METROPOLITAN EMERGENCY MANAGEMENT DISTRICTS

Risk assessment report

'Highlighting potential disaster impacts'

NORTH METROPOLITAN
DISTRICT EMERGENCY MANAGEMENT COMMITTEE

CENTRAL METROPOLITAN
DISTRICT EMERGENCY MANAGEMENT COMMITTEE

EAST METROPOLITAN
DISTRICT EMERGENCY MANAGEMENT COMMITTEE

SOUTH METROPOLITAN
DISTRICT EMERGENCY MANAGEMENT COMMITTEE

Disclaimer:

The risk assessment results discussed in this report are based explicitly on the credible worst-case hazard scenarios outlined in Section 2 and the views of those who participated in each risk assessment workshop. Risks and impacts other than those discussed here are possible depending on the nature of future hazards.

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Front and back cover: Aerial view of Cottesloe Beach - courtesy of Garry Norris Photography.

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SEMC
STATE EMERGENCY MANAGEMENT COMMITTEE

State Risk Project

An Australian Government Initiative

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Executive summary

This document summarises the results of the *State Risk Project* risk assessment workshops in the Metropolitan Emergency Management (EM) districts. It covers seven priority hazards as identified by the Metropolitan District Emergency Management Committees (DEMCs): fire (for this assessment only bushfire was considered and is hereafter referred to as bushfire), cyclone, earthquake, flood, HAZMAT, heatwave and storm. The effects of these hazards were measured against five key impact areas (economy, public administration, people, environment and social setting) using 358 specific risks, called risk statements. The Perth metropolitan area is separated into four EM districts: North, South, East and Central. For the purpose of the risk assessment process, the four districts were combined to provide an understanding across the entire metropolitan region.

Within the emergency risk management process, this report sits between the risk analysis and risk evaluation steps as it presents the results of the analysis to stakeholders in order for them to evaluate which risks require treatment (Figure 1).

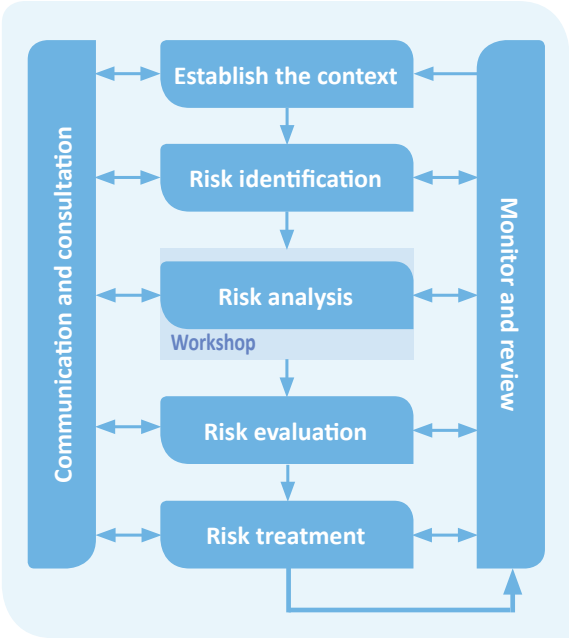


Figure 1: Emergency risk management process.[1]

Forty-one agencies were represented throughout the workshop series which followed the methodology and criteria outlined in the *WA Emergency Risk Management Guide 2015* and the *National Emergency Risk Assessment Guidelines 2015 (NERAG)*[2]. The risk statements were assessed using a tailored *NERAG* consequence table (Appendix C), which is based on the gross area product ($189.78 billion) and the population (2.2 million) of the EM district.

[1] Adapted from AS/NZS ISO 31000 - Reproduced under SAI Global copyright Licence 1411-c083
[2] *National Emergency Risk Assessment Guidelines* (2015) Australian Government Attorney-General's Department

The results reveal that 9% of the risks assessed were high risk, 29% were medium, 46% low, and 16% very low. There were no extreme risks for the metropolitan region. Fewer than 4% of risks had catastrophic consequences and all of these were a result of the earthquake scenario.

Each impact area had risks ranging from high to very low. The people area had the greatest number of high risks (16%) of all the impact areas. Most of these risks focused on deaths and injuries caused by the earthquake and HAZMAT scenarios, but all hazards were anticipated to cause at least three deaths. The impact area with the lowest percentage of high risks was social setting (1%). With the exception of heatwave, the risks for each hazard were assessed to range from high to very low. Heatwave was limited to medium (13%) and low risks (87%).

A significant hazard to the metropolitan region is the earthquake scenario, with 23% of its risk statements being evaluated as high. It is estimated that at least 22 deaths and 508 serious injuries could occur. Damage to buildings was anticipated to be significant, with estimates of 30% of the metropolitan building stock sustaining moderate to complete damage. More specifically, damage to heritage buildings could result in permanent loss of objects of identified cultural significance. The earthquake is also likely to cause damage to roads and create a high demand for materials which may increase repair costs. Road damage, congestion and increased travel times may cause people and freight to be delayed, increasing costs for many industries, including the mining sector. It should be noted that if the earthquake damaged a hospital (more likely Fremantle or Rockingham Hospitals due to their close proximity to the epicentre) the health system would become stretched as there is no capacity for existing patients to be moved.

The earthquake scenario also presents the highest risks to the environment, along with the cyclone scenario. Potential contamination of the environment from the spillage of chemicals, and release of raw sewerage and asbestos from damaged buildings, is a high risk for earthquake. The cyclone is anticipated to cause significant erosion along beaches, impacting various ecosystems and causing a loss of aesthetic value. In both cases, intervention programs would be required in some areas to restore environmental value.

The aviation industry has two notable risks. The cyclone scenario could cause extensive damage to aircraft and result in repair and replacement costs and an inability to maintain passenger demand in the short term. Some aircraft may be flown out prior to the cyclone arriving, but there is typically millions to billions of dollars of aircraft assets at the airport at any one time. When assessing this statement Perth Airport considered the 1999 Sydney hail storm, which damaged aircraft. The HAZMAT scenario poses a medium risk to fuel supplies for aircraft, as typically only one day's fuel is kept on site and the scenario could disrupt re-supply.

As a utility, the metropolitan power supply would be the most impacted in these scenarios. Both the storm and cyclone scenarios were evaluated to pose high risks to the power

supply. Western Power commented that storm events with high winds and lightning often cause significant damage to overhead power infrastructure. Response and repair activities could take multiple days and Western Power would need to manage staff member fatigue. Impacts to power will also have flow-on impacts to communications, water and sewage systems, particularly if power is disrupted for a long time. This is in addition to any physical damage caused to the infrastructure.

During the cyclone, earthquake, flood, HAZMAT and storm scenarios, response and recovery agencies (Department for Child Protection and Family Support, Department of Fire and Emergency Services, WA Police, ambulance services and the Department of Health) would be impacted, with some anticipating that they would be unable to provide core services to their normal level. The scale of these events exceeds normal planning measures. In addition, staff members of the agencies would likely be managing their own personal affairs and may not be able to assist in the response. A critical issue raised, particularly for the earthquake scenario, was that many members of public may not have immediate help from emergency services and would need to be prepared to rely upon themselves.

The majority (62%) of bushfire risks were assessed as low, 32% were medium and one was a high risk. The high risk addressed the damage to private buildings and contents in the impacted areas. Participants estimated that approximately 300 houses could be impacted by the fires. Similarly, the majority (66%) of the HAZMAT scenario statements were assessed as low and very low risks. Approximately 8% of the statements were assessed as high risks. The high risks related to potential deaths and injuries, increased demand on Department for Child Protection and Family Support (CPFS) services and response and recovery activities.

The *NERAG* uses a prioritisation system to rank risks for treatment decisions and/or for further investigation. There are no Priority 1 (highest) statements, 4% are Priority 2, 25% are Priority 3, 32% are Priority 4, and 39% of the statements are Priority 5 (lowest). The following table (Table 1) shows the Priority 2 risk statements in full and those risk statements with catastrophic consequences. Catastrophic consequence statements are included because if these impacts do occur they could potentially stretch or outstrip the district's resources and therefore should be considered during the treatment phases.

Table 1: Risk statements for the Perth metropolitan region with Priority level 2 or catastrophic consequences.

Hazard	Risk statement	Impact area	Consequence	Risk level	Confidence level	Priority level
Earthquake	will impact private buildings and contents, resulting in financial losses.	Economy	Catastrophic	High	Moderate	2
Earthquake	will impact commercial buildings, contents and services, resulting in financial losses.	Economy	Catastrophic	High	Moderate	2
Earthquake	will cause contamination to the surrounding environment from the release of toxic substances (e.g. of non-natural materials).	Environment	Catastrophic	High	Moderate	2
Earthquake	will impact main road transport routes, resulting in recovery costs and financial losses to the district.	Economy	Catastrophic	High	Low	2
Earthquake	will impact power infrastructure, resulting in costs to the district and financial losses.	Economy	Major	Medium	Low	2
Earthquake	will impact tourism in the district, including aspects that support the tourism industry (such as access routes, facilities, historical buildings and sites, motels, food and fuel outlets), resulting in costs to the district and financial losses.	Economy	Major	Medium	Low	2
Bushfire	will impact private buildings and contents, resulting in financial losses.	Economy	Major	High	High	2
HAZMAT	will result in an increased demand (surge) on CPFS services, impacting their ability to deliver core services.	Public Administration	Major	High	Low	2
HAZMAT	will impact the health of people and cause death(s).	People	Major	High	Moderate	2
Storm	will cause an increased demand on DFES services, impacting their ability to maintain core services.	Public Administration	Major	High	Moderate	2
Storm	will impact culturally important events such as Skyworks.	Social Setting	Major	High	Moderate	2
Cyclone	will impact coastlines, resulting in beach erosion.	Environment	Major	High	Moderate	2

Hazard	Risk statement	Impact area	Consequence	Risk level	Confidence level	Priority level
Cyclone	will impact the aviation sector (including damage to aviation infrastructure), resulting in recovery costs and financial losses.	Economy	Major	High	Moderate	2
Cyclone	will impact the health of people and cause injury and/or serious illness.	People	Major	High	Moderate	2
Bushfire	will impact main roads to access the CBD, including Mounts Bay Road, Thomas Street and Kings Park Road, resulting in financial losses to the district.	Economy	Moderate	Medium	Low	2
Storm	will require response and recovery works to be undertaken by Department of Education, impacting their ability to deliver core services.	Public Administration	Moderate	Medium	Lowest	2
Earthquake	will disrupt business activities, resulting in financial losses.	Economy	Catastrophic	High	High	3
Earthquake	will result in recovery activities, resulting in costs to the district.	Economy	Catastrophic	High	High	3
Earthquake	will cause an increased demand (surge) on Department for Child Protection and Family Support services, impacting their ability to deliver core services.	Public Administration	Catastrophic	High	High	3
Earthquake	will cause an increased demand (surge) on ambulance services, impacting their ability to deliver core services.	Public Administration	Catastrophic	High	High	3
Earthquake	will cause an increased demand (surge) on WA Police services, impacting their ability to deliver core services.	Public Administration	Catastrophic	High	High	3
Earthquake	will impact hospital buildings, impacting their ability to deliver core services.	Public Administration	Catastrophic	High	High	3
Earthquake	will impact the health of people and cause death(s).	People	Catastrophic	High	High	3
Earthquake	will impact the health of people and cause injury and/or serious illness.	People	Catastrophic	High	High	3

1 Introduction

A series of risk assessment workshops were conducted in the Metropolitan Emergency Management (EM) districts as part of the *State Risk Project*. The project aims to assess the risk posed to the state from all prescribed hazards using a consistent and comprehensive approach. This approach follows the ISO 31000:2009 standard and the methodology outlined in the *National Emergency Risk Assessment Guidelines (NERAG) 2015*. Assessing risks at state, district and local levels allows for comparison and the prioritisation of future resources with an emphasis towards prevention and preparedness activities.

The metropolitan area has 34 local governments and is separated into four EM districts: North, South, East and Central. For the purpose of the risk assessment process, the four districts were combined to provide an understanding across the entire metropolitan region.

Initially, the highest priority hazards for each district are assessed. The seven priority hazards for the metropolitan region, as identified by the Metropolitan District Emergency Management Committees (DEMCs) are: bushfire, cyclone, earthquake, flood, HAZMAT, heatwave and storm. All hazards were assessed within a workshop setting (see Table 2 for schedule) and used a credible worst-case hazard scenario. The credible worst-case scenarios were developed by relevant hazard experts and are chosen with the rationale that planning and risk reduction activities for the largest event will address impacts of smaller events, even if the smaller events are more frequent.

During each workshop relevant experts presented the hazard context, the anticipated district vulnerabilities and impacts, and described the scenario. Following this, as a group, the participants worked through a series of risk statements to estimate the potential consequences of the scenario event. Each risk statement depicts an impact that is likely to eventuate given the scenario (see Table 1 for examples) and is collectively assigned a likelihood, consequence and confidence level using the *NERAG 2015* criteria. Discussion was encouraged among participants to explore different aspects of the hazards and impacts. Decisions were based on group consensus. Risk statements are grouped into five impact areas: economy; people; public administration; social setting; and environment with approximately 50 risk statements assessed per hazard. Data were captured and analysed following the workshop. The results are presented in this report.

Table 2: Location and date of risk assessment workshops.

Hazard	Location of workshop	Date of workshop
Bushfire	Perth	21 June 2016
Cyclone	Perth	28 September 2016
Earthquake	Perth	21 June 2016
Flood	Perth	2 August 2016
HAZMAT	Perth	6 September 2016
Heatwave	Perth	6 September 2016
Storm	Perth	2 August 2016

A range of agencies from across the region were invited to attend the workshops. Agency representation is shown in Table 3.

Table 3: Agencies involved in each risk assessment workshop for the metropolitan region, listed in alphabetical order. Note: EQ = earthquake.

Agency	Hazard						
	Bushfire	Cyclone	EQ	Flood	HAZMAT	Heatwave	Storm
Botanic Gardens and Parks Authority	x		x				
Bureau of Meteorology				x	x	x	x
Chamber of Commerce and Industry of Western Australia				x			x
City of Armadale					x	x	
City of Bayswater				x			x
City of Belmont				x			x
City of Canning				x			x
City of Cockburn	x		x				
City of Fremantle	x		x	x			x
City of Gosnells					x	x	
City of Kwinana		x					
City of Mandurah				x			x
City of Melville				x			x
City of Perth	x		x	x			x
City of Rockingham				x			x
City of South Perth				x			x
City of Stirling	x		x				
City of Swan	x		x	x			x

Agency	Hazard						
	Bushfire	Cyclone	EQ	Flood	HAZMAT	Heatwave	Storm
City of Wanneroo	x		x				
Department of Fire and Emergency Services	x	x	x	x	x	x	x
Department for Child Protection and Family Support	x	x	x	x			x
Department of Agriculture and Food WA	x		x	x	x	x	x
Department of Environment Regulation	x		x		x	x	
Department of Health	x	x	x	x	x	x	x
Department of Parks and Wildlife	x	x	x	x			x
Department of Transport				x			x
Department of Water		x		x			x
Insurance Council Australia		x					
Main Roads WA	x	x	x		x	x	
Office of Emergency Management (facilitators)	x	x	x	x	x	x	x
Public Transport Authority					x	x	
Rottnest Island Authority	x		x				
Shire of Kalamunda	x		x				

Agency	Hazard						
	Bushfire	Cyclone	EQ	Flood	HAZMAT	Heatwave	Storm
Shire of Mundaring	x		x				
Shire of Waroona		x					
St John Ambulance		x		x	x	x	x
Telstra	x	x	x		x	x	
Town of Bassendean				x			x
Town of Victoria Park				x			x
WA Police	x	x	x	x	x	x	x
Water Corporation	x	x	x	x	x	x	x
Western Power	x	x	x		x	x	

2 Hazard scenarios

The seven scenarios were developed with significant contributions made by:

- Bureau of Meteorology Western Australia (BOM)
- Department of Fire and Emergency Services (DFES)
- Department of Health (DOH)
- Department of Parks and Wildlife (P&W)
- Geoscience Australia (GA)
- Office of Emergency Management (OEM)
- Water Corporation
- WA Police
- Western Power

Bushfire scenario

The bushfire scenario was developed by BOM, DFES, P&W, and WA Police and has approximately a 4.88% chance of occurrence in any given year.

During the second week of December two major bushfire incidents occur in Helena Valley and Bullsbrook. The weather is forecast as a typical summer trough movement with some lightning likely.

Three days prior to the Helena Valley and Bullsbrook incidents (Day -3) a bushfire south-east of Busselton mobilised much of the available resources in the south-west of WA. The Busselton fire has been contained and resources are expected to be released in the next 24 hours. In addition, a fire began in Kings Park the day prior (Day -1). This fire mobilised heavy DFES resources with some metro bushfire brigade presence. No other resources are expected to be available for re-assignment until the day after.

On the day of the incident approximately 40% of the metropolitan resources are available. The Kings Park fire is not contained and covers about 200 ha. As the trough moves, lightening initiates fires in a band from Gingin through to Mount Dale. The fires are quickly contained by property owners, brigades and P&W. Brigade resources are 15% of normal strength and P&W at about 10% as a result of previous fires. Two of the lightning strike fires cannot be attacked before they escalate. These become two major fires, known as the Helena Valley Fire and Bullsbrook Fire. Predictions of fire spread are developed and the fires are expected to become large. The temperature at 9 am is 33°C with gusty west to south-west winds in the wake of a surface trough. Gusts reached about 70 km/h until 4 pm. The day after (Day 1) winds tended south to south-easterly 30 km/h with gusts to 45 km/h after 9 am.

The Helena Valley Fire starts a few hundred metres east of Helena Valley Primary School near Ridge Hill Road. Within 20 minutes the fire is pushed up a steep slope burning in heath/shrub fuels. The fire crosses Helena River 30 minutes after ignition and reaches Maslin Crescent 60 minutes after ignition. The Incident Management Team (IMT) is located at Kalamunda and an Incident Support Group (ISG) is assembled and operational in Kalamunda within 30 minutes. The Regional Operations Centre is set up at Cockburn.

The day after the ignition (Day +1) the Helena Valley Fire is still uncontained. The fire reaches the Great Eastern Highway at Darlington, Mahogany Creek and Mundaring. The fire is contained south of Mundaring and under control before it reaches Sawyers Valley. However, the edge of the fire on both sides of Helena Valley is threatening to push back to Greenmount and Boya, north of the river and towards Kalamunda in the south by south-east winds. Figure 2 shows the extent of the fire spread 24 hours after ignition.

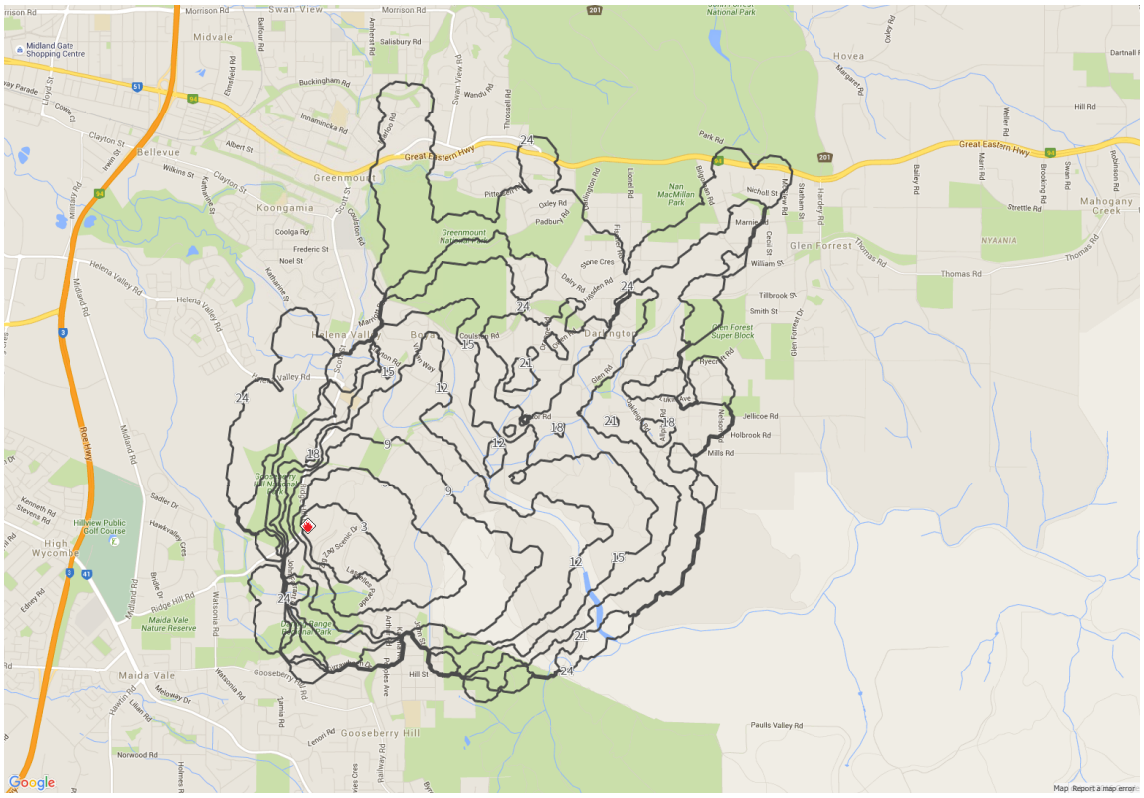


Figure 2: Aurora Fire modelling—Helena Valley Fire. Source: Fire Watch Aurora. Image supplied by DFES.

