FLOOD VULNERABILITY RESEARCH AT GEOSCEINCE AUSTRALIA

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Abstract

Australia has experienced devastating floods in recent years which have resulted in significant financial loss and disruption to communities. Even though flood events have regularly impacted Australian communities comparatively few research initiatives have been taken in Australia to address the flood vulnerability of buildings and to develop cost-effective mitigation strategies.

Estimation of flood losses is considered to be a crucial component of flood mitigation decisions that are increasingly being made on the basis of cost-benefit analyses. Geoscience Australia (GA) has developed flood vulnerability models based on the observations from the 2011 Queensland floods as a fundamental contribution towards flood management. The aim was to improve and augment existing vulnerability models for residential, commercial and industrial buildings. A dataset of flood losses collected through field and postal surveys was then utilised to validate the developed models.

Building on research to date, GA now leads the Cost-Effective Mitigation Strategy Development for Flood Prone Buildings Project within the new Bushfire and Natural Hazards Cooperative Research Centre (BNHCRC). The overall aim of this research project is to develop an evidence base to inform decision making on risk mitigation for flood prone buildings. The work will focus on benefit versus cost analysis for key mitigation options for selected flood prone building types.

This paper provides an overview of the GA's work on flood vulnerability and describes the future research activities of the BNHCRC project and anticipated outputs.

Introduction

Australia has experienced floods on a regular basis and some communities have been impacted repeatedly over a period of few years. 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.

Furthermore, it is generally recognised that climate change is likely to exacerbate a range of natural hazards in Australia leading to more severe community impacts in the future. Flood hazard is one of these as some catchments are expected to experience more severe rainfall and increased tail-water levels at the coast due to sea level rise. Increasing population and associated building exposure to flood hazard in flood prone areas has been raising community risk in Australia.

The need to understand current risk is generally accepted but the evidence base is lacking to inform this process. Therefore research is underway at GA to improve the understanding of flood risk by assessing vulnerability of elements at risk. This paper provides an overview of flood vulnerability research being conducted at GA along with future work under the new BNHCRC.

Research methodology

As a first step towards assessing flood impacts and risk to community a research methodology has been developed to define the primary inputs. Flood impact assessment requires knowledge of the hazard, the number and nature of properties exposed and their vulnerability to flood damage as outlined by Edwards (2012) and presented in Figure 1. Each of the elements in Figure 1 is described briefly:

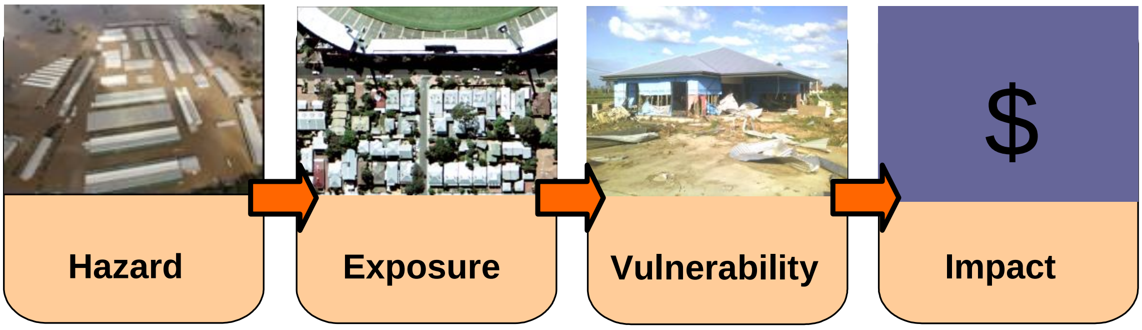

Figure 1: Impact assessment framework that describes schematically the translation of severe hazard through exposure and vulnerability to give impact

Hazard describes the severity and associated likelihood of a rapid onset hazard at a locality of interest. In GA's studies, the hazard is defined in terms of flood depth above ground floor level.

Exposure describes the assets of value that are potentially exposed to the hazard. These assets can be physical (buildings, contents, essential infrastructure), social (populations and social systems), economic (businesses and regional scale economic activity) and environmental.

Vulnerability describes the susceptibility of assets to hazard exposure and provides a relationship between building loss and severity of hazard, i.e., inundation. In general there are three major approaches to asses building vulnerability namely, analytical /computational, empirical and expert judgement.

Impact describes the economic losses resulting from the building damage during an event.

Development of flood vulnerability functions

Several initiatives have been taken at GA as part of a strategy for developing building vulnerability functions.

