CLIMATE CHANGE – THE FUTURE IS UNCERTAIN

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Abstract

Floodplain risk management involves dealing with a wide range of current and future uncertainties. With climate change the scale of potential uncertainty increases.

Available historic flood data is generally limited by the amount of data available on rainfall, catchment condition and flood levels in previously developed areas. The data available for the most significant events is often considerably less than for events that may have occurred more recently. While modelling relies on this incomplete data, it requires decisions upon a range of assumptions that may impact on flooding.

Changing the time location of modelling, from historical situations to present time or into the future involves further assumptions on what will change and by how much? This has led to modelling based upon a range of assumptions affecting flows and flood levels and, therefore, predicted flood behaviour.

However, climate change has the potential to add significantly to this degree of uncertainty. This paper will discuss how the issue of climate change should be considered and canvass how decision making can be made more robust in light of increasing uncertainty.

The ramifications of these decisions may include:

- increased development costs and the potential to sterilise areas if decisions are too conservative; and
- increased frequency of inundation and damage if uncertainty is dismissed.

**Key Words:** Uncertainty, Climate Change, Flooding, Risk Management

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1. Introduction

The Inter-governmental Panel on Climate Change (IPCC) 2001 Assessment Report (Ref 3) concludes that sea level rise and climate change are inevitable, irrespective of the success of emission reduction strategies, and that these strategies now need to be complemented with adaptation strategies.

The New South Wales Government has accepted international scientific opinion that increased concentrations of greenhouse gases in the atmosphere are causing changes in our climate.

In short, climate change is occurring and needs to be considered in the preparation and implementation of floodplain risk management plans. Warmer global temperatures (Figure 1a) cause expansion of ocean waters and the melting of icecaps resulting in accelerating sea level rise as evidenced in Figure 1b. Global sea level rise is now estimated at 3 mm per year over the last ten years compared with 1 mm per yr over the preceding forty years. The rate of rise is expected to increase. In addition, general climate change predictions for south eastern Australia indicate an expectation of reducing annual rainfalls in many areas, but with the potential to result in increased storminess (ie less annual rainfall but more significant storm events) and associated higher rainfall intensities. The frequency of extreme events is also expected to increase.

Recent modelling by CSIRO of annual extreme events (Abbs et al Ref 5) highlights the potential for climate change to have significant implications for flooding due to an increase in occurrence of flood producing weather systems with associated increase in frequency of flood events for coastal areas of NSW. This work also predicts an increase in the confluence of extreme wind and rainfall events, with associated potential impacts on the level of wave activity (and ocean levels) during flood events with expected changes in ocean storm surge and run-up levels. This is in addition to changes in mean sea levels.

![Figure 1a - Global Temperatures 1860 to 2000](source Leuliette et al (Ref 4))

Figure 2 indicates the difference in key ocean levels for various climate change scenarios to 2100 (after Lord & Nally, Ref 6). Significantly, this graph simply demonstrates that should the IPCC, (Ref 3) high climate change scenario occur by 2100 then current mean high water springs will be below mean sea level; and current 1% AEP ocean level will be equivalent to mean high water springs. This would mean that the current 1% AEP ocean level would be exceeded on most monthly tide cycles. Even with the low climate change scenario by 2100 the current 1% AEP ocean level will be below the 10% AEP ocean level.
The potential changes in annual extreme rainfall intensities on the eastern seaboard due to increased concentrations of greenhouse gases in the atmosphere is the basis of ongoing work by CSIRO (Ref 5). Preliminary results from this work generally show a trend for maintaining existing rainfall intensities to 2030 with increased rainfall intensities across the NSW coast by 2070 across the full range of ARIs assessed. However, interpreting the graphs of changing ARIs in this preliminary work indicates that the differences between figures for the current and 2030 and 2070 climate scenarios increases as the ARI of the event increases. Therefore, the impacts of climate change on rarer events, of more interest in flood risk management, appears to be greater than in more frequent events and could be well in excess of 10% by 2030 and 20% by 2070. Therefore increasing rainfall intensities in higher ARI events is a real possibility for NSW even with a reduction in average annual precipitation.