The Bullsbrook fire is ignited 1.5 km east of Bullsbrook on farmland. Within 30 minutes the fire is pushed up a steep slope. The fire is burning in a mixture of eucalypt woodland and rough pasture. The fire reaches Monger Brook after 10 minutes of ignition and after 60 minutes, the fire is located among rural residential properties along and east of Smith Road. Visibility on the ground makes assessment of the situation and direction of suppression very difficult. The incident management team (IMT) is located at Bullsbrook but is planned to be moved to Midland. An incident support group (ISG) is being considered but is not yet in place.

The day after the ignition (Day +1) the fire is held west of Avon Valley National Park and north of Avon Valley, as well as south of Chittering Road. However, there is a significant risk of fire being pushed back to the west and north-west by south-east winds. Figure 3 shows the fire's extent 24 hours after its ignition.

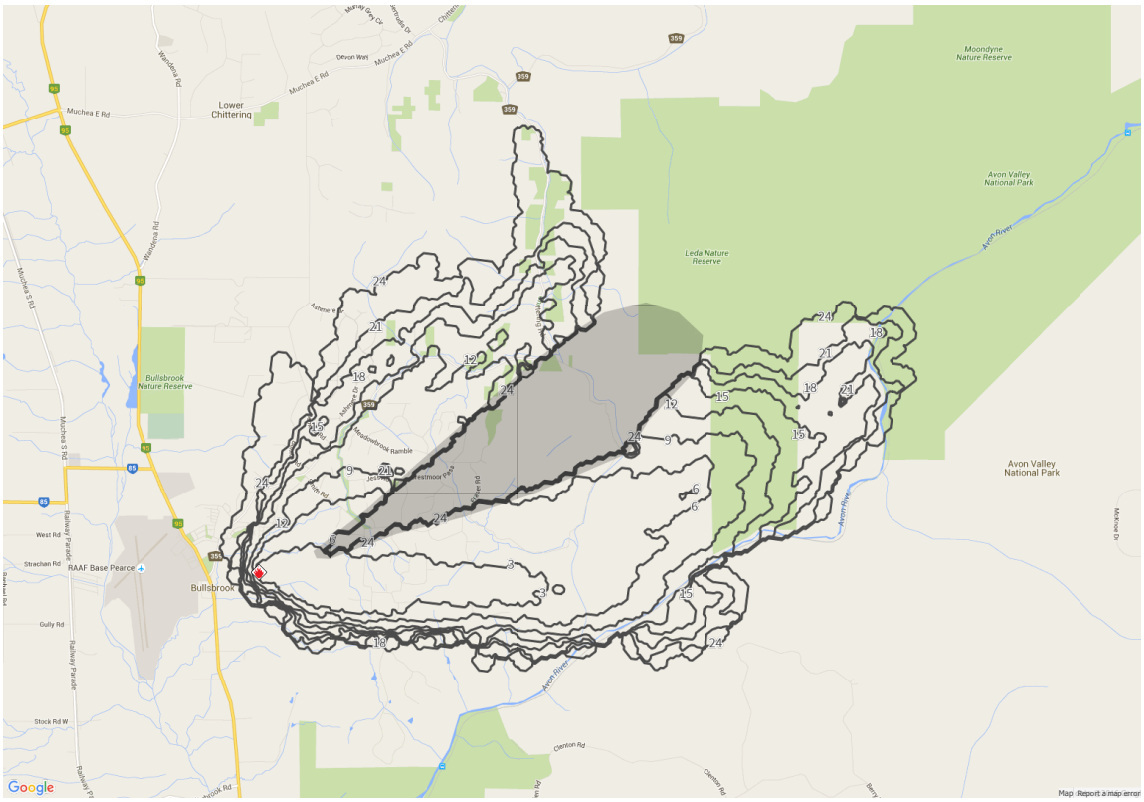


Figure 3: Aurora Fire modelling—Bullsbrook East Fire. Source: Fire Watch Aurora. Image supplied by DFES.

Cyclone scenario

The cyclone scenario was developed by BOM, DFES, P&W, and WA Police and has approximately a 0.995% chance of occurrence in any given year.

On 29 March, a Category 3 cyclone is located north-west of Geraldton. On the same day, as it tracks east, the cyclone dissipates to become a Category 2 west of Jurien Bay. It continues its path in the direction of Perth on 30 March and is downgraded to a Category 1 at 2 am. The cyclone makes landfall at Perth on 30 March at about 8 am and continues south-east, exiting west of Esperance at 8 pm as a tropical low. Figure 4 illustrates the timing and path of the cyclone.

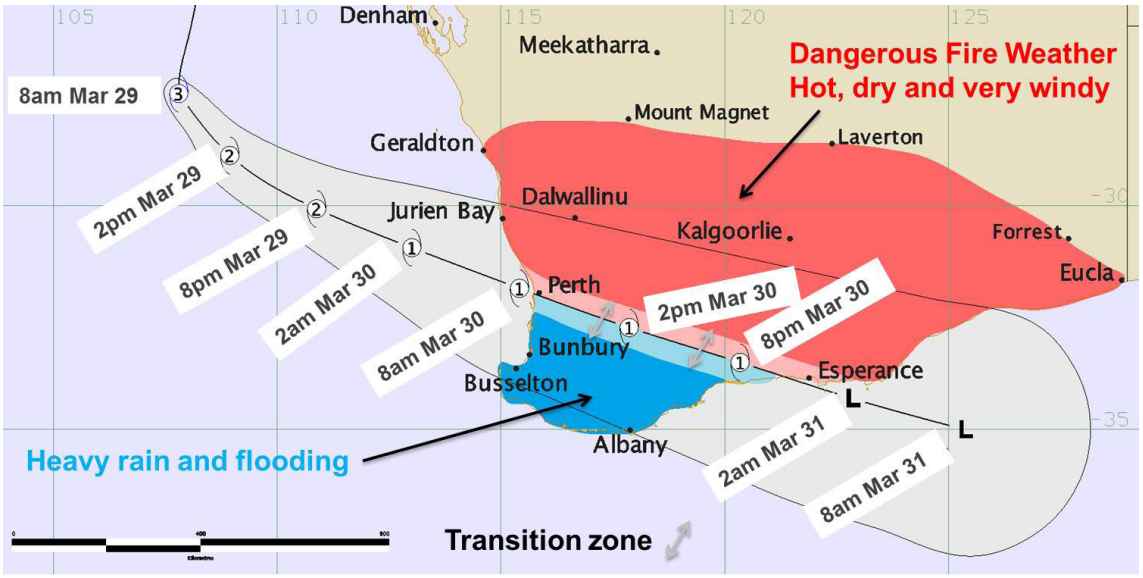


Figure 4: Cyclone path and timing. Red zone is hot, dry and very windy. Blue zone has heavy rain and flooding. Grey is the transition zone. Image supplied by BOM.

To the north of the cyclone track (red zone), weather conditions are hot (about 28 to 30°C), dry and windy with widespread gusts of 90–100 km/h and isolated gusts in excess of 125 km/h. The combination of these conditions leads to severe to catastrophic fire weather conditions. In addition, a storm surge is expected along the coast with abnormally high tides and potential coastal erosion.

To the south of the track, wind gusts reach 90–100 km/h near the centre of the system. Widespread rainfall of approximately 25–50 mm is expected, with scattered rainfall between 100 and 150 mm. These conditions lead to flash flooding and major riverine flooding of the Swan Coastal, lower Murray and Harvey catchments. Short and long-term impacts on infrastructure, including roads, are expected. This is likely to inundate Belmont Race Course, the Town of Bassendean, Roe Highway and Great Northern Highway.

The worst conditions are expected to last for approximately 6 hours with severe weather continuing between 6 and 12 hours. Destructive winds up to 125 km/h are expected with structural damage and falling trees.

At 6 am on the same day, the fire rating is catastrophic and a fire starts 8 km west of York. Resources from the metropolitan region are mobilised to assist with the fire. At 9 am, eight other fires are ignited in the region (Figure 5).

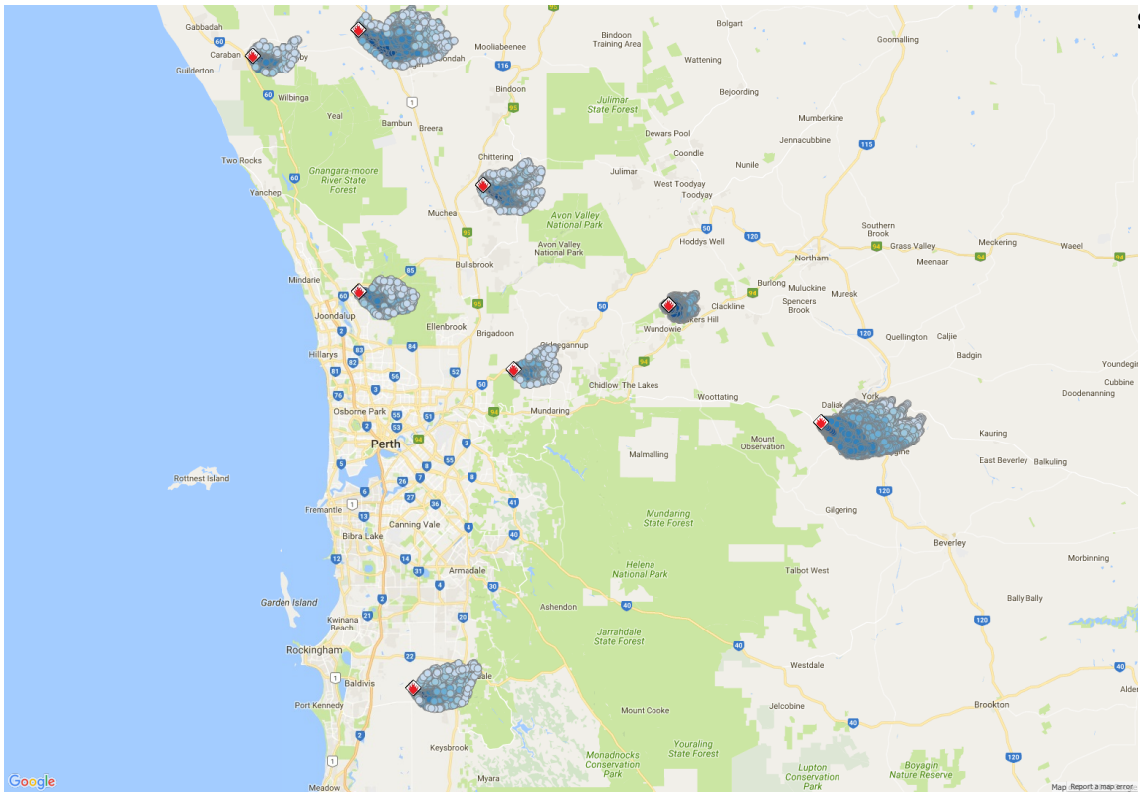


Figure 5: At 9 am on March 30 eight fires are ignited in the metropolitan area. Final fire shapes shown.

Earthquake scenario

The earthquake scenario was developed by GA and has approximately a 0.04% chance of occurrence in any given year.

A magnitude 6.4 earthquake occurs west of Rottnest Island at the beginning of June. Ground shaking of 4 Modified Mercalli Intensity (MMI) through to greater than 7.5 MMI is experienced across the metropolitan region. Figure 6 shows a map of ground shaking from the earthquake and Table 4 lists expected impacts of the differing shaking intensities. A loss model was also developed and Figure 7 shows the loss ratio (the ratio of the repair cost to the total replacement cost) of buildings by suburb. A summary of the estimated total residential building loss is given in Table 5. Based on the building loss and occupation statistics, Table 6 provides an estimate of potential injuries and fatalities for the event.

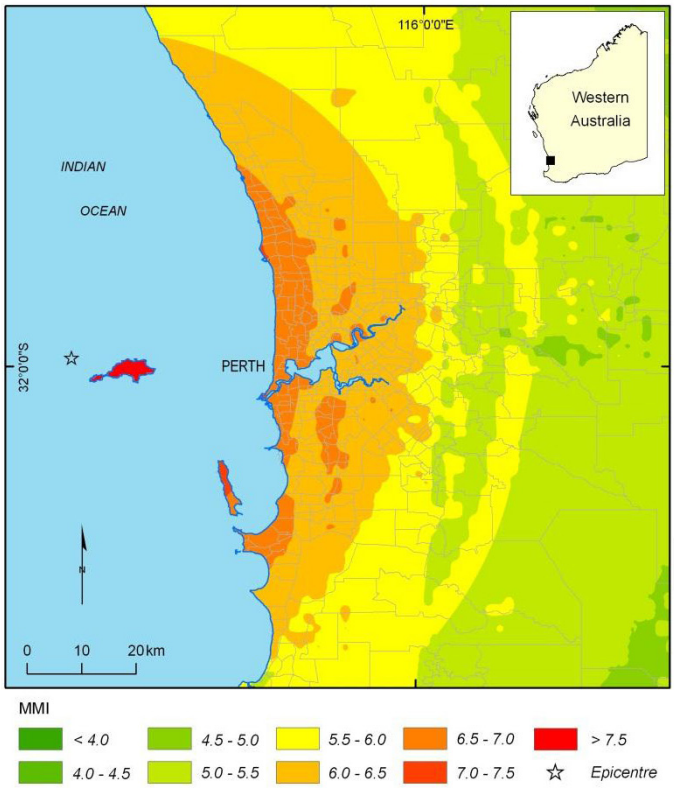


Figure 6: Ground shaking intensity in Perth from earthquake. Image supplied by GA.

Table 4: Comparison of MMI values with example event and expected impact.

MMI	Expected impact	Example event
V (5)	Cracking of vulnerable masonry (e.g. parapets & chimneys) with minor falls. Minor cracking to masonry houses.	Kalgoorlie CBD 20 April 2010
VI (6)	Collapse of vulnerable masonry and severe cracking to other masonry structures.	Boulder CBD 20 April 2010
VII (7)	Severe damage to unreinforced masonry (URM) buildings, some damage to housing, damage to low ductility framed buildings, with some collapses.	Newcastle 27 December 1989
VIII (8)	Severe to complete damage to URM buildings, severe damage to low ductility buildings.	Christchurch 22 February 2011
IX (9)	Destruction of URM and low ductility framed buildings, damage to all other types.	Meckering 14 October 1968

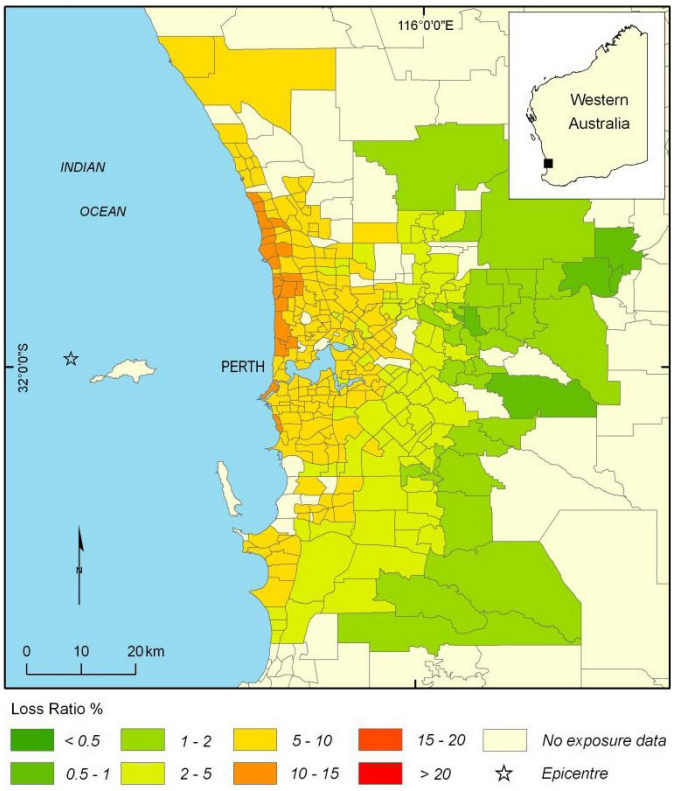


Figure 7: Perth earthquake average loss ratio across all building types by suburb. Image supplied by GA.

Table 5: Estimated residential building loss and number of buildings.[3]

Mean loss ratio	Number of buildings damaged			
	Slight	Moderate	Extensive	Complete
6.3%	119,444 (22.3%)	82,270 (15.4%)	59,635 (11.2%)	39,077 (7.3%)

Table 6: Estimated injuries and fatalities (based on ATC-13 methodology).[3]

Minor injuries	Major injuries	Fatalities
3,793	508	127

[3] Geoscience Australia Earthquake Impact Scenario for Western Australia, created by M. Wehner, H. Ryu, N. Corby, D. Robinson and M. Edwards.

Flood scenario

The flood scenario was developed by BOM, DFES, P&W, and WA Police and has approximately a 0.499% chance of occurrence in any given year.

Above average rainfall is experienced in the year preceding the event and catchments are wet due to rainfall in the days prior. A slow moving cold front with a rainband resulting in heavy rainfall moves over the metropolitan region, resulting in a multi-day flood event (Table 7).

More than 300 mm of rain falls over four days with a peak daily rainfall of 150 mm. The Swan River catchment experiences major flooding over two days, the Lower Murray for a day and the Harvey catchment for over three days (Table 7). Flooding in the Swan catchment impacts Beverley, York and Northam, before it impacts the metropolitan region.

Table 7: Estimated flood severity over the course of the rainfall event for three catchments.

Flood severity	Below minor	Minor	Moderate	Major

Catchments	20/6	21/6	22/6	23/6	24/6	25/6	26/6	27/6	28/6
Swan coastal									
Lower Murray									
Harvey									

HAZMAT scenario

The HAZMAT scenario was developed by in conjunction with the HAZMAT Emergency Advisory Team (HEAT) and has approximately a 0.995% chance of occurrence in any given year.

A chemical plume is released from a Kwinana industrial complex. Further details of the scenario were given in the workshop, but are not included in this report.

Heatwave scenario

The heatwave scenario was developed by the DOH, BOM, Western Power and the Water Corporation and has approximately a 4.88% chance of occurrence in any given year.

In early January after a long period of unseasonable cool weather across the south-west of WA temperatures are expected to rise sharply over a seven-day period to reach a forecast peak of 44°C. This period also includes three consecutive days at 40°C or above. People are unaccustomed to such high temperatures due to a cool start to the summer. The average maximum temperature during December was 27.7°C, and the first few days of January peaked in the low thirties (Figure 8). A severe to extreme heatwave advice is issued for the metropolitan region (Figure 9).

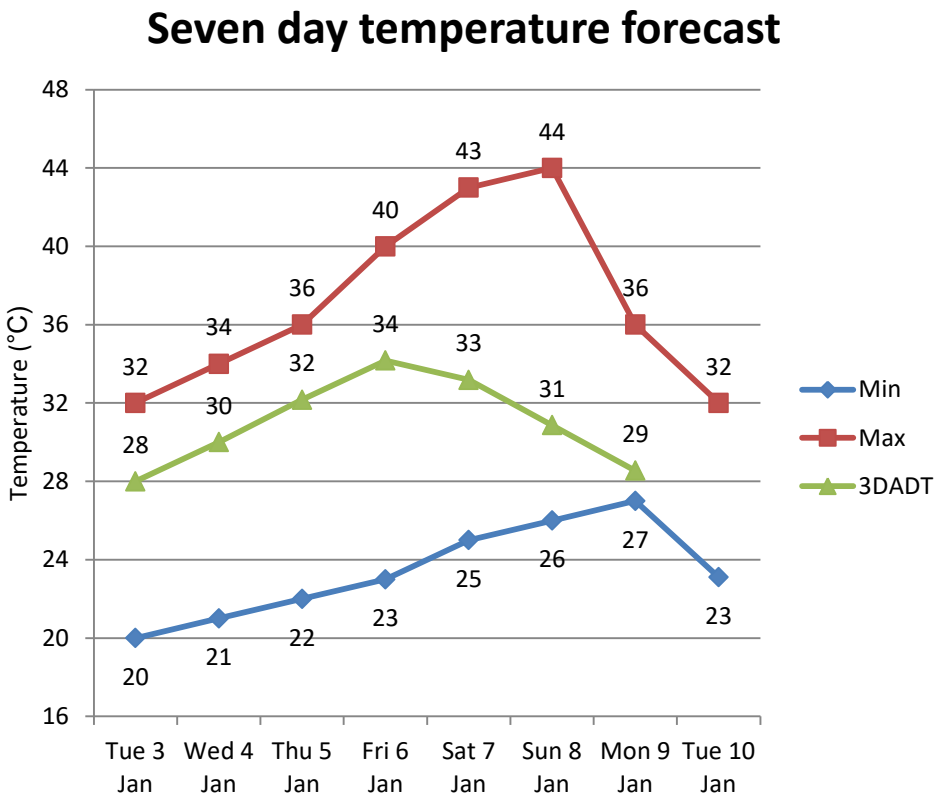


Figure 8: Temperature forecast for the seven-day period. Red: maximum temperatures. Blue: the minimum temperatures. Green: the 3-day average of average daily temperatures (3DADT). Source: BOM.

