LIVING WITH FLOODS: KEY LESSONS FROM FOUR AUSTRALIAN FLOOD REVIEWS AND SIMILAR REVIEWS FROM THE NETHERLANDS, CHINA AND THE USA

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ABSTRACT

2010-2011 saw some of the biggest flood events in Australia's history. The large scale of events prompted numerous inquiries and review processes by different governments and organizations. As climate change is expected to increase the severity and likelihood of flooding events in the future, a project was developed to analyse these reviews and determine if they offered any lessons for climate change adaptation. The project focused on four recent reviews from Queensland and Victoria. The project also compared Australia's review processes and findings with similar processes from the Netherlands, China and the USA to determine points of similarity that reinforced Australian findings and to explore differences.

This paper presents some of the major findings of the reviews. We explore the surprising failure of Australian flood inquiries to address future flood risks from climate change. Conclusions are also drawn as to where Australia is innovating in flood management future and where reforms are needed. Our findings suggest there is potential for Australia to explore ecosystem approaches to flood control, and that reform is needed of land use planning and disaster relief funding. We also look at the adaptive potential of structural and non-structural measures and the role of flood insurance and relocation.

INTRODUCTION AND METHODOLOGY

2010-2011 saw some of the biggest flood events in Australia's history, with approximately 80% of Queensland declared a disaster zone and extensive flooding in other eastern states, notably Victoria. The scale of events, the number of lives lost and the damage incurred prompted numerous inquiries and review processes by different governments and organizations. As climate change is expected to increase the severity and likelihood of flooding events in the future, a project funded by the National Climate Change Adaptation Research Facility was developed to analyse reviews and determine if they offered any lessons for climate change adaptation (Wenger et al., *forthcoming*). This paper summarises findings from that project.

Four Australian flood reviews were analysed in depth for the project:

- Brisbane City Council's Flood Response Review Board report, or 'Brisbane Review' (Arnison et al., 2011)
- Queensland Floods Commission of Inquiry, or 'QFCI' (QFCI, 2012, QFCI, 2011)
- Victorian Review of the 2010-11 Flood Warnings and Response, or 'Comrie Review' (Comrie, 2011)
- Parliament of Victoria's Environment and Natural Resources Committee Inquiry into Flood Mitigation Infrastructure in Victoria, or 'ENRC Inquiry' (Parliament of

Victoria, 2012)

Review processes and findings were compared with similar processes overseas, including the Netherlands, China and the USA to determine points of similarity that reinforced Australian findings and to explore differences. A series of semi-structured, in-depth interviews was also conducted with professionals from relevant sectors including insurance, emergency services, floodplain managers, ecosystem researchers, local government and urban utilities. Interviews were used to validate the research and to obtain a deeper understanding of issues relevant to climate change and adaptation to flooding. An end users committee guided research and identified project communication needs.

The project categorized activities using the standard emergency management framework Prevention-Preparation-Response-Recovery (PPRR) to facilitate communication of the results. As the framework represents a sequential or cyclical timeframe, this also enabled assessment of the effectiveness of different phases of intervention. Consideration was also given to the relative merits of structural and non-structural approaches and to adaptive characteristics such as cost effectiveness, 'no regrets' and multiple benefits.

IMPACTS OF CLIMATE CHANGE ON FLOODING IN EASTERN AUSTRALIA

Anthropogenic climate change is expected to exacerbate natural extremes of flood and drought. Flood patterns are likely to change and it is no longer sufficient to rely on historical data to predict floods:

> Due to changing climate, the frequency and magnitude of floods in the near future is expected to vary across Australia. It has been established that changing climate will have notable impacts on the rainfall runoff process and thus hydrologic time series (e.g., flood data) can no longer be assumed to be stationary. It has serious implications in regional flood estimation, as these are based on past data, which can no longer be taken to represent the future under a changing climate regime. A failure to take climate change into account can undermine the usefulness of the concept of return period, and can lead to underestimation / overestimation of design flood estimates, which in turn will have important implications on the design and operation of water infrastructure.
>
> (Rahman et al., 2010)

RAINFALL

A rise in the global mean temperature of between 1.4 and 5.8^{0}C above 1990 levels is expected by 2100. This will change flood patterns due to changes in precipitation and sea level rise. There is expected to be increased precipitation intensity, as higher sea surface temperatures result in greater evaporation and warm air can hold more water vapour. Changing circulation patterns will affect rainfall distribution (Meehl et al., 2007).

