DEVELOPMENT OF FLOOD MITIGATION STRATEGIES FOR AUSTRALIAN RESIDENTIAL BUILDINGS

Non-peer reviewed research proceedings from the Bushfire and Natural Hazards CRC & AFAC conference
Brisbane, 30 August – 1 September 2016

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Version	Release history	Date
1.0	Initial release of document	01/09/2016

Publisher:
Bushfire and Natural Hazards CRC

September 2016

INTRODUCTION

Globally floods cause widespread damage and 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 basis than any other national disaster (HNFMSC, 2006). The fundamental causes of this severity of damage and the key factors contributing to flood risk, in general, are the vulnerable buildings constructed within floodplains and land-use planning.

Recent events in Australia (2011, 2013 and 2015) highlighted the vulnerability of housing to flooding which originates from inappropriate development in floodplains. While there is a construction standard issued by the Australian Building Code Board (ABCB, 2012) for new construction in some types of flood-prone areas, a large proportion of the existing building stock has been built in flood-prone areas across Australia (HNFMSC, 2006). Flood losses from the recent events highlight the requirement of implementing effective and efficient mitigation measures to reduce losses in future.

The Australian Government has developed the National Strategy for Disaster Resilience that defines the role of government and individuals in improving disaster resilience (NSDR, 2011). The strategy also emphasises the responsibility of governments, businesses and households to assess risk and take action to reduce the risk by implementing mitigation plans (Productivity Commission, 2014). Therefore, an in-depth understanding of the effects of floods on building stock is required for the development of risk mitigation and adaptation strategies, in particular considering the limited financial resources available. In this respect, reliable information about the costs and benefits of mitigation are crucial to inform decision-making and develop policies, strategies and measures to prevent or reduce the impact of flood.

The Bushfire and Natural Hazards Cooperative Research Centre project entitled 'Cost-effective mitigation strategy development for flood-prone buildings' (BNHCRC, 2016) is examining opportunities for reducing the vulnerability of new and existing Australian residential buildings. 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. This project investigates methods for upgrading existing residential building stock in floodplains to increase their resilience to future flood events. The project also aims to make assessments of the reduction in damage losses that will result from the implementation of a range of mitigation measures developed by the project.

COMPLETED PROJECT ACTIVITIES

A summary of the activities which have been completed is presented below.

Development of building schema

This research requires a building vulnerability classification, or schema. The classes identified within the schema have to represent the variety of housing within the nation's residential building stock and, more specifically, the variation in vulnerability across the nation's building stock. Furthermore, the schema must identify specific classes for which the project will develop mitigation strategies.

In this research, 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 the USA (FEMA, 2007a), Germany (Schwarz and Maiwald, 2008), Philippines (Pacheco et al. 2013), New Zealand (NIWA, 2010), Australia (Wehner et al. 2012) and UNISDR Global Assessment Report (Maqsood et al. 2014).

Based on the literature review a schema was proposed that represents a fundamental shift from describing the complete building as an entity to one that focuses on sub-components (Maqsood et al. 2015a). The proposed schema divides each building into its major components (i.e. foundation, ground floor, upper floors [if any] and roof) enabling the vulnerability of each of these components to be assessed separately (Figure 1). Each storey type is then classified using the following six attributes.

- Construction period (pre-1960 or post-1960)
- Fit-out quality (standard or low)
- Storey height (3.0m or 2.7m or 2.4m)
- Bottom floor system (slab-on-grade or raised timber or raised particleboard)
- Internal wall material (masonry or plasterboard or timber)
- External wall material (brick veneer or weatherboard or masonry)

With the exclusion of combinations that are invalid in an Australian context, the schema defines 60 discrete storey types based on the above-listed attributes. Additionally, the schema proposes six roof types based on the material and pitch of the roof.

This approach facilitates the development of vulnerability models for taller buildings, buildings with basements, buildings with mixed usages and those with different construction materials used at different floor levels. Therefore, the new approach provides a mechanism to represent building stock in a better way and to improve the quality of flood risk assessment.