On Thursday 5 January, two power sub-stations, Gosnells and Southern River (located in the Armadale area) are taken out of service due to a malicious attack which occurs at 6 pm. The outage leaves 10,000 customers without power. The restoration time is unknown but it may be weeks before a full repair can be made.

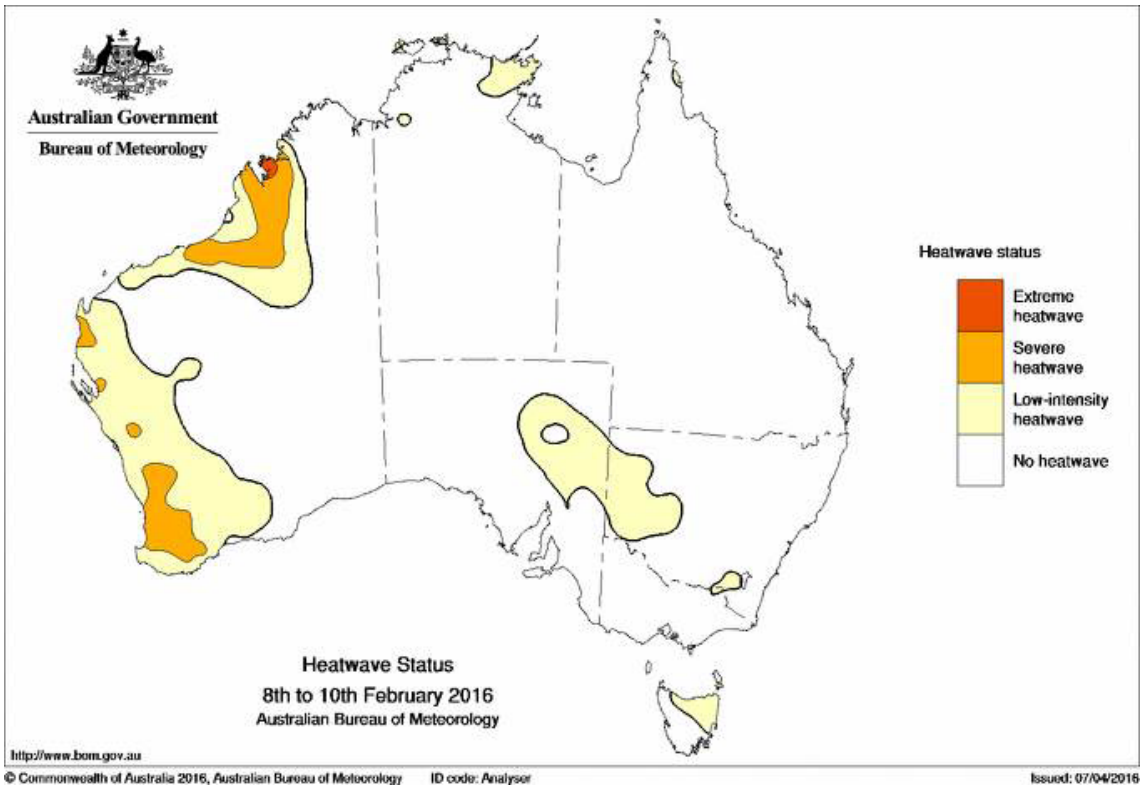


Figure 9: Example of heatwave status for 8–10 February 2016 across Australia. Source: BOM.

On Saturday 7 January, temperatures of 45°C are recorded and a large bushfire starts in the Cockburn-Baldivis area. On the same morning, a water pipe bursts in North Perth, resulting in a water supply outage lasting 2 to 6 hours. Demographics indicate the majority are senior citizens. A second water pipe bursts late morning on Beeliar Drive, impacting a large area of the adjacent suburb. The pipe is difficult to fix, leaving people without any water for 12 to 26 hours.

On Sunday 8 January, temperatures of 46.4°C are recorded and the bushfire is still burning. A further two water mains burst in Bentley and Yokine. The supply outage in both suburbs is expected to last 2 to 6 hours. Both areas have a significant proportion of elderly residents and the rupture in Yokine affects high density houses and units with a significant number of foreign-born residents (who may not have experienced prior heatwaves).

During the heatwave, significant sport and cultural events are held, including the Hopman Cup, Perth Scorchers 20/20 Match and the Fringe World Festival.

Storm scenario

The storm scenario was developed by BOM, DFES, P&W, and WA Police and has approximately a 0.995% chance of occurrence in any given year.

During the Australia Day Skyworks show (26 January), in the early evening, a warm season storm occurs in the metropolitan region bringing severe thunderstorms, lightning, heavy rainfall conducive to flash flooding and large hail and winds in excess of 90 km/h.

Earlier in the day the storm tracks south through Gingin at 30 km/h. A wind gust of 126 km/h is reported there at 3.40 pm. By 4.30 pm, the thunderstorm has developed destructive winds of greater than 125 km/h, heavy rainfall (40–50 mm/h) and large hailstones (>2 cm diameter). A warning is issued describing the storm as unusually intense and producing dangerous conditions in parts of the warning area (Figure 10).

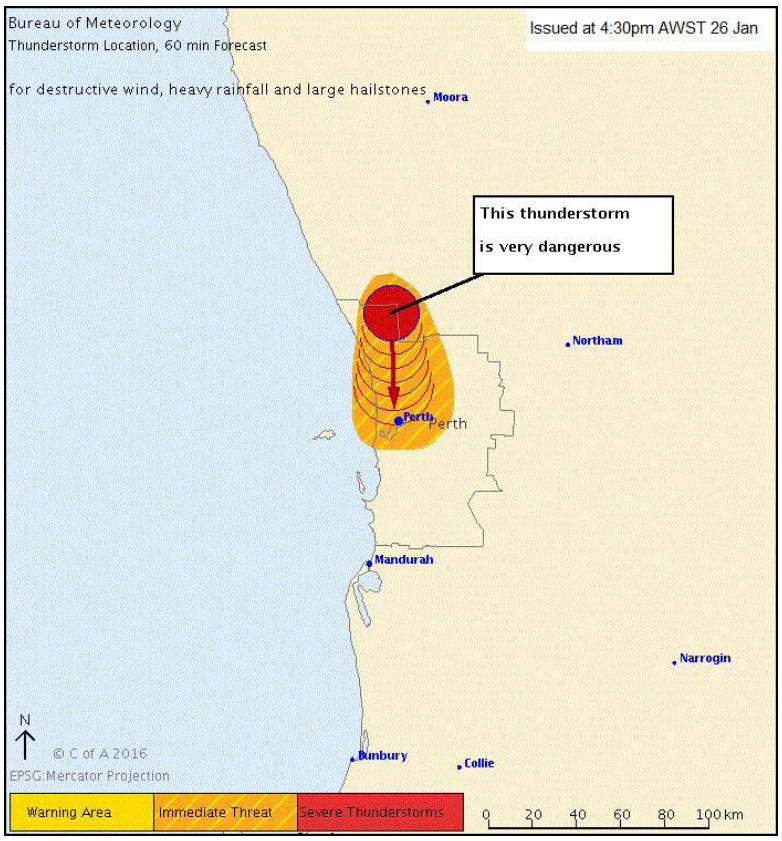


Figure 10: Thunderstorm location at 4.30 pm 26 January 2017. Image supplied by BOM.

Later in the afternoon, as the storm continues south, a wind gust of 123 km/h is reported at Ocean Reef at 5.05 pm.

On its current trajectory, the storm is expected to be over the southern suburbs of the Perth metropolitan region about 6:00 pm and near Mandurah about 6.30 pm. Hail up to 6 cm in diameter has been reported in the suburbs of Wanneroo, Warwick and Osborne Park.

3 Assessed risk statements

A total of 358 risk statements were assessed across the seven hazard scenarios: bushfire (50); cyclone (61); earthquake (53); flood (47); HAZMAT (53); heatwave (46) and storm (48).

Table 8 provides the number of risk statements for each hazard in each impact area—economy, people, public administration, social setting and environment. The statements were generated to cover all foreseen impacts of the scenario events.

The risk statements were assessed using the tailored *NERAG* consequence table for the metropolitan region (found in Appendix C). The consequence levels are based on the gross area product ($189.78 billion) and the population (2.2 million) of the region.

Table 8: Number of risk statements assessed for each hazard in the Perth metropolitan region.

Hazard	Impact area				
	Economy	People	Public administration	Social Setting	Environment
Bushfire	15	4	12	14	5
Cyclone	17	4	23	11	6
Earthquake	14	4	19	14	2
Flood	13	4	17	8	5
HAZMAT	13	6	19	11	4
Heatwave	19	6	12	7	2
Storm	16	4	14	10	4

4 Metropolitan EM regional risk profile

The risk profile for the metropolitan region for the seven assessed hazards is shown in Figure 12 (following page). This diagram shows the percentage of risk statements for each hazard as they sit on the *NERAG 2015* risk matrix. The matrix is used to categorise risk statements by their likelihood, consequence and risk level. The bar graph below (Figure 11) combines the data and categorises it by hazard and risk level.

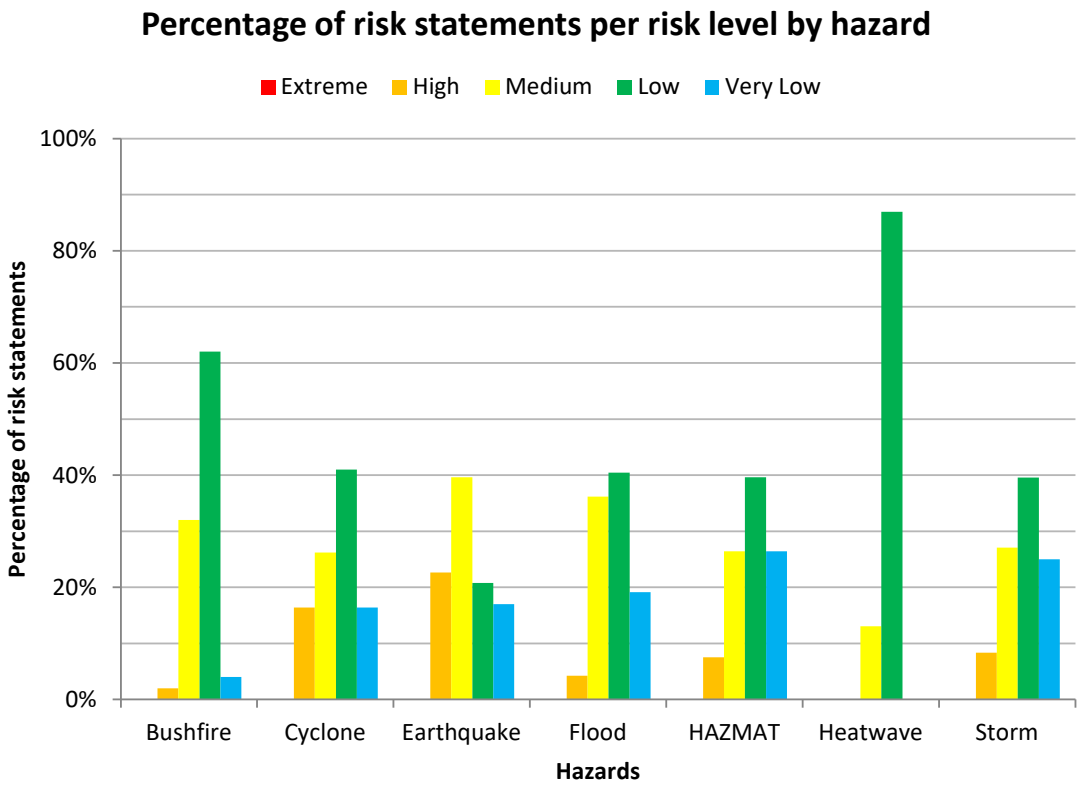


Figure 11: Percentage of risk statements at each risk level for each hazard. Note each hazard sums to 100%.

Of the 358 statements assessed for all seven hazards, none are extreme risks, 9% are high, 29% are medium, 46% are low, and 16% are very low. Individual hazard summaries can be found in Appendix A.

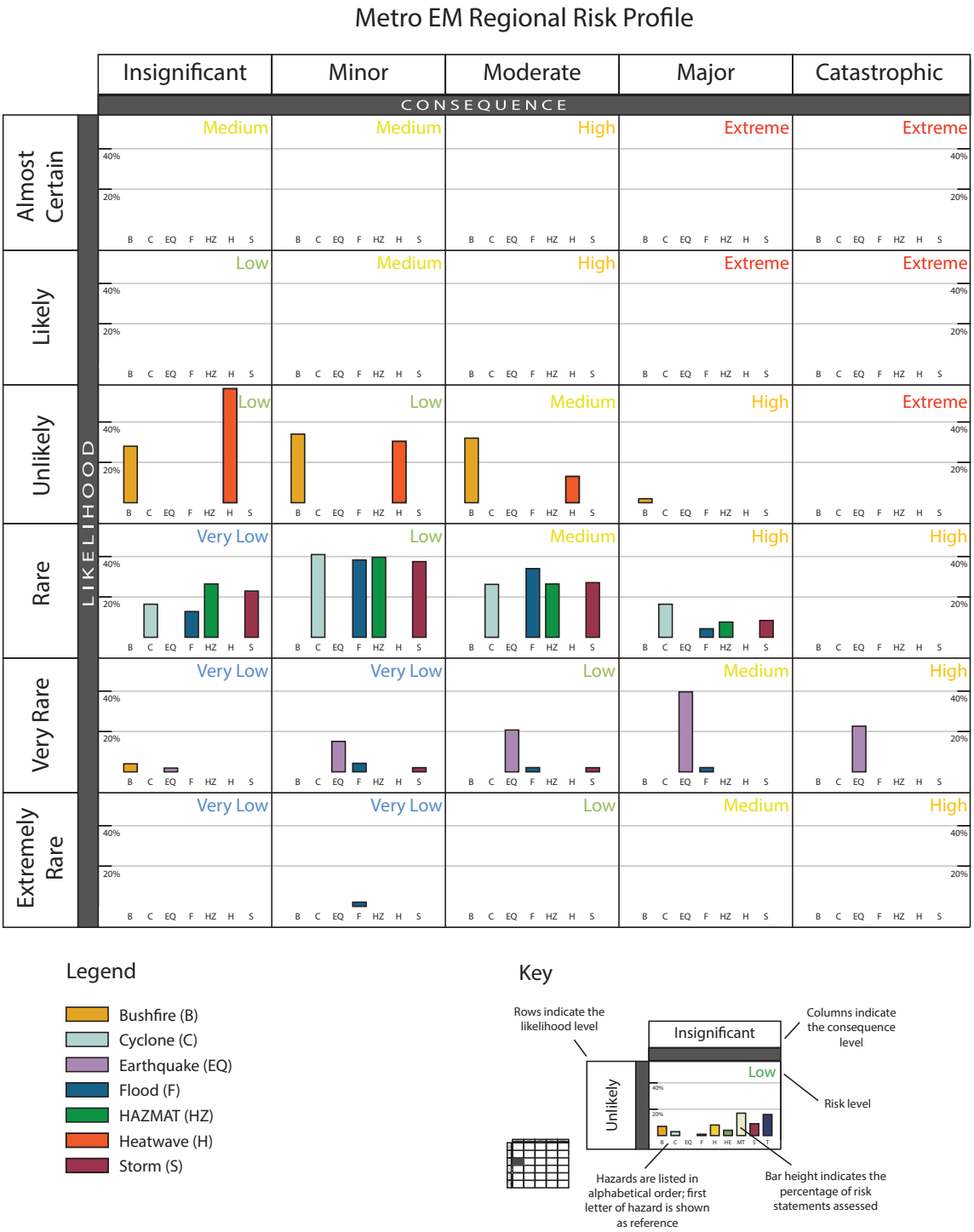


Figure 12: Percentage of risk statements for each hazard assessed in the Perth metropolitan region categorised by their likelihood, consequence and risk level.

Earthquake has the greatest proportion of high risks (23%) and was the only hazard to produce catastrophic consequences (Figure 12). While they have a lower probability of occurring, these catastrophic consequences are important to consider as they have the potential to strain or outstrip the district's resources. These statements centred upon the impacts to private and commercial buildings, business activities, environmental contamination from toxic substances, transport routes, recovery activities, and the service delivery of CPFS, WA Health and ambulances services. Of note is the potential to cause catastrophic consequences through deaths, critical or serious injuries. The potential loss of a hospital was also assessed as a high risk.

A critical issue stakeholders raised was that many members of the public may not have immediate help from emergency services and would need to be prepared to rely upon themselves.

Figure 13 shows the spread of the risks to the metropolitan region across the five impact areas. The impact area with the greatest percentage of high risks is people (16%), primarily from deaths and injuries resulting from the earthquake and HAZMAT scenarios. This is followed by the public administration, environment, and economy. Overall risk to the social setting are lowest with 60% low risks and 29% very low risks.

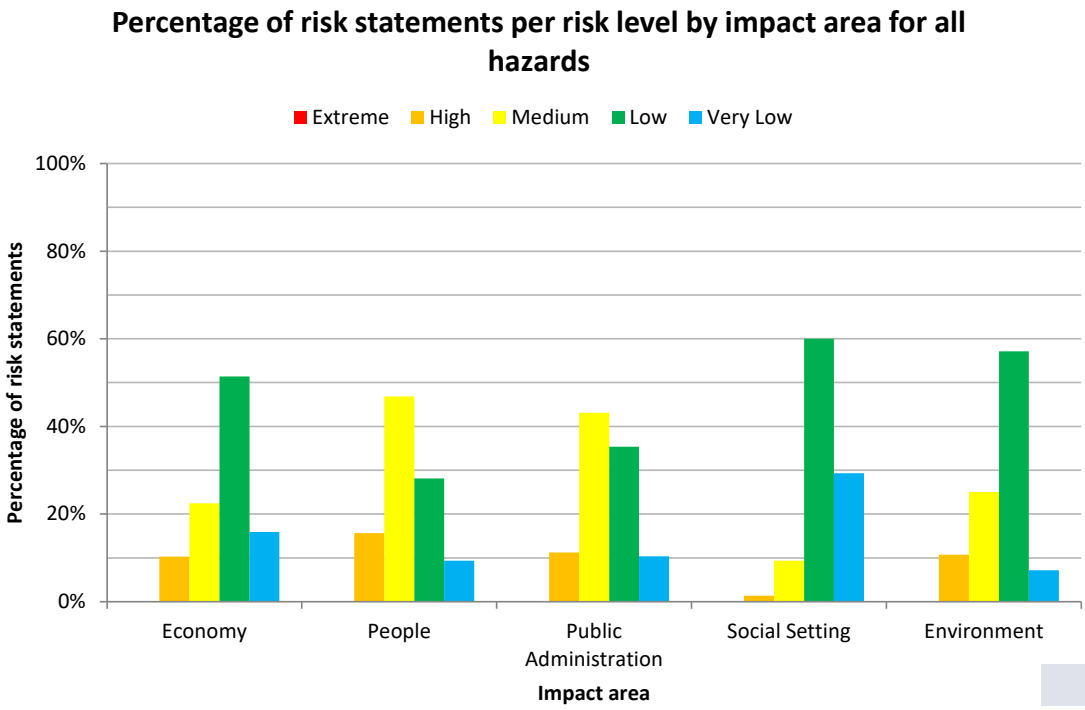


Figure 13: Percentage of risk statements per risk level, by impact area for all hazards. Note: each impact area sums to 100%.

