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INFLUENCE OF ROAD CHARACTERISTICS ON FLOOD FATALITIES IN AUSTRALIA

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Version	Release history	Date
1.0	Initial release of document	29/08/2017

Publisher:
Bushfire and Natural Hazards CRC

August 2017

Citation: Gissing, A., Tofa, M., Opper, S. & Haynes, K. (2017) Influence of road characteristics on flood fatalities in Australia. Melbourne: Bushfire and Natural Hazards CRC

Cover: Adelaide flooding, South Australia SES

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ABSTRACT

A recent analysis of flood fatalities in Australia identified that 49 percent of flood fatalities were vehicle related (Haynes et al., 2017). In total, some 229 flood fatalities were associated with vehicles between 1960 and 2015 (Haynes et al., 2017).

There has been some effort in recent years to address this issue through educational campaigns. There has, however, been no previous research into how the characteristics of roadways influence the decisions taken, possibility of a vehicle being washed off a roadway and the survivability of people in vehicles that enter floodwater.

This research report outlines research to determine the influence of road characteristics on flood fatalities including road structure type; roadway side barriers; downstream depths adjacent to the roadway; signage; warning systems; lighting; road pavement; road alignment; road grade; speed restrictions; traffic volume; downstream vegetation; ability for a vehicle to be turned around prior to crossing the floodway, causeway or bridge and presence of road side markers and curb and guttering.

The results of this research indicate some road characteristics that are common among sites where motorists have entered floodwaters and fatalities have occurred. These 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. It is necessary to consider the influence of different road characteristics on the risks posed to motorists during floods. Observations are also made regarding the need to consider the role of road side barricades in increasing safety and to review signage to ensure it is clear and can be readily interpreted.

INTRODUCTION

Research globally has highlighted risks to motorists during flood events. In Australia, (Haynes et al., 2017) found that 49 percent of flood fatalities were vehicle related, and Fitzgerald et al (Fitzgerald et al., 2010a) similarly found that 48.5% of flood deaths between 1997 and 2008 were vehicle related. In total, some 229 flood fatalities were associated with vehicles between 1960 and 2015 (Haynes et al., 2017). Some 64 percent of vehicle related flood fatalities have been associated with sedans and 19 percent 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 four wheel drive vehicles has increased (Haynes et al., 2017). In the last fifteen years they have contributed an equal share (Haynes et al., 2017).

In the United States, Ashley and Ashley (2008) found that 63 percent of flood fatalities were vehicle related. Similarly, Špitalar et al. (2014) found that 68 percent of flash flood fatalities were vehicle related and Terti et al. (2016) 68 percent. Jonkman and Vrijling (2008), in a study of flood fatalities across Europe and the United States identified that 32 percent of deaths were associated with vehicles. In Greece, some 40 percent of flood fatalities have been associated with vehicles (Diakakis and Deligiannakis, 2015a), with this proportion growing over-time (Diakakis and Deligiannakis, 2016). In other countries the proportions have been lower though yet significant with France 30 percent (Vinet et al., 2016) and Portugal, 14 percent (Pereira et al., 2017).

Floodwaters can submerge vehicles or sweep them away. Motorists may deliberately enter floodwaters, enter flood water un-expectantly (Yale et al., 2003) or find themselves in circumstances where floodwaters rise around their vehicle (Diakakis and Deligiannakis, 2015b). 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 centimeters of floodwater for a small passenger vehicle to become unstable and only 30 centimeters for a four-wheel drive vehicle.

Once vehicles enter water they undertake a three phase process of floating, sinking and submersion (Molenaar et al., 2014). Empirical studies have demonstrated that 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 (Molenaar et al., 2014, McDonald and Giesbrecht, 2013b). Vehicles may enter floodwater upright or roll into the stream (Smith et al., 2017). Occupants may experience difficulty in escaping their vehicles due to flood conditions, physical trauma, failure of electric windows, automatic locking doors or the activation of airbags (Molenaar et al., 2014). Vehicles entering deeper water have been associated with lower survival rates (McDonald and Giesbrecht, 2013a).

Research indicates that people drown in their vehicle as a result of the vehicle being inundated, being washed away (Drobot et al., 2007, Kellar and Schmidlin, 2012, Yale et al., 2003), attempting to escape a vehicle by trying to swim or walk to safety (Drobot et al., 2007, Kellar and Schmidlin, 2012, Yale et al., 2003) or by being ejected from a vehicle (Kellar and Schmidlin, 2012).