Exposure Information

The initial step has been the collection of building attributes to classify the Australian building stock into a limited number of typical building types and developing an exposure database. GA has developed a National Exposure Information System (*NEXIS*) that provides information about building attributes at a range of resolutions (Nadimpalli, 2009).

Furthermore, GA has developed the Rapid Inventory Capture System (*RICS*) which captures street view imagery. *RICS* is a vehicle borne camera system that takes geo-located images from a moving vehicle and is available as open source software (Habili et al. 2011). The equipment is shown in Figure 2 and comprises cameras, associated tripods, GPS receiver, hazard light and a laptop computer.

The images captured by *RICS* can then be interrogated by the Field Data Analysis Tool (*FiDAT*) shown in Figure 3. This tool was developed by GA to enable the interpretation of data to develop a building inventory and to assess damage. The tool can use data from several sources including *RICS* imagery, Google street view imagery, aerial imagery, information captured in the field using hand held computers and *NEXIS*. From the *FiDAT* processing building characteristics are assessed which include the attributes of building age, usage, wall and roof material, ground floor height, presence of a basement and/or garage etc. The information captured is fundamental for assigning an appropriate vulnerability model to each building in the study area.

Figure 2: The Rapid Inventory Collection System (*RICS*) mounted on a car

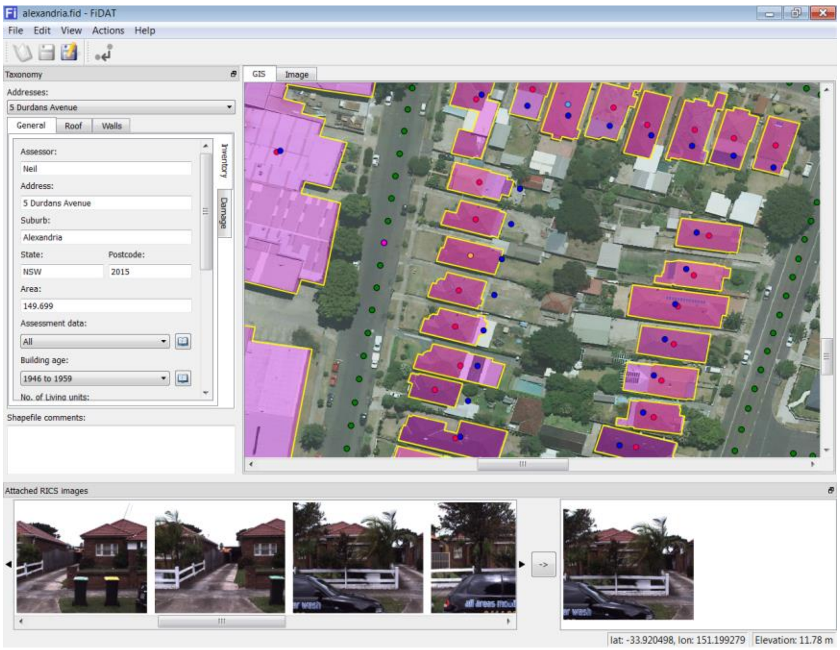

Figure 3: Interface of the Field Data Analysis Tool (*FiDAT*)

Australianisation of Black's curves

GA's flood vulnerability research on the flow related building loss was based on a study undertaken in the United States in 1975 by Richard Black (Black, 1975). Black (1975) developed curves to provide a means of assessing the overall stability of a number of basic houses when water depth and velocity were known. The houses studied by Black were not considered typical Australian structures, in terms of both size, form and construction material. Therefore Dale et al. (2004) conducted research to develop curves which were applicable to Australian construction. Figure 4 presents the results of the study on the adaptation of the Black's curves for a limited suite of Australian building types.

