Adapting For Climate Change Impacts on Flooding

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ABSTRACT

Climate science advises a range of trends in changes to the environment that are now and will continue to impact on flood risk, irrespective of the effectiveness of climate change mitigation strategies. Recent information from the Intergovernmental Panel on Climate Change, IPCC (2007) provides further advice on the potential impacts of climate change on sea level rise and flood producing rainfall events. This paper discusses current climate trends and the associated ramifications for the management of the flood threat to existing and future development in NSW. It addresses the potential impacts of climate change and discusses the range of ways in which these impacts may be able to be managed and their relative benefits.

1 INTRODUCTION

The primary objective of the NSW Government's Flood Prone Land Policy is to reduce the impacts of flooding and flood liability on individual owners and occupiers of flood prone property and to reduce private and public losses resulting from floods, utilising ecologically positive methods wherever possible. This objective needs to consider that flood prone land is a valuable resource that should not be sterilised by unnecessarily precluding its development and that a merit based approach to decision making is necessary rather than rigid and proscriptive criteria.

Floodplain risk management (FRM) is a partnership between all spheres of government and it is therefore of interest to all to ensure that flood risk is effectively managed. In NSW local government have primary responsibility for managing flood risk with the State Government providing technical, policy and financial support through DECC and the State Emergency Service having responsibility for emergency response management and associated planning. The Commonwealth provides some financial support in partnership with the State.

The impacts of climate change on sea levels and flood producing rainfall events will have a flow on effect on flood behaviour which may result in key flood levels being reached more frequently and floods of the same average recurrence interval, ARI, being of a larger magnitude. The climate change factors influencing flood behaviour and their ramifications to the community will vary with the location.

The Floodplain Development Manual indicates that climate change is to be considered in developing and implementing FRM plans. To assist council further

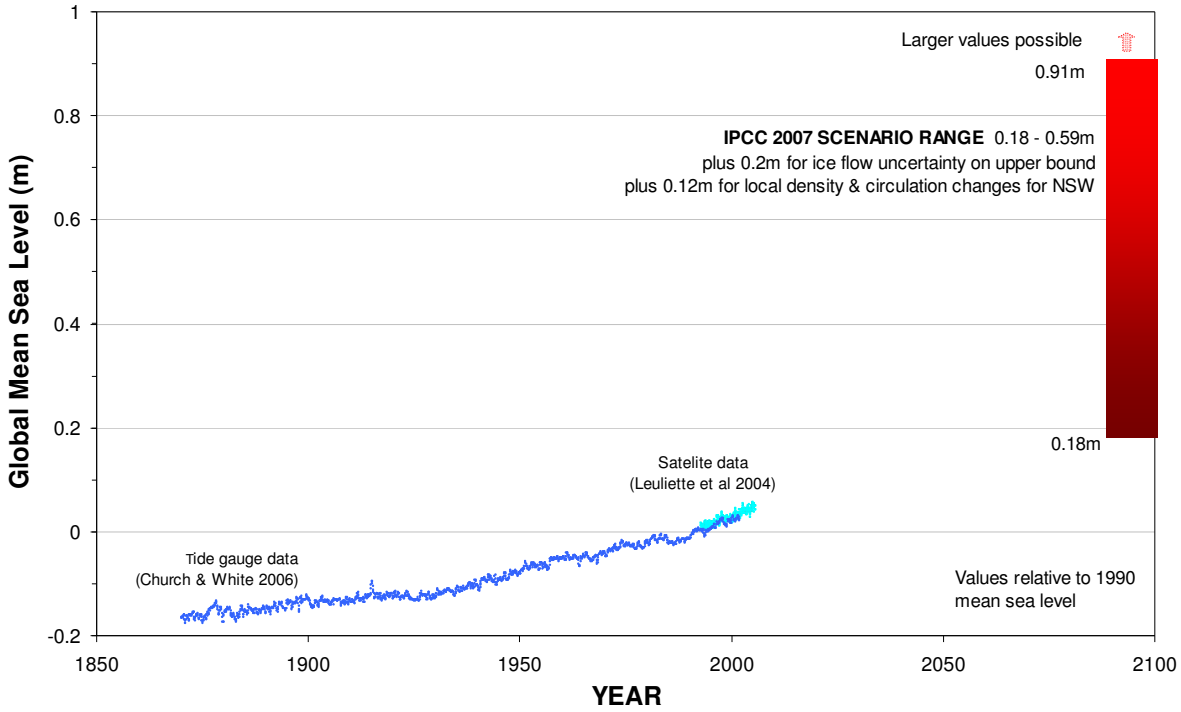
understanding the risk posed by climate change the DECC has released a FRM Guideline on the Practical Consideration of Climate Change. This provides additional advice on the consideration of climate change in developing and implementing floodplain risk management plans. Given the potential impacts of climate change on flood behaviour and the associated ramifications, and the weight of scientific knowledge, there is little wisdom of ignoring climate change impacts in decision making today.

