmania, plotted according to the location of the epicentre of the earthquake and its magnitude.

Table 6.1 Analysis of previous significant earthquake events in Tasmania.

Event	Year	Magnitude	Depth (km)	Impact Summary	Maximum MMI (Felt Intensity)
Mole Creek 2004	2004	4	10	Mole Creek. Felt in other NW towns as well as Hobart.	I-II
Lake Sorell 2002	2002	4.3	10	Lake Sorell. Felt widely in Tasmania.	II-III
Lake Edgar 2000	2000	3.5	12	Small quake recorded at Lake Edgar fault.	N/K
Launceston 1997	1997	4.2	5	Launceston. Felt widely throughout Tasmania.	II-III
East of Flinders Island earthquake	1929	5.0 – 5.6	10	Damage to Launceston Hospital, a church and other houses in that area. Impacts in Hobart – rattling of windows and tremors felt.	V-VI
Earthquake in NE Tasmania	1928	5.4	10	Severe shaking felt at Fingal and Midlands, where articles dislodged from shelves.	IV-V
Earthquake off Port Arthur	1927	4.3	10	Articles on shelves in Port Arthur displaced. Felt in Hobart.	IV-V
West Coast 1924	1924	5.2	0	Magnitude determined from isoseismal map.	V
Queenstown 1908	1908	5	0	Magnitude determined from isoseismal map.	V
Tasman Sea Earthquake Swarm	1883-1892	6.9	N/K	Epicentre of swarm was east of Flinders Island. Buildings damaged in Launceston during 1884.	VI-VII
Lake Edgar (18000 yrs. ago)	N/K	6.8-7.0	N/K	N/K – Last major movement of this fault line.	N/K

Figure 6.3 Historical earthquakes recorded across Tasmania.



Source: Geoscience Australia.

6.3 Climate change implications

Climate Change predictions were considered by the risk study team when determining the likely consequences arising from a major earthquake event. Research has suggested that long-term climate change may lead to an increased risk of earthquake in regions experiencing uplift as overlying ice volume is reduced[35] or as a result of increased tectonic plate motion[36]. However, the scientific evidence supporting any link between rapid climate change and geological movements that induce earthquake in Tasmania was not sufficient for the purposes of influencing any aspect of this risk assessment.

6.4 Current arrangements

Under the Tasmanian Emergency Management Plan, DSG's Mineral Resources Tasmania (MRT) division has responsibility for advice to SEMC, and is the lead management authority in respect to prevention and mitigation. Under current arrangements, see Table 6.2, the SES has responsibility for preparedness activities, and Tasmania Police takes the lead for response to earthquake events.

Table 6.2 Current arrangements for the emergency management of earthquake in Tasmania.

Hazard	SEMC Advisory Agency	Management Authority		
		Prevention and Mitigation	Preparedness	Response
Earthquake	DSG (MRT)	SES	SES	DPFEM

Mitigation of earthquake risk is predominantly served through compliance with building design standards. These standards are informed by the level of exposure to the hazard (refer to earthquake hazard maps mentioned above).

6.5 Worst-case scenario

Although Tasmania has not experienced any previous earthquakes that are considered to have had a significant impact, it is clear that Tasmania has an earthquake risk. Current earthquake research, the existence of known faults and the lessons learned following intra-plate region earthquakes in other parts of the world demonstrates the potential for a major earthquake to impact Tasmanian communities.

For the purpose of assessing state-level risk and based on the available data, the risk study team considered what would be a realistic worst-case scenario for earthquake in Tasmania. Two hypothetical scenarios were identified and subsequently used in the assessment:

- **Scenario #1 – Dam Failure** Key characteristics associated with this reference event are:
  - A complete rupture (earthquake) of the fault situated in SW Tasmania occurs (see below map).
  - This results in an earthquake of magnitude 7.0 or higher at that location.
  - One or more of the major dams at that location fails (piping failure).
  - The assessment considered the impact of shaking expected to be felt by nearby communities, along with the impact of inundation arising from the dam failure.
  - The initiating event is assessed as having an Annual Exceedance Probability (AEP) of 0.004% (1:25,000 years), based on current research.
- **Scenario #2 – City Epicentre** Key characteristics associated with this reference event are:
  - An earthquake occurs close to a major population centre such as Hobart, at a magnitude based on an AEP of 0.04% (1:2,500 years).
  - This return period equates to an earthquake magnitude of 5.5, which has been experienced in Tasmania on three previous occasions in its known history.
  - A level of ground shaking is assumed. Based on the proximity of the hypothetical earthquake to Hobart, the scenario assumes a MM felt intensity of VI is experienced in the city of Hobart.

The workshop participants were provided with additional information relating to the potential distribution and severity of earthquake in Tasmania based on historical records and research. The geographic distribution of earthquake risks as well as the causes of recorded events were discussed in order to frame the overall nature of the hazard.

6.6 Existing controls

The outcomes of the expert review of the earthquake controls survey are shown in Table 6.3. In general, physical and behavioural controls have very low strength and expediency in Tasmania. This was perceived to be due to a general lack of awareness by the public that earthquakes can occur in Tasmania. Relevant organisations (e.g. Hydro Tasmania, the emergency response network) are aware of the risk and have many procedural controls that are generally considered strong and expedient, being well-developed parts of day-to-day protocols. Improving the understanding of the local geological features and the risks they present would benefit the PPRR process.

Table 6.3 Earthquake controls (Str. = control strength, Exp. = control expediency).

Earthquake Controls								
Material / Physical	**Str.**	**Exp.**	**Procedural**	**Str.**	**Exp.**	**Behavioural**	**Str.**	**Exp.**
Pre-1990 building code	VL	VL	Seismic monitoring network	H	H	Household response preparation and awareness	-	-
Post-1990 building code	M	M	Infrastructure maintenance	H	H	Household maintenance	-	-
Structural stability	H	L	Land use planning schemes	H	VL	Media liaison systems	-	-
Assessing hazards	VL	VL	Household / property insurance	M	L	Community warnings	-	-
Eliminating utilities	L	VL	Recovery	L	VL	Community resilience	-	-
Community warnings	VL	VL	Activate SDP	H	H	Targeted awareness programs	-	-
Reconnaissance	-	-	Maintenance of infrastructure	H	H			
Control affected areas	VL	VL	Earthquake hazard maps	VL	VL			
Recovery	VL	H	Fault studies – monitoring	L	L			
Retrofitting of old structures	VL	VL	Emergency management plans	H	H			
Automatic systems / Mechanical shutdowns	M	M	Incident management arrangements	H	H			
			Funding arrangements	H	L			
			Exercise programs	H	M			
			Building standards	H	H			
			Dam safety legislation	H	H			
			National road / bridges specifications	H	H			

6.7 Earthquake risk analysis

The workshop participants divided into two groups, each considering a single scenario. Each group had good confidence in most sectors, agreeing that the controls in place were likely to mitigate most of the more catastrophic risks associated with dam failure, hence the lower likelihood rating (see Figure 6.4). The most devastating impacts of the earthquake scenarios considered were associated with a major dam failure. An earthquake alone was expected to be of minor to moderate impact across all sectors. However, due to high construction standards, dam failure was considered unlikely with an earthquake of the magnitude presented in the scenario.

In the instance of an 'extremely rare' event of dam failure, loss of life was expected to be limited to major (<49 people). The area of impact was considered to be quite constrained, with time available for evacuation. Although earthquake specific community warning systems are not practised in Tasmania, the regular practice of community warning and evacuation associated with bushfire was considered a good analogue. Such an event would have potentially devastating economic impact on industry, and some of these may choose to leave Tasmania, rather than rebuild. The loss of a major dam would probably impact on the state electricity supply, which in turn might result in unrecoverable operational losses for some large industrial operations. Directly affected primary industries (agriculture and aquaculture) and some critical infrastructure (bridges and roads) were expected to take 5-10 years to rebuild or recover, with financial and expert assistance required from the Commonwealth. The economic cost of rebuilding the dam would be $1 billion alone, while all other economic impacts could total around $100 million. Rebuilding of a dam was deemed possible, but likely to be extremely slow and difficult due to the complex environmental and engineering requirements associated with such large projects.

`Environmental experts did not identify a species or region that would be completely lost or destroyed. Some consideration was given to marine reserves in the impact zone, or the Lake Pedder Galaxid; however, it was unknown if either of these would be impacted in any serious way. Culturally, a loss of significant industry would force people to relocate, impacting on the cohesion of those societies, but this would be localised, not statewide. Some historical sites or heritage-listed buildings are at risk of damage or complete destruction. It was deemed unlikely that any major cultural events would be significantly affected (unless timing was coincidental).

Figure 6.4 The risk of earthquake to each subsector of society as determined by TSNDRA 2016. The central position is the confidence-weighted-average across working groups for both consequence and likelihood (confidence implied the expertise of the group). The whiskers represent the minimum and maximum ratings across groups.

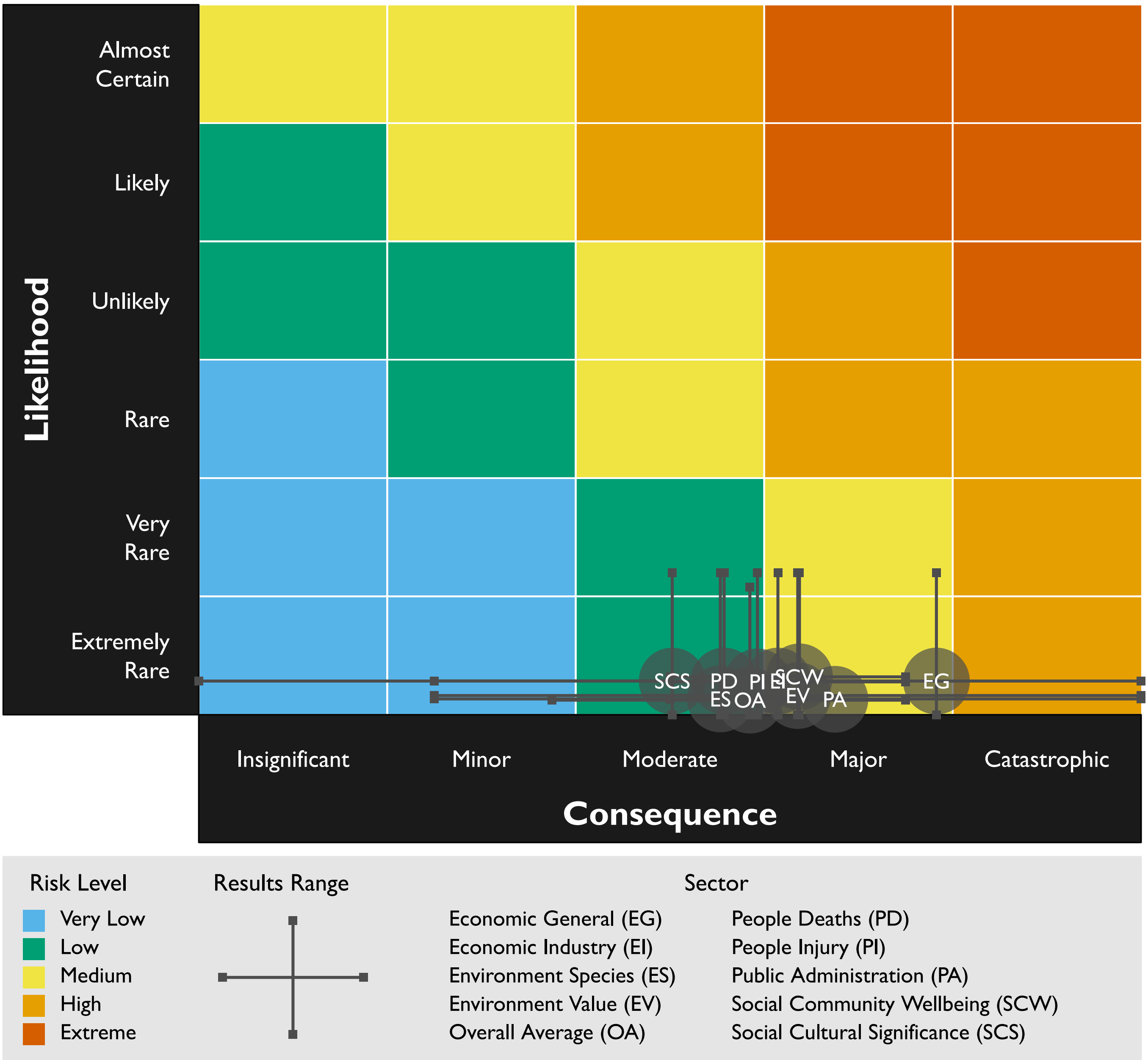


Figure 6.5 The risk of the sub-hazard Earthquake – Dam Failure to each subsector of society as determined by TSNDRA 2016. The central position is the confidence-weighted-average across working groups for both consequence and likelihood (confidence implied the expertise of the group). The whiskers represent the minimum and maximum ratings across groups.

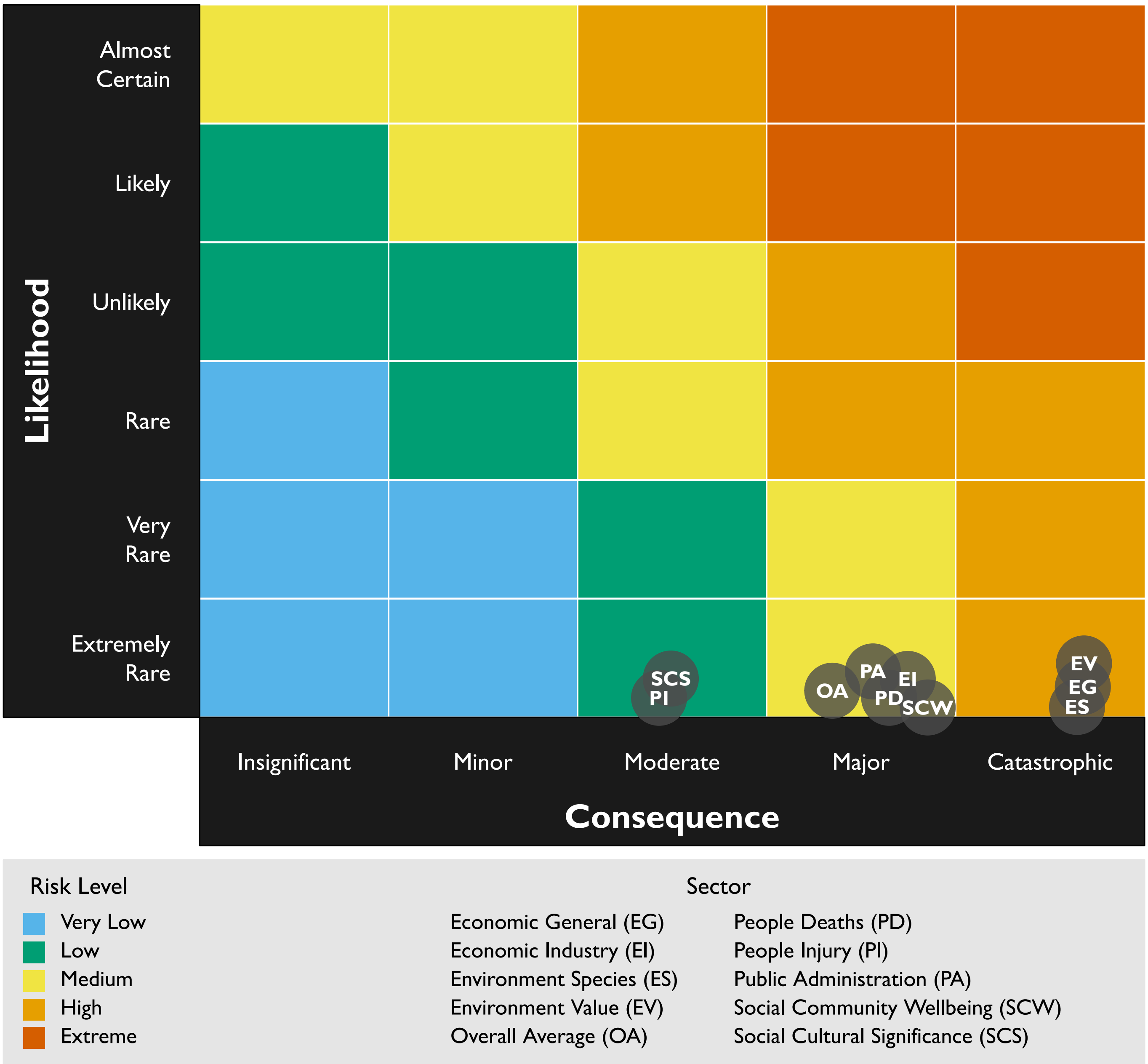
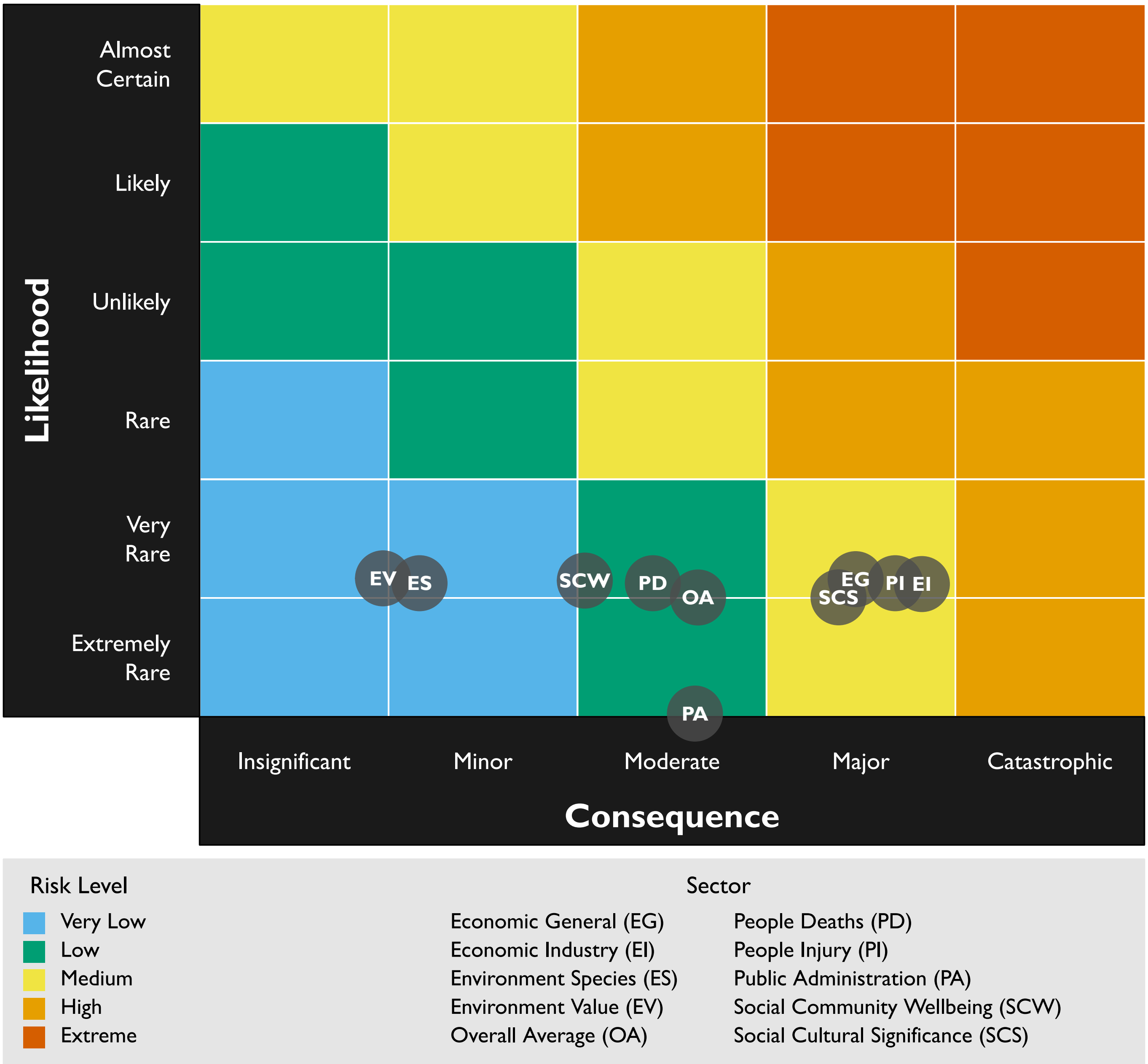


Figure 6.6 The risk of the sub-hazard Earthquake – City Epicentre to each subsector of society as determined by TSNDRA 2016. The central position is the confidence-weighted-average across working groups for both consequence and likelihood (confidence implied the expertise of the group). The whiskers represent the minimum and maximum ratings across groups.



6.8 Earthquake comparison between 2012 and 2016

The change in the risk of earthquake to each sector between TSNDRA 2012 and TSNDRA 2016 is presented in Figure 6.7 and 6.8.

6.8.1 Participants

Following a recommendation from the author of TSNDRA 2012, the TSNDRA 2016 process made a deliberate effort to engage a larger number of experts, with a broader range of expertise than was possible during TSNDRA 2012. This results in some large changes in public administration, which are described below (see Figure 6.7).

6.8.2 General

Earthquake incorporates two distinctly different hazards: Earthquake – City Epicentre; and Earthquake – Dam Failure. These hazards were considered in isolation within TSNDRA 2012 and this approach was repeated in TSNDRA 2016. The likelihood of any earthquake was reduced from 'Rare' to 'Very Rare'. In the instance of 'Earthquake – Dam Failure', the likelihood was reduced even further, to 'Extremely Rare', as experts believed the major dams in Tasmania are engineered to withstand the magnitude of earthquake considered in the scenario.

6.8.3 People

City Epicentre: A risk level of 'Medium' remained unchanged. For the scenario considered, workshop participants expected a large number of structural failures at any location in Tasmania. As a result, more than five deaths were expected, but less than 50 deaths. This is an increase from 'Moderate' in TSNDRA 2012 to 'Major' in TSNDRA 2016. However, the likelihood of such an event was decreased from 'Rare' in TSNDRA 2012 to 'Very Rare' in TSNDRA 2016.

Dam Failure: The risk level decreased from 'Medium' in TSNDRA 2012 to 'Low' in TSNDRA 2016. This decrease is due to a decrease in both consequence (from 'Major' to 'Moderate') and likelihood (from 'Very Rare' to 'Extremely Rare'). Consequences were rated lower, as emergency response for a major dam failure at vulnerable locations around the State had recently been exercised and, given the warning times available, it seemed reasonable that people could be moved out of the danger zone before rapid inundation occurred.

6.8.4 Economic

City Epicentre: The risk level decreased from 'High' in TSNDRA 2012 to 'Medium' in TSNDRA 2016 due to a reduction in the expected likelihood from 'Rare' to 'Very Rare'.

Dam Failure: A risk level of 'Medium' remained unchanged despite a decrease in the expected likelihood from 'Very Rare' to 'Extremely Rare'. There was no change in the expected consequences.

6.8.5 Environment

City Epicentre: A risk level of 'Very Low' remained unchanged. This was due to an increase in expected consequences from 'Insignificant' to 'Minor coupled with a decrease in expected likelihood from 'Rare' to 'Extremely Rare'.

Dam Failure: The risk level increased from 'Low' in TSNDRA 2012 to 'Medium' in TSNDRA 2016. This was due to an increase in expected consequences from 'Moderate' to 'Major', despite a decrease in expected likelihood from 'Very Rare' to 'Extremely Rare', in accordance with the reasons above.

6.8.6 Public administration

City Epicentre: The risk level decreased from 'High' in TSNDRA 2012 to 'Low' in TSNDRA 2016. This was due to a decrease of expected consequences from 'Major' to 'Moderate', where the expectation was that government could continue operations regardless of the impacts. However, the major driver for the decrease in risk is from a very large decrease in likelihood from 'Rare' to 'Very Rare'.

Dam Failure: The risk level decreased from 'Medium' in TSNDRA 2012 to 'Low' in TSNDRA 2016. This is due to a decrease in both expected consequences from 'Major' to 'Moderate' as well as a decrease in likelihood from 'Very Rare' to 'Extremely Rare', in accordance with the reasons above.

6.8.7 Social setting

City Epicentre: A risk level of 'Medium' remained unchanged. This is despite an increase in expected consequences from 'Moderate' to 'Major' as the knowledge is improved on the social impacts of natural disasters. However, as likelihood decreases from 'Rare' to 'Very Rare', the risk level remains the same.

Dam Failure: The risk level decreased from 'Medium' in TSNDRA 2012 to 'Low' in TSNDRA 2016. The expected consequences decreased from 'Major' to 'Moderate' as vulnerable communities are made more aware of the risk, so the level of preparation is improving. The expected likelihood decreased from 'Very Rare' to 'Extremely Rare', in accordance with the reasons above.

6.9 Earthquake risk register

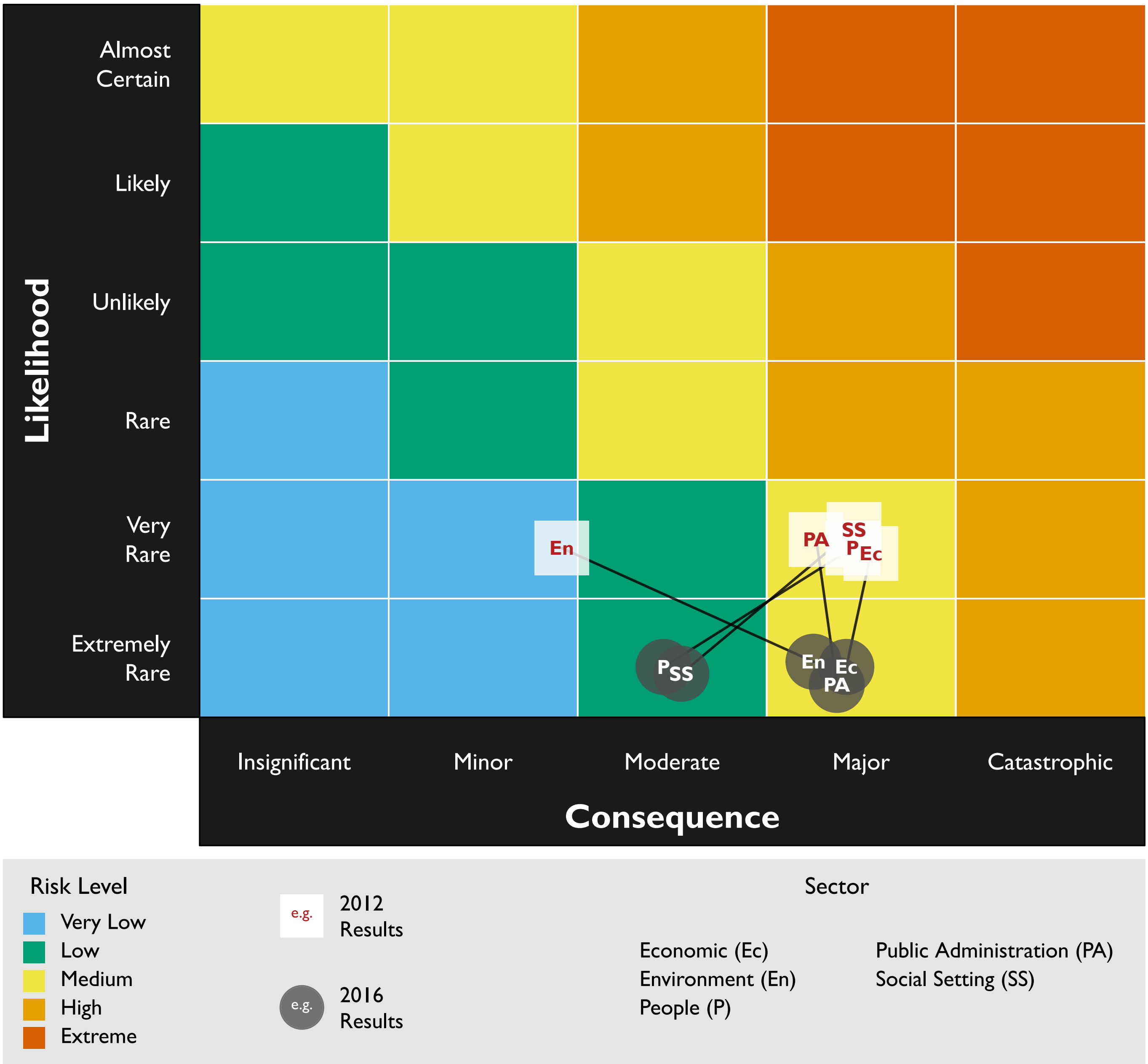
The earthquake risk register, presented in Appendix B: Risk Register, was created by the project team following the process described in the NERAG 2015.