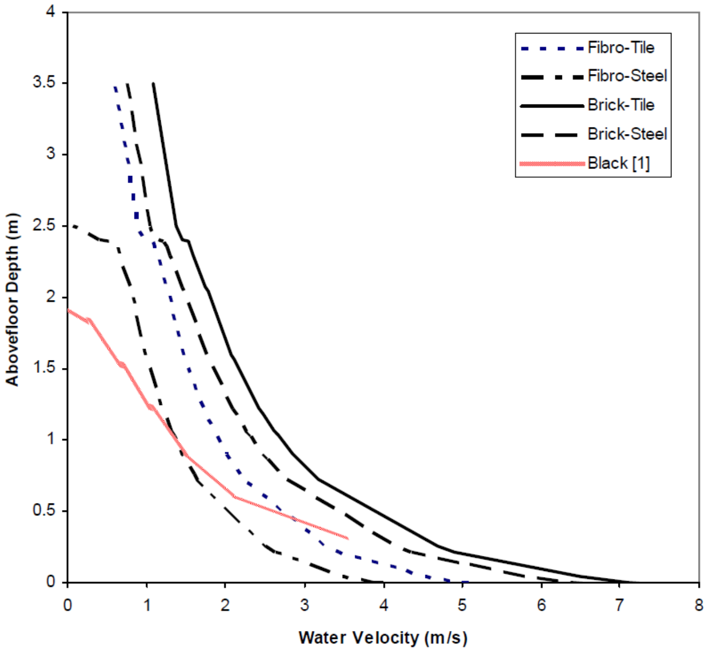

Figure 4: Stability curves for Australian residential construction (Dale et al. 2004)

2011 Queensland floods

After the devastating 2011 Queensland floods GA conducted post-disaster surveys to assess building damage due to flood inundation. The surveys consisted of a *RICS* survey capturing an overview of the damage within the flood extents; foot surveys capturing detailed building attributes and damage incurred; and postal surveys to assess building repair costs and social consequences due to floods.

After the field surveys, the building information captured was utilised to develop a building database which was then used to categorise surveyed building into 11 generic house types as presented in Table 1. For each generic house type the building fabric was divided into components. For each component of each generic house type, the repair work to reinstate the building was identified at each of 10 increasing inundation depths. Different repair strategies were identified for an insured house and for one that was not. Finally, each item of repair method was quantified and costed by a quantity surveyor thus enabling costing to be based on a detailed break-down of repair work (Wehner et al. 2012). For each generic house type vulnerability models were developed providing relationships between flood height above ground floor and associated building loss in terms of a Damage Index (a ratio of repair to replacement cost). Figure 5 presents an example of a developed vulnerability function.

Table 1: Vulnerability models developed after 2011 Queensland floods

No.	Vulnerability Model	Occupancy type	Description
1	FCM1	Residential	1 storey, raised floor, weatherboard cladding, plaster board lining, no integral garage
2	FCM2	Residential	1 storey, raised floor, weather board or panel cladding, timber lining, no integral garage
3	FCM3	Residential	2 storey, slab-on-grade, cavity masonry lower storey, weatherboard upper storey, metal roof, no integral garage
4	FCM4	Residential	2 storey, slab-on-grade, cavity masonry lower storey, weatherboard upper storey, metal roof, integral garage
5	FCM5	Residential	2 storey, slab-on-grade, weatherboard cladding, plaster board lining, partial lower floor, integral garage
6	FCM6	Residential	2 storey, raised floor, weatherboard cladding, plaster board lining, no integral garage
7	FCM7	Residential	1 storey, slab-on-grade, masonry veneer, plaster board lining, integral garage
8	FCM8	Residential	1 storey, slab-on-grade, masonry veneer, plaster board lining, no garage
9	FCM9	Residential	1 storey, raised floor, masonry veneer, plaster board lining, no garage
10	FCM10	Residential	1 storey, slab-on-grade, cavity masonry, no garage
11	FCM11	Residential	1 storey, raised floor, cavity masonry, no garage

Further to these analytically derived vulnerability models, data later captured during GA postal surveys of flood affected buildings were utilised to derive empirical damage indices and to validate the analytical models developed earlier. In Figure 6 boxes represent 25th to 75th percentiles and the horizontal bars represent the lowest and highest damage indices. The median is shown by a horizontal bar within the box. Figure 6 shows a comparison of the empirical data with the vulnerability model derived analytically. In general, the empirical data fits well with the analytical curve, however, there is a scatter in the data which is quite expected as the generic house actually represents an array of different, although broadly similar, houses; and a range of repairs undertaken for similar inundation depths (Wehner et al. in preparation).

