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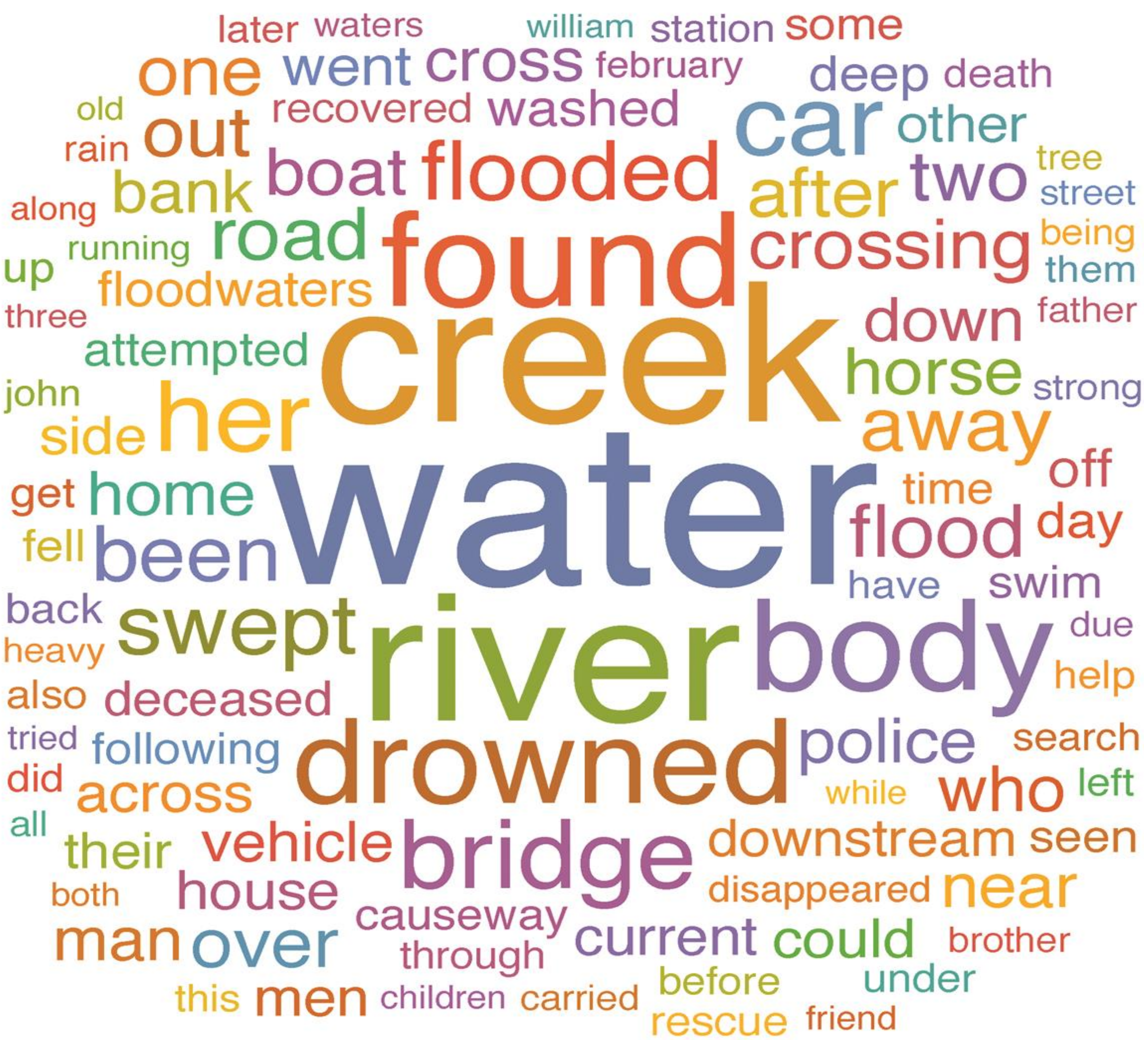
AN ANALYSIS OF HUMAN FATALITIES FROM FLOODS IN AUSTRALIA 1900-2015

Katharine Haynes, Lucinda Coates, Felipe Dimer de Oliveira, Andrew Gissing, Deanne Bird, Rob van den Honert, Deirdre Radford, Rebecca D'Arcy, Chloe Smith

Risk Frontiers, Macquarie University

Bushfire and Natural Hazards CRC



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Cover: A word cloud of the most dominant words within the PerilAus flood database.

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EXECUTIVE SUMMARY

This report examines the socio-demographic and environmental circumstances surrounding flood fatalities in Australia between 1900 and 2015. It is the first major milestone from the Bushfire and Natural Hazards Cooperative Research Centre funded project "*An analysis of human fatalities and building losses from natural disasters in Australia*".

The foundation for this work is the use of the Risk Frontiers' database *PerilAUS*, which contains historical data on the incidence (magnitude, affected locations, etc.) and consequences (property damage and fatalities, etc.) of natural hazard events in Australia. *PerilAUS* contains many of the names of the deceased, which, during the course of this project has enabled the collection of more detailed information on the circumstances of many of the fatalities from coronial inquest reports. Since project commencement, the Flood Database has increased in total number of flood events by 75%. The number of fatal flood events has increased by 100% over the length of the project. Importantly, the percentage of named fatalities has increased from 50% to 90%, in addition to an increase in the overall numbers of fatalities.

The data has been analysed in relation to informing the understanding of the circumstances surrounding the deaths and how this information could best be utilised for emergency management policy and practice. This has included an examination of the data around the following themes: demographics, cause of death, location of the fatality and transport, activity and reason behind action prior to death, capacity and awareness, and flood type and severity.

RESULTS

Demographics

- The total number of recorded deaths is 1859 with an average national annual death rate of 2.91 fatalities per 100,000 people per year. Death rates have steadily declined through time.
- The majority of people died from drowning (54.9%, n=1020), followed by those who were likely to have died from drowning or where drowning was an associated cause (33.1%, n=615).
- The majority of the deaths have occurred in events where two or less people have died (67.1%, n=1248; 1076 flood events).
- 79.1% of the fatalities have been males. However, since the 1960s the proportion of female to male fatalities has increased.
- Children and young adults (< 29 years of age) make up the greatest proportion of deaths (43.4%, n=806). The highest proportion of males are in the 10-29 age brackets (30.1%, n=443) and the highest proportion of females in the younger 0-19 age brackets (45.6%, n=166). For both genders the proportion of fatalities then decreases steadily with age.

- An analysis of the average age of the fatalities through time follows the Australian average. However, the average age for females is much lower than the Australian average in the years between 1920 and 1960.
- The greatest number of fatalities overall have occurred in Queensland (37.8%, n=702) and NSW (36.7%, n=683), together accounting for 74.5% of the fatalities across the nation.
- When deaths are examined in relation to the per capita population, the heightened level of risk in the NT is highlighted.

Activity and reason behind action

- The highest proportions of women died while attempting to cross a bridge, causeway, culvert, road, etc. (38.2%, n=139), followed by those engaged in an activity not near a usual watercourse, e.g. in their home or driving through town (22.5%, n=82).
- The highest proportions of men died while attempting to cross a bridge, causeway, culvert, road, etc. (men: 43.4%, n=639) followed by those engaged in an activity near the water (bank) (11.8%, n=173).
- Of the total of both men and women engaged in an activity not near a usual watercourse (n=226), 46.9% (n=106) were in a house, 13.3% (n=30) were on a house, and 23.9% (n=54) were outside. Prior to death, because of the rapid nature of the flooding or their particular circumstances the majority of these people were engaged in an evacuation, awaiting a planned rescue / evacuation or were in their home and unaware.
- Being engaged in an activity near the water (bank) was the second highest cause of death for men (11.8%, n=173) and the third highest for women (11.3%, n=41). The majority of these victims were recreating (40.0%, n=86).
- For those attempting to cross a bridge, causeway, culvert, road, etc. the risk is broadly split across all age ranges although the highest number of fatalities is seen within the 10-29 year age range (32.4%, n=255).
- Children and young people (0-19 years) accounted for the greatest proportion of fatalities engaged in activities near the water and in or near stormwater drains (48.4%, n=104; 69.4%, n=34, respectively). The highest proportion of those 0-19 years were recreating prior to death (32.5%, n=181).
- Young people and young adults (10-29 years) made up the majority of fatalities engaged in activities in the water (67.3%, n=78).
- The greatest proportion of fatalities among females occurred while recreating (19.8%, n=72) while the greatest proportion of fatalities among males occurred while en route (15.4%, n=227).

Capacity and awareness

- The majority of fatalities were capable of independent action (53.6%, n=997) and, of these, 59.5% (n=593) were aware of the flood but the depth and / or speed of the water took them by surprise.
- The second highest proportion in terms of capacity, were those following the decision making of others (such as children or passengers in a car) (15.7%, n=292) followed by a child or group of children on their own who are under the age of 11 (9.3%, n=173). Of those following the decision making of others, 37.0% (n=108) were aged between 0-9 years and 21.2% (n=62) are aged 10-19 years.
- There were a considerably higher proportion of males that were capable of independent action (59.5%, n=875) than any other capacity category. In comparison, the highest proportions of females were following the decision making of others (36.3%, n=136) and capable of independent action (32.7%, n=119). In terms of children who were on their own or in a group of children, 69.4% were male (n=120) and 28.9% were female (n=50).
- The highest proportion of fatalities (36.6%, n=681) occurred in daylight. Of those who were aware of the flood risk but the depth and / or speed took them by surprise, the greatest proportion occurred in daylight hours (38.5%, n=312).
- In terms of transport, the highest proportions were on foot (25.9%, n=482) and in a vehicle/ 4WD/ horse drawn vehicle (24.4%, n=462). However, there is a decrease in fatalities on foot, horses and horse drawn vehicles and an increase of those in motorised vehicles, over time. In particular, fatalities associated with 4WD vehicles have dramatically increased over the last 15 years.

Fatalities associated with catchments and flood type

- The top two catchments in terms of the great number of fatalities are both in Queensland: the Fitzroy River Basin (28.0%, n=125) and Brisbane River (23.5%, n=105). The remaining three of the top five are located in NSW: Murrumbidgee River (16.6%, n=78), Hunter River (17.4%, n=74) and Georges River (14.5%, n=65).
- The highest proportion of women (36.6%, n=52 of a total of 142) died in urban settings in relation to a local flash flood or low-level short duration flood.

Clusters of fatalities

- Seven cases were identified where 20 or more clusters of fatalities occurred: December 1916, Queensland; February 1927, Queensland; April 1929, Tasmania; October-November 1934, Victoria; February 1954, New South Wales; February 1955, New South Wales; December 2010-January 2011, Queensland.

A closer look at fatalities between 2000 and 2015

- 50.0% of the 178 fatalities that occurred in the period from 2000-2015 were aware of the flood risk but the depth and / or speed took them by surprise. Of this group, 48.3% (n=43) were capable of independent action and 31.5% (n=28) were influenced by drugs or alcohol.
- The largest proportion of male fatalities occurred in the 10-19 year age group (19.3%, n=23).
- The majority of people (male and female) aged between 10-19 years were either on foot or swimming (71.0%, n=22) and recreating (64.5%, n=20) prior to perishing in/near floodwater.
- A higher proportion of people in the 20-29 year age group died while on foot or swimming (55.0%, n=11) than being in a vehicle (30.0%, n=6).
- The detailed data for 121 of the 178 cases allowed for a spatial analysis of location of fatality compared to home. Results showed 26.5% (n=32) of fatalities occurred within 5 km of their home and 57.9% (n=70) were within 20 km of their home.

The implications of these results are discussed in Section 5 in regards to potential changes to emergency management policy and practice.

INTRODUCTION

The Bushfire and Natural Hazards Cooperative Research Centre has been set up to conduct applied research to reduce the risks and consequences of natural disasters and to build a disaster-resilient Australia. The *Scenarios and Loss Analysis* cluster project entitled "*An analysis of human fatalities and building losses from natural disasters in Australia*"[1] aims to measure and understand the impacts of natural hazards in terms of the toll on human health and the built environment.

This examination is a fundamental first step to providing an evidence base for future emergency management policy, practice and resource allocation and to enable efficient and strategic risk reduction strategies. Outputs will also feed into other ongoing research projects in the CRC and elsewhere. The analysis underpinning the project will be based on an examination of the historical record of losses caused by natural hazards in Australia since 1900.

The overall objectives of the project are:

1. An analysis of fatalities, in terms of demographics, social and environmental circumstances surrounding deaths.
2. An analysis of people otherwise affected by natural hazards – injured, near-misses, rescued.
3. An analysis of building damage and losses arising from natural hazard events over the last century.

The hazards to be studied include: floods, cyclones, earthquakes, heatwaves, severe storms and bushfires[2].

This report focuses on the first deliverable of the project which is a detailed longitudinal analysis of Australian flood fatalities. The foundation for this work is the use of the Risk Frontiers' database *PerilAUS*. The database contains historical data (dating back to the earliest days of European settlement in Australia) on the incidence (magnitude, affected locations, etc.) and consequences (property damage and fatalities, etc.) of such events. *PerilAUS* was deemed a good basis for this project due to the length of period covered, the wealth of descriptive detail concerning the hazard impact and the inclusion of data about any fatalities caused by that hazard. As part of this project this data has been augmented through extensive data collection from the print media, coronial and archive offices. In particular, the original data contained many of the names of the deceased, which has enabled the collection of more detailed information on the circumstances of the death from coronial records. Since project commencement, the Flood Database has increased in total number of flood events by 75%. The number of fatal flood events has increased

[1] http://www.bnhcrc.com.au/research/economics-policy-and-decision-making/235

[2] Bushfire loses will be investigated for building loses only. A detailed analysis of bushfire fatalities has already been conducted in previous projects and will only be included here in terms of an overall analysis and comparison of the fatalities from all hazard events.

by 100% over the length of the project. Importantly, the percentage of named fatalities has increased from 50% to 90%, in addition to an increase in the overall numbers of fatalities. This allows a far greater percentage of fatalities to be verified and a more detailed picture of the circumstances surrounding their death to be gleaned from coronial inquests.

The social and environmental factors of interest include:

Social - Age, gender, occupation, preparation, risk reduction activities, knowledge and warnings received, activities and decisions leading up to and at the time of death, capacity to act, mode of transport, medical cause of death etc.

Environmental - Details of the location and particular hazard: e.g. flood type, flood height and intensity (such as "a one in 100 event"). This will also include, where possible, details on the location of the deceased with respect to the hazard.

The report will begin with a literature review in order to explore and present relevant international research on flood fatalities. A detailed methodology will be presented followed by the results. The findings will then be discussed in relation to policy and practice recommendations. These recommendations are based on expert opinion and also wider findings and discussion within the literature.

LITERATURE REVIEW

GLOBAL FLOOD MORTALITY

According to the International Federation of Red Cross and Red Crescent Societies (2015), some 59,092 flood fatalities have occurred worldwide between 2005 and 2014, with the large majority of these occurring in Asia. Despite the significance of flood mortality, few studies have explored trends and characteristics associated with flood fatalities (Jonkman and Vrijling 2008) and those that have generally focus on western contexts.

Globally, flooding is a significant cause of drowning (World Health Organization 2014, Jonkman and Kelman 2005), with drowning being a significant cause of flood deaths (Diakakis and Deligiannakis 2015, Haynes *et al*. 2009, Jonkman 2014, Jonkman and Kelman 2005, 2009, Jonkman *et al*. 2009). Other causes of death include physical trauma, heart attack, electrocution, carbon monoxide poisoning, fire (Jonkman and Kelman 2005) and hypothermia (Vinet *et al*. 2012). Most commonly, the circumstances of the fatality involve people taking risks and entering floodwater either on foot or in a vehicle, of which vehicle related fatalities are most frequent (Ashley and Ashley 2008, Diakakis and Deligiannakis 2013, Jonkman and Kelman 2005, Jonkman and Vrijling 2008, Kundzewicz and Kundzewicz 2005, Špitalar *et al*. 2014). Other circumstances include being trapped within a building, being in a boat or a failed rescue attempt (Jonkman and Kelman, 2005).

A significant number of flood fatalities have been attributed to unnecessary risk taking behaviors (Jonkman and Kelman 2005). Where people have deliberately entered floodwaters, reasons for doing so have been to continue their intended travel; engage in recreational pursuits; continue their work; and evacuate or carry out a rescue of a person or pet (Haynes *et al*. 2009).

In the United States, studies have concluded that between 56% and 68% of fatalities were vehicle related (Ashley and Ashley 2008, Kundzewicz and Kundzewicz 2005, Špitalar *et al*. 2014). Jonkman and Vrijling (2008), in a review of flood fatalities within Europe and the United States, found that 32.8% of deaths were related to vehicles. In Greece, vehicle related deaths have been identified as constituting approximately 40% of all flood fatalities (Diakakis and Deligiannakis 2015). In the Australian context, FitzGerald *et al.* (2010) found that 48.5% of fatalities were vehicle related, and Haynes *et al.* (2009) found that 31% of Australian flash flood deaths were related to vehicles.

Not surprisingly, a significant proportion of flood rescues performed by rescue agencies are also of people from vehicles. Haynes *et al.* (2009) analysed flood rescues performed during New South Wales' Hunter Valley June 2007 floods, and found that 36% had been from vehicles.

In regards to other circumstances of fatalities, FitzGerald *et al*. (2010) found that 26% of fatalities were associated with people engaged in swimming or surfing in flooded streams, and 16% were associated with attempts to swim or wade across flooded areas.

When considering gender in western societies, males are over represented in fatality statistics (Ashley and Ashley 2008, Coates 1999, FitzGerald *et al*. 2010, Haynes *et al*. 2009, Jonkman 2014, Jonkman and Kelman 2005, Jonkman and Vrijling 2008, Kundzewicz and Kundzewicz 2005) and injury statistics (Haynes *et al*. 2009). Jonkman and Vrijling (2008) found that 70% of flood fatalities were male, Coates (1999) 80.6%, FitzGerald *et al.* (2010) 71.2%, and Diakakis and Deligiannakis (2015) 62.9%. The over representation has been attributed to the high proportion of males who drive vehicles (Jonkman and Kelman 2005), occupations held by males and the risk taking behavior of males (Coates 1999, Haynes *et al.* 2009, Jonkman and Kelman 2005).

The over-representation of males is not apparent in South East Asian flood events, with Yeo and Blong (2010) finding that analysis of Asian flood disasters reveals that women are more likely to be at risk. For example in the 1991 Bangladesh Cyclone four times more women died in the storm surge then men (Chowdhury *et al.* 1993). Reasons given for the trend are: women are more likely not to evacuate as they are often care providers; the way women dress restricts movement; possible cultural shame if women escape to public areas if their clothing is ripped; inability to swim; and malnourishment (Yeo and Blong 2010).

The age of flood victims varies across studies. In Poland, Kundzewicz and Kundzewicz (2005) found that the majority of victims were aged between 20 and 59 and similarly in Greece, Diakakis and Deligiannakis (2015) found fatalities to be concentrated between people 20 to 69 years old. However in Australia, Haynes *et al*. (2009) found that mortality was greatest between 0-29 and 60-69 years, and FitzGerald *et al.* (2010) found mortality was concentrated between 10-29 years and over 70 years. Likewise in the United States, Ashley and Ashley (2008) found fatalities were most prevalent in people aged between 10 and 29 and over 60 years. In the aftermath of Hurricane Katrina, Jonkman *et al*. (2009) found that the majority of deaths were elderly people, with only 15% of victims being aged less than 51 years. Similarly, Vinet *et al.* (2012), in an analysis of two flood events in France, found that two-thirds of victims were aged over 60 years.

Fatalities associated with specific floods can be related to the magnitude of the impact, and the potential for warning (Jonkman 2014). Flood fatalities tend to cluster in a small number of big events. Coates (1999) found that 20 percent of Australian fatalities occurred in just 10 events and in India, Singh and Kumar (2013) found that severe floods were responsible for some 50% of all fatalities.

Jonkman and Vrijling (2008) concluded that flash flooding was associated with the highest rates of mortality, likely due to the associated characteristics of flash flooding including its sudden and destructive nature and limited opportunity to effectively warn and evacuate residents. During flash flood events, the availability of suitable shelter which will not be destroyed or fully submerged has been identified as a key factor for enhancing safety (Haynes *et al.* 2009, Jonkman and Vrijling 2008). When exposed to severe and sudden flash flooding, children, the elderly (Jonkman and Vrijling, 2008) and people with limited mobility (Haynes *et al*., 2009) are considered the most vulnerable.

Time of day has been identified as a contributing factor, with nighttime found to be the peak period for fatalities to occur (Diakakis and Deligiannakis, 2015, Špitalar *et al*. 2014). Analysis of vehicle related fatalities in Greece and the United States showed that most deaths had occurred at night (Diakakis and Deligiannakis 2013, 2014, Maples and Tiefenbacher 2009, Špitalar *et al*. 2014), with it hypothesised that drivers are not able to see flooded roads and therefore enter floodwater by accident (Špitalar *et al*. 2014), or that drivers are not able to assess the depth and velocity of water due to poor visibility (Maples and Tiefenbacher 2009). Alcohol and drugs may also contribute (Jonkman and Kelman 2005), as well as social pressures caused by passengers (Pearson and Hamilton 2014).

In Australia the greatest number of fatalities has occurred in NSW and Queensland (Coates 1999, FitzGerald *et al*. 2010). Some international studies have identified that fatalities occur more frequently in rural areas rather than urban areas (Diakakis and Deligiannakis 2015, Špitalar *et al*. 2014). Possible reasons provided for this trend include greater distance for emergency services to respond and lower population density may mean there is a lower chance someone may be rescued by a passer-by (Špitalar *et al.* 2014).

VEHICLE RELATED FLOOD MORTALITY

Floodwaters can inundate vehicles, or wash them away. Some 30cm of floodwater is enough for a small passenger vehicle to float (Shand *et al*. 2011). Moreover, motorists may be unable assess what lies beneath flooded roadways.

Research indicates that people drown in their vehicle as a result of the vehicle being inundated, being swept away (Drobot *et al.* 2007, Kellar and Schmidlin 2012, Yale *et al*. 2003), trying to escape a vehicle by attempting to swim or walk to safety (Drobot *et al*. 2007, Kellar and Schmidlin 2012, Yale *et al*. 2003) or by being thrown from a vehicle (Kellar and Schmidlin 2012). Vehicles can either be willingly driven into floodwaters, enter floodwater without warning (Yale *et al*. 2003) or be parked and suddenly surrounded by floodwater (Diakakis and Deligiannakis 2013).

