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COST-EFFECTIVE MITIGATION STRATEGY DEVELOPMENT FOR FLOOD PRONE BUILDINGS

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Geoscience Australia, ACT



An Australian Government Initiative



Australian Government
Geoscience Australia

PROJECT MANAGEMENT TEAM

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PROBLEM STATEMENT

- Australia has experienced floods on a regular basis and some communities have been impacted repeatedly over a period of few years due to inappropriate urban development in flood plain areas.
- The flood events have resulted in significant logistics for emergency management and disruption to communities. They have also resulted in considerable costs to all levels of government to repair damage and enable community recovery.

PROBLEM STATEMENT

Some recent floods in Australia

- 2005 Lismore flood
- 2010 Victorian flood
- 2010-11 Queensland flood
- 2011 Victorian flood
- 2013 Queensland/NSW flood



RESEARCH OBJECTIVE

- To develop cost-effective strategies to mitigate damage to residential buildings from riverine floods.
- To provide the evidence base for decisions concerning the buildings having the greatest vulnerability in Australian communities by providing strategies for retrofit.

MITIGATION OPTIONS

- Structural/non-structural options

- Dams, levees
- Flood gates, retarding basins
- Land use planning
- Flood forecasting and warning
- Flood awareness, community readiness
- Evacuation arrangements

- Addressing the housing ← Project's focus

- Retirement and relocation <1%
- Raising floor levels (elevation) 5%
- Rebuild with revised ground floor use 12%
- Repair with more flood resistant material 19%
- Raising electrical outlets and hardware 8%
- Repair as previously* *60%

Responses from the postal survey after the 2011 Queensland flood

TASKS

- Classification of residential building stock
- Literature survey of existing mitigation options
- Australian specific mitigation options and costing, experimental testing of selected building materials
- Vulnerability assessment of current and retrofitted buildings
- Benefit verses cost analysis of retrofit and new construction options
- Identification of optimal retrofit strategies
- Stakeholder workshops

BUILDING STOCK CLASSIFICATION (COMPLETED)

- Classification of residential building stock: review
 - HAZUS (USA): 11, structural system, storey class
 - Riskscape (New Zealand): structural system, wall and roof material, storeys, usage etc.
 - EDAC (Germany), 6, structural system, based on EMS-98, vulnerability classes
 - UPD (The Philippines): 15, structural system, storey class, wall material
 - UNISDR (Asia-Pacific): 27, structural system, 1, 2 or 3 storey, elevated/non-elevated, water susceptibility, usage
 - NSW Office for Environment and Heritage (NSW): 3, 1 or 2 storey, elevated/non-elevated
 - Geoscience Australia (QLD and NSW): 19, 1 or 2 storey, elevate/non-elevated, external and internal wall material, garage

BUILDING STOCK CLASSIFICATION (COMPLETED)

- Classification of residential building stock: adopted

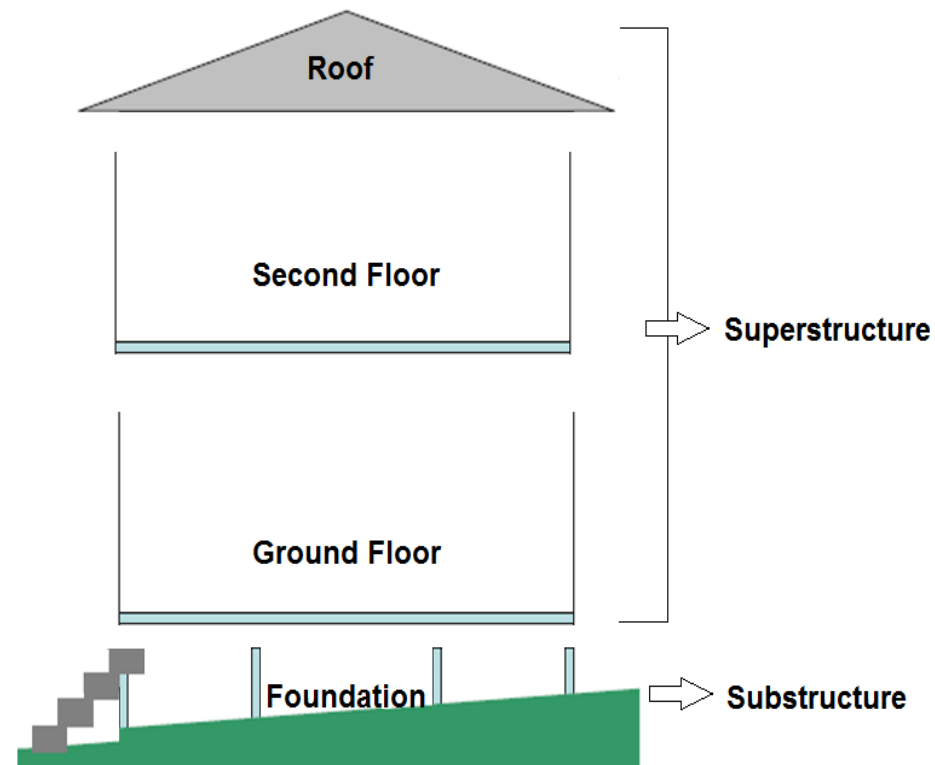
Floor level attributes:

- *Construction Period*
- *Fit-out Quality*
- *Storey Height*
- *Bottom Floor System*
- *Internal Wall Material*
- *External Wall Material*

60 possible combination of floor system

Roof attributes:

- *Pitch*
- *Material*



REVIEW OF MITIGATION OPTIONS (COMPLETED)

- Sources

- Building standards
- Guidelines
- Project reports
- Conference papers
- Journal articles

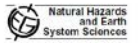


Impact of the 2010–11 floods and the factors that inhibit and enable household adaptation strategies

Deanne Bird, David King, Katharine Haynes, Pamela Box, Tetsuya Okada and Kate Nairn



Met. Research Bank Syst. Sci., 12, 1907–1918 (2012)
www.met-research.com/doi/10.1007/s11067-012-9121-2
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Springer