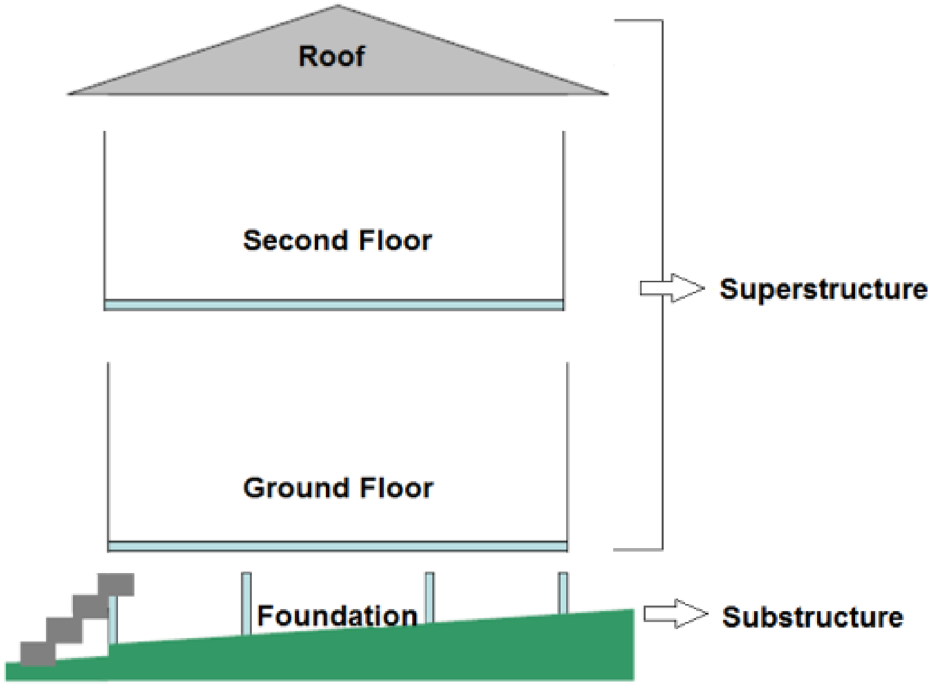


FIGURE 1: BUILDING STRUCTURE DIVIDED INTO MAIN COMPONENTS (MAQSOOD ET AL. 2015A)

Literature review of mitigation strategies

A literature review has been conducted to identify mitigation strategies used in several countries and for various severities of flooding (Maqsood et al. 2015b). The review has considered literature available through peer-reviewed journals, international conferences, research reports and guideline documents, and a summary of the review is provided here.

Bouwer et al. 2011 classified the different types of retrofit or mitigation measures into nine basic categories in which a distinction was made between mitigation measures that focus on hazard reduction and those that focus on vulnerability reduction. The use of insurance to recover from a disaster and to provide incentives for mitigation works was studied by Kunreuther (2006) and Crichton (2008). The use of spatial zoning and land-use changes was presented by Burby et al. 2000 and Poussin et al. 2012. Another widely used broader classification of mitigation measures is based on whether the strategies utilise engineering and administrative methods to reduce flood risk or modify the flood characteristics and human occupancy of the floodplain. These are broadly divided into structural and non-structural approaches (Brody et al. 2010) or hard and soft measures (Productivity Commission, 2014). Both approaches have benefits and limitations. Mitigation strategies that have been applied in Australia and internationally to minimise vulnerability and future losses of residential buildings can be summarised below (Maqsood et al. 2016).

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

Development of costing modules for selected retrofit options

Out of 60 possible types, five typical storey types have been selected for the remainder of the research which represent most common residential types in Australia. These are a subset of the schema proposed earlier in this paper. Key characteristics of these storey types are presented in Table 1. Further, based on the characteristics of the selected storey types, a floodproofing matrix has been developed which excludes the mitigation options noted in Section 2.2 that are invalid and considered to be inappropriate in the Australian context (see Table 2). As part of this project costing modules are being developed by quantity surveying specialists to estimate the cost of implementing all appropriate mitigation strategies for these five storey types. A summary of mitigation measures considered for the costing is provided below.

Elevating a structure is one of the most common mitigation strategies which aims to raise the lowest floor of a building above the expected level of flooding. This can be achieved by (i) extending the walls of an existing structure and raising the floor level, (ii) changing the use of ground floor and constructing a new floor above the existing one, (iii) through raising the whole structure on new substructure. Figure 2 shows the three techniques to elevate a building. The applicability of these techniques for the five selected storey types is presented in Table 2.