2 FACTORS AFFECTING CLIMATE CHANGE ON FLOOD RISK

Climate change is causing rising sea levels and is expected to impact adversely on rainfall intensities in flood producing storm events. These changes have the potential to significantly influence flood behaviour at specific locations.

The IPCC 2007 trends indicate that average global sea level rise (ignoring ice flow melt) may be between 0.18m to 0.59m by between 2090 and 2100. Add to this the ice flow melt uncertainty advised of up to 0.2m gives an adjusted global range of 0.18 to 0.79m. IPCC 2007 and recent CSIRO modelling (McInnes et al 2007) indicate that mean sea level along the NSW coast is expected to rise by more than the global mean by as much as 0.12m by 2070. Combining the relevant global and local information indicates that sea level rise on the NSW coast is expected to be in the range of 0.18 to 0.91m by 2090 to 2100 (**Figure 1**) and the IPCC cautions that it may exceed this amount. Sea level rise beyond 2100 is common to all scenarios with ultimate stabilisation levels (for thermal expansion only) in the range of 0.4 to 1.4m for the low level emissions path and up to 1.0 to 3.7m for high level (IPCC).

Figure 1 – Sea Level Data and Predictions (relative to 1990)



Climate change is also expected to impact on flood producing rainfall events with a trend toward larger scale storms (rainfall totals for the 40 year average recurrence interval (ARI) 1 day storm events) tend to increase (**Table 1)**. The impacts on shorter duration storms are expected to be more significant and CSIRO are currently undertaking work in this area. **Figure 2** shows the potential impacts of changes in current design ARIs due to increases in rainfall.

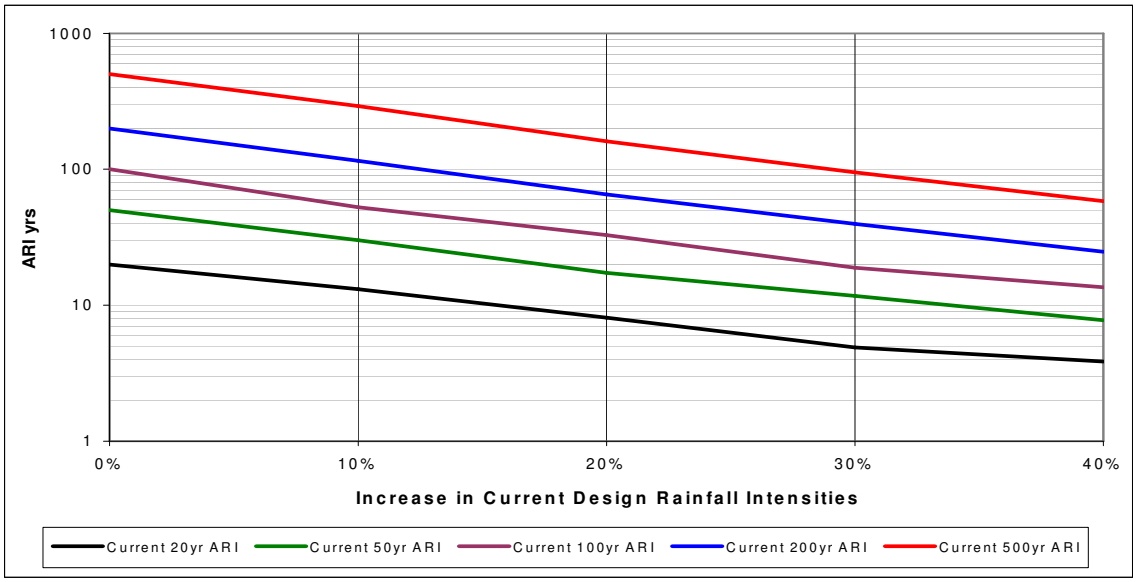
Table 1 Indicative Change in Extreme Rainfall 1 day Totals & Evaporation 2030 & 2070

