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COST-EFFECTIVE MITIGATION STRATEGY DEVELOPMENT FOR FLOOD PRONE BUILDINGS

Annual project report 2014-2015

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Cover: Flood mitigation strategy: elevating floor level

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EXECUTIVE SUMMARY

The motivation for this project arises from the experience and observations made during the recent flooding in Australia in 2011 and 2013, which caused widespread devastation in Queensland. The flood events also resulted in significant logistics for emergency management and disruption to communities. Considerable costs were sustained by all levels of government and property owners to effect damage repair and enable community recovery.

A fundamental reason for this damage was inappropriate development in floodplains and a legacy of high risk building stock in flood prone areas. The vulnerability and associated flood risk is being reduced for newer construction by adopting new standards (ABCB, 2012), building controls and land use planning, however, the vulnerability associated with existing building stock remains. The vulnerability of existing building stock contributes disproportionally to overall flood risk in many Australian catchments.

The Bushfire and Natural Hazards Collaborative Research Centre (BNHCRC) project entitled "Cost-effective mitigation strategy development for flood prone buildings" aims to address this issue and is targeted at assessing mitigation strategies to reduce the vulnerability of existing residential building stock in Australian floodplains. The project addresses the need for an evidence base to inform decision making on the mitigation of the flood risk posed by the most vulnerable Australian houses and complements parallel BNHCRC projects for earthquake and severe wind.

To date, the project within the BNHCRC has developed a building classification schema to categorise Australian residential buildings into a range of typical building types. Mitigation strategies developed nationally and internationally have been reviewed. In the following years of the project appropriate strategies will be costed for key building types through the engagement of quantity surveying specialists. Vulnerability of predominant building types will be assessed along with the factors affecting vulnerability. The information on vulnerability is fundamental to evaluate mitigation strategies and to examine the opportunities for reducing the vulnerability. The research will also entail experimental testing of preferred material types to ascertain their resilience to flood water exposure. Cost benefit analysis will be conducted to find optimal mitigation strategies for selected building types located within a range of catchment types.

This project is investigating methods for upgrading existing housing stock in floodplains to increase their resilience in future flood events. It is important that the latest research and economically optimum upgrading solutions are applied to existing houses to optimise the use of finite mitigation resources. The project will provide an evidence base to inform decision making by governments and property owners to reduce flood risk. The risk mitigation achieved will decrease human suffering, improve safety and ensure amenity for communities.

END USER STATEMENT

Leesa Carson, Geoscience Australia, *ACT*

Floods cause widespread devastation, disruption and cost to communities. A key contributing factor to flood risk is the presence of buildings within flood prone areas.

This project will provide an important evidence base to assist governments and householders make informed decisions on retrofit options for existing houses to reducing the vulnerability of these buildings to flooding.

The project has achieved its scheduled tasks; the development of an initial Australian specific building classification schema and a literature review of existing mitigation strategies. The schema was presented at the Flood Plain Management Association Conference in May this year, and was well received. In addition, the project team undertook a request to survey Dungog after the April flood event. The survey will assist the project in understanding the vulnerability of buildings to high flow velocity flood events.

The project team is actively engaging in BNHCRC workshops and with project leaders to ensure, where relevant, there are connections between projects. The building classification schema will provide valuable input into other BNHCRC projects in the Hardening Building and Infrastructure Cluster. Ongoing communication of project progress is essential to ensure the relevance of the project with key stakeholders.

INTRODUCTION

White (1945) wrote that floods were acts of God but flood losses were largely acts of man. Due to major developments in floodplains which are acts of humans, flood losses are not considered acts of God as humans have played a key role in changing the land use (Green et al. 2011). Globally, floods cause widespread damage with loss of life and property. An analysis of global statistics conducted by Jonkman (2005) showed that floods (including coastal flooding) caused 175,000 fatalities and affected more than 2.2 billion people between 1975 and 2002. In Australia floods cause more damage on an average annual cost basis than any other natural hazard (HNFMSC, 2006). The fundamental cause of this level of damage and the key factor contributing to flood risk, in general, is the presence of vulnerable buildings constructed within floodplains due to ineffective land use planning.