Common themes from high risk statements

ECONOMY		• Disruption to transport routes *(earthquake only with catastrophic consequences)*. • Impacts to aviation *(cyclone only)*. • Impacts to commercial activities *(earthquake only with catastrophic consequences)*. • Impacts to commercial buildings, contents and services *(for earthquake these are catastrophic consequences)*. • Impacts to private buildings and contents *(for earthquake these are catastrophic consequences)*. • Response and recovery activities *(for earthquake these are catastrophic consequences)*.
PEOPLE		• Deaths *(for earthquake these are catastrophic consequences)*. • Injuries and illnesses *(for earthquake these are catastrophic consequences)*.
PUBLIC ADMINISTRATION		• Demand on public facilities *(cyclone only)*. • Emergency services *(for earthquake these are catastrophic consequences)*. • Government services *(for earthquake these are catastrophic consequences)*. • Health services *(earthquake only with catastrophic consequences)*. • Impacts to power supply service delivery. • Response and recovery activities.
SOCIAL SETTING		• Culturally significant facilities and customs *(storm only)*.
ENVIRONMENT		• Coastal erosion *(cyclone only)*. • Contamination from toxic substances *(for earthquake these are catastrophic consequences)*. • Flora and fauna (*storm only)*.

5 Analysis of risk profile

In order to understand any potential relationships, the assessed risks have been grouped into categories to determine common themes or if certain areas and sectors are at higher risk.

In the following tables, risk statements are represented by showing the hazard name under the assigned risk level. Where a number follows the hazard name, more than one statement from that hazard fits into that category and risk level. There may also be more than one statement for a hazard in a category. For example, statements addressing horticulture, crops and agriculture infrastructure would all appear in the impacts to agriculture and pastoral activities category. Risk statements were written for each hazard to address anticipated impacts; therefore, there are categories where not all hazards appear.

Risks to economy

One hundred and seven economy risk statements (Table 9) address impacts to a significant industry or the decline in economic activity across the region (see Appendix C for criteria).

Table 9: Impacts to economy by hazard and risk level. Note: EQ = earthquake.

Category	Risk level				
	Extreme	High	Medium	Low	Very Low
Disruption to transport routes		EQ	Bushfire (2)	Cyclone Flood Storm	HAZMAT (2)
Impacts to agricultural and pastoral activities			Flood Storm	Bushfire Cyclone (2) Flood Heatwave (3) Storm	
Impacts to aviation		Cyclone		Bushfire Heatwave Storm	EQ Flood
Impacts to bridges or their approaches			EQ	Cyclone Storm	
Impacts to commercial activities		EQ	Bushfire HAZMAT (2)	Heatwave (3)	
Impacts to commercial buildings, contents and services		Cyclone EQ Flood	HAZMAT Storm	Bushfire Heatwave	

Category	Risk level				
	Extreme	High	Medium	Low	Very Low
Impacts to communication infrastructure			Storm	Bushfire Cyclone Flood Heatwave	EQ HAZMAT
Impacts to fuel supplies			HAZMAT		
Impacts to marine infrastructure and industry			EQ Storm	Cyclone Flood Heatwave	
Impacts to natural gas distribution				Heatwave	Cyclone Storm
Impacts to power supply infrastructure			EQ	Bushfire Cyclone Flood Heatwave Storm	HAZMAT
Impacts to private buildings and contents		Bushfire Cyclone EQ	Flood Storm	HAZMAT	
Impacts to rail infrastructure			Bushfire	EQ Heatwave (2)	
Impacts to road infrastructure				HAZMAT Heatwave	
Impacts to sewerage systems				EQ Flood	Bushfire Cyclone Storm
Impacts to timber industry			Cyclone		
Impacts to tourism			EQ Flood	Bushfire Heatwave Storm	Cyclone
Impacts to transport infrastructure				Flood Storm	Cyclone HAZMAT
Impacts to water supply infrastructure				Bushfire (2) EQ Flood HAZMAT Heatwave	Cyclone Storm
Response and recovery activities		EQ HAZMAT	Bushfire Cyclone Storm	Heatwave	
Workforce productivity losses				Heatwave	

The bushfire, cyclone, flood and HAZMAT scenarios generated high risk economy statements, a decline in economic activity and/or loss of asset value greater than $759 million. The earthquake scenario also produced high economic risk statements equating to greater than $7.59 billion of losses.

Impacts to commercial and private buildings produced the most high risk statements in the economy impact area. The earthquake scenario was assessed to affect thousands of buildings, while the bushfire was assessed to affect hundreds of private buildings. Damage from the 2010 Perth hail storm was used as a gauge for expected damage to residences from the cyclone event.

Response and recovery activities generated high risks due to both the HAZMAT and the earthquake scenarios. The HAZMAT scenario had a major consequences, due to potential for costs associated with deaths and clean-up; the earthquake scenario presented catastrophic consequences, due to the large number of buildings that would suffer damage (Table 5).

The earthquake impacts to commercial activities were evaluated as high risk based on the amount of building damage anticipated and flow-on effects to commercial activities. Assessing premises following the earthquake could be delayed by inspections and relocating to undamaged premises may not be possible.

Stakeholders evaluated the disruption to transport routes to have a catastrophic consequence for the earthquake scenario. The earthquake is likely to cause damage to roads and high demand for materials may increase repair costs. Road damage and congestion may also cause people and freight to be delayed, which would increase costs for many industries, including the transport and mining sectors. Detours would be required for first responders and recovery activities. The damage to roads may also cause increased vehicle operating costs.

Perth Airport commented that the cyclone could cause extensive impact to the aviation sector due to the cost of the aircraft, repair, replacement and inability to maintain passenger demand in the short term. Some aircraft may be flown out prior to the cyclone arriving, but there could be millions to billions of dollars of aircraft assets at the airport at any one time. When assessing this statement Perth Airport to into consideration the 1999 Sydney hail storm, which damaged aircraft.

Risks to people

Thirty-two risk statements assessed the impact to people (Table 10), addressing deaths, injuries or illnesses, and further deaths or illnesses/injuries as a result of the event's impact on emergency services (primarily medical transport and health services) (see Appendix C for criteria).

Table 10: Impacts to people by hazard and risk level. Note: EQ = earthquake.

Category	Risk level				
	Extreme	High	Medium	Low	Very Low
Deaths		EQ HAZMAT	Bushfire Cyclone Flood HAZMAT Heatwave Storm		
Disease outbreak			Flood Heatwave		
Emergency services			Bushfire Cyclone	HAZMAT Heatwave Storm	EQ Flood Storm
Health services			EQ HAZMAT	Bushfire Cyclone HAZMAT Heatwave	
Injuries and illnesses		Cyclone EQ HAZMAT	Bushfire Flood Heatwave	Heatwave Storm	

High risk statements relating to people were due to the impacts from the earthquake, HAZMAT and cyclone scenarios.

Stakeholders assessed that deaths and injuries as a direct result of the earthquake scenario (Table 6) would be exacerbated by the potential loss of a hospital as a result of the event. In addition, at least 22 deaths (major consequence) could occur due to limited intensive care unit (ICU) beds in Perth. The scenario estimates that there could potentially be 508 serious injuries requiring ICU beds; however, WA Health note there are only about 100 ICU beds available in the metropolitan region.

Further deaths eventuating from emergency services (including ambulance and medical transport services) being overwhelmed during the earthquake scenario were assessed as very low risk, (between 1 and 3 deaths) because their response would be based on medical priority. However this was assessed with low confidence by St John Ambulance as the breadth of impact and variety of the situation is difficult to determine.

It was estimated that the HAZMAT scenario could cause ~30 deaths, which may include the industry's employees and nearby residents. The number of injuries and illnesses would depend on how much antidote was available and the speed of application. There may be limited stock of the antidote available in the metropolitan region.

The remaining hazards (bushfire, cyclone, flood, HAZMAT, heatwave and storm) all have a medium risk of death. Each of these scenarios was estimated to cause between 3 to 21 deaths.

In the injuries and illnesses category, participants assessed that the cyclone scenario could cause injuries from the associated bushfires, flying debris, and mental illnesses.

Risks to public administration

One hundred and sixteen risk statements addressed public administration impacts (Table 11) which relate to the continuity of an agency's core services. For example, at medium risk or higher, either a significant reduction in services would occur or external assistance from outside the region would be required to maintain service levels (see Appendix C for criteria).

Table 11: Impacts to public administration by hazard and risk level. Note: EQ = earthquake.

Category	Risk level				
	Extreme	**High**	**Medium**	**Low**	**Very Low**
Demand on ChemCentre services			HAZMAT		
Demand on public facilities		Cyclone	Flood	EQ	Storm
Disruption to aviation services			Cyclone Storm		
Disruption to supply of natural gas					Bushfire Cyclone HAZMAT
Emergency services		Cyclone EQ Storm	Bushfire (3) Cyclone (2) EQ (3) Flood (2) HAZMAT (3)	Cyclone (2) EQ Flood Heatwave Storm (3)	Flood Storm
Government services		Cyclone EQ Flood HAZMAT	Bushfire Cyclone EQ (4) HAZMAT (2) Heatwave	Cyclone HAZMAT (2) Heatwave Storm	HAZMAT
Health services		EQ (2)	Bushfire Cyclone HAZMAT Heatwave	Storm	Flood

Category	Risk level				
	Extreme	**High**	**Medium**	**Low**	**Very Low**
Home care services			Cyclone	Cyclone Storm (2)	Flood
Impacts to communication service delivery			Storm	Bushfire Cyclone EQ Flood Heatwave	HAZMAT
Impacts to port and marina services			Cyclone Storm	Heatwave	
Impacts to power supply service delivery		Cyclone Storm	EQ Flood Heatwave	Bushfire HAZMAT	
Impacts to public transport services			Flood		
Impacts to sewerage service delivery			Cyclone EQ Flood	Bushfire HAZMAT	
Impacts to water supply service delivery			Cyclone EQ Flood	Bushfire Flood HAZMAT Heatwave	
Response and recovery activities		Cyclone	Bushfire Cyclone EQ (2) Flood Storm	Bushfire Cyclone (2) Flood HAZMAT (2) Heatwave (2) Storm	Flood HAZMAT

The high risk statements to public administration were due to the impacts from the cyclone, earthquake, flood, HAZMAT and storm scenarios.

The earthquake scenario was evaluated as impacting: government services, emergency services and health services with catastrophic consequences. The increased demand on the services of CPFS, WA Police, Ambulance services and WA Health, may mean they would be unable to deliver core functions. The large number of injured and displaced people and a workforce who would also be impacted by the earthquake themselves are contributing factors. A critical issue raised in the workshop was that many members of the public would not have immediate help from emergency services and would have to be prepared to rely upon themselves.

The impact on hospital buildings was also assessed and the possible loss of Fremantle or Rockingham Hospital was considered a high risk. It would create significant issues as a major evacuation would be required and there is no capacity elsewhere for existing patients.

The cyclone scenario could affect emergency and government services through its impact on DFES and P&W. DFES indicated they would initiate cross-regional transfer of staff from outside the region, with the potential requirement for interstate assistance, which may impact their ability to maintain core services. Similar circumstances are expected for the flood scenario. P&W commented that they would likely be in charge of a number of the bushfires caused by the cyclone event, which would drain their district resources. They would likely require assistance from other areas; however, it may be difficult to mobilise resources if the roads are busy, closed or damaged.

The flood and HAZMAT scenarios could affect the ability of CPFS to provide core services. Over the course of the flood event large numbers of people could be displaced for greater than two weeks, which could put a strain on CPFS resources and local government resources, such as public buildings. Similarly, for the HAZMAT event CPFS would be responsible for the evacuation centre, though this would depend on the number of residences affected. The greatest impacts on CPFS services would be in the long term as it is likely that people may present psychological trauma after the incident and may need counselling.

Both the storm and cyclone scenarios were evaluated to pose high risk to power supply delivery. Western Power commented that storm events with high winds and lightning often cause significant damage to overhead power infrastructure. Response and repair activities could take multiple days and Western Power would need to manage staff member fatigue.

The cyclone scenario was assessed to increase the demand on public buildings and response and recovery activities. Local governments mentioned it would likely take at least two weeks to get themselves and their buildings back up to normal function, depending on staffing resources. During this time, all resources would be consumed and recovery plans would be required. They also noted that local government roads may require repair.

Risks to social setting

Seventy-five risk statements assessed the impact to the social setting (Table 12) focusing on the impacts to the district community's wellbeing, community services and culturally important activities and objects (see Appendix C for criteria).

Table 12: Impacts to social setting by hazard and risk level. Note: EQ = earthquake.

Category	Risk level				
	Extreme	High	Medium	Low	Very Low
Availability of essential supplies				Bushfire (2) Cyclone (2) Flood HAZMAT	EQ (2) Storm
Breakdown of social networks				Bushfire	EQ
Community services and events			EQ		EQ
Culturally significant facilities and customs		Storm	EQ	Bushfire (2) Heatwave Storm	Cyclone
Death/injury of animals				Bushfire Heatwave (2)	Cyclone EQ HAZMAT
Displacement or isolation of communities			EQ Flood (2)	Bushfire Cyclone HAZMAT	Cyclone Storm (2)
Educational facilities				Bushfire Cyclone EQ Storm	Flood HAZMAT
Facilities for vulnerable people				Bushfire Cyclone EQ Flood HAZMAT Heatwave (2)	Storm
Impacts to people's health				Bushfire Cyclone EQ Flood HAZMAT Heatwave	Storm
Impacts to tourism				Bushfire	
Loss of income				Bushfire EQ Heatwave	HAZMAT

Category	Risk level				
	Extreme	High	Medium	Low	Very Low
Psychological and emotional stress			HAZMAT		
Public unrest				HAZMAT	
Residential building damage			EQ	Bushfire Cyclone HAZMAT Storm	Flood
Social service providers				Bushfire HAZMAT	Cyclone EQ Flood Storm

The only high risk social setting statement addresses the storm's impact on the Australia Day Skyworks show. The impact would depend on the time that the storm came through. If the storm came through at 4.30 pm then then the event could potentially go ahead as the storm would have passed through the area before the main show started. If the storm arrived in Perth between 8.00–9.00 pm then the Skyworks show would be cancelled. Crowds typically gather along the Swan River foreshore hours prior to the start of the show and could be exposed to hail. An evacuation of large numbers of people would be required at short notice.

Likewise, the earthquake hazard was assessed to have several risks with major consequences (medium risks due to the lower likelihood). The impact to community wellbeing was due to the extensive building damage, loss of people's contents and the resulting displacement from their homes (Table 5). These were expected to result in the community's social fabric being significantly broken, extraordinary external resources required to return the community to functioning normally, and significant permanent dispersal (external to the metropolitan region). Participants estimated there would also be widespread permanent damage or localised permanent loss of objects of identified cultural significance. It was noted that heritage buildings are highly vulnerable and there is the opportunity for some to be completely lost. Major culturally important community events such as the Royal Show, horse racing, concerts, tennis and cricket matches could be cancelled or significantly delayed following the event. It is likely they would continue the following year.

Psychological and emotional stress due to the HAZMAT incident was a medium risk as some people may be concerned about the effects of hazardous contaminants and may leave the region.

Risks to environment

Twenty-eight risk statements were assessed for the environment (Table 13), addressing impacts to ecosystems, species and landscapes (see Appendix C for criteria).

Table 13: Impacts to environment by hazard and risk level. Note: EQ = earthquake.

Category	Risk level				
	Extreme	**High**	**Medium**	**Low**	**Very Low**
Coastal erosion		Cyclone			
Contamination from toxic substances		EQ	Bushfire Cyclone	EQ	HAZMAT
Debris or pollutants entering the riverine or marine environment				Bushfire Cyclone Flood Storm	HAZMAT
Flora and fauna		Storm	Bushfire Flood Storm (2)	Bushfire (2) Cyclone (2) Flood (2) HAZMAT (2) Heatwave (2)	
Impacts to estuaries			Cyclone		
Soil erosion				Flood	

Environment high risks were caused by the earthquake, storm and cyclone scenarios.

Contamination of the surrounding environment from the release of toxic substances during the earthquake was assessed as high risk. Contaminants could be sourced from the uncontrolled discharge of chemicals (particularly in the Kwinana Industrial Area), asbestos in collapsed buildings, raw sewerage released from overwhelmed systems, underground storage tanks or tanker or truck spillages. Riverine systems and coastal areas would be the most difficult sites to clean.

Contamination from the chemical released in the HAZMAT scenario was assessed as a very low risk as the chemical is not expected to impact the soil or groundwater, nor have an effect on the marine environment.

Coastline beach erosion from the cyclone scenario was also assessed as high risk. Stakeholders commented that different parts of the coastline are valued differently. In some areas, coastal erosion may affect industry or ecosystems, while in other areas such as Cottesloe Beach there may be a loss of aesthetic value. A program of intervention would likely be required for specific areas of the coastline, including artificial beach re-nourishment.

Impacts to the fauna due to the storm scenario were assessed as high risk. Stakeholders considered impacts to cockatoos, which are recognised at the national level.

Risks by theme

Risk statements were assessed across the five impact areas (economy, public administration, people, social setting and environment) following the *NERAG* consequence criteria. However, some risks crosscut multiple impact areas. By combining them into themes, common risks are highlighted for different sectors and actors.

The themes identified for the Perth metropolitan region are: buildings; community; education; government; health; industry/commercial; tourism; transport; and utilities. The environment category is not shown here as the data are the same as that represented in Table 13.

The colour coding in these tables follows the impact areas: pink—economy; orange—public administration; blue —people; purple—social setting; green—environment.

Buildings

The natural hazards have the greatest impact on buildings (Table 14).

The earthquake building loss model indicated potentially 30% of the buildings in the metropolitan region may sustain moderate to complete damage (Table 5). The potential loss of a hospital from the earthquake, most likely Fremantle or Rockingham, would impact health.

The cyclone and flood impacts on commercial and private buildings, coupled with demand on public facilities are likely to be greater than the 2010 Perth Storm event, which caused more than $1 billion worth of damage. Stakeholders also commented that public facilities are likely to take at least two weeks to become operational.

Table 14: Risks related to buildings. Note: EQ = earthquake.

Buildings					
Category	**Extreme**	**High**	**Medium**	**Low**	**Very Low**
Demand on public facilities		Cyclone	Flood	EQ	Storm
Emergency services			EQ	Cyclone Flood	Storm
Health services		EQ			

Buildings					
Category	**Extreme**	**High**	**Medium**	**Low**	**Very Low**
Impacts to commercial buildings, contents and services		Cyclone EQ Flood	HAZMAT Storm	Bushfire Heatwave	
Impacts to private buildings and contents		Bushfire Cyclone EQ	Flood Storm	HAZMAT	
Residential building damage			EQ	Bushfire Cyclone HAZMAT Storm	Flood

Community

The majority (55%) of community risk statements were low (Table 15).

The possible cancellation of the annual Australia Day Skyworks show was assessed to have a major consequence (high risk) for culturally significant customs. Similarly, the expected cancellations and delays of cultural activities as a result of the earthquake scenario could have major cultural consequences, though it has a lower likelihood.

The displacement of people from their homes is another area of risk to the community. The estimated damage or destruction of 30% of buildings (~180,000) for the earthquake would render many displaced for a long period of time. The destruction of heritage buildings brings the risk of a permanent loss of culture. The flood was estimated to cause displacement of people for more than two weeks.

There may be significant reductions in provision of core services offered by NGOs such as Meals on Wheels, which rely on volunteers. If volunteers are personally impacted and unable to assist, the core services can be substantially impacted. Historically this has occurred.

The psychological and emotional stress caused by the HAZMAT scenario has the potential to cause permanent displacement from the metropolitan region (moderate consequence, medium risk).

Table 15: Risks to the community. Note: EQ = earthquake.

Community					
Category	**Extreme**	**High**	**Medium**	**Low**	**Very Low**
Availability of essential supplies				Bushfire (2) Cyclone (2) Flood HAZMAT	EQ (2) Storm
Breakdown of social networks				Bushfire	EQ
Community services and events			EQ		EQ
Culturally significant facilities and customs		Storm	EQ	Bushfire (2) Heatwave Storm	Cyclone
Death/injury of animals				Bushfire Heatwave (2)	Cyclone EQ HAZMAT
Displacement or isolation of communities			EQ Flood (2)	Bushfire Cyclone HAZMAT	Cyclone Storm (2)
Facilities for vulnerable people				Bushfire Cyclone EQ Flood HAZMAT Heatwave (2)	Storm
Home care services			Cyclone	Cyclone Storm (2)	Flood
Loss of income				Bushfire EQ Heatwave	HAZMAT
Psychological and emotional stress			HAZMAT		
Public unrest				HAZMAT	
Social service providers				Bushfire HAZMAT	Cyclone EQ Flood Storm

Education

Risks to education were assessed as low and very low (Table 16). Bushfire, cyclone, earthquake and storm could impact schools for several weeks if buildings are damaged during the event. However, the Department of Education has the ability to relocate students in the meantime, and does not anticipate learning outcomes would be affected.

Table 16: Risks related to education. Note: EQ = earthquake.

