Appendix 1: Storm Tide and Evacuation Mapping Literature Review

Developing a "best practice" for public-facing risk communication products relating to storm tide inundation hazard and evacuation mapping: A review of current practices, literature and experiences

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1.0 Introduction

The damaging effects of storm tide inundation associated with tropical cyclones and low pressure systems on affected areas across the globe are well documented. Whether the inundation occurred in Queensland, New South Wales or farther afield in the United States, India or throughout Europe, the noted effects include threats to life, property and the coastal landscape. The risk associated with these events requires awareness and coordinated preparation by various tiers of governments, emergency managers and the public in order to promote resilience and recovery. Communicating risk to various stakeholders is an integral component of disaster preparedness upon which resilience and recovery depend on. Communication products exploring risk are developed for a range of end users including planners, emergency managers and emergency services providers, but often inadequately communicate messages that are clearly understood by the general public. In Queensland, there is a lack of consistency in public-facing hazard or evacuation planning relating to storm tide inundation between Local Government Areas (LGAs). Given the spatial scale of cyclonic and east coast low events, it is likely that storm tide inundation may occur across local government boundaries and affect a range of persons of various levels of vulnerability, and as such it is critical that consistent, clear and easily understood hazard and evacuation information designed for the public is communicated across the State.

1.1 Purpose

Arising from a recommendation identified by the Office of Inspector-General Emergency Management (IGEM), this review forms part of a project intended to achieve consistency in public-facing risk communication products related to hazard and evacuation mapping for storm tide inundation across Queensland. This review is intended to provide a research-based foundation for the development of a standard in public-facing risk communication against which the public-facing mapping and evacuation plans of 45 Local Government Areas (LGAs) vulnerable to storm tide can be audited and inform future guidelines within the disaster management framework in Queensland.

1.2 Scope

This review aims to deliver a “best practice” approach for public-facing risk communication products relating to evacuation planning and hazard mapping as informed by academic literature, international experiences in risk communication and expectations outlined in existing guidelines. This will be achieved through the exploration of challenges and debates surrounding the development of public-facing risk communication products relating to storm tide inundation across Queensland.

Acknowledgement is made by the author of the importance of appropriate modelling that will form the basis of any risk communication to the public. It should be noted that the technical nature of storm tide modelling is the focus of various other projects being undertaken by the Department of Science, Information Technology, Innovation and the Arts (DSITIA), the Bureau of Meteorology (BoM) and the Department of Natural Resources and Mines (DNRM). While the relevancy of storm tide modelling is recognised, it will not be explored in any depth.

For the purposes of this project, while it is acknowledged both by the author and various literatures that the “public” is not comprised of a homogenous group, it is utilised as an identifier during this project to differentiate between laypersons and industry professionals such as emergency managers, town planners and relevant authorities.

1.2.1 Relevant Products and Focus

There are a range of risk communication products used in disaster management including evacuation plans and hazard maps. While these can be used independently, there has been a movement towards integration of these products, especially for use in the public realm. This has meant that definitions relating to hazard maps and evacuation plans have evolved in recent years. Traditionally, "hazard maps" refer to maps highlighting areas at risk of inundation at various probability scenarios[1,2]. Evacuation plans usually refer to detailed documents to guide responses to a hazard event and are often developed for use by the authorities. Recent risk communication practices, especially those developed for use by the public are blurring these traditional understandings and are promoting the use of products known as Flood Hazard Maps (FHM) and Flood Emergency Response Maps (FERMaps), creating new understandings of the phrase "hazard maps".

These integrated products harmonise evacuation information such as shelters, routes and critical support services such as hospitals with hazard areas that are translated into evacuation zones[2,3,4,5,6]. These are for use across the timeline of a disaster event, both in preparation and in conjunction with real-time warnings and updates as well as being complementary to traditional evacuation plans. These integrated products are thought to maximise risk communication and disaster preparedness [5,4,7] by allowing better evacuation planning and hazard awareness[4]. These products are differentiated from risk maps, which are used predominantly by industry professionals for planning purposes and highlight economic consequences of a disaster, and highlight buildings, infrastructure and industry at risk, and can also be referred to as vulnerability maps [2,8,9].

This review focusses on public-facing evacuation plans and integrated hazard maps, to the exclusion of traditional, non-integrated hazard maps and risk maps. Unless specified, the use of the phrase "hazard maps" will indicate an integrated product. For the purposes of this project, "public-facing" will indicate products designed specifically to communicate risk to the public, and as and such, the research will focus on factors influencing the acceptance of risk information by the public.

1.3 Method

In order to develop a "best practice" approach for public-facing evacuation planning and hazard mapping, a range of academic literatures were consulted to explore issues surrounding concepts of different end-user needs, discussions in public risk perception and understanding, and to investigate previous research and hypotheses relating to best practices in cartographic-based risk communication. Peer-reviewed journals such as *Natural Hazards*, *Natural Hazards and Earth System Sciences*, *Environmental Hazards* provided the bulk of consulted articles. They were further supplemented by a range of other peer-reviewed materials sourced from *Journal of Applied Communication Research* and *Journal of Contingencies and Crisis Management.* Both journals were found through the use of the University of Queensland's (UQ) Library catalogue. These were located through the use of key words in various combinations, such as "storm tide", "storm surge", "inundation", "hazard", "evacuation", "risk communication", "best practice", "planning", "emergency", "coastal hazard", "public facing" and "mapping". The reference lists of relevant articles were screened and provided further resources. Efforts were made to draw on a large temporal range of resources in order to understand the development of relevant discussions over time, but limitations in availability of older articles through the UQ Library Catalogue meant that the majority of resources are post-2000. While this means that they reflect recent developments within

the risk perception and risk communication discussions, this review may lack the depth that older articles may have provided. As there is a notable lack of research into storm tide specific risk communication, any specific standards were supplemented by riverine flood mapping and communication methods which are more common throughout literature. Official guidelines, both locally and internationally, regarding flood mapping and evacuation planning were consulted in order to ensure that any standard created for the use of this project reflects industry standards and does not greatly deviate from both past and current practices.