Motorists often willingly enter floodwater to reach a destination (Coates 1999, Diakakis and Deligiannakis 2013), to rescue someone, recover something (Diakakis and Deligiannakis 2013) or to evacuate (Becker *et al*. 2011). Explanations for motorists deliberately entering floodwater include: not taking warnings seriously (Drobot *et al*. 2007), not understanding the dangers (Drobot *et al*. 2007), underestimating the risk (Diakakis and Deligiannakis 2013, Maples and Tiefenbacher 2009), being impatient and thinking that they are invincible (Franklin *et al*. 2014). Drivers may develop a false sense of security whilst inside a vehicle (Diakakis and Deligiannakis 2013, Jonkman and Kelman 2005, Maples and Tiefenbacher 2009) and it is possible that motorists may not fully appreciate flood conditions such as the depth and speed of floodwaters, and the influence such conditions may have on safety (Diakakis and Deligiannakis 2013, Yale *et al*. 2003,). It has also been suggested that motorists may recognise the risk but fail to personalise it, believing that the risk does not apply to them (Pearson and Hamilton 2014).

Ruin *et al*. (2007) found that motorists with the longest itineraries and those with no prior flash flood experience were more likely to underestimate the level of risk associated with entering floodwater. Previous flood experience has, however, been associated with a greater likelihood of motorists entering floodwater (Pearson and Hamilton 2014).

METHODOLOGY

The project was completed in two steps: 1) updating the data held within PerilAUS relating to human fatalities from flood events, and 2) statistical analysis to determine the lives lost and the environmental and social circumstances surrounding those fatalities.

PerilAUS is a database of impacts and consequences of natural hazards in Australia held by Risk Frontiers. It was deemed a good basis for this project due to the length of period covered, the wealth of descriptive detail concerning the hazard impact and the inclusion of data about any fatalities caused by that hazard. To meet the needs of this project, however, it was recognized that the database needed to be enriched in breadth and detail. The following material describes PerilAUS prior to the commencement of the CRC project and how the data has been updated.

DATA SOURCES

PerilAUS prior to project commencement

PerilAUS contains detailed information on natural hazard events impacting Australia from European settlement (1788) and before, but with good confidence from 1900. The data includes information relating to fatalities, injuries, building damage, costs and event characteristics.

Each event report in *PerilAUS* contains, where available, data on location – state/territory, nearest town, postcode, latitude, longitude and dates – year, month, day, hour and duration. Where available, physical attributes of each event are recorded, and every attempt is made to give some notion of the event magnitude and/ or the intensity.

Fatality data includes, where available, the demographics of the deceased; date, time and cause of death; occupation and circumstances at time of death – for example, what the deceased was doing at the time of/ just before death.

The data is based on material collected from news media, government departments and the published literature. A total of 21,777 references have been included in *PerilAUS* thus far for the total of 14,965 event records from the year 1900. The data covers 12 peril types: bushfire, earthquake, flood, hailstorm, extreme heat, landslide, lightning strike, rainstorm, tornado, tropical cyclone, tsunami and windstorm. The database has served to underpin some twenty other hazard- and risk-related studies: for example, Blong (2004), Coates *et al.* (1993), Coates (1996), Coates (1999), Coates *et al.* (2014), Crompton *et al.* (2010), Haynes *et al.* (2009), Haynes *et al.* (2010) and Blanchi *et al.* (2014).

The dominant sources used initially for PerilAUS were The *Sydney Gazette* and the *Sydney Morning Herald* (the colony's first newspapers, dating from 1803 and 1831 respectively). In more recent years events drawn from the main newspaper of each Australian state and the Australian Capital Territory (ACT) from the mid-1990s have been included via Factiva - an online search tool and current international news database that provides access to sources such as newspapers, newswires, journals, industry publications, websites, company reports, television and radio transcripts and more.

The increase in the availability of scanned newspaper reports available online through such information resources as Trove (National Library of Australia) and the advent of the World Wide Web has ensured that *PerilAUS* now includes at least the major hazard impacts in all states and territories. In recent years, Factiva has included local news media in its available online resources of event coverage – often these data sources provide valuable detail around human health impacts.

Depending on the hazard type and data availability, government and other official reports have been accessed. This has included publications by Geoscience Australia, the Australian Bureau of Statistics (ABS) and the Australian Institute of Health and Welfare (AIHW), and the Bureau of Meteorology (BoM). In particular, historical state meteorological accounts, published from 1839 to 1950 (depending on the state or territory), provided much information for the first half of last century. For the latter half, the severe weather summaries of Laurier Williams' News Archive as well as the BoM Significant Weather Summaries and Monthly Weather Reviews were employed.

In addition, case reports and historical and topical reports, inquiries and case studies have been consulted. Articles on floodplain management, specific events and general information on flooding in Australia were searched from the available literature for more substantive information. Furthermore, a search was undertaken of the historical literature on a national, state-wide and local basis.

In order to make a scientific analysis for policy and emergency management reform the existing PerilAUS data needed to be further augmented and verified as detailed below (3.1.2).

Updating PerilAUS

Since project commencement, the Flood Database has increased in total number of flood events by 75%. The number of fatal flood events has increased by 100% over the length of the project. Importantly, the percentage of named fatalities has increased from 50% to 90%, in addition to an increase in the overall numbers of fatalities. This allows a far greater percentage of fatalities to be verified and a more detailed picture of the circumstances surrounding their death to be gleaned from coronial inquests.

The *PerilAUS* Flood Database now includes, from 1900, 2487 flood event records, 528 of which have one or more concomitant deaths, and 1859 flood fatalities.

Coronial inquests

An important component of the current project was the examination, where possible, of coronial data relating to flood fatalities. A coronial inquest may be carried out if a death is sudden or untimely (amongst other reasons), but it should be understood that inquests will not be carried out for every flood fatality that has occurred.

The data required in order to locate an inquest file are generally the name of the deceased and the date of death, although sometimes other data such as location of death are helpful.

A number of archives offices were accessed: those of Victoria (Vic), South Australia (SA), Queensland (Qld), New South Wales (NSW), Tasmania (Tas) and the Northern Territory (NT).

Coronial inquests were found to be a crucial means of verification and adding further detail to the circumstances surrounding flood fatalities, especially by enabling a better determination of the social, demographic and environmental circumstances of the deceased.

Almost all the inquests located revealed additional data, including confirmation of a flood-related fatality rather than a non-natural hazard-related drowning.

In general, inquests include a coroner's report and witness statements. The coroner's report lists the correct name, occupation, the location of the deceased, the people who were with the deceased and other witnesses and the time and date of death and when found. The witness statements give a fuller account of the deceased and details up to the time of death, including age, name of relatives, where the deceased came from, the reasoning behind decisions made which led to the death, the actions of the deceased and their knowledge or forewarning about the flood dangers, details of weather and the state of the river (e.g. speed and depth of flood waters), type of flood and distance from entering the river to where the body was found and its location (e.g. in a tree).

Each State and Territory of Australia has a unique set of policies and procedures around the public availability of inquests. This includes the holding period – the length of time between when an inquest is carried out and when it becomes publicly available. This information is summarised in Table 1.1.

State	Publicly available?	Holding period	Other comments
Qld	Yes	35 yrs	State Archives: 1900-1978 files held and available. Coroner's: 1979 onwards by application for Genuine Researcher status: did not hear back in time for analysis.
NSW	Yes	None	Records Office: 1900-1915: inquest registers only; 1916-1939: <10% files kept; Jul 1942-Jun 1963: files held and available. Coroner's: 1963-2014 records available via application; did not hear back in time for analysis.
ACT	Yes	NA but…	Archives/ Coroner: 1900-2014 generally publicly accessible BUT staff extract the required records and Coroner decides whether permission is granted to view on a case by case basis. No response was given by the office to our enquiries.
Vic	Yes	75 yrs from 1986 but…	Public Records Office: 1900-1985 files held and available. Coroner's/ ethics committee:1986-2000 accessible via application. NCIS: records for all states 2000-2014 available on application.
Tas	Yes	75 yrs	Records Office: 1900-1940 files held and available. Coroner's: 1941-2014 records available via application.
SA	Yes	70 yrs at Records Office	Records office: 1900-1953 files held and available. Coroner's: 1954-2014 via application; did not hear back in time for analysis.

WA	Possibly, with the permission of Ethics Committee		Applications for access to all files are referred to an Ethics Committee. Records of non-natural death are normally destroyed after 30 years but inquests are kept indefinitely: however, no records exist prior to the late 1970s. Very late responses meant analysis could only be carried out on NCIS-held files 2000-2014.
NT	No	NA	Coroner's: a modest number of records available via application; we were able to access the majority of records we wished to.

TABLE 1.1: DATA AVAILABLE FROM ARCHIVES OFFICES (1900 ONWARDS ONLY)

The NSW State Records centre exemplifies one of the challenges in locating inquest files, in that even when an inquest has been carried out, the files are not always available. Inquest files in NSW have been disposed of for the period 1900 to 1915, and decimated for the period 1916 to 1939.

It is possible, by applying directly to the relevant Coroner, to obtain inquest reports after the holding period by applying to the Coroner and/ or, sometimes, an ethics committee, so access is by no means assured. Even when such applications are successful, there is often a significant period of time between when an application is submitted and when access is granted.

Weather data

The Australian Bureau of Meteorology (BoM) has proved a most valuable source of information for *PerilAUS*. Of the 21,777 references included in *PerilAUS* thus far, a total of 6082 BoM references have been utilized.

Despite the employment of these references, at the start of this project the *PerilAUS* database was deficient in some of the physical characteristics data from flood events. These events were originally researched and entered from the mid to late 1990s and, at that stage, records available via the internet were quite limited. Notwithstanding the relative abundance of such freely available data sources now, there is limited availability of specific physical characteristic information through BoM for, mainly, events distant in time and minor in impact and/ or intensity.

Supplementary information was sought from the earliest fatal flood records of interest – that is, from 1900. This and the paucity of information available from the usual BoM sources meant that the majority of data was sourced from Trove. This presented a number of difficulties as flood events are mainly reported and discussed in terms of human effects rather than precise physical aspects: there has been a high incidence of events which exist purely to record the deaths of individuals. This is particularly the case for lesser known (generally more moderate to minor) events. Trove-sourced media articles generally make no mention of information such as duration, flood type, flood severity, maximum height and other comments on flood intensity. Factiva was utilized to gain further physical characteristic data for the more recent events.

Biases and data limitations

Newspaper articles, while containing valuable narrative detail, can contain inaccuracies and bias towards newsworthy events and the early part of the *PerilAUS* record contains a certain spatial bias towards New South Wales (NSW), especially Sydney (as the main newspaper from only one of Australia's capital cities was examined), and other long-established, well-populated areas having the means and inclination to communicate with the media.

The inclusion of government, scientific, historical and other reports has balanced the bias. In particular, the verification of the data through the searching of inquest reports has allowed the majority of inaccuracies from the news media to be identified and removed.

Access to some of these sources has proved difficult, despite having ethics approval from Macquarie University. For example, access to the Western Australian archives offices was not granted until it was too late to include the data in our analysis; access to those of the ACT has still not been granted. In a few cases, it has been impossible to source data in the format required. For example, neither ABS nor AIHW will release unit record death data.

It is impossible to assert that *PerilAUS* has captured every detail of every flood event that has impacted Australia since 1900. It can be asserted, though, that it represents the best collection of such data in Australia, in both length and breadth of record and event coverage. It can be stated with good confidence that coverage includes the majority of the Insurance Council of Australia-listed insurance loss events and other major and moderate events and the majority of flood events that included one or more fatalities.

DATA ANALYSIS

The data was analysed in relation to informing the understanding of the circumstances surrounding the deaths and how this information could best be utilised for emergency management policy and practice. The data was grouped into the following broad themes (the full coding scheme is available in the appendix):

Demographics

Division into age and gender groups allowed the analysis to consider whether certain groups possess a heightened vulnerability and how this has changed through time.

Cause of death

This covered an assessment of the actual cause of death: that is, was the death caused by drowning, exposure, an injury or a heart attack. Many of the earlier deaths are noted within the media and official documentation to have been caused by drowning while a number of the recent deaths, where full autopsies have been performed, are noted as being due to heart attacks. It is therefore likely that drowning deaths are overrepresented in our data. However, the heart attacks are certainly associated with drowning and in some cases the coroner assigns both as the cause of death.

Location of the fatality and transport

This determines where the deceased was i.e. were they outside in a flooded watercourse, other floodwaters or inside or on a house or structure. The deceased were also categorised in terms of their transport at the time of death in terms of being in a car or another form of closed or open transport and if they exited from the vehicle.

Activity and reason behind action prior to death

This category defined people in terms of what they were doing (attempting to cross a watercourse or engaged in an activity in their home etc) and why they were doing it (attempting to evacuate, en route to work or home, recreating, looking after livestock etc). The reasons behind the actions taken were divided, if different, into actions prior to death and also at the time of death.

Capacity and awareness

Understanding the level of awareness of the flood risk, any warnings received or visible signs and capacity to take action is crucial in terms of interpreting why people took a particular course of action and how policy and practice can best be amended to have the greatest impact. Although the available information is limited, particularly for the early deaths, we have tried where possible to categorise people's decision-making. For awareness this involved dividing the data between those who were aware of the flood but did not expect to encounter it (e.g. walking their dog on the riverbank), those where the depth, speed and/ or debris took them by surprise (e.g. driving through floodwaters) and those who were unaware and taken by surprise (e.g. in their home when flash flooding hit).

The coding for capacity involved categorising the data into those who were capable of independent action and those who were not because of a number of reasons including: a disability, inability to swim, under the influence of drugs or alcohol, looking after dependants and being encumbered with clothing and possessions. This code also recognised those who were likely to have followed the decision making of others such as passengers in a vehicle.

The varying levels of detail available for each fatality sometimes required a small number of assumptions to be made. This made the coding a balance between the need to maximise the usefulness of the information extracted without diminishing the accuracy of the interpretation of the data. For example, unless otherwise stated all those who entered floodwaters in order to perform a rescue or continue their journey were coded as "Awareness category 2: knew there was a flood but depth, speed, debris took them by surprise". It is likely that a majority of those who were entering floodwaters at night were not aware and therefore this data is presented in relation to the timing of the event and potential visibility.

In terms of capacity, unless otherwise stated the fatality was coded as "Capacity category 1: capable of independent action. However, many of those labelled in this way may well have been influenced by unknown factors. Furthermore it has been assumed that all drivers were capable of independent action: however, it is likely that they were influenced by passengers. All children who were with their parents or guardian were assumed to have followed the instructions of adults and were not in control of the decisions taken that led to their deaths. Children on their own who were less than 11 years old were coded in their own category. Following consultation with child disaster experts the age of 11 was considered to be the most appropriate age cut off although it is understood that children younger than 11 are more than capable of independent decision.

Flood type and severity

Data was categorized according to flood type (flash flooding, coastal or inland riverine, dam failure etc) and flood severity (minor, major, record etc).

RESULTS

The total number of recorded deaths is 1,859 with an average national annual death rate of 2.91 fatalities per 100,000 people per year. The data is examined for the entire period 1900 to 2015. Where appropriate, averages have been taken and compared for 20-year blocks of data and statistical tests have been performed in order to identify any significant changes. A spatial analysis is performed on the 2000 to 2015 data where the most detail was available on the location of the fatality. An analysis of major flood events where 20 or more people perished is also presented.

DEMOGRAPHICS

Figure 4.1 shows the time series of fatalities by gender since 1900. The majority of deaths have occurred in events where two or less people died (67.1%, n=1,248 in 1,076 flood events). Events where 5 or more people have died correspond to 18.9% of the fatalities (n=352 in 35 flood events) (Table 4.1).

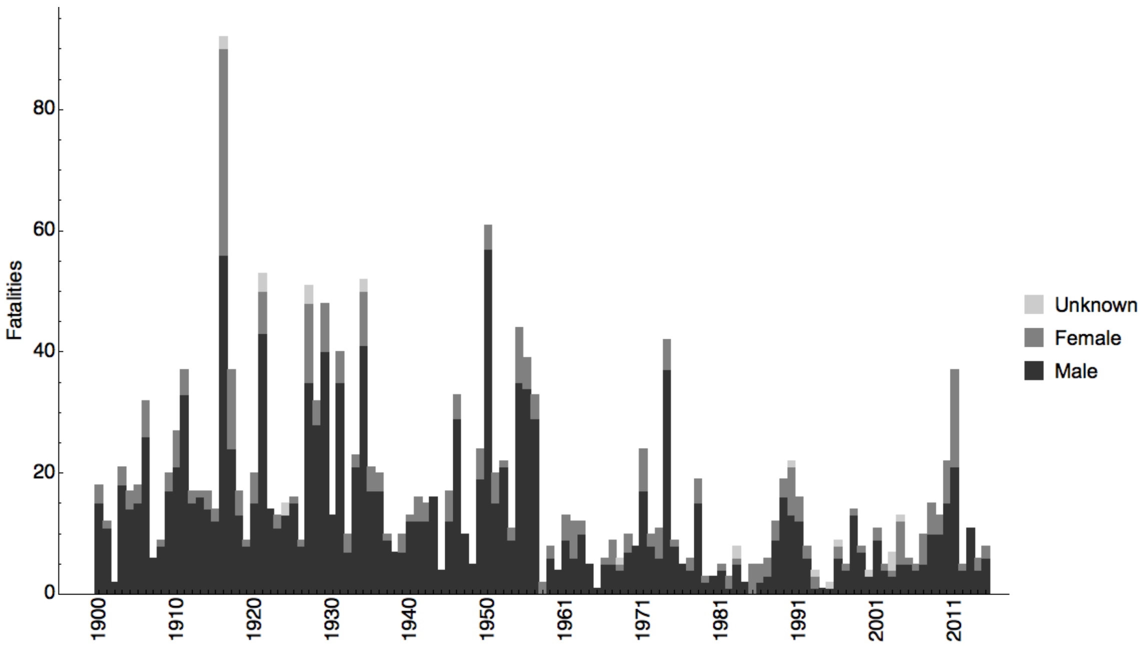

FIGURE 4.1: TIME SERIES OF FATALITIES BY GENDER SINCE 1900

N (Number of fatalities in the event)	Total number of fatalities for events with N or more fatalities	Number of events
1	1859	1186
2	969	282
3	611	110
4	452	59
5	352	35
6	267	19
10	159	7

TABLE 4.1: DISTRIBUTION OF FLOOD EVENTS BY NUMBER OF FATALITIES

Death rates have steadily declined over the years (Figure 4.2). Table 4.2 clearly shows that the majority of these deaths have been males (79.1%, n=1471 out of 1859). Figure 4.3 show that the ratio of male-to-female fatalities has steadily decreased over time, with a statistically significant decline ($p<0.01$) from the 1960s, indicating a greater proportion of female fatalities in more recent times. A total of 35 people of Australian indigenous heritage are listed within the data set, making up 1.9% of the total fatalities. However, it is likely that a large proportion of indigenous deaths have been unrecorded and their deaths are underrepresented.

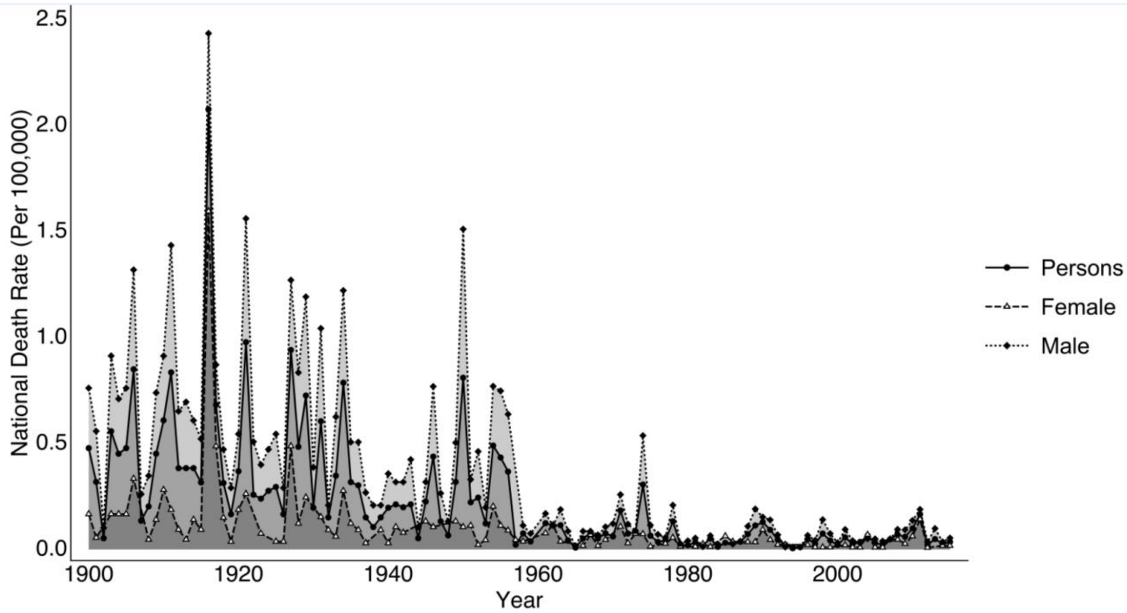

FIGURE 4.2: NATIONAL DEATH RATES DUE TO FLOOD 1900-2015

	Male	Female	Unknown	Total
1900-1909	132 (9.0%)	23 (6.3%)	0 (0.0%)	155 (8.3%)
1910-1919	212 (14.4%)	70 (19.2%)	2 (8.3%)	284 (15.3%)
1920-1929	222 (15.1%)	41 (11.3%)	8 (33.3%)	271 (14.6%)
1930-1939	174 (11.8%)	30 (8.2%)	2 (8.3%)	206 (11.1%)
1940-1949	131 (8.9%)	22 (6.0%)	0 (0.0%)	153 (8.2%)
1950-1959	210 (14.3%)	34 (9.3%)	0 (0.0%)	244 (13.1%)
1960-1969	52 (3.5%)	21 (5.8%)	1 (4.2%)	74 (4.0%)
1970-1979	110 (7.5%)	27 (7.4%)	0 (0.0%)	137 (7.4%)
1980-1989	45 (3.1%)	21 (5.8%)	2 (8.3%)	68 (3.7%)
1990-1999	64 (4.4%)	21 (5.8%)	4 (16.7%)	89 (4.8%)
2000-2009	58 (3.9%)	26 (7.1%)	5 (20.8%)	89 (4.8%)
2010-2015	61 (4.1%)	28 (7.7%)	0 (0.0%)	89 (4.8%)
Total	**1471 (100.0%)**	**364 (100.0%)**	**24 (100.0%)**	**1859 (100.0%)**

TABLE 4.2: GENDER BREAKDOWN 1900-2015 (% OF COLUMN TOTALS)

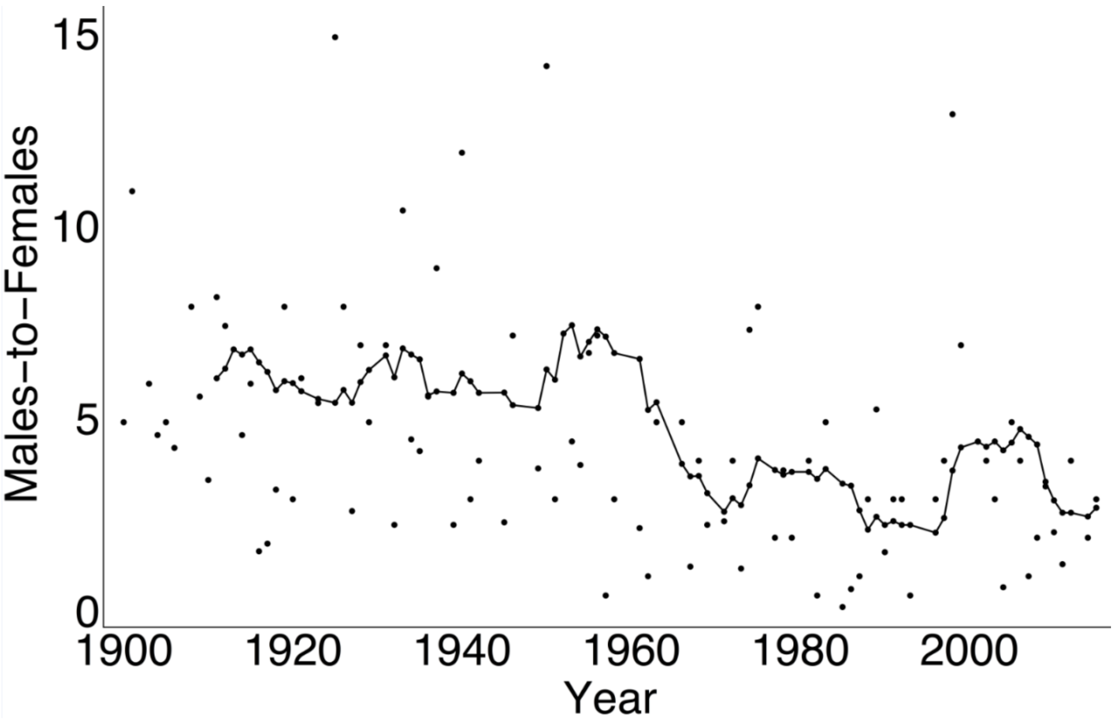

FIGURE 4.3: MALES TO FEMALE DEATH RATES 1900-2015

The breakdown by age (Table 4.3, Figure 4.4) demonstrates the distinct high-risk groups of children and young adults (< 29 years of age) who make up the greatest proportion of deaths (43.4%, n=806 out of 1859). The gender breakdown by age shows the highest proportion of males in the 10-29 age brackets (30.1%, n=443) and the highest proportion of females in the younger 0-19 age brackets (45.6%, n=166). For both genders the proportion of fatalities then decreases steadily with age. Over 50% of the female deaths occur in those under 29 years (56.3%, n=205) and over 50% of the male deaths occur in those under 39 years (51.2%, n=753).

