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Developing a holistic risk management plan in mitigating flooding risks for buildings adjacent to the Swan River in Perth, Western Australia

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Abstract

Climate change as a major issue in the 21st century has seen the rise of the sea level and worse storm surges. This has impacted on the further distribution of salinity and flooding of low laying areas even in further inland areas. As the consequence, buildings in the proximity of riverbanks are left susceptible to potential damages and shortened life cycles. Thus, there is a real need to change the way buildings in these areas to be designed and how risk of damages can be mitigated and managed. The city of Perth in Western Australia, like many other cities around the world, is laying on the riverbank of a large river, the Swan River. As the population of Perth increases dramatically, it will become important to ensure sustainability of its buildings to support the ever growing populations and hence its needs. There are myriads of approaches in mitigating and managing these risks. This research project aims to investigate the contemporary risk management practices in mitigating flooding risk in buildings adjacent to the Swan River and bring them together as a holistic risk management approach. The findings of this research can be proposed to the Western Australian government to assist them in developing further policies in ensuring sustainable buildings fit for the future. At this point of writing, the research project is on its early stage of conducting literature review and designing the research methodology. It is intended to conduct a pilot survey, followed by case study approach of contemporary buildings adjacent to the Swan River to contextualize the research. This paper presents the current progress of this research.

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Keywords:flooding; risk management; sustainable buildings

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1. Introduction

Climate change can be considered one of the greatest social and environmental issues facing the world in the 21st century. Sea levels are expected to rise by 0.28 to 0.61 meters based on low emissions levels and from 0.52 to 0.98 meters based on high emissions levels by 2100 (BOM and CSIRO 2014). Western Australia (WA) is expected to experience similar to the global phenomena (Bricknell 2010). Eliot (2012) found that water levels in the Swan River in Perth, WA are in fact rising in line with global predictions to date. In the 2014 IPCC report, 'Climate Change: Impacts, Adaptation and Vulnerability' it is stated that approaches to planning for climate change impacts in Australia have changed significantly in the past two decade, though the application of these approaches remains piecemeal.

Planning for sea level rise is a long-term strategic move, as mapping and anticipated rises are based on 2100 water levels. Ozcoasts (2013) maps illustrate the 2100 level of sea based on three scenarios; love, medium and high impacts, much the same as the anticipated levels by the IPCC (2014) mentioned above. What can be inferred from these maps is that despite low or high emissions levels, there will be significant impact on the Swan River region. Aside from the actual water levels rising, one of the main implications of sea levels rising is to be increased storm surges, which is a component of water levels that does not relate to the periodic forcing of the moon and the sun (Swan River Trust 2007). These surges can have two major impacts, the first of which involves the distribution of salinity and the second being the flooding of low lying areas.

Present Western Australian planning procedure requires all buildings to be designed for a 'once in 100 year flood' (Bricknell 2010) which may also be referred to as a Q100 event or a 1% Annual Exceedance Probability (AEP). The concept of a 1% AEP is that, based on historical data, the risk of a flood reaching a certain level is likely to be once in a hundred years, though, there is a one percent chance each year that one of these floods may occur (BOM 2014; Brisbane City Council 2011).

The current theory in government documentation is that for the Swan River, the Department of Environment's recommended 1% AEP (Q100 flood level) should be maintained and that the level of risk has not increased, or decreased (Department of Industry, Tourism and Resources 2005, p.138). However in a recent report, Eliot (2012) recommends the incorporation of this proven sea level change into flood mitigation policy with this also being illustrated in older material from the Swan River Trust (2010), stating that in order to protect infrastructure, planning legislation must incorporate moving infrastructure away from rivers.

Floodplain management is about finding most equitable solution with the least amount of risk or hazard and incorporates mitigation, adaptation and preparedness rather than prevention entirely (Genovese 2006). This means that there will always be a level of 'acceptable flood risk', as weather patterns and historical data are not one hundred percent reliable nor is it economical to fully remove the risk (Brisbane City Council 2011). It is then considered important to best plan for these risks irrespective of the anticipated flood levels, hence there is a need to develop measures of controlling and minimizing the level of damage incurred (Hansson *et al*. 2007).