2.0 Context

Storm tide inundation is a result of challenging to predict meteorological events[10], and has been the subject of official investigations by various levels of governments and academia, particularly in relation to how best to predict outcomes and to communicate warnings within existing disaster management frameworks. Within Queensland, the responsibility for adequate hazard and evacuation planning lies with local governments. The current *Queensland Evacuation Guidelines* (*the Guidelines*)[11] offer limited guidance to LGAs on how to best translate official predictions, warnings and expectations into publically palatable products that can effectively contribute to event preparedness and response within the public realm in a manner that is consistent across the State. This has been identified as a problem, especially as inefficiencies in emergency planning can undermine preparedness, response capacity and resources during disaster events[12]. Understanding how the nature of storm tide events contributes to the uncertainty in developing public-facing risk communication products and how to best develop products that communicate that uncertainty whilst still providing relevant information suitable for use by the public is a challenge that has been discussed in academic circles in recent years, with significant variation on how this topic should be approached.

2.1 Storm tide inundation in brief

Cyclonic events and intense low-pressure systems are seasonal occurrences along the Queensland coastline, bringing high winds, heavy rainfall and the threat of storm tide inundation to coastal communities[13]. "Storm tide" refers to the total water level resulting from the interaction of storm surge, wave setup and astronomical tides, acting like a rapidly rising tide and elevating water levels across localised areas in response to wind and low pressure effects on water[13,14]. When this occurs coincidentally with higher tides, the storm tide can rise above the Highest Astronomical Tide (HAT) and push inland with percussive force that has the potential to cause destructive flooding, erosion, damage to local infrastructure and danger to life in the immediate vicinity[10,13,14].

It must be noted that not all storm tide events will exceed HAT and pose an inundation risk, but there are a number of factors that increase the likelihood of enhanced storm tide heights. These include the size, force and approaching angle of the cyclone, distance from landfall site, the coastal geometry of the area including gentleness of the slope of the seabeds approaching the coastline, whether there are protective structures such as reefs in the area, and whether the affected area is embayed or part of an estuary system and therefore may be prone to a funnelling effect[13,10]. In short, the more perpendicular the angle of approach of the cyclone to the coastline, and the faster and higher intensity the cyclone will result in a higher surge and greater inundation extent[14]. The Queensland coastline provides storm tide enhancing conditions, particularly along the wide and shallow continental shelf, the Great Barrier Reef lagoon and within the Gulf of Carpentaria[15]. Uncertainty in tracking cyclones and predicting landfall sites and timings means that there is significant uncertainty in predicting likely storm tide heights and therefore inundation extents, particularly if heavy rainfall has caused riverine flooding in the area[14]. A more in-depth explanation of the technical aspects contributing to inundation extents due to storm tide are covered in *A guide to 'good practice' for storm tide inundation mapping and modelling* (*in drafting, unpublished*)[14].

2.1.1 Responses to storm tide inundation

Across Queensland, there are legislated efforts being made to alter long-term land use and planning policies to increase resilience to natural hazards including storm tide events[16]. These include the

potential and projected impact that climate change and sea level rise will have on these processes [16, 17,18]. This reflects industry awareness that long-term spatial planning is the best defence to reduce the vulnerability of coastal populations to hazards[19]. It should be noted that evacuation is seen as both a maladaptive "last resort" after protective measures have failed[19,20] as well as an effective disaster management strategy[21] that improves resilience and safety if properly planned, communicated and implemented[19,20]. In Queensland, evacuation is considered to be an appropriate disaster management response to a storm tide event if "it is reasonably likely that the event may pose a threat to human life or risk of illness or injury"[13]. Alternatively, sheltering in place is the recommended course of action[11].

Storm tide warnings are issued by BoM in conjunction with Cyclone Warnings if it is expected that there will be storm tide event exceeding HAT; warnings will be issued 12 hours before the expected onset of 100km/hr winds and updated every 6 hours until the threat has passed[13]. This is to allow a window of time for emergency managers to either encourage voluntary evacuation or issue direct evacuation orders, as evacuation is generally deemed unsafe when winds reach 100km/hr[11,13].

2.2 Understanding vulnerability

Vulnerability is one of three interacting dimensions contributing to disaster risk, the other two being the hazard and the level of exposure[22]. Vulnerability is a much discussed concept that is commonly used as a "catch-all" phrase[23]. Highly specific disciplinary definitions across various institutional and academic spaces[7,23] are extrapolations of the common understanding of "being prone or susceptible to risk or injury"[23]. Within the natural hazards space, vulnerability is used both as an understanding of the "statistical definition of risk", referring to expected economic impacts of Average Recurrence Intervals of events (ARI)[24], the risk inherent in the natural environment, and the results of the social, structural and political frameworks that influence how people respond to hazards[23].

In this way, vulnerability is commonly used to inform methods of assessing risk to communities when faced with ongoing stresses such as climate change or episodic shocks such as natural disasters[23,24]. Across literature, conditions of vulnerability are seen to be the interactions of a range of complex social processes and exposure to environmental hazards that often result in populations being unequally affected based on their physical location, socio-demographic status and political support, or a mix thereof [20,23,24,25]. Perceptions and understandings of risk are known to influence preparedness on both community and household levels[6,9,23,26] and affect resiliency, or the ability of households and communities to adapt to change[27]. It has been noted throughout literature that those who belong to lower social classes or with lower levels of education commonly have lower awareness of risk and less knowledge of how to respond to a hazard as well as less resources to utilise during evacuation and return[28].

Traditionally the focus of vulnerability studies have been lower-income populations, particularly in least developed countries that lack financial and social capital. In recent years there has been an expansion of investigations of vulnerability in industrialised countries centred around concepts of "risk societies", in which levels of modernisation and technology afford wealthier populations greater protection from perceived ecological risks through management protocols[23], but also expose them to "unforeseen or unintended" outcomes, such as the effects of climate change[29]. Social preferences and technological aspects also contribute to people placing themselves in higher risk areas and increasing the potential for damage in the event of a natural disaster[30]. This blurs the line

between natural and man-made hazards[31] and is increasingly relevant to storm tide inundation, when cyclone consequences are increasingly seen as "man-made", due to insufficient preparation or response to warnings[4]. This raises questions over responsibility in both preparedness and recovery and how effective the precautionary principle can be if the proper implementation of preparation mechanisms within localised disaster management spheres are neglected[29] due to concepts of the "exceptional" nature of natural disasters[23] impacting on perceptions of risk and hazard as understood by the public[31,32] .