Retrospective analysis show large benefits from disaster risk reduction (DRR) in the contexts of many developed and developing countries. A study conducted by the U.S. Federal Emergency Management Agency (FEMA) found an overall benefit-cost ratio of four suggesting that DRR can be highly effective in future loss reduction (MMC, 2005). However, in spite of potentially high returns, there is limited research in Australia on assessing benefits of different mitigation strategies with consequential reduced investment made in loss reduction measures by individuals and governments. This is true not only at an individual level but also at national and international levels. According to an estimate, international donor agencies allocate 98% of their disaster management funds for relief and reconstruction activities and just 2% is allocated to reduce future losses (Mechler, 2011).

The Bushfire and Natural Hazards Collaborative Research Centre project entitled 'Cost-effective mitigation strategy development for flood prone buildings' (BNHCRC, 2015) is examing the opportunities for reducing the vulnerability of Australian residential buildings to flood. It addresses the need for an evidence base to inform decision making on the mitigation of the flood risk posed by the most vulnerable Australian building types and complements parallel BNHCRC projects for earthquake and severe wind.

This project investigates methods for the upgrading of the existing residential building stock in floodplains to increase their resilience in future flood events. It aims to identify economically optimum upgrading solutions so the finite resources available can be best used to minimise losses, decrease human suffering, improve safety and ensure amenity for communities.

PROJECT BACKGROUND

Recent events in Australia (2011 and 2013) highlight the vulnerability of housing to flooding which originates from inappropriate development in floodplains. While there is now a construction standard published by the Australian Building Code Board (ABCB, 2012) for new construction in flood prone areas, a large proportion of the existing building stock has been built in flood prone areas across Australia (HNFMSC, 2006). The Australian Government has developed a national strategy which defines the roles of government and individuals in improving disaster resilience (NSDR, 2011). The Australian Government also emphases the responsibility of governments, businesses and households in assessing risk and taking action to reduce the risk by implementing mitigation plans (Productivity Commission, 2014).

An in-depth understanding of the effects of floods is required for the assessment of risk and the development of mitigation strategies, particularly in the context of limited financial resources. In this respect, reliable information about the costs and benefits of mitigation are crucial to inform decision-making and the development of policies, strategies and measures to prevent or reduce the impact of flood.

The objective of this project is to provide an evidence base for two target groups to inform their decision making process around mitigation against flood risk: government and property owners. Federal, State/Territory and local governments have an interest in the losses arising from past or future flood events and require vulnerability information to support several objectives including decision making concerning the allocation of funding and risk management. Property owners are also interested in vulnerability and mitigation assessment to know the potential risk to their properties due to floods and to make decisions on undertaking mitigation measures to reduce risk and possibly insurance premiums (Meyer et al. 2012). Therefore, this project aims to provide an evidence base to inform decision making on the mitigation of flood risk by providing information on the cost-effectiveness of a range of mitigation strategies involving alterations to existing residential buildings.

WHAT THE PROJECT HAS BEEN UP TO

The first two tasks have been completed by the end of June 2015 in line with the project schedule. A summary of the two activities is provided below:

BUILDING CLASSIFICATION SCHEMA

Within Australian communities there is a wide range of building types. These vary in many attributes that include floor area, number of storeys, age, architectural style, fit out quality, construction material types and the level of maintenance. For mitigation research it is necessary to take this range of building types and geometrics and discretise it into building classes or categories of similar, if not identical, vulnerability. This "pigeon holing" strategy makes research on impact, risk and mitigation more tractable in that vulnerabilities can be assigned to each class with the reduced variability within the class captured in the uncertainty of the model. Available exposure information can also be mapped to the schema along with building types that can particularly benefit from retrofit interventions.