Education					
Category	**Extreme**	**High**	**Medium**	**Low**	**Very Low**
Education facilities				Bushfire Cyclone EQ Storm	Flood HAZMAT

Government

The majority of risks (63%) to government activities in the metropolitan region are medium or high (Table 17). There would be a need for state agencies (e.g. DFES, CPFS, P&W) to bring in resources from outside of the region, including interstate resources, in order to maintain their core service delivery.

The earthquake scenario could generate catastrophic consequences for WA Police, ambulance services, and CPFS, such that they would be unable to provide some of their core services. Furthermore the workforce of organisations could be reduced or strained for several weeks as many staff members would be addressing their own personal issues.

Table 17: Risks related to government activities. Note: EQ = earthquake.

Government					
Category	**Extreme**	**High**	**Medium**	**Low**	**Very Low**
Demand on ChemCentre services			HAZMAT		
Emergency services		Cyclone Storm	Bushfire (2) Cyclone EQ (2) Flood (2) HAZMAT (2)	Cyclone Heatwave (2) Storm	

Government					
Category	**Extreme**	**High**	**Medium**	**Low**	**Very Low**
Government services		Cyclone EQ Flood HAZMAT	Bushfire Cyclone EQ (4) HAZMAT (2) Heatwave	Cyclone HAZMAT (2) Heatwave Storm	HAZMAT
Response and recovery activities		EQ HAZMAT	Bushfire Cyclone Storm	Heatwave	
Response and recovery activities		Cyclone	Bushfire Cyclone EQ (2) Flood Storm	Bushfire Cyclone (2) Flood HAZMAT (2) Heatwave (2) Storm	Flood HAZMAT

Health

The health high risks were generated by the earthquake, HAZMAT and cyclone scenarios (Table 18).

The earthquake scenario would have catastrophic impacts on health through deaths, injuries and the potential loss of a hospital. Loss modelling estimated at least 220 deaths, and at least 508 major injuries could occur (Table 6). These deaths and injuries could be further exacerbated as there are only 100 ICU beds to cater for these 508 injuries, and there is the chance a hospital could be damaged. Furthermore, there are up to 2000 life support patients who currently rely upon life support systems. The loss of power to these systems may cause fatalities.

The HAZMAT scenario was assessed to cause ~30 fatalities. Injuries would depend on how much antidote is available. There may be limited stock of the antidote available in the state.

The cyclone was assessed to cause critical injuries through flying debris, poor water quality, and injuries that residents sustain when protecting their property from subsequent bushfires. Participants believe that there could be notable mental trauma as individuals may not have been exposed to cyclone conditions before.

Table 18: Risks related to health. Note: EQ = earthquake.

Health					
Category	**Extreme**	**High**	**Medium**	**Low**	**Very Low**
Deaths		EQ HAZMAT	Bushfire Cyclone Flood HAZMAT Heatwave Storm		
Disease outbreak			Flood Heatwave		
Emergency services			Bushfire Cyclone	HAZMAT Heatwave Storm	EQ Flood Storm
Emergency services		EQ	HAZMAT	Heatwave	Flood
Health services			EQ HAZMAT	Bushfire Cyclone HAZMAT Heatwave	
Health services		EQ	Bushfire Cyclone HAZMAT Heatwave	Storm	Flood
Impacts to people's health				Bushfire Cyclone EQ Flood HAZMAT Heatwave	Storm
Injuries and illnesses		Cyclone EQ HAZMAT	Bushfire Flood Heatwave	Heatwave Storm	
Workforce productivity losses				Heatwave	

Industry/commercial

The single high risk statement related to the earthquake's impact to commercial activities (Table 19). This statement centred upon the scenario model output which indicated that there could potentially be approximately 30% of buildings suffering moderate to catastrophic damage (Table 5). Access to premises, insurance claim delays and difficulties sourcing alternative accommodation would be contributing factors. The workforce will also be limited for the first few weeks as people will be addressing their own personal recovery issues.

Table 19: Risks related to industrial/commercial activities. Note: EQ = earthquake.

Industry/commercial					
Category	**Extreme**	**High**	**Medium**	**Low**	**Very Low**
Impacts to agricultural and pastoral activities			Flood Storm	Bushfire Cyclone (2) Flood Heatwave (3) Storm	
Impacts to commercial activities		EQ	Bushfire HAZMAT (2)	Heatwave (3)	
Impacts to marine infrastructure and industry			EQ Storm	Cyclone Flood Heatwave	
Impacts to port and marina services			Cyclone Storm	Heatwave	
Impacts to timber industry			Cyclone		

Tourism

The earthquake scenario posed a medium risk to the tourism industry, resulting in financial losses (Table 20). This centred upon the decline of economic activity and/or loss of asset value of $759 million to $7.6 billion. Tourism WA noted that:

- non-essential visitation and activities would stop entirely for one month,
- the metropolitan area would be unserviceable (e.g. potential disruption to power and sanitation) for one to three months,
- reputational damage will impact visitation for six months,
- the rebuild of attractions on Rottnest Island and in the city could take three years,
- there would be limited market opportunity to rebuild visitation.

The flood scenario was also a medium risk for the tourism industry, resulting in financial losses of $76 million to $759 million. The Swan Valley, Barrack Sreet Jetty and Elizabeth Quay are particularly likely to be affected by the flooding.

Table 20: Risks related to tourism. Note: EQ = earthquake.

Tourism					
Category	**Extreme**	**High**	**Medium**	**Low**	**Very Low**
Impacts to tourism			EQ Flood	Bushfire Heatwave Storm	Cyclone
Impacts to tourism				Bushfire	

Transport

The highest risk to the road transport networks is from the earthquake scenario (Table 21). The earthquake is likely to cause damage to roads and congestion, resulting in delays and detours and increasing transport costs. The damage to roads may also cause increased vehicle operating costs.

The cyclone scenario posed a high risk to the aviation sector with estimated economic losses of more than $759 million. Perth Airport commented there could be extensive impact to the aviation sector due to the cost of the aircraft, repair, replacement and the inability to maintain passenger demand in the short term. Some aircraft may be flown out prior to the cyclone arriving but there can be millions to billions of dollars of aircraft assets at the airport at any time.

The flood was assessed to have a medium risk to public transport services through Perth Underground Station being flooded, affecting bus and train services.

Table 21: Risks related to transport. Note: EQ = earthquake.

Transport					
Category	**Extreme**	**High**	**Medium**	**Low**	**Very Low**
Disruption to aviation services			Cyclone Storm		
Disruption to transport routes		EQ	Bushfire (2)	Cyclone Flood Storm	HAZMAT (2)

Transport					
Category	**Extreme**	**High**	**Medium**	**Low**	**Very Low**
Emergency services			Bushfire Cyclone	EQ	
Impacts to aviation		Cyclone		Bushfire Heatwave Storm	EQ Flood
Impacts to bridges or their approaches			EQ	Cyclone Storm	
Impacts to public transport services			Flood		
Impacts to rail infrastructure			Bushfire	EQ Heatwave (2)	
Impacts to road infrastructure				HAZMAT Heatwave	
Impacts to transport infrastructure				Flood Storm	Cyclone HAZMAT

Utilities

The natural hazards have the largest impact to utilities (Table 22). In general, disruption to services is of greater risk than the economic cost of repairs. Results indicate that power supply delivery is the most vulnerable, followed by the sewerage and water supply delivery. The cyclone and storm scenarios could potentially cause $759 million to $7.6 billion worth of lost assets and/or decline in economic activity. Western Power noted that storm events with high winds and lightning often cause significant damage to overhead infrastructure. Response and repair times for cyclone and storm could take multiple days.

The HAZMAT scenario may affect the supply of fuel and have a financial impact on the airport as there are limited fuel reserves. Perth Airport is geographically isolated so aircraft fuel reserves are critical.

Table 22: Risks related to utilities. Note: EQ = earthquake.

Utilities					
Category	**Extreme**	**High**	**Medium**	**Low**	**Very Low**
Impacts to natural gas distribution				Heatwave	Cyclone Storm
Disruption to supply of natural gas					Bushfire Cyclone HAZMAT
Impacts to communication infrastructure			Storm	Bushfire Cyclone Flood Heatwave	EQ HAZMAT
Impacts to communication service delivery			Storm	Bushfire Cyclone EQ Flood Heatwave	HAZMAT
Impacts to fuel supplies			HAZMAT		
Impacts to power supply infrastructure			EQ	Bushfire Cyclone Flood Heatwave Storm	HAZMAT
Impacts to power supply service delivery		Cyclone Storm	EQ Flood Heatwave	Bushfire HAZMAT	
Impacts to sewerage systems				EQ Flood	Bushfire Cyclone Storm
Impacts to sewerage service delivery			Cyclone EQ Flood	Bushfire HAZMAT	
Impacts to water supply infrastructure				Bushfire (2) EQ Flood HAZMAT Heatwave	Cyclone Storm
Impacts to water supply service delivery			Cyclone EQ Flood	Bushfire Flood HAZMAT Heatwave	

6 Risk evaluation

The next step in the risk management process is to evaluate the risks, determining whether identified risks are acceptable or require treatment (Figure 14).

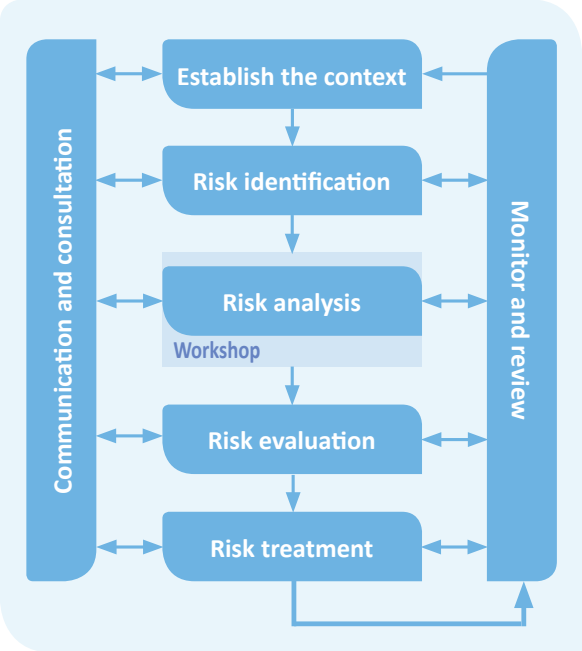


Figure 14: Emergency risk management process.[4]

The *NERAG* uses a prioritisation system to rank risks for treatment decisions and/or for further investigation. *NERAG* priority is based on the risk level and confidence associated with each assessed risk. Priority ranges from 1 (highest priority) to 5 (lowest priority). The following prioritisation of risks is a helpful tool to focus attention on the more significant risks. However, the determination of whether a risk is acceptable or should be treated has governance, financial and societal implications and is best administered by the appropriate level(s) of government.

As shown in Figure 15, there are no Priority 1 statements, 4% are Priority 2, 25% Priority 3, 32% Priority 4 and 39% of the statements are Priority 5. Priority 5 statements are considered to be broadly acceptable risks that require no further action, apart from monitoring and reviewing during the next assessment phase.

The Priority 2 risks, however, have a high priority for further investigation and/or treatment (Table 23). The Priority 2 risks are primarily caused by the earthquake (6 statements), cyclone (3) storm (3), bushfire (2) and HAZMAT (2) scenarios and these span all impact areas (Figure 15).

Half of the statements in Table 23 were assessed as high risks, while four were a medium risk. The medium risks have low or lowest confidence and would benefit from further investigation, which may change their priority level.

[4] Adapted from AS/NZS ISO 31000 - Reproduced under SAI Global copyright Licence 1411-c083

Table 23 contains the Priority 2 risk statements in full, in addition to those risk statements with catastrophic consequences. Catastrophic consequence statements are included because if these impacts do occur they could potentially stretch or outstrip the district's resources and therefore should be considered during the treatment phases.

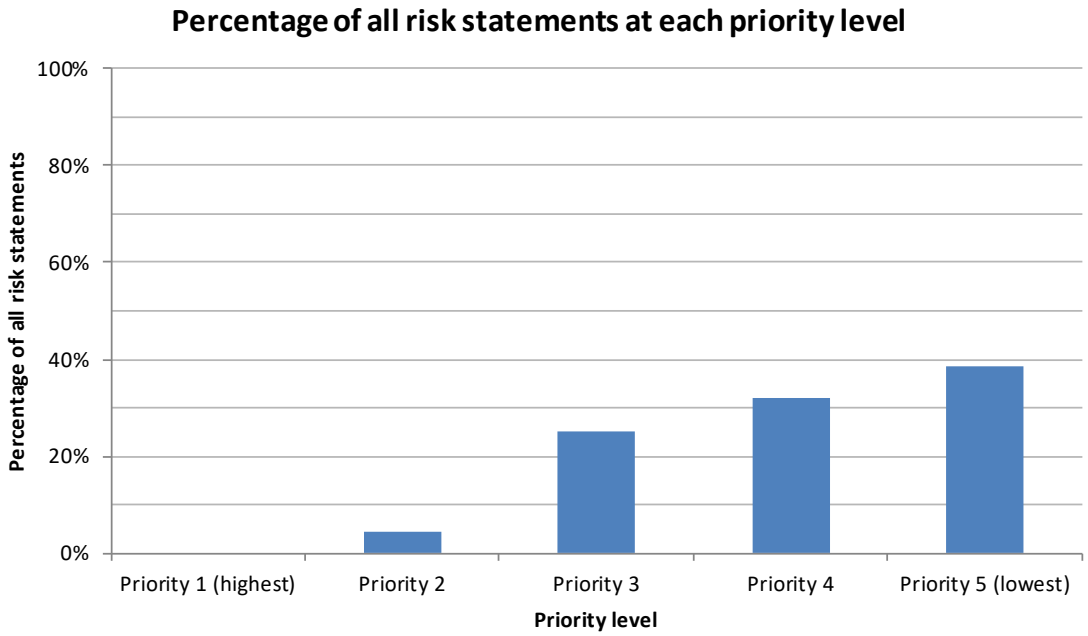


Figure 15: Percentage of all risk statements at each priority level. Priority 1 – highest; Priority 2 – high; Priority 3 – medium; Priority 4 – low; Priority 5 – lowest.

Table 23: Risk statements for the Perth metropolitan region with Priority level 2 or catastrophic consequences.

Hazard	Risk statement	Impact area	Consequence	Risk level	Confidence level	Priority level
Earthquake	will impact private buildings and contents, resulting in financial losses.	Economy	Catastrophic	High	Moderate	2
Earthquake	will impact commercial buildings, contents and services, resulting in financial losses.	Economy	Catastrophic	High	Moderate	2
Earthquake	will cause contamination to the surrounding environment from the release of toxic substances (e.g. of non-natural materials).	Environment	Catastrophic	High	Moderate	2
Earthquake	will impact main road transport routes, resulting in recovery costs and financial losses to the district.	Economy	Catastrophic	High	Low	2
Earthquake	will impact power infrastructure, resulting in costs to the district and financial losses.	Economy	Major	Medium	Low	2
Earthquake	will impact tourism in the district, including aspects that support the tourism industry (such as access routes, facilities, historical buildings and sites, motels, food and fuel outlets), resulting in costs to the district and financial losses.	Economy	Major	Medium	Low	2
Bushfire	will impact private buildings and contents, resulting in financial losses.	Economy	Major	High	High	2
HAZMAT	will result in an increased demand (surge) on CPFS services, impacting their ability to deliver core services.	Public Administration	Major	High	Low	2
HAZMAT	will impact the health of people and cause death(s).	People	Major	High	Moderate	2
Storm	will cause an increased demand on DFES services, impacting their ability to maintain core services.	Public Administration	Major	High	Moderate	2
Storm	will impact culturally important events such as Skyworks.	Social Setting	Major	High	Moderate	2
Cyclone	will impact coastlines, resulting in beach erosion.	Environment	Major	High	Moderate	2

Hazard	Risk statement	Impact area	Consequence	Risk level	Confidence level	Priority level
Cyclone	will impact the aviation sector (including damage to aviation infrastructure), resulting in recovery costs and financial losses.	Economy	Major	High	Moderate	2
Cyclone	will impact the health of people and cause injury and/or serious illness.	People	Major	High	Moderate	2
Bushfire	will impact main roads to access the CBD, including Mounts Bay Road, Thomas Street and Kings Park Road, resulting in financial losses to the district.	Economy	Moderate	Medium	Low	2
Storm	will require response and recovery works to be undertaken by Department of Education, impacting their ability to deliver core services.	Public Administration	Moderate	Medium	Lowest	2
Earthquake	will disrupt business activities, resulting in financial losses.	Economy	Catastrophic	High	High	3
Earthquake	will result in recovery activities, resulting in costs to the district.	Economy	Catastrophic	High	High	3
Earthquake	will cause an increased demand (surge) on Department of Child Protection and Family Support services, impacting their ability to deliver core services.	Public Administration	Catastrophic	High	High	3
Earthquake	will cause an increased demand (surge) on ambulance services, impacting their ability to deliver core services.	Public Administration	Catastrophic	High	High	3
Earthquake	will cause an increased demand (surge) on WA Police services, impacting their ability to deliver core services.	Public Administration	Catastrophic	High	High	3
Earthquake	will impact hospital buildings, impacting their ability to deliver core services.	Public Administration	Catastrophic	High	High	3
Earthquake	will impact the health of people and cause death(s).	People	Catastrophic	High	High	3
Earthquake	will impact the health of people and cause injury and/or serious illness.	People	Catastrophic	High	High	3

7 Future actions

A preliminary treatment discussion will be held with relevant agencies to review the risk assessment results and begin the conversation concerning risk tolerability and potential treatment strategies.

Appendix A: Individual hazard risk assessment summaries

This appendix contains a summary of the assessed risks for each of the hazards against the five impact categories.

Bushfire

This section summarises the risk to the Perth metropolitan region from the bushfire scenario. The percentage of risk statements at each risk level for the bushfire scenario is shown in Figure 16.

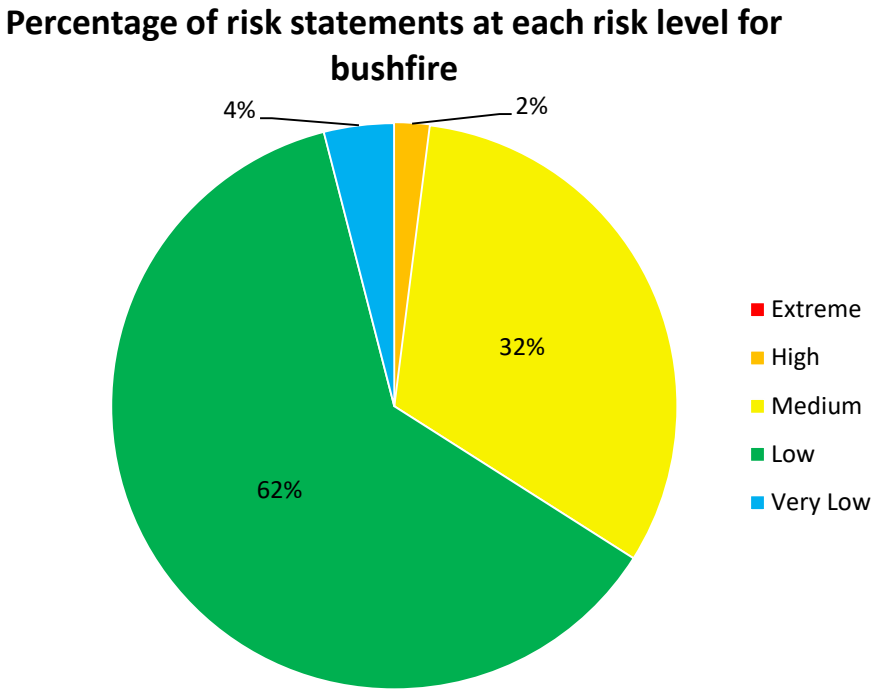


Figure 16: Percentage of risk statements at each risk level for bushfire.