In Queensland, vulnerability to storm tide is a concern, not only due to the exposure potential inherent with 88% of the population living within 50km of the coastline, but also the projected increase in potentially vulnerable peoples that make up that population[33]. It is expected that climate change may increase the likelihood and impact of severe weather events, including cyclones that contribute to storm tide events and therefore may put larger populations at risk and affect resilience across a range of scales[17,18,24]. According to the Department of Communities, Child Safety and Disability Services' *People with vulnerabilities in disasters: A framework for an effective local response*[34] indicates that a person's level of vulnerability is determined by several indicators, including those that increase susceptibility such as proximity to affected area, reception of warnings and information, health, access to financial and social resources and those that may act as protective factors including social connection, personal security and adequate understanding of circumstances. This is in addition to understandings of vulnerability in Queensland that identify vulnerable peoples as those who are "unable to comply with evacuation messages with assistance"[11]and include the frail, physically or mentally impaired, or those unable to understanding warnings and directions including those who speak languages other than English as well as those who lack social support structures[33].

2.3 The Role of Risk Communication Products

Risk communication products encompass a variety of emergency planning documents that are designed to improve disaster preparedness and act as a substitute for direct experience[35,36]. Reflecting a movement towards an "integrated risk management approach", public-facing hazard maps and evacuation plans are aimed at increasing people's knowledge of a hazard, affecting a behavioural change in response to a risk and providing clear and understandable resources pre-event[2,9]. These integrated and complementary products are also designed to reflect a holistic whole-of event approach to disaster planning that encourages various stakeholders to take responsibility for preparedness and action[28,36,37] and as such are both risk and crisis communication products[36,38,39]. However, these products are only effective if they reach the attention of the highest number of people at risk[9], especially during an event when demand for information usually outpaces supply[35] and poorly designed or disseminated resources can hinder orderly and safe evacuation from hazard zones[40]. In this way, developing risk communication products that adequately reflect the differing needs of various end-users and address the various components of vulnerability both pre-, during- and post-event has been identified as being the most effective way to maximise risk mitigation throughout the various stages of an event[26,31,37].

While hazard maps and evacuation plans are only a portion of the risk communication products available, they will be the focus of this review. These products are not meant to be used in isolation, but are aimed at improving risk perception pre-event, and improving the efficacy of emergency messaging during an event when used in conjunction with real-time forecasts[26,41]. Improvised

evacuation plans result in higher levels of danger to populations in hazard areas and successful evacuation of these populations is most likely when plans and hazard areas are identified and communicated in advance[19]. In particular, the perception that storm tide events are the lesser threat during a cyclone highlights the need for adequate pre-planning[15,26].

2.4 Current industry-based communication/guidelines

While efforts have been made both locally and internationally to develop guidelines for designing flood risk maps for numerous types of flooding, these are generally aimed for use by local governments, community councils and emergency managers and therefore focus on technical aspects[9,29,26,28]. In Queensland, there are published guidelines and handbooks that contribute to risk communication standards for industry professionals, including *Tropical Cyclone Storm Tide Warning – Response System Handbook* (*the Handbook*)[13], which indicates that "with suitable modification" storm tide warnings and the mapping model intended for emergency managers can be passed on to the public if the *Queensland Evacuation Guidelines for Disaster Management Groups* (*the Guidelines*)[11], the preferred resource for developing public-facing hazard-based evacuation maps has not been adopted. *The Guideline* encourages the development of various evacuation and hazard maps for both public and emergency manager use as part of LGA Evacuation Sub-Plans. It suggests, rather than prescribes, aspects to be included in evacuation maps for the public, including[11] :

- Evacuation zones (colour coded)
- Evacuation routes
- Public points of reference to aid local orientation such as landmarks

It further suggests avoiding technical terms such as ADH (Australian Height Datum) or HAT and to communicate evacuation zones in relation to severity (minor, moderate, major or extreme that should be informed by datasets available through request if LGAs do not already have their own) and by colour[11]. While consistency is encouraged between LGAs in choice of language, colour and format, there is no further guidance on which colours, language or format should be adopted.

3.0 Identifying End-User Needs

Literature agrees that developing risk communication products which reflect the needs of different end users, that is the general public, emergency managers or town planners, is integral to encouraging appropriate risk perception and therefore appropriate response behaviour[2,9,26]. For cartographic representations of risk in particular, it should be noted that "one size does not fit all"[9] as different user groups require different levels of information and complexity[26]. It has been noted that the needs of the general public have been neglected when developing risk communication products[2,9,26], and has been the topic of discussion in recent years (eg. [37,39,42]), especially in regards to increases in social media use and the potential for interactivity (eg. [1,43,44,45,46,47,48]). However, this does not mean that commonly accepted cartographic methods used for industry professionals cannot be applied. Rather, it means there are additional considerations to make while adapting these products for public use.

3.1 Considerations unique to public-facing risk communication products

Public-facing risk communication products have a different set of considerations than those developed for industry professionals. Not only does the complexity of the information need to be adjusted for those who are unfamiliar with technical terminology, but there are a range of social, emotive and psychological factors that affect how the public interprets information[26,36,49]. In order for hazard and evacuation products to be effective in achieving their goals of improving risk preparedness through maximising risk perception, information needs to be adapted to these social, emotional and psychological frameworks in terms of content, readability and usability and also needs to consider how the public perceives the risk of a hazard[1,31,49]. There has been varied discussion relating to choice of information and design appropriateness for public-facing risk communication, but there are several key themes that can be distilled. Choice in colour, phrasing, map extent and format as well as associated imagery and language have all been identified as important in contributing to the extent the intended information is understood[2,4,6,7,26,41,49,50]. This demonstrates a need to develop specific risk communication products that extend beyond the technical aspects and that draw on the contextualisation of historical events and personal experience[2]. Public-facing risk communication can help people prepare for natural disasters by allowing them to "envisage the negative emotional consequences of natural disasters"[31], either by drawing on existing experience or personalising the message on an individual level[51,52] and by encouraging information-seeking behaviour[1].