	Male	Female	Unknown	Total
0-9	153 (10.4%)	88 (24.2%)	4 (16.7%)	245 (13.2%)
10-19	233 (15.8%)	78 (21.4%)	1 (4.2%)	312 (16.8%)
20-29	210 (14.3%)	39 (10.7%)	0 (0.%)	249 (13.4%)
30-39	157 (10.7%)	30 (8.2%)	1 (4.2%)	188 (10.1%)
40-49	144 (9.8%)	19 (5.2%)	1 (4.2%)	164 (8.8%)
50-59	117 (8.0%)	22 (6.0%)	1 (4.2%)	140 (7.5%)
60-69	100 (6.8%)	17 (4.7%)	0 (0.0%)	117 (6.3%)
70-79	53 (3.6%)	12 (3.3%)	0 (0.0%)	65 (3.5%)
80-89	12 (0.8%)	6 (1.6%)	0 (0.0%)	18 (1.0%)
Unknown	293 (19.9%)	53 (14.6%)	16 (66.7%)	362 (19.4%)
Total	**1471 (100.0%)**	**364 (100.0%)**	**24 (100.0%)**	**1859 (100.0%)**

TABLE 4.3: BREAKDOWN OF THE FATALITIES BY AGE AND GENDER (% OF COLUMN TOTALS)

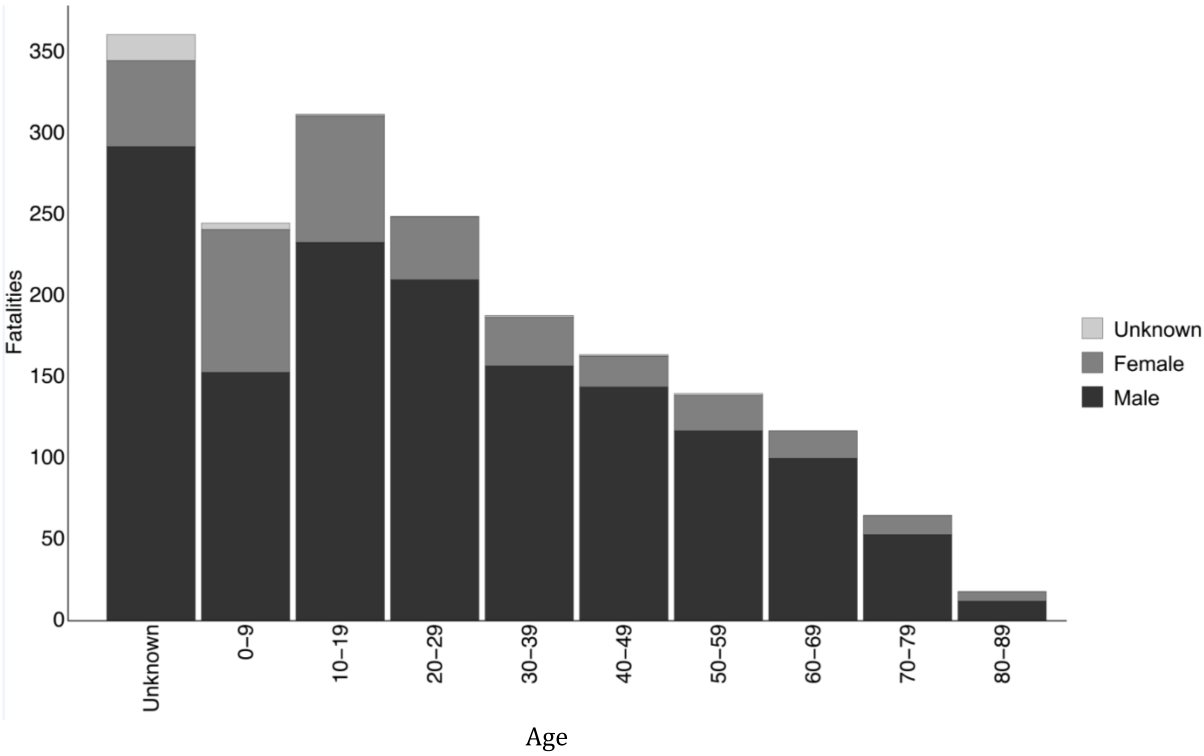

FIGURE 4.4: BREAKDOWN OF FATALITIES BY AGE AND GENDER

A detailed examination of the fatalities under 18 by gender (Figure 4.5) shows the heightened vulnerability of males, particularly among 2 year olds, children (8-11 years) and young adults (18 years). Interestingly, we see increased numbers of fatalities for two year old and also six and seven year old females.

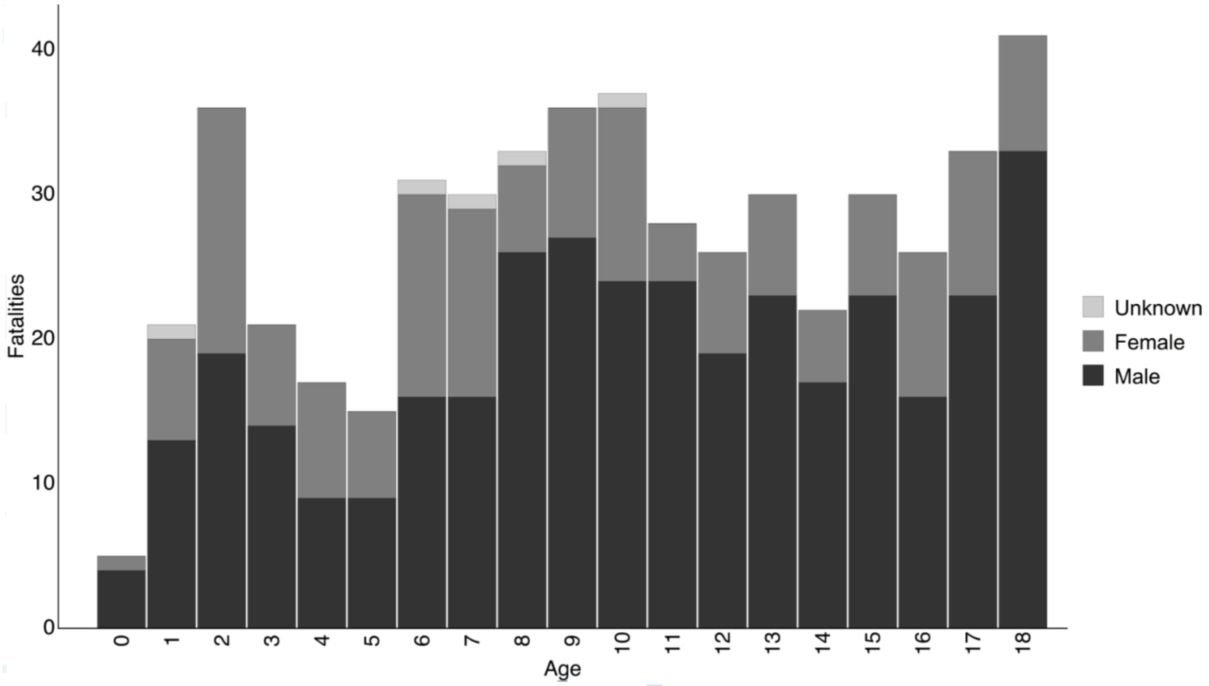

FIGURE 4.5: DISTRIBUTION OF FATALITIES BY AGE AND GENDER FOR PEOPLE 18 YEARS AND YOUNGER.

When the age breakdown of fatalities is examined over time (Figure 4.6), a trend is seen of an increasing average age of the fatalities for both males and females. This mirrors Australia's ageing population rate over time. However, the average age of flood fatalities for females is much lower than the Australian average in the years between 1920 and 1960. In comparison, the average age of male flood fatalities has, throughout the last century, more or less followed the Australian average.

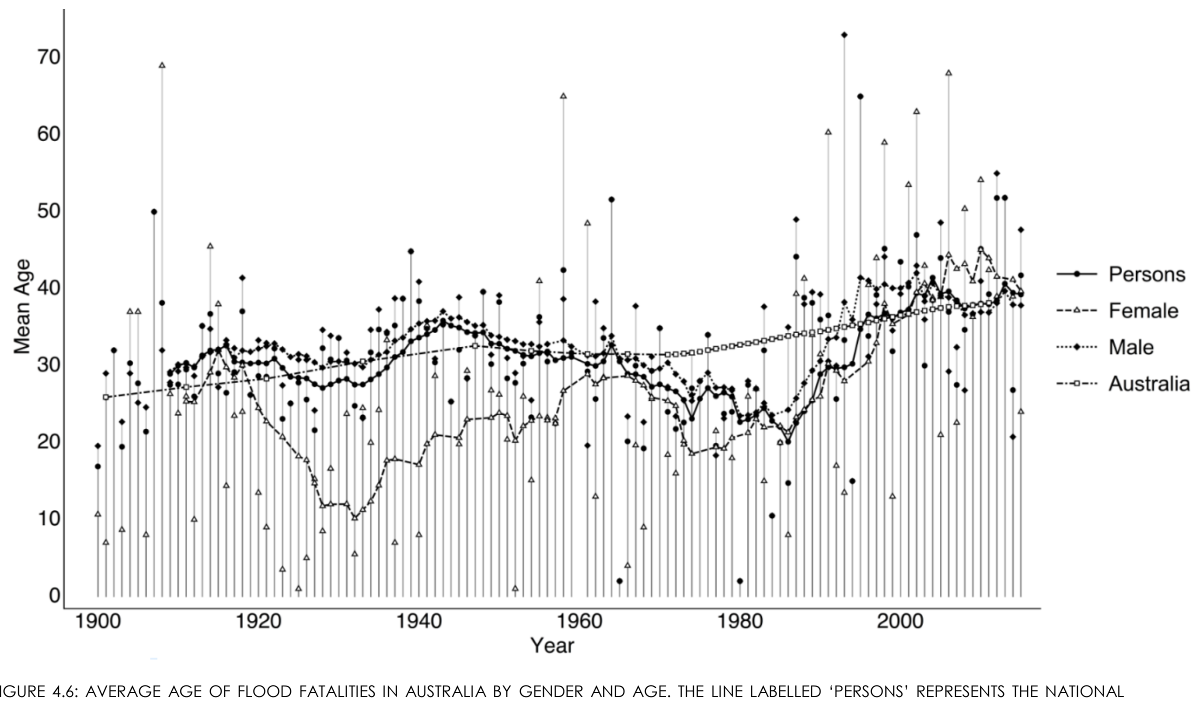

FIGURE 4.6: AVERAGE AGE OF FLOOD FATALITIES IN AUSTRALIA BY GENDER AND AGE. THE LINE LABELLED 'PERSONS' REPRESENTS THE NATIONAL MEAN POPULATION AGE OVER TIME.

The greatest number of fatalities (Figure 4.7) have occurred in Queensland (37.8%, n=702) and NSW (36.7%, n=683), accounting for 74% of the overall fatalities across the nation. Victoria is the third highest with 13.2% of fatalities (n=245).

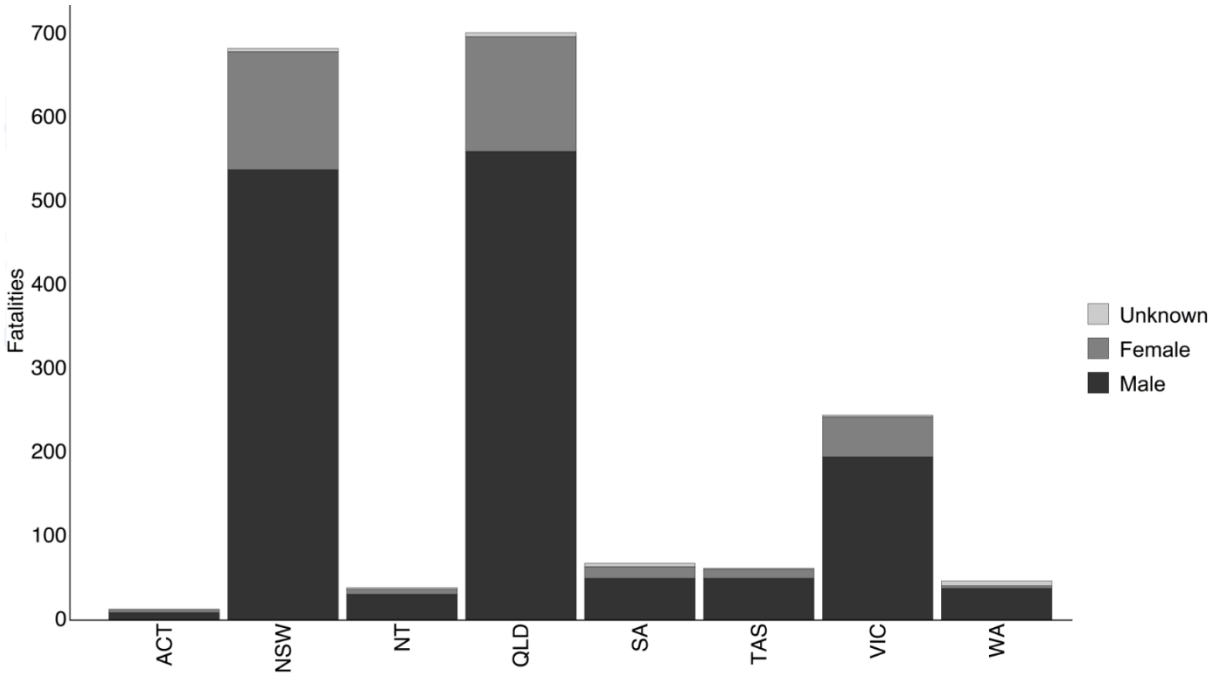

FIGURE 4.7: NUMBER OF FATALITIES PER STATES AND TERRITORIES FROM 1900 TO 2015

When deaths are examined in relation to the population size (Figure 4.8), the heightened level of risk in the NT is highlighted, followed by the moderately high level of risk in Queensland and the ACT, the moderate risk in NSW and Tasmania, and the relatively lower level of risk in SA, Victoria and WA.

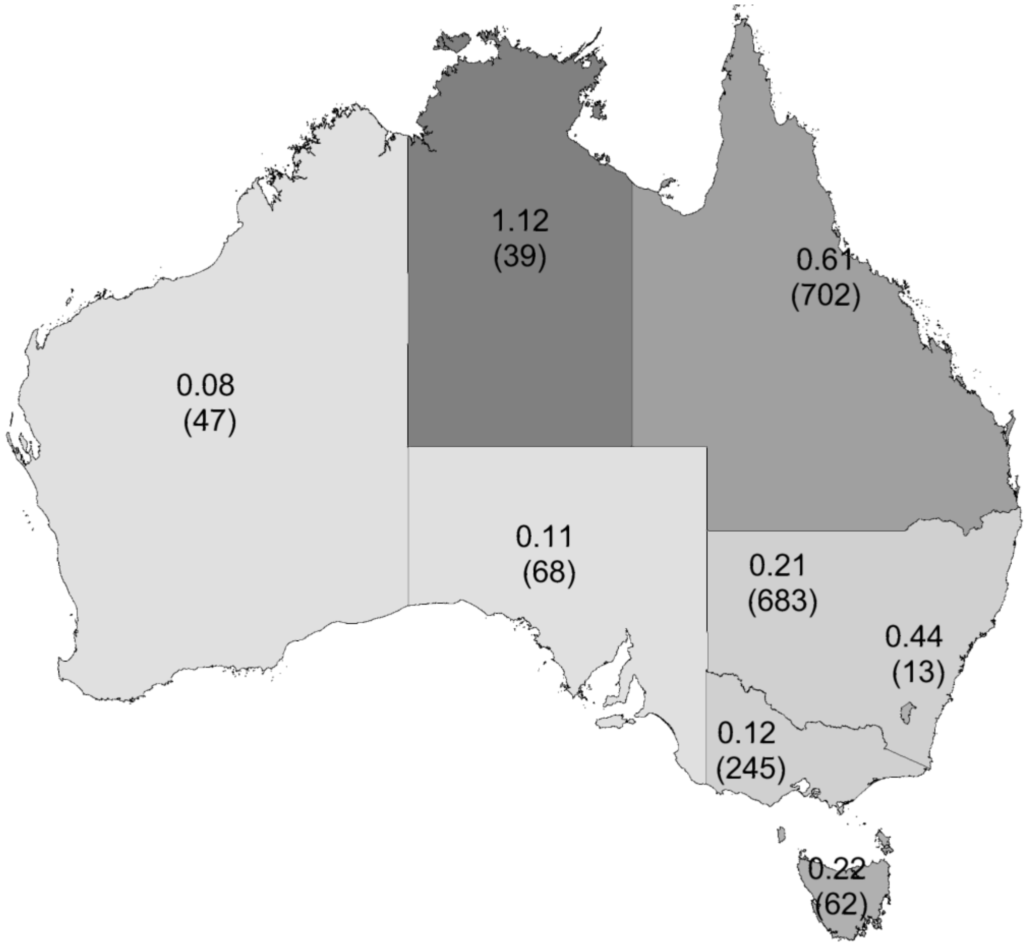

FIGURE 4.8: FATALITY RATE PER 100,000 PEOPLE BY STATE

When fatalities in the various states and territories are examined longitudinally (Table 4.4), we see an expected downward trend in deaths over time, apart from in the Northern Territory.

	ACT	NSW	NT	QLD	SA	TAS	VIC	WA	Total
1900-1909	0 (0.0%)	49 (7.2%)	0 (0.0%)	32 (4.6%)	11 (16.2%)	8 (12.9%)	49 (20.0%)	6 (12.8%)	155 (8.3%)
1910-1919	0 (0.0%)	73 (10.7%)	1 (2.6%)	138 (19.7%)	9 (13.2%)	4 (6.5%)	52 (21.2%)	7 (14.9%)	284 (15.3%)
1920-1929	1 (7.7%)	71 (10.4%)	1 (2.6%)	138 (19.7%)	9 (13.2%)	27 (43.5%)	22 (9.0%)	2 (4.3%)	271 (14.6%)
1930-1939	0 (0.0%)	68 (10.0%)	0 (0.0%)	76 (10.8%)	15 (22.1%)	1 (1.6%)	40 (16.3%)	6 (12.8%)	206 (11.1%)
1940-1949	0 (0.0%)	54 (7.9%)	2 (5.1%)	66 (9.4%)	7 (10.3%)	3 (4.8%)	14 (5.7%)	7 (14.9%)	1573(8.2%)
1950-1959	1 (7.7%)	154 (22.5%)	2 (5.1%)	47 (6.7%)	5 (7.4%)	5 (8.1%)	29 (11.8%)	1 (2.1%)	244 (13.1%)
1960-1969	1 (7.7%)	54 (7.9%)	1 (2.6%)	9 (1.3%)	5 (7.4%)	3 (4.8%)	1 (0.4%)	0 (0.0%)	74 (4.0%)
1970-1979	8 (61.5%)	57 (8.3%)	8 (20.5%)	45 (6.4%)	2 (2.9%)	4 (6.5%)	12 (4.9%)	1 (2.1%)	137 (7.4%)
1980-1989	2 (15.4%)	24 (3.5%)	4 (10.3%)	25 (3.6%)	1 (1.5%)	1 (1.6%)	3 (1.2%)	8 (17.%)	68 (3.7%)
1990-1999	0 (0.0%)	32 (4.7%)	5 (12.8%)	34 (4.8%)	4 (5.9%)	3 (4.8%)	7 (2.9%)	4 (8.5%)	89 (4.8%)
2000-2009	0 (0.0%)	32 (4.7%)	6 (15.4%)	32 (4.6%)	0 (0.0%)	3 (4.8%)	11 (4.5%)	5 (10.6%)	89 (4.8%)
2010-2015	0 (0.0%)	15 (2.2%)	9 (23.1%)	60 (8.5%)	0 (0.0%)	0 (0.0%)	5 (2.0%)	0 (0.0%)	89 (4.8%)
Total	**13 (100%)**	**683 (100%)**	**39 (100%)**	**702 (100%)**	**68 (100%)**	**62 (100%)**	**245 (100%)**	**47 (100%)**	**1859 (100%)**

TABLE 4.4: FATALITIES BY STATES AND TERRITORIES BY DECADE, 1900-2015 (% OF COLUMN TOTALS)

The seasonal breakdown of deaths by states and territories (Table 4.5) shows that the majority of fatalities in Queensland, NSW and Northern Territory occurred during the summer/monsoon season, predominantly in December, January, February and March, although there is a fairly high proportion of NSW deaths in June that are associated with winter storms. In contrast, the SA, Victoria, WA and Tasmanian deaths are more evenly distributed throughout the year.