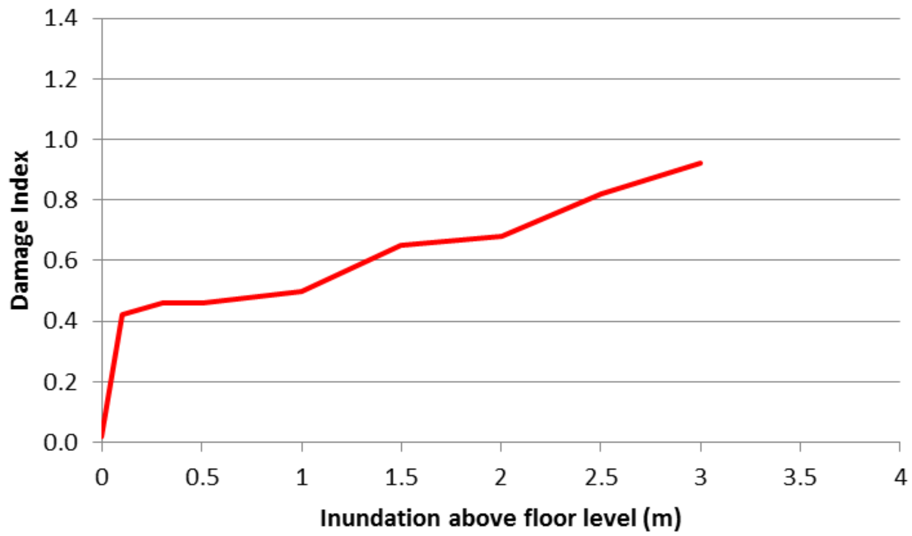

Figure 5: Vulnerability model for FCM8 Insured (Wehner et al., 2012)

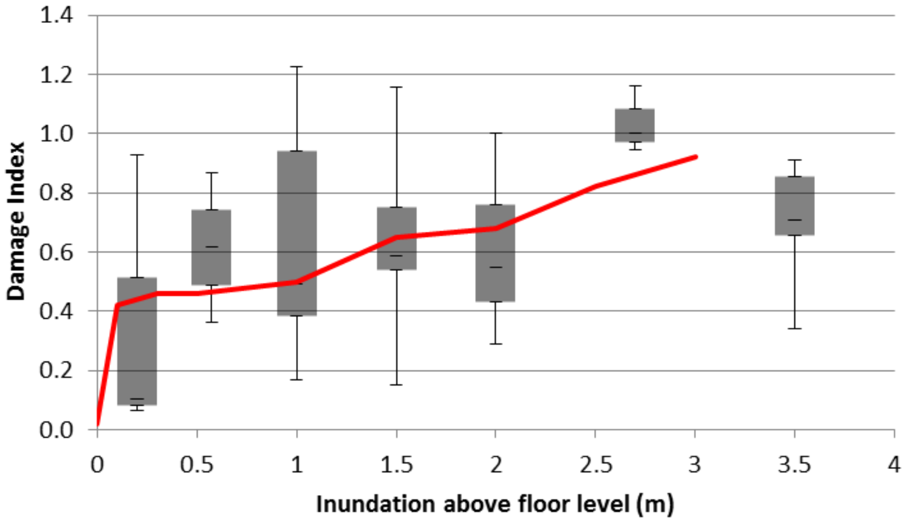

Figure 6: Comparison of vulnerability model for FCM8 Insured with empirical data (Wehner et al., in preparation)

Alexandra Canal flood study

Collaboration was undertaken between GA and the City of Sydney (CoS) which was facilitated by the Sydney Coastal Council Group (SCCG) and supported by the then Department of Climate Change and Energy Efficiency (DCCEE). The project sought to model flood impacts in the Alexandra Canal catchment area in South Sydney to examine how loss changed with improving exposure and vulnerability information. As part of this work, GA conducted a foot survey of buildings in the catchment area and noted that the area, developed in Victorian times with significant redevelopment, had many building types not represented by the Queensland flood vulnerability model suite presented in Table 1 (Maqsood et al. 2013). To address this gap a further eight supplementary models were identified for development which included commercial, industrial and mixed used building types as shown in Table 2.

Table 2: Vulnerability models developed during Alexandra Canal Flood Study

No.	Vulnerability Model	Type	Description
1	ACFS1a	Residential	Terrace, 1 storey, without basement
2	ACFS1b	Residential	Terrace, 1 storey, with basement
3	ACFS2a	Residential	Terrace, 2 storey, without basement
4	ACFS2b	Residential	Terrace, 2 storey, with basement
5	ACFS3	Mixed use	Retail/residential, 2 storey, without basement
6	ACFS4	Commercial	Showroom/office, 2 storey, without basement
7	ACFS5	Commercial	Warehouse/garage, 2 storey, without basement
8	ACFS6	Industrial	Factory, 1 storey, without basement

In the scenario study, each property in the catchment was assigned an appropriate vulnerability model and a depth of inundation above ground floor level for the selected scenario (1% Annual Exceedance Probability (AEP) event with a 20% rainfall intensity increase and 0.55m sea level rise), impact was computed in terms of both building Damage Indices as well as aggregate monetary loss ($). Four combinations of flood impact input information were explored i.e. two approaches to assess ground floor height (assumed and *FiDAT* assessed) and two sets of vulnerability functions, those developed by the NSW Government (McLuckie, 2007) and GA (Wehner et al. 2012). The results showed that the loss values were significantly refined by more detailed impact assessment inputs provided by GA (Maqsood et al. 2013).