3.1.1 Factors affecting public risk perception

Risk perception is widely accepted to influence disaster preparedness, particularly shaping willingness to act for events that may require evacuation[26,41,49,50,52]. It is assumed that greater risk perception will lead to greater preparedness, and those who lack an understanding of risk will be less likely to respond to warnings and evacuation cues[31]. However, understanding and adapting risk communication products to reflect the range of psychological, social and political factors including aspects of vulnerability that contribute to how both individuals and communities perceive risk and form attitudes towards risk messages has been the topic of widespread discussion (eg. [19,31,49,51,52]).

Across the literature, there are several commonly accepted factors that are recognised to affect public risk perception:

3.1.1.1 Previous Experience

Experience can be widely characterised into direct and indirect experience, whereby "direct" indicates having actively lived through a hazard, and "indirect" indicates information gleaned from secondary sources such as media and friends or family[9,31]. An individuals' previous experience with a hazard (or lack thereof) is acknowledged to give rise to a subjective judgement of consequences that can have both positive and negative influences on risk perception[31,53,54]. Over time, people's behaviour reflects a multitude of factors related to experiences and personal values and subjective assessments, which can be mediated by official risk communication[9]. If an individual has had direct previous experience with a hazard of a severe nature, it can positively influence risk perception[31,53,54]. This is due to an overestimation of the consequences of a hazard, leading to increases in information seeking behaviour, cautionary behaviours and responsiveness to risk messages and evacuation cues[31,36,41,50,53,54]. Alternatively, if an individual has direct experience with hazards of a mild nature or has lived through multiple events with little immediate hardship to themselves or people they know, it can increase a person's self-confidence in their self-sufficiency, undermine their perception of credibility of messages and reduce their willingness to act or respond to official warning messages due to an underestimation of danger[20,31,52,54]. This has been flagged as an issue if the severity of a hazard "fades" from public memory[31,54] or if recent events have been of a mild nature and the public begins to perceive warnings as overreactions likened to a "cry wolf" scenario[15,26,31,36].

Indirect experience, characterised not by living through an event but by observing through media, listening to narratives or being exposed to information campaigns can replace the effect of direct experience on risk perception by providing a frame of reference for potential consequences and prompting emotional responses[31,52,53]. However, utilising this as a vehicle to improve risk perception has been noted to only be effective if the target population is aware that there is a risk to them[31,51,54], highlighting the need for appropriate education and dissemination methods[31,36,53].

3.1.1.2 Trust

How the public perceives the credibility of both the message and the authorities issuing a message is integral to the message's reception. Trust and credibility is built up through ongoing interaction with the public, and can be leveraged throughout event timelines to increase public response[19,39,49,53]. Trusting the message and the institution issuing the message is considered by Rod[49] to be the strongest determinant in whether a message is accepted or rejected, and a lack of credibility is thought to increase the probability of harm by Seeger[39]. A lack of trust or perceived credibility of information, including information gaps between need and provision of information causes delays in response and corrective action both pre- and during events[20,26,42]. Negative emotions towards authorities and available information inhibit the effectiveness of risk messages as people, spurred on by emotion-based processing methods, access social networks to aid in decision making[20,26,42].

In Australia, like most western countries, a culture of government-based responsibility has been fostered whereby an individual assumes that it is the government's responsibility to communicate risk and subsequent response requirements to the public[36,53]. This has been highlighted as an issue by Wachinger[31], Demeritt[28] and Maidl[36] as it is believed that high levels of trust in governance structures can encourage individuals to forgo personal preparedness measures including information seeking behaviours. In recent years, there has been a movement by governance structures to

encourage a shift towards individual self-responsibility and efficacy in relation to disaster preparedness[1,12,36], but public realisation of this shift has been slow[1] .

3.1.1.3 Awareness of proximity to hazard area

Having the public being aware that risk messaging applied to them is integral to successful risk communication. However, the public has been acknowledged as not only being unaware of their proximity to expected hazard areas[36,51,55], but choosing to ignore or deny information that does not suit them[9,28]. While much of this can be attributed to the perception that the home space is an intrinsically safe space, it also highlights how the public's risk perception significantly differs from that of authorities[1], and highlights how the perception of technical terminology that encourages the public to think of hazards as "exceptional" events[23]. In relation to storm tide inundation, proximity to the coastline is highly correlated to exposure to storm tide hazard. As such, awareness of accurate geographical location in proximity to the coastline and the results of storm tide processes are necessary to affect appropriate preparedness responses[51].

Maidl[36], Arlikatti[51], Demeritt[28] and Li[54] all noted that many people within possible storm tide hazard areas were either unaware of being in a hazard area or unable to accurately pinpoint their home locations on hazard maps. The lack of awareness of spatial location in proximity to potential hazard areas is problematic for several reasons; the first is that people who are in a hazard area and who do not believe that is the case are less likely to heed risk communication both pre and during a hazard event, and therefore will be less likely to evacuate[51]. Secondly, people who are not in a hazard area but believe they are within a hazard area will needlessly evacuate, adding to road congestion and overcrowding in public shelters and increasing risk to those who do need to evacuate[51].

An individuals' spatial understanding and map interpretation is due to an interaction of cognitive processes and geographic awareness that results in highly individualised cognitive maps[51]. Considering this, appropriate scale and spatial extent of hazard maps can significantly impact evacuation decisions, particularly if the product is not of an extent or scale that an individual can accurately locate their home address or area[51].