Relocation of a building is the most dependable technique, however, it is generally the most expensive as well (USACE, 1993). Relocation involves moving a structure to a location that is less prone to flooding or less exposed to flood-related hazards such as erosion or scouring. Relocation normally involves placing the structure on a wheeled vehicle, then transporting it to a new location and setting it on a new foundation (FEMA, 2012). In the present study this is found to be appropriate only for Building Type 1 which is a lightweight timber frame building with weatherboard exterior walls.

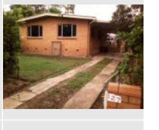
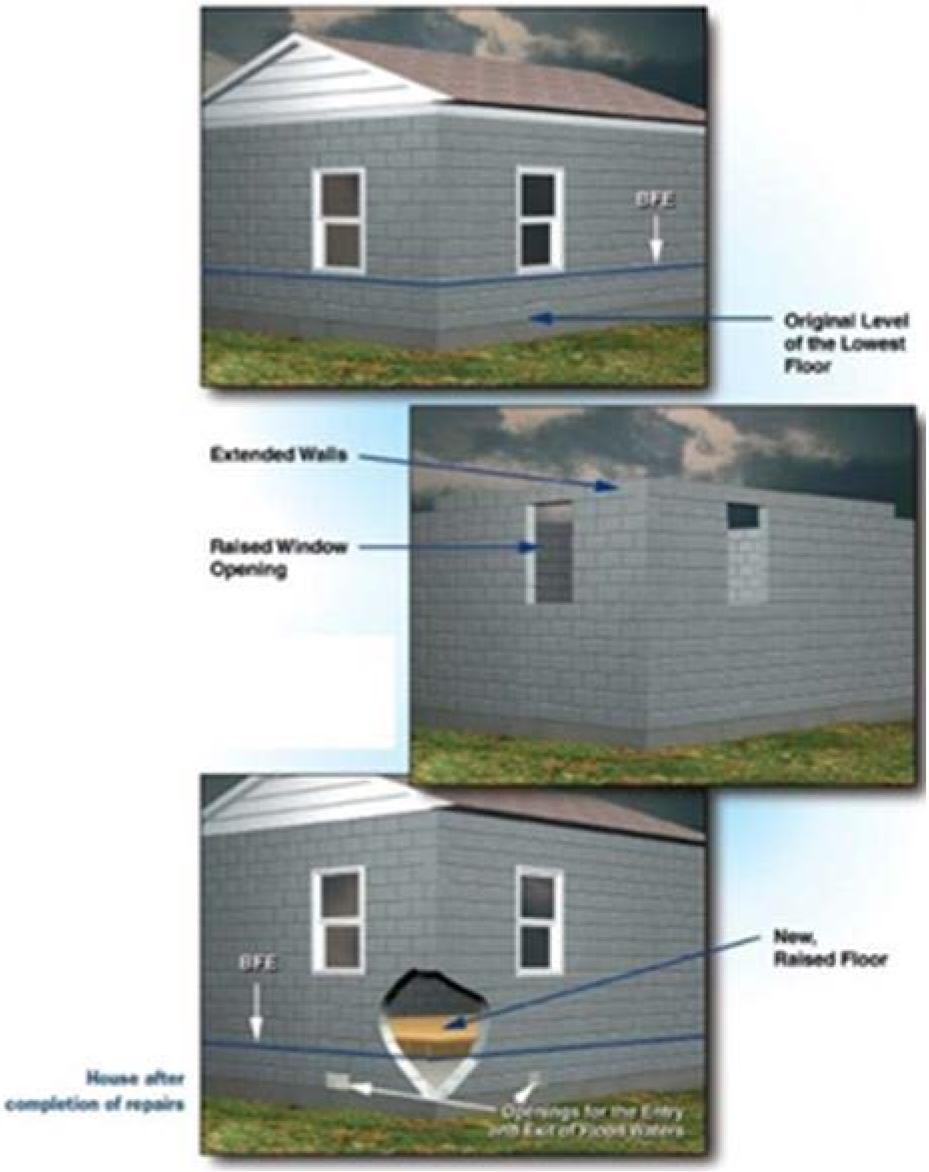
Storey Type	Construction period	Bottom floor system	Fit-out quality	Storey height	Internal wall material	External wall material	Photo
1	Pre 1960	Raised timber	Low	2.7m	Timber	Weatherboard	
2	Pre 1960	Raised timber	Low	3.0m	Masonry	Solid masonry	
3	Pre 1960	Raised timber	Low	2.4m	Masonry	Cavity masonry	
4	Post 1960	Raised timber	Standard	2.4m	Plasterboard	Brick veneer	
5	Post 1960	Slab-on-grade	Standard	2.4m	Plasterboard	Brick veneer	

