Driving through Floodwater:
Risks, Fatalities and Challenges for Emergency Services Personnel

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Statement of Originality and Ethical Accordance

I hereby declare that this thesis is my own work and that, to the best of my knowledge, all sources of information previously published or written have been cited in this body of work. All assistance provided in the research and writing of this thesis has been acknowledged. I also declare that the work in this thesis has not been previously submitted to any other institution for, or as part of, a degree.

This study was granted approval by the Macquarie University Human Research Ethics Committee (HREC (Human Sciences & Humanities) (Ref No. 5201700133) and was conducted in accordance with the guidelines stipulated. The approval letter is attached.

Mozumdar Arifa Ahmed
Signature:

19 July, 2019

Thesis by Publication Statement

This thesis has been prepared following the 'thesis by publication' guidelines format outlined by Macquarie University. The contributions by myself and co-authors are outlined in the chapters that have been published. All Chapters have been written and prepared as independent publications. As such, there is some overlap in the arguments and literature cited leading to some repetition across chapters, although I have attempted to minimise this as much as possible. The formatting in this thesis conforms to the American Psychological Association's Publication Manual 6th edition, and each published chapter has been formatted accordingly, while the content remains unchanged.

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General abstract

In 2018, floods affected more people globally than any other type of natural disaster and were cited as causing the second largest number of deaths after earthquakes. In Australia floods are the second greatest cause of natural hazard-related fatalities, after heatwaves. Australia has a long history of flooding, with many towns, cities, and roads at risk of inundation and driving through floodwaters is a relatively common experience for people living in areas prone to flooding. Recent flood events in Australia illustrate the dangers of flooding, in particular, those associated with motor vehicles deliberately entering floodwater.

Despite communication campaigns that urge people not to enter floodwater, the behavior persists even when it is evident that vehicle-related flood deaths are avoidable. Therefore, numerous general questions arise: Why do people drive through floodwater? What are the unknown factors underlying and influencing their risk taking behaviour? What types of interventions could stop this behaviour? These questions are explored in the early part of this thesis. Further, adding an additional perspective, what happens if the behaviour is required and unavoidable? There is a group of people occupationally exposed to driving in flood situations, they are State Emergency Services (SES) personnel.

In Australia, response to floods and storms is the primary responsibility of SES. A central question for SES agencies is, despite the presence of potentially life-threatening risk and clear official warnings instructing people to avoid driving into floodwater why do people engage in such behaviour? Moreover, as they are tasked with a duty of care for their own employees, what do SES personnel do when *they* encounter floodwater in vehicles?

This thesis has four specific aims, all of which focus on the behaviour of entering floodwater in motorised road vehicles, e.g. cars, utility vehicles:

1. To understand the significance of the problem within, and outside, Australia.
2. To explore the contexts surrounding motor vehicle-related flood fatalities in Australia.
3. To explore the risk perceptions and decision-making processes of SES personnel entering floodwater in vehicles.
4. To investigate whether differences in the use of information in the environment (cue utilisation) can be identified in SES personnel in flood contexts, and if so, whether higher cue utilisation is related to improved ability to floodwater hazard assessment.

The thesis is, by its nature, exploratory. Each chapter explores different, but interlinked, perspectives on the overarching problem of driving through floodwater. Four research studies utilise a range of approaches and existing concepts to advance practical, applied, organisational, and public safety issues. Four individual research papers address the noted study aims. These papers include: a review of academic literature on flood fatalities and driving through floodwater; a search and analysis of coronial reports and other evidence to investigate the circumstances surrounding vehicle-related flood fatalities in Australia; a survey exploring the risk perception and decision making of SES personnel when encountering floodwater at work; and an experimental study of SES personnel's cue utilisation in assessing floodwater risks. Brief outlines of these studies and their findings follow.

Study 1 was a systematic review of research relating to flood fatalities and driving through floodwater, revealing the nature, pattern and magnitude of the problem internationally. To undertake the literature review, information was collected from a number of electronic databases for publications, specific search strategies were developed, and according to a set of selection criteria articles were selected for review. Although the review was systematic and comprehensive, it was limited to peer reviewed literature written in English Language. Most of the relevant and accessible publications found were from Australia, the United States, and Europe. The findings of the review highlighted the significance of the problem internationally and classified the risk factors into broad categories. Theoretical models were reviewed and used to conceptualise the relationship among risk factors that contribute to risk perception, and intervention strategies were reviewed to produce an integrated intervention model to combat these risks. The findings of this study contributed to identifying the research gaps and show pathways for further research in this field.

Study 2 focused on the analysis of vehicle-related flood fatalities in Australia, in an effort to provide a better understanding of the circumstances of fatalities related to driving and floodwater. Data relating to 96 fatalities (in 74 incidents) between 2001 and 2017 were studied. To extract the information the study used the Australian National Coronial Information System (NCIS) database to search for incidents and to develop a register consisting of variables that provided a systematic description of the circumstances under which each incident occurred, including details of the surrounding environment, location specifics on the incident and demographic details of the individuals involved. Analyses identified some common findings regarding demographic (age, gender), temporal (time of day, season), spatial (road, location) and situational (proximity to home, location familiarity, journey characteristics) risk factors. Moreover, by collating data, this study identified a number of novel findings about the influence of passengers, factors associated with survival, and the influence of drugs and alcohol. From a sub-analysis of detailed case studies it was concluded that floodwater with high flow and the presence of alcohol and drugs were major contributing factors to fatalities, with drugs and alcohol leading to impaired responses, or impacting mobility, reducing the chance of survival. The patterns and trends identified in this research produced implications for the development of intervention strategies and targeting those at risk.

Study 3 involved conducting an online survey of SES personnel to explore emergency service workers' experiences of driving through floodwater while operational and to describe the contexts and conditions under which emergency services personnel entered floodwater. This was undertaken to identify the risk factors for driving through floodwater in operational contexts, to explore how those factors independently or mutually contribute to shaping drivers' perceptions of risk, and to begin exploring how risk perception affected decision-making during reported incidents of driving through floodwater. The findings indicated that location type (e.g. rural location), water depth, and water flow made the most salient contributions to risk perception. In addition, three factors 'organisational training and safety', 'external locus of control' and 'absence of risk signals' were found to be most strongly associated with risk perception in influencing decisions to drive through floodwater. These findings have a number of practical implications for the improvement of workplace health and safety, such as upgrading risk assessments strategies and approaches to decision-support, enhancing risk management systems, and increasing the capacity to work safely through continuous advancements in training - increasing awareness and improving skills and knowledge about floodwater hazards on roads.

Study 4 involved the development of a prototype suite of online tasks for assessing cue utilisation in SES personnel in the context of floodwater and driving, using the software platform EXPERTise 2.0. Past research in cue utilisation in other occupational settings has shown that higher cue utilisation is associated with higher performance in skilled tasks. The 'Driving through Floodwater' version of EXPERTise 2.0 was designed to assess behaviour consistent with the utilisation of cues within the context of flood. In this study, six tasks were developed in the EXPERTise testing environment for floodwater hazards. The study was administered to SES personnel as expert group, and was piloted successfully. Following established data protocols, a cluster analysis enabled the identification of two groups, reflecting relatively higher and lower levels of cue utilisation. However, these results did not support the proposition that those with higher cue utilisation would perform better in a floodwater hazard assessment performance task. A number of possible explanations for the lack of expected findings are proposed and recommendations for future advancement of cue-based decision-making approaches in this context are made.

Overall findings from this body of research have practical implications for both the public and emergency service groups. Primarily, these are in the development of communication campaigns for the former, and workplace health and safety practices and procedures and training interventions for the latter. Translation of these findings may lead to a reduction in the number of flood-related rescues and severity of injuries and associated costs due to driving through floodwater; ultimately saving human lives.

Chapter 1: Introduction

Introduction

Floods are among the most widespread of natural disasters and are cited as the highest cause of mortality due to drowning throughout the world (Ashley and Ashley, 2008; Berz et al., 2001). A reported risk factor of many drowning fatalities is driving through flooded waterways, with 54% of flood-related river drowning deaths between 2002 and 2012 in Australia (n = 2965) a result of non-aquatic transport (Peden, et al., 2017). Over half (53%) of all unintentional flood-related drowning deaths between 2004/05 and 2014/15 were as a result of driving through floodwaters (Australian Water Safety Council, 2016). Drowning death research conducted in Australia in the period 1997-2008 found that the use of a motor vehicle was involved in drowning deaths 49% of the time and 40% of this was attempting to negotiate flooded bridges, streams, and roads (FitzGerald et al., 2010). Other noteworthy research has found between 35% and 60% of all drowning deaths to be vehicle-related (Coates, 1999; Jonkman and Kelman, 2005).

Although research indicates that driving through floodwaters is a common type of flood experience (Franklin et al., 2014), and there is growing research evidence on the risk factors related to motor vehicle-related drowning (Becker et al., 2015; Haynes et al., 2015; Peden et al., 2017; Smith et al., 2017), there are still limitations in understanding how people engage in this risky driving behaviour (World Health Organization, 2014; Yale et al., 2003). The focus of this thesis is on studying this life-threatening behaviour: driving through floodwater. The main aim of this thesis is to understand the risks and decision-making process of this risky driving through floodwater behaviour in four separate studies.

This general introduction chapter introduces relevant background of the studies conducted in this thesis by reviewing past studies, theoretical models and important preventive strategies related to driving through floodwater behaviour.

First, a literature review scopes the problem, including flood fatality research throughout the world, flood drowning death research in Australia and risk factors associated with driving through floodwater, which are mostly relevant to Study 1 (Chapter 2) and Study 2 (Chapter 3). Then it will focus on the emergency services as the main participant group for Study 3 (Chapter 4) and Study 4 (Chapter 5) describing the need of addressing the safety of this occupational group which is at higher risk of encountering floodwater on roads.

This chapter will provide a detailed description of the theoretical aspects that have been used to explain the behaviour, including psychological theory applied to driving through floodwater research, previous psychological research applied to driving through floodwater and theoretical concepts used in the current studies. These theoretical aspects are essential, and are used to explain perception of risks and decision-making factors that influence drivers and lead them to drive through floodwater in Chapters 4 and 5. Then it will draw attention to existing prevention strategies and their effectiveness in reducing the risks of the behaviour and the necessity of developing advanced intervention programs, which are highly relevant to all empirical studies in this thesis. Finally, it will provide a brief overview of each chapter including the research focus and key methods used in the current studies.

1.1 Flood fatality research throughout the world

Flood fatality research has identified that people entering floodwaters in vehicles constitutes one of the major causes of flood fatalities Internationally (Ashley and Ashley, 2008; Diakakis and Deligiannakis, 2013; Drobot et al., 2007; Fitzgerald et al., 2010; Gissing et al., 2016; Jonkman and Vrijling, 2008; Jonkman and Kelman, 2005; Kellar and Schmidlin, 2012; Peden et al., 2017; Pereira et al., 2017; Salvati et al., 2018; Terti et al., 2015). In the United States of America, Ashley and Ashley (2008) found that 63% of flood fatalities were vehicle-related. Similarly, Sˇpitalar et al., (2014) found that 68 % of flash flood fatalities were vehicle-related and Terti et al., (2015). Jonkman and Vrijling (2008), in a study of flood fatalities across Europe and the United States, identified that 32 % of deaths were associated with vehicles. In Greece, some 40 % of flood fatalities have been associated with vehicles (Diakakis and Deligiannakis, 2013), with this proportion growing over-time (Diakakis, 2016). A study of flood and landslides in Italy across a 50-year period between 1965 and 2014 found 38% of all flood-related fatalities occurred on roads and highways and 16 % on bridges, and involved predominately male victims (Salvati et al., 2018). In other countries the proportions have been lower, though significant, with France 30% (Vinet et al., 2016) and Portugal, 14 % (Pereira et al., 2017).

No international review on vehicle-related flood fatality research was found when this current body of research was conducted. Moreover, mostly flood fatality research has investigated a broad set of risk factors relevant to all types of flood deaths, rather than focusing on vehicle-related deaths and driving-related behaviour as a reason for flood death. To identify the research gaps, **Study 1** (**Chapter 2)** of this thesis comprises an international review to bring together knowledge from across the international literature, to combine this information to reveal the consequences of this driving behaviour in flood situations, and to identify interventions being employed or suggested to reduce risks.

1.2 Flood fatality research in Australia

A number of flood fatality studies in Australia have recorded and calculated vehicle-related flood fatalities (Coates, 1999; Fitzgerald et al., 2010; Haynes et al., 2017; Peden et al., 2017). However, these studies have done so in the context of investigating all types of flood fatalities and they have covered differing time periods. No study has been conducted specifically to analyse vehicle-related flood fatalities in Australia with recent fatality data. Study 2, presented in **Chapter 3** of this thesis, was designed to investigate recent vehicle-related flood fatality incidents in Australia that occurred between 2001 and 2017 to improve understanding of the contexts of vehicle-related flood deaths specifically within Australia.

1.3 Risks associated with driving through floodwater

Floodwater conditions and vehicle instability

Research investigating the risks of driving through flooded waterways suggests that approximately 15 centimetres of water will reach the floor pan of most passenger cars which can cause loss of control and stalling, and 60 centimetres of water will cause virtually all cars including four- wheel drives to float (Franklin et al., 2014). Smith et al. (2017) tested the impact of various flood conditions on vehicles with results indicating that in fast flowing floodwater of three metres per second it can take just 15 centimetres of floodwater for a small passenger vehicle to become unstable and only 30 centimetres for a four-wheel drive (4WD) vehicle. It is evident that use of four-wheel drive vehicles is increasing in Australia. In total, 229 flood fatalities were associated with vehicles between 1960 and 2015 (Haynes et al., 2017). Some 64 % of vehicle-related flood fatalities have been associated with sedans and 19 % with four-wheel drive vehicles in Australia (Haynes et al., 2017). Since 1960 the prevalence of fatalities associated with sedans has decreased, whilst fatalities involving 4WD vehicles has increased (Haynes et al., 2017). In the last fifteen years they have contributed an equal share (Haynes et al., 2017).

When a vehicle becomes buoyant, the flow of water can push it sideways. Empirical studies have demonstrated that, when a vehicle is caught in water the floating phase may last from 30 to 120 seconds, followed by the sinking phase, which is typically completed within two to four minutes of contact with the water (McDonald and Giesbrecht, 2013; Molenaar et al., 2015). Vehicles may enter floodwater upright or roll into a waterway (Smith et al., 2017) leaving those inside with only seconds to escape. Once a person starts to drown, the outcome is often fatal. Occupants may have trouble escaping their vehicles due to floodwater conditions, physical trauma, failure of electric windows, automatic locking doors or the activation of airbags (Molenaar et al., 2015). Vehicles entering deeper water have been associated with lower survival rates (McDonald and Giesbrecht, 2013).

Road-related risk factors

International research indicates that motorists drown through a variety of ways: while in their vehicle as a result of the vehicle being submerged or swept away (Diakakis and Deligiannakis, 2013; Drobot et al., 2007; Kellar and Schmidlin, 2012; Yale et al., 2003) while attempting to escape a vehicle by trying to swim or walk to safety, or by being ejected from a vehicle (Kellar and Schmidlin, 2012). Vehicles can be deliberately driven into floodwaters, can enter floodwater unexpectedly (Yale et al., 2003) or be parked and suddenly surrounded by floodwater (Diakakis and Deligiannakis, 2013). The majority of vehicle-related incidents occurred on paved roads adjacent to waterways, on bridges and on artificial ford river crossings (Ahmed et al., 2018; Diakakis and Deligiannakis, 2013; Stjernbrandt et al.,2008), mostly close to the home (Diakakis and Deligiannakis, 2013; Haynes et al., 2017; Maples and Tiefenbacher, 2009). These findings suggest that certain road-water situations and locations, as well as drivers' environmental familiarity with the road and presumably an increased probability of being in the location (near home) all may be influencing risk perception and behaviour. Diakakis and Deligiannakis (2013) reported that 70% (out of 60 fatal incidents) of fatalities occurred in rural areas, which is lower (23%) in comparison with the incidents that happened in urban areas.

Gissing et al., (2019) investigated the influence of road characteristics on flood fatalities in Australia based on a site analysis of 21 road sections where fatalities had occurred. The results of this research indicated that some characteristics are common among sites where flood fatalities have occurred. Key risk factors identified through this research are summarised in Table 1.1. Findings of this research indicated that small upstream catchment size (which can cause a fast rate of rise in the water), the absence of road barricades, depth of flooding adjacent to the roadway, absence of lighting, dipping road grade, lack of curb and guttering and the inability of motorists to easily turn around (due to space constraints) were the most frequently observed factors (Gissing et al., 2019).

Table 1.1

Road-related risk factors (Source: Gissing et al., 2019)

Factor	Description
Factors that may influence a motorist to enter floodwater	
Presence of signage	Signage is aimed at informing motorists of the likely presence of water over a roadway
Road alignment	A tight bend in a roadway directly before a floodway may result in little to no chance for a motorist to take action to avoid entering floodwater
Road grade	The falling grade of a road may result in a motorist entering shallow water before progressing into much deeper water.
Road Pavement	Gravel road surfaces have been shown to have a lower friction coefficient when compared to sealed road pavements, therefore making it easier for motorists to slide off a gravel road.
Presence of lighting	Lighting of a roadway allows motorists to observe floodwater during evening hours
Traffic Volume	Traffic volume represents the number of motorists that may be at risk of entering floodwater whist travelling a specific road section. Large volumes of traffic may also hinder the ability of a motorist to turn a vehicle around.
Speed limit	Speed limit may influence the possible speed a motorist was travelling whilst observing signage and in making decisions to enter floodwater.
Ease of turning around	The width and lane structure of a road (i.e. one way or two way) influences the ability of a motorist to turn a vehicle around.
Factors that may influence survivability of motorists once washed from the road	
Depth and velocity of floodwaters	Particular thresholds of floodwater increase the likelihood of a vehicle being washed from a road (Smith et al., 2017).
Rate of rise (catchment size)	Rate of rise reflects the speed at which floodwater may rise or fall. Fast rates of rise are associated with smaller catchment sizes.
Presence of roadside barriers	Roadside barricades provide protection against a motorist leaving a roadway.
Curb and guttering	Curb and guttering provide some degree of protection against a motorist leaving a roadway.
Distance water was over the road	Water covering a long distance of a roadway may result in motorists becoming disorientated.
Rate of rise (catchment size)	Fast rising floodwater enhances the dynamic nature of downstream conditions.
Flood depths downstream	Vehicles will sink in deep floodwater directly downstream of roadway.
Downstream flood velocities	Fast flowing floodwaters may rapidly sweep a vehicle downstream.

Prevalence of motorists entering floodwater

Some studies have considered the prevalence of motorists entering floodwater. Gissing (2016) observed a section of flooded road that had been closed using barricades on the NSW South Coast in 2015. Results showed that 84% of motorists chose to ignore road closure signs and barricades, and drove through floodwater. Although the types of vehicles being driven varied, the largest proportion was 4WDs and SUVs (48%). The majority of drivers were male.

Wright et al., (2010) noted a survey of residents in Richmond, Windsor, Woronora and Lismore, where some 50% of respondents thought that it was safe to walk or drive through six inches of floodwater. In a different survey of eight NSW communities, 49% of respondents suggested that they would turn around if faced with a flooded road, with 22% indicating that they would travel on with care (Wright et al., 2010). The majority of those involved in focus groups supporting the study recognised that floodwater could be dangerous and that it should not be underestimated. Some admitted that they had driven on flooded roads before even though they recognised the dangers. It appeared that people had developed their own criteria for assessing the dangers. For example, some would not drive across a flooded road if they thought the water was fast flowing. Others would get out of their vehicle to test the depth and speed by walking into it (Wright et al., 2010). It was concluded that males between 18 to 35 years of age and drivers of SUVs and trucks were most at-risk of driving into floodwater (Wright et al., 2010).

A research study to inform the Queensland (QLD) “if it’s flooded forget it” campaign (Prevention of flood-related deaths working group, 2016) identified that 29% of respondents had driven through floodwater. This rate was higher amongst males and those that drove 4WDs, in particular young males aged 18-24 years who drove 4WDs. A total of 49% of respondents indicated that they would never drive through floodwater. The most significant deterrents for people entering floodwater were identified as the presence of police/officials, the sight of another vehicle in trouble, the presence of road closed signs, their own judgement and being asked to stop by a passenger in their vehicle (Prevention of flood-related deaths working group, 2016).

In Arizona, United States, a study by Coles et al. (2009) found that some 61% of drivers had driven through floodwater. Larger vehicles were found to be more likely to be driven into floodwater than smaller vehicles. Education levels were not found to be a significant determinant of behaviour. It is important to note that in some cases motorists may not have chosen to enter floodwater and may have simply become overwhelmed by the rapid rise of floodwater or been unaware of the presence of floodwater prior to entry (Martin, 2010).

It is evident that there are several risk factors that have been addressed in different ways in different studies. In this thesis, **Study 1 (Chapter 2)** discusses risk factors identified in the academic literature by systematic review that provide thoughtful insight into decisions to drive into floodwater. The study also categorised and reported, briefly, on why motor vehicle-related flood accidents occur.

Based on risk factors identified in Study 1, **Study 2 (Chapter 3)** analysed the relevance of those factors in recent vehicle-related flood fatalities in Australia. Some individuals encountered floodwater directly or indirectly in the context of their work (Becker et al., 2015), whist a significant number were engaging in their normal activities, including commuting to work (Haynes et al., 2009; League 2009; Ruin 2008). In Australia, 12% of flood fatalities between 1788 and 1996 were identified as being work-related (Coates 1999). Some vulnerable groups identified were miners (2.8%), rescue personnel (1.4%), and mail delivery personnel (0.9%) (Coates 1999). From the findings of later flood fatality research which focused on vulnerable or ‘‘at risk’’ groups for driving through floodwater (Becker et al. 2015; Haynes et al., 2009), emergency services personnel were identified as occupationally vulnerable groups who work in flood conditions and are required to enter the floodwater frequently. Becker et al., (2015) recommended that provision should be made for working with at-risk groups who are more likely to enter floodwater (Becker et al., 2015). Research on vulnerable populations in other topic areas (e.g., health) has found that targeting and working with specific groups on particular topics can provide support to such populations and help change attitudes and behaviors in a positive way (Soole et al. 2007; Howat et al. 2001; Hill 1998; Finnis 2004). However, there is no coverage in the literature available on flood related deaths and behaviour in and around floodwater specific to emergency services. Thus, there is a dearth of understanding about how this risky behaviour can be explained in the context of the emergency services.

1.4 Emergency management and a focus on emergency services personnel

Emergency services workers in Australia operate in challenging environments, dealing with violence, distress and often death. Since 2003 that work environment has claimed the life of 47 first responders (Safe Work Australia, 2016). Figure 1 presents an infographic of first responder fatalities and injuries sourced from Safe Work Australia’s work-related traumatic injury fatalities dataset 2016 and national dataset for compensationbased statistics 2015-16. Emergency service professionals experience a high rate of serious injury and fatalities related to their work compared to other occupations. This infographic looks at the rate and cause of fatalities amongst first responders, and the key factors attributed to serious claims. Data from the infographic reported 47 first responders' fatalities since 2003: 21 fire and emergency workers; 4 ambulance officers and paramedics; 22 police officers; 38 of these fatalities were male and 9 were female. The most common cause of fatalities was vehicle collision at 40%. The fatality rate in 2016 was 2.1, higher than the national rate of 1.5 per 100,000 employees. The most common cause of serious claims was: mental stress 13%, lifting/carrying people 7%, assault 5% and falls on level ground 5%. The serious claims rate is 4 times higher for first responders than for all occupations, at 37.9 claims per 1000 employees. The annual incident rate for first responders declined 7% between 2000-01 and 2015-16.

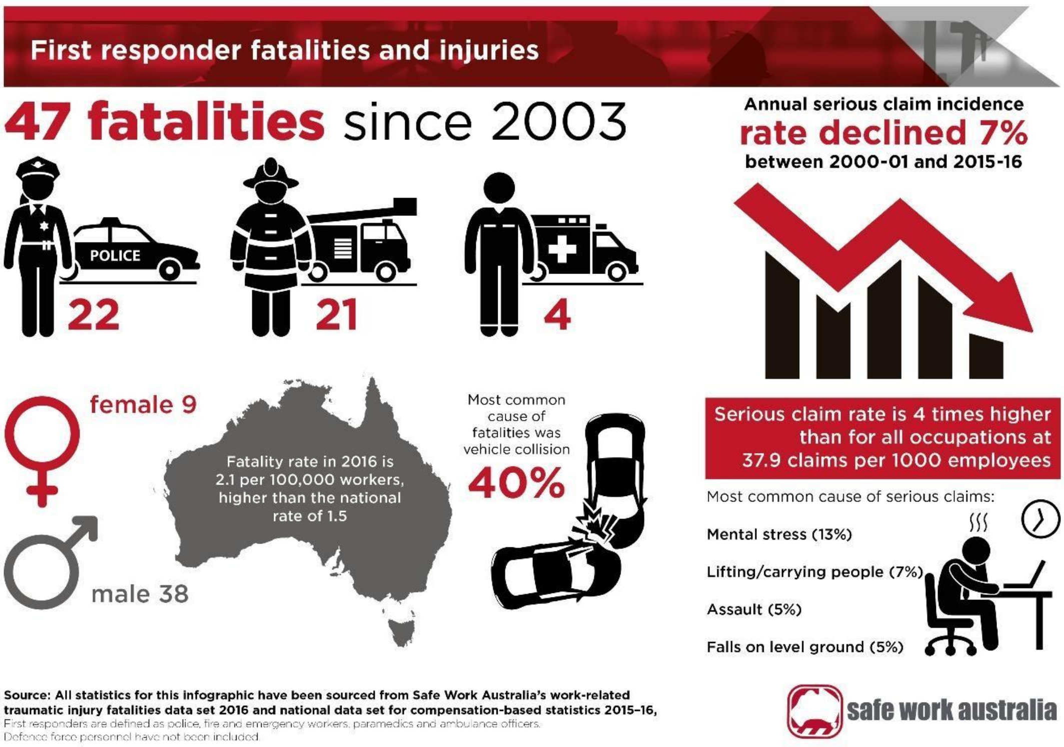

Figure 1.1 Infographic: First responder fatalities and injuries (Safe Work Australia, 2016).

A significant number of flood-related deaths have been linked to avoidable behavior, such as voluntarily entering floodwaters (Ashley and Ashley 2008; Coates 1999; Haynes et al., 2009; Drobot et al. 2007; Jonkman and Kelman 2005; WHO 2002). Whereas for most of the public it is a "voluntary action" which could be avoidable, for emergency services it is, more than likely, a "partially voluntary" decision they have to make about entering floodwater. This decision is perhaps influenced by an expectation of their occupational role (for example, to rescue victims trapped in floodwater) or the decision might be triggered as a result of their sense of responsibility to perform their professional duties.

In floods, this increasing number of vehicle-related flood incidents and rescues have become an emergency management challenge for emergency services. The State Emergency Services (SES) agencies - the leading emergency services in Australia responsible for response to floods, storms, and tsunamis, dedicate their efforts (physically and economically) each year to save and discourage people from engaging in this intentional risky driving behaviour, which also puts the lives of members of their organisations at risk. Research data supported approximately a third of some 300 flood rescues performed by New South Wales State Emergency Service (NSW SES) during flooding around Sydney in June, 2016 were from vehicles (Smith et al., 2017). Such rescues place emergency services personnel at high risk. Moreover, a challenge for emergency managers is how to encourage people to stay out of harm's way and keep out of flooded areas (Becker et al., 2015).

As first responders in transport-related flood rescue events, the occupational health and safety issues of emergency service personnel in emergency events need to be addressed, as a matter of priority. No empirical research is evident to address the need of emergency service workers to understand their own decision-making when encountering floodwater in vehicles, in this thesis **Study 3 (Chapter 4)** will address that research gap.

Brief overview of SES

State Emergency Services (SES) are the focus of the occupational research reported in this thesis. Each State and Territory in Australia has its own SES agency and although their general responsibilities are very similar, they operate under different jurisdictional legislation and are led and administered independently. All SES agencies comprise a core of paid (salaried) members and a larger volunteer member workforce. To introduce the roles and activities of an SES agency operating in Australia, a short description of New South Wales State Emergency Service (NSW SES) is provided as an example.

The NSW SES is the lead agency for floods, storms and tsunami as specified by the State Emergency and Rescue Management Act 1989. Initially, in the 1950s, it was based around an ethos of wartime civil defense and it gradually became fully focused on non-war type emergencies in the 1970s. NSW SES was established in 1955 in response to extensive flooding that occurred in the Hunter Valley and North-West New South Wales NSW. At the end of 2017-18, NSW SES was made up of 9,110 volunteer members, including reserves, and 355 staff members (representing an FTE of 324.84 agency, contract and casual roles). The

Service had 258 volunteer units covering almost every Local Government Area in the State, led by a Unit or Local Controller (NSW SES, 2018).

NSW SES exists to mitigate the risk and consequence of emergencies in communities. The range of emergency situations which NSW SES deals with is very broad, however, core business is the management of the effects of floods, storms and tsunami. All NSW SES units respond to damage caused by storms and have an active role in flood management. NSW SES volunteers are highly-skilled, experienced and well-trained in the wide variety of roles they perform. Each unit is unique in its pattern of work because of the vast mix of risks and roles required in the diverse locations and communities in which the units are situated. In addition to responding to flood, storm and tsunami, NSW SES provides specialist capabilities including general land rescue, vertical rescue, road-crash rescue, driver reviver (fatigue management), alpine and remote area search and rescue. NSW SES frequently assists other emergency services in a variety of roles, including searches for evidence and missing people with NSW Police Force and community first responder roles in rural locations with the Ambulance Service of NSW.

From 2012-2017 the NSW Government invested $46 million for the procurement, maintenance and control of the 637 strong SES operational vehicle fleet. The NSW SES Operational Fleet Replacement Program will continue to replace SES vehicles and also fund the purchase of equipment inventory, marine vessels and trailers. The funding will enable the provision of 270 vehicles, 124 marine vessels, and 95 trailers. In 2018-19, 78 vehicles, 37 marine vessels, 30 trailers and 5 snowmobiles will be delivered.

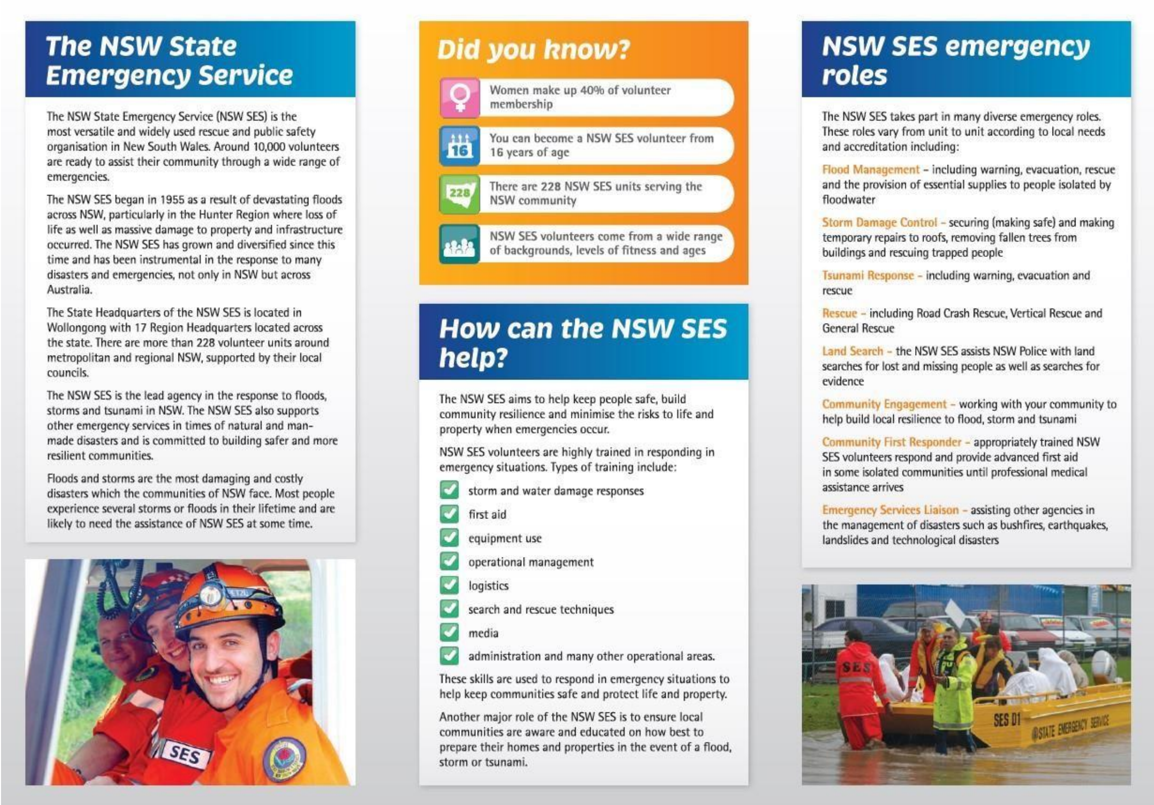

Figure 1.2 New South Wales State Emergency Service Brochure (NSW SES, 2018)

To focus on emergency services' occupational issues relevant to this thesis, **Study 3 (Chapter 4)** and **Study 4 (Chapter 5)** were designed to explore the behaviour of driving through floodwater by SES personnel in their occupational contexts, and their ability to assess risks in this context, respectively. These studies include exploration of occupational safety and hazard issues; detailed experiences of driving through floodwater; the challenges and barriers of performing their duties; risk perception of SES members about entering floodwater; and how they use cues to assess the risks of floodwater in the context of driving and water on roads.

1.5 Possible explanations underlying decisions to enter into floodwater in vehicles

Explanations for why drivers, in general, deliberately enter floodwater include: not taking warnings seriously (Drobot et al., 2007), underestimating the risk (Diakakis and Deligiannakis, 2013; Drobot et al., 2007; Maples and Tiefenbacher, 2009) and 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 drivers 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).

Psychological theory applied to driving though floodwater research

In an extensive search of the literature, the Theory of Planned Behaviour (TPB) is the only theoretical approach that has been found to have been applied to the context of people's behaviour around floodwater and driving vehicles.

The TPB (Ajzen, 1991) is a prominent decision-making model that has been applied to understand health and risk behaviours. The model states intention as the most proximal predictor of behaviour, with intention determined by three social-cognitive variables: attitudes (overall positive/negative evaluations of performing the behaviour), subjective norms (perceived social pressure from important others to perform the behaviour), and perceived behavioural control (perceived amount of control over behavioural performance; also theorised to predict behaviour directly). Meta-analytic studies support the use of the TPB in predicting individuals' behaviours (Armitage and Conner, 2001; McEachan et al., 2011), including risky water-related behaviours such as swimming (Hamilton and Schmidt, 2013; Pearson and Hamilton, 2014). Figure 1.3 provides an outline of the TPB.

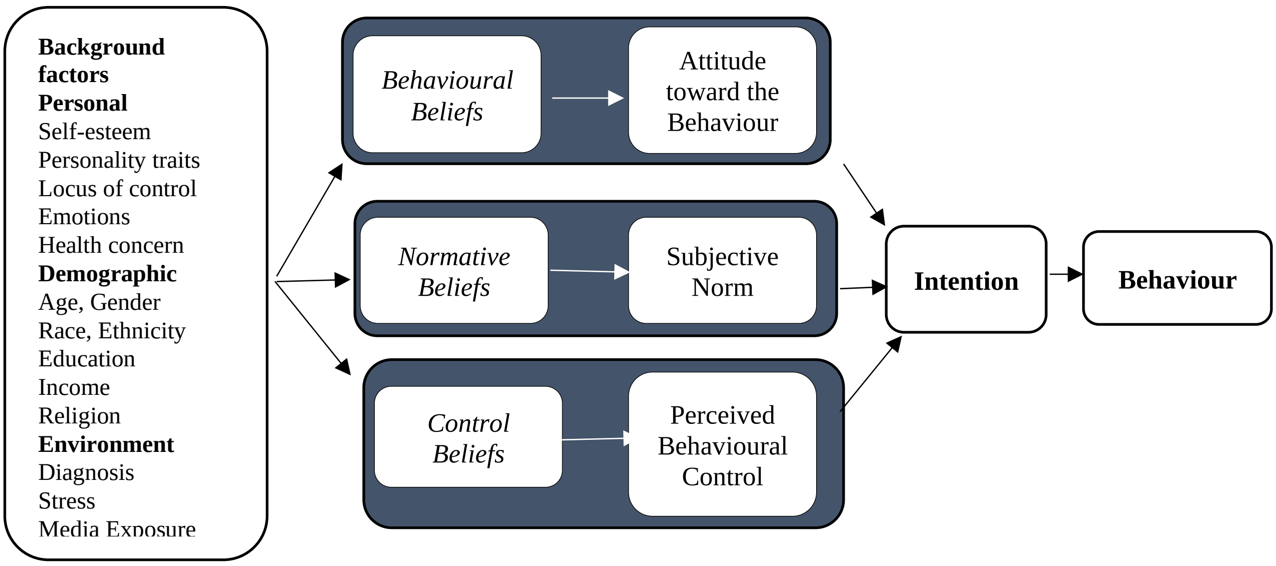

Figure 1.3 The theory of planned behaviour (Ajzen, 1991)

An important feature of the TPB is the hypothesis that the antecedents of attitudes, subjective norms, and perceived behavioural control are corresponding salient behavioural, normative, and control beliefs, respectively, reflecting the systems of beliefs that underpin an individual's intention and behaviour (Ajzen, 1991, 2015). These beliefs can be used to develop theoretically-based and empirically-driven behaviour change messages that are relevant to the target group (Ajzen, 1991, Epton et al., 2015). Formative research on beliefs, therefore, is necessary not only for depth of understanding of the behaviour in a given population but to test theory and the efficacy of the TPB mechanisms in changing behaviour; although researchers seldom conduct this necessary formative work (Ajzen, 2015; Epton et al., 2015). An emerging number of studies have adopted the TPB framework to elicit beliefs for risky water safety behaviours including swimming between the flags at Australian beaches (Hamilton, et al., 2016b), swimming while intoxicated (Hamilton and Schmidt, 2013) and, relevant to this context, driving through floodwaters (Hamilton, et al., 2016a; Pearson and Hamilton, 2014). In addition, the TPB has been successfully applied to behaviour change interventions (Fife-Schaw et al., 2007; Parker, et al., 1996). The model, however, is not without shortcomings, particularly its focus on static prediction rather than dynamic change in behaviour (Sniehotta, et al., 2014). Notwithstanding these, the TPB has been proposed as a useful framework to adopt as a starting point in the development of more comprehensive, integrated theories toward a better understanding of human behaviour (Hagger, 2015; Hagger and Chatzisarantis, 2014).

Previous psychological research applied to driving though floodwaters

Previous research has provided emerging evidence for the psychological factors that influence individuals' decisions to drive through floodwater (Hamilton et al., 2016a, Pearson and Hamilton, 2014, Taylor et al., 2016). These factors include past experience, attitudes, social pressure, self-efficacy beliefs, and risk perceptions. Regarding the latter, the severity of the risk has been shown to have an effect on drivers' willingness to enter floodwater, but not the susceptibility of the risk (Pearson and Hamilton, 2014). Pearson and Hamilton (2014) explained that drivers may recognise the risk but fail to personalise it, demonstrating 'optimism bias'. Similarly, Taylor et al. (2016) found that merely understanding the risk and associated consequences does little to change individuals' behaviour when faced with a flooded path.

Building on this previous research, Hamilton and colleagues have recently published a series of studies using qualitative, mixed method, and experimental designs to better understand the influences on individuals' beliefs and intentions to drive and avoid driving through floodwater (Hamilton et al.,2018; Hamilton, et al., 2019). It is important to understand the beliefs guiding behavioural alternatives (i.e. intentionally driving through floodwater, intentionally avoiding driving through floodwater) as there is research to suggest that performing and not performing a given behaviour are not conceptual opposites, and that different motivational pathways may operate in guiding individuals' decisions to engage in an action or behaviour (Richetin, et al., 2011;).

Findings (Hamilton et al., 2019) indicated four overarching themes that emerged in drivers' descriptions of factors that influenced their decision to drive through floodwaters:

- past experience, e.g. successfully having driven through floodwaters before,
- individual factors, e.g., pressure to arrive at destination, situation perceived as different to warnings,
- the social environment context, e.g. pressure and encouragement from others, seeing other motorists driving through, and
- self-efficacy judgements (belief in one's own ability to successfully drive through floodwaters).

Three overarching themes: behavioural beliefs (e.g. safety first and foremost), normative beliefs (e.g. think of the rescuers) and control beliefs (e.g. destination wasn't that important) based on the TPB belief-based framework emerged in drivers' descriptions of factors that influenced decisions to avoid driving through floodwaters (Hamilton et al., 2019).

1.6 Theoretical concepts used in current thesis

Research included in this thesis applied a number of concepts from two theories that had not been used previously in this context. These theories are: The Extended Parallel Process Model (EPPM) and the Recognition Primed Decision-Making Model (RPD). The concepts and model of these theories is described below:

The Extended Parallel Process Model (EPPM)

The EPPM borrows heavily from three antecedent theories: fear-as-acquired drive model (Hovland, et al., 1953), parallel process model (PPM) (Leventhal, 1971) and protection motivation theory PMT (Rogers, 1975). Specifically, the EPPM utilizes the protection motivation theory linkages among perceived levels of severity, susceptibility, response efficacy, and self-efficacy that lead to message acceptance and, ultimately, attitude, intention and behaviour changes. Yet PMT does not specify directly in either the original or the revised model when and why people reject these recommendations. The PPM, however, argues that protective behaviour stems from attempts to control a real or potential threat (cognitions), not attempts to control fear resulting from the process (emotions). In comparison, the EPPM offers 12 specific propositions and predictions as to the separate conditions under which fear/emotion and danger/cognition responses should occur, thereby elucidated why fear appeals messages should both succeed (i.e., danger control) and/or fail (i.e., fear control). Although both the PMT and PPM are very useful frameworks for viewing responses to fear appeals messages, the EPPM appears to be a more inclusive framework for conducting this formative evaluation. The overall organization of the EPPM is presented in Figure 1.4.

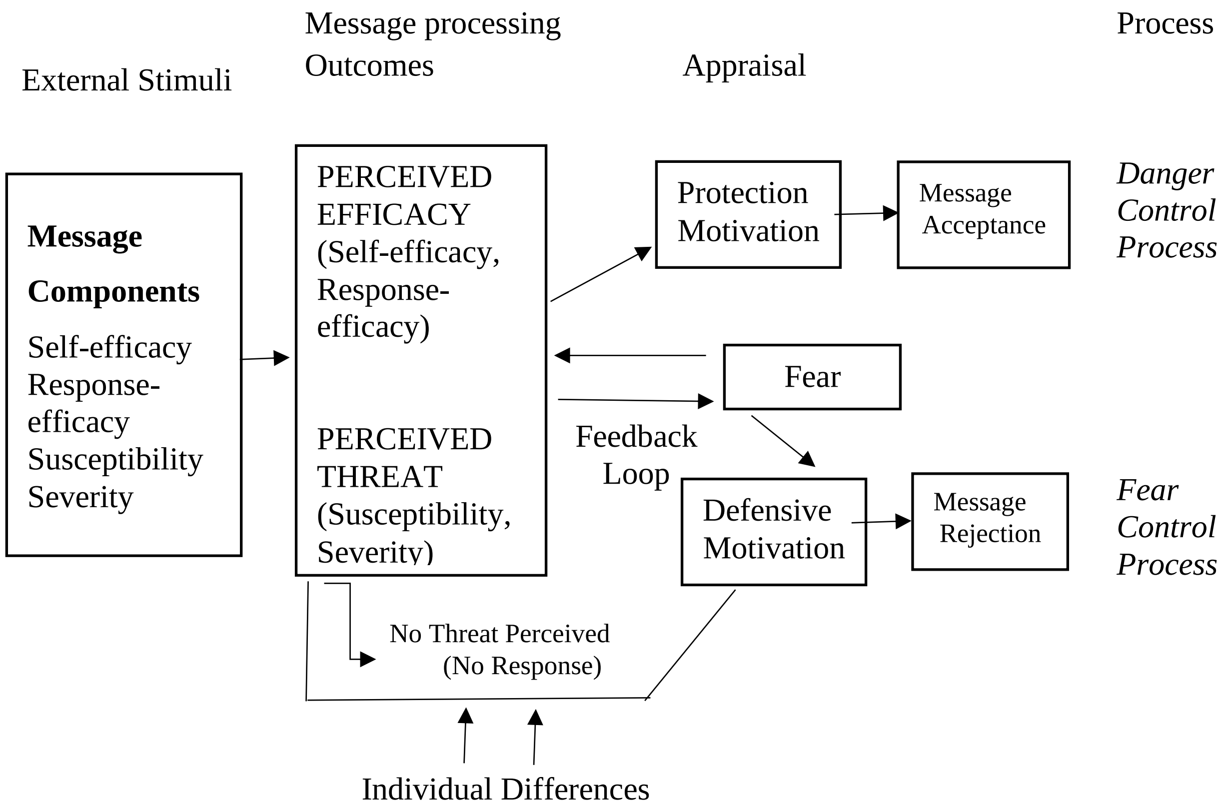

Figure 1.4 The extended parallel process model (Witte, 1992)

The EPPM suggests that when presented with a risk message, individuals engage in two appraisal processes which produces one of four outcomes (see Table 1.2).

Table 1. 2

Interactions between threat and efficacy to produce danger control and fear control responses

	High Efficacy Beliefs that one is able to effectively avert a threat	**Low Efficacy** Beliefs that one cannot avert a threat, and even if she/he could, it wouldn't work anyway
High Threat Beliefs that one is at risk of a significantly harmful threat	**Danger Control** People taking protective action against health threat.	**Fear Control** People in denial about health threat, reacting against it.
Low Threat Beliefs that a threat is irrelevant and/or trivial	**Reduced level of Danger Control** People taking some protective action, but not really motivated to do much	**No Response** People not considering the threat to be real or relevant to them; often not even aware of threat

First, individuals appraise whether they are susceptible to the identified threat and whether the threat is severe. Perceived susceptibility is the extent to which an individual feels at risk for a particular (health) threat, whereas perceived severity is the extent to which an individual believes the threat to be serious or harmful. If the threat is perceived as either trivial or irrelevant, they will ignore the risk message and not even think about recommended behaviours (because the threat is not of concern to them).

Second, if individuals believe they are susceptible to a severe threat (i.e. high perceived threat, which comprises both perceived susceptibility and perceived severity) and fear is aroused, they are motivated to act and appraise the extent to which the recommended response effectively deters the threat (i.e. response efficacy) and the extent to which they are able to perform the recommended response (i.e. self-efficacy). When perceived threat is high and individuals believe themselves able to perform a recommended response that effectively minimizes the threat, they will control the danger and follow the recommended guidelines. However, when the perceived threat is high but individuals doubt their ability to effectively minimize the threat (such as personal, social or physical barriers), they turn instead to controlling their fear and engage in denial, or defensive avoidance.

In sum, perceived threat (i.e. perceived susceptibility and severity) motivates action. Perceived efficacy (i.e. recommended response efficacy and self-efficacy) determines whether individuals control the danger and make behavioural changes or control their fear through psychological defence mechanisms, such as defensive avoidance or reactance.

EPPM is one of the major theories within the domain of psychological research on health behaviour. Research using EPPM covers a large number of health-related topic: drug abuse (Allahvardipour et al., 2007); fear appeals (Witte and Allen, 2000); train crossing (Witte and Donohue, 2000); smoking (Wong and Cappella, 2009). A small number of studies were identified that used EEPM to explore vehicle-related behaviour, specifically, speeding (Lewis, et al., 2007), and driver fatigue (Tay and Watson, 2003). Studies applying EPPM to natural hazards are rare.

A systematic review on application of behavioural theories to disaster and emergency health preparedness (Ejeta, et al., 2015) showed few studies assessed health workers' preparedness for emergency response, applying Witte's Extended Parallel Process Model (EPPM) (Balicer et al., 2010; Barnett et al., 2010; Errett et al., 2013). A number of studies have applied the EPPM to assess preparedness in the context of disease outbreaks, e.g. H5N1(Siu, 2010). The rationale for application of EPPM are its usefulness to understand adaptive behaviour in the face of unknown risk (Barnett et al., 2010), its usefulness to understand how health care may positively or negatively influence healthcare workers' willingness to fulfil the response expectations (Balicer et al., 2010), and to test the model's suitability to the disease context generally (Siu, 2010).

In the United States, EPPM has been used as a strong theoretical framework in research on hurricane preparedness (Hoang, 2015) for understanding hurricane risk. This researcher performed a content analysis on national and local weather blogs about Hurricane Ike. EPPM components for each weather blog were examined. Posts were analysed for blogger and user activity (i.e. providing links, quotes, pictures, etc.) and message content (i.e. perceived susceptibility, perceived severity, response efficacy, and self-efficacy). The results of the content analysis of weather blogs indicated that a significant portion of the posts were likely failing to motivate behaviors to circumvent, or reduce, the effects of hurricane risks. The most frequently conveyed message component in the blogs was perceived severity followed by perceived susceptibility, and did not the efficacy components. The findings suggest that when blog posts do not communicate the anticipated outcomes or damage, or the intensity of the hurricane, the audience may be less likely to perform adaptive behaviors including buying supplies, securing loose outdoor items, or evacuating (Hoang, 2015). Choi and Lin, (2008) also used the EPPM to analyse newspaper coverage of three major hurricanes in 2005 during a one-week period before the storms actually occurred.

The strength of the EPPM has allowed researchers to apply the model in efforts to prevent the risk of occupational safety hazards as well. Murray-Johnson et al., (2004) evaluated the EPPM dimensions in addition to subjective norms and channel preferences of coal miners' regarding hearing loss and hearing protection. Among the findings, all participants agreed hearing loss was harmful, serious, and affecting their quality of life. Witte et al., (1993), also report unexpected perceptions of preventing tractor-related injuries and deaths. While tractor operators recognise the severity of farm equipment accidents, they do not feel particularly vulnerable.

In this thesis EPPM has been used in Study 3 on the assumption that, in the context of driving through floodwater, the concepts from the EPPM model might help us to understand the driver's perception of the issue. This includes consideration perceived severity, perceived susceptibility, response efficacy, and self-efficacy. Understanding the interactions between threat and efficacy to produce danger control and fear control responses explained by the EPPM model might lead to explanations for drivers' decisions to drive through, or avoid, floodwater.

The Recognition Primed Decision-Making Model (RPD)

The Recognition Primed Decision Model has been developed within naturalistic decision-making research, which lies within a more general framework of cognitive task analysis (Militello, et al., 2009). The RPD Process was created by research psychologists Gary Klein, Roberta Calderwood and Anne Clinton-Cirocco in the late 1980s. Klein then published it in his 1999 book, "Sources of Power: How People Make Decisions." The researchers developed the process after studying professionals who regularly make quick, life-or-death decisions, such as firefighters, emergency medical technicians/paramedics, and nuclear technicians. They found that existing decision-making models didn't adequately explain how people make good decisions under pressure.

Recognition-primed decisions are common in complex, time-constrained domains in which decision makers have a high level of expertise, ranging from 42% of all decisions for tank platoon leaders up to 95% for naval Aegis commanders (Klein, 1998). The model has four major features: the recognition of cases as typical, situational understanding, serial evaluation, and mental simulation. To elaborate, first, the RPD model proposes that on the basis of their experience with a variety of cases, experts can recognize whether a situation is typical or familiar. Second, the RPD model proposes that in recognising a situation as familiar, the decision maker can draw on prior experience for guidance on how to proceed with respect to four different types of information: (1) plausible goals, that is, what is possible to accomplish in the situation; (2) critical cues and causal factors, that is, what cues to attend to and what their causal implications are; (3) expectancies, that is, what is likely to happen and when; and (4) typical actions, that is, what responses are typical in the situation. Third, the RPD model proposes that experienced decision makers engage in serial evaluation of options whereby they assess options one at a time until a satisfactory one is found (as opposed to concurrent evaluation of options whereby a set of options is generated and evaluated comparatively). Moreover, the first option selected by experienced decision makers is the most typical option and, therefore, has a high likelihood of being effective. Fourth, the RPD model proposes that experienced decision makers evaluate one option at a time by the use of mental simulation or, in other words, by imagining how an action or option will be carried out within the specific setting. Mental simulation allows the decision maker to forecast the adequacy of an action. The model is presented graphically in Figure 1.5.

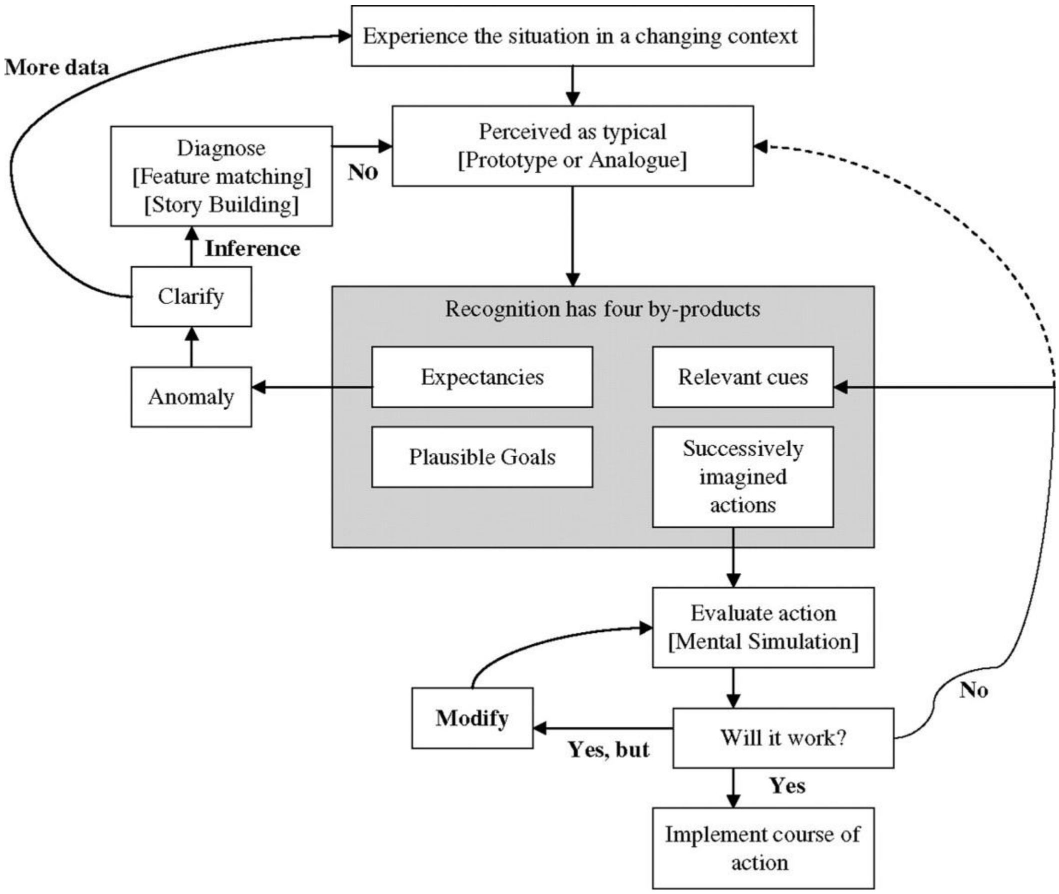

Figure 1.5 The RPD model (Klein, 1993)

Decision-making, or the process by which a decision is formulated can be described as a subset of an individual’s information processing capacity (Wickens and Flach, 1988; Wickens and Hollands, 2000). The initial assessment of a situation is a critical aspect of decision making, since the accuracy of the process determines, in large part, the accuracy of the response. Referred to as situation assessment, it constitutes a significant component of the RPD model of expert decision making and involves a process of matching features in the environment to feature-event associations in memory. It is this repertoire of feature-event associations or cues that enables the recognition of a situation as familiar and the application of an appropriate response. The ability to make use of appropriate cues has recently been developed into an approach to measure and evaluate expert performance (Wiggins et al.,2015). This set of cue-based tasks has successfully differentiated competent and expert diagnostic performance in a range of domains.

Contemporary cue utilisation theory

Cue utilisation refers specifically to an individual's application of cue-based processing as assessed by patterns of behaviour that are indicative of the utilisation of cues (Newell and Simon, 1972; Wiggins, 2012). Cue utilisation circumvents the subjective nature of classifying features as having greater or lesser predictive validity, with the distinguishing feature of focusing on the way that humans acquire and utilise cues, rather than focusing on specific feature or cues themselves (Loveday, et al., 2013; Weiss and Shanteau, 2003; Wiggins, et al., 2014).

Cue utilisation is based on the proposition that the effective use of cues, irrespective of the specific cues used, will result in predictable patterns of behaviour (Wiggins, 2012, 2015). For example, a skilled power distribution network controller may respond appropriately to a loss of supply in the system based on the number of substations and the type of fault on the feeder. Another operator, just as skilled, may respond in the same manner based on different features, such as the type of distribution feeder and the current temperature. While the operators are relying on different cue-based associations, they both respond in an adaptive and predictable manner. Based on this theory, **Study 4 (Chapter 5)** will detail an experiment in which a measuring tool was developed to assess cue-utilisation in the context of floodwater and driving. This study sought to explore cue utilisation in SES personnel

1.7 Prevention strategies

The World Health Organization's (2014) global report on drowning recommended that prevention is vital to combat drowning rates, given the often-fatal outcome. The Australian Water Safety Council (2012) has established the goal of achieving a 50% reduction in drowning deaths by the year 2020 (Australian Water Safety Council, 2012). Consistent with this goal, the Australian Water Safety Strategy 2016-2020 has targeted reducing the impact of disaster and extreme weather on drowning deaths, with driving through floodwaters identified as a priority behaviour. Key objectives in achieving these aims are to implement strategies that raise community resilience and awareness of water safety, and promote better education and skills to prevent drowning from motor vehicle-related aquatic activities (Australian Water Safety Council, 2016). Research has highlighted the importance of adopting a systems approach to changing behaviour (Ahmed et al., 2018; Haynes et al., 2017). Peden et al. (2004), in a World Health Organisation review of road traffic injury prevention, concluded that road safety campaigns were able to influence behaviour when used in conjunction with legislation and law enforcement. Strategies to prevent flood fatalities associated with vehicles and people entering floodwater can be categorised into engagement, engineering, enforcement/incentive and emergency response (Ahmed et al., 2019; Gissing et al., 2016; Hynes et al., 2017; Peden et al., 2017)). These are outlined below.

Communication and Engagement

Australian emergency services in Queensland, New South Wales, and Victoria have conducted major campaigns aimed at reducing the incidence of individuals entering floodwater. These have included "If it's flooded forget it" (QLD and NSW), "15 to float" (Victoria, Figure 1. 6) and "You don't know what you're getting into" (Victoria, NSW). These campaigns have involved a combination of television, radio or print advertising, accompanied by promotion through social media.

Figure 1.6 15 to float graphic campaign

In 2018 NSW SES utilised a series of social media videos recreating real stories of those who entered floodwater, spoken by the individual. During recent flood operations in 2017 they also utilised the hashtag "floodwit" to discourage people from entering floodwater (Figure 1.7), and potentially engage with a younger audience segment. Victoria SES (VICSES) have also previously conducted an online campaign called "Whose poo", focused on communicating that floodwater is contaminated with a range of unpleasant things.

Figure 1.7 NSW SES social media graphic

Nationally, the Royal Life Saving Society (RLLS) delivered a campaign titled "Respect the river". This campaign focuses on the reduction of drowning on inland waterways, including those incidents that result from flooding. Further, in 2016 the RLLS, in partnership with the motoring organisation NRMA and Griffith University, developed a social media campaign using a video infographic called "For Life's Sake – The Dangers of Driving Through Floodwater".

Campaign Evaluation

Despite campaigns, people in Australia still enter floodwater. For example, in NSW, research following flooding in March 2017 identified that 47% of community members surveyed had entered floodwater on foot and 4% had driven through floodwater (Haynes et al., 2017). Generally, it appears that communication campaigns are not well evaluated. However, it can be challenging to find evidence of evaluation or access evaluation reports as they are not openly available. Limited evaluation evidence regarding the QLD “If it’s flooded forget it” campaign indicated that around 70% of those surveyed recalled the campaign, mostly through television advertising. Only 58% of respondents indicated that it was enough to stop them from entering floodwater and only 56% thought it was relevant to them. Evaluation results also indicated that there was ambiguity around the meaning of “flooded” (Prevention of flood-related deaths working group, 2016)

It is a common misbelief that people choose to enter floodwater because of a lack of knowledge about the dangers of driving through floodwater (Franklin et al., 2014). In fact, given increased attention to this risky driving behaviour in the media, Hamilton et al. (2018) found that the dangers are known to many Australians and that individuals can recall and understand the risks of driving through floodwaters yet continue to ignore safety messages and drive through. These results have been supported by others (Taylor et al., 2016; Shevellar and Riggs, 2015). Even though drivers commended safety campaigns and messages, some drivers perceive them as not relevant to their own circumstances, believing their specific situation to be different from those referred to in the warnings (Shevellar and Riggs, 2015). This highlights that having knowledge does not always translate into behaviour, suggesting that the behavioural decision-making in vehicles around floodwater is based on more than knowledge acquisition alone (Gissing, 2016, Pearson and Hamilton, 2014, Taylor et al., 2016).

Key Messages

Key messages across Australia do vary slightly and sometimes compete with “how to” messages provided by 4WD groups. Although seen as appropriate, how practical flood safety messages are has been challenged given that, in many cases, motorists have in the past successfully crossed flooded roadways (Affum, et al., 2015). Messages promoted within the 4WD community commonly encourage motorists to check the depth of an inundated roadway by walking the flooded section of a road or river crossing. In some instances, it may be possible for an adult to safely wade across a flooded road, but not to drive across the same section due to the increased vulnerability of vehicles in the specific circumstance (Australian Institute of Disaster Resilience, 2017). Table 1.3 shows some recent key messages by each Australian jurisdiction.

Table 1.3

Key Messages by Australian jurisdictions.

Jurisdiction	Key Message	Source
QLD	If it's flooded, forget it. Just a small amount of floodwater can wash your vehicle away.	QFES
NSW	Never drive, ride or walk through floodwater. You don't know what you're getting into.	NSW SES
WA	Driving on roads during or after a flood is extremely hazardous. Roads may be damaged, bridges destroyed and communities may be isolated by floodwaters for days, weeks or months. Do not drive into water of unknown depth and current.	DFES
VIC	Floodwater is dangerous – never drive, walk or ride through floodwater. Floodwater is toxic – never play or swim in floodwater.	VICSES
SA	Never attempt to drive in floodwaters. Never enter floodwaters and in particular do not allow children to play in or near them.	SA SES
TAS	Never drive, ride or walk through floodwater – this is the main cause of death during floods. Floodwater may be deeper and faster flowing than you think and may contain hidden snags and debris. This includes causeways and low-lying roads.	TAS SES
NT	Do not let children play in or near floodwater. Do not walk through floodwater. Do not drive through floodwater.	NT SES
ACT	Never enter or travel through floodwater	ACT SES

Additional Engagement Avenues

Concerns have been expressed about the impact of television advertising and media footage that provides imagery of 4WD vehicles driving through floodwater or reporters engaging in unsafe behaviours, standing in floodwater (Campbell, 2014). No research exists regarding the impact of advertisements on driver behaviour: however, research into the influence of advertising that illustrates other forms of risky driving behaviour concluded that there was no immediate effect of brief exposure to such advertisements on risk-taking behaviour, though the risks associated with accumulated exposure were unknown (Vingilis et al., 2015). Motor vehicle advertising in Australia is governed by a voluntary code of practice. This code states that motor vehicle advertisements cannot promote illegal driving behaviours or show motorists driving in an unsafe manner (Kaye et al., 2015). Campbell (2014) researched the influence of media imagery through a public survey, finding that some 17% of respondents had been significantly or somewhat influenced to enter floodwater as a result of imagery shown by the media.