6.10 Earthquake risk treatment options

It is important to note that the proposed risk treatment options, presented in Appendix C: Proposed Treatment Options, have been developed for the purpose of informing further discussion at SEMC/Management Authority level. It is appropriate that these options be reviewed by the management authorities and referred to SEMC for further decision.

Figure 6.7 Change in Earthquake – City Epicentre risk level to each sector of society between TSNDRA 2012 and TSNDRA 2016 as rated by the NERAG process.

Figure 6.8 Change in Earthquake – Dam Failure risk level to each sector of society between TSNDRA 2012 and TSNDRA 2016 as rated by the NERAG process.



7 Section Seven Flood risk assessment

Image: Department of Police, Fire and Emergency Management

7 Flood risk assessment

	2016	2012
Maximum Risk Level:	High	High*
Maximum Consequence:	Catastrophic	Major*
Maximum Likelihood:	Likely	Likely*
Average Confidence:	High	N/A^

* The 2012 values have been re-calibrated following changes in methodology under NERAG 2015 (see Section 2.1)
^ No average confidence values were provided in TSNDRA 2012

7.1 Context and definition

A number of definitions of flooding exist and are used for different purposes. As previously mentioned, the TSNDRA has adopted a definition that enables consideration of flooding risk in general terms, allowing an event-centric assessment from the state-level perspective. In the TSNDRA context, flooding is defined as a general and temporary condition of partial or complete inundation of normally dry land areas from overflow of inland waters from the unusual and rapid accumulation or run-off of surface waters from any source.

Water management in Tasmania is a major activity. Tasmania supports 12% of Australia's freshwater resources in an area of less than 1% of the total Australian land area. The State has an extensive network of rivers and streams with approximately 150,000 kilometres of waterways. The two major river systems in Tasmania are the Derwent and the South Esk. There are many smaller systems, especially in the western region, which flow to the west coast.

The combination of mountainous topography, prevailing westerly winds, and annual storm cycles results in a large variation in rainfall across Tasmania. Splitting Tasmania into three regions of east, west and north gives roughly equal areas but significantly different annual totals and seasonal variations of rainfall. The west receives prolonged heavy rainfall events, especially in winter, associated with a westerly airstream, whereas the north generally receives shorter duration rainfall events in mid to late autumn in moist north-easterly airstreams, commonly associated with cut-off low pressure systems. These cut-off lows can occasionally produce extreme rainfall events in east and south-east Tasmania and into the midlands, but these events are less frequent in the north.

Tasmanian rivers and catchments are subject to flooding following heavy rainfall events, particularly after a period of more than a few days' heavy rain in one area. Individual catchment behaviours are sometimes difficult to predict, with river systems differentially able to cope with heavy rainfall events depending on where precisely the rain falls and the prevailing conditions. Communities downstream of large catchments, particularly those situated on floodplains, are exposed to flooding from time to time.

7.2 Previous significant events

In terms of previous impacts, most communities situated on floodplains around the State have experienced some level of flooding over the past century. It was noted that while the majority of flooding events produce localised minor to moderate impacts, Tasmania has experienced one flood that resulted in catastrophic consequences from the state-level perspective.

The most significant flooding event in Tasmania was the widespread flooding that affected the north-east and parts of the north-west during April 1929[37]. More than 500 mm of rain fell over three days, resulting in flooding to most rivers. Launceston was flooded and approximately 4500 people were temporarily displaced. This flood resulted in 22 deaths.

While many parts of the north were flooded, the most significant impacts were realised in Derby, where the failure of the Briseis Dam resulted in 14 people being killed, and in Gawler, where the driver of a truck tried to cross a flooded bridge and was swept away, killing the truck's eight occupants.

In 2011 there was a series of floods that impacted mostly north-eastern Tasmania during the months of January, March and August. In isolation, each of these floods had only relatively minor impacts, however the cumulative effect of these floods was significant for local communities. The resulting damage to local infrastructure and property from the 2011 floods resulted in several requests for Natural Disaster Relief and Recovery Arrangements (NDRRA) assistance, highlighting the state-level significance of these events.

As stated, the cumulative effect of hazard events that impact an area in a short space of time is difficult to assess as part of the TSNDRA methodology; however, the recent events provided valuable lessons and learnings which were discussed and highlighted during the flood risk assessment. The complete flood history for Tasmania is available from the Bureau of Meteorology website[38], and a summary of some of the most significant events is provided in Table 7.1.

Table 7.1 Analysis of previous significant flood events in Tasmania's history.

Broad Flood Type	Year	Month/Date	Impact Summary
Riverine flooding	1970	Aug	Record flooding occurred in the Mersey and Meander Rivers, with extensive damage at Deloraine. One man, employed by the Hydro, died at Devils Gate Dam after he was washed off a ladder by flood spill. A police officer managed to escape from his car as it was swept down Buttons Creek. Nineteen people were trapped on the back of a truck in water up to their knees for six hours overnight on Railton Rd at Sherwood. A father and son were trapped on the roof of their house in Railton with flood waters up to their feet. In the Latrobe district, 100 people were evacuated from 40 houses by trucks, boats and helicopters.
Riverine flooding	1960	Apr	At Macquarie Plains 12 homes were destroyed.

Broad Flood Type	Year	Month/Date	Impact Summary
Riverine flooding	1929	Apr	Eight lives were lost near Ulverstone when a motor truck plunged into the flooded Gawler River after the approaches to the bridge had been washed away. Considerable portions of the Longford, Inveresk, Invermay and other low-lying parts of Launceston were flooded to a depth upwards of ten feet. Approximately 4,500 people in Launceston were evacuated. The Duck Reach Power Station and Cataract Gorge suspension bridge were washed away.
Dam safety emergencies	2011	Jan	More than 100 farm dams in the north-west were overtopped, some of which were at a high risk of failure. One bridge was washed away.
Dam safety emergencies	1929	Apr	The Bresies Dam disaster claimed 14 lives in Derby.
Dam safety emergencies	1921	Jul	The Serpentine Mine dam failure flooded the main street of Zeehan.
Other	2011	22-27 March	Major flooding occurred in the South Esk River basin. Peak heights in the upper and middle reaches were comparable to the major floods of May 1969 and just slightly below those of April 1929. At Longford major flooding occurred, with the observed peak the third highest level on record after May 1969 and April 1929. The flooding caused significant damage to roads and bridges, and many roads were closed and some towns temporarily isolated.
Other	2011	12-17 January	Major flash flooding and major flooding in the Mersey and Meander Rivers resulted in 100 homes and business being evacuated. The most badly affected areas included St Helens, Scamander, Railton, Penguin, Wynyard, Forth, Gunns Plains and Cooee. Roads, bridges and rail lines were washed away, isolating some families in the north-west for weeks. St Helens was cut off and several sections of the Tasman Highway were destroyed. Tourist attractions such as the Gunns Plains Caves and Wings Wildlife Park were inundated with water and closed for weeks. On 14 January over 50 Railton homes and businesses were damaged by floodwaters.

Broad Flood Type	Year	Month/Date	Impact Summary
Other	2005	October	St Helens, Binalong Bay and Poole were isolated due to road closures and damage to local bridges. A bridge on the Leven River was washed away. There is a report of a car being swept away in the NW, although the two occupants swam to safety.
Other	1944	5-Jul	Floodwaters completely destroyed the Marlborough Highway Bridge over the Ouse River. People were evacuated from their homes in the Mersey River basin.
Other	1885	28-29 November	Many bridges washed away over local rivers around Hobart.
Other	1852	17-24 July	Two lives were lost at Broadmarsh On the South Esk River, the Fingal Bridge was washed away.
Other	1852	11-18 August	Launceston suffered its highest and most destructive flood to date in 1852. Three lives were lost at Avoca (not confirmed) and two lives were lost at Longford.

7.3 Climate change implications

Climate change predictions were considered by the risk study team as part of its assessment of the likely consequences arising from a significant flooding event. Current modelling suggests there will be fewer rainy days across the State but more frequent and intense extreme rainfall events. This is particularly so in the south-west and north-east, but also in the Central Highlands. According to the Climate Futures for Tasmania project[39], these changes are "likely to increase the risk of flooding".

Flood modelling undertaken for catchments of the Mersey River, Forth River, Huon River and Derwent River suggested that climate change was unlikely to have a significant impact on flooding in large catchments that have significant upstream storage capacity. Significant changes are predicted for flood levels in smaller flood-prone catchments that do not have significant upstream storages. More frequent and intense rainfall events may also increase the risk of flash flooding. These predicted changes were taken into account as part of the TSNDRA assessment of flooding.

7.4 Current arrangements

The State Emergency Service (SES) provides the main flood response capability in Tasmania, primarily through its volunteer workforce. This response is delivered in conjunction with local council arrangements.

For riverine flooding, the SES is the designated SEMC Advisory Agency under the TEMP, and DPIPWE holds the responsibility for flooding of dams. Local councils are responsible for prevention and mitigation activities, including risk assessments, while SES often take a leadership role in respect to coordinating effort in flood risk mitigation. The arrangements to manage the PPRR for flood in Tasmania is presented in Table 7.2.

Table 7.2 Current arrangements for the emergency management of flooding in Tasmania.

Hazard	SEMC Advisory Agency	Management Authority		
		Prevention and Mitigation	Preparedness	Response
Flood (Dams)	DPIPWE	DPIPWE	DPIPWE	TASPOL (assisted by the dam owner)
Flood (Rivers)	SES	Councils	SES	SES

7.5 Worst-case scenario

With consideration to historical flooding events, climate change implications and current arrangements, a realistic worst-case scenario was designed for use in the flooding risk assessment workshops. The scenario was designed in consultation with SES, DPIPWE and the Bureau of Meteorology and was later validated by the risk study team. The scenario used for the assessment was described as follows:

- The flooding scenario to be considered is based on the most significant flooding event in Tasmania's history – the Floods of 3-7 April 1929. Key characteristics associated with this reference event are:
  - A low pressure weather system(s) moves over Tasmania bringing moisture from the tropics and producing intense heavy rainfall in a short period of time.
  - The rainfall continues for more than three days, and results in major flooding of multiple catchment areas across the State.
  - The riverine flooding impacts more than one township, and has the potential to breach existing levee systems.
  - The flooding also leads to at least one dam failure in a catchment. This failure produces a flash flood that inundates at least one downstream community.

- Localised flash flooding is also present in more than one area.
- Multiple residential dwellings and businesses are inundated.

The scenario was designed to ensure that all relevant preventative, preparatory, response and recovery controls would come into play, while retaining the characteristics of a realistic feasible flooding event.

7.6 Existing controls

Flood hazard had a large number of controls identified, as shown in Table 7.3. Although a number of material/physical controls were seen as being particularly strong, the classification of both control strength and expedience as medium or low suggests that a number of treatments could be implemented to further reduce the likelihood of severe consequences resulting from this hazard scenario.

Physical flood controls were observed to be highly fragmented in a statewide context, with many operated, maintained and owned by private landholders. The difficulty in establishing permanent levee systems reflected this. Such systems need to acquire land, often in rural areas surrounding townships. Dams were also noted to serve a dual purpose during time of flood even though their role is not flood mitigation. This conflict of interest may lead to complex and expert-driven operation for flood defence. Other mechanisms such as detention basins were seen as effective in less significant flooding scenarios, but in the case of the scenario considered would have little impact. High costs were also noted in many of the hard infrastructure options (stormwater drainage, raised access routes, etc.).

Floodplain modelling and mapping was seen to be both a limitation and a key research question. The current state of such mapping was described as "haphazard", of mixed geographic coverage and age, and without a standardised approach or methodology. Challenges in releasing such maps for broader use due to perceived insurance, land valuation and planning concerns were a compounding constraint noted by both groups.

There was an observed weakness in the strength of planning schemes, as shown in Table 7.3. The upward integration of these datasets into a wider risk management framework was also noted as an opportunity that could fall under the wider remit of the Disaster Resilient Australia agenda.

Although rainfall/river gauges were seen as a critical control, with knock-on effects on forecasting and warning systems, funding cutbacks were noted as limiting the ability to monitor stream flow. The situation is further complicated by distributed ownership and maintenance falling across departments, utilities and local councils. Centralisation of this dataset under one agency was flagged as a potential opportunity to strengthen this control.

Spatial variation in local knowledge – particular in new subdivision areas – was noted to lead to a lack of knowledge of floodplain areas, exposure, and consequently household awareness. In contrast, local councils were noted as relying on the knowledge of long-established farming communities in mapping and responding to flood areas. In both instances, potential treatments could focus on better taking account of (and educating about) local flood conditions.

The Launceston Flood Management Act 2015[40] is the new act, providing a range of new functions and powers to the Regional Controller, Launceston City Council, and LFA.

Table 7.3 List of controls currently active to mitigate flood risks or consequences (Str. = control strength, Exp. = control expediency).

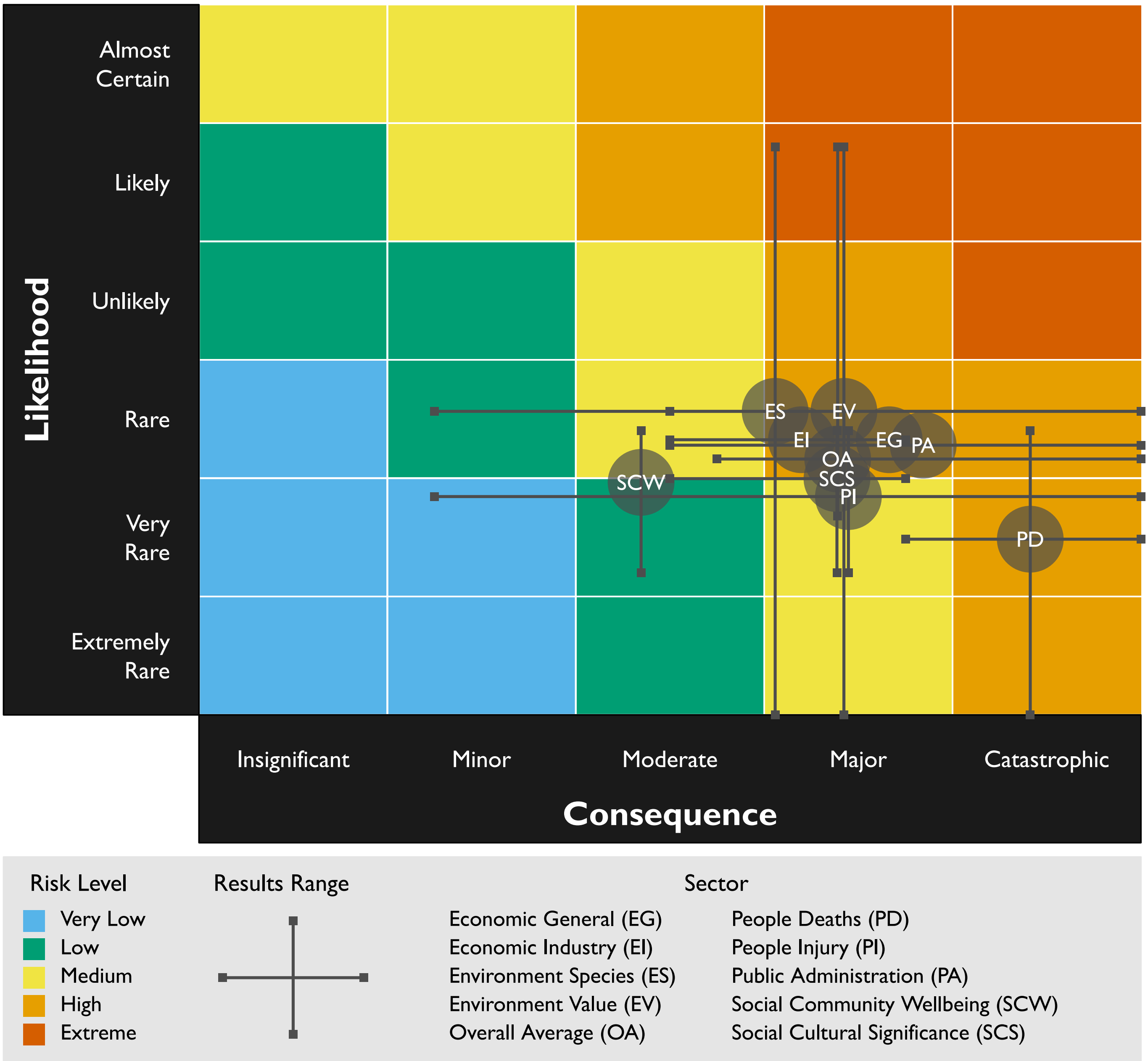
Flood Controls								
Material / Physical	**Str.**	**Exp.**	**Procedural**	**Str.**	**Exp.**	**Behavioural**	**Str.**	**Exp.**
Permanent levee systems	M	L	Dam maintenance and audit programs	M	M	Community awareness programs	M	L
Raised access routes	H	L	Floodplain models and mapping	L	L	Household preparedness	M	L
Sandbag stockpiles	L	VL	Flood response plans	M	L	Local knowledge of floodplains	M	L
Building code	H	L	Water Management Act	L	L	Community resilience	M	M
Total flood warning system	H	H	Response capability	H	M	Targeted awareness programs	H	L
Land use and building controls	H	L	Recovery arrangements	H	M	Floodplain behaviour awareness	H	L
Dams	VL	VL	Floodplain studies	M	M	Warning / alert access	M	L
Detention basins	L	VL	Community flood response plans	L	M	Media liaison arrangements	M	L
Diversions	H	L	Plans / Dam Safety Act	M	M	Response advice	H	M
Flood barriers	H	M	Flood risk management framework	L	L	Recovery advice	M	L
Investment in infrastructure	H	L	Rainfall / Flood forecasting	M	M	Community awareness of info sites	M	L
Alternative access routes / roads	H	L	Weather warnings and broadcasts	M	M	Awareness of clean-up procedures	L	L
Vessels (SAR)	VL	VL	Planning schemes	VL	L	Emergency response training	H	H

Flood Controls								
Material / Physical	**Str.**	**Exp.**	**Procedural**	**Str.**	**Exp.**	**Behavioural**	**Str.**	**Exp.**
Evacuation centres	H	H	Rainfall / river gauges	M	H	Personnel interagency networks	H	H
Recovery centres	H	H	Interagency coordination	M	H			
Portable levee systems	H	M	NDRP funding arrangements	M	M			
Utility zoning (re: flood zones)	H	H	Rapid impact / damage assessments	M	H			
Clearance / cleaning of creeks	H	L	NDRRA program	M	M			
			Flood insurance	L	L			
			Levee gate systems	L	L			
			Levee maintenance / audit	L	VL			
			Flood evacuation plans	M	M			

7.7 Flood risk analysis

A summary of the assessed risk of flooding by sector is shown in Figure 7.1. Confidence in assessments of a worst-case scenario varied significantly with sector. Some detailed studies provided firm evidence for both consequence and likelihood in the people category, while environmental impacts were viewed as being largely unknown. Studies specific to Trevallyn Dam, for example, indicate multiple fatalities being likely following a dam failure, putting this impact firmly in the 'Catastrophic' category, with the waterfront taking less than 20 minutes to travel to Launceston thus making preventative controls extremely challenging. A second group, however, dropped their classification to 'Moderate', with significant disagreement within the group (and limited awareness of the study cited above). Scotts Peak Dam failure was thought to have a similar result, although in both cases these eventualities were viewed as being 'Very Rare' (with an Annual Exceedance Probability of less than 1%) which is a limiting factor in this assessment. In the case of a non-dam failure event, the view that human behaviour would lead to a loss of life regardless of controls was noted to lead to a higher likelihood for less severe consequences (such as 1-2 deaths from drownings due to a car driving into flood water).

Figure 7.1 The risk of flood to each subsector of society. The central position is the confidence-weighted-average across working groups for both consequence and likelihood (confidence implied the expertise of the group). The whiskers represent the minimum and maximum ratings across groups.



Worst-case economic consequences were similarly severe, falling into the 'Major' category due to damage to roads, houses, Queen Victoria Museum and other infrastructure in central Launceston. Damage to the aquaculture industry was estimated to fall in the $100 million range on its own, with the cumulative impacts across all industries not considered to total greater than $1 billion. This level of impact was considered to be rare, with an increasing exposure as asset volumes increase over time not able to be accounted for through the NERAG 2015 processes. It was also considered that little that could be done in terms of controls to protect potentially affected industries (agriculture and aquaculture).

Most species were thought to be well adapted to flooding; however, the knock-on effect of human development reducing species strength was seen to potentially lead to already endangered species being wiped out. As a result, confidence in the 'Moderate' classification of worst-case environmental impacts was 'Low'. Sediment impact on marine communities, in particular, was cited as an area for future research. There were instances of specific species that were susceptible to extinction from flood hazards. However, it was recognised that these did not have to be a worst-case scenario – almost any flood would be enough. It was the view of DPIPWE experts these species are in grave danger of extinction.

Public administration impacts were assessed as 'Catastrophic', 'Major' and 'Moderate' by the three groups, each with a high level of confidence. Limited local expertise in flooding and dam-failure recovery was viewed as stretching resources, as well as the requirements for large-scale infrastructure rebuilding that might result from a worst-case event.

It was suggested that there have been incidents of farmers not returning to the land following significant floods, although these reports remain unsubstantiated. Culturally significant events and the potential loss of the Queen Victoria Museum and Gallery, however, resulted in 'Moderate' and 'Major' worst-case cultural consequences, but these were viewed as being very specific flood conditions, with a likelihood classification of 'Rare' as a result.

7.8 Flood – differences between 2012 and 2016

The change in the risk of flood to each sector between TSNDRA 2012 and TSNDRA 2016 is presented in Figure 7.2.

7.8.1 Participants

Following a recommendation from the author of TSNDRA 2012, the TSNDRA 2016 process made a deliberate effort to engage a larger number of experts, with a broader range of expertise than was possible during the TSNDRA 2012 process. This results in some large changes in the economic and social setting sectors.

7.8.2 General

The likelihood of the scenario considered was reduced across all the sectors from 'Unlikely' in TSNDRA 2012 to 'Rare' (and in one case to 'Very Rare') in TSNDRA 2016. This is primarily due to the statewide scope of the assessment, the 'worst-case' nature of the scenario required and the localised nature of typical flood events. It was recognised smaller more frequent, localised events could result in significant consequences but, given the statewide nature of the assessment, these level events fell outside of the project scope and were recommended more appropriate for regional or municipality level assessments.

A comparison of the results from TSNDRA 2012 and TSNDRA 2016 risk assessment is presented in Figure 7.2.

7.8.3 People

The risk of flood to people remained unchanged at 'Medium'. In TSNDRA 2016 experts agreed the scenario considered would result in 'Major' consequences (>5 deaths), which is an increase from 'Moderate' (<5 deaths) in TSNDRA 2012. This increase is largely due to the expected impact of this scenario on the greater Launceston region, with many households inundated. Participants considered more than five unavoidable deaths, but less than 50, a reasonable assessment due to a general improvement in emergency broadcast systems and public awareness since 1929, despite the increase in the number of people vulnerable to this hazard. The largest consequences were associated with cascading dam failure. The likelihood of such an event was expected to decrease substantially, changing from 'Unlikely' in TSNDRA 2012 to 'Very Rare' in TSNDRA 2016. DPIPWE are currently undertaking a statewide analysis of this risk.

7.8.4 Economic

The risk of flood on the economy remained unchanged at 'High'. Consequences remained 'Major', but likelihood was reduced from 'Unlikely' in TSNDRA 2012 to 'Rare' in TSNDRA 2016. This change had no impact on the overall risk rating.

7.8.5 Environment

The risk of flood on the environment saw a dramatic shift from 'Low' in TSNDRA 2012 to 'High' in TSNDRA 2016. This change is attributed to an increase in expected consequences from 'Insignificant/Low' in TSNDRA 2012 to 'Major' in TSNDRA 2016. This large change is due to engaged experts from DPIPWE who could identify species at risk of local and global extinction from flood event hazards at numerous sites around Tasmania.

7.8.6 Public administration

The risk of flood on public administration increased from 'Medium' in TSNDRA 2012 to 'High' in TSNDRA 2016. This change was due to an increase in consequence, despite a decrease in likelihood. Expected consequences increased from 'Moderate' to 'Major' as recent work informed the impact such a scenario would have on fresh drinking water supplies. Although this was tempered by a decrease in likelihood from 'Unlikely' to 'Rare', the overall risk still increased.

7.8.7 Social setting

The risk of flood on social setting decreased from 'High' in TSNDRA 2012 to 'Medium' in TSNDRA 2016 due to a decrease in both consequence and likelihood. Expected consequences were decreased from 'Major' to 'Moderate'. The scenario was not expected to force the permanent relocation of people away from a community or significantly disrupt any culturally significant events for more than a single season/year. Likelihood was decreased from 'Unlikely' to 'Rare', due to the required scale for the scope of this assessment.

Figure 7.2 Change in flood risk level between TSNDRA 2012 and TSNDRA 2016 as rated by the NERAG process.

7.9 Flood risk register

The flood risk register, presented in Appendix B: Risk Register, was created by the project team following the process described in the NERAG 2015.

7.10 Proposed flood risk treatment options

It is important to note that the proposed risk treatment options, presented in Appendix C: Proposed Treatment Options, have been developed for the purpose of informing further discussion at SEMC/Management Authority level. It is appropriate that these options be reviewed by the management authorities and referred to SEMC for further decision.

8 Section Eight
Heatwave risk assessment

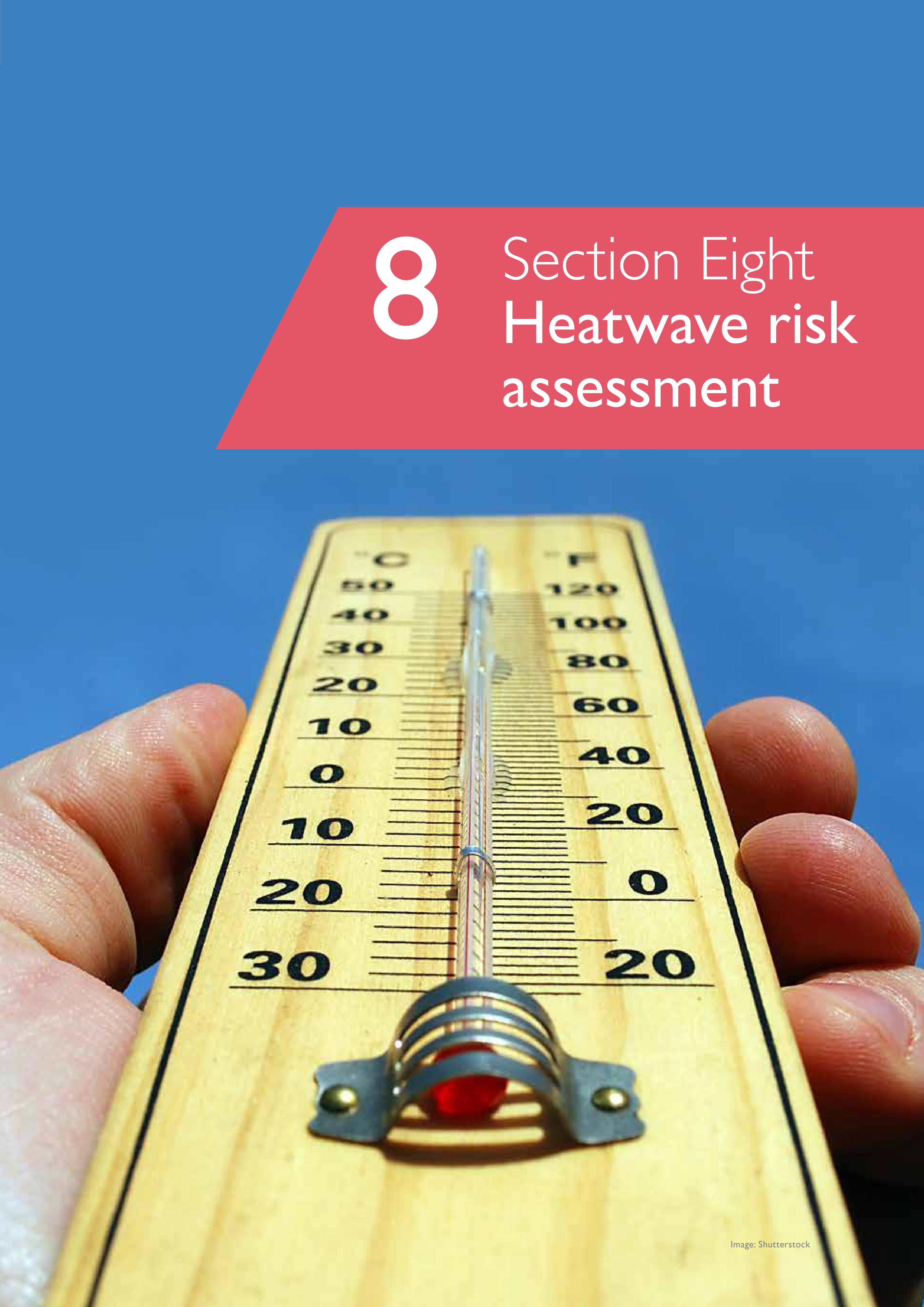


Image: Shutterstock

8 Heatwave risk assessment

	2016	2012
Maximum Risk Level:	Extreme	N/A*
Maximum Consequence:	Major	N/A*
Maximum Likelihood:	Likely	N/A*
Average Confidence:	High	N/A*

* Heatwave was not assessed in TSNDRA 2012

8.1 Context and definition

Heatwaves were not considered in TSNDRA 2012. Their exclusion from TSNDRA 2012 was due to a combination of factors including limited awareness of the exposure/danger of heatwave in Tasmania and limited data on the impacts of historical events available within the Tasmanian context. Of relevant significance, heatwave has only been included as a hazard in the TEMP since 2015 in Issue Eight. Heatwaves, until recently, also lacked a consistent definition in the broader Australian context, with the Bureau of Meteorology (BoM) only developing a clear definition of a heatwave using the Excess Heat Factor (EHF) index in 2013[13]. The EHF takes into account local variability, night-time and day-time temperatures, and the adaptation of individuals and infrastructure to heat over time.