Increasing urban development (Weisse *et al*. 2013; Ranger *et al.* 2011; Genovese 2006), also impacts heavily on flood planning with the potential for legislation that prevents building in flood prone areas to be conflicted with the increasing need to develop Brownfield sites, and provide more housing for increasing populations (Wilby and Keenan 2012; Ranger *et al*. 2011). Effects of greater development include less area for water to drain to, more buildings to damage and a more concentrated population of people to harm.

Sea level rise and its impacts of flood risk and planning are becoming an increasing factor of concern for most countries around the world. For the Swan River region in Western Australia it does not appear to be a high priority with much of the data being rather outdated, based on the fast paced development of climate change research. This research aims to fill that research gap, developing the idea presented by the IPCC (2014) that Australia is not fully implementing methods of mitigating and managing sea level change. Flood plans in Western Australia are also only updated after a major flooding event, as this is when there is more data available to model from. With increased water depths due to sea levels rising, this provides important 'new data' to be worked with for future flood planning.

The Swan River region has been chosen as the location for this research as it is a low lying area and is only in the last ten years experiencing rapid population growth and development (Law 2013; Committee for Perth 2011). Perth City is only 11.2 meters above sea level (City of Perth 2014), and Fremantle at only 8.31 meters above sea level (Digital Atlas 2014), this means that there is an increased likelihood of flooding and damaging waves to further penetrate inland due to increased storm surges due to a rise in sea levels (Swan River Trust 2010). It is then proposed to limit research to flood risks for events of a Q100 nature and smaller, as frequent smaller floods may cause a greater level of damage cumulatively (Melbourne Water 2014).

In light of the ongoing discussion, a research project has been set up aiming to investigate the impacts of sea-level changes on flood planning for building construction in the Swan River region in Western Australia and to propose a contemporary risk management model that can be utilized by authority figures and builders.

The following objectives outline the individual processes that are required to achieve the aim of this research:

1. To identify the potential impact of sea-level changes and the current flood trends and planning procedures in the Swan River region.
2. Investigate current practice in flood planning and anticipation for sea level rise, both formally and informally for building construction projects in the Swan River region.
3. Prepare a preliminary risk management model for the Swan River region, concentrating on management techniques that can be implemented in the planning and approvals stage in construction.
4. Compare and contrast prepared risk management model with Government (Local and State) planning requirements and current practice in the local industry.
5. Produce a final risk management model, recommending ways that planning can be modified to incorporate sea-level changes.

2. Literature review

The objective of completing this literature review is to gain a substantial grasp of the terms, issues and existing theories surrounding flooding and flood management, the impact of climate change upon flooding with relation to building and construction in Perth, Western Australia. The research scope has been narrowed to once in a hundred year floods (Q100) and those smaller, as these are the highest level of floods that are required to be factored into building design in Australia.

Perth is the capital of Western Australia and geographically located at latitude 31^{o} S, longitude 115^{o} E. The altitude of Perth is 11.2 meters above sea level. The population of Perth Metropolitan area is currently estimated at 1.74 million with the largest growth in the Western Australia State (the population of the WA State is currently estimated at 2.35 million). The following figure 1 presents the map of the Perth Metropolitan area including the Swan River.