Gissing (2016) identified that emergency service vehicles also entered floodwater along a closed section of road, possibly sending the wrong message to other motorists that driving along a flooded road that had been closed was safe. Further work is required in this area to identify the level of influence such actions have on general motorist behaviour, but it is considered likely to undermine engagement efforts to modify behaviour.

Work-related flood fatalities and rescues do occur. There is scope to further encourage businesses as part of their work health and safety systems to adopt policies that discourage their employees from entering floodwater. In the broader road safety context, work-related road safety has grown in importance and has been recognised as a possible conduit for improving broader community road safety (Wallington et al., 2014). A case study of British Telecommunications showed that improving organisational road safety practices and culture resulted in more than halving collision rates and costs (Wallington et al., 2014). In the Australian context, research has concluded that organisations need to place greater priority on road safety risk management practices (Warmerdam et al., 2017).

Engineering

A floodway is defined as a longitudinal depression in a roadway specifically designed to accommodate the passage of floodwater (Affum, et al., 2015). Floodways are typically utilised in situations where there are no other practical alternatives to provide a bridge or culvert (Affum, et al., 2015). Most floodways are located on rural roads (Affum, et al., 2015). A large portion of floodways in Australia are found to be inadequate in terms of design and signage standards (Affum, et al., 2015). Floodways though similar to fords are different in that they attempt to provide a dry crossing environment, where as a ford is typically a wet crossing within a stream. Specific guidelines for the construction of floodways are outlined in Austroads (2013) and further detailed in Affum, et al., (2015), including the safety considerations: adequate approach sight distance should be provided to allow motorists time to recognise flooded roads; the depth of water over the floodway should be as uniform as possible; road closure should be considered when floodwater reaches 300mm or more over the road surface; floodways should not be placed on horizontal curves and design should resist scour and washouts; the length of a floodway should not exceed 300m so that motorists do not become disorientated; motorists should be able to turn vehicles around and seek alternative routes; and signage consistent with Australian standards (including AS 1742.2) should be provided including road subject to flooding signs, floodway or ford signs and depth markers.

In the United States, there is evidence that numerous hazard management bodies have undertaken activities to upgrade floodways (low level crossings), as referenced in the City of Austin Hazard Mitigation Plan (City of Austin, 2016). In Australia, at present there is no accepted process for prioritisation or planning for floodway upgrades to reduce the incidence of motorists entering floodwater.

Signage

Current signage standards for water crossings are based on AS 1742.2 (2009). Affum, et al., (2015) state that Given that all designated floodways will at some time have water flowing over the road with varying flood levels, all water crossings must have in place a ford or floodway sign, depth indicator and water over road sign. Depth markers also require knowledge of critical flood thresholds, which motorists and other individuals may not have (Affum, et al., 2015). Common flood signage also tends to warn motorists of the possibility of a flooded road rather than the actuality of a road being flooded (Martin, 2010). Affum, et al., (2015) conclude that existing signage does not provide the most important information, this being, in their view, the product of water depth and velocity for a given vehicle. Although technology exists to measure the product of depth and velocity, it is not considered cost effective for low volume roads (Affum, et al., 2015).

Affum, et al., (2015) found that it was uncommon to find all required signs and guideposts present at floodways, therefore placing motorists at greater risk. Gissing et al., (2019) identified that signage was present at only twelve of twenty-one different sites where flood fatalities had occurred. Further, where road barricades and closure signage were present, Gissing (2016) identified that some 84% of motorists chose to ignore them. The fact that motorists continue to enter floodwater where signage is present suggests that motorists either ignore, misinterpret or simply do not see signage. Coles et al. (2009) found that 90% of survey respondents would be strongly influenced by signage in their decision not to enter floodwater. Similarly, 90% of respondents thought signs indicated the likelihood of flood danger: however, only 44% thought signs indicated the degree of danger (Coles et al., 2009). It has also been found that leaving road closed signs up after floodwater recedes has a negative effect by reducing the trust motorists have in this advice (Wright et al., 2010).

Flood signage is largely passive. Research in the context of railway crossings has shown that active controls - for example flashing lights, gate controls and sound signals (including in vehicle audio) - are more effective then passive stop signs (Liu, et al., 2016; Tey, et al., 2011;

Tey, et al., 2013). Rumble strips on roadways have been proven to be less effective than active controls (Tey et al., 2013). Despite the effectiveness of active controls, vehicle collisions still occur at railway crossings with active controls (Tey et al., 2013).

Further, research in the context of school zones has shown mixed results, with some researchers identifying a positive effect from utilizing signs, whilst others argue that signs have little to no effect on driver behaviour (Strawderman, et al., 2015). The combination of text signs and flashing lights has been shown to be more effective than flashing lights or text signs in isolation in reducing speeding (Gregory, et al., 2016).

Enforcement / Incentive

Regulation is frequently utilised to change behaviour: for example, reducing speeding and drink driving, and eliminating smoking from public spaces. There are specific examples of motorists being charged with dangerous driving offences in QLD and in NSW as a result of driving into floodwater. In 2012, a QLD man was convicted of manslaughter and jailed after driving into a flood after his action was responsible for a passenger’s death (Gissing et al., 2015). In the United States, the State of Arizona in 1995 passed the “Stupid Motorist Law”, which holds a person who recklessly enters floodwater in a vehicle liable for the cost of their rescue. A similar law was voted on in the State of Virginia in 2016, but was not passed. No such specific legislation exists in Australia.

It has been suggested that motorists who require rescue as a consequence of entering floodwater should be liable for the costs of the rescue efforts. However, it has been suggested that this may result in a resistance by those in need to seek emergency assistance from rescue agencies, placing them at greater risk (Prevention of flood-related deaths working group, 2016).

The central premise of deterrence theory is that crime can be prevented when punishment is certain, quick and severe (Goldstein, et al., 2011; Eassey and Boman, 2016). General deterrence is aimed at reducing a certain action by directing threat of sanction at all possible offenders. Specific deterrence is aimed at reducing a certain action by applying a sanction to a specific offender (Sentencing Advisory Council, 2011).

The effectiveness of deterrence mechanisms has been well studied in the context of road safety. The enforcement of drink driving laws has been shown to be effective both in Australia and internationally. The introduction of random breath testing in New South Wales in 1982 led to a 48% decrease in fatal crashes over an initial four and half month period and a decrease in fatal crashes over a subsequent ten-year period (Terer and Brown, 2014). Further random breath testing led to reductions in fatal crashes of 28% in Western Australia and 35% in QLD (Terer and Brown, 2014). In Canada, the introduction of laws targeting speeding and drink driving were attributed in the two-year period after their implementation to reducing fatal vehicle crashes by 21% (Brubacher et al., 2014). In the context of criminal justice, it has been concluded that the threat of imprisonment has a small general deterrent effect. The certainty of apprehension and punishment has been consistently found to be associated with the greatest impacts (Sentencing Advisory Council, 2011).

Emergency operations

Warnings

The purpose of a flood warning system is to provide information to inform decision making of emergency response agencies and the community to enable proactive actions to mitigate the impacts of flooding. The Total Flood Warning System (Australian Emergency Management Institute, 1995) consists of the following components:

Monitoring of rainfall and river level conditions that may result in flooding;

- Prediction of flood severity and time of onset of particular flood levels;
- Interpretation of flood predictions to determine the likely consequences on the community;
- Construction of warning messages;
- Communication of warning messages to communities;
- Response to the warnings by communities and emergency response agencies;
- and Review of the warning system after flood events.

In the context of reducing the number of people entering floodwater, warning messages contain specific advice messages to people not to enter, or to avoid entering, floodwater. Several different types of flood warning products exist. These include: Flood Watch; Flood Warning; and Severe Weather Warning.

At many sites where flood-prone roads exist there are unlikely to be specific flood warning systems. The advice to individuals contained in more generalised severe weather warning and flood watch products should be to encourage motorists to check local road conditions before embarking on a journey.

Road/Traffic Information

Road closure and traffic information is typically in high demand during floods. This information is commonly provided via websites, radio stations, phone hotlines and social media. Commonly utilised sources include local government and road operator webpages and apps (e.g. Live Traffic). There can be challenges in collating up to date road information and, in some cases, there is no single source of information, with road information being supplied by different road operators. Specific examples exist of attempts to specifically communicate road information in relation to floods. The City of San Antonio and Bexar County in the United States has developed a web-based mapping portal to display alternative routes around flood-prone road crossings. Information on the website is supported by sensors (High Water Alert Lifesaving Technology) at each site that detect when floodwater is present. Information can also be sent by text message or email alerts for certain sites that subscribers may be interested in. Bexar County has installed some 150 flood sensors (Bexar County, 2017).

Summary

This section provided an overview of many different strategies that are used to reduce or prevent drivers entering floodwater. Many relate to physical control measures, such as barriers, or to messaging and information that increase general awareness and reinforce the level of threat. Drawing on EPPM, these latter approaches may work to increase perceived severity and perceived vulnerability in relation to the threat, but do little to provide alternative solutions to increase self-efficacy. As such they may also serve to drive maladaptive behaviours, such as wishful thinking and denial that may lead to risk-taking, e.g. believing that a negative outcome won't occur 'to me', or that it can't be that dangerous to drive through. Although approaches enabled through improved technology, such as better real-time road and traffic information and active warning systems, provide better quality information for drivers there is, as yet, no apparent evidence to suggest that they are effective at preventing this risky behaviour.

It should be noted that the strategies reviewed in this section are those directed at all road users. In addition to these, emergency services may be subject to organisational approaches, such as workplace health and safety policies, and supported with training in risk-based decision-making strategies. These organisational aspects are considered further in Chapter 4.

1.8 Thesis Aims and Overview

Floods are the most frequently occurring disaster worldwide, and are responsible for the majority of disaster victims, the largest number of deaths, and the greatest economic costs of all disasters (Guha-Sapir, et al., 2012). Drowning is a major public health issue that accounts for 7% of all injury-related deaths making it the third leading cause of unintentional death worldwide (World Health Organization, 2014).

During a flood, one of the behaviours that places people at greatest risk of flood- related drowning is intentionally driving through floodwater (FitzGerald, et al., 2010). People are engaging in this risky driving when it is evident that vehicle-related flood drownings are often avoidable. From the literature, it also emerged that those who work in specific occupations (e.g., emergency services, utility maintenance workers, mail delivery personnel, and miners) are more likely to enter floodwater (Becker et al., 2015).

As the primary response agency for floods, storms, and tsunamis, State Emergency Services (SES) members are at higher risk of driving into floodwater, despite the risks and costs involved. This thesis includes studies with this occupational group, and addresses the issue of encountering floodwater as a workplace health and safety issue.

This thesis has four overarching aims, designed to build on contemporary academic literature and applied knowledge to investigate the behaviour of driving through floodwater. These aims are as follows

1. To investigate the significance of the problem within, and outside, Australia and identify the main risk factors associated with driving through floodwater.
2. To explore the contexts surrounding motor vehicle-related fatalities in Australia, as an important public safety issue.
3. To explore the risk perceptions and decision-making processes of SES personnel when they encounter floodwater on the road, using this group as a higher risk group for entering floodwater in vehicles.
4. To investigate whether differences in the way SES personnel use information in the environment (cue utilisation) can be differentiated, and if so, whether higher cue utilisation is related to improved ability to assess floodwater risk.

In order to achieve these aims, four studies were conducted (Figure 1.8).

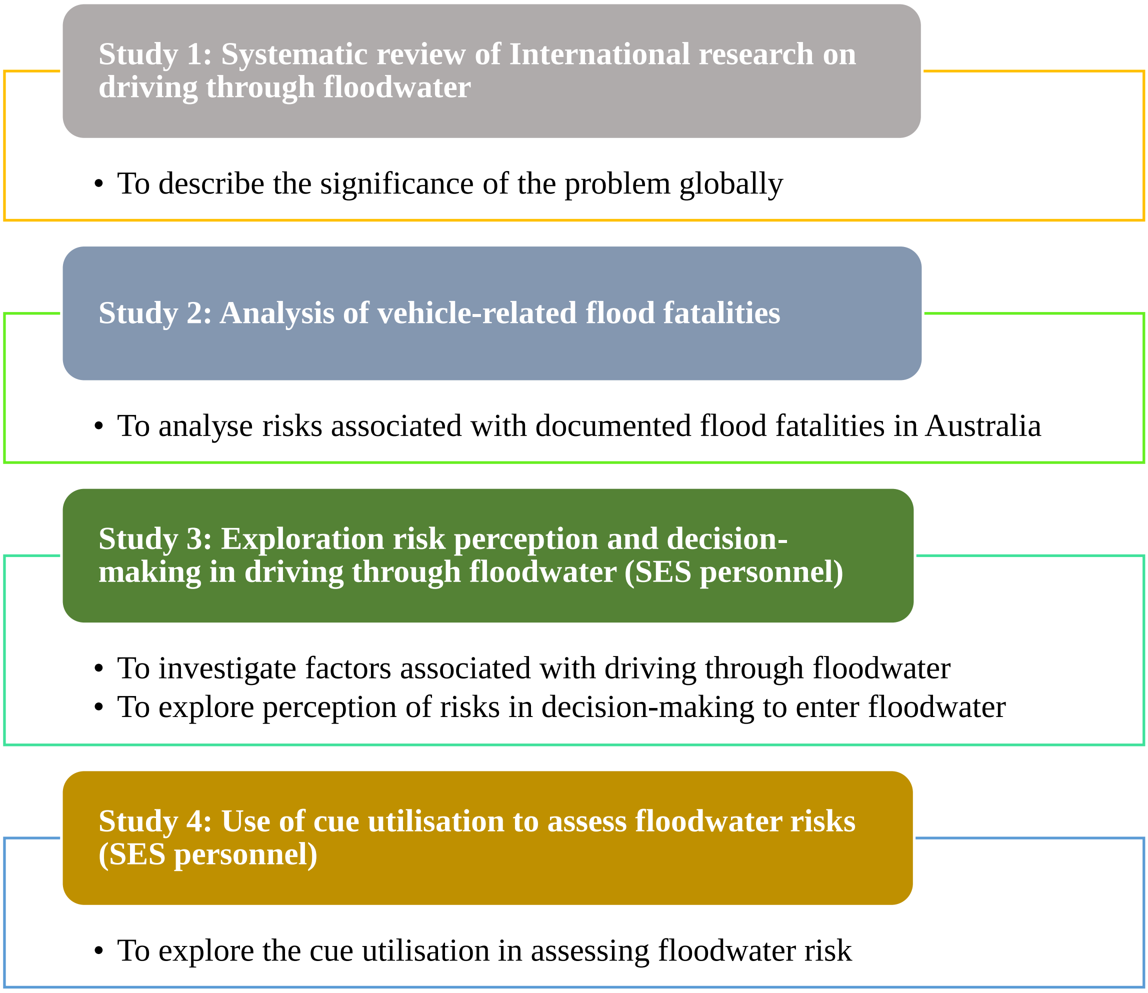

Figure 1.8 A summary of the research aims in the programme of research

The research chapters for this thesis are presented as follows:

Chapter 2 (Study 1) systematically reviews the literature related to driving through floodwater, to see the impacts of driving into floodwater in flood fatality data **(Aim 1),** to identify the risk factors responsible for the fatalities; to explore the application of different theories and models; and to explore possible interventions to reduce risks. Findings from this chapter are used to present and compare the number of vehicle-related flood deaths in different countries, to explore the risk factors, and propose a holistic intervention framework. This chapter's findings are used to select variables and contribute to the design of the questionnaire used for **Study 3.**

Chapter 3 (Study 2) analysed the National Coronary Information System (NCIS) database to explore the circumstances of recent vehicle-related flood deaths in Australia **(Aim 2).** Findings from this chapter make an important contribution to our understanding how and why vehicle-related flood fatalities occur, and how they have changed over time.

Chapter 4 (Study 3) involved the design of a detailed survey for emergency services personnel to explore their experiences of driving through floodwater. This survey investigated the contexts and conditions under which emergency services personnel entered floodwater; to identify risk factors in the operational contexts they work in; to explore how those factors contribute to shaping drivers' perceptions of risk, and how that risk perception is affected by socio-cognitive influences on decision-making. The study proposes a conceptual model of decision-making in the context of driving through floodwater for emergency services, using concepts taken from the Recognition-Primed Decision Model and EPPM. The results of this study identify the direction and degree of relationship between risk perception and socio-cognitive influences on decision-making by SES drivers **(Aim 3).**

Chapter 5 (Study 4) documents the development of a novel set of tasks, using the Expert Skills Evaluation (EXPERTise 2.0) software shell platform (Wiggins et al., 2015) to assess the cue utilisation of SES personnel in the context of assessing floodwater risk and to explore relationships with other demographic and performance variables **(Aim 4)**.

Chapter 6 presents a general discussion. It provides a summary of the main findings and discusses the findings from each empirical study by linking them to previous findings and integrating them within a framework for designing future intervention programs. It also provides direction for the wider implications of the findings from the studies presented in this thesis.

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Interlude 1: Exploring past research

Driving through floodwater is a common but potentially dangerous behaviour that causes the deaths of people every year. The goals of the research presented in this thesis are to explore the risks, risk perceptions, and decision-making that relate to this behaviour, with a focus on emergency services personnel who are occupationally exposed to this hazard.

The introduction chapter outlined the scope and flow of the thesis. It scoped the issue of driving through floodwater, including the public safety significance of the problem and some of the theoretical and conceptual approaches that have been used to explore and explain this risky behaviour. In addition, the previous chapter introduced the occupational group of interest, the Australian State Emergency Services, and the strategies used by this group and other stakeholders to prevent or reduce the prevalence of this behaviour.

To begin the exploration of driving through floodwater, it is necessary to understand and summarise what is already known and has been published in the area. Therefore, the research component of this thesis begins with a comprehensive systematic literature review to explore existing research knowledge about this behaviour. This includes investigation of the following:

- fatalities across countries and the impact of the behaviour in an international context;
- demographic and other risk factors associated with driving into floodwater;
- the reasons for, and the contexts in which, people enter floodwater in vehicles;
- theories and models used to explain the behaviour; and
- policies and practices used to mitigate the risks of driving through floodwater.

The following chapter provides details about what is known about the behaviour and assists with identifying the gaps in knowledge and understanding to direct the subsequent research studies.

Chapter 2: Systematic International Review

STUDY 1

Publication history

Study 1 was published in the "*International Journal of Disaster Risk Reduction, 2018"*. This paper is entitled "Driving into floodwater: A systematic review of risks, behaviour and mitigation". The International Journal of Disaster Risk Reduction has an impact factor of 2.568. The author of the present dissertation wrote approximately 80% of this paper. See Appendix for published manuscript.

Reference:

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Driving into floodwater: A systematic review of risks, behaviour and mitigation

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Abstract: This systematic review summarises the findings of research focused on the risks associated with driving into floodwater. The review aims to compare and document the magnitude of the problem internationally; identifying the risk factors; exploring the application of theories and presence of theoretical models to explain people's risky behaviour; and documenting the intervention strategies utilised or proposed. Literature were searched from a number of databases (e.g. PsycInfo, ScienceDirect, Informit) for publication dates to 31 August 2017, then assessed based on their titles, abstracts and full texts and finally 24 articles were selected. This review compares flood fatality data from four countries (Australia, United States, Greece, and Sweden), groups identified risk factors from these selected studies into seven categories, and proposes a holistic integrated intervention model. The results of the review indicate that studies were predominantly conducted in Australia (10 studies) and USA (7 studies). People's decisions to drive into, or turn back from, floodwater are identified as a consequence of both their risk perception and the combined impact of all other factors (e.g. individual, social, environmental etc.) that interdependently contribute to shape decision-making, The theory of Planned Behaviour (TPB) was the only theory that has been utilised within the literature to understand drivers' willingness to take risks. Improving people's decision-making through educational initiatives, advanced structural mechanisms, regulating existing edicts, and regularly evaluating the effectiveness of current strategies are identified as the best approaches to addressing the challenges in this area. Findings suggest that future studies require data and analysis from a larger range of countries, more comparative analyses within and between countries, an exploration of the relationship between risk factors and their relative level of influence and a greater application of behavioural and decision-making theories.

Key words: Flood, vehicles, driving, drowning, fatalities, risk factors, risk perception, behavioural theories, risk mitigation measures

Driving into floodwater: A systematic review of risks, behaviour and mitigation

2.1 Introduction

Floods are the highest cause of mortality due to drowning throughout the world (Berz et al., 2001; Ashley and Ashley, 2008). Previous literature notes that driving through floodwater is a common flood experience (Franklin et al. 2014) and constitutes a major cause of flood fatalities internationaly (Mauro, 2012; Diakakis and Deligiannakis, 2015; Fitzgerald et al., 2010; Jonkman and Kelman, 2005; Jonkman and Vrijling, 2008; Kellar and Schmidlin, 2012; Peden et al., 2016; Ashley and Ashley, 2008; Terti et al., 2015; Yale et al., 2003). Despite its importance as a cause of flood-related mortality, motor vehicle–related drowning as well as the risk perceptions and motivations of people in undertaking this risky behaviour remain poorly understood.

The number of studies and reviews within this field are limited with the majority being country-specific or focused on specific locations. Furthermore, many flood-related research studies have investigated a broad set of risk factors, rather than focusing on driving-related behaviour per se, and few have applied a theoretical approach to explain people's decision-making. Thus, an international review was considered necessary to draw lessons from across the international literature, to consolidate our understanding of the nature and patterns of people's driving behaviour in flood situations, to identify interventions being employed or suggested to reduce risks, and to identify research gaps.

The main objectives of this review, therefore, are: to quantify the impacts of driving into floodwater (through review of fatality data); to identify the factors that influence the decisions of people to drive into floodwater; to explore the application of different theories and models that may explain perceptions and complex decision-making processes; and to explore possible interventions to engage the public and reduce risks. To fulfill the objectives, the study will present and compare the number of vehicle-related flood deaths in different countries, categorise and explore the risk factors, and develop a holistic intervention framework. The study will also identify priority research gaps for further study in the context of driving into floodwater.

2.2 Methods

2.2.1 Study Design

This study used a systematic literature review in order to investigate past research that considered the action of driving into floodwater and specifically any patterns, risk factors, and possible interventions. A systematic literature review protocol was prepared to guide the development of the study objectives, questions, inclusions and exclusions criteria, and then search strategies were developed. This protocol was registered with the International Prospective Register of Systematic Reviews (PROSPERO) on 18 July 2017 and was last updated on 31 August 2017 (registration number CRD42017071343).

2.2.2 Inclusion and Exclusion Criteria

The inclusion criteria used for this systematic review were: studies conducted in all regions across the world; original articles that have been published in peer reviewed journals; and studies that included motor vehicle-related flood experience. There was no restriction applied to the date of studies sampled, and all databases were searched for studies published up to the 31 August 2017. Exclusion criteria included studies not related to driving and vehicles, non-English language articles, and studies on other natural hazards. The protocol developed for this study led to the identification of 24 relevant articles fulfilling these criteria.

2.2.3 Information sources and search strategies

The sources of information used for this systematic review were PsycInfo, ScienceDirect, Taylor and Francis Online, ProQuest, American Meteorological Society (AMS), Springer Link, Wiley Online Library, Informit, and the Australian Bushfire and Natural Hazards Cooperative Research Centre (CRC) databases. A search for relevant articles was also conducted in Google scholar. The search terms used for the review were; ‘flood’, ‘risk’, ‘drowning’, ‘driving’ and ‘vehicles’. See Table 2.1 for search strategies used in this review.

Table 2.1

Search Strategies

Keywords	Databases	Search Outcome	Last date of search
(“risky behavio*" OR “risk*” OR “willingness” OR "driving behavio*" OR "reasoned action" OR motivation) AND (“flood*” OR “flashflood”) AND (“vehicle*” OR “automobile*” OR “car” OR “cars”)	Wiley Online Library PsycInfo Taylor and Francis Online Springer ScienceDirect American Meteorological Society ProQuest Informit Bushfire and Natural Hazards Cooperative Research Centre	647 330 320 226 145 66 45 30 19	21/08/2017; 12:12 pm

2.2.4 Study selection

This review adopted a three-stage screening process for selecting potential studies. Firstly, articles were assessed based on their titles, and secondly on the basis of abstracts in order to exclude articles not fulfilling the inclusion criteria. Finally, the remaining articles' full texts were accessed and read, and at this stage, articles that did not meet the set of inclusion criteria were rejected. See Figure 2.1 for the article selection flowchart.

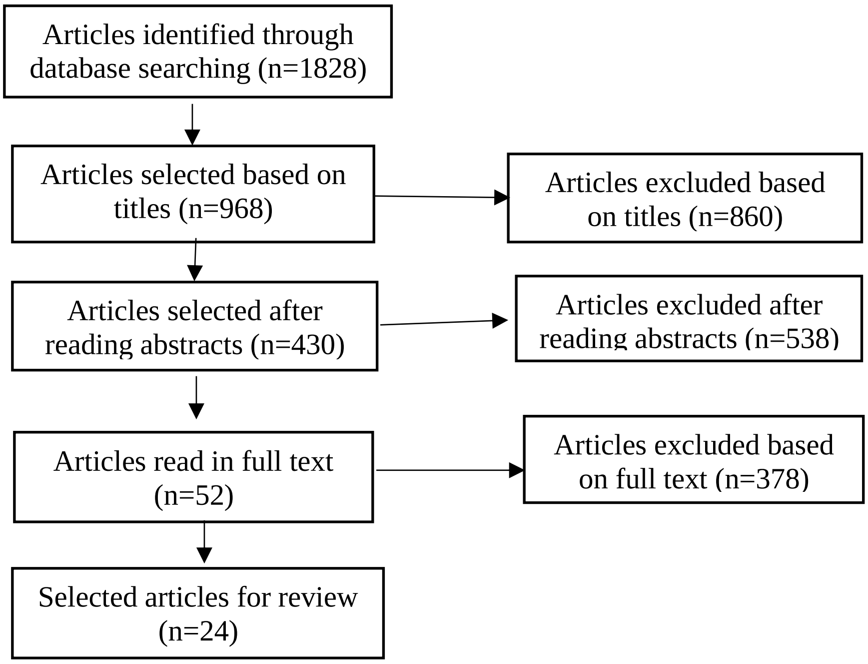

Figure 2.1 Article selection flow chart

2.2.5 Data extraction and management

Two reviewers independently extracted data from all sources using pre-prepared and piloted data extraction forms based on the review objectives. Extracted information included: study goals, methodology, study area, study population and participant demographics, theoretical basis, types of analyses, results of studies (including number of vehicle-related flood incidents and fatalities), factors associated with risks, and suggested interventions. Finally, all extracted information was cross-checked and accepted by reviewers after discussions. Endnote X8 was used to manage the references. Reviewers also assessed the methodological quality of the included studies which involved critical appraisal of the methods of data collection, the type of statistical analyses, quality of reporting, and other potential sources of bias.

2.2.6 Data Synthesis

A systematic narrative synthesis was conducted. First, a preliminary synthesis of findings of included studies (tabulation and groupings) was undertaken. This was followed by an exploration of the relationship and findings both within and between the included studies and an assessment of the robustness of the synthesis. See the Figure 2.2 for synthesis process conducted by this review.

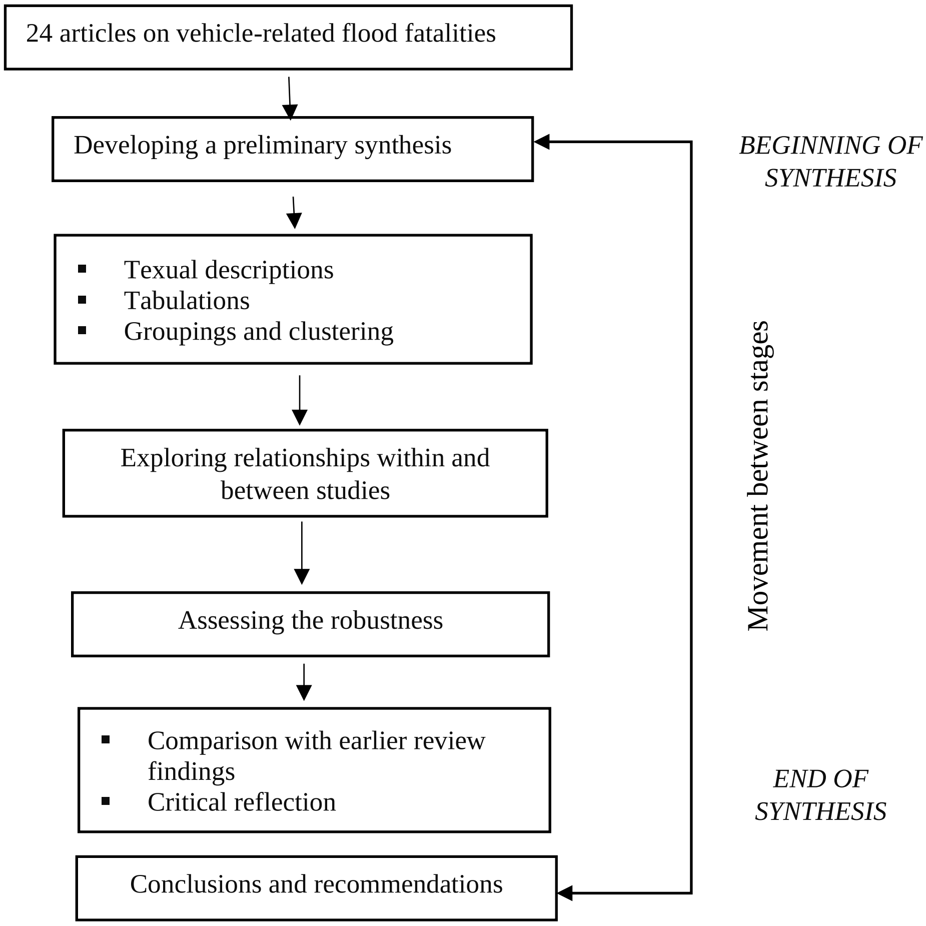

Figure 2.2 Synthesis process for this systematic review (following Guidance from Centre for Reviews and Dissemination, University of York)

2.2.7 Assessment of the risk of failure

Assessment of the risk of failure (for instance missing important information due to systematic bias in the search methodology) was conducted, independently, by two reviewers from different disciplines; psychology and geography. This assessment involved critically appraising the methods of data collection, the type of statistical analyses, quality of reporting and other potential sources of bias (for example publication bias, in which only positive results are published and therefore over-represented).

2.3 Results

From all databases, 968 titles, 430 abstracts and 52 full texts of articles were assessed for eligibility criteria. A total of 24 articles fulfilling the inclusion criteria were selected to be reviewed. A list of the selected studies and justification for their selection in this review is presented in Table 2.2.

Table 2.2

List of selected studies.

Authors and year of publication	Country	Sources of Data		Justification for selection
		Primary	Secondary	
Coates (1999)	Australia	-	✓	Analyzed historical, spatial and temporal flood fatality trends in order to identify those populations most at risk within Australia
Yale et. al. (2003)	USA	✓	-	Assessed risk factors for motor vehicle–related drowning associated with inland flooding and to describe the circumstances of these deaths
Jonkman and Kelman (2005)	Europe and USA	-	✓	Investigated understanding of the causes and circumstances of flood disaster deaths.
Drobot et al. (2007)	USA	✓	-	Determined risk factors associated with driving into flooded roads
Ruin et al. (2007)	France	✓	-	Assessed motorists' flash flood risk-perception on daily itineraries
Ashley and Ashley (2008)	USA	-	✓	Constructed a database of fatalities associated with all flooding events in the United States from 1959 to 2005
Stjernbrandt et al. (2008)	Sweden	-	✓	Explored crash and injury mechanisms in motor vehicle-related drownings in a Swedish population during 1992 through 2006 in order to suggest preventive countermeasures
Haynes et. al. (2009)	Australia	✓	✓	Examined the circumstances in which a 'shelter-in-place' strategy may be a viable alternative to evacuation during flash floods.
Maples and Tiefenbacher (2009)	USA	-	✓	Examined the geographical processes that create flood hazards associated with automobile travel to discern the most important factors in their genesis
Fitzgerald et al., (2010)	Australia	-	✓	Described the incidence and causes of deaths directly associated with floods in contemporary Australia.
Sharif et al. (2010)	USA	-	✓	Discussed the results of a study of motor vehicle–related flood fatalities in Texas for the period between 1959 and 2008.
Kellar and Schmidlin (2012)	USA	-	✓	Described the demographic, spatial, and temporal patterns of vehicle-related flood fatalities in the United States, and contribute to the natural hazard mortality literature
Diakakis and Deligiannakis (2013)	Greece	-	✓	Examined the conditions under which these vehicle-related incidents occur, in order to improve understanding on the variables affecting road safety during flooding events.

Špitalar et al.(2014)	USA	-	✓	Analysed human impacts across the U.S. 21549 flash flood events
Pearson and Hamilton. (2014)	Australia	✓	-	Explored the underlying decision-making process guiding people's willingness to drive through a flooded waterway
Franklin et al. (2014)	Australia	✓	-	Explored the perceptions of residents of a regional city in North Queensland of how to remain safe during flood events, also to explore reasons for and how to prevent risk-taking behaviour in floodwater
Becker et.al (2015)	-	-	✓	Explored people's behaviour in and around floodwater
Gissing et al. (2016)	Australia	✓	-	Examined the effectiveness of the current combination of warnings, education and road signage to stop motorists entering floodwater.
Diakakis (2016)	Greece	-	✓	Investigated qualitative changes in flood mortality in Greece between 1960 and 2010.
Hamilton et al. (2016)	Australia	✓	-	Identified the key behavioural, normative, and control beliefs that guide people's willingness to drive through a flooded waterway
Pereira et al. (2017)	Portugal and Greece	-	✓	Analyzed research on behaviour and decision-making, and how they can be influenced
Haynes et al. (2017)	Australia	-	✓	Analyze the social and environmental circumstances surrounding 1859 fatalities that have occurred due to flooding in Australia from 1900 to 2015
Gissing et al. (2017)	Australia	-	✓	Analysed the influence of road characteristics on flood fatalities
Peden et al. (2017)	Australia	-	✓	Conducted a cross sectional study to identify trends and causal factors of unintentional river flood related fatal drownings

A descriptive summary of the characteristics of the selected studies, including: study goals, numbers of participants, a summary of participant characteristics, methods, type of analyses and outcomes is provided separately (attached in Appendix 1). To address the aims of the review, the findings analysed from these selected studies were grouped into the following sections: vehicle-related flood fatalities, risk factors associated with driving into floodwater, application of theories and development of models, and suggested interventions. The review findings are presented below following this structure.

2.3.1 Vehicle-related flood fatalities

To understand the international exposure of vehicle-related flood hazards, we identified 12 articles that described analysis of fatalities in the following countries: USA (4 articles), Australia (4 articles), Europe and United States combined (1 article), Greece (1 article), Sweden (1 article) and Greece and Portugal combined (1 article). An overview of the findings from these studies is presented in Table 2.3. The aim was to conduct an international review of vehicle-related flood research. However, no peer-reviewed research from a number of continents / countries with significant flood events was identified, including a number of European countries, South America, Africa and Asia.

Table 2.3

Overview of vehicle-related flood fatality study findings

Study authors	Time period of study data	Study Area	No. of flood events	No. of flood fatalities	Percentage of vehicle-related flood deaths	No. of vehicle-related flood deaths
Peden et al., (2017)	2002-2012	Australia	-	129	55%	-
Haynes et al., (2017)	1900-2015	Australia	-	1874	49%	-
Pereira et al. (2017)	1960–2010	Greece	737	189	40%	-
		Portugal	498	114	14%	-
Špitalar et al.(2014)	2006-2012	USA	21,549	326	-	222
Diakakis and Deligiannakis (2013)	1970-2010	Greece	54	151	40%	-
Kellar and Schmidlin (2012)	1995-2005	USA	355	-	-	555
Sharif et al. (2012)	1959-2009	USA	854	839	77%	-
Fitzgerald et al., (2010)	1997–2008	Australia	36	73	48%	-
Stjernbrandt et al. (2008)	1992-2006	Sweden	-	-	-	83
Ashley and Ashley (2008)	1959-2005	USA	-	4586	63%	-
Jonkman and Kelman (2005)	1989-2002	Europe	7	95	32%	-
		USA	6	152	-	-
Coates (1999)	1788-1996	Australia	926	2213	4%	-

Of the12 fatality studies, four were conducted in Australia (Coates, 1999; Fitzgerald et al., 2010; Haynes et al., 2017; Peden et al. 2017). Flooding has been identified as Australia’s second most deadly natural hazard (Coates, 1999). Geographically, the Eastern states of Queensland (Qld.) and New South Wales (NSW) are the most flood prone states accounting for 74% of all fatalities nationally (Haynes et al., 2017). Overall, flood deaths in Australia are declining, apart from across Northern Australia where an increase is seen. Over the last 20 years, 81 people have died driving into floodwater, which accounts for 43% of all flood fatalities during this period. Just over a third (35%) of these involved the driving of four-wheel drive

(4WD) vehicles (Haynes et al., 2017). In the early part of the twentieth century, before widespread availability of many motorised vehicles, transport- related flood deaths only accounted for 8.4% of the known flood fatalities (n=1406) (Coates,1999). Since 1960 vehicle-related fatalities have increased, particularly those associated with 4WD vehicles (n=51; 11% of transport-related deaths) and sedans (n=147; 31% of deaths from a known form of transport) (Haynes et al., 2017).

Flooding is also the second deadliest weather-related hazard, after heat, in the United States (USA) (Ashley and Ashley, 2008). Our review found one in-depth study by Kellar and Schmidlin (2012) which analysed the spatial, temporal, and demographic patterns of vehicle-related flood deaths in USA from 1995 to 2005. Findings of their study reported that ‘flash floods’ accounted for the largest number of vehicle-related flood deaths during the study period, totaling 347 fatalities, that comprised more than half of all flash flood fatalities in USA. The annual number of vehicle-related deaths during this period ranged from a high of 95 deaths in 1996 to a low of 26 in 2005, with an average annual number of 50.5. Texas, Missouri, California, Pennsylvania, and North Carolina were in the top five states, accounting for 150 of the 355 deadly storm events (42%) and 262 of the 555 vehicle-related deaths (47%). A study based on data from Texas recorded the highest rate of vehicle-related fatalities. From 1959 through 2008, more than three quarters of total flood fatalities (n=471 of 616; 77%) were vehicle-related (Sharif et al. 2012).

In Greece, an inventory of 60 fatalities associated with the use of vehicles, from 37 flood events between 1970 and 2010, was studied by Diakakis and Deligiannakis (2013). Their analysis showed an increase (from 32% to 68%) in vehicle-related cases over the period of study, with the majority of the incidents occurring after 1990.

In Sweden, 83 fatalities occurred in 64 vehicles during the period 1992 through 2006. In-depth analyses performed by the Swedish Road Administration were reviewed and analysed by Stjernbrandt et al., (2008). Drowning was the major cause of deaths; most events took place in waters directly adjacent to a roadway (36%) or bridge (34%) and found that the nationwide share of land motor vehicle–related drownings is 1.5% of all traffic deaths and 3.3% of all single vehicle fatalities.

Our review identified two comparative flood fatality studies, one between Europe and the United States (Jonkman and Vrijling, 2008), and another between Portugal and Greece (Pereira et al., 2017). Jonkman and Vrijling (2008) found that during the period 1989-2002, 27% of flood deaths in Europe were in a vehicle compared with 63% of flood deaths in the United States during the same period. In Greece, fatalities that occurred inside a vehicle, increased from 30%

to 58% during the period 1960-2010. In Portugal fatality rates were generally lower, but also increased in the last three decades with 25% of total flood fatalities between 2001 and 2010 being vehicle-related (Pereira et al., 2017).

The findings presented in this section clearly reveal the magnitude of vehicle-related flood deaths from a range of studies worldwide. Due to the differing time periods studied in the literature it is difficult to make comparisons of fatality rates and to show any specific trends of increasing or decreasing rates between the countries. Undoubtedly though, there is a need to identify the risks associated with risky driving behaviour in floodwater to reduce a number of potentially avoidable deaths from flooding. In the next section, our review discusses risk factors identified in the academic literature that may provide insight into decisions to drive into floodwater.

2.3.2 Research on the risk factors associated with driving into floodwater

Almost all the studies selected in this review addressed the many factors associated with why motor vehicle-related flood accidents may, or do, occur. These factors have been classified into seven categories, and are reported under these subheadings:

- Reasons for driving into floodwater:
  - traveling, working/commuting, evacuating or driving to attend a rescue.
- Demographic factors:
  - age, gender, location.
- Situational factors:
  - road type and characteristics, water depth, type of vehicle.
- Environmental factors:
  - time of day, seasons, weather conditions
- Flood risk indicators:
  - road sign, height or water depth indication
- Social factors:
  - the driving behaviour of others, the influence of vehicle occupants, peer pressure
- Individual factors:
  - personal beliefs, past experience, self-efficacy, drug/alcohol use

The specific factors within each category are numerous, and many of the studies reviewed mention the same risk factors, therefore, in summarizing the risk factors below, examples are selected from a sample of the research studies, rather than all that mentioned a single factor.

2.3.2.1 Reasons for driving into floodwater

The reasons for driving into floodwater are of obvious importance for determining ways to reduce vehicle-related flood fatalities, and are an important influence on the decision to enter floodwater. In an Australian study (Haynes et al., 2009), people reported entering floodwater in a vehicle for a variety of reasons, including continuing their intended travel, continuing their work, evacuating in a flood situation, or to carry out a rescue. Haynes et al. (2009) analysed flood rescue incident reports following flooding in the Hunter River Catchment, in NSW, in June 2007 and found that a large percentage of flood rescues undertaken by emergency services (36%) were also vehicle-related. In their study, Becker et al. (2015) identified five predominant reasons for driving into floodwater, including attempting to reach a destination; going to retrieve property, livestock, or pets; undertaking employment duties; and rescuing or assisting with evacuation.

Data from flood fatality studies indicated that, in Greece, entering floodwaters to reach a destination, to rescue someone, to recover something, or to evacuate were identified as the dominant reasons for entering floodwater (Diakakis and Deligiannakis, 2013). In a recent Australian fatality study, Peden et.al. (2017) reported in almost a third (30%) of non-aquatic transport victims were intending to travel to their own home or to a friend's home, and 25% of those who drowned were intending to travel to work/appointments at the time of their drowning.

2.3.2.2 Demographic Factors

In terms of gender, results of the selected studies indicated that males were overrepresented in vehicle-related flood death statistics (Diakakis and Deligiannakis, 2013; Drobot et al., 2007; Gissing et al., 2016; Haynes et al., 2017; Jonkman and Kelman, 2005; Kellar and Schmidlin, 2012; Maples and Tiefenbacher, 2009; Sharif et al., 2010). Franklin et al., (2014) found that more males drove into floodwater than females. Males are consistently at an increased risk of entering floodwater, usually attributed to a greater sense of confidence in ability to drive through floodwater (Becker et al, 2015).

Analysis of demographic trends relating to fatalities in the United States reveal that the majority of motorist flood deaths are for people aged 20 to 69 years (Kellar and Schmidlin 2012), while Diakakis and Deligiannakis (2013), in their analysis of data from Greece, found most victims were aged 40 to 69 years. However, Drobot et al. (2007) found that younger drivers (18-35 years) were more likely to indicate that they would be willing to drive into floodwater. The difference in death rates between genders was small at ages 19 and younger, but males died at twice the rate of females for ages 40 and older (Kellar and Schmidlin, 2012).

With regard to the types of location in which people are more likely to enter floodwater, research findings are mixed. Sharif et. al. (2010) identified that the highest numbers of fatalities that occurred in Texas from 1959–2008 were in major urban areas. In contrast, in Greece, Diakakis and Deligiannakis (2013) for the period 1970–2010 indicated that most events occurred in rural areas of the country. Diakakis (2016) concludes from their Greek data that the prevalence of fatalities in urban environments gradually decreased over this period in favour of rural settings.

2.3.2.3 Situational Factors

Situational factors such as road types, and characteristics such as steepness of the road and visibility of danger (Gissing et al., 2017), water depth (Stjernbrandt et al., 2008), type of car (Gissing et al., 2016; Haynes et al., 2017; Peden et al. 2017), number of occupants in the vehicle (Gissing et al., 2016; Peden et al., 2017), roadway familiarity (Maples and Tiefenbacher, 2009; Haynes et al., 2017) distance and route of travel (Maples and Tiefenbacher, 2009; Haynes et al., 2017) have all been identified as factors that impact a driver's decision-making about driving into floodwater.

Gissing et al. (2016) investigated the influence of road characteristics on flood fatalities in Australia based on a site analysis of 21 road sections where fatalities had occurred. Small upstream catchment size (increased rate of rise), the absence of road barricades, depth of flooding adjacent to the roadway, absence of lighting, dipping road grade, lack of curb and guttering, and the inability of motorists to easily turn around were the most frequently observed situational factors associated with fatality sites (Gissing et al., 2016). In Sweden, a study by Stjernbrandt et al (2002) identified that most events took place in waters directly adjacent to a roadway or bridge, the vehicles were most often found upside down (72%), and most fatalities (65%) occurred in shallow water where the depth was less than two meters.

Our review found three studies in Australia that collected data on the types of vehicles driven into floodwater. The types of vehicles observed being driven into floodwater during a flooding event in NSW, varied in size and type (Gissing et al., 2016). In terms of vehicles associated with flood fatalities, four-wheel drive vehicles (4WDs) and sport utility vehicles (SUVs) were the most frequently noted (Peden et al., 2017, Haynes et al., 2017). Almost two-thirds of vehicle-related flood fatalities (64%) have been associated with sedans and 19% with 4WD vehicles (Haynes et al., 2017). In the observational study of Gissing et al., (2016), vehicle types that turned around and did not enter floodwater were predominantly two-wheel-drive utility vehicles, sedans, and station wagons.

Regarding the number of occupants in the vehicle, research by Peden et al. (2017) into the causal factors of drowning deaths associated with driving into floodwaters identified that two thirds of those who drowned were the drivers of the vehicle and were alone in the car when they drove into floodwaters. Almost two thirds (61%) occurred on roads that were known to be open at the time of the incident. Drivers were alone in the vehicle in 58% of road open cases: the remaining 42% of drivers drove into floodwaters with passengers in the vehicle (Peden et al., 2017). Occupants even included a school bus full of children in one incident reported by Gissing et al., (2015) in their observational study. It is worth noting here that the numbers of those entering and exiting floodwater in vehicles successfully is likely to be high, however, the numbers of successful versus unsuccessful crossings in unknown.

Roadway familiarity may also have an emboldening influence on decisions to enter floodwater (Maples and Tiefenbacher, 2009). Distance to travel may be another reason to enter floodwater, as drivers with the longest routes to travel were identified in one study as the most likely to incorrectly judge levels of risk (Ruin et al., 2007). In contrast to this, Haynes et al. (2017) discovered that the majority of vehicle-related flood fatalities occurred within 20 km of the individual's home address, indicating that familiarity with the journey and the road could also be factors associated with driving into floodwater. Maples and Tiefenbacher (2009) also noted that a person's familiarity with the environment was likely to lead to an underestimation of the risks and make people more likely to voluntarily enter floodwater.

2.3.2.4 Environmental Factors:

Research selected in our review identified environmental factors, such as time of day (Haynes et al., 2017; Maples and Tiefenbacher, 2009), lighting (Maples and Tiefenbacher, 2009), weather condition (Haynes et al., 2017), and seasons (Fitzgerald et al., 2010; Haynes et al., 2017) to be associated with the risk of driving into floodwater.

Analysis of vehicle-related fatalities in Australia, Greece, and the United States shows that most fatalities occurred at night (Diakakis and Deligiannakis, 2013; Maples and Tiefenbacher, 2009; Špitalar et al., 2014; Haynes et al., 2017). The amount of natural light has been found to be a major factor in influencing visibility and it is hypothesised that it may be difficult to judge the depth and speed of flowing water at night when driving (Maples andand Tiefenbacher, 2009; Špitalar et al., 2014). There does not appear to be a trend in the United States with regard to seasonal fatality patterns (Kellar and Schmidlin, 2012). In Australia, however, most flood-related deaths occur in the summer, with February as the peak month (Fitzgerald et al., 2010). Summer storms in the northeast of Australia are more often associated with flash flooding and therefore more likely to result in fatalities (Haynes et al., 2017). Peden et al. (2017) found that recent vehicle-related river-flood related deaths were more likely in winter, when compared to drowning as a result of other activities. In the same study, the largest proportion of drowning deaths occurred in the afternoon (38%), however, time of day was not found to be statistically significant.

2.3.2.5 Flood risk indicators

Physical cues in the environment, or messages such as flood risk warnings (Drobot et al., 2007; Yale et. al., 2003; Franklin et al., 2014), road closed or blocked signage (Gissing et al., 2015; Peden et al., 2017), height or depth indicators, and barricades (Stjernbrandt et al. 2008; Gissing et al., 2015) were all found to influence decision-making around driving into floodwater. A United States study in Denver and Austin indicated a key construct in determining whether a person is likely to drive into water is whether they take flash flood warnings seriously or not (Drobot et al., 2007). Yale et. al. (2003) also suggested that many of the vehicle-related deaths during Hurricane Floyd, in the United States, involved people who were aware of flash flood warnings, but did not feel personally threatened by the possibility of encountering dangerous floodwaters. Moreover, people who do not know that motor vehicles are involved in more than half of all flood fatalities were found to be significantly more likely to drive into floodwater (Drobot et al., 2007). Franklin et al. (2014) directly asked participants in their survey about what they thought the main reason was that people drive into floodwater and 62% of people said 'lack of awareness'.

In another study Stjernbrandt et al. (2008) indicated that most fatalities occurred where guardrails were either lacking or did not effectively guard the watercourse. Gissing et al. (2015) highlighted similar issues, noting that passive warnings, such as road closed signage and barricades, were less effective in stopping motorists because they are able to drive around them. Peden et al. (2017) identified almost two thirds of fatalities (n=71; 61%) occurred on roads that were known to be open at the time of the incident, indicating that no physical barriers or road closed signage was present.

2.3.2.6 Individual factors

Individual characteristics, including personal belief (Hamilton et al., 2016; Pearson and Hamilton, 2014), self-efficacy (Hamilton et al., 2016; Pearson and Hamilton, 2014), confidence level (Franklin et al., 2014), past experience (Hamilton et al., 2016; Pearson and Hamilton, 2014; Ruin et al., 2007), risk perception (Becker et al., 2015), and alcohol abuse (Jonkman andand Kelman, 2005; Diakakis andand Deligiannakis, 2013; Stjernbrandt et al., 2008; Peden et al., 2017) have been found to influence the risk of driving into floodwater, and are categorised as individual factors in this review.

Attitudinal beliefs, social expectations, and self-efficacy were identified as the significant factors in willingness to enter floodwater in two studies (Hamilton et al., 2016, and Pearson and Hamilton, 2014). Previous flood experience emerged as a key factor in a number of studies (Hamilton et al., 2016; Pearson and Hamilton, 2014; Ruin et al., 2007). Findings exploring drivers’ behaviours indicated that those with no prior experience of flooding were most likely to underestimate the level of risk associated with entering floodwater in a vehicle (Ruin et al., 2007) and this lack of experience was associated with a greater likelihood of entering floodwater (Pearson and Hamilton, 2014). Drivers were typically found to underestimate risks rather than overestimate them (Becker et al., 2015). In a survey by Franklin et al. (2014) around a third of respondents (31%) stated that they had driven into floodwater because they believed they were ‘‘invincible,’’ suggesting an overconfidence in their abilities and a belief that nothing bad would happen to them.

Alcohol and drugs are other factors identified as important in the decision-making of drivers to enter floodwater (Jonkman and Kelman, 2005) and associated with flood fatalities. For example, around one-third of Swedish drivers (32%) involved in vehicle-related flood fatalities tested positive for alcohol (Stjernbrandt et al., 2008), and alcohol was known to be present in just over a fifth (21%) of all flood related non-aquatic transport incidents in a recent Australian study (Peden et al., 2017).

2.3.2.7 Social factors

Driving into floodwater has been classified as a social behaviour that is likely to carry consequences for others (Pearson and Hamilton, 2014). A number of studies (Becker et al., 2015; Franklin et al., 2014) reported that drivers would often follow others or drive into floodwater if they had seen the car in front of them cross successfully. In many cases social pressures caused by passengers within the vehicle also influence drivers’ decisions (Pearson and Hamilton, 2014). In their 2016 study Hamilton et al. identified a number of social factors that could influence the decision making of drivers for driving into floodwater including: avoiding isolation; pressure from other drivers; encouragement by passengers; behaviour of other drivers; and security of others being present if rescue was needed.

2.3.2.8 Summary of identified risk factors

Risk factors for driving into floodwater, as identified by the articles included in this review, have been summarized in Figure 2.3. Our review acknowledges risk perception as a core influential factor in the decision to drive into floodwater. The figure 2.3 indicates that how people perceive the risks and other factors, collectively contributes to construct their overall perception of risk. Although the relationship between risk factors and their relative level of influence was not assessed in the reviewed studies, they are all likely, to varying degrees, to influence drivers’ risk perceptions and behaviour. It is anticipated that future research in this area may assist with clarifying the relationships and the degree of influence of these various risk factors in the decision-making process to drive into floodwater.

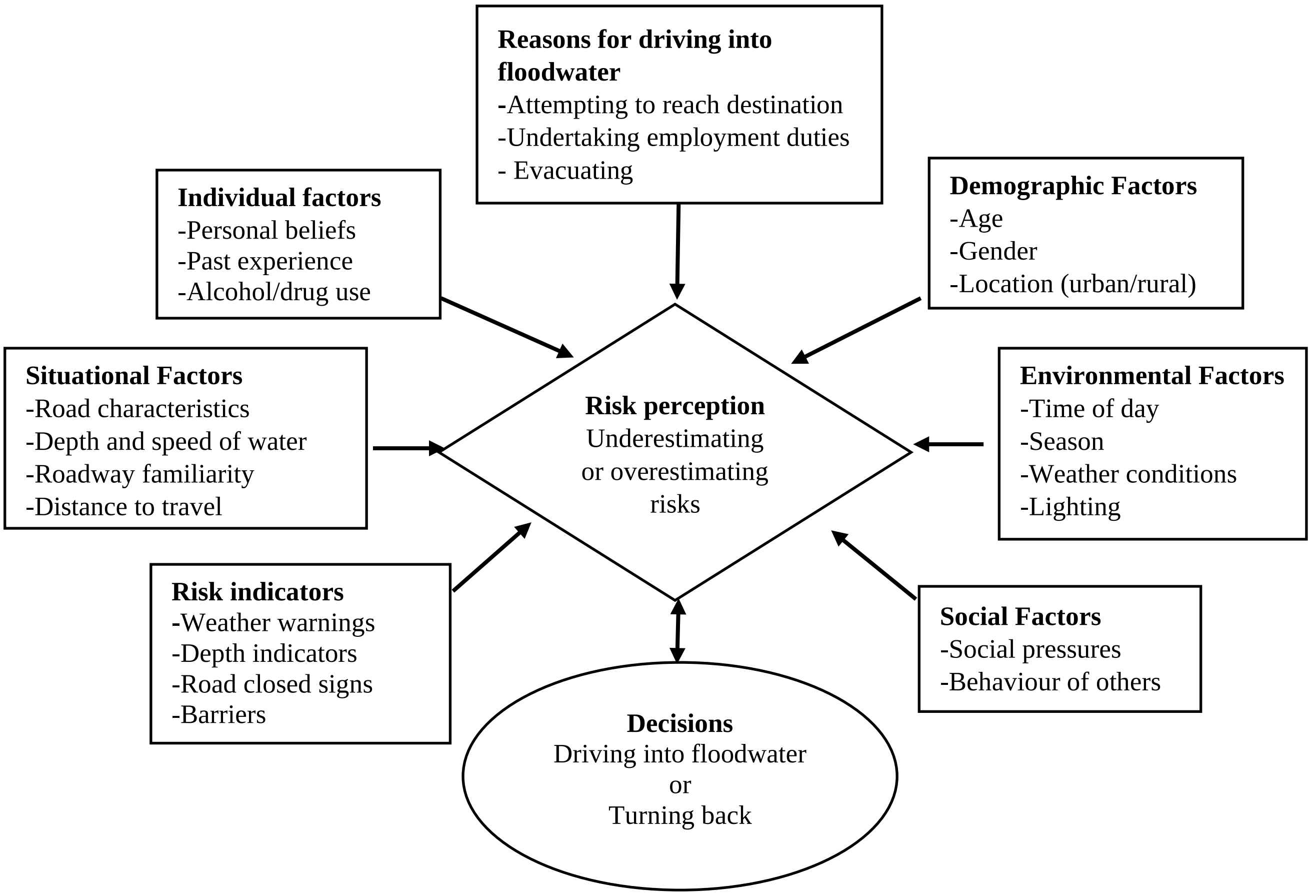

Figure 2.3 Synthesis of risk factors that influence decision-making to drive into, or turn back from, floodwater. Adapted from Becker et al. (2015) with additional information from Jonkman and Kelman, (2005); Ruin et al., (2007); Drobot et al., (2007); Stjernbrandt et al., (2008); Maples and Tiefenbacher, (2009); Haynes et al., (2009); Sharif et al., (2010); Fitzgerald et al. (2010); Kellar and Schmidlin, (2012); Diakakis and Deligiannakis, (2013); Franklin et al., (2014); Pearson and Hamilton, (2014); Becker et al., (2015); Hamilton et al., (2016); Gissing et al., (2016); Gissing et al., (2017); Haynes et al., (2017); Peden et al. (2017).

Although this section of the review assisted with the identification of a wide range of risk factors associated with floodwater, questions still remain regarding why people engage in risky driving behaviour, and what are the determinants of behaviour that lead people to take such risks while driving. The next section of our review focuses on the application of psychological or behavioural theories used in the studies under review, and the models developed in explaining the behaviour of driving into floodwater.

2.3.3 Application of theories and models developed to explain driving into floodwater

To understand the application of theories in explaining people's risky behaviour around floodwater with vehicles this review identified three studies that applied two different theories: the Theory of Planned Behaviour (TPB) (Hamilton et al., 2016; Pearson and Hamilton, 2014) and the Protection Motivation Theory (PMT) (Franklin et al., 2014). Only one study built a model to explain the decision-making process of drivers to enter, or not to enter, floodwater (Maples and Tiefenbacher, 2009). The use of these theories and the model are summarised below.

2.3.3.1 The theory of planned behaviour (TPB)

TPB (Ajzen, 1991; Ajzen and Madden, 1986) is a well-validated decision-making model which states 'intention' as the most proximal predictor of behaviour determined by three social-cognitive variables: attitudes (overall positive/negative evaluations of performing the behaviour), subjective norms (perceived social pressure from important others to perform the behaviour), and perceived behavioural control (perceived amount of control over behavioural performance; also theorized to predict behaviour directly) (Ajzen, 1991).

Pearson and Hamilton, (2014) and Hamilton et al., (2016) adopted the TPB model to understand risky driving behaviours in the context of flooded waterways, as the model had been successful in explaining a variety of risky driving behaviour including texting/calling while driving (Walsh et al., 2008); dangerous over-taking (Forward, 2009); speeding in rural areas (Letirand and Delhomme, 2005; Warner and Åberg, 2008) and urban areas (Elliott et al., 2003; Elliott et al., 2005; Warner and Åberg, 2008). The base model, i.e. comprising attitude, subjective norm and perceived behavioural control, was conceptualised as per the original TPB proposed by Ajzen (1991); however, a number of adjustments were proposed in the 2014 study to develop an augmented model in order to gain a better understanding of why people may drive into flooded waterways. Pearson and Hamilton propose that a measure of willingness to drive into floodwater is potentially more appropriate than measuring an individual's intent to drive into floodwater, due to the risky nature of driving into flooded waterways. The study also sought to investigate perceptions of risk in a floodwater context and argued that past behaviour may be a useful addition to the TPB (Conner and Armitage, 1998). Therefore, the 2014 and 2016 studies adopted the TPB-based approach and augmented the model to include the concepts of 'willingness' from the prototype willingness model (PWM), perceptions of risk from the Health Belief Model (HBM), and past behaviour.

The Pearson and Hamilton, (2014) study demonstrates the utility of an augmented TPB approach, as attitude, subjective norm, and perceived behavioural control significantly predicted behavioural willingness to enter floodwater. In both low-risk and high-risk situations, people may not perceive there to be substantial consequences for the behaviour; however, they may recognize the severity of the consequences for the behaviour in situations of greater risk (i.e., where floodwaters are at a substantially higher depth). Hamilton et al., (2016) also support using the TPB belief-based approach to the understanding of risky transport-related aquatic activities. The results found that a range of beliefs play in guiding people's willingness to drive through flooded waterways.

2.3.3.2 The protection motivation theory (PMT)

The protection motivation theory (PMT) was initially developed by (Rogers, 1975) to help explain how fear-arousing communication could lead to health behaviour change; however, it has recently been used to explore people's behaviour in relation to natural hazards, e.g. Grothmann and Reusswig, 2006, and Milne, et al. 2000. As a social-cognitive model, PMT consists of seven constructs organized as two pathways linking perceptions to behaviour. *The threat appraisal pathway* - an evaluation of a person's perception of the threat; and *the coping appraisal pathway*- an evaluation of a person's ability to cope with the threat.

Franklin et al. (2014) applied the PMT to consider how residents responded when asked to promote safety, reduce harm during floods, and consider why people engage in risk-taking behaviour during flood events. The study was not specifically about driving behaviour, it included consideration of other risk behaviours in this context, however, it may be useful to apply to the driving into floodwater context to identify information needs which should be communicated to the public to influence the individual's decision to respond, and the corresponding action taken.

2.3.3.3 Event-specific contextual model

Maples and Tiefenbacher (2009) developed a unique event-specific conceptual model to represent the factors influencing the risk of automobile deaths on flooded roadways. They used this in order to understand the factors that contribute a vehicle avoiding or becoming entrapped in the water and a drowning death occurring. The model considered all components that contribute to the hazard and identifies those that are unique to a specific event. The model comprised four primary interacting parts with the driver activating their decision-making system in the context of social factors, cognitive processes, and interaction with the technology of their automobiles, to traverse the landscape of the hazard ('hazardscape') in which interactions with the built environment are also considered. (Maples and Tiefenbacher, 2009). They suggested that the increasing frequency of vehicle-related flood death is a function of the changing patterns of humans interacting with the flooded roadway hazards: which include changing natural landscapes, changing patterns of development, and changing technologies (Maples and Tiefenbacher, 2009).

2.3.4 Recommendations for policy and practice to mitigate the risk of people driving into floodwater

Our review identified several recommendations for reducing the risk of driving into floodwater. These have been grouped into the following three categories:

- Educational Strategies
- Structural Mechanisms
- Law and Regulations

2.3.4.1 Educational Strategies

A number of studies (Fitzgerald et al., 2010; Sharif et al., 2012; Diakakis and Deligiannakis, 2013; Becker et al., 2015) gave importance to developing effective and successful educational strategies to reduce the risks of vehicle-related flood fatalities.

Ashley and Ashley (2008) indicated that the public's general knowledge of the awareness of flood threats is inadequate and the recommendations to flood policy makers were to target specific groups, especially those that may be more vulnerable than others, with flood safety awareness programs to include local citizen involvement. Such as, educating parents on flood dangers through parent-teacher groups highlighting the fact that many children are killed by floods when they are driven into floods by a parent or guardian.

Fitzgerald et al. (2010) and Sharif et al., (2012) recommended public awareness raising through educational strategies and public warnings and that knowledge of the leading causes of flood fatalities should inform awareness programs and public safety police enforcement activities.

Diakakis and Deligiannakis (2013) suggested that the warning agencies need to focus education efforts on ensuring that the public understands warnings, the importance of paying close attention to warnings, and the dangers inherent in driving into flooded roads. They noted the potential efficacy of identifying receptive moments, such as public service announcements during popular television programs, but they also indicated that messages need to be tailored to the risk groups.