It is now recognised that the physiological impacts of extreme heat have killed more Australians than all other natural disasters combined over the last century[9]. Night-time temperatures are a critical factor in these mortality rates, with higher temperatures preventing recovery from the impacts of heat stress on core body temperatures and function. The impact of heatwaves also varies with both demographics and existing physical conditions: those most at risk are the very young, elderly, lower socio-economic groups, those who work outside, and those who have existing illnesses[41].

Analysis of extreme heat data subsequent to TSNDRA 2012 has also demonstrated some of the additional impacts of heatwaves on institutional capacity and key controls such as emergency response units. As shown in Table 8.1, extreme heat events in Hobart in the summers of 2011-12 and 2012-13 resulted in a 25-30% spike in ambulance call-outs, putting strain on the ambulance service.

Heatwaves are caused by a combination of factors, including large-scale climate variability, antecedent soil moisture, persistent high-pressure systems and localised effects such as hard surfaces, evapotranspiration rates and topography. Climate records show an increase in heatwave frequency and intensity in Australia, with the annual number of heatwave days observed in Hobart having increased from 4 to 5 over the last half-century, and the average peak day intensity rising by 1.7 °C[42 43]. This increase in the likelihood of heatwave events occurring in Tasmania provides additional justification for the inclusion of heatwave hazard in TSNDRA 2016, beyond the improving availability of data cited above.

Table 8.1 Ambulance call-outs during extreme heat events in Hobart. Source: Campbell 2015[44].

HOBART	Average daily ambulance call outs *(n)*		Extreme heat event	
Summer period	Non-heatwave periods	Heatwave periods	Start date	End date
08–09	51.43	–	–	–
09–10	56.02	–	–	–
10–11	56.00	–	–	–
11–12	60.69	81.00	25/02/2012	26/02/2012
12–13	60.97	72.50	3/01/2013	4/01/2013
13–14	63.89	–	–	–
14–15	66.78	–	–	–
Average	**59.40**	**76.75**		

8.2 Previous significant events

A thorough investigation to identify historical heatwaves in Tasmania has not been conducted, although preliminary studies have been completed for some locations. These are presented in Table 8.2. The most recent extreme heatwave event in Tasmania, which occurred over the 34 January 2013, was responsible for a significant increase in presentations and call-outs within the medical sector, resulting in high workloads. This event is described in the worst-case scenario below.

Table 8.2 Previous events of heatwave in targeted locations around Tasmania[45].

Location	Days in Historical Record	Number of Extreme Heatwaves (EHF > 2T)	Extreme Heatwaves Per Year
Hobart	34,907	43	0.45
Bushy Park	18,836	32	0.62
Launceston	27,146	48	0.65
Burnie	17,739	27	0.56
Swansea	20,661	35	0.62
Strahan	4,348	11	0.92

8.3 Climate change implications

The Climate Futures for Tasmania project found that for most regions of Tasmania under the high A2 emissions scenario, the number of summer days warmer than 25 °C is projected to double or triple, relative to the recent past[46 47]. Some areas of Tasmania will see an expansion of the 'summer season' by 40 additional days per year by the end of the 21st century. The largest increases in extreme temperatures are projected to occur in the spring and autumn months, with increases of greater than 4.0 °C. This increase is substantially greater than the projected mean temperature change. The greater temperature changes in these seasons imply an extension of the summer season, with heatwaves occurring more frequently. For example, the number of heatwaves at Launceston is projected to increase progressively throughout the century, occurring on average twice per year by the end of the century, approximately four times more frequently than currently experienced.

8.4 Current arrangements

Under the TEMP, the DHHS Public Health Services is the designated SEMC Advisory Agency, as well as the Management Authority for prevention and mitigation, preparedness and response. Accordingly, DHHS assumes overarching management responsibility, and takes a leadership role in developing and coordinating PPRR arrangements for heatwaves.

Due to the recent inclusion of heatwave into the TEMP, formal incident management arrangements are in the early years for the State; however, collaboration between key stakeholders is emergent. The arrangements for heatwaves are detailed in the State Special Emergency Management Plan: *Tasmanian Public Health Emergencies Management Plan 2014* under the TEMP, along with the *Heatwave Incident Associate Plan 2014*. A key aspect of this hazard management is that it is recognised heatwave is highly likely to co-occur with bushfire, and as such, responding organisations should consider surge capacity to ensure preparedness and planning are robust and functional.

Table 8.3 Current arrangements for the emergency management of heatwave in Tasmania.

Hazard	SEMC Advisory Agency	Management Authority		
		Prevention and Mitigation	Preparedness	Response
Heat stress related mortality and morbidity	DHHS	DHHS	DHHS	DHHS

8.5 Worst-case scenario

The scenario developed for use in TSNDRA 2016 is detailed below. An event similar to the scenario presented occurred in the period immediately following the release of TSNDRA 2012, with a number of heat-related records being broken. It is also of note that although the scenario that occurred in 2013 was in parallel with the severe bushfire events commonly known as the Dunalley Bushfires, the NERAG 2015 structure does not allow for the consideration of cascading consequences from multiple hazards. Similarly, severe storm, flooding and landslide impacts can have compounding consequences if occurring simultaneously.

- The scenario is based on the most recent significant heatwave event, which occurred over 3-4 January 2013 (the week of the Dunalley Bushfires). Key characteristics associated with this event are:
    - Temperatures in the east, south-east and Derwent Valley districts rise into the mid-30s on Day 1 and into the low 40s on Day 2 as a high pressure system over the Tasman Sea combined with an approaching low pressure trough and cold front directing a very hot northerly airflow over Tasmania.
    - Hobart and several other centres in the south-east record the warmest temperature on record.
    - Minimum temperatures are also quite warm in the south-east on Day 2 with temperatures not dropping below 20 degrees Celsius between 9 am on Day 1 and 9 am on Day 2.
    - Record temperatures in Tasmania are part of a heatwave that affects much of Australia.
    - There is a significant increase in heat-stress related emergency illness and death.
    - Severe to Catastrophic fire danger protocols are in effect.
    - Given the time of year, a high number of tourists (Tasmanian, interstate and international travellers) are distributed throughout Tasmania, often in heat-exposed and remote areas.
    - A major outdoor multi-day festival is being held (such as the *Taste of Tasmania*, or the *Marion Bay Falls Festival*).

8.6 Existing controls

Table 8.4 shows the controls identified for heatwaves through the controls survey and refined through the workshop process. Due to the lack of previously-identified controls, and the general lack of procedures relating to extreme heat, the number of controls associated with this hazard is relatively limited.

Table 8.4 Heatwave controls (Str. = control strength, Exp. = control expediency).

Heatwave Controls								
Material/Physical	**Str.**	**Exp.**	**Procedural**	**Str.**	**Exp.**	**Behavioural**	**Str.**	**Exp.**
Emergency response resources (e.g. ambulance units)	M	M	Community alerts	H	H	Community knowledge of heat behaviour	M	L
TasNetworks control operations	H	M	Emergency management plans	M	M	Workplace knowledge of heat behaviour	M	L
Public cool spaces	L	VL	Training for responders	H	M	Media awareness / liaison	M	L
Medical Priority Dispatch System (MPDS) protocol	M	L	Effective response plan	M	M	Tourist knowledge of heat behaviour	M	VL
A/C power availability	H	H	Forecasting and alerts for EMS	H	H	Community education programs	L	VL
Extreme heat equipment standards	M	M	Research and understanding	H	M	Personnel knowledge of assets	H	H
Public health resources	M	M	Exercises to test arrangements	H	VL	Operating assets to avoid fail	H	H
Emergency hospital planning	M	M	Media engagement protocols	M	M	Training for responders	H	H
Public advice (radio / website)	M	H	Interoperability and support	M	M	Agreements with bus services	H	H
Drinking water availability	H	M	Heat-stress response plans	M	L			
Access to swimming areas	H	L	Heat-alert systems	H	H			
			Heat procedures for asset operations	H	H			
			Asset heat-threshold monitoring	H	M			
			Asset auto-detection systems	H	H			
			Contact with vulnerable people	H	VL			
			Manual load shedding	H	M			

In general, the utilities sector was a key strength in terms of hazard response. The physical infrastructure, existing procedures and personnel training were all in place for managing extreme heat conditions. A number of these controls were automated, reducing the dependency on personal knowledge or human error. Many of these processes had been adopted following the bushfires across south-eastern Australia during the severe 2009 extreme heat event. The interaction with extreme wind and bushfire, however, was flagged as being more problematic, with the intersection of these three hazards seen as presenting different problems to the network than when assessed individually. Failure of the electricity network was also noted to have critical knock-on effects in terms of household cooling through fans and air-conditioning, with network damage being both a direct consequence resulting from the hazard, and a crucial control factor. Access to drinking water was also seen as a strength.

A number of control weaknesses were associated with the lack of public awareness of the risks associated with extreme heat: a result of limited historical exposure, the lack of clear definition mentioned above, and the lack of 'visibility' of extreme heat events. One example flagged was that Tasmania does not have an embedded cultural behaviour of going to shopping centres and publicly accessible cool spaces during a heatwave. Beaches, however, were seen as a key 'cool space' resource during extreme heat given the lower ocean temperatures, although proximity is obviously an important factor for accessibility. However, this behaviour in itself is a public health risk given the increased risk of severe sunburn.

Public health systems as a whole were central to many of the controls, with a medium level of strength and expedience observed in most categories identified. Good emergency response procedures for vulnerable groups were noted to be in place through St John Ambulance Services and the Australian Red Cross (well developed/ integrated in other jurisdictions, although not necessarily a regular protocol in Tasmania).

Opportunities were identified to exist through the appropriation of existing response and emergency management frameworks (for instance, community alert systems used for fire and flooding). The ability for BoM to forecast extreme heat with increasing accuracy in advance of heatwave events was also seen as a potential opportunity for future collaboration around warning systems and pre-event mitigation (for instance, through increased resourcing, early warning systems, or identification of cool spaces in built-up areas). There was also an awareness that, given the State's cool-climate reputation, many tourists and short-term visitors do not expect – and are therefore not prepared for – extreme heat. Collaboration with tourism operators and event managers can also reduce visitor exposure.

8.7 Heatwave risk analysis

The most severe consequences that participants thought possible as a result from the worst-case heatwave scenario described above were associated with death, injury and/or illness, as shown in Figure 8.1. However, the lack of local evidence on the basis of the 2013 event meant that this assessment was largely anecdotal and would ideally be supported by further research. Groups were highly confident in greater than five deaths ('Major') attributed to heatwaves at least every 10 years (likely); however, catastrophic consequences were discussed at length, with a conservative approach agreed given the lack of evidence. One group was, however, only moderately confident in a similar categorisation of human impacts in the injury/illness category.

Other sectoral consequences were assessed as varying significantly (with the localised loss of crops – particularly stone and berry fruit seen to be highly exposed depending on the time of year) with flow-on impacts through occupational health and safety issues associated with field hands and outdoor workers. The general economic impact was considered to be greater than $100 million, while long-term damage to critical industry or commercial sectors was viewed as limited, with an ability to bounce back in subsequent seasons without the need for any structural change.

Environmental consequences were classified as likely to be 'Minor' and up to 'Moderate', with most ecosystems adapted to temporary heat effects. However, the participants identified the 'Moderate' evidence as anecdotal with a general absence of research in the field, which was flagged by the participants as an area for improvement. Further research was thought to be needed with regard to specific nationally or locally significant species present in some of the cooler climate areas. It was noted that climatic shifts which affect overall ecology throughout the year were to be considered separately from sub-seasonal extreme heat.

Community wellbeing was thought to be difficult to assess, particularly given the varied impacts of heat on community members, with some questions as to whether communities within the State (for instance, sub-groups such as mental health patients, or the elderly) would register in a statewide assessment. Better engagement with elderly community members was also seen by some as a potential positive impact during a heatwave event if promoted and managed effectively.

There was little variation between the likelihood of the heatwave occurring (once every 2-5 years) and sectoral consequence, with all falling within the 'likely' category (a 1-10% Annual Exceedance Probability) (see Figure 8.1).

8.8 Heatwave comparison between 2012 and 2016

Heatwaves were not considered in TSNDRA 2012. As such, a comparison between 2012 and 2016 was not possible.

8.9 Heatwave risk register

The heatwave risk register, presented in Appendix B: Risk Register, was created by the project teamfollowing the process described in the NERAG 2015.

8.10 Proposed heatwave risk treatment options

It is important to note that the proposed risk treatment options, presented in Appendix C: Proposed Treatment Options, have been developed for the purpose of informing further discussion at SEMC/Management Authority level. It is appropriate that these options be reviewed by the management authorities and referred to SEMC for further decision.

Figure 8.1 The risk of heatwave to each subsector of society as determined by TSNDRA 2016. The central position is the confidence-weighted-average across working groups for both consequence and likelihood (confidence implied the expertise of the group). The whiskers represent the minimum and maximum ratings across groups.

9 Section Nine
Landslide risk assessment

Image: Department of State Growth

9 Landslide risk assessment

	2016	2012
Maximum Risk Level:	High	High*
Maximum Consequence:	Catastrophic	Major*
Maximum Likelihood:	Almost Certain	Likely*
Average Confidence:	Highest	N/A^

* The 2012 values have been re-calibrated following changes in methodology under NERAG 2015 (see Section 2.1)
^ No average confidence values were provided in TSNDRA 2012

9.1 Context and definition

Landslide is generally defined as the movement of earth, rock or debris down a slope, and can also be referred to as 'slope failure'. While it is acknowledged that many landslide events can involve a combination of failure modes (complex, or transitional slope failures), landslide research tends to recognise five distinct types of landslide that present a hazard or risk to communities. The five main types are: Slides (Shallow and Deep-Seated); Flows (Debris and Earth); Falls (Rock, Earth, Debris); Topples; Spreads.

Slides involve movement of material along recognisable shear surfaces or zones and are usually considered within two categories – shallow and deep-seated. Shallow slides are more common than deep-seated and more frequently associated with property damage. Larger deep-seated slides are more easily recognised and are generally slow-moving with impacts realised over a longer term. Both types of slide are known to occur in populated and settled areas across Tasmania.

Flows refer to the movement of earth or debris in a fluid motion and are generally associated with heavy rainfall. An initial shallow slide can develop into a rapid flow if there is excess water on the ground. A debris flow occurs when rocks and other debris mix with water and flow down a slope until it meets some type of barrier or the slope flattens out.

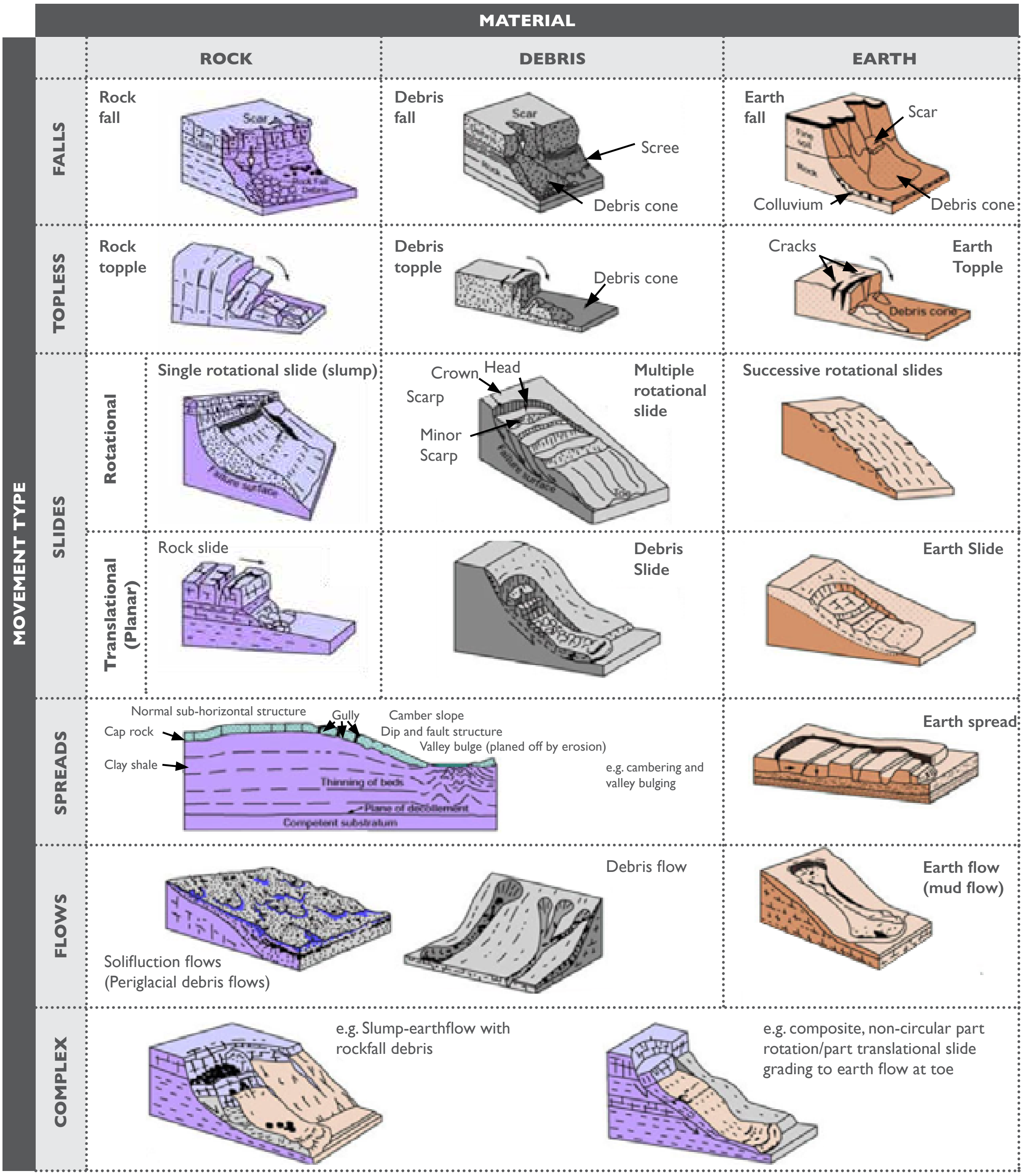
Falls and topples involve a detachment and rapid movement of earth from a steep slope, are short in duration but can cause significant damage to anything located downslope of the earth movement location. Large rockfalls can sometimes produce an avalanche. The precise impact of a fall or topple will depend on what happens to be in that location at the time of the event. These sorts of events generally present risk on steep slopes and cliffs, which are prevalent across the Tasmanian landscape.

A spread refers to a slope failure or displacement of earth on a relatively flat or level area of land. Spreads can occur anywhere across Tasmania but have been noticeable in several areas of the north-west landscape. Spreads are typically very slow moving and so can present a risk to property but not necessarily to human life.

Where a slope failure event involves either a combination of types or transition from one landslide type to another, it is referred to as a complex or transitional landslide event. An example is the 1872 event in Humphrey's Rivulet, Glenorchy, where it is believed an initial debris flow created a debris dam in the rivulet, which then burst and created a flash flood comprising water, earth and debris.

Figure 9.1 depicts the basic approach to categorising landslides and is consistent with the way landslides are identified within Tasmania.

Figure 9.1 Landslide categorisation.



Source: British Geological Survey[48].

9.2 Previous significant events

The most significant events from a state-level perspective are reproduced in Table 9.1. It should be noted that the statewide total known landslide damage is included as a single event (1950-present) to illustrate the overall impact of landslide from a state perspective. Other landslide events are then discussed individually for contextual purposes.

Mineral Resources Tasmania (MRT), a division of the Department of State Growth, has evidence of over 150 buildings in Tasmania that have been damaged or destroyed by landslide since the 1950s. As shown in Table 9.1, this includes 125 residential premises, with the majority of the damage recorded in the areas of Lawrence Vale (Launceston), Beauty Point and Taroona. Limitations in the reporting and recording process for landslide damage suggest the figures are probably higher. In addition to building damage, it is acknowledged that damage to infrastructure has occurred throughout Tasmania over many years[49].

The only significant sudden impact event that was identified during the analysis of previous events was the Humphrey's Rivulet debris flow that occurred in Glenorchy in 1872. The other landslides referred to in the table are deep-seated, slow-moving landslides that caused damage to property over a long period of time. They are listed here mainly for contextual purposes and to inform discussion around the nature of landslide hazard in Tasmania.

It was noted that over the years there have been many rockfall, debris flow and other slope failure events that have occurred around the State; however, these events are generally low impact and tend to be managed and resolved within the capacity of local resources.

9.3 Climate change implications

Climate change predictions were considered by the project team when determining the likely consequences arising from a major landslide event. Data published by the Climate Futures for Tasmania project[25] were used to inform the study. Current predictions suggest a rise in mean sea level, combined with a drier, warmer climate, but with more frequent heavy rainfall events[24].

Sea level rise has the potential to cause coastal erosion and instability which could lead to an increased risk of landslide in vulnerable areas. Any change to rainfall patterns is likely to influence the frequency and severity of landslide hazards and, while a drier climate has the potential of reducing the likelihood of landslide activity, an increase in the frequency and intensity of heavy rainfall events may lead to a greater chance of debris flow and other slope failures. Research also suggests that shallow slides may be more likely in a warmer, drier climate scenario, particularly in areas with shallow slopes of reactive clay soils[33].

Table 9.1 Analysis of previous significant landslide events in Tasmania.

Event	Date	Buildings Destroyed, Demolished or Damaged	People Injured
Landslide Damage (State Total)	1950-Present	Total of 150 buildings damaged, including 125 houses, 76 of which have been destroyed or demolished.	Nil
Humphreys Rivulet Debris Flow Event	1872	Several houses and farms destroyed or damaged. Bridges damaged. Many buildings and properties inundated, likely due to debris dam failure.	Nil
Lawrence Vale Landslide Area	1950-Present	43 houses destroyed, demolished or removed due to extensive damage.	Nil
Beauty Point Landslides	1950-Present	15 houses and a police station destroyed/ demolished. 13 houses damaged and a further 15 moved. Streets and roads requiring repair.	Nil
Taroona Landslides	1950-Present	10 houses damaged, 1 demolished. Damage to school and local infrastructure.	Nil

9.4 Current arrangements

Department of State Growth's MRT division has primary responsibility for management of landslide and other geological hazards from a state research and policy development perspective. It is worth noting that this capability is relatively unique in that few other jurisdictions in Australia maintain a landslide hazard advice, mapping and awareness capability. Most other jurisdictions choose to outsource specific tasks as required.

Under the TEMP, Department of State Growth is the designated SEMC Advisory Agency for landslide with MRT specifically responsible for prevention and mitigation. Local council has responsibility for landslide preparedness predominantly as a result of its role in land-use planning and development approval. It is noted that landslide risk in Tasmania is generally mitigated through controls associated with land use and development. The plan outlines the responsibilities, presented in Table 9.2.

Table 9.2 Current arrangements for the emergency management of landslide in Tasmania.

Hazard	SEMC Advisory Agency	Management Authority		
		Prevention and Mitigation	Preparedness	Response
Landslide	DSG (MRT)	DSG (MRT)	Councils	TASPOL

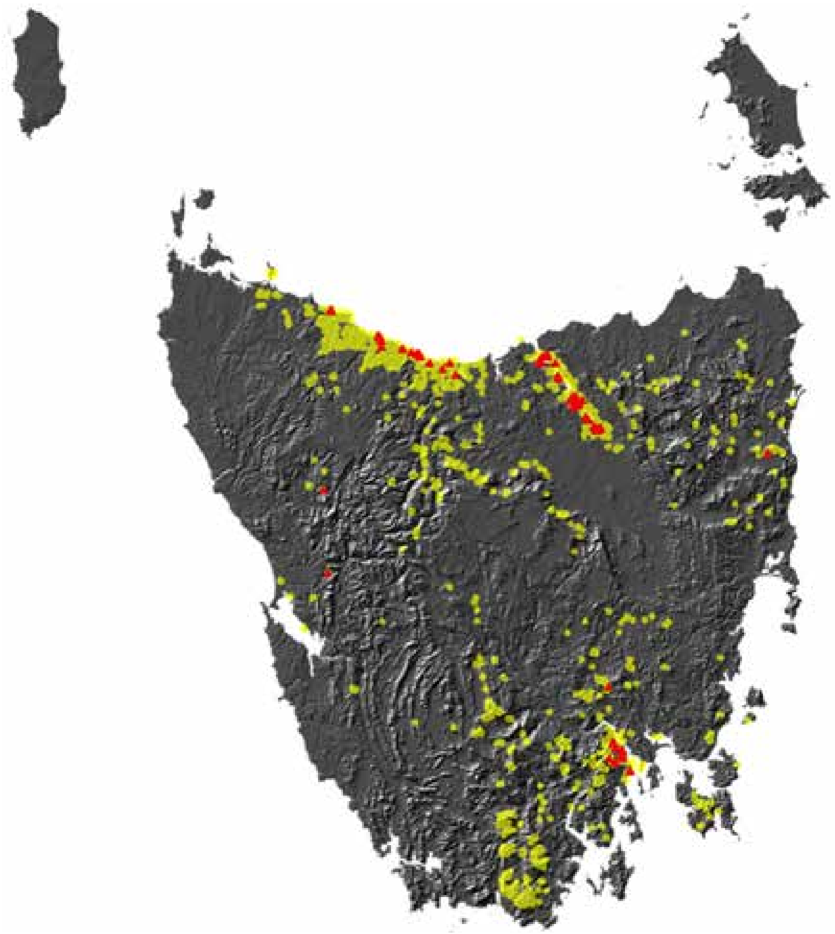
MRT continues to undertake research into areas of Tasmania known to have experienced landslides or considered potentially susceptible to slope failure based on its geology. Over the years MRT has produced a suite of documents designed to help understand and articulate landslide hazard, particularly focused on informing decisions relating to the use, development and zoning of land. This includes the Tasmanian Landslide Map Series (see Figure 9.2) which comprises a landslide inventory, information maps and advisory maps that are used to inform site assessments and the development of planning schemes.

The MRT landslide database categorises landslides according to whether they are recent or active, which means they are known to have moved or are moving at present, or where there is evidence of slope failure but no known evidence of recent movement (Activity Unknown).

This information is used to identify areas of land with known or potential instability, or 'landslide zones', of which there are three main types in Tasmania:

- Proclaimed (Declared) Landslip A and B areas – areas proclaimed under the authority of the *Mineral Resources Development Act 1995*, designed to restrict use of unstable land
- Zones on advisory maps – including susceptibility mapping products
- Known landslides – including the landslide inventory maps, as illustrated in the below table (note the red points denote where damage was actually caused).

Figure 9.2 Landslides events across Tasmania. Yellow points are records of known landslides. Red points are records of known landslide damage to buildings and infrastructure (at least 125 houses)[49]. Approximately 2,700 landslide occurrences are stored in the MRT landslides database (as of April 2013); in reality many more will not have been reported or mapped.



9.5 Worst-case scenario

With consideration to historical landslide events, potential climate change implications and Tasmania's current emergency management arrangements, the TSNDRA 2016 workshop participants considered and validated three scenarios considered realistic worst-case events.

- **Scenario #1 – Debris Flow** A significant debris flow event impacting on a downstream community. The scenario was based on a historical event, the 1872 Humphrey's Rivulet Debris Flow that impacted the Glenorchy area. Key characteristics associated with this reference event are:
  - Initiated by an Annual Exceedance Probability (AEP) of 1% (1:100 ARI) rainfall event (~110-200 mm of rain), a debris flow of ~100,000 m^3 follows a rivulet through a heavily developed and populated area on the slopes of Mt Wellington.