Long term development and effectiveness of private flood mitigation measures: an analysis for the German part of the river Rhine

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Abstract. Flood mitigation measures implemented by private households have become an important component of contemporary urban and flood risk management in Germany and many other countries. Despite the growing responsibility of private households to contribute to flood damage reduction, the nature of private flood mitigation measures, their effectiveness in reducing vulnerability over time, and their effectiveness in reducing the long-term development of flood damage, remain unclear. This paper examines the long-term development, current implementation level, and effectiveness of private flood mitigation measures, assessed data from 72 flood-prone households along the German part of the Rhine as presented. It is found that four types of flood mitigation measures developed gradually over time ranging from no mitigation, with private flood being important trigger for an accelerated implementation. At present, only a large share of respondents has implemented multiple flood mitigation measures, despite the high exposure of the assessed households to flood. The results of household's flood damage to content and structure during two consecutive flood events with similar hazard characteristics in 1993 and 1997 show that an expected preparation of the population led to substantially reduced damage during the long event. Regarding the efficiency of subsequent structural flood risk management, it is concluded that additional private measures are required in order to further reduce the level of participation of the flood-prone population. This especially concerns households in areas that are less frequently affected by flood events.

1 Introduction
In line with general flood research some integrated flood risk management approaches, the existence of private households to flood damage reduction gained increasing importance. Countries, as well as in European and global level (Laska, 1990; Rijk, 2010; Pan, 2010; Federal Environment Agency, 2010; Betsch et al., 2012). Comparatively to traditional flood prevention, such integrated approaches also aim at reducing the potential consequences of flood, through the improvement of flood hazard. Previous research indicated that these measures are effective in reducing damage and are cost-effective in many situations (Cretney et al., 2005; O'Brien, 2005; Kreibitz et al., 2010). The cost-effectiveness of damage mitigation measures at the household level has also been investigated for other national levels, such as national and state level (e.g. Betsch and Frenn, 2008; Betsch et al., 2012).
In Germany, private households' responsibility for flood damage reduction has been increasingly emphasized and established into flood risk management in response to severe floods in 1997 and 1999 along the river Rhine and Meuse and in 2005 along the Elbe and Danube (Federal Environment Agency, 2010). Especially the severe flood in 2005, which caused 12 fatalities and more than 451 billion of economic damage in Germany (Thielen et al., 2008), revealed the significant failure expected in the regulation and implementation of damage mitigation measures (Frenn et al., 2006). As a consequence, regulations regarding non-gradually
¹http://www.met-research.com/doi/10.1007/s11067-012-9121-2

Published by Copernicus Publications on behalf of the European Geosciences Union.



Above the Flood:
Elevating Your
Floodprone House

FEMA 347 / May 2000

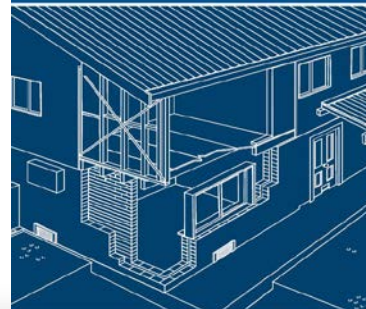


Homeowner's Guide
to Retrofitting

Six Ways to Protect Your Home From Flooding
FEMA P-312, 3rd Edition / June 2014



REDUCING VULNERABILITY OF
BUILDINGS TO FLOOD DAMAGE
Guidance On Building In Flood Prone Areas



Construction of Buildings
in Flood Hazard Areas



2012
VERSION 2012.2

STANDARD

REVIEW OF MITIGATION OPTIONS (COMPLETED)



- Raising floor level: elevating the house



- Relocation: moving to higher ground



- Demolition: tearing down damaged house



- Wet flood proofing: allowing water to enter



- Dry flood proofing: sealing a house



- Barriers: flood wall or levee around a house

REVIEW OF MITIGATION OPTIONS (COMPLETED)

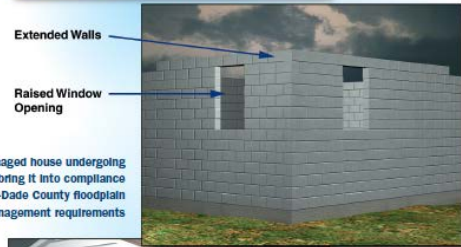
- Raising floor levels: elevation

Option 1



Extend the walls of the house upward and raise the lowest floor.

Original Level of the Lowest Floor



Extended Walls
Raised Window Opening

Substantially damaged house undergoing repairs that will bring it into compliance with Miami-Dade County floodplain management requirements



New, Raised Floor

House after completion of repairs

Openings for the Entry and Exit of Flood Waters

Option 2



Convert the existing lower area of the house to non-habitable space and build a new second story for living space.

New Second Story Above BFE



Substantially damaged house undergoing repairs that will bring it into compliance with Miami-Dade County floodplain management requirements

Openings for the Entry and Exit of Flood Waters



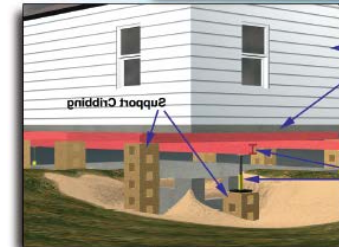
Lower Area Converted to Non-Habitable Space for Storage, Parking, or Building Access

House after completion of repairs

Option 3



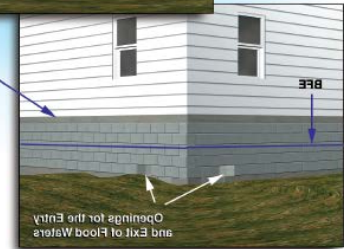
Original Level of the Lowest Floor



House Lifting I-Beams and Joist Lifting

Support Chipping

Substantially damaged house undergoing repairs that will bring it into compliance with Miami-Dade County floodplain management requirements