Gissing et al. (2016) suggested that to be successful the educational campaigns must use messages and communication channels that target risk groups and involve multiple partner agencies, not just the emergency services. It was also noted that work is needed to educate workers from government agencies about the importance of not driving into floodwater to reduce occupational risks of entering floodwater (Gissing et al., 2015; Haynes et al., 2017).

Becker et al., (2015) reviewed several existing education programs and identified addressing risk perception, considering social influences, focusing on vulnerable or ‘‘at risk’’ groups and ensuring an effective warning system were four important issues that need to be considered for developing effective public education programs.

Other researchers noted that education programs should address the motivations for people entering floodwater and their perceptions of the dangers (Pearson and Hamilton, 2014; Hamilton, 2016). Developing campaigns incorporating attitudinal change strategies, highlighting the social disapproval of others, and challenging people’s beliefs about their ability to perform the behaviour, as well as positively reinforcing self-efficacy beliefs that people can avoid the behaviour, were recommended by Hamilton et al. (2016).

Peden et al. (2017) identified additional aspects, recommending that education strategies highlighting risks for both driver *and passengers* are critical, as over half of all females who died in their study data were passengers in the vehicle. Also, drivers of larger vehicles were identified as requiring targeting for education and prevention efforts, as they were known to be more likely to try to travel across floodwater (Coles, 2008).

2.3.4.2 Structural Mechanisms

A number of studies (Stjernbrandt et al., 2008; Fitzgerald et al., 2010; Franklin et al. 2014; Maples and Tiefenbacher, 2009) focused on recommendations for improving structural mechanisms. Strategies are suggested for improving three major areas including: physical barriers, road structures, and flood risk indicators.

Physical barrier improvements included guarding the watercourses and improving barriers at high-risk locations (Yale et al., 2003; Stjernbrandt et al., 2008; Fitzgerald et al., 2010; Franklin et al. 2014). Road structure recommendations included reducing roadway hazards by avoiding dense network of roadways, reducing the impacts of infrastructure development on the drainage regime (Maples and Tiefenbacher, 2009), and building infrastructure and bridges to enable safe travel across flood-prone locations (Fitzgerald et al., 2010; Diakakis and Deligiannakis, 2013; Peden et al., 2017).

Recommendations to improve flood risk indicators included providing warnings and using signage in high-risk locations (Yale et al., 2003; Diakakis and Deligiannakis, 2013), and communicating flood warnings and information about flooded roads to drivers ‘in-vehicle’, in real time through live devices. The greater use of visual cues was also suggested, such as blinking red lights on flooded roadways, especially at night when drivers may not judge the water depth, current or location on the roadway (Kellar and Schmidlin, 2012), improving road lighting in high risk location (Diakakis and Deligiannakis, 2013; Gissing et al., 2015), and installing automated warning devices (Fitzgerald et al., 2010; Kellar and Schmidlin, 2012; Gissing et al., 2015).

2.3.4.3 Law and Regulations

Some studies emphasised better forecasting, monitoring and reporting of hazards and enforcement of new laws.

Sharif et al. (2012) recommended that improved hydrometeorological forecasting and timely and appropriate action by local emergency and safety authorities could be prioritised to reduce flood fatalities. Kellar and Schmidlin (2012) suggested that their results were relevant to emergency managers and flood forecasters and could be used in targeting locations and populations for flood preparedness initiatives, which could be used to create risk measures to save the loss of lives. Yale et al., (2003) recommended the use of citizen action, using weather spotter networks to report flooded roadways.

The key message from Franklin et al. (2014) study results was that timely and context-specific reminders of the dangers inherent in floodwater should be used. They suggested that these reminders should be located at the source of the hazard, along with an emphasis on the types, effectiveness, and cost of protective responses, and that this could be used as one mechanism to remind residents both prior to and during the wet season.

Regulation is often used to change behaviour: for example, enforcing speed limits and seat belt use. Punishment of offenders who ignore the signage (Franklin et al., 2014); imposing fines and license disqualifications for careless risky driving could be introduced for discouraging people willingness to enter into flooded roads (Gissing et al., 2016). Further research is required to determine the effectiveness and implications for disobeying road closure signage and barriers. This should be considered alongside exploring other prevention strategies, such as enforcing the culpability of those who deliberately drive into floodwaters and put others' lives at risk, and the use of regulations to hold drivers liable for costs incurred during their rescue from floodwaters (Peden et al., 2017). Incentives and consequences to encourage voluntary behaviour have also been identified as important (Gissing et al., 2016). Similarly, the use of worksite polices to provide financial or other disincentives for employees to commute to work during floods has been suggested, and should be explored (Yale et al., 2003).

2.3.4.4 The need for a whole of community approach

The specific behaviour associated with flood fatalities that is mostly intentional and controllable is driving into floodwater (Sharif et al., 2012). In their study, Gissing et al., (2015) highlight that a more holistic behavioural change focus is required and that to be successful strategies need to involve multiple partner agencies, and not be limited only to emergency services. Work is needed to educate workers from government agencies about the importance of not driving into floodwater. In achieving the goal of appropriate behaviour around floodwater, it is important that communities and organisations work together in partnership including community members, emergency managers, local authorities, the media, and other relevant organisations (Becker et al., 2015).

2.3.4.5 Summary of recommendations for policy and practice to mitigate risk of people driving into floodwater

After analyzing all the findings and recommendations, this current review proposes an integrated model (Figure 2.4) to reduce the risks of people driving into floodwater.

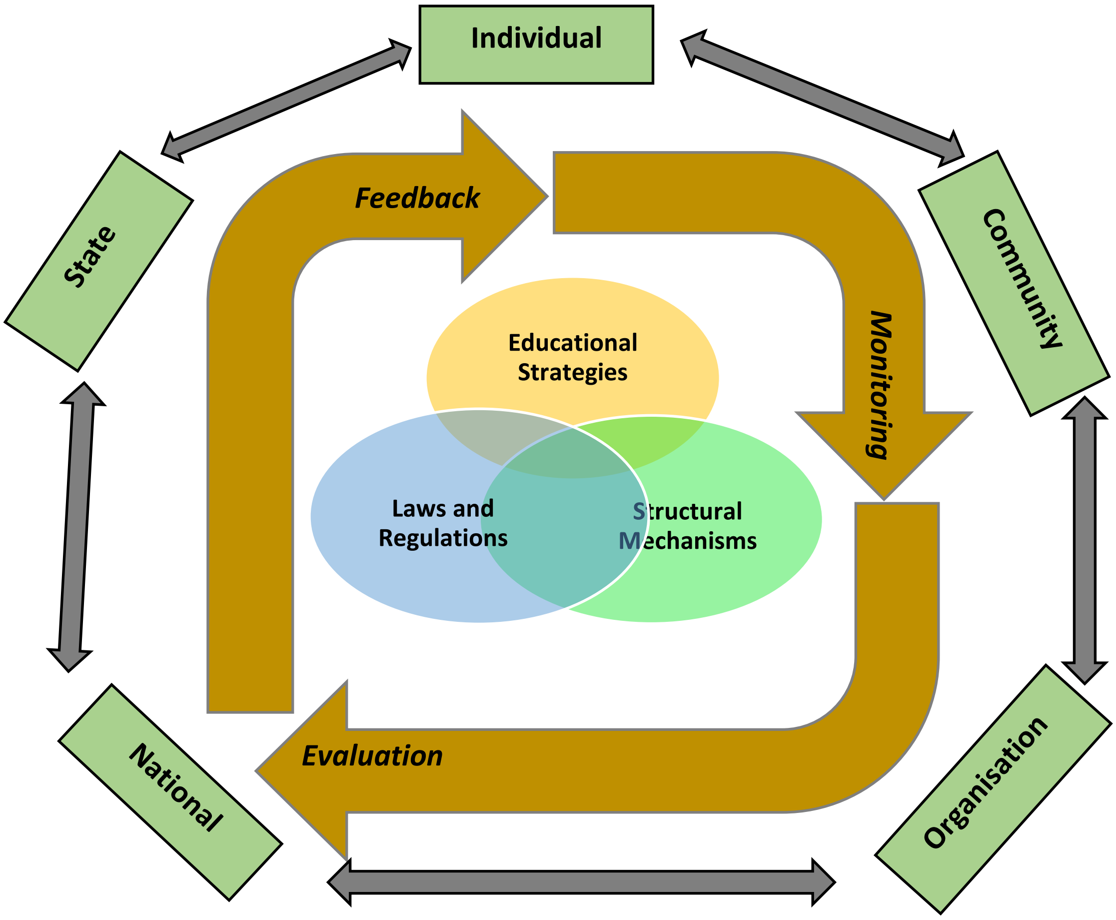

Figure 2.4 Proposed integrated intervention model to reduce the risk of people driving into floodwater

The model advocates for a systems approach in which the three major intervention strategies are activated together; including educational initiatives for awareness building, structural developments through advanced technology and equipment for improving decision accuracy; and law and regulation activities. In addition, the model specifies the monitoring and evaluation of the three strategies at five different levels including individuals (public, workers, employees); communities and local government (e.g. local authorities, council, community groups and clubs); organisations (e.g. corporates, insurance companies, financial institutions); state (e.g. police, state emergency services, hospitals); and national (e.g. government ministries, policy makers, implementers, and planners).

2.4 Discussion

This review of peer-reviewed research focusing on the risks of driving into floodwater has been informed by analysis of 12 flood fatality studies from 20 years of research in this field, and a number of risk-related research projects that have either included driving into floodwater as a risk factor as part of wider flood-risk research, or, in a small number of cases, has focused on this risk specifically.

The primary outcomes of this review have been a scoping of the magnitude of flood deaths internationally due to driving into floodwater, a summary of the multitude of risk factors associated with driving into floodwater, brief consideration of the use of theories and models to explain people's risky driving behaviour in floods, and the consideration of multiple study recommendations to develop an integrated model for providing direction, and use, in future community intervention initiatives. The identification of research gaps for further research in the context of entering floodwater in vehicles is a secondary outcome of this study and these gaps have been noted along the way.

The majority of articles reviewed identified the risk factors associated with driving into floodwater and assessed people's risk perceptions, attitudes, and the key beliefs that guide the decision-making process and behaviour. Exploring preventive measures and improved intervention strategies was also identified as one of the primary goals in a few of the studies. However, analysing the relative contributions of risk factors to the act of driving into floodwater, and examining the effectiveness of current interventions was not possible, due to a lack of evidence in the literature at this time.

In terms of research design, it seems quantitative approaches (Coates, 1999; Diakakis, 2016; Diakakis and Deligiannakis, 2013; Fitzgerald et al., 2010; Haynes et al., 2017; Jonkman and Kelman, 2005; Kellar and Schmidlin, 2012; Maples and Tiefenbacher, 2009; Sharif et al., 2010; Stjernbrandt et al., 2008; Ashley and Ashley, 2008; Yale et al., 2003) outweigh qualitative approaches (Drobot et al., 2007; Franklin et al., 2014; Hamilton et al., 2016; Pearson and Hamilton, 2014). Consequently, many researchers depended on secondary sources of data such as databases, coronial records and archive records, for their analyses. The use of surveys through self-administered questionnaires, focus groups and interviews that generally provide in-depth primary data in qualitative or a semi-quantified form, are relatively rare. In future, more surveys to collect primary data, be it qualitative to understand issues in-depth, or quantitative to enable statistically sound generalizations, are needed.

Surprisingly almost 80% of the selected studies in this review are from the USA and Australia, and more than 10% from Greece, while studies from other continents / countries with significant flood risk, such as Asia and South America were not identified. In developing countries it is likely that data are not well-recorded and also that fatalities on foot may remain higher than in vehicles. However, of particular interest is that other than Greece, no other European studies were identified where it is likely that vehicle-related fatalities are high. Further research on this is needed.

The number of vehicle-related flood deaths identified in each study undoubtedly showed the significance of the problem worldwide, however, comparative study between countries are very few, only two (Jonkman and Vrijling, 2008; Pereira et al., 2017) were identified by this review. Further studies that enable a comparative analysis between and within countries (for example, by locations and by year) would be useful to reveal more patterns or trends in death rates. Moreover, greater comparison of fatality rates and trends between countries and regions could be determined by calculating and comparing “deaths per miles driven” or “deaths per vehicles registered”. This information was not available in any of the studies reviewed.

Although many studies identified the probable demographic, economic, social, and behavioural factors associated with driving into floodwater, many other factors are still unexplored; particularly those that would assist in better understanding the decision-making processes of this risk taking behaviour. This review identified risk perception as a prime determinant of decision making, consistent with Becker et al., (2015). An assessment of the relative contribution of each factor to risk perception and decision-making in further research would be useful. In general, drivers use personal judgement and experience to cross water on roads. However, this decision making is not easy. For example, the loss of stability of a vehicle in floodwater is a complex mechanical phenomenon, which involves flood characteristics (e.g. flow regime), vehicle characteristics (e.g. shape, weight, elevation of the vehicle) (Pregnolato et al. 2017; Arrighi et al., 2015; Xia et al., 2011; Shu et al., 2011) and also the characteristics of the road and crossing (Gissing et al.2016). The mobilization of vehicles by floodwater can occur at very low water depths (e.g. less than 2 m found in Stjernbrandt et al (2002) study) if associated with high flow velocities, as in flash floods. Therefore, further studies are needed that investigate flood mechanics (e.g. flood depth/velocity) and vehicle parameters and consequences (e.g. how quickly water enters and the velocities and depths required to move different vehicles (Pregnolato et al. 2017) and how best to communicate this information to the public (Hamilton et al., 2018). The mechanics of the phenomenon has been recently studied both in a computational (Arrighi et al., 2015) and in an experimental fashion (Xia et al., 2011; Shu et al., 2011). Investigating how this information can be used to mitigate risk is certainly a worthwhile area to explore in future research.

If we consider the application of theories in this regard, only the behavioural theories of TPB and PMT have been applied to date. Many other leading decision-making theories and theoretical behaviour approaches exist but have not been utilised, e.g. the Protective Action Decision Model (PADM), the Recognition-Primed Decision Model (RPD), the Task-Capability Interface model (TCI),), the Extended Parallel Process Model (EPPM); or the Multidimensional Locus of Control Theory (MLOC). Consideration of some of these other theories may provide a better route for explanation of the causal factors that influence people's decision-making processes and protective actions in stressful situation, such as entering floodwater in motor vehicles.

Advanced measures beyond traditional techniques such as cognitive mapping (Ruin et al., 2007), scenario based audio-visual stimulus, or simply a detailed case study dealing either with incidents resulting in deaths or 'near misses' could be more helpful to an understanding of the rationale behind the behaviour. Randomised control trials and more realistic driving simulations may also help inform our knowledge of driver decision-making in this context and be a valuable addition to the evaluation of intervention approaches.

Australian management strategies have relied upon education and rescue interventions as primary management tools (Gissing et al., 2016). However, limited research has been conducted to evaluate these initiatives and their efficacy remains largely unknown. One recent exception is an evaluation conducted by Hamilton et al., (2018) who designed and evaluated a video infographic that highlights the dangers of driving through floodwaters. The study identified that the infographic was effective in reducing positive attitudes and social pressure to drive into floodwaters immediately after watching the video (Hamilton et al., 2018). In-depth research is essential to identify the gaps and successes of these initiatives in order to build an evidence-base for future programs (Franklin et al., 2014).

In conducting this systematic literature review we have also considered the limitations imposed by our selection criteria and search approach. One of the main limitations is that we have only included peer-reviewed academic literature published prior to 31 August 2017. From an examination of the literature it appears that two recent and relevant publications were excluded, a Hamilton et al., (2018) publication that documents the evaluation of an infographic (discussed above), and a Hamilton et al., (2017) publication that utilised the theory of planned behaviour to explore drivers' experiences and beliefs with respect to driving through floodwater. Other forms of publication, such as non-peer reviewed journal articles and conference proceedings, technical reports, and grey literature have been excluded, which could have provided further useful information. In addition, searches were limited to databases that were accessible. Other databases (e.g. ProQuest) may have yielded additional research. However, we do believe that despite these limitations this review contributes significantly to the existing literature on the impacts of driving into floodwater research and provides a robust platform for further extension and additional research in the area.

2.5 Conclusion

The findings of the current review highlight that the number of vehicle-related flood fatalities internationally is significant, and demands more attention from researchers, policy makers, and emergency services alike. Although there are a large number of identified risk factors for driving into floodwater, and a degree of consistency across studies, the findings of this review suggest that more research is needed to explore salient factors and their relative influence, to explain risk-taking behaviour more reliably. The findings from recommendations for emergency management plans, policy, and practices strongly support a holistic behavioural change approach to overcome the challenges inherent in lowering the incidence of driving into floodwater and reducing the risk of harm. To move towards this, an integrated model and intervention strategy involving education, structural interventions, law and regulation has been proposed. This approach will be most effective if co-developed with, and designed according to the needs of, those at risk, ranging from different age groups (children, youth, adults, aged), genders (male, females, others), and roles, including: parents, teachers, drivers, passengers, emergency service workers, law enforcers, the media, policy planners.. Partnership, association, and collaboration between all levels of community (individual, community and local government, organisations, states and national agencies) is crucial to initiate, design and implement effective and successful prevention strategies. Moreover, continuous evaluation, monitoring and feedback of initiatives will ensure accountability, adaptability and improved efficacy.

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Interlude 2: Exploring vehicle-related flood fatalities in Australia

Chapter 2 presented a comprehensive review of the academic literature, published in the English language, that explored the behaviour of driving through floodwater. This included flood fatality statistics from several countries, the reasons for entering floodwater, risk factors associated with this behaviour, theories and models used to explore and explain this behaviour, current mitigation approaches, and research gaps.

This global review revealed that there is extensive coverage of flood-related deaths and behaviour in and around floodwater in the literature, albeit from a limited number of countries. However, there are very few studies reporting vehicle-related flood fatality data specifically, and the reporting of vehicle-related flood fatalities in broader flood fatality studies is scant.

The literature review in Chapter 2 revealed that, in Australia, flooding is the second most deadly natural hazard. During the period 1995 – 2015, 81 people died driving into floodwater, which accounted for 43% of flood-related deaths (Haynes et al., 2017). Historical flood fatality research in Australia articulated the need to understand this behaviour better, to enable the development of more effective interventions and strategies to reduce fatalities.

Investigation of academic and grey literature revealed that there was no detailed review of vehicle-related flood deaths in Australia. Further exploration revealed that this data was held in the Australian National Coroners Information System (NCIS), and could be searched for and identified, extracted, and analysed.

The following chapter details an analysis of Australian vehicle-related flood fatality data undertaken to characterise the situations and contexts in which recent fatalities have occurred, with a view to making recommendations for policy and practice.

Chapter 3: Risks and Fatalities in Australia

STUDY 2

<u>Publication history</u>

Study 2 was submitted on 26 March 2019 for publication in the "*Journal of Flood Risk Management, JFRM-0054-19, 2019"*. The paper is entitled "Vehicle-related flood fatalities in Australia, 2001–2017". Journal of Flood Risk Management has an impact factor of 3.24. The author of the present dissertation wrote approximately 80% of this paper.

Conference Publications: Poster Presentations

Ahmed M., Haynes, K, Taylor M. Vehicle-related flood deaths in Australia, 2001- 2017. Paper presented at Floodplain Management Australia Conference. Canberra, 2019.

Ahmed, M.A., Haynes, K., Taylor, M. (2018). Vehicle-related flood deaths in Australia, 2001-2017. Paper presented at AFAC Conference, Perth, 2018.

Vehicle-related flood fatalities in Australia, 2001–2017

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Abstract: This study analyses the circumstances of vehicle-related flood fatalities between 2001 and 2017, in Australia. The research identified 96 deaths from 74 incidents during this period. The aim of this analysis is to better understand the demographic, spatial and temporal patterns, and the situational conditions in which deaths have occurred. This is important for informing efficient and strategic risk reduction strategies. Data were accessed from the Australian National Coroners Information System (NCIS); which includes witness and police statements, forensic documents, and detailed coronial inquest reports. The most recent fatality cases, that were not yet available in NCIS, and additional information not recorded in NCIS records, was gathered from archived newspaper reports and relevant websites such as the Australian Bureau of Statistics (ABS) and the Australia Bureau of Meteorology (BoM).

Analysis was conducted in two phases. In phase one, data were coded and categorised according to a range of factors previously identified as significant in vehicle-related flood fatalities internationally. These were: demographic (driver and passenger age/gender), spatial (State, location, location type), temporal (year, month, day of the week, season, time of day), and situational factors (speed/flow of water, type of vehicle involved, journey characteristics, weather conditions, proximity to driver's home, presence of alcohol, whether undertaking work-related duties, causes of death, etc.). In phase two, a detailed analysis was conducted on eleven selected incidents for which there were complete sets of records. This enabled exploration of the full range of circumstances surrounding these events, including exploration of additional factors, such as water depth, width of floodwater at water crossing and signage, as well as judicial findings, such as causes, punishments, and recommendations. This detailed analysis provides insight into the multifaceted nature of fatal vehicle-related flood fatality incidents.

The overall results reveal that, for drivers, fatality incidence is higher for males than females, and in addition to younger drivers, older males are over-represented in the fatality statistics. As passengers, young women and children are over-represented. From the detailed analysis of incidents, our study identifies floodwater with high flow and the presence of alcohol and drugs to be common contributing factors, with drugs and alcohol leading to impaired responses, or impacting mobility, thus reducing the chance of survival for the vehicle occupants. The study concludes with recommendations for policy and practice reform

Keywords: driver, drowning, flood, fatalities, natural hazard, passenger, vehicles

Vehicle-related flood fatalities in Australia, 2001–2017

3.1 Introduction

Vehicle-related incidents account for a significant proportion of flood fatalities globally (Diakakis and Deligiannakis, 2015; FitzGerald et al., 2010; Jonkman and Kelman, 2005; Jonkman and Vrijling, 2008; Kellar and Schmidlin, 2012; Peden et al., 2016; Ashley and Ashley, 2008; Terti et al., 2015; Yale et al., 2003). In the United States, Ashley and Ashley (2008) reported 63% of all flood deaths were vehicle-related. Similarly, in relation to flash flood deaths specifically, Špitalar et al. (2014) and Terti et al., (2015) both identified that 68% of fatalities were vehicle-related. Jonkman and Vrijling (2008) identified that vehicle-related deaths were lower in Europe than the United States during the period 1989–2002, with only 27% of flood deaths associated with a vehicle in Europe compared to 63% in the United States. In Greece, fatalities that occurred inside a vehicle, increased from 30% to 58% during the period 1960–2010 (Diakakis and Deligiannakis, 2016). In Portugal fatality rates were generally lower (14%), but also increased in the last three decades with 25% of total flood fatalities between 2001 and 2010 being vehicle-related (Pereira et al., 2017). In Australia, FitzGerald et al. (2010) reported that between 1997 and 2008 49% of flood fatalities were vehicle-related, similarly Haynes et al. (2017) identified 49% between 1900 and 2015. Recent research in Australia (Haynes et al., 2017, Peden et al., 2017) has documented and quantified vehicle-related flood fatalities, however, these studies have done so in the context of an investigation of all flood fatalities over an extended time frame, and gaps remain in our understanding of vehicle-related flood deaths specifically.

The focus of this study is recent vehicle-related deaths in Australia that occurred between 2001 and 2017. Our research explores the circumstances surrounding these fatalities using coronial inquest records to better understand the situational, demographic, and environmental conditions under which these deaths occurred. The study explores the age and gender patterns of the vehicle occupants, specifically: how many people were inside the vehicle when one or more fatalities occurred; the distribution of deaths - the driver or the passenger/s; gender and age of the drivers and passengers; and, circumstances of survivors- number of survivors, approximate age and in-vehicle role of survivors, what influenced the survivability of those who are able to escape the vehicle - compared to those who were unable to. This research also provides a record of the spatial and temporal patterns and the environmental circumstances surrounding these fatal events and makes an important contribution to the growing international body of knowledge of how and why vehicle-related flood fatalities occur.

3.2 Methods

3.2.1 Data

The Australian National Coroners Information System (NCIS) was accessed to gather information on all vehicle-related flood fatalities that occurred between 2001 and 2017. A few recent fatality cases that were not yet available within NCIS were identified from archived newspaper reports. Additional information was also accessed from archived newspaper reports and relevant websites such as the Australian Bureau of Statistics (ABS) and the Australian Bureau of Meteorology (BoM). To search for specific incidents in Australian newspapers, the Factiva database was used, alongside a number of online news portals, e.g. ABC News, the Northern Star, the West Australian. Google maps was utilised to investigate the spatial context of each fatality.

All fatalities included in this study were carefully selected from the NCIS database as those directly attributed to flood events and the use of motor vehicles. The variables of interest were based on a previous review of international literature (Ahmed et al., 2018), and were selected to mirror the important risk factors that were identified e.g. gender, age, role in vehicle, influence of drugs and alcohol etc. The initial search for relevant fatality case identification was time consuming as the classification of flood fatalities and lists of casualties were not consistently described in the database coding structure. Coroner's reports were not available for all cases, especially recent cases which were not yet closed, or were noted as not having had the inquest yet. Despite these shortcomings, the NCIS database allowed the researchers the retrieval of witness and police statements, forensic documents (e.g. autopsy reports), and detailed findings contained in coronial inquest reports for the majority of the fatalities.

3.2.2 Analysis

The data search identified a total of 96 deaths that occurred between 2001 and 2017 due to flood-related vehicle incidents; 79 from the NCIS database and 17 from archived newspapers. A detailed register of the 96 fatalities was developed in Microsoft Excel which contained a set of selected variables describing the circumstances of the incident. The formation of the register allowed the development of a systematic record of data, based on evidence fragmented across several reports, and provided standardisation of the information for analysis. The complete analysis of the 96 fatalities was conducted in two phases, detailed below.

Phase 1

In this stage, 22 incidental variables were selected based on the vulnerability factors of fatalities which were directly associated with motor vehicles and caused due to flood events. The variables were grouped into four major categories-demographic, spatial, temporal and situational. Next the variables under these major categories were classified into subcategories (see Table 3.1) and each subcategory was coded using numerical coding schema to turn the qualitative data into quantitative data for analysis. The research team completed the full coding task crosschecking the entire register. After coding, simple mathematical operations were used to quantify percentages of subcategories of each variable in Phase 1 to provide a broad overview. Descriptive approaches were used to summarise the findings. To investigate the representation of a limited set of variables in the observed fatality data, i.e. age, gender, vehicle occupant role – driver/passenger, simple (2x2) chi square analyses were conducted.

Table 3.1

Variable categories and sub categories included in coding fatality and incident data.

Major Category	Variables	Sub categories
Demographic	▪ driver/passenger/s age	▪ age groups: 0-9 (small children), 10-19 (child), 20 -29 (youth), 30-39 (young adult), 40-49 (adult), 50-59 (middle aged), 60-69 (middle aged), 70-79 (elderly), 80+ (old)
	▪ driver/passenger/s gender	▪ gender: male, female
Spatial	▪ state	▪ state: QLD, NSW, ACT, WA, NT, VIC, TAS
	▪ location/suburb	▪ suburb: postcode used for point location map
	▪ location type	▪ location type: a low-water crossing, bridge, or causeway, a ford or weir, a normal stretch of road
Temporal	▪ year	▪ year: 2001-2017
	▪ month	▪ month: January-December
	▪ day of the week	▪ day: Monday - Sunday
	▪ season	▪ season: summer, autumn, winter, spring
	▪ time of day	▪ time of day: morning (07:00am to 11:00 am), around noon (11:00am to 03:00 pm), afternoon (03:00 pm to 5:00 pm), evening/night (7:00 pm to 4:00 am) and twilight (4:00 am to 7:00am - dawn and 5:00 pm to 7:00pm - dusk)
	▪ lighting conditions	▪ lighting conditions: daylight (good light), dawn/dusk (fading/golden glow), dark (poor lighting)
Situational	▪ number of fatalities per incident	▪ number
	▪ number of occupants in the vehicle	▪ number
	▪ number of occupants who survived	▪ number
	▪ presence of alcohol/drugs	▪ presence of alcohol/drugs: yes, no
	▪ work-related duties	▪ engaged in work-related duties/on duty: yes, no
	▪ causes of death	▪ causes of death: drowning, injury with drowning, others (e.g. heart attack)
	▪ weather conditions	▪ weather condition: no rain, raining but not heavy, heavy rain, others (e.g. storm/wind, overcast)
	▪ water flow	▪ water flow: no flow/still, moderate flow, fast flow
	▪ proximity to driver's home	▪ proximity to home: less than 10 km, 10-20 km, 20-50 km, more than 50 km
	▪ type of vehicle	▪ type of vehicle: cars, sport utility vehicles (SUVs), utility vehicles (utes), motorbikes, trucks, vans, tractors, other
	▪ journey characteristics	▪ journey details and reasons for entering floodwater: travelling en route to/from home/work/other destinations, evacuating, working, attempting to rescue/retrieve property etc.

***Note.** Where functional information was missing, the fatalities were labelled as unknown in that sub category

Phase 2

In this phase, eleven incidents from across Australia with full report findings were selected for further qualitative analysis. The steps involved in selecting the eleven incidents are summarised in Figure 3.1.

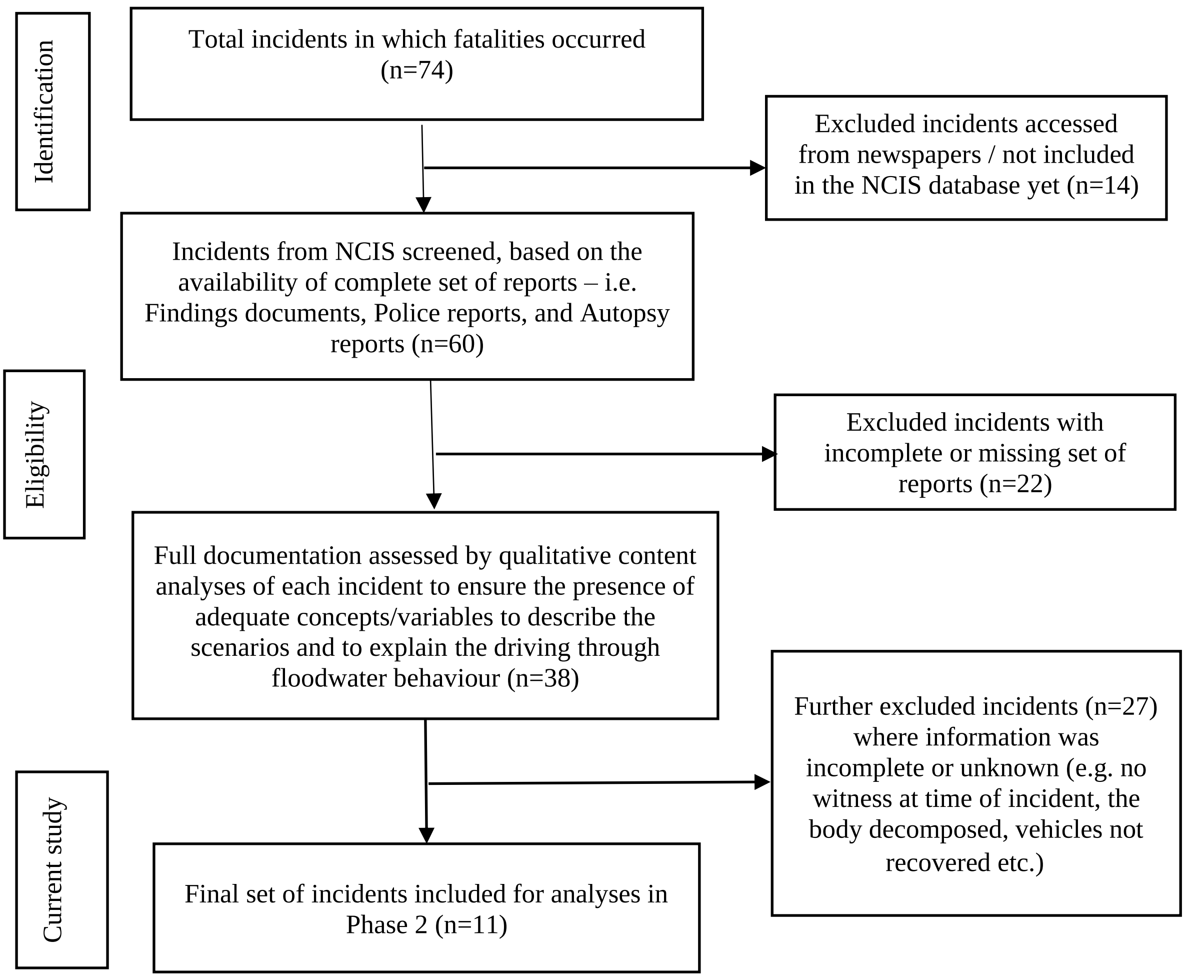

Figure 3.1. Selection of incidents for further analysis.

The inclusion criteria for incident selection were: first, the availability of a full set of reports in the NCIS database which was, indisputably, important to explain the incident scenario adequately; secondly, presence of those factors in each incident that previous literature had demonstrated as important in understanding decision-making and the behaviour of driving into floodwater (Ahmed et al., 2018). To assess the availability of information, basic qualitative content analyses (Weber, 1990) was undertaken. Exclusion criteria were: incidents accessed from newspaper and other sources, which were not open in NCIS database; incidents for which all reports-findings, police and autopsy report were not available in the NCIS database; and incidents for which information identified as important for understanding the scenario was incomplete or unknown, such as, lack of a witness statement, lack of evidence for causes of death, missing vehicle information where vehicles were not recovered.

Systematic narrative syntheses of the selected incidents were then undertaken from the evidence: how environmental and physical cues were understood to have influenced the driver's decision-making; the errors or mistakes made; what form of rescue attempt was made to save the victims and recover the deceased; the presence and possible impact of warnings and risk indicators that were present; and the role of passengers, or others, who were present at the scene. This analysis also explored the vehicle status and floodwater characteristics during the incidents, the actions taken by the deceased prior to death, their reported level of awareness or knowledge of the flooding and possible dangers, and the reported capacity of the victim to act.

3.3 Results and Discussion

The final database contained the details of 96 individual vehicle-related flood fatalities in Australia that occurred between 2001 and 2017. These deaths took place during 74 flood-related vehicle incidents, with a mean of 1.3 fatalities per incident.

The following sections report on the Phase 1 analysis, and include the demographics of the fatalities, the spatial and temporal patterns of the fatalities and incidents, and the situational factors surrounding the fatal vehicle incidents. The Phase 2 analysis follows, with a more detailed breakdown of the 11 selected incidents.

3.3.1 Phase 1 Analyses

3.3.1.1 Demographic Factors

The ages and genders of the fatalities were categorised, and are shown in Figure 3.2.

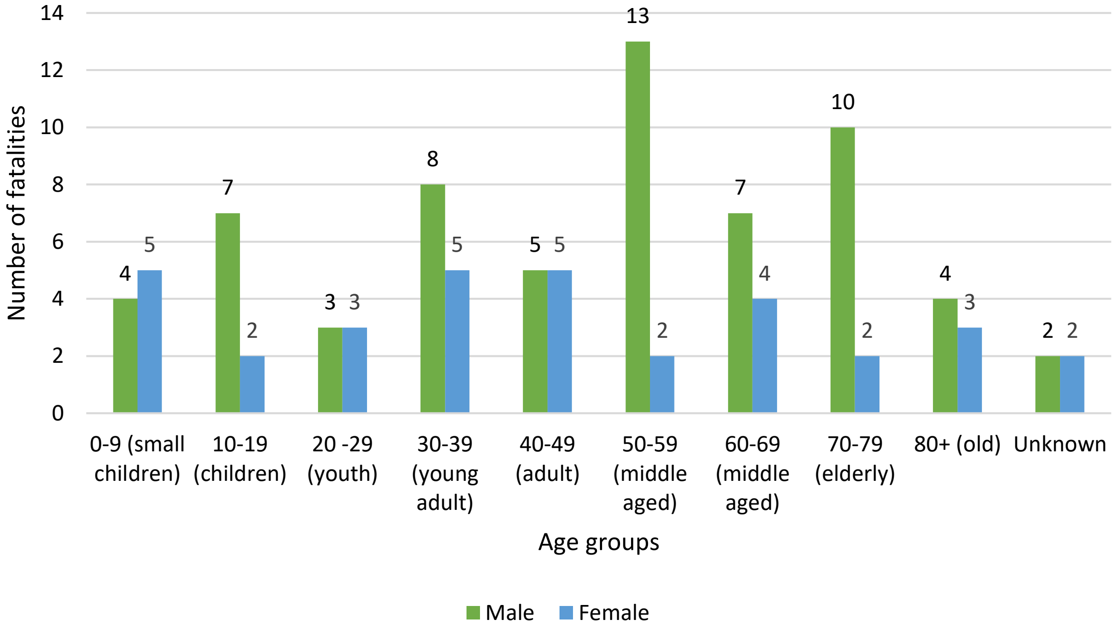

Figure 3.2 Breakdown of vehicle-related fatalities by age and gender.

Data in Figure 3.2 indicate that, overall, a slightly greater number of fatality cases were noted for those aged 50-79 years (n=15) and 30-39 years (n=13), and fewer for those aged 20-29 year (n=6) and over 80 (n=7). However, due to the relatively small numbers involved, overall differences across age groups are not statistically significant. This finding is different to the pattern seen in longer time series of flood-related fatalities due to all causes in Australia. Haynes et al. (2017) explored flood fatalities due to all causes from 1900-2015 and in these data, youth and young adults are overrepresented.

Males accounted for a higher number of deaths overall (66%; n=63) than females (34%; n=33). This notably higher proportion of male to female deaths is in accord with male overrepresentation in vehicle-related flood death statistics reported in the broader literature (Diakakis and Deligiannakis, 2013; Drobot et al., 2007; Haynes et al., 2017; Jonkman and Kelman, 2005; Kellar and Schmidlin, 2012; Maples and Tiefenbacher, 2009; Sharif et al., 2010).

When gender data are examined across age groups, the number of male deaths is notably higher in most age groups; the exceptions being small children (0-9 years), youth (20-29 years), and adults (40-49 years). Gender differences are generally more apparent in those aged over 30, where the number of male deaths recorded for those aged 50–59 and 70-79 were approximately six times and five times higher than the number of female deaths, respectively. The relationship between age and gender was tested using Chi Square tests, however, this relationship was found not to be statistically significant (χ^2 =.801, df=1, p=0.371).

With regard to the victims' in-vehicle roles (Figure 3.3 and Figure 3.4), 60% of the total fatalities were drivers (n=58), 31% were passengers (n=30) and 8% were unknown. Of the 58 drivers, 72% were male (n=42), 28% female (n=16) and of the 30 passengers, 57% were male (n= 17), 43% female (n=13). The proportion of female to male fatalities is higher for passengers than drivers, i.e. 43% of passenger fatalities were female compared to 28% of driver fatalities. The distribution of driver fatalities across age and gender is shown in Figure 3.3, and the distribution of passenger fatalities across age and gender is shown in Figure 3.4.

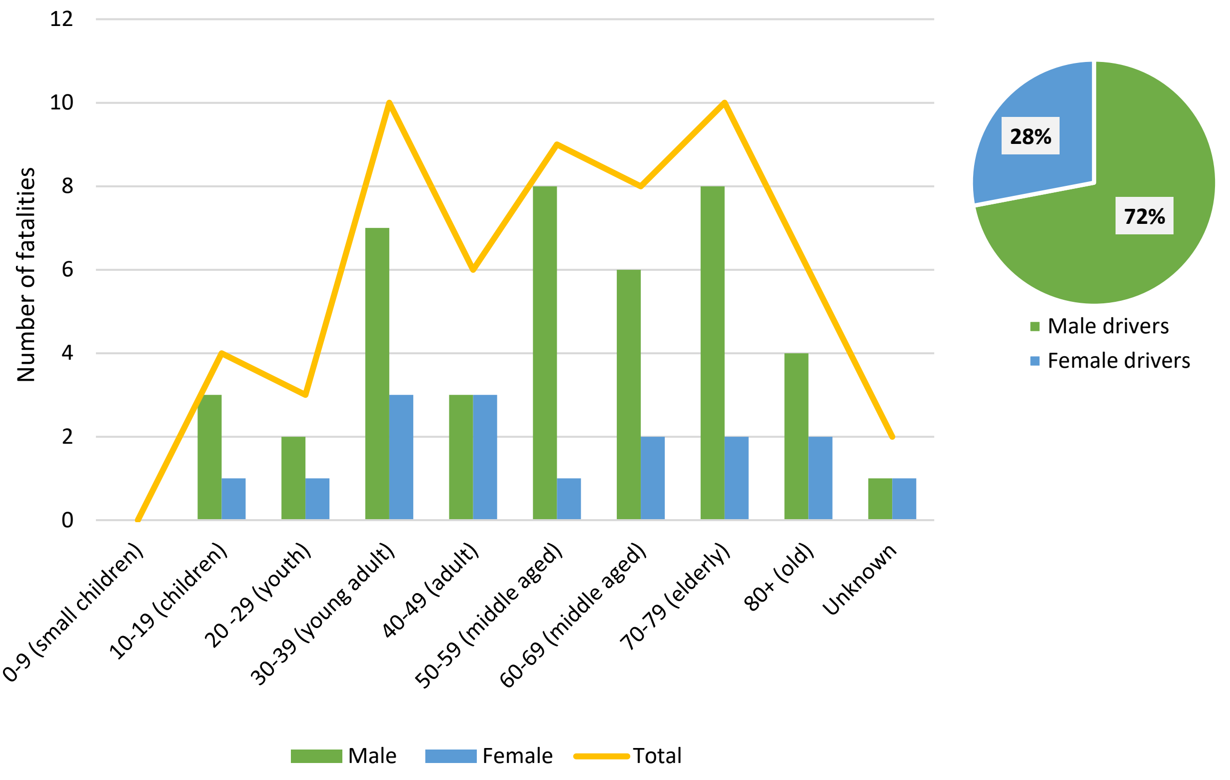

Figure 3.3 Breakdown of driver fatalities by age and gender

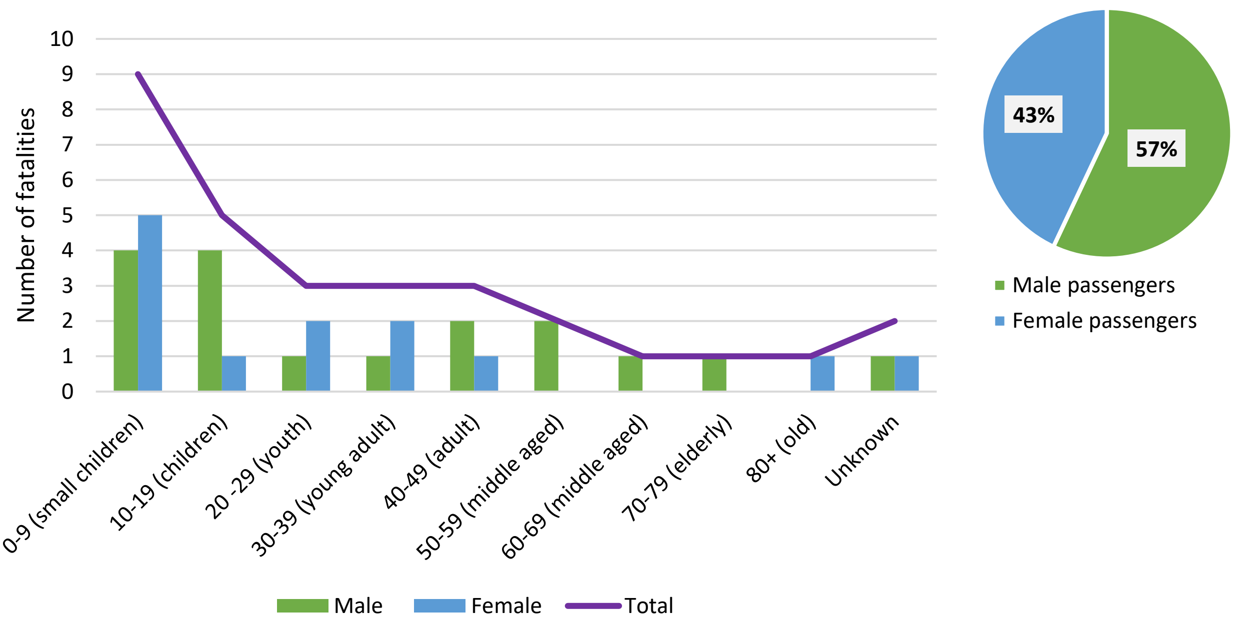

Figure 3.4 Breakdown of passenger fatalities by age and gender

The age distribution of the driver fatalities shows that the majority 88% (n=49) are aged over 30 years. As might be expected for passengers, the number of child fatalities (n=14, 46%) is higher than adult fatalities. These distributions were compared using Chi Square tests and differences were highly statistically significant (χ^2 =16.53, df=1, p <0.001).

The results of demographic trends (driver and passenger dimensions) identified in this research have implications for the development of intervention strategies targeting those at risk. It is imperative that more is done to communicate the risks of entering floodwater in a vehicle from a passenger's point of view, particularly for children and young female adults. This could involve messaging, or approaches, that persuade drivers to put the responsibility for their passengers ahead of their journey and also assist passengers to understand their risks and provide approaches to enable them to express their concerns to the vehicle driver.

It is also important to note the prevalence of males in these fatality statistics. Although this is not a surprising finding, the relatively greater numbers of older males perhaps goes against the stereotype of young, reckless drivers making risky impulsive decisions. This finding also suggests that driving experience and complacency may play a greater role in these incidents and that possibly there is a higher degree of cognitive engagement in these decisions. This has implications for risk messaging and education, where questioning assumptions, based on experience or ability, may be helpful.

3.3.1.2 Spatial and Temporal Patterns

The annual number of fatalities during the period 2001 to 2017 is shown in Figure 3.5. The annual death toll is highest in 2011 with 17 fatalities (attributable to a widespread severe flooding event in Queensland in January 2011). The mean death toll across the study time period is 5.65 fatalities per year. Data show a moderate rising trend from 2001 to 2011. Since 2006, the annual number of fatalities has continued above the mean almost every year, except 2012 and 2014. No vehicle-related fatalities were recorded in 2014. In recent years, since 2015, the number of fatalities annually appears to have increased again in comparison with the early 2000s.

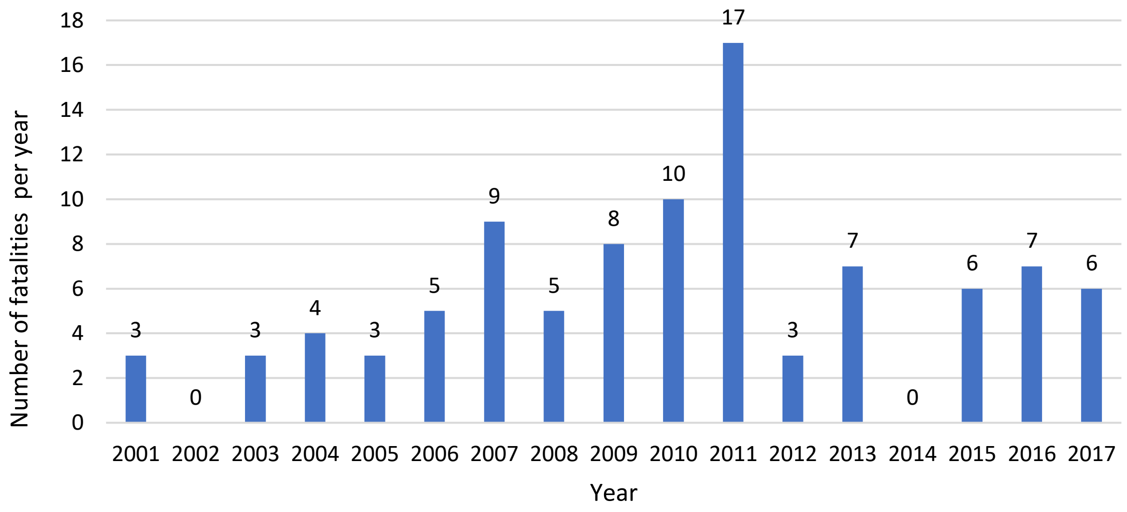

Figure 3.5 Annual number of vehicle-related flood fatalities from 2001 to 2017

Fatalities with respect to the month of occurrence are summarised in Figure 3.6, and fatalities by Australian State/Territory are shown in Table 3.2.

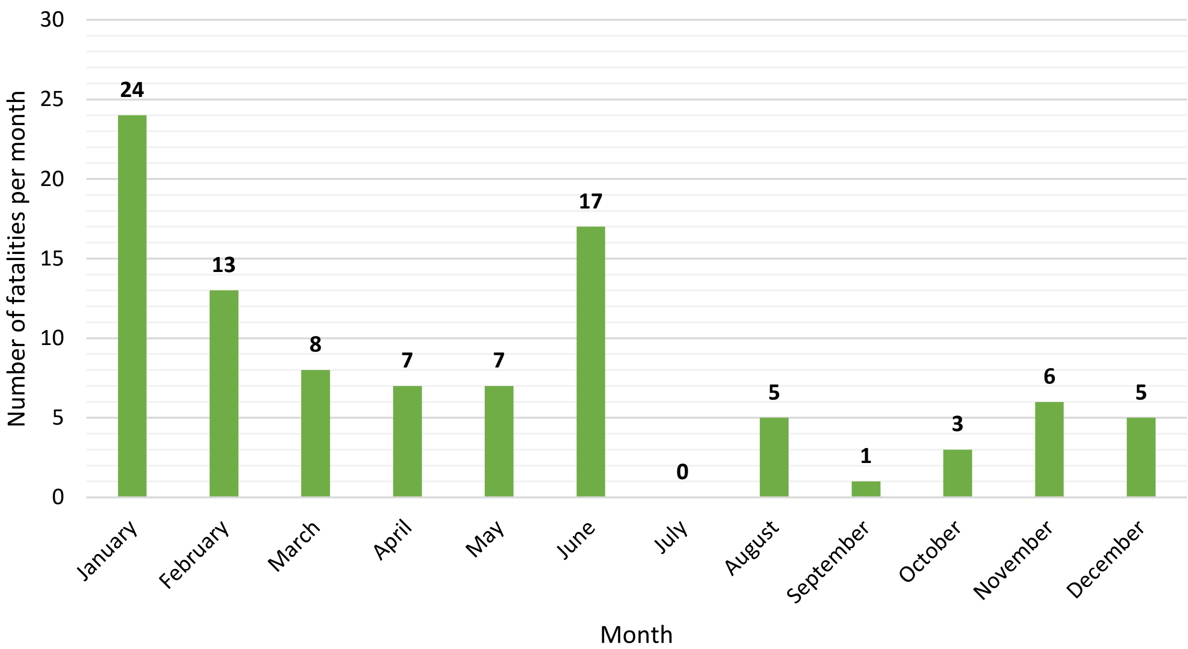

Figure 3.6 Monthly distribution of vehicle-related flood fatalities during the period 2001-2017

A higher number of fatalities occurred during the Australian summer months of January (n=24; 25%) and February (n=13; 14%), and the winter month of June (n=17; 18%).

Table 3.2

Vehicle-related flood fatalities (2001-2017) and population distribution by State and Territory.

States	**Vehicle-related flood fatalities**		**Population (Dec 2017)**	
	(n)	**(%)**	**(n) '000**	**(%)**
Queensland (QLD)	52	54.2	4965.0	21.6
New South Wales (NSW)	29	30.2	7915.1	34.4
Victoria (VIC)	6	6.3	6385.8	27.7
Western Australia (WA)	4	4.2	2584.8	11.2
Tasmania (TAS)	3	3.1	524.7	2.3
Australian Capital Territory (ACT)	1	1.0	415.9	1.8
Northern Territory (NT)	1	1.0	246.7	1.1

By states, Queensland (QLD) and New South Wales (NSW) account for 84% of the overall number of fatalities (n=81). Other states accounted for 16% of all fatalities (n = 15). Of note in Table 3.2, is the proportionally higher number of fatalities in QLD (54%), despite its relatively low population compared to other states (only 22% of the Australian population). Whereas 28% of the population live in VIC, but only 6% of the vehicle-related flood fatalities occurred in that State. Significant meteorological differences exist between these two states, and help to explain these findings, i.e. QLD has a more tropical climate with monsoonal and cyclonic impacts. However, both states have been subject to multiple major flooding events during the period of our study.

The fatality point location map (Figure 3.7) shows that the majority of fatalities have occurred along the east coast of QLD and NSW. The coastal strip from mid-NSW (Wollongong) to mid-QLD (Marlborough) has been identified previously as the most hazardous zone in Australia with regard to flood fatalities generally (Coates, 1999).

Figure 3.7 Point location map of vehicle-related fatalities in Australia (2001-2017).

Fatality statistics also have been broken down by State, for both year and month, and are shown in Figures 3.8 and 3.9.

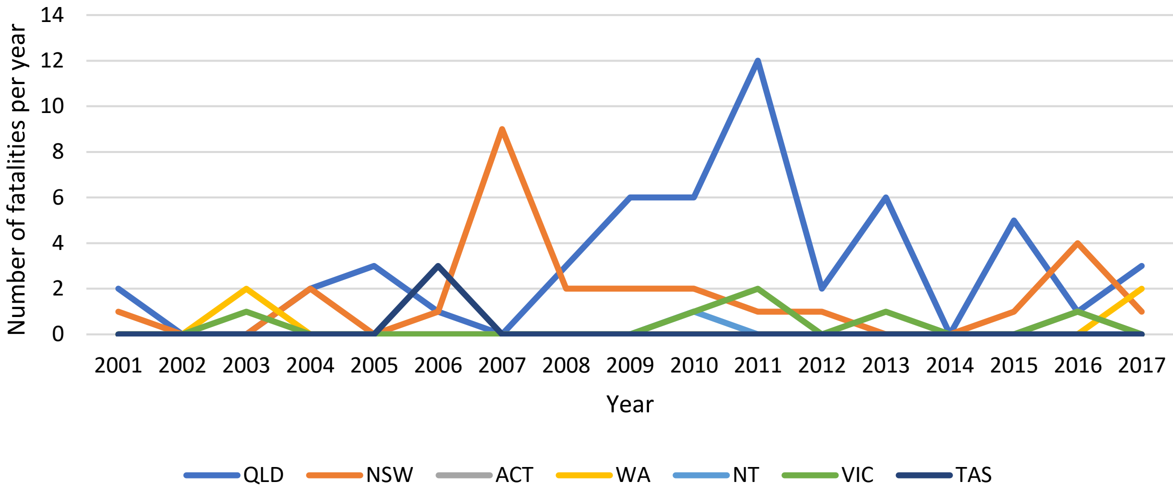

Figure 3.8 Annual number of vehicle-related flood fatalities from 2001 to 2017 by State

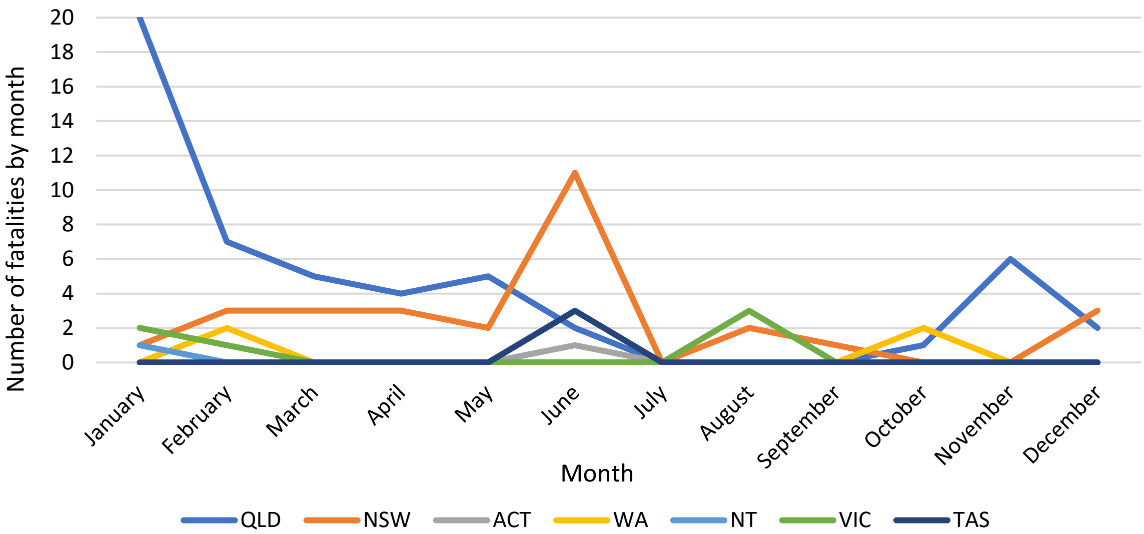

Figure 3.9 Monthly distribution of vehicle-related flood fatalities during the period 2001-2017 by State

Peaks in vehicle-related flood fatality numbers can be seen in QLD and NSW and in the months of January and June, respectively. These mostly relate to two large flooding events. QLD experienced the highest annual number of deaths (n=12) in 2011, with most fatalities overall occurring in the month of January. Between late November 2010 and mid-January 2011 widespread flooding occurred across QLD (BoM, 2012). During the second week of January, 2011 the most severe flooding of the season (including river and flash flooding) occurred in the State capital city of Brisbane and southeast QLD. A total of 30 flood-related fatalities occurred in QLD during this event, with 12 being vehicle-related and reported in this study. The second highest number of annual fatalities occurred in NSW in June 2007 (n=9). June 2007 was notable for four major 'east coast low' weather events which brought heavy rain and severe winds to the region. Substantial flooding occurred in the Hunter Valley and in coastal areas between Sydney and Newcastle during the second week of the month (BoM, 2007). These spatial and temporal patterns of fatalities by annual and monthly distribution have implications in terms of developing, maintaining and prioritising engagement in risk messaging and interventions in relation to time (season) and location (state). It can also assist in terms of more seasonally-focused forecasting, monitoring and reporting of flood hazards on roads.

Further analysis was undertaken to investigate a range of additional temporal and spatial factors associated with vehicle-related flood fatalities. For this section, data were calculated by incident. As there were, on average 1.3 fatalities per incident, reporting by incident more accurately reflects some of the temporal and situational factors, e.g. location type and vehicle type, and avoids overrepresentation in the overall presentation of the data. This approach also provides potentially more useful road safety information regarding 'higher risk' locations, times of day, etc. Figure 3.10 provides a breakdown by season, time of day, day of the week, and location type for the 74 fatal incidents.

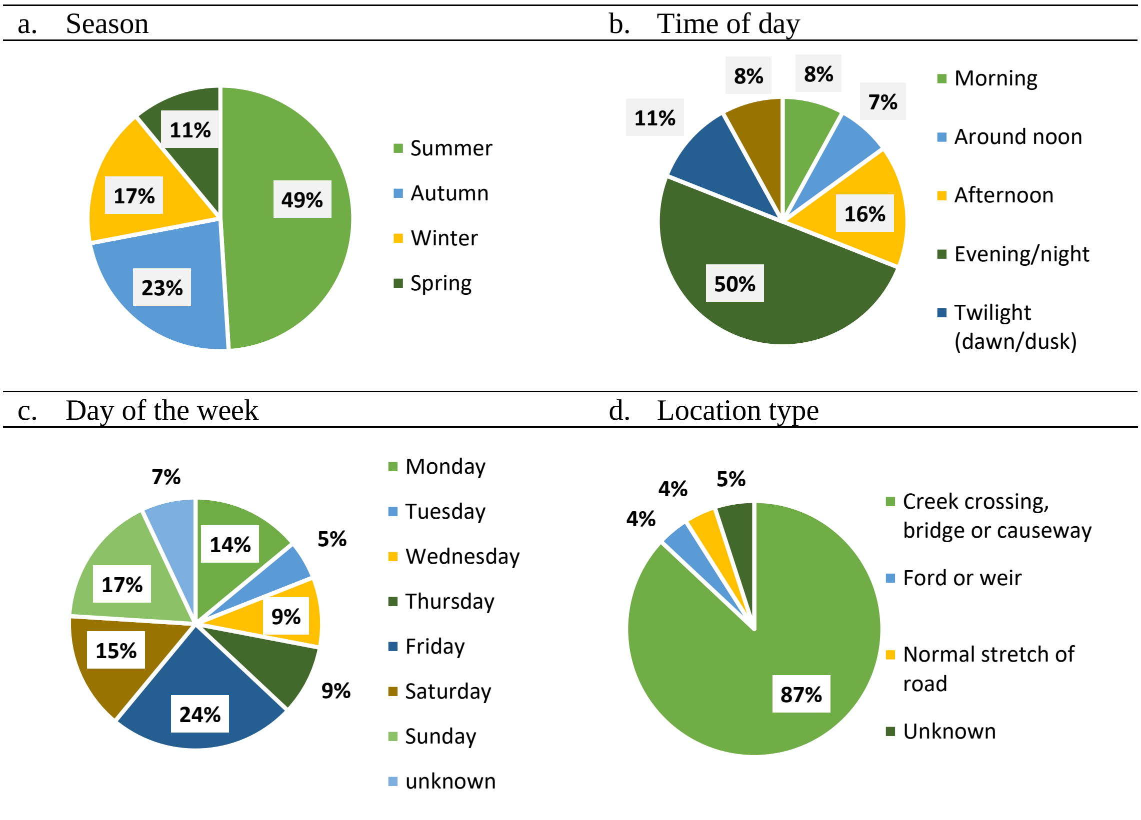

Figure 3.10. Breakdown of incidents (n=74) by: (a) season, (b) time of day, (c) day of the week, and (d) location type.

As can be seen from Figure 3.10, more fatal incidents occur in summer (49%, n=36) and in the evening/at night (50%, n=37). In our study we categorised time of incidents into four main groups to explore the influence of light at the time of the incident (see Table 3.1). This categorisation is adopted from Peden et al. (2016). However, in our study we added an additional category - twilight (4:00 am to 7:00am - dawn and 5:00 pm to 7:00pm - dusk) determined on an incident by incident basis and dependent on the season and time/time adjustment in the relevant States. The addition of a twilight category helps to minimise potential confusion about general lighting conditions at the time of the incident, for example: in summer, 6:00 pm is still daylight, whereas in winter it is dark/night, and in QLD there is no daylight-saving time adjustment.

The results of our analysis identified that the largest proportion of fatalities occurred in the evening and night when it was dark (50%, n= 37) which support a recent review study of previous research concerning vehicle-related fatalities in Australia, Greece, and the United States which showed that most fatalities occurred at night (Ahmed et al., 2018). Eleven per cent of incidents occurred in twilight (semi-darkness or half-light) when light levels were reduced, and 31% (n= 23) of incidents occurred in daylight when natural lighting was good. When daylight incidents are considered, the majority occurred in the afternoon 16% (n= 12), 8% in the morning (n= 6) and 7% occurred around noon (n=5). Regarding day of the week, incidents occurred mostly just before weekend (Friday, 24%; n=17) and in many cases at night, and noticeably at weekends (Sunday, 17%; n= 13 and Saturday, 15%; n= 11). On working days, large numbers of incidents occurred on Mondays (14%; n=10).

In terms of the types of locations where fatal incidents occurred, the majority of incidents occurred when victims were attempting to cross creeks, bridges or causeways (87%; n=64) and the crossings were flooded due to rising water levels. Much smaller proportions occurred at a ford or weir, or on a normal stretch of (flooded) road.

The findings around the temporal aspects of vehicle-related flood fatalities have implications for emergency services and emergency broadcasters regarding the timing of communication campaigns and broadcast messaging. Although emergency services are likely to be familiar with overall weather patterns to optimise the timing of their campaigns, the ability to better target the timing of public safety messages on radio or social media can be informed by these findings.

3.3.1.3. Situational factors

Detailed analysis was undertaken to identify the main situational factors associated with vehicle-related flood fatalities. These include: the presence of alcohol, whether engaged in work duties/on duty, the flow of the water, the weather conditions, proximity to driver’s home, and the reasons for entering into floodwater. In addition, other factual information about the incidents, such as the type of vehicle involved, the number of fatalities per event, the number of occupants present in the vehicle, the number of occupants who escaped from the vehicle, and the causes of death has also been extracted and collated. A number of additional situational variables were considered for this analysis, such as water depth, signage, width of floodwater at crossing, vehicle status at the time of incidents, peer or group or social influence, however details in coronial records were insufficient, or too inconsistent, to incorporate these variables for the majority of incidents.