Explanations for motorists deliberately entering floodwater include: not taking warnings seriously (Drobot et al., 2007), underestimating the risk (Diakakis and Deligiannakis, 2013, Maples and Tiefenbacher, 2009, Drobot et al., 2007), 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, Maples and Tiefenbacher, 2009, Jonkman and Kelman, 2005) and it is possible that motorists may not fully appreciate flood conditions such as the depth and speed of floodwaters, and the influence such conditions may have on safety (Diakakis and Deligiannakis, 2013, Yale et al., 2003). It has also been suggested that motorists may recognise the risk but fail to personalise it, believing that the risk does not apply to them (Pearson and Hamilton, 2014). Hamilton et al. (2016) identify 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.

A large percentage of flood rescues undertaken by emergency services are also vehicle related. Haynes et al. (2009) analysed flood rescue incident reports following flooding in the Hunter River Catchment, NSW in June 2007 and found that 36 percent of rescues had been from vehicles. Further approximately a third of the some 300 flood rescues performed by New South Wales State Emergency Service during flooding around Sydney in June, 2016 were from vehicles (Smith et al., 2017). Such rescues place emergency services personnel at high risk.

Existing approaches utilised in Australia to reduce the instance of vehicle related flood fatalities have focused on education and engagement campaigns such as the Queensland Government's "If it is flooded, forget it" campaign and most recently the Victorian Government's "15 to float" campaign. In the United States, authorities have conducted a campaign called "Turn around don't drown". The effectiveness of these campaigns are largely unknown in terms of reducing the actual incidence of motorists entering floodwater. 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. However, the authors found in isolation education, information and publicity generally did not deliver tangible and sustained reductions in deaths and serious injuries.

Engineering measures in the form of signage and flood closure gates are utilized to influence driver behavior when making decisions to enter floodwaters. Signage is the more frequently used measure consisting of depth markers and advisory signs. In addition, road operators and emergency services will attempt to place physical barricades across flooded roads to prevent drivers from entering floodwater.

Enforcement of dangerous driving laws has also been used to dissuade motorists from entering floodwater and has grown over recent years in Australia. Similar law enforcement practices occur in the United States for example specific state legislation in the State of Arizona focused on prevention of drivers entering floodwater. Despite these efforts many motorists continue to enter floodwaters.

The risk of a motorist entering floodwater is dependent upon the decision making of a driver and the characteristics of a flood prone road. Previous research on flood fatalities in Australia has focused on the demographics of the deceased; activity at time of incident; location; and reasoning (Haynes et al., 2009, FitzGerald et al., 2010b, Coates, 1999, Haynes et al., 2017). Little research to date has focused on the characteristics of roadways where fatalities have occurred. Austroads (2015), a 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, lack appropriate signage and that depth gauges can be miss-interpreted. Further they propose that implementation of safety measures at floodways should consider the level of risk, appropriate treatments and resources necessary for implementation.

Floodways are typically constructed where it is impracticable to build a bridge or culvert based structure (Austroads, 2015). Austroads (2015) state that floodways should be designed so that the road provides the level of access required and where flood flows exceed the design, the road should be closed. However, this is often difficult due to the limited resources of road operators and emergency services.

Specific guidelines for the construction of floodways are outlined in Austroads (2013) and further detailed in Austroads (2015), including the following safety considerations:

- That adequate approach sight distance is 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 that design should resist scour and washouts;
- The length of a floodway should not exceed 300m so that motorists do not become disorientated;
- That motorists should be able to turn vehicles around; and
- Signage consistent with Australian standards (including AS 1742.2) should be provided including road subject to flooding signage and depth markers.

METHODS

To investigate road design at sites where flood fatalities have occurred a combination of the Risk Frontiers PerilAus database and recent media articles were used to identify locations where vehicle related flood fatalities had occurred. A selection of twenty-one sites across the Australian jurisdictions of New South Wales (NSW), Queensland (QLD), Western Australia (WA), Victoria (VIC) and the Australian Capital Territory (ACT) were identified for analysis based upon the quality of information available and ease of access to the site. These sites accounted for 28 deaths, representing approximately 50 percent of total vehicle related flood fatalities between 2010 and March 2017. Table 1 provides a list of the sites that were inspected including location and year of incident. The location of sites is shown in Figure 1.