The 2007 IPCC report indicates that while rainfall intensity will increase, rainfall over eastern Australia is likely to decrease overall. Modelling also indicates seasonal changes, with rainfall increasing in summer but decreasing in winter, particularly in the south (Christensen et al., 2007). The 'State of the Climate 2012' report anticipates increased spring and summer monsoonal rainfall across the north with a 66%

probability of fewer cyclones but an increased proportion of intense cyclones (CSIRO and BoM, 2012).

SEA LEVEL RISE

Sea level rise (SLR) is among the best known effects of climate change. Australian sea levels are increasing but at different rates. The central east and southern coasts of Australia are rising at a rate of around 3mm per year, similar to the global average, whereas the north and northwest of Australia have been rising 7-11mm per year. At this point the rises are primarily linked to warming of ocean waters causing them to increase in volume (CSIRO and BoM, 2012).

In recent years projections have been regularly revised upwards as information improves, which suggests risk assessments will also require regular revision and responses will need to be flexible. Projections presented at international fora in 2009 ranged from 0.75 to 1.9m by 2100, with 1.1m being the new mid-range (Australian Government, 2009). SLR of 1.1m could expose $226 billion of Australian coastal assets to flood damage and erosion (Australian Government, 2011).

OTHER FACTORS

Changing precipitation patterns and sea level rise are not the only factors influencing flooding. Others include storm surge, land subsidence, soil movements (due to increased erosion), population increase, urbanisation (associated with impermeable surfaces that increases water run-off), landscape modifications (eg, levees), vegetation cover and soil moisture level. Many of these are exacerbated by climate change.

Vegetation cover in Australia is likely to become sparser with climate change, due to more prolonged droughts (Pittock, 2003). Sparser vegetation impairs the ability of the landscape diffuse raindrop intensity, to slow run-off and absorb moisture. According to Nott, such landscapes are more likely to have high run-off and more destructive flash flooding (Nott, 2006).

ADAPTATION APPROACHES AND UNCERTAINTY

Much of the uncertainty in climate change science can be attributed to difficulties in determining how much observable change is due to natural variation that occurs over multi-decadal scales and how much is due to anthropogenic causes. In some places, it will be another forty years before changes in precipitation patterns become statistically detectable and distinguishable from natural variation. Hallegatte (2009) suggests and that it is a mistake to wait so long for modeling to be fully validated as by that time maladaptive decisions may have been made. . Moreover, projection ranges continue to be large despite improved information, and no matter how advanced the modelling becomes it is unlikely to yield the degree of certainty that planners require. . Decision making frameworks need to accommodate this uncertainty rather than delaying action until certainty improves.

Hallegatte presents a number of adaptation characteristics that are less dependent on information certainty, including no-regrets strategies that are beneficial even in the absence of climate change; reversibility; ease of incorporating low-cost safety margins; soft strategies (which by their nature are generally reversible); avoiding long term

commitment (uncertainties increase further into the future); and synergies, which consider externalities to other sectors (Hallegatte, 2009). Adaptive characteristics such as these were considered when analysing measures proposed to address flood risks by Australian flood reviews and overseas. For more detail please refer to Appendix 3 of Wenger et al (forthcoming).

KEY FINDINGS

REVIEW PROCESSES AND TREATMENT OF CLIMATE CHANGE

One of the most notable findings was that Australian reviews virtually ignored the issue of climate change and its impact on flooding. The ENRC Inquiry was the only one of the four reviews to make a definitive statement about anticipated effects of climate change on flooding when setting the context for the review, but even it did not assess the suitability of the measures it proposed to address *future* threats.