Data relating to situational factors are shown in Figure 3.11 and Table 3.3 for the 74 fatal incidents. Additional situational data relevant to the 96 individual fatalities is shown in Figure 3.12.

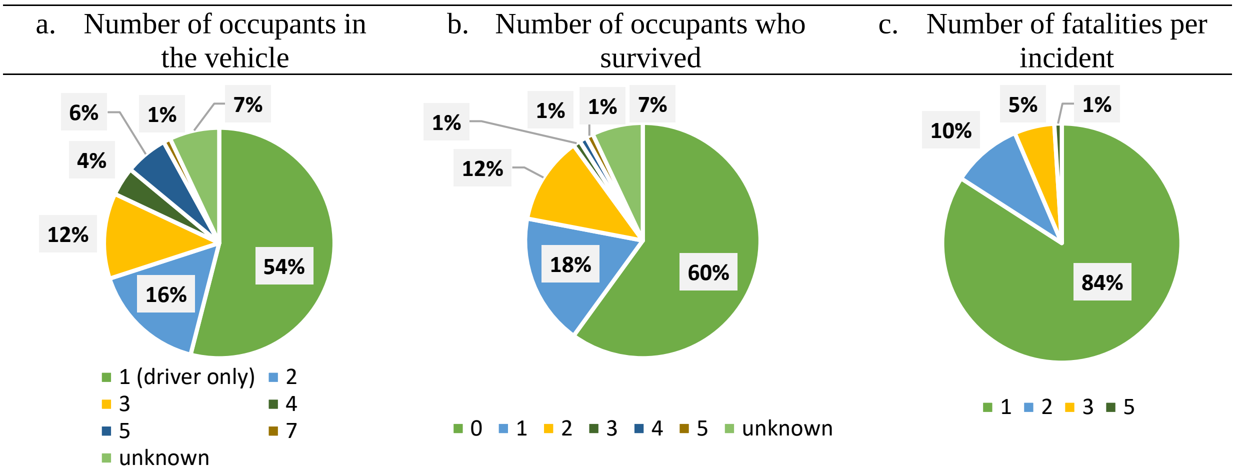

Figure 3.11. Distribution of the incidents (n=74) with respect to (a) number of occupants in the vehicle (b) number of occupants who survived and (c) number of fatalities per incident

The number of occupants in the vehicle at the time of the incident ranged from 1 to 7, whereas number of survivors ranged from 0 to 5. In total, at least 131 individuals were involved in the 74 incidents, 43 of whom survived (33%). For five incidents (7% of incidents overall accounting for 8 fatalities), information relating to the number of occupants in the vehicle and number of occupants who survived was not reported in fatality/case records. In 54% of incidents (n=40) the driver was the sole occupant of the vehicle and was, therefore, also the sole fatality in the incident. In just over a third of incidents there was one or more passengers in the vehicle (39%; n=29) at the time of the incident, in 7% of incidents this figure was unknown. In more than two thirds of incidents (60%; n=44) no individual was recovered alive; this statistic comprised 40 single occupant incidents/sole driver fatalities, and four multiple fatality incidents.

A total of 62 incidents (84%) were single fatality incidents, and in the majority of these (n=40; 64% of single fatality incidents) drivers were alone in the vehicle when they drove into floodwaters. Twelve passengers died in single fatality incidents, where the driver managed to escape (Table 3.3).

Table 3.3

Distribution of fatalities (n=96) by incident (n=74) and in-vehicle role (driver/passenger).

Number of fatalities per incident	Number of incidents		Number of driver fatalities		Number of passenger fatalities		Number of unknown (driver / passenger) fatalities	
	N	%	N	%	N	%	N	%
1	62	83.8	49	51.0	12	12.5	1	1.0
2	7	9.5	3	3.1	7	7.3	4	4.2
3	4	5.4	5*	5.2	7	7.3	3	3.1
5	1	1.4	1	1.0	4	4.2	0	0
Total	74	100	58	60.4	30	31.3	8	8.3

*Note: one incident involved a group of bikers who were categorised as 'drivers' in the analysis.

According to post-mortem reports, drowning was identified as the primary medical cause of death in 66% of the recorded fatalities, 24% occurred due to injury while drowning, e.g. injury to head, chest, neck etc. In 8% of fatalities death occurred due to physical conditions triggered by trauma before or after drowning (coronary atherosclerosis, hypertensive heart disease, emphysema, anoxia) (see Figure 3.12a).

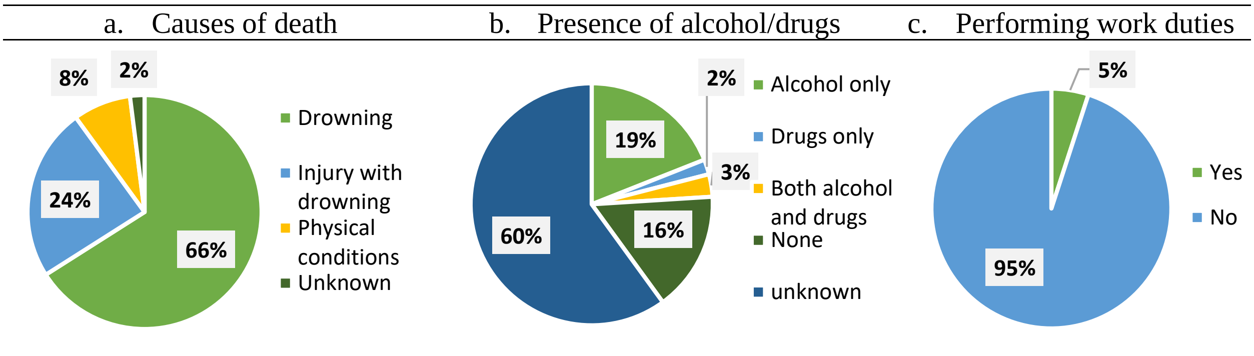

Figure 3.12. Distribution of the fatalities (n=96) with respect to (a) causes of death (b) presence of alcohol/drugs (c) whether the deceased was performing work duties at the time of the incident.

The presence of alcohol and drugs was identified as an important factor in vehicle-related flood fatalities (Figure 3.12b). For the 38 fatality cases in which drug and alcohol levels were tested/able to be tested, 55% of the fatalities (n=21) were identified to have alcohol in their urine or blood from autopsy reports (three of which had both alcohol and drugs present). In most fatality cases in which the presence of alcohol was unknown (n=58), an alcohol level was not identified due to decomposition of the body (when the recovery of the deceased had been delayed) or not verified by police after incidents where the driver survived but was responsible for a passenger death.

There were 21 fatalities in which alcohol was recorded. These fatalities occurred in 16 incidents, and comprised nine drivers; eight sole driver/single fatality incidents and one multiple fatality incident, and nine passengers in five incidents. Three unknown role fatalities occurred in two incidents. This result is supported by a recent study in Australia where alcohol was identified as present in just over a fifth (21%) of all flood-related non-aquatic transport incidents (Peden et al., 2017) and in a study in Sweden where one third of drivers (32%) tested positive for alcohol in vehicle-related flood incidents (Stjernbrandt, et al., 2008). In addition, there were two fatalities, both sole driver/single fatality incidents, in which drugs were present, but no alcohol was recorded.

Although it is not a significant proportion, it is worth noting that 5% of fatalities (n=5) occurred to individuals who were performing work-related duties (on duty) at the time of the fatal incident (Figure 3.12c). The occupations involved include an emergency service worker (fire fighter), two truck drivers, a rail track maintenance worker, and a caretaker of a rural property.

Weather, water flow conditions, and journey characteristics at the time of entering floodwater are noted in Figure 3.13.

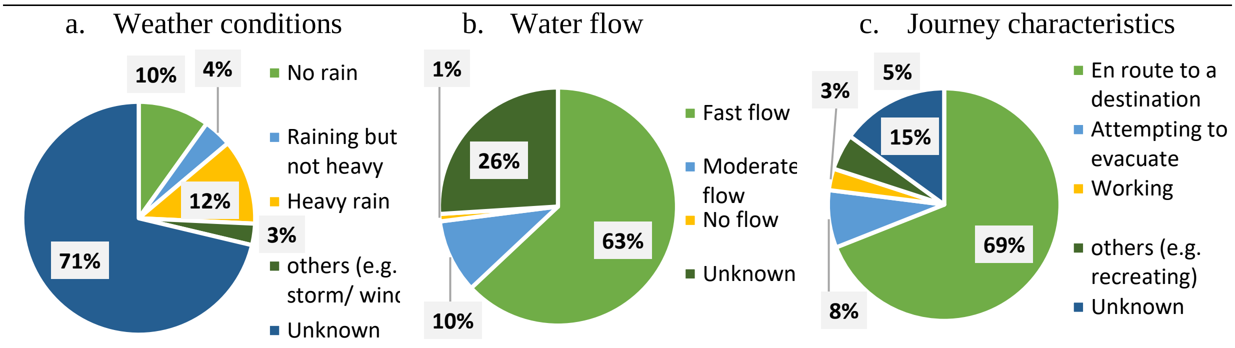

Figure 3.13. Distribution of the incidents (n=74) with respect to (a) weather conditions (b) water flow and (c) journey characteristics at the time of entering floodwater.

In investigating weather conditions (Figure 3.13a) at the time of the incident, information was not available for a large propotion of incidents (71% of incidents), however, heavy rainfall was reported during 12% of incidents (n=9). There was no rain at the time of seven incidents (10%), but heavy rainfall was reported by witnesses just prior to these incidents. Regarding the water itself, fast flowing or rapidly increased floodwater over crossings, bridges or causeways were the environmental characteristics present in almost two thirds of incidents (63%; n=46), and moderate water flow was reported in eight incidents (10%) (Figure 3.13b). Fast-moving, unpredictably rapidly rising floodwater was mentioned in many incidents, which lifted or floated vehicles within very short times. More than two thirds of vehicles (68%, n=51) were being driven en route to a destination; with the majority of these journeys en route to home (n=22, 43%), 8% (n=6) were attempting to evacuate, and 3% were working/on duty when the vehicle entered the floodwater (Figure 3.13c). The proximity of the incident from the driver's home was calculated for all incidents where home address information of the driver was noted. These data are presented in Table 3.4.

Table 3.4

Distribution of incidents (n=74) with respect to proximity to driver's home.

Proximity to driver's home	N	Percentage
Less than 10 km	21	28.37%
10-20 km	11	14.86%
20-50 km	3	4.05%
More than 50 km	12	16.21%
Role Unknown (whether driver or passenger)	3	4.05%
Address Unknow (passenger fatality incidents where driver survived)	15	20.27%
Address Unknow (driver fatality incidents but address unavailable)	11	14.86%
Total	76*	103%

*Note: one incident involved three motorcyclists who were categorised as 'drivers' in the analysis, therefore there are 76 drivers in 74 incidents

It was identified that out of 74 incidents, just under half (43%; n=33) occurred within 20 km of home. One incident occurred only 550m from the home of the deceased. Less than a quarter of incidents occurred more than 20km from home; with 4% occurring 20-50km from home and 16% occurring >50km from home. The findings suggest that a combination of familiarity and/or opportunity is an important feature of the fatality data. Although it is likely that drivers are more familiar with locations closer to their homes, and may feel more confident to judge local risks (and possibly be more prone to making errors) it is also likely that, statistically, they would be driving in these locations more frequently, and hence have more opportunity to be in these areas.

Characteristics of the motor vehicle were regarded as important features to capture in our analysis, however we faced difficulties in classifying vehicles as their characteristics were reported in various ways; for example: by size, i.e. small, medium, large; by manufacturer, i.e. Toyota, Holden, Land Rover; by type, i.e. SUV, ute (utility vehicle), van, truck; and by wheel operation, i.e. 2WD, 4WD, all-wheel drive. Table 3.5 summarises vehicle type, as this category of description was used most frequently in official records.

Table 3.5

Distribution of incidents with respect to vehicle type

Vehicle type	N	%
Car e.g. Sedan, Hatchback	21	22.3
Sports Utility Vehicle (SUV), e.g. Range Rover, Land Cruiser	19	20.2
Utility vehicle (‘ute’), e.g. dual cab, pick-up truck	15	15.9
Motorbike	4	4.2
Truck	3	3.1
Station wagon	2	2.1
Van	1	1.0
Tractor	1	1.0
Other (Gator - on/off-road utility vehicle)	1	1.0
Unknown	7	7.4

As can be seen from Table 3.5, just under a quarter of incidents (22%) occurred in sedan cars, a fifth (20%) in sports utility vehicles (SUVs) and 15% in utility vehicles (utes). At least 29% of all vehicles trapped in floodwater were officially reported as four-wheel drive vehicles (4WD). This finding represents a well-established trend noted in Australia (Haynes et al., 2017, Peden et al., 2017) in which 4WD vehicles account for an increasing number of vehicle-related flood fatality incidents. In total, some 229 flood fatalities were associated with vehicles between 1960 and 2015 (Haynes et al., 2017) where 64% of vehicle-related flood fatalities have been associated with sedans and 19% with 4WDs in Australia (Haynes et al., 2017). Since 1960, the prevalence of transport related fatalities associated with sedans has decreased (76 death before 1960 and 147 since 1960), whilst fatalities involving 4WDs has increased (only 2 deaths prior to 1960, 51 death since 1960) (Haynes et al., 2017). Recent flood fatality analysis on non-aquatic transport incidents in Australia (Peden et al., 2017) reported, victims were commonly in cars (38.5%), utilities (30.8%) and 4WDs (23.1%).

Findings relating to situational factors provide rich data to inform communication and education campaigns and other mitigation measures. For example, knowing that fatalities are more likely to occur in driver-only situations and knowing higher risk location and journey characteristics mean that these conditions can be used in advertising and other media. These aspects are also less likely to be salient to drivers or be the ones highlighted in typical road safety campaigns. For instance, drivers may have good awareness of water characteristics and be good at associating deep or fast flowing water with danger, but they might believe that passengers are more likely to encourage risky driving and not think that just ‘normal’ journeys (rather than urgent one) are likely to result in risk taking in this context.

3.3.2 Phase 2

3.3.2.1 Analyses of selected incidents

The 11 incidents with complete sets of reports/data selected for more detailed description (refer Figure 3.1) were analysed in relation to the following:

- Description: who, when, where, and how the incidents occurred
- Circumstances: water, weather, lighting conditions, location details, vehicle status
- Reasons identified for accident and death: main findings after the investigation
- Punishment: what kind of punishment was imposed by law for risky driving
- Warnings and risks indicators: warnings, barricades, depth markers, guard rails, signage
- Recommendations: suggestions by councils, law enforcers, road transport authority, court

As can been seen from the listing above, focusing on a smaller number of detailed incidents enabled us to identify and report on a number of additional features not reported on in the Phase 1 analysis, such as reasons for the incident, the outcome/punishment of drivers who survived, and the status and role of warnings and risk indicators at the scene.

The listing below, picks out some distinct elements contained within the official documentation for each of the incidents to highlight key points that were reported to have influenced driver behaviour, or contributed to the fatal incident:

- Incident 1: Underestimating the risks, overconfidence in the vehicle and personal ability, past-experience of successful crossings
- Incident 2: The effect of alcohol and drug consumption responsible for slower reaction times
- Incident 3: Ignoring risk warnings and indicators such as water-depth indicators and signs in the environment (heavy rain). This represents a typical situation for most vehicle-related flood cases
- Incident 4: Ignoring road closure signs, familiarity with location and crossings
- Incident 5: Fatigue due to overtime work, inappropriate flood depth marker
- Incident 6: Failure of an emergency service worker to identify water hazards
- Incident 7: Where legal measures were taken and a punishment imposed for risky driving
- Incident 8: Absence of road signage and warnings
- Incident 9: Disobeying the directions of emergency services by the drivers
- Incident 10: When no adequate alternative route available to change journey plan
- Incident 11: Resource constraints for rescue operations by emergency services

A systematic summary of the data contained in the 11 incidents is provided in Table 3.6

Table 3.6
Summary of selected incidents

Incident number	Description		Circumstances of the incident			Reasons for accident and death	Punishment	Warnings/Signage
	Time of day and journey information	Fatalities and survivors	Water & weather characteristics	Location details	Vehicle status			
1	Twilight, evening, en route	2 deceased (>10 years, both passengers) 2 adults (including driver) survived	▪ width of floodwater at crossing >30m water to travel through ▪ water depth<1.3 m ▪ flow smooth, still ▪ after heavy rains	Low level river crossing, river current was powerful, rural area	4WD, SUV, Engine cut during crossing, washed away by currents down the river	▪ underestimated the risks ▪ overconfidence in vehicle and personal ability ▪ past-experience of successful crossings ▪ had history of drug use	no – due to lack of evidence (blood test was not taken after the event)	flood warning signage and depth marker was present
2	Afternoon, returning from work	5 deceased, 2 adults (including driver) and 3 children (no one survived)	▪ road crack and collapsed due to flood ▪ stormy with wind and torrential rain	major highway, urban area	Sedan car, entered the void created by road collapse and fell into the water below	▪ poor visibility due to rain ▪ combined effect of drug and alcohol ▪ failure to react in time to avoid the hole ▪ lack of risk warnings and inadequate signage	no	no road closure sign present
3	Night, en route	1 deceased (>16 years, passenger); driver survived	▪ width of floodwater at crossing 20-30 m ▪ water depth <2 m ▪ very strong flow and full of debris ▪ raining heavily	crossing a bridge	Sedan car, had electric windows	▪ rapidly rising water in the creek, night time, darker ▪ lack of sufficient street lighting, ▪ the submergence of the one-meter flood warning signs and absence of 2 m depth marker	no	1m depth gauge, guard rail on both side, yellow warning sign and advisory speed limit warnings was present
4	Morning, en route to home	3 deceased (1 adult, 2 children, all drivers) 2 survived (both adults, and both driver)	▪ width of floodwater at crossing 4-5m ▪ water depth 40-50 cm ▪ strong current and rapid rising water	creek crossing, sealed track	1 motorcycle and 2 recreational quad bikes, swept down the river	▪ ignoring road closure sign ▪ lost footing to move stuck ATV ▪ wrong estimation of the water level and flow ▪ familiarity with location and crossings	no	track closure sign was placed at the either end of the track
5	Night, returning from work	1 deceased (adult, driver) Sole driver fatality	▪ water depth 70-80 cm ▪ raining heavily ▪ main stream flow	culvert, flooded causeway	4WD, strong flow pushed sideways, submerged and washed off causeway	▪ fatigue-due to overtime work ▪ alcohol intoxication ▪ false reading of actual water level by depth markers	no	badly positioned depth marker was present with error reading of actual depth
6	Afternoon, On duty	1 deceased (emergency service worker,	▪ torrential storm rain ▪ flood water full of debris	mountainous, unsealed and 2 WD track	4WD, ute, working vehicle,	▪ extremely bad weather ▪ hazardous flooded hilly terrain	no	no signage was present

		driver), 1 survived (adult, passenger)	▪ significant velocity		stopped when it was half way, water pushed sideways	▪ unsuccessful rescue attempts due to confusion, panic, lack of knowledge ▪ inability to assess and judge the dynamics of flowing water		
7	Twilight, very early morning, en route from recreation to home	1 deceased (young, disabled, passenger), 2 adults survived (including driver)	▪ raining lightly ▪ water depth 20-30 cm ▪ rising water swiftly ▪ bridge was under water	bridge over creek crossing	Van stalled and tipped onto its side and swept down the creek, then hit a tree	▪ alcohol intoxication ▪ drink driving ▪ incapacity to walk and swim	Yes, 100 hours of unpaid community service and disqualified from holding a driver's license for six months period	the bridge was not included in local council flood operations procedure which includes temporary flood signage locations at known spots at risk of flooding
8	Morning, en route	1 deceased (adult, driver) Sole driver fatality	▪ water was running 1 m above over the crossing ▪ strong current	causeway style crossing	dual cab utility, 4WD, washed off and submerged	▪ lack of signage and warnings ▪ adverse road conditions	no	▪ no line markings on road ▪ no side rails ▪ no warnings
9	Night, en route	1 deceased (adult, driver) Sole driver fatality	▪ water covered 150m of the road ▪ 70 cm height of water ▪ flowing incredibly fast ▪ raining heavily	flooding on major road	Motorcycle, stranded by cyclist, then washed downstream with flow	▪ low level of alcohol in the urine found ▪ ignoring the road closure sign ▪ rescue attempt was unsuccessful due to fast current	no	road closure sign was present and emergency services were on standby to prevent any vehicles from crossing
10	Morning, travelling from home to attend a doctor's appointment	1 deceased (adult, passenger) 1 survived (adult, driver)	▪ water depth was in excess of 1.5-2 m ▪ The area was subject to a major meteorological event just the day before ▪ many roads in the area were closed	flooding on major road	Utility vehicle, 4WD, stalled, then restarted for traversing but swept away into the stream	▪ extreme flood event ▪ no adequate alternative route to change journey plan ▪ ignoring warning sign	no	yellow reflective floodway warnings sign placed at either side of the floodway
11	Afternoon, travelling to friend's home	2 deceased (1 adult, driver; 1 passenger-child), 1 survived (passenger-child)	▪ under severe storms and flash flooding ▪ water level rising and exceeding 2 m ▪ rapid moving storm water	intersection of streets	Sedan car all occupants exited and climbed onto roof of the car	▪ no signage ▪ rapid rise water at this intersection ▪ emergency services had arrived late after the deceased persons had been swept away	no	intersection was not closed and was not subject to any police presence or control

3.3.2.2. Findings from incident analyses

Incident analyses (Table 3.6) provided a more detailed description of circumstance regarding the water, weather, lighting and vehicle status at the time of the incident. The analysis of coroner’s findings and witness reports of selected incidents indicated the lowest water depth was 20 cm and the deepest was more than 2 m at the time when incidents occurred. Incidents that occurred at night all had reported absence of adequate street lighting. Visibility was also interrupted by moderate to heavy rain and in some incidents due to branches or broken parts of long trees on roads. The fast-moving rapidly rising floodwater often surprised and misguided the drivers to negotiate floodwaters which resulted in the fatal incidents. In most incidents the vehicle/s stalled midway through the floodwater, floated, and were washed away, with the vehicle becoming submerged leaving occupants a short time to escape. In some cases, electric auto windows did not open when the engine cut out, and made it difficult to escape.

The effect of alcohol and drugs was also reported to impede survivability in some incidents, being attributed to an incapacity to act or immediate respond just prior to death in various ways, such as judging the water depth and velocity, causing slower reaction times to take decisions to avoid the water course or to enter the water, to escape from vehicle, and/or to help others to escape.

The major reasons identified for accidents and deaths found through investigation of coroner’s inquests were: underestimating the risks, overconfidence in the vehicle and driver’s own-ability, past successful crossing experience, familiarity with place and crossings, alcohol and drug intoxication, ignoring warnings and indicators, fatigue, inappropriate flood depth markers, lack of warnings and inadequate risk indicators (no road closure signs), lack of knowledge of assessing water hazards on the road, and incapacity to move or swim that led directly to the fatal incident.

Analysis regarding warnings and signage, found that drivers in fatal incidents were not likely to see or follow warnings, signage and indicators. This in part supports claims that the public's general knowledge and awareness of flood threats on roads is inadequate (Ashley and Ashley, 2008). However, this is as much about ensuring the adequacy of signage and warnings as educating drivers and passengers. In particular, as a number of incidents occurred when visibility was poor, work needs to prioritise communications or structural changes that will have an impact day or night and in heavy rain. Identifying potential high-risk locations is important in order to prioritise and implement time- and place-specific flood operations procedures, such as putting up flood signage, where relevant, either temporarily or permanently. Checking the effectiveness of existing risk indicators and evaluating their efficacy with road users regularly is highly recommended. Inappropriate depth gauges or badly positioned water level markers and false readings of actual depth were identified as a major contributing factor in one incident in this study. In another incident, the submergence of one-meter warning signs and the absence of two-meter flood warning signs confused the driver who then decided to enter floodwater. Installation of sensor systems linked to a flashing light system which indicates “Road closed when flashing” was recommended by court in that particular incident.

Vehicle drivers died in six (3 drivers in one incident) of the 11 incidents and therefore, punishments (usually meted out to the driver/controller of the vehicle) could not be applied in those cases. Of the remaining five incidents, legal punishment was only handed down in one case, for a driver who was convicted of careless driving, and who received unpaid community service work and licence disqualifications (6-12 months). None of the selected incidents reported legal action taken for disobeying road closure signage and barriers.

Analysis of incidents found that a number of rescue attempts were too late, or failed, and recovery processes of the deceased were delayed in a few incidents. These findings highlight the situational complexity of some incidents and also the resource constraints of emergency service agencies, particularly during emergency periods, i.e. during or immediately after flooding rains. Further training of emergency personnel particularly agencies who traditionally do not focus on flood hazards (e.g. fire, police, paramedics) in identifying water hazards would be helpful when facing dangerous operational and rescue activities was recommended in one incident in this study. Fatigue management, safe driving operations and structuring working schedules differently during times of difficult driving conditions (working hours, rosters) could reduce fatalities associated with work duties, and was recommended in another incident in the present study.

3.3.3 Strengths and limitations of the study

As noted, although our study has a number of strengths, there are also limitations, such as those related to missing or incomplete data. Although the study included a systematic interrogation of the best source of fatality data and official records of fatalities in Australia, we also identified 14 recent incidents (2016 and 2017) from archived newspapers that were not found in the NCIS database. It is possible, therefore, that more fatal vehicle-related flood incidents occurred during this time that have been missed in our current analysis. Also, although closed cases from NCIS were included in this study (in which the investigation is completed and reasons for death determined) there were still some incidents with incomplete sets of reports (i.e. missing Findings documents, Police reports). There was also minimal information available about drivers involved in fatal incidents where they survived (with data mostly relating to the deceased persons). This meant that some data, such as driver's proximity to home and driver's alcohol level at the time of the incident were unknown/unreported, making interpretation of some incidents less accurate than others, especially regarding drivers' decision-making, risk taking, and other factors that may have been relevant to the incident. To compensate for missing data, and the use of a restricted set of variables in the Phase 1 analysis, a brief synthesis of 11 incidents was provided for which more complete data were available, making it possible to provide a more comprehensive understanding of the features of recent vehicle-related flood fatality incidents. The findings from both phases of analysis provided directions for future research to explore the influence of a number of variables on drivers' decisions to drive into floodwater, and also highlighted the need for greater community engagement in flood risk education, and communication campaigns.

3.4 Conclusions

This research contributes to our knowledge of the demographic, spatial, contextual and temporal patterns of vehicle-related flood hazards by investigating 74 recent vehicle-related flood incidents in Australia. The study explored age and gender patterns from the viewpoint of both driver and passenger dynamics.

Middle aged, and older males were identified as a high-risk group as drivers, whereas young women and children are a vulnerable group as passengers. Most incidents occurred in the east coast of Queensland, in summer (January), on a Friday, in dark (poor lighting) conditions during the evening/night, and in heavy rain. Most of the fatalities occurred whilst crossing a causeway. They mostly occurred close to home, where drivers might have been expected to be familiar with the locations and the nature of the roads. The use of alcohol and drugs was identified in official records as a major contributing factor to death in a number of incidents. Water flow/velocity influenced most accidents even when the lowest water level was reported as only 20 cm. Vehicles were mostly 4WD in operations and ranged from small to large vehicles. Detailed analysis of a subset of 11 fatal incidents suggested that often vehicles stalled midway through crossing floodwater, only to be swept away and submerged.

Considering the results of the study, educational strategies should be tailored according to need of specific groups such as by age and gender (older and middle-aged male, young women), high- risk groups (children, emergency workers), in-vehicle role (passengers). Educational campaigns must involve local councils, schools, emergency service agencies, and police as well as vehicle manufactures, and insurance companies to ensure participation and collaboration amongst all, and reinforcing messages about the potential dangers of entering floodwater in vehicles. More should also be done to communicate the risks of entering floodwater in a vehicle from the passenger's point of view, both to support advocacy of passengers (including children) as well as to encourage drivers to view risks from the perspectives of others in the vehicle.

The results also demonstrate a need for improved flood depth indicators and warning signage, with installation of visual cues (flash lighting and automated barricades) in high-risk locations and the enhancement of legal obligations (such as increasing fines and demerit points or licence disqualifications) to stop drink driving.

3.5 References

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Interlude 3: State Emergency Services – Moving to consider those occupationally exposed to floodwater on roads

Chapter 3 provided a detailed profile of vehicle-related flood fatalities in Australia from 2001 to 2017. This included consideration of the demographic characteristics of 96 individuals, and the temporal and situational characteristics associated with the 74 incidents in which they lost their lives.

This analysis uncovered patterns of characteristics associated with fatal incidents that had only previously been recorded as part of individual incidents, but emerged when data were collated. These findings and the accompanying statistics can be used in future communication and education campaigns to highlight the 'hidden' risk factors associated with decisions to drive through floodwater.

Up to this point the research in this thesis has considered *all* drivers, i.e. the general population, rather than the specialist emergency service population of interest, i.e. State Emergency Service (SES) personnel. This is because, firstly, there are very few studies that have focussed on driving through floodwater, and second, within these studies there has been little or no information relating to occupational groups or work-related risk factors.

In Australia, SES is the official emergency service that is legally deployed to work in flood and storm situation to rescue the people and help the community with flood preparedness. SES personnel are, therefore, of interest in this thesis because they are occupationally-exposed to floodwater, and consequently have a greater opportunity to drive through it and make decisions about driving through, or not, when they encounter it.

In the research conducted to this point, it has not been possible to explore the decision-making factors of drivers to understand what influenced them most to decide to drive through floodwater, and in most cases, it can be argued that entering floodwater for the public is a voluntary and, hence, an avoidable activity. Considering SES personnel, it may be argued that, at best, this behaviour is partially voluntary in nature. SES personnel are subject to occupationally-related influences that may make them more, or less, predisposed to drive through floodwater. Specifically, they may be more likely to drive through floodwater due to the urgency of their work situation, e.g. in flood rescue operations, or due to organisational pressures, or due to driving larger or specialised work vehicles. Conversely, and they may be less likely to drive through floodwater due to better training and ability to judge risk, or due to organisational workplace health and safety policies and procedures, or because they are driving a vehicle that is owned and insured by their organisation, or maybe because their organisation tells the public not to drive through floodwater and they wish to uphold their organisation's professional reputation. All these additional aspects make the SES an interesting and important sub-group to study.

The study of the literature in Chapter 2 identified risk factors that are associated with driving through floodwater and the analysis of vehicle-related flood fatalities in Chapter 3 provided an opportunity to identify the characteristics of situations and people that have the greater potential to result in fatal incidents. This information provides a good baseline against which to assess the behaviours and decision-making of SES personnel, who will be the focus of the two final studies in this thesis.

In Chapter 4 the research explores the behaviours and decision-making of SES personnel when they encounter floodwater at work. As there has been no research in this area, the next study investigates and compares the characteristics of SES personnel who have and have not driven through floodwater in the last two years. The research goes on to examine the contexts and situations in which SES personnel have driven through floodwater (exploring similar variables to those used in the Chapter 3 fatality study), and then investigates in more detail the factors that influenced their decisions to drive through floodwater.

In terms of the theoretical and conceptual approach taken, although the theory of planned behaviour (TPB) model has so far been identified by researchers as the most applicable psychological theory to explain the behaviour, the next study uses the Recognition-Primed Decision (RPD) model to explain the decision-making process with additional insight from concepts used in the Extended Parallel Process Model (EPPM). The RPD was chosen because it was developed in the emergency services context (firefighting) and is applicable to situations that have time-critical components.

Chapter Four: Encountering floodwater at work: perception of risks and decision-making by State Emergency Services

STUDY 3

Publication history

Study 3 has been submitted for publication to the journal titled "*Progress in Disaster Science"*, manuscript ID: PDISAS-D-19-00100. The paper is entitled "Duty or safety? Exploring emergency service personnel's perceptions of risk and decision-making when driving through floodwater". The author of the present dissertation wrote approximately 75% of this paper.

Conference Publications: Oral Presentation

Ahmed A., Sato L., Haynes K., Taylor M., (2018). Calculated risk? Understanding NSW emergency service workers' decisions to drive into floodwater. Floodplain Management Australia National Conference 2018.QLD, May 31, 2018.

Conference Publications: Poster Presentations

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Duty or safety? Exploring emergency service personnel's perceptions of risk and decision- making when driving through floodwater

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Abstract

Vehicle-related flood fatalities and rescues due to driving into floodwater are a significant emergency management issue for emergency services. To reduce fatalities, injuries, and costs associated with this risky driving behaviour it is essential to develop strategies to stop or reduce the incidence of people driving into floodwater. In Australia, people are told not to enter floodwater – on foot or in vehicles – with the phrase 'If it's flooded, forget it' widely used in official messaging. As first responders responsible for floods, storms and tsunamis, Australian State Emergency Service (SES) personnel are working in flood conditions regularly and are considered an occupationally 'at-risk' group for driving into floodwater. Although SES agencies across states and territories in Australia are independently led, they typically promote policies of not entering floodwater to their personnel. Such policies are important for meeting duty of care obligations to employees, for protection of assets (vehicles and equipment), and for upholding organisational reputation (leading by example). This study was undertaken to explore the behaviour of driving through floodwater by SES personnel. Initially exploring the characteristics of those who have and have not driven through floodwater, and then using detailed situations in which SES personnel entered floodwater in vehicles to analyse their perception of risks, the conditions and contexts in which they entered floodwater, and to identify what influenced their decision to enter.

Following an earlier systematic literature review, a detailed online questionnaire was developed and administered to SES personnel from a single agency. Data from 670 respondents indicated that 54.8% had driven through floodwater in the previous two years, and a number of differences in the profile of those who had/had not driven through floodwater were identified. Those more likely to have driven through floodwater included males, volunteer personnel with longer lengths of service, those doing more driving hours per week, those deployed to work in flood conditions, and those with current flood rescue qualifications. The location type, water depth, and water velocity were conditions that contributed more to perception of risk at the time personnel drove through the floodwater. Detailed information about an experience of entering floodwater was obtained from 201 respondents and six factors relating to the decision to drive through floodwater were extracted. ‘Organisational training and safety’, ‘External locus of control’ and ‘Absence of risk signals’ were identified as having the greatest influence on risk perception leading to decisions to drive through floodwater. The findings of the study have a number of practical implications for the improvement of occupational safety management; such as upgrading risk assessments strategies, enhancing training, increasing skills and knowledge of emergency services personnel about floodwater hazard situations, and improving internal flood risk communication materials.

Key words: driving, floodwater, emergency services, risk perception, decision making, occupational safety

Duty or safety? Exploring emergency service personnel's perceptions of risk and decision- making when driving through floodwater

4.1 Introduction

People entering floodwater in vehicles is a leading cause of flood-related drowning deaths globally (Ahmed, et al., 2018; Ashley and Ashley, 2008; Diakakis and Deligiannakis, 2013; Kellar and Schmidlin, 2012; Sˇpitalar et al., 2014; Salvati et al., 2018; Sharif et al., 2010). In Australia, driving through floodwater is a common flood experience for people (Fitzgerald et al., 2010). Recent Australian flood fatality data showed that at least 96 deaths occurred in 74 incidents between 2001 and 2017 due to flood-related vehicle accidents with a mean of 1.3 fatalities per incident and the mean death toll across the study time period was 5.7 fatalities per year (Ahmed et al. 2019). State Emergency Service (SES) agencies in Australia devote significant time and money to rescuing people who have intentionally driven into floodwater in vehicles each year. One research study (Haynes et al., 2009) conducted following flash floods in the Hunter Valley (120km north of Sydney) on 8-9th June 2007 reported that, of the 36 rescues, 16 (36%) were rescuing people from vehicles. In another recent study during a flooding event in June 2016 (Smith et al., 2017), approximately a third of 300 flood rescues involved rescuing people from flooded vehicles. It is a significant emergency management challenge for SES personnel to perform potentially life-threatening and costly rescue operations for an increasing number of vehicle-related incidents during floods, and for SES agencies to communicate the dangers to the public to reduce the incidence of this risky driving behaviour.

Generally, the nature of SES personnel's work in flood and storm contexts demands that they make quick and safe decisions under time pressure and in shifting conditions. This places them amongst the top of those professions who work in natural hazard-related emergency settings, in terms of balancing their own safety with their duty. Working in hazardous situations with vehicles in flood conditions engages these emergency workers in a potentially complex combination of risk scenarios. They must arrive quickly at the emergency scene, at any time of the day or night. Incidents may be located in remote and difficult to access areas (mountainous or hilly areas, bridge or river crossings with rapid, rising floodwater), with changing and sometimes extremely difficult weather conditions (heavy rain and wind), including the unpredictability of the road conditions (road grade, road pavement integrity, or road alignment under water).

In general SES agencies rely on safety management practices and interventions to encourage their personnel to avoid floodwater risks, yet there is no evidence available to know whether personnel adhere to these influences or ifthey are obliged to follow these safety policies as part of their role. SES in the state of Victoria (VICSES) have recently developed operational doctrine to support personnel in assessing and managing the risk associated with encountering floodwater in VICSES vehicles (Victoria State Emergency Service, 2018). In addition, in revising its values, VICSES members agreed to incorporate ‘Safety Drives Our Decisions’ to reflect the importance of safety to the organisation, and this was rated as one of the highest of their five organisational values (Taylor et al, 2019). Still it is important to acknowledge that because of the service they provide the organisation may never be able to create a regulation to reduce risk to zero and stop its personnel from ever driving through floodwater. However, this issue needs to be addressed as a matter of priority, as it relates to occupational health and safety risks for this emergency service group. To reduce the costs of physical damage to vehicles and other assets, to protect personnel’s lives, there is an urgent need to understand the real experiences of SES personnel who have encountered and driven through floodwater and the decisions that directed their actions. Thus, the aims of the current study are to explore SES personnel’s experiences of driving into floodwater; to see the differences between those who had driven through and who did not, to explore their perception of risks of a recalled event of driving through floodwater, to identify what influenced their decision-making to drive through, and to test whether there is an association between their perceived level of risks and decision-making factors.

4.1.1 Vehicle-related flood fatality research

Consideration of flood fatality research literature is important for helping to understand the circumstances in cases where driving into floodwater has been deadly. It also enables us to compare the circumstances in which our SES personnel cohort had driving through floodwater.

International flood fatality research involving vehicles identified incorrect assessment of flood conditions (Diakakis and Deligiannakis, 2013; Yale et al., 2003) and underestimating risks (Diakakis and Deligiannakis, 2013; Drobot et al., 2007; Maples and Tiefenbacher, 2009) leads drivers to making inaccurate decisions which can lead to fatal incidents. Flood conditions are typically described in research using the following categories: floodwater characteristics (water flow and depth), roadway characteristics (location, road type, crossing type), vehicle characteristics (vehicle type and operation, e.g. four-wheel drive (4WD)) and environmental circumstances (weather, lighting). Floodwater characteristics such as depth and flow are primary influencers of vehicle (in)stability, and have been described in recent research (Smith et al., 2019). Research on vehicle stability in floodwater describes a three-phase process; of floating, sinking and submersion (Molenaar, et al., 2015). Research has demonstrated that the floating phase may last only 30 to 120 seconds, followed by the sinking phase which is typically completed within two to four minutes of contact with the water (McDonald and Giesbrecht, 2013; Molenaar et al., 2015). Research into the dynamics of vehicles in floodwater has found that in fast-flowing floodwater of three metres per second or greater, it can take just 15 centimetres of floodwater for a small vehicle to become unstable, and only 30 centimetres for 4WDs (Smith et al., 2017). Vehicles may enter floodwater upright, or roll due to rapid flow (Smith et al., 2017).

The risks associated with driving through floodwater may also be determined by the characteristics of the location (Diakakis and Deligiannakis, 2013; Maples and Tiefenbacher, 2009) and roadway characteristics such as road structure type; roadway side barriers; road side topography; downstream depths adjacent to the roadway; signage; warning systems; lighting; road pavement; road alignment; road grade; speed restrictions; traffic volume, presence of road side markers and curb and guttering (Gissing et al., 2019). Vehicle characteristics like vehicle size, type, or operational drive control may also give drivers confidence in their ability which may minimise the sense of risk (Gissing et al., 2016).

One recent study (Ahmed et al., 2019) rigorously explored the circumstances of recent vehicle-related deaths in Australia, to help understand the flood conditions associated with vehicle-related flood fatalities. This research reported that the shallowest water depth responsible for one fatal incident was only 20 cm. Almost two thirds of fatalities (63%) included reports of very fast flowing and rapidly rising floodwater, and most victims (87%) were attempting to cross creeks, low bridges or causeways. Much smaller proportions (4%) occurred at a ford or weir, or on a normal stretch of (flooded) road. Regarding the environmental conditions, the largest proportion of fatalities occurred in the evening and night when it was dark (50%) and in the incidents that occurred at night, all reported an absence of adequate street lighting.

4.1.2 Concepts from theories

To understand the behaviour and underlying decision-making processes of driving through floodwater by emergency services in occupational situations, the present study developed a conceptual framework based on psychological theories. To address the behavioural and cognitive thinking aspects, the study adopted concepts from two theories to help understand behaviour, which had not been applied previously in driving through floodwater research. These theories are the Recognition Primed Decision-Making Model (RPD), and the Extended Parallel Process Model (EPPM).

4.1.2.1 The Recognition Primed Decision-Making Model (RPD)

Naturalistic decision-making research has shown that experienced people under pressure in complex situations do not generally use the classical approach to decision-making (Klein, et al., 1986). Under these circumstances, people tend to operate in a manner depicted by the recognition-primed decision (RPD) model (Klein, 1998). RPD model development evolved from field observations and interviews with fire fighters, neo-natal intensive care nurses, surgeons, weather forecasters, military field commanders and pilots. Thus, the context for the research was situations which are circumstance-dependent and may be subject to rapid change which appears to be a good fit with emergency workers' situations in emergency events.

As described by Klein et al., (1998), the process involves a decision-maker noticing situation-generated cues, recognising patterns formed by the cues (based on experience), focussing on a potential solution or 'action script,' and imagining potential outcomes of action implementation. The latter involves experience again in the form of the decision-maker's mental model of the overall operations. If the imagined outcome is 'good enough,' then the action is implemented. In short, the RPD process highlights three simple steps: experiencing the situation, analysing the situation, and implementing the decision.

The current study utilised the RPD model approach to help conceptualise the decision-making process for emergency service personnel in flood situations. In these situations, they need to form a risk assessment based on synthesis of a number of contextual and conditional components.

4.1.2.2 The Extended Parallel Process Model (EPPM)

EPPM is one of the major theories within the domain of psychological research on health behaviour. Research using EPPM covers a large number of health-related topics such as drug abuse (Allahverdipour et al., 2007) but has also been used in vehicle-related behaviour, e.g. driver safety (Lewis et al., 2014) and driver fatigue (Tay and Watson, 2003). However, studies applying EPPM to natural hazards situations have not been identified to date. The EPPM posits that when presented with a risk message, individuals engage in the following outcomes via two appraisal processes: danger control process and fear control process (Popova, 2012).

- Outcome I: Danger Control—People take protective action against the threat.
- Outcome II: Fear Control—People in denial about threat react against it.
- Outcome III: Lesser Amount of Danger Control—People take some protective action, but are not motivated to do much.

- Outcome IV: No Response—People do not consider the threat to be real or relevant to them, or are often not even aware of the threat.

4.1.2.3 Psychological research applied to driving though floodwaters

Internationally, Hamilton and colleagues are the only researchers found to have published research investigating the application of psychological theory to this field of research directly. These researchers conducted a series of studies based on TPB model to better understand the influences on individuals' beliefs and intentions to drive and avoid driving through floodwater (Hamilton et al., 2019, 2016; Pearson and Hamilton, 2014). This research postulated that performing, and not performing, a given behaviour are not conceptual opposites, and that different motivational pathways may operate in guiding individuals' decisions to engage in an action or behaviour (Richetin et al., 2011). Four overarching themes emerged from drivers' descriptions of factors that influenced their decision to drive through floodwaters. These were past experience, individual factors, the social and environmental context, and self-efficacy judgements. Three overarching themes, based on the TPB belief-based framework, emerged from drivers' descriptions of factors that influenced their decision to avoid driving through floodwaters. These were behavioural beliefs, e.g. safety first and foremost, normative beliefs, e.g. think of the rescuers, and control beliefs, e.g. destination wasn't that important (Hamilton et al., 2019).

4.1.3 Conceptual framework for the current study

Supported by the previous research findings and theories, just outlined, the present study uses the following conceptual framework as a model for the decision-making process of driving through floodwater for this emergency service occupational group. (Figure 4.1).

Similar to the RPD process, the model (Figure 4.1) proposes the steps of decision-making including: experiencing the situation, analysing the situation, mental simulation of action, and implementing the decision into behaviour. Supported by findings from previous review papers (Ahmed et al., 2018; Becker et al., 2015) the model proposes risk perception as the core aspect of the decision-making process to take the decision to drive through floodwater.

The model features perception of risk determined by two components: risk assessment factors and influences on decision-making. Risk assessment informs risk perception through evaluating the physical characteristics of the context and the environment, and a number of socio-cognitive factors influence decision-making to guide risk processing and inform risk perception. After initial mental simulation of the action, the final steps of the decision-making process include two processes from the EPPM model: protection motivation (danger control process), and defensive motivation (fear control). The outcome of these two processes leads into the final decision being formed, which is then implemented into behaviour.

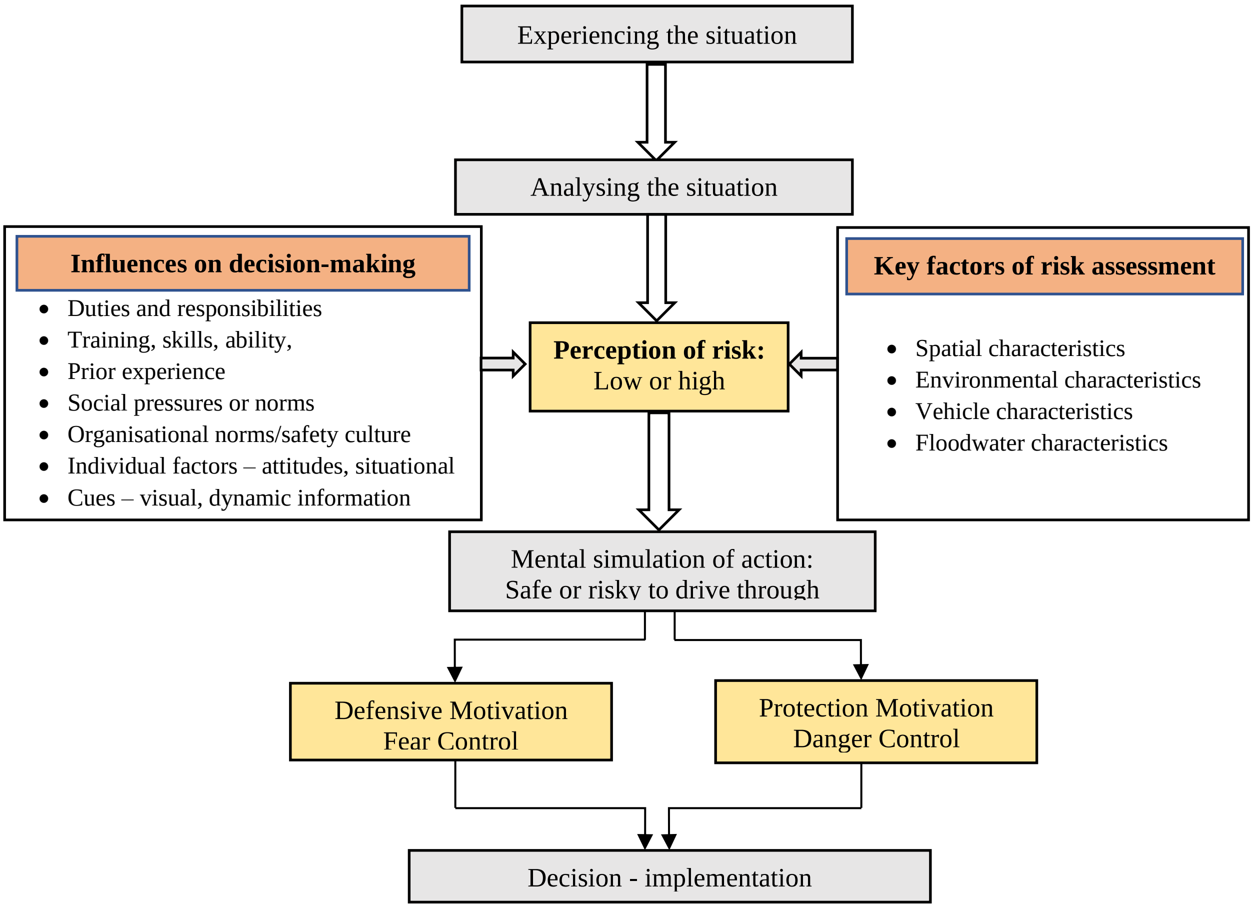

Figure 4.1. Conceptual decision-making model of driving through floodwater for emergency service personnel.

4.2 Methods

4.2.1 Study Design and procedure

The study was administered using the online platform Survey Monkey. The Macquarie University Human Research Ethics Committee granted ethical and scientific approval for this study on 12th September 2017 (Reference number: 5201700133). Participation was voluntary, with all participants ensured confidentiality and anonymity of responses prior to commencing. Participants were recruited via an email from the SES Deputy Commissioner endorsing the study, which was sent to all personnel. This email was distributed when the study opened on the 16th July 2018 and a reminder email was sent one week prior to the study closing date, which was the 13th of August 2018.

4.2.2 Participants

A non-random convenience sample of SES personnel (N = 670) was recruited via email. The average age range of the respondents was 45-54 years. The majority of respondents (77.1%, n= 517) were over 35 years of age, with just over two thirds being male (67.9%, n=455). Volunteer employees made up the majority of the sample (89.1%, n= 597), and most (80.6%, n=540) had held a full driving licence for more than 10 years. The majority (91.5%, n=184,) had experience of deployment to local flood events. Almost three quarters (73.1%, n=490) had received flood rescue training to a minimal level of qualification. Participants had received a range of other relevant training experience with over three quarters (78.1%, n=157) receiving general operational driver training and just under half (48.8%, n=98) receiving four-wheel drive vehicle training.

4.2.3 Measures

The behaviour of focus is the act of driving through floodwater by an SES member as a driver, i.e. the person in command of the vehicle. The term floodwater was defined based on a definition provided by the Department of Geoscience Australia (2014): "an overflowing of water onto land that is normally dry and is not limited to roads". This study employed a more driving- and road-specific definition that was agreed in consultation with SES project officers before the study so that it would be relevant to personnel.

Participants received the definition of floodwater in the following way.

"Currently, there is no clear definition of floodwater. For the purposes of this survey, we will define floodwater as an environment with:

1. Water across the road surface.
2. Little to no visibility of the road surface markings under the water (i.e., uncertain of road quality/integrity and possibly depth).
3. Water on normally dry land – flowing or still

Based on the floodwater definition above…"

After this definition was presented, participants were asked to recall how many times they had driven through floodwater in the last two years (responses were Never, 1-2 times, 3-6 times, more than 6 times). They were then asked if they could recall a situation in which they had driven through floodwater, ideally their most memorable experience of entering floodwater in the last few years in working conditions.

4.2.3.1 Exploratory variables

In addition to a range of demographic variables, the questionnaire included the following contextual variables, linked to the specific event of driving through floodwater that they had recalled, to measure risk assessment factors, decision-making influences, and level of perceived risk associated with the recalled event of driving through floodwater.

*Key Factors of Risk Assessment***:**

To measure the key factors of risk assessment the following variable categories were included in this study:

Spatial characteristics:

Previous research on flood fatalities in Australia has focused on geographical areas, locations and roads (Coates, 1999; Fitzgerald et al., 2010; Haynes et al., 2009; Haynes et al., 2017) as an important factor for flood fatalities. As spatial variables, the present study included location type (urban, suburban, regional, rural and remote); road type (major, minor/suburban, sealed, unsealed, causeway) and type of crossing (a low-water crossing, bridge, or causeway, a ford or weir, a normal stretch of road) as spatial variables to explore how these variables influenced the decisions taken.

Environmental characteristics:

Environmental components, such as time of day, lighting conditions, and weather have been found to influence both the cognitive process of floodwater hazard identification on roads and decision-making (Maples and Tiefenbacher, 2009). It has been hypothesised that drivers, at night/in dark conditions, are either not able to see flooded roads and possibly enter floodwater by accident (Sˇpitalar et al., 2014), or they are not able to assess the depth and velocity of water due to poor visibility (Maples and Tiefenbacher, 2009). To identify the environmental variables in this study, time of day (lighting conditions (daylight, dark daylight, dawn/dusk, night with streetlight, night with no streetlight) and weather conditions (clear, overcast, light rain, steady rain, heavy rain) were assessed.

Floodwater Characteristics during incident:

Previous studies have found that water characteristics such as water depth, water flow, and presence of debris or mud have significant influence on driver's decision making to enter floodwater. Floodwaters can submerge vehicles or sweep them away. Motorists may enter floodwaters unexpectedly (Yale et al., 2003) or find themselves in circumstances where floodwaters rise around their vehicle (Diakakis and Deligiannakis, 2015). In the present study, the variable water depth at the time of the driving event was measured using a 6-point categorical scale grouped as A. “Less than 15cm”, B. “15cm to 30cm”, C. “30cm to 45cm”, D. “45cm to 60cm”, E. “60cm to 95cm”, and F. “Greater than 95cm”. Participants were provided with an image as a reference to reduce inconsistency in their estimations of the depth of each category level (Figure 4.2). The present study also included water flow as a variable to understand the characteristics of water in drivers’ decision-making (still, slow, medium, rapid flow).

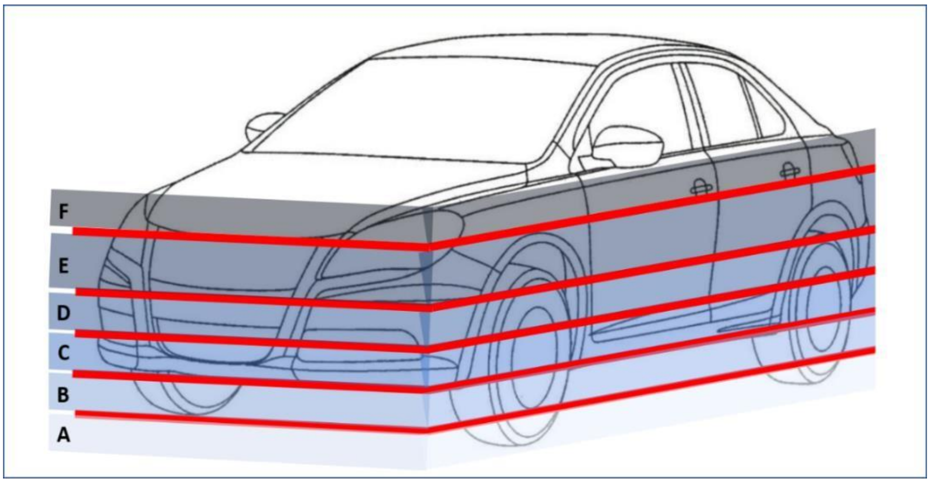

Figure 4.2 Image provided in the survey as a reference for depth of water driven through.

Vehicle characteristics:

Research in Australia which explored the types of vehicles driven into floodwater, found that they varied considerably in size and type (Gissing et al., 2016). For emergency response in operational situations, SES is well equipped with vehicles suited to their work. However, SES personnel also drive work passenger vehicles, as well as their own private vehicles in the context of their work, e.g. in day to day situations, travelling to/from duty and deployments. In consultation with SES, the study included vehicle types representative of all SES vehicles, e.g. medium / heavy truck, light truck / dual cab, passenger vehicle, and other types of SES vehicles (SUV, Ute etc.). Vehicle operation (all-wheel drive, four-wheel drive, and two-wheel drive) was also included separately to capture potential influences of the ability of the vehicle (as well as size) on the driver’s willingness to drive through floodwater (Hamilton et al., 2016).

Influences on decision-making:

The study used a list of 18 potential influences to explore socio-cognitive and other potential influences on drivers’ decision-making processes. These included environmental cues, individual attitudes and situational contexts (e.g. journey characteristics), efficacy responses, social influences, past experience, familiarity with road and place, organisational safety attitude and professional skills and knowledge. The items (see Table 4.1) were based on the findings of previous research (Ahmed et al, 2018; Hamilton et al., 2019). Respondents were asked the extent to which these 18 aspects influenced their decision to drive through the floodwater on this occasion. A 7-point Likert scale of response choices was used, ranging from (1) not at all to (7) a great deal.

Table 4.1

Items used in this study to measure the influences on the decision to drive through floodwater

Item no.	Items used
1	The journey was urgent
2	No alternative route
3	Impractical alternative route (time/distance)
4	Lack of signage/indicators to show depth or danger
5	Behaviour of others, e.g. others driving through without problems
6	Careful consideration of the situation
7	Knowing the road well
8	Driving through floodwater previously without problem
9	Professional SES training/knowledge
10	Reassurance or encouragement from others in the vehicle
11	Belief in my own physical ability to drive through
12	Close proximity to destination/operational situation
13	Gut-feeling that it would be all right
14	Being directed to drive through the water by other emergency services/council
15	SES's attitude towards safety
16	Excitement - it being fun to do
17	Organisational pressure to complete my duty
18	My personal desire to complete my duty

Perception of Risk:

A single item was used to assess the level of perceived risk when the driver drove through the floodwater. Respondents were asked "How risky do you think it was to drive into floodwater on this occasion?" A slider scale was used to indicate the level of perceived risk, with endpoints labelled 'not at all risky' to 'extremely risky'. The slider registered values from 0 (not at all) to 100 (extremely).

Demographic Information:

Demographic and background information collected in this study included:

- Age, in categories, ranging from 18-24 to 75 or older
- Gender, in categories, male, female, rather not to say
- Years holding full driving license, with response categories ranging from "0 (still Provisional/Learner status)" to "More than 10 years"

- Average number of hours driving each week, with categories ranging from ‘less than 2 hours’, to ‘15 or more hours’
- Years’ experience as a paid, or unpaid SES member, with responses ranging from “Less than one year” to “More than 20 years”
- Current qualifications in Flood Rescue, with responses ranging from “Yes, Flood Rescue Awareness” to “No, I have no Flood Rescue Qualifications”
- The respondents were asked “Do you get deployed to work in flood/storm conditions?” with responses options “yes” or “no”.
- Frequency of driving SES vehicles, with responses ranging from “Rarely” to “All the time”

4.2.4 Approach to analysis

All data analysis was conducted using Statistical Package for Social Sciences (SPSS version 25). Both non-parametric (chi -square, k-means cluster analyses and principal component analyses for factor analyses) and parametric (correlations and linear regressions) statistical tests were used in conducting different stages of analyses in this study. Data analysis was undertaken in a number of phases; first with the full sample (n=670), then with the subsample who had driven through floodwater, who provided detailed information about a specific event when they drove through floodwater in a work context (n=201). This progressive approach to analysis was used to explore the following research questions:

Phase 1: Chi square and post hoc tests

For the whole sample

- Are there any differences in terms of demographic variables between those who have, and have not, driven through floodwater in the last two years?

Phase 2: Descriptive statistics, frequency and percentage distribution

For those who had driven through floodwater in the last two years:

- What are the contexts and conditions in which SES personnel have driven through floodwater?
- What are the key factors that influenced risk perception when SES personnel drove through floodwater?

Phase 3: K-means cluster analyses, chi square test and multiple regression

In relation to a specific event of driving through floodwater

- What was the level of risk perceived at the time of event?
- What are the relationships between the expected risk factors and risk perception of the event?
- Which risk factors contributed more to risk perception when they drove through floodwater?

Phase 4: Exploratory factor analysis - Principal component analysis

- What are the key factors influencing decision-making that are associated with driving through floodwater?

Phase 5: Correlation and Hierarchical multiple regression

- Is there any association between risk perception and the key decision-making factors that are associated with driving through floodwater?
- Which decision-making factors predict risk perception in situations that led to driving through floodwater?

4.3 Results and Discussion

4.3.1 Phase 1. Exploring demographic differences between those who have, and have not, driven through floodwater

Overall, in the sample of 670 SES personnel, 54.8% (n=367) had driven through floodwater as a driver in the last two years, compared to 45.2% (n=303) who reported not having driven through.

Using a chi square analysis, significant relationships were revealed between the decision to drive through floodwaters in the last two years and participant demographics. These included: age; gender; years of holding a full licence; length of service with the SES; driving hours per week; flood rescue qualifications; frequency of driving an SES work vehicle and; deployment to work in floodwater conditions (see Table 4.2). Post hoc analysis of the multilevel variables within the chi square was undertaken. Fisher's exact approach and odds ratio analysis were then used to determine what level of participant demographics were contributing to the observed variance.

Table 4.2

Frequencies, Percentages, and Adjusted Standardised Residuals (ASR) for driving through floodwaters in the last two years

Variables	Had driven through floodwater once or more in the last two years									
	No				Yes				Total	χ^2 (p value)
	f	%	f_e	ASR[a]	*f*	%	f_e	ASR[a]		
Gender										
Male	179	26.7	205.8	-4.5	276	41.2	249.2	4.5	455	19.812, p=.001
Female	124	18.5	97.2	4.5	91	13.6	117.8	-4.5	215	
Age										
18 to 34	52	34.8	67.3	-2.8	97	65.1	81.6	2.8	149	12.575, p=.002
35 to 54	111	43.5	115.2	-0.6	144	56.4	139.7	0.6	255	
55 and above	138	52.6	118.4	3.1	124	47.3	143.5	-3.1	262	
Years holding full driving licence										
Less than 10 years	39	5.8	52.5	-2.8	79	11.8	65.5	2.8	118	7.669, p=.006
More than 10 years	254	37.9	240.5	2.8	286	42.7	299.5	-2.8	540	
Driving hours per week										
Less than 2 hours	37	5.5	23.3	4.0	15	2.2	28.7	-4.0	52	27.572, p=.001
2-7 hours	132	19.7	122.7	1.5	142	21.2	151.3	-1.5	274	
8 - 14 hours	81	12.1	83.7	-0.5	106	15.8	103.3	0.5	187	
15 hours or more	45	6.7	65.4	-3.8	101	15.1	80.6	3.8	146	
Length of service (paid personnel)										
Less than 5 years	31	4.6	29.0	0.7	32	4.8	34.0	-0.7	63	0.601, p=.740
5-10 years	11	1.6	12.4	-0.6	16	2.4	14.6	0.6	27	
More than 10 years	11	1.6	11.5	-0.2	14	2.1	13.5	0.2	25	
Length of service (volunteer personnel)										
Less than 5 years	130	19.4	112.8	2.9	129	19.3	146.2	-2.9	259	10.005, p=.007
5-10 years	52	7.8	52.3	-0.1	68	10.1	67.7	0.1	120	
More than 10 years	78	11.6	94.9	-2.9	140	20.9	123.1	2.9	218	
Current flood rescue qualifications										
Yes	196	29.3	216.1	-3.7	294	43.9	273.9	3.7	490	13.412, p=.001
No, or not current	92	13.7	71.9	3.7	71	10.6	91.1	-3.7	163	
Deployed to work in flood conditions										
Yes	212	31.6	229.2	-3.2	298	44.5	280.8	3.2	510	10.206, p=.001
No	85	12.7	67.8	3.2	66	9.9	83.2	-3.2	151	
Frequency of driving SES work vehicles										
Rarely	119	17.8	92.0	4.7	93	13.9	120.0	-4.7	212	23.715, p=.001
Occasionally	78	11.6	89.8	-2.0	129	19.3	117.2	2.0	207	
Often	54	8.1	70.3	-3.0	108	16.1	91.7	3.0	162	
All the time	8	1.2	6.9	0.5	8	1.2	9.1	-0.5	16	

Note. [a] The adjusted standardised residual is the observed frequency—expected frequency/estimated standard error.