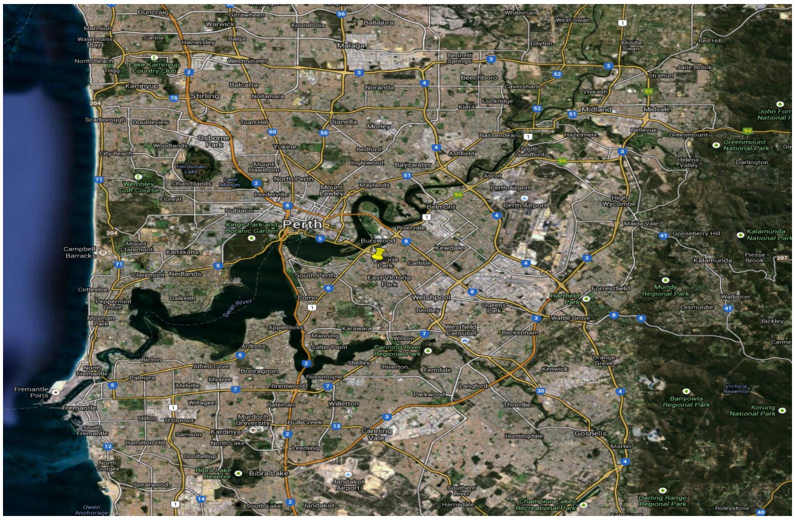

Figure 1. Map of Perth city (source: Google Earth 2014)

The first point of understanding flood research was to establish the consensus on the definition of a Q100 event, it is agreed throughout literature that it may also be called a 1% Annual Exceedance Probability (AEP), meaning that based on historical data the risk of a flood reaching a certain level is likely to be once in a hundred years, though, there is a one percent chance each year that one of these floods may occur (BOM 2014; Brisbane City Council 2011). One of these events, the risk must be reassessed as Australia has such a short period of flood records every major flood event must be taken into account to establish the most accurate data. It must be noted that this is a design flood only, and may be exceeded but is the best measure to be had with the given data. Flooding and weather events are entirely random, this is backed up throughout all literature read, it is a case of managing the risks as best as possible.

There is a plethora of information regarding the impacts of climate change, and more specifically its impacts on flooding and other natural disasters. There is a common theme within literature that the main cause of damage is increased storms and precipitation, openly omitting the impacts of sea levels rising forms their data analysis. The current state of rainfall in Perth, Western Australia, is trending towards below average. Some months have an average or well above average rainfall, though overall Perth is continuing to remain dry (Department of Water 2013). History does show that Perth can be subject to damaging floods, as documented by Water and Rivers Commission (2000) though the last Q100 flood event was in 1872, with the latest event being a Q10 flood in 1983. Current research shows that if there was an extreme flooding event the worst hit areas would be Midland, Guildford, Maylands, Belmont, Bayswater and Bassendean, though areas such as Riverside Drive, Langley park and Fremantle would also be impacted on in a major flood event (Ozcoasts 2013).

The current theory in government documentation is that for the Swan River, the Department of Environment's recommended 1% AEP should be maintained and that the level of risk has not increased, or decreased (Department of Industry, Tourism and Resources 2005, p. 138). Contrastingly, though not specific to the issue of flooding, in the 2014 IPCC report it details that planning for sea level rise has increased significantly in the last two decades and shows diversity in its approaches though the implementation of these approaches remains piecemeal. The most up-to-date research on sea levels rising in the Swan River is Eliot (2011), where a sea level change was found within the river, much like it has been stated in the IPCC (2014) report, Eliot recommends the incorporation of this proven sea level change into flood mitigation policy.

Flood planning is a fine balance between social, environmental and economic issues (Chan *et al*. 2013; Brisbane City Council 2011) and this is also the case around the world (Ranger *et al*. 2011). Floodplain management is about compromising between these factors to find the most equitable solution with the least amount of risk or hazard and is about mitigation, adaptation and preparedness rather than prevention entirely (Genovese 2006). This means that there is a constant level of 'acceptable flood risk', as weather patterns and historical data are not one hundred percent reliable nor is it economical to fully remove the risk (Brisbane City Council 2011).

The impacts and damages caused by flooding are split into direct and indirect (Ranger *et al.* 2011, 149) and/or tangible and intangible (Melbourne Water 2014). Genovese (2006, 18) the losses are split first into direct and indirect then further into tangible and intangible impacts, to provide a thorough breakdown of possibilities. Introduced by Genovese (2006, p.18) is another category, relief costs, which separates the costs of life supporting services after and during the flood. This damage can be seen as the impact of risk, and it is these outcomes that are evaluated when trying to manage flooding. Large floods, such as the Q100 may cause costly damage; though if the risk of smaller floods is not also monitored the cumulative damage can be fairly significant (Melbourne Water 2014). Irrespective of the magnitude of potential flood levels, there is a need to develop measures of controlling and minimizing the level of damage incurred (Hansson *et al.* 2007).