The general failure to address future flood threats constitutes a missed opportunity. It can be attributed primarily to the terms of reference of the reviews which were concerned with assessing performance during the recent flood event and on managing events of similar scale. None of the terms of reference made any mention of climate change or other future conditions that might affect flooding, nor did they offer the flexibility for reviewers to address aspects not covered by the ToRs. This contrasts markedly with overseas reviews, where concerns that climate change will significantly worsen future flooding are often a driving force behind review processes, for example, the Dutch Deltacommissie review (Deltacommissie, 2008).

AUSTRALIAN REVIEW FINDINGS

Australian reviews varied greatly in their scope. The QFCI and the Brisbane Review covered all PPRR phases. The Comrie Review was very much focused on response, though preparation and immediate recovery were also covered. The ENRC Inquiry looked at selected aspects of prevention, largely constrained by its terms of reference to consideration of infrastructure and waterways maintenance activities such as vegetation clearance.

The reviews overwhelmingly point to the need for improvements in non-structural measures, such as development planning, production and availability of quality flood management information, emergency response management and community participation.

When land is developed it is rarely reversible, and then only at great cost and inconvenience. Development restrictions and building codes are thus a high priority for adaptive management. They depend on information, policy, legislation, tools and processes. The QFCI reveals considerable deficiencies in Queensland's development planning systems at the time of the 2010-11 floods. Development issues were only touched on by the Comrie Review but several points echo QFCI findings, suggesting that issues may not be unique to any one state. Issues relating to development legislation include:

- **provisions that are non-mandatory**, for example, the inclusion of the Queensland Planning Provisions' standard flood hazard overlay in planning schemes was not mandatory.

- **mandatory provisions have conditional application**, for instance, in Queensland SPP1/03 relating to flood risk only applies if planning schemes adopt both a defined flood event and have a flood map; Victorian Planning Provisions only apply if flood mapping has been carried out.

- **mandatory provisions are subject to exemptions**, for example, 'material change of use that is code assessable' is not subject to SPP1/03. Community infrastructure not listed in SPP1/03, including childcare and aged care facilities is exempt, as is development that has 'overriding public interest'.

- **satellite planning schemes** operate under different legislation to facilitate development with specific aims such as affordable housing, essential services, specified localities and significant projects. These provide inadequate or non-existent consideration of flood risk.

- **inadequate building codes**: at the time of the floods, there was no national standard for construction in flood prone areas; the Queensland Development Code did not cover construction in flood prone areas; Queensland's Plumbing and Wastewater Code did not cover flood resilience; Victoria's Building Act 1993 only regulated floor height and did not cover other design features or flood resilient materials.

Inconsistent development legislation results in *ad hoc* consideration of flood risk and is likely to reflect conflicting policy objectives, such as immediate requirements for affordable housing versus long term costs in terms of safety and disaster relief. There is a fundamental disconnect in that the majority of relief and recovery funding is supplied by the federal government, whereas development decisions are made by state and local governments. Many legislative exemptions appear to increase the vulnerability of disadvantaged groups and compromise the resilience of essential infrastructure. This is an area where major reform is needed.

Building codes can enable people to live in areas subject to less severe flooding and studies suggest that incorporating flood compatibility into the original design is more economical than retrofitting (Jones et al., 2006). Flood reviews suggest building codes at both the national and state level are inadequate, though state building codes are expected to be revised to comply with new national standards for residential property in flood prone areas (ABCB, 2012).

Reviews also revealed inadequacies in the administration of planning processes. In one example, lack of accountability by state government agencies responsible for assessing and approving local planning schemes resulted in non-compliant planning schemes for places such as Brisbane and Emerald. Issues included failure to adopt a defined flood event (DFE) and inadequate flood mapping (QFCI, 2012).