3.1.1.4 Risk versus Amenity

Natural hazards are, to some extent, associated with spatial amenity and each of these have opposite effects on housing value[55,56]. In the coastal environment, the risk of storm tide inundation, coastal erosion and wind hazards come with desirable amenities such as proximity to water and beachfront and water views[56] and in such a way, positive location characteristics are often thought to be valued higher than the potential of hazards, and therefore push housing prices up[55,56,57]. While human settlements are seen to be largely risk averse[58], technological hazards and the uncertainty surrounding climate change are thought to be placing more people at risk[23,29,30], as is underdeveloped perceptions of risk[55,59]. If people perceive a personal risk to themselves due to a perceived hazard, their willingness to pay for amenity has been noted to significantly decrease, but in the case of the coastal housing market, perceived amenity generally outweighs perceived risk[55].

Risk communication and the assignation of potential risk and hazard zones is largely seen by the public to negatively affect wealth distribution and property prices, resulting in a "winner-loser" mentality and creating a distrust and contesting of information[59]. While there is public perception that risk zoning negatively impacts property prices, insurance costs and land values, there is no consensus on the extent of this in the literature, as insurance premiums are expected to balance out

any perceived discount in property value, and authors regularly highlight the need for more research, particularly as coastal markets exhibit different characteristics to those which are simply within riverine floodplains[56,59,60]. While location in a potential hazard zone may not have a direct impact on property values, especially when considering amenity value, the perception itself that there is a lowering of property values has been highlighted as an impact[60].

3.1.2 Understanding technical terminology

It is acknowledged within literature that the public is confused by technical terminology used throughout the natural hazards space[1,2,23,31,32]. This includes terminology such as "1-in-100 year", which the public has a different contextual interpretation of than experts[32]. Although it is intended as a comparable risk assessment, it is suggested that such terminology has created ideas of "flood prone" and "flood free" within the public mind, encouraging the public to believe that there is less of a cause for concern and less need to be prepared[32]. Additionally, such terminology is often interpreted to mean that natural disasters are of a cyclical nature, whereby if an event has occurred during an individual's lifetime, they assume that they will not experience another[31], creating a concept that natural disasters are "exceptional" events[23]. As risk communication should be easily understood by those who are at risk, it is suggested that terminology such as "1-in-100 year flood" should be replaced by statistically equivalent, probabilistic phrasing such as "1% in a year", or preferably completely avoided and explained in alternative manners[1,2,28]. Considering the huge variability and uncertainty in cyclone and storm tide events, it is likely that avoiding statistical and probabilistic terminology in favour of contextual knowledge from previous experiences in pre-event risk communication will elicit greater preparedness[2].

4.0 Developing a "Best Practice" Standard

The concept of a "best practice" in risk and crisis communication is topical across risk and emergency management research, promoting learning from and correcting the mistakes of the past in order to encourage continuous improvement[61] with consideration to contextual factors and specific target audiences[39]. Such a standard should be designed to promote mutually beneficial relationships between stakeholders, respond to their various needs[38], and create continuously evolving products that can be utilised as a framework both for the development of products and as an assessment tool[35,37,38]. The influence of Seeger's[39], Sellnow's[38], and to a lesser extent Alexander's[12] research into "best practice" standards for risk and crisis communication can be seen across the literature, both in an explicit sense (eg. [37,42,43,61]) and implied (eg. [6,26,28]). The premise is that a successful plan includes appropriate communication products that draw on previous hazard experiences and is tailored to end-user needs will improve future decision making[31,39]. For the public, end user needs are commonly highlighted as "what does it mean to them, what does it mean to the family, and what do they need to do"[62]. Generating hazard maps for the public is valuable as it translates the essence of an evacuation plan, framing information in terms of hazard and response in a streamlined manner without the additional detail that authorities include in evacuation plans[39,63].

4.1 Commonly accepted "best practices" in risk and crisis communication

Seeger[39] and Sellnow[38] have developed key elements which are considered "best practice" in risk and crisis communication, both of which are relevant to hazard and evacuation mapping due to these products bridging pre-and during-event communication. Unsurprisingly, there is some overlap between the two.

Sellnow[38] promotes:

- infusing risk communication into policy decisions
- treating risk communication as a process
- accounting for uncertainty inherent in risk
- designing risk communication messages to be culturally sensitive
- acknowledging the diverse levels of risk tolerance
- involving the public in dialogue about risk
- presenting risk messages with honesty
- meeting risk perception needs by remaining open and accessible to the public
- collaborating and coordinating about risk with credible information sources

Seeger[39] also promotes:

- pre-event planning
- treating the public as a legitimate partner
- understating and taking account public concerns
- working with credible sources
- using honest communication that acknowledges uncertainties
- working pro-actively with the media
- providing concrete actions that people can take

These elements have formed the basis of conversations surrounding risk and crisis communication for the better part of the last decade, and as such will be influential in creating a best practice standard.

4.2 Content-specific inclusions for public-facing evacuation plans

Public-facing evacuation plans and integrated hazard maps are complementary products that communicate the essence of evacuation plans developed for use by authorities. In this manner, public-facing evacuation plans provide context to hazard maps and rationalise the information they contain, as well as providing additional detail. While hazard maps are streamlined representations of evacuation plans, written accompaniments to these should also promote clarity of information and forgo many of the inclusions of evacuation plans developed for authorities such as personnel roles and responsibilities during events. Public-facing written evacuation plans should include at a minimum[64]:

- Identification of expected hazard area
- Information regarding warnings and additional resources
- Identify evacuation shelters or assembly points
- Evacuation guidance information such as road network information, including roads that may become congested, impassable or are within hazard zone
- Preferred method of evacuation.

It should be noted that *the Guidelines* promote evacuation communication through the use of hazard maps. However, supplementing this product with further, more detailed information would be good practice in risk communication by providing greater detail, rational to the maps and avenues for greater preparedness on behalf of the public. It may also reduce subjective interpretation.

4.3 Content-specific preferred practices for public-facing hazard maps

Across literature, it is widely acknowledged that not only are the information needs and expectations of the public considerably differ to those of industry professionals, but the layout, format, accompanying language and colour as well as personal and local context all play significant roles in whether risk information is accepted or denied[7,26,31,41,50]. The content of hazard and evacuation risk communication products is markedly different than products for emergency managers or town planners. As described in Demuth[62], the public doesn't understand science and what they want from emergency communication products is more straightforward regarding personal impact and expected response. While some specific approaches are believed to stimulate information-seeking behaviour [53], bridging the gap between risk perception and action with effective risk communication is more about the adapting the content of the messaging[31].