  - Triggers are primarily heavy and intense rainfall, compounded by the presence of debris in the watercourse.

- **Scenario #2 – Deep-Seated Landslide** A sudden slide within a significant community development. The scenario considered feasible is for a 5-10 m deep failure of a section of land, with sudden overnight slide of approximately 30-40 m. Key characteristics associated with this reference event are:
  - In this scenario it is considered approximately 4-5 residential properties would be destroyed or significantly damaged.
  - For the purpose of the assessment, the example used was the steep escarpments in the Parklands suburb of Burnie, a landslide-prone area in which there are several properties at risk.

- **Scenario #3 – Rockfall** The scenario considered feasible is a sudden rockfall above a roadway causing a fully-occupied vehicle to crash, either from rocks and debris directly striking the vehicle or as a consequence of the rocks and debris blocking the roadway. Key characteristics associated with this reference event are:
  - Rockfalls are generally triggered by heavy and intense rainfall events, but can be compounded by fires or other activities that reduce vegetation/cover on the landscape.
  - Vulnerable areas considered as part of the scenario discussion include: St Marys Pass; sections of the Lyell & Murchison Highway on the west coast; and any of Tasmania's roads that have been cut into or through the hillside. Such areas are prevalent throughout Tasmania given the terrain.
  - The trigger event considered was an AEP 10% (1:10 ARI) equivalent rainfall event.

Workshop participants were presented with additional information relating to the potential distribution and severity of landslide in Tasmania based on historical records and recent research. This included recent work by Mineral Resources Tasmania concerning the risk of debris flows, especially around Mt Wellington. This helped to frame the scope of the landslide and focus the areas to consider in assessing the risks.

9.6 Existing controls

The outcomes of the breakout-group review of the landslide controls survey are shown in Table 9.3. It was noted by all groups that there was some difficulty assessing the strength of many of the controls from a 'whole-of-state' perspective given the local nature of landslide hazard.

Physical controls were seen to be relatively high impact. Land-use planning, weather observations, knowledge of landslide zones and regular monitoring of those known zones were generally considered effective controls. Limited efficacy was believed to be gained by plantations / reforestation and catch fences. These are easy to erect and prevent some smaller rockfalls, but they are ineffective for larger events.

Landslide risk maps are readily available and often used, for example during the building approvals process. Arrangements to respond to a natural hazard event are well developed in general; however, landslide specific response is not regularly drilled and could be improved. There is also room for improvement in the Tasmanian building code, education of regulators and development of regular monitoring (which is currently inconsistent). There is currently very limited capacity to insure against landslide risks, but this would need to be addressed through legislation.

Community awareness is very low, with limited general knowledge of the risks presented by landslide in Tasmania, or how a household could aim to prevent, prepare, respond or recover from the event.

9.7 Landslide risk analysis

During the risk analysis activity, participants were divided into three groups, with each focusing on one of the three scenarios. Participants assessing the debris flow scenario estimated 50-60 deaths in the Glenorchy area due to the rapid onset and limited capacity to provide warning to exposed people, as shown in Figure 9.3. Economic impacts were quite localised but devastating, thereby increasing their impact.

Participants assessing deep-seated landslide suggested the scope of impact would be quite localised, but could impact on 20-30 people (4-5 households). Deaths seemed unlikely as there are often warning signs with these kinds of landslides and those at the highest risk in Tasmania have been informed of their situation. The scenario terminology of a 'deep-seated' landslide was challenged as the participants felt it more important to define the 'volume' and 'speed-of-onset' of an event rather than its broader characterisation; both shallow and deep landslides can be equally devastating. It was recommended the scenario description be adjusted to reflect this in the final report.

Participants assessing rockfall quickly determined that it did not fall within the significance of a statewide risk and recommended this should not be considered in this or future statewide risk assessments. The scenario described dictated the level of human injury at <5 people, so a moderate impact. This seemed too high to the participants, but fits within the classification system. No economic impacts were expected.

Economic impacts were seen to be minimal, even in the case of a road closure as this would only be quite temporary (1-7 days) with alternative routes available in most cases. In all considered scenarios, consequences were considered either insignificant or minor for environmental, public administration or social sectors of Tasmania due to the localised nature of any one event. For example, of the 12-20 species that are known to occupy only a single site, none are within a suspected landslide zone. The minor and moderate level risks associated with rockfall and broad-rapid onset landslide offset the potentially devastating effects of a debris flow.

Table 9.3 Landslide controls (Str. = control strength, Exp. = control expediency).

Landslide Controls								
Material / Physical	**Str.**	**Exp.**	**Procedural**	**Str.**	**Exp.**	**Behavioural**	**Str.**	**Exp.**
Building codes / standards	M	M	Mapping	H	H	Community awareness programs	L	M
Stabilisation plantations	L	VL	Land-use planning schemes	M	M	Preparedness / maintenance	VL	L
Stabilisation mechanisms	H	L	Arrangements and response	H	H	Knowledge of hazard	L	M
Catch fences / barriers	L	H	Household / property insurance	VL	VL	Community resilience	VL	VL
Drainage control	M	L	Planning controls	H	H	Targeted awareness programs	VL	VL
Land use planning	H	H	Known landslide monitoring	L	L			
Weather observations	H	H	Education of regulators	M	L			
Monitoring / landslide gauges	H	H	Building Act (TAS)	M	M			
			Maintenance of infrastructure	M	L			
			Site-specific risk assessments	H	H			
			Emergency management plans	M	M			
			Landslip zones management	L	L			
			Incident management arrangements	H	H			
			Funding arrangements	H	H			
			Exercise programs	VL	VL			

Figure 9.3 The overall risk of landslide (across all sub-hazards) to each subsector of society as determined by TSNDRA 2016. The central position is the confidence-weighted-average across working groups for both consequence and likelihood (confidence implied the expertise of the group). The whiskers represent the minimum and maximum ratings across groups.

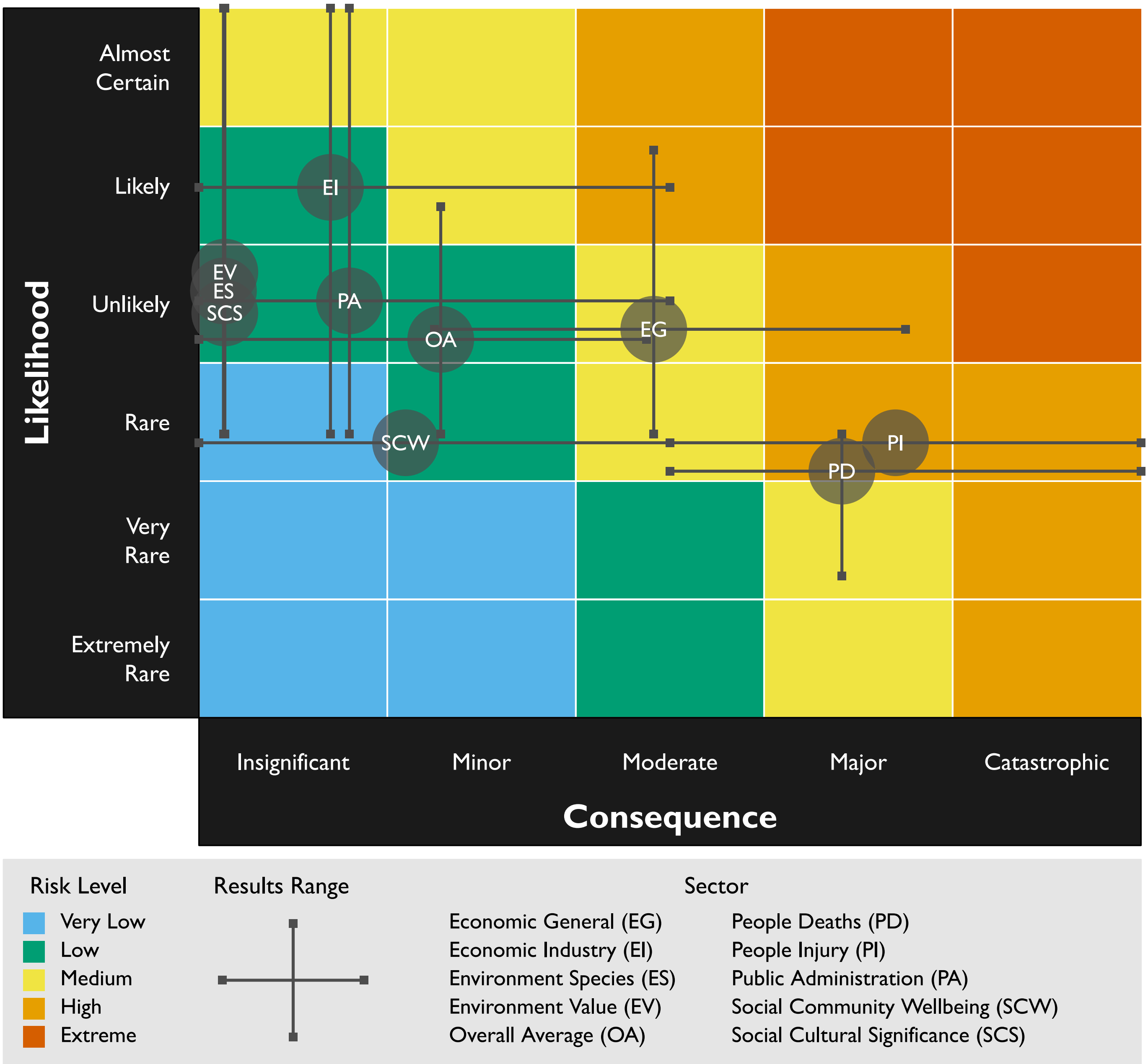


Figure 9.4 The risk of Landslide – Debris Flow to each subsector of society as determined by TSNDRA 2016. The central position is the confidence-weighted-average across working groups for both consequence and likelihood (confidence implied the expertise of the group). The whiskers represent the minimum and maximum ratings across groups.

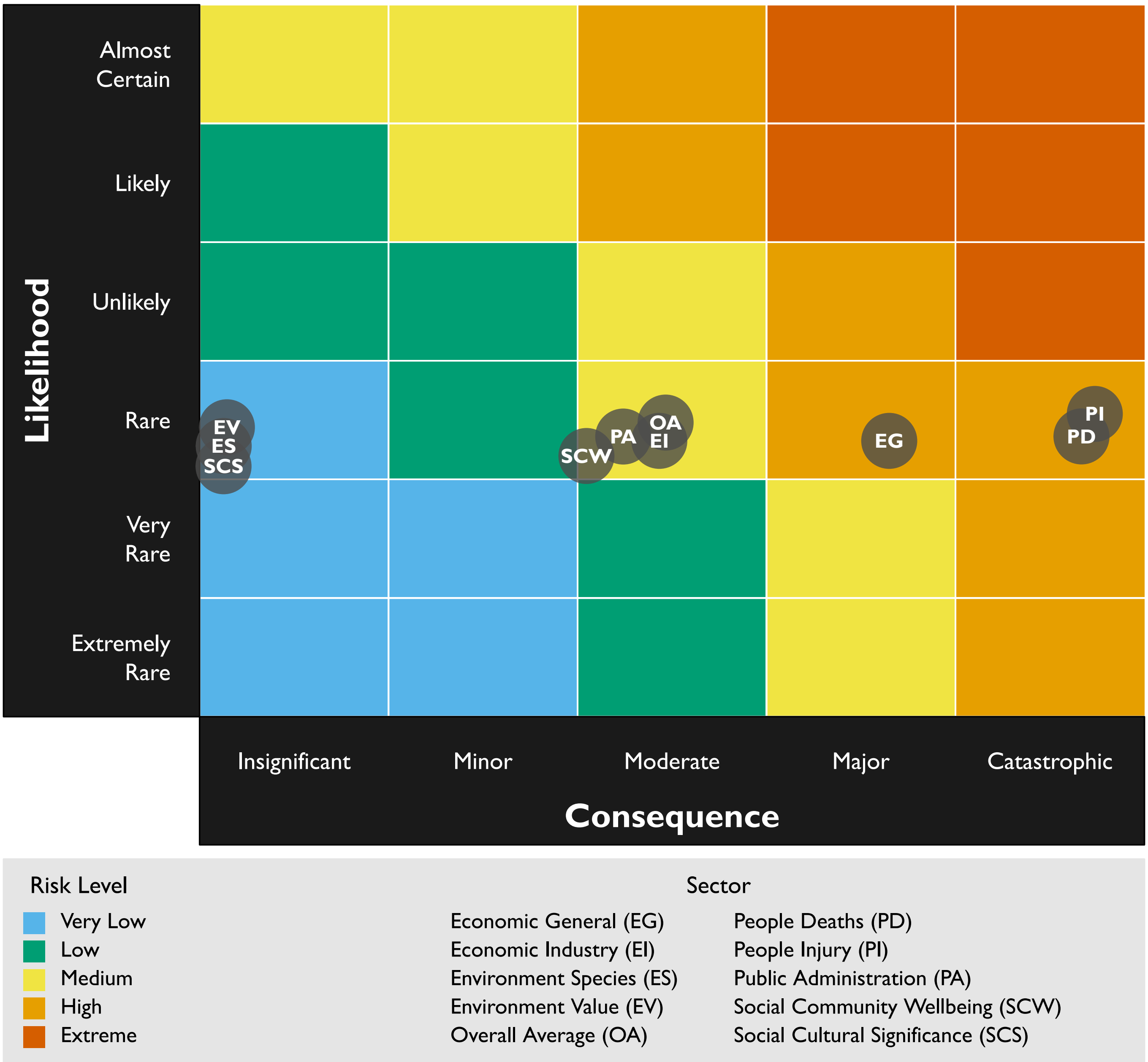


Figure 9.5 The risk of Landslide – Deep-Seated to each subsector of society as determined by TSNDRA 2016. The central position is the confidence-weighted-average across working groups for both consequence and likelihood (confidence implied the expertise of the group). The whiskers represent the minimum and maximum ratings across groups.

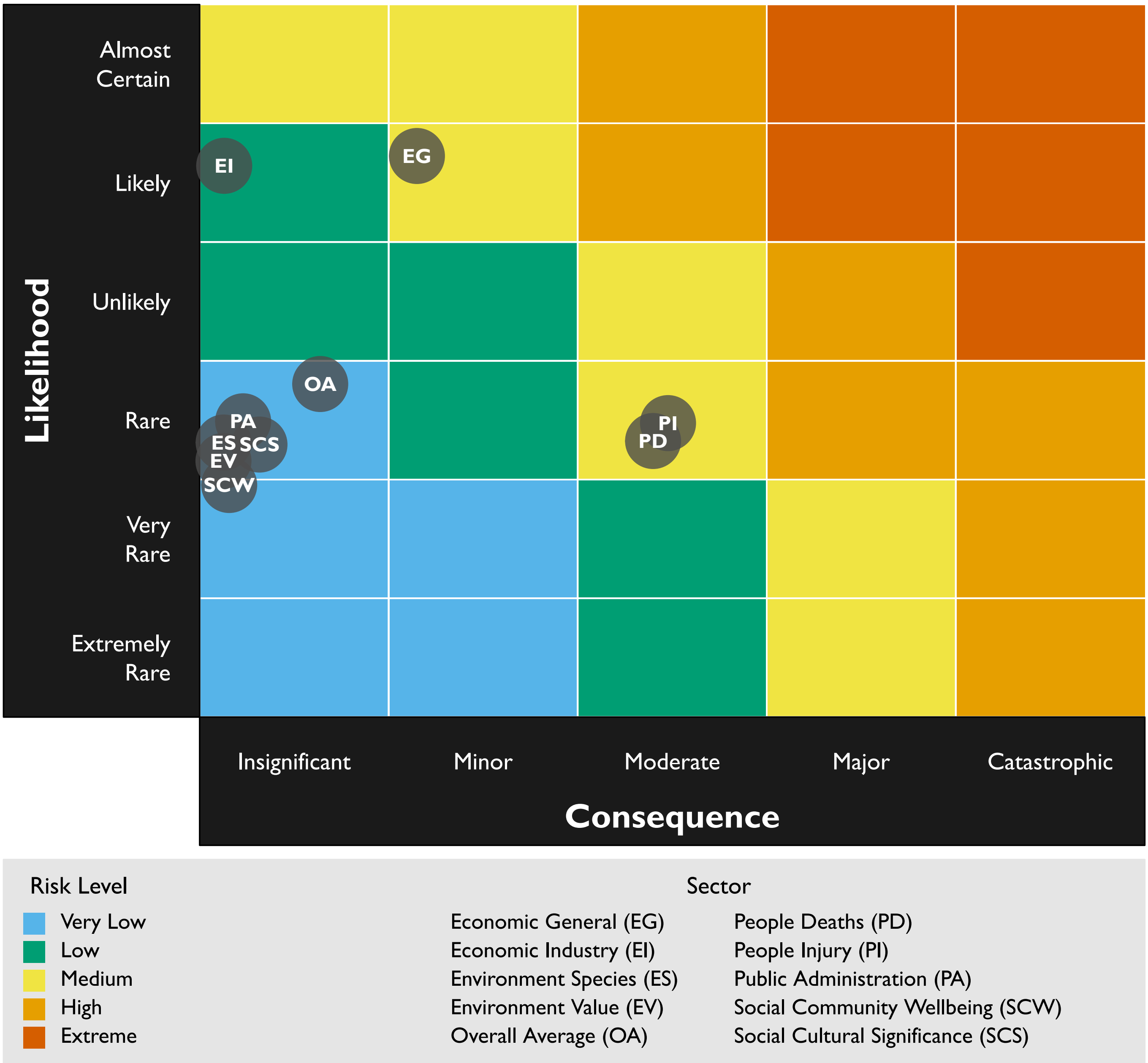
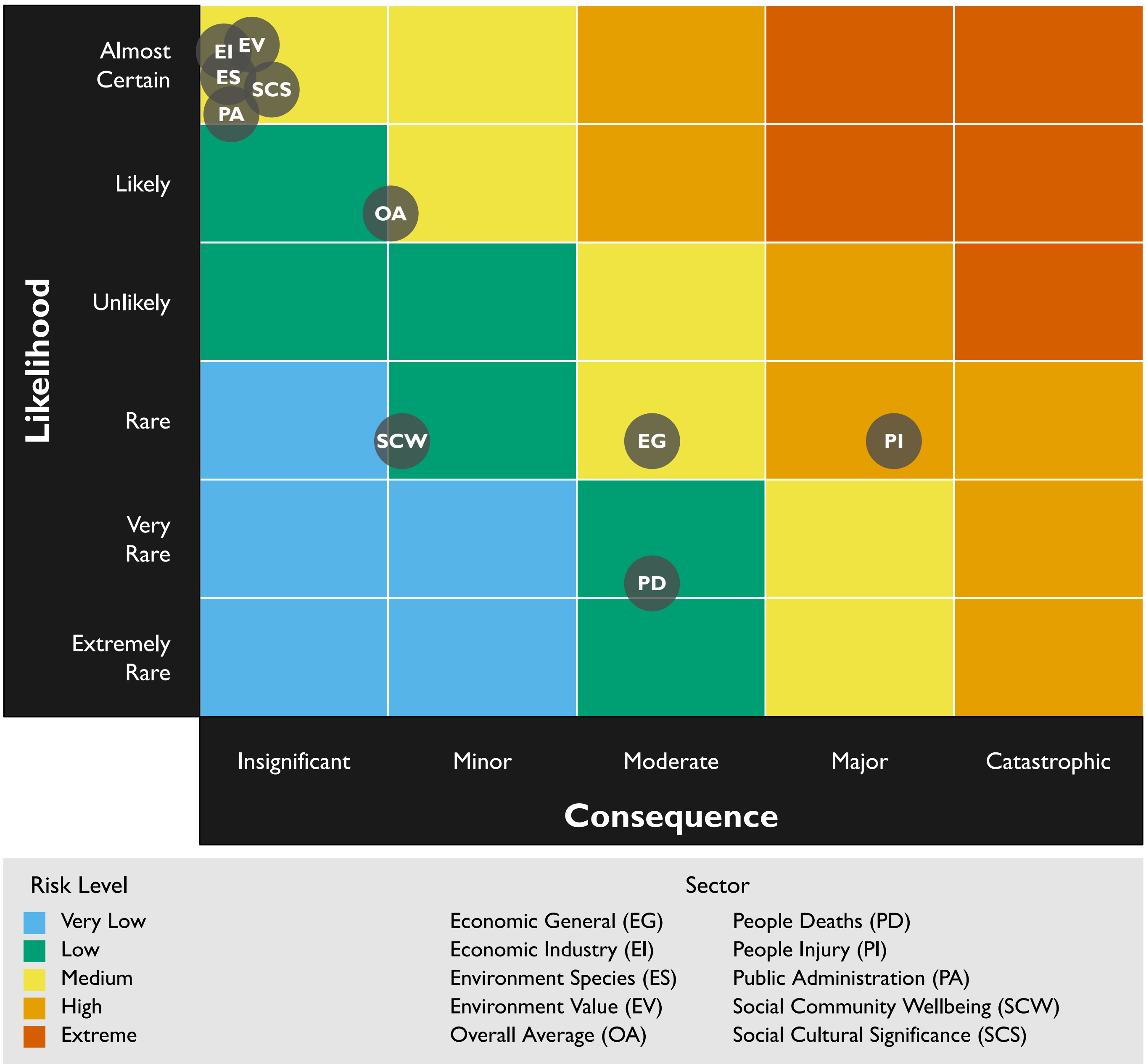


Figure 9.6 The risk of Landslide – Rockfall to each subsector of society as determined by TSNDRA 2016. The central position is the confidence-weighted-average across working groups for both consequence and likelihood (confidence implied the expertise of the group). The whiskers represent the minimum and maximum ratings across groups.



9.8 Landslide comparison between 2012 and 2016

9.8.1 Participants

Following a recommendation from the author of TSNDRA 2012, the TSNDRA 2016 process made a deliberate effort to engage a larger number of experts, with a broader range of expertise than was possible during TSNDRA 2012. This could be responsible for most of the changes, which are described below (also see Figures 9.7 to 9.9).

9.8.2 General

Landslide incorporates three distinctly different hazards: Landslide – Debris Flow; Landslide – Deep-Seated; and Landslide – Rockfall. These hazards were considered in isolation within TSNDRA 2012 and this approach was repeated in TSNDRA 2016. The different sub-hazards have distinctly different profiles and direction of change. Also, following TSNDRA 2012, new research has significantly improved the understanding of both Landslide – Debris Flow and Landslide – Deep-Seated.

With regards to Landslide – Rockfall, as it was considered within TSNDRA 2012, it was decided worthwhile to be included in TSNDRA 2016. However, it is the recommendation of expert participants that rockfall should not be considered in future reviews, as rockfall hazards are typically highly localised, with localised consequences and are not expected to ever require a statewide response. Furthermore, rockfall hazards are routinely managed as core business of the State Roads division of government.

9.8.3 People

Landslide – Debris Flow: The risk of debris flow to people remained unchanged at 'High'. Despite the expected consequences increasing from 'Major' to 'Catastrophic', driven by recent research informing the speed of onset, a steady expectation of likelihood resulted in no-change in the overall risk.

Landslide – Deep-Seated: The risk of deep-seated landslide to people remained unchanged at 'Medium'. Although consequences were increased from 'Moderate' to 'Major', the likelihood of such consequences was decreased substantially from 'Unlikely' to 'Rare'. Deep-seated landslides are often preceded by numerous physical warnings that encourage those in the area to evacuate, reducing the likelihood of worst-case impacts.

Landslide – Rockfall: The risk of rockfall to people remained 'Medium', despite a decrease in the likelihood of from 'Unlikely' to 'Rare'. The scenario dictated a particular consequence, which must be at least 'Moderate'; however, experts were aware that these incidents happen occasionally and are part of the core business of emergency services and State Roads.

9.8.4 Economic

Landslide – Debris Flow: The risk of debris flow to the economy remained unchanged at 'High', with no changes to either expected likelihood or consequences.

Landslide – Deep-Seated: The risk of deep-seated landslide on the economy was increased from 'Low' in TSNDRA 2012 to 'Medium' in TSNDRA 2016 due to an increase in likelihood. Recent research has identified more areas at risk of landslide. Furthermore, lobbying by property developers has limited the capacity of councils to implement planning schemes and prevent approval of development within known landslide zones. In some cases, areas at risk of landslide that have been developed have not implemented appropriate engineering and hydrological solutions to limit future damage or impacts. As such, the risk to the economy is increasing.

Landslide – Rockfall: The risk of rockfall to the economy remained unchanged at 'Low', despite an increase in likelihood from 'Unlikely' to 'Likely'. Experts agreed it was reasonable to expect an isolated community to have an access road cut off by a rockfall about every 10 years. However, they commented that the road would only ever be closed for a short period of time (2-7 days), or alternative access routes would be available so consequences would remain as insignificant.

9.8.5 Environment

Landslide – Debris Flow: The risk of debris flow to the environment increased from 'Very Low' in TSNDRA 2012 to 'Low' in TSNDRA 2016, exclusively due to the increase in likelihood of an event. Recent research has identified many areas around Tasmania susceptible to debris flow, the vast majority of which are in isolated areas. This increases the expected occurrence and therefore the expected impact on the natural environment.

Landslide – Deep-Seated: The risk of deep-seated landslide to the environment remained unchanged at 'Low' despite an increase in likelihood from 'Unlikely' to 'Likely'. Environmental impacts are still considered insignificant from this hazard as all endangered species are not in at-risk areas (i.e. populated flat areas) or widely dispersed to escape extinction from a single event (e.g. spotted handfish).

Landslide – Rockfall: The risk of rockfall on the environment remained unchanged at 'Low'. There was no change to consequence or likelihood.

9.8.6 Public administration

Landslide – Debris Flow: The risk of debris flow on public administration was decreased from 'High' in TSNDRA 2012 to 'Medium' in TSNDRA 2016 due to a decrease in the expected consequences from 'Major' to 'Moderate' and no change in likelihood. Recent work within councils to identify and manage the risk of debris flow has improved the understanding and impact an event will have on a broad scale. Although such an event will be devastating, it is expected to be highly localised, with capacity from throughout the State available to assist in response and recovery activities.

Landslide – Deep-Seated: The risk of deep-seated landslide on public administration was increase from 'Low' in TSNDRA 2012 to 'Medium' in TSNDRA 2016. This was due to an increase in likelihood, from 'Unlikely' to 'Likely'. Although the expected consequences decreased from 'Minor' to 'Insignificant', the high likelihood of the event ensures a 'Medium' risk rating. Experts were aware that government is already addressing deep-seated landslide issues, with the expectation this workload will increase with time. However, it was also believed this was within capability to absorb.

Landslide – Rockfall: The risk of rockfall on public administration was increased from 'Very Low' in TSNDRA 2012 to 'Low' in TSNDRA 2016 due to an increase in likelihood from 'Rare' to 'Unlikely'. Consequences remain insignificant as they fall within the core business of all responsible agencies.

9.8.7 Social setting

Landslide – Debris Flow: The risk of debris flow on social setting was reduced from 'Low/Moderate' in TSNDRA 2012 to 'Low' in TSNDRA 2016 due to a decrease in expected consequences. Any impact of debris flow on a community is expected to be short-to-medium term, with no permanent displacement of residents or businesses.

Landslide – Deep-Seated: The risk of deep-seated landslide on social setting remained unchanged at 'Low' despite an increase in likelihood from 'Unlikely' to 'Likely'.

Landslide – Rockfall: The risk of rockfall to social setting was increased from 'Very Low' in TSNDRA 2012 to 'Low' in TSNDRA 2016 due to an increase in likelihood from 'Rare' to 'Likely'. This large change in likelihood is due to the consideration of a road closure impacting on an isolated community about once every decade, but with consequences expected to remain as 'Insignificant' (i.e. an inconvenience).

9.9 Landslide risk register

The Landslide risk register, presented in Appendix B: Risk Register, was created by the project team following the process described in the NERAG 2015.

9.10 Proposed Landslide risk treatment options

It is important to note that the proposed risk treatment options, presented in Appendix C: Proposed Treatment Options, have been developed for the purpose of informing further discussion at SEMC/Management Authority level. It is appropriate that these options be reviewed by the management authorities and referred to SEMC for further decision.

Figure 9.7 Change in Landslide – Debris Flow risk level to each sector of society between TSNDRA 2012 and TSNDRA 2016 as rated by the NERAG process.

Figure 9.8 Change in Landslide – Deep-Seated risk level to each sector of society between TSNDRA 2012 and TSNDRA 2016 as rated by the NERAG process.