Adoption of a DFE is a key planning tool in both Queensland and Victoria. Queensland's state planning instrument for flood risk, SPP1/03, cannot be applied unless planning schemes adopt a DFE. The DFE is based on an historic flood and generally a 1:100 year event is selected, with an additional freeboard of 300-500 millimetres (Comrie, 2011, QFCI, 2012). Recent studies suggest that the use of the 1:100 year event standard for flood control may be inadequate, particularly in countries with a short term flood records like Australia (Wenger et al., 2012). As flood frequency is calculated on past flood events, any subsequent severe flood adds to data and can lead to recalculations. Inaccuracies can also occur as a result of out of date techniques and assumptions. Whether due to inaccurate data, climate change or urbanisation, the 1:100 flood line is not static but can move. This can place people at unacceptable risk of flooding.

There are significant barriers to incorporating up-dated information into planning schemes in both Victoria and Queensland, including a ten-year interval before some planning instruments become due for revision, complex approval processes, cost, compensation liabilities and competing policy pressures. These can all prevent timely incorporation of flood data into planning schemes (Wenger et al., 2012). Climate change risks are not consistently managed in land-use planning schemes, with local governments hampered by a lack of guidance from state governments and financial and expertise constraints (Productivity Commission, 2012). Projects such as Queensland's Inland Flood Study and Engineers Australia's Australian Rainfall and Runoff Revision Project could improve incorporation of climate change risks into future flood studies.

Accurate flood information is a prerequisite for the application of planning legislation and instruments that address flood. It also enables risk assessment and implementation of mitigation measures. However, it has proved challenging to gather and incorporate flood information into planning schemes in most municipalities, even without factoring in the added threats of climate change.

Analysis of reviews revealed gross inadequacies in the generation and dissemination of flood information. In Victoria, 80% of floodplains were reportedly mapped for a 1:100 year event but only 70% of these mapped areas were incorporated into planning schemes. In Queensland, most towns and cities are built on floodplains but only 37% of planning schemes contained any flood related mapping. Of these, only 23.6% were completed in accordance with the SPP 1/03 Guideline (QFCI, 2012, Comrie, 2011).

Reviews do not consider future flood risks when assessing the relative merits of different types of flood information. For example, when discussing likelihood mapping, the QFCI does not acknowledge that stationarity is likely to cease with climate change and that historical likelihood will no longer be accurate (QFCI, 2012). This is a notable omission that suggests a lack of comprehension about how climate change is expected to influence future flooding.

The collection and use of locally based flood information is hampered by insufficient local government resources (both technical and financial) to fund flood studies and to defend and compensate development decisions that are made as a result of using that information. Other issues include municipal boundaries that inhibit the production of catchment-scale flood studies, community cost in terms of lower land values and higher insurance costs and difficulties in downscaling climate change information. Such barriers need to be overcome to facilitate production, availability and use of flood information. The Queensland Reconstruction Authority's (QRA) maps were produced cheaply, covering floodplains over the entire state. They provide a positive example of how some of these difficulties can be overcome.

All reviews were cautious about recommending structural measures such as use of levees and other engineering methods. Where levees were viewed as appropriate it was mainly in terms of protecting existing urban development or individual assets. Significant failings were found in levee regulation, particularly in Queensland where levees are sometimes completely unregulated. Victoria's ENRC Inquiry made many administrative and legal recommendations, suggesting that strong regulation is required where levees are used, and that failure to do so can result in heightened flood risk (QFCI, 2012, Parliament of Victoria, 2012). These findings were strongly supported by the US case study.

Dams were generally found to have mitigated the effects of flooding (including in the case of Wivenhoe Dam). The likelihood that dams might have encouraged the development of flood prone land below them, thereby increasing the consequences of

flooding, was not discussed by the Inquiry, despite the interim QFCI reporting 'a popular misconception that Wivenhoe Dam would contain all floods emanating in the upper Brisbane River' (QFCI, 2011).

The conflict between water supply and flood mitigation is likely to be exacerbated with climate change as more severe droughts as well as floods are anticipated. This conflict is clearly demonstrated by the QFCI, with administrative deficiencies blocking the temporary alteration of the full supply level of Wivenhoe dam to accommodate forecast floods.