New Level of the Raised Floor

Openings for the Entry and Exit of Flood Waters

House after completion of repairs

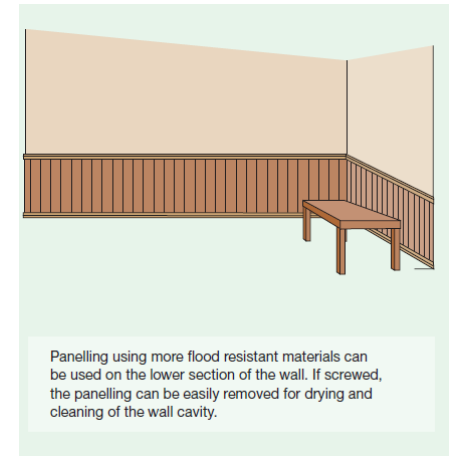
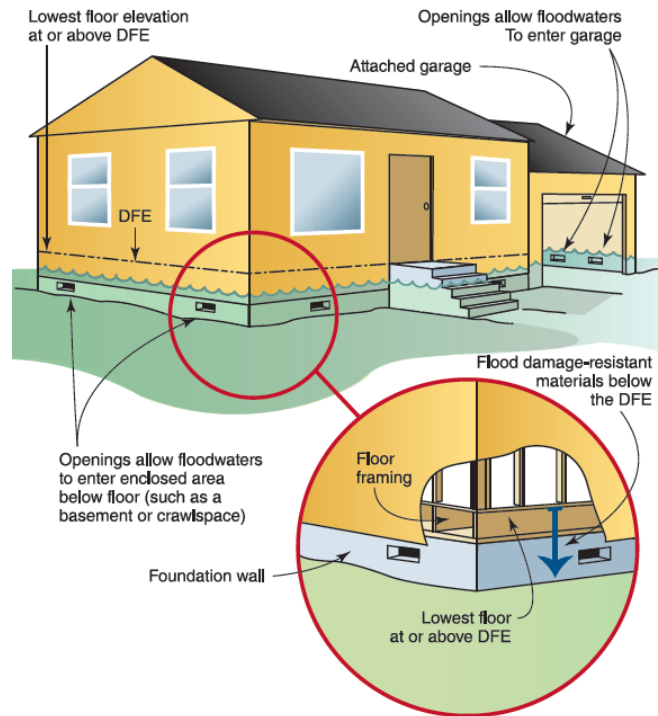
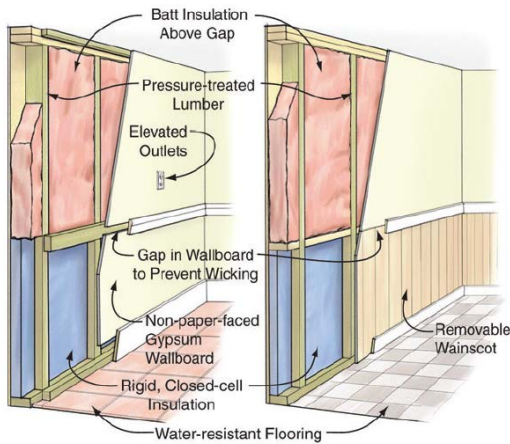
REVIEW OF MITIGATION OPTIONS (COMPLETED)

- Relocation



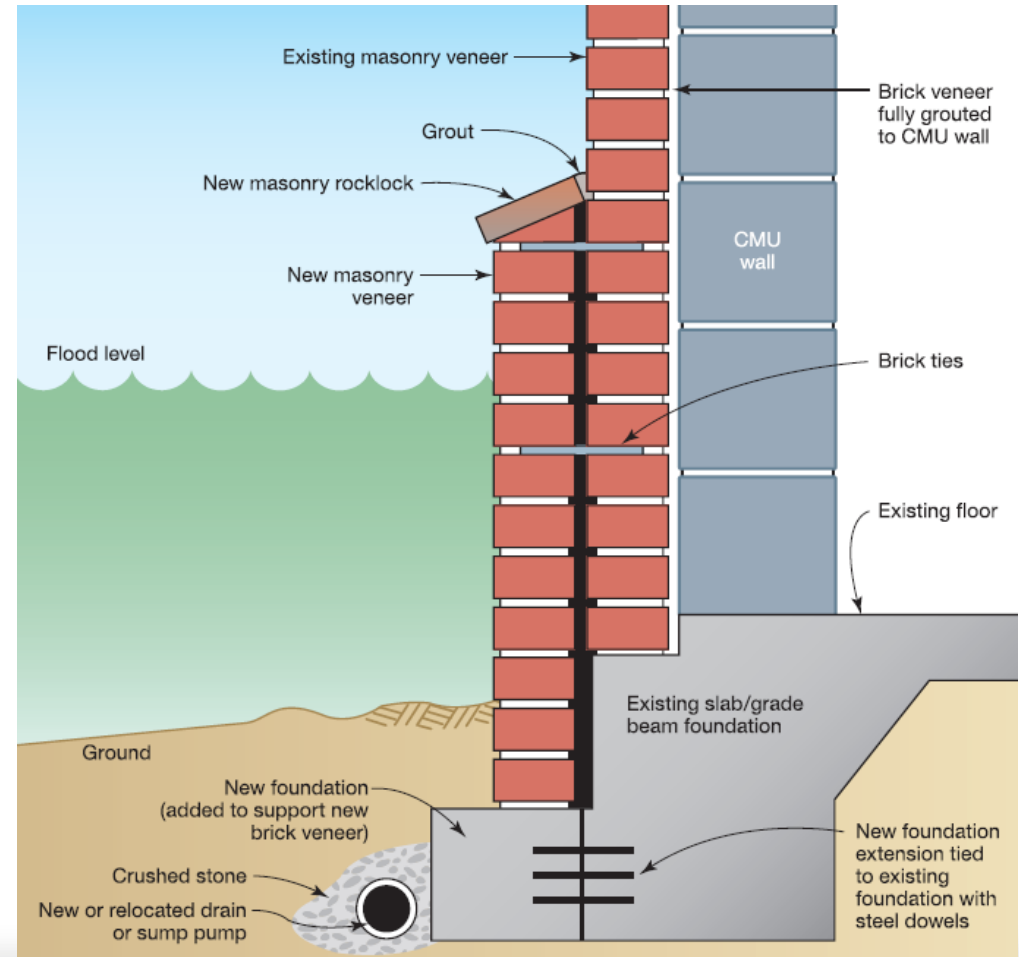
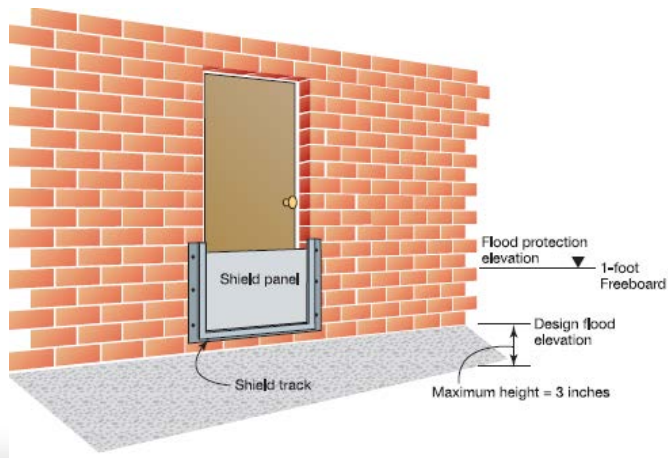
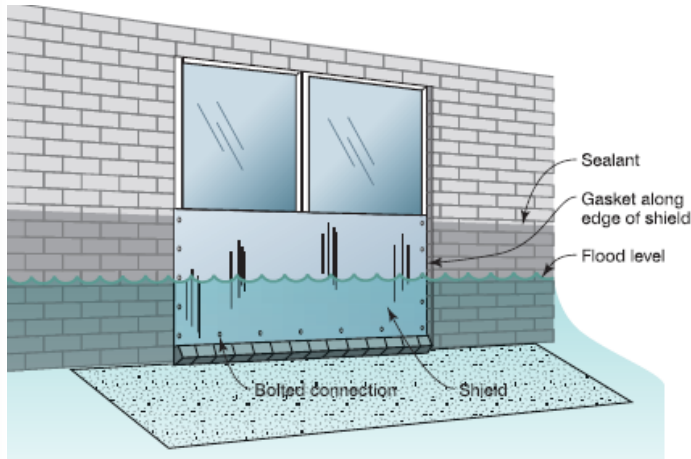
REVIEW OF MITIGATION OPTIONS (COMPLETED)