Flood vulnerability workshop

With DCCEE support a workshop was convened in Brisbane in March 2012 which brought together representatives a number of researchers involved in flood research from Australia, New Zealand and the Philippines. These include those in academia, state government departments, local governments, research agencies and the insurance industry. The major outcomes included the recognition of GA's vulnerability models to be nationally consistent damage functions and acceptance of the quantity surveying approach followed by GA to develop vulnerability models (Wehner et al. 2012).

UNISDR-GA vulnerability workshop

GA organised and hosted a multi-hazard regional expert elicitation vulnerability workshop in November 2013 which was supported by the office of United Nations International Strategy for Disaster Reduction (UNISDR). The workshop aimed at developing vulnerability models for 5 hazards (flood, earthquake, severe wind, tsunami and volcanic ash) for 24 countries in the Asia-Pacific region.

The expert judgement or expert elicitation is considered to be a useful process in order to provide estimates when no or limited empirical data is available or when there are constraints related to time and resources to perform analytical studies. The process consists of building a consensus among selected experts on the vulnerability of better understood building types by considering individual judgments. Each expert is then tasked to provide an assessment for the rest of the building types in the schema and his/her confidence level. In some cases, an opportunity is provided to each expert to view the assessments from all the experts and given the liberty to modify his/her own assessment. At the end of the process, feedback from all experts is pooled together and is combined through a weighting schema (Maqsood et al. in preparation).

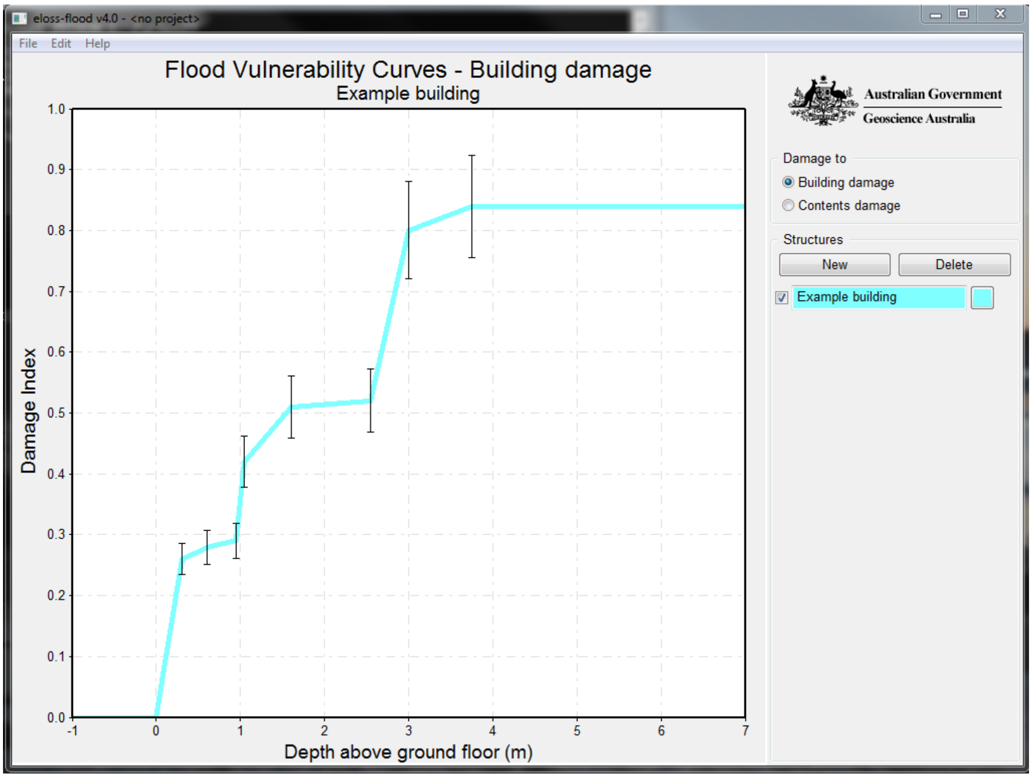

Figure 7: Example of *ELoss* interface

The vulnerability model development process engaged 40 experts from 12 countries within the Asia-Pacific region and used *ELoss* as a tool. *ELoss* is a graphical user interface which facilitates experts to reach consensus by displaying multiple vulnerability curves at a single time and allows users to interactively adjust a target curve's parameters whilst viewing the target curve against a background of reference curves. An example of the *ELoss* interface is shown in Figure 7.