	ACT	NSW	NT	QLD	SA	TAS	VIC	WA	Total
January	7 (53.8%)	102 (14.9%)	14 (35.9%)	176 (25.1%)	9 (13.2%)	1 (1.6%)	12 (4.9%)	4 (8.5%)	325 (17.5%)
February	1 (7.7%)	131 (19.2%)	7 (17.9%)	183 (26.1%)	10 (14.7%)	1 (1.6%)	15 (6.1%)	7 (14.9%)	355 (19.1%)
March	1 (7.7%)	64 (9.4%)	14 (35.9%)	83 (11.8%)	1 (1.5%)	2 (3.2%)	15 (6.1%)	9 (19.1%)	189 (10.2%)
April	1 (7.7%)	46 (6.7%)	3 (7.7%)	59 (8.4%)	3 (4.4%)	22 (35.5%)	10 (4.1%)	3 (6.4%)	147 (7.9%)
May	1 (7.7%)	39 (5.7%)	0 (0.0%)	21 (3.%)	4 (5.9%)	6 (9.7%)	4 (1.6%)	3 (6.4%)	78 (4.2%)
June	1 (7.7%)	79 (11.6%)	0 (0.0%)	19 (2.7%)	5 (7.4%)	9 (14.5%)	23 (9.4%)	8 (17.0%)	144 (7.7%)
July	0 (0.0%)	51 (7.5%)	0 (0.0%)	21 (3.%)	4 (5.9%)	6 (9.7%)	25 (10.2%)	5 (10.6%)	112 (6.0%)
August	0 (0.0%)	53 (7.8%)	0 (0.0%)	1 (0.1%)	8 (11.8%)	6 (9.7%)	35 (14.3%)	1 (2.1%)	104 (5.6%)
Septembe r	0 (0.0%)	24 (3.5%)	0 (0.0%)	2 (0.3%)	7 (10.3%)	4 (6.5%)	39 (15.9%)	2 (4.3%)	78 (4.2%)
October	0 (0.0%)	30 (4.4%)	0 (0.0%)	11 (1.6%)	8 (11.8%)	1 (1.6%)	20 (8.2%)	3 (6.4%)	73 (3.9%)
November	0 (0.0%)	32 (4.7%)	0 (0.0%)	17 (2.4%)	3 (4.4%)	4 (6.5%)	27 (11.%)	1 (2.1%)	84 (4.5%)
December	1 (7.7%)	32 (4.7%)	1 (2.6%)	109 (15.5%)	6 (8.8%)	0 (0.0%)	20 (8.2%)	1 (2.1%)	170 (9.1%)
Total	**13 (100%)**	**683 (100%)**	**39(100%)**	**702 (100%)**	**68 (100%)**	**62 (100%)**	**245(100%)**	**47 (100%)**	**1859 (100%)**

TABLE 4.5: FATALITIES BY STATES AND TERRITORIES BY MONTH (% OF COLUMN TOTALS)

In terms of cause of death, the majority died from drowning (54.9%, n=1020), followed by those who were likely to have died from drowning (33.1%, n=616) (Table 4.6). The latter group cannot be accurately categorized as drowning due to lack of specific data about whether or not injury, exposure or heart attack was the root cause. As many of the early deaths were often classified as drowning without a proper autopsy it would be most correct to state that 88% of deaths were caused by drowning with injury, exposure or heart attack likely to be a contributing factor in many of these.

Cause of death	Total
Drowning	1020 (54.9%)
Exposure	4 (0.2%)
Drowning/injury/exposure/heart attack	615 (33.1%)
Injury - other	2 (0.1%)
Injury - Hit: by flood debris or hit a rock etc	8 (0.4%)
Injury - Flood-or rain-induced washaway / landslide	4 (0.2%)
Injury - Vehicle accident	9 (0.5%)
Injury - Flood-or rain-induced building collapse	1 (0.1%)
Injury – Tree fall, tree limb fall	3 (0.2%)
Heart attack, over-exertion, shock, collapse	20 (1.1%)
Electrocution (fallen power lines etc)	7 (0.4%)
Missing presumed dead (cause unknown)	41 (2.2%)
Unknown	125 (6.7%)
Total	**1859 (100%)**

TABLE 4.6: CAUSE OF DEATH

ACTIVITY AND REASON BEHIND ACTION

The highest proportions of both men and women died while attempting to cross a bridge, causeway, culvert, road, etc. (men: 43.4%, n=639; women: 38.2%, n=139) (Table 4.7). For females, the second highest activity at the time of death, accounting for nearly a quarter of all female fatalities, was being engaged in an activity not near a usual watercourse, e.g. driving through town or in their home and unaware of the flood waters (22.5%, n=82). This group do not attempt to cross floodwaters but are surprised by flash flooding outside of a usual water channel. For men this was the third highest cause of death (9.6%, n=141). Of the total number involved in this activity (n=226), 46.9% (n=106) were in a house (70.8%, n=75 of these were in a house that was destroyed), 13.3% (n=30) were on a house (86.7%, n=26 of these were on a house that was destroyed), and 23.9% (n=54) were outside. Prior to death, the majority of these people were engaged in an evacuation, awaiting a planned rescue / evacuation or in their home and taken by surprise (n=138) (Table 4.8).

	Male	Female	Unknown	Total
Attempting to cross bridge/ causeway/ crossing/ culvert/ ford/ watercourse	639 (43.4%)	139 (38.2%)	9 (37.5%)	787 (42.3%)
Attempting to cross floodwaters away from watercourses (water over fields / town)	67 (4.6%)	10 (2.7%)	0 (0.0%)	77 (4.1%)
Engaged in an activity near the water (on the bank / bridge)	173 (11.8%)	41 (11.3%)	1 (4.2%)	215 (11.6%)
Engaged in an activity in/ near stormwater drain	37 (2.5%)	12 (3.3%)	0 (0.0%)	49 (2.6%)
Engaged in an activity in the water (rescue, swimming)	94 (6.4%)	22 (6.0%)	0 (0.0%)	116 (6.2%)
Engaged in an activity on the water (boat)	77 (5.2%)	16 (4.4%)	0 (0.0%)	93 (5.0%)
Engaged in an activity not near usual watercourse (e.g. in their home)	141 (9.6%)	82 (22.5%)	3 (12.5%)	226 (12.2%)
Other	5 (0.3%)	1 (0.3%)	0 (0.0%)	6 (0.3%)
Unknown	238 (16.2%)	41 (11.3%)	11 (45.8%)	290 (15.6%)
Total	**1471 (100%)**	**364 (100%)**	**24 (100%)**	**1859 (100%)**

TABLE 4.7: FATALITIES BY ACTIVITY PRIOR TO DEATH AND GENDER (% OF COLUMN TOTALS)

	Attempting to cross bridge/ causeway/ crossing/ culvert/ ford/ road/ watercourse	Attempting to cross floodwaters	Engaged in an activity near the water (bank/ bridge)	Engaged in an activity in/ near stormwater drain	Engaged in an activity in the water (rescue, swimming, joyride etc)	Engaged in an activity on the water (boat)	Engaged in an activity not near usual watercourse	Other	Unknown	Total
Attempting vertical evacuation	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	41 (18.1%)	0 (0.0%)	0 (0.0%)	41 (2.2%)
Being rescued/ evacuated	0 (0.0%)	8 (10.4%)	2 (0.9%)	0 (0.0%)	0 (0.0%)	11 (11.8%)	9 (4.0%)	0 (0.0%)	1 (0.3%)	31 (1.7%)
Awaiting a planned rescue/ evacuation	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (1.8%)	0 (0.0%)	0 (0.0%)	4 (0.2%)
Refused to be evacuated	1 (0.1%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	6 (2.7%)	0 (0.0%)	1 (0.3%)	8 (0.4%)
Evacuating	7 (0.9%)	8 (10.4%)	2 (0.9%)	0 (0.0%)	1 (0.9%)	0 (0.0%)	24 (10.6%)	0 (0.0%)	3 (1.0%)	45 (2.4%)
Late evacuation	0 (0.0%)	0 (0.0%)	0 (0.%)	4 (8.2%)	0 (0.0%)	0 (0.0%)	5 (2.2%)	0 (0.0%)	0 (0.0%)	9 (0.5%)
No attempt at evacuation as unaware	0 (0.0%)	1 (1.3%)	15 (7.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	55 (24.3%)	0 (0.0%)	0 (0.0%)	71 (3.8%)
En route	231 (29.4%)	13 (16.9%)	8 (3.7%)	4 (8.2%)	0 (0.0%)	13 (14.0%)	4 (1.8%)	0 (0.0%)	7 (2.4%)	280 (15.%)
En route from home	89 (11.3%)	2 (2.6%)	7 (3.3%)	2 (4.1%)	0 (0.0%)	1 (1.1%)	2 (0.9%)	0 (0.0%)	0 (0.0%)	103 (5.5%)
En route to home	159 (20.2%)	8 (10.4%)	3 (1.4%)	1 (2.0%)	2 (1.7%)	2 (2.2%)	1 (0.4%)	5 (45.5%)	5 (1.7%)	181 (9.7%)
Recreating/ visiting	38 (4.8%)	2 (2.6%)	86 (40.0%)	25 (51.0%)	90 (77.6%)	27 (29.0%)	8 (3.5%)	1 (9.1%)	3 (1.0%)	280 (15.1%)
Carrying out repairs due to flood damage etc	4 (0.5%)	0 (0.0%)	11 (5.1%)	2 (4.1%)	0 (0.0%)	2 (2.2%)	1 (0.4%)	0 (0.0%)	1 (0.3%)	21 (1.1%)
Collecting provisions	18 (2.3%)	2 (2.6%)	1 (0.5%)	0 (0.0%)	0 (0.0%)	2 (2.2%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	23 (1.2%)
Attempting to retrieve flotsam	0 (0.0%)	0 (0.0%)	5 (2.3%)	0 (0.0%)	1 (0.9%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	6 (0.3%)
Collecting people	2 (0.3%)	0 (0.0%)	1 (0.5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.2%)
Rescuing People, Property Livestock	13 (1.7%)	9 (11.7%)	12 (5.6%)	1 (2.0%)	13 (11.2%)	14 (15.1%)	5 (2.2%)	1 (9.1%)	0 (0.0%)	68 (3.7%)
Working, attending livestock or livelihood	107 (13.6%)	14 (18.2%)	28 (13.0%)	3 (6.1%)	4 (3.4%)	9 (9.7%)	19 (8.4%)	0 (0.0%)	7 (2.4%)	191 (10.3%)
Other	2 (0.3%)	0 (0.0%)	4 (1.9%)	0 (0.0%)	1 (0.9%)	3 (3.2%)	0 (0.0%)	1 (9.1%)	0 (0.0%)	11 (0.6%)
Unknown	116 (14.7%)	10 (13.%)	30 (14.0%)	7 (14.3%)	4 (3.4%)	9 (9.7%)	42 (18.6%)	3 (27.3%)	262 (90.3%)	483 (26.0%)
Total	**787 (100%)**	**77 (100%)**	**215 (100%)**	**49 (100%)**	**116 (100%)**	**93 (100%)**	**226 (100%)**	**6 (100%)**	**290 (100%)**	**1859 (100%)**

TABLE 4.8: FATALITIES BY REASON BEHIND ACTION AND ACTIVITY PRIOR TO DEATH (% OF COLUMN TOTALS)

Being engaged in an activity near the water (bank) was the second highest cause of death for men (11.8%, n=173) and the third highest for women (11.3%, n=41) (see Table 4.7). The majority of these victims were recreating (40.0%, n=86) (see Table 4.8).

For those attempting to cross a bridge, causeway, culvert, road, etc. the risk is broadly split across all age ranges, although the highest number of fatalities are seen within the 10-29 year age range (32.4%, n=255) (Table 4.9). When the distinct age ranges are examined the data shows that although high numbers of those in the 0-9 and 10-19 age range are attempting to cross a watercourse the proportions engaged in this activity are smaller than for all the other age ranges. In particular, those in the 0-9 age range are relatively evenly split, with 25.3% (n=62) attempting to cross a watercourse, and 23.7% (n=58) engaged in an activity near the bank. In the 10-19 age range a higher proportion are attempting to cross a watercourse. However, within this age group is the highest proportion of those engaged in an activity in the water (17.3%, n=54). Overall in terms of activities the highest number of fatalities engaged in activities near the water (bank) and in or near a stormwater drain are within the 0-19 year age ranges (48.4%, n=104; 69.4%, n=34, respectively). For those engaged in activities in the water, the majority of 67.3% (n=78) are in the 10-29 year age range. The highest proportion of those engaged in an activity not near a usual watercourse is in the 0-9 year age range (17.7%, n=40).

Please note the percentages in the above paragraph are taken across the row i.e within a specific age range of Table 4.9 and do not correspond to the down column percentages reported in the table.

	Attempting to cross bridge/ causeway/ crossing/ culvert/ ford/ road/ watercourse	Attempting to cross floodwaters (fields, town)	Engaged in an activity near the water (bank)	Engaged in an activity in/ near stormwater drain	Engaged in an activity in the water (rescue, swimming,)	Engaged in an activity on the water (boat)	Engaged in an activity not near usual watercourse	Other	Unknown	Total
0-9	62 (7.9%)	5 (6.5%)	58 (27.0%)	18 (36.7%)	11 (9.5%)	13 (14.0%)	40 (17.7%)	2 (33.3%)	36 (12.4%)	245 (13.2%)
10-19	121 (15.4%)	13 (16.9%)	46 (21.4%)	16 (32.7%)	54 (46.6%)	12 (12.9%)	15 (6.6%)	1 (16.7%)	34 (11.7%)	312 (16.8%)
20-29	134 (17.0%)	9 (11.7%)	20 (9.3%)	6 (12.2%)	24 (20.7%)	16 (17.2%)	16 (7.1%)	1 (16.7%)	23 (7.9%)	249 (13.4%)
30-39	96 (12.2%)	11 (14.3%)	16 (7.4%)	1 (2.0%)	13 (11.2%)	15 (16.1%)	11 (4.9%)	1 (16.7%)	24 (8.3%)	188 (10.1%)
40-49	92 (11.7%)	10 (13.0%)	19 (8.8%)	1 (2.0%)	5 (4.3%)	5 (5.4%)	15 (6.6%)	0 (0.0%)	17 (5.9%)	164 (8.8%)
50-59	77 (9.8%)	10 (13.0%)	12 (5.6%)	1 (2.0%)	4 (3.4%)	2 (2.2%)	20 (8.8%)	0 (0.0%)	14 (4.8%)	140 (7.5%)
60-69	48 (6.1%)	4 (5.2%)	12 (5.6%)	3 (6.1%)	2 (1.7%)	9 (9.7%)	16 (7.1%)	1 (16.7%)	22 (7.6%)	117 (6.3%)
70-79	37 (4.7%)	3 (3.9%)	6 (2.8%)	1 (2.%)	0 (0.0%)	2 (2.2%)	8 (3.5%)	0 (0.0%)	8 (2.8%)	65 (3.5%)
80-89	6 (0.8%)	1 (1.3%)	4 (1.9%)	0 (0.0%)	0 (0.0%)	2 (2.2%)	4 (1.8%)	0 (0.0%)	1 (0.3%)	18 (1.0%)
Unknown	114 (14.5%)	11 (14.3%)	22 (10.2%)	2 (4.1%)	3 (2.6%)	17 (18.3%)	81 (35.8%)	0 (0.0%)	111 (38.3%)	361 (19.4%)
Total	**787 (100%)**	**77 (100%)**	**215 (100%)**	**49 (100%)**	**116 (100%)**	**93 (100%)**	**226 (100%)**	**6 (100%)**	**290 (100%)**	**1859 (100%)**

TABLE 4.9: FATALITIES BY ACTIVITY AND AGE (% OF COLUMN TOTALS)

When the reasons behind the actions taken prior to death are examined in detail (Table 4.10), the highest numbers of fatalities occurred en route to a destination (30.3%, n=564). Of these, where information was known, the greatest proportion was on their way home (9.7%, n=181), followed by those who were en route from home (5.5%, n=103). When this data is examined by gender, a very similar proportion of fatalities are seen for both men and women (men 30.1%, n=443 and women 30.8%, n=112). The second highest reason behind death for both genders is recreating (15.1%, n=280). However, the highest proportion of these deaths is seen among females with 19.8% (n=72) compared to 14.1% males (n=208). For men, the third highest reason leading to flood deaths is working, attending to livestock or livelihoods (12.3%, n=181). The third highest reason for women is evacuating (including vertical evacuation, being rescued, awaiting a rescue and late evacuation), which accounts for 15.4% (n=56), followed by those who were in their homes and unaware and therefore made no attempt at evacuation (8.2%, n=30).

	Male	Female	Unknown	Total
Attempting vertical evacuation	20 (1.4%)	21 (5.8%)	0 (0.0%)	41 (2.2%)
Being rescued/ evacuated	15 (1.0%)	16 (4.4%)	0 (0.0%)	31 (1.7%)
Awaiting a planned rescue/ evacuation	4 (0.3%)	0 (0.0%)	0 (0.0%)	4 (0.2%)
Refused to be evacuated	7 (0.5%)	1 (0.3%)	0 (0.0%)	8 (0.4%)
Evacuating	24 (1.6%)	18 (4.9%)	3 (12.5%)	45 (2.4%)
Late evacuation	8 (0.5%)	1 (0.3%)	0 (0.0%)	9 (0.5%)
No attempt at evacuation as unaware	41 (2.8%)	30 (8.2%)	0 (0.0%)	71 (3.8%)
En route	227 (15.4%)	48 (13.2%)	5 (20.8%)	280 (15.1%)
En route from home	70 (4.8%)	29 (8.0%)	4 (16.7%)	103 (5.5%)
En route to home	146 (9.9%)	35 (9.6%)	0 (0.0%)	181 (9.7.%)
Recreating	208 (14.1%)	72 (19.8%)	0 (0.%)	280 (15.1%)
Carrying out repairs due to flood damage	21 (1.4%)	0 (0.0%)	0 (0.0%)	21 (1.1%)
Collecting provisions	21 (1.4%)	2 (0.5%)	0 (0.0%)	23 (1.2%)
Attempting to retrieve flotsam	6 (0.4%)	0 (0.0%)	0 (0.0%)	6 (0.3%)
Collecting people	1 (0.1%)	2 (0.5%)	0 (0.0%)	3 (0.2%)
Rescuing people, property, pets	62 (4.2%)	6 (1.6%)	0 (0.0%)	68 (3.7%)
Working, attending to livestock or livelihood	181 (12.3%)	9 (2.5%)	1 (4.2%)	191 (10.3%)
Other	8 (0.5%)	3 (0.8%)	0 (0.0%)	11 (0.6%)
Unknown	401 (27.3%)	71 (19.5%)	11(45.8%)	483 (26.0%)
Total	**1471 (100%)**	**364 (100%)**	**24 (100%)**	**1859 (100%)**

TABLE 4.10: FATALITIES BY REASON PRIOR TO ACTION AND GENDER (% OF COLUMN TOTALS)

When this data is explored by age ranges (Table 4.11), the highest proportions of those in the 0-19 year age groups were recreating (32.5%, n=181), followed by those en route to a destination (24.8%, n=138). For all other age groups the highest proportions are recorded in the en route category.

	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	Unknown	Total
Attempting vertical evacuation	6 (2.4%)	1 (0.3%)	0 (0.0%)	1 (0.5%)	5 (3.0%)	3 (2.1%)	0 (0.0%)	1 (1.5%)	2 (11.1%)	22 (6.1%)	41 (2.2%)
Being rescued/ evacuated	14 (5.7%)	4 (1.3%)	2 (0.8%)	1 (0.5%)	2 (1.2%)	1 (0.7%)	2 (1.7%)	2 (3.1%)	1 (5.6%)	2 (0.6%)	31 (1.7%)
Awaiting a planned rescue/ evacuation	0 (0.0%)	0 (0.0%)	1 (0.4%)	0 (0.%)	0 (0.0%)	0 (0.0%)	2 (1.7%)	0 (0.0%)	0 (0.0%)	1 (0.3%)	4 (0.2%)
Refused to be evacuated	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (2.1%)	1 (0.9%)	1 (1.5%)	0 (0.0%)	3 (0.8%)	8 (0.4%)
Evacuating	8 (3.3%)	3 (0.9%)	7 (2.8%)	5 (2.7%)	2 (1.2%)	6 (4.3%)	3 (2.6%)	3 (4.6%)	0 (0.0%)	8 (2.2%)	45 (2.4%)
Late evacuation	5 (2.0%)	1 (0.3%)	1 (0.4%)	1 (0.5%)	0 (0.0%)	0 (0.0%)	1 (0.9%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	9 (0.5%)
No attempt at evacuation as unaware	18 (7.3%)	8 (2.5%)	4 (1.6%)	4 (2.1%)	5 (3.0%)	6 (4.3%)	6 (5.1%)	2 (3.1%)	1 (5.6%)	17 (4.7%)	71 (3.8%)
En route	23 (9.4%)	35 (11.2%)	46 (18.5%)	32 (17.0%)	31 (18.9%)	24 (17.1%)	23 (19.7%)	11 (16.9%)	4 (22.2%)	51 (14.1%)	280 (15.1%)
En route from home	14 (5.7%)	23 (7.4%)	14 (5.6%)	11 (5.9%)	8 (4.9%)	12 (8.6%)	2 (1.7%)	6 (9.2%)	2 (11.1%)	11 (3.0%)	103 (5.5%)
En route to home	22 (9.0%)	21 (6.7%)	28 (11.2%)	21 (11.2%)	23 (14.0%)	18 (12.9%)	17 (14.5%)	12 (18.5%)	2 (11.1%)	17 (4.7%)	181 (9.7%)
Recreating	78 (31.8%)	103 (33.0%)	39 (15.7%)	20 (10.6%)	14 (8.5%)	6 (4.3%)	9 (7.7%)	1 (1.5%)	3 (16.7%)	7 (1.9%)	280 (15.1%)
Carrying out repairs due to flood damage etc	0 (0.0%)	3 (1.0%)	4 (1.6%)	2 (1.1%)	2 (1.2%)	2 (1.4%)	3 (2.6%)	1 (1.5%)	0 (0.0%)	4 (1.1%)	21 (1.1%)
Collecting provisions	2 (0.8%)	8 (2.5%)	4 (1.6%)	3 (1.6%)	0 (0.0%)	0 (0.0%)	1 (0.9%)	1 (1.5%)	0 (0.0%)	4 (1.1%)	23 (1.2%)
Attempting to retrieve flotsam	2 (0.8%)	4 (1.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	6 (0.3%)
Collecting people	1 (0.4%)	0 (0.0%)	0 (0.0%)	1 (0.5%)	1 (0.6%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.2%)
Rescuing People, Property Livestock	2 (0.8%)	15 (4.8%)	11 (4.4%)	11 (5.9%)	9 (5.5%)	5 (3.6%)	4 (3.4%)	1 (1.5%)	1 (5.6%)	9 (2.5%)	68 (3.7%)
Working, attending livestock or livelihood	0 (0.0%)	23 (7.4%)	47 (18.9%)	26 (13.8%)	23 (14.0%)	26 (18.6%)	9 (7.7%)	7 (10.8%)	1 (5.6%)	29 (8.0%)	191 (10.3%)
Other	1 (0.4%)	3 (1.0%)	0 (0.0%)	3 (1.6%)	1 (0.6%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.8%)	11 (0.6%)
Unknown	49 (20.0%)	57 (18.3%)	41 (16.5%)	46 (24.5%)	38 (23.2%)	28 (20.0%)	34 (29.1%)	16 (24.6%)	1 (5.6%)	174 (47.9%)	484 (26.0%)
Total	**245 (100%)**	**312 (100%)**	**249 (100%)**	**188 (100%)**	**164 (100%)**	**140 (100%)**	**117 (100%)**	**65 (100%)**	**18 (100%)**	**361 (100%)**	**1859 (100%)**

TABLE 4.11: FATALITIES BY REASON BEHIND ACTION AND AGE (% OF COLUMN TOTALS)

CAPACITY AND AWARENESS

In terms of capacity and awareness (Table 4.12), the majority of fatalities (53.6%) were considered to be capable of independent action (n=997) and, of these, 59.5% (n=593) of victims were aware of the flood but the depth and/ or speed of the water took them by surprise. For capacity, the second highest proportion were those following the decision making of others (such as children or passengers in a car) (15.7%, n=292), followed by a child or group of children on their own who are under the age of 11 (9.3%, n=173).