- Wet flood proofing



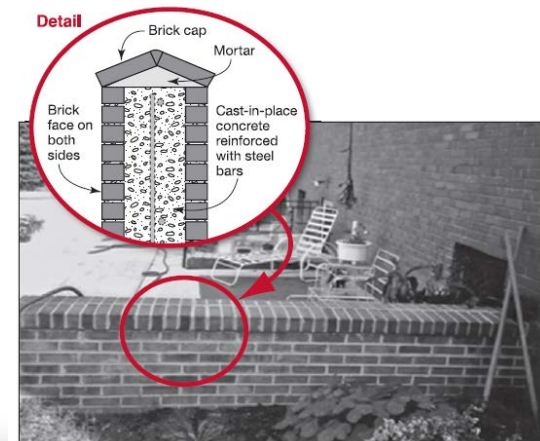
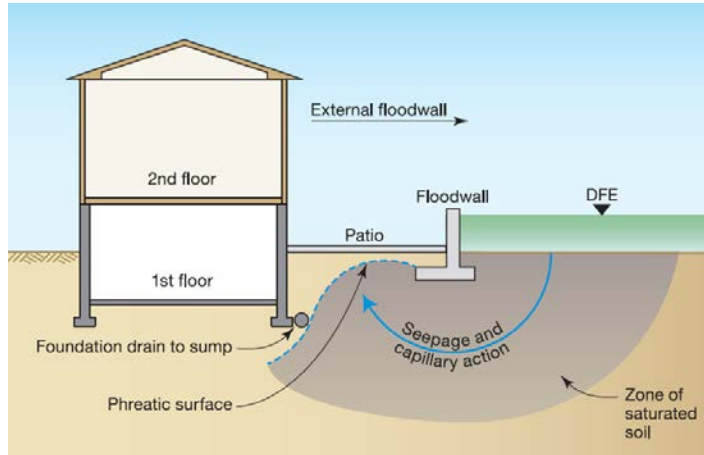
REVIEW OF MITIGATION OPTIONS (COMPLETED)

- Dry flood proofing



REVIEW OF MITIGATION OPTIONS (COMPLETED)

- Barriers: flood walls



REVIEW OF MITIGATION OPTIONS (COMPLETED)

- Raising floor levels: elevation

Advantages	Disadvantages
<ul style="list-style-type: none">• Reduces flood risk to the structure and its contents• Often reduces flood insurance premiums (elevation only)• Uses established techniques• Can be initiated quickly• Reduces the physical, financial, and emotional strains that accompany flood events	<ul style="list-style-type: none">• Elevation/demolition: May be cost-prohibitive• Elevation: May adversely affect the structure's appearance• Elevation: May adversely affect access to the structure• Relocation: Requires locating a new site• Wet proofing: Usually requires a flood warning to prepare the building and contents for flooding• Wet proofing: Requires human intervention to evacuate contents from the flood-prone area• Dry proofing: Requires ongoing maintenance• Dry proofing: Cannot be used in areas with high-velocity water flow unless special measures are taken• Barriers: Only applicable to low inundation• Barriers: May fail or be overtopped by large floods• Barriers: Requires periodic maintenance and interior drainage

REVIEW OF MITIGATION OPTIONS (COMPLETED)

- Making decision to retrofit

Hazard level	Building type	Government rules	Decision
<ul style="list-style-type: none">• Catchment type• Flood hazard• Flood levels• Duration	<ul style="list-style-type: none">• Age• Foundation type• Construction materials• Fit outs• Condition	<ul style="list-style-type: none">• Local regulations/codes• Technical assistance• Financial assistance	<ul style="list-style-type: none">• Available options• Benefit/Cost assessment• Approvals• Retrofit