Bushfire risk assessment		
ECONOMY		**Extreme risks** Nil. **High risks** The financial costs due to the impacts on private buildings and contents. Approximately 300 houses could be impacted. **Medium risks** The financial losses from the disruption of business activities, particularly if there are issues accessing the CBD. The disruption of eastern train lines and main road networks, including Mounts Bay Road, Thomas Street, Kings Park Road, Roe Highway, Great Eastern Highway and Great Northern Highway, could result in financial losses. The recovery costs for the three fires were estimated to be greater than $75 million. **Low risks** Financial losses due to damage of commercial buildings and their contents, the impacts on utilities infrastructure (including critical water infrastructure, power lines and communications), impacts to tourism, viticulture and Perth Airport. **Very Low risks** Costs associated with the impact on the sewerage system.
PEOPLE		**Extreme and High risks** Nil. **Medium risks** Death, injuries and/or illness could result from car accidents, individuals becoming trapped, and from exacerbating existing medical conditions (heart attacks, respiratory diseases, etc.). The congestion on the roads and poor visibility could complicate the emergency service response, causing further deaths directly attributable to the bushfire. **Low risks** The health services being overwhelmed, causing further deaths directly attributable to the bushfire. **Very Low risks** Nil.
PUBLIC ADMINISTRATION		**Extreme and High risks** Nil. **Medium risks** The impact on local governments' abilities to deliver core services would depend the size of their area. Smaller ones would be more affected than the City of Perth. The impact on the ability of agencies such as DFES, emergency services (WA Police, ambulance), CPFS and metropolitan health to deliver their core services. Disruption or damage to transport networks delaying emergency services from providing assistance. **Low risks** The ability for state agencies, such as DAFWA, Department of Education and Main Roads to deliver their core services. The impacts on utilities including power infrastructure, mobile and landline communications, water infrastructure and sewerage services. **Very Low risks** The impact to the natural gas supply.

Bushfire risk assessment		
SOCIAL SETTING		**Extreme, High and Medium risks** Nil. **Low risks** Impacts to the community as a result of death and injuries, damage to residential dwellings and contents, changes to the aesthetics of the area, the separation of children from their parents, losses of income, and death, displacement or injury to domestic animals. The impacts to tourism, heritage and culturally significant facilities, social services provision, availability of basic commercial products and services, the day-to-day functionality of education facilities and facilities for vulnerable people (such as aged care, childcare and disability support) were also low risks. **Very Low risks** Nil.
ENVIRONMENT		**Extreme and High risks** Nil. **Medium risks** Contamination of the environment due to the release of toxic material. The main concern is illegal dumping sites, and what unknown materials may be burned. The impacts on the biodiversity of the Kings Park Botanical Gardens are likely to be short term. Recovery efforts may be required, but impacted species could be replaced and biodiversity would be maintained in the long term. **Low risks** The impact on flora and the health of wildlife. The contamination of river systems and ocean areas from debris and pollutants. **Very Low risks** Nil.

Cyclone

This section summarises the risk to the Perth metropolitan region from the cyclone scenario. The percentage of risk statements at each risk level for the scenario is shown in Figure 17.

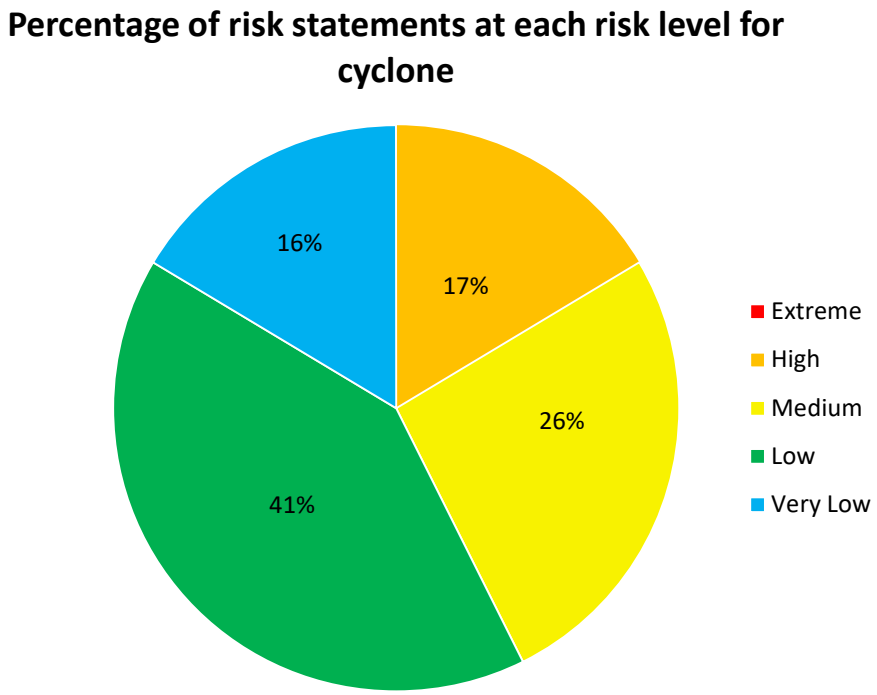
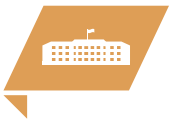


Figure 17: Percentage of risk statements at each risk level for cyclone.

Cyclone risk assessment	
ECONOMY	**Extreme risks** Nil. **High risks** Financial losses associated with damage to private and commercial buildings and contents as well as commercial services. A large number of homes are likely to be affected, with impacts expected to be greater than the 2010 Perth Storm. Impacts to the aviation sector (including infrastructure), resulting in financial losses due to the cost of the aircraft, repair, replacement and inability to maintain passenger demand in the short term. **Medium risks** Impacts to: response and recovery activities where resources are stretched, vessels and marine infrastructure, and the timber industry. The expected recovery costs and financial losses in each case was $76 million to $759 million. Financial losses of approximately $80 million in economic trade were anticipated if Fremantle Port was closed for a day. A fire as a result of the ex-tropical cyclone could potentially damage 20,000 ha of timber available for timber production. **Low risks** Recovery costs and financial losses due to impacts to transport routes, power infrastructure, the aviation sector, agriculture and horticulture. **Very Low risks** Impacts to potable water and sewerage, rail lines and tourism.

Cyclone risk assessment	
PEOPLE 	**Extreme risks** Nil. **High risks** Injury or serious illness. There is likely to be a significant amount of mental health issues, particularly for people who have not experienced these types of events before. **Medium risks** Deaths due to the event itself, and from emergency services being overwhelmed. These may be due to power outages and the overwhelming of communications (particularly in rural areas) preventing calls for assistance. Ambulances may not arrive in time due to the impacts from the storm. In addition, people may injure themselves, possibly resulting in death, when undertaking repairs on their home. **Low risks** Health services being overwhelmed, resulting in further deaths directly attributable to the hazard event. **Very Low risks** Nil.
PUBLIC ADMINISTRATION 	**Extreme risks** Nil. **High risks** The ability for DFES, P&W and Western Power to maintain core services. DFES and P&W indicated they would seek assistance from outside the region. P&W commented that they would likely be in charge of a number of the bushfires due to the event, which could drain their district resources. Increased demand on public buildings, and recovery works undertaken by local governments. **Medium risks** Water service infrastructure separate from the main Integrated Water Scheme (IWS) and sewerage systems are likely to be impacted as a result of more than 720 pump stations stopping operation. The impacts on both water and sewerage would be dependent on the duration of power outages. For WA Police, duration would be an issue. The impact to them would depend on how quickly other agencies mobilise. WA Health has surge plans; however, their impact would depend on a loss of power and water. Backup generators are available but these would be limited to critical functions. Impacts to aviation services could last for 3–5 days. Damage to transport infrastructure preventing or delaying emergency services from providing assistance. Impacts to the delivery of core services of: communication infrastructure; service providers (e.g. NGOs or Meals on Wheels); local government response; and port and marinas. **Low risks** Impacts to core service delivery of St John Ambulance, CPFS, health care and home-based service providers, port and marina zones, response and recovery works undertaken by other state agencies and emergency service response buildings. **Very Low risks** Nil.

Cyclone risk assessment		
SOCIAL SETTING		**Extreme and High risks** Nil. **Medium risks** Damage to commercial outlets and service providers, resulting in isolated reductions in the availability of goods and services. Larger companies such as Coles and Woolworths may either recover quickly while smaller businesses could take up to two to three years to recover. **Low risks** Impacts to the district community due to impacts to: health of residents through serious injury or illness; residential dwellings and contents; main roads in the district (disrupting the availability of essential goods); the day-to-day functionality of facilities for education and vulnerable people; and displacement (>14 days). **Very Low risks** Impacts to the district community through death or injury to animals, injury or displacement of persons; impact to social service providers; damage to heritage buildings, churches and places of worship resulting in a loss of cultural significance; and displacement (<14 days).
ENVIRONMENT		**Extreme risks** Nil. **High risks** Impacts to the coastline, resulting in beach erosion. It was noted that different parts of the coastline have differing values. In some areas, coastal erosion may affect industry or ecosystems, while in other areas—such as Cottesloe Beach—it may be a loss of aesthetic value. A program of intervention would likely be required for specific areas of the coastline, including artificial beach re-nourishment. **Medium risks** Contamination to the surrounding environment from the release of toxic substances and impacts to estuary and sea walls. Impacts are likely to be localised and contamination would depend on the type of businesses in the impact area, and the severity of impact. **Low risks** Impacts to fauna and flora; and debris and pollutants flowing into riverine, estuarine, marine environments causing contamination. **Very Low risks** Nil.

Earthquake

This section summarises the risk to the Perth metropolitan region from the earthquake scenario. The percentage of risk statements at each risk level for the scenario is shown in Figure 18.

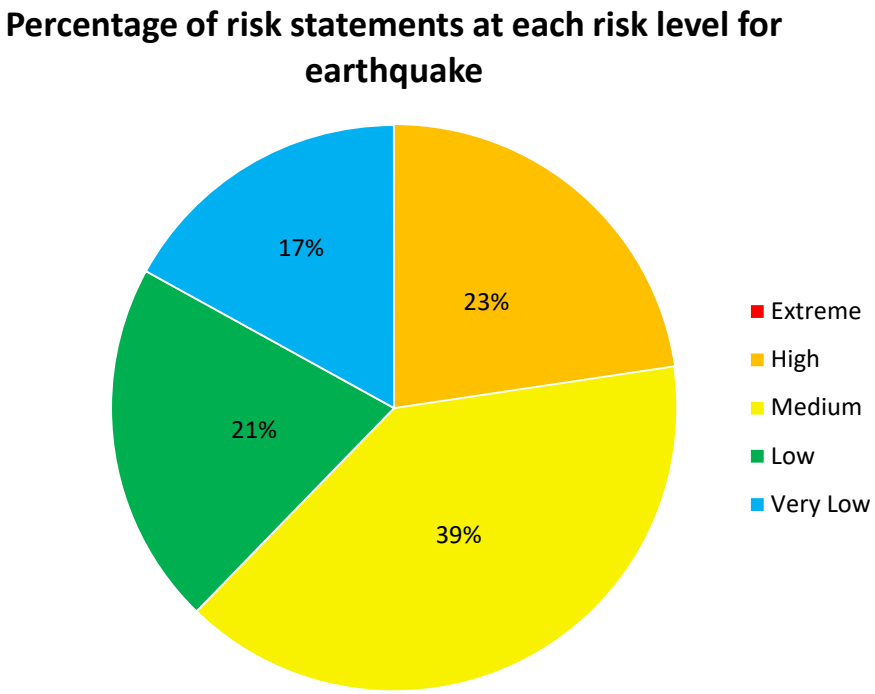


Figure 18: Percentage of risk statements at each risk level for earthquake.

Earthquake risk assessment	
ECONOMY	**Extreme risks** Nil. **High risks** Impacts to private and commercial buildings, business activities, transport routes and recovery activities. The buildings and business activities assessments were based on building loss model data (Table 5). **Medium risks** Damage to bridges, power infrastructure, tourism and port and marina facilities. A critical issue for each of these risks is the length of time required to restore the operation of infrastructure. **Low risks** Impacts to rail lines, water and sewerage infrastructure. **Very Low risks** Damage to communications infrastructure and impacts to Perth Airport.

Earthquake risk assessment		
PEOPLE		**Extreme risks** Nil. **High risks** The earthquake scenario is expected to result in at least 22 deaths, and 508 serious injuries. Limited ICU beds and the potential loss of a hospital as a result of the earthquake could exacerbate both deaths and injuries. **Medium risks** Health services (e.g. ICU units, hospitals, clinics) being overwhelmed, resulting in further deaths directly attributable to the earthquake. Resources are likely to be stretched beyond their limits because of the low number of ICU beds, lack of power affecting life support, combined with a reduction in staff attendance, and damage to infrastructure and equipment. **Low risks** Nil. **Very Low risks** Emergency services (including ambulance and medical transport services) being overwhelmed, resulting in further deaths directly attributable to the hazard event.

Earthquake risk assessment

Extreme risks

Nil.

High risks

Impacts to the core service delivery of WA Police, CPFS, ambulance services and WA Health services. Each of these organisations would be unable to deliver their core functions. This is due to a large number of displaced people (~2000) and a limited workforce due to staff members being impacted by the earthquake and dealing with their own issues. Many members of the public may not receive immediate help from emergency services and would need to be self-reliant. WA Health advised that if one hospital were lost (most likely Fremantle or Rockingham) the impacts would be extreme, as there is no capacity for existing patients to be moved and major evacuations would be required.

Medium risks

All services mentioned would have a severe reduction in the delivery of their core functions. Much of the workforce in each organisation also would be addressing their own personal issues. The earthquake would have a major and prolonged impact on DFES as their responsibilities cover earthquake, fire, collapse, and urban search and rescue activities. All of these services are likely to be required during an earthquake of this magnitude. Emergency response buildings and facilities in western suburbs from Fremantle to Wanneroo would be impacted with a loss of SES and volunteers firefighting buildings and equipment. Consequently, backup equipment would be required. Many local governments would require state assistance. The greatest impact to government offices, works depots and facilities, would be on Rottnest Island and in Fremantle and the western central suburbs. A critical issue would be the amount of rubble generated which would need to be removed and would affect their ability to maintain normal work practices. Any damage sustained by water pipes would impact water availability and could cause wastewater services to cease, which would become a public health issue. Water services could be limited to only half the region's population and repairs would likely take a long time. Other services would also be impacted: WA Police, Botanic Gardens and Parks Authority, Department of Education, Main Roads, government services (Centrelink, court services, disability services, licencing services), power supply services.

Low risks

Impacts to the delivery of core services of communications and public facilities were considered a low risk.

Very Low risks

Nil.

Earthquake risk assessment	
SOCIAL SETTING 	**High risks** Nil. **Medium risks** Impacts to the community wellbeing as a result of damage to residential dwellings and contents, and the displacement of people. This could result in the community social fabric being significantly broken, extraordinary external resources required to return the community to normal function, and/or significant permanent dispersal (external to the metropolitan region).The impact to heritage buildings could result in widespread permanent damage or localised permanent loss of objects of identified cultural significance. Impact on major community buildings and events, particularly delays to culturally important events. **Low risks** Impacts to the wellbeing of the community due to losses of income/ employment and impact to the health of the residents in the area causing death and serious injury/illness. Impact to the day-to-day functionality of facilities for education and vulnerable people (e.g. aged care, childcare, disability support). **Very Low risks** Disruption to the district community due to: death, injury or displacement of animals; damage to commercial retail outlets, service providers and arterial road networks impacting the availability of basic commercial products and services; impacts to social service providers and community buildings; and the breakdown of existing support networks.
ENVIRONMENT 	**Extreme risks** Nil. **High risks** Contamination of the surrounding environment from the release of toxic substances during the earthquake. Contaminants could be sourced from the uncontrolled discharge of chemicals, asbestos in collapsed buildings, raw sewerage released from overwhelmed systems, underground storage tanks or tanker or truck spillages. **Medium risks** Nil. **Low risks** Contamination of the surrounding environment from the release of non-toxic substances—e.g. effluent, sediments, debris, sanitation. **Very Low risks** Nil.

Flood

This section summarises the risk to the Perth metropolitan region from the flood scenario. The percentage of risk statements at each risk level for the scenario is shown in Figure 19.

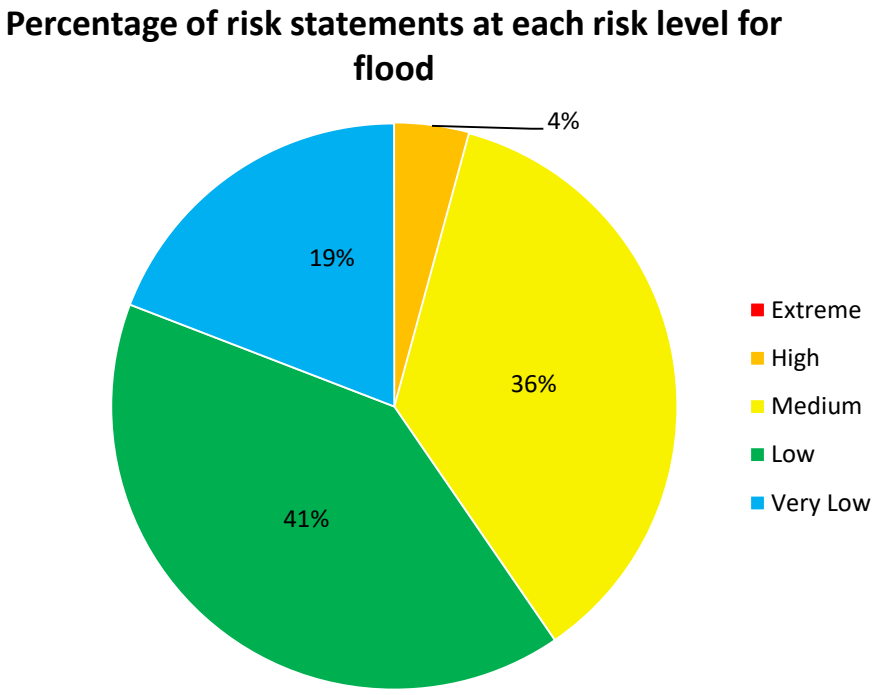
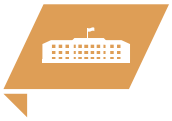


Figure 19: Percentage of risk statements at each risk level for flood.

Flood risk assessment	
ECONOMY	**Extreme risks** Nil. **High risks** Damage to commercial buildings and contents. The risk to commercial buildings was higher than residential buildings as commercial buildings are typically of higher value. **Medium risks** Impacts to residential buildings. The tourism industry could be affected by this flood event, particularly tourism activities, businesses and sites located in the Swan Valley, Barrack Street Jetty and Elizabeth Quay. Impacts to cropping and viticulture in the district were assessed as a medium risk as heavy rainfall could damage crop leaves and roots. **Low risks** Impacts to transport infrastructure (including bridges and transport routes), power infrastructure, water supply systems, sewerage systems, large communication exchanges, and yacht and boat clubs. **Very Low risks** Damage to Perth Airport.

Flood risk assessment	
PEOPLE 	**Extreme and High risks** Nil. **Medium risks** There is a potential for deaths and injuries as a result of the flood. Entering floodwaters on foot or in a vehicle and the potential for landslides in some areas were cited as potential causes of injury and/or death. Health effects from stagnant water and waterborne diseases were assessed as a medium risk. **Low risks** Nil. **Very Low risks** Emergency services (including ambulance and medical transport services) being overwhelmed, resulting in further deaths directly attributable to the hazard event.
PUBLIC ADMINISTRATION 	**Extreme risks** Nil. **High risks** Increased demand on CPFS, impacting their ability to deliver core services. The displacement of people for greater than two weeks would put a strain on CFPS resources as well as local government resources such as public buildings. **Medium risks** Impacts to the power and transport infrastructure. The floodwaters would mostly affect underground assets which take longer to repair than overhead assets. Perth Underground Station (both rail and busport) and approaches to some bridges would be underwater, resulting in reduced public transport services. Damage and inundation of sewerage systems and road drainage systems would impact the Water Corporation's core services. An increased demand on public facilities, DFES and WA Police services is expected. **Low risks** Response and recovery works; impacts to emergency service response buildings and facilities, potable water supplies and communication services. The WA Police Maylands Incident Control Centre (MICC) would likely be flooded. There are backup facilities elsewhere in the metropolitan region, however, and it is not anticipated to result in a significant reduction of WA Police core services. **Very Low risks** Impacts to the services provided by the Department of Education, WA Health, ambulance, home-based care organisations and NGOs were deemed very low.

Flood risk assessment	
SOCIAL SETTING 	**Extreme and High risks** Nil. **Medium risks** Both short and long term (>14 days) displacement from people's homes and work places, impacting community wellbeing. **Low risks** Impact the health of residents and cause death or serious injury/illness, impacting the wellbeing of the district community. Damage to commercial retail outlets and service providers, affecting the availability of basic commercial products and services. Impacts to the day-to-day functionality of facilities for vulnerable people (aged care, childcare, disability support). **Very Low risks** Impacts to the community as a result of damage to residential dwellings and contents. Social service provision and educational facilities may also be impacted.
ENVIRONMENT 	**Extreme and High risks** Nil. **Medium risks** Impact oxygenation systems in the Canning River, reducing the river's oxygen levels. In the Canning River there are three systems which pump oxygen into the river to keep the ecosystem healthy and prevent algae blooms. The physical infrastructure should not be impacted by the floodwaters unless there are significant amounts of debris. The additional flushing of the river by the floodwaters may also assist in algal bloom prevention. **Low risks** Impacts to fauna and flora, including protected flora and fauna in conservation parks. The flooding may cause soil erosion in river catchments, and the contamination of river systems and ocean areas from debris and pollutants. **Very Low risks** Nil.