TABLE 1. SITES VISITED FOR THIS STUDY

Site Number	Location	Date of Incident	No of incidents	No of fatalities
1	Lismore / Kyogle, NSW	2016	1	1
2	Esperance, WA,	2017	1	1
3	Jerdacuttup, WA	2017	1	1
4	Lockhart, NSW	2011	1	1
5	Mullumbimby, NSW	2014	1	1
6	Bowral, NSW	2016	1	1
7	Leppington, NSW	2016	1	1
8	Maitland, NSW	2015	1	1
9	Canberra, ACT	2016	1	1
10	Seymour, VIC	2016	1	1
11	Karrabin, QLD	2011	1	1
12	Greenbank, QLD	2013	1	1
13	Glen Cairn, QLD	2013	2	2
14	Junction View, QLD	2010	1	1
15	Brymaroo, QLD	2011	1	1
16	Toowoomba East Creek, QLD	2011	1	2
17	Helidon, QLD	2011	1	1
18	Grantham, QLD	2011	1	3
19	Caboolture, QLD	2015	2	5
20	Burpengary, QLD	2015	1	1
21	Bundaberg, QLD	2016	1	1

Analysis of each site involved observational assessment of 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; downstream vegetation; ability for a vehicle to be turned around prior to crossing the floodway, causeway or bridge and presence of road side markers and curb and guttering. Eighteen of the twenty-one site were directly inspected on site, whilst the remainder were analysed (Lismore / Kyogle, Mullumbimby and Bundaberg) using Google street view and media imagery.

To ensure that the data collected through site visits reflected the condition of the roadway at the time of the incidents as much as possible, Google Earth and media imagery were cross referenced and local emergency service personnel and road operators were consulted.

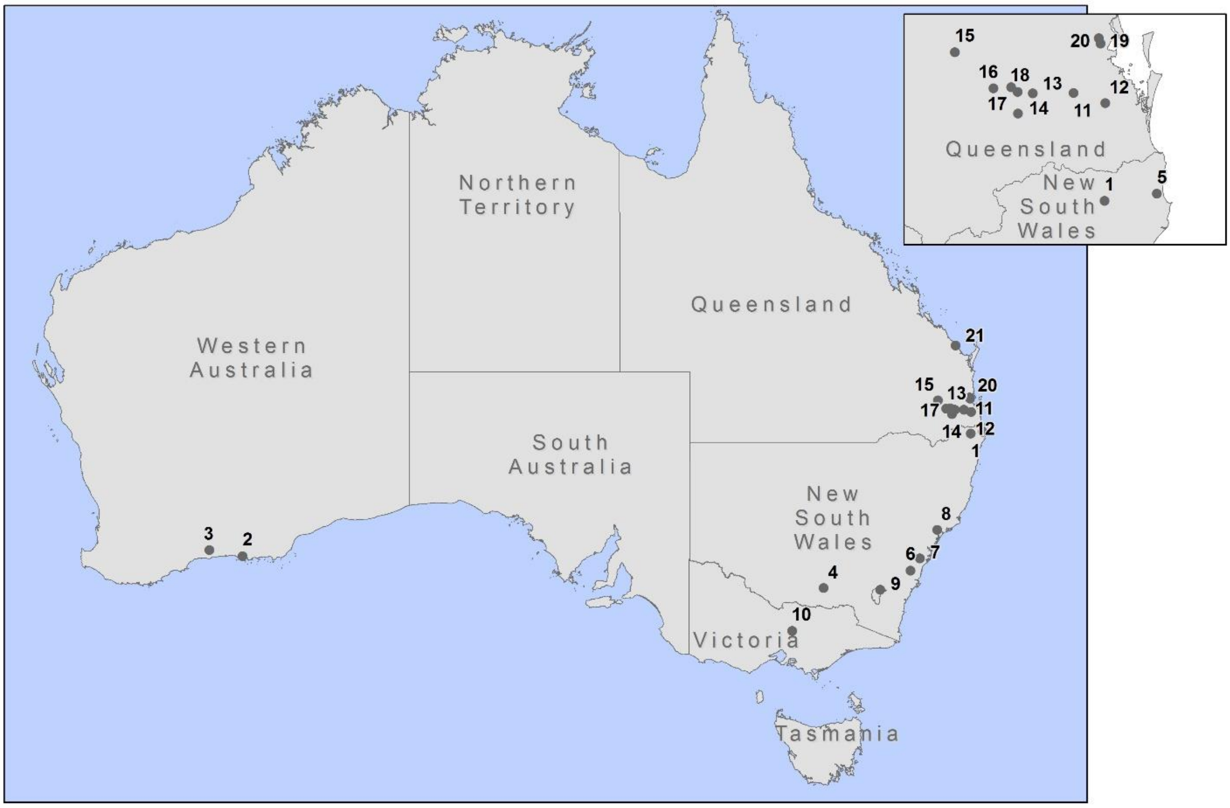

FIGURE 1: LOCATION OF SITE INSPECTIONS.