MATERIAL SUSCEPTIBILITY TO WATER (CURRENT)

- Building material susceptibility to water



Flood Damage-Resistant Materials Requirements

for Buildings Located in Special Flood Hazard Areas in accordance with the National Flood Insurance Program

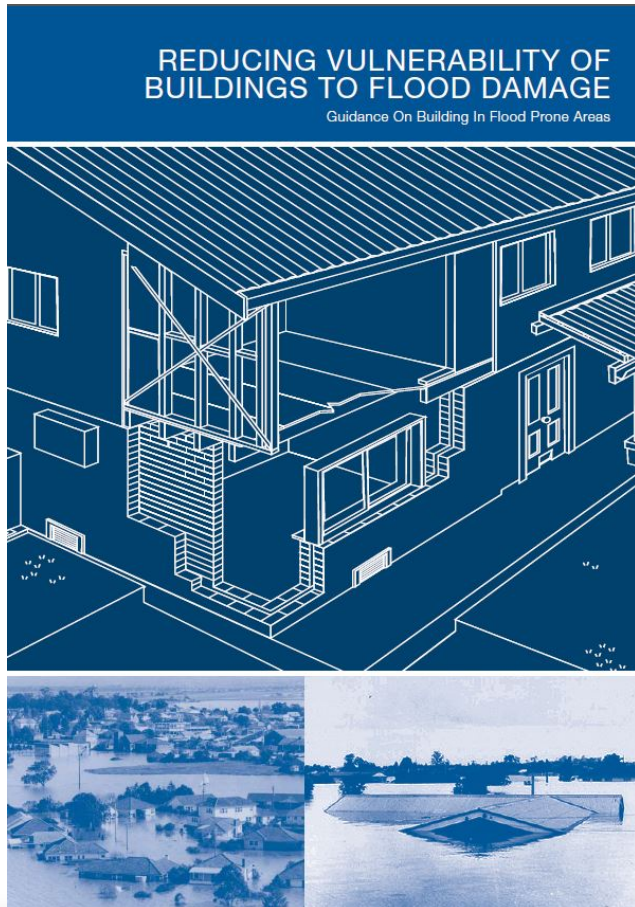
Technical Bulletin 2 / August 2008



Types of Building Materials	Uses of Building Materials		Classes of Building Materials					
	Floors	Walls/Ceilings	Acceptable		Unacceptable			
			5	4	3	2	1	
Structural Materials (floor slabs, beams, subfloors, framing, and interior/exterior sheathing)								
Wood								
Solid, standard, structural (2x4s)		■		■				
Solid, standard, finish/trim		■			■			
Solid, decay-resistant ¹	■	■	■					
Solid, preservative-treated, ACQ or C-A		■		■				
Solid, preservative-treated, Borate ²		■		■				
Finish Materials (floor coverings, wall and ceiling finishes, insulation, cabinets, doors, partitions, and windows)								
Asphalt tile ⁵								
With asphaltic adhesives	■				■			
All other types	■							■
Cabinets, built-in								
Wood		■				■		
Particle board		■						■
Metal ³		■		■				
Carpeting	■							■
Ceramic and porcelain tile								
With mortar set	■	■		■				
With organic adhesives	■	■					■	
Concrete tile, with mortar set	■		■					
Corkboard		■					■	
Doors								
Wood, hollow		■					■	
Wood, lightweight panel construction		■					■	
Wood, solid		■					■	
Metal, hollow ³		■		■				
Metal, wood core ³		■		■				
Metal, foam-filled core ³		■		■				
Fiberglass, wood core		■		■				
Epoxy, formed-in-place	■		■					

MATERIAL SUSCEPTIBILITY TO WATER (CURRENT)

- Building material susceptibility to water



ABSORBENCY				
CLASS	HIGH	MODERATE	LOW	NIL
A	<ul style="list-style-type: none"> • masonry • concrete 		<ul style="list-style-type: none"> • solvent-based neoprene adhesives • two-part epoxy adhesives • rubber based sealants • silicone sealants 	<ul style="list-style-type: none"> • copper • brass • plastic membranes and sheeting • nylon fittings • glass • glass bricks
B	<ul style="list-style-type: none"> • plasterboard 	<ul style="list-style-type: none"> • plywood • hardwood 		
C		<ul style="list-style-type: none"> • low durability timbers • good quality adhesives • low quality tiles • water-based paints 	<ul style="list-style-type: none"> • high durability timbers • good quality tiles • rubber-based adhesives • epoxy putty sealants • stone epoxy formed in place 	<ul style="list-style-type: none"> • galvanised steel • aluminium
D	<ul style="list-style-type: none"> • insulation • building paper • wall paper • ceiling plasterboard* • normal particle-board 	<ul style="list-style-type: none"> • hardboard • dry area adhesives • water-based acrylic adhesives • water-based urethane adhesives • water-based acrylic sealants • PVA emulsion cements • lino, carpets, cork 	<ul style="list-style-type: none"> • oil based paints 	<ul style="list-style-type: none"> • bright steel

A minimal damage under most circumstances
 B susceptible to physical damage when wet, otherwise no long-term damage
 C subject to damage after prolonged immersion, but will recover when effectively dried
 D subject to permanent damage if subjected to relatively short periods of wetness
 * plasterboard fails due to increased weight and weakened state

MATERIAL SUSCEPTIBILITY TO WATER (CURRENT)

- Building Resilience Rating Tool



BRKD > External Walls > Cladding > Hardwood Weatherboard > Hardwood Weatherboard
 BRKD > Inundation > Inundation - Freshwater > Hardwood Weatherboard

Hardwood Weatherboard

PRODUCT RESILIENCE RATING 4

Hazard:
 Inundation - Freshwater

External cladding is the exterior facing for the building and typically does not bear weight or contribute to the stability of the structure. Weatherboard serves as a layer of protection between the internal structure and the elements and also has an aesthetic role.

Hardwoods come from 'broadleaf' trees that lose their leaves in winter and are typically denser and stronger than softwoods. Hardwood is usually more expensive than softwood.