2. Impacts on Flood Behaviour and the Associated Ramifications

Likely impacts of our changing climate on flood behaviour include:

- higher mean sea levels resulting in an increased area of tidal influence;
- storm surge and wave run-up may be higher;
- an increased number of flood producing rain events is likely;
- an increased potential for the confluence of rain and wind events with associated ocean effects;
- increased rainfall for the same AEP flood events. This may mean the same flood levels are reached more regularly, ie, the design levels for levees and the flood level against which protection of new development is designed may be reached more regularly. This will result in increased frequency of exposure of people to perilous situations and an increased frequency of damage. For example, with a 20% increase in rainfall intensity, the current estimated 1% AEP (1 in 100 yr ARI) flood level may be reached once every 20 years, ie, the same flood level will be reached 5 times as often; and
- floods of the same AEP will be higher and, therefore, result in increased flood damage and exposure of people to more danger for that design condition.

Assessing the scale of potential impacts of these changes on flood exposure is essential to inform decision making on management options for both existing and future development. Both flood damages and danger to people need to be considered. Figure 3 shows a curve of
damages versus above floor inundation depth for a typical house (derived through Ref 7). This has been used to consider the potential impacts of climate change on flood damages.

2.1 Areas Where Flooding is Driven Solely by Ocean Levels

In areas where flooding is driven by ocean levels the impacts of climate change can be directly related to both the increase in frequency of flood events and the increase in scale of damages for particular events.

Figure 4 provides an example of the difference in damages for a typical house with a floor level built at the current 1% AEP flood level plus 0.5m freeboard (a typical minimum floor level requirement for new development in New South Wales) for different AEP events and incorporating sea level rise for different climate change scenarios. Note that this figure and subsequent calculations ignore any increase in rainfall intensities and associated ramifications and are therefore likely to be non-conservative. All figures are in present day dollars.
This figure highlights that flood damages increase markedly as both the frequency of damages and the damages for the same event frequency increase with ocean level rise. This results in changes to modelled annual average damage (AAD) from flooding from the current situation of $270 to $1,150 and $4,480 for low and high scenario IPCC projections at 2100 respectively.

Therefore, on the basis of sea level rise alone (ignoring growth in the extent of flooding, the number of affected houses and changes in rainfall intensity), the AAD from flooding in coastal areas for a house built with protection from the current 1% AEP ocean level could more than quadruple for the low IPCC scenario and increase more than 16 fold for the high IPCC scenario over today’s estimated damages.

2.2 Areas Where Flooding is Driven by Rainfall/Runoff rather than Ocean Levels

Away from areas where flooding is driven by ocean levels, climate change will relate more to the impact of rainfall intensity increases and the associated impacts upon flood levels and may alter future inundation extents and risk exposure.

Indicative impacts of increasing rainfall intensities by between 10 to 40% are provided in Figure 5. These impacts are assessed considering that all other catchment factors (including antecedent moisture conditions) are constant between current and future scenarios. This figure shows that current design events would happen more frequently as rainfall intensities increase. For instance, the current 100 year event could occur every 50 years as a result of an increase in rainfall intensity of just over 10%. The same event could occur every 20 years with a 30% increase in rainfall intensity. This may result in more regular damaging flood events with resultant increase in the frequency the community is exposed to the associated hazards and damages. Economic and social impacts could be potentially devastating.

The effects of increased rainfall on runoff and associated flood levels and damage are very dependent upon the conveyance/configuration of the individual floodplain, and exposure of development to hazard. Considering these changes on a floodplain, significant increases in flood related AADs would be expected as rainfall intensities increase (see Figure 6).
It is understood (pers. comm. Brian Taylor) that the Bureau of Meteorology is to undertake work on the impact of climate change on probable maximum precipitation in conjunction with the Queensland Government.