TABLE 1: CHARACTERISTICS OF SELECTED STOREY TYPES

(A) Technique 1: extending the walls of an existing structure and raising the floor level



(B) Technique 2: changing the use of ground floor and constructing a new floor above the existing one

(C) Technique 3: raising the whole structure on new substructure

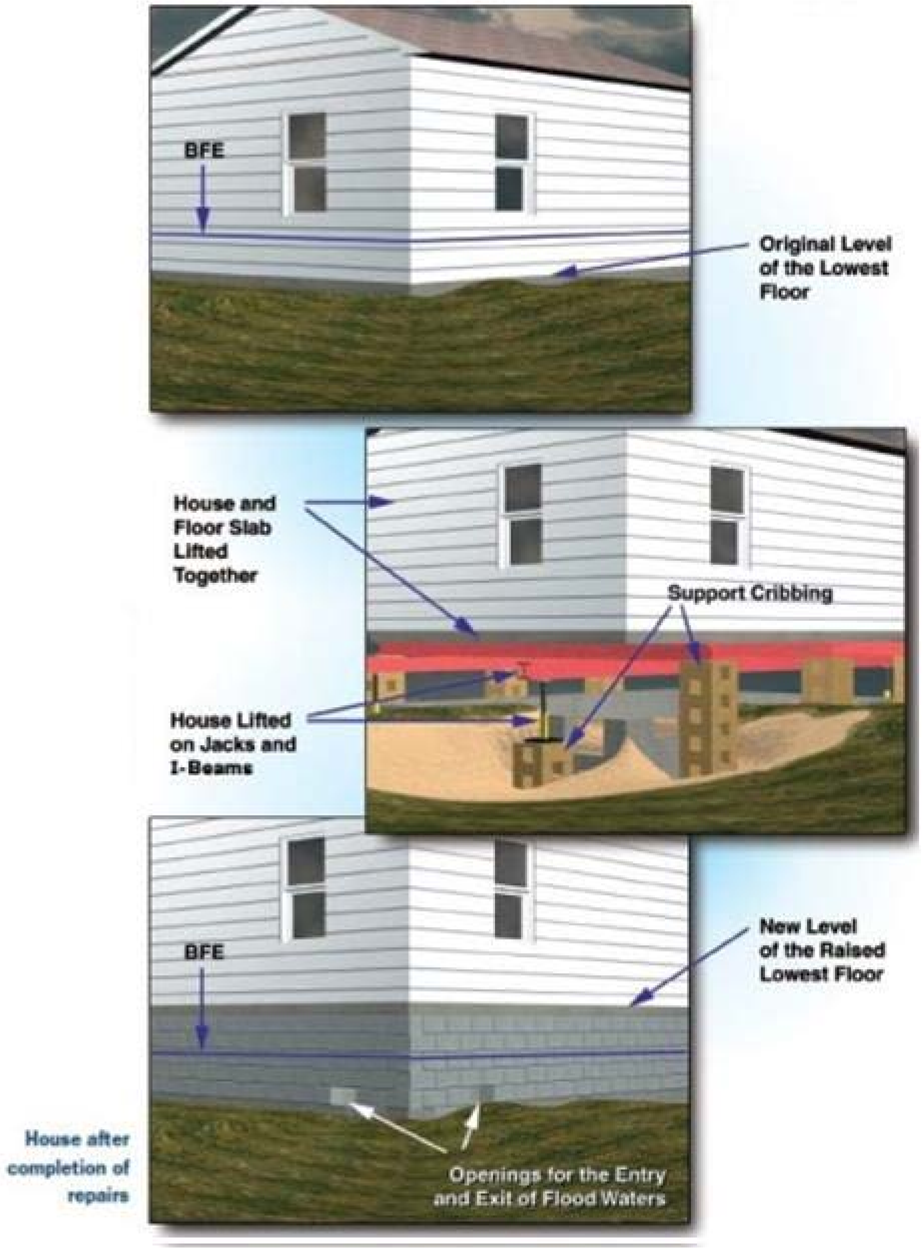


FIGURE 2: TECHNIQUES FOR ELEVATION (FEMA, 2000)