Figure 9.9 Change in Landslide – Rockfall risk level to each sector of society between TSNDRA 2012 and TSNDRA 2016 as rated by the NERAG process.

10 Section Ten
Pandemic influenza risk assessment

Image: Richard Bugg, Ambulance Tasmania

10 Pandemic influenza risk assessment

	2016	2012
Maximum Risk Level:	Extreme	N/A*
Maximum Consequence:	Catastrophic	N/A*
Maximum Likelihood:	Unlikely	N/A*
Average Confidence:	Highest	N/A*

* Pandemic Influenza was not assessed in TSNDRA 2012

10.1 Context and definition

TSNDRA 2012 included a recommendation to consider adding pandemic influenza to future iterations of the TSNDRA. It was noted that human pandemic influenza is a threat and preparedness must be maintained.

A pandemic is an outbreak of disease affecting a large number of people over a wide area, usually crossing international borders. Increasingly, pandemic influenza is being considered in the context of natural hazards and all-hazards emergency management frameworks. While it is a naturally-occurring hazard, there are two important differences between pandemic influenza and other natural hazards, which have important implications for preparedness:

1. Most natural hazards affect a defined, often localised area, whereas a pandemic affects a large area, with global impact. Accordingly, the Tasmanian response to pandemic influenza will align with the national response informed by evidence available at the time.

2. Most natural hazards have relatively short emergency response phases followed by potentially lengthy recovery periods, whereas pandemic influenza is likely to have a protracted response phase, with illness potentially progressively affecting communities in waves for up to four-to-six months, at least until a pandemic vaccine is developed and widely available.

Influenza is a highly infectious, potentially serious illness caused by influenza viruses. It spreads easily through respiratory droplets (for example from an uncovered cough), including up to 24 hours before the onset of symptoms. It typically exhibits sudden onset of fever, cough, fatigue and body aches, and is generally seasonal – in temperate climates affecting communities mostly over winter months.

The main controls for influenza are pre-existing community immunity developed by people being infected by influenza viruses over time, and vaccine. Influenza viruses are constantly evolving, necessitating yearly updates to the vaccine.

Influenza viruses can also undergo sudden, major changes resulting in substantially new human influenza viruses. There may be limited pre-existing community immunity to a new influenza virus and it may take up to six months for vaccine to be developed and widely available. In the interim, illness can spread quickly, triggering a pandemic – with illness potentially more severe than seasonal influenza, including in the young, fit and healthy.

The World Health Organisation (WHO) coordinates global surveillance of circulating influenza viruses and monitors the emergence of new viruses that may have pandemic potential. While other diseases may cause pandemics, the WHO perceives influenza as the most likely cause and pandemic PPRR focuses on influenza. A pandemic caused by another disease may require different treatments and controls.

Workshop participants noted that extensive research continues globally on pandemic controls and their effectiveness, and evidence-based recommendations are provided in the *Australian Health Management Plan for Pandemic Influenza (2014)* (AHMPPI). Participants agreed any new controls and treatment options would need to be considered in line with national and global evidence and considered by relevant national specialist committees.

10.2 Previous significant events

When a pandemic occurs, Tasmania will be affected. There were three pandemics in the 20th century, and so far there has been one in the current century. The impact of these pandemics is outlined in Table 10.1.

Table 10.1: The impact of the most recent pandemics and seasonal influenza.

Event	Impact
Spanish Flu (1918)	Caused an estimated 20-50 million deaths worldwide (more than the First World War); significant community, social and economic disruption.
Asian Flu (1957-58)	Caused an estimated 1-2 million deaths worldwide. Spread limited by development of a vaccine; deaths limited by the availability of antibiotics to treat secondary infections. A second wave of illness appeared to have more impact than the first.
Hong Kong Flu (1968-1970)	Caused an estimated 1-4 million deaths worldwide. A second wave of illness caused more deaths than the first wave.
Pandemic (H1N1) 2009	Caused an estimated 284,000 deaths (potentially up to 575,400 deaths) globally[50] with an estimated infection rate of 24% and mortality rate of .02% of those infected[51]. Many general practices in Tasmania reported surges in patients with influenza-like illness.
Yearly seasonal influenza	Causes 250,000 to 500,000 deaths globally per annum[52], mostly in elderly people and people with pre-existing medical conditions.

10.3 Climate change implications

Climate change was not considered for the 2015 pandemic risk assessment. Although there is conjecture about the potential for climate change to influence the frequency of pandemics, there is no evidence to link climate change and the emergence of new influenza viruses. It is not possible to attribute environmental factors in isolation from other more likely influences, such as economic and demographic variables, the rapid expansion of industrial production of livestock and changes in population dietary habits[53].

10.4 Current arrangements

Effective pandemic preparedness requires effort across whole-of-government. Accordingly, under the TEMP, the Department of Premier and Cabinet (DPAC) is the SEMC Advisory Agency for pandemic influenza and the management authority for preparedness. DHHS is the management authority for prevention and mitigation and response phases, working closely with the Tasmanian Health Service. Table 10.2 shows the management authority for pandemic influenza across emergency stages.

Table 10.2: Pandemic influenza management authority across emergency stages.

Hazard	SEMC Advisory Agency	Management Authority		
		Prevention and Mitigation	Preparedness	Response
Pandemic influenza	DPAC	DHHS	DPAC	DHHS

Tasmania's pandemic response will align with the national response. It will be managed within Tasmania's existing emergency management framework using the five potential emergency response levels: Standby, Levels 1-3, and Stand-down. Movement between levels will be driven by the command, control and coordination requirements at the time. A Level 3 response is unlikely but may be triggered by a severe pandemic.

The incident controller for pandemic influenza is generally the Director of Public Health, who has statutory authority under the *Public Health Act 1997*. If a whole-of-government Level 3 response is activated, the response will be controlled by the State Controller (Commissioner of Police) with support from the State Health Commander (likely to be the Director of Public Health).

Further detail about the pandemic emergency management arrangements is provided in the SSEMP: *Tasmanian Public Health Emergencies Management Plan* and its Associate Plan: *Tasmanian Health Action Plan for Pandemic Influenza 2016.*

10.5 Worst-case scenario

It is assumed that pandemic influenza will be highly infectious and spread easily. The worst-case scenario is for the pandemic to cause severe illness in a high proportion of people infected. In this scenario, the level of impact may be similar to that of the 1918 pandemic, overwhelming the health system and causing significant disruption to the economy, workplaces and society. The focus would be on maintaining essential services.

A more likely scenario is a pandemic of mild to moderate clinical severity. However, even if most people infected experience mild to moderate illness, as experienced in 2009, some will suffer severe illness and there may be significant morbidity that may push health services to capacity for a time and potentially beyond capacity briefly. Strategies to support at-risk groups may be required.

Two scenarios were considered by workshop participants, using information provided in the AHMPPI.

- **Scenario #1: Clinical severity is low**
    - Most people infected with the virus will experience mild to moderate illness.
    - People in 'at-risk' groups of severe illness (for example, the aged and infants) may experience severe illness.
    - Strategies to support at-risk groups may be required.
    - At the peak of the pandemic, and particularly for a highly transmissible virus, health services (especially GP, emergency care, acute care and respiratory illness services) are likely to be stretched to capacity.
    - The impact on the community may be similar to severe seasonal influenza or pandemic H1N1 (2009).
- **Scenario #2: Clinical severity is high**
    - Widespread severe illness will cause concern and challenge the health sector.
    - General practice, emergency departments, hospital services, pharmacies and aged care facilities will be stretched to capacity to support essential care requirements.
    - Heavy prioritisation will be essential within hospitals to maintain essential services.
    - The demand for specialist equipment and staff is likely to be greater than capacity.
    - Pressure on health services will be more intense, rise more quickly and peak earlier the more infectious the virus is.
    - Healthcare staff may be ill or have to care for ill family members, further exacerbating pressures on healthcare providers.
    - The community focus will be on maintaining essential services.
    - The level of impact may be similar to that of the 1918 H1N1 Spanish flu pandemic.

10.6 Existing controls

A list of Tasmania's existing controls for pandemic influenza was provided to workshop participants for analysis in two groups. It was acknowledged that some controls (for example, the use of personal protective equipment by healthcare workers) would be effective at reducing the hazard for individuals and be vital for the health response but would have limited effect in controlling a pandemic. When considering the strength of each control, it was agreed the focus would be on its strength to reduce the hazard at a population level.

Two particular controls were assessed by participants as having high strength for controlling a pandemic, and this assessment aligns with the evidence-based AHMPPI. These are:

- customised pandemic vaccine
- neuraminidase inhibitors (antivirals).

A number of controls were assessed by participants as having high strength for controlling a pandemic, but were generally regarded as less effective by the AHMPPI. While many of these are important activities likely to be undertaken during a pandemic to protect individuals and minimise or manage consequences, they may have limited effect on the course of an influenza pandemic at a population level because of the highly transmissible nature of most influenza viruses.

Across all controls, four were assessed by participants as high strength but low expediency. A focus on improving the expediency of these controls, where possible, is important. These controls are:

1. Tasmanian Health Service primary health facilities (including district hospitals, community health centres, multipurpose centres) and flu clinics (when activated during a response)
2. Vaccine, which may take 4-6 months to be developed and widely available
3. Respiratory etiquette (note there is a lack of evidence to support this as an effective control at the population level, and there was inconsistent assessment of this control by participants)
4. The *Biosecurity Act 2015* (Commonwealth).

A further nine controls were assessed as high strength but medium expediency. A focus on improving the expediency of these controls is important. These controls are:

1. Ambulances
2. GP clinics
3. Emergency departments
4. Antivirals (assuming they are available in large enough quantities, able to be administered to patients within 48 hours of symptom onset and antiviral resistance does not develop)
5. Business continuity planning
6. Expert committees and networks (Australian Health Protection Principal Committee, the Communicable Diseases Network of Australia, and the Public Health Laboratory Network)

7. Hand hygiene (note there is a lack of evidence to support this as an effective control at the population level, and there was inconsistent assessment of this control by participants)
8. Existing health sector knowledge
9. Public Health Emergency Operations Centre.

The *Tasmanian Health Action Plan for Pandemic Influenza 2016* was assessed as a medium-strength control. It was noted this plan is not (at the time of the workshop) operational and has not been tested; this is a priority.

Participants assessed key public information tools (TasALERT, the Tasmanian Emergency Information Service, Public Health Alerts) as having medium strength in controlling a pandemic, noting they may help individuals protect themselves and minimise the load on services, but are unlikely to save lives in isolation from other controls or generate such high levels of compliance as to significantly stall the progress of a pandemic at a population level. However, there was inconsistency in the assessment of the *expediency* of public information. Group 1 assessed public information as highly expedient, with processes and resources in place and routinely used to distribute information quickly and easily. Group 2 assessed public information as having low expediency because of the need for lead time to ensure message uptake and community knowledge.

There was also inconsistency in the assessment of hand and respiratory hygiene. Group 1 assessed hand hygiene and respiratory etiquette as being highly expedient and important for protecting individuals, but having low strength in reducing the spread of influenza at a population level. Group 2 assessed hand hygiene and respiratory etiquette as having low to medium expediency but high strength in controlling a pandemic. *(Nationally, communication strategies to improve public hand hygiene and cough etiquette during a pandemic are recommended. This measure is considered easy to implement and provides the public with a method of reducing their individual risk. Some studies have shown a mild to moderate benefit in settings such as households and workplaces, if practised frequently[54].)*

Table 10.3 outlines the existing pandemic controls and their strength and expediency as assessed by workshop participants.

Table 10.3: Pandemic influenza controls and their assessed strength and expediency (Str. = control strength, Exp. = control expediency).

Pandemic Influence Controls								
Material/physical	**Str.**	**Exp.**	**Procedural**	**Str.**	**Exp.**	**Behavioural**	**Str.**	**Exp.**
Personal protective equipment for healthcare workers	M	M	Emergency management framework	H	H	Restriction of hospital visitors	H	H
Emergency departments	H	M	Evidence-based research	H	H	Public information	M	L

Pandemic Influence Controls								
Material/physical	**Str.**	**Exp.**	**Procedural**	**Str.**	**Exp.**	**Behavioural**	**Str.**	**Exp.**
GP clinics	H	M	AHMPPI	M	M	Border control	M	L
Ambulances	H	M	Surveillance	M	H	Hand hygiene	H	M
Antivirals	H	M	Hospital pandemic plans	M	H	Workplace knowledge	M	L
Hospital wards	M	M	Business continuity planning	H	M	Health sector knowledge	H	M
Hospital isolation rooms	L	L	Australian infection control guidelines	M	L	Community knowledge	M	L
Hospital equipment (e.g. ventilators)	L	VL	Pandemic exercises and staff training	M	L	Respiratory hygiene	H	L
Healthdirect Australia	L	H	Expert committees and networks *	H	M	Home isolation of cases	M	L
GP Assist (an after-hours GP support service)	M	M	State Service interoperability arrangements	L	M	Home quarantine of case contacts	M	L
Tasmanian Health Service primary health facilities and flu clinics	H	L	State Special Emergency Management Plan: Human Influenza Pandemic Emergencies	L	M	Cancellation of mass gatherings	M	L
The Tasmanian Emergency Information Service	M	H	Tasmanian Health Action Plan for Pandemic Influenza 2016	M	M	Social distancing – 1 metre	L	VL
Hand, respiratory hygiene facilities	L	H	Tasmanian Notifiable Diseases Database	L	M	Public health alerts	M	H
TasALERT	M	H	Hospital influenza patient management protocols	M	M			
Vaccine, when available	H	L	Public Health Act 1997	H	H			
Public information material, signage	L	H	Biosecurity Act 2015	H	L			
Testing laboratories	VL	M						
Public Health Emergency Operations Centre	H	M						

* Expert networks and committees include the Australian Health Protection Principal Committee, the Communicable Diseases Network of Australia and the Public Health Laboratory Network.

10.7 Pandemic influenza risk analysis

Group 1 used the high clinical severity scenario and Group 2 used the mild to moderate severity scenario to assess the likelihood and consequences of an influenza pandemic against the NERAG 2015 categories: environment, social setting, economy, public administration and people.

10.7.1 Consequence

Participants were extremely confident an influenza pandemic could have catastrophic consequences in terms of the numbers of deaths and critical illnesses with long-term or permanent incapacitation, including in young and previously-healthy adults.

Participants were very confident an influenza pandemic could have moderate to major consequences for the Tasmanian economy, through loss of productivity that may occur with high levels of staff absenteeism across sectors during waves of illness. While no specific industry is likely to fail, sectors hardest hit would be the government health sector, which participants estimated may incur 10-20 per cent extra costs over a 12-month period, including for staff overtime payments, influenza-specific health services, vaccination services and antivirals; and the tourism sector, which may experience a downturn in visitor numbers due to a global reduction in people movement.

Participants were very confident an influenza pandemic could have moderate to major consequences for public administration across all sectors because of high rates of temporary staff absenteeism due to illness, potential home quarantine, caring for household members who are sick or caring for children unable to attend school or childcare due to staff shortages. Vital support services, including information technology and payroll services, may also be affected at times.

Participants were extremely confident an influenza pandemic would have insignificant impact on the environment, and were on average very confident it would have a minor impact on social settings including community wellbeing and major cultural events. It was noted the impact on cultural events may be higher if waves of illness occur over summer months.

10.7.2 Likelihood

Participants agreed all pandemic consequences are unlikely because using the NERAG assessment guidelines and based on intervals between past pandemics, the overall probability of a pandemic is unlikely. It was agreed the controls in place are not capable of reducing the likelihood of a pandemic, but could reduce the impact on the population in general.

Participants were extremely confident in their assessment of the likelihood of potential consequences across most categories (people, environment, public administration, social and community wellbeing, and social cultural significance), and very confident to extremely confident in their assessment of the likelihood of potential consequences to the economy.

Using the qualitative risk matrix shown in Figure 10.1, participants assessed the overall level of risk for people as ‘Catastrophic’, for public administration as ‘Major’, for the economy as ‘Moderate’, for social settings as ‘Minor’ and environment as ‘Insignificant’.

Figure 10.1 The risk of pandemic influenza to each subsector of society as determined by TSNDRA 2016. The central position is the confidence-weighted-average across working groups for both consequence and likelihood (confidence implied the expertise of the group). The whiskers represent the minimum and maximum ratings across groups.

10.8 Pandemic influenza risk register

The pandemic influenza risk register, presented in Appendix B: Risk Register, was created by the project team following the process described in the NERAG 2015.

10.9 Pandemic influenza proposed risk treatment options

It is important to note that the proposed risk treatment options, presented in Appendix C: Proposed Treatment Options, have been developed for the purpose of informing further discussion at SEMC/Management Authority level. It is appropriate that these options be reviewed by the management authorities and referred to SEMC for further decision.

11 Section Eleven
Severe storm risk assessment

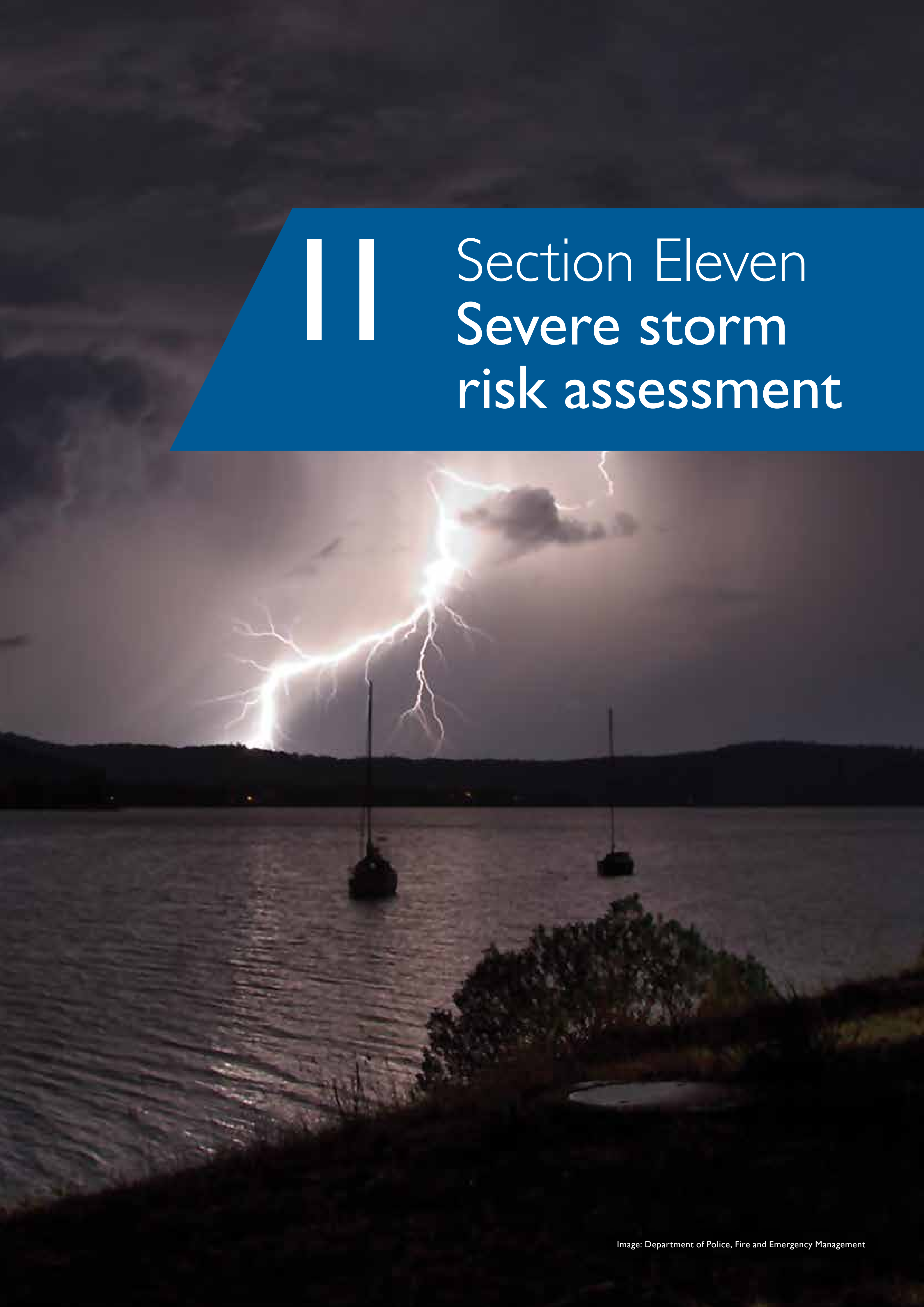


Image: Department of Police, Fire and Emergency Management

11 Severe storm risk assessment

	2016	2012
Maximum Risk Level:	Extreme	Medium*
Maximum Consequence:	Major	Moderate*
Maximum Likelihood:	Likely	Likely*
Average Confidence:	High	N/A^

* The 2012 values have been re-calibrated following changes in methodology under NERAG 2015 (see Section 2.1)
^ No average confidence values were provided in TSNDRA 2012

11.1 Context and definition

No single location in Tasmania is more than 115 km from the ocean. This proximity to the ocean results in Tasmania exhibiting a temperate maritime climate where temperature is moderated by the surrounding seas. Tasmania lies in the 'Roaring 40s' belt of westerly airflow. The cycle of westerly winds is a key driver of the seasonal rainfall pattern, especially in the western and central regions of Tasmania. These persistent westerly systems are related to features of the general circulation of the atmosphere in the southern hemisphere. The principal characteristic of the Tasmanian climate is the interaction between prevailing westerly wind and the mountain ranges near the west coast and the central plateau, which results in Tasmania experiencing regular storms and severe weather.

Storms affect all parts of Tasmania; however, as mentioned above, different areas of the State have varying levels of exposure to different storm scenarios. The north-east of the State is exposed to slow-moving low pressure systems that sit off the east coast of Australia and generate water-laden easterly winds that bring heavy rainfall. These systems are known as 'east coast lows'. The north-east is also affected by the westerly frontal systems and occasionally fronts that move up from the south. The south-east is reasonably protected from the prevailing westerlies due to the mountain ranges in the west, but is affected by east coast lows, although to a lesser extent than the north-east. The west and north-west coast is particularly exposed to the prevailing storm weather.

The TSNDRA is interested in state-level risks, therefore it was agreed that the focus of the study would be storms that are of a severe nature. Severe storm events, although widely recognised as a long-standing feature of the Tasmanian climate, vary significantly in their nature and as a consequence have wide-ranging possible impacts. As defined by the Bureau of Meteorology, a storm event is classified as severe if it produces one or more of the following phenomena:

- a tornado
- hail with a diameter of 2 cm or greater
- wind gusts of 90 km/h or greater
- very heavy rain, resulting in flash flooding.

11.2 Previous significant events

An analysis of previous significant storm events was undertaken. It was noted that the majority of storm events produce localised minor to moderate impacts; however, public concern is usually significant in the face of such events. A small number of people have been killed during storm events in Tasmania, with the most severe impacts usually relating to roofing damage and damage caused through power loss.

A number of significant events have been experienced across the State over the last half-century, with impacts on housing, food crops/exports, transport networks and a number of recorded deaths. Damage estimates from a 2001 event in Launceston recorded an estimated $2 million of damage, requiring a statewide emergency response. A similar event in 2008 led to 65,000 households losing power, while disruptions to major events such as Taste of Tasmania and the Hobart Cup have also occurred. Although beyond the State's direct control, the storm event that hit the 1998 Sydney to Hobart Yacht Race resulted in the sinking of five boats, six deaths and a rescue effort involving more than 50 military and civilian aircraft and marine vessels – Australia's largest ever peacetime rescue operation. A list of previous significant storm events is attached to the appendices. The list of recent significant storm events is provided in Table 11.1.

Table 11.1 Analysis of previous significant severe storm events in Tasmania.

Event	Impact
March 1980 (Hobart)	Several houses unroofed and 2 houses totally destroyed due to gale force winds. 50% of the apple export crop ruined.
November 1992 (Smithton)	Extensive damage to a dozen homes and local infrastructure occurred when a tornado cut inland of Smithton. Wind gusts of up to 280 km/h.
December 2001 (Launceston)	Tornadoes believed to be present in the storm that damaged 114 houses in the Launceston suburbs of Summerhill and Prospect. Emergency workers came from across the State for temporary repairs. Estimated $2m damage bill.
June 2003 (Hobart)	A young girl killed by a falling branch at Waterworks Reserve during a gusty wind event in Hobart.
April 2008 (Tasmania)	An overnight event wreaked havoc across Tasmania, damaging over 1,000 houses and leaving 65,000 customers without power for less than a day, and 1,000 customers for more than a day. Short-term closure of tourism sites. Roads closed for short periods. Gusts recorded of up to 177 km/h. $2m in damage claims by RACT, and similar rates for other insurers. $1m repair costs reported by Aurora.
April 2009 (north coast)	A line of severe thunderstorms swept over the north coast producing several tornadoes, including wind gusts recorded at second highest ever.

Event	Impact
July 2014 (Tasmania)	A series of six cold fronts, associated with low pressure systems to the south of Tasmania crossed the State between 27 and 31 July 2014. Damaging winds and widespread showers and rain were associated with these cold fronts. Wind gusts up to 160 km/hr at Maatsuyker Island on 29 August were the highest recorded since 1963. On the evening of 28 July sudden violent gusts of wind occurred at Round Hill. One member of the public died during the clean-up of storm damage on private property. 1 home was destroyed and 1 caravan that was a primary place of residence was also destroyed. 6 primary places of residence with damaged and not habitable. 341 primary places of residence were damaged including 12 units at the Karingal Aged Care facility in Devonport. Damage was reported at the Launceston Gardens Villages aged care facility. 2 businesses at Round Hill near Burnie were destroyed and statewide a further 9 businesses were damaged. TasNetworks customers across the State experienced lengthy disruptions to supplies. Many roads were temporarily blocked by fallen trees or power lines in the north-west region. Only two roads were closed for greater than 24 hours. Storm damage was sustained to the Launceston Airport car park. Several cars were significantly damaged by falling trees. Damage was reported to 64 schools across the State. King Meadows High School suffered significant storm damage and had to be evacuated. Damage was reported at a childcare centre in South Launceston. The Turners Beach Bowls Club and Turners Beach Memorial Hall/Scout Hall were damaged. The Central Highlands Council Chambers and Hall in Hamilton were damaged. Mt Field National Park was temporality closed due to the falling of many tall trees. Cradle Mountain was temporarily closed due to snow. A barge washed up on Maria Island. All Launceston parks and reserves were closed due to severe winds and for the purposes of protecting the community.

11.3 Climate change implications

Climate change predictions suggest a very minimal decrease in mean wind speed across Tasmania by the end of the century[55]. There is also expected to be more frequent intense rainfall events in the future. While this suggests a greater risk of flooding, it is also relevant to a discussion about storm risks and so was considered during the assessment.

11.4 Current arrangements

The State Emergency Service (SES) provides the main storm response capability in Tasmania.
This is delivered primarily through its volunteer workforce in conjunction with local council arrangements.

The SES is the designated SEMC Advisory Agency under the TEMP (see Table 11.2). Local councils are responsible for prevention and mitigation activities, including risk assessments; however, the SES often takes a leadership role in respect to coordinating efforts in storms risk mitigation.

Table 11.2 Current arrangements for the emergency management of severe storm events in Tasmania.

Hazard	SEMC Advisory Agency	Management Authority		
		Prevention and Mitigation	Preparedness	Response
Severe Storm	SES	SES	SES	SES

11.5 Worst-case scenario

With consideration to historical storm events and advice from the Bureau of Meteorology, a realistic worst-case scenario was designed for use in the severe storm risk assessment workshops. The scenario was designed in consultation with the workshop participants and was later validated during the assessment. The scenario used for the storms assessment was described as follows:

- The storm scenario considered was based on the most potentially damaging storm conditions that have been observed in Tasmania. Characteristics of this storm were:
  - A broad-scale active frontal system or squall line moves across Tasmania from the west to east.
  - The storm produces severe thunderstorms and tornadoes that impact upon at least one community.
  - Such storms are quite frequent historically, but usually impact unsettled areas and have rarely caused significant damage in the built environment.

The scenario was designed to ensure that all relevant PPRR controls would come into play, while retaining the characteristics of a realistic feasible storm event. While the scenario implies a focus on the northern part of the state, the workshop team discussed previous events in the south and ensured the assessment addressed the broader state-level risks from this hazard.

11.6 Existing controls

Severe storm controls identified by participants were heavily focused on procedures and processes, with few formal behavioural controls in place (as reflected by more generic behavioural control classifications, such as 'community resilience' and 'community acceptance').

A large number of physical controls were, however, seen to be highly effective in reducing the likelihood of exposure to severe storm damage and consequences, with aspects of built form, as well as the enforcement of the building standards that underpin the built form itself, seen as being both strong and expedient. The full list of identified controls is shown in Table 11.3.