4.3.1 Risk categorisations and uncertainty

The premise of risk communication is promoting precautionary approaches and preparedness in the case of a disaster event[15]. However, storm tide events are highly uncertain events that require specific interaction of a range of topographic and meteorological processes in order to attain worst case scenarios. As such, using probabilistic approaches in communicating risk to the public can be problematic when forecasts can be uncertain up until 12 hours before landfall[15,51] due to both uncertainties in modelling and in natural processes[8]. Throughout the natural hazards space, return

periods are commonly used to express likelihood and potential severity, but are accompanied with technical terminology that is often contextually interpreted by the public in unintended ways and with much confusion[15,8]. The precautionary approach demands the inclusion of low probability, high consequence events to inform worst case scenarios that are particularly relevant for potential evacuation situations[15,35]. However, there is some debate whether uncertainty should be communicated to the public[Error! Bookmark not defined.]. Hydro-meteorological models are considered to be t he most objective way of assigning risk and hazard extents, but should be regularly updated at a sufficient level of detail in order to remain "accurate"[59].

As uncertainty is inherent in storm tide events, it is recommended that uncertainty be communicated to the public but minimised within the public mind and framed as a "precautionary approach"[15], which is especially relevant as "waiting until all uncertainty is gone means that the warning is too late"[39]. As the public struggles with technical terminology, it is suggested that subjective interpretation encouraged by probabilistic communication is minimised through the adoption of "frequent, medium or seldom/rare", "low, medium, high" probability categorisations or "most likely or worst case" scenarios[1,15] where the "medium" probability is equivalent to a 1-in-100 year event[8]. EXCIMAP[8] suggests that the uncertainty inherent in these calculations can be communicated through the use of interval classes (of inundation extent) that are translated into these categories for public use. This is echoed by Chen[4], who suggests that while inundation risk as presented on a non-classed continuum is useful for expert use, it is too complex and subjective for the public to accurately assess their risk. Instead, classed maps with risk areas that clearly align with evacuation zones based on different levels of risk is the preferred method, favoured for its clarity of information and less subject to interpretation[4,15].

It is also widely considered that the inclusion of risk classes that align with possible evacuation reduces subjective interpretation by communicating a degree of uncertainty and framing the information within a "precautionary approach"[15,8]. By providing the public with information on "most likely" and "worst case" scenarios, uncertainty is communicated, allowing the map to provide information relating to possible evacuation relating to hazard vulnerability in an objective manner[6,15,26].

It should be noted that the BoM categorisations of extreme, major, moderate and mild are encouraged for use within Queensland by *the Guidelines*. This aligns with the avoidance of technical terminology that is promoted throughout the literature, but may require framing within "most likely" and "worst case" frameworks to be interpreted correctly.

4.3.2 Language

The response that the public has to the language used throughout risk communication has been identified across the literature (eg.,[4,26,28,41]). Fear appeals are commonly used to incite interest in seeking information and in the natural hazards space, language such as "will die" and "destruction" are used to increase urgency[41]. However, such language often has unintended defensive responses such as denial, avoidance and message rejection[4,26,41]. This language if often received as less credible and overly dramatic[41]. Alternatively, positive language such as "save lives" has been determined to elicit improved responses in both evacuation intent and preparedness[4,26], especially when paired with products that highlight risks to critical services and infrastructure[41].

4.3.3 Symbology and Colours

In a highly visual society, there are a range of cognitive and cultural associations with colours and visualisation techniques that encourage map viewers to alternatively minimise and highlight information[6,7]. For the public in particular, studies in map interpretation have revealed particular interest in colour coded information that is strongly contrasted[2,6,7]. Additionally, information clutter needs to be minimised and the message clearly identifiable with minimal perusal as the public has been recognised to skim identifying information rather than extensively studying legends[1,7].

Colour coding based on discrete risk classes from low to extreme is considered to be best practice for public use, and graduated continuums are harder to interpret[6,8]. For hazard maps, it is considered good practice to utilise colours such as red, orange, yellow and green for risk classes rather than various colours of blue[6,8,58,65]. This is due to social conditioning that suggests that red is commonly seen as associated with risk, danger or harm, orange as caution, and green and less contrasting colours are seen as conveying messages of safety[6,8,58,66]. For risk maps, rather than hazard and evacuation maps, where inundation is seen to be the primary message, graduation of blue are seen as associative with water depth and extent, but while adequate for increasing empathy and awareness, are also acknowledged to be too confusing for public use in relation to evacuation planning[1,8,58]).

It is considered better for clarity of information based on map reading studies undertaken by Fuchs[7] that non-necessary information is minimised through the use of paler colours so that important information is well contrasted[2]. It was found that orthophotos or infrared photos as backgrounds provided better contextual information and better information exploration than black and white depictions[7].

4.3.4 "Vividness"

Vividness of information is highly related to personalisation of risk[1,4,26]. This can be achieved through the inclusion of local historical information such as pictures and historical flood heights and eyewitness accounts that can be combined and compared with risk and hazard information to provide contextual framing and act as points of reference[1,4,8]. Local context is important, as the public has been noted to react more strongly and perceive greater awareness of risks when presented with historical event information that is relevant to their specific local area in conjunction with projected impacts[1,4].

4.3.4 Geographic markers and scale

Risk communication is only effective if the public can identify risk in relation to themselves. Spatial information of detail and scale that allows individuals to accurately locate their home addresses in relation to a hazard area, and is supported by commonly known landmarks is integral for the public to be able to personalise risk[26]. As such, roads, railways, houses, property boundaries and permanent water bodies are encouraged by EXCIMAP[8] to be included to geographic reference and is thought to promote accurate self-location by individuals within risk areas[28,36,51]. Additionally, maps should be of a scale that individuals can locate specific addresses[26].