Analysis by age, found that those over 55 years of age were least likely to have driven through floodwater. Compared to this group, those aged 18 to 34, and those aged 35-55 were significantly more likely to have driven through (OR 2.07 and 1.44, respectively), $\chi 2$ (2, N = 666) = 9.747, p > .0076. A two-way chi square revealed a significant relationship between gender and driving through floodwater, with males more likely to have driven through floodwaters in the last two years (OR 2.03).

Most participants had held a full driving licence for 10 years or more (82%). This group was more likely to have driven through floodwater in the last two years, compared to those who had held their driving licence for less than ten years (OR 1.79). The amount of time an individual spent driving each week was found to relate to whether they had driven through floodwaters in the last two years. Generally, more time spent driving on average each week related to an increasingly greater likelihood of having driven through floodwater, e.g. those who drove more than 15 hours per week on average were 5.6 times more likely to drive through floodwaters than individuals who drove less than 2 hours per week, $\chi2$ (3, N = 146) = 14.75, p > .002).

Increasing length of service, for volunteer personnel, was associated a lower likelihood of having driven through floodwater in the last two years. Generally, those with over ten years of service were least likely to drive through floodwaters, with individuals with 5-10 years' service (1.37 times more likely) and those with less than 5 years' experience (1.75 times) more likely to have driven through floodwaters in the last two years.

Two-way chi square analysis revealed significant differences in the increased likelihood of having driven through floodwater in the last two years for those who had current flood rescue qualifications compared to those without flood rescue qualifications (OR 1.94), and those who get deployed to work in floodwaters (OR 1.81) compared to those who don't get deployed.

Post hoc analysis of frequency of driving SES vehicles found that individuals who rarely drove an SES vehicle were the least likely to have driven through floodwaters in the last two years $\chi2$ (3, N = 338) = 21.752, p > .000, compared to individuals that drove an SES vehicle all the time (OR 1.28), those who drove an SES vehicle often (OR 2.56) and, those who drove an SES vehicle occasionally (OR 2.12).

This phase of analysis revealed that even though personnel are encouraged by the organisation not to drive through floodwater at work, the proportion of participants who had driven through in the last two years was high (54%). Interestingly, in this occupational sample male personnel were found to be significantly more likely to drive through floodwater than females. This supports findings in the literature, that males are more likely to engage in driving through floodwater (Diakakis and Deligiannakis, 2013; Drobot et al., 2007; Gissing et al., 2016; Haynes et al., 2017; Jonkman and Kelman, 2005; Kellar and Schmidlin, 2012; Maples and Tiefenbacher, 2009; Sharif et al., 2010; Peden et al., 2017; Hamilton et al., 2016).

The results regarding length of driving experience and flood deployment indicated that those who had been driving longer and those who get deployed to work in floods and storms were more likely to have driven through floodwater. These former findings suggest that experience, and possibly confidence, play a part in driving through floodwater. Obviously, those who are deployed to work in flood conditions are likely to have been exposed more to floodwater on the road in the last two years. Therefore, a combination of confidence and familiarity with driving in flood conditions, as well as increased exposure/potential to drive through floodwater may be having an influence. Analysis found that SES personnel who have current flood rescue qualifications are also more likely to have experience of driving through floodwater in the last two years. Again, there is potential that such individuals will have been sent to perform flood rescues in flood conditions and therefore be more exposed to floodwater on the road when travelling. However, it is also more likely that they will have received training more recently and have been educated about the risks involved with floodwater. Training might also increase confidence, leading to personnel minimising the risks of driving through floodwater on roads.

4.3.2 Phase 2: Exploring the conditions in which SES personnel drove through floodwater

To explore the conditions and contexts of the floodwater when they drove through it, participants were asked to recall their most recent or memorable experience of entering floodwater with vehicles in work conditions, ideally in the last few years. A total of 201 participants completed this detailed section. Table 4.4 summarises the various characteristics and conditions in which participants reported driving through floodwater.

Regarding spatial and environmental characteristics, around half of these events (49.3%, n=99) took place in rural and remote areas, and a similar proportion of events (54.2% (n=109) occurred on minor or residential road. Interestingly, a majority drove through the floodwater on a normal stretch of road (78.1%, n=157). A noted earlier, recent fatality data indicated that a large majority of fatalities (87%) took place when vehicles were driven across creeks, bridges or causeways (Ahmed et al., 2019 under review), suggesting that most of the events described by participants are likely to have not been life threatening, in this specific aspect.

Although around two thirds of events occurred in daylight (64.2%, n=129), just under a quarter took place at night (23.4%, n=47) and 22 of these events (10.9%) occurred in locations without street lighting. In these latter situations, it is likely that accurate assessment of the floodwater conditions would have been challenging. It was raining in 51.7% of incidents (n=104), which varied from light rain to heavy rain.

In terms of the floodwater characteristics of water depth and water flow, key factors known to affect vehicle stability, around three quarters of events occurred in water that was estimated to be more than 15cm (77.1%, n=155). This is above the level at which some vehicles are at a risk of becoming unstable (Smith et al., 2019) and above a level that is generally communicated to the public to be particularly unsafe to enter. The results regarding velocity of water indicated that, although SES personnel took risks entering deeper water, they mostly drove through water with low velocity (slow or still water) (92.0%, n=185). A minority of event (16.9%, n=34) took place in water deeper than 45cm, and 7.9% (n=16) took place in water with moderate or rapid flow. Clearly, these less frequent but seemingly more risky events need to be investigated more closely.

In terms of vehicle characteristics, dual cabs/light truck vehicles were most frequently being driven (44.2%, n=89) and in the majority of events vehicles had four-wheel drive (67.7%, n=136) indicating that vehicles typically larger and heavier than passenger vehicles were mostly being driven when floodwater was entered.

In a third of events (32.8%, n=66) visible signage indicating flooded road conditions, such as road closure, depth indicators and flood warnings signage was present, but was ignored. In just under two thirds of reported events (64.2%, n=129) there was no visible signage on the road when they drove through. In 2015, Austroads, the peak body for road management in Australia, stated that the vast majority of the approximate 20,000 floodways in Australia and New Zealand were not constructed in accordance with required design and hydraulic standards, and lacked appropriate signage. They also reported that depth gauges could be misinterpreted, posing a risk to road users in flood situations (Affum, et al., 2015).

4.3.3 Phase 3: Relationship between key risk assessment factors and risk perception

The conceptual decision-making model of the present study (Figure 4.1) indicated that risk assessment factors (spatial, environmental, floodwater, vehicle characteristics) existing at the time of the event contribute to construct the individual's risk perception. This part of the analysis sought to identify the relationship between risk assessment factors and level of risk perception, and verify the degree of contribution of those risk factors to risk perception.

To investigate the level of perceived risk associated with the reported events of driving through floodwater a K-means cluster analysis, using the z-scores, was performed on the variable 'perceived risk'. This approach was used to divide the sample into two risk typologies; those who perceived the event to be higher (High) risk, and those who perceived the event to be lower (Low) risk. This K-means cluster analysis is summarised in Table 4.3.

Table 4.3

Cluster Centroids for the perceived level of risk score

Perceived level of risk score	Cluster 1	Cluster 2	F	df	p	Distances between final cluster centres
	Low risk	High risk				
Z Score	-.36770	1.8719	446.601**	199	<.001	2.240
Number of cases	168	33				

**Significant at the .01 level (two-tailed).

The first cluster, labelled 'low risk' comprised 83.6% (n=168) participants, and the second cluster labelled 'high risk' comprised 16.4% (n=33). Next chi square analyses were conducted to investigate differences between these two clusters in terms of event-specific contextual variables.

Table 4.4

Frequencies, Percentages, and Adjusted Standardised Residuals (ASR) for the contexts and conditions in which SES personnel drove through floodwater and the level of perceived risk associated with these events.

Contextual variables	Low perceived risk				High perceived risk				Total	χ^2
	f	%	f_e	ASR[a]	f	%	f_e	ASR[a]		
Location Type										
Urban/suburban	63	37.5	57.7	2.1	6	18.2	11.3	-2.1	69	11.209, p=0.004**
Regional	31	18.4	27.6	1.8	2	6.06	5.4	-1.8	33	
Rural/remote	74	44.0	82.7	-3.3	25	75.7	16.3	3.3	99	
Road Type										
Highway/major	45	26.7	47.6	-1.1	12	36.3	9.4	1.1	57	3.552, p=0.169
Minor/residential	96	57.1	91.1	1.9	13	39.	17.9	-1.9	109	
Unsealed/track	27	16.0	29.3	-1.1	8	24.2	5.7	1.1	35	
Crossing type										
Normal stretch of road	133	79.1	131.2	0.8	24	72.7	25.8	-0.8	157	1.389, p=0.499
A ford or weir	8	4.7	7.5	0.4	1	3.03	1.5	-0.4	9	
Bridge or causeway	27	16.0	29.3	-1.1	8	24.2	5.7	1.1	35	
Depth of water										
Less than 15 cm	44	26.1	38.4	2.5	2	6.06	7.6	-2.5	46	6.33, p=0.012*
More than 15 cm	124	73.8	129.6	-2.5	31	93.9	25.4	2.5	155	
Water velocity										
Low	161	95.8	154.6	4.5	24	72.7	30.4	-4.5	185	20.099, p<0.001***
High	7	4.1	13.4	-4.5	9	27.2	2.6	4.5	16	
Lighting conditions										
Day light	113	67.2	107.8	2.1	16	48.4	21.2	-2.1	129	5.847, p=0.054
Dusk/dawn	21	12.5	20.9	0.1	4	12.1	4.1	-0.1	25	
Night -dark	34	0.59	39.3	-2.4	13	39.3	7.7	2.4	47	
Weather conditions										
Rain	84	50.0	86.9	-1.1	20	60.6	15.9	1.1	104	1.243, p=0.265
No rain	84	50.0	81.1	1.1	13	39.9	17.1	-1.1	97	
Vehicles operation type										
4WD	116	69.0	113.7	0.9	20	60.6	22.3	-0.9	136	.898, p=0.343
AWD/2WD	53	31.5	54.3	-0.9	12	36.3	10.7	0.9	65	

Note. [a]The adjusted standardised residual is the observed frequency—expected frequency/estimated standard error. *p < .001

The analysis presented in Table 4.4 revealed that 55.9.% (n=94, low risk cluster) of SES personnel perceived their experience of entering floodwater in urban/suburban and regional areas as low risk, whereas 75.7% (n=26, high risk cluster) of personnel entering floodwater in rural/remote areas perceived the event as high risk ($\chi 2$ =11.209, p<0.005). In terms of depth of water, 93.9% (n=31) of personnel in the high risk cluster perceived the event as high risk when the water was more than 15 cm water deep, compared to 73.8% (n=124) who considered it high risk in the low perceived risk cluster ($\chi 2$ =6.33, p<0.05). The result showed the most significant chi-square score for the variable water velocity ($\chi 2$ =20.099, p<0.001). Only 4.1% (n=7) of personnel in the low perceived risk group reported high water velocity when they drove through floodwater, compared to 27.2% (n=9) personnel in the high perceived risk group. The differences were not significant for other variables like road type, crossing type, lighting conditions, weather conditions and vehicle operation type. Overall, results suggest that the risk perception of SES personnel was most differentiated by the three key features: location, water depth and water flow. These appeared to be affecting risk assessment more than the other variables. Based on these results multiple regression analysis was conducted to see which category of these three variables are contributing more to predict risk perception (Table 4.5).

Table 4.5

Summary of multiple regression analysis for location, water depth and water velocity on perceived level of risk

Factors	β	SE B	*R*	R^2	*df*	*F*
Location			.238	.057	198	5.94**
Rural/remote	.231*	3.3				
Urban/suburban	-.010	3.5				
Depth of water			.189	.036	199	7.37**
Less than 15 cm	.189**	2.8				
Water velocity			.342	.117	199	26.32***
High	.342***	4.1				

Note: * p <0.05. ** p <0.01. *** p <0.001.

Multiple regression analysis using dummy coding for categorical variables (location, water depth and water velocity) revealed that perception of risk was significantly associated with these three variables. The results indicated that those driving in rural/remote areas, or where water depth was more than 15 cm, and in situations with high water velocity were more likely to perceive the risk of their driving through floodwater event as high. Conversely, they were more likely to perceive the risk of driving through floodwater as ‘low risk’ when the location was urban/suburban, or water depth was less than 15 cm, or water velocity was low (slow/still).

Examining how emergency services personnel perceived the risks of driving through floodwater and investigating the relationships between the key risk factors and their link to risk perception is helpful for a better understanding of the risk assessment process when entering floodwater. From the overall result of this phase of the analysis, it can be concluded that these three characteristics – water depth, water flow, and location, played an important role in the risk assessment of SES personnel. Although how these three features work together is not identified in this study, it is nonetheless evident that these key features contribute significantly to risk perception, and could usefully be exploited in engagement and communication around the risks of driving in floodwater.

4.3.4 Phase 4: Factors influencing decision-making

In our conceptual model (Figure 4.1), socio-cognitive influences form a large part of the risk processing component of the model. These affect the 'situational analysis' along with the key factors of risk assessment to inform risk perception.

To identify the key influences on decision-making during the event of driving through floodwater in this study, exploratory factor analysis was conducted on a set of 18 influencing items used in the questionnaire, using principal components analysis (PCA) as the method of factor extraction. To decide what factors to retain, the study used the scree plot. Initially an oblique rotation was used to assess factor correlation and later varimax was used as a final rotation. Individual loadings of 0.40 or greater were used in the factor designation. Extracted factors were examined and named based on an analysis of the items loading on each factor. Cronbach alpha (α) was used to estimate the internal consistency of the items constituting a factor. The Kaiser–Meyer–Olkin test and Bartlett test of Sphericity were undertaken. This analysis indicated that the Kaiser–Meyer–Olkin coefficient for this dataset was .735 and the Bartlett test of Sphericity was statistically significant ($\chi2 =742.809$, df = 153, $P <0.0001$) indicating that properties of the correlation matrix justified factor analysis being carried out. Table 4.6 showed the factor loading score for each item.

Table 4.6

Factor Loadings for Exploratory Factor Analysis with Varimax Rotation of Influences on decision-making

Items	**Factors**					
	1	**2**	**3**	**4**	**5**	**6**
The journey was urgent	.312	.203	-.004	**.661**	-.310	.079
No alternative route	.215	.105	.166	**.661**	-.065	.074
Impractical alternative route (time/distance)	-.154	-.028	.134	**.745**	.208	-.026
Lack of signage/indicators to show depth or danger	-.066	.022	-.059	.086	.124	**.885**
Behaviour of others, e.g. others driving through without problems	.021	-.123	.046	.101	**.804**	.175
Careful consideration of the situation	**.625**	-.090	.154	.223	.046	-.359
Knowing the road well	.141	-.287	**.662**	.101	-.128	-.047
Driving through floodwater previously without problem	.094	.183	**.666**	.240	.063	-.112
Professional SES training/knowledge	**.820**	.062	.116	.083	-.086	.051
Reassurance or encouragement from others in the vehicle	.362	.318	-.009	-.002	**.433**	-.058
Belief in my own physical ability to drive through	**.430**	.078	**.672**	.070	-.037	.017
Close proximity to destination/operational situation	.283	.225	.303	.317	.105	.323
Gut-feeling that it would be all right	-.152	.247	**.709**	-.031	.274	.097
Being directed to drive through the water by other emergency services/council	-.055	**.595**	-.072	.221	.288	-.230
SES's attitude towards safety	**.682**	.135	.062	.016	.104	.038
Excitement - it being fun to do	-.008	.360	.092	-.215	**.487**	.008
Organisational pressure to complete my duty	.084	**.805**	.048	.028	-.021	.072
My personal desire to complete my duty	.208	**.742**	.206	.126	-.054	.162

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
Note. Factor loadings > .40 are in boldface.

Varimax factor rotation identified six latent factors. Extraction of factors was based both upon Kaiser's criterion for Eigenvalues of equal to or greater than unity and use of a Scree plot. The six factors identified accounted for 60.0% of the total variance within the data (See Table 4.7). One of the items ("close proximity to destination") was removed, as its highest factor loading was below 0.30. In addition, the item had low communality scores, indicating that the extracted factors explain little of these items' variance. A sixth factor contained a single item ("lack of signage /indicators to show depth or danger"), this factor was retained, as the item had a high factor loading and it was uncorrelated with other variables.

Table 4.7

Total Variance Explained by Principal Component Analysis for influencing factors of decision-making.

Component	Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %
1 Organisational training and safety	3.755	20.861	20.861
2 External locus of control	1.986	11.031	31.892
3 Self-efficacy judgements	1.524	8.465	40.357
4 Journey characteristics	1.394	7.747	48.103
5 Social influences	1.131	6.283	54.386
6 Absence of risk signals	1.015	5.640	60.026

Significant factor loadings were used to identify and interpret themes, then each factor was labelled with a factor name that the research team felt best represented the overarching theme. The first factor, labelled "organisational training and safety" describes the professional experiences, training and knowledge participants felt they had to negotiate the risks of driving in flood conditions. This factor encompasses three items covering issues such as Professional SES training/knowledge; SES's attitude towards safety and Careful consideration of the situation. This factor accounted for 20.86% of the total variance and had a total eigenvalue of 3.75.

The second factor labelled "External locus of control" refers to how much people attribute the decision to drive through floodwater to external factors. People with a high internal locus of control (`internals') tend to believe that most things that happen are their own fault, regardless of objective cause. On the other hand, those with a high external locus of control (`externals') tend not to accept blame for anything, preferring instead to believe in environmental reasons, even if they have clearly instigated an event. In the present research, three items that generally covered external influences loaded onto this factor. The items are organisational pressure to complete my duty, my personal desire to complete my duty, and being directed to drive through the water by other emergency services/council. Although the second item contained an element of internal motivation ('my personal desire') it was felt that it was the external act of 'duty', or service to others, that was being triggered in the context of these other externally-driven items for this factor. This factor accounted for 11.03% of the total variance and had a total eigenvalue of 1.98.

The third factor, labelled "Self-efficacy judgement", grouped together items that appeared to describe a combination of self-efficacy and optimism. Self-efficacy is the belief in one's own ability to do something (Bandura, 1978). Self-efficacy refers here to the belief of the driver that the behaviour – "driving through floodwater" can be executed successfully. This encompasses four items covering issues such as gut feeling that it would be all right, knowing the road well, driving through floodwater previously without problem, and belief in my own physical ability to drive through. This factor accounted for 8.46% of the total variance and had a total eigenvalue of 1.52.

The fourth factor labelled as “journey characteristics” comprises three items and covers the issues no alternative route, urgency to continue journey and impractical alternatives to change journey plan based on time and distance. This factor accounted for 7.74% of the variance and had a total eigenvalue of 1.39.

The fifth factor labelled “social influences” includes items that describe the perceived social pressures or encouragements from others to perform the behaviour. This factor comprises three items covering the behaviour of others, e.g. others driving through without problems, reassurance or encouragement from others in the vehicle, the behaviour being exciting ‘fun to do’. This factor accounted for 6.28% of the total variance and had a total eigenvalue of 1.13.

The final, sixth, factor labelled “Absence of risk signals” related to the absence of warnings, signage and indicators that signal danger. This factor included only one item and accounted for 5.64% of the variance and had an Eigenvalue of 1.01.

Previous research findings supported the relevance of these themes as key influences in driving and health behaviour-related contexts. Rogers (1994) states "There is a fundamental link between training, experience and technological competence that provides the knowledge required to make intuitive decisions." Locus of control research (Montag and Comrey, 1987) found that it clearly relates to driving, in areas such as skill and accident involvement. Individuals with an internal locus of control are more attentive, motivated, and adept at avoiding aversive situations; hence, internality is negatively related to accident involvement (Montag and Comrey, 1987). Perceived self-efficacy (Bandura, 1997), in contexts such as health behaviour change (Hamilton, et al., 2017; Zhou et al., 2015 and 2017), has been associated with adaptive behaviours and more positive outcomes. In recent years, route-choice modelling has been the topic of several theoretical studies (Juhász, 2017) which indicate that journey characteristics, specifically travellers’ route choice, is important in decision-making aspects of driving. Lindsey et al. (2014) studied the effects of pre-trip information on route-choice decisions when travel conditions are congested and stochastic. Yang and Jiang (2014) developed an enhanced route choice model which can realistically identify risk attitudes and time reliability demands.

Regarding social influences, in disaster situations where options are often ambiguous and decisions need to be made quickly, it is argued that people often look to see what other people are doing to manage the situation and then act accordingly (Aronson, et al., 2010). Research findings are also evident for absence of risk signals. Prior research in the United States has found that drivers make judgements on whether to drive through floodwaters based on visual cues in the environment such as depth indicator signs (Balke et al., 2011; Higgins, et al., 2012). In contrast, the themes emerged from factor analyses in the present study are grouped rationally different than previous psychological research applied to driving though floodwaters (Hamilton et al., 2019) where the key influences on driver decision making were themed as successful past experiences, individual deliberative motivational and impulsive influences, social and environmental context, and judgements of self-efficacy.

4.3.5 Phase 5: Predicting perceived level of risks from the factors that influence decision- making

Previously research (Hamilton et al., 2019) has identified the key influences on driver decision- making. However, how those influences relate with each other and work in a model of decision-making has not been explored. In this final phase of analysis, we sought to use quantitative statistical methods to investigate the link between socio-cognitive influences of risk perception in the set of events in which SES personnel drove through floodwater.

A six-step hierarchical multiple regression analysis was performed on the dependent variable of perceived level of risk. The 'Organisational training and safety' factor was entered in step 1. The 'External locus of control factor' was entered at step 2, the 'Self-efficacy judgement' factor at step 3, 'Journey characteristics' at step 4, 'Social influences' at step 5, and 'Absence of risk signals' at step 6. Intercorrelations between the multiple regression factors are reported in Table 4.8 and the regression statistics are in Table 4.9.

Table 4.8

Means, standard deviations and bivariate correlations between all variables (influencing factors of decision-making and perceived level of risk) in the model.

Sl.	Variables	1	2	3	4	5	6	Mean	SD
1	Organisational training and safety	-						14.01	4.72
2	External locus of control	.224**						6.72	4.13
3	Self-efficacy judgements	.317**	.203**					16.11	5.98
4	Journey characteristics	.274**	.244**	.287**				12.61	5.17
5	Social influences	.133	.264**	.160*	.039			6.85	3.52
6	Absence of risk signals	-.100	.076	-.032	.085	.138		2.49	1.89
7	Perceived level of risk	-.285**	.096	-.102	.042	.103	.219**	28.01	16.46

Note: * $p < 0.05$. ** $p < 0.01$.

Table 4.9

Summary of hierarchical regression analysis for variables predicting perceived level of risks

Factors	B	SE B	β	*R*	R^2	ΔR^2	*F*	ΔF
Step 1				.285	.081	.081	17.58**	17.58**
Organisational training and safety	-.993	.23	-.285**					
Step 2				.329	.108	.027	12.01**	6.002*
Organisational training and safety	-1.125	.24	-.323**					
External locus of control	.672	.27	.169*					
Step 3				.331	.110	.001	8.07**	.285
Organisational training and safety	-1.087	.25	-.312**					
External locus of control	.693	.27	.174*					
Self-efficacy judgements	-.105	.19	-.038					
Step 4				.347	.120	.011	6.69**	2.390
Organisational training and safety	-1.155	.25	-.331**					
External locus of control	.620	.28	.156*					
Self-efficacy judgements	-.166	.20	-.060					
Journey characteristics	.356	.23	.112					
Step 5				.366	.134	.014	6.03**	3.082
Organisational training and safety	-1.181	.25	-.339**					
External locus of control	.500	.28	.126					
Self-efficacy judgements	-.203	.20	-.074					
Journey characteristics	.383	.23	.120					
Social influences	.572	.32	.122					
Step 6				.396	.156	.023	5.99**	5.181*
Organisational training and safety	-1.102	.25	-.316**					
External locus of control	.469	.28	.118					
Self-efficacy judgements	-.180	.19	-.066					
Journey characteristics	.323	.22	.102					
Social influences	.465	.32	.100					
Absence of risk signals	1.337	.58	.154*					

Note. n = 201; *p < .05, **p < .01

The hierarchical multiple regression revealed that at stage one, organisational training and safety contributed significantly to the regression model, F (1,199) = 17.58, p< .01) and accounted for 8.1% of the variation in perceived level of risk. Introducing the external locus of control factor explained an additional 2.7% of variation in perceived risk level and this change in R^2 was significant, Fchange (1,198) = 6.002, p < .05. Adding self-efficacy judgement, Fchange (1,197) = .285, p >.05 at stage 3; Journey characteristics, Fchange (1,196) = 2.39, p >.05 at stage 4 and Social influences, Fchange (1,195) = 3.08, p >.05 at stage 5 to the regression model explained additional 0.1%; 1.1% and 1.4% of the variation in perceived risk level, respectively and this change in R^2 was not significant (p >0.05). Finally, the addition of Absence of risk signals to the regression model explained an additional 2.3% of the variation in perceived risk level and this change in R^2 square was also significant, F (1,194) = 5.18, p < .05. When all six independent variables were included in the final stage of the regression model, External locus of control was not a significant predictor of perceived risk. The most important predictor of perceived risk was Organisational training and safety, which uniquely explained 28.5 % of the variance. Together the six independent variables accounted for 39.6% of the variance in perceived risk.

The results of the analysis indicated that the organisational training, knowledge and safety factor was significantly negatively associated with perceived risk, and had most significant contribution to risk perception. It revealed that those who felt their professional skills, training and safety attitudes had a greater influence on their decision to drive through floodwater were more likely to perceive the risk of driving through the floodwater on that occasion as low. Seemingly, belief in being highly trained and skilled at considering risks in the situation at hand was associated with feeling it was not risky to drive through the floodwater. On the other hand, the external locus of control factor was significantly positively associated with perceived level of risk. This suggests that an increased sense of duty and organisational pressure to perform one’s duty was associated with driving through floodwater that was considered higher risk.

Absence of risk signals was the other remaining factor that was linked to perceived risk. The analysis indicated that absence of risk signals (road signage, depth markers, warnings and messages) was significantly positively associated with perception of risk, such that those who felt that an absence of risk signals contributed more to their decision to drive through floodwater also felt it was riskier when they drove through the floodwater.

4.4 Applications/Implications of the study

There is no similar research exploring the situations in which emergency services personnel engage in risky driving behaviour in floodwater, or other contexts. The findings of the study have a number of practical implications for the development of occupational safety management strategies to ensure the safety of the emergency services personnel in operational context and also preventing and reducing the number and severity of injuries and associated costs of driving through floodwater on roads.

4.4.1 Practical implications of the study

4.4.1.1 Educational awareness, skills training and knowledge

Emergency workers need to be provided with the knowledge and skills to enable them to assess the risk associated with the different floodwater situations they may encounter during their operational activities. This includes understanding of the consequences of those risks and possible preventive measures that may be taken to mitigate risks. As the general policy is not to enter floodwater, there is no current training program in the SES organisation under study that was related to driving in floodwater. The findings of the study revealed that certain groups such as younger personnel (aged 35-55 years), volunteer personnel with less than 10 years' of service, those who are often deployed in floods and those who frequently drive SES vehicles were more likely to drive through floodwater Additional training or interventions might be designed that are tailored to different groups of personnel, e.g. 'refresher' training for those with longer service, or 'focussed risk analysis training' for those with greater frequency of flood deployment or who work in more dangerous operational conditions for longer periods of time. This study's finding suggest that more training is required for identification of water-related hazards on roads during flood, as well as development of more effective risk assessment strategies, more effective internal flood risk messaging. Given the prevalence of driving through floodwater in work vehicles, increased engagement of personnel around the dangers of driving in floodwater could be beneficial, with the use of photographs, video clips, and scenarios as training tools. Facilitated group discussions may help in influencing risk assessment and decision-making, particularly in complex environments with competing priorities, e.g. personal vs. public safety.

4.4.1.2 Refining risk assessment strategies

Poor quality risk assessment and risk management, and poor decision-making about risk, have been identified as contributing factors in workplace fatality, injury, disease and ill-health and in many major disasters (Dekker, et al., 2011). Understanding and managing risk is central to achieving the outcomes and targets of the Australian Work Health and Safety Strategy 2012-2022 (Safe Work Australia, 2012). The findings of the current research could be used to tailor an effective risk assessments strategy for emergency services.

4.4.1.3 Improving organisational safety

The results of this study also have implications for evaluating the emergency services' existing safety management practices, exploring personnel common beliefs and attitudes towards safety as part of possible intervention strategies. The findings revealed more needs to be done to explore organisational safety climate (the shared perceptions of safety policies and practices among personnel of the organisation) regarding this behaviour.

Flood risk communication public messaging and campaigns:

Providing critical safety and preparedness information to help communities prepare for, respond to and recover from emergencies and disasters is one of the major functions that the SES does. The findings of the study could help SES design more effective flood risk communication messaging for the public and enhance community emergency response capacity and capability. Identifying factors that influence the SES when driving through floodwater might be transferable to the decision-making of the public. Therefore, research findings may help to design more effective public messaging campaigns to reduce driving through floodwater.

4.4.2 Theoretical implications of the study

This study is some of the first work where the concepts from the RPD and EPPM models had been used together to examine floodwater driving decisions based on perception of risks. The study findings outlined the factors that impact risk-based decision-making processes. According to the conceptual model of decision-making in the current study, perception of risks is at the center of decision-making. Decisions about risk are influenced by how the risk is perceived by those making decisions. Event specific risk perception is not fixed, but is constructed based on several internal (personal characteristics -skills, ability, prior experience, safety beliefs etc.) and external factors (situational characteristics-spatial, environmental, social, organizational contexts etc.) which develop the driver's mental model about a situation. In a practical sense, the normative value of the RPD model is in emphasising the importance of mental models. Improving the breadth and validity of mental models then becomes the practical strategy for improvements to decision-making (Klien 1998,2003). Further study is required to know how this mental model could work to choose the best course of actions from decision options.

4.5 Strengths and limitations of the study

This study is the first of its kind in Australia to investigate emergency services driving through floodwater. The current study has a number of strengths. The use of a definition of floodwater on the road, and a reference image for estimating the depth of water driven through were important additions to the study that will have resulted in better quality data. The use of an independent research team investigating safety practices and ensuring the anonymity of respondent, should also have improved the integrity of the data. The study was supported by senior management in the SES and the sample size was adequate for statistical power in analysis. The survey collected very detailed information about the contexts and conditions in which SES personnel drove through floodwater, and the data collected has the potential to be very useful for the organisation in understanding the behaviour of its personnel and for improving occupational health and safety. However, like any study of this nature, there are a number of limitations that need to be acknowledged. The first, is that the participants of this study were from an East Coast jurisdiction of SES which might not be representative of all jurisdictions in Australia. Although the sample size is adequate for analysis, statistical findings should be viewed as vigorous, but indicative of the sample, rather than representative of the whole organisation. Second, this is a cross sectional study and provides only a snapshot of a set of incidents, not all incidents, of driving through floodwater. As we requested details about a single recent or memorable event, participants probably recalled more salient, and possibly more extreme, events. In relation to the degree of risk associated with an event, we have

no way of knowing objectively how risky or safe it was. A combination of recall bias and social desirability may have influenced responses. In an organisational situation where SES personnel are discouraged from driving through floodwater, there would potential for embarrassment in admitting to acting unsafely, therefore participants may have felt a need to minimise or excuse their risk-taking in the way they answered some questions, although we would expect that assurances of anonymity and confidentiality would have reduced some of these impacts. The study could not identify whether the decisions during driving through floodwater events were fully voluntary, or not. There might have been differences in terms of willingness to drive through floodwater between 'business as usual' type behaviours (for example, as a SES member driving SES vehicles or private vehicles to do normal business or everyday jobs), and emergency situations (for example, when operational and involved in flood rescue. In the application of findings, it would probably be useful to note that different circumstances will have an impact on decision-making. Finally, the study included the EPPM theory concepts in the final step of the decision-making model, which proposed that individual's fear, or danger control processes turn mental simulation outcomes into action. However, the study could not assess and interpret clearly how these two processes (fear or danger) relate to risk perception. Further research is required to explore the relevance of the EPPM theory constructs in this decision-making model of driving through floodwater behaviour to further explore and verify the model.

4.6 Conclusion

This research contributes to our understanding about risk perception and how it relates to driving through floodwater by emergency services personnel. The study found that more than half of those surveyed had driven through floodwater in the last two years in work conditions. Males, those doing more driving per week, and volunteers with more than 10 years SES experience were among some of the groups more likely to have driven through floodwater in last two years. Most incidents of driving through floodwater occurred in regular working conditions (not under lights and sirens), with adequate light (during the day), in good weather condition (no rain), crossing water on the normal stretch of (flooded) road, with low water flow. These factors helped respondents drive through floodwater successfully on most occasions without damage to vehicles or personal injuries. As driving in floodwater is discouraged it is interesting to consider why many respondents took risks driving through floodwater, unable to be entirely certain of the safety of the situation (e.g. water flow, road integrity) to perform non-urgent work. Although there is only a small number of cases, some personnel drove through floodwater in conditions when risk of harm is known to be greater, i.e. through water deeper than 15 cm, at night with no streetlights, in steady or heavy rain, ignoring road signage.

Location, water depth, and flow contributed notably to risk perception and three factors that influenced the decision to drive through floodwater were found to be most strongly associated with risk perception These were ‘Organisational training and safety’, ‘External locus of control’ and ‘Absence of risk signals’. Thus, SES personnel who felt their professional skills and training and careful consideration of the situation contributed to their decision also felt that risks were lower when they drove into floodwater. Conversely, high external locus of control and an absence of risk signals (warnings, signs and indicators) led personnel to perceive higher risks when the drove through floodwater.

The results from this study indicate that more needs to be done with emergency services personnel to communicate the risks of entering floodwater in work vehicles. These findings identify some key aspect that have salience in risk processing and risk perception that can be used to help design more effective risk assessment strategies, to design training tools and safety programs and contribute overall to improvements in organisational health and safety management practices of the SES.

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Interlude 4: Testing a novel approach to hazard assessment

Chapter 4 explored the behaviour and decision-making of SES personnel when they encounter floodwater at work in vehicles. This research found that driving through floodwater was quite a common behaviour, with 55% of respondents reporting driving through floodwater in the last two years.

Within the sample certain subgroups were found to be more likely to have driven through floodwater, specifically, males, those who have held a driving licence for more than 10 years, those who get deployed in floods, those who typically drive more hours in a week, and those with flood rescue qualifications. These findings suggest that a combination of experience, exposure, and opportunity lead to a higher incidence of driving through floodwater.

The research also identified that factors which had the greatest influence on decisions to drive through floodwater included occupational factors, such as professional training and skills, and a sense of responsibility to perform (their) duties. To strengthen and maintain workplace health and safety standards it is important to identify approaches to support personnel in assessing the risks associated with driving through floodwater.

Specific events of driving through floodwater were analysed to investigate situational characteristics that were associated with higher levels of risk perception. This analysis found that environmental features, in particular water depth and flow information played an important role in risk perception - which is the part of the risk assessment before taking the decision to drive through.

Cue based decision-making provides a strong theoretical framework to help explain how experts use feature-event associations in the environment (cue utilisation) to make better and more efficient decisions. Assessment of cue utilisation has been applied in many industries and contexts to differentiate skilled performance in hazardous and safety-critical work-setting.

In the current context, if cue utilisation was found to predict expert hazard assessment it would have potential uses in safety training settings as a measure of training effectiveness. In the final study in this thesis, an approach to cue utilisation assessment (using an online software platform called EXPERTise 2.0) was modified and developed for floodwater hazard assessment. This was tested on a sample of SES personnel who took part in the previous study, reported in Chapter 4.

Chapter Five: Cue Utilisation and decision-making

STUDY 4

Publication history

This paper from Study 4 is entitled “Expertise in identifying and assessing the hazards of floodwater on roads: a pilot study of cue utilisation in emergency services personnel”. The paper is ready to submit in a peer reviewed journal. The author of the present dissertation wrote approximately 75% of this paper.

Expertise in identifying and assessing the hazards of floodwater on roads: a pilot study of cue utilisation in emergency services personnel

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Abstract

Ensuring the safety of emergency services personnel, who are more likely to encounter hazardous environments, is an important organisational safety management issue for all emergency services organisations. In Australia, the State Emergency Service (SES) is the emergency service agency responsible for floods, storms and tsunamis and, as such, SES personnel regularly deploy in hazardous flood environments. Driving into floodwater is a specific occupational safety concern for emergency service organisations as it can result in personal injury or death, damage to vehicles and equipment, and reputational damage. As a risk that is avoidable, driving into floodwater whilst on duty is generally discouraged by SES organisations.

Engagement in hazardous behaviour, such as driving into floodwater, is typically explained as the consequence of either failure to attend to the risks associated with an activity, the misidentification of the risks associated with the activity, or the minimisation of the risks associated with the activity. However, all explanations are predicated on the assumption that individuals possess the capacity to acquire and interpret information sufficiently to identify and interpret the risks associated with an activity. This is the core focus of cue utilisation.

The aim of the present study was to develop an assessment of cue utilisation in the context of floodwater and driving, to examine whether experienced emergency service personnel can be differentiated, based on their hazard assessment capacity, and whether subsequently this capacity can be linked to decision-making performance accuracy.

A set of six online tasks to assess behaviour indicative of cue utilisation in a floodwater context was developed using an online software shell (EXPERTise 2.0), and an additional video-based performance task was created. Data from 82 SES personnel was used in analysis. A cluster analysis reliably differentiated two groups of participants and the EXPERTise 2.0 tasks mostly separated between the clusters in expected directions and gave confidence that these represented a group with higher and a group of lower cue utilisation. However, further analysis found no

statistically significant relationship between cue utilisation and hazard assessment performance. Findings of the study have implications for further development of cue utilisation research, and for our understanding of how cues may be acquired and used in complex environmental conditions.

Expertise in identifying and assessing the hazards of floodwater on roads: a pilot study of cue utilisation in emergency services personnel

5.1 Introduction

Responding to vehicle-related flood rescues caused by people driving into floodwater is a significant task for emergency services, often making up around a third of all flood rescues (Smith, et al., 2017). In addition to dangers inherent in flood rescues, being deployed in storm and flood conditions exposes emergency services personnel to the risks of driving in floodwater directly, making this a potential workplace health and safety consideration. In a number of cases, driving into floodwater has been identified as a premeditated and deliberate behaviour, and the result of a careful decision-making process (Hamilton, Peden, Keech & Hagger, 2019), for emergency services personnel it happens as part of their professional duties. Due to the nature of their work, which involves responding to incidents in floods and storms, the decision- making processes of State Emergency Services (SES) personnel when they encounter floodwater in vehicles are complex. In emergencies, SES personnel are required to make rapid situational assessments under time pressure and often in ambiguous or rapidly changing situations. Recent research has attempted to understand the psychological mechanisms that may guide individuals' decisions to engage in safety compromising behaviours around water (Hamilton, et al., 2016; Hamilton and Schmidt, 2013, 2014; Hamilton, et al., 2015; Pearson and Hamilton, 2014). Although this research provides some useful insights into understanding why individuals may engage in risky driving behaviour into floodwater, the role of environmental cues in decision-making has not been explored by any research in this context to date. As this area of research could assist with building a safer workforce, there is clear value in exploring the quantification of cue utilisation in this challenging context to discover whether it may contribute to supporting the decision- making of this occupationally at-risk group. Potential solutions, through enhanced education about the dangers of entering floodwater and the development of skills to assist with appropriate decision-making are needed (Becker et al., 2015).

5.1.1 Decision-making and cue utilisation

Decision-making is a subset of an individual's information processing capacity. According to the recognition-primed decision (RPD) model of decision-making (Klein, 1989, 1993) the capacity to accurately assess a situation constitutes a significant component of expert decision-making and involves a process of matching features in the environment to feature-event associations or "cues" in memory. In the context of decision-making, a cue represents a concept, generally embodied in an environmental feature(s) that, having been attended to, is able to cue the retrieval of associated concepts from memory (Wiggins, 2006; Wiggins and O'Hare, 2003). The ability to retain and use these familiar associations, triggered by features in the practice setting, is referred to as cue utilisation (Wiggins, 2012; Wiggins, Brouwers, Davies & Loveday, 2014). Thus, the capacity for cue utilisation is dependent upon the identification of predictive features in the environment, the association between features with events or objects in memory, the retention of these cue-based relationships, and the appropriate application of cues in response to environmental features (Wiggins, 2012). The utilisation of cues involves focusing of attention, integrating task-relevant information, priming appropriate responses and acknowledging the context in which the application of these cues applies (Wiggins, Brouwers et al., 2014).

Cues are essentially feature-event/object relationships in memory that enable the rapid assessment of a situation and, subsequently, the formulation of a response (Wiggins, 2006, 2012). For example, Morrison, Wiggins, Bond and Tyler (2013) demonstrated that, in comparison to non-experts, expert forensic investigators were relatively consistent and responded more rapidly in assessing the relatedness of feature/event pairs relating to a murder investigation. Similarly, Wiggins and O'Hare (1995) established that the acquisition of weather-related information differed between experts and non-expert pilots, with the former being less likely to access information in the sequence in which it was presented. This behaviour has been interpreted as evidence to suggest a greater level of cue utilisation amongst experts. The association between levels of cue utilisation and expertise has been established in the sport of squash (Abernethy, 1990), power control (Loveday, T., Wiggins, M. W., Harris, J. M., O'Hare, D., & Smith, N., 2013), paediatric assessment (Loveday, T., Wiggins, M. W., Searle, B. J., Festa, M., & Schell, D., 2013), and aviation (Wiggins Azar, Hawken, Loveday, & Newman, 2014). Measures of cue utilisation have also differentiated performance in the context of software engineering (Loveday and Wiggins, 2014).

Cue utilisation has previously been assessed using an online software shell called the EXPERT Intensive Skills Evaluation (EXPERTise 2.0) situation judgment test (Wiggins, Loveday & Auton, 2015, Brouwers, Wiggins, Helton, O'Hare & Griffin, 2016; Brouwers, Wiggins, Griffin, Helton & O'Hare, 2017; Small, Wiggins & Loveday, 2014). EXPERTise provides a composite assessment of cue utilisation, incorporating experimental tasks that assess distinct behaviours that characterise aspects of the utilisation of cues (Wiggins et al., 2015). These tasks can be adapted, using suitable stimuli and scenarios, to capture behaviours that characterise cue utilisation in a wide range of contexts. The behaviours examined include response latency to key features, the accuracy with which key features are recognised, the specificity of feature–event relationships in memory, the capacity to discriminate relevant from less relevant features during problem-solving, and the prioritisation of features during problem identification (Loveday, Wiggins, Searle, Festa & Schell 2013; Morrison, et al., 2013; Pauley, O'Hare, & Wiggins, 2009).

Using standardised task scores, a profile is generated that differentiates participants based on their behaviour in response to the task-related features (Loveday, T., Wiggins, M., Festa, M., Schell, D., & Twigg, D., 2013; Wiggins, et al., 2018). Where some participants may demonstrate faster response latencies to key features, they may be less capable of differentiating relevant from less relevant features during problem solving. Nevertheless, on balance, their profile may place them in the typology that demonstrates relatively higher cue utilisation in comparison to other participants. This type of profiling reflects the fact that the acquisition of cues, as a cognitive strategy, is nonlinear, and that different cognitive strategies may be engaged at different stages of skill acquisition, to facilitate cue utilisation (Sturman et al., 2019).

Higher cue utilisation would, therefore, allow individuals to rapidly and accurately detect and perceive important feature-event relationships in the environment. Cue utilisation is additionally a trait that differs across individuals and is stable across time (Wiggins et al., 2014). There is individual variance not only in the extent to which individuals utilise cues, but also differences in their ability to create new cues (Wiggins et al., 2014). Therefore, in contexts where individuals are required to regularly attend to, or be exposed to, natural environmental hazards for the purposes of their employment (e.g. for emergency service operations) identifying individuals with higher cue utilisation would potentially assist in improving safety outcomes by identifying individuals likely to respond quickly to training efforts. When emergency service responses are required for floodwater related emergencies, responders with higher levels of cue utilisation would have the ability to correctly and rapidly identify floodwater hazards and associated risks in the environment, improving safety outcomes for both self and others.

5.2 The Pilot Study

The aims of the present pilot study were to develop an assessment of cue utilisation in the context of floodwater and driving (using EXPERTise 2.0), to examine whether experienced emergency service personnel can be differentiated, based on their hazard detection capacity, and whether subsequently this capacity can be linked to decision-making performance accuracy.

Whereas previous approaches to the assessment of expertise have typically involved comparisons between experts and novices (Wiggins et al., 2014), the present study was initiated to examine cue utilisation in a sample of SES personnel who have experience in driving and exposure to flood conditions in their working environment. In this study, participants were considered ‘experienced’ not ‘expert’. As previous literature identified experts with many years of experience develop, store, and apply learned associations between features present in the environment and events (Crane et al., 2018). These associations are accurate and refined in those considered to be experts in their field and are a critical ingredient for expert performance (Wiggins, 2012; Wiggins, et al., 2014).

This research study set out to address the following research questions –

- Following methods used previously, using EXPERTise 2.0 testing, is it possible to develop a suite of tasks related to floodwater hazard assessment and detect differences in cue utilisation between members of an SES participant group?
- If differences in cue utilisation are found, is it possible to identify differences in situation assessment accuracy between those with higher and lower cue utilisation?

5.3 Method

5.3.1 Participants

Ninety-two SES personnel were recruited via email to participate in the pilot study. However, data from 10 participants was excluded from analysis due to incomplete or corrupted data. This left 82 participants in the final analysis (61 males, 18 females, and 3 did not specify). The average age range of the participants was 45 to 55 years. Participants had previously taken part in a questionnaire study about encountering floodwater at work and had agreed to be contacted about follow-up research. Inclusion criteria for the study were that participants held a full drivers’ licence and had approval to drive SES work vehicles.

5.3.2 Measurement of Cue Utilisation

Cue utilisation was assessed using the Expert Skills Evaluation (EXPERTise 2.0) software shell (Wiggins et al., 2015). EXPERTise 2.0 is designed to assess behaviour consistent with the utilisation of cues within a specific context. It consists of experimental tasks that have been individually and collectively associated with differences in performance at an operational level (Loveday, et al., 2013a; Loveday, et al., 2013b; Loveday, et al., 2013c). The six tasks developed in the EXPERTise testing environment for floodwater hazards comprised a Feature Identification Task (FIT), a Feature Recognition Task (FRT), two Feature Association

Tasks (FAT1 and FAT2), a Feature Discrimination Task (FDT), and a Feature Prioritisation Task (FPT).

A summary of the EXPERTise task parameters is displayed in Table 5.1, and each task is described in detail subsequently.

Table 5.1

Summary of EXPERTise 2.0 Tasks

Task	**Cognitive skill examined**	**Task description**	**Measure**	**Validity/reliability**
FIT	Identification of predictive features	Identify, as quickly as possible, the area of potential concern in the image of floodwater on roads.	Response latency	Loveday et al., (2013); Wiggins et al., (2014)
FRT	Identification of predictive features	Estimate the depth of floodwater in an image displayed for 500 ms	Accuracy	Loveday et al. (2013)
FAT	Feature-event relationships in memory	Rate the comparative relationship between pairs of words related to the experience of floodwater and driving (features- related with floodwater on roadsand events-driving)	Variance divided by response latency	Morrison et al. (2013)
FDT	Discrimination between predictive features	Rate the relative importance of features during a task-related problem-solving process (Task -to make decision to drive or not to on flooded routes)	Variance	Pauley et al. (2009)
FPT	Prioritisation of feature-event relationships	Acquire task-related information to solve a problem-solving process. (prioritise key features relating to a flood scenario to select the route to reach the destination)	Ratio of sequential to non-sequential menus accessed	Wiggins and O'Hare, (1995); Wiggins et al., (2002)

Note. EXPERTise - EXPERT Intensive Skills Evaluation; FIT - feature identification task; FRT - feature recognition task; FAT - feature association task; FDT - feature discrimination task; FPT - feature prioritisation task. (Adapted from Sturman et al., 2019)

Feature Identification Task (FIT)

In the FIT, participants were presented with 14 different images of scenes of floodwater on roads, as viewed from the perspective of a car driver. Each image (Figure 5.1) was accompanied with the instructions, "Imagining you are the driver of the car, click on the part of the road scene that you pay the most attention to because it is an area of potential concern when deciding whether to proceed." On selecting an area of concern (with a mouse click), participants are then presented with the next image. In the FIT, participants must identify a key feature from an array. The FIT requires participants to identify key features from scenes, and is based on the observation that experts are able to identify and utilise visual features in the environment that are more diagnostic of the system state compared with novices (Müller, et al., 2006; Schriver, et al., 2008). Response latency is measured as the time in milliseconds from the initial presentation of the image to the selection of an area of concern. Higher cue utilisation is associated with a lower mean response latency (Loveday, et al., 2013; Schriver et al., 2008).

Figure 5.1 Example image used in FIT task

Feature Recognition Task (FRT)

The FRT exposed participants to a series of 15 different photographs of roads, as viewed from the driver's seat of a car. Each of the images was displayed for 500ms, and after exposure to an image, the participant was requested to estimate the depth of the floodwater at its deepest point using the image below as a guide (Figure 5.2), with four multiple-choice options:

A. Below the hubcap (< 15 cm)

B. The middle of the tyre/hubcap (approx. 40 cm)

C. The top of the hubcap/bottom edge of front headlight (approx. 70 cm) D. The top of headlight/door handles (approx. 90 cm)

Figure 5.2 Reference guide used for the FRT.

The images included photographs of different types of road (highways, major, residential, sealed, unsealed), locations (suburban, urban and rural), type of crossing (causeway, river crossing), signage (depth marker, barricade), reference vehicles (small, medium and heavy vehicles in the image) and the roads appeared in varying lighting conditions (cloudy, rainy, dusk, etc.). An example image is shown in Figure 5.3.

Figure 5.3 Example image used in FRT task to estimate water depth (500ms timed exposure)

The FRT is designed to assess the capacity to rapidly extract key information from the scene and form an accurate judgement (Sturman et al., 2019). Higher cue utilisation is associated with a greater number of correct responses (Brouwers et al., 2017).

Feature Association Task (FAT)

This task has two stages. In stage 1, a series of 17 paired words/short phrases, representative of feature-event/object terms were presented. The words/short phrases were related to the experience of floodwater and driving, and participants indicated the extent to which they believed each pair are related in the context of floodwater on roads. For example, one phrase pair consisted of ‘electric windows’ (feature) and ‘escape’ (event). The initial phrase ‘electric windows’ appeared on-screen, followed by a blank screen with a red ‘X’ indicating the fixation point, and then the second phrase ‘escape’ appeared for 1,000ms. Participants were then presented with a 6-point Likert scale slider (from 1 ‘extremely unrelated’ to 6 ‘extremely related’) accompanied by the instructions, ‘Please use the slider to indicate how related you believe the two phrases to be.’

Stage 2 also consists of 17 trials, during which participants are presented again with different phrases that are relevant to the experience of floodwater and driving (e.g., ‘debris,’ ‘current’), but this time the phrases appeared side by side on the screen at the same time. For each trial, two terms are displayed, after which participants rate the extent to which they believe the two terms are related in the context of floodwater on roads on a 6-point Likert scale ranging (from 1 ‘extremely unrelated’ to 6 ‘extremely related’). As cue utilisation requires the identification of predictive feature–event relationships, higher cue utilisation is associated with greater variance in the perceived relatedness of terms (Morrison, et.al., 2013; Schvaneveldt, et al., 2001).

Feature Discrimination Task (FDT)

In the FDT, participants were presented with one half-page, short written description of a way-finding driving scenario. In this scenario, they were required to make a decision about which of two routes to take in a heavy rain/potential flood situation, to arrive at a destination for an important meeting. Participants were able to consider the written scenario without any time limit and were then prompted to select their response from three available options: (a) Take Route A (b) Take Route B (c) Stay home/Cancel the meeting. Following their decision, participants were presented with a list of 14 features that were embedded in the scenario description and, using a 10-point Likert scale (from 1 ‘not important at all’ to 10 ‘extremely important’), were asked to rate the importance of each of these in arriving at their decision. These features included information such as ‘current rainfall,’ ‘forecast weather,’ ‘current time’, ‘meeting time,’ ‘time to destination on Route A and Route B,’ ‘distance to destination’, ‘local radio message advising about localised flooding and instructed people not to drive through floodwater’ etc. Effective cue utilisation requires features to be identified as more or less relevant (Pauley et al., 2009; Weiss and Shanteau, 2003). Higher cue utilisation is associated with a greater variance in ratings (Brouwers et al., 2017).

Feature Prioritisation Task

Finally, in the Feature Prioritisation Task, participants were presented with a scenario that required a choice between two different routes of travel (Route A and Route B) to visit the hospital for an appointment with a specialist. Participants are told that arriving in time is important otherwise it will require them to wait three months before another appointment is available. This way-finding scenario is accompanied by 17 drop-down lists of key features relating to the scenario. Each drop-down menu is feature-labelled (e.g., ‘current time’, ‘clinic opening hours’, ‘map of route A and B’, ‘current weather’, ‘rain radar’, ‘rainfall’, ‘river height information’, ‘flood warning post from Facebook’, ‘vehicle type’ etc.), and upon selection, provides participants with information pertaining to feature and potentially relevant to the scenario. The information was provided in a range of formats, from written information to customised screenshots of weather radar and Facebook posts.

Above the 17 options were the instructions: ‘You only have 120 seconds to access any information necessary (from the dropdown tabs below)’. After 2 minutes (120 second), no further drop-down information could be accessed and participants were asked to decide on which route to select to reach the destination (hospital). The FPT assesses participants’ capacity to prioritise feature cue acquisition, as the task is time pressured (Wiggins and O’Hare, 1995; Wiggins et al., 2002). Lower cue utilisation is more likely to be associated with the selection of information in the sequence in which it is presented (e.g., from top to bottom as they appear on the display screen), while higher cue utilisation is associated with a lower ratio of menus selected in the sequence in which they are presented (Wiggins et al., 2002).

5.3.3 Measurement of accuracy in assessing the floodwater hazard (Performance task)

An additional computer-based task was included in this study to assess participants' accuracy in assessing the hazard of floodwater in the context of driving. This task was incorporated into the EXPERTise battery of tasks, but was not one of the six core EXPERTise tasks. During this task, participants viewed 17 short videos (typically around 5 seconds duration) of cars driving into floodwater. Each video was accompanied by the question 'Do you think the car in the video will make it through the flood water?' Response options were 'yes' or 'no'.

Each video contained information of the scene thought to be useful, e.g. location/situating information, road type, water movement, vehicle type, etc. The video, however, was stopped before the outcome was known, i.e. the vehicle was seen entering the water, and usually driving in the floodwater for a while, but it stopped before the vehicle either successfully exited the floodwater, or became swamped/stopped/swept away. The sum of correct responses (based on the final 'known' outcome) was used as a final score in the main analysis. From previous research, higher cue utilisation is associated with a greater number of correct responses in a performance task (Brouwers et al., 2017).

5.3.4 Questionnaire Measures

Demographic and background information that were collected in the preceding survey research (reported in Chapter 5) were linked to the EXPERTise data. The following data were used in the analysis:

- Age (<35, >35)
- Gender (male/female)
- Years of holding a full driving licence (<10yr, >10 yr)
- Time spent driving, per week (<2hr, 2-7hr, 8-14hr, >15hr)
- Length of service (Volunteer members) (<5yr, 5-10yr, >10yr)
- Deployed to work in flood/storms (yes/no)
- Frequency of driving SES vehicles (rarely, occasionally, often, all the time)
- Current Flood Rescue qualifications (yes/no)
- Frequency of encountering flooded roads – per year (never, 1-2, 3-6, >6)
- Driven through floodwater in the last two years (yes/no)

5.4 Results

5.4.1 Cue utilisation typologies

The first stage of analysis was to identify the cue utilisation typologies that corresponded to relatively higher and lower levels of cue utilisation. These typologies were based on the outcomes of the EXPERTise tasks and were calculated in accordance with previous methodological approaches used in EXPERTise studies (Loveday et al.,2013b, c; Loveday and Wiggins,2014; Wiggins et al.,2014, Sturman et al., 2019). The calculation of typologies began with the aggregation of the responses within the tasks, the calculation of z-scores, and a cluster analysis to identify whether two, meaningful typologies could be established.

The cluster analysis was implemented successfully, with five of the six individual tasks within each cluster forming in the expected direction. The FDT task did not contribute in the expected direction and was excluded from further analysis. The first cluster, labelled 'higher cue utilisation', consisted of participants who had a shorter response latency on the FIT, greater accuracy on the FRT, a greater mean ratio of variance to reaction time (RT) on the FAT,1 and FAT2, and a lower ratio of sequential selections in the FPT. The second cluster, labelled 'lower cue utilisation', consisted of participants who had a greater response latency on the FIT, lower accuracy on the FRT, a lower mean ratio of variance to reaction time (RT) on the FAT1 and FAT2, and a higher ratio of sequential selections in the FPT.

Independent samples t-tests demonstrated significant differences in FIT, FRT, FAT 1 and FAT 2 scores between the higher and lower cue utilisation groups (see Table 5.2). Differences were not significant for the FPT.

Table 5.2

Cluster Centroids for the EXPERTise Task Scores

Perceived level of risk score	Cluster 1(n=32)	Cluster 2 (n=50)	t	df	p
	Higher cue utilisation	Lower cue utilisation			
FIT	-.36979	.23666	-2.789**	80	.007
FRT	.42063	-.26920	3.218**	80	.002
FAT1	.96312	-.61640	10.977***	80	.000
FAT2	.84943	-.54364	8.380***	80	.000
FPT	-.00732	.00469	-.053	80	.958

Note. EXPERTise = EXPERT Intensive Skills Evaluation; FIT = feature identification task; FRT = feature recognition task; FAT = feature association task; FPT = feature prioritisation task.
*Significant at the .05 level (two-tailed). **Significant at the .01 level (two-tailed). ***Significant at the .001 level (two-tailed).

Thirty-two participants (39.0%) were classified in the higher cue utilisation group and 50 (61.0%) participants were classified in the lower cue utilisation group.

5.4.2 Demographic Statistics:

A chi-square test indicated that cue utilisation was not related to participant demographic variables (see Table 5.3). Consequently, these covariates were excluded as potential explanatory variables in the next phase of analysis.

Table 5.3

Frequencies, Percentages, and Adjusted Standardised Residuals (ASR) for demographics variables with cue utilisation clusters

	Higher cue utilisation				Lower cue utilisation				χ	p
	f	%	f_e	ASR[a]	*f*	%	f_e	ASR[a]		
Age									.8	.67
18-34	9	45.0	7.9	.6	11	55.0	12.1	-.6		
35-54	12	34.3	13.9	-.9	23	65.7	21.1	.9		
55 and above	10	43.5	9.1	.4	13	56.5	13.9	-.4		
Gender									.025	.874
Male	25	41.0	24.7	.2	36	59.0	36.3	-.2		
Female	7	38.9	7.3	-.2	11	61.1	10.7	.2		
Years of holding a full driving licence									1.787	.181
<10 years	5	62.5	3.2	1.3	3	37.5	4.8	-1.3		
>10 years	27	38.0	28.8	-1.3	44	62.0	42.2	1.3		
Time spent driving per week									4.3	.231
<2 hours	3	75.0	1.6	1.5	1	25.0	2.4	-1.5		
2-7 hours	15	41.7	14.5	.2	21	58.3	21.5	-.2		
8-14 hours	5	25.0	8.1	-1.6	15	75.0	11.9	1.6		
>15 hours	8	47.1	6.8	.6	9	52.9	10.2	-.6		
Length of service (Volunteer members)									3.098	.213
<5 years	13	50.0	10.6	1.2	13	50.0	15.4	-1.2		
5-10 years	3	21.4	5.7	-1.6	11	78.6	8.3	1.6		
>10 years	15	41.7	14.7	.1	21	58.3	21.3	-.1		
Deployed to work in flood/storms									.428	.513
Yes	27	39.1	27.9	-.7	42	60.9	41.1	.7		
No	5	50.0	4.1	.7	5	50.0	5.9	-.7		
Frequency of driving SES work vehicles									3.738	.291
Rarely	11	44.0	9.9	.6	14	56.0	15.1	-.6		
Occasionally	12	38.7	12.2	-.1	19	61.3	18.8	.1		
Often	4	25.0	6.7	-1.3	12	75.0	9.7	1.3		
All the time	3	75.0	1.6	1.5	1	25.0	2.4	-1.5		
Current flood rescue qualifications									.039	.843
Yes	26	40.0	26.3	-.2	39	60.0	38.7	.2		
No	6	42.9	5.7	.1	8	57.1	8.3	-.1		
Frequency of encountering flooded roads (per year)									2.357	.502
Never	4	66.7	2.4	1.4	2	33.3	3.6	-1.4		
Rarely	20	40.8	19.8	.1	29	59.2	29.2	-.1		
Occasionally	7	35.0	8.1	-.6	13	65.0	11.9	.6		
Frequently	1	25.0	1.6	-.6	3	75.0	2.4	.6		
Driven through floodwater in the last 2 years									1.231	.267
Yes	20	44.4	17.6	1.1	25	55.6	27.4	-1.1		
No	12	32.4	14.4	-1.1	25	67.6	22.6	1.1		

Note. [a] The adjusted standardised residual is the observed frequency—expected frequency/estimated standard error.

5.4.3 Cue utilisation and Performance:

The mean accuracy score for performance task was 11.6, out of a possible maximum score of 17 (minimum =5 and maximum =16) and SD=2.11. One-way analysis of variance was used to test the relationship between cue utilisation and accuracy in the performance task, incorporating the two-level cue utilisation typology as the independent variable and performance task accuracy as the dependent variable. The analysis (Table 5.4) revealed that the typologies identified in the study were not statistically significant for performance accuracy. The mean performance task score for the higher cue utilisation group was 11.19 (SD=2.18) and the lower cue utilisation group was 11.78 (SD=2.06).

Table 5.4

One-Way Analysis of Variance of Performance Task Score by Cue Utilisation

Source	*df*	*SS*	*MS*	*F*	*p*
Between Groups	1	6.850	6.850	1.542	.218
Within Groups	80	355.455	4.443		
Total	81	362.305			

5.5 Discussion

This is the first research undertaken to explore cue utilisation in the context of assessing floodwaters hazards, experimentally. The present study included development of a novel set of floodwater-related EXPERTise 2.0 tasks designed to capture behaviour indicative of different levels of cue utilisation. The study aimed to test whether experienced emergency service personnel could be differentiated, based on cue utilisation typology, and whether subsequently this capacity can be linked to decision-making performance accuracy.

Cue utilisation has been established previously as a characteristic of expertise (Loveday et. al., 2013c), and this suggests that the capacity to identify, acquire, and retain feature– event/object relationships in memory may be a necessary part of situational assessment of expertise in many domains. Exposure to repeated pairing of features and events increases the likelihood that these associations will become stored in long-term memory and be available for activation (Wiggins, 2006; Wiggins & Bollwerk, 2006; Wiggins & O’Hare, 2003; Zacks, Speer, Swallow, Braver, & Reynolds, 2007). Experts are understood to have well-refined cue associations between clusters of features and events that allow precise and rapid responses in the domain of expertise (Wiggins & O’Hare, 2003).

To assess cue utilisation, a new floodwater hazard version of EXPERTise 2.0 was developed and piloted successfully. Performance on the tasks within EXPERTise 2.0 enabled the identification of two typologies reflecting relatively higher and lower levels of cue utilisation. Individual tasks within EXPERTise 2.0 worked as predicted, from prior research in the field, therefore providing confidence that this new battery of floodwater tasks was a valid indicator of cue utilisation.