When the age ranges (Table 4.13) of those following the decision making of others are examined, 37.0% (n=108) are in the 0-9 category and 21.2% (n=62) are in the 10-19 category (percentages here run across the row). The breakdown of capacity by gender (Table 4.14) shows that the majority of male victims (59.5%, n= 875) were capable of independent action, a far higher proportion than for any of the other categories. In comparison, the highest proportion of female victims were following the decision making of others (36.3%, n=132), although this is followed closely by females who were capable of independent action (32.7%, n=119). In terms of children who were on their own or in a group of children, 69.4% were male (n=120) and 28.9% were female (n=50).

	Aware but did not expect to encounter the flood	Aware but depth and or speed took them by surprise	Unaware and taken by surprise	N/A – child < 11	N/A – other	Unknown	Total
Capable of independent action	158 (66.4%)	593 (73.2%)	148 (60.4%)	2 (0.7%)	10 (58.8%)	86 (33.0%)	997 (53.6%)
Physically and or mentally disabled or incapable	3(1.3%)	13 (1.6%)	4 (1.6%)	1 (0.3%)	3 (17.6%)	4 (1.5%)	28 (1.5%)
Cannot swim	14 (5.9%)	27 (3.3%)	7 (2.9%)	1 (0.3%)	2 (11.8%)	2 (0.8%)	53 (2.9%)
Influenced by drugs or alcohol	9 (3.8%)	49 (6.0%)	20 (8.2%)	0 (0.0%)	0 (0.0%)	7 (2.7%)	85 (4.6%)
Following the decision making of others	39 (16.4%)	81 (10.0%)	39 (15.9%)	126 (43.8%)	2 (11.8%)	5 (1.9%)	292 (15.7%)
A child or group of children on their own < 11 years old	6 (2.5%)	6 (0.7%)	1 (0.4%)	156 (54.2%)	0 (0.0%)	4 (1.5%)	173 (9.3%)
Unfamiliar with the area	1 (0.4%)	13 (1.6%)	11 (4.5%)	0 (0.0%)	0 (0.0%)	1 (0.4%)	26 (1.4%)
Encumbered with clothing, possessions or equipment	2 (0.8%)	11 (1.4%)	2 (0.8%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	15 (0.8%)
Looking after dependents	0 (0.0%)	5 (0.6%)	3 (1.2%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	8 (0.4%)
N/A	0 (0.0%)	0 (0.0%)	3 (1.2%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.2%)
Unknown	6 (2.5%)	12 (1.5%)	7 (2.9%)	2 (0.7%)	0 (0.0%)	152 (58.2%)	179(9.6%)
Total	**238 (100%)**	**810 (100%)**	**245 (100%)**	**288 (100%)**	**17 (100%)**	**261(100%)**	**1859 (100%)**

TABLE 4.12: FATALITIES BY CAPACITY AND AWARENESS (% OF COLUMN TOTALS)

	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	Unknown	Total
Capable of independent action	0 (0.0%)	165 (52.9%)	170 (68.3%)	123 (65.4%)	118 (72.0%)	93 (66.4%)	74 (63.2%)	38 (58.5%)	7 (38.9%)	209 (57.9%)	997 (53.6%)
Physically and or mentally disabled or incapable	0 (0.0%)	2 (0.6%)	0 (0.0%)	4 (2.1%)	4 (2.4%)	4 (2.9%)	6 (5.1%)	4 (6.2%)	2 (11.1%)	2 (0.6%)	28 (1.5%)
Cannot swim	0 (0.0%)	16 (5.1%)	14 (5.6%)	7 (3.7%)	3 (1.8%)	5 (3.6%)	1 (0.9%)	1 (1.5%)	0 (0.0%)	6 (1.7%)	53 (2.9%)
Influenced by drugs or alcohol	0 (0.0%)	7 (2.2%)	11 (4.4%)	15 (8.%)	13 (7.9%)	14 (10.%)	11 (9.4%)	8 (12.3%)	3 (16.7%)	3 (0.8%)	85 (4.6%)
Following the decision making of others	108 (44.1%)	62 (19.9%)	35 (14.1%)	16 (8.5%)	7 (4.3%)	11 (7.9%)	5 (4.3%)	5 (7.7%)	2 (11.1%)	41 (11.4%)	292 (15.7%)
A child or group of children on their own < 11 years old	135 (55.1%)	33 (10.6%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	5 (1.4%)	173 (9.3%)
Unfamiliar with the area	0 (0.0%)	7 (2.2%)	4 (1.6%)	2 (1.1%)	3 (1.8%)	2 (1.4%)	1 (0.9%)	0 (0.0%)	0 (0.0%)	7 (1.9%)	26 (1.4%)
N/A	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.7%)	1 (0.9%)	0 (0.0%)	0 (0.0%)	1 (0.3%)	3 (0.2%)
Encumbered with clothing, possessions or equipment	0 (0.0%)	3 (1.0%)	2 (0.8%)	2 (1.1%)	3 (1.8%)	1 (0.7%)	1 (0.9%)	0 (0.0%)	0 (0.0%)	3 (0.8%)	15 (0.8%)
Looking after dependents	0 (0.0%)	2 (0.6%)	2 (0.8%)	1 (0.5%)	2 (1.2%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.3%)	8 (0.4%)
Unknown	2 (0.8%)	15 (4.8%)	11 (4.4%)	18 (9.6%)	11 (6.7%)	9 (6.4%)	17 (14.5%)	9 (13.8%)	4 (22.2%)	83 (23.0%)	179 (9.6%)
Total	**245 (100%)**	**312 (100%)**	**249 (100%)**	**188 (10.1%)**	**164 (100%)**	**140 7.5%)**	**117 (100%)**	**65 (3.5%)**	**18 (100%)**	**361 (100%)**	**1859 (100%)**

TABLE 4.13: FATALITIES BY CAPACITY AND AGE RANGE (% OF COLUMN TOTALS)

	Male	Female	Unknown	Total
Capable of independent action	875 (59.5%)	119 (32.7%)	3 (12.5%)	997 (53.6%)
Physically and or mentally disabled or incapable	24 (1.6%)	4 (1.1%)	0 (0.0%)	28 (1.5%)
Cannot swim	47 (3.2%)	6 (1.6%)	0 (0.0%)	53 (2.9%)
Influenced by drugs or alcohol	64 (4.4%)	20 (5.5%)	1 (4.2%)	85 (4.6%)
Following the decision making of others	150 (10.2%)	136 (36.3%)	10 (41.7%)	292 (15.7%)
A child or group of children on their own < 11 years old	120 (8.2%)	50 (13.7%)	3 (12.5%)	173 (9.3%)
Unfamiliar with the area	20 (1.4%)	6 (1.6%)	0 (0.0%)	26 (1.4%)
N/A	3 (0.2%)	0 (0.0%)	0 (0.0%)	3 (0.2%)
Encumbered with clothing, possessions or equipment	13 (0.9%)	1 (0.3%)	1 (4.2%)	15 (0.8%)
Looking after dependents	6 (0.4%)	2 (0.5%)	0 (0.0%)	8 (0.4%)
Unknown	149 (10.1%)	24 (6.6%)	6 (25.0%)	179 (9.6%)
Total	**1471 (100%)**	**364 (100%)**	**24 (100%)**	**1859 (100%)**

TABLE 4.14: FATALITIES BY CAPACITY AND GENDER (% OF COLUMN TOTALS)

An analysis of the time of day and whether the fatality occurred during daylight or darkness (Table 4.15) demonstrates that the highest proportion of the fatalities, 36.6%, occurred in daylight (n=681) compared to 23.7% (n=440) that occurred during twilight or darkness. Of those who have been classified as aware of the flood but depth and/ or speed of the floodwaters took them by surprise (43.6%, n=810), almost a quarter (24.2%, n=196) perished in the dark or twilight, compared to 38.5% (n=312) who perished in the daylight.

	Dark	Daylight	Unknown	Total
Aware but did not expect to encounter the flood	71 (16.1%)	87 (12.8%)	80 (10.8%)	238 (12.8%)
Aware but depth and or speed took them by surprise	196 (44.5%)	312 (45.8%)	302 (40.9%)	810 (43.6%)
Unaware and taken by surprise	73 (16.6%)	97 (14.2%)	75 (10.2%)	245 (13.2%)
N/A – child < 11 years old	59 (13.4%)	143 (21.0%)	86 (11.7%)	288 (15.5%)
N/A – other	4 (0.9%)	4 (0.6%)	9 (1.2%)	17 (0.9%)
Unknown	37 (8.4%)	38 (5.6%)	186 (25.2%)	261 (14.0%)
Total	**440 (100%)**	**681 (100%)**	**738 (100%)**	**1859 (100%)**

TABLE 4.15: FATALITIES BY AWARENESS AND TIME OF DAY (% OF COLUMN TOTALS)

In terms of transport, the highest proportions were on foot (25.9%, n=482) and in a vehicle/ 4WD/ horse drawn vehicle (24.4%, n=462), followed by those who were on a horse (10.5%, n=195). The detailed breakdown by vehicle type has:

- 219 in or exiting a sedan car
- 107 in or exiting a horse drawn vehicle
- 45 in or exiting a 4WD
- 26 in or exiting a truck
- 8 in or exiting a ute
- 13 in a train

Furthermore, 8 were on a pushbike, 8 on a flying-fox, and 17 on other forms of transport (e.g. motorbike). In 19 cases the vehicle type was unknown.

When transport is examined over time (Table 4.16), a decrease in fatalities on foot, horses and horse drawn vehicles is seen and an increase of those in motorised vehicles. In particular, fatalities associated with 4WD vehicles have dramatically increased over the last 15 years.

Of those who were in a vehicle (all types), 49.4% (n=228) were coded as capable of independent action as they were the drivers, while 34.4% (n=159) were coded as following the decision making of others as they were passengers (Table 4.17). These numbers do not include all those in vehicles as it is unknown for some cases if they were drivers or passengers. A total of 4.6% of victims (n=85) were influenced by drugs and alcohol. Of these, 35.3% (n=30) were on foot, 38.8% (n=33) were driving in a vehicle; 75.3% (n=64) were male. Of all those who were in or driving a 4WD, 26.7% (n=12) were influenced by drugs or alcohol, accounting for a high portion of the recent vehicle related deaths. Drugs include, in this analysis, recreational and/ or above-normal doses of prescription.

When horse drawn vehicles are removed we see, in terms of gender, n=237 males (70.5% of all fatalities) and n=97 females (28.9% of all fatalities) were killed in a vehicle. In 2 cases the gender was unknown. Where data is available, of those who were driving a vehicle, 85.3% were men (n=122) and 14.7% were females (n=21). Of those who were passengers, 52.6% were males (n=71) and 45.9% were females (n=62). Of these fatalities 25.3% were in the 0-19 age range, the majority of whom were passengers.

In terms of the time of day, (when known) we see, the highest proportions of those on foot perished during daylight hours (daylight = 47.3%, n=228; darkness = 21.6%, n=104). In comparison, where time of fatality is known, the highest proportion of those in a vehicle (with horse drawn vehicles removed) perished at night or during twilight (daylight = 24.4%, n=82; darkness = 44.6%, n=150).

A more detailed analysis of those who were killed associated with vehicles is provided in the Appendix.

	1900-1909	1910-1919	1920-1929	1930-1939	1940-1949	1950-1959	1960-1969	1970-1979	1980-1989	1990-1999	2000-2009	2010-2015	Total
On foot	36 (23.2%)	46 (16.2%)	80 (29.5%)	62 (30.1%)	36 (23.5%)	85 (34.8%)	260 (35.1%)	29 (21.2%)	18 (26.5%)	19 (21.3%)	29 (32.6%)	16 (18.0%)	482 (25.9%)
Swimming (boogie board etc)	5 (3.2%)	27 (9.5%)	29 (10.7%)	22 (10.7%)	10(6.5%)	10 (4.1%)	4 (5.4%)	13 (9.5%)	2 (2.9%)	11 (12.4%)	8 (9.0%)	14 (15.7%)	155 (8.3%)
Carried by others	0 (0.0%)	1 (0.4%)	1 (0.4%)	3 (1.5%)	1(0.7%)	4 (1.6%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	10 (0.5%)
On horse	31 (20.0%)	36 (12.7%)	46 (17.0%)	38 (18.4%)	15(9.8%)	20 (8.2%)	3 (4.1%)	4 (2.9%)	1 (1.5%)	0 (0.0%)	1 (1.1%)	0 (0.0%)	195 (10.5%)
On vehicle: push bike	0 (0.0%)	1 (0.4%)	0 (0.0%)	2 (1.0%)	3(2.0%)	1 (0.4%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (1.1%)	0 (0.0%)	8 (0.4%)
On boat	10 (6.5%)	8 (2.8%)	16 (5.9%)	21 (10.2%)	22(14.4%)	25 (10.2%)	2 (2.7%)	11(8.0%)	2 (2.9%)	14 (15.7%)	3 (3.4%)	3 (3.4%)	137 (7.4%)
On rope/ cable/ flying fox	0 (0.0%)	1 (0.4%)	2 (0.7%)	2 (1.0%)	1(0.7%)	2 (0.8%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	8 (0.4%)
4WD	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.4%)	2 (2.7%)	0 (0.0%)	6 (8.8%)	3 (3.4%)	17 (19.1%)	16 (18.0%)	45 (2.4%)
Vehicle	0 (0.0%)	16 (5.6%)	12 (4.5%)	27 (13.1%)	20 (13.1%)	45 (18.4%)	34 (45.9%)	53 (38.7%)	19 (28.0%)	23 (25.8%)	26 (29.2%)	27 (30.3%)	302 (16.2%)
Horse drawn vehicle	5 (3.2%)	46 (16.2%)	30 (11.0%)	8 (3.9%)	9 (5.9%)	7 (2.9%)	0 (0.0%)	0 (0.0%)	2 (2.9%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	107 (5.8%)
Other transport	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (2.2%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.2%)
Unknown	64 (41.3%)	55 (19.4%)	29 (10.7%)	18 (8.7%)	27 (17.6%)	24 (9.8%)	3 (4.1%)	15 (10.9%)	11 (16.2%)	15 (16.9%)	4 (4.5%)	0 (0.0%)	265 (14.3%)
N/A – in house / caravan	4 (2.6%)	46 (16.2%)	26 (9.6%)	3 (1.5%)	9 (5.9%)	20 (8.2%)	0 (0.0%)	9 (6.6%)	2 (2.9%)	4 (4.5%)	0 (0.0%)	13 (14.6%)	136 (7.3%)
N/A other	0 (0.0%)	1 (0.4%)	0 (0.0%)	0 (0.0%)	0 (0.%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	5 (7.4%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	6 (0.3%)
Total	**155 (100%)**	**284(100%)**	**271(100%)**	**206(100%)**	**153 (100%)**	**244 (100%)**	**74 (100%)**	**137 (100%)**	**68 (100%)**	**89 (100%)**	**89 (100%)**	**89 (100%)**	**1859 (100%)**

TABLE 4.16: MODE OF TRANSPORT COMPARED AGAINST DECADE (% OF COLUMN TOTALS)

	Capable of independent action	Physically and or mentally disabled or incapable	Cannot swim	Influenced by drugs or alcohol	Following the decision making of others	A child or group of children on their own < 11 years old	Unfamiliar with the area	N/A	Encumbered with clothing, possessions or equipment	Looking after dependents	Unknown	Total
On foot	239 (24.0%)	15 (53.6%)	15 (28.3%)	30 (35.3%)	27 (9.2%)	123 (71.1%)	8 (30.8%)	0 (0.0%)	4 (26.7%)	1 (12.5%)	20 (11.2%)	482 (25.9%)
Swimming (boogie board etc)	103 (10.3%)	0 (0.0%)	10 (18.9%)	10 (11.8%)	1 (0.3%)	21 (12.1%)	6 (23.1%)	0 (0.0%)	2 (13.3%)	0 (0.0%)	2 (1.1%)	155 (8.3%)
Carried by others	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.%)	8 (2.7%)	2 (1.2%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	10 (0.5%)
On horse	154 (15.4%)	2 (7.1%)	16 (30.2%)	1 (1.2%)	5 (1.7%)	1 (0.6%)	2 (7.7%)	0 (0.0%)	5 (33.3%)	1 (12.5%)	8 (4.5%)	195 (10.5%)
On vehicle: push bike	6 (0.6%)	0 (0.0%)	0 (0.0%)	1(1.2%)	0 (0.0%)	1 (0.6%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	8 (0.4%)
On boat	79 (7.9%)	1 (3.6%)	6 (11.3%)	4 (4.7%)	36 (12.3%)	1 (0.6%)	1 (3.8%)	0 (0.0%)	2 (13.3%)	1 (12.5%)	6 (3.3%)	137 (7.4%)
On rope/ cable/ flying fox	6 (0.6%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	8 (0.4%)
N/A – in house / caravan	59 (5.9%)	3 (10.7%)	0 (0.%)	5 (5.9%)	40 (13.7%)	2 (1.2%)	4 (15.4%)	0 (0.0%)	1 (6.7%)	4 (50.0%)	18 (10.1%)	136 (7.3%)
N/A other	5 (0.5%)	0 (0.0%)	0 (0.0%)	0 (0.%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.6%)	6 (0.3%)
Other transport	3 (0.3%)	0 (0.0%)	0 (0.0%)	0 (0.%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.2%)
Unknown	121(12.1%)	0(0.0%)	1(1.9%)	1 (1.2%)	14 (4.8%)	20 (11.6%)	3 (11.5%)	0 (0.0%)	1 (6.7%)	0 (0.0%)	104(58.1%)	265 (14.3%)
4WD	13 (1.3%)	1 (3.6%)	0 (0.0%)	12 (14.1%)	16 (5.4%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (12.5%)	2 (1.1%)	45 (2.4%)
Vehicle (including horse drawn)	209 (21.0%)	6 (21.4%)	5 (9.4%)	21 (24.7%)	143 (48.9%)	2 (1.2%)	2 (7.7%)	3 (100.0%)	0 (0.0%)	0 (0.0%)	18 (10.1%)	409 (22.0%)
Total	**997 (100%)**	**28 (100%)**	**53 (100%)**	**85 (100%)**	**292 (100%)**	**173 (100%)**	**26 (100%)**	**3 (100%)**	**15 (100%)**	**8 (100%)**	**179 (100%)**	**1859 (100%)**

TABLE 4.17: MODE OF TRANSPORT COMPARED AGAINST CAPACITY (% OF COLUMN TOTALS)

FATALITIES BY CATCHMENT

In total, 457 deaths occurred in five catchments across the nation. The top two catchments in terms of the greatest number of fatalities are both in Queensland: the Fitzroy River Basin (28.0% of the fatalities in these top 5 catchments, n=125) and Brisbane River (23.5% of the fatalities in these top 5 catchments, n=105). The remaining three of the top five are located in NSW: Murrumbidgee River (16.6%, n=78), Hunter River (17.4%, n=74) and Georges River (14.5%, n=65). These top five catchments in terms of fatalities capture only 24.6% of all deaths, demonstrating that there is a large spread of fatalities across river catchments – the top ten catchments with the greatest number of fatalities captures only 616 fatalities, 33.1% of all deaths due to flooding.

The Fitzroy River Basin, with its headwaters in the Carnavon Ranges in Central Queensland and encompassing the city of Rockhampton along with six major river systems in an area 142,665 km^2, is the largest river basin flowing out along the east coast of Australia (FBA, 2013). The Brisbane River catchment, beginning in the Brisbane Ranges about 140 km from the city of Brisbane, drains approximately 13,500 km^2 (Centre for the Government of Queensland, 2015). The Hunter River catchment, with an area of about 21,500 km^2, lies approximately 100 km north of Sydney and encompasses Newcastle, the second largest city in NSW (Department of Primary Industries, no date). The Murrumbidgee River catchment in southern NSW covers an area of approximately 84,000 km^2 and includes Canberra and NSW's largest inland city, Wagga Wagga (Department of Primary Industries, no date). The Georges River catchment is the smallest in the group of five, covering an area of 1,890 km^2 and including Australia's largest city, Sydney (Department of Primary Industries, no date).

As expected, the greatest proportion of fatalities corresponds to large events (see Section 4.6). The Fitzroy River catchment experienced 50.4% (n=63) of its fatalities in 1910-1919, the Brisbane River catchment had 23.8% of its fatalities (n=25) in 2010-2015, and the Hunter (41.9%, n=31), Murrumbidgee (23.1%, n=18) and Georges River (18.5%, n=12) catchments' greatest human losses all fell in the decade from 1950-1959.

The greatest proportion of fatalities in the Fitzroy River catchment occurred while the deceased were engaged in an activity not near a usual watercourse (48.8%, n=61) (Table 4.18), whereas the greatest proportion of fatalities in each of the other four catchments occurred while the deceased were attempting to cross a bridge, causeway, culvert, road, etc. (Brisbane River: 28.6%, n=30; Hunter River: 40.5%, n=30; Murrumbidgee River: 46.2%, n=36; Georges River: 33.8%, n=22).