Participants observed some difficulty in identifying the operating thresholds for infrastructure – particularly drainage systems – in coping with heavy rainfall and high wind speeds, with overflows being empirically observed to occur frequently but with limited consequence. While a wide range of controls was in place, a notable gap between the general strength of controls and their expedience was evident. For instance, SES staff training and Storm Preparation Awareness Programs were categorised as being very strong, but under-resourced. Other areas were seen as too challenging, for instance participants noted that maintaining and distributing sandbag stockpiles was difficult to implement and not cost effective.

Early warning systems were seen as easy to use, however variability in their accuracy made building responses from these challenging. Similarly, Municipal Emergency Management Plans were noted as being up to date and well maintained, however lacking in capacity to respond, therefore limiting their implementation.

Private insurance was again observed to be patchy across the State, both in terms of under-insurance and areas with perceived poor levels of general insurance cover uptake. Limits within insurance contracts in terms of the types of storm damage covered were also raised.

The limited use of National Disaster Resilience Grants Program funding to support research into the impacts and frequency of severe storms was seen as a weak current control that could be strengthened, with the potential to have significant impacts on response processes, as well as better understanding of exposure across the State. It was suggested that analysis of the response phase immediately following events, including clean-up, and procedures such as Rapid Impact and Damage Assessments, would be of significant benefit in improving their actions both national and local governments in subsequent storm events. Community-level and private sector preparations for severe storms were also seen as a key limitation that could be improved.

Table 11.3 Severe storm controls (Str. = control strength, Exp. = control expediency).

Severe Storm Controls								
Material/Physical	**Str.**	**Exp.**	**Procedural**	**Str.**	**Exp.**	**Behavioural**	**Str.**	**Exp.**
Drainage systems	M	M	Agency training	H	L	Storm preparation awareness programs	M	M
Sandbag stockpiles	L	L	Drainage maintenance schedules	M	M	Shared responsibility	H	M
Building standards	H	H	Exercising	H	VL	Recovery advice	L	H
Planning standards	H	H	Extreme wind hazard mapping	H	M	Media and communications	L	L
Weather forecasts	M	H	Situation awareness by Control Room	M	H	Household preparation	M	L
Power restoration procedures	H	H	Insurance	H	M	Community resilience	H	M
Asset design standards	H	M	Interagency coordination	H	H	Community acceptance	-	-
Storm shutters	H	H	Local council planning schemes	H	M	Clean-up programs	-	-
Hail covers	M	L	Municipal emergency management plans	M	H	Awareness of clean-up procedures	-	-
Government generators	H	M	NDRP funding arrangements	H	L			
Post-event improvements	-	-	Rapid impact / damage assessment	M	H			
Clearance around power lines	M	L	SES permanent staff training	H	VL			
Evacuation centres	-	-	BoM advice management by SES	H	L			
			SES volunteer training	H	H			
			SOPs for adverse conditions	L	L			

Severe Storm Controls								
Material/Physical	Str.	Exp.	Procedural	Str.	Exp.	Behavioural	Str.	Exp.
			State emergency management plans	M	H			
			Storm preparation awareness programs	H	VL			
			Storm response plans	-	-			
			Warning systems	H	H			
			Water Management Act	-	-			
			Weather forecasts / GIS displays	H	H			
			Weather monitoring stations	H	H			

11.7 Severe storm risk analysis

Relative to the other hazard categories expert participants were notably confident in their assessment of severe storm risks, as is evident in Figure 11.1. In terms of economic impacts, for instance, there was strong consensus that while combined losses from crops, infrastructure and housing could reach multiples of $10 million, such losses were unlikely to reach the $100 million mark required to shift the consequences into the 'Major' category. Notably, rebuilding and crop loss was not viewed as extending beyond a one year period. The likelihood of storms occurring at critical cropping times reduces the risk classification, falling within the 'Likely' category on an annual basis. Complications arose regarding the impacts of storm surge on critical marine industries such as oyster farming; however, the higher of the discussed consequence categories ('Moderate') was selected to reflect this. Group 2 observed that a worst-case scenario seriously impacting on a specific industry sector involved in primary production was "once in a decade".

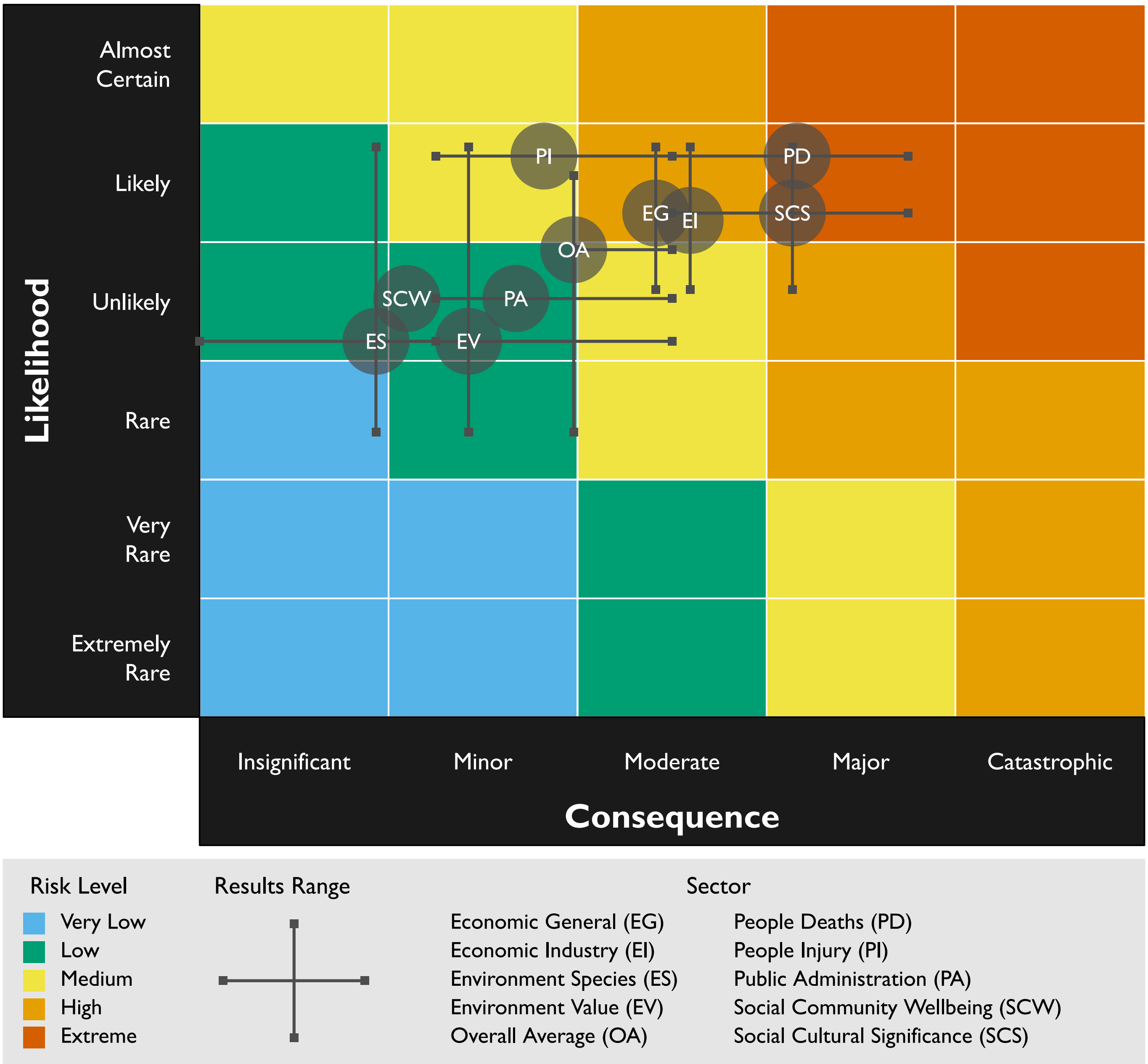
Participants cited data that even without severe storms, between five and 50 trees fall each month onto roads. Flying debris during storm events was considered a critical issue. Nonetheless, the historical rarity of deaths resulted in the assessment that people consequences could reach into the 'Major' category in a worst-case scenario, with more than five people being killed. Long-term or critical injury was viewed as being more limited (rated at 'Moderate'). An increasing population and behaviour change were assessed as increasing the number of people exposed, and it was also observed that "...there are always going to be people that will place themselves at risk".

While habitat loss was not seen as a direct consequence, the potential to trigger an oil spill through shipping was considered by one group. Localised impacts on already fragile species or habitat, leading to loss of value, were also assessed as potentially having a minor consequence at a state level. There was also seen to be little that could be done by the SES in this area, particularly in relation to remote ecosystems. Groups were split in assessing the likelihood of worst-case consequences, with the two categories assessed as either 'Rare' or 'Likely' by the groups respectively.

Public administration impacts were viewed to have most impact through inter-state requests for assistance, with utilities potentially needing interstate help to return services within an acceptable timeframe. Business continuity planning was felt to adequately limit this risk, although questions were raised as to what whole-of-government arrangements were in place with regard to back-up power generation. As a result of strong controls and a lack of precedent, the worst-case public administration consequences were considered to be unlikely in a given year (less than a 10% AEP).

Some disagreement existed regarding the potential consequences for events of cultural significance. Although permanent dispersal was seen as very unlikely by both groups, precedents such as Salamanca Markets being closed due to wind, as well as relocation of parts of Taste of Tasmania, were viewed as likely consequences, with any cancellation of major events such as Falls Festival and the Sydney to Hobart Yacht Race viewed as having large potential cultural – as well as economic – impacts. However, in general the short-term nature of storm events meant that postponement rather than cancellation was seen to be more likely. Given the different frequency of these events (Salamanca Markets weekly; Taste of Tasmania once per year), the groups found establishing an overall likelihood for a 'generic' cultural event challenging. Both groups agreed that worst-case consequences were unlikely in any given year.

Figure 11.1 The risk of severe storm to each subsector of society as determined by TSNDRA 2016. The central position is the confidence-weighted-average across working groups for both consequence and likelihood (confidence implied the expertise of the group). The whiskers represent the minimum and maximum ratings across groups.



11.8 Severe storm comparison between 2012 and 2016

11.8.1 Participants

Following a recommendation from the author of TSNDRA 2012, the 2016 process made a deliberate effort to engage a larger number of experts, with a broader range of expertise than was possible during the 2012 process. This results in some large changes in the economic and social setting sectors (also see Figure 11.2).

11.8.2 People

The risk of severe storm to people increased from 'Medium' in 2012 to 'High' in 2016 due to an increase in likelihood from 'Unlikely' to 'Likely'. Experts believed the scenario was more likely than previously considered, although the consequences were generally unchanged.

11.8.3 Economic

The risk of severe storm to the economy increased from 'Medium' in 2012 to 'High' in 2016 due to an increase in consequence from 'Minor' to 'Moderate'. A better appreciation for the impact a severe storm can have on forestry, aquaculture and agricultural produce, as well as the potential to interrupt or cancel large outdoor festivals, was incorporated into the 2016 assessment, increasing the expected consequences.

11.8.4 Environment

The risk of severe storm to the environment remained unchanged at 'Low'. An increase in expected consequences from 'Insignificant' to 'Minor' was offset by the decreased likelihood of these consequences from 'Likely to 'Unlikely'. This recognises the capacity of severe storms to do significant damage to the natural environment, but it is relatively uncommon for that damage to be broad scale enough, or destructive enough, to cause ecological shifts.

11.8.5 Public administration

The risk of severe storm to public administration remained unchanged at 'Low'. An increase in expected consequences was offset by a decrease in expected likelihood.

11.8.6 Social setting

The risk of severe storm to social setting was increased from 'Low' in 2012 to 'Medium' in 2016. This was due to a large increase in expected consequences from 'Insignificant' to 'Moderate'. The 2016 participants place greater emphasis on the risk to cultural events around the State. Many communities rely on large festivals as an opportunity to bring the community together as well as to encourage the local economy. Severe storms have historically been a risk to such events, reducing visitor numbers, or cancelling events completely. This aspect was incorporated into the assessment in 2016.

Figure 11.2 Change in severe storm risk level to each sector of society between TSNDRA 2012 and TSNDRA 2016 as rated by the NERAG process.

11.9 Severe storm risk register

The severe storm risk register, presented in Appendix B: Risk Register, was created by the project team following the process described in the NERAG 2015.

11.10 Proposed severe storm risk treatment options

It is important to note that the proposed risk treatment options, presented in Appendix C: Proposed Treatment Options, have been developed for the purpose of informing further discussion at SEMC/Management Authority level. It is appropriate that these options be reviewed by the management authorities and referred to SEMC for further decision.

12 Section Twelve
Tsunami risk assessment

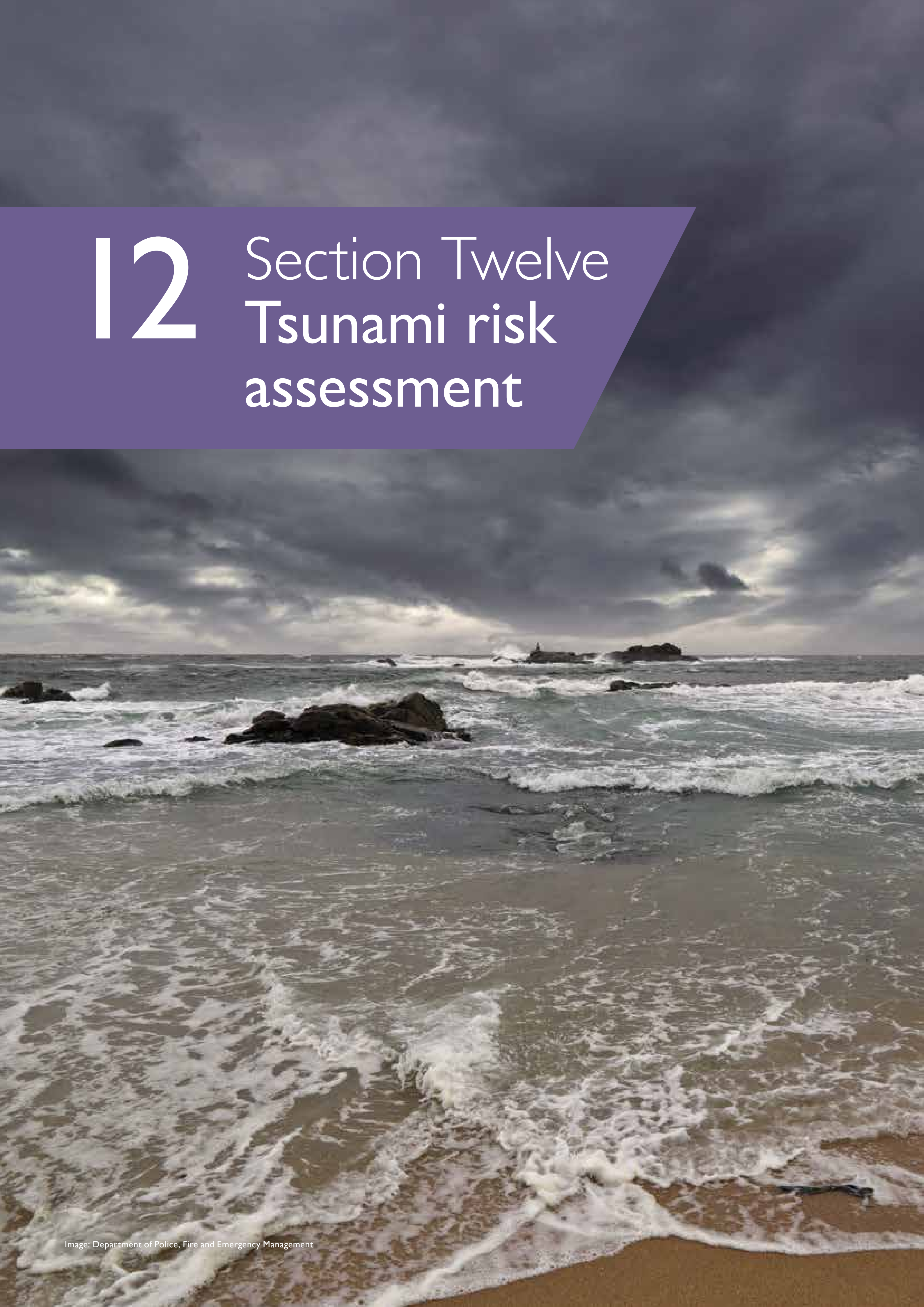


Image: Department of Police, Fire and Emergency Management

12 Tsunami risk assessment

	2016	2012
Maximum Risk Level:	High	Medium*
Maximum Consequence:	Catastrophic	Major*
Maximum Likelihood:	Very Rare	Very Rare*
Average Confidence:	Highest	N/A^

* The 2012 values have been re-calibrated following changes in methodology under NERAG 2015 (see Section 2.1)
^ No average confidence values were provided in TSNDRA 2012

12.1 Context and definition

Tsunami is a Japanese word meaning 'harbour wave'. A tsunami is a series of waves generated by sudden movement of the sea floor, usually as a result of an earthquake[56]. Volcanic eruptions, landslides and meteorite strike can also cause tsunamis. Tsunamis are different to wind-generated ocean waves that only cause movement of water near the surface. A tsunami involves movement of water from the surface to the sea floor[33].

In the deep ocean, the wave height of a tsunami is usually less than 2 metres. As a tsunami leaves deeper water and approaches shallower waters around a coastline it slows down and grows in height, creating a wall of water that can be very destructive[33]. Harbours, bays and lagoons can create a funnelling effect that amplifies the impact of the tsunami.

Tsunami risk is generally associated with large earthquakes that occur in subduction zones[33]. While Tasmania has not been significantly impacted by a tsunami in its recent history, its proximity to the subduction zones that stretch from Papua New Guinea to New Zealand give rise to the potential for tsunami activity, particularly along the east coast.

Research into tsunami activity in Tasmania indicates that unusual wave activity has been detected around the coastline on at least sixteen occasions since 1852, and that this activity is likely to have been associated with a tsunami event[57]. Geoscience Australia has identified the greatest tsunami risk to Tasmania is likely to be from the tectonically active Puysegur Trench area off the south coast of New Zealand.

It is important to note that earthquakes occur in the Puysegur Trench quite frequently, but they do not always result in a tsunami. If a tsunami were to be generated from this location it would approach Tasmania from across the Tasman Sea. The extent of inundation would depend on several factors, including the size of the earthquake, the size of the tsunami it generated, the shape of the seabed and topography of the coastline.

While not necessarily significant in terms of understanding tsunami risk, it is interesting to note that the first tsunami historically recorded to affect Australia impacted Tasmania in 1858[58].

12.2 Previous significant events

As part of the workshop process, an analysis of previous significant tsunami events was undertaken. Due to the lack of historical records, unusual wave activity and tide gauge recordings following international tsunami events were included in the analysis. A copy of this analysis is attached in the appendices; however, the most significant events from a state-level perspective are reproduced in Table 12.1 below.

Table 12.1 Analysis of previous significant tsunami events in Tasmania.

Event	Date	Trigger	Origin	Impact Summary
2012 Puysegur Trench event	19 Jan	Magnitude 6.2 earthquake	Puysegur Trench	Tide gauge at Southport recorded 170 mm MWH.
2009 Puysegur Trench event	15 Jul	Magnitude 7.9 earthquake	Puysegur Trench	NZ shifted 30 cm closer to AUS. 12 cm at Spring Bay tide gauge, Southport recorded 55 cm. First Tsunami warning issued from new Joint Australian Tsunami Warning Centre (JATWC).
2007 Puysegur Trench event	30 Sep	Magnitude 7.4 earthquake	Puysegur Trench	Tide gauge at Triabunna recorded 200 mm fluctuations. Reports from St Helens, Spring Bay and Fortescue estimates 300-350 mm
2004 Boxing Day tsunami	26 Dec	Magnitude 9.0 earthquake	Indonesia	Tide Gauge at Spring Bay recorded 600mm MWH
2004 Macquarie Island event	23 Dec	Magnitude 8.1 Earthquake	Macquarie Island	Tide Gauge at Spring Bay recorded 150mm MWH
2004 Puysegur Trench event	22 Nov	Magnitude 7.3 earthquake	Puysegur Trench	Not known
1989 Macquarie Island event	23 May	Magnitude 8.1 earthquake	Macquarie Island	Various tide gauges showed fluctuations up to 300 mm
1960 Chile event	22 May	Magnitude 9.5 earthquake	Chile	Tide gauge at Hobart recorded MWH of 460 mm. Surges in NW
1953 Bridport 'freak wave'	14 Nov	N/K	Bridport	Freak wave observed travelling up Brid River, approx. 2.4 m high. Damaged jetty and one child on beach was drowned
1858 earthquake, Tasmania	5 Feb	N/K	New Town Bay	Tidal ebb and flow noted at New Town Bay
1883 Krakatoa eruption	27 Aug	Volcanic eruption	Indonesia	Tidal disturbance observed at the Huon River, up to 900 mm higher

12.3 Climate change implications

Climate change projections were considered by the project team when determining the likely consequences arising from a major tsunami event. Data published by the Climate Futures for Tasmania project suggest a rise in mean sea level is expected as a result of climate change[27]. Any rise in sea level naturally would increase the inundation experienced as a result of a tsunami; however, there is no evidence to directly link the frequency of Tsunami with climate variability or change as they are discretely different earth system processes. Climate change is a longer-term issue, unrelated to the sudden geological movements that instigate tsunami events.

12.4 Current arrangements

The Tasmanian Emergency Management Plan establishes the responsibilities with respect to tsunami hazard, presented in Table 12.2.

Table 12.2 Current arrangements for the emergency management of landslide in Tasmania.

Hazard	SEMC Advisory Agency	Management Authority		
		Prevention and Mitigation	Preparedness	Response
Tsunami	DPFEM	SES	SES	DPFEM

The Joint Australian Tsunami Warning Centre (JATWC) has responsibility for issuing tsunami warnings. The standard defined for the Australian Tsunami Warning System (ATWS) is to provide a minimum of 90 minutes warning to Australian coastal communities for tsunami-generated earthquakes occurring on tectonic plate boundaries in the Indian, Pacific and Southern Oceans. The JATWC is able to issue initial tsunami warning bulletins within 30 minutes of the origin time of earthquakes within the Australian region[58].

The Puysegur Trench has the shortest tsunami arrival time under the JATWC estimates. It is presently estimated that it would take a tsunami from that zone approximately 2 hours from the time of the earthquake to arrive on the coastline of Tasmania. This gives DFPEM and other emergency services approximately 90 minutes to respond to the initial threat.

12.5 Worst-case scenario

With consideration to historical tsunami and tidal events, potential climate change implications and Tasmania's current emergency management arrangements, the risk study team agreed on a scenario considered the most realistic worst-case event. The scenario was used in the risk assessment workshop, and is summarised as follows:

- Scenario: A major fault movement (earthquake of Magnitude 8.7) occurs in the Puysegur Trench off the coast of New Zealand. The whole subduction zone at Puysegur is ruptured.

- This causes a tsunami that impacts the Tasmanian coastline.
- Current modelling suggests a wave height at a water depth of 100m to be 4.2 m.
- This magnitude of event equates to an Annual Exceedance Probability of 0.00008% (1:13,000 years).
- The modelling used is based on the event occurring during the Highest Astronomical Tide (HAT). This takes into account the potential for storm surge etc. The group noted there was a significant difference in the modelling between the level of inundation expected between a HAT event and a Mean Sea Level (MSL) event.

Workshop participants were presented with additional information relating to the potential impacts of this worst-case tsunami scenario on Tasmania, including the area of inundation, magnitude of wave energy and estimated frequency over long time-periods.

This scenario has been well modelled, with the impact expected to be of greatest severity in the south and east of the State. It was noted that there are two other major faults that could impact on Tasmania on either the west coast or the north-east coast. Although there is no available modelling associated with these events, they were considered throughout the assessment when the geographic location of impact was important for the consequence rating that may apply. For example, the relative impact of a tsunami on the Flinders Island community has different implications to that of Hobart due to the cultural significance of the region and the limited capacity for preparation: as warning systems may not be effective in contacting isolated parts of the community prior to the event.

12.6 Existing controls

The outcomes of the break-out group review of the tsunami controls survey are shown in Table 12.3. It was noted by all groups that there was some difficulty assessing the strength of many controls from a 'whole-of-state' perspective, especially as the controls have not been tested in the context of a major tsunami. Many of the controls for a tsunami have been tested in response to other hazards, such as different warning systems. These controls are well developed, rapidly implemented and well coordinated around the State (although it was recognised there are still some small communities that remain a challenge to reach in the relevant timeframe).

Procedural controls in place for tsunami were generally considered strong and expedient, although tsunami–specific training and/or funding programs were limited. Recommendations for improvement included more regular tsunami-specific training for incident controllers and targeted funding to improve knowledge around the potential risks and possible mitigation strategies. Tsunami inundation maps available for operational use were seen as valuable, as were revised land-use planning schemes that reflect the relative risk of tsunami, or limit development in known 'high-risk' areas.

Current physical controls to mitigate tsunami risk were mostly considered absent, difficult to implement, or both. Participants thought this was due to the mitigation measures being expensive and politically difficult to implement, coupled with a popular perception (and scientific estimates) that tsunamis are of very low frequency in Tasmania.

Behavioural controls were considered very low across the board, reflected in a lack of systems to promote awareness/knowledge of the tsunami risk in Tasmania with regard to how to prepare, prevent, respond or recover from an event. These were identified as an area for improvement.

Table 12.3 Tsunami controls (Str. = control strength, Exp. = control expediency).

Tsunami Controls								
Material / Physical	**Str.**	**Exp.**	**Procedural**	**Str.**	**Exp.**	**Behavioural**	**Str.**	**Exp.**
Sea walls	VL	VL	Community alerts	H	H	Media liaison	M	H
Coastal embankments	VL	VL	Development permits	L	VL	Tsunami education programs	VL	VL
Building code / standards	VL	L	Inundation mapping	L	M	Maintenance and mitigation	L	L
Tsunami detection buoys	M	M	Signage	M	VL	Community resilience	VL	VL
Tide gauges	VL	VL	Maintenance of infrastructure	H	H	Targeted awareness programs	VL	VL
Satellite data	VL	L	Land-use planning schemes	L	VL			
Recovery resourcing	M	M	Tsunami warning service	H	H			
			Seismic monitoring	H	H			
			Emergency Management plans	M	M			
			Incident management arrangements	H	M			
			Funding arrangements	H	L			
			Exercise programs	H	L			
			Agency Training	H	H			
			Insurance	H	VL			
			Interagency arrangements	H	H			
			Rapid impact / damage assessment	H	H			

12.7 Tsunami risk analysis

The 'Extremely Rare' likelihood of tsunami in Tasmania, coupled with the lower-consequence environmental, social and economic impacts, offset the potentially 'Catastrophic' impacts in relation to death, injury and economic-industry (see Figure 12.1).

Workshop participants expressed the highest level of confidence in their analysis of likelihood, as this was dictated by the scientific estimate of the return intervals of tsunami in Tasmania (1:13,000 years), although the two groups chose to round this value in different ways (one group considered 13,000 years to be equivalent to 10,000 years, while the other considered 13,000 years to be greater than 10,000 years). High levels of confidence also surrounded the consequences of a worst-case scenario.

As the Hobart waterfront is an area at risk, it was considered 'Likely' >50 people could be exposed to risk of death and injury, resulting in a 'Catastrophic' rating. However, it was noted the time-of-day and day-of-year that the event occurred would have a large positive or negative impact on the number of people at risk, with potentially >10,000 people exposed during an event like the Taste of Tasmania. It was therefore still considered 'Likely' to be >50 irrespective of timing as many coastal dwellings in the south and east were at risk of rapid inundation. Similarly, severe injuries were considered likely.

Economic consequences were deemed to be at least 'Major', with an expectation coastal industries such as oyster, salmon and fishing would experience devastating loss of critical infrastructure. It seemed likely a large event could encourage an industry to relocate to another council, state, or even another country (depending on economic conditions at the time).

Participants in the workshop expressed concern regarding a lack of knowledge surrounding the impact of tsunami on the environment, with highly uncertain responses (except for if the tsunami triggered a secondary disaster, such as an oil spill). Subsequently, the project team obtained perspectives from experts in biological and coastal morphological sciences. The red handfish was understood by experts to be the most critically endangered fish in Australian waters, as it has been found only on a single 70 m reef near Primrose Sands. If this location were impacted significantly, that species would be lost (a catastrophic impact), although the impact of a tsunami on this reef is highly uncertain. Otherwise, species are expected to be either resilient enough to survive the event, or distributed widely enough to recolonise the affected areas.