Resilience information

Title	Description	Details	Source
Hardwood Weatherboard	Mild effects	Details	2007, Hawkesbury-Nepean Floodplain Management Steering Committee, Reducing Vulnerability of Buildings to Flood Damage: Guidance on Building in Flood Prone Areas.
Hardwood Weatherboard	Water resistant	Details	2011, Snow, M. and Prasad, D., Climate Change Adaptation for Building Designers: An Introduction, Environment Design Guide
Hardwood Weatherboard	Higher water resistance	Details	2011, Growth Management Queensland, Repairing your house after a flood - Water resilient products and building techniques.

- Gap analysis of building resilience
- Testing and certification of building products
- Methodology for relating vulnerability to cost to determine the resilience ratings



DUNGOG FLOOD REPORT (COMPLETED)

- Dungog, a country town in Hunter Valley, NSW
- Impacted by flash flooding on 20-21 April 2015
- 233mm rainfall recorded at Dungog Post office
- 46 Damaged houses
- 4 houses washed away
- 3 deaths



DUNGOG FLOOD REPORT (COMPLETED)

- High water level (several metres)

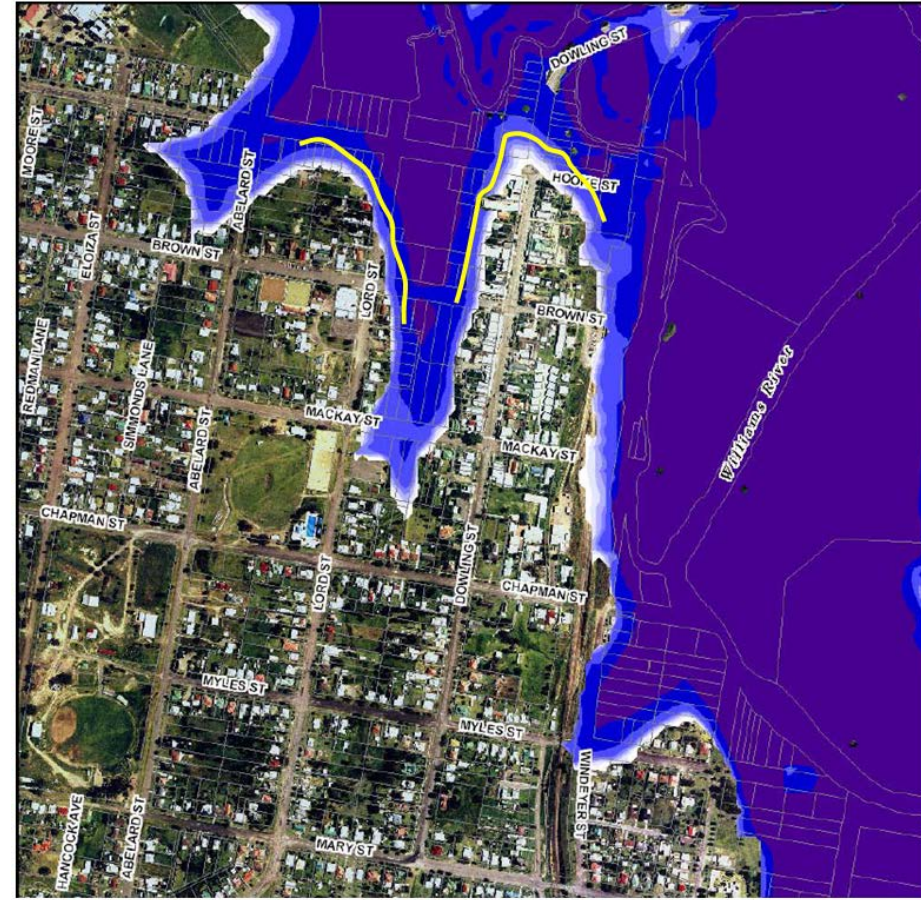


DUNGOG FLOOD REPORT (COMPLETED)

- Flood study for the William River (BMT WBM, 2009)



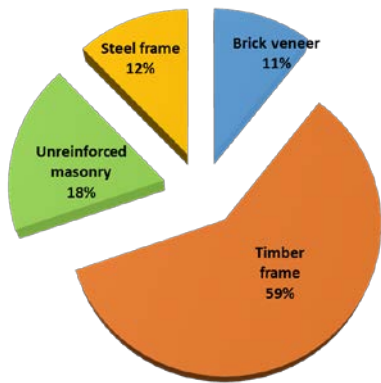
(A) 0.5% AEP Flood Event



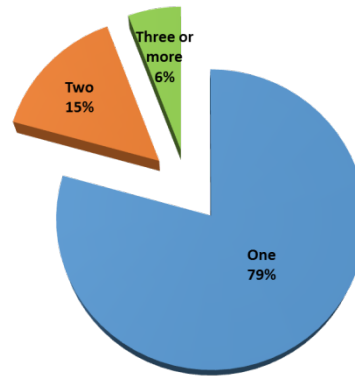
(B) Probable Maximum Flood Event

DUNGOG FLOOD REPORT (COMPLETED)