2.3 All Areas

Given the scale of these impacts, their persistence and associated ramifications, it is difficult to justify ignoring them in making informed floodplain risk management decisions. Future decisions should be both robust and adaptable in order to address likely future impacts.

3. NSW Government Floodplain Risk Management Policy

The NSW Government’s preferred strategy for managing flood hazards as outlined in the Government’s Flood Prone Land Policy and the Floodplain Development Manual (2005) (Ref 8) is through the preparation and implementation of floodplain risk management plans with a strategic focus, prepared through the floodplain risk management process (Ref 9).

The policy assigns responsibility for implementing the strategy to Local Government, with the State Government providing technical and financial assistance through the Department of Natural Resources.

The preparation of management plans requires detailed consideration of flood behaviour and the extent of hazard over varying timeframes and ranges of events to enable effective management of the risk to both people and infrastructure (public and private). There are over 100 management plans completed and adopted in NSW. Some plans are in draft form and with background studies and investigations leading to informed management plans now being undertaken in many areas across NSW.

A key issue for these management plans is, therefore, the potential influences of any change in the catchment (level or density of development or stream condition) and change in climate on flood behaviour and the associated impacts upon people and property within the floodplain. These issues need to be considered in the preparation of management plans as without
4. Consideration of the Impacts of Climate Change on Decision Making

The Manual indicates the need for climate change to be considered in both the flood study and the management study to determine both the potential impacts on flood behaviour and to enable robust and informed decisions on appropriate adaptive strategies for managing flood risk into the future.

This concept (as shown in Figure 7) fits well within the concept put forward by the Allen Consulting Group (Ref 2) based upon earlier work.

Figure 7 – Managing Climate Change Impacts (Adapted from Allen Consulting Group (2005) Ref 2)

Figure 7 highlights the need to:

- understand the exposure of the community to flood hazard. This is the purpose of the flood study;
- understand the sensitivity of flood behaviour at the specific location to climate change to identify the significance of impacts. The sensitivity analyses undertaken should consider the science available at the time and the precautionary principle. As such, at this stage it is recommended that analyses be undertaken to assess the sensitivities of flood behaviour to the following scenarios:
  - sea level rises considering the range of rise anticipated by the IPCC by 2100. Consideration of rises of 0.18, 0.53 and 0.88m is recommended;
  - rainfall intensities. Consideration of changes in rainfall intensity of between 10% and 40% are recommended to provide an understanding of the sensitivity of the floodplain to these changes; and
  - envelopes of combined sea level rise and rainfall intensity changes identified above to understand the combined impacts, where applicable.
- understand the potential impacts of climate change on flood behaviour and associated ramifications for people, property and infrastructure as part of the management study to inform decision making of the associated ramifications;
- examine options to manage the impacts of climate change. This may involve additional assessment of options as part of management studies, and re-examination of existing management strategies in review of management plans. This may require consideration...
of the potential need for new or revised strategies to manage increases in risk in an adaptive way as clarity improves on the scale of likely change; and

- consider different strategies for dealing with impacts in developed areas compared to planned land releases. This would be undertaken as part of management studies and management plan review.

The remainder of this paper will consider the adaptive capacity of current strategies and put forward some concepts of how adaptive capacity could be further built into future floodplain risk management decision making for both existing and future development.

5. Adaptive Capacity of Existing Flood Risk Management Decisions

The Floodplain Development Manual requires consideration of the full range of flood risk as part of the floodplain risk management process. This provides a good basis for informed decision making as it enables the identification of changes in behaviour of floods of different magnitude.

The management process, if followed strategically, leads to management decisions for both existing and future development, as discussed below. The process is sufficiently robust and flexible to allow for consideration of the impacts of climate change.

5.1 Future Development

Future development, by its nature, should be easier to manage when accommodating the potential impacts of climate change. A number of important steps to consider in managing flood risk to future development are outlined below.