The second phase of analysis, however, failed to confirm the predicted direct relationship between cue utilisation and floodwater hazard assessment performance, despite this task working well, in terms of seemingly discriminating between the ability of participants (i.e. providing a good distribution of scores). The reasons for this lack of finding are unclear. Evidence in the literature for a link between cue utilisation and performance is very strong, and therefore the most obvious assumption is that there is a mismatch between the performance captured by the video task, and the cue utilisation derived through EXPERTise 2.0. It is possible that, although there are differences in cue utilisation across this experienced group of participants, these cues are not being applied, or are not generalisable to the situations shown in the video task or perhaps the cue approach is less applicable to the specific circumstances of driving through flood water An alternative, and simpler, explanation is that the video task failed to capture performance adequately. Although experience in the practice setting may mean that cues are more likely to be formed, this does not necessarily mean that cues are always applied (Crane et al., 2018). Therefore, just as experience is often weakly associated with performance, so too cue utilisation lacks a strong association with an operator's experience. Experts are understood to have well- refined cue associations between clusters of features and events that allow precise and rapid responses in the domain of expertise (Wiggins & O'Hare, 2003). The lack of relationship between cue utilisation and performance in the present study suggests that there may be a role for more cue-based training with these emergency service personnel to establish stronger associations between features in operational environment and events. This would support development of new feature-event associations (cues) and aid in more accurate and efficient assessment of floodwater hazards

5.6 Limitations and future research

While this pilot study demonstrated that a novel assessment of cue utilisation in floodwater and driving worked well and it was possible to differentiate those with higher and lower cue utilisation, it remains unclear how, or if, cue utilisation contributes to more accurate hazard assessment and improved decision-making outcomes. Further research should consider the design and development of improved performance measures.

Although this study used an established approach to the assessment of cue utilisation (via EXPERTise 2.0) used with personnel from a range of other industries, it was not possible to control the testing environment or conditions due to the remote, online administration of tasks . Participants were instructed to complete the tasks without distractions, but whether this was achieved is unknown. Assessment of the raw data and written post-study feedback (collected at the end of the testing session) indicated that some participants had difficulties with their internet connections and tasks that included photographs and videos did not load quickly or run as required. Through the process of data checking, a number of outliers were identified and removed, and participants with incomplete data and those who reported problems with internet connections that affected the running of EXPERTise 2.0 tasks were excluded from the analysis (n=10). Although this was a necessary step to ensure data integrity, loss of data, and a smaller high utilisation cluster size (n=32), also affected statistical power for analysis due to sample size constraints. Further research therefore, could include additional approaches to improve the control of testing conditions, consider avoiding the use of video tasks if administered online, and should seek to maximise sample sizes to ensure that the loss of (incomplete) data does not affect analysis.

In the present study, the design of the scenarios used in FDT and FPT tasks employed a personal scenario (e.g. travelling to a personal appointment) so that the same tasks could be used with SES and public for comparison in future research. However, this may have had an effect on the findings as the SES personnel might make different choices depending on whether they are in a work setting, or undertaking personal business. The effect of cue utilisation on other decision-making factors, such as socio-cognitive influences, and the effect on search patterns and cognitive load remains unclear, and could be undertaken in follow-up research. Further experimental studies could also be undertaken, using cue-based training interventions to see if cue utilisation can be manipulated and explore whether higher cue utilisation reduces cognitive load and improves performance. Certainly, these relationships should be established before measures of cue utilisation can be applied more broadly (Sturman et al., 2019).

5.7 Applications of the findings

In contexts of natural environmental hazards for the purposes of emergency service operations, identifying individuals with relatively higher cue utilisation may assist in improving safety outcomes by identifying individuals likely to respond quickly to training efforts. When emergency service responses are required for floodwater related emergencies, responders with relatively higher levels of cue utilisation would have the ability to correctly and rapidly identify floodwater hazards and associated risks in the environment, improving safety outcomes for both the self and others.

The decisions made in complex environments are often in response to a dynamic, unfolding situation requiring decisions to be made in real time in response to environmental events (Brehmer, 1992). The complex and time constrained nature of dynamic situations makes it difficult for decision-makers to engage normative decision strategies, as vast quantities of information need to be considered within a limited time frame (Perry, Wiggins, Childs, & Fogarty, 2012). On this point, cue utilisation could assist to develop decision strategies which reduce the processing effort required to make decisions in emergency operations settings as higher cue utilisation is associated with relatively lower perceived cognitive demands during sustained attention tasks, evident in previous research (Brouwers et al., 2016; Perry et al., 2012; Wiggins, 2011).

5.8 Conclusion

The aim of this pilot study was to develop a novel measure of cue utilisation in the context of floodwater and driving, and to see if this measure could differentiate those with higher and lower cue utilisation from a sample of experienced emergency service personnel. The resultant two clusters, based on performance in five cue utilisation tasks, indicated that a valid measure of high and low cue utilisation could be achieved. However, the expected link between cue utilisation and performance accuracy was not found. Future research is required to develop an improved assessment of performance, and a number of potential study improvements are suggested.

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Interlude 5: Synthesis of research findings

Chapter 5 described the process of development of a cue-based floodwater hazard assessment tool. The ‘Floodwater Hazard Assessment’ version of the EXPERTise 2.0 cue utilisation assessment included modification of a series of tasks that have been found to differentiate those whose behaviour suggests higher and lower cue utilisation.

The research, described in Chapter 5, was able to reliably differentiate a higher and lower cue utilisation group in the SES sample. However, further analysis failed to find the predicted positive association between higher cue utilisation and better hazard assessment performance. It is recommended that the mechanisms of cue utilisation in the flood hazard assessment context require better understanding which will then require further refinement of the tasks and more expert end user consultation and piloting.

Chapter 5 was the final research chapter of the thesis. In the following concluding Discussion chapter, the specific and overall findings from the four research studies will be reviewed, with a synthesis of the findings, and consideration of their practical and theoretical implications, and recommendations for future research.

Chapter Six: Discussion

Discussion

6.1 Thesis Summary

This body of research had four overarching aims, all related to the behaviour of driving through floodwater, they were:

1. To understand the significance of the problem within, and outside, Australia.
2. To explore the contexts surrounding motor vehicle-related flood fatalities in Australia.
3. To explore the risk perceptions and decision-making processes of SES personnel entering floodwater in vehicles.
4. To investigate whether differences in cue utilisation can be identified in SES personnel, and if so, whether higher cue utilisation is related to improved ability to assess floodwater risk.

Within the main body of this thesis there are four studies. Study 1 was a systematic review of driving through floodwater research, revealing the characteristics and significance of the problem internationally. Study 2 used the National Coronial Information System (NCIS) database to analyse the circumstances of vehicle-related flood fatalities between 2001 and 2017, in Australia. Study 3, involved the development and administration of a questionnaire survey that explored emergency service workers' experiences of driving through floodwater while at work. This study describes the contexts and conditions under which emergency services personnel entered floodwater in vehicles, and analyses the influences on decisions to drive through. Study 4 employed an experimental design, and used an online software shell (EXPERTise 2.0) to develop a novel set of tasks to investigate cue utilisation in the context of floodwater and driving. Like Study 3, Study 4 collected data from a sample of emergency services workers (State Emergency Service personnel). The findings from this thesis are summarised below.

6.1.2 Findings from Study 1: Literature Review (Chapter 2)

The first study of this thesis was an international literature review on driving into floodwater research. The main objectives of this review were to understand the impacts of driving into floodwater behaviour in floods internationally, to catalogue the risk factors associated with this behaviour, and to explore the recommended prevention strategies to eliminate the risks. Through a systematic review process, and applying a number of inclusion and exclusion criteria, 24 articles were selected for review.

The review presented an overview of the issue in an international context. First, the number of vehicle-related flood deaths from different parts of the world such as USA, Australia, Europe, Greece, Sweden and Portugal were presented and compared. Second, the risk factors associated with vehicle-related flood deaths were summarised and classified into seven broad categories and a brief synthesis of risk factors that influenced decision-making to drive into, or turnaround from, floodwater was presented. An important contribution of this paper was reviewing the applications of theories and models to explain this risky driving behaviour. The review identified theories and models that had been used to explain the decision-making process of drivers. It described how those theories were used and identified theories that could be applied in further research. Finally, following consideration of multiple study recommendations, an integrated model for in future community intervention initiatives was proposed. A graphical representation of a model for a systems approach was advocated, in which the three major intervention strategies (educational strategies, structural mechanisms and law & regulations) are activated together. The model emphasised that partnership, association, and collaboration across all levels of society are crucial to initiate, design and implement effective and successful prevention strategies. It concluded that continuous assessment, monitoring and feedback of all initiatives are required for strategies to be effective

6.1.3 Findings from Study 2: Vehicle-related flood fatalities (Chapter 3)

From the findings of Study 1 it was revealed that research in Australia had contributed greatly to our understanding of flood fatality events historically. However, research exploring motor vehicle-related fatalities in floods, specifically, had not been undertaken. To understand the behaviour of driving through floodwater in Australia there was a need to conduct rigorous research. The aim of Study 2 was to bridge this research gap. Investigating recent vehicle-related deaths in Australia and exploring the contexts under which the deaths occurred was the broad aim of this study. An important contribution of this study was exploring the roles of vehicle passengers in those fatal incidents and the circumstances of survivors. This research also provided a detailed record of the spatial and temporal patterns and explored the environmental and situation contexts which makes an important contribution to the research and our knowledge of how and why vehicle-related flood fatalities occur.

The major findings of this study are as follows:

Fatality trend:

A total of 96 deaths occurred in 74 incidents between the period 2001 and 2017. The mean death toll was 5.65 per year, and a moderate rising trend was identified between 2001 and 2011, with highest number of fatalities in 2011 due to a severe flooding event in QLD.

Gender and age patterns

Of the total fatalities, the numbers of males are higher than females; this overrepresentation of males in fatality numbers generally, is also present in the proportion of male driver fatalities. Male fatalities are 44% higher than females, as drivers, but in passenger fatalities the number of male deaths is comparatively lower than females. Male death rate is highest in the 50-59 age range; whereas female is highest in the 30-49 age range. Children and infants are identified as the most high-risk group as passengers.

Spatial and temporal patterns

Most incidents occurred along the east coast of QLD and NSW (84%); in the summer season (Jan/Feb 39%); on a Friday (24%), during the evening/night (50%) and most fatalities occurred whilst on a creek crossing, bridge, or causeway (87%).

Situational factors

Drowning is the leading cause of death; presence of alcohol and drug intoxication was found in the bodies of the deceased in 55% incidents where it was measured; no individual was recorded alive in 60% of fatal incidents; 84% incidents were single death incidents, and of these 64% happened when the driver was alone. Twelve passengers died in single fatality incidents where the drivers managed to escape; 43% incidents occurred just within 20 km of the driver's home address; lowest water depth was only 20 cm and fast flowing water was reported as the cause of vehicle submersion in 63% incidents.

Findings from selected incident analysis

The major reasons identified for accidents and deaths, found through investigation of coroner's inquests were: underestimating the risks, overconfidence in the vehicle and driver's own-ability, past successful crossing experience, familiarity with place and crossings, alcohol and drug intoxication, ignoring warnings and indicators, fatigue, inappropriate and wrongly placed flood depth markers, lack of warnings and inadequate risk indicators (e.g. no road closure signs), lack of knowledge assessing water hazards on the road, and incapacity to move or swim.

The findings also identified some difficulties in emergency response after fatal incidents such as unsuccessful rescue attempts to rescue the people from the vehicles they were trapped in, and delays in recovery processes of the deceased in some events. These findings highlighted the occupational risks and safety issues, and the resource constraints of emergency services. The study recommended that advance training was required to enable emergency workers to identify water hazards so they could pursue safe operations in rescue activities.

6.1.4 Findings from Study 3: Encountering floodwater at work (Chapter 4)

The facts and findings about flood fatalities due to driving through floodwater from Study 2 raised basic questions; Why do people drive through floodwater when there are considerable risks, and the behaviour is avoidable in most cases? How do they perceive the risks associated with driving through floodwater? and What decision-making processes are involved with taking risks? Study 3 was designed to search for some answers. Australian State Emergency Services (SES) personnel were chosen as a participant group for this study for two specific reasons: one, there was no research that had been conducted with this occupationally exposed high-risk group to address their workplace health and safety issues when working in these hazardous conditions, on tasks that are time-critical and complex. The other reason, is that despite discouraging driving through floodwater, emergency services cannot make provisions for their members to stop driving on flooded roads entirely, as they are responsible for performing emergency rescues and saving people in danger of drowning, and emergency services workers are likely to feel a sense of duty, and pressure, to enter floodwater to get to rescue locations. Exploring the viewpoints of members of emergency services about entering into floodwater in vehicles is also essential for emergency services organisations, as they are required to set workplace safety standards, goals and common safety practices among the work force.

The broad aims of the study were to investigate who drives through floodwater, and to explore the risk perception and underlying decision-making processes of emergency services about driving through floodwater in working conditions. Study 3 is the most important study of this thesis. The analysis was conducted in five phases. The major findings are listed below.

Phase 1. Exploring differences between those who have, and have not, driven through floodwater

Most participants had recent experience of driving through floodwaters, which revealed that it is a common behaviour for SES members. Male personnel and those with more than 10 years' service as a volunteer were more likely to have experience of driving into floodwater. Differences between those who had, and had not, driven through floodwater in the last couple of years related to age, driving experience, weekly driving hours, frequency of driving SES work vehicles, having been deployed to work in flood situations, and having current flood rescue qualifications.

Phase 2: Exploring the conditions in which SES members drove through floodwater

The research identified that SES members mostly drove through floodwater in normal working conditions with adequate levels of light (daytime) were present, and in good weather conditions (no rain). They mostly drove through water on normal stretches of road, with low velocity, without injuries or damage to lives and vehicles, and in what appear to be safer flood situations. However, a minority took considerable risks, driving through deeper floodwater, at night with no streetlights, with interrupted visibility due to steady or heavy rain, or ignoring road signage.

Phase 3: Relationship between key risk factors and perceived level of risk

A significant relationship was found between three key risk assessment factors and risk perception. Those three factors were location, water depth, and water velocity. The results indicated that if drivers had driven through floodwater in rural/remote locations, or where water depth was more than 15 cm, or in situations with high water velocity, they were more likely to have perceived the risk associated with driving through floodwater as high. Water velocity acted as the most salient factor in risk assessment for SES members, more so than water depth.

Phase 4: Factors influencing decision-making

Analysis of a list of socio-cognitive that influenced the decision to drive through floodwater identified six latent factors, based on factor loading scores. The factors were named: organisational training and safety; external locus of control; self-efficacy judgements; journey characteristics; social influences; and risk signals.

Phase 5: Predicting perceived level of risks from the factors that influence decision-making

The organisational training and safety factor were found to be the most important predictor of risk perception. Findings indicated that organisational training, knowledge and safety attitude were significantly negatively associated with perceived risk, i.e. if personnel felt their decision to drive through floodwater was more highly influenced by their training and knowledge and careful consideration of the situation, the were more likely to rate the decision to drive through floodwater as lower risk. On the other hand, the external locus of control factor was significantly positively associated with perceived level of risk. This indicated that if the decision to drive through floodwater previously was felt to be more influenced by a sense of external pressures, e.g. duty, and organisational pressure, they were more likely to associate their action to drive through floodwater as higher risk.

6.1.5 Findings from Study 4: Cue utilisation in floodwater hazard assessment (Chapter 5)

The aim of the Study 4 was to develop a novel online set of tasks, using software shell EXPERTise 2.0, to assess cue utilisation in the context of floodwater and driving. An established approach was used and adapted to capture indicators of behaviour linked to cue utilisation. The stimuli developed included images and videos of flooded roads and vehicles driving in floodwater, and way-finding scenarios built around driving in flood conditions. Those with higher cue utilisation were expected to be more accurate at assessing floodwater hazard in a performance task.

The major findings are listed below.

- The floodwater-related EXPERTise tasks performed well and were able to distinguish reliably a group with higher and a group with lower cue utilisation.
- In this study it was not possible to show a relationship between cue utilisation and the performance task, or a range of demographic variables. A number of possible explanations for this lack of finding were identified.

6.1.6 Comparing emergency services and the general public

The findings from the four studies of this thesis collectively contribute to further our understanding of the role of risk perception, the factors that influence decision-making, and the risks and consequences of driving through floodwater. A thematic analysis of the findings from this research is presented in (Appendix 2).

Although it was not an intended aim of this body of research to make direct comparisons between the emergency services (SES) and the general public, the findings of the studies in this thesis have enabled some tentative comparisons to be drawn between the two groups. However, in making comparisons between the general public data and SES data it should be noted that the results presented in this thesis refer primarily to situations surrounding public *fatalities* (Study 2), whereas SES data refer to general (non-fatal) reports of driving through floodwater (Study 3). This poses limitations on group comparisons, but still provides some useful insights that could have implications for future research.

Voluntary or involuntary entry into floodwater – does operational duty influence driving behaviour?

In considering the general public and SES personnel driving into floodwater it is interesting to consider differences in the degree of choice, or external influences, that may impact on decision-making. For the general public the act of driving through floodwater is generally regarded as a voluntary, and hence, avoidable behaviour, whereas for the SES it may be regarded as partially voluntary or in some cases involuntary due to the urgency, and sometimes life-or-death nature, of their work. Indeed, the main anticipated differences between the public and SES is in their general exposure to floodwater and the additional demands placed on them by operational duty.

From the findings relating to the purpose of the journey in fatal incidents (Study 2) it was identified that traveling 'enroute to a destination' featured most prominently (69% of total incidents, n=74). This was similar to previous research findings about why people voluntarily enter floodwater (Becker et al. 2010; Coates 1999; Coates and Haynes 2008; Franklin et al. 2014; League 2009; Ruin et al. 2007). Although not a large proportion of fatalities overall, research in Australia noted that individuals who encountered floodwater directly or indirectly in the context of their work were a potentially at-risk group. Of 97 fatalities recorded between 1950 and 2008, 4.1% were professional rescuers, firemen, or police, and 2.1% were volunteers attempting to rescue others (Coates and Haynes 2008). French et al.'s (1983) study reported rescuers being 3% of fatalities in the United States. A study of fatalities in the United States and Europe by Jonkman and Kelman (2005) attributed 1.2% of fatalities to rescuers, and a flash flood in Nimes, France, revealed higher percentages—two of nine people who drowned in the flood were rescuers (Duclos et al., 1991). In terms of injuries and near misses, Coates and Haynes' (2008) study found that 5.8% were professional rescuers and 3.5% were volunteer rescuers.

Data in this thesis relating to SES personnel indicated that in more than half of reported incidents of driving through floodwater, they were on operational duties, such as conducting emergency response. This clearly confirms the expectation that occupational exposure and the nature of emergency service work is a risk factor for this group.

Demographic and situational characteristics

In the vehicle-related flood fatality data, males aged 50-59 years appeared to be the highest risk group, whereas in the SES data younger males (aged 18-34 years) were more likely to drive through floodwater. Findings from past research regarding age supports that both this gender and these age groups i.e. males aged 50-59 and 18-35 years are higher risk groups for driving through floodwater, and certainly the clearest demographic targets for risk intervention strategies.

Environment contexts plays an important role in risk assessment for both public and SES groups. In the Hamilton et al., 2019 study with the public and their behaviour when encountering floodwater in vehicles, they included consideration of whether the water was flowing, depth judgement, and whether it was a known location. The majority of drivers indicated that fast flowing water would likely prevent them making the decision to drive though, the depth of water was also perceived to be influential with some drivers reporting that they felt comfortable driving through water up to a certain depth and the drivers also described that the risk was perceived to be lower if the length of the crossing (i.e. distance across the flooded section of road) was not far and the other side was visible. It was also often reported that drivers felt more confidence in their ability to perceive the depth and conditions and in their ability to make it through the water when it was a known location. The SES study in this thesis identified that three elements: location type, water depth, and water velocity worked together to shape the risk perception of SES drivers in driving through floodwater, with water flow being the strongest of the three.

The individual case study analysis detailed in Study 2 revealed that ignoring warnings and signage, being misguided by inappropriate depth markers, and an absence of risk signals were linked to a number of fatal incidents. These findings are supported by past research such as a study by Coles et al. (2009) that examined the effectiveness of signage and barricades in deterring people from driving into floodwater in Tucson, Arizona. These researchers found that signs and barricades often do not deter motorists from entering floodwater. Respondents who suggested they had not driven into the floodwater reported slightly higher levels of trust in signs and barricades than those who had driven into the waters.

Findings from the SES study reported here found that, in a third of reported cases of driving through floodwater, risk indicators and road signage were ignored by drivers when they entered floodwater during an emergency response. In half of reported cases of driving through floodwater there were no risk indicators or signage in place, including even simple water depth indicators. The findings suggest a need to reinforce operational doctrine to ensure that SES personnel are aware of potential additional risks if they drive through floodwater when these risk signals are absent.

In a study of lived experience, with the general public who had driven through floodwater (Hamilton et al., 2019) social influence, such as passenger influence or influence by other drivers played an important role in public risk perception, sometimes in form of pressure, encouragement or as a sense of security. In fatal incidents it was identified that mostly the passengers were friends, family members or children when the drivers failed to cross successfully, in some cases drivers survived but were responsible for passenger’s death. For SES, the study also noted that passengers influenced the decision to drive through floodwater. In this case passengers were mostly SES colleagues (64%) or civilians (23%). This aspect needs further exploration in the SES study to understand the role of colleagues and other drivers on decisions to drive through floodwater. Professionally trained passengers in these situations could potentially play a useful role in preventing risky driving behaviour if targeted training interventions around passenger safety advocacy were developed and directed towards the broader SES workforce.

Influences on decision making

Detailed analysis of vehicle-related flood fatalities identified the contexts surrounding fatal incidents, however with few surviving vehicle occupants and limited data it is hard to explore what influenced driver decision-making. Identified reasons that contributed to drivers' decision-making, found in coronial reports, had some common attributes with those identified in recent research about understanding individuals' decisions to drive through floodwater (Hamilton et al., 2019) such as past experiences of successful crossings, familiarity with locations, lack of alternative routes to change journey plans, confidence about vehicles and personal ability. These researchers found that many drivers reported positive self-efficacy judgements, such as feeling confident, skilled, and sufficiently knowledgeable about their ability to drive through the floodwater due to influences such as past experience (without adverse consequences), their perceived ability to assess and mitigate risk. Many also perceived their vehicles to be capable of driving through the floodwater and all these elements led to what they believed to be an informed decision regarding whether it was safe to drive through the flooded waterway. A number of drivers reported that taking alternate routes was not appealing due to a number of factors such as such as time constraints or having already tried at least one alternative option.

For SES personnel there was some overlap with aspects that influenced their decision-making processes and their generally high self-efficacy. They reported that careful consideration of the situation and their professional skills and training influenced their perception of risks to a greater extent than other factors. In addition, SES personnel reported that aspects linked to an external locus of control featured in their decision-making, such as a desire to complete their duty and organisational pressures. These findings further reinforce the role of occupational context in influencing their decisions to drive through floodwater

6.2 Implication of research findings

6.2.1 Practical implications of findings

6.2.1.1 Practical implications of findings for the public

The findings of thesis have implications for designing educational initiatives, improving structural interventions for regular road users to increase road safety and re-examining the implications of existing laws and regulations to discourage people from intentionally driving through floodwater. Some of these implications are discussed below:

Educational initiatives targeting vulnerable groups

Previous research has found that targeting and working with specific groups on particular topics can provide support to such populations and help change attitudes and behaviours in a positive way (Soole et al. 2007; Hill, 1998; Howat et al., 2001; Finnis 2004). Analysis of NCIS fatality records identified several vulnerable groups that were overrepresented in vehicle-related deaths. Middle-aged, and older males were identified as a high-risk group, as drivers, whereas young women and children are vulnerable groups, as passengers (Study 2). Prevention strategies should be targeted at males, those who drive through flooded rivers (particularly truck drivers and motorcycle riders) and those residing in the northern areas of Australia prone to tropical rainfall (Peden, et al., 2017).

Structural interventions

Changing road structures

The findings from Study 1 and 2 of this thesis showed that the majority of vehicle-related fatalities (87%) occurred on roads near to waterways, on bridges and on river crossings, indicating that the level of safety at these types of locations where drivers can come into contact with water/floodwater is inadequate. Similar findings were reported by Diakakis and Deligiannakis, (2013). In addition, Study 2 found that reported fatalities that occurred at night all had absence of adequate street lighting and, in some incidents, due to the visual obstruction of branches or trees, there was poor visibility or an unclear view to see depth indicators. Similar to the research findings of Gissing et al., (2019) on the influence of road characteristics on flood fatalities, current findings suggested that a large number of road sites may not be constructed in accordance with required design and hydraulic standards. Typically, road safety agencies measure risk through the utilisation of historical data; for example, crash, hospital and insurance data (Austroads, 2006). Currently in Australia this information is not routinely collected and there is no standard system to categorise flood rescue severity after an incident (Gissing et al., 2019). To design and implement a simple system that will record if a vehicle has been swept from a roadway, or not, can help road operators to be able to assess and prioritize risks posed in order to implement improvement measures (Gissing et al.,2019).

Effective Road signage

Findings related to the effectiveness of risk indicators present on roads clearly identified inappropriate depth gauges or badly positioned water level markers. False reading of a water depth indicator was identified as the cause of death in one incident (Study 2). In another incident, the submergence of one-metre warning signs and the absence of two-metre flood warning signs confused a driver who then decided to enter floodwater (Study 2). Further work is certainly required to explore how to make road signage and risk indicators more effective. This finding supports conclusions made by Gissing et al., (2016) and (Affum, et al., 2015) that current signage requires review so that it can be readily seen and easily interpreted by road users. Peden et al., (2017) study also shows signage appears to be ineffective, with 64% of non-aquatic transport incidents in remote and very remote areas known to have occurred on roads that were open at the time of the drowning incident. Signage and detour routes are reactive strategies and hard to enact if authorities do not know if there is water on the road in such isolated locations (Franklin, et al., 2014).

The thesis recommended introduction of more dynamic signage. Installation of sensor systems linked to a flashing light indicating “Road closed when flashing” could be more effective than passive signage. Higgins et al., (2013) in the context of flood signage, concluded that drivers placed more trust in dynamic signage and they emphasised the need to provide visual cues to inform driver decision making. Similar research in the context of railway crossings has shown higher rates of compliance with dynamic signage when compared to passive signage (Tey, et al., 2011). Existing signage is also one-dimensional. Consideration should be given to signage that communicates risk not only about flood depth, but also the dangers that exist below the surface, such as water velocity (Affum, et al., 2015).

Location-specific flood operations procedures

Findings related to the spatial and temporal patterns of vehicle-related flood fatalities indicated that the majority of fatalities have occurred along the east coast of QLD and NSW. The coastal strip from mid-NSW (Wollongong) to mid-QLD (Marlborough) has been identified previously as the most hazardous zone in Australia with regard to flood fatalities generally (Coates, 1999). Those who drowned in the Northern Territory and Queensland were at a significantly increased risk for river flood-related drowning. This is related to their tropical climate and wet season (Peden, et al., 2016). Recommendations from the current research suggest that prevention strategies should consider those at an increased risk related to local rainfall patterns and climate differences (Peden et al, 2017).

Addressing risk perception

Underestimation of risks is one of the major reasons for flood fatalities (Study 2) and risk perception was found to influence risk assessment and decision-making (Study 3). While people are generally aware of flood risk, they continue to be unaware of, or underestimate, the actual dangers posed by floodwater. They are optimistic that if they do enter, they will not suffer any negative effects (Weinstein, 1980) and this can lead people to making a decision to voluntarily enter floodwater (Becker et al., 2015). The research conducted by Hamilton et al., (2019) into the key beliefs underpinning people's decisions to drive through floodwaters, found that people regularly ignore road closed and flood warning signs if they had previous experience of driving on roads that regularly flooded (Hamilton et al., 2019; Franklin et al., 2014). Further qualitative studies that focus on people who reside in flood-prone areas and who have driven through floodwaters may assist in the development of effective prevention strategies for this group (Peden et al., 2017). Future public education efforts need to continue to emphasise the actual dangers and consequences of entering floodwater (Franklin et al., 2014). A better understanding of the negative consequences of entering flooded areas may go some way toward helping encourage appropriate behaviour (Becker et al., 2015).

Law and regulations

Findings of Study 2 indicate that in many cases drivers were not convicted or did not receive punishments where they were responsible for passengers' deaths, such as in situations where a parent was responsible for the death of children. Legal punishment was only handed down in one case that was studied; for a driver who was convicted of careless driving, and who received unpaid community service work and licence disqualifications (6-12 months). None of the 11 selected incidents reported legal action taken for disobeying road closure signage and barriers, or taking drugs or drinking alcohol during/before driving. The incident analysis findings from Study 2 recommended the enhancement of legal obligations (such as increasing fines and demerit points or licence disqualifications) to stop drivers disobeying road instructions and drink driving. Recommendations made from the current research were that regulations should be designed for drivers that make them put their responsibility to their passengers ahead of the journey, and that efforts should be made to assist passengers in understanding their risks and advocating for their own safety.

6.2.1.2 Practical implications of findings for emergency services

The main applications of the findings of the current research for emergency services personnel are in addressing workplace health and safety issues, to reduce workplace fatalities, injuries, and psychological trauma that could arise from working in hazardous situations around floodwater. Some implications have been presented below.

Educational awareness, training and knowledge:

Study 3 in this thesis represents a first attempt at research which explores the circumstances of risky driving behaviour of emergency services personnel in floodwater, and captures their real-life experiences of encountering floodwater in vehicles. The results of this research have several implications for the development of educational intervention strategies to improve the safety of this high-risk occupational group.

First, findings of the research could be disseminated to increase the knowledge of emergency services personnel to the types of risk they may encounter when driving through floodwater during their operational activities. The findings regarding the differences between those who have, and have not, driven through floodwater in last two years provides evidence that will enable the tailoring of educational awareness initiatives. The content of the training could be designed to incorporate scenarios that link to characteristics associated with an increased likelihood of driving into floodwater, such as length of service, gender, frequency of deployment, and frequency of driving SES work vehicles.

The findings from Study 2 indicated that the mental health issues of emergency service also need to be addressed. Emergency responders have a higher risk than other workers of experiencing trauma (rescuing severely injured victims or recovering bodies of those who have drowned in vehicles) in the course of their duties. Fatal incidents, serious injury of victims, and unsuccessful rescue attempts to save survivors or other rescue workers, can have profound effects on emergency service personnel, seriously impairing their response at the emergency scene and impacting their mental health. Personnel need to be trained and supported in how to deal with such situation; supporting their mental health (Hauke et al., 2011).

The findings from Study 4 about cue utilisation and hazard identification might have implications that relate to the training of emergency responders who work in flood situations and perform rescue operations. The results from Study 4 demonstrated that cue utilisation typologies within a specific domain were not a function of years of experience in that domain. Consequently, regardless of SES members' years of experience, proactive approaches may be beneficial for increasing cue utilisation amongst experienced personnel. For instance, qualified members assessed as having relatively lower cue utilisation could be targeted with cue-based training interventions, whereby they are given the opportunity to acquire cues that can be generalised to the broader operational environment (Ivancic and Hesketh, 2000; Klayman, 1988; Scherer et al., 2008; Wiggins and O'Hare, 2003; Wiggins, 2015). However, this recommendation needs to be taken with caution as the assumption of positive association between cue utilisation and decision performance outcomes was not proven in Study 4. More research is essential to explore this novel approach of cue-based decision-making to reduce the risks of driving through floodwater.

Risk assessment strategy development

Risk assessment at a disaster scene must remain dynamic, especially in situations that are uncertain or rapidly changing, and could result in 'domino effects'; for instance, where the situation may deteriorate and lead to further damage and danger (Hauke et al., 2011). Results from Study 3, relating to the contribution of key risk factors in risk assessment (location, water depth and water velocity), have applications for the design a brief risk assessment strategy for emergency workers when they deployed in a flood emergency situation. Knowing how certain factors influence risk perception (and relate to the consequences of entering floodwater) may help with the development of risk assessment checklists or decision support tools that could be used to assess possible risks before encountering flooded roads.

Selection and recruitment of emergency services personnel

The findings from Study 4 about cue utilisation, although requiring further refining and evidence, have potential implications for the selection and recruitment of emergency services personnel. Assessments of cue utilisation could be used to select workers for certain roles in high-risk rescue operations in natural hazard environments. Personnel who are able to develop cue-based associations, and utilise these associations in their operational environments, should be able to respond quickly and adaptively to meet the needs of critical situations (Klein, 2008). Further, by consuming fewer cognitive resources during the completion of their primary tasks, emergency responders with higher cue utilisation should retain greater residual cognitive resources, allowing them to better manage the demands of secondary tasks (Wickens, 2002). Consequently, a future capacity to identify qualified SES workers with higher cue utilisation (or the capacity to develop higher cue utilisation) may assist in the selection of job applicants who are better able to maintain performance during demanding situations.

Optimising cue utilisation to reduce the cognitive load of decision-making

The tool developed in Study 4 to assess cue utilisation might help contribute, longer term, to reduce the cognitive load required for decision-making in emergency situations. Previous cue utilisation literature indicated that the activation and retrieval of cues from long-term memory is an automatic and nonconscious process (Kahneman and Klein, Gary, 2009; Klein, 1993, 1998). Consequently, cue utilisation has the advantage of imposing relatively fewer demands on working memory resources (Chung and Byrne, 2008; Evans and Fendley, 2017). Operators with higher cue utilisation should, therefore, consume cognitive resources at a slower rate during operational tasks, compared to operators with lower cue utilisation (Brouwers et al., 2016, 2017; Small et al., 2014). Given a period of time, a lower consumption of cognitive resources will result in greater residual cognitive resources, better enabling the management of changes in the system state (Hockey, 1997; Wickens, 2008). Consequently, based on resource depletion theory (Helton and Warm, 2008; Parasuraman et al., 2009), operators with higher cue utilisation should be able to sustain attention for longer periods before reaching overload, resulting in greater sustained attention, compared to operators with lower cue utilisation. After further research and development, a measure of cue utilisation could be used to track the effectiveness of training, or other interventions, and assist in supporting more efficient decision- making and performance over sustained periods, such as those encountered in emergency response.

Effective public messaging and campaigns

Working with community to help build local resilience to flood is one of the core roles of SES. SES agencies have developed a series of flood risk communication campaigns (for example “If it’s flooded forget it”, “15 to float”) for creating awareness within community to avoid driving into floodwater. Recent motor vehicle-related flood fatality data, from the findings of Study 2, indicate that people in Australia still continue to drive through floodwater, and that this behaviour can prove fatal. The findings from this thesis about the influences on decision-making and its relationship with risk perception, and the utilisation of cues in floodwater hazard assessment are likely to be translatable to the public, and may help the SES create more effective flood risk communication materials. Providing emphasis on recognising features from the environment and scaffolding cue-based learning could be an effective way to engage the public in this risk, and would probably be more effective than the current approaches that simply tell the public to ‘forget it’ (i.e. that close down any discourse about how to interpret the risks). These approaches could be translated to trigger visual simulation using imagery in posters and videos, and using social or online media to support messaging.

6.2.2 Theoretical Implications

The findings presented in this thesis have some theoretical implications of relevance to the development of intervention strategies to reduce the incidence of driving through floodwater. In terms of theoretical importance, Study 3 adopted a sound theoretical approach combining two models; the Recognition Primed Decision (RPD) model, which was used to analyse the pathway to explain the causal factors that influence people's decision-making processes, and the Extended Parallel Process Model (EPPM), which is used to explain protective actions in the context of potentially stressful situation such as conducting emergency responses. Although the initial work of developing the RPD model began by observing fire ground commanders (FGCs) and studying their decisions in handling non-routine incidents during emergency events (Klein 1989; Klein, et al., 1986), it has never been used to investigate the decision-making processes of emergency services personnel when entering floodwater. Klein and Klinger (1991) reported that FGCs saw themselves as acting and reacting on the basis of prior experience; they were generating, monitoring, and modifying plans to meet the needs of the situations. In line with Klein (1989) who suggested that decision makers in emergency situations focused more on situation assessment than on option selection, i.e. evaluating options through mental simulation and selecting the first satisfactory one, the current study found that SES personnel reported that they rely on careful consideration of the situation. Their situation analyses start with the assessment of risks factors of flood environments such as floodwater characteristics and spatial characteristics. Organisational training and professional skills, past experiences, and other influences then play an important role in forming their risk perception.

At this stage of decision-making, i.e. following formulation of risk perception, the EPPM model helps to understand the behavioural actions underlying decisions by the driver. The EPPM explains the possible responses people may have to a fear appeal messages and places these responses into three broad categories: non-responses, danger control responses, and fear control responses. The theory makes predictions about which of these three response types individuals will demonstrate depending upon the interaction between their perceptions of the threat and their perceptions of efficacy to avert the threat. The EPPM provides a clear rationale for behaviors that occur as a result of fear appeals. Specifically, Witte et al. (1996) stated, "the EPPM adopts the original Protection Motivation Theory's explanation of danger control processes that lead to message acceptance (one side of the parallel process model), and defines and expands the fear control processes which lead to message rejection (the other side of the parallel process model)" (p.337). Aligned with the explanation of behaviour from the EPPM model, the current study model proposed that fear appeal message acceptance or rejection could arise from mental simulation (safe or risky) of behavioural action in two ways; either defensive motivation or protection motivation.

Study 3 in this thesis marked just the beginning of applying concepts derived from the RPD model and proposed a model in order to study the behaviour of driving through floodwater. More research is required to explore how intervention programs for emergency services could be designed emphasising the role of situation assessment, which will allow holistic non-comparative option adoption strategies and will assist in finding an action that is “workable," "timely," and "cost effective". Similarly, the current study provided insights through giving importance to the use of EPPM constructs in the context of driving through floodwater, offering predictions about attitudinal, intentional, and behavioural responses to fear appeal messages based on appraisals of the two central constructs: threat and efficacy.

6.3 Strengths and limitations of this research

Research included in this thesis has strengthened and advanced the knowledge base in this applied research area and has a number of strengths. These include: exploring the consequences of the driving through floodwater from both public and occupational perspectives; using a high quality national database to thoroughly examine recent vehicle-related flood fatalities; addressing an important occupational health and safety issue for a sector that relies on a professional workforce to assess risks and faces challenges, whilst protecting public safety; collecting data from a good-sized sample of participants to take a robust quantitative analytical approach to investigate the factors that influence decision-making; and developing and exploring new areas that may offer solutions to reduce risks in future, through enhanced hazard identification. These strengths provide confidence in the data integrity, in the conclusions in the research, and in the significance of the issue, in terms of occupational health and safety/duty of care and public safety. As such, this research has potential for translation into a range of useful interventions, improved practices, and more effective policy.

However, as with all areas of research there are a number of limitations that should be acknowledged. First, as an area of research, the risks of driving through floodwater and analysis of this behaviour is still in its infancy. There is limited research in this field, and being a complex interdisciplinary challenge, the research literature is generated from many different disciplinary perspectives, e.g. hydrological and structural engineering, meteorology and physical geography, as well as social geography and social science. The advantage of this situation is that there is a great deal to discover, the disadvantage is that the literature is scant in places. The study uses the concepts from RPD and EPPM model to explain the behaviour for first time, however, the implications of those theoretical models remain unidentified.

More specifically, a number of additional limitations within each research study are noted. In Study 1, the number of vehicle-related flood deaths identified in each study undoubtedly showed the significance of the problem internationally, however, it was not possible to calculate death rates to allow a comparative analysis of the issue. More cross-sectional comparative research is required to fully scope the significance of the issue and to identify the contextual difference of vehicle-related flood fatalities, and associated risks in different countries. This would enable greater understanding of the causes of fatalities and highlight additional ways to address the problem.

In study 2, as this study used data for cases where a coroner must investigate, there is a period of time where there is limited information about a case. Until the case is officially closed by the coroner (i.e. no longer under investigation and a cause of death has been determined) there is minimal data available about the circumstances surrounding the drowning death (Peden et al.,2017). Hence, a focus on more recent fatalities also led to some issues with incomplete data. The period analysed in Study 2 (2000-2017) was chosen deliberately to be recent so that findings would be a relevant and useful as possible to those with interests in this area, e.g. taking into account advances in vehicle design, road safety, and other related improvements that would not have been present if older data had been included, as in previous analyses (Haynes et al, 2017). Also, fatalities resulting from driving into floodwater are only one measure of the risk associated with this behaviour. It would be helpful for more information to be available to identify the antecedents of these severe outcomes. As suggested by Gissing et al., 2019, future efforts could be taken to build a simple data recording system to record recent accidents, and capture non-fatal events in which, for example, vehicles are swept from roadways, or vehicles are ‘written off’ following entry into floodwater.

In Study 3, the use of an online survey leads to potential concerns of self-selection, and bias in the sample, leading to limitation in the ability to generalise the findings. Similarly, the detailed study of a recent event of driving into floodwater presents the possibility of recall bias. Events may have been recalled due to their severity and salience, rather than their recency. The lived experience approach, used in Study 3, is well suited to understanding behaviour, but it relies on participants accurately recalling their experience and the thought processes at the time of their experience, Individual differences in recall are unknown to the researcher (Hamilton et al., 2019), although more salient events are, perhaps, more likely to have been recalled in more detail. Although these limitations are acknowledged, collecting a set of exemplar situations in this level of detail was a valuable aspect of the research project, and one that may be valuable for the development of training scenarios in future. Another limitation in the research is the limited consideration of organisational safety management practices and safety culture. Further research in this area is warranted to better understand the role of the organisation in promoting safety messages and understanding how the safety culture relates to risk taking behaviour.

Finally, the fourth study, used an established approach to assessing cue utilisation, but this was the first pilot study in this area and needs greater refinement. The lack of association between cue utilisation and performance was unexpected and suggests that further research is needed both to explore and capture ‘performance’ better, and to explore the possibility that cue utilisation may not generalise to the novel and information-rich, complex situations encountered in the field.

6.4 Recommendations for future research

Although SES agencies typically promote policies of not entering floodwater, currently the situation is unclear as to whether SES personnel are obliged to follow these policies, or whether they are enforced. SES personnel generally share common safety values and follow safety principles voluntarily to reflect the positive organisational attitudes towards safety. The findings from this research indicate that further research is required to identify, revise or enhance SES operational safety policies which might help to reduce perceived organisational pressures and job role demands. Further research is also essential to provide more advice to improve organisational safety for other emergency service workers and essential workers who also have to work in flood situations, e.g. police, paramedics, roadside assistance personnel, and utilities companies field workers.

The current study was able to differentiate a range of common aspects of risk perception and decision-making which will be instrumental in planning future research and interventions aimed at reducing the number of fatal and non-fatal incidences as a result of engaging in this risky driving behaviour for both public and SES group. It is obvious that SES members’ decision-making processes in encountering floodwater with vehicles are contextually different to the public. SES members have to take decisions when situations are risky, time pressure is high and there are expectations on them to perform their roles, however, very little is known from this study about how their thought processes and actions are different to those of the public. The concepts of the RPD model help us to understand that, when operational, SES members’ decisions to enter floodwater are generated based on mental simulations from situational analyses where variables like skills, training or experience might play role. Further research can explore how this mental simulation works and how it could improve decision-making processes. In spite of having strong evidence from many previous research and theoretical models that cue utilisation could improve decision performance the study here could not explore why the cue utilisation study outcomes proved tricky. Further study is required in future to understand how cue utilisation operates in assessing floodwater hazard assessment. Therefore, the study presented in this thesis may act as a useful initial project that can lead to create an upgraded version of the EXPERTise tool for driving through floodwater.

6.5 Conclusion

The current body of research was designed to investigate a number of aspects of ‘driving through floodwater’. Emergency services personnel were the focus of study, as an occupational group at high risk of engaging in this behaviour, and for whom their employing agency has a duty of care under workplace health and safety legislation.

The research encompassed four studies to achieve four overarching aims. Risks associated with recent fatal incidents of driving into floodwater were identified, and used to inform the design of a survey conducted with emergency services personnel. This survey investigated experiences of driving into floodwater in work contexts and identified factors that influenced decision-making. The final research study took a first step towards developing an assessment tool that could be used to gauge differences in the ability of emergency services personnel to use cues in the environment to assess floodwater hazards.

The findings of the research establish a need to work internationally to explore ways to reduce vehicle-related flood deaths and separate out the complexities surrounding these fatalities to find better ways to intervene. Within Australia, these research findings offer a number of approaches to improve flood risk communication, generally, and to target training and other interventions for emergency services personnel that will improve approaches to risk assessment and decision-making in risk critical situations, leading to better occupational health and safety outcomes for emergency services agencies.

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List of Appendix

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6	Manuscript submission letter for study 2
7	Manuscript submission letter for study 3
8	Paper abstract titled "Calculated risk? Understanding NSW Emergency Service Workers' Decisions to Drive into Floodwater". Presented in Floodplain Management Australia Conference 2018, QLD, Australia. May.
9	Poster titled "Flood risk communication to reduce vehicle -related flood fatalities". Presented in AFAC BNHCRC Annual Conference. Perth, September. 2018.
10	Poster titled "Vehicle related flood deaths in Australia, 2001-2017". Presented in AFAC BNHCRC Annual Conference. Perth, September. 2018.
11	Poster titled "Vehicle related flood deaths in Australia, 2001-2017". Presented in Floodplain Management Australia Conference. Canberra, May 15, 2019.
12	Poster titled "Encountering floodwater at work: Factors contributing to decisions to drive into floodwater". Presented in Floodplain Management Australia Conference. Canberra, May 15, 2019.
13	Presentation titled "Australia Speaks –National survey exploring experiences and attitudes towards entering floodwater". Presented in Floodplain Management Australia Conference. Canberra, May 15, 2019.

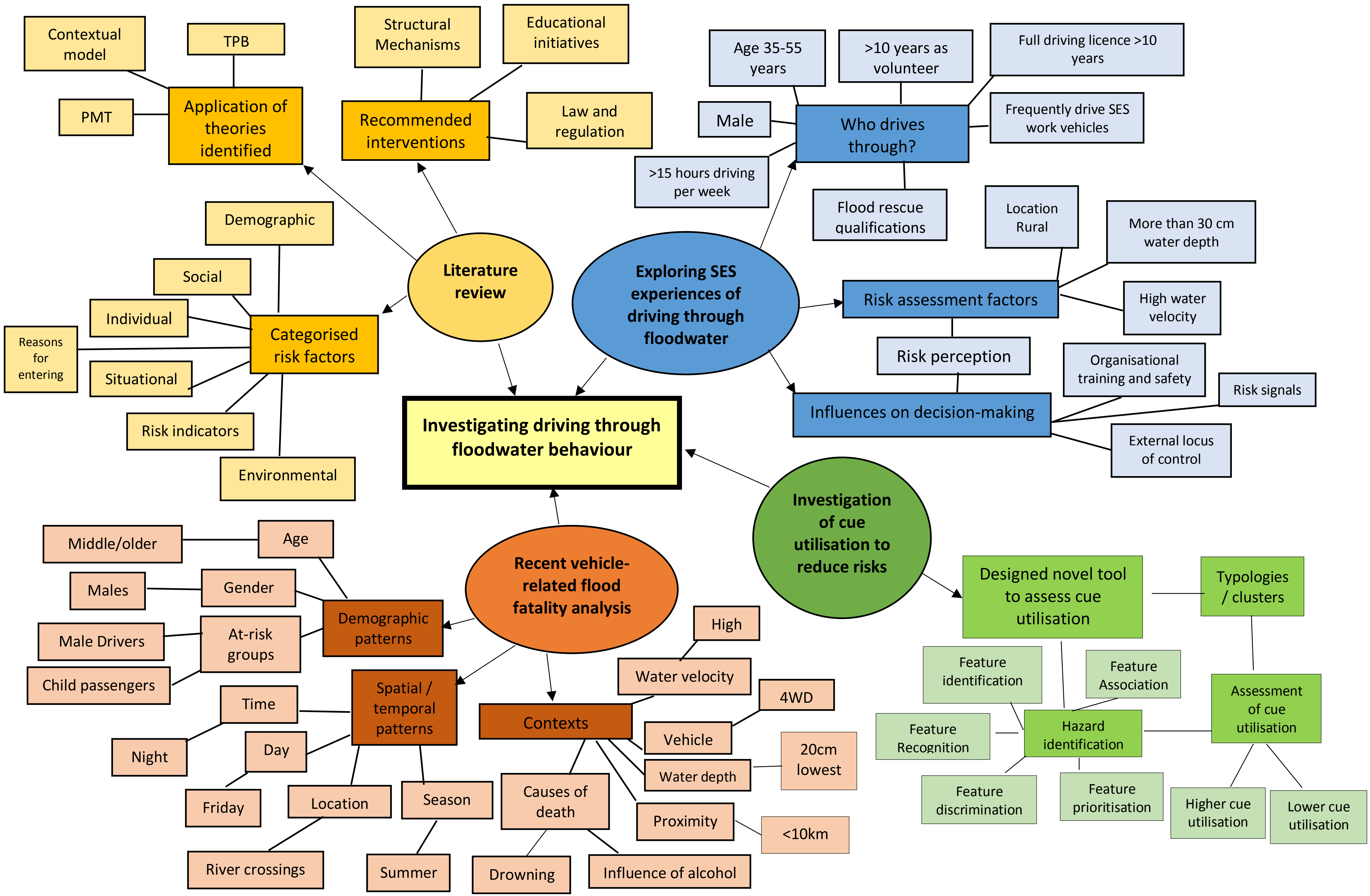
Appendix 1: Summary of selected studies

References	Topic/Title	Participants	Sources	Type of analysis	Outcomes
Coates (1999)	Flood fatalities in Australia, 1788-1996	N/A	Newspapers, historical accounts, and government and scientific reports	1125 references used (944 of those being newspaper articles) Qualitative analyses Descriptive statistics	Most fatalities (38.5 per cent) have occurred through attempts to cross creeks, bridges or roads in times of flooding. Of the total known deaths, work-related fatalities have accounted for 12.4 per cent, and recreational pursuits for 5.7 per cent.
Yale et. al. (2003)	Motor Vehicle—Related Drowning Deaths Associated with Inland Flooding After Hurricane Floyd: A Field Investigation	Proxy informants who knew the deceased persons well	A case-control study, a review of medical examiner records and a survey of proxy informants	Descriptive statistics	Motor vehicle occupants in weather-related crashes are more likely to drown if their vehicles are submerged or swept away. Vehicle submersion may often be a consequence of deliberately driving into flooded roadways.
Jonkman & Kelman (2005)	An analysis of the causes and circumstances of flood disaster deaths	N/A	Thirteen flood cases, resulting in 247 flood disaster fatalities	Classification method for flood disaster deaths	Approximately two-thirds of the deaths occurred through drowning. Males are highly vulnerable to dying in floods and unnecessary risk-taking behaviour contributes significantly to flood disaster deaths.
Drobot et al. (2007)	Risk factors for driving into flooded roads	Approximately 6000 surveys mailed flood-plain residents.	Questionnaire survey	The logistic regression models the stepwise regression analyses the Hosmer–Lemes how goodness-of-fit statistic	People who do not take warnings seriously are more likely to drive through flooded roads, as are people aged 18–35.
Ruin et al. (2007)	How to get there? Assessing motorists' flash flood risk perception on daily itineraries	200 people	Cognitive mapping	Spatial products analyses	Risk perception largely depends on the recency, frequency and intensity of personal experience with past events of similar nature.
Ashley & Ashley (2008)	Flood fatalities in the United States	N/A	Monthly reports from volumes 1–47 of the National Climatic Data Center's (NCDC) Storm Data	The database of 1959–2005 flood-related fatalities	People between the ages of 10 and 29 and older than 60 years of age are found to be more vulnerable to floods. Findings reveal that human behavior contributes to flood fatality occurrences.
Stjernbrandt et al. (2008)	Land Motor Vehicle-Related Drownings in Sweden		Autopsy reports (including toxicological analyses), police records, and relevant hospital records	Toxicological analyses performed at the Department of Forensic Chemistry and in-depth analyses for all fatal traffic events by the Swedish Road Administration(SRA)	The vehicles were most often (72%) found upside down, and most drownings occurred in shallow water (65% depth <2 m). One third (32%) of the drivers tested positive for alcohol. The majority (69%) of the fatalities could possibly have been prevented if effective guardrails had been in place.

Haynes et. al. (2009)	'Shelter-in-place' vs. evacuation in flash floods	Flood and emergency managers	Literature review and interviews with flood and emergency managers.	Percentage distribution	The majority of flash flood fatalities (75.7 per cent) have occurred outside when people have entered floodwaters in a vehicle or on foot for a range of reasons, including to continue their intended travel, engage in recreational pursuits, continue their work, and evacuate or carry out a rescue.
Maples & Tiefenbacher (2009)	Landscape, development, technology and drivers: The geography of drownings associated with automobiles in Texas floods, 1950–2004	N/A	The National Climatic Data Center Storm Events database (NCDC, 2005) and the Spatial Hazard Events and Losses Database for the United States database (SHELDUS, 2005) from 1950 through the end of 2004 for Texas.	○ Decadal examination ○ Cross tabulation ○ Correlation analyses	Roadway familiarity might have had an emboldening influence on decisions to attempt to surmount water rushing across a road, and time of day was clearly a dominant characteristic of cases of drowning on flooded roadways, while roadway characteristics, and sex and age of the driver were not likely to have been key contributing factors.
Fitzgerald et al., (2010)	Flood fatalities in contemporary Australia (1997–2008)	N/A	The Disaster Database maintained by Emergency Management Australia	A record was constructed, including the number and location of fatalities, age and gender of the victims, circumstances of fatalities and date of incident	48.5% fatalities related to motor vehicle use. 26.5% fatalities occurred because of inappropriate or high-risk behaviour during floods.
Sharif et al. (2010)	Motor Vehicle-Related Flood Fatalities in Texas, 1959–2008	N/A	National Climatic Data Center Storm Data publications	Total of 600 publications were reviewed.	Most fatalities are motor vehicle related (77%). Males are much more likely to be the victims of motor vehicle–related flood accidents than are females. Most motor vehicle–related fatalities happened at night (56%) and resulted from flash floods
Kellar & Schmidlin (2012)	Vehicle-related flood deaths in the United States, 1995-2005	N/A	The National Climatic Data Center and National Oceanic and Atmospheric Administration's *Storm Data* event database	The demographics of the fatalities, the meteorological situations of the floods, and the spatial and temporal patterns of the deaths were shown.	555 vehicle-related flood deaths that occurred in 355 flooding events during 1995–2005.Males accounted for 60% of the deaths. The difference in death rates between the sexes was small at ages 19 and younger but males died at twice the rate of females for ages 40 and older.
Diakakis & Deligiannakis (2013)	Vehicle-related flood fatalities in Greece	N/A	The Flood database developed for the entire Greek territory for the period 1880–2010	An inventory of 60 fatalities associated with the use of vehicles, induced during 37 flood events between 1970 and 2010, was studied	Found an increase in vehicle-related cases over the period of study, with the majority of the incidents occurring after 1990. Most events occurred during nighttime and in rural areas of the country. Drowning was found to be the primary cause of death. drivers, pursued an active, rather than a passive, stance in the majority of incidents, attributed, in certain occasions, to an underestimation of risk.

Špitalar et al.(2014)	Analyses of flash flood parameters and human impacts in the US from 2006 to 2012	N/A	Storm data reports collected by the National Weather Service, USA	21,549 flash flood events were analyzed from 2006 to 2012	The factors that emerged as the most influential on human impacts are short flood durations, small catchment sizes in rural areas, vehicles and nocturnal events with low visibility.
Pearson & Hamilton. (2014)	Investigating driver willingness to drive through flooded waterways	174 Australian holding a current unrestricted driver license	Cross-sectional study through online survey	Hierarchical multiple regression analysis	The augmented TPB as attitude, subjective norm, PBC predicted behavioural willingness. Support was also found for perceived sevierity in the risk but not in the low risk scnerio.
Franklin et al. (2014)	Washed away"-assessing community perceptions of flooding and prevention strategies	130 residents in in North Queensland, Australia	Online survey	Percentage distribution	About half of respondents (55 %) had some experience with floods of which driving through floodwater (38 %) was the most common type of flood experience listed and was more common amongst male respondents.
Becker et.al (2015)	A review of people's behaviour in and around floodwater	N/A	Literature review	Qualitative analyses	Five predominant reasons for entering floodwater were identified. Two primary influences on entering floodwater were found, namely risk perception and social influences.
Gissing et al. (2016)	Motorist behaviour during the 2015 Shoalhaven floods	154 motorists in total	Based on fieldwork carried out during flooding in the Shoalhaven region of NSW, Australia, in August 2015	Proportion and percentage distribution	84 per cent of drivers at a monitored site, notably males and four-wheel-drive (4WD) vehicles, dismissed road closure signs and drove into floodwater.
Diakakis (2016)	Have flood mortality qualitative characteristics changed during the last decades? The case study of Greece		Fatal incident descriptions included in scientific publications and flood databases	During the 50 years of the study period, a total of 189 fatalities were recorded and examined	The increase in the use of vehicles, the improvements in the structural integrity of buildings and the advances in early warning and civil protection practices are found to influence mortality both in qualitative and in quantitative terms.
Hamilton et al. (2016)	Stop there's water on the road! Identifying key beliefs guiding people's willingness to drive through flooded waterways	174 Australian individuals ranging in age from 17 to 65 years	Cross-sectional study through online survey	The Pearson correlation matrix Multiple regression analysis	Factors possibly influencing decision making including past experience; pressures to arrive at a destination; perception that a situation is different to warnings; avoiding isolation; lack of motivation to take alternate options; pressure from other drivers; encouragement by passengers; behavior of other motorists; security of others being present if rescue was needed; believing they had the knowledge and skills; belief in their ability to accurately assess the risk; and belief in their vehicle.

Pereira et al. (2017)	Comparing flood mortality in Portugal and Greece (Western and Eastern Mediterranean)	N/A	DISASTER database for Portugal and Greek	Flood fatalities are examined and compared in terms of frequency, temporal evolution, spatial distribution, deadliest flood types, gender of the victims, circumstances surrounding fatalities, and individual and societal risk.	Gender distribution of fatalities indicates that males are more vulnerable. The circumstances surrounding fatalities showed that fatalities occurring inside buildings have been gradually reducing in time, while vehicle-related deaths have been rising, showing that individuals hold an active role when they voluntarily enter in floodwaters during a flood.
Haynes et al., (2017)	An analysis of human fatalities from flood hazards in Australia, 1900-2015	N/A	the Risk Frontiers' database PerilAUS	Coronial inquests of information from the database	Overall there have been 1859 fatalities identified, with distinct trends in relation to gender, age, activity and reason behind the activity.
Gissing et al., (2017)	Influence of road characteristics on flood fatalities in Australia	N/A	the Risk Frontiers' database PerilAUS and media articles	21 site analyses which are accounted for 28 deaths	Road characteristics variously influence the risk that motorists knowingly or unknowingly enter floodwater, the ability of motorists to turn around upon seeing floodwaters, and the likely survivability of entering floodwaters
Peden et al., (2017)	Causal pathways of flood related river drowning deaths in Australia	N/A	The Australian National Coronial Information System (NCIS)	A cross-sectional, total population audit of all (129 deaths) known unintentional river flood related fatal drownings.	There were 129 (16.8%) deaths involving river flooding, representing a crude drowning rate of 0.06 per 100,000 people per annum. Non-aquatic transport incident victims were commonly the drivers of four-wheel drive vehicles and were alone in the car, whilst attempting to reach their own home or a friend's.



Appendix 2. Thematic map of the findings identified in this thesis

Appendix (Ethics Approval) of this thesis has been removed as it may contain sensitive/confidential content

Encountering Floodwater (Survey for SES members)

Introduction

What is this survey about?

The purpose of this survey is to investigate the attitudes and behaviours of SES personnel around floodwater, specifically, water over the road. We want to know how you approach this potential risk and your experiences of driving through, or turning around from, floodwater in vehicles.

Who is conducting this survey?

This research is being led by researchers at Macquarie University (Dr Mel Taylor and Dr Katharine Haynes) with funding from the Bushfire and Natural Hazards CRC and with the support of XXX SES. This research will also form part of the research theses of two students; Mozumdar Arifa Ahmed, and Rachel Begg, both from the Department of Psychology, Macquarie University, to meet the requirements of Doctor of Philosophy and Masters of Organisational Psychology, respectively.

What information do I provide?

The survey will collect information about you, your perceptions of floodwater, and your experience of driving into, or turning back from, floodwater (either as a driver or a passenger).

How long will it take?

The survey will take approximately 15-20 minutes to complete. It is mostly tick-box questions with some spaces for optional comments.

What happens to the information I provide?

Any information or personal details gathered in the course of the study are strictly confidential and non-attributable. No individual will be identified in any publication of the results. Participant data will only be available to the named lead researchers - Dr Mel Taylor and Dr Katharine Haynes, and the co-investigators, Mozumdar Arifa Ahmed and Rachel Begg. De-identified survey data may be made available to other researchers for future Human Research Ethics Committee-approved research projects, if applicable.

A summary of findings will be provided for distribution to members, and the study findings will be used by SES to help increase their understanding of the challenges faced by SES members when out in storm and flood conditions, and to inform approaches to strengthening member safety.

Conditions and support

Participation in this study is entirely voluntary and you are free to withdraw at any time without any penalty and consequence. Please note that some questions in the survey may have the capacity to cause levels of distress. If at any time during the process you become distressed in

any way, you are free to discontinue. If you require general and counselling support, please contact the Lifeline Services (13 11 14), Mission Australia Helpline (1300 886 999), or your Employee Assist Program (EAP) Service.

Contact

If you require any support or have further questions about this study, please contact the researchers, Dr Mel Taylor at mel.taylor@mq.edu.au, Dr Katharine Haynes at katharine.haynes@mq.edu.au, or Rachel Begg at rachel.begg@students.mq.edu.au.

The ethical aspects of this study have been approved by the Macquarie University Human Research Ethics Committee. If you have any complaints or reservations about any ethical aspect of your participation in this research, you may contact the Committee through the Director, Research Ethics & Integrity (telephone (02) 9850 7854; email ethics@mq.edu.au). Any complaint you make will be treated in confidence and investigated, and you will be informed of the outcome.

Consent

Clicking on the "I AGREE" button below indicates that you have read and understood the statements above, you are 17 years of age or older, and you voluntarily agree to take part in the study. If you do not wish to take part please click on the "I DON'T AGREE" button.

* 1. Having read and understood the statements above

- ◯ I AGREE to take part in this survey
- ◯ I DON'T AGREE to take part in this survey (if you click this button you will exit the survey)

Driving Licence

2. Did you complete the pilot survey exploring driving into floodwaters?

◯ Yes

◯ No

* 3. Do you hold a driving licence? (any type)

◯ Yes ◯ No

General driving experience

4. What type of driving licence do you hold?

- ◯ Full licence (C class - standard car licence)
- ◯ Provisional (P2) Green 'Ps'
- ◯ Provisional (P1) Red 'Ps'
- ◯ Learner (L)

Other/Additional licence class/type (please specify)

[ ]

5. For how many years have you held a full licence?

- ◯ 0 (still Provisional/Learner status)
- ◯ 6 - 10 years
- ◯ Less than 3 years
- ◯ More than 10 years
- ◯ 3 - 5 years

6. Approximately how many hours do you spend driving EACH WEEK?

- ◯ Less than 2 hours (less than 20 mins a day, on average)
- ◯ 8 - 14 hours (around 1-2 hours a day, on average)
- ◯ 2 - 7 hours (around 20 min - 1 hour a day, on average)
- ◯ 15 hours or more (more than 2 hours a day, on average)

Comment (if needed)

[ ]

7. How would you rate...

	Very low	Low	Moderate	High	Very high
your driving ability/competence?	◯	◯	◯	◯	◯
your confidence as a driver?	◯	◯	◯	◯	◯

8. What type of PRIVATE vehicle do you usually drive?

- ◯ Small car (e.g. Mazda 2, Yaris, Micra, Barina)
- ◯ Medium or Large car (e.g. Corolla, Mazda 3 or 6 Commodore,)
- ◯ Station wagon
- ◯ SUV
- ◯ Utility vehicle (Ute)
- ◯ Sports car
- ◯ Other (please specify)
- ◯ Van, minibus, small truck
- ◯ Light / Medium rigid truck
- ◯ Heavy rigid truck / Articulated truck
- ◯ Bus/Coach
- ◯ Motorcycle

[ ]

9. Is this vehicle model...

- ◯ All wheel drive (AWD)
- ◯ Four wheel drive (4WD, 4X4)
- ◯ Two wheel drive
- ◯ Not sure
- ◯ Not applicable

10. (Optional) Space for comments/clarification, if needed

Driving Approval

* 11. Do you have approval to drive SES vehicles?