In this project a literature review has been conducted which reviewed building schemas developed nationally and internationally for a range of uses within different projects. The reviewed schemas are from HAZUS, USA (FEMA, 2007), UNGAR, Global (Maqsood et al. 2014a), Earthquake damage Analysis Center, Germany (Schwarz and Maiwald, 2008), GMMA RAP, Philippines (Pacheco et al. 2013), RiskScape, New Zealand (NIWA, 2010) and Geoscience Australia, Australia (Wehner et al. 2012).

After the literature review a new schema has been proposed which is a fundamental shift from describing the complete building as an enitity to one that focuses on sub-components. The proposed schema divides each building into the sub-elements of foundations, bottom floor, upper floors (if any) and roof to describe its vulnerability. Through this approach it is possible to assess the vulnerability of structures with different usage or construction material used in different floors, and also to assess the vulnerability of tall structures with basements where only basements and/or bottom floors are expected to be inundated (Maqsood et al. 2015a). The schema classifies each floor system based on the following attributes:

- Construction period
- Fit-out quality
- Storey height
- Bottom floor
- Internal wall material
- External wall material

Excluding combinations that are invalid in an Australian context, the draft schema defines 60 discrete vulnerability classes based on the above mentioned attributes. Furthermore, the schema proposed 6 roof types based on material and pitch of the roof.

This proposed schema is the initial categorisation of residential structures as to vulnerability class for this project. It is expected to change and be refined as the project is taken forward and the specific building types for retrofit research are identified. The concept of “nestability” may be subsequently used where mitigation research focuses on several building types that fall within a single broader category and become sub-classes. The draft schema has been developed in recognition of the current and projected ability to define national building exposure and of the parallel BNHCRC mitigation projects examining vulnerability to earthquake and severe wind. While vulnerability schemas are hazard specific, alignment has been sought with the schemas for other hazards where possible.

LITERATURE REVIEW OF FLOOD MITIGATION STRATEGIES

The succeeding task completed in this project has been the literature review of mitigation strategies developed nationally and internationally. The review helps to evaluate the strategies that suit Australian building types and typical catchment behaviours for adoption in Australia. The review has considered literature available through peer-reviewed journals, international conferences and research reports.

Strategies in the international literature have been developed for different types of floods and the adoption of a particular strategy depends upon the characteristics of flood hazard and building stock along with any mitigation incentives and associated cost benefit analysis (Maqsood et al. 2015a). The review discusses the commonly used strategies and summarises the advantages and disadvantages of each of them. The review categorises mitigation strategies into the following categories:

- Elevation
- Relocation
- Dry floodproofing
- Wet floodproofing
- Flood barriers

Elevation is traditionally considered to be an easier and effective strategy and is the one which generally results in incentives such as a reduction in insurance premiums (Bartzis, 2013). However it is difficult to implement for slab-on-grade structures. Relocation is the surest way to eliminate flood risk by relocating outside the floodplain but, as in the case of elevation, it becomes more difficult to implement for heavier and larger structures. Dry floodproofing and flood barriers are efficient only in shallow low velocity hazard areas and are generally not practical in deep fast flowing waters. Wet floodproofing is suitable in low to moderate depths of water with inundation duration of not more than a day.

NEXT STEPS

The tasks for the balance of the project are summarised below:

DEVELOPMENT OF AUSTRALIAN SPECIFIC RETROFIT OPTIONS AND COSTING

New strategies will be developed as required and appropriate strategies will be costed for key building types through the engagement of quantity surveying specialists. The research may also entail experimental testing of preferred material types to ascertain their resilience to flood water exposure.

VULNERABILITY ASSESSMENT FOR CURRENT AND RETROFITTED BUILDING TYPES

The vulnerability of selected building types to a wide range of inundation depths will be assessed and supplemented by both a significant body of flood vulnerability research by Geoscience Australia and a body of damage and socio-economic survey activity in Australia. The outputs of this research will be suitable for use in other CRC research concerning risk assessment and impact forecasting in the immediate aftermath of an actual event.