HAZMAT

This section summarises the risk to the Perth metropolitan region from the HAZMAT scenario. The percentage of risk statements at each risk level for the scenario is shown in Figure 20.

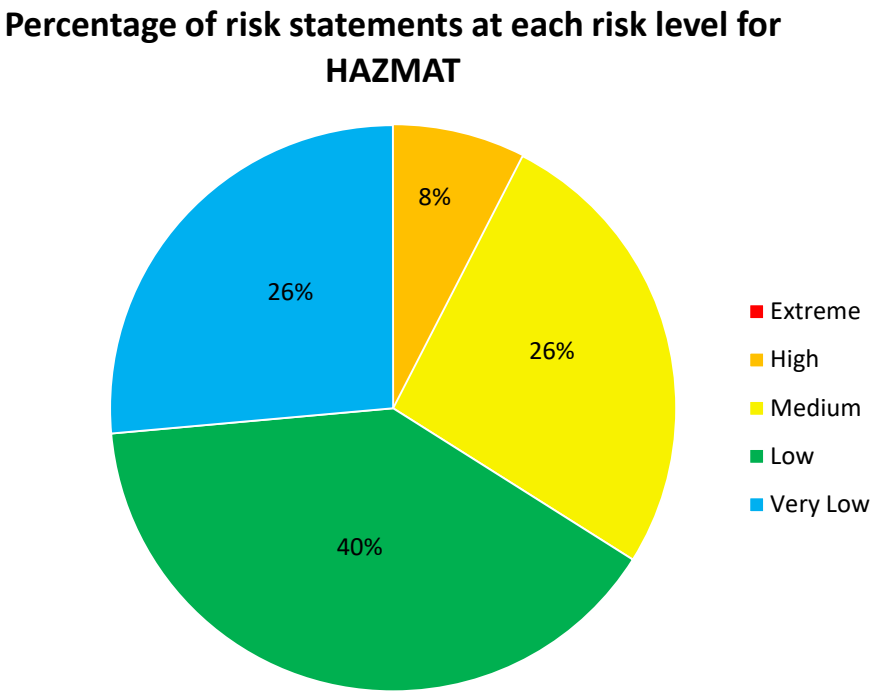
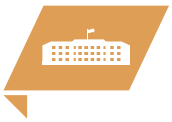


Figure 20: Percentage of risk statements at each risk level for HAZMAT.

HAZMAT risk assessment	
ECONOMY	**Extreme risks** Nil. **High risks** Financial losses associated with response and recovery activities, including costs associated with fatalities and incident clean-up. **Medium risks** The financial impact on commercial buildings, and businesses in the Kwinana Industrial Area. A decrease in visits to businesses in the area may be expected due to people's concern about the pollutant. Furthermore, the east end of the impact area may experience a loss of power as insulators may be damaged. Western Power may have to wait until the area is declared safe before restoring these services. Impacts on the airport due to fuel disruption as there is only storage for one day's operation. As Perth Airport is isolated, fuel reserves are essential. Previous disruption has been experienced and it can significantly restrict airport activities. Airlines would be advised to change to lighter aircraft and many aircraft arriving at Perth Airport would not be able to depart. **Low risks** Costs from road closures and from damage to private buildings, their contents, and water infrastructure. **Very Low risks** Costs and financial losses related to transportation (rail and bus), power infrastructure and communication.

HAZMAT risk assessment	
PEOPLE 	**Extreme risks** Nil. **High risks** The impact on the health of people, including death and injuries and/or serious injuries. It was estimated that the HAZMAT scenario could cause approximately 30 deaths, potentially including the industry employees and nearby residents. The number of injuries and illnesses would depend on how much antidote was available and the speed of application. **Medium risks** Further death(s)/injury(s)/illness due to the limited availability of the antidote in the metropolitan region and the potential delay in medical treatment. **Low risks** Further death(s)/injury(s)/illness directly attributed to the hazard event due to the emergency and health services being overwhelmed. **Very Low risks** Nil
PUBLIC ADMINISTRATION 	**Extreme risks** Nil. **High risks** Impacts to the core service delivery of CPFS. The greatest impacts on CPFS services may be in the long term with people presenting psychological trauma after the incident, requiring counselling. **Medium risks** Impacts to the core service provision of DFES, WA Police, ambulance, metropolitan health services, Main Roads, Department of Environment and Regulation (DER) and ChemCentre. The greatest consequences for WA Police may be in the long term, particularly for the forensic unit and recovery. WA Police may seek interstate support for forensic and coronial assistance. Ambulance services may divert resources to maintain core services. ChemCentre has limited resources; however their impacts will be short term. **Low risks** Impacts to the core service delivery of Public Transport Authority, Department of Agriculture and Food WA and local governments and utilities services including power, water and sewerage. **Very Low risks** The impact on the ability to maintain core services for Department of Mines and Petroleum, and P&W. Impacts to natural gas distribution and communications.

HAZMAT risk assessment		
SOCIAL SETTING		**Extreme and High risks** Nil. **Medium risks** Psychological and emotional stress may cause some people to permanently leave the region. **Low risks** Impacts due to: serious illness and death within the community, damage to residential dwellings and contents; social unrest and distress. Impacts to the availability of basic commercial products and services, and the day-to-day functionality of services for vulnerable people. Evacuation of people from homes and work places. **Very Low risks** Impacts on the district community due to displacement, death or injury of animals, the functionality of educational facilities and losses of income/ employment.
ENVIRONMENT		**Extreme, High and Medium risks** Nil. **Low risks** Impacts to fauna and flora in the district. **Very Low risks** Contamination of soil and/or groundwater, and riverine and marine systems.

Heatwave

This section summarises the risk to the Perth metropolitan region from the heatwave scenario. The percentage of risk statements at each risk level for the scenario is shown in Figure 21.

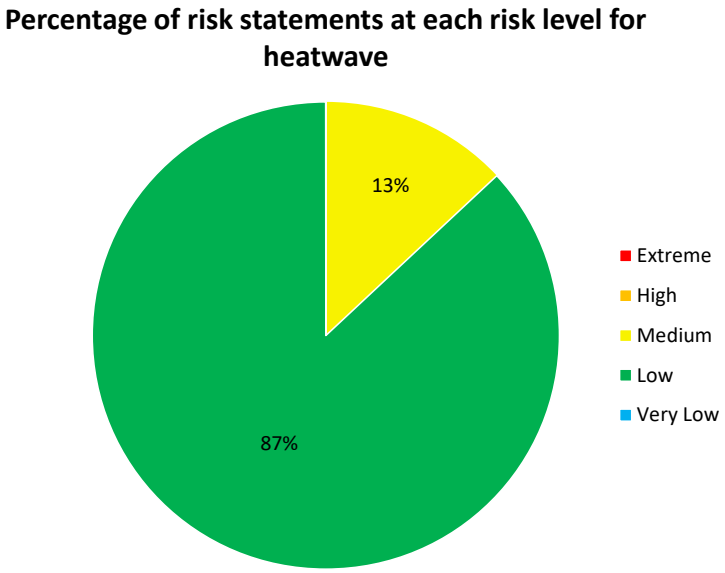


Figure 21: Percentage of risk statements at each risk level for heatwave.

Heatwave risk assessment		
ECONOMY		**Extreme, High and Medium risks** Nil. **Low risks** Financial losses associated with impacts to utilities infrastructure including power, communication, gas and water; transport services including roads, rail, and Perth Airport. The costs to businesses, food retailers, and Fremantle Port. The impacts to agriculture including livestock, viticulture and irrigated agriculture. Impacts on sport and music events and outdoor activities. Recovery costs are expected to be minor across the region ($7.6 million to $76 million). **Very Low risks** Nil.
PEOPLE		**Extreme and High risks** Nil. **Medium risks** The heatwave scenario is expected to result in at least three deaths; people with pre-existing or poor health conditions are more susceptible. It is often difficult to attribute a death (or illness) directly to a heatwave event. Impacts on the health of people including injuries, illnesses, and the potential increase in gastrointestinal outbreak. **Low risks** Further death, illness and/or injuries caused by health and emergencies services being overwhelmed. Increase in illnesses (e.g. gastrointestinal illnesses) due to impacts on waterways. **Very Low risks** Nil.
PUBLIC ADMINISTRATION		**Extreme and High risks** Nil. **Medium risks** Impact to the core service provision of health services, CPFS and power services providers. Between 2000 and 3000 people may lose power for a number of days. In addition, the response personnel to repair the infrastructure require specialist skills; thus power service providers may encounter a specialised workforce shortage. **Low risks** Impacts to the core service delivery of ambulance services, WA Police, DFES, Water Corporation, communication services, PTA, Fremantle Ports Authority, P&W, Main Roads, and local government. Some services may be impacted by a loss of power, however the impact would be minimal. **Very Low risks** Nil.

Heatwave risk assessment	
SOCIAL SETTING	**Extreme, High and Medium risks** Nil. **Low risks** Impacts to the community caused by health issues of residents and animals (including domestic animals and livestock), losses of income/ employment, and impacts on sports events. The impacts to the day-to-day facilities of vulnerable people including aged care, childcare and disability support. **Very Low risks** Nil.
ENVIRONMENT	**Extreme, High and Medium risks** Nil. **Low risks** The threat to fauna and flora. **Very Low risks** Nil.

Storm

This section summarises the risk to the Perth metropolitan district from the storm scenario. The percentage of risk statements at each risk level for the scenario is shown in Figure 22.

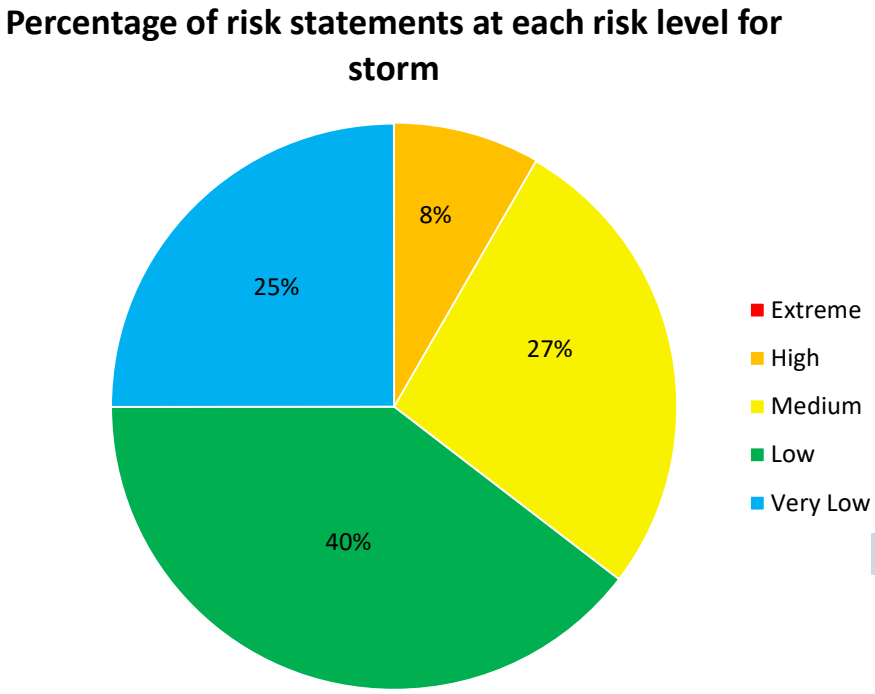
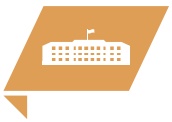


Figure 22: Percentage of risk statements at each risk level for storm.

Storm risk assessment	
ECONOMY 	**Extreme and High risks** Nil. **Medium risks** Financial losses associated with damage to: private buildings and contents; commercial buildings and contents and commercial services; communications infrastructure; marine infrastructure and vessels; and response and recovery activities. Telstra commented that the 2010 Perth Storm damaged many smaller telecommunications sites due to lightening; however, they were able to restore their equipment within a week. In addition, there were hundreds of individual premises that suffered damage to communication cabling and equipment. With impacts to horticulture, stakeholders commented that vineyards would likely take about 2 to 3 years to get back to full production after damage sustained during this scenario. **Low risks** Financial losses associated with damage to: transport infrastructure, power infrastructure, aviation sector, tourism industry, and agricultural and horticultural industry infrastructure. **Very Low risks** Financial losses associated with damage to: potable water, sewerage systems, and natural gas distribution.
PEOPLE 	**Extreme and High risks** Nil. **Medium risks** Stakeholders considered there is a medium risk of death, as many people will be exposed to extreme weather while attending the Skyworks show. This was based on comparisons with the 2010 Perth Storm. **Low risks** Injuries due to the storm, and further injuries and deaths as a result of lack of access for emergency services. **Very Low risks** Emergency services (including ambulance and medical transport services) being overwhelmed, resulting in further deaths directly attributable to the storm.

PUBLIC ADMINISTRATION



Storm risk assessment

Extreme risks

Nil.

High risks

Impacts to services provided by Western Power and DFES. Western Power commented that storm events with high winds and lightning often cause significant damage to overhead power infrastructure. Response and repair could take multiple days. DFES would seek assistance from outside the region, and their incident management teams could be stretched.

Medium risks

Impacts to response and recovery activities of other state agencies. However, the impact would vary between the different agencies. The impact on DAFWA would be insignificant; conversely, there would be greater impact on the Department of Education. The start of the school term may be delayed for 1–2 weeks while they relocate students and teachers. Impacts are expected to telecommunication service delivery due to lightning damage of electronic equipment. Telstra suggested they could restore most sites within 1–2 days of a major storm; however, end users would have to wait for the repair or replacement of cable faults, phones and modems. Stakeholders determined that the impacts on port and marine zones service delivery would be medium risk due to the port closure. Ships would likely be put into a holding pattern until the port was reopened and operational. Also, there would be thousands of recreational vessels on the water watching the Skyworks show requiring management.

Low risks

Impacts to the services of the CPFS, emergency services (police, ambulance), all WA Health services, home care and home-based services sector (GP services, home care providers, Silver Chain etc), service providers (e.g. NGOs such as Meals on Wheels), and recovery works undertaken by local governments.

Very Low risks

Damage to emergency service response buildings and facilities and the increased demand (surge) on public facilities (including public buildings), affecting standard service provision.

Storm risk assessment		
SOCIAL SETTING		**Extreme risks** Nil. **High risks** Impact on the Australia Day Skyworks show. The degree of impact would depend on the time that the storm came through. Crowds typically gather along the Swan River foreshore hours prior to the start of the show and could be exposed to hail. An evacuation of large numbers of people would be required at short notice. **Medium risks** Nil. **Low risks** Impact on residential dwellings and contents, impacts to the day-to-day functionality of educational facilities, and damage to heritage buildings, churches and places of worship. **Very Low risks** Short and long-term displacement, the day-to-day functionality of facilities for vulnerable people, and disruption to social service providers.
ENVIRONMENT		**Extreme risks** Nil. **High risks** Impacts to the fauna, such as cockatoos, which are recognised at the national level. **Medium risks** Destroying or harming of protected flora and fauna. **Low risk** Impacts caused by debris and pollutants flowing into marine, estuarine and/or riverine environments, causing contamination and/or impacting ecosystems. **Very Low risks** Nil.

Appendix B: Perth metropolitan region profile

The Perth metropolitan region has a population of approximately 2.2 million residents and covers a geography of 8060 km^2. It has a coastal strip to the west with coastal plains and dunes structures and Perth Hills to the east. The Swan and Canning Rivers are major landscape features.

It has 34 local governments and is separated into four EM districts: North (Figure 24), South (Figure 25), East (Figure 26) and Central (Figure 27). For the purpose of this report all four districts were combined to provide an understanding across the entire metropolitan region (Figure 23).

The region has high density and rural living, a major port, highways, freight rail and passenger rail network, national parks and most state government central office facilities. It also contains several hospitals, university campuses, cultural centres as well as domestic and international airports.

The metropolitan region experiences a diverse range of hazard events across both man-made and natural hazards. Priority hazards, as identified by the metropolitan DEMCs, are: bushfire, cyclone, earthquake, flood, HAZMAT, heatwave, storm.

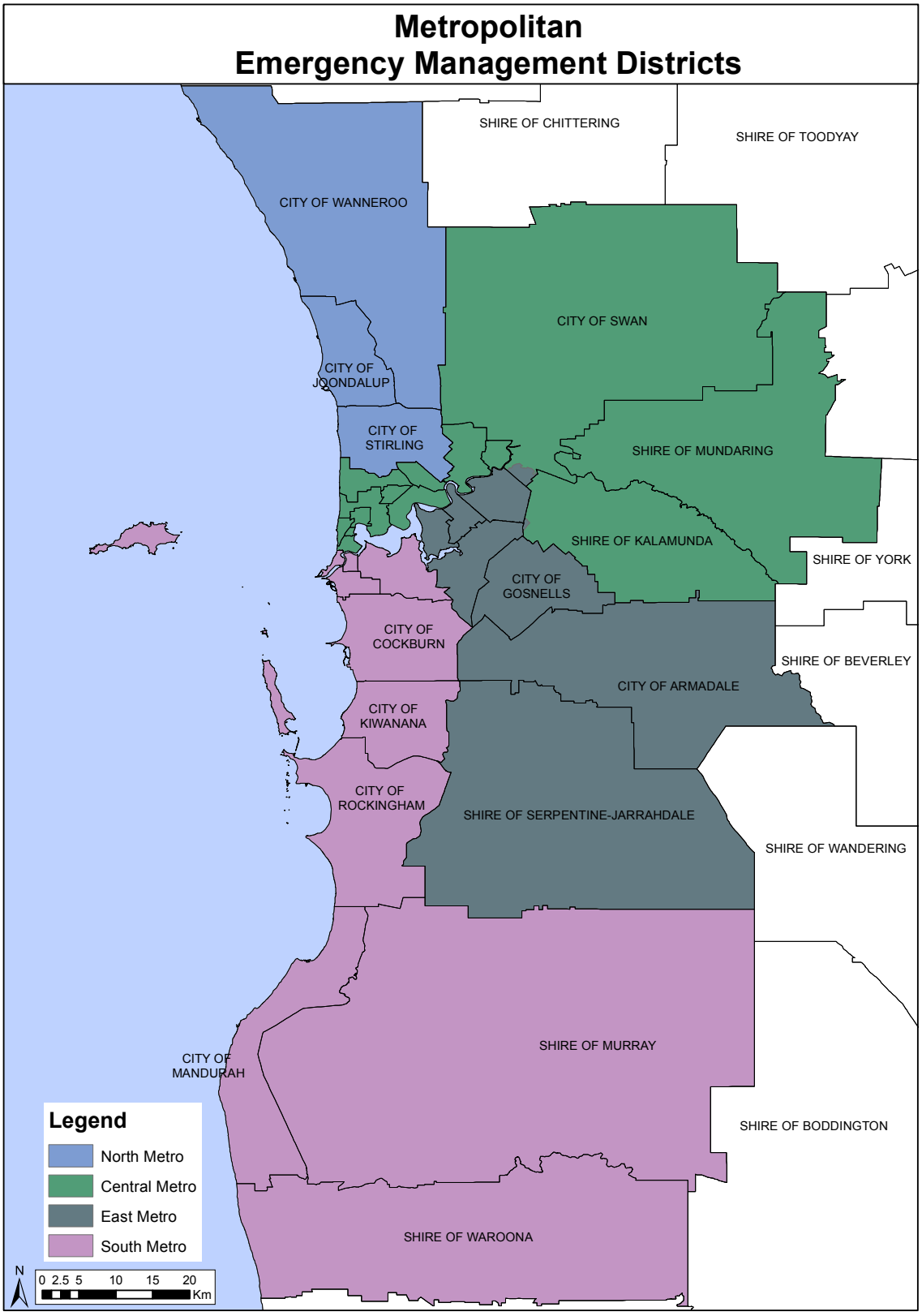


Figure 23: Perth metropolitan emergency management districts map.

