A submission to the Senate Standing Committees on Environment and Communications on "Recent trends in and preparedness for extreme weather events"

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Preface

This is a combined submission by the abovementioned authors who are all members of the Water Research Centre and the School of Civil, Environmental and Mining Engineering at the University of Adelaide. All the authors have extensive research and industry experience in the climate extremes of flooding and drought.

In particular, Dr Westra and Dr Leonard are both contributing to the revision of Australia's national flood estimation guidance document, Australian Rainfall and Runoff (ARR), which forms the basis of flood estimation practice nationally. Dr Westra is also currently working on a number of federal- and state-government funded projects investigating climate extremes, including an Australian Research Council (ARC) Discovery grant on precipitation and flood extremes, a CSIRO Adaptation Flagship Collaboration Fund grant on estimating climate risk, and a Goyder Institute grant investigating Adelaide's future water security. Dr Leonard is working on a project on extremes with the CSIRO Adaptation Flagship Collaboration Fund, and as a result of his involvement in the Queensland Flood Commission of Inquiry has since been investigating catchments with complex flooding mechanisms. Dr Mark Thyer has published extensively in international journals on the impact of Australian climate variability on hydrological processes. He is currently leading a project for the Goyder Institute investigating the hydrological catchment response to climate change forecasts, and is a chief investigator on an ARC Discovery grant with the aim of developing a new flood design methodology for a variable and changing climate. Finally, Professor Lambert is on the technical committee of the ARR flood guidelines, and also the current chair of the National Committee on Water Engineering. He is Principal Chief Investigator for an ARC Discovery grant examining a new flood design methodology for a variable and changing climate. He has also developed simulation models of Australian rainfall for flood prediction.

Our submission will focus on extreme precipitation and flood risk, reflecting our expertise in this area and the importance of better understanding and managing flood risk. **We note that flooding currently costs Australia $377m at 2008 prices (BITRE, 2008) on average per year, while a 2008 Newcastle flood caused $1.5B worth of insurance damages alone, and the 2011 Brisbane flood had a damage bill exceeding $4 billion dollars.** Furthermore, the value of national infrastructure devoted to flood prevention is likely to run into the tens of billions of dollars, comprising stormwater drainage infrastructure, bridges, levees, coastal defence infrastructure, spillways, reservoirs devoted to flood detention, and so on.

Estimating the risk of a flood event is a major ongoing challenge due to the high variability of the climatic and hydrological processes driving our flood extremes. **Changes to flood risk therefore will be one of the most important and complex types of climate extremes facing Australia over the coming decades, and therefore should be a primary focus of this inquiry.**

Introduction

Climate extremes receive regular media attention and – as the recent Queensland and Victorian floods of 2011 clearly demonstrate – they can have significant adverse impacts on individuals, communities and the wider Australian economy. The disruption caused by such events extends not only to the immediate impact of specific events, but also to longer-term decision making. For example zoning decisions regarding where people may live, the economic value of housing, the cost of insurance, public and private investments in flood prevention infrastructure, and various other measures are all designed to manage flood risk, and should be considered in addition to the immediate impacts associated with individual floods. The question of whether such events will become more frequent or severe under a future climate is therefore of significant importance to a diversity of stakeholders.

The notion of changing risk profiles through time is likely to provide a fundamental challenge to decision makers across all levels of government, and represents a break with past practice in which flood risk has been assumed to be constant over time [*Westra et al.*, 2010]. For example it has been estimated that 80% of Australians live near the coastline, with 711,000 homes, businesses and properties being less than 6m above sea level and within 3km of the coast [*Australian House of Representatives Standing Committee on Climate Change*, 2009]. Many of these properties are not currently flood affected but some of them might become so as a result of projected sea level rise associated with human emissions of greenhouse gases. Responses to address this issue could include large public or private investments in flood defence infrastructure, government sponsored resettlement of affected communities, increased insurance premiums for flood affected properties, and so on. Each of these options is likely to be economically expensive and will face substantial challenges to implement.

In our submission we argue that in order to successfully adapt to future flood risk in Australia, further information is needed to form scientifically defensible projections of how flood risk might change in the future. **At present we cannot answer the question of whether flood risk will increase or decrease across large parts of the Australian continent,** with the possible exception of coastal catchments which would be affected by an increase in sea level. This submission will describe the basis for this statement, summarise the reasons why this question has not yet been answered, provide a brief overview of some activities currently underway to answer this question, and sketch some future activities which will assist in providing a more solid foundation for answering this question and thereby adapting to future flood risk.