The QFCI raised a number of issues about dam safety that could be cause for concern if they are to cope with increased amounts of water in the future due to climate change. Separate studies into dam safety indicate compliance with ANCOLD standards by private dam owners is poor, with high dam failure rates posing threats to downstream communities (Pisaniello, 2010). Pisaniello's study coupled with the findings of the QFCI suggest an Australia-wide review of dam safety might be advisable, including assessment of future threats such as population movements and increase inflows due to climate change.

Only the ENRC Inquiry looked at the management of natural assets on a landscape scale as a method to address flood impacts and this was limited to the management of riparian vegetation and debris. The QFCI touched on vegetation management but yielded no recommendation. The ENRC Inquiry found that in most cases vegetation clearance had a negligible effect on flood depth, while vegetation growing in and around rivers had significant flood reduction benefits. Vegetated waterways were found to delay peak discharge and reduce both flood depth and velocity on a catchment scale. This challenges popular perceptions and practices of removing vegetation from watercourses.

Most Australian flood studies and management measures are carried out on a local level. However, catchment scale management is needed to manage of flood risks, and mitigation measures such as levees, vegetation management and development planning. In Victoria, the development approval process provides a catchment perspective through the official involvement of Catchment Management Authorities as designated referral agencies. These powers are currently under threat (Parliament of Victoria, 2012).

Community resilience and shared responsibility are currently receiving much attention, and if climate change is expected to deliver large scale flood events in the future, helping people to become more self-reliant will be a benefit if emergency services are overwhelmed. There was strong support in all reviews for public availability of flood risk information to help achieve these outcomes. Recommendations relate to methods of communicating flood risk, and improved forecasting and warning. The Comrie Review reported successful outcomes using the FloodSafe program. However, the same report also noted significant difficulties in modifying human behaviour as opposed to more proactive approaches such as development controls. Furthermore, while public awareness of flood risk is important, the capacity of vulnerable groups such as the poor and the aged to avoid or mitigate flood risk is limited.

All reviews reveal issues with flood data collection and the coverage of warning networks. This has relevance to climate change as better coverage can help manage 'unprecedented' events and increase warning times for flash flood. The Comrie Review endorsed the use of the Total Flood Warning System as best management practice. Resourcing was found to be the biggest impediment to improved data collection.

Emergency management frameworks were found to suffer significant governance, capability and capacity issues. Reviews found inadequate resourcing of local governments and response agencies, lack of clarity regarding roles and responsibilities and inadequate oversight and accountability. Reviews also highlighted a need for improved evacuation planning by local authorities (QFCI, 2011, Comrie, 2011, Arnison et al., 2011).

While an 'all hazards, all agencies' approach was recognized as the ideal, this was far from being realized in practice. Improved interoperability of both agencies and technology were needed and in Victoria, trigger mechanisms to enable scale-up of operations.

In terms of immediate recovery, administrative processes such as processing individuals requiring assistance; volunteer management and complexity of recovery grants and reimbursement processes were identified.

Of the four reviews studied most closely, the QFCI dealt with insurance issues in greatest detail, and they were also the subject of industry specific reviews. Assessment processes to handle bulk claims were generally found to be appropriate and the majority of claims were determined in the 1-2 month period. More problematic were the availability and affordability of flood insurance and the need for greater availability of flood risk information. Particular issues were identified for low income earners who are susceptible to being uninsured or underinsured (QFCI, 2011, Trowbridge et al., 2011).

Betterment, or rebuilding to more resilient standards, was covered in most detail by the Comrie Review. While technically allowed by the Natural Disaster Relief and Recovery Arrangements, at the time of writing, no betterment project had ever been approved (Comrie, 2011). This exposes Australia to repeat damage costs. The most significant impediment to achieving betterment is the need for damaged infrastructure to be rebuilt as soon as possible. However betterment projects, requiring both an application and cost benefit analysis, take time to prepare and approve. Agreed processes to identify and pre-approve infrastructure eligible for betterment could improve future resilience.

The COAG National Strategy for Disaster Resilience lists as a priority outcome:

> Following a disaster, the appropriateness of rebuilding in the same location, or rebuilding to a more resilient standard to reduce future risks, is adequately considered by authorities and individuals
>
> (COAG, 2011)

There were isolated examples of relocation following the 2010-11 floods at Grantham, QLD and in the Lower Loddon, VIC, but relocation is not a consistent policy and the lack of functional betterment provisions makes it clear that COAG's aspirational objective is far from being realised.