Source: CSIRO, reports prepared for the NSW Government, 2007. Climate Change in NSW Catchments Series

Catchment	Extreme Rainfall (40 Year 1 day rainfall total) Projected Change 2030	Extreme Rainfall (40 Year 1 day rainfall total) Projected Change 2070	Evaporation Projected Change 2030	Evaporation Projected Change 2070
Border Rivers-Gwydir	+3 to +7%	+10 to +15%	+2 to +13%	+4 to +40%
Central West	-3 to +20%	-3 to +15%	+2 to +13%	+4 to +40%
Hawkesbury-Nepean	-3 to +12%	-7 to +10%	+1 to +8%	+2 to +24%
Hunter-Central Rivers	-10 to +12%	-7 to +10%	+1 to +13%	+2 to +40%
Lachlan	-3 to +25%	-7 to +29%	+2 to +13%	+4 to +40%
Lower Murray-Darling	+0 to +25%	+0 to +29%	+2 to +13%	+4 to +40%
Murray	-3 to +25%	-7 to +29%	+2 to +13%	+4 to +40%
Murrumbidgee	+7%	+5%	+1 to +13%	+2 to +40%
Namoi	+3%	+10%	+2 to +13%	+4 to +40%
Northern Rivers	-10 to +5%	+5 to +10%	+1 to +13%	+4 to +40%
Southern Rivers	+7%	+5%	+1 to +13%	+2 to +40%
Sydney Metropolitan Catchments	-3 to +12%	-7 to +10%	+1 to +8%	+2 to +24%
Western Catchments	-10 to +34%	-7 to +16%	+1 to +13%	+4 to +40%
Maxima	-10 to +34%	-7 to +29%	+1 to +13%	+2 to +40%
Average	-2 to +15%	-1 to +15%	+1 to +12%	+3 to +38%

Figure 2 – Indicative Change in Design ARI as Rainfall Intensities Increase

McLuckie et al (2005)



3 POTENTIAL IMPACTS OF CLIMATE CHANGE ON FLOOD RISK

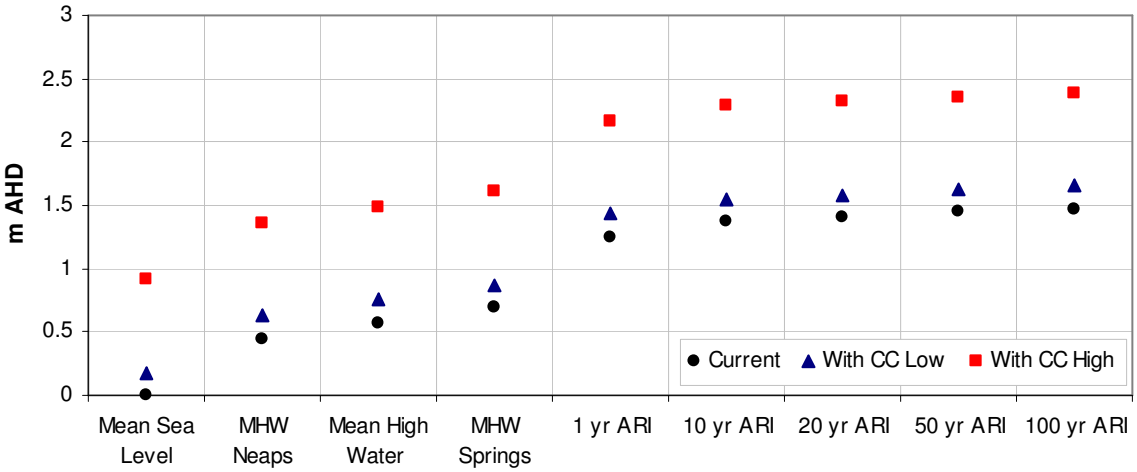
The climate change factors affecting flood behaviour and their degree of influence vary with location. Therefore it is essential that studies for specific locations consider these impacts and their ramifications which may include:

- *Sea level rise* will impact on flooding in the lower reaches of river systems where tailwater levels affect flood levels. This could have dramatic implications along the coast resulting in more frequent inundation of low lying areas rendering some areas unviable or in need of protection from more frequent flooding. Drainage of relatively low lying areas will become more difficult or impractical which may result in the need for pumped stormwater systems.