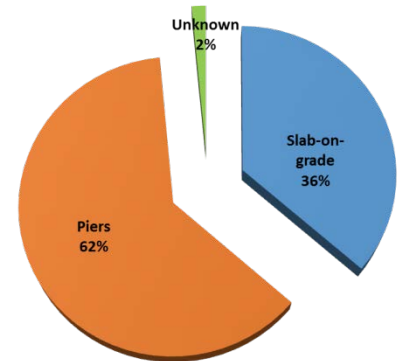
- Statistics of surveyed buildings



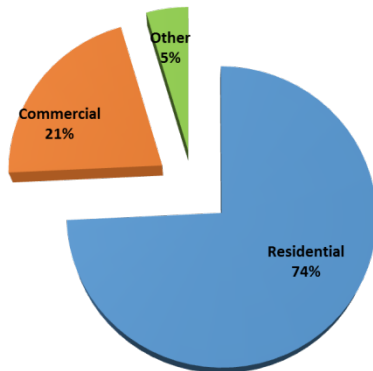
(A) Building structure



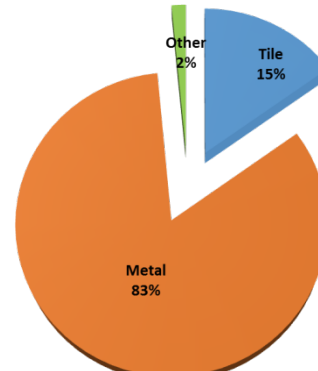
(B) Number of storeys



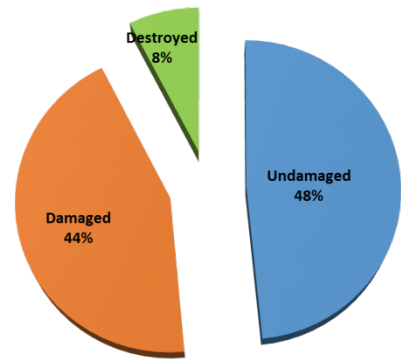
(C) Foundation type



(D) Building usage



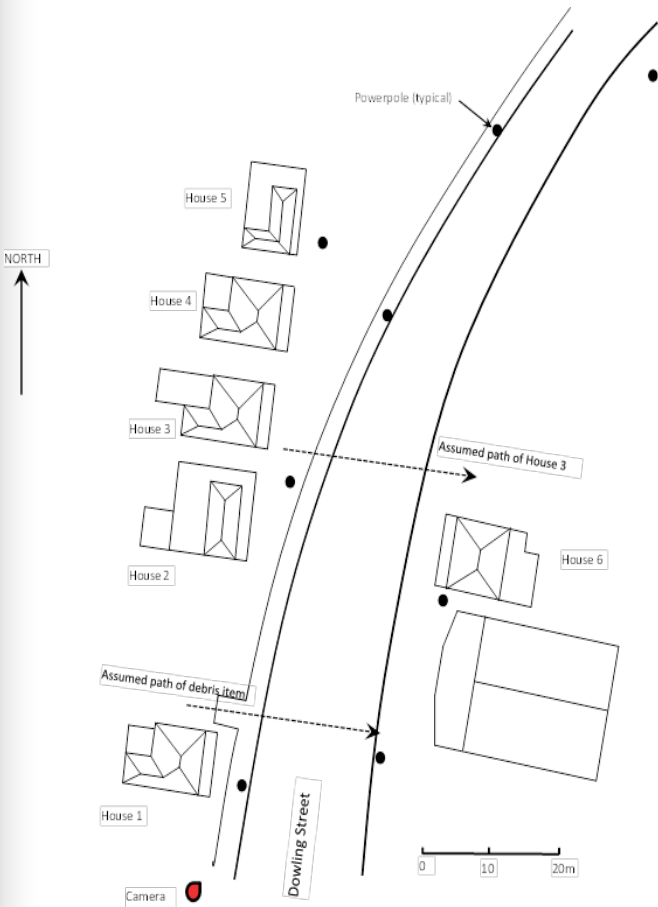
(E) Roof material



(F) Building damage

DUNGOG FLOOD REPORT (COMPLETED)

- Observations and video to estimate flow velocity



(A) Sketch map



(B) Stills from Youtube (2015) video

DUNGOG FLOOD REPORT (COMPLETED)

- Velocity related damage to 6 houses (Dowling st.)



(1) Intact



(3) Floated and washed away



(5) Destroyed



(2) Destroyed



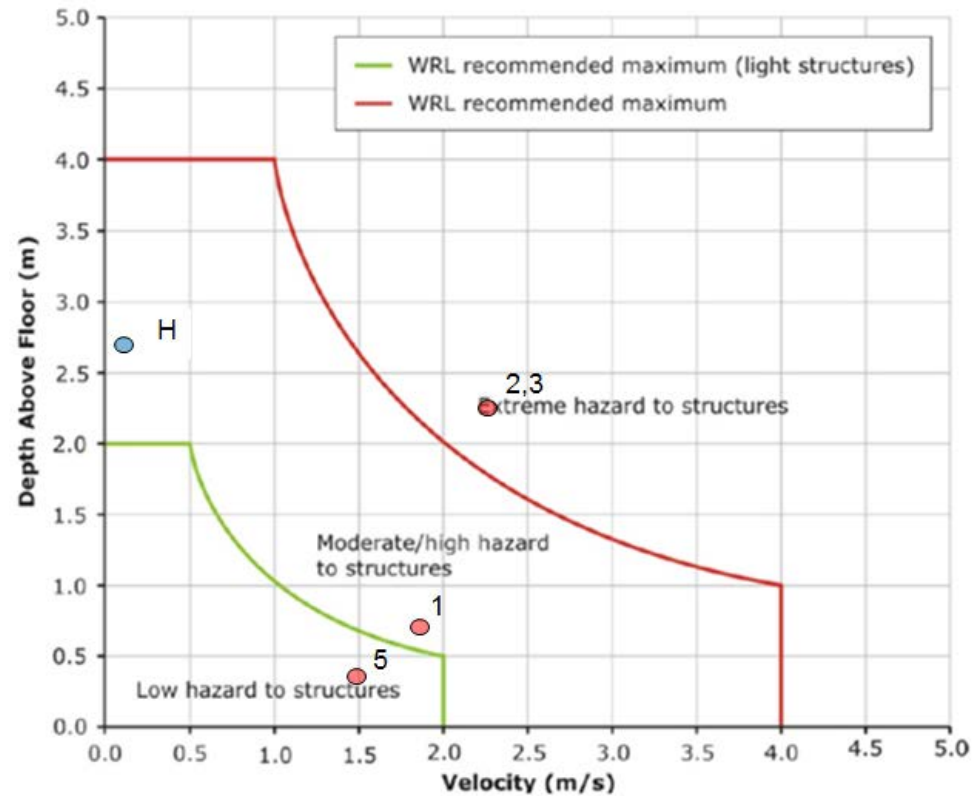
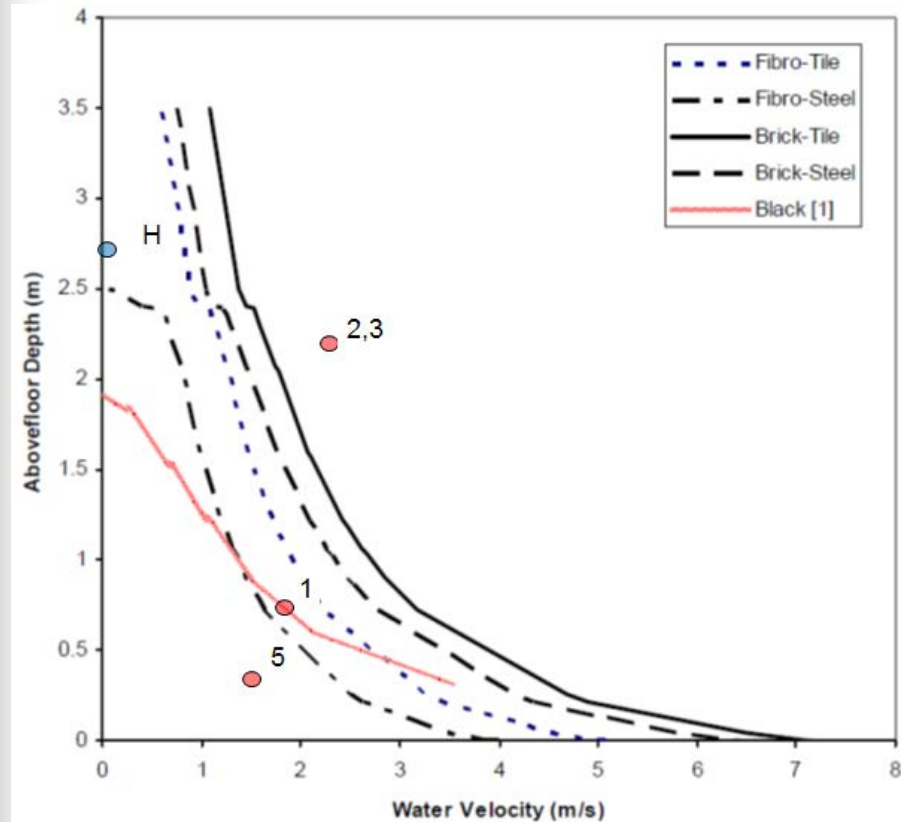
(4) severely damaged and moved off