OVERSEAS FINDINGS

In contrast to Australian reviews, overseas reports overwhelmingly point to a need for ecosystem approaches to flood control. The Netherlands and China rely heavily on dyke systems and although they are strengthening key dykes, they are dismantling or allowing 'flow through' of others. In the Netherlands, 'Room for the River' programs put in place measures such as levee setback, land purchase and reversing channel straightening activities to give more room for floodwaters. These programs have a

strong focus on integrating the interests of stakeholders to find optimal solutions, resulting in multi-functional landscapes and minimal conflict (Dutch Government, 2006, De Boer and Bressers, 2011).

In China, integrated river basin management is a key strategy. Logging bans and revegetation of upper catchments is combined with reversing land reclamation practices that have seen large inland lakes shrink by as much as 80%. The aim of these measures is to reduce significant erosion and sedimentation and to increase the water storage capacity of the landscape (CCICED, 2004, Government of China, 2007, Te Boekhorst et al., 2010, Pittock and Xu, 2011).

Relocation is a strategy used by all three countries. It can provide flood storage capacity when vacated land is assigned to flood compatible uses such as nature conservation, recreation or flood compatible farming.

In the US, ecosystem approaches are starting to find favour as the limitations and costs associated with structural approaches become more apparent. Numerous US reviews and reports present a convincing case for the view that levees are an expensive measure that should only be used as a last resort (Wenger et al., *forthcoming*). Ecosystem approaches are actively promoted and the use of levees discouraged by the USA's Federal Emergency Management Agency in floodplain management courses and text books (Freitag et al., 2009).

The US reports look in some detail at the role of flood insurance, the adequacy of the 1 in 100 year event standard and government disaster relief and mitigation funding.

Initially voluntary, participation in the National Flood Insurance Program (NFIP) became pseudo-mandatory when the federal government introduced the Flood Disaster Protection Act in 1973. This prohibited federal agencies from providing communities with assistance in floodplain acquisition or construction unless they participated in the program. As in Australia, land use planning is the responsibility of state and local government in the USA. However, the NFIP has enabled federal involvement in development control through the provision of incentives. Those who voluntarily participate are subject to mandatory provisions, and in return receive flood insurance (Wright, 2000). While federal flood insurance is unlikely to be a suitable solution for Australia, some NFIP initiatives, such as the provision of supplementary insurance to enable people to rebuild or repair to improved standards, could be adopted by insurers as an optional product to help people mitigate against future damages.

Widely used in Australia as a de facto standard for flood management, the 1:100 year flood event was first selected for this purpose in the USA. It originated as a purely arbitrary actuarial standard to implement the NFIP and was never intended to be a safety standard. The numerous reports and review processes studied for this project point to its inadequacy, with many recommending use of the 1:500 year event, particularly for urban areas where the consequences of flooding are greater and evacuation more difficult. The Netherlands, unlike the US, takes a highly conservative approach to planning controls and in some coastal areas the safety standard is as high as the 1:10,000 year event (1:1,250 for riparian areas). With 50% of its land area below sea level, the Netherlands cannot afford any mistakes and it manages floods with the consequences of failure in mind.

US reports provide a cautionary tale for the provision of over-generous disaster relief, as this can remove the incentive for communities to put in place adequate preventative measures. The US's federal disaster relief is increasingly merging with mitigation, with 15% of funding being required to be spent on measures such as voluntary land purchase, relocation and house raising. Evidence suggests that this has resulted in billions of dollars of savings in avoided damage costs from subsequent flooding events

(Wright, 2000, Freitag et al., 2009). In view of enormous taxpayer expenditure following Australia's 2010-11 floods and the virtual impossibility of obtaining approval to rebuild to more flood resilient standards through the Natural Disaster Relief and Recovery Arrangements, these findings are highly relevant to Australia, and consideration could be given to allocating a set proportion of disaster recovery funds towards improving the future flood resilience.