	Brisbane River	Fitzroy River	Hunter River	Murrumbidgee River	Georges River	Total
Attempting to cross bridge/ causeway/ crossing/ culvert/ ford/ road/ watercourse	30 (28.6%)	28 (22.4%)	30 (40.5%)	36 (46.2%)	22 (33.8%)	146 (32.7%)
Attempting to cross floodwaters	10 (9.5%)	5 (4.0%)	1 (1.4%)	0 (0.0%)	2 (3.1%)	18 (4.%)
Engaged in an activity near the water (bank/ bridge)	12 (11.4%)	5 (4.0%)	11 (14.9%)	26 (33.3%)	7 (10.8%)	61 (13.6%)
Engaged in an activity in/ near stormwater drain	4 (3.8%)	0 (0.0%)	4 (5.4%)	1 (1.3%)	14 (21.5%)	23 (5.1%)
Engaged in an activity in the water (rescue, swimming, joyride etc)	16 (15.2%)	2 (1.6%)	4 (5.4%)	3 (3.8%)	7 (10.8%)	32 (7.2%)
Engaged in an activity on the water (boat)	4 (3.8%)	5 (4.%)	8 (10.8%)	4 (5.1%)	2 (3.1%)	23 (5.1%)
Engaged in an activity not near usual watercourse	19 (18.1%)	61 (48.8%)	9 (12.2%)	2 (2.6%)	2 (3.1%)	93 (20.8%)
other	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (1.5%)	1 (0.2%)
unknown	10 (9.5%)	19 (15.2%)	7 (9.5%)	6 (7.7%)	8 (12.3%)	50 (11.2%)
Total	**105 (100%)**	**125 (100%)**	**74 (100%)**	**78 (100%)**	**65 (100%)**	**447 (100%)**

TABLE 4.18: FATALITIES BY RIVER BASIN AND ACTIVITY PRIOR TO DEATH (% OF COLUMN TOTALS)

As expected, the greatest proportion of males and females perished in floodwaters in the Fitzroy River catchment (males: 26.1%, n=89; females: 33.3%, n=35) (Table 4.19). It is interesting to note that a much higher proportion of males died in flooding in the Murrumbidgee catchment (males: 20.8%, n=71; females: 6.7%, n=7), while a higher proportion of females perished in the Georges (males: 13.2%, n=45; females: 19.0%, n=20) and Hunter River catchments (males: 16%, n=55; females: 18%, n=19), as well as the Fitzroy River catchment, as noted above.

	Male	Female	Unknown	Total
Brisbane River	81 (23.8%)	24 (22.9%)	0 (0.0%)	105 (23.5%)
Fitzroy River	89 (26.1%)	35 (33.3%)	1 (100.0%)	125 (28.0%)
Hunter River	55 (16.1%)	19 (18.1%)	0 (0.0%)	74 (16.6%)
Murrumbidgee River	71 (20.8%)	7 (6.7%)	0 (0.0%)	78 (17.4%)
Georges River	45 (13.2%)	20 (19.0%)	0 (0.0%)	65 (14.5%)
Total	**341 (1003%)**	**105 (100%)**	**1 (100%)**	**447 (100%)**

TABLE 4.19: FATALITIES BY RIVER BASIN AND GENDER (% OF COLUMN TOTALS)

FATALITIES ASSOCIATED WITH FLOOD TYPE AND FLOOD SEVERITY

Most fatalities (71.3%, n=1325) occurred close to the coast, either on short coastal rivers (54.1%, n=1005) associated with heavy rainfall within a small catchment, causing a short duration rapid flood or flash flood event, or longer coastal rivers (17.2%, n=320), where floodwater rose rapidly over a longer period (up to 4 days). A further 295 (15.9%) deaths occurred along inland rivers, where extensive but slow moving flooding was caused by widespread rainfall. Other fatalities occurred in an urban setting in a local flash flood or low-level short duration flood (7.6%, n=142), on normally dry inland rivers that experienced sudden runoff (3.7%, n=68), and from dam failure (0.9%, n=16). The flood type of 13 fatalities (0.7%) is unknown.

The greatest percentage (36.6%, n=52 of a total of 142) of women died in urban settings in relation to a local flash flood or low-level short duration flood. The next highest (21.3%, n=214 of a total of 1005) were associated with short coastal rivers, longer coastal rivers (15.6%, n=50 of a total of 320) and inland rivers (12.2%, n=36 of a total of 295). As expected, the highest number of people killed per event correlate with the more severe floods (Table 4.20).

Events Where N Persons Died	Minor/ moderate flood	Major flood	Severe/ Record flood	Unknown	Total
1	68 (11.1%)	20 (8.2%)	33 (7.8%)	40 (6.8%)	161 (8.7%)
2	26 (8.5%)	14 (11.5%)	10 (4.7%)	17 (5.8%)	67 (7.2%)
3	18 (8.9%)	9 (11.1%)	11 (7.8%)	17 (8.7%)	55 (8.9%)
4	11(7.2%)	9 (14.8%)	3 (2.8%)	8 (5.5%)	31 (6.7%)
5	12 (9.9%)	5 (10.2%)	5 (5.9%)	5 (4.3%)	27 (7.3%)
6	8 (7.9%)	3 (7.4%)	6 (8.5%)	8 (8.22%)	25 (8.1%)
7	4 (4.6%)	0 (0.0%)	3 (5.0%)	1 (1.2%)	8 (3.0%)
8	2 (2.6%)	2 (6.6%)	2 (3.8%)	6 (8.2%)	12 (5.2%)
9	1 (1.5%)	2 (6.6%)	1 (2.1%)	2 (3.1%)	6 (2.9%)
10	1 (8.2%)	0 (0.0%)	0 (0.0%)	2 (3.4%)	3 (1.6%)
11	2 (3.6%)	2 (9.0%)	1 (2.6%)	1 (1.9%)	6 (3.6%)
12	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (6.2%)	3 (1.9%)
13	1 (0.2%)	0 (0.%)	1 (3.1%)	1 (2.2%)	3 (2.1%)
14	0 (0.0%)	0 (0.0%)	2 (6.6%)	0 (0.0%)	2 (1.5%)
15	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (2.6%)	1 (0.8%)
16	1 (0.2%)	1 (6.6%)	0 (0.0%)	1 (2.7%)	3 (2.6%)
17	2 (5.6%)	0 (0.0%)	0 (0.0%)	1 (2.9%)	3 (2.7%)
18	0 (0.0%)	1 (7,.4%)	0 (0.0%)	0 (0.0%)	1 (1.0%)
19	0 (0.0%)	0 (0.0%)	3 (25.6%)	1 (3.3%)	4 (4.1%)
20 or more	4 (15.6%)	0 (0.0%)	0 (0.0%)	5 (22.9%)	9 (12.3%)
Total number of fatalities	**609 (100%)**	**244 (100%)**	**422 (100%)**	**584 (100%)**	**1859 100%)**

TABLE 4.20: NUMBER OF EVENTS IN WHICH A GIVEN NUMBER OF FATALITIES OCCURRED, BY FLOOD SEVERITY (% OF TOTAL FATALITIES IN EACH SEVERITY CATEGORY)

CLUSTERS OF 20 OR MORE FATALITIES

The dataset was interrogated for clusters of fatalities relating to the same peril type, within the same geographic region and time period. All up, seven particular cases of flooding were identified where 20 or more fatalities occurred. These are described in detail below.

December 1916

The central Queensland town of Clermont was a 19th century gold mining town situated between a lagoon and Sandy Creek in the Fitzroy River catchment. Torrential rain associated with a tropical cyclone impacted the region, causing the banks of the Wolfgang and Sandy Creek to fail resulting in a wall of water

~4.5 metres high rushing through the main street without warning (Coates, 2012).

The 1916 event was the worst in terms of the number of lives lost in the 1900–2015 dataset, with a reported total of at least 65 fatalities (ABC, 2011). The age of most (69.3%, n=43) of the 62 recorded fatalities is unknown. Of those recorded, 61.3% (n=38) were male and 38.7% (n=24) were female. The greatest proportion of people (41.9%, n=26) drowned while attempting vertical evacuation. Several bodies were never found. More than 50 buildings and the railway line were also destroyed in this event (Coates, 2012).

In order to prevent a similar tragedy from happening again, the remaining Clermont residents took a radical approach and relocated the town to higher ground (Text box 4.1) with a steam tractor engine. Colloquially, Clermont became known as the "The Shifting Town" (ABC, 2011). Relocation due to flood risk had only occurred once before in Australia, when the township of Gundagai was relocated from between two rivers to higher ground after some 35.6% (n=89) of the 250 population drowned in the floods of 1852.

> *"Clermont, our neighbour up the road had an awful flood..., and of course in those days it actually took about three weeks for the authorities to even find out that they were flooded. I'm only here because my great-grandfather had an orchard* [near Clermont] *and he sold that a week before the flood happened, and moved the family into a pub that he'd bought in Clermont. The family that bought the orchard and farm off them all died, they were all drowned in their beds, and that's Theresa and Sandy Creek when they flood, they come up so silent and so fast. There was a lot of life lost...my grandparent's pub was the only one that didn't flood so everyone was staying there, and they basically had to ban the sale of alcohol until they had dealt with all the dead bodies and the dead animals, as well. When you drive to Clermont you can still see, there's an ornamental piano up a tree. It was stuck there after that great flood, and they've left it there every since and replaced it over the years, that's what that's showing is the height of that flood. They then relocated the entire town to higher ground, and there's a wonderful book...of photographs from when that town was relocated. They literally did it with horse teams and huge big logs, and there's classic photo of...the boarding houses all being moved...they moved and restumped the entire town."*

TEXT BOX 4.1: LOCAL RESIDENTS' RECOLLECTION OF THE GREAT FLOOD THAT LED TO THE RELOCATION OF CLERMONT (EXERT FROM BIRD *ET AL*. 2013; P.71).

February 1927

Floods occurred in rivers from Cairns through to Toowoomba due to a large rain depression after Tropical Cyclone Willis crossed the Queensland Coast north of Cairns in February 1927. An unprecedented flood on the Herbert River, lying adjacent to the township of Ingham, washed away more than 12 houses and businesses and caused much damage to rural industries and many railway washouts. There was an estimated £300,000 (£1927) worth of damage in the Herbert River district alone.

Of the 37 recorded fatalities that were identified as being associated with these floods, 29.7% (n=11) were aged between 0-9 years, 48.6% (n=18) were following the decision making of others, and most were males (59.5%, n=22).

A monument at the Old Ingham Cemetery commemorates the 13 people of Italian origin who drowned in the flood (Monument Australia, no date). There was also extensive loss of livestock with 2,500 cattle and 1,500 horses drowned in Ingham (BoM, 2010).

April 1929

The north and northwest region of Tasmania was impacted by gale force winds and considerable rainfall in early April 1929, causing serious flooding in many parts of Tasmania. Overall, 22 people were killed, 40 people were injured, 2000 buildings were damaged and more than 100 were destroyed (Maiden, 2009). While the rainfall impacted a widespread region, an isolated event occurred in Derby where 14 people lost their lives. Excessive rains caused the newly built Cascade Dam at Briseis Mine (Cascade Valley) to fail, sending a wall of water through a narrow gorge on the Cascade River and on for 5.6 km to the township of Derby. It is reported that a 12-foot wall of water went through Derby, crushing houses and carrying with it a ten-tonne granite boulder (Rimon, 2010). The force of the dam-burst also caused the Ringarooma River to run uphill for almost six hours (Maiden 2009, Rimon 2010).

During the same rain event, at Gawler, eight people died when the truck they were in plunged into the Gawler River, *en route* from Gawler to Ulverston. Much damage was caused, and 4,500 were left homeless in Launceston.

October-November 1934

Continuous and heavy rainfall throughout October and into November contributed to widespread flooding. This was the heaviest rainfall experienced in October in Melbourne for 65 years. One early incident in late October resulted in three deaths in Muckleford South, where floods caused damage to roads, bridges and water channels, costing £3,000 (£1934) damage to the Shire.

Record floods occurred in November 1934 in the Yarra River, eastern Port Phillip streams, and central and southern Gippsland, leading to unprecedented property damage and at least 25 deaths. Flood areas were widespread around the Yarra River, ARI 100 in Melbourne, and it was considered the 'greatest flood in the history of the Yarra'. Nine deaths occurred at Collingwood on the Yarra. Three deaths occurred at Eskdale (the Mitta Mitta River at Tallandoon had a 55 ARI), eight at the Bunyip River at Koo Wee Rup (>150 ARI and the largest flood on record). Four fatalities were recorded at Yarram, where widespread heavy rainfall resulted in flooding in the valleys of the Upper Murray basin including Mitta Mitta, Kiewa, Ovens, Loddon, Yarra, Latrobe and Maribyrnong Rivers. One death occurred at Eddington.

February 1954

The tropical cyclone that made landfall near the southern Queensland boarder on 20 February 1954 caused some of the largest recorded floods across New South Wales catchments (Roche *et al*. 2013), affecting some 8,000 km^2. This event has been described as the worst flood disaster in NSW.

An estimated £4M (£1954) of damage occurred in Lismore, affecting 75% of homes and washing away at least two homes in the Tweed River area, with

2,000 people homeless, and 19 deaths in the Richmond River area. One death occurred at Morpeth (Hunter River); one at Grafton; five at Armidale and one at Murwillumbah (Tweed River), where houses were destroyed and livestock drowned.

The wall of water that rushed through Kyogle took 10 lives during the early hours of 21 February (Burin, 2014). Of the 19 recorded fatalities in the Richmond River area, seven (36.8%) were in the 0-9 year age group.

February 1955

Torrential rain caused rivers west of Sydney to the Queensland border to flood. Creeks and waterways were already swollen due to the incessant rain that had fallen from October 1954 to February 1955 as a result of a La Nina cycle.

Record floods at Maitland and Singleton were the most disastrous in NSW to that date (1955) in economic terms, causing £10-15,000,000 damage in the Hunter Valley, with 135 houses destroyed and about 3,000 damaged, over 22,000 homeless, 6,000 evacuated, road and rail traffic and telegraph lines disrupted and about 120,000 sheep and 2,000 cattle lost. At least 18 deaths occurred in the Hunter region.

The Central West was also affected by these floods, with about 18,000 more homeless. The damage cost was estimated at £5,000,000 (£1955), including five houses destroyed, 250 badly damaged and over 1,000 damaged at Dubbo, and over three quarters of buildings to be rebuilt at Gilgandra, which was almost wiped out by the floods. Gilgandra, Gulargambone and Coonamble were isolated; houses were flooded at Warren and Nyngan. Singular flood fatalities occurred at Dubbo, Lithgow, Quirindi, Gunnedah, Wee Waa, Gilgandra, Coonamble and Moree.

December 2010-January 2011

A moist easterly flow covered much of Queensland at the end of December 2010 (the wettest December on record for Queensland) following very extensive and heavy rainfall periods during the previous few months – the wettest spring on record for Queensland, meaning many catchments were already wet before the flooding rain. It was Australia's wettest July to October on record and also the wettest July to December on record. The rains of late 2010 took place during a very strong La Niña event in the Pacific Ocean.

An exceptional rain event occurred over eastern Queensland during the week of 23 December 2010 causing river flooding along the tropical Queensland coast before producing record breaking flood levels particularly through the Central Highlands, Wide Bay and Burnett and the Darling Downs and Maranoa.

On 10 January 2011, two intense thunderstorms crossed the south-east coast and joined, directing high rainfall intensities towards the Toowoomba range and into the Brisbane River catchment. The runoff on the eastern side of the Great Dividing Range flowed into the upper tributaries of the Lockyer Creek in the Lockyer Valley; that which fell on the escarpment itself flowed into the catchments of the Gowrie and Oakey creeks to the east and west of Toowoomba. Two deaths occurred in Toowoomba; but the 2010-11 flooding in

Queensland had the greatest impact in the Lockyer Creek catchment. Early afternoon on the 10 February 2011, a destructive 7 metre wall of water flooded towards the town of Grantham, sweeping adjacent buildings into Murphy's Creek (van den Honert & McAneney, 2011). Almost all houses on the floodplain were severely impacted, with some being washed off their foundations and others totally destroyed. A total of 19 fatalities occurred in the Lockyer Valley, including 12 in Grantham. The flooding also destroyed 120 houses and damaged 40 bridges (Rogencamp & Barton, 2012).

Essential services and road and rail infrastructure in Queensland were significantly affected. The original and normalised 2011 damage cost was $2380M for Toowoomba and Lockyer Valley.

As with Clermont, local authorities had a rapid and drastic response to prevent such a tragedy from occurring again, despite the political resistance and bureaucratic turmoil, by relocating the township of Grantham (Okada *et al*. 2014). Known as the land-swap scheme, the voluntary program gave impacted residents the opportunity to resettle on adjacent to the original town but, importantly, free from flood.

AN EXPLORATION OF THE FATALITIES BETWEEN 2000 – 2015

There were a total of 178 fatalities over this period. Of these, two thirds are male (66.9%, n=119) and almost one third are female (30.3%, n=54). The majority of people died while attempting to cross a watercourse (53.4%, n=95), followed by those engaged in an activity in the water (14.0%, n=25). Of those engaged in an activity not near a normal watercourse (11.2%, n=20), a total of 8 fatalities (4.5%) were in a house or structure that was destroyed, 6 fatalities (3.4%) were in a house or structure that was not destroyed, and 2 fatalities (1.1%) were on a house or structure that was not destroyed.

The highest proportions of both female and male deaths were on route, with a total of 84 fatalities recorded (47.2%). Of these the highest proportions of both genders were en route to home. Recreating was the second highest reason behind action for both genders (29.2%, n=52).

In terms of transport the highest proportion of recorded fatalities were in a vehicle at the time of death (48.3%, n=86), followed by those who were on foot (25.3%, n=45). A total of 22 fatalities (12.4%) were swimming.

The greatest proportion of fatalities occurred during the summer/ monsoon season in the NT and Queensland (Table 4.21), with the greatest proportions of fatalities experienced in January (NT: 53.3%, n=8; Queensland: 44.6%, n=41). Fatalities in NSW mostly occurred in January to March (57.4%, n=27), with a spike in June (19.1%, n=9). No fatalities have occurred in the ACT or SA during this period.

	ACT	NSW	NT	QLD	SA	TAS	VIC	WA	Total
January	0 (0.0%)	7 (14.9%)	8 (53.3%)	41 (44.6%)	0 (0.0%)	0 (0.0%)	1 (6.2%)	0 (0.0%)	57 (32.0%)
February	0 (0.0%)	9 (19.1%)	5 (33.3%)	16 (17.4%)	0 (0.0%)	0 (0.0%)	4 (25.0%)	0 (0.0%)	34 (19.1%)
March	0 (0.0%)	11 (23.4%)	1 (6.7%)	8 (8.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (40.0%)	22 (12.4%)
April	0 (0.0%)	2 (4.3%)	1 (6.7%)	2 (2.2%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (20.0%)	6 (3.4%)
May	0 (0.0%)	3 (6.4%)	0 (0.0%)	5 (5.4%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	8 (4.5%)
June	0 (0.0%)	9 (19.1%)	0 (0.0%)	2 (2.2%)	0 (0.0%)	3 (100.0%)	0 (0.0%)	0 (0.0%)	14 (7.9%)
July	0 (0.0%)	1 (2.1%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.6%)
August	0 (0.0%)	1 (2.1%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (18.8%)	0 (0.0%)	4 (2.2%)
September	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (1.1%)	0 (0.0%)	0 (0.0%)	2 (12.5%)	0 (0.0%)	3 (1.7%)
October	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (1.1%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (40.0%)	3 (1.7%)
November	0 (0.0%)	1 (2.1%)	0 (0.0%)	7 (7.6%)	0 (0.0%)	0 (0.0%)	4 (25.0%)	0 (0.0%)	12 (6.7%)
December	0 (0.0%)	3 (6.4%)	0 (0.0%)	9 (9.8%)	0 (0.0%)	0 (0.0%)	2 (12.5%)	0 (0.0%)	14 (7.9%)
Total	**0 (100%)**	**47 (100%)**	**15 (100%)**	**92 (100%)**	**0(100%)**	**3 (100%)**	**16 (100%)**	**5 (100%)**	**178 (100%)**

TABLE 4.21: FATALITIES BY MONTH OF FATALITY AND STATE / TERRITORY (% OF COLUMN TOTALS)

A large number of the fatalities occurred on or near short coastal rivers associated with heavy rainfall within a small catchment, causing a short duration rapid flood or flash flood event (46.1%, n=82) or, in an urban setting, a local flash flood or low-level short duration flood (32.0%, n=57). With respect to gender, female fatalities are more or less evenly spread among the age groups (Table 4.22). Male fatalities, however, are fewest among the 0-9 and 60-89 year age groups and largest in the 10-19 year age group (19.3%, n=23).

Also with respect to age, the majority (71.0%, n=22) of people (male and female) aged between 10-19 years were either on foot or swimming prior to perishing in/near floodwater. Only 29.0% (n=9) were in a vehicle. A higher proportion of people in the 20-29 year age group also died while on foot or swimming (55.0%, n=11) than being in a vehicle (30%, n=6). While fatalities in the older age groups are still associated with travelling on foot or swimming, the greatest proportions are related to vehicles (30-39 years: 65.0%, n=13; 40-49 years: 52.4%, n=11; 50-59 years: 59.3%, n=16; 60-69 years: 41.2%, n=7; 70-79 years: 71.4%, n=10; 80-89 years: 55.6%, n=5).

	Male	Female	Unknown	Total
0-9	9 (7.6%)	7 (13.0%)	2 (40.0%)	18 (10.1%)
10-19	23 (19.3%)	8 (14.8%)	0 (0.0%)	31 (17.4%)
20-29	15 (12.6%)	5 (9.3%)	0 (0.0%)	20 (11.2%)
30-39	14 (11.8%)	5 (9.3%)	1 (20.0%)	20 (11.2%)
40-49	13 (10.9%)	7 (13.0%)	1 (200.%)	21 (11.8%)
50-59	20 (16.8%)	6 (11.1%)	1 (20.0%)	27 (15.2%)
60-69	11 (9.2%)	6 (11.1%)	0 (0.0%)	17 (9.6%)
70-79	8 (6.7%)	6 (11.1%)	0 (0.0%)	14 (7.9%)
80-89	5 (4.2%)	4 (7.4%)	0 (0.0%)	9 (5.1%)
Unknown	1 (0.8%)	0 (0.0%)	0 (0.0%)	1 (0.6%)
Total	**119 (100%)**	**54 (1003%)**	**5 (100%)**	**178 (100%)**

TABLE 4.22: FATALITIES BY AGE AND GENDER (% OF COLUMN TOTALS)

As expected, most people in the 10-19 year age group were recreating prior to perishing in/ near floodwater (64.5%, n=20). 54.8% (n=17) of these people were engaged in an activity either in the water (n=12) or in/near a stormwater drain (n=5), while a further 35.5% (n=11) were attempting to cross a bridge, causeway, crossing, culvert, road, etc.