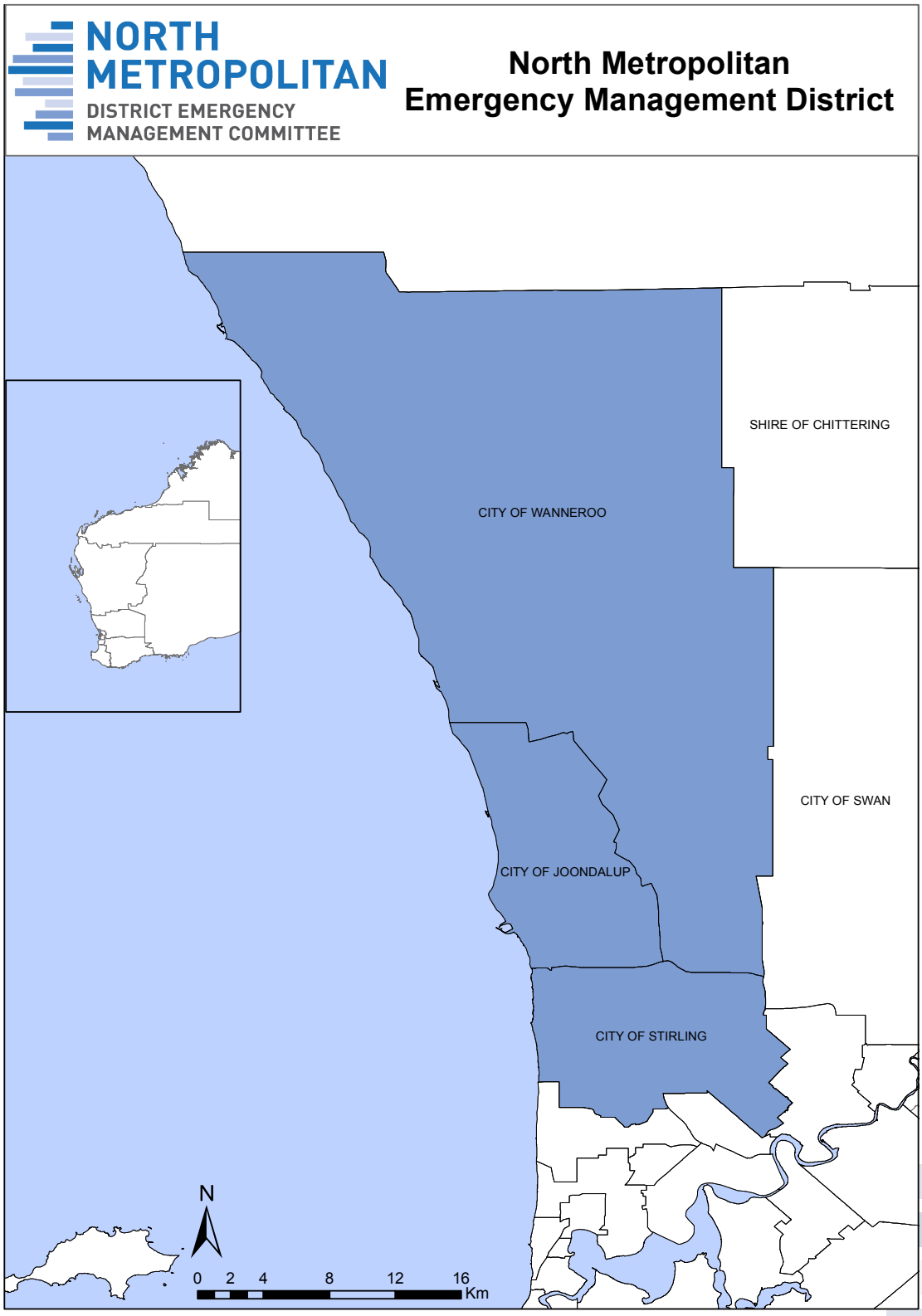


Figure 24: North Metropolitan EM District map.

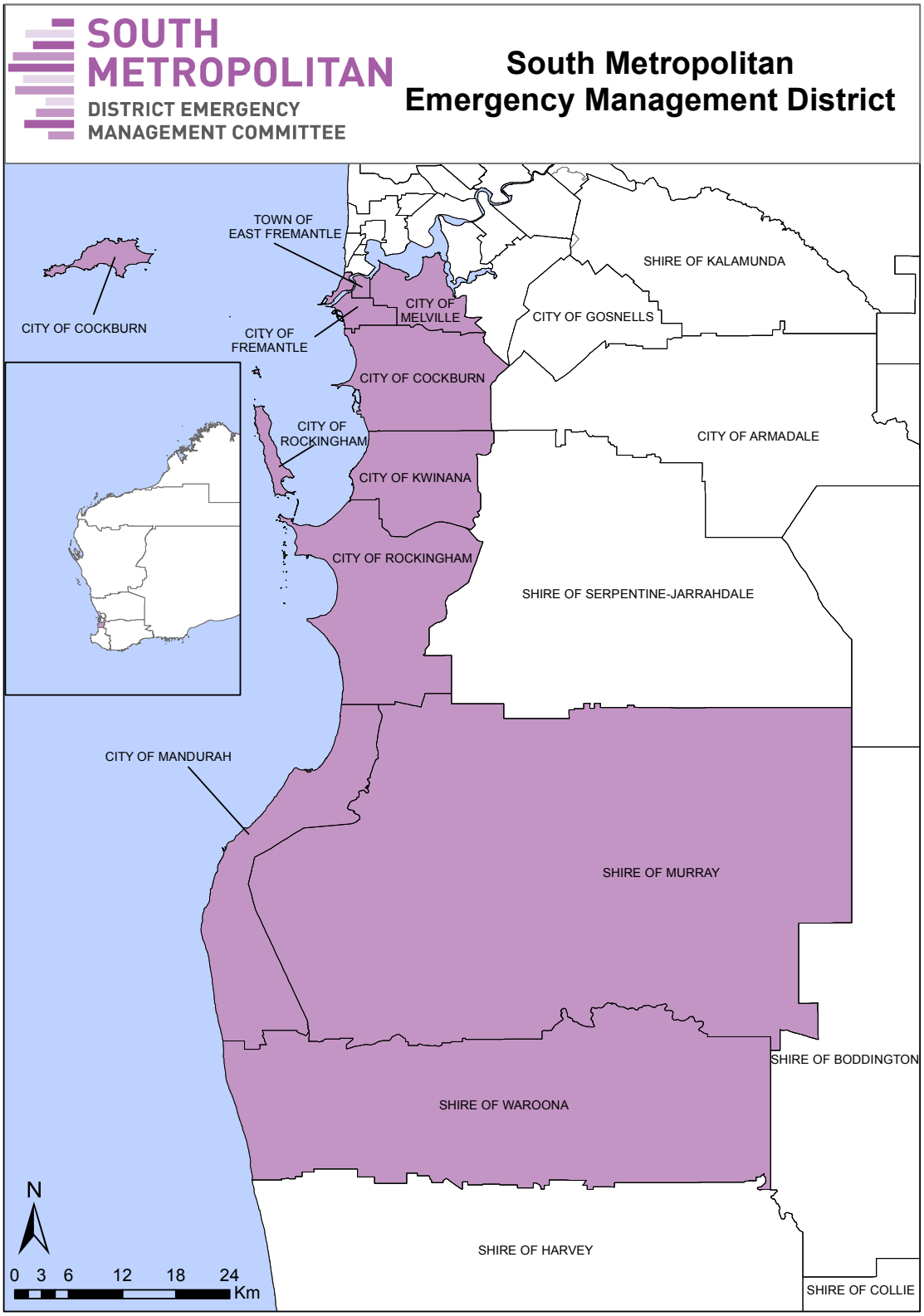


Figure 25: South Metropolitan EM District map.

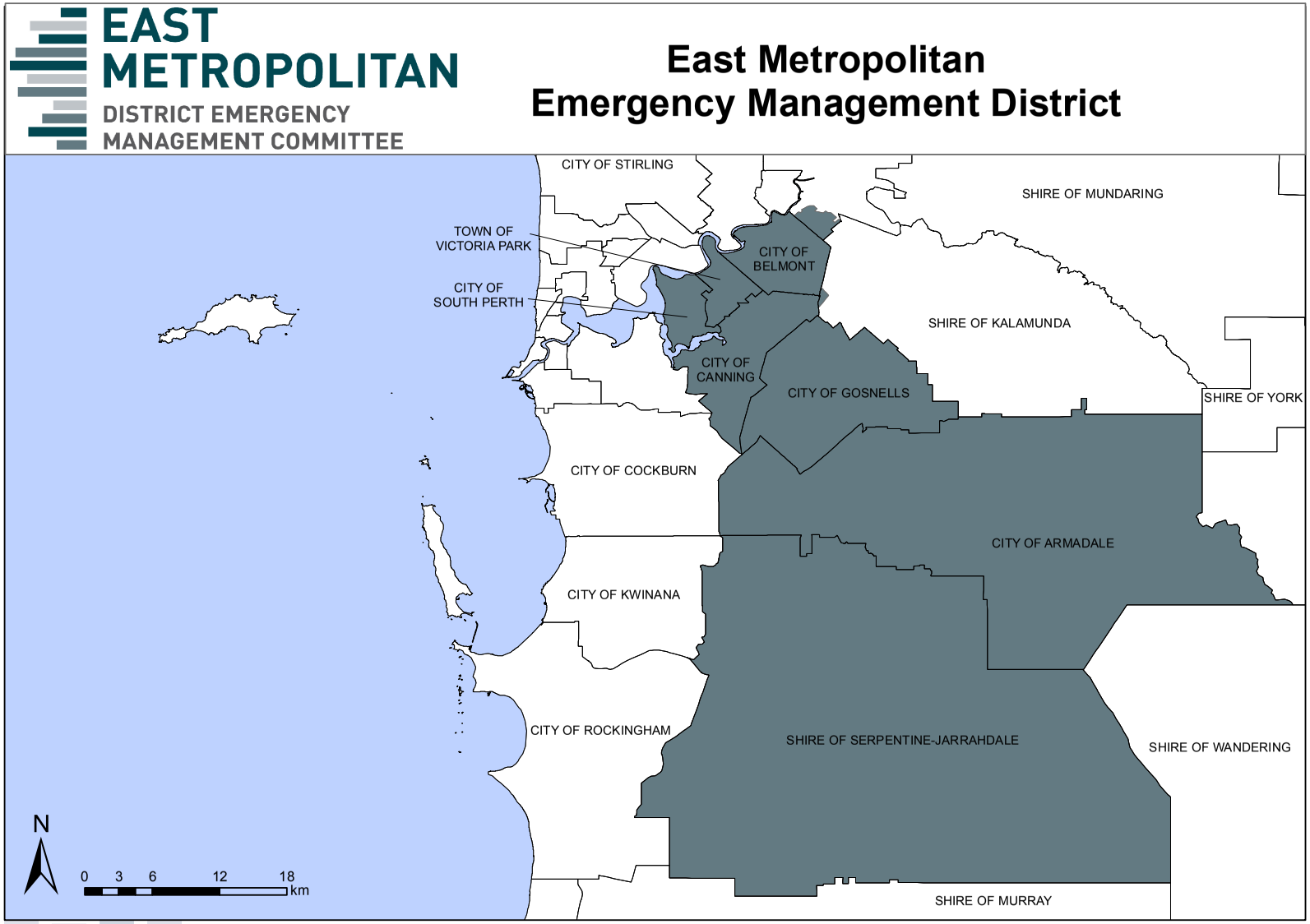


Figure 26: East Metropolitan EM District map.

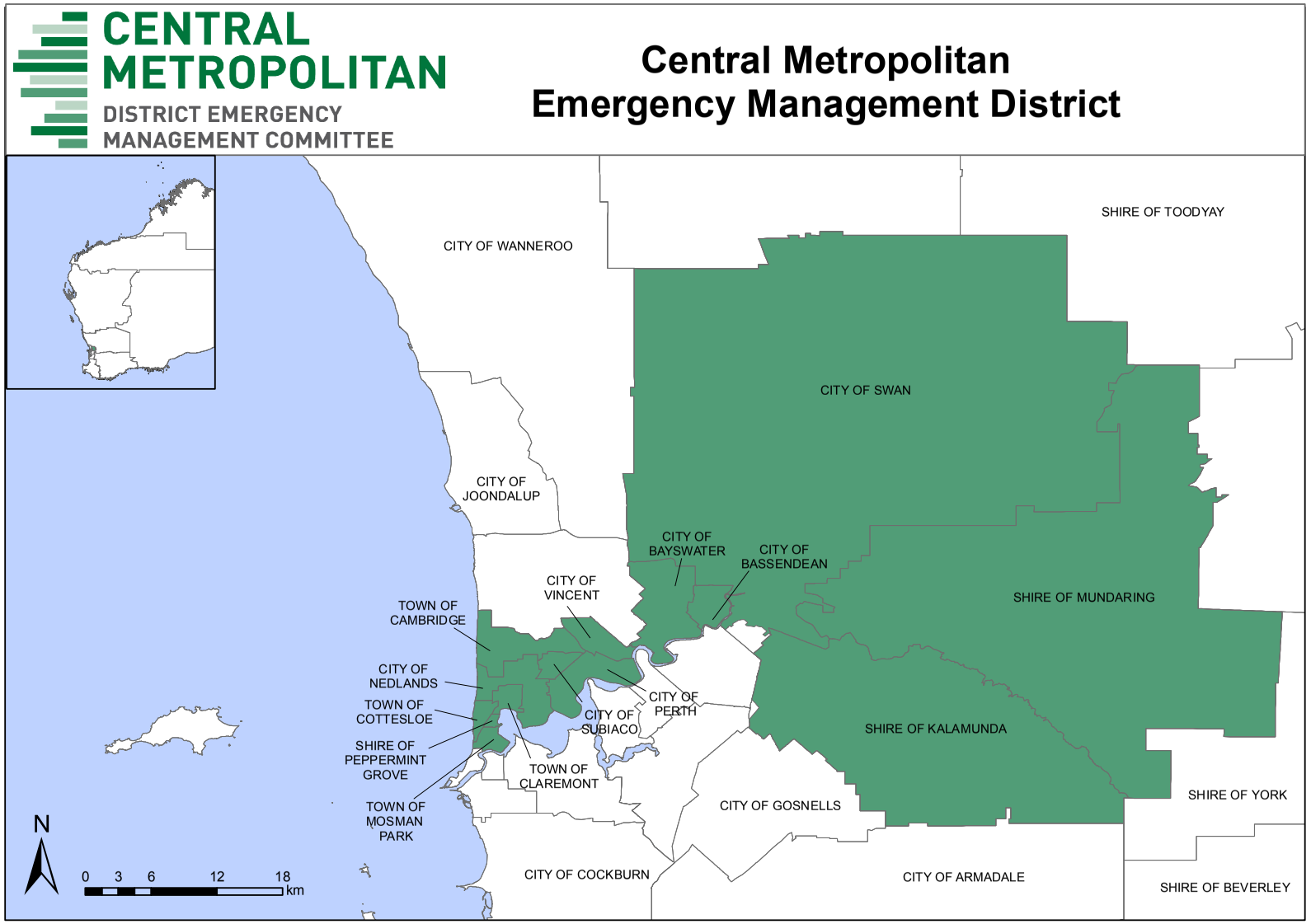


Figure 27: Central Metropolitan EM District map.

Appendix C: Perth metropolitan region consequence table

(based on population: 2.2 million; gross area product: $189.78 billion)

	Insignificant	Minor	Moderate	Major	Catastrophic
People*					
Mortality	Not Applicable	At least 1 death	At least 3 deaths	At least 22 deaths	At least 220 deaths
Injuries / Illness	Less than 3 serious injuries or any minor injuries	1 person critically injured with long-term or permanent incapacitation or more than 3 serious injuries	More than 3 critical injuries with long-term or permanent incapacitation or more than 22 serious injuries	More than 22 critical injuries with long-term or permanent incapacitation or more than 220 serious injuries	More than 220 critical injuries with long-term or permanent incapacitation or more than 2200 serious injuries
Economy					
Loss in economic activity and/or asset value	Decline of economic activity and/or loss of asset value < $7,591,200	Decline of economic activity and/or loss of asset value > $7,591,200	Decline of economic activity and/or loss of asset value > $75,912,000	Decline of economic activity and/or loss of asset value > $759,120,000	Decline of economic activity and/or loss of asset value > $7,591,200,000
Impact on important industry	Inconsequential business sector disruption	Significant industry or business sector is impacted by the emergency event, resulting in short-term (i.e. less than one year) profit reductions	Significant industry or business sector is significantly impacted by the emergency event, resulting in medium-term (i.e. more than one year) profit reductions	Significant structural adjustment required by identified industry to respond and recover from emergency event	Failure of a significant industry or sector
Environment					
Loss of species and/or landscapes	No damage to ecosystems at any level	Minor damage to ecosystems and species recognised at the local or regional level	• Minor damage to ecosystems and species recognised at the state level • Significant loss or impairment of an ecosystem or species recognised at the local or regional level	• Minor damage to ecosystems or species recognised at the national level • Significant loss or impairment of an ecosystem or species recognised at the state level • Severe damage to or loss of an ecosystem or species recognised at the local or regional level	• Permanent destruction of an ecosystem or species recognised at the local, regional, state or national level • Severe damage to or loss of an ecosystem or species recognised at the national or state level • Significant loss or impairment of an ecosystem or species recognised at the national level
Loss of environmental value	Inconsequential damage to environmental values of interest	Minor damage to environmental values of interest	Significant damage to environmental values of interest	Severe damage to environmental values of interest	Permanent destruction of environmental values of interest
Public Administration					
Governance Functions	Governing bodies' delivery of core functions is unaffected or within normal parameters	Governing bodies encounter limited reduction in delivery of core functions	• Governing bodies encounter significant reduction in the delivery of core functions • Governing bodies are required to divert some available resources to deliver core functions or seek external assistance to deliver some of their core functions	• Governing bodies encounter severe reduction in the delivery of core functions • 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 their core functions	Governing bodies are unable to deliver their core functions
Social Setting					
Community wellbeing	• Community social fabric is disrupted • Existing resources sufficient to return the community to normal function • No permanent dispersal	• Community social fabric is damaged • Some external resources required to return the community to normal function • No permanent dispersal	• Community social fabric is broken • Significant external resources required to return the community to normal function • Some permanent dispersal	• Community social fabric is significantly broken • Extraordinary external resources are required to return the community to functioning effectively • Significant permanent dispersal	• Community social fabric is irreparably broken • Community ceases to function effectively, breaks down • Community disperses in its entirety
Community Services	Inconsequential / short term impacts	Isolated / temporary reductions	Ongoing reductions	Reduced quality of life	Community unable to support itself
Culturally important objects	Minor damage to objects of cultural significance	Damage to objects of identified cultural significance	Damage or localised widespread damage to objects of identified cultural significance	Widespread damage or localised permanent loss of objects of identified cultural significance	Widespread and permanent loss of objects of identified cultural significance
Culturally important activities	Minor delay to a culturally important community event	Delay to or reduced scope of a culturally important community event	Delay to a major culturally important community event	Temporary cancellation or significant delay to a major culturally important community event	Permanent cancellation of a major culturally important community activity

*Criteria for people have been rounded up to the nearest whole person.

Appendix D: Glossary and risk matrix

Annual Exceedance Probability (AEP)	The probability of an emergency event of a given size or larger occurring in any given year, expressed as a percentage.
AS/NZS ISO 31000:2009	International standard for risk management which forms the basis of the Emergency Risk Management process.
Consequence	Impact(s) of an event on the five key areas: environment, economy, people, social setting and public administration.
Emergency	The occurrence or imminent occurrence of a hazard which is of such a nature or magnitude that it requires a significant and coordinated response.
Emergency Risk Management (ERM)	A systematic process which contributes to the wellbeing of communities and the environment. The process considers the likely effects of hazardous events and the controls by which they can be minimised.
Hazard	Source of potential harm or a situation with a potential to cause loss.
Impact	To have a noticeable or marked effect on.
Level of risk (risk level)	Magnitude of a risk or a combination of risks, expressed in terms of the combination of consequences and their likelihood.
Likelihood	Chance of something happening. It is used as a general descriptor of probability and may be expressed qualitatively or quantitatively.
Recovery	The support of emergency affected communities in the reconstruction and restoration of physical infrastructure, the environment and community, psychological and economic wellbeing.
Response	The combatting of the effects of an emergency, provision of emergency assistance for casualties, reduction of further damage, and help to speed recovery.
Risk	The combination of the probability of an event and its negative consequences.

The matrix[5] below calculates risk levels based on the consequence and likelihood levels assigned to a risk statement. Please note the likelihood of a statement in this report is determined by multiplying the scenario probability (AEP) by the probability of the risk statement occurring (as determined in workshops).

	Consequence level				
Likelihood	**Insignificant**	**Minor**	**Moderate**	**Major**	**Catastrophic**
Almost Certain (63% per year or more)	Medium	Medium	High	Extreme	Extreme
Likely (10% to <63% per year)	Low	Medium	High	Extreme	Extreme
Unlikely (1% to <10% per year)	Low	Low	Medium	High	Extreme
Rare (0.1% to <1% per year)	Very low	Low	Medium	High	High
Very Rare (0.01% to <0.1% per year)	Very low	Very low	Low	Medium	High
Extremely rare (<0.01% per year)	Very low	Very low	Low	Medium	High

[5] from the *National Emergency Risk Assessment Guidelines* (2015) Australian Government Attorney-General's Department

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SEMC
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State Risk Project

An Australian Government Initiative