Specific comments to the terms of reference

(a) recent trends on the frequency of extreme weather events, including but not limited to drought, bushfires, heatwaves, floods and storm surges;

There is some evidence that the frequency and/or intensity of many extreme weather events is increasing. At the global scale, the most authoritative reference on this issue is the Intergovernmental Panel on Climate Change Special Report on Extreme Events [*IPCC*, 2012] which provides a comprehensive review of the scientific literature and addresses all major classes of climatic extremes. Coverage of flood-related extremes specifically pertaining to the Australian situation is limited, however, and we therefore add some further information which we feel is relevant to the Inquiry.

It should be noted that evidence supporting increases in extreme weather events is stronger for certain climate variables than for others. For example, there is strong evidence supporting an increase in globally averaged temperatures, and this will very likely lead to an increase in heatwaves. Our group recently has found strong evidence for an increase in annual maximum daily rainfall on average globally [*Westra et al.*, 2012a] based on a global rainfall observing network comprising 8326 stations, although there are also distinct regional variations, with changes in Australia being smaller than in the tropics and higher-latitude northern hemisphere continental areas. This result was also found in climate models, adding confidence to the conclusions [*Kharin et al.*, 2012]. Focusing in on Australia, in contradistinction to the global-scale analysis, the studies by [*Westra et al.*, 2012a] and [*Westra and Sisson*, 2011] did not provide compelling observational evidence that daily extreme precipitation was changing, and therefore conclusions made at global scales may not be directly relevant to the Australian situation.

Of potentially more concern for Australia is emerging evidence that short-duration rainfall bursts may be increasing in intensity. Such short-duration bursts are caused by intense convective activity, last typically for less than an 3 hours, and can lead to flash flooding. Such flooding is particularly hazardous to human life due to the difficulty in providing timely warnings for such short-duration events, and in our view this is one of the reasons that the Toowoomba flash floods was the single event within the Queensland floods which resulted in the greatest loss of life. The rainfall which falls intensely over short durations often is driven by different meteorological mechanisms to rainfall which is sustained over periods of a day or longer, and evidence is mounting that such high-intensity, short-duration rainfall is particularly likely to change as a result of a warmer atmosphere [*Hardwick-Jones et al.*, 2010; *Jakob et al.*, 2011; *Lenderink and van Meijgaard*, 2008; *Lenderink et al.*, 2011; *Westra and Sisson*, 2011; *Westra et al.*, 2012b]. **At the moment there is a paucity of observational and climate model-based studies looking at rainfall changes at this time scale, and we believe this is something that should receive increased attention by the research community if we are to develop robust projections of changes to flash flood frequency and/or intensity.**

From a societal perspective, the key variable of interest is the change in the risk of flood peaks and volumes. Forecasting changes in flood risk under a changing climate is a significant challenge, because large floods are due to extreme rainfall falling on wet catchments. Hence, as noted by [*Westra*, 2011] the role of antecedent moisture (the issue of whether a catchment is wet or dry prior to the flood-producing rainfall event) will play an important role in determining future flood risk [see also *Pathiraja et al.*, 2012]. Although flood-producing rainfall may be increasing in intensity, projections for many parts of Australia (and in particular the south west of Western Australia and the southern parts of South Australia and Victoria) are for catchments to become dryer on average [*CSIRO*, 2010; *CSIRO & Bureau of Meteorology*, 2007]. This may account for the finding of [*Ishak et al.*, 2010] that flood risk appears to have decreased in parts of southern Australia over the past several decades. There is currently a lack of substantive research studies into understanding how the interaction of likely increases in flood-producing rainfall and the net drying of catchments will influence future flood risk. For this reason, **we do not believe it is currently possible to say with confidence whether flood risk will increase or decrease in the majority of Australia, with the possible exception of coastal areas which are affected by increases in sea level.**

(b) based on global warming scenarios outlined by the Intergovernmental Panel on Climate Change and the Commonwealth Scientific and Industrial Research Organisation of 1 to 5 degrees by 2070:

(i) projections on the frequency of extreme weather events, including but not limited to drought, bushfires, heatwaves, floods and storm surges,