4.3.5 Format and Layout

Fuchs et al[7] explored map format and layouts and found that there is tendency to follow information that is presented in a vertical format, and that use of the legend was maximised when placed to the right and organised vertically, which is supported by research by Meyer et al[2] and good practice as

outlined by LAWA[5]. Within the legend, it was considered most effective if there is a maximum of 5 discrete classes that were presented as decreasing values[7], while the title was found to be most effective at the top or upper left of the map and heavily contrasted, unlike some industry mapping protocols[5,7].

4.4 Dissemination Methods

In the modern age, there are a range of dissemination methods that are thought to best target different audience and an individuals' choice of information source is thought to be determined by its availability, accessibility, cost and the trust that is placed in the distributor[26]. Simply making information available is considered ineffective in influencing people's risk perception, and as such, the public's willingness to seek out information based on their assessment of how the information is presented needs to be considered[9,36]. Janoske et al[42] highlighted how the public is more likely to pay attention to messages that are received through a range of different media and strategies, which is supported by Kjellgren's[9] research that attributes improvements in risk perception and uptake of risk messages when products are paired with long-term integrated media campaigns that include a variety of communication tools and strategies. The internet is considered one of the most underutilised tools for risk communication, as it provides a low-cost dissemination methods that limits the prevalence of outdated data and is accessible by most of the population[1,8,9]. However, because the internet is utilised less by some sub-populations including the elderly or underprivileged, internet based dissemination of maps should also be supplemented through public education campaigns, school based education and distribution or availability of maps in public offices such as libraries, town halls and police stations[1,8,9]. Promoting hazard and evacuation information and utilising public media campaigns should be seen as a method of maintaining dialogue between authorities and the public[39].

4.4.1 Interactivity and web-based mapping services

One of the benefits of the internet is increased levels of visualisation through web-based mapping services. These allow greater access and greater integration of a range of different information including supplementary contextual information which improves vividness and personalisation[1,67]. This allows the development of interactive multimedia platforms which fulfils the needs of information-seekers, and communicates spatial information and uncertainty at different levels of risk far more effectively than static paper maps[67]. It also allows real-time information such as updated forecasts and gauge levels to be updated throughout events across a range of devices, both hand held and otherwise, which can be important in conveying changing expectations regarding hazard and evacuation areas based on updated information[1,4].

However, GIS based mapping software platforms and products involving high levels of interactivity have been noted as being potentially too complex and confusing for the public, as too many functions without adequate contextual knowledge can decrease readability and decrease message effectiveness through dilution and over-complication[1,31,67]. Simpler web-based mapping services designed to limit the level of interaction by providing thematic layers have been successfully used in parts of Europe[67], and have been found to be positive supplements for increasing public awareness when paired with traditional print and television methods[4]. Developing public-specific GIS mapping portals as "spin-offs" of industry portals has been highlighted by EXCIMAP[8] as a viable option for interactive multimedia platforms to including pictures, sound, and video for vividness and local context[1,67].

4.4.3 Social Media

Social media is considered both a help and hindrance within the natural hazards space, as it can be leveraged as a dissemination tool, promote campaigns and expedite real-time information that can improve situational awareness, but it is also prone to misinformation and requires continuous monitoring and management[43]. As a platform for information sharing, the public uses social media to share geo-tagged information, eye-witness accounts such as video and pictures, and also spread and seek information from authorities in what can broadly be considered a two-way dialogue[43]. During disaster events, it should be noted that information from authorities was the most shared and watched as the public considered it highly credible information, but once it was considered too "old", then they began to look for other sources of information[42,43]. This highlights its effectiveness as a tool not only to disseminate hazard and evacuation maps, but to stir interest and information-seeking behaviour if used as part of a campaign in pre-event communication.

4.5 Limitations

It is acknowledged throughout literature that there is research lacking on the effectiveness of particular communication strategies on public risk perception[2,9,26,36]. Additionally, it is noted throughout literature that two-way methods of communication, including public consultation, meetings and joint development of evacuation plans maps is far more effective than top-down, one-way communication such as hazard and evacuation maps, despite their usefulness[36]. However, Maidl et al[36] and Meyer et al[2] suggests that hazard and evacuation maps can be considered as a method of two-way communication as it provides the public with hazard risks which can motivate them to seek out further communication and therefore acts as a foundation or starting point for dialogue based strategies. The impact of the internet and social media on risk communication has been highlighted as an area that requires significantly more research and attention, but is also acknowledged as a highly underutilised tool that if managed well can be highly effective at all stages throughout the disaster management cycle[1,9,36,43].

5.0 "Best Practice" Criteria for Audit

In developing criteria that reflects "best practice" in public-facing risk communication for cartographic mediums as debated throughout literature, there are some practical factors that also have to be taken into consideration, particularly regarding the practicality of implementation and resources available to LGAs to develop appropriate hazard and evacuation maps.

The below criteria matrix aims to translate the concepts outlined by industry literature into a workable framework for assessing LGA's public-facing storm tide hazard and evacuation mapping while being sensitive to resources and practicality. It should be noted that the matrix is intended as a starting point for further product development, and that further considerations regarding the practicality of product development, including resources available have been acknowledged and attempted to be included in the matrix. As such, in addition to "Low", "Medium" and "High" descriptions of elements relating to metrics, categories of "Not Available" and "Exceeds Expectations" have also been added to reflect a range of possibilities within LGA products and to include elements that require significant resources, both financial and human, in order to be practicably viable such as social media utilisation and GIS web-based mapping platforms. The purpose of including these categories is to create a criteria fit for use for the planned audit that is able to accurately capture the current state of risk communication and to highlight the range of products that are currently in use while highlighting practical outcomes and identifying areas for improvement. In this way, "Exceeds Expectations" is included to capture LGA products that are highly advanced and meet best practice as accepted throughout literature, while "Not Available" aims to capture holes in risk communication. The "High" category is intended to reflect integrated hazard maps that effectively communicate risk and response expectations, but do not yet meet best practice, which is understood to be possibly resource intensive. The "Medium" category is intended to capture integrated products of a basic level that could benefit from improvement. The "Low" category is intended to capture products that are not integrated products, and reflect more traditional hazard mapping products.