Building Type	Elevation (Extending the walls)	Elevation (Building a second storey)	Elevation (Raising the whole house)	Relocation	Flood barriers (permanent)	Flood barriers (temporary)	Dry flood-proofing	Wet flood-proofing
1	N/A				N/A	N/A	N/A	
2	N/A		N/A	N/A				
3			N/A	N/A	N/A	N/A	N/A	
4	N/A		N/A	N/A	N/A	N/A	N/A	
5	N/A		N/A	N/A				

TABLE 2: FLOODPROOFING MATRIX

Dry floodproofing consists of measures to seal the portion of a structure that is below the expected flood level to make it substantially impermeable to floodwaters. Such an outcome is achieved by using sealing systems which include wall coatings, waterproofing compounds, impervious sheeting over doors and windows and a supplementary leaf of masonry (FEMA, 2012). Dry floodproofing is generally not recommended in flood depths exceeding one metre based on tests carried out by the US Army Corps of Engineers as the stability of the building becomes an issue above this threshold depth (USACE, 1988; Kreibich et al. 2005). Dry floodproofing may also be inappropriate for light timber frame structures (Building Type 1), structures with raised timber floors (Building Type 1, 3 & 4) and structures which are not in good condition and may not be able to withstand the forces exerted by the floodwater (FEMA, 2012).

Wet floodproofing includes modifying the building by (i) replacing existing building components/materials with more water-resistant materials, (ii) adapting to the flood hazard by raising key services and utilities to a higher level, and (iii) installing flood openings to equalise the hydrostatic pressure exerted by floodwaters on the interior and exterior of the building and thus reducing the chance of building failure. With this technique, as the building components below the flood level are wetted, all construction material and fit-outs should be water-resistant and/or can be easily cleaned following a flood (USACE, 1993; FEMA, 2007b). This strategy can be used for all storey types.

Flood barriers considered in this research are those built around a single building and are normally placed some distance away from it to avoid any structural modifications to the building. There are two kinds of barriers: permanent and temporary. An example of a permanent barrier is a floodwall which is quite effective because it requires little maintenance and can be easily constructed and inspected. Generally, it is made of reinforced masonry or concrete and has one or more passageways that are closed by gates. There are also several types of temporary flood barriers available in the market which can be moved, stored and reused. Examples of temporary flood barriers are shown in Figure 3. Flood barriers may be inappropriate for structures with raised floors (Building Type 1, 3 & 4) because of the high cost of barriers for height more than 1 m.