In relation to awareness, 50.0% of the 178 fatalities that occurred in the period from 2000-2015 were aware of the flood risk but the depth and / or speed took them by surprise (Table 4.23). Of this group, 48.3% (n=43) were capable of independent action and 31.5% (n=28) were influenced by drugs or alcohol. This includes some cases where people may have accidentally taken extra doses of prescription drugs. The second largest proportion of deaths fell in the 'unaware and taken by surprise' category (23.0%, n=41). This group had similar results as the first, with 51.2% (n=21) capable of independent action and 26.8% (n=11) influenced by drugs or alcohol.

	Aware but did not expect to encounter the flood	Aware but depth and or speed took them by surprise	Unaware and taken by surprise	N/A – child < 11 years old	N/A – other	Unknown	Total
Capable of independent action	6 (46.2%)	43 (48.3%)	21 (51.2%)	0 (0.0%)	2 (100.0%)	3 (27.3%)	75 (42.1%)
Physically and or mentally disabled or incapable	1 (7.7%)	2 (2.2%)	1 (2.4%)	0 (0.0%)	0 (0.0%)	2 (18.2%)	6 (3.4%)
Cannot swim	2 (15.4%)	1 (1.1%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (1.7%)
Influenced by drugs or alcohol	3 (23.1%)	28 (31.5%)	11 (26.8%)	0 (0.0%)	0 (0.0%)	2 (18.2%)	44 (24.7%)
Following the decision making of others	1 (7.7%)	8 (9.0%)	4 (9.8%)	14 (63.6%)	0 (0.0%)	0 (0.0%)	27 (15.2%)
A child or group of children on their own < 11	0 (0.0%)	2 (2.2%)	0 (0.0%)	8 (36.4%)	0 (0.0%)	0 (0.0%)	10 (5.6%)
Unfamiliar with the area	0 (0.0%)	1 (1.1%)	2 (4.9%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (1.7%)
Encumbered with clothing, possessions or equipment	0 (0.0%)	0 (0.0%)	1 (2.4%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.6%)
Looking after dependents	0 (0.0%)	1 (1.1%)	1 (2.4%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (1.1%)
Unknown	0 (0.0%)	3 (3.4%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (36.4%)	7 (3.9%)
Total	**13 (100%)**	**89 (100%)**	**41 (100%)**	**22 (100%)**	**2 (100%)**	**11 (100%)**	**178 (100%)**

TABLE 4.23: FATALITIES BY CAPACITY AND AWARENESS (% OF COLUMN TOTALS)

The level of detail included in the NCIS data between 2000 and 2015 enabled a spatial analysis on the location of fatality compared to distance from home. Of the total 178 records, 121 contained data on the location of the fatality and their home address. Figure 4.9 shows cumulative percentage of fatalities as distance from home increases. Of these 121 fatalities more than a quarter occurred within 5 km of their home (26.4%, n=32) and 57.9% (n=70) were within 20 km of their home. Fewer than 22% of fatalities occurred more than 100 km from the victim's home (21.5%, n=26). There were no age or gender trends evident in this data, with 57% male (n=45) and 60% female (n25) fatalities occurring within 20 km of their home (Table 4.24).

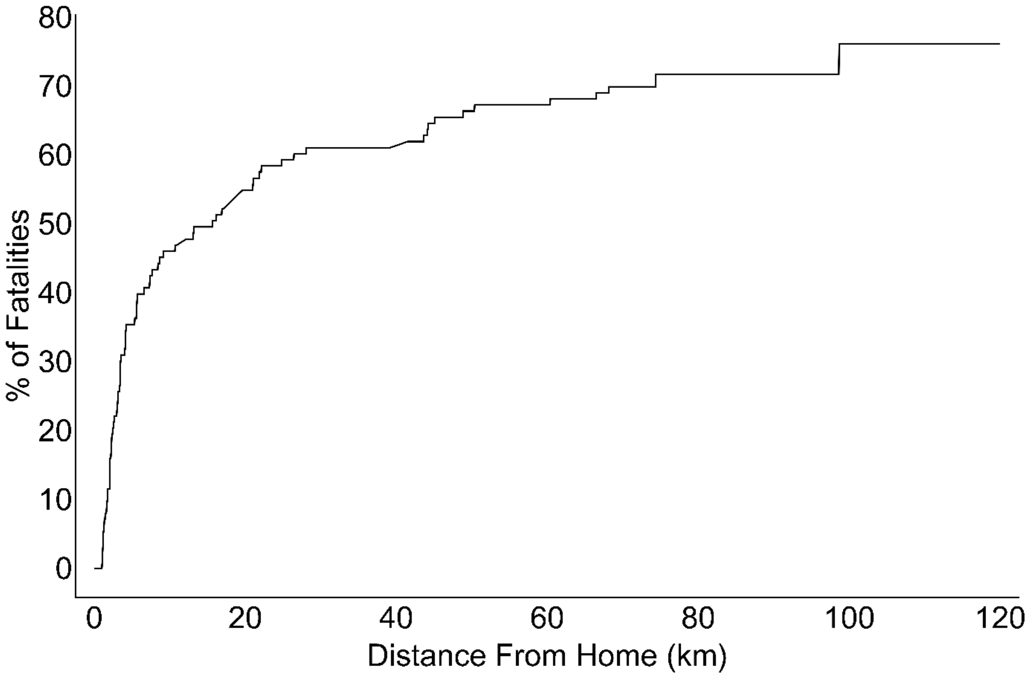

FIGURE 4.9: CUMULATIVE PERCENTAGE OF FATALITIES BY DISTANCE FROM HOME

	Male	Female	Total
0-2km	5 (6.3%)	5 (11.9%)	10 (8.3%)
2-5km	18 (22.8%)	4 (9.5%)	22 (18.2%)
5-10km	10 (12.7%)	3 (7.1%)	13 (10.7%)
10-20km	12 (15.2%)	13 (31.0%)	25 (20.7%)
20-50km	9 (11.4%)	3 (7.1%)	12 (9.9%)
50-100km	6 (7.6%)	7 (16.7%)	13 (10.7%)
>100km	19 (24.1%)	7 (16.7%)	26 (21.5%)
Total	**79 (100%)**	**42 (100%)**	**121 (100%)**

TABLE 4.24: FATALITIES BY DISTANCE THE DEATH OCCURRED FROM THE VICTIM'S HOME

DISCUSSION AND RECOMMENDATIONS

SALIENT RESULTS

A total number of 1859 flood fatalities occurred in Australia between 1900 and 2015 of these 79.1% have been males. The majority of these deaths (67.1%, n=1247) occurred in events where two or less people died. The analysis of flood severity against numbers killed per event demonstrates that the majority of these occurred in minor-moderate floods. The greatest percentage of women died in urban settings in relation to a local flash flood or a low-level short duration flood.

Death rates have steadily declined which, together with an increasing Australian population over this time, indicate that the per capita risk of death by flooding in Australia has decreased. In particular, it is evident that a reduction in fatalities has occurred since 1960. This observation is likely to be due to the following:

- The establishment of formalised flood prediction and warning systems
- Enhanced organisation and capacity for emergency response operations through the creation of State Emergency Services.
- Increased investment in structural flood mitigation, in particular in NSW following the 1955 Hunter flood.

Further improvements in later decades included accurate flood mapping, systematic approaches to land-use planning and the implementation of community education programs. However, despite this female to male fatality ratio has steadily increased indicating a greater proportion of female fatalities over time and the need for a gendered approach to risk mitigation.

The data highlights the distinct high-risk groups of children and young adults (< 29 years of age) who make up the greatest proportion of deaths (44%). Across all ages male fatalities are higher apart from two, six and seven year olds where deaths are more gender balanced. In particular, both genders show a high and equal death rate for those who are two years old and it is likely that this is when children have learnt to walk and are able to quickly wander from adult supervision.

The greatest number of fatalities occurred in Queensland and NSW, accounting for 74% of the overall fatalities across the nation. However, when deaths are examined in relation to the per capita population, the heightened level of risk in the NT is highlighted. Overall, the majority of deaths occurred between January and March during the summer / monsoon season. A spatial analysis of fatalities between the years 2000 and 2015 shows that 58% died within 20km of their home. The more detailed analysis of this recent data also shows the increased proportion of flood deaths in the NT.

The highest proportions of both men and women died while attempting to cross a bridge, causeway, culvert, road, etc. Of all those who were en route at the time of their death, the greater number were on their way home. For females, the second highest activity at the time of death, accounting for nearly a quarter of all female fatalities, was being engaged in an activity not near a usual watercourse, e.g. driving through town or in their home. This was the third highest cause of death for men. Of all the people engaged in this activity, 45% (n101) were in or on a house that was destroyed. Although the highest proportions of children and youth also perished while attempting to cross a watercourse, the overall data also shows their heightened vulnerability to activities in or near the water while recreating. For those between the age of 10 and 29 these latter activities become the dominant actions at the time of death in the 2000 to 2015 data set.

The majority of fatalities died while capable of independent action and aware of the flood. However, the speed and or depth took them by surprise. An analysis of fatalities by time of day revealed that almost a quarter of all fatalities that entered floodwaters did so in the dark or twilight when visibility would have been poor. However, a higher proportion, over one third perished during the day when visibility is likely to have been better. Higher proportions of deaths occurred among children and females who were following the decisions of others and also among children and youths who were on their own or in a group of children. Of this latter group the majority were boys (69%).

Fatalities that were on foot have decreased slightly through time but remain a high proportion. However, an increase of fatalities associated with motorised vehicles is seen over recent decades. In particular, fatalities associated with 4WD vehicles have increased over the last 15 years. This is likely to be a combination of increased 4WD ownership together with the more detailed coronial inquest reports available over this period. The vast majority of those driving a vehicle were men (85%) while the gender breakdown of the passengers shows slightly more men. A quarter of the fatalities in vehicles were children and youth, the majority of whom were passengers. The highest proportion of those in a vehicle perished at night or during twilight (45%).

In order to reduce deaths the following groups should be targeted: children, teens, young adults and their parents around the danger of recreating in flood waters; young men <29 concerning driving and entering floodwaters; 4WD drivers; gender specific campaigns for females around the dangers of entering floodwaters; females and children to raise their awareness specifically of the dangers of being driven through floodwaters in order that they are aware and empowered to change the actions of the driver. Education, incentives and structural interventions to reduce deaths are discussed in section 5.2.

MANAGEMENT INSIGHTS

People entering floodwaters by vehicle

Limited research has previously been conducted to evaluate many initiatives historically utilised to reduce the instances of people entering flood water. This section draws upon available research and provides some ideas for further discussion and research to assist in reducing flood deaths. Further work is also required to assess the overall costs and benefits of measures identified before wide scale implementation.

Typically, Australian management strategies have relied upon education and rescue interventions as primary management tools. A more holistic behavioural change focus such as implementing a continuum of interventions is likely required. Meyer-Emerick (2015) identifies that engagement and social marketing techniques can be used in conjunction with other techniques to achieve preparedness outcomes. A continuum of interventions is referred to by Rothschild (1999) and is inclusive of the following strategies:

- Education – containing messages to attempt to voluntarily change behaviour;
- Incentives and consequences – to encourage voluntary behaviour change; and
- Law / regulation – attempting to create behaviour change involuntarily.

The importance of using a holistic strategy has been demonstrated by Peden *et al.* (2004) in a World Health Organisation review of road traffic injury prevention that concluded that road safety campaigns were able to influence behaviour when used in conjunction with legislation and law enforcement. However, when education was used in isolation, the authors found that generally it did not deliver tangible and sustained reductions in deaths and serious injuries.

In the context of this problem, elements of a holistic strategy should include education, incentives and consequences / law and regulation, structural intervention and consequence management. Strategies that underpin such an approach are outlined in Gissing *et al*. (2015) and are discussed in the sections below.

Education

Both education campaigns and safety messages in public warnings have been the primary strategies used to change motorist behaviour. Typically, campaigns comprise signs, commercials, digital media and broadcast media engagement. The United States 'Turn around don't drown' campaign is now some ten years old and is internationally recognised. However, few campaigns have been evaluated. To be successful the campaigns must utilise messages and communications channels that target key risk groups and involve all key partner agencies. Partner agencies include those related to road safety, motoring, water safety, insurance, health and education.

Roadside flood markers are frequently used to indicate the possible depths of flooding. Current markers indicate the depth of flooding, but leave motorists to interpret the risk rather than providing them a clear safety message. Existing flood signage providing messages such as 'road subject to flooding' and 'water over the road', may also provide an ambiguous message to motorists. Research in the context of warning signage at railway crossing has found that active signage involving flashing lights is more effective than passive signage (Tey et al., 2011). Further research is required to assess driver's interpretation of markers and road side signage, and assess the need for any modifications that might be required.

The dissemination of road information is also key so drivers are aware of flooded roads and can choose safe travel routes that avoid entering flooded roadways. Today, live traffic and road closure information is more widely available using web-based tools, radio broadcasts and broadcasting directly into car GPS units.

Additional methods for consideration in education and awareness campaigns include:

- Implementation of specific location-based warning systems at high risk locations. These may include broadcasts through car radio systems or lights and sirens.
- Inclusion of educational messages in driver training programs.
- Implementation of a national campaign to deliver consistent messages. This campaign may be best focused at males who drive four wheel drive vehicles, and dispel the images frequently portrayed in four wheel drive sales advertising which, it might be argued, encourage risk-taking behaviour.
- Enhancement of flood warning systems in flash flood environments, enabling agencies to effectively warn communities, pre-deploy resources and close roads in a proactive manner.

Gissing (2016)observed a number of emergency service and government vehicles entering floodwaters, hence providing inconsistent messages to motorists regarding the safety of entering floodwaters. Consultation with NSW SES found that their safe driver policy discourages members from entering floodwaters and that no current specific training is delivered to better equip SES volunteers to drive through floodwater than the general public. This fact is further supported by the number of emergency service vehicles which have been left stranded in floodwaters as a consequence of members to attempt to drive along flooded roads. Flood management agencies should consider developing an educational package for emergency services and government agencies about the dangers of entering floodwaters, so as to ensure messages are promoted consistently by all authorities to the community.

Incentives and consequences / Law and regulation

Regulation is often used to change behaviour: for example, enforcing speed limits and encouraging seat belt use. Regulation, however, has not been widely employed across all Australian jurisdictions to stop motorists from driving though floodwater. Queensland Police have enforced careless driving charges for motorists entering floodwater, resulting in fines and license disqualification. Enforcement of driving laws is a measure used more commonly in the United States where at least three states charge individuals for rescues as consequence of recklessness (Wogan, 2013a) Little evidence exists regarding the effectiveness of regulation in this area due to a lack of research (Wogan, 2013b). Evaluations of traffic safety measures in other contexts finds overall positive results with some variation in effectiveness across different contexts (Albalate et al., 2013)

Laws and incentives that could be considered to influence behaviour may include:

- Motorists requiring rescue being required to pay for the cost of their rescue where behaviour is deemed reckless, or motorists have ignored road closure signage. Revenue could be re-invested into education programs. Similarly, motorists who remove road closure barriers to allow their vehicle to pass could be prosecuted. In doing so they have 'opened' the road to other vehicles and encouraged risk-taking actions.
- Insurance companies not being obliged to pay claims for vehicles damaged as a consequence of driving through floodwater where motorist behaviour is deemed reckless.

Structural intervention

Structural intervention includes structures to prevent people entering floodwaters, road design which increases the safety of motorists if they were to enter floodwater, and vehicle design.

The closure of roads by authorities typically occurs when flooding happens or is imminent. The erection of barricades and signage aims to prevent motorists from entering floodwater. Due to the portable nature of barricades, motorists are able to relocate them or possibly drive around them, although often flooding may also occur before authorities can establish barriers. Gissing et al., (2016) identified in a case study of flooding in NSW that a high percentage of motorists ignored road closure barricades.

To enhance the effectiveness of barriers the following could be considered:

- Manning of barricades in high risk areas with personnel with the authority to direct motorists not to proceed, and
- Establishment of automatic gates in high risk areas that are activated remotely or when triggered by a warning system.

However, these measures may be limited in their effectiveness due to a lack barricades to be deployed, resources to man barricades, or due to the cost of automatic gates.

Road design in flood prone areas could have a critical influence on the survival outcomes of motorists once their vehicle becomes buoyant and should be an area of further research. Specifically, research is required to identify the influence of the following designs:

- The presence of roadside barriers high enough to prevent vehicles from being swept off a roadway,
- The height of the road above surrounding terrain,
- The presence of vegetation to act as a natural barrier to prevent a vehicle from being swept downstream, and
- The presence of road lighting to allow motorists to observe dangers at night.

If these factors were proved to have a significant impact, their consideration in road design and in prioritising resources to close roads could assist in reducing the risk.

Vehicle design has been a major influence in reducing the overall road death toll, with innovations such as seat belts and airbags now commonplace. Yet existing vehicle design would appear to have few, if any, elements incorporated to reduce risks to motorists during floods. However, future innovations may be possible, including through the future use of autonomous vehicles. These vehicles have the potential to remove many of the factors which contribute to the overall road toll, such as speeding, fatigue, drugs / alcohol, and distraction. If such vehicles are programmed to avoid flooded roads this would be helpful in reducing the risk.

Consequence Management

Rescue is the primary consequence management strategy. Emergency services have long-standing flood rescue capabilities and significant investment has occurred of late in rescue capabilities for swift water. There is still much to learn about the overall influence of flood rescue in reducing the death toll of motorists during flooding. Some of the questions primarily relate to the timing of fatalities in relation to rescue intervention. For example: do most flood fatalities occur before rescue resources arrive or before bystanders can act, meaning that, unless resources were on scene within seconds, the death would have occurred anyway? Or do they occur after rescue resources arrive, indicating the overall effectiveness of the intervention when applied in reducing deaths? No matter the answers, however, it must be concluded by the existing rate of death that rescue is not a perfect solution, and that to reduce deaths focus must be applied to the above-mentioned preventative measures as well.

People entering floodwaters by foot

No holistic strategies have been developed to specifically address people entering floodwater by foot, again there is limited evaluations of existing measures and research to form a strong evidence base. This problem is potentially hard to address due to the geographical diversity of possible incidents, which could in theory occur anywhere on a floodplain. A similar framework, however, to that outlined to address people entering floodwater in vehicles could and should be developed.

Education campaigns are currently a key strategy and focus on discouraging people from entering flood water for recreation or other purposes. Signage and fencing is often in place around known hazard areas such as drains and detention basins to raise awareness of the possible risks present in the environment and prevent access. Fencing has been shown as effective in the context of reducing drowning in swimming pools and spas (Bennett and Linnan, 2014).

The possible public appetite for regulation to prevent people from playing in floodwater by imposing fines is likely debateable, but essentially unknown. Proactive intelligence-led efforts could be utilised to discourage people observed entering flood waters by proactive monitoring of identified hotspots by police, SES and other emergency services, as currently implemented by Queensland Police.

Proactive monitoring of social media and the media could also be key. Where people are identified as engaging in risky behaviour on social media, these platforms should be utilised to refute the behaviour by reinforcing key messages of safe behaviours. Likewise, media engagement is necessary to ensure images of risky behaviour are not broadcast, and reporters demonstrate behaviours in-line with key messages.

Failure or inability to evacuate

Reviews and research conducted after major evacuations have identified that evacuation rates are highly variable (Baker, 1991). The timing which people choose to leave following a warning to evacuate is also extremely variable (Sorensen, 1991). Failing to evacuate, or evacuating too late may result in fatal consequences.

The main reason for people evacuating is the perception that the anticipated hazard is a significant threat (Baker, 1991). Research after hurricane evacuations has demonstrated that the stronger the storm and the closer its proximity, the greater the chance that people will evacuate (Smith and McCarty 2009). People are more likely to evacuate when they understand that a warning applies to them (Baker 1991, Huang *et al,* 2012): the more personalised the form of delivery, the greater the response (Baker 1991, Huang *et al*. 2012). In general, research supports that mandatory evacuations may be more effective than voluntary evacuations, although they can result in community anger and social turmoil (Bobrowsky 2013).

The main reason why people don't evacuate is they do not perceive the threat of the anticipated hazard to be sufficient enough to act (Baker 1991, Gissing *et al,* 2008, Smith and McCarty 2009) or simply are unable to act due to the fast onset of the hazard. Other reasons for not evacuating include:

- Desire to protect their property from the hazard (Baker 1991, Gissing *et al*. 2008),
- Need to fulfil obligations to employers (Baker 1991, Smith and McCarty 2009),
- Concern about looters (Baker 1991),
- Inconvenience and effort incurred in having to evacuate (Baker 1991),
- Care of pets and animals (Smith and McCarty 2009, Bird *et al*. 2011),
- No transport or nowhere to go (Baker 1991, Smith and McCarty 2009),
- Not aware of warnings (Smith and McCarty 2009), and
- Medical conditions (Smith and McCarty 2009).

Key management actions to improve the success of evacuation are discussed in the following sections.

Ensure that evacuation is a consideration in land use planning

The safest place to be during a flood is away from the affected area. Land use planning needs to ensure that there is an ability to completely evacuate communities within plausible worst case scenarios. This means that a warning system exists that will allow adequate time for existing and future residents to leave areas threatened by flooding, and that road networks are sufficient to enable the movement of residents to safety within the time available and without disruption by flooding. Where this is not possible – for example in areas where flooding occurs quickly – other development design options such as shelter-in-place might be considered, but are unlikely to provide the degree of safety provided for by safely managed evacuation. Though it may be possible to construct buildings that can withstand flood forces, and offer shelter to inhabitants in the most severe of events, isolation is likely to occur. There is no safe period of isolation, due to the possible loss of utilities and risk of medical emergency, fire and other incidents that may threaten human life. There can also be no guarantee regarding how building inhabitants may behave, as there is a risk they may attempt to evacuate through floodwater after flooding has commenced by vehicle or foot, placing at risk their safety. Alternatively, inhabitants may simply be too vulnerable due to their age, capacity or medical condition to shelter in place during a severe flood.

In the context of flash flooding the Australasian Fire and Emergency Service Authorities Council recommends (Australasian Fire and Emergency Services Authorities Council, 2013; p. 2):

"Given the life risk posed by flash flooding and the inherent limitations on how it can be managed, new urban areas should be designed within the limits of existing flash flood forecast capability, should facilitate rapid and safe evacuation from flash flood-prone locations, should account for the likelihood that some people might become trapped inside buildings, and should involve a thorough understanding on how people will behave in a flash flood event and the risks they face."

In areas where evacuation is possible, there is still no guarantee that all residents will evacuate. In this case, safe refugees could be incorporated into the design of new buildings to provide some degree of safety more significant than simply attempting to shelter in the high point of a building, which may eventually be overwhelmed by a flood. However, though possibly enhancing safety, this option could incur additional construction costs, may not be practical in all flood environments and may deter evacuation. Such a measure should be considered based upon the life safety risks present within a local flood environment.