- ◯ Yes
- ◯ No

Work-based driving experience

12. For how long have you had approval to drive SES vehicles?

- ◯ Less than one year
- ◯ 1-2 years
- ◯ 3-5 years
- ◯ 6-10 years
- ◯ More than 10 years

13. What type of vehicle do you drive most often?

- ◯ Medium / Heavy truck
- ◯ Light truck / Dual cab
- ◯ Other (please specify)
- ◯ Passenger vehicle

14. How often do you drive a SES vehicle?

- ◯ Rarely (not more than once a month)
- ◯ Occasionally (a few times a month)
- ◯ Often (most weeks)
- ◯ All the time (almost every day)

15. (Optional) Space provided for comments/clarification, if needed

Encountering Floodwater (Survey for SES members)

Demographics

16. What is your age?

- 18 to 24
- 25 to 34
- 35 to 44
- 45 to 54
- 55 to 64
- 65 to 74
- 75 or older
- Rather not say

17. What is your gender?

- Female
- Male
- Gender not specified
- Rather not say

18. What is your highest level of formal education?

- School Certificate / Year 10 or below
- Higher School Certificate / Year 12 / 6th form
- TAFE Certificate/Diploma
- Degree from a University, College of Advanced Education, or other tertiary institute
- Other (please specify)

19. What is your residential postcode? (just the four digits)

20. How often do you encounter flooded roads? (i.e. driving in the areas you live and work)

- Quite frequently – more than half a dozen times a year
- Occasionally – 3-6 times a year
- Rarely - once or twice a year
- Never

Deployment

21. Do you get deployed to work in flood/storm conditions?

- ◯ Yes
- ◯ No

22. If you get deployed, how many times have you been deployed in the last two years...

	0	1 - 2	3 - 5	6 - 10	10+
to local flood events (where you can travel to/from location within the same day)	◯	◯	◯	◯	◯
to regional flood events (within your State/Territory - but where you have had to stay overnight/longer periods)	◯	◯	◯	◯	◯
to large interstate flood events (in another State/Territory - where you have stayed for a number of days/longer periods)	◯	◯	◯	◯	◯

23. (Optional) Comments/Clarification about SES deployment

Your work with SES

24. Are you...

- ○ a paid staff member of SES
- ○ a volunteer member of SES
- ○ both a paid staff member and a volunteer

25. For how many years have you been...

	less than 1 year	1 - 5 years	6 - 10 years	11 - 20 years	More than 20 years
a paid member of SES?	○	○	○	○	○
a volunteer member of SES?	○	○	○	○	○

Comment (if needed)

26. What is your SES region? (versions used contain list of options)

27. Do you have current qualifications in Flood Rescue? (tick the highest level, if applicable)

- ○ Yes, Flood Rescue Awareness
- ○ Yes, Level 1
- ○ Yes, Level 2
- ○ Yes, Level 3
- ○ Yes, but qualifications are not current
- ○ No, I have no Flood Rescue Qualifications

28. Have you attended any of the following training courses? (tick all that apply)

- ☐ Drive operational vehicles
- ☐ Four wheel drive operations
- ☐ Maintain team safety
- ☐ Participate in a rescue operation
- ☐ Team leader
- ☐ I haven't attended any of these courses
- ☐ Other training in/around water, driving skills, or safety-related training - not already noted

29. Do you volunteer for any other organisations (e.g. Royal Lifesaving Society, Red Cross, Fire Service)?

- ◯ No - I never have
- ◯ Yes
- ◯ No - not currently, but I have previously

If YES, what organisation/s do you volunteer for?

30. How would you rate...

	Very low	Low	Moderate	High	Very high
your swimming ability?	◯	◯	◯	◯	◯
your level of confidence in and around water?	◯	◯	◯	◯	◯

Water on Roads (Image 1 of 4)

In this section you will be asked to look at FOUR images of water on a road and answer a short set of questions about each one. Please imagine you are in the work and private vehicles you normally drive (the ones identified earlier in the survey).

31. Would you consider driving through this water...

	No, definitely not	No, Probably not	Maybe/unsure	Yes, probably would	Yes, definitely would
In a SES vehicle - in a normal, everyday WORK situation?	◯	◯	◯	◯	◯
In a SES vehicle - in an urgent WORK situation (e.g. getting to a critical incident/rescue)	◯	◯	◯	◯	◯
In your own (private) vehicle - in a normal situation?	◯	◯	◯	◯	◯
In your own (private) vehicle - in an urgent situation (e.g. getting to an important interview/meeting, or if you were late to collect young children from school)	◯	◯	◯	◯	◯

32. Would you consider this road flooded?

No, definitely not	No, probably not	Maybe/unsure	Yes, probably	Yes, definitely
◯	◯	◯	◯	◯

Briefly, why did you give this answer? (what is it about the water/image that led you to give this response?)

Water on Roads (Image 2 of 4)

33. Would you consider driving through this water...

	No, definitely not	No, probably not	Maybe/unsure	Yes, probably would	Yes, definitely would
In a SES vehicle - in a normal, everyday WORK situation?	○	○	○	○	○
In a SES vehicle - in an urgent WORK situation (e.g. getting to a critical incident/rescue)	○	○	○	○	○
In your own (private) vehicle - in a normal situation?	○	○	○	○	○
In your own (private) vehicle - in an urgent situation (e.g. getting to an important interview/meeting, or if you were late to collect young children from school)	○	○	○	○	○

34. Would you consider this road flooded?

No, definitely not	No, probably not	Maybe/unsure	Yes, probably	Yes, definitely
○	○	○	○	○

Briefly, why did you give this answer? (what is it about the water/image that led you to give this response?)

Water on Roads (Image 3 of 4)

35. Would you consider driving through this water...

	No, definitely not	No, probably not	Maybe/unsure	Yes, probably would	Yes, definitely would
In a SES vehicle - in a normal, everyday WORK situation?	○	○	○	○	○
In a SES vehicle - in an urgent WORK situation (e.g. getting to a critical incident/rescue)	○	○	○	○	○
In your own (private) vehicle - in a normal situation?	○	○	○	○	○
In your own (private) vehicle - in an urgent situation (e.g. getting to an important interview/meeting, or if you were late to collect young children from school)	○	○	○	○	○

36. Would you consider this road flooded?

No, definitely not	No, probably not	Maybe/unsure	Yes, probably	Yes, definitely
○	○	○	○	○

Briefly, why did you give this answer? (what is it about the water/image that led you to give this response?)

Water on Roads (Image 4 of 4)

37. Would you consider driving through this water...

	No, definitely not	No, probably not	Maybe/unsure	Yes, probably would	Yes, definitely would
In a SES vehicle - in a normal, everyday WORK situation?	◯	◯	◯	◯	◯
In a SES vehicle - in an urgent WORK situation (e.g. getting to a critical incident/rescue)	◯	◯	◯	◯	◯
In your own (private) vehicle - in a normal situation?	◯	◯	◯	◯	◯
In your own (private) vehicle - in an urgent situation (e.g. getting to an important interview/meeting, or if you were late to collect young children from school)	◯	◯	◯	◯	◯

38. Would you consider this road flooded?

No, definitely not	No, probably not	Maybe/unsure	Yes, probably	Yes, definitely
◯	◯	◯	◯	◯

Briefly, why did you give this answer? (what is it about the water/image that led you to give this response?)

Experience of driving through floodwater

Currently, there is no clear definition of floodwater. For the purpose of this survey, we will define floodwater as an environment with:

1. Water across the road surface
2. Little to no visibility of the road surface markings under the water (i.e. uncertain of road quality / integrity and possibly depth)
3. Water on normally dry land - flowing or still

39. Based on the floodwater definition above.

How many times have you driven through (or been driven through) floodwater in the last two years…

	0	1 - 2	3 - 6	> 6
In a SES vehicle – as the driver?	○	○	○	○
In a SES vehicle – as a passenger?	○	○	○	○
In your own private vehicle – as a driver?	○	○	○	○

* 40. Can you recall an event in which you drove (or were driven) through floodwater - in a SES vehicle - ideally the most memorable occasion in the last few years?

○ Yes

○ No, I can't recall an event like this

○ No, but I can recall a recent event when I drove through floodwater in my own (private) vehicle

Details of event - driving through floodwater

41. How long ago did this event happen?

- ◯ Within the last couple of years
- ◯ Around 3 - 5 years ago
- ◯ More than 5 years ago (before 2014)

42. In what type of location did this happen?

- ◯ Urban
- ◯ Suburban
- ◯ Regional
- ◯ Rural
- ◯ Remote

43. What type of SES vehicle were you in?

- ◯ Medium / Heavy truck
- ◯ Light truck / Dual cab
- ◯ Passenger vehicle
- ◯ Other type of SES vehicle
- ◯ N/A - it was my own private vehicle

Please specify 'other type of SES vehicle', or the type of private vehicle (e.g. large car, ute, or make/model)

[ ]

44. Was the vehicle model...

- ◯ All Wheel Drive (AWD)
- ◯ Four Wheel Drive (4WD, 4x4)
- ◯ Two Wheel Drive (2WD)
- ◯ Not sure
- ◯ Not applicable

45. How many people were in the vehicle (in total)?

- ◯ 1 (driver only)
- ◯ 2 (driver +1)
- ◯ 3 (driver +2)
- ◯ 4 (driver +3)
- ◯ 5 or more (driver +4 or more)

46. Were you the driver or the passenger?

- ◯ Driver
- ◯ Passenger

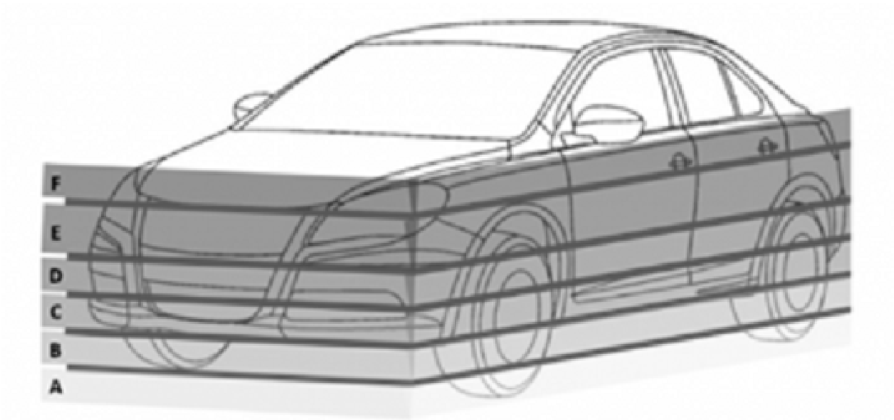
47. Who were the other people in the vehicle with you? (tick all that apply)

- [ ] N/A - no others in the vehicle (sole driver)
- [ ] SES colleague/s
- [ ] Emergency service or other 'official' personnel
- [ ] Civilian/s

48. Did passengers in the vehicle influence the decision to drive into the floodwater?

- ◯ Yes
- ◯ N/A - no passengers in the vehicle
- ◯ No

If the passengers influenced the driver of the vehicle, what did they do?



Features of the water

49. What was the approximate depth of the water (use Figure above - with water heights shown against a sedan - to help estimate the depth)

- ◯ (A) Less than 15cm
- ◯ (D) 45cm – 60cm
- ◯ (B) 15cm – 30cm
- ◯ (E) 60cm- 95cm
- ◯ (C) 30cm – 45cm
- ◯ (F) 95cm or above

Other conditions

50. What was the water movement / flow like, at the time of this event?

- ◯ Still
- ◯ Medium/moderate flow
- ◯ Slow flow
- ◯ Rapid / swift flow

Additional details about the water (e.g. drop in levels/heights of road/water surfaces etc.)

51. What was the lighting condition like at the time?

- ◯ Daylight (good light)
- ◯ Night with streetlights
- ◯ Dawn/dusk (fading/low light)
- ◯ Glare (harsh sunlight)
- ◯ Night with no streetlights
- ◯ Other (please specify)

52. What was the weather like at the time?

- ◯ Clear
- ◯ Steady rain
- ◯ Light rain
- ◯ Heavy rain (poor visibility)
- ◯ Other (please specify)

53. What type of road were you driving on?

- ◯ Highway / Major road
- ◯ Unsealed road / track
- ◯ Minor / Residential road
- ◯ Other (please specify)

54. How familiar were you with this road? (please drag slider to preferred position)

Not at all (had never driven it before) — Extremely familiar (had driven it often)

55. Did you enter the water on...?

- ◯ A low-water crossing, bridge, or causeway
- ◯ A normal stretch of road
- ◯ A ford or weir
- ◯ Other (please specify)

56. Please describe the road signage (tick all that apply)

- [ ] No signage
- [ ] Flood warning signage
- [ ] Road closure signs/barriers
- [ ] Flood depth indicator/s
- [ ] Other (please specify)

57. What were you doing?

- ○ Emergency response (under lights and sirens)
- ○ Routine work
- ○ Emergency response (not under lights and sirens)
- ○ Travelling to/from a SES unit, but not on duty
- ○ Training/Exercise
- ○ Private journey
- ○ Other (please specify)

58. What were other emergency services personnel in vehicles doing?

- ○ N/A - no other emergency services/official vehicles were there
- ○ Turning around
- ○ Mix of behaviours
- ○ Driving through the water
- ○ Other (please specify)

59. What were members of the general public in vehicles doing?

- ○ N/A - no members of the general public/vehicles were there
- ○ Turning around
- ○ Driving through the water
- ○ Mix of behaviours
- ○ Other (please specify)

Risks

60. How risky do you think it was to drive into floodwater on this occasion? (please drag slider to preferred position)

Not at all risky — Extremely risky

61. What level of risk do you think there was of...

	No risk	Low risk	Moderate risk	High risk
Damage to the vehicle	◯	◯	◯	◯
Personal injury	◯	◯	◯	◯
Potential for drowning	◯	◯	◯	◯

Other risks (please specify)

62. (Optional) Additional comments about the event

63. Do you think others in the vehicle felt the same way as you about the level of risk at the time?

- ◯ N/A – sole driver
- ◯ Yes, I think we all felt similarly about the level of risk
- ◯ No, others generally seemed to think it was more dangerous than I did
- ◯ No, others generally seemed to think it was less dangerous than I did
- ◯ Unsure how others felt

Factors that might have influenced your decision to drive through the floodwater

64. To what extent did the following influence your decision to drive through the floodwater on this occasion?

	Not at all 1	2	3	4	5	6	A great deal 7
The journey was urgent	○	○	○	○	○	○	○
No alternative route	○	○	○	○	○	○	○
Impractical alternative route (time/distance)	○	○	○	○	○	○	○
Lack of signage/indicators to show depth or danger	○	○	○	○	○	○	○
Behavior of others, e.g. others driving through without problems	○	○	○	○	○	○	○
Careful consideration of the situation	○	○	○	○	○	○	○
Knowing the road well	○	○	○	○	○	○	○
Driving through floodwater previously without problem	○	○	○	○	○	○	○
Professional SES training/knowledge	○	○	○	○	○	○	○
Reassurance or encouragement from others in the vehicle	○	○	○	○	○	○	○
Belief in my own physical ability to drive through	○	○	○	○	○	○	○
Close proximity to destination/operational situation	○	○	○	○	○	○	○
Gut-feeling that it would be all right	○	○	○	○	○	○	○
Being directed to drive through the water by other emergency services/council	○	○	○	○	○	○	○
SES's attitude towards safety	○	○	○	○	○	○	○
Excitement - it being fun to do	○	○	○	○	○	○	○
Organisational pressure to complete my duty	○	○	○	○	○	○	○
My personal desire to complete my duty	○	○	○	○	○	○	○

(Optional) Comments

* 65. Please tick the following box to be directed to the last couple of sections of the survey

○ Tick here

Experience of NOT driving through floodwater

In this section we are interested in finding out about a situation in which you decided NOT to drive through floodwater. We are interested to find out about uncertain situations where you *might* have driven through, but decided not to - a 50/50 situation – rather than a situation that was clearly dangerous or extreme that no one would consider driving through.

Currently, there is no clear definition of floodwater. For the purpose of this survey, we will define floodwater as an environment with:

1. Water across the road surface
2. Little to no visibility of the road surface markings under the water (i.e. uncertain of road quality / integrity and possibly depth)
3. Water on normally dry land - flowing or still

66. Based on the floodwater definition above.

How many times have you turned around from floodwater (or been a passenger in a vehicle that turned around from floodwater) in the last two years…

	0	1 - 2	3 - 6	> 6
In a SES vehicle – as the driver?	◯	◯	◯	◯
In a SES vehicle – as a passenger?	◯	◯	◯	◯
In your own private vehicle – as a driver?	◯	◯	◯	◯

* 67. Can you recall an event in which you (as a driver or passenger) turned around from floodwater in a SES vehicle - in a situation in which you think a SES colleague might have continued driving through?

◯ Yes

◯ No, I can't recall an event like this

◯ No, but I can recall a recent event when I turned around from floodwater in my own (private) vehicle

Details of event - NOT driving through floodwater

68. Thinking about the most memorable event when you turned around from floodwater. How long ago did this event happen?

- ◯ Within the last couple of years
- ◯ Around 3 - 5 years ago
- ◯ More than 5 years ago (before 2014)

69. In what type of location did this happen?

- ◯ Urban
- ◯ Suburban
- ◯ Regional
- ◯ Rural
- ◯ Remote

70. Were you the driver or the passenger?

- ◯ Driver
- ◯ Passenger

71. What type of SES vehicle were you in?

- ◯ Medium / Heavy truck
- ◯ Light truck / Dual cab
- ◯ Passenger vehicle
- ◯ Other type of SES vehicle
- ◯ N/A - it was my own private vehicle

Please specify 'other type of SES vehicle', or the type of private vehicle (e.g. large car, ute, or make/model)

[ ]

72. Was the vehicle model...

- ◯ All Wheel Drive (AWD)
- ◯ Four Wheel Drive (4WD, 4x4)
- ◯ Two Wheel Drive (2WD)
- ◯ Not sure
- ◯ Not applicable

73. How many people were in the vehicle (in total)?

- ◯ 1 (driver only)
- ◯ 2 (driver +1)
- ◯ 3 (driver +2)
- ◯ 4 (driver +3)
- ◯ 5 or more (driver +4 or more)

74. Who were the other people in the vehicle with you? (tick all that apply)

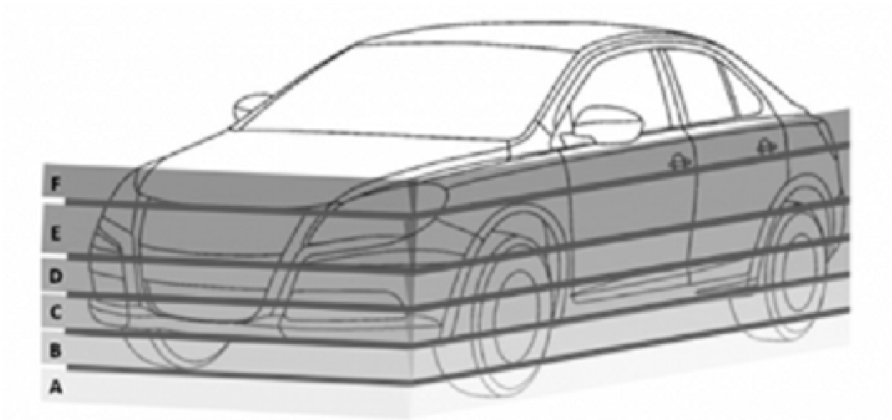
- [ ] N/A - no others in the vehicle (sole driver)
- [ ] SES colleague/s
- [ ] Emergency service or other 'official' personnel
- [ ] Civilian/s

75. Did passengers in the vehicle influence the decision to turn around from the floodwater?

- ◯ Yes
- ◯ No
- ◯ N/A - no passengers in the vehicle

If the passengers influenced the driver of the vehicle, what did they do?

Features of the water



76. What was the approximate depth of the water (use Figure above - with water heights shown against a sedan - to help estimate the depth)

- ◯ (A) Less than 15cm
- ◯ (B) 15cm – 30cm
- ◯ (C) 30cm – 45cm
- ◯ (D) 45cm – 60cm
- ◯ (E) 60cm- 95cm
- ◯ (F) 95cm or above

77. What was the water movement / flow like, at the time of this event?

- ◯ Still
- ◯ Slow flow
- ◯ Medium/moderate flow
- ◯ Rapid / swift flow

Additional details about the water (e.g. drop in levels/heights of road/water surfaces etc.)

Other conditions

78. What was the lighting condition like at the time?

- Daylight (good light)
- Night with streetlights
- Dawn/dusk (fading/low light)
- Glare (harsh sunlight)
- Night with no streetlights
- Other (please specify)

79. What was the weather like at the time?

- Clear
- Steady rain
- Light rain
- Heavy rain (poor visibility)
- Other (please specify)

80. What type of road were you driving on?

- Highway / Major road
- Unsealed road / track
- Minor / Residential road
- Other (please specify)

81. How familiar were you with this road? (please drag slider to preferred position)

Not at all (had never driven it before) — Extremely familiar (had driven it often)

82. Did you enter the water on...?

- A low-water crossing, bridge, or causeway
- A normal stretch of road
- A ford or weir
- Other (please specify)

83. Please describe the road signage (tick all that apply)

- [ ] No signage
- [ ] Flood warning signage
- [ ] Road closure signs/barriers
- [ ] Flood depth indicator/s
- [ ] Other (please specify)

84. What were members of the general public in vehicles doing?

- ( ) N/A - no members of the general public/vehicles were there
- ( ) Turning around
- ( ) Driving through the water
- ( ) Mix of behaviours
- ( ) Other (please specify)

85. What were you doing?

- ( ) Emergency response (under lights and sirens)
- ( ) Routine work
- ( ) Emergency response (not under lights and sirens)
- ( ) Travelling to/from a SES unit, but not on duty
- ( ) Training/Exercise
- ( ) Private journey
- ( ) Other (please specify)

86. What were other emergency services personnel in vehicles doing?

- ( ) N/A - no other emergency services/official vehicles were there
- ( ) Turning around
- ( ) Mix of behaviours
- ( ) Driving through the water
- ( ) Other (please specify)

Risks

87. How risky do you think it would have been to drive into floodwater on this occasion? (please drag slider to preferred position)

Not at all risky — Extremely risky

88. What level of risk do you think there was of...

	No risk	Low risk	Moderate risk	High risk
Damage to the vehicle	○	○	○	○
Personal injury	○	○	○	○
Potential for drowning	○	○	○	○

Other risks (please specify)

89. Do you think others in the vehicle felt the same way as you about the level of risk at the time?

- ○ N/A – sole driver
- ○ Yes, I think we all felt similarly about the level of risk
- ○ No, others generally seemed to think it was more dangerous than I did
- ○ No, others generally seemed to think it was less dangerous than I did
- ○ Unsure how others felt

90. (Optional) Comments

Factors that might have influenced your decision NOT to drive through the floodwater

91. Please indicate the extent to which you think the following influenced your decision to turn around and not drive through the floodwater on this occasion

	Not at all 1	2	3	4	5	6	A great deal 7
The journey was not urgent	○	○	○	○	○	○	○
Available alternative route	○	○	○	○	○	○	○
Easy alternative route (time/distance)	○	○	○	○	○	○	○
Lack of signage/indicators to show depth or danger	○	○	○	○	○	○	○
Behavior of others, e.g. others drivers turning around	○	○	○	○	○	○	○
Careful consideration of the situation	○	○	○	○	○	○	○
Knowing the road well	○	○	○	○	○	○	○
A bad experience driving through floodwater in the past	○	○	○	○	○	○	○
Professional SES training/knowledge	○	○	○	○	○	○	○
Reassurance or encouragement from others in the vehicle	○	○	○	○	○	○	○
Not confident in my own physical ability to drive through	○	○	○	○	○	○	○
Gut-feeling that it would be better to turn around	○	○	○	○	○	○	○
Being directed to turn around by other emergency services/council	○	○	○	○	○	○	○
SES's attitude towards safety	○	○	○	○	○	○	○
Fear of the consequences (if driving through had gone wrong)	○	○	○	○	○	○	○

(Optional) Comments

Personal attitudes to the risk of driving through floodwater

92. How acceptable do you feel it would be for the general public to drive through the floodwater shown in the image above...

	Not at all	A little	Somewhat	Very	Extremely
in normal/everyday situations (e.g. work, shopping)?	◯	◯	◯	◯	◯
in an emergency situation (e.g. to get a sick person to hospital)?	◯	◯	◯	◯	◯

93. How acceptable do you feel it would be for SES personnel to drive through the floodwater shown in the image above...

	Not at all	A little	Somewhat	Very	Extremely
in normal/everyday situations (e.g. performing regular duties)?	◯	◯	◯	◯	◯
in an emergency situation (e.g. to get to a rescue)?	◯	◯	◯	◯	◯

94. How well do you think the risk of driving through floodwater is....

	Not at all	A little	Somewhat	Very	Extremely
understood by SES members?	◯	◯	◯	◯	◯
communicated within SES to its members?	◯	◯	◯	◯	◯
understood by the public?	◯	◯	◯	◯	◯
communicated to the public in safety/educational campaigns?	◯	◯	◯	◯	◯

95. How would you rate your general willingness to take risks in comparison to other people, such as friends, peers, colleagues? (drag slider to preferred position)

I'm much less willing to take risks | I'm much more willing to take risks

96. (Optional) Space provided for any comments about the risk of driving through floodwater

Organisational safety climate **in XXX SES**

In this FINAL section we would like to find out how you feel about XXXSES's safety practices and principles.

This is a standardised organisational safety questionnaire that will allow us to compare XXX SES members' responses with employees in other organisations.

97. Please indicate to what extent you agree or disagree with the statements below,

	Strongly agree	Agree	Neither agree not disagree	Disagree	Strongly disagree
Management acts decisively when a safety concern is raised	○	○	○	○	○
In my workplace management acts quickly to correct safety problems	○	○	○	○	○
Safety information is always brought to my attention by my line manager/supervisor	○	○	○	○	○
There is good communication in my organisation about safety issues which affect me	○	○	○	○	○
I believe that safety issues are not assigned a high priority	○	○	○	○	○
Management considers safety to be equally as important as serving the public	○	○	○	○	○
Some health and safety rules are not really practical	○	○	○	○	○
Some safety rules and procedures do not need to be followed to get the job done safely	○	○	○	○	○
I am strongly encouraged to report unsafe conditions	○	○	○	○	○
I can influence health and safety performance in my organisation	○	○	○	○	○
I am involved in informing management of important safety issues	○	○	○	○	○
I am involved with safety issues at work	○	○	○	○	○
Safety is the number one priority in my mind when completing a job	○	○	○	○	○
It is important to me that there is a continuing emphasis on safety	○	○	○	○	○
In my workplace the chances of being involved in an accident are quite high	○	○	○	○	○
I am sure it is only a matter of time before I am involved in an accident	○	○	○	○	○
Operational targets often conflict with safety measures	○	○	○	○	○
Sometimes I am not given enough time to get the job done safely	○	○	○	○	○
I would drive through floodwater if there was an occupational need	○	○	○	○	○
I would risk my own safety to save another life	○	○	○	○	○

98. (Optional) Final comments - about organisational attitudes to safety, or any other issues covered by the survey.

99. We are looking for a small number of people to take part in the second phase of this research later in the year. It is also related to floodwater and driving and is computer-based.

If you would consider taking part in this research please leave contact information below (you are under no obligation to take part if/when contacted, and your contact details will only be seen by the research team)

Name (optional) ____________________

Email Address ____________________

Thank you for taking the time to complete this survey, your contribution is greatly appreciated.

Pages 247-257 of this thesis have been removed as they contain published material. Please refer to the following citation for details of the article contained in these pages.

Ahmed, M. A., Haynes, K., & Taylor, M. (2018). Driving into floodwater: a systematic review of risks, behaviour and mitigation. *International Journal of Disaster Risk Reduction*, 31, p. 953-963.

DOI: 10.1016/j.ijdrr.2018.07.007

Vehicle-related flood fatalities in Australia, 2001–2017

Journal:	*Journal of Flood Risk Management*
Manuscript ID	JFRM-0054-19
Manuscript Type:	Original Manuscript
Date Submitted by the Author:	26-Mar-2019
Complete List of Authors:	Ahmed, Mozumdar; Macquarie University, Psychology Haynes, Katharine; Macquarie University, Geography and Planning; Bushfire and Natural Hazards Cooperative Research Centre Taylor, Mel; Macquarie University, Psychology; Bushfire and Natural Hazards Cooperative Research Centre
Keywords:	Disaster Risk Reduction, Emergency management, Flash flood, Risk analysis

Progress in Disaster Science

Duty or safety? Exploring emergency service personnel's perceptions of risk and decision-making when driving through floodwater

--Manuscript Draft--

Manuscript Number:	PDISAS-D-19-00100
Full Title:	Duty or safety? Exploring emergency service personnel's perceptions of risk and decision-making when driving through floodwater
Short Title:	Exploring emergency service personnel's perceptions of risk and decision-making when driving through floodwater
Article Type:	Research Paper
Section/Category:	Understanding disaster risk
Keywords:	Driving through floodwater; Emergency services occupational safety; risk perception and decision-making
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	Mel Taylor
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Manuscript Region of Origin:	AUSTRALIA
Abstract:	Vehicle related flood fatalities and rescues due to driving through floodwater becomes a major emergency management issue for emergency services. To reduce fatalities, injuries, and the number of costs related with this risky driving behaviour, it is essential to develop a detailed understanding of the risks and contexts of driving behaviour into floodwater by emergency service personnel while operational. This study was undertaken to explore the behaviour of driving through floodwater by State Emergency Service personnel. Results indicated "floodwater characteristics" significantly associated with drivers' perceived level of risks; and "organizational training and safety" attitude have significant influences on their decision-making.
Suggested Reviewers:	Dr. Kyra Hamilton Griffith University School of Applied Psychology kyra.hamilton@griffith.edu.au She focuses on how psychological factors such as beliefs, attitudes, social support and norms, self-efficacy, self-monitoring, habit, and motivation affect people's decisions and what individuals, healthcare professionals, and policy makers can do to change health and risky-related behaviours
	Amy E Peden James Cook University College of Medicine and Dentistry amy.peden@my.jcu.edu.au She conducts quantative and qualitative research including producing the National

Calculated risk? Understanding NSW Emergency Service Workers' Decisions to Drive into Floodwater

M Ahmed[1], L Sato[1], K Haynes[1,2], M Taylor[1,2]
[1]Macquarie University, Sydney, NSW
[2]Bushfire and Natural Hazards Cooperative Research Centre, Melbourne, VIC

Vehicle related flood fatalities and rescues are a significant emergency management and road safety problem. Around 49% of flood fatalities in Australia are vehicle related (Haynes, et al. 2017). A large percentage of flood rescues undertaken by emergency services are also vehicle related (Haynes, et al., 2009). To reduce fatalities, injuries, and the number of costly and dangerous rescues, it is essential to develop a detailed understanding of the risks, beliefs, decision-making processes and, where relevant, the organisational safety attitudes of 'at-risk' groups. This study is part of a wider program of research with the Bushfire and Natural Hazards CRC to understand and communicate flood risk to the public and occupationally 'at-risk' groups.

The aims of this study were to explore emergency service workers' experiences of driving into floodwater; to assess the risks and challenges of their occupational contexts, and to explore attitudes towards organisational safety policies and practices. Following a systematic literature review, an online survey was developed and conducted with personnel working in a range of NSW emergency service organisations. Study data will be presented. Firstly, reviewing the environmental and situational contexts in which emergency services personnel drive into, and turn back from, floodwater and, secondly, presenting the outcomes of statistical modeling, identifying the demographic, social, operational, and occupational factors involved in decisions to drive into floodwater.

References:

Haynes, K., L. Coates, R. Leigh, J. Handmer, J. Whittaker, A. Gissing, J. McAneney and S. Opper (2009). "'Shelter-in-place' vs. evacuation in flash floods." Environmental Hazards 8(4): 291-303.

Haynes, K., L. Coates, R. van den Honert, A. Gissing, D. Bird, F. Dimer de Oliveira, R. D'Arcy, C. Smith and D. Radford (2017). "Exploring the circumstances surrounding flood fatalities in Australia—1900–2015 and the implications for policy and practice." Environmental Science & Policy 76: 165-176.

Flood risk communication to reduce vehicle-related flood fatalities

Mel Taylor [1], Katharine Haynes [2], Arifa Ahmed [1], Lisa Sato [1], Rachel Begg [1], Ian Faulks [3], Julia Irwin [1]

[1] Department of Psychology, Macquarie University, NSW. [2] Department of Geography and Planning, Macquarie University, NSW.
[3] Centre for Accident Research and Road Safety, Queensland University of Technology, QLD.

Aim: To develop a better understanding of the motivations, beliefs, decision-making processes, and information needs of at-risk groups for flood fatalities.

Goal: To use this knowledge to improve flood risk communication and education that will lead to a reduction in vehicle-related flood rescues and human fatalities.

PROJECT INTRODUCTION

This project commenced in July 2017 and comprises two phases:

1. Understanding behaviour in and around floodwater, and
2. Evaluating and adapting flood risk communication materials.

Based on the findings of an earlier BNHCRC project *An analysis of building losses and human fatalities from natural disasters* we are focusing on the two behaviours most frequently associated with flood fatalities

1. Driving into floodwater in a motor vehicle, and
2. Recreating in floodwater.

The focus will be on the at-risk groups identified from this earlier research[1] including young male drivers, and children and young adults who play in floodwater.

Year 1 Activities

- Understanding propensity to drive into water on the road (novice drivers, traffic offenders, emergency services personnel, flood experts)
- Encountering floodwater at work (emergency services personnel)
- National survey – encountering floodwater (general population)
- Initial planning for dynamic group decision making research - driving into floodwater and playing in floodwater (young males, children, families)

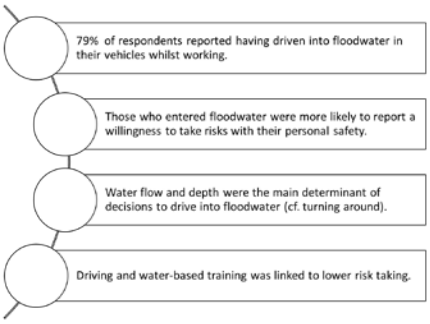
Reference

1. Haynes, K., et al., (2017). Exploring the circumstances surrounding flood fatalities in Australia—1900–2015 and the implications for policy and practice. *Environmental Science and Policy, 76*, 165-176.

EMERGENCY SERVICES PERSONNEL ENCOUNTERING FLOODWATER AT WORK

In the first six months of the project we undertook initial survey research with 230 personnel from three NSW-based emergency services agencies about their experiences of driving into, and turning around from, floodwater when at work.

Key findings



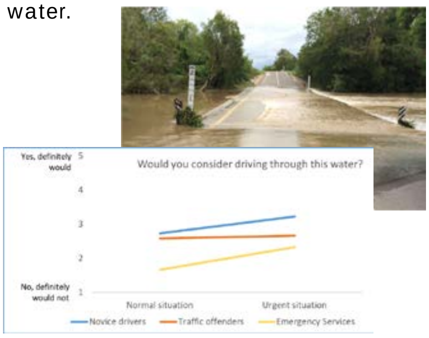
Following these preliminary findings we have expanded this research across a number of SES jurisdictions.

WATER ON THE ROAD – PUBLIC DEFINITION OF FLOODWATER AND PROPENSITY TO DRIVE THROUGH IT

The main goal of this project is to improve flood risk communication. To understand how to communicate better, we first need to understand what the public perceives to be a 'flooded road'.

If imagery in public risk communication always presents a fast flowing, clearly dangerous body of water, how do we expect drivers to behave when faced with more benign-looking water on the road? The official message is still the same – 'if it's flooded, forget it".

In this research, through testing with 250+ people, we have reduced an initial set of 44 photographs of water on the road to a group of four images that discriminate well between participants, when asked whether they would consider driving through the water.



We are using this image set within our surveys to provide a context-relevant risk propensity measure.

In addition, we have been asking participants whether they consider the road 'flooded'. This research is enabling us to identify subtleties in how the public identifies, or discounts, this risk, providing useful insights for risk communication and engagement.

Australian Government Department of Industry, Innovation and Science
Business Cooperative Research Centres Programme
MACQUARIE University

bushfire&natural HAZARDSCRC

Vehicle-related flood deaths in Australia, 2001 –2017

Mozumdar Ahmed[1], Katharine Haynes[1&2], Mel Taylor[1&2]

[1] Macquarie University, NSW [2] Bushfire & Natural Hazards CRC, VIC, [3] Risk Frontiers, NSW

AIM

- Previous studies (Haynes et al.,2017, Peden et al., 2017) have explored the circumstances of flood related fatalities in detail. However, these studies considered all flood related fatalities an extended time frame. This study aimed to explore the detailed circumstances of recent vehicle related fatalities between 2001 and 2017 to better understand the situational, demographic and environmental conditions under which these deaths occurred.

METHOD

- The Australian National Coroners Information System was accessed to gather information on all vehicle related flood fatalities that had occurred between 2001 and 2017.
- In a few cases extra information was accessed from archived newspaper reports.

FATALITY TREND

- 2001-2017; 71 events, 94 deaths
- The data shows a moderate but increasing fatality trend up to 2011 followed by a fluctuating decline to 2017.

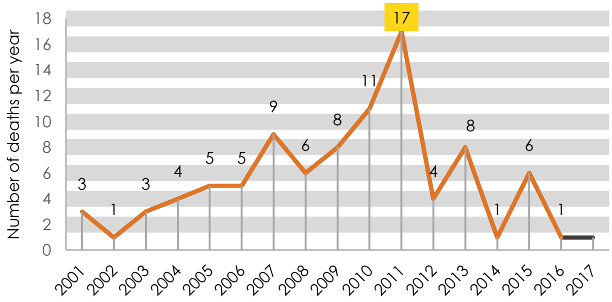


Figure1. Annual number of vehicle- related flood deaths

GENDER AND AGE PATTERNS

- Of the total 66% male, 34% female,
- Of the total 59% were drivers and 28% passengers and 13% unknown
- Of total drivers, 74% are male, 26% Female
- Of total passengers, 54% are male, 46% female
- Male death rate highest in the 50-59 age range; female highest in the 30-49 age range
- The difference in death rates between the sexes was small in the 30-49 age range but males died at twice the rate of females in the 50-59 and older 70-79 age ranges.
- Children and infants are the most high-risk group as passengers followed by females

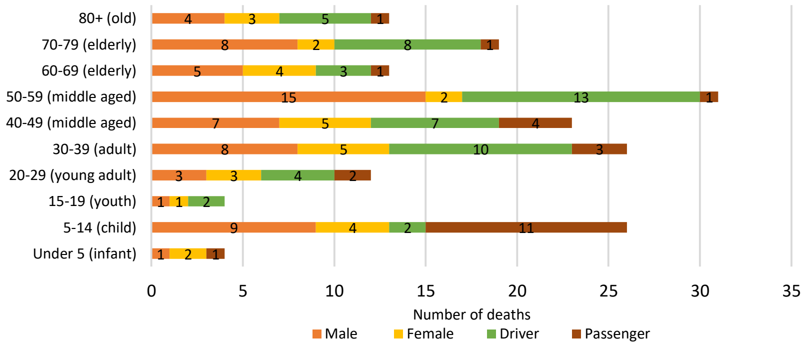


Figure2. Breakdown of fatalities by age, gender and in-vehicle role

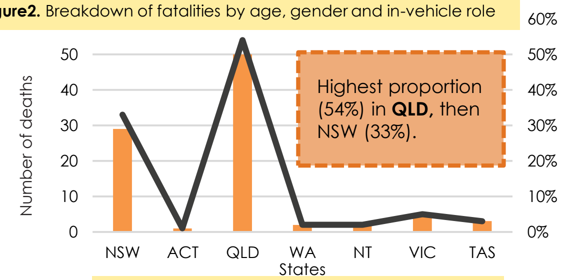
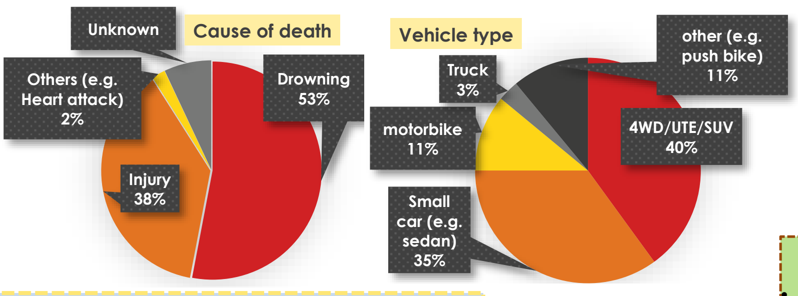


Figure3. Vehicle - related flood deaths by states



SURROUNDINGS

- **Drowning** is the leading cause of death (53%), injury 38%
- 40% incidents happened in **4WD/SUV/UTE**, 35% in small cars (e.g. Sedan), 11% in motor bike
- 57% incidents occurred in **daylight**, 27% at night
- Majority (87%) died **crossing** a bridge or watercourse or flooded roads.
- Most (77%) ***en route*** to a destination; mostly on their way home, 5% attempting to evacuate, 3% were working

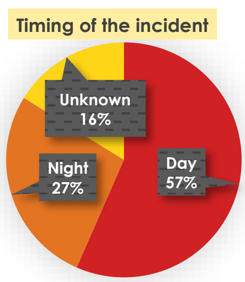


Figure4. Distribution of cases with respect to the cause of death, vehicle type and the timing of the incident

NEXT STEPS AND UTILIZATION

- The final details on the fatalities are to be added to the data set and analysed.
- The research will then be published in a peer reviewed journal.
- The results and trends identified in this research have implications for the development of intervention strategies and targeting those at risk. In particular it is now evident that in addition to younger drivers, older men are increasingly at risk. It is also clear that more needs to be done to communicate the risks of entering floodwater in a vehicle from a passengers point of view, particularly children and adults. This may involve messaging that persuades a driver to put the responsibility of their passengers ahead of their journey and also assists passengers understand their risks

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MACQUARIE University SYDNEY·AUSTRALIA

bushfire&natural HAZARDS CRC

Vehicle-related flood deaths in Australia, 2001 –2017

Mozumdar Ahmed[1], Katharine Haynes[1,2], Mel Taylor[1,2]

[1] Macquarie University, NSW [2] Bushfire & Natural Hazards CRC, VIC

AIM

- To better understand the situational, demographic, and environmental conditions under which vehicle related flood deaths occur.
- To explore age and gender patterns of the vehicle occupants. Specifically: how many people were inside the vehicle when one or more fatalities occurred; the distribution of deaths - the driver or the passenger/s; gender and age of the drivers and passengers; and, circumstances of survivors- number of survivors, approximate age and in-vehicle role of survivors, what influenced the survivability of those who were able to escape the vehicle - compared to those who were unable to.

METHOD

- The Australian National Coroners Information System was accessed to gather information on all vehicle-related flood fatalities that had occurred between 2001 and 2017
- Two phases of analyses - numerical coding for quantitative analyses and qualitive content analyses for selected incidents

FATALITY TREND

- 2001-2017; 74 incidents, **96 deaths**
- Mean death toll = 5.65 per year
- Highest (n=17) in 2011 due to severe flooding event in QLD
- Moderate rising trend between 2001 and 2011

SPATIAL AND TEMPORAL PATTERNS

Most incidents occurred

- along the east coast of QLD and NSW (84%)
- in the summer season (Jan/Feb 39%)
- on a Friday (24%)
- during the evening/night (50%)

Most fatalities occurred whilst on a **creek crossing, bridge, or causeway** (87%).

GENDER AND AGE PATTERNS

- Of the total fatalities **66% male**, **34% female**; 60% drivers, 31% passengers, 8% unknown
- Of total driver fatalities: 72% male, 28% female
- Of total passenger fatalities: 57% male, 43% female
- Male death rate highest in the **50-59 age range**; female highest in the 30-49 age range
- Children and infants are the most high-risk group as passengers

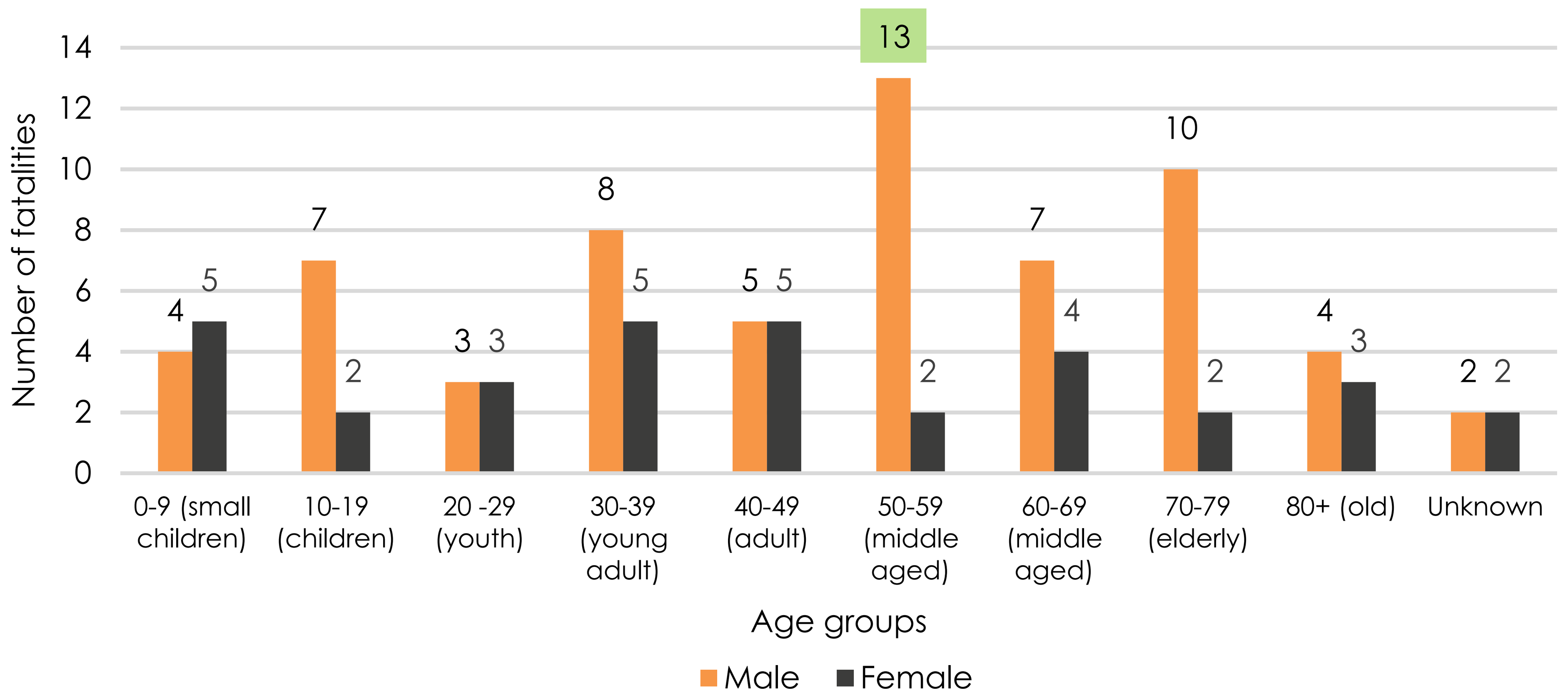

Figure1. Breakdown of fatalities by age and gender

SITUATIONAL FACTORS

- **Drowning** is the leading cause of death (66%)
- **Presence of alcohol** in deceased body found in 55% (n=21/38) incidents.
- No individual was **recovered alive** in 60% (n=44) incidents
- 62 (84%) incidents were **single fatality incidents**; of these 64% (n=40) happened when the **driver was alone**
- Twelve **passengers died** in single fatality incidents, where the driver managed to escape
- 43% (n=33) occurred within **20 km of driver's home address**
- Lowest **water depth was only 20 cm**, 63% reported **fast flowing water**

APPLICATION OF THE FINDINGS

- Results and trends have implications for the development of intervention strategies targeting those at risk.
- In addition to younger drivers, older men are increasingly at risk.
- More needs to be done to communicate the risks of entering floodwater in a vehicle from the passenger's perspective, e.g. messaging that persuades drivers to put their responsibility for passengers ahead of the journey, and also assists passengers to understand their risks and advocate for their safety - especially children/females.
- Floodwater with high flow and the presence of alcohol and drugs are common contributing factors identified, with drugs and alcohol leading to impaired responses, or impacting mobility - reducing the chance of survival.

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MACQUARIE University SYDNEY·AUSTRALIA

bushfire&natural HAZARDSCRC

Encountering floodwater at work: Factors contributing to decisions to drive into floodwater

Mel Taylor[1,2], Katharine Haynes[1,2], Mozumdar Ahmed[1], Matalena Tofa[1,2]

[1] Macquarie University, NSW [2] Bushfire & Natural Hazards CRC, VIC

RATIONALE

- Just under half of all flood-related fatalities in Australia (45%) are attributed to people entering floodwater in motor vehicles.
- As the primary response agency for floods, storms, and tsunamis across Australia, State Emergency Service (SES) personnel are exposed to flooded roads whilst at work/on duty, or when traveling to/from work/duty.
- At an organisational level, alongside WH&S considerations, driving into floodwater in work vehicles can lead to significant financial impacts due to vehicle and equipment damage.
- With a cornerstone of public flood risk messaging being 'If it's flooded, forget it' SES agencies also risk reputational damage if they are seen to be flouting their own advice – especially if vehicles are damaged or require rescue.

AIMS

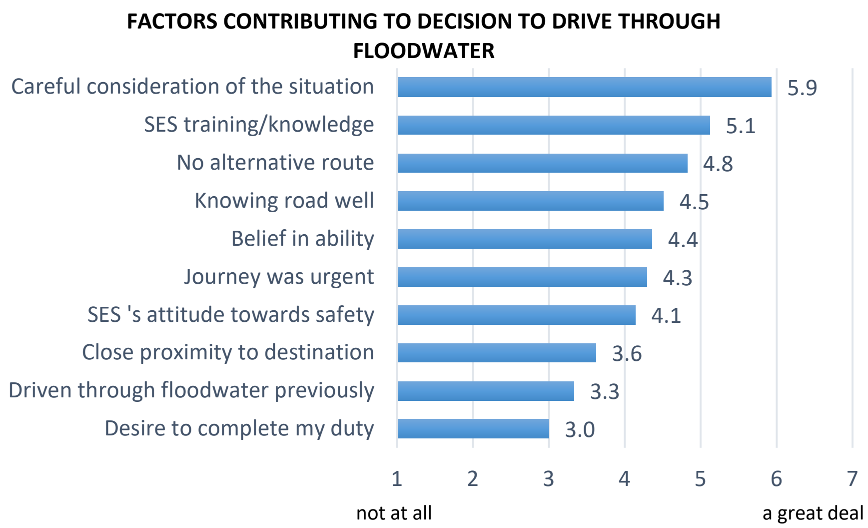
- To understand how SES personnel view the risks of driving into floodwater.
- To understand the circumstances in which SES personnel have entered floodwater on the road when in SES vehicles.
- To determine factors that relate to higher risk driving into floodwater on roads.

APPROACH

- Online survey developed with SES agencies from across Australia.
- Included demographics (e.g. experience, deployment, training), details of a recent experience of driving into floodwater, attitudes to risk, organisational safety climate.
- Data collection in two waves across multiple SES jurisdictions – first wave (reported here). Collection ongoing.

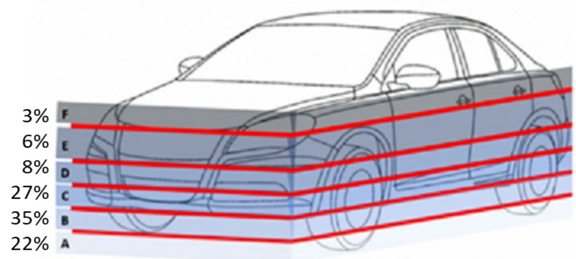
RESULTS

- 695 respondents in this analysis (data collection is ongoing).
- **In the last 2 years 35% had driven through floodwater in an SES vehicle as a driver**. 36% as a passenger, 49% had driven through in a private vehicle
- 272 respondents (39%) provided detailed information about a recent experience of driving/being driven through floodwater in an SES vehicle.
- 22% reported that passenger/s influenced decision to drive through.
- 47% drove into floodwater during an emergency - no lights and sirens.



HOW DEEP? HOW FAST?

- The majority drove through water less than 30cm deep (57%), and slow flow (47%)
- 9% drove through water more than 60cm deep, and 10% moderate or rapid flow



APPLICATION OF FINDINGS

- When data collection is finalised we will be analysing data to investigate the impacts of current training, work contexts, environmental conditions, and the personal characteristics that lead to riskier driving decisions.
- Findings have the potential to influence future training, WH&S policy development, and recruitment.

Australian Government
Department of Industry, Innovation and Science
Business Cooperative Research Centres Programme

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MACQUARIE University SYDNEY·AUSTRALIA

Australia Speaks – National survey exploring experiences and attitudes towards entering floodwater

Floodplain Management Australia National Conference

15 May 2019

Mel Taylor, Katharine Haynes, Matalena Tofa, Arifa Ahmed /
Macquarie University

@bnhcrc @bnhcrc

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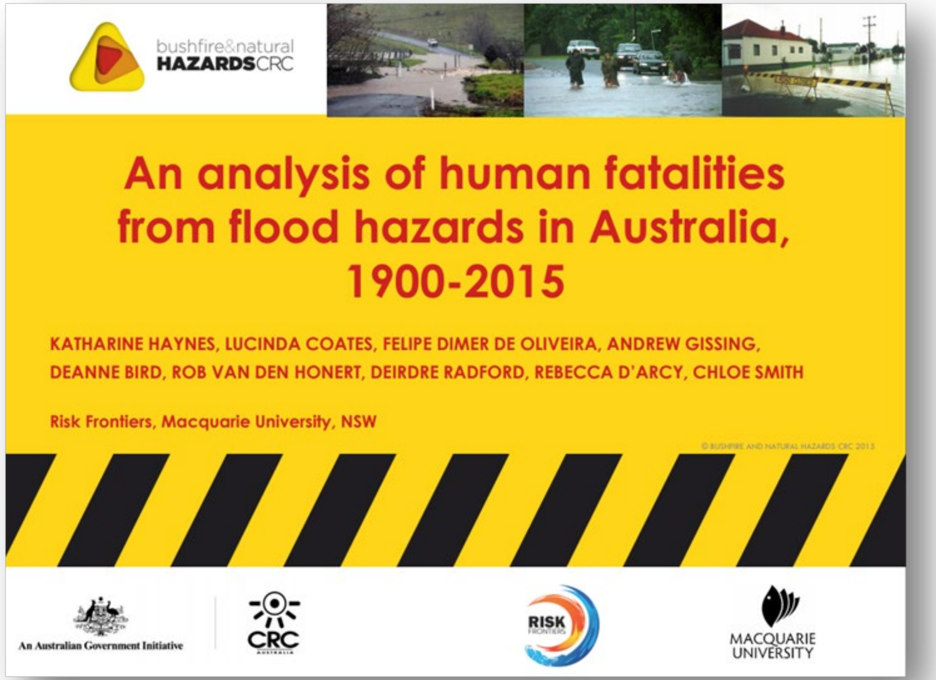
Australian Government Department of Industry, Innovation and Science

Business Cooperative Research Centres Programme

Project outline – Flood risk communication

- Understanding behaviour in and around flood water
  - Highest risk behaviours
    - Entering floodwater in a vehicle
    - Recreating in floodwater
- Evaluating flood risk communication materials

NSW STATE EMERGENCY SERVICE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An analysis of human fatalities from flood hazards 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, NSW

An Australian Government Initiative

CRC

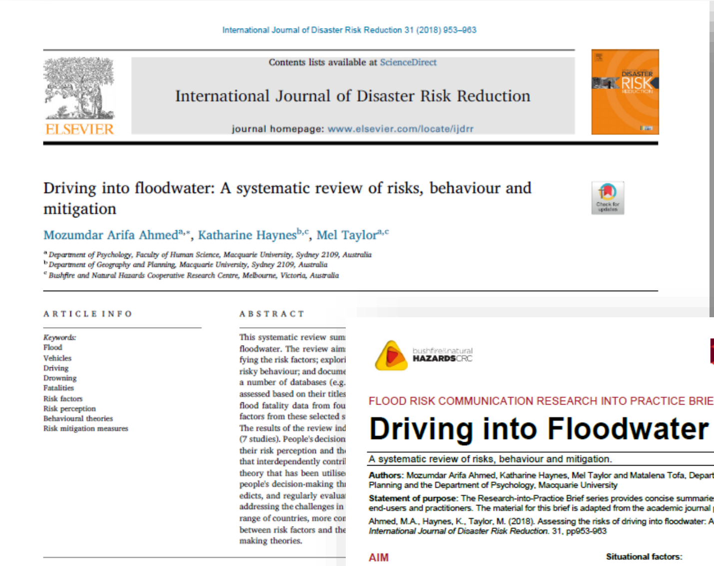
RISK FRONTIERS

MACQUARIE UNIVERSITY

see also Haynes et al., Environmental Science and Policy 76 (2017) 165-176

https://www.bnhcrc.com.au/research/floodriskcomms

Project outputs


International Journal of Disaster Risk Reduction 31 (2018) 953–963

Contents lists available at ScienceDirect

International Journal of Disaster Risk Reduction

journal homepage: www.elsevier.com/locate/ijdrr

Driving into floodwater: A systematic review of risks, behaviour and mitigation

Mozumdar Arifa Ahmed[a,*], Katharine Haynes[b,c], Mel Taylor[a,c]

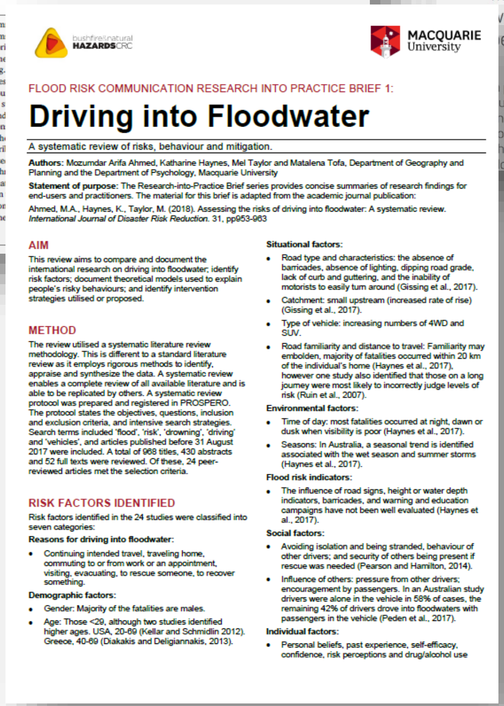
[a] Department of Psychology, Faculty of Human Science, Macquarie University, Sydney 2109, Australia
[b] Department of Geography and Planning, Macquarie University, Sydney 2109, Australia
[c] Bushfire and Natural Hazards Cooperative Research Centre, Melbourne, Victoria, Australia

ARTICLE INFO

Keywords:
Flood
Vehicles
Driving
Drowning
Fatalities
Risk factors
Risk perception
Behavioural theories
Risk mitigation measures

ABSTRACT

This systematic review sum… floodwater. The review aim… fying the risk factors; explori… risky behaviour; and docume… a number of databases (e.g.… assessed based on their titles… flood fatality data from fou… factors from these selected s… The results of the review ind… (7 studies). People's decision… their risk perception and th… that interdependently contri… theory that has been utilise… people's decision-making th… edicts, and regularly evalua… addressing the challenges in… range of countries, more con… between risk factors and the… making theories.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MACQUARIE University

FLOOD RISK COMMUNICATION RESEARCH INTO PRACTICE BRIEF 1:

Driving into Floodwater

A systematic review of risks, behaviour and mitigation.

Authors: Mozumdar Arifa Ahmed, Katharine Haynes, Mel Taylor and Matalena Tofa, Department of Geography and Planning and the Department of Psychology, Macquarie University

Statement of purpose: The Research-into-Practice Brief series provides concise summaries of research findings for end-users and practitioners. The material for this brief is adapted from the academic journal publication:

Ahmed, M.A., Haynes, K., Taylor, M. (2018). Assessing the risks of driving into floodwater: A systematic review. International Journal of Disaster Risk Reduction. 31, pp953-963

AIM

This review aims to compare and document the international research on driving into floodwater; identify risk factors; document theoretical models used to explain people's risky behaviours; and identify intervention strategies utilised or proposed.

METHOD

The review utilised a systematic literature review methodology. This is different to a standard literature review as it employs rigorous methods to identify, appraise and synthesize the data. A systematic review enables a complete review of all available literature and is able to be replicated by others. A systematic review protocol was prepared and registered in PROSPERO. The protocol states the objectives, questions, inclusion and exclusion criteria, and intensive search strategies. Search terms included 'flood', 'risk', 'drowning', 'driving' and 'vehicles', and articles published before 31 August 2017 were included. A total of 968 titles, 430 abstracts and 52 full texts were reviewed. Of these, 24 peer-reviewed articles met the selection criteria.

RISK FACTORS IDENTIFIED

Risk factors identified in the 24 studies were classified into seven categories:

Reasons for driving into floodwater:

- Continuing intended travel, traveling home, commuting to or from work or an appointment, visiting, evacuating, to rescue someone, to recover something.

Demographic factors:

- Gender: Majority of the fatalities are males.
- Age: Those <29, although two studies identified higher ages. USA, 20-69 (Kellar and Schmidlin 2012). Greece, 40-69 (Diakakis and Deligiannakis, 2013).

Situational factors:

- Road type and characteristics: the absence of barricades, absence of lighting, dipping road grade, lack of curb and guttering, and the inability of motorists to easily turn around (Gissing et al., 2017).
- Catchment: small upstream (increased rate of rise) (Gissing et al., 2017).
- Type of vehicle: increasing numbers of 4WD and SUV.
- Road familiarity and distance to travel: Familiarity may embolden, majority of fatalities occurred within 20 km of the individual's home (Haynes et al., 2017), however one study also identified that those on a long journey were most likely to incorrectly judge levels of risk (Ruin et al., 2007).

Environmental factors:

- Time of day: most fatalities occurred at night, dawn or dusk when visibility is poor (Haynes et al., 2017).
- Seasons: In Australia, a seasonal trend is identified associated with the wet season and summer storms (Haynes et al., 2017).

Flood risk indicators:

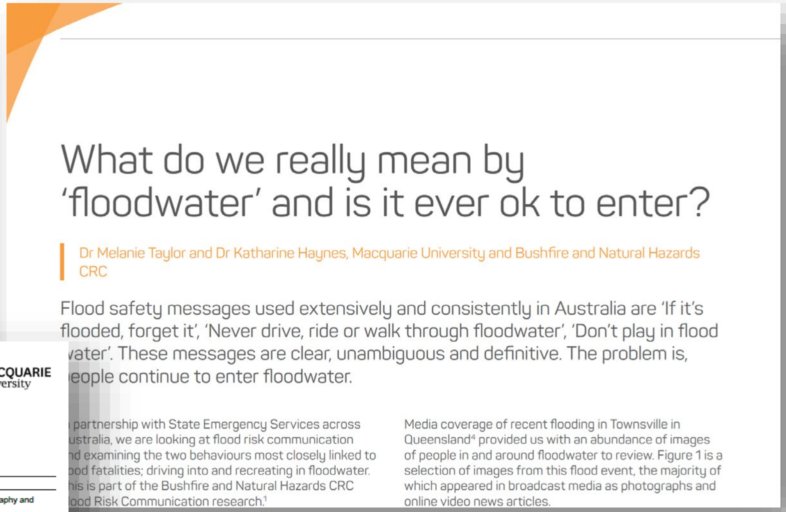
- The influence of road signs, height or water depth indicators, barricades, and warning and education campaigns have not been well evaluated (Haynes et al., 2017).