(6) Destroyed

DUNGOG FLOOD REPORT (COMPLETED)

- Building stability and observations



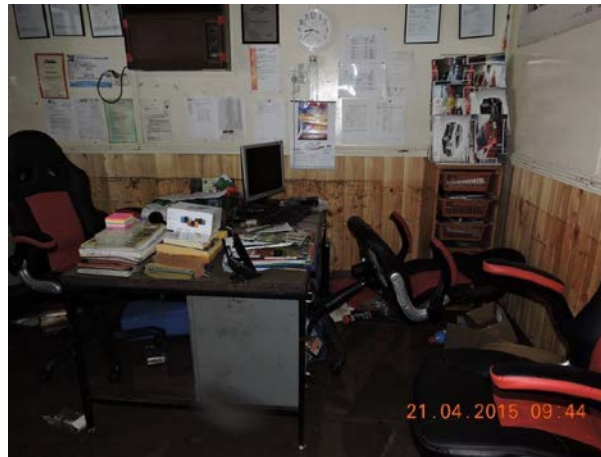
(A) Thresholds for building stability (Dale et al. 2004) (B) Thresholds for building stability (Smith et al. 2014)

DUNGOG FLOOD REPORT (COMPLETED)

- Commercial Buildings



(A) Glulam Factory



(B) Motor Vehicle Repair



(C) Farm Machinery Repair

DUNGOG FLOOD REPORT (COMPLETED)

- Infrastructure: Myall Creek bridge



(A) Approach embankment



(B) Northern abutment



(C) Southern abutment

PARALLEL ACTIVITIES

- Engagement with other projects within the cluster
- Engagement with other projects outside the cluster
- Engagement with Insurance Council Australia (ICA) and Edge Environment Consultant
- Engagement with CSIRO
- Advising South Australian Government on Flood Resilience Scorecards for Aged Care facilities

PROJECT TIMELINES

	Start	Mar-14	Jun-14	Sep-14	Dec-14	Mar-15	Jun-15	Sep-15	Dec-15	Mar-16	Jun-16	Sep-16	Dec-16	Mar-17	Jun-17
Project Management - Work Plan, Communication, Collaborations															
Classification of building stock into vulnerability classes															
Review of literature, NEXIS and international practices															
Report on building classification															
Literature survey of existing mitigation options															
Review of literature, national and international practices															
Publication on proposed research at AFAC and BNHCRC Conference															
Report on review of existing mitigation strategies															
Development of Australian specific mitigation options and costing modules															
Identification of Australian specific mitigation options															
Developing costing modules of different mitigation strategies															
Publication on retrofit options and costing modules															
Report on retrofit options and developing of costing modules															
Development of strategies for new construction, quantity surveying and experimental plan															
Strategies for new construction															
Quantity surveying															
Experimental plan for testing of materials to flood resilience															
Report on strategies for new constructions and quantity surveying															

CONCLUDING REMARKS

- The project is on track and progressing smoothly.
- The deliverables have been completed on time including:
 - Project Management Plan (April 2014)
 - Quarterly reports (FY2013-14, FY2014-15, FY2015-16)
 - Annual report FY2013-14 (June 2014)
 - Report on building schema (June 2014)
 - Poster presentation at AFAC&BNHCRC Conference Wellington (Sept 2014)
 - Paper published and oral presentation at FMA National Conference Brisbane(May 2015)
 - Report on review of mitigation strategies (June 2015)
 - Annual report FY2014-15 (June 2015)
 - Poster presentation at AFAC&BNHCRC Conference Adelaide(Sept 2015)
 - Report on Dungog Floods, NSW (Sep 2015)

THANK YOU

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