BENEFIT VERSUS COST ANALYSIS

Retrofit options entail an investment that will realise a benefit over future years through reduced average annualised loss due to severe flood exposure. Decisions to invest in reducing building vulnerability, either through asset owner initiatives or the provision by government or the insurance industry incentives, will depend upon the benefit versus cost of the retrofit. In this exercise all retrofit options will be assessed through a consideration of a range of severity and likelihood of flood hazard covering a selection of catchment types. The work will provide information on the optimal retrofit types and design levels in the context of Australian construction costs and catchment behaviours.

DISSEMINATION

The work will provide information on the retrofit types suitable for Australian building types and associated cost-benefit analysis. The output will be an evidence-base to inform decision making on the mitigation of the community risk posed by Australian residential buildings located in flood plain environments. The outcomes will be communicated to stakeholders through workshops, reports and conference/journal publications. Using the outcomes of the stakeholder workshop and the research, tailored retrofit information will be developed to inform decision making by governments and property owners to reduce flood risk.

OTHER ACTIVITIES

Other activities during the last financial year include:

- Engagement with Project Leaders within the Hardening Buildings and Infrastructure Cluster to discuss research status. Key points raised were development of a Glossary to use consistent terminology in each project, engaging end-users, informing them about progress and seeking feedback, identifying project/hazard specific future requirements from NEXIS (Attributes/data) and suggestions for Exposure Framework Development project in the cluster.
- Engagement with other Project Leaders within the BNHCRC to identify possible linkages. The decision support tool being developed by Prof Holger Maier's project in the Economics and Strategic Decisions Cluster is considered to be quite relevant and could be linked to this project and to the whole cluster.
- As part of collaboration within the BNHCRC, a set of 19 vulnerability models (that GA developed in the last few years) has been provided to Prof Holger Maier to incorporate into the Decision Support Tool. The vulnerability models will enable the assessment of direct economic impacts of flood to residential, commercial and industrial land use. Further collaboration will be required to correctly implement the model set in case studies.
- Consultation with Dr David Henderson at James Cook University (JCU) to explore possible collaboration on floodwater susceptibility of building materials. Dr Henderson has indicated that JCU can to collaborate with GA and has the ability to conduct the experiments. A research proposal has also been drafted to engage a PhD student at JCU.
- Attended the Exposure Framework Workshop in Melbourne (2 December 2014). Contribution to the workshop by identifying fundamental data requirements for buildings, people, businesses, economy and infrastructure.
- Attended the Multi-hazard Economic Loss Project Workshop in Melbourne (2 December 2014). Contribution to the workshop by providing perspective on the loss estimation methods to be applied in the project.
- Attended the BNHCRC Research Advisory Forum (RAF) in Melbourne (3-4 December 2014). Delivery of a presentation providing details of the project activities and completed tasks. The forum was attended by researchers, senior partner representatives and end-user representatives within the BNHCRC. The attendance and presentation helped to engage with end-users and to inform them about project goals and achievements.
- Meeting with the BNHCRC Research Manager Michael Rumsewicz (18 March 2015) to discuss the progress of the project and updating him about the current key project activities.

- Attended the BNHCRC Research Advisory Forum (RAF) in Sydney (9 April 2015). Delivery of a presentation providing details of the project activities and completed tasks. The forum was attended by researchers and end-user representatives. The attendance and presentation helped to engage with end-users and to inform them about project goals and achievements.
- Engagement with Insurance Council of Australia and Edge Environment Consultants to discuss the work done in material susceptibility to water and to identify existing gaps in the state of the research.
- Consultation with CSIRO and survey of the research preformed by CSIRO in the late 1990s to evaluate the resistance of typical construction types to flood loading.
- Dungog post-disaster survey. Dungog located in the Hunter Valley, NSW, was impacted by flash flood on 21 April 2015 resulting in 4 deaths, 4 houses washed away and damage to 46 houses and 5 businesses. The project team conducted a post- disaster survey to gather data about the affect of high velocity water flow on lightweight timber frame structures. During the survey building damage, building attributes and field measurements to document flood depth and flow velocity were recorded.