Even most threatened marine species, such as the spotted handfish found only in south-east Tasmania[59], were thought likely to be impacted, but widely enough distributed to not experience extinction. Insights from coastal morphology experts suggested that at-risk areas of environmental value are mainly coastal sand dunes. Destruction/reconstruction processes are a natural part of these systems and in many cases were expected to continue. However, there are known sites where human development has altered (or halted) the way these natural processes work. In these regions, the coastal dune systems would not recover and would be lost (which would be a catastrophic impact on environmental-value). Discussions with both biological and coastal morphology experts revealed a lack of knowledge of how ecosystem-succession following any natural disaster would play out. A destructive tsunami may allow for exotic pests to take hold and destroy currently robust ecosystems in both the terrestrial and marine environments. For example, it takes many sea urchins to convert a kelp forest into a bare-rock-ecosystem, but only a small number to maintain a bare-rock environment if the kelp forest has been destroyed.

Such ecosystem change would be a catastrophic loss of environmental value, but this was not taken into account during the risk assessment, as it is speculative.

Public administration systems were deemed capable of maintaining operations, although external support in both personnel and financial assistance from the Commonwealth would be required throughout the response and recovery phases.

Major events may be delayed or cancelled in the year of the event, but not indefinitely. Limited permanent dispersal, if any, was expected in most communities. However, the impact on isolated communities, such as those on the islands in Bass Strait, could be 'Catastrophic', especially if much needed assistance was slow in arriving. Some participants at the workshop also suggested that if the Aboriginal community on Cape Barren Island was significantly impacted and dispersed, it would be a 'Major' cultural disaster for Tasmania and Australia.

12.8 Tsunami comparison between 2012 and 2016

12.8.1 Participants

Following a recommendation from the author of TSNDRA 2012, the TSNDRA 2016 process made a deliberate effort to engage a larger number of experts, with a broader range of expertise than was possible during the TSNDRA 2012 process. This results in some large changes in the economic and social setting sectors (also see Figure 12.2).

12.8.2 General

The annual exceedance probability of the tsunami scenario pre-defined the likelihood of event. This translated into a decrease in likelihood relative to TSNDRA 2012. The fact tsunami can be caused by other geological events (such as an underwater landslide) was considered in this assessment by one of the working groups (but not the other) and should be explicitly incorporated into the scenario in future iterations.

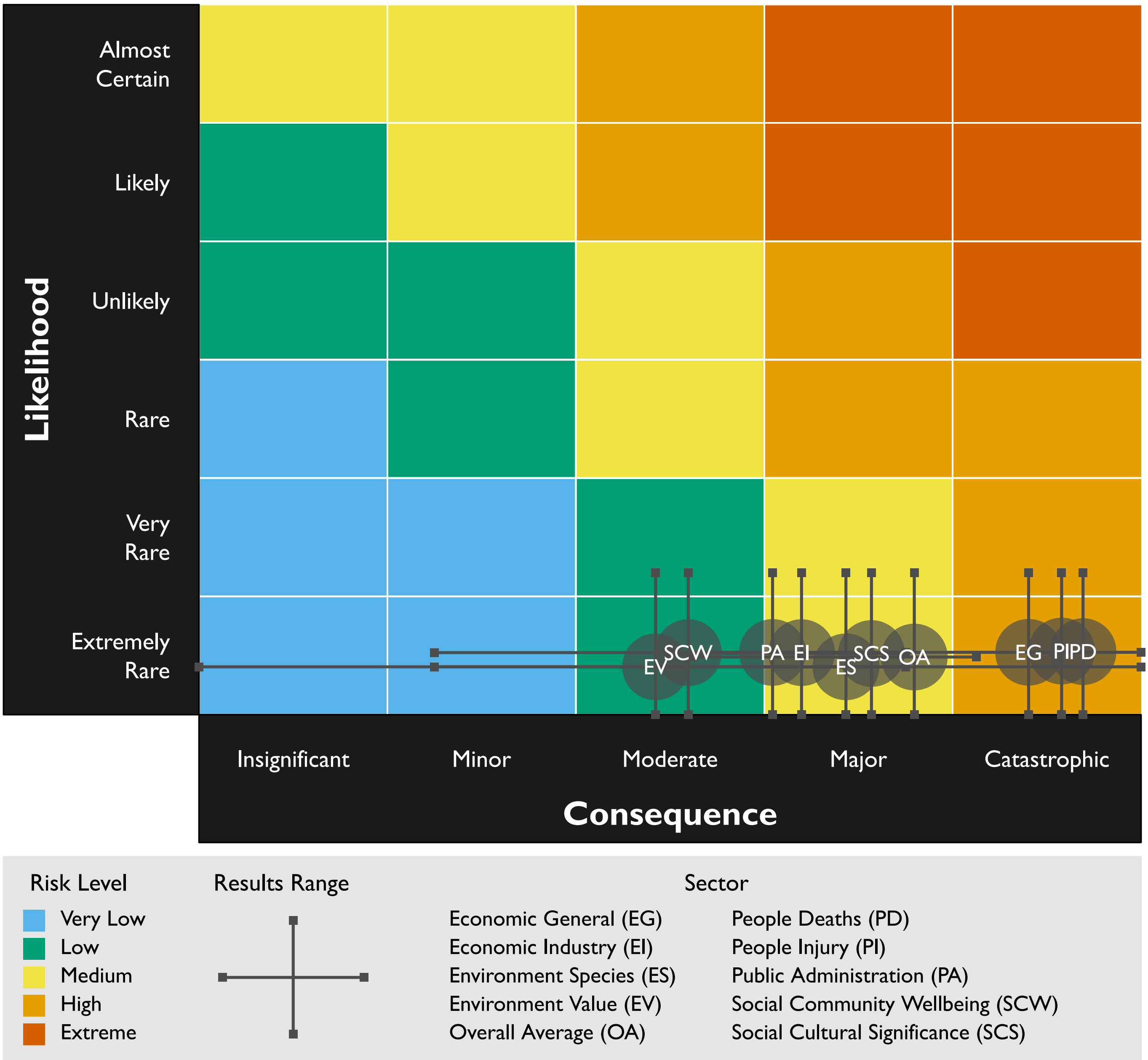
12.8.3 People

The risk of tsunami to people was increased from 'Medium' in TSNDRA 2012 to 'High' in TSNDRA 2016 due to an increase in consequence from 'Major' to 'Catastrophic', despite a decrease in likelihood to 'Extremely Rare'. Experts believed that the rapid onset of this event (less than 3 hours warning in perfect conditions) limited the capacity of the emergency services to inform all vulnerable areas or people and as such it seemed realistic to expect more than 50 deaths or serious injuries. As the region of greatest vulnerability includes the Hobart waterfront, a busy place at regular times throughout the week and year, the evacuation during a large event was also considered. The likelihood of the event was decreased based on the annual exceedance probability defined in the scenario.

12.8.4 Economic

The risk of tsunami to the economy remained unchanged at 'Medium' despite a decrease in the expected likelihood from 'Very Rare' to 'Extremely Rare'.

Figure 12.1 The risk of tsunami to each subsector of society as determined by TSNDRA 2016. The central position is the confidence-weighted-average across working groups for both consequence and likelihood (confidence implied the expertise of the group). The whiskers represent the minimum and maximum ratings across groups.



12.8.5 Environment

The risk of tsunami to the environment was increased from 'Very Low' in TSNDRA 2012 to 'Low' in TSNDRA 2016 due to an increase in expected consequence from 'Insignificant' to 'Moderate'. Experts considered the impact of a tsunami on the coastal and marine ecosystems and identified a number of potential species and habitats that could be at risk. Although coastal habitats have evolved in a construction-destruction-construction cycle, some of these constructive systems have been interrupted by human development or invasive species (both terrestrial and marine). This leaves the existing ecosystem vulnerable to destructive forces with no expectation it would regenerate. Also, a number of exceedingly rare species are only found in waters surrounding south-eastern Tasmania. A significant disruption like a destructive tsunami could result in extinction, although this is just conjecture.

12.8.6 Public administration

The risk of tsunami to public administration remains unchanged at 'Medium' despite a decrease in likelihood from 'Very Rare' in TSNDRA 2012 to 'Extremely Rare' in TSNDRA 2016.

12.8.7 Social setting

The risk of tsunami to social setting remains unchanged at 'Low' despite a decrease in likelihood from 'Very Rare' in TSNDRA 2012 to 'Extremely Rare' in TSNDRA 2016.

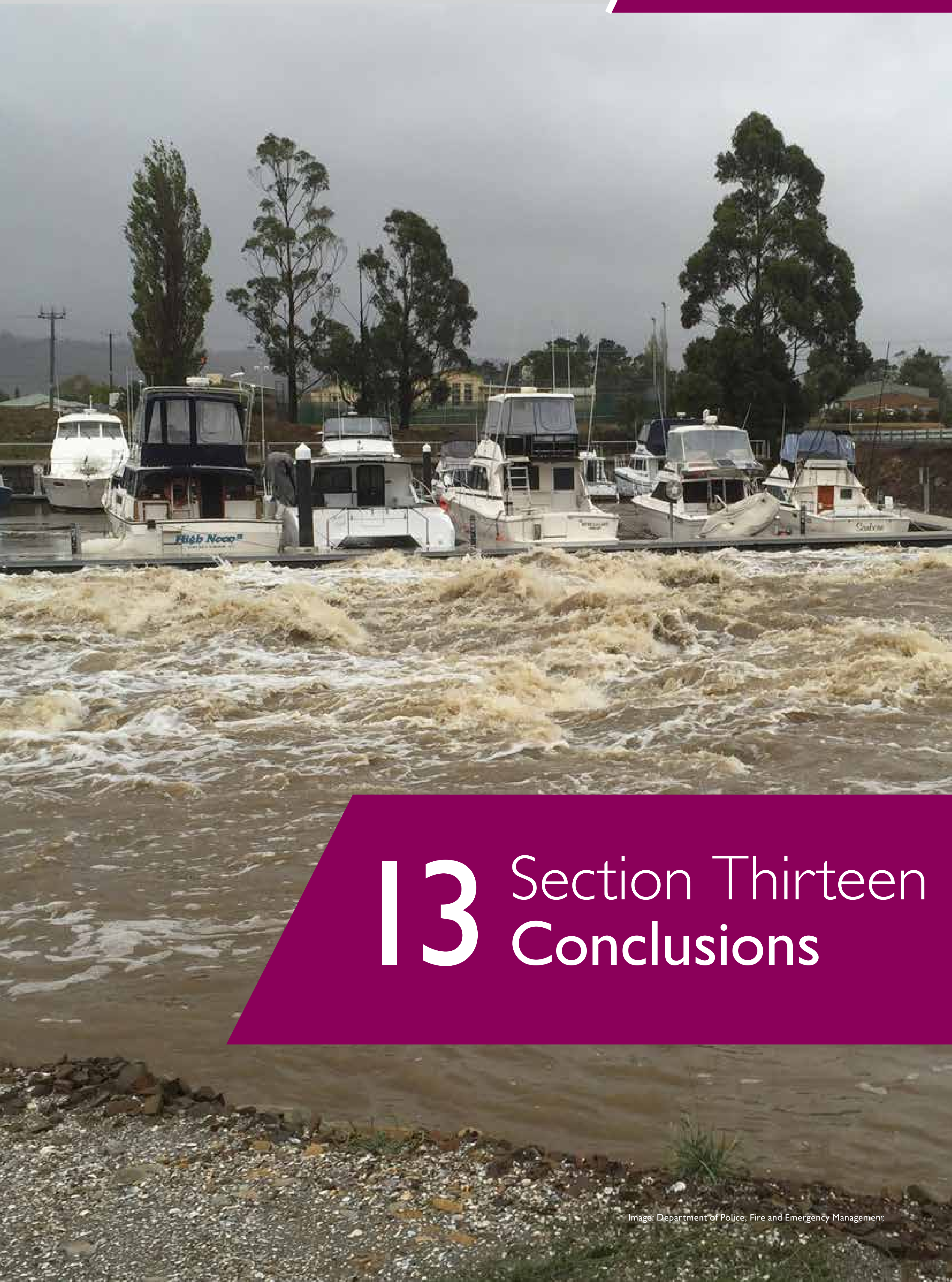
12.9 Tsunami risk register

The tsunami risk register, presented in Appendix B: Risk Register, was created by the project team following the process described in the NERAG 2015.

12.10 Tsunami proposed risk treatment options

It is important to note that the proposed risk treatment options, presented in Appendix C: Proposed Treatment Options, have been developed for the purpose of informing further discussion at SEMC/Management Authority level. It is appropriate that these options be reviewed by the management authorities and referred to SEMC for further decision.

Figure 12.2 Change in tsunami risk level to each sector of society between TSNDRA 2012 and TSNDRA 2016 as rated by the NERAG process.



13 Section Thirteen Conclusions

Image: Department of Police, Fire and Emergency Management.

13 Conclusions

Natural disasters will continue to occur. How we cope as individuals, communities and governments is reliant upon our knowledge of these hazards and the impacts that they may have. By reviewing TSNDRA 2012 and systematically working through an updated risk assessment and management process, we can build upon our understanding of the nature and extent of the risks and therefore improve our control over their impacts.

For governments, this better understanding of risk can help in prioritising the use of limited funds and resources in the most effective way to lessen the consequences and help build resilience.

For individuals, understanding the nature of the hazards and the potential impacts will allow them to share in the responsibility for preparing for, responding to and recovering from disasters.

Disaster resilience is a joint responsibility of government, business, the non-government sector and individuals. By working together with a shared sense of responsibility and focus our efforts will be far more effective.

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Appendices

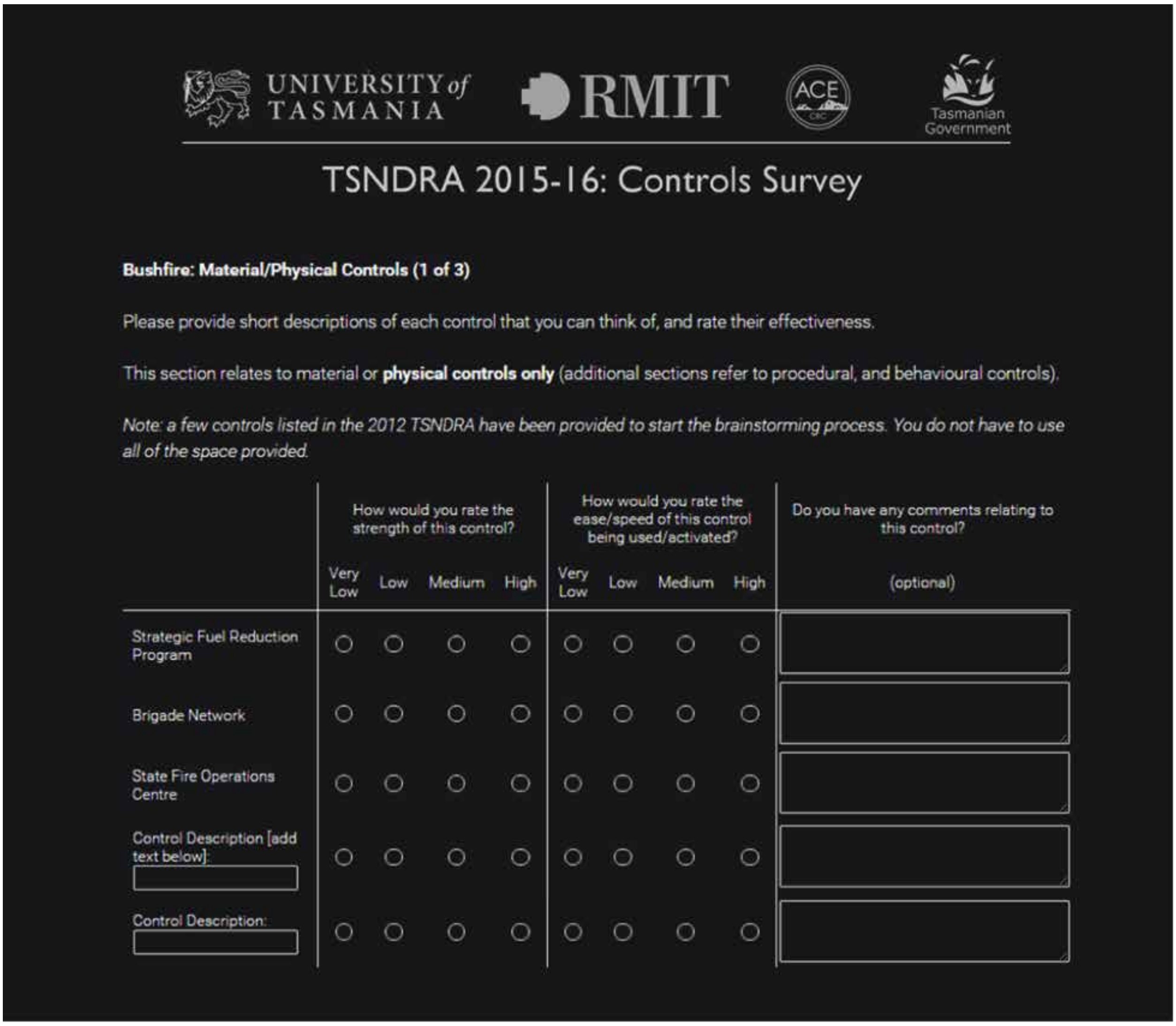
Image: Department of State Growth

Appendix A: Methods

A.1 Initial collation of current controls

Three weeks prior to the workshop series, workshop invitees and relevant experts were asked to participate in a 'Hazard-Specific Controls Survey'. A snapshot of the 'Hazard-Specific Controls Survey' is shown in Figure A.1. The purpose of the survey was to collate a list of state-level controls that acted to reduce the likelihood of consequences occurring. These individual responses were collated for review during the workshop.

Figure A.1 Snapshot of the controls survey used by the review team to obtain data from the workshop participants.



UNIVERSITY of TASMANIA RMIT ACE Tasmanian Government

TSNDRA 2015-16: Controls Survey

Bushfire: Material/Physical Controls (1 of 3)

Please provide short descriptions of each control that you can think of, and rate their effectiveness.

This section relates to material or **physical controls only** (additional sections refer to procedural, and behavioural controls).

Note: a few controls listed in the 2012 TSNDRA have been provided to start the brainstorming process. You do not have to use all of the space provided.

	How would you rate the strength of this control?				How would you rate the ease/speed of this control being used/activated?				Do you have any comments relating to this control?
	Very Low	Low	Medium	High	Very Low	Low	Medium	High	(optional)
Strategic Fuel Reduction Program	○	○	○	○	○	○	○	○	
Brigade Network	○	○	○	○	○	○	○	○	
State Fire Operations Centre	○	○	○	○	○	○	○	○	
Control Description [add text below]:	○	○	○	○	○	○	○	○	
Control Description:	○	○	○	○	○	○	○	○	

A.2 Confirmation and assessment of current controls

The collated list of controls was reviewed by breakout groups. Tasks were to identify duplicates, add missing controls and confirm the strength and expediency of each control. Participants were strongly encouraged to provide rationale and expert opinion for these assessments. This process was worthwhile in itself and prompted some interesting discussions.

A.3 Worst-case scenario consequence rating

These control assessments formed the basis of the central risk analysis activity in each workshop, priming participants to be acutely aware of the current controls before rating the consequences of each hazard scenario. This ensured the outcome of the process was an assessment of *residual* rather than *inherent* risk. With reference to an agreed 'worst-case scenario' for each hazard, participants determined the consequences level in relation to the five NERAG 2015 consequence categories and their sub-categories: (1) People, (2) Economic, (3) Environmental, (4) Public Administration, and (5) Social Setting (see Tables 2.1-2.5 in the main document). Each group was encouraged to note down key points of discussion and the rationale for the chosen rating. Breakout groups were also asked to assess their collective confidence in the rating, using the confidence level descriptions provided by NERAG 2015. In the event of a group feeling they lacked the expertise required, the review team followed up with additional experts in the weeks after the workshop, integrating these results into the process as a separate 'working group'.

A whole-of-workshop discussion and 'report-back' session was used to compare the responses of each breakout group, discuss common themes and identify, where necessary, any additional experts or departments that should be consulted for follow-up information. The group responses were later collated to determine the average rating of each impact category, sector, sub-sector and the hazard risk profile.

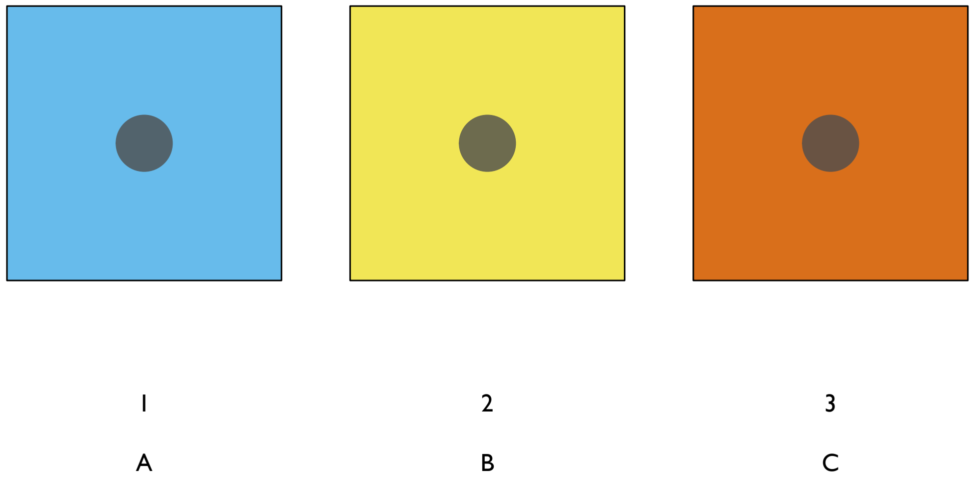
A.4 Averaging multiple categorical responses

With multiple responses to the same task during the assessment, a method that accurately averaged between groups was required. This problem is deceptive, as it appears simple, but basic assumptions can skew results if the data is not handled properly. To illustrate the problem, here are three examples. Using the categories 'A', 'B', 'C'.

Example 1

If results are collected from a single working group, there is no problem; values are discrete categorical values: A=1, B=2, C=3. This can be easily visualised, as can be seen in Figure A.2.

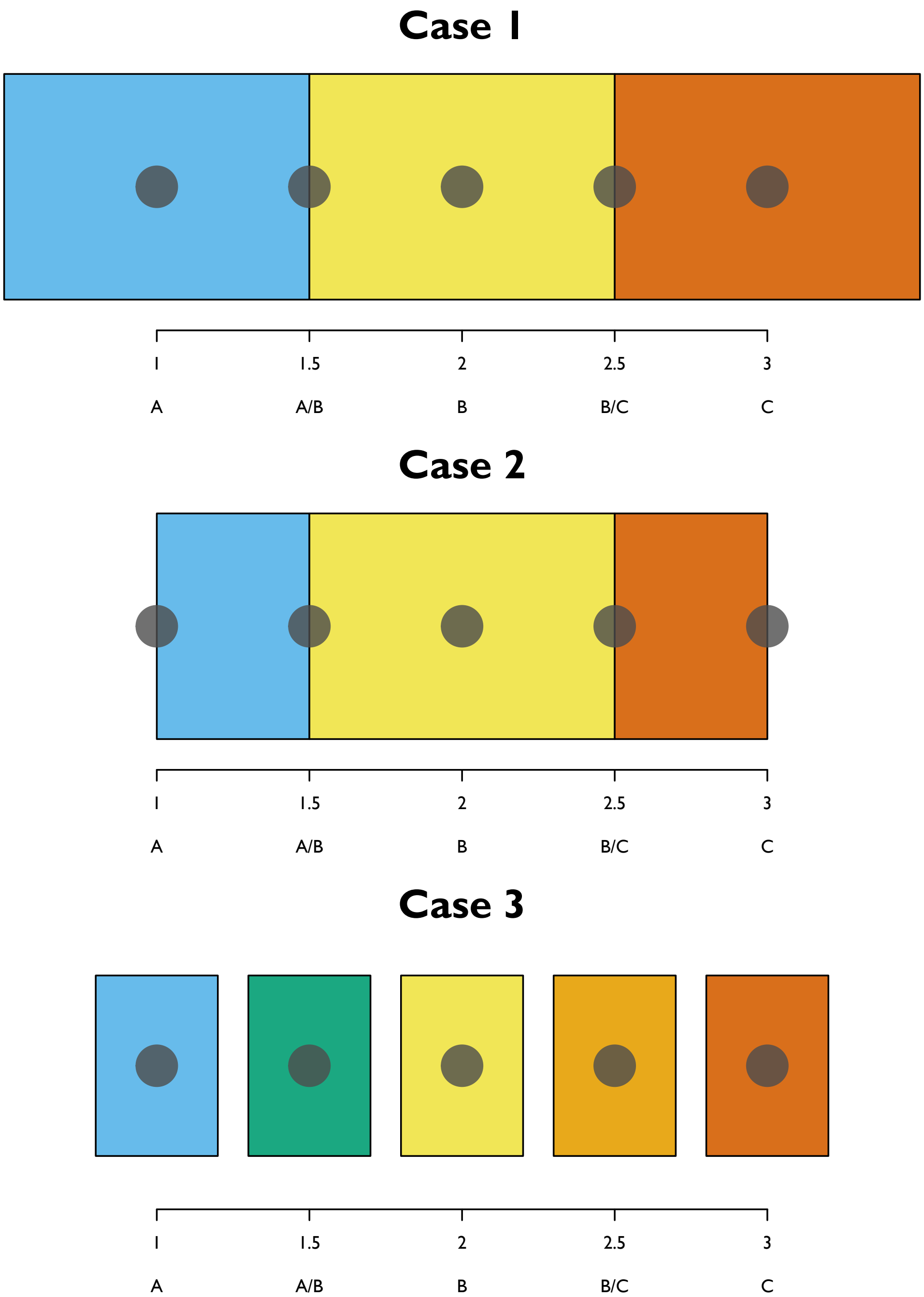
Figure A.2 Example visualisation of simple categorical data collected from a single group. Data are non-continuous, discrete values.



Example 2

If results are collected from two working groups (or from one group who cannot decide on a single categorisation) and a straight average of both groups is sensible (for weighted-average solutions see below), there is a slight problem as half values can occur. If half values are accepted, this has the inherent by-product of creating more categories: A=1, A/B=1.5, B=2, B/C=2.5, C=3. Visualising this data has three basic methods, shown as Cases 1, 2 and 3 in Figure A.3. In Case 1, drawing boxes of the same size (plus/minus 0.5 from integers) seems to make intuitive sense. However, this is incorrect, as it is impossible to get values less than 'A' (or the numeric 1) and greater than 'C' (the numeric 3). So to correctly visualise this instance, Case 2 must be used. This highlights the way the central category 'B' has been over represented in this visualisation. As such, in the instance of 'half values', a decision must made either: to always round up/down to return to the 3 categories (see Figure A.2), ultimately disregarding one group's input; or to create the two new categories 'A/B' and 'B/C' to represent the disagreement between groups, as presented in Case 3. Where each is shown as non-continuous discrete categories.

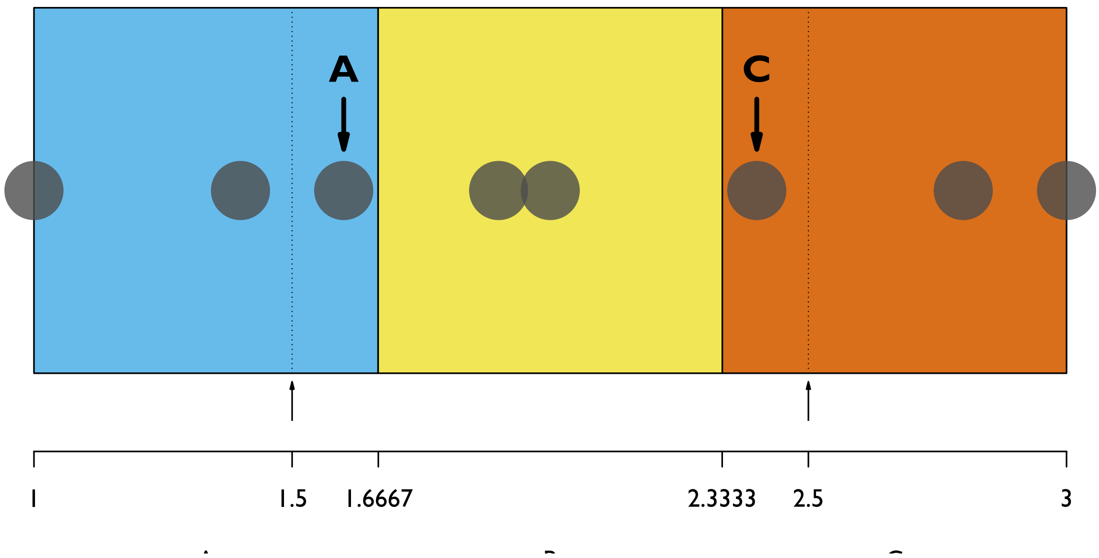
Figure A.3 Example visualisations of inadvertent bias that can occur when applying a non-weighted average to simple categorical data collected from two groups (or from one group who cannot decide on a single categorisation). Case 1 is how it would intuitively be achieved if interpreted as continuous values. Case 2 demonstrates the inadvertent bias introduced using the intuitive approach. Case 3 demonstrates how in this example averaged results should still be treated as non-continuous, discrete values and therefore, presented as such to accurately reflect the indecision/disagreement between groups.