RESULTS

Overall results are summarised in Table 2 and outlined here. The twenty-one sites assessed comprised a mixture of different roadway structures, with the most frequent roadway structure where flood fatalities occurred being floodways (10 sites) and bridges (7 sites). In 86 percent of cases roads were sealed (18 sites) and in 14 percent of cases they were gravel (3 sites). Gravel roads have a lower co-efficient of friction associated with sliding then sealed roads (Smith et al., 2017). Fifteen sites (73 percent) were located in rural environments, with only one site classified as being in an urban location. The remainder were classified as peri-urban.

Road speed limits varied from 50 to 110 km/h, averaging at some 70km/h. No data was available regarding the likely speed that the vehicles may have been travelling when entering the floodwater.

Some 95% of sites were located in upper catchment areas with small channel sizes where rates of rise may have been rapid and associated with fast flowing floodwater. In at least three cases it has been reported that water either rose rapidly around the vehicle or that the vehicle was struck by a wave of water washing it downstream. For example, during flooding in Toowoomba, Queensland, 2011 a driver stopped her vehicle in very shallow water, waiting to see if it was safe to proceed. Floodwater then rapidly rose around the vehicle eventually sweeping its occupants downstream (Office of the State Coroner, 2012). Rapid rates of rise would also mean that if a vehicle was swept downstream into a survivable location, rising floodwaters could quickly inundate or sweep the vehicle further downstream. This was observed in the 2016 Canberra, ACT case, where a vehicle was first swept onto a small gravel island within a stream only for floodwaters to rise and sweep the vehicle further downstream. To ensure limited bias was introduced in the selection of sites a qualitative assessment of the remaining sites where fatalities occurred between 2010 and March 2017 was performed utilizing google maps to assess catchment size. It demonstrated that 78% of remaining sites were also associated with being located in the upper reaches of catchments.

At 14 of the sites, the roads were local and would normally accommodate low traffic flows (66 percent). At 4 of the sites the roads were identified as major roads that would usually accommodate a high traffic flow (19 percent). It is possible that during floods that traffic flow may vary from normal in particular if a road is a nominated evacuation route, or if a major traffic route has been closed. The number of vehicles travelling along the road not only increases the number of motorists exposed, but may also reduce the ability of motorists to turn around or to reverse if floodwaters are observed on a roadway or if flash flooding were to strike a road experiencing traffic gridlock. This was the case in a fatal incident on the Warrego Highway, Queensland, in 2011, where a motorist attempted to reverse but was unable to due to traffic behind the vehicle (Office of the State Coroner, 2012).

TABLE 2 - RESULTS

	Small Catchment size	Side barriers at point of entry	Signage	Deep water adjacent to roadway	Downstream vegetation or obstacle	Local Road	Roadside marker
Count of Characteristic observed	20	0	12	17	17	14	12
Total observations	21	21	20	20	21	21	21
Percent	*95*	*0*	*60*	*85*	*81*	*66*	*57*
	Lighting	**Bend in road before point of entry**	**Dipping road grade**	**Turn around with ease**	**Curb and guttering**	**Low traffic volume**	**Road Sealed**
Count of Characteristic observed	2	6	11	6	5	14	18
Total observations	7	21	21	20	20	21	21
Percent	*29*	*29*	*52*	*30*	*25*	*66*	*86*

At 90 percent of the sites, motorists were washed from the road pavement. It is likely the remainder of victims accidently drove off the road and into floodwater. For example at Bowral in 2016, where the victim may have accidently reversed into the floodwater.

At two of the sites, two fatal incidents in separate vehicles occurred during the same flood. In 35% of cases, multiple persons were inside the vehicle at the time of the incident and at least one person was able to survive. For example, at Junction View near Toowoomba, Queensland in 2010 a family of four was in a vehicle that was struck by floodwater as it crossed a creek bed. Three of the four occupants survived (Calligeros, 2010).