There are plenty of methods of managing flood risks, these vary based on the stage at which the flood is at, there is the use of legislation and design controls prior to the event which are preventative activities, prevention and response activities, response, evacuation procedures, recovery activities and rebuilding and restoration (Melbourne Water 2014; Brisbane City Council 2011; Ranger *et al.* 2011). These phases are all common, though the primary focus of this research is into the preventative measures, such as planning policy, and the factors affecting their currency and implementation.

Increased building and potential for a lack of regulation of building on floodplains in the future has been a feature in many pieces, due to expanding populations and need for land for housing as well as flood insurance schemes.

Legislation reducing building in flood prone areas may be conflicted with the increasing desire to develop brownfield sites, as well as the need for more housing with increasing populations (Wilby and Keenan 2012; Ranger *et al*. 2011). The insurance scheme impact is an interesting one, as there is a high level of benefit and cost associated with it. With flood insurance, the risk is being transferred off the property owners and onto companies (Hansson *et al.* 2007, p.468), so it can be ensured that there is the capital available to rebuild or repair after a flood event (Ranger *et al.* 2011, 159), but contrastingly it may create cause for less care to be taken in ensuring buildings are not erected in flood prone areas as there is capital there if needed to recover from any damage (Wilby and Keenan 2012, p. 349).

Flood management relating to climate change for river ways is primarily investigated in the United Kingdom (McMinn *et al*. 2010; Hansson *et al.* 2007) and Europe (Weisse *et al*. 2013; Marchi *et al*. 2010), with many focusing on central European cities (Priest *et al*. 2011; Genovese 2006), with few examples being drawn from Asia (Chan *et al*. 2013; Ranger *et al*. 2011) and Northern America (Hamlet *et al*. 2013; Mariotti and Fagherazzi 2013). Flood management incorporating sea level rise is all about managing the risks in the long term, as sea levels rising is a long term risk for the community. It should also be kept in mind that as years go on, there will be even greater urban development (Weisse *et al*. 2013; Ranger *et al.* 2011; Genovese 2006). This means less area for water to drain to, more buildings to damage and a more concentrated population of people to harm.

The Australian National Construction Code (ABCB 2013a) has recently been updated to include for performance requirement and a standard for construction in flood hazard areas. "The standard covers Class 1, 2, 3, 9a and 9c buildings and Class 4 parts of buildings i.e. buildings where people may sleep, reflecting the primary purpose of the standard which is life safety." The application of these provisions relates back to each state, and their local governments design flood level (DFL), which is the level to which the flood will rise in the areas defined flood event (DFE). A DFE, is the chosen 'worst case scenario' that has to be designed for, and in Western Australia that is usually the calculated Q100 flood event. In QLD the flood areas and compliance regulations are instead set within the Building Act 1975 and the Queensland Development Code (ABCB 2013b) as this is a more flood prone State.

A suggested method of developing new policy is by modelling those in place around the world (Hansson *et al.* 2007, p.466), this has been started in WA by the Peel-Harvey Catchment Council (2011), though not directly relating to the Swan River, they have complied sources from around Australia and the world that have considered climate change in flood management framework to further assess implementation themselves. The Gold Coast City Council, Queensland, have ensured that a sea level factor has been added into their Q100 flood event due to their proximity to the ocean (Peel-Harvey Catchment Council 2011). There, for the most part, appears to be a gap between the level of research into coastal planning and its implementation in structures and the planning on a local government scale (Weisse *et al*. 2013).

3. The Proposed Research Methodology

To achieve the above objectives and therefore the research aim, data will be collected and analyzed systematically. The research being conducted can be considered exploratory in nature, using mixed methods of data collection. This will allow for a greater level of reliability in results and analysis, as trends and outliers will be identified. However, the potential for reliability also relies heavily on a substantial sample size responding for each data collection method (Robson 2011).