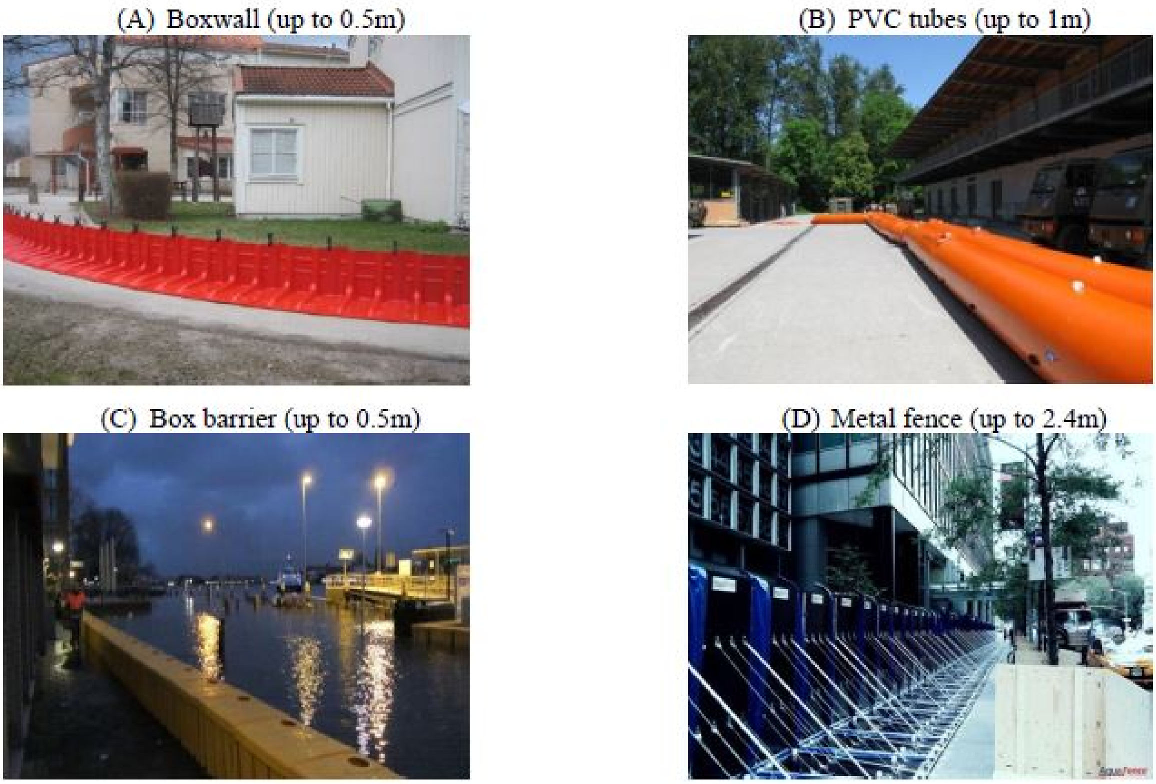


FIGURE 3: EXAMPLES OF TEMPORARY FLOOD BARRIERS (BLUEMONT, 2015)

FUTURE PROJECT ACTIVITIES

A brief overview of the future activities of the project is given below.

Experimental testing of selected building materials

In this project the strength and durability implications of immersion of key structural elements will be examined in slow water-rising conditions to ascertain where deterioration due to wetting and subsequent drying needs to be addressed as part of repair strategies. An analysis will be conducted to identify research gaps in building material susceptibility to flood water in Australia. This research will also entail experimental testing of preferred material types to ascertain their resilience to flood water exposure in FY 2016-17.

Vulnerability assessment for current and retrofitted building types

The vulnerability of selected storey types to a wide range of inundation depths will be assessed. It will also be supplemented by both a significant range of flood vulnerability research by Geoscience Australia which includes flood vulnerability models for a range of usage (e.g. residential, commercial, industrial) and a body of damage survey activity in Australia.

Benefit versus cost analysis

Retrofit options entail an investment that will realise a benefit over future years through reduced average annualised loss. Decisions to invest in reducing building vulnerability, either through asset owner initiatives or incentives provided by government or the insurance industry, will depend upon the benefit versus cost of the retrofit. In this research all retrofit options will be assessed in future years through a consideration of a range of severity and likelihood of flood hazard covering a selection of catchment types.

OUTCOMES

The result will be an evidence base to inform decision-making by government and property owners on mitigation of flood risk by providing information on the cost-effectiveness of different mitigation strategies and optimal solutions for different cases of building and 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 by the end of the project in 2020.

SUMMARY

Economic losses due to floods have been increasing during the last decades due to vulnerable construction types and because of rapid urban development in floodplains which increases exposure to flooding. The increase in loss emphasises the need to improve flood risk management and to reduce future flood losses.

Flood risk management not only includes the measures taken by government but also includes mitigation measures adopted by private property owners to reduce the potential losses. These measures include elevating structures above the expected flood level, relocating the structure outside the floodplain, dry floodproofing to make the structure water tight, wet floodproofing by using water-resistant materials and installing flood barriers to keep water away from the building. These efforts have a significant potential to reduce flood damage to buildings and contents particularly in low to moderate flood levels losses (Kreibich and Thieken, 2008).

This project within the Bushfire and Natural Hazards CRC aims to conduct a comprehensive analysis of mitigation options and evaluate each of them through cost benefit analyses for use in Australian conditions. The result will be a clear understanding of cost and benefits involved in implementing any of these mitigation measures. This evidence base will facilitate and encourage governments and property owners to make informed and optimal decisions to reduce flood risk.

Acknowledgements

The support of the Commonwealth of Australia through the Cooperative Research Centre program is acknowledged. This paper is published with the permission of the CEO, Geoscience Australia.

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