  Tides will propagate further up open estuaries as mean sea levels rise. Higher sea levels will likely coincide with flood peaks. Therefore flood levels for rare events will be higher and the perception is likely to be that rare events occur more

frequently. Figure 3 demonstrates the impacts of sea level rise on key static ocean levels. This shows that with a high climate change scenario the mean high water springs is above the current 100yr ARI static ocean level. This may mean that foreshore land may be more frequently inundated which may render some areas unsuitable for current uses, including habitation, even where development floor levels are raised.

Figure 3 Differences in Key Ocean Levels – 2090 - 2100



For intermittently closing and opening lakes and lagoons or ICOLLS the impacts will be different and are largely dependent on the morphology of the beach, lagoon and foreshore and the subsequent beach response to sea level rise. Responses are likely to involve more or less frequent natural opening of the lake or increased elevation and landward migration of the entrance bar with sea level rise but may also include complete loss/destruction of the entrance bar.

Lake entrance management strategies may be in place in ICOLLS to control water levels upstream of the bar by encouraging bar breakout during flood events or to open the lagoon for water quality purposes. If the entrance bar is built up by climate change the maintenance of the same entrance regime will require the bar management strategy to be activated more frequently. The practicality of this regime may be questionable and it may need to be revised with subsequent impacts on potential flood levels. Alternatively, a permanent or more frequently opened entrance may expose low lying development to more frequent inundation from elevated tide and ocean levels. The solution is different in each case and therefore each individual case must be considered separately.

In addition to flood implications other impacts resulting from sea level rise alone must be taken into consideration including coastal recession, loss of coastal wetlands, loss of shallow water nursery areas, loss of estuary fringe, sandy foreshore and foredune habitats, impacts on aquatic species and foreshore and recreational facilities, and infrastructure and broader environmental impacts.

An example of the ramifications of change on property is damage to a house built at the flood planning level (FPL) in an area where flood levels are directly controlled by ocean levels. These could increase by more than 1000% due to a high sea level rise scenario by 2090 to 2100.

- *Increased frequencies of events due to increased rainfall intensities*. Predicted increases in flood producing rainfall events will influence the frequency of occurrence of key flood levels. For example, in a particular town not influenced by sea level rise, a 30% increase in rainfall intensity could increase average annual damage (AAD) by 300%.

- *Increased impacts for the same average recurrence interval (ARI) event*. More damage and danger will occur from the same ARI flood event due to changed flood behaviour and storm intensity. This may be related to increased depths of water or flow velocities or new floodways developing.

4 WHY CONSIDER THE IMPACTS OF CLIMATE CHANGE ON FLOOD RISK

Managing flood risk relies upon FRM options including mitigation works, development controls and emergency response management. Adverse changes to flood behaviour, such as more frequent occurrence of rare events and storms of the same ARI being more extreme will make mitigation options and development controls based upon the flood situation of today more vulnerable to failure in the longer term. Impacts of the change will vary with location and the associated ramifications will alter with changes in exposure of people and property to the flood hazard. As FRM options and development decisions are vulnerable to climate changes they cannot be ignored in decision making today.

Therefore, the 2005 Floodplain Development Manual requires flood investigations to consider the implications of climate change and where necessary assess how decisions or management options or the community can adapt to these changes over time. Adaptation may involve consideration of management options that are more robust now or management options that enable effective adaptation to climate change in the future, i.e. building adaptive capacity into options. This requires informed strategic level FRM decisions which consider the best possible information on flood behaviour and its potential change into the future. Ignorance of potential change and its implications will result in poor long term risk management decisions with the potential for significant and costly mitigation works.