As discussed in relation to Item (a), short-duration (hourly and shorter-duration) precipitation extremes might be expected to increase much more strongly compared with longer-duration extremes (greater than 24 hours). Several overseas studies [*Lenderink and van Meijgaard*, 2008; *Lenderink et al.*, 2011; *Utsumi et al.*, 2011] suggest increases between 7% and 14% per degree change in near-surface atmospheric temperature, which would translate to an increase of up to 35%-70% assuming temperature increases of 5°C, and this clearly would be an extremely difficult and expensive change to adapt to. Although preliminary evidence in Australia supports such scaling relationships [*Hardwick-Jones et al.*, 2010; *Westra and Sisson*, 2011; *Westra et al.*, 2012b], the sparse nature of Australia's precipitation observing network for short-duration extremes, and the limited number of climate model studies looking at such short-duration events, implies that urgent research on possible changes to extreme rainfall at this timescale is required. To this effect, some research recently has been commissioned by Geoscience Australia (as part of the Australian Rainfall and Runoff revision project) to examine changes in precipitation extremes over the greater Sydney basin. **We believe that such research needs to be extended into a national, coordinated, multi-institutional research programme looking at all the contributing factors that might cause short-duration extreme rainfall to change.**

As outlined in the previous section, there remains high uncertainty as to whether flood risk will increase or decrease in large parts of Australia, due to the interplay between a probable net drying of catchments particularly in the southern parts of the country, and an increase in the intensity and/or frequency of flood-producing rainfall. The exceptions are coastal catchments which are vulnerable to an increase in mean sea level, and possibly small catchments which are vulnerable to shorter, intense rainfall bursts; in both these cases it is likely that flood risk will increase.

In Australia, **the likely direction and magnitude of changes in future flood risk will vary significantly from region to region**. There is likely to be a geographical gradient, with an increase in risk likely in the northern parts of Australia (because extreme rainfall generally occurs in the wet season) while in the southern parts of Australia it is difficult to say whether risks will increase or decrease, let alone estimate the magnitude of the change. The flood risk may reduce in a catchment where the antecedent moisture conditions play an important role in producing significant flood events (e.g. large catchments and/or deep soils) experiences net drying, while flood risk may increase for catchments where antecedent moisture is less important (smaller catchments and/or shallow soils).

Identifying the direction and magnitude of likely changes in future flood risk in different parts of Australia requires a comprehensive study to determine the varying impact of (a) changes in antecedent moisture conditions (due to changes in long-term rainfall, increases in temperature and also the influence of catchment physiographic properties such as size, soil type, slope, vegetation, etc) of the particular catchment; (b) changes in the precipitation-generating mechanisms which cause floods in that particular region (e.g. tropical cyclones, thermal convection, frontal systems and so on); (c) whether there has been any other human activity in the catchment (e.g. changes in land-use or construction of dams and levees) on future flood levels. Techniques to achieve this are being developed [Li et al., 2012], however, further work is needed to achieve practical outcomes. Catch-all statements such as "climate change will cause flood risk to increase in Australia" are not helpful and are extremely misleading. **Any guidance that is provided at the national scale must account for the diversity of local conditions which will have a significant influence on future flood risk.**

(ii) the costs of extreme weather events and impacts on natural ecosystems, social and economic infrastructure and human health,

As described above, the cost of flooding not only includes the costs of individual disasters such as the recent Queensland floods, but also the large costs associated with preventative measures such as stormwater infrastructure, levees, spillways and so on. Furthermore, there are opportunity costs associated with planning decisions that prohibit development in otherwise habitable areas due to a perceived risk of flooding. **To our knowledge there has not been a holistic attempt at calculating the full cost associated with both flood prevention and recovery in Australia.**

Two additional types of cost present themselves in the presence of climate change:

(1) The issue of changing risk profiles through time, which could mean that properties or other assets which are currently not classified as flood-prone will become so in the future. The options in addressing such situations are generally much more limited and expensive compared to the situation where the flood risk is constant over time.
(2) This changing risk profile through time also implies that we cannot use the historical record directly as an analogue to future flood risk. This invariably and unavoidably means an increase in uncertainty associated with flood risk estimation, which will have a direct economic cost. For example, under uncertainty one must develop infrastructure which is more flexible and robust to a larger variety of future conditions; such infrastructure can be expected to be much more expensive than infrastructure which has been designed to very precise estimates of future risk.