INTERVIEWS WITH AUSTRALIAN EXPERTS

Interviews revealed strong support for development controls by the vast majority of participants. Significant issues to be overcome included competing policy priorities; the lack of availability of flood free land; the limitations of development approval processes; flood studies that are done on a local rather than a catchment scale; lack of accountability and consequences for those who make development decisions; and difficulties involved with rezoning land when there are inadequate resources to provide compensation.

Generally interviewees did not favour levees as a solution to flooding on a rural landscape scale but there was support for levees that protect existing built development. Numerous issues were identified by participants, among them cost, externalities, difficulties regulating pseudo-levees, impaired drainage and levee failure due to breaching or flooding from unexpected sources.

In terms of response, flood warnings and flash flooding, evacuation, flood planning and community resilience were key concerns and recommendations relating to these in the reviews were supported.

Another strong finding was the potential for use of ecosystem approaches to flood management, by reducing floodwater velocity (identified by many as causing the greatest damage to assets) and flood depth. Crucially, these approaches also delay flooding, which is of value in increasing warning times. This has significance to climate change scenarios that are likely to bring more intense rainfall and flash flooding.

Unsurprisingly, ecosystem approaches tended to be strongly supported by ecosystem researchers and floodplain managers, though other sectors had less familiarity with these approaches and were more cautious. Positive examples of the cost effectiveness of this approach were provided, with measurable cost benefits for water supply and water quality (Queensland Government, 2012, QCC, 2012). To enable this approach, a catchment scale approach to planning and implementation is needed and funding mechanisms, such as payment for ecological services schemes would have to be investigated. Incorporation of ecosystem approaches is needed in flood management courses that currently have an engineering focus, and the level of understanding about such measures also needs to be raised among decision makers and the general public.

There was strong criticism of the government's lack of funding for flood mitigation and betterment, and many found disaster relief over-generous and untargeted. It was not felt that disaster relief in its current form would increase Australia's resilience to disaster. This is a significant issue if the government wants to improve Australia's capacity to adapt and lessons could be learnt from America about merging recovery efforts with mitigation.

Interviews with insurance professionals suggest the industry has limited means of factoring climate change projections into policies due to the need to be cost competitive, though one interviewee noted this is more likely to be achieved if local

flood studies incorporate climate change scenarios. However, the industry is very vulnerable to losses if it underestimates risks. One option could be to facilitate and provide incentives for policy holders to undertake flood prevention measures. Following the American example, there may also be potential for the industry to offer new products such as supplementary insurance for improved rebuilds.

CONCLUSION

It is extraordinary that the Australian reviews don't address climate change threats. However they do highlight many opportunities for improving management of flood risks. The majority of recommendations are non-structural, covering aspects such as governance, legislation, administrative processes, communication and resourcing at all stages of PPRR. Improved development planning, emergency planning, flood information and warning systems received particular attention. One positive innovation is the QRA maps that have provided economical baseline flood mapping in Queensland, and consideration could be given to duplicating this exercise across Australia. In terms of Hallegatte's adaptive strategies, these measures are no regrets, soft and reversible and are a high priority.

Structural measures are associated with the greatest number of problems. Such solutions can be appropriate to protect existing assets but they are inflexible, costly and are often associated with negative externalities. Where such measures are used, careful assessment and management are needed, considering contingencies and cumulative impacts across catchments.

This analysis shows that ecosystem approaches are a neglected area in Australian flood management, but are well supported by findings of the ENRC Inquiry. Such measures have the potential to reduce flood peaks and velocity and can benefit existing development. As ecosystem approaches often come with co-benefits, they have great adaptive potential. Implementation requires administrative systems that support a catchment based approach. Other areas requiring more attention include a more systematic approach to voluntary buy back of repetitively flooded properties and processes to incorporate flood resilience into reconstruction.

To improve future resilience to floods in Australia, reform is needed to relief and recovery funding to emphasize betterment, and barriers need to be removed to ensure consistent consideration of flood risk in development planning and legislation.

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