In 48% of cases, the deceased was discovered inside the flooded vehicle and in 43% the deceased was discovered outside of the vehicle indicating that they either had attempted to escape from the vehicle or were washed from it. In the remainder of cases it was not possible to determine the location of where the deceased was recovered.

None of the sites assessed had side barriers at the point the vehicle is likely to have entered floodwater based on an assessment of coronial and media information available about the incident. Barriers are seen as important to contain a vehicle on a roadway. In some cases, some form of barrier may have been present, but did not provide entire coverage along the road edge adjacent to the floodplain. An example of this is bridges where barriers were commonly present on the decking over the main waterway but not at the flood prone approaches. Curb and guttering was also largely absent, with it being observed at only three sites.

It is difficult to assess the flooding conditions present at the site directly when the victim's vehicle was washed away and there are no precise measurements of depths directly adjacent to the roadway. Assuming floodwaters covered the road pavement at the time of the incident it is likely that in 16 cases motorists entered deep water directly adjacent to the edge of the roadway, with average depths immediately downstream based upon an estimation of the height of the road pavement above the channel bed being equal to some two metres.

At 17 of the sites, downstream vegetation or obstacles (e.g. rocks and fences) were identified as being present within the channel or the adjacent floodplain. The influence of downstream vegetation or obstacles was identified as likely to have both positive and negative impacts. From a positive perspective, it was identified that vegetation may provide an opportunity for drivers and their passengers to escape the vehicle and hold onto after being swept away or that obstacles may provide points for a vehicle to temporally rest providing time for possible rescue or escape. However, vegetation or other obstacles may block the passage of a vehicle downstream allowing it to rapidly submerge. For example, in Seymour, Victoria, 2016 a small van was swept downstream into the main channel of a creek. The vehicle's passage was blocked almost immediately by a large tree within the middle of the channel, which resulted in the van rapidly submerging.

At 12 of the sites signage was likely present at the time of the incident. Though it is difficult to be absolutely definitive as changes may have occurred to signage after the incident and before research evidence was collected. Depth markers were the most common and were present at 50 percent of sites, followed by "*road subject to flooding*" signs (29 percent) and "*floodway*" or "*causeway*" signs (11 percent). Though signs may have been absent or obscured, in the main these results suggest that motorists either ignore, misinterpret or simply do not see signage.

Seven incidents occurred during evening hours, of which street lighting was present at only two of these sites. No specific road side flood warning systems that may have provided specific flood alerts to motorists in a dynamic fashion were present at any of the sites.

Dipping road grades were identified at 11 sites (52 percent), meaning that vehicles may have entered floodwater that then become deeper or that floodwater may have been difficult to see as the driver approached. The majority of structures at sites where dipping grades were observed were floodways.

At six sites (29 percent) the alignment of the road may have meant that the driver was unable to adequately see the floodwater as they approached. In several of these cases tight bends directly before floodways were identified.

At 14 sites (70 percent) it was identified that a driver would not be able to turn-around with ease upon observing floodwater on the road. Factors that would have constrained the ability to turn around included traffic flow, vehicle size, narrow road width and soggy or steep road edges. Such results would challenge the flood education campaign tag line of “turn around don’t drown”.

At eight sites (38 percent) emergency services or passers-by were available within seconds to several minutes to either call for further assistance or to attempt rescue. This result is indicative of how quickly flood fatalities can occur and that it is not possible to rescue all people who enter floodwater even when other people or emergency services are present. Given that 15 sites (73 percent) were in rural locations (some with limited or no cellphone reception), it would be difficult for emergency services to attend the scene within minutes of a vehicle being washed away.

DISCUSSION

This research has assisted to identify road characteristics that influence vehicle related flood fatalities. This is the first study of its kind and further investigation is required for these results to be considered definitive.

Some roadways are clearly more dangerous than others, though at present differing risk profiles are largely not considered in emergency planning or existing floodplain risk management approaches which tend to focus on urban flood risk. The large number of flood-prone road sections means that ultimately methods are required to prioritise on a risk basis roads that require safety improvements.

Risk factors identified by this research can be separated into those that may influence a motorist entering floodwater; factors influencing if a vehicle would be washed or driven from the road and factors that influence survivability once washed or driven from the road. These factors are outlined and described in Table 3.