The objective to be satisfied by the pilot questionnaire is establishing the current industry trends and opinion from industry professionals. Surveys will aim to gain preliminary data that will assist in shaping the research questions for the interview stage of the project. The survey will be distributed using an Internet survey program such as 'Survey Monkey' rather than via post as this allows for an instantaneous response and minimal effort is required from the questionnaire recipient. This data collection process will also allow for a narrower field to be developed of those industry professionals willing to continue on to the interview phase of research. The return rate for the questionnaire will ideally be 30%, so in order to achieve the desired sample size of 30 completed responses, it was found necessary to circulate the survey to at least 300 recipients.

The professionals to be contacted will come from a range of backgrounds, those involved in local and state government, private sector building surveyors, builders and contractors, project managers, hydraulic engineers and academics within this field. These candidates will be contacted via connections established though employment and professional roles and through professional organizations such as the Australian Institute of Building. Some will have to be cold contacted, though it will be ensured that all surveys are directly sent to individuals being sought. Other relationships will be formed will be via existing relationships, which will potentially heighten the rate of return and increase the probability of continuing to the interview stage (Robson 2011, 405).

Subsequent to the questionnaire survey, case studies will be utilized as a research strategy, these will be exploratory case studies that will assist in developing the research questions (Yin 2012) and provide information about current planning policy and trends along with the 'risk levels' felt by builders and developers with regard to sea level change and flooding. The two case studies to be explored are both residential developments in locations that are considered to be 'at risk' areas based on both low to high impact levels of sea level change (Ozcoasts 2013). The first is a low rise luxury apartment development in the East Fremantle. The second case study is another low rise luxurious apartment project in South Perth. The researcher has secured contacts with the client and contractors firms of these two projects.

After all preliminary and pilot data has been collected, it will be analyzed and compiled into a preliminary risk management model. This model will assess the potential risks and recommend treatment options associated with the planning and approvals stage in building construction. The model will be prepared according to the guidelines and definitions contained in AS/NZS ISO 31000:2009. During this process a 'risk scoring' system will be developed to provide a method of gauging potential impacts if management techniques are or are not applied.

Once the model has been developed, the researcher will return to the data collection stage where there will be continued literature review, interviews and focus group assessment. The purpose of retuning to this stage is to compare and contrast the produced risk management model with both formal and informal models and management techniques that have been produced in the past and those that are being currently used. The literature review will be used primarily for the comparison with formal documentation such as peer reviewed articles, government documents and local government planning information and requirements.

The informal process data is to be collected using the interview and focus group data collection techniques where the prepared preliminary model will be issued prior to interviews and focus group meetings, to ensure that all respondents are aware of the content being discussed during these meetings. Both of these data collection methods have been selected as they provide an environment that enables the researcher to ask probing and open-ended questions, as well as the interviewee being able to provide feedback on the model. In the first instance, 6 interviewees will be targeted for semi-structured (Berg 2004) interviews and will continue to the point of data saturation. This will be followed by a focus group meeting involving 3-4 interviewees to refine and validate the outcome of the research. These sample sizes have been selected to ensure a range of responses will be collected and that the final risk management model has sound justification in collected data.

4. Conclusion and Further Research

This paper presents the current stage of a research project aiming to investigate the contemporary risk management practices in mitigating flooding risk of buildings adjacent to the Swan river in Perth, WA. The research is on its early stage, i.e. literature review and research methodology design.

The next stage of the research involves designing the pilot questionnaire to gather the contemporary practices of risk management of the above mentioned followed by an analytical comparison with the AS/NZS ISO 31000:2009 guidelines. The outcome of the analysis will be utilized to develop a risk management plan that incorporates current practices and future needs of the area. This will be followed by a validation and refinement process to increase the credibility of the research findings. Following a refinement, a holistic risk management plan will be developed and will be suggested to the Western Australia government to assist them in developing further policies supporting sustainable buildings.

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