In the case that no mapping can be found, the section of the criteria relating to "Evacuation Information" can be applied to written public-facing evacuation plans if they are available. In the same way, the remainder of the criteria can be applied to integrated products that are not supplemented by written public evacuation plans. This has been designed to further capture the full possibilities of public-facing risk communication products across Queensland; but as explored throughout the literature review, a detailed written evacuation plan without visual representation through a hazard map (and vice versa) only partially fulfils the information requirements of the public.

Based on the literature and the influence of existing guidelines, a minimum best practice for public-facing storm tide hazard and evacuation mapping can be described as:

An integrated product that combines hazard/risk areas and evacuation planning by translating risk/hazard zones into evacuation zones and:

- is of a scale appropriate to identifying individual land lots,
- contains geographic markers such as roads, shelters, hospitals and major landmarks for reference,

- clearly highlights evacuation routes, and alternative evacuation routes,
- avoids technical terminology in favour of BoM categories of extreme, major, moderate and mild,
- highlights evacuation zones through the use of bright colours that not only contrast with the background but also trigger cognitive associations, such as red for extreme risk, orange or yellow for medium risk, and green for low risk,
- is preferably an interactive product that can be produced in static paper form,
- contains a clear legend that is vertically arranged, preferably on the right hand side of the map,
- contains historical and contextual data relating to the local community to allow risk assessment.
- is accompanied by positively framed language and context about storm tide events and
- is supplemented by a streamlined written public-facing evacuation plan.

5.1 Intended Audience

This criteria matrix is intended for use in the audit of public-facing storm tide evacuation plans and hazard maps across Queensland, as part of a project aimed at achieving consistency in these products in the future. It aims to capture a current state of public-facing risk communication products and highlight areas of improvement and potentially provide guidance for moving forward. The intended audience for this matrix is disaster management stakeholders across Queensland.

Metric	Elements	Not Available	Low	Medium	High	Exceeds Expectations
		1	2	3	4	5
Hazard/Evacuation Plan in existence	Product type	One or both not available	Non-complementary products	Complementary Products	Integrated Product	Interactive Integrated Products with different levels of risk visualisation and scalability
Risk Categorisations/ Evacuation Zones		Not Available	Single category system	3-category system	In line with BOM's 4-level categorisation	
		Not Available	Continuous graduation	Discrete categories	Discrete categories based on a clearly communicated risk scenario	Interactive with discrete categories. May include alternative risk scenarios
	Historical data	Not Available	Contains no reference to previous events		Includes reference to or outlines areas previously exposed to an event	
Evacuation Information	Shelter location	Not Available	Contains no reference to evacuation shelters	Contains location of evacuation shelters	Contains detailed information about location and holding capacity of multiple evacuation shelters (including alternative options)	In addition to "High" standard, in an interactive environment, contains capacity monitoring of shelters
	Road network information	Not Available	Contains no reference to road network problems or alternatives	Contains minimal road network information and highlights preferred routes or areas to avoid	Contains detailed road network information including impassable areas, congestion hot-spots, road closures, alternative routes	In addition to "High" standard, is an interactive environment that contains real-time updates concerning road closures during an event
	Evacuation Processes (including warning	Not Available	Contains no evacuation information and does	Contains minimal evacuation	Details evacuation processes, expectations and	In addition to "High" standard, in an interactive

	information and additional resources)		not refer to another resource	information or refers to another resource	warning lead times, or refers to another resource	environment updates evacuation processes/road closures in real time
Colours/Symbology	Colours	Not Available	Colours other than red-orange-yellow-green	Colours other than red-orange-yellow-green [blue]	Red-Orange-Yellow-Green [blue]	
	Geographical Markers	Not Available	No geographical markers included	Roads and Evacuation Shelters Marked clearly	Roads, Hospitals/major landmarks, Evacuation Shelters and Evacuation Routes marked clearly	Roads, Hospitals, major landmarks, Evacuation Shelters, Preferred/Alternative Evacuation Routes marked clearly
	Background	Not Available	No land use zones outlined	Representative land use zones outlined	Orthophoto background or land use representative background delineated by land lots	Orthophoto background or map background representative of roads, homes
Scale	Identification of location in proximity to risk/hazard area	Not Available	Not of a scale where a home or land parcel can be accurately located	Of a scale that where the location of individual land lots can be inferred from geographical markers	Of a scale appropriate to locating individual land lots	Interactive- changeable scale
Vividness	Supplementary information providing local context ie. Pictures, video, eyewitness accounts, historical inundation levels/previous event impact	Not Available	No inclusion of historical data or visual/written supplementation	Minimal inclusion of historical data or visual/written supplementation	Contains images, eyewitness statements or historical inundation levels relating to the local context	Contains interactive information regarding past events and including historical data relating to the local context, and includes real-time gauge information
Layout/Format		Not Available	No legend	Legend available but not clear	Legend arranged vertically, clearly arranged and not	Interactive with appropriate and clear format

					overcrowded, include common mapping conventions including direction and scale	
Message Framing	Related situational context	Not Available	No contextual framing	Minimal contextual framing	Detailed levels of contextual framing	
	Language	Not Available	Negatively frames response		Positively frames response	
Dissemination	Format	Not available online	Not available online	Available online and in supporting formats	Interactive basic and available in supporting formats	Interactive with information available across many mediums including video or audio for those who are visually/hearing impaired
	Publicity	Not Available	Not utilised or referred to as part of education campaign		Included as part of a campaign/education opportunity	

6.0 Moving Forward

Public-facing risk communication has been highlighted as an area requiring further investigation within academic literature, particularly in relation to raising risk awareness and how interactivity and social media will shape risk dialogues moving forward. As such, the criteria developed as part of this research is designed to highlight basic desired elements and to be used as a basic assessment tool in order for areas of improvement to be identified. Unfortunately, communication and interpretation is highly subjective, and as such there is significant room for subjectivity within this framework. This should not be seen as drawback, but rather as an opportunity for improvement and flexibility as more research is undertaken, especially as research into public-facing risk communication relating to hazard areas and evacuation plans is still relatively young.

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