TABLE 3 – RISK FACTORS

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 co-efficient 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 maybe 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 if a vehicle was washed or driven from a 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 road side barriers	Roadside barricades provide protection against a motorist leaving a roadway.
Curb and guttering	Curb and guttering provides 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.

Factors that may influence survivability of motorists once washed or driven from the road	
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 road way.
Downstream flood velocities	Fast flowing floodwaters may rapidly sweep a vehicle downstream.

Vegetation, though a possible factor in the survivability of vehicle occupants, cannot be considered a definitive risk factor as it may have both positive and negative impacts. Downstream velocity and distance of flooding over the roadway were unable to be assessed by this study due to the lack of flood flow observations at the time of the fatal incident.

Of the measures assessed small upstream catchment size (rate of rise); the presence 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 factors. Each of these factors were observed in at-least fifty percent of cases studied. In addition the probability of a roadway being flooded and exceeding vehicle stability criteria must be considered a precursor condition.

Given the large number of road sections that may not be constructed in accordance with required design and hydraulic standards it is important for road operators to be able to assess and prioritize risks posed in order to implement improvement measures.

Typically road safety agencies measure risk through the utilisation of historical data; for example, crash, hospital and insurance data (Austroads, 2006). Emergency services could assist road operators to identify high risk road sections by providing data about the location of flood rescues, hence enabling locations with a high frequency of rescues to be identified. Though useful the frequency of flood rescues at specific sites requires information about the severity of the incident to also be available. Currently in Australia this information is not routinely collected and there is no standard system to categorise flood rescue severity post an incident. A simple system could be to record if a vehicle has been swept from a roadway or not. Overall, such methods will identify road sections where risk has occurred historically, but possibly miss others where future incidents may occur (Austroads, 2006). This may certainly apply where the incidence of flooding is not geographically uniform, meaning that some areas may be underestimated because flooding has not recently occurred or the area has recently been developed.

Road safety agencies also undertake proactive assessments of risk. In the context of vehicle related flood risks a multi-criteria methodology could be utilised by drawing on key risks identified in this study that were most frequently present at sites inspected.

Results should assist in guiding the future design of floodways. The effectiveness of roadside barricades in reducing vehicle related flood fatalities requires some further investigation. Feedback from rescuers indicates that they are useful in controlling the scene of a rescue by preventing a vehicle from being swept further downstream and could be engineered to allow the attachment of rescue equipment hence possibly improving the effectiveness of any rescue attempt. It is unknown, however, the overall benefit cost of installing barriers and if the presence of barriers may encourage motorists to enter floodwaters by providing a false sense of security. Given that many of the sites identified are along Local Government owned roads consultation with the Local Government sector would be useful to identify any existing issues regarding the installation of roadside barricades. These might include the cost of installation, maintenance and repair.

This study supports conclusions made by Gissing (2016) and (Austroads, 2015) in relation to the limitations of road side signage in preventing motorists from entering floodwater. Current signage requires review so that it can be readily seen and easily interpreted. The introduction of more dynamic signage may assist in improving compliance. Higgins et al. (2012) in the context of flood signage concluded that drivers placed more trust in dynamic signage and emphasized 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 ignoring the critical role of velocity (Austroads, 2015) and does not indicate dangers that may exist below floodwater. Therefore, consideration should be given to signage that communicates risk rather than flood depth.

Given that at many sites it was assessed as difficult to turn a vehicle around consideration should be given to encouraging motorists to undertake proactive actions before they are faced with a decision to enter floodwater. These will include encouraging motorists to plan their journeys before commencement during times of severe weather utilizing up to date road information.

The conduct of a site analysis utilizing the same methodology as this study where flood rescues have been successfully performed would be beneficial. Such an analysis would provide further research evidence regarding risk factors and the effectiveness of controls when compared to the results of this study.

To build a further evidence base to understand the influence of road characteristics on vehicle related flood fatalities it is important that this research be continued to investigate future vehicle related flood deaths.

CONCLUSION

This research clearly shows that road characteristics have the potential to influence flood risks posed to motorists when travelling along flood prone roads. The assessment of risks associated with roadways should be an important consideration for floodplain risk management as well as in the prioritization of emergency management activities during floods. This research assists practitioners to define road characteristics that influence the level of risk associated with particular road sections and will assist to inform risk assessment processes.

Attempts will be made to analyze further data regarding flood rescues to enable a comparison of results between situations where vehicle occupants survived and where fatalities occur. This should be an area for future systematic study to ensure a continuing evidence base is built.

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