(iii) the availability and affordability of private insurance, impacts on availability and affordability under different global warming scenarios, and regional social and economic impacts;

No comment.

(c) an assessment of the preparedness of key sectors for extreme weather events, including major infrastructure (electricity, water, transport, telecommunications), health, construction and property, and agriculture and forestry;

No comment.

(d) an assessment of the preparedness and the adequacy of resources in the emergency services sector to prevent and respond to extreme weather events;

Emergency services are underpinned by a knowledge and understanding of the risks and potential impacts posed by natural hazards. With the example of the 2011 Queensland Floods there were numerous factors which would have benefitted from a more rigorous and quantitative understanding of flood risks:

(i) The effect of La Niña conditions on the rate, magnitude and extent of flood and cyclonic events across large regions as the coincidence of these factors stretches the emergency response. For example, *Sun et al (2012)* showed that during a strong La Niña, the 1 in 100 year rainfall can be up to 50% higher than under normal conditions.

(ii) A better quantitative understanding of flood risks to assist in decisions that must trade-off different types of impacts, for example, the short-term withholding of dam-waters to prevent flooding of roads used for evacuation against the longer-term risk of releases which might damage urban infrastructure.

(iii) A better understanding of short-duration and localised bursts of rainfall, unprecedented in existing observations, that lead to flash-flooding.

(e) the current roles and effectiveness of the division of responsibilities between different levels of government (federal, state and local) to manage extreme weather events;

No comment.

(f) progress in developing effective national coordination of climate change response and risk management, including legislative and regulatory reform, standards and codes, taxation arrangements and economic instruments;

No comment.

(g) any gaps in Australia's Climate Change Adaptation Framework and the steps required for effective national coordination of climate change response and risk management; and

Significant, coordinated efforts have been made at improving knowledge of fundamental climate science, with organisations such as the CSIRO and the ARC Centre of Excellence for Climate System Science providing scientific leadership in this area. Furthermore, similar efforts have been made at improving our understanding of adaptation through the CSIRO Climate Adaptation Flagship and the National Climate Change Adaptation Research Facility (NCCARF). Each of these programs have had significant success, but none of them deal directly with quantifying future climate impacts (i.e. floods, bushfires, etc) which are likely to have the most immediate impact on Australian society. In contrast a recently commissioned study funded by Geoscience Australia as part of the revision of the Australian Rainfall and Runoff guidance document aims to quantify changes to flood risk, but only focuses on a specific region (greater Sydney).

For this reason, at present we are unable to answer fundamental questions such as whether flood risk in Australia will increase or decrease. In the absence of being able to answer such questions, adaptation efforts can at best focus on robust decision making (i.e. decision making which accounts for all possibilities), and which is likely to lead to significant inefficiencies in allocation of investment.

We believe that a national, multi-institutional, decade-long research program should be initiated, and should focus on better understanding specific climate impacts such as flooding. Such an initiative can be styled on the South Eastern Australian Climate Initiative (SEACI), with a national ambit and with the inclusion of universities where a large quantum of Australia's climate impacts expertise is located, together with the CSIRO and the Bureau of Meteorology. **In the absence of such a program, it is unlikely that many of the questions raised by this Senate Inquiry can be comprehensively or even adequately answered.** The substantial progress in other aspects of climate science in the past decade suggests, however, that significant progress is possible over this time horizon.

(h) any related matter.

Recommendations

- The notion of changing risk profiles through time is likely to provide a fundamental challenge to decision makers across all levels of government, and represents a break with past practice in which flood risk has been assumed to be constant in any given year.
- There is a paucity of observational and climate model-based studies looking at rainfall changes at the short duration (less than 3 hours) timescale, and we believe this is something that should receive increased attention by the research community if we are to develop robust projections of changes to flash flood frequency and/or intensity.
- Research needs to be extended into a national, coordinated, multi-institutional research programme looking at all the contributing factors that might cause short-duration extreme rainfall to change.
- A national, multi-institutional, decade-long research initiative should be initiated and funded. This initiative and should focus on better understanding the complex interaction of changes in climate on specific climate impacts such as flooding. Such an initiative can be styled on the South Eastern Australian Climate Initiative (SEACI), with a national ambit and with the inclusion of universities where a large quantum of Australia's climate impacts expertise is located, together with the CSIRO and the Bureau of Meteorology

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