Given the IPCC's position, the weigh of scientific opinion, and the mainstream acceptance of the occurrence of climate change within the Commonwealth and State Government, it could reasonably be expected that risk management decisions which could be significantly influenced by climate change should consider its potential impacts and their ramifications, particularly where these decisions have long term implications.

The Minister for the Environment, Malcolm Turnbull in releasing the Commonwealth's Climate Change Adaptation Actions for Local Government (2007) reportedly indicated (Age Marian Wilkinson, 4/10/07) that councils could face big legal liability costs if they failed to identify threats to their regions from climate change.

The report quotes relevant advice from the Local Government Association of Tasmania (2004) *"Local government provides for the health, safety and welfare of its community and if a council cannot show that it has taken preventative action against any threat to the health, safety and welfare of its community, it faces the possibility of liability costs which can be reduced if a council identifies the threats to its community and implements appropriate strategies to prevent these threats"* and indicates that it has been documented that the two areas where liability related to climate change may arise are compensation or common law negligence due to a breach of the duty of care (Planning Institute of Australia, 2004).

5 CONSIDERING THE IMPACTS OF CLIMATE CHANGE ON FLOOD RISK

Assessment of climate change impacts for a specific location through modelling of potential changes provides a more appropriate basis for the consideration of climate change than the arbitrary estimates of potential impacts. Decisions based upon actual modelling would be expected to withstand closer scrutiny and be more defensible than arbitrary decisions and associated management allowances.

Decisions need to be made as to what will influence climate change for the location. Are there coastal influences or is rainfall increase the primary driver and if so do influences such as the length of the critical flood event impact upon the degree of change to consider.

When deciding which climate change scenarios to consider it should be recognised that the implications of climate change even with mitigation (CO_2 management) will continue beyond this century. The 2070 and 2090-2100 predictions can be expected to be reached or exceeded in the future as climate change continues. Therefore the precautionary principle suggests consideration of the full range of scenarios over this timeframe.

Figures 1 to 3 indicate the potential climate change impacts on sea levels and on flood producing rain well into this century. The precautionary principle suggests that the 2070 (rainfall) and 2090-2100 (ocean) timeframes should be selected as the basis for current decisions for development and management options unless it can be shown to the satisfaction of the council or DECC that the associated decisions or options will not be relevant by this timeframe. Longer timeframes should also be considered, particularly where critical infrastructure is involved and may be a consideration of regional scale planning.

The FRM guideline recommends that where sea level is relevant to the study area the ramifications of 0.18m, 0.55m and 0.91m in ocean level rise should be assessed. In addition until more work is completed in relation to the climate change impacts on rainfall intensities, sensitivity analyses for 10%, 20% and 30% increase in peak rainfall and storm volume should be undertaken. The combination of impacts of ocean level and flood event is possible and may be more likely with climate change and therefore may need to be considered where applicable. The combination of ocean and flood event ARIs should be discussed with DECC FRM staff due to joint probability issues where these may occur.

The FRM guideline also provides advice about the consideration of climate change in the FRM process and indicates that this is ideally undertaken in studies. However, if a project has progressed past this stage without climate change being considered, it should be considered as part of the current stage even when starting to implement management measures to ensure that decisions are robust to or adaptable for the impacts of climate change.

If climate change is not considered in strategic FRM decision making for new development this has the potential to lead to the need for substantial mitigation works to protect this new development in the future. Whilst building future mitigation works may be a valid option its practicality and financial feasibility (particularly where the future viability of existing vacant land may be questionable) need to be considered and may lead to altered development decisions and controls to build in adaptive capacity for the future.

6 ARE THE RAMIFICATIONS OF CLIMATE CHANGE SIGNIFICANT?

The potential impacts of climate change and the associated ramifications will vary significantly with location. Therefore the Manual and FRM guideline highlight the need for climate change to be considered in both the flood study and the FRM study to assess the location specific impacts and ramifications and consider associated adaptive FRM strategies. Any management measures relating to a specific ARI flood event are more susceptible to climate change than those relating to an extreme or probable maximum flood (PMF) event as associated emergency response management decisions for the PMF are inherently more robust.