In the flood sub-workshop, a total number of 47 curves were developed and mapped to the UN's 2015 Global Assessment Report on Disaster Risk Reduction (GAR15) categorisation applicable to flood hazard to give a combined suite of 135 vulnerability models.

The vulnerability models will be used in global natural hazards risk assessment and the results will be published in the UN's GAR15 (Maqsood et al. in preparation).

Bushfire and Natural Hazards Cooperative Research Centre

GA is leading the 'Cost Effective Mitigation Strategy Development for Flood Prone Buildings' Project within the new Bushfire and Natural Hazards Cooperative Research Centre (BNHCRC). The new CRC draws together all Australian and New Zealand emergency services agencies with leading experts across a range of scientific fields to explore the causes, consequences and mitigation of natural disasters (BNHCRC, 2014).

The flood project aims to deliver information tailored to decision making in government, regulation, industry and private individuals that gives a clear evidence-base for optimal retrofit of flood prone existing buildings in Australian communities and for more cost-effective construction of flood resistant structures in the future. The key tasks of the project will include building stock categorisation, literature review of mitigation strategies, vulnerability assessment of current and retrofitted building types and cost benefit analysis of key retrofit options. The project will assess all retrofit options through a consideration of a range of severity and likelihood of flood hazard covering a selection of catchment types.

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.

Summary

This paper provides an overview of GA's activities in the field of flood vulnerability assessment for Australian buildings. The paper summarises the tools that GA has developed to facilitate the development of vulnerability models such as *RICS*, *FiDAT* and *ELoss*. A short description of various types of post-disaster surveys that GA conducted after 2011 Queensland floods is presented. Tables referring to generic building types representing residential, commercial, industrial and mixed-use constructions are included in this paper for which vulnerability models have been developed. Furthermore, two workshop activities conducted by GA have been described that sought to derive consensus among experts on building vulnerability. Finally, future research regarding developing cost-effective flood mitigation strategies within the new BNHCRC is presented.

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References

Black, R. 1975. Flood Proofing Rural Residences. A Project Agnes Report, Department of Agricultural Engineering. Cornell University, New York.

BNHCRC. 2014. Bushfire and Natural Hazards Cooperative Research Centre. An Australian Government initiative. http://www.bnhcrc.com.au/ last accessed 24th March 2014

Dale, K. Edwards, M., Middelmann, M.H. and Zoppou, C. 2004. Structural flood vulnerability and the Australianisation of Black's curves. Proc. Risk 2004 Conference. Risk Engineering Society, Melbourne, Australia

Edwards, M. 2012. Impact assessment framework. A report submitted by Geoscience Australia to Department of Climate Change and Energy Efficiency. June 2012

Habili, N. 2011. Open-source tools for field data collection and analysis at Geoscience Australia, Open Source Developers Conference Canberra, available at: http://2011.osdc.com.au/schedule/#opensourcetoolsfo (accessed December 2012)

McLuckie, D. 2007. Floodplain risk management guideline. Department of Environment and Climate Change. NSW Government. 25 October 2007

Nadimpalli, K. 2009. National exposure Information System (NEXIS) – A Capability for Evidence Based disaster Management. Proc. 7th FIG Regional Conference Spatial Data Serving People: Land Governance and the Environment – Building the Capacity Hanoi, Vietnam

Maqsood, S.T., Senthilvasan, M., Corby, N., Wehner, M. and Edwards, M. 2013. Improved assessment of flood impact: an urban storm water case study of a City of Sydney catchment. Proc. Floodplain Management Association National Conference, Tweed Heads, Australia

Maqsood, S.T., Ryu, H., Wehner, M., Edwards, M. and Dale, K. (in preparation). GAR15 vulnerability functions. Geoscience Australia, Canberra, Australia

Wehner, M., Maqsood, S.T., Corby, N., Edwards, M. and Middelmann-Fernandes, M. 2012. Augmented vulnerability models for inundation. Technical report submitted to DCCEE. Geoscience Australia, Canberra, Australia

Wehner, M., Juskevics, V., Edwards, M. and Corby, N., (in preparation). Vulnerability of Queensland housing to riverine inundation. Geoscience Australia, Canberra, Australia