PUBLICATIONS LIST

- Project Management Plan. Submitted to BNHCRC. 31 March 2014.
- First Quarterly report of FY2013-14. Submitted to BNHCRC. 31 March 2014.
- Second Quarterly report of FY2013-14. Submitted to BNHCRC. 30 June 2014.
- Report on building classification schema (Maqsood et al. 2014b). Submitted to BNHCRC. 25 June 2014.
- Annual report of FY2013-14. Submitted to BNHCRC. 30 June 2014.
- Cost-Effective Mitigation Strategy Development for Flood Prone Buildings (Maqsood et al. 2014c). 2014 AFAC & BNHCRC Conference, Wellington, New Zealand. Poster presentation.
- First Quarterly report of FY2014-15. Submitted to BNHCRC. 30 September 2014.
- Second Quarterly report of FY2014-15. Submitted to BNHCRC. 24 December 2014.
- A schema to categories residential buildings in Australian floodplains (Maqsood et al. 2015a). 2015 Floodplain Management Association National Conference, Brisbane, Australia. Full length paper. 16 March 2015.
- Third Quarterly report of FY2014-15. Submitted to BNHCRC. 31 March 2015.
- A schema to categories residential buildings in Australian floodplains. 2015 Floodplain Management Association National Conference, Brisbane, Australia. Oral presentation. 20 May 2015.
- Report on literature review of flood mitigation strategies (Maqsood et al. 2015b). Submitted to BNHCRC. 29 June 2015.
- Annual report of FY2014-15. Submitted to BNHCRC. 30 June 2015.

CURRENT TEAM MEMBERS

DR TARIQ MAQSOOD

Dr Maqsood is a structural engineer at Geoscience Australia. He is a member of Civil College of Engineers Australia and also a member of the Australian Earthquake Engineering Society (AEES). During the last twelve years Dr Maqsood has focused his research on vulnerability and risk assessment of built environment from natural hazards. In 2011, Dr Maqsood conducted a flood impact assessment case study in the Alexandra canal catchment in Sydney and highlighted the importance of modelling rigor required for risk/impact assessment. In March 2012 Dr Maqsood organised an international flood vulnerability workshop convened in Brisbane attended by over 25 recognised experts from Australia and regional countries that served to validate GA flood research and derive directions for future research. He has also been a part of several international initiatives, such as the Global Earthquake Model, the Greater Metro Manila Risk Assessment (flood), the UNISDR Global Assessment Report and the Earthquake Risk Assessment in Pakistan. He has published several papers in international refereed conferences and reputed journals.

MR MARTIN WEHNER

Mr Wehner is a structural engineer at Geoscience Australia. He has 22 years of experience as a practising structural engineer designing buildings of all sizes and types both in Australia and internationally. Since joining Geoscience Australia his research work has centred on the vulnerability of structures to flood, wind and earthquake. He has participated in post-disaster damage surveys to Padang (Earthquake), Brisbane (Flood), Kalgoorlie (Earthquake) and Christchurch (Earthquake). In each case he has led the post-survey data analysis to develop vulnerability relationships and calibrate existing relationships. He has led the development of Geoscience Australia's suite of flood and storm surge vulnerability curves. He is a Member of Engineers Australia and IABSE.

DR KEN DALE

Dr Dale is a structural engineer at Geoscience Australia who obtained his Bachelor Degree (1994) and PhD (2001) at Monash University. He undertook Post-Doctoral research in Japan related to the earthquake behaviour of steel beam-to-column connections (2001-2003) before joining Geoscience Australia in 2003. Research interests include the behaviour of structures and other infrastructure under extreme loads (blast, flood, tsunami, and earthquake). Research in the flood area has included modifying damage curves that incorporate flood height and velocity to suit Australian construction, and the development of stage-damage curves for a small suite of residential structures. Flood experience also includes leading teams on post-event damage surveys in Melbourne (2004) and Brisbane (2011).

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