Example 3

If results are collected from three or more groups (or from two groups but requires a weighted-average), averaging values returned can become continuous, (e.g. (1+1+2) / 3 = 1.3333). This means in order to convert continuous values back into categories, data-bins of equal size are required: 1 <= A < 1.6667; 1.6668 < B < 2.3333; 2.3334 < C <= 3. Note how thresholds selected are not midway points between the integers, to account for the fact the minimum and maximum values possible are existing integers. The effect of this approach on categorisation is visualised in Figure A.4. This visualisation is useful for highlighting the importance of using appropriate and accurate binning techniques when summarising categorical data from multiple sources. If the midway point between two integer values is used, the first and last categories are under-represented, as the bins are not of equal size. It is appealing to keep the continuous values to reflect the relative differences between nearby neighbours; however, it is the underlying category that is of interest ('A', 'B', or 'C'), not the numerical value used to identify the appropriate category.

Figure A.4 Example visualisation of how appropriate binning of values can change the final category when incorporating data from multiple working groups.



Appendix B: Risk register

Hazard	Sector	Consequence Rating	Consequence Confidence	Likelihood Rating	Likelihood Confidence	Risk Level	Confidence Table	Priority	Priority if more confident	Category	Risk Code
Bushfire	People Deaths	Major	Highest	Unlikely	High	High	High	2	3	1	TAS-2016-BUS-011
	People Injury	Major	Highest	Likely	High	Extreme	High	2	2	1	TAS-2016-BUS-012
	Economic General	Catastrophic	High	Unlikely	High	Extreme	High	2	2	1	TAS-2016-BUS-021
	Economic Industry	Catastrophic	Highest	Unlikely	High	Extreme	High	2	2	1	TAS-2016-BUS-022
	Environment Species	Major	Highest	Unlikely	High	High	High	2	3	1	TAS-2016-BUS-031
	Environment Value	Major	High	Likely	High	Extreme	High	2	2	1	TAS-2016-BUS-032
	Public Administration	Moderate	Moderate	Likely	Moderate	High	Moderate	2	3	1	TAS-2016-BUS-041
	Social Community Wellbeing	Moderate	High	Unlikely	High	Medium	High	3	4	1	TAS-2016-BUS-051
	Social Cultural Significance	Moderate	Moderate	Likely	High	High	Moderate	2	3	1	TAS-2016-BUS-052
	People Average	Major	Highest	Likely	High	Extreme	High	2	2	1	TAS-2016-BUS-010
	Economic Average	Catastrophic	High	Unlikely	High	Extreme	High	2	2	1	TAS-2016-BUS-020
	Environment Average	Major	Highest	Unlikely	High	High	High	2	3	1	TAS-2016-BUS-030
	Public Administration Average	Moderate	Moderate	Likely	Moderate	High	Moderate	2	3	1	TAS-2016-BUS-040
	Social Average	Moderate	High	Unlikely	High	Medium	High	3	4	1	TAS-2016-BUS-050
	Overall Average	Major	High	Unlikely	High	High	High	2	3	1	TAS-2016-BUS-000

Hazard	Sector	Consequence Rating	Consequence Confidence	Likelihood Rating	Likelihood Confidence	Risk Level	Confidence Table	Priority	Priority if more confident	Category	Risk Code
Coastal Inundation	People Deaths	Major	High	Unlikely	Highest	High	High	2	3	1	TAS-2016-COA-011
	People Injury	Minor	Highest	Unlikely	High	Low	High	4	5	1	TAS-2016-COA-012
	Economic General	Major	High	Unlikely	Highest	High	High	2	3	1	TAS-2016-COA-021
	Economic Industry	Minor	High	Unlikely	Highest	Low	High	4	5	1	TAS-2016-COA-022
	Environment Species	Moderate	Highest	Unlikely	Highest	Medium	Highest	4	4	1	TAS-2016-COA-031
	Environment Value	Moderate	Highest	Unlikely	Highest	Medium	Highest	4	4	1	TAS-2016-COA-032
	Public Administration	Minor	Highest	Unlikely	Highest	Low	Highest	5	5	3	TAS-2016-COA-041
	Social Community Wellbeing	Minor	High	Unlikely	Highest	Low	High	4	5	1	TAS-2016-COA-051
	Social Cultural Significance	Major	High	Unlikely	Highest	High	High	2	3	1	TAS-2016-COA-052
	People Average	Moderate	High	Unlikely	Highest	Medium	High	3	4	1	TAS-2016-COA-010
	Economic Average	Moderate	High	Unlikely	Highest	Medium	High	3	4	1	TAS-2016-COA-020
	Environment Average	Moderate	Highest	Unlikely	Highest	Medium	Highest	4	4	1	TAS-2016-COA-030
	Public Administration Average	Minor	Highest	Unlikely	Highest	Low	Highest	5	5	3	TAS-2016-COA-040
	Social Average	Moderate	High	Unlikely	Highest	Medium	High	3	4	1	TAS-2016-COA-050
	Overall Average	Moderate	High	Unlikely	Highest	Medium	High	3	4	1	TAS-2016-COA-000

Hazard	Sector	Consequence Rating	Consequence Confidence	Likelihood Rating	Likelihood Confidence	Risk Level	Confidence Table	Priority	Priority if more confident	Category	Risk Code
Earthquake	People Deaths	Moderate	High	Extremely Rare	Highest	Low	High	5	5	3	TAS-2016-EAR-011
	People Injury	Moderate	Moderate	Extremely Rare	Highest	Low	Moderate	4	5	1	TAS-2016-EAR-012
	Economic General	Major	High	Extremely Rare	Highest	Medium	High	4	4	1	TAS-2016-EAR-021
	Economic Industry	Major	High	Extremely Rare	Highest	Medium	High	4	4	1	TAS-2016-EAR-022
	Environment Species	Moderate	Moderate	Extremely Rare	Highest	Low	Moderate	4	5	1	TAS-2016-EAR-031
	Environment Value	Major	Moderate	Extremely Rare	Highest	Medium	Moderate	3	4	1	TAS-2016-EAR-032
	Public Administration	Major	High	Extremely Rare	Highest	Medium	High	4	4	1	TAS-2016-EAR-041
	Social Community Wellbeing	Moderate	High	Extremely Rare	Highest	Low	High	5	5	3	TAS-2016-EAR-051
	Social Cultural Significance	Moderate	Moderate	Extremely Rare	Highest	Low	Moderate	4	5	1	TAS-2016-EAR-052
	People Average	Moderate	Moderate	Extremely Rare	Highest	Low	Moderate	4	5	1	TAS-2016-EAR-010
	Economic Average	Major	High	Extremely Rare	Highest	Medium	High	4	4	1	TAS-2016-EAR-020
	Environment Average	Major	Moderate	Extremely Rare	Highest	Medium	Moderate	3	4	1	TAS-2016-EAR-030
	Public Administration Average	Major	High	Extremely Rare	Highest	Medium	High	4	4	1	TAS-2016-EAR-040
	Social Average	Moderate	Moderate	Extremely Rare	Highest	Low	Moderate	4	5	1	TAS-2016-EAR-050
	Overall Average	Major	High	Extremely Rare	Highest	Medium	High	4	4	1	TAS-2016-EAR-000

Hazard	Sector	Consequence Rating	Consequence Confidence	Likelihood Rating	Likelihood Confidence	Risk Level	Confidence Table	Priority	Priority if more confident	Category	Risk Code
Flood	People Deaths	Catastrophic	High	Very Rare	Highest	High	High	3	3	1	TAS-2016-FLO-011
	People Injury	Major	High	Very Rare	Highest	Medium	High	3	4	1	TAS-2016-FLO-012
	Economic General	Major	Moderate	Rare	Highest	High	Moderate	2	3	1	TAS-2016-FLO-021
	Economic Industry	Major	Moderate	Rare	Highest	High	Moderate	2	3	1	TAS-2016-FLO-022
	Environment Species	Major	High	Rare	High	High	High	3	3	1	TAS-2016-FLO-031
	Environment Value	Major	High	Rare	High	High	High	3	3	1	TAS-2016-FLO-032
	Public Administration	Major	High	Rare	Highest	High	High	3	3	1	TAS-2016-FLO-041
	Social Community Wellbeing	Moderate	Highest	Rare	Highest	Medium	Highest	5	5	3	TAS-2016-FLO-051
	Social Cultural Significance	Major	High	Rare	Highest	High	High	3	3	1	TAS-2016-FLO-052
	People Average	Major	High	Very Rare	Highest	Medium	High	3	4	1	TAS-2016-FLO-010
	Economic Average	Major	Moderate	Rare	Highest	High	Moderate	2	3	1	TAS-2016-FLO-020
	Environment Average	Major	High	Rare	High	High	High	3	3	1	TAS-2016-FLO-030
	Public Administration Average	Major	High	Rare	Highest	High	High	3	3	1	TAS-2016-FLO-040
	Social Average	Moderate	Highest	Rare	Highest	Medium	Highest	5	5	3	TAS-2016-FLO-050
	Overall Average	Major	High	Rare	Highest	High	High	3	3	1	TAS-2016-FLO-000

Hazard	Sector	Consequence Rating	Consequence Confidence	Likelihood Rating	Likelihood Confidence	Risk Level	Confidence Table	Priority	Priority if more confident	Category	Risk Code
Heatwave	People Deaths	Major	High	Likely	High	Extreme	High	2	2	1	TAS-2016-HEA-011
	People Injury	Moderate	High	Likely	High	High	High	3	4	1	TAS-2016-HEA-012
	Economic General	Moderate	Low	Likely	Moderate	High	Low	2	2	1	TAS-2016-HEA-021
	Economic Industry	Minor	Moderate	Likely	Moderate	Medium	Moderate	3	4	1	TAS-2016-HEA-022
	Environment Species	Minor	High	Likely	High	Medium	High	4	4	1	TAS-2016-HEA-031
	Environment Value	Insignificant	High	Likely	High	Low	High	4	5	1	TAS-2016-HEA-032
	Public Administration	Minor	High	Likely	High	Medium	High	4	4	1	TAS-2016-HEA-041
	Social Community Well-being	Insignificant	Highest	Likely	High	Low	High	4	5	1	TAS-2016-HEA-051
	Social Cultural Significance	Minor	High	Likely	High	Medium	High	4	4	1	TAS-2016-HEA-052
	People Average	Major	High	Likely	High	Extreme	High	2	2	1	TAS-2016-HEA-010
	Economic Average	Moderate	Moderate	Likely	Moderate	High	Moderate	2	3	1	TAS-2016-HEA-020
	Environment Average	Minor	High	Likely	High	Medium	High	4	4	1	TAS-2016-HEA-030
	Public Administration Average	Minor	High	Likely	High	Medium	High	4	4	1	TAS-2016-HEA-040
	Social Average	Insignificant	Highest	Likely	High	Low	High	4	5	1	TAS-2016-HEA-050
	Overall Average	Minor	High	Likely	High	Medium	High	4	4	1	TAS-2016-HEA-000

Hazard	Sector	Consequence Rating	Consequence Confidence	Likelihood Rating	Likelihood Confidence	Risk Level	Confidence Table	Priority	Priority if more confident	Category	Risk Code
Landslide	People Deaths	Major	Highest	Rare	Highest	High	Highest	3	3	1	TAS-2016-LAN-011
	People Injury	Major	Highest	Rare	Highest	High	Highest	3	3	1	TAS-2016-LAN-012
	Economic General	Moderate	High	Unlikely	High	Medium	High	3	4	1	TAS-2016-LAN-021
	Economic Industry	Insignificant	Highest	Likely	Highest	Low	Highest	5	5	3	TAS-2016-LAN-022
	Environment Species	Insignificant	Highest	Unlikely	Highest	Low	Highest	5	5	3	TAS-2016-LAN-031
	Environment Value	Insignificant	Highest	Unlikely	Highest	Low	Highest	5	5	3	TAS-2016-LAN-032
	Public Administration	Insignificant	Highest	Unlikely	Highest	Low	Highest	5	5	3	TAS-2016-LAN-041
	Social Community Wellbeing	Minor	Highest	Rare	Highest	Low	Highest	5	5	3	TAS-2016-LAN-051
	Social Cultural Significance	Insignificant	Highest	Unlikely	Highest	Low	Highest	5	5	3	TAS-2016-LAN-052
	People Average	Major	Highest	Rare	Highest	High	Highest	3	3	1	TAS-2016-LAN-010
	Economic Average	Minor	Highest	Unlikely	Highest	Low	Highest	5	5	3	TAS-2016-LAN-020
	Environment Average	Insignificant	Highest	Unlikely	Highest	Low	Highest	5	5	3	TAS-2016-LAN-030
	Public Administration Average	Insignificant	Highest	Unlikely	Highest	Low	Highest	5	5	3	TAS-2016-LAN-040
	Social Average	Insignificant	Highest	Rare	Highest	Very Low	Highest	5	5	3	TAS-2016-LAN-050
	Overall Average	Minor	Highest	Unlikely	Highest	Low	Highest	5	5	3	TAS-2016-LAN-000

Hazard	Sector	Consequence Rating	Consequence Confidence	Likelihood Rating	Likelihood Confidence	Risk Level	Confidence Table	Priority	Priority if more confident	Category	Risk Code
Pandemic Influenza	People Deaths	Catastrophic	Highest	Unlikely	Highest	Extreme	Highest	2	2	1	TAS-2016-PAN-011
	People Injury	Catastrophic	Highest	Unlikely	Highest	Extreme	Highest	2	2	1	TAS-2016-PAN-012
	Economic General	Moderate	High	Unlikely	Highest	Medium	High	3	4	1	TAS-2016-PAN-021
	Economic Industry	Moderate	High	Unlikely	Highest	Medium	High	3	4	1	TAS-2016-PAN-022
	Environment Species	Insignificant	Highest	Unlikely	Highest	Low	Highest	5	5	3	TAS-2016-PAN-031
	Environment Value	Insignificant	Highest	Unlikely	Highest	Low	Highest	5	5	3	TAS-2016-PAN-032
	Public Administration	Major	High	Unlikely	Highest	High	High	2	3	1	TAS-2016-PAN-041
	Social Community Wellbeing	Minor	High	Unlikely	Highest	Low	High	4	5	1	TAS-2016-PAN-051
	Social Cultural Significance	Minor	Highest	Unlikely	Highest	Low	Highest	5	5	3	TAS-2016-PAN-052
	People Average	Catastrophic	Highest	Unlikely	Highest	Extreme	Highest	2	2	1	TAS-2016-PAN-010
	Economic Average	Moderate	High	Unlikely	Highest	Medium	High	3	4	1	TAS-2016-PAN-020
	Environment Average	Insignificant	Highest	Unlikely	Highest	Low	Highest	5	5	3	TAS-2016-PAN-030
	Public Administration Average	Major	High	Unlikely	Highest	High	High	2	3	1	TAS-2016-PAN-040
	Social Average	Minor	Highest	Unlikely	Highest	Low	Highest	5	5	3	TAS-2016-PAN-050
	Overall Average	Moderate	Highest	Unlikely	Highest	Medium	Highest	4	4	1	TAS-2016-PAN-000

Hazard	Sector	Consequence Rating	Consequence Confidence	Likelihood Rating	Likelihood Confidence	Risk Level	Confidence Table	Priority	Priority if more confident	Category	Risk Code
Severe Storm	People Injury	Minor	High	Likely	Highest	Medium	High	4	4	1	TAS-2016-STO-012
	Economic General	Moderate	Highest	Likely	Highest	High	Highest	4	4	1	TAS-2016-STO-021
	Economic Industry	Moderate	Highest	Likely	Highest	High	Highest	4	4	1	TAS-2016-STO-022
	Environment Species	Insignificant	High	Unlikely	Moderate	Low	Moderate	4	5	1	TAS-2016-STO-031
	Environment Value	Minor	High	Unlikely	Moderate	Low	Moderate	4	4	1	TAS-2016-STO-032
	Public Administration	Minor	Highest	Unlikely	Highest	Low	Highest	5	5	3	TAS-2016-STO-041
	Social Community Wellbeing	Minor	Highest	Unlikely	High	Low	High	4	5	1	TAS-2016-STO-051
	Social Cultural Significance	Major	High	Likely	Highest	Extreme	High	2	2	1	TAS-2016-STO-052
	People Average	Moderate	Highest	Likely	Highest	High	Highest	4	4	1	TAS-2016-STO-010
	Economic Average	Moderate	Highest	Likely	Highest	High	Highest	4	4	1	TAS-2016-STO-020
	Environment Average	Minor	High	Unlikely	Moderate	Low	Moderate	4	4	1	TAS-2016-STO-030
	Public Administration Average	Minor	Highest	Unlikely	Highest	Low	Highest	5	5	3	TAS-2016-STO-040
	Social Average	Moderate	Highest	Unlikely	Highest	Medium	Highest	4	4	1	TAS-2016-STO-050
	Overall Average	Moderate	Highest	Likely	High	High	High	3	4	1	TAS-2016-STO-000

Hazard	Sector	Consequence Rating	Consequence Confidence	Likelihood Rating	Likelihood Confidence	Risk Level	Confidence Table	Priority	Priority if more confident	Category	Risk Code
Tsunami	People Deaths	Catastrophic	Highest	Extremely Rare	Highest	High	Highest	4	4	1	TAS-2016-TSU-011
	People Injury	Catastrophic	Highest	Extremely Rare	Highest	High	Highest	4	4	1	TAS-2016-TSU-012
	Economic General	Catastrophic	High	Extremely Rare	Highest	High	High	3	4	1	TAS-2016-TSU-021
	Economic Industry	Major	High	Extremely Rare	Highest	Medium	High	4	4	1	TAS-2016-TSU-022
	Environment Species	Major	Moderate	Extremely Rare	Highest	Medium	Moderate	3	4	1	TAS-2016-TSU-031
	Environment Value	Moderate	Moderate	Extremely Rare	Highest	Low	Moderate	4	5	1	TAS-2016-TSU-032
	Public Administration	Major	Highest	Extremely Rare	Highest	Medium	Highest	4	4	1	TAS-2016-TSU-041
	Social Community Wellbeing	Moderate	High	Extremely Rare	Highest	Low	High	5	5	3	TAS-2016-TSU-051
	Social Cultural Significance	Major	Highest	Extremely Rare	Highest	Medium	Highest	4	4	1	TAS-2016-TSU-052
	People Average	Catastrophic	Highest	Extremely Rare	Highest	High	Highest	4	4	1	TAS-2016-TSU-010
	Economic Average	Major	High	Extremely Rare	Highest	Medium	High	4	4	1	TAS-2016-TSU-020
	Environment Average	Moderate	Moderate	Extremely Rare	Highest	Low	Moderate	4	5	1	TAS-2016-TSU-030
	Public Administration Average	Major	Highest	Extremely Rare	Highest	Medium	Highest	4	4	1	TAS-2016-TSU-040
	Social Average	Moderate	Highest	Extremely Rare	Highest	Low	Highest	5	5	3	TAS-2016-TSU-050
	Overall Average	Major	Highest	Extremely Rare	Highest	Medium	Highest	4	4	1	TAS-2016-TSU-000

Appendix C: Proposed treatment options

	Treatment	
Bushfire	Improve the strategic resource-to-risk skills mix (recruitment, retention, capacity), including investigating difference models of volunteering within the TFS Brigade Network.	Continue the Fuel Reduction Program.
	Monitor effectiveness of new Land Use Planning and Building System reforms to evaluate effectiveness of delivering desired outcomes.	Review legislation relating to Fuel Stove only areas, Fire Permit System and Total Fire Bans to ensure appropriate incentives to modify individuals' behaviour.
	Continue the development and implementation of community level Bushfire Mitigation Plans.	Build capacity to enable IMTs to manage the likely increased frequency and intensity of major fire events.
	Continue the Bushfire Ready Neighbourhoods Program.	Maintain adequate seasonal fire crew resources across the fire agencies.
	Consider outcomes of national review of warnings and review resilience of warning systems' infrastructure.	Develop, implement, review and exercise inter-agency community evacuation and recovery plans across the State.
	Continue the Community Bushfire Protection Program with a renewed focus on vulnerable groups.	Introduce child-centred household level disaster risk reduction strategies in school programs.
	Expand the existing Fire Ready Schools Program with enhanced support and incorporate other sites used by vulnerable groups.	
Coastal Inundation	Assess vulnerability of ecosystems and species to coastal inundation.	Review coastal inundation evacuation and response plans.
	Utilise coastal mapping to assess need for coastal defences.	Assess options for managed coastal retreat.
	Develop coastal inundation education materials that meet the needs of exposed communities.	Improve understanding of the weather systems that cause storm surge events to improve predictability and warnings.
	Improve the understanding of the vulnerability of critical infrastructure.	Improve understanding of how coastal inundation events interact with riverine flood events.
	Include consideration of coastal inundation in land use planning for new developments and uses.	Make coastal mapping available to public.
	Improve understanding of the allocation of ownership across government, business and individuals.	Improve beach morphology mapping to understand coastal inundation, including post-event surveys.
	Review building controls to ensure they are adaptive to changing coastal inundation risks.	
Earthquake	Review seismic monitoring network alert systems to ensure emergency managers are on the contact lists.	Exercise time-critical decision making processes within the context of an earthquake scenario.
	Review all hazards response and recovery plans to ensure they address likely earthquake consequences.	Improve the coordination and delivery of the National seismic monitoring program.
	Develop a strategic plan for the operation and management of the seismic monitoring network in Tasmania.	Develop and deliver earthquake hazard awareness products.
	Develop enablers and capacity for Tasmanian earthquake risk owners.	Review the allocation of responsibilities for earthquake risk management.

	Treatment	
Flood	Identify and anlalyse the location of critical infrastructure within defined flood areas.	Integrate clean-up arrangements into emergency plans.
	Actively manage riparian vegetation to manage flood dynamics.	State to develop a Swift Water rescue capability.
	Integrate Storage Operating Rules with downstream flood response plans.	Integrate non-government entities into emergency response and recovery arrangements.
	Promote the use of Water Sensitive Urban Design in stormwater systems.	Build flood capable infrastructure.
	Develop flood evacuation plans for at risk communities.	Review legal liability of participants in prevention and mitigation preparedness, response and recovery activities.
	Develop a statewide flood hazard map for use within the Tasmanian Planning System.	Improve maintenance of flood mitigation infrastructure.
	Raised access routes.	Review flood response sustainment capacity of organisations.
	Integrate existing capabilities into a Total Flood Warning System.	Assess water supply resilience in the case of an interruption.
	Develop and implement a targeted community flood awareness program.	Improve insurance affordability.
	Develop and deliver flood incident response management training to SES personnel.	Review temporary bridge stockpile for adequacy (DSG).
	Review environmental risks associated with hazardous uses within flood prone areas.	Increase SES Capability and Capacity to respond to flood event.
	Ensure appropriate levels of insurance of public assets from flood risks.	Locate and design new public infrastructure so that it can continue to operate during flood events.
	Deliver Flood Studies.	

Heatwave	Improve knowledge and understanding of the effect heatwaves coinciding with other hazard events have on the effectiveness and capability of response and recovery capabilities	Develop innovative response models of patient care to improve surge capacity.
	Exercise heatwave arrangements with a focus on the public administration sector and management of vulnerable people	Improve information about electricity demand during heatwaves .
	Identify facilities that can be used as cool spaces during heatwaves and establish linkages between operators and emergency management organisations	Quantify the effect of heatwaves on vulnerable people.
	Develop arrangements to identify and communicate with people vulnerable to heat stress,	Incorporate heatwave surge response planning into business continuity planning.
	Review community information and warning systems to ensure they cater for heatwave messages	Improve community educational information.
	Create a stakeholder plan template to aid heatwave preparedness and response in facilities occupied by people vulnerable to heatwaves (e.g. nursing homes)	Include heatwave in existing preparedness programs.

	Treatment	
Landslide	Provide information on landslide hazards and risks to decision makers.	Investigate the potential effectiveness of economic and financial mechanisms to manage the risk appetites of land owners.
	Make property level information on landslide hazards publicly available	Incentivising safer sites (charge people less rates and discounts for defensive actions by land managers).
	Monitor effectiveness of new Land Use Planning reforms to evaluate effectiveness of delivering desired outcomes.	Raise public awareness of the limitations of general insurance relating to landslide.
	Nuance the exercises for flood / dam-break / debris flow to incorporate consideration.	Conduct research into changes of owners' and occupiers stated and revealed risk tolerance and preference for treatment measures before and after natural hazard events.
	Further development of Landslide Hazard Banding of the State (MRT).	Pro-actively manage landslide areas.
	Development mechanisms to support small councils to manage treatment across the PPRR spectrum (across all hazards).	Ensure landuse planning and building systems, including appeal mechanisms, are transparent, equitable and integrated at the municipal, State and national levels.
	Increased regulation of landslide risk assessment.	Establish arrangements to enable the buy-back of specified landslip prone land.
	Assessment of council's capacity to manage land effectively.	Undertake local level emergency management planning for areas at risk of debris flow.
	Develop linkages between landslide risk assessors and building engineers/structural works.	

Pandemic Influenza	Personal protective equipment (masks, gowns, gloves, goggles) – enhance stocktake methods.	Review Tas Govt interoperability arrangements.
	Personal protective equipment (masks, gowns, gloves, goggles) – review supply/distribution arrangements.	Encourage businesses to consider human influenza pandemics in business continuity planning.
	Personal protective equipment (masks, gowns, gloves, goggles) – review fit-testing vs fit-checking.	Deliver human influenza pandemic training and exercises in THS and other key organisations.
	Review Ambulance Tasmania surge capacity.	Advocate for an National Notifiable Diseases Database.
	Provide training sessions to GPs to improve their understanding of their roles, options and obligations relating to human influenza pandemic.	Improve integration of health information systems.
	Clarify the relationship between the DHHS and THS in the establishment of flu services.	Develop a disaster client record system.
	Enhance business continuity planning by the Tasmanian Health Service.	Implement a database management approach for notifiable disease record systems.
	Develop a flexible plan for establishing flu-specific services.	Test the Biosecurity Act 2015.
	Review and exercise the Tasmanian Mass Vaccination Plan.	Implement a social marking program to promote improved respiratory etiquette and hygiene.
	Review State Special Emergency Plan: Human Influenza Pandemic Emergencies.	Relax the requirement for medical certificates in the event of an outbreak.

	Treatment	
Severe Storm	Ensure people designing and certifying buildings are appropriately trained and qualified.	Undertake inter-agency severe storm exercises.
	Continue the enhancement of forecast and warning services.	Enhance the community development program.
	Develop and implement a community storm safe awareness program.	Establish emergency services ICT redundancy arrangements for damage loss of communications infrastructure.
	Review volunteering arrangements to improve recruitment and retention.	Up-skill isolated communities in emergency PPRR skills.
	Improve working relationship with the insurance industry to access impact information.	Develop SOP for recovery package.
	Review interagency information sharing arrangements.	Develop and exercise Severe Storm Emergency Management Plan.
	Develop capacity to utilise the new high-resolution satellite products now available.	Develop a community education strategy for when to call 000, 131 444, and 132 500.
	Formalise response triage arrangements.	Identify and analyse statewide storm hazard risk.
	Engage with industry bodies to explore opportunities to better understand and manage risks.	

Tsunami	Increase understanding of the Puysegur Trench dynamics to improve certainty around the likelihood and magnitude of future Tsunamis.	Deliver updated inundation mapping.
	Investigate the costs and benefits in enhancing the current Tsunami detection buoy network.	Investigate the costs and benefits of delivering a public education and awareness program.
	Investigate usefulness of satellite data for PPRR planning.	Review current all-hazards emergency management arrangements to evaluate if they adequately address Tsunami response and recovery requirements.
	Ensure sufficient investment in controls across the PPRR spectrum with a focus on Prevention and Mitigation.	Extend current tsunami maritime hazard modelling project to deliver coastal inundation modelling.
	Investigate the costs and benefits in enhancing the current Tsunami warning arrangements with signage and audible warning systems at key exposed locations (e.g. Port Arthur and Kingston Beach).	