Social factors:

- Avoiding isolation and being stranded, behaviour of other drivers; and security of others being present if rescue was needed (Pearson and Hamilton, 2014).
- Influence of others: pressure from other drivers; encouragement by passengers. In an Australian study drivers were alone in the vehicle in 58% of cases, the remaining 42% of drivers drove into floodwaters with passengers in the vehicle (Peden et al., 2017).

Individual factors:

- Personal beliefs, past experience, self-efficacy, confidence, risk perceptions and drug/alcohol use


What do we really mean by 'floodwater' and is it ever ok to enter?

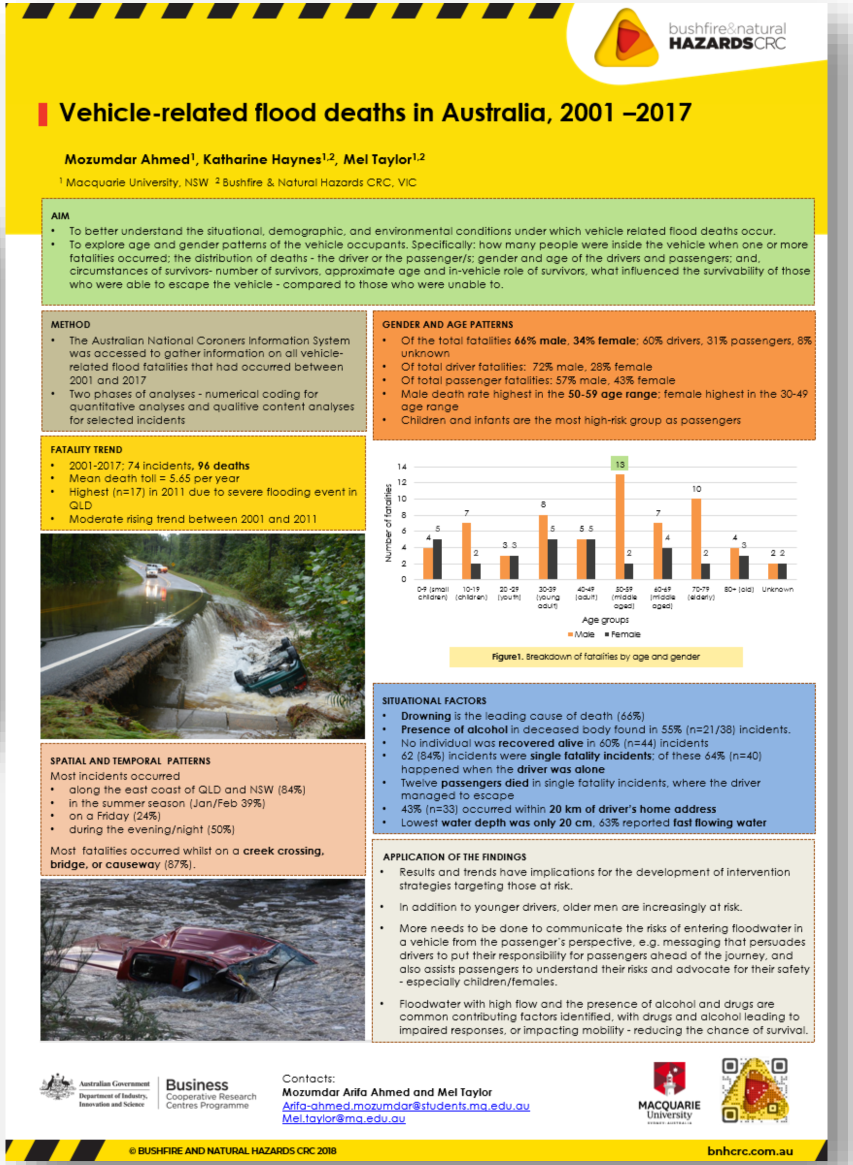
Dr Melanie Taylor and Dr Katharine Haynes, Macquarie University and Bushfire and Natural Hazards CRC

Flood safety messages used extensively and consistently in Australia are 'If it's flooded, forget it', 'Never drive, ride or walk through floodwater', 'Don't play in flood water'. These messages are clear, unambiguous and definitive. The problem is, people continue to enter floodwater.

…partnership with State Emergency Services across …ustralia, we are looking at flood risk communication …nd examining the two behaviours most closely linked to …ood fatalities; driving into and recreating in floodwater. …his is part of the Bushfire and Natural Hazards CRC …ood Risk Communication research.[1]

Media coverage of recent flooding in Townsville in Queensland[4] provided us with an abundance of images of people in and around floodwater to review. Figure 1 is a selection of images from this flood event, the majority of which appeared in broadcast media as photographs and online video news articles.

AJEM Vol 34 (2) April 2019


bushfire&natural HAZARDSCRC

Vehicle-related flood deaths in Australia, 2001 –2017

Mozumdar Ahmed[1], Katharine Haynes[1,2], Mel Taylor[1,2]

[1] Macquarie University, NSW [2] Bushfire & Natural Hazards CRC, VIC

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- To better understand the situational, demographic, and environmental conditions under which vehicle related flood deaths occur.
- To explore age and gender patterns of the vehicle occupants. Specifically: how many people were inside the vehicle when one or more fatalities occurred; the distribution of deaths - the driver or the passenger/s; gender and age of the drivers and passengers; and, circumstances of survivors- number of survivors, approximate age and in-vehicle role of survivors, what influenced the survivability of those who were able to escape the vehicle - compared to those who were unable to.

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- Two phases of analyses - numerical coding for quantitative analyses and qualitive content analyses for selected incidents

GENDER AND AGE PATTERNS

- Of the total fatalities **66% male**, **34% female**; 60% drivers, 31% passengers, 8% unknown
- Of total driver fatalities: 72% male, 28% female
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Figure1. Breakdown of fatalities by age and gender

SPATIAL AND TEMPORAL PATTERNS

Most incidents occurred

- along the east coast of QLD and NSW (84%)
- in the summer season (Jan/Feb 39%)
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Most fatalities occurred whilst on a **creek crossing, bridge, or causeway** (87%).

SITUATIONAL FACTORS

- **Drowning** is the leading cause of death (66%)
- **Presence of alcohol** in deceased body found in 55% (n=21/38) incidents.
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APPLICATION OF THE FINDINGS

- Results and trends have implications for the development of intervention strategies targeting those at risk.
- In addition to younger drivers, older men are increasingly at risk.
- More needs to be done to communicate the risks of entering floodwater in a vehicle from the passenger's perspective, e.g. messaging that persuades drivers to put their responsibility for passengers ahead of the journey, and also assists passengers to understand their risks and advocate for their safety - especially children/females.
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MACQUARIE University

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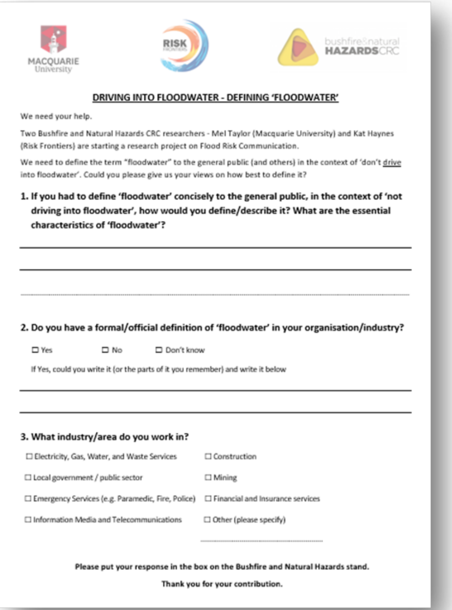
Poster presentation: Thursday 3.28 – 3.31pm

Survey-based research



DRIVING INTO FLOODWATER - DEFINING 'FLOODWATER'

We need your help.

Two Bushfire and Natural Hazards CRC researchers - Mel Taylor (Macquarie University) and Kat Haynes (Risk Frontiers) are starting a research project on Flood Risk Communication.

We need to define the term "floodwater" to the general public (and others) in the context of 'don't drive into floodwater'. Could you please give us your views on how best to define it?

1. If you had to define 'floodwater' concisely to the general public, in the context of 'not driving into floodwater', how would you define/describe it? What are the essential characteristics of 'floodwater'?

2. Do you have a formal/official definition of 'floodwater' in your organisation/industry?

☐ Yes ☐ No ☐ Don't know

If Yes, could you write it (or the parts of it you remember) and write it below

3. What industry/area do you work in?

☐ Electricity, Gas, Water, and Waste Services ☐ Construction
☐ Local government / public sector ☐ Mining
☐ Emergency Services (e.g. Paramedic, Fire, Police) ☐ Financial and Insurance services
☐ Information Media and Telecommunications ☐ Other (please specify)

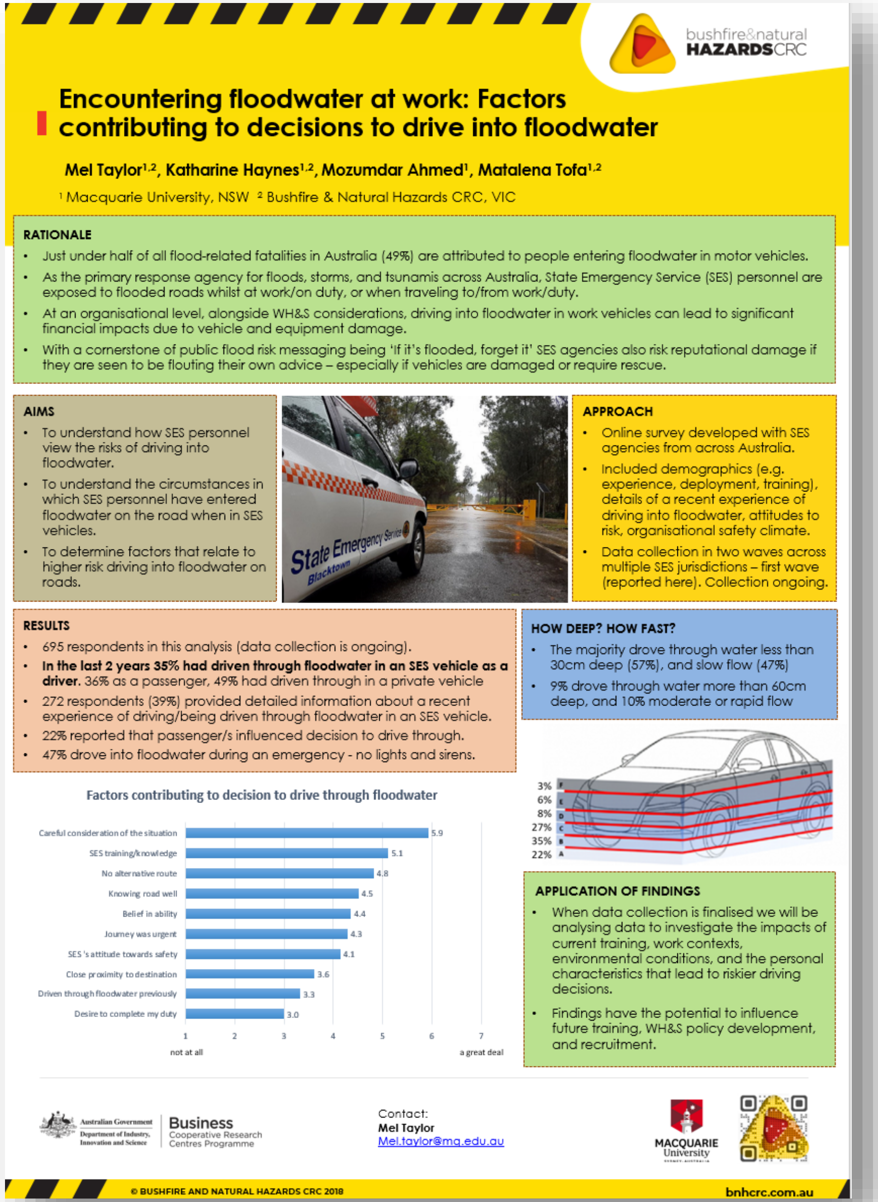
Please put your response in the box on the Bushfire and Natural Hazards stand.

Thank you for your contribution.

1. Defining floodwater

2. Encountering floodwater at work
   - multiple SES jurisdictions

3. Driving and playing in floodwater
   - public survey



Encountering floodwater at work: Factors contributing to decisions to drive into floodwater

Mel Taylor[1,2], Katharine Haynes[1,2], Mozumdar Ahmed[1], Matalena Tofa[1,2]

[1] Macquarie University, NSW [2] Bushfire & Natural Hazards CRC, VIC

RATIONALE

- Just under half of all flood-related fatalities in Australia (49%) are attributed to people entering floodwater in motor vehicles.
- As the primary response agency for floods, storms, and tsunamis across Australia, State Emergency Service (SES) personnel are exposed to flooded roads whilst at work/on duty, or when traveling to/from work/duty.
- At an organisational level, alongside WH&S considerations, driving into floodwater in work vehicles can lead to significant financial impacts due to vehicle and equipment damage.
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AIMS

- To understand how SES personnel view the risks of driving into floodwater.
- To understand the circumstances in which SES personnel have entered floodwater on the road when in SES vehicles.
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APPROACH

- Online survey developed with SES agencies from across Australia.
- Included demographics (e.g. experience, deployment, training), details of a recent experience of driving into floodwater, attitudes to risk, organisational safety climate.
- Data collection in two waves across multiple SES jurisdictions – first wave (reported here). Collection ongoing.

RESULTS

- 695 respondents in this analysis (data collection is ongoing).
- **In the last 2 years 35% had driven through floodwater in an SES vehicle as a driver.** 36% as a passenger, 49% had driven through in a private vehicle
- 272 respondents (39%) provided detailed information about a recent experience of driving/being driven through floodwater in an SES vehicle.
- 22% reported that passenger/s influenced decision to drive through.
- 47% drove into floodwater during an emergency - no lights and sirens.

HOW DEEP? HOW FAST?

- The majority drove through water less than 30cm deep (57%), and slow flow (47%)
- 9% drove through water more than 60cm deep, and 10% moderate or rapid flow

APPLICATION OF FINDINGS

- When data collection is finalised we will be analysing data to investigate the impacts of current training, work contexts, environmental conditions, and the personal characteristics that lead to riskier driving decisions.
- Findings have the potential to influence future training, WH&S policy development, and recruitment.

Australian Government Department of Industry, Innovation and Science | Business Cooperative Research Centres Programme

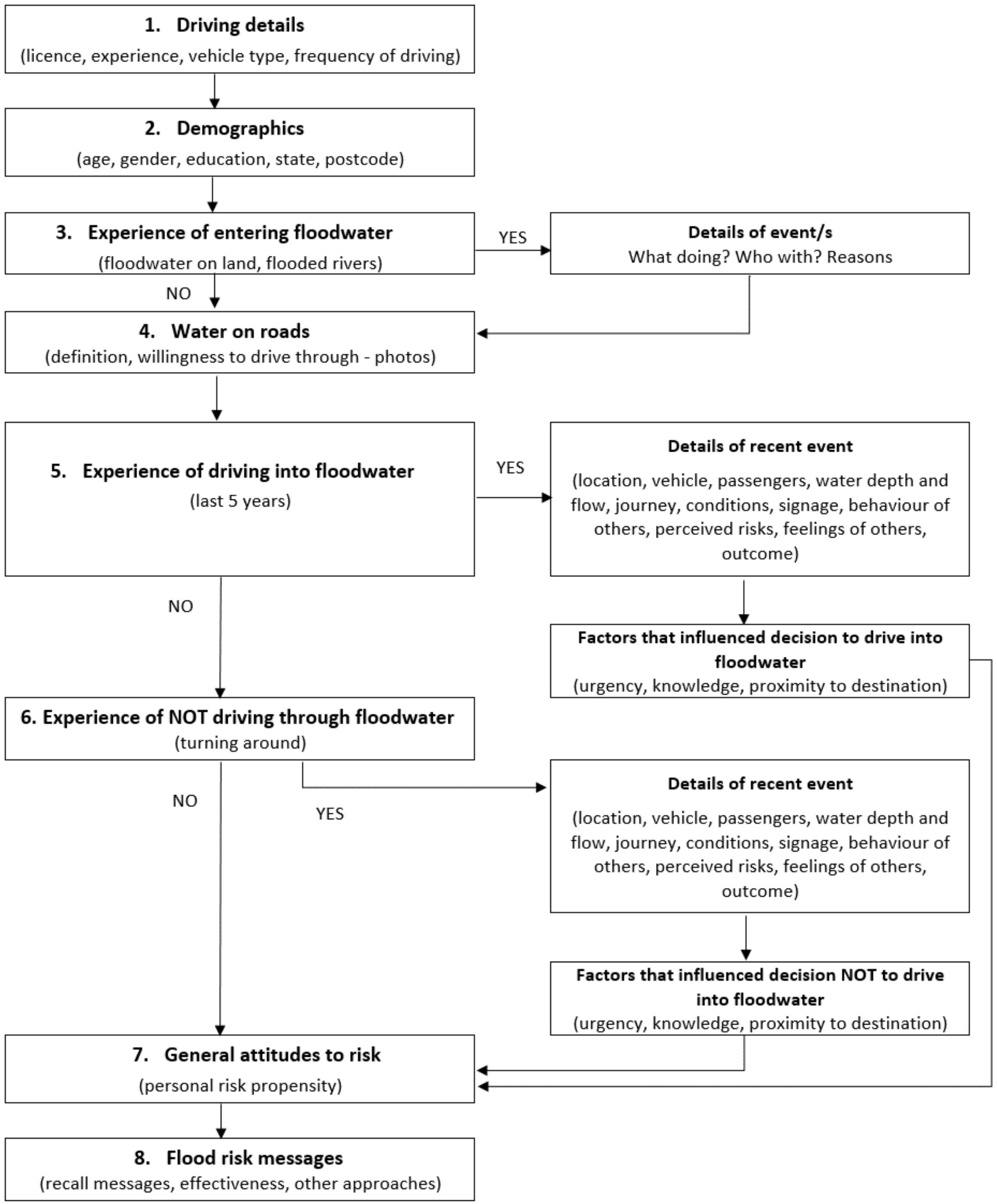
Contact:
Mel Taylor
Mel.taylor@mq.edu.au

bnhcrc.com.au

Poster presentation: Thursday 1.21 – 1.24 pm

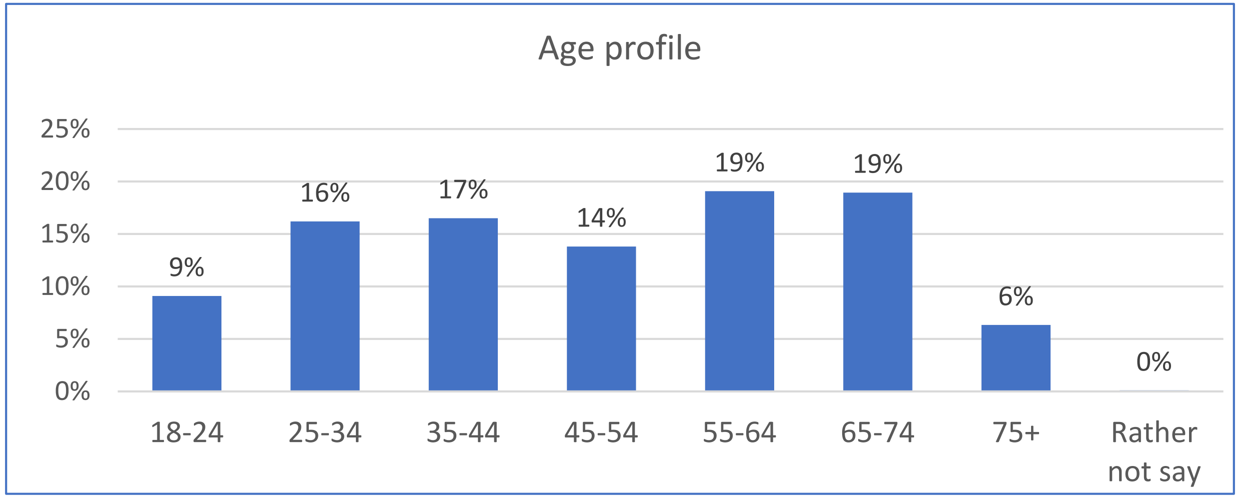
Australia speaks

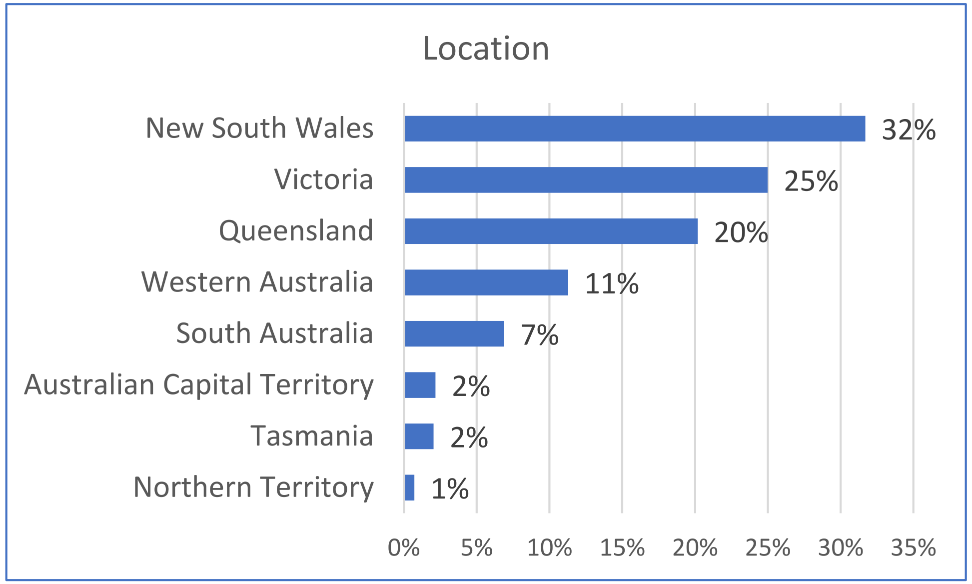
- Online survey
- Data collected
    - Dec 2018 – Jan 2019
- Structure
    - multiple sections
    - tick boxes - efficient to complete
    - mirrored occupational survey (SES)



Driving details and demographics

- Sample characteristics
  - 2270 respondents
  - 51% male, 49% female





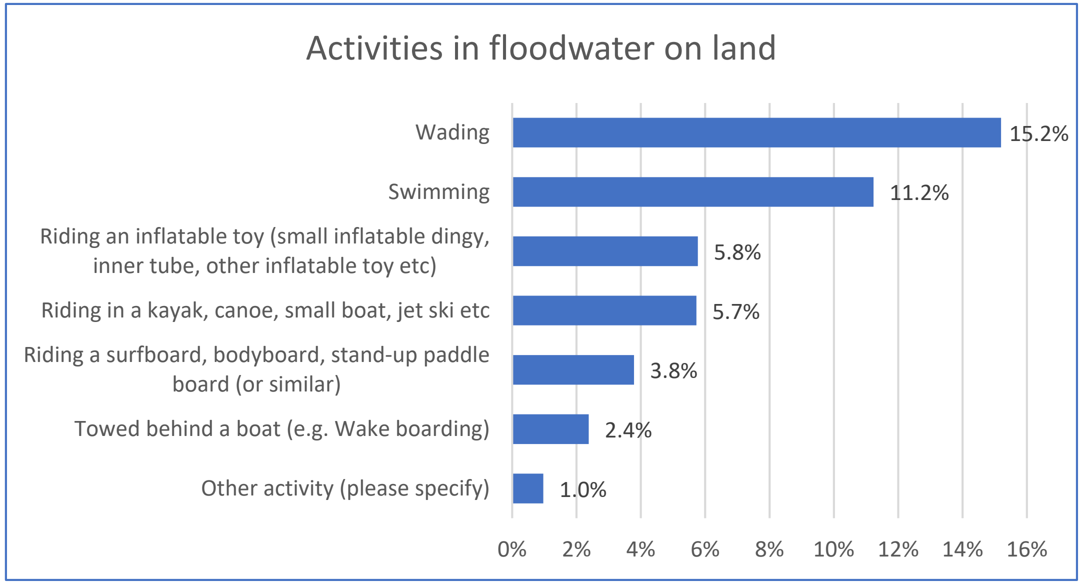
- Driving characteristics
  - 91% drivers
  - 76% had held a driving licence for 10+ years
  - 44% usually drive medium/large cars
  - 41% drive 2-7 hours per week
  - 53% 2WD, 16% 4WD, 16% AWD

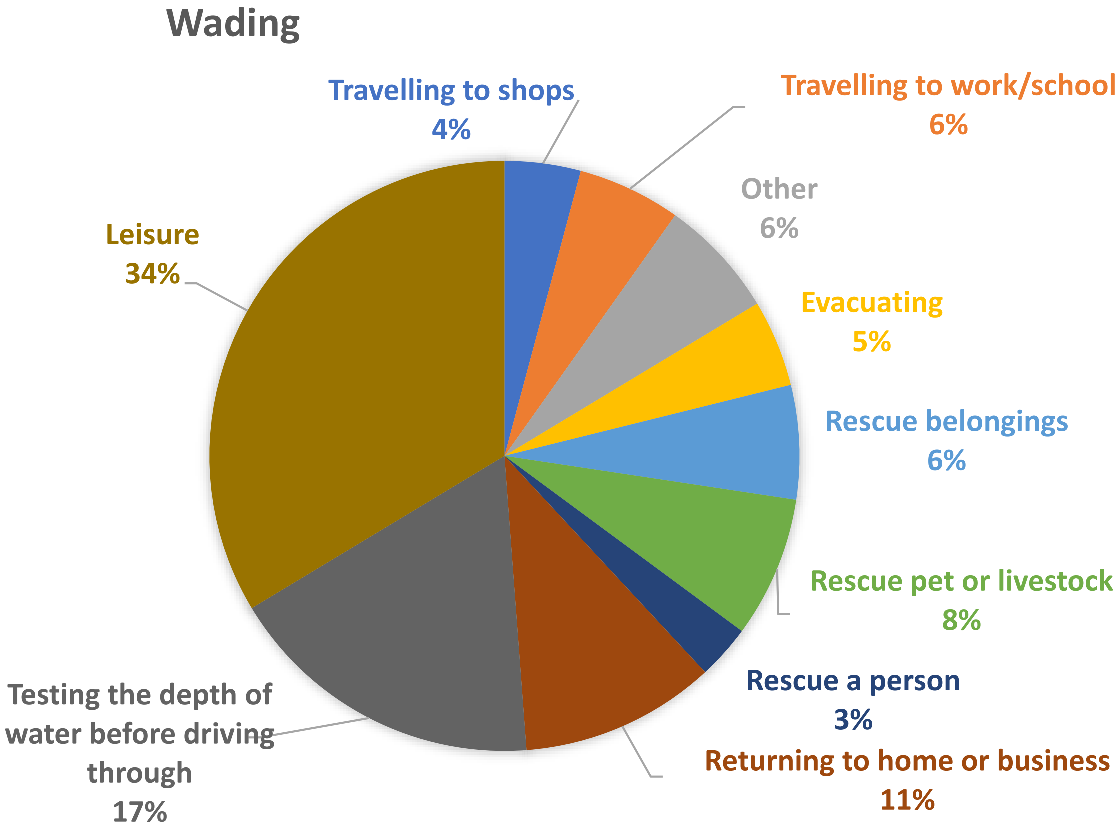
Entering floodwater on land

- Floodwater on land

(where it normally isn't, e.g. flooded park or street)

  - 28% had engaged in activities in floodwater on land



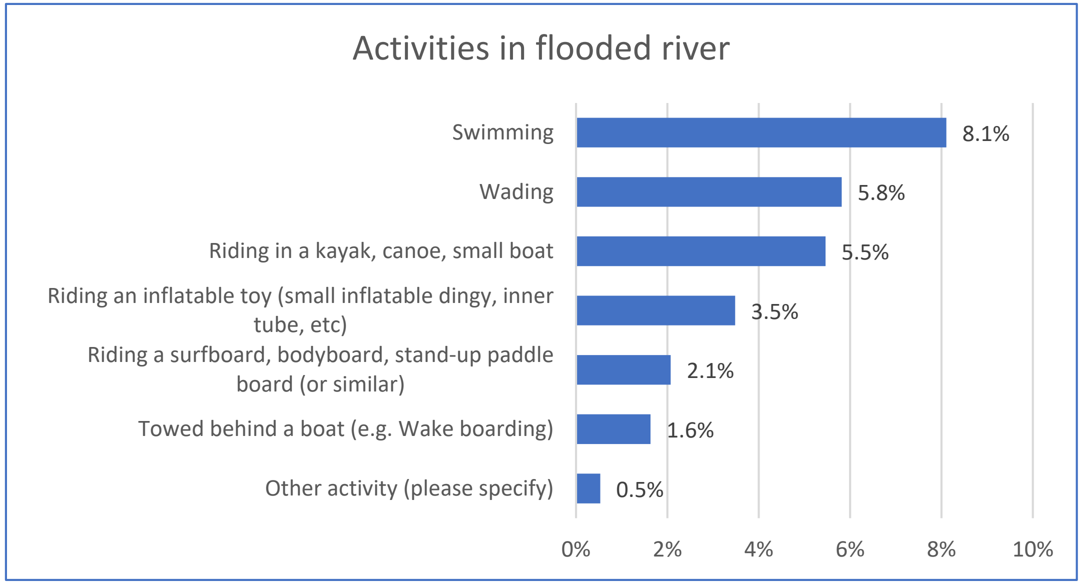


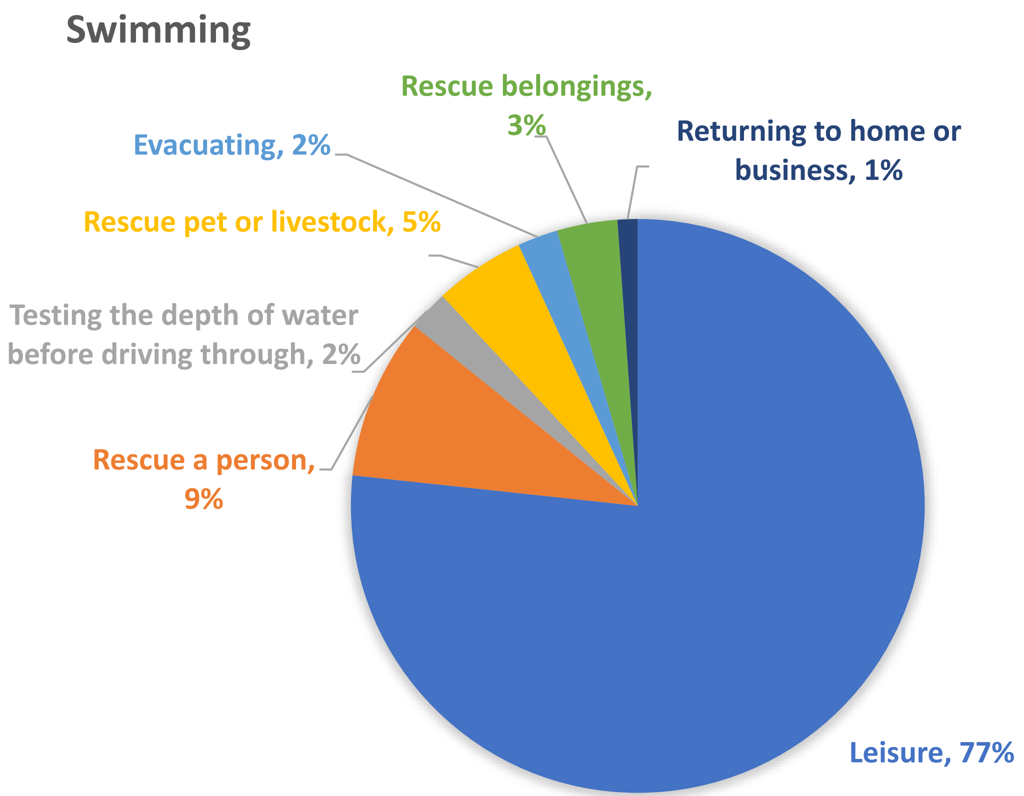
Entering flooded river

- Flooded river

  (deeper/faster flowing than normal)

  - 19% had engaged in activities in a flooded river





Water on roads

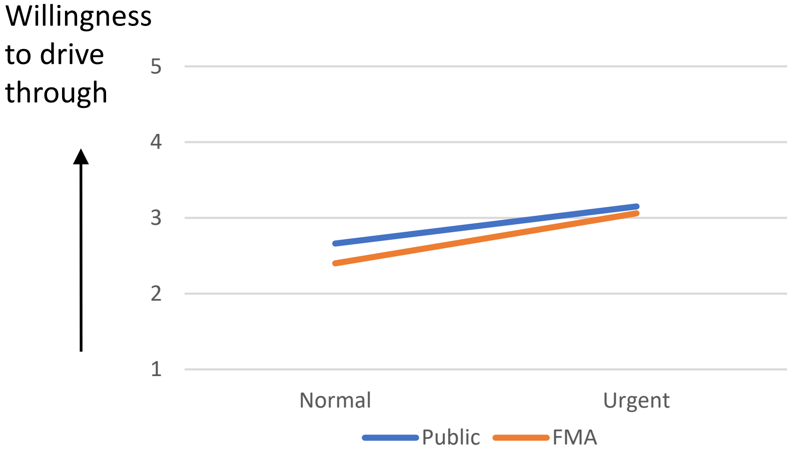
Willingness to drive through water over the road

- Extensively piloted – including at FMA 2018
- Data collected from a number of different groups

1. Would you consider driving through this water…
   - in normal/everyday situation?
   - in urgent situation?
2. Would you consider this road flooded?

Water on roads

Image 1



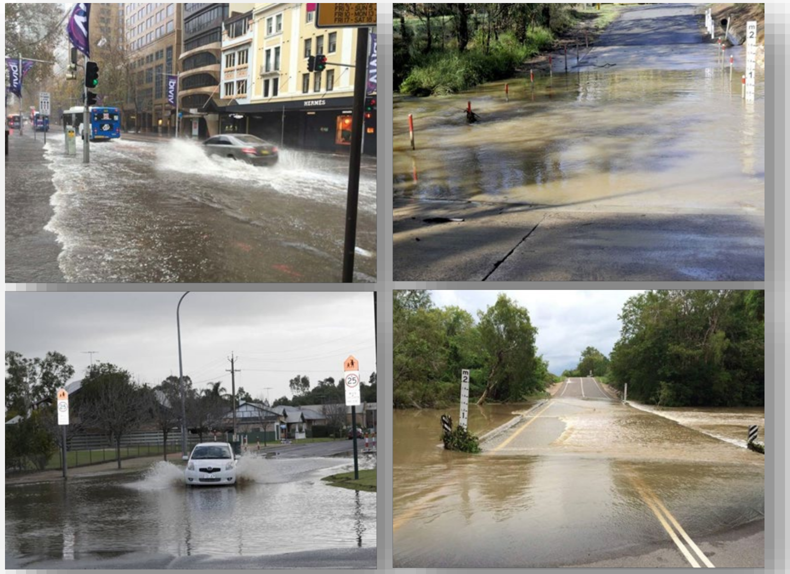


Image 2

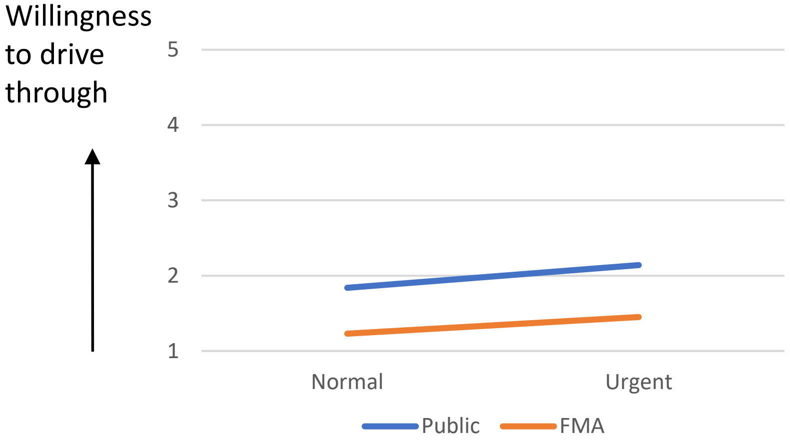


Image 3

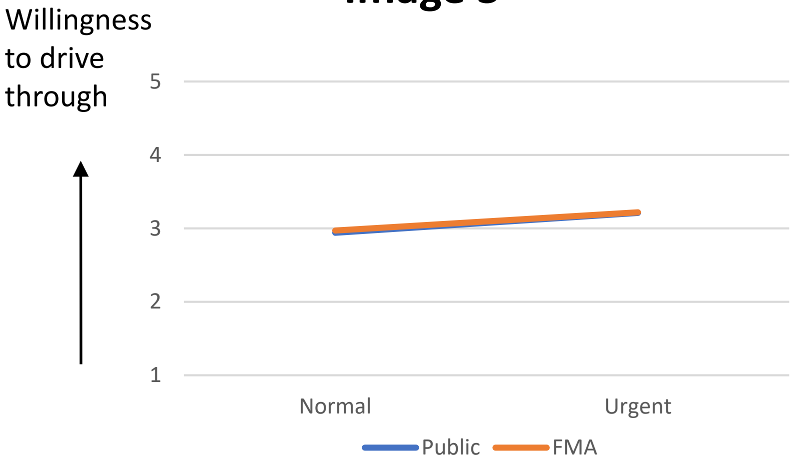
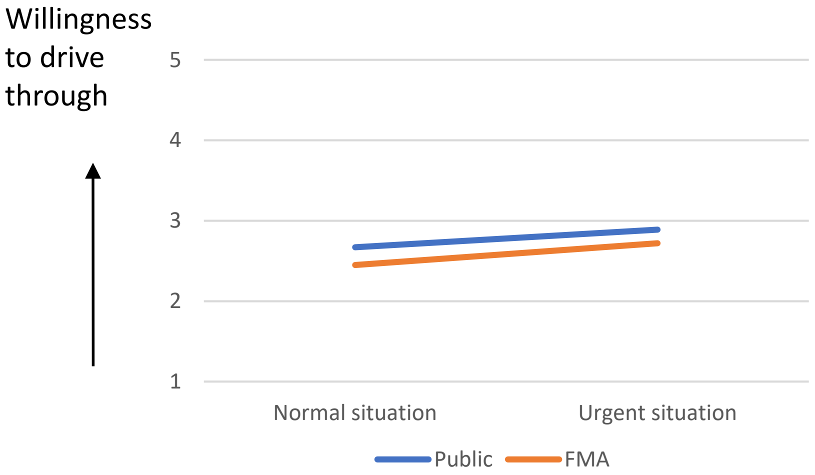


Image 4



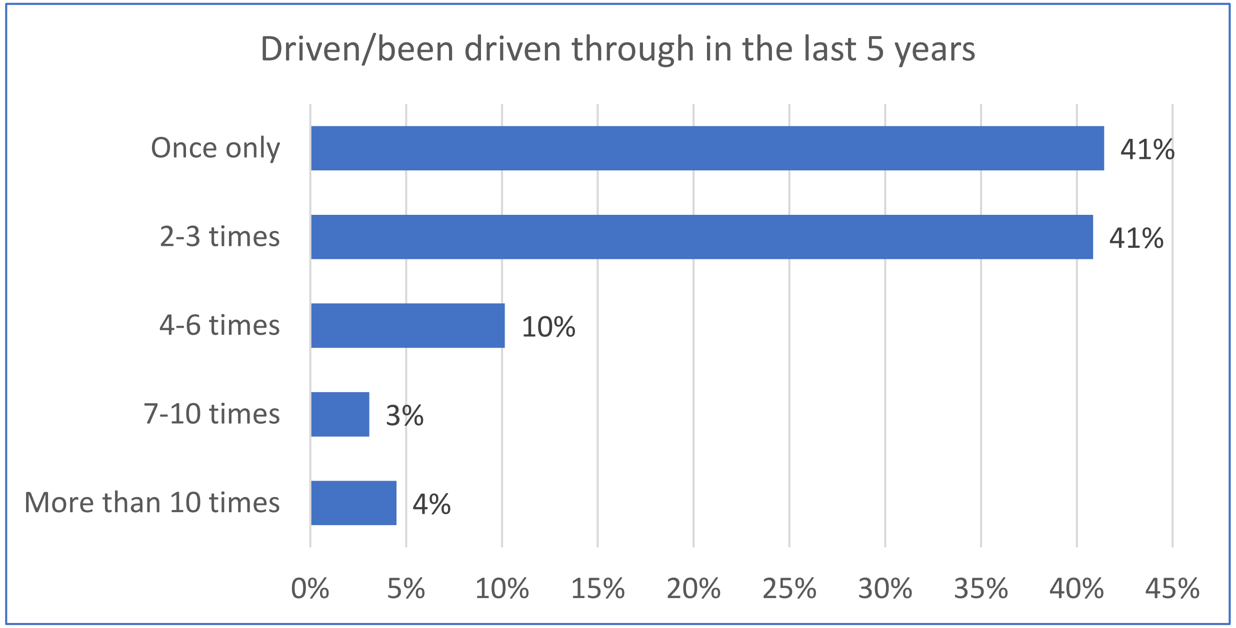
Experience of driving into floodwater

Definition

- Water across the road surface
- Little to no visibility of the road surface markings under the water (i.e. uncertainty of road quality/integrity and possibly depth)
- Water on normally dry land – flowing or still

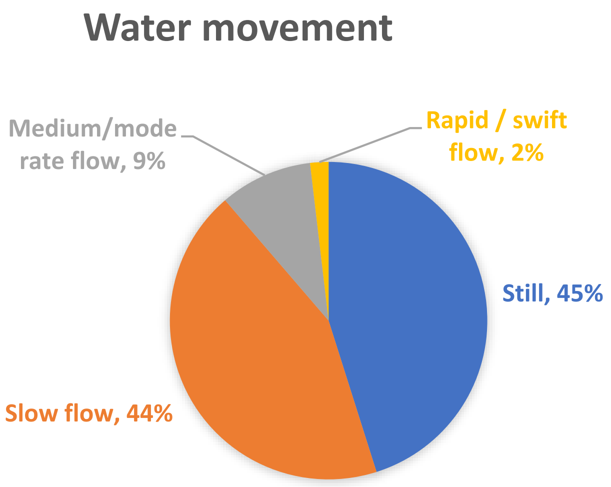
56% - ever driven/been driven through floodwater

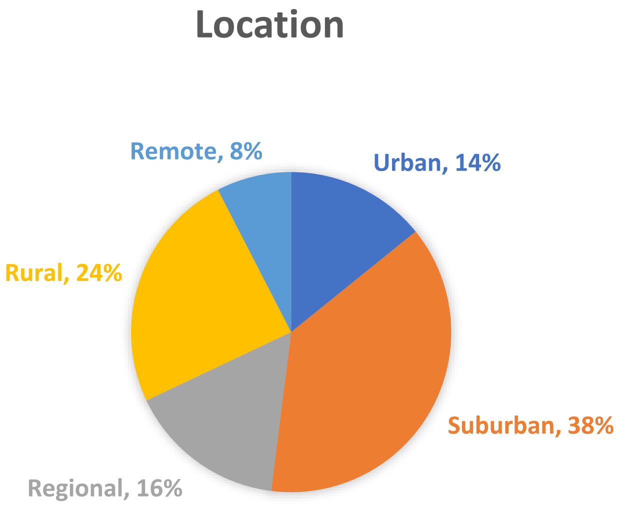
- More likely – if male, rate driving ability high, undertaken advanced driving course, higher weekly driving hours.

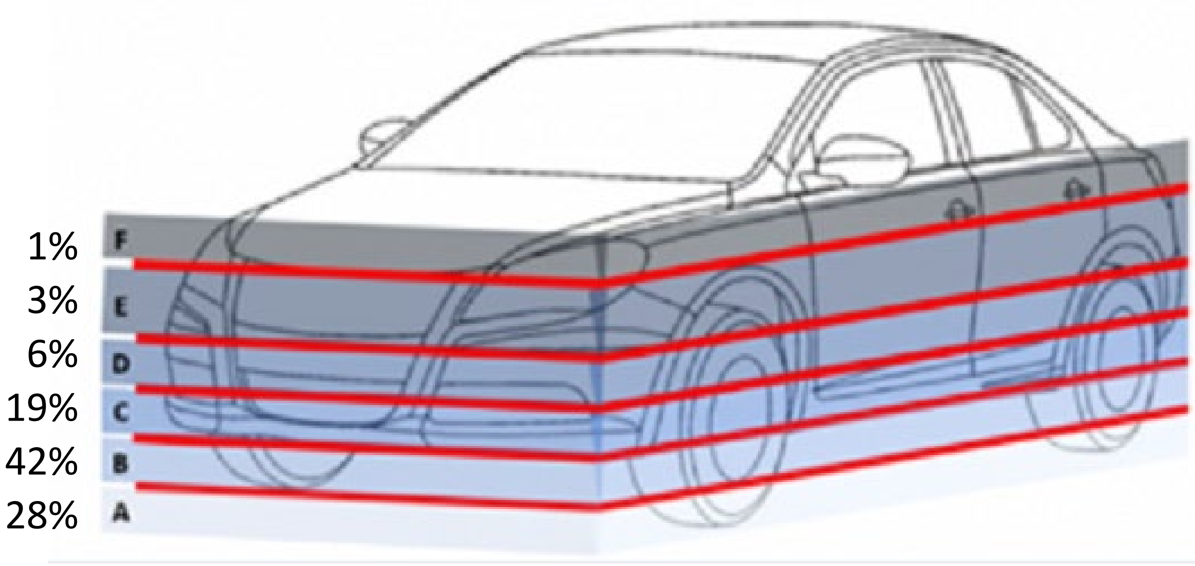


Experience of driving into floodwater

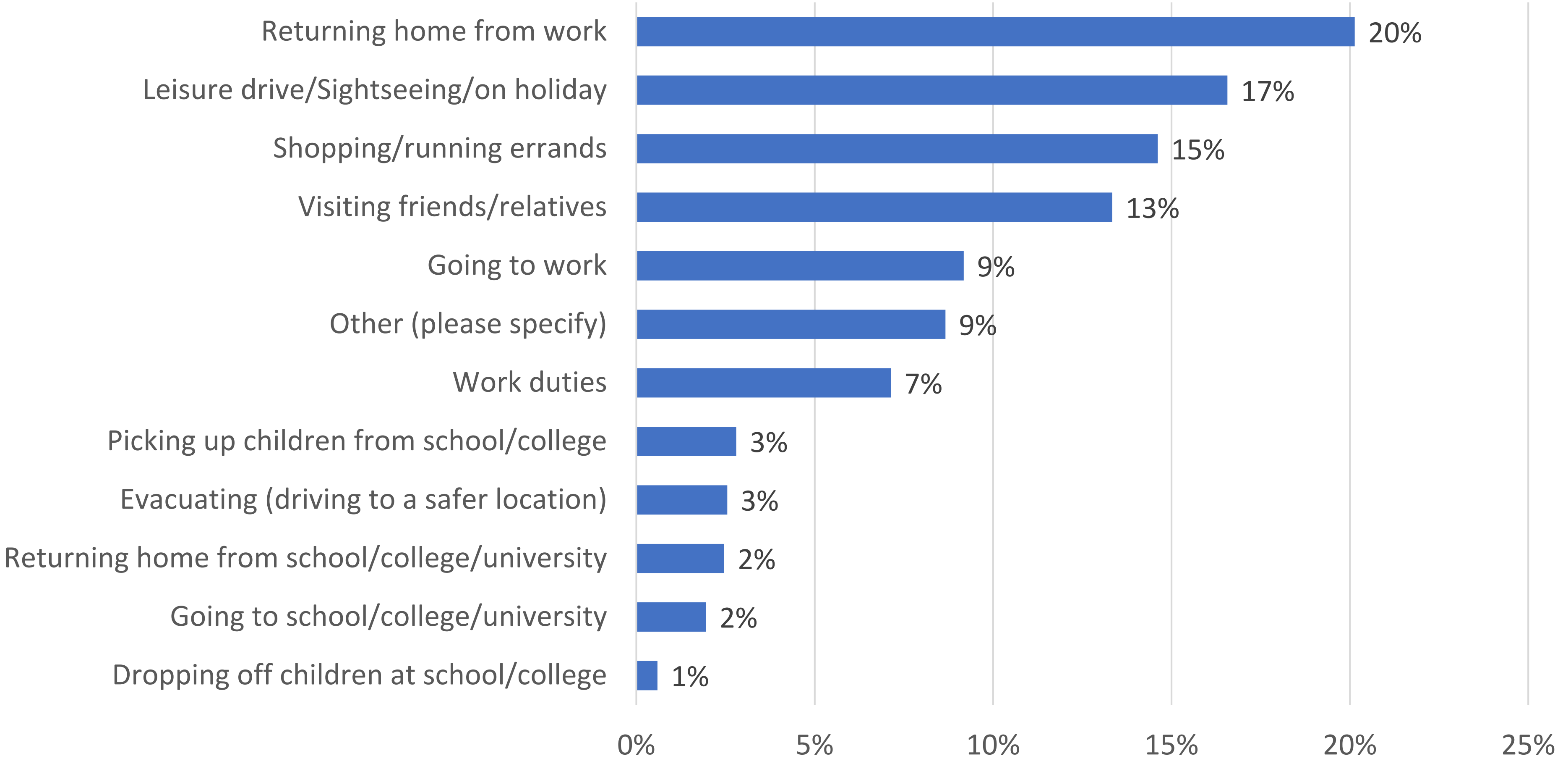
- 55% of sample (n=1157) provided details of a single recent/memorable experience of driving through floodwater



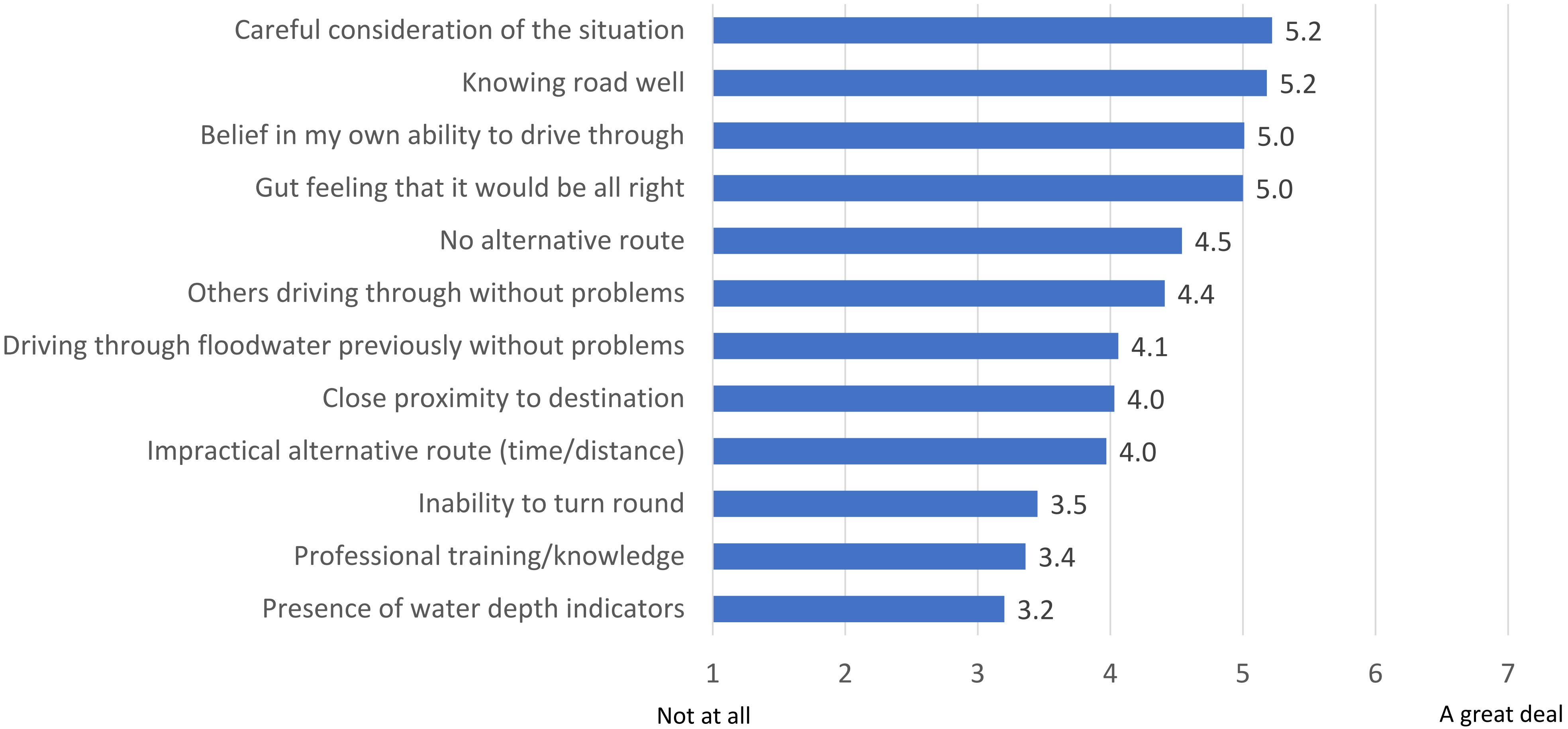




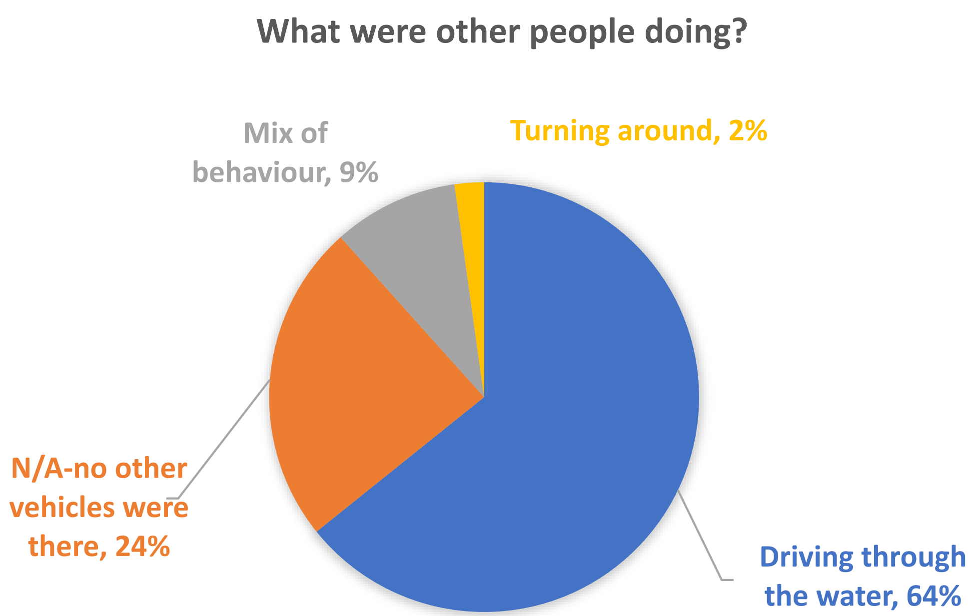
What were you doing?



Factors influencing decision to drive through floodwater



Influence of others

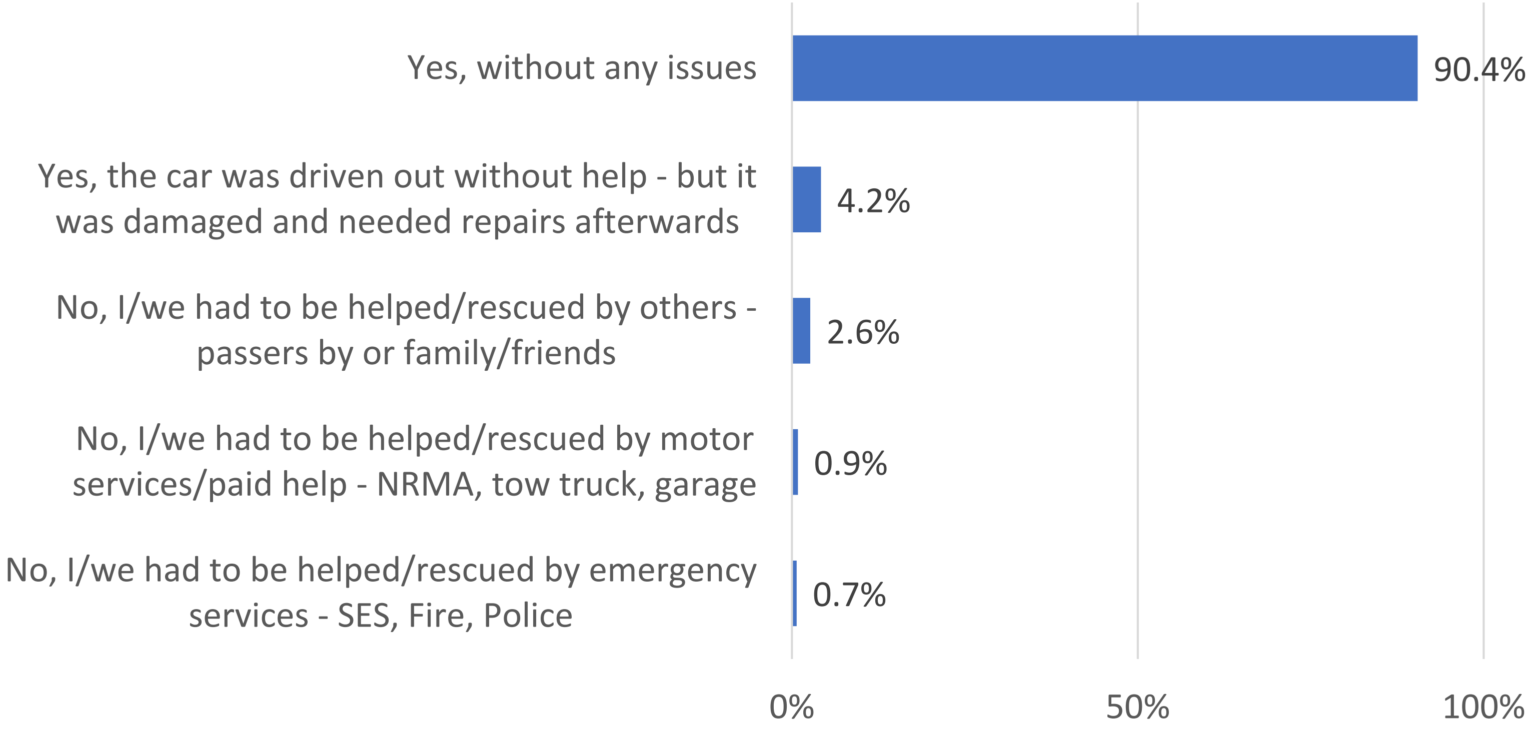


15% reported that passengers influenced their decision to drive through floodwater.

Themes	No. (/97)	
Coercion/pressure (suggested – convinced – told)	30	“Husband said it would be ok has driven through worse”, “Yes, kids were nagging”, “My father told me to floor it”, “Convinced the driver that it was safe to go thru”
Consensus (agreed – discussed – decided)	25	“With mates we all assessed and it looked fine”, “We both agreed it was ok”
Urgency of journey	13	“We needed to get to the airport”, “My daughter was due to sit an exam at school”, “Getting dark”, “We had to get out now or we would have been cut off without food”
Wading first	4	‘Walked it for me first”, “My partner checked it out by walking across it”

Outcomes of driving into floodwater

Did you succeed in driving through floodwater on this occasion? (n=1172)



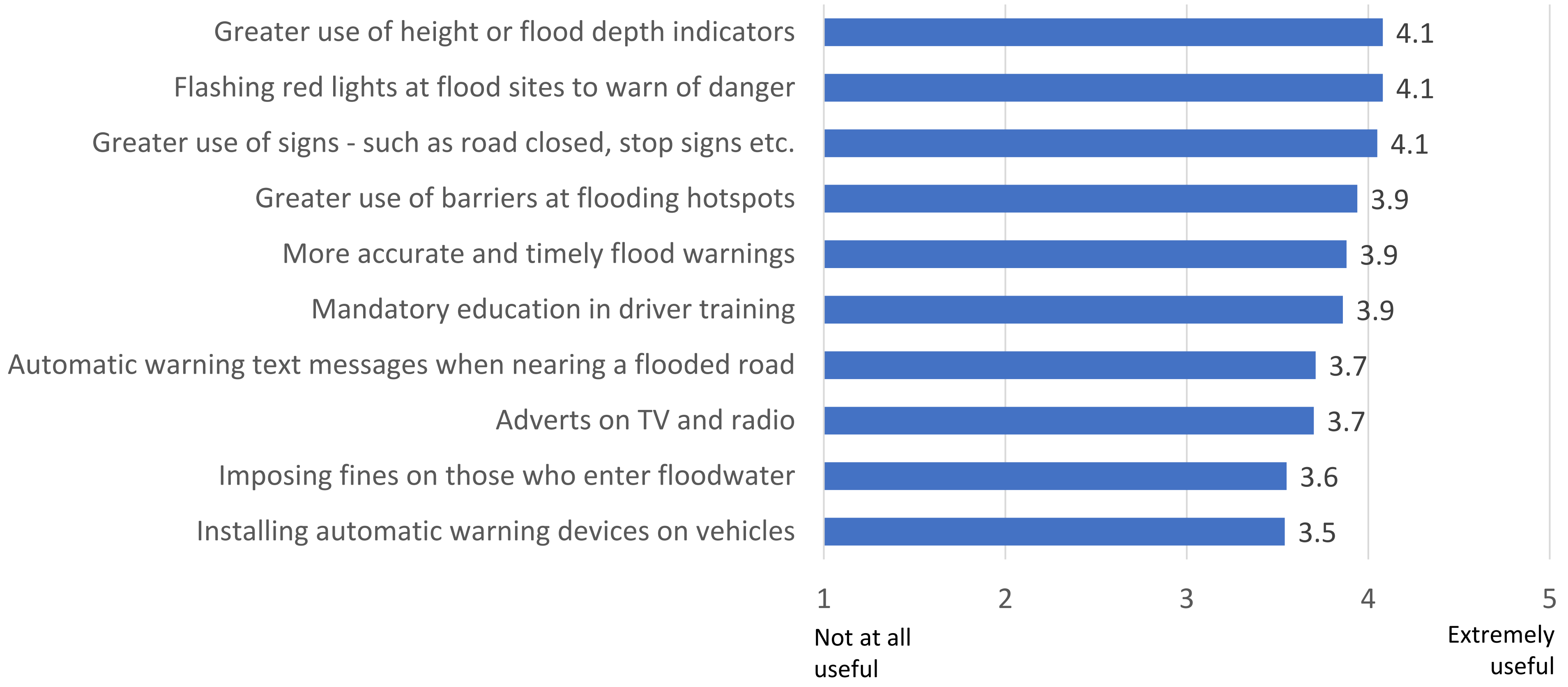
Recall of flood risk messaging

40% (n=852) recalled seeing official campaigns aimed at preventing people driving or playing in floodwater.

Of those, 134 respondents (16%) accurately recalled ‘If it’s flooded, forget it’

- “A car can float in 15cm of water”, “only a small amount of water can float a car”, “more than 10 cm can wash your car away”
- “Things might be submerged”, “you can’t see what’s under the water”, “There could be hidden dangers”
- “Not driving or riding in floodwater”, “Don’t walk through floodwaters”, “If it’s flooded, don’t do it”
- “It’s not worth the risk”, “Stay out of floodwaters”, “consider the people who have to rescue you”, “Don’t swim in flooded creeks or rivers”, “keeping children out of floods and not getting stuck in drains”, “Poo”.

Useful approaches (from list)



Summary / next steps

- Survey data are informing how we might improve risk communication and engagement
- More analysis needed to drill down further
- Ability to compare data from the public to SES personnel and to fatality statistics
- Encourage those with interest in the data to contact our team/BNHCRC

Thank you

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