Plan for the evacuation of residents

In areas of existing flood risk, evacuation plans should be developed in partnership with communities to enable the movement of people to safety during the occurrence of flooding. Key considerations include:

- Determination of principles of when evacuation will be necessary in reference to available flood risk information,

- The availability of flood warning systems, and warning dissemination mechanisms,
- Resources to assist in the evacuation of the community, in particular vulnerable residents,
- Suitability of evacuation routes,
- Methods by which residents will evacuate,
- Where residents will be encouraged to evacuate to and what shelter maybe available, and
- When will evacuees be able to return, and what measures will be implemented to assist in the process.

A specific guideline has been developed by the Australasian Fire and Emergency Services Authorities Council (2013) to assist emergency services in emergency planning to protect human life during a flash flood event. It addresses the inherent difficulties in implementing evacuation strategies in flash flood environments. The guideline states:

"Where the available warning time and resources permit, evacuation should be the primary response strategy" (Australasian Fire and Emergency Services Authorities Council, 2013; p. 4).

"If insufficient time or resources are available for a full evacuation, incident controllers must consider whether a partial evacuation, starting with structures triaged as clearly unsuitable, can be carried out" (Australasian Fire and Emergency Services Authorities Council, 2013; p.6).

"Public information should advise people to leave at-risk areas early, not to attempt to escape through floodwater, and if they become trapped to move to the highest point of a suitable building to await the end of the event, and to call 000 if they require recue. This may include providing advice to people on moving from obviously unsuitable buildings to more suitable ones" (Australasian Fire and Emergency Services Authorities Council, 2013; p.6).

Improving response to evacuation warnings

Much has been achieved in the last decade to enhance the communication of emergency warnings, including those for evacuation. The expansion of mobile phone systems, proliferation of the internet and smart phones, and the birth of social media has meant that warnings have become more accessible to individuals. Constant effort is required, however, to engage with community members about warnings, and how they should react when they are received.

Keys (2015) argues that residents need to be persuaded in 'quiet time', when there is no flooding, that evacuation will, on occasions, be a necessary intervention. As part of this campaign, people will need to understand the limitations of levees, that the prediction of floods is not an exact science, and that flooding more severe than that experienced historically is inevitable. The persuasion is best achieved through community engagement in which people have an opportunity to discuss and test what is being communicated by authorities. It is also argued that the dangers of being caught in floodwaters need further attention in education campaigns. In such circumstances, people may face snakes, spiders, insects and vermin invading their homes, floodwater containing raw sewage, oils and chemicals, or lose essential services such as power, water and communications.

When a flood is imminent, residents need clear information before the occurrence of flooding about what areas are likely to be affected and (if evacuation is necessary) about when to leave and where to go (Keys, 2015). Emergency services need to prepare evacuation warnings well ahead of time to ensure they can be delivered in a timely manner, and disseminate them utilising a range of communications techniques.

People living in high hazard areas

Many communities have inherited the legacy of land use planning decisions that have not sufficiently addressed the safety of people living or working on floodplains. In flood prone communities, a flood plain risk management process is necessary to minimise the existing and future risks posed by flooding. Such a process ensures that flood risks are well understood and that appropriate risk treatments can be planned and implemented. The Australian Government (2013) have developed a guideline titled "Managing the Floodplain", which outlines in full the floodplain risk management process.

Land use planning is critical to the management of future flood risk. Unrestricted development in flood prone areas will likely result in intolerable life safety risks, significant financial costs and community disruption. For this reason, management measures limiting the growth of future flood risk are designed and implemented. These measures include:

- Controls to limit the impacts of new development on the flood risk posed to existing development, and
- Limiting where different types of new development can occur and ensuring that development is compatible with the nature of flooding (Australian Government, 2013).

These measures are achieved through land use zoning and building controls. Some debate has occurred in relation to land use zoning that is based on the probability of flooding, typically in the Australian context of the one in one hundred year event (1:100). Such a measure does not account for flood consequences and therefore the totality of flood risk. Smith (2004) outlines three key problems with the adoption the 1:100 year standard:

- *"Major differences in the flood height-range between locations;*
- *Lack of consideration of floods that exceed the standard; and*
- *Lack of consideration of over-floodplain flow velocities".*

McAneney *et al.* (2015) argue that the 1:100 year standard is a flawed risk metric in the Australian context. This point is illustrated by an analysis of flood height ranges between the 1:100 year flood and Probable Maximum Flood, identifying variance of a few tens of centimetres to nine metres across different Australian catchments (McAneney *et al.* 2015). The authors concluded that the risk to property will vary considerably across different catchments, therefore inferring that a blanket standard across all at-risk communities is inappropriate.

Wenger *et al.* (2013a) outlines concerns regarding the uncertainties involved in the establishment of the 1:100 year flood level such as lack of data, out of date data, influences of new data, changes in estimation techniques and changing future conditions such as climate change. Wenger *et al.* (2013a) highlights the case study of Wagga Wagga, which discovered that its previous 1:100 year flood level was actually closer to the 1:60 year level, which has now required debate about raising the city's levees to match the new standard. Wenger *et al.* (2013b) concludes that the 1:100 year standard may be inadequate in the Australian context due to the short records available on historical flooding.

Molino and Karwaj (2012), in a survey of community members regarding the acceptability of flood risks, concluded that the current flood planning standard of 1:100 year is not acceptable to the majority of community members, and that the community expects a much higher degree of protection. The standards applied across hazards are also inconsistent: for example, in the Australian context, earthquake building standards are set at an average recurrence interval of 1:475 years.

The practice of applying the 1:100 year standard without full consideration of flood risk may result in development occurring in some floodplain environments that may be considered intolerable, and establishes a concentration of risk just above an arbitrary level. Land use planning policies must be risk-based and allow for the consideration of flood consequences. Smith (2004) argues that it is imperative that risks to communities from events that could be life threatening, such as high flood depths and velocities, are incorporated into the planning process. Therefore, given these criticisms, the use of the 1:100 year flood as a standard requires review.

FUTURE RESEARCH

There has been limited research to date that rigorously evaluates the efficacy of existing education, incentives and structural measures in reducing loss of life in flood events. In order to reduce lives lost and ensure efforts are targeted effectively this needs to be redressed. In relation to the findings of this project and in discussion with end-users, particularly the NSWSES, the following research priority areas are highlighted.

- Evaluating messaging and terminology used with different socio-demographic groups, particularly women, men, and children and also culturally and linguistically diverse groups.
- Evaluate and compare the efficacy of education, incentives and enforcement.
- Evaluate signage options and smart technology for warning people about flood waters and dangers ahead.
- Explore the decision making of those who do and do not drive through floodwaters.

- Exploring decision making dynamic between passengers and drivers and how passengers can be better educated and empowered to influence driver behavior.
- Exploring available rescue and near miss data

In terms of data, recent coronial records are extremely detailed concerning the circumstances surrounding the deceased. However, the record of rescues remains poor and rests within agencies who may have limited capacity to collect and store the information. A national data base of rescues from flood events would significantly improve the research and evidence to support actions in reducing flood deaths and rescues

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APPENDIX – ANALYSIS OF FATALITIES AMONGST OCCUPANTS OF VEHICLES

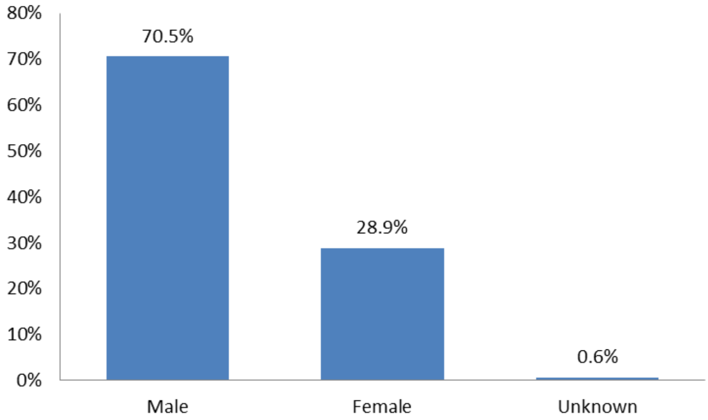
A total of n=336 flood fatalities were attributed to occupants of vehicles. This is made up as follows:

219	in or exiting a sedan car
45	in or exiting a 4WD
26	in or exiting a truck
8	in or exiting a ute
13	in a train
8	on pushbike
17	on other forms of transport (e.g. motorbike)

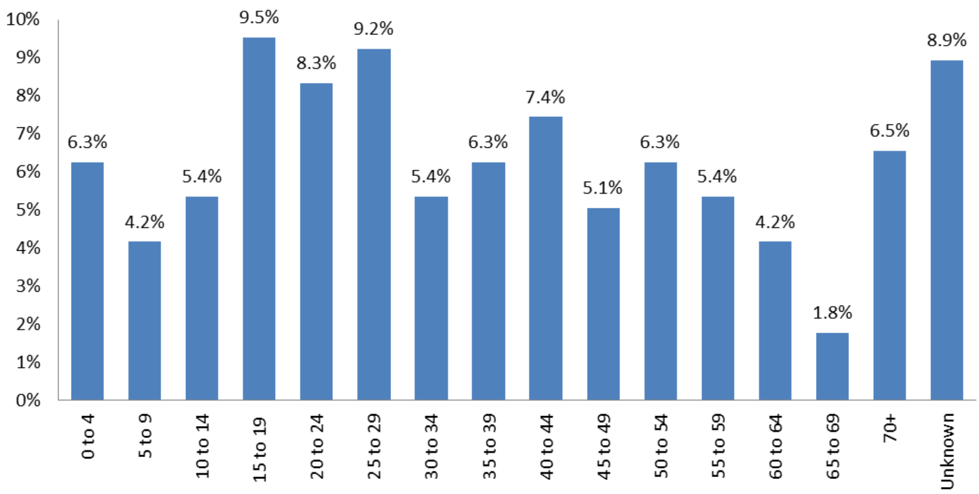
Fatalities in horse-drawn vehicles and those in which the vehicle type is unknown have been omitted from this analysis.

This Appendix presents charts describing the characteristics of this subset of fatalities.

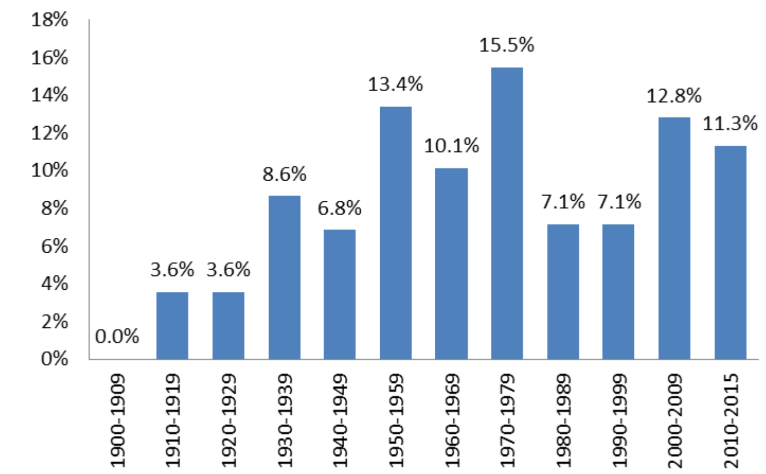
A.1 Fatalities by gender



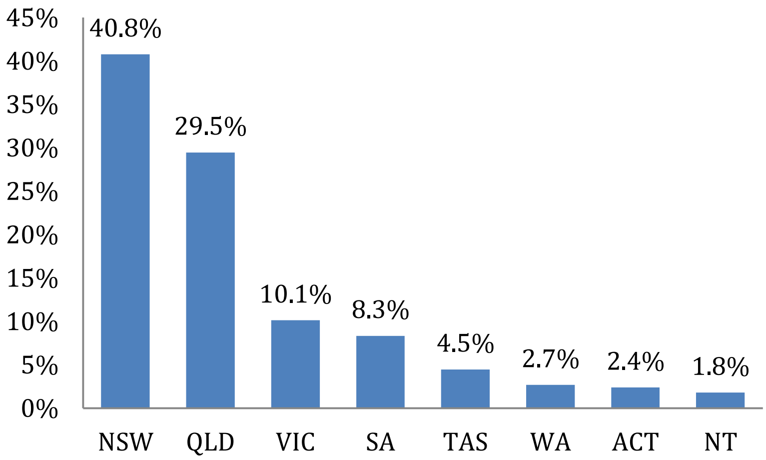
A.2 Fatalities by age



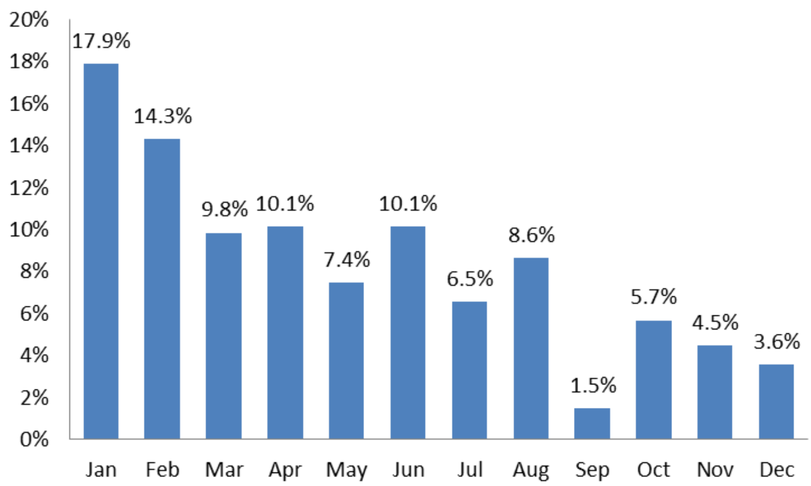
A.3 Fatalities by decade



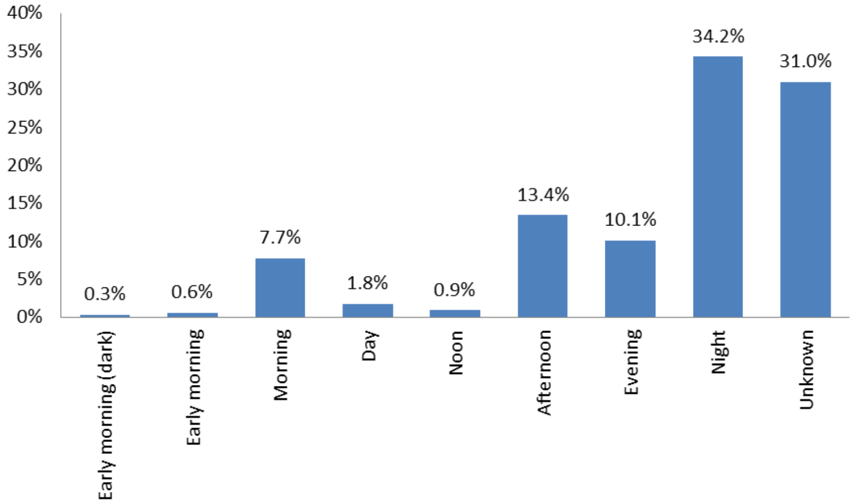
A.4 Fatalities by state



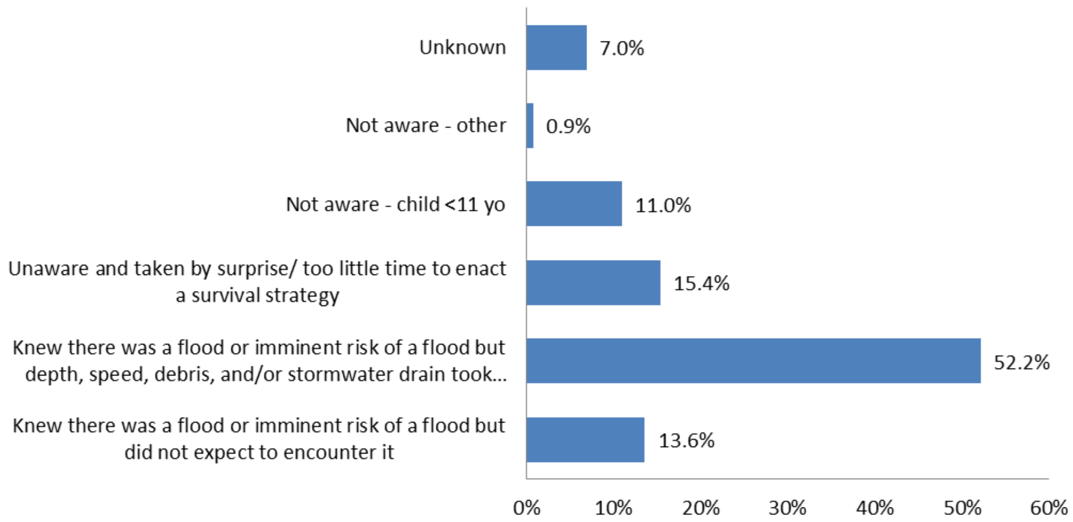
A.5 Fatalities by month of the year



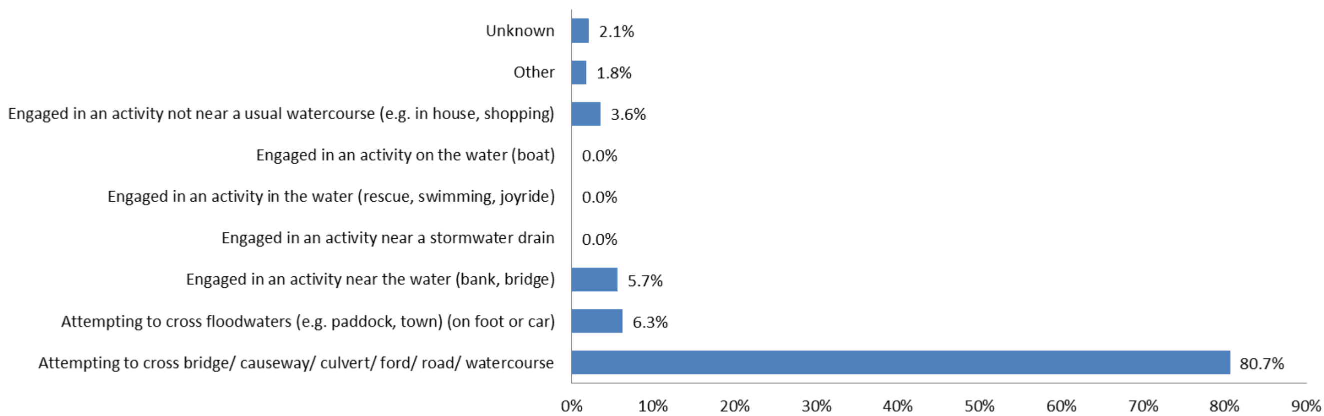
A.6 Fatalities by time of day



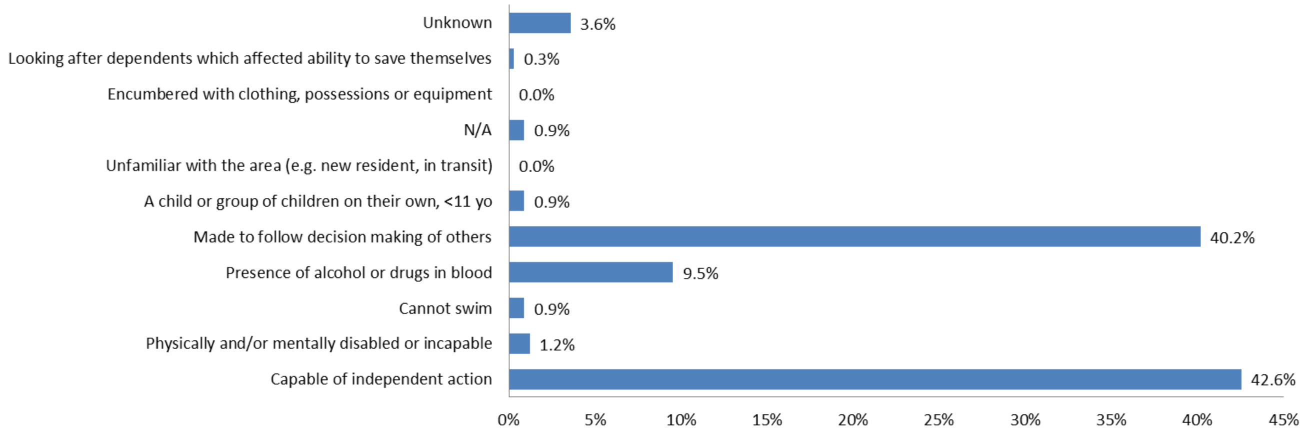
A.7 Fatalities by awareness



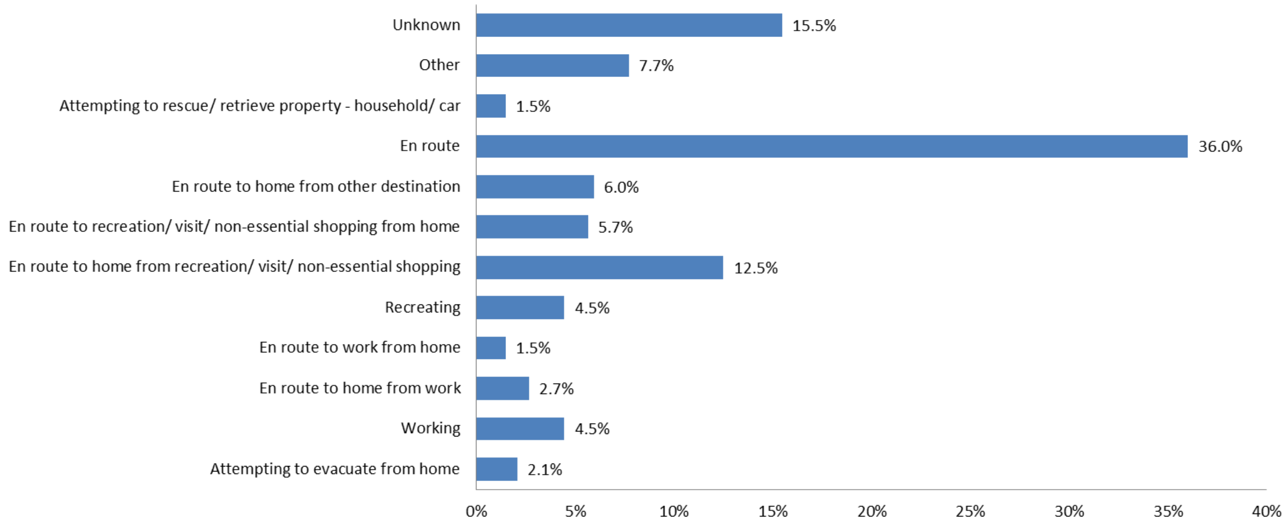
A.8 Fatalities by activity prior to death



A.9 Fatalities by primary capacity



A.10 Fatalities by reason behind action prior to death



A.11 Fatalities by flood type