Whilst climate change impacts may vary within and between study areas, significance is likely to relate to the development of new floodways, changes in flood hazard and the frequency of inundation and frequency of exposure to hazard. The ramification of changes will depend upon the exposure of the existing and future community to the changed flood hazard and any additional impacts on flood damage and danger to people. If significant changes in ramifications are expected it is important to consider whether management options are still appropriate, if they are still effective or are in need of modification to remain practical. In addition consideration needs to be given to whether proposed development options and associated controls are still appropriate or require modification.

7 MANAGING VULNERABILITY OF DEVELOPMENT DECISIONS

The FRM guideline provides advice in relation to the adaptation of development decisions for climate change and the associated questions that need to be asked when considering the ramifications of climate change. The need to adapt and the degree of adaptation necessary will depend upon the significance of the ramifications of climate change to the specific location and the particular decision.

In development decisions it is important to consider the impacts of climate change on land viability separate to its impacts on development of the land as there are occasions where climate change may render the future occupation of the land unviable, particularly due to increased frequency of inundation. It needs to be recognised that once land is zoned for a particular use the cost of reducing that usage through options such as voluntary purchase is significant. Therefore developing a viable alternative to VP which may limit the length of tenure against agreed and measurable circumstances may be a way of ensuring that land can be effectively utilised whilst viable but cost effectively abandoned when it becomes unviable. Some certainty in this regard will facilitate commercial decisions.

In relation to development conditions that apply to land that is viable for occupation with climate change, key questions that need to be considered include: will development controls provide long term protection relevant to the length of tenure? Will protection works be required, is land available and will these be practical?

This may lead to a range of climate change management options for development of land as outlined in the FRM guideline. These include options that: leave land vacant; utilise it under agreed circumstances or as part of broader developments enable effective change in use over time; increase development controls to allow for climate change; provide for some form of protection over time whilst not including specific requirements for climate change in development controls.

8 MANAGING VULNERABILITY OF MANAGEMENT OPTIONS

The FRM guideline provides advice on adaptation of management options for climate change and the associated questions that need to be asked when considering the ramifications of climate change. The need to adapt and the degree of change necessary will depend upon the significance of the ramifications of climate change for the particular location.

When it comes to management (and in particular mitigation) options the ramifications of the impacts of climate change may mean that a particular option may not be viable or it may need modification to make it viable. Therefore the FRM guideline recommends that the viability of options be tested to climate change impacts to see if there are circumstances in which they may not be viable. Viability may relate to the relative frequency of inundation of the land. In cases where options may not remain viable great care needs to be given to whether this is still the appropriate option.

Where the option remains viable with climate change the ability to build adaptability into it needs to be considered, as does the question of whether to build this capacity in now or add it in the future. The FRM guideline addresses this issue in more detail.

9 TAKE HOME MESSAGES

The Commonwealth in its Climate Change Adaptation Actions for Local Government (2007) quotes advice indicating that Local Government may have liability for not considering climate change in decision making. Given this advice and the weight of scientific opinion and Government acceptance of the potential impacts of climate change the authors do not see how councils can ensure legal indemnity under s733 of the Local Government Act, 1993 or fulfil their duty of care to manage flood risk if they do not assess the potential impacts of climate change in studies and do not consider this in their long term FRM decision making.

The DECC FRM Guideline on Practical Consideration of Climate Change supports the Floodplain Development Manual by providing guidance for councils on how to consider climate change in developing and implementing FRM decisions. The guideline is available through local DECC FRM project support staff or can be obtained by emailing duncan.mcluckie@dnr.nsw.gov.au . The DECC intend to have this and other FRM guidelines available on its website in the near future.

10 REFERENCES

DECC FRM Guideline, Practical Consideration of Climate Change, October 2007. **The guideline includes a wide range of references not included in this paper due to space constraints.**

Church, J. A. and White, N. J., (2006). A 20th century acceleration in global sea level rise. *Geophysical Research Letters* 33, L01602, doi: 10.1029/2005GL024826.

Leuliette E.W., Nerem R.S. Mitchum G.T. (2004) Calibration of TOPEX/Poseidon and Jason Altimeter Data to Construct a Continuous Record of Mean Sea Level Change. *Marine Geodesy*, 27, 79–94.

SMEC Australia for Australian Greenhouse Office & Dept of the Environment & Water Resources Climate Change Adaptation Actions for Local Government, 2007