F1. Identify areas where development should be avoided or at least severely limited. These include:

- areas where development may have a significant impact upon flood behaviour in other areas, generally defined by floodways and major flood storage areas;
- areas where development may have a significant impact upon emergency response in other areas;
- areas where the location itself will have significant emergency response difficulties that need to be managed if safe occupation is to occur;
- areas that need to be set aside to offset the impacts of urbanisation on flood behaviour, for example, land for detention basins; and
- areas where the continuing hazard from flooding, even allowing for the implementation of development conditions, is excessive.

F2. Identify suitable development opportunities. These could include land outside the areas identified above. That is, areas where the impacts of development on adjoining properties and impacts of flooding on the development and its occupants can be effectively managed.

F3. Identify types of development that may be appropriate in particular areas earmarked for development. For example, some forms of industrial, commercial or agricultural development may be suitable in an area where residential development is not appropriate due to likely flooding impacts and available management options.

F4. Determine appropriate conditions to reduce hazard exposure and impacts to acceptable levels in areas earmarked for future development.

F5. Where necessary, identify works (particularly detention basins) to offset the impacts of development for a current design event (1% AEP).
Points F1 to F3 aim to limit inappropriate development in the most hazardous areas of the floodplain. This will generally allow for robust management of flood risk as it considers both the 1% AEP event for damage issues and the probable maximum flood (PMF) for emergency response issues. However, in areas where new floodways form during events slightly larger than the design event, additional care needs to be taken in development decisions. It also needs to be acknowledged that the frequency of emergency response operations would increase with increased flood frequency.

Point F4 relates to the decision to apply conditions to provide a certain level of protection (1% AEP) to reduce flood frequency and therefore manage flood damages. In practice this means the derivation of flood planning levels (FPLs) in accordance with the Manual. FPLs include a freeboard which, in effect, acts as a factor of safety which should never be relied on to manage risk in events larger than the flood used to derive the FPL. The Manual indicates that freeboard should allow for the following:

- uncertainties in the estimates of flood levels. These can arise from a relatively short database of past floods and past storm surges in coastal waters, together with uncertainties and simplifications in the models used to predict flood discharges and flood levels. This does not include uncertainty for climate change.
- differences in water levels across the floodplain because of 'local factors'. These factors are not able to be determined in floodplain modelling, which assumes a static water level;
- increases in water level as a result of wave action are also not determined in floodplain modelling. Wave action can be of two types. Wind-induced waves across fetches of open water and waves induced by boats and vehicles moving through flooded areas. For example, wave action may be significant in the wide floodplains of the western rivers as a wind fetch 2 kilometres long could readily generate waves up to 0.5m high;
- an allowance for changes in rainfall patterns and ocean water levels as a result of climate change. A typical freeboard of 0.5m would generally include little allowance for the impacts of climate change; and
- the cumulative effect of subsequent infill development of existing zoned land.

Therefore, FPLs may have an allowance for climate change. If however, no allowance or inadequate allowance is made in freeboard for climate change the level of protection provided by the FPL will diminish with time as frequency of exposure to flood hazard and flood damages increases with climate change.

Whilst FPLs can be revised as improved information on the degree of change is available (ie) they can be adapted, this does not assist in managing the flood risk for development that will occur between now and when better information is available. Give the scale of potential change in exposure, it should not be considered appropriate to wait for definitive information on the impacts to occur before reacting. This could hardly be considered a strategic response to climate change. This view is consistent with the precautionary principle, where a lack of certainty about the likely extent of climate change impacts is not a reason to fail to address the issue at all.

Point F5, relating to mitigation works such as detention basins, is governed by a particular design event. These works are less effective, and may be ineffective, for larger scale flood events. If the original design event becomes more frequent under climate change, their capacity and capabilities will be exceeded more frequently.
5.2 Existing Development

There are numerous options for managing flood risk to existing development. However, it should be acknowledged that managing the flood risk from climate change for existing development presents significantly more challenges than instigating appropriate management for future development. Some key considerations in relation to options for managing flood risk to existing development are discussed below:

E1. Levees are designed to exclude flooding for a particular design event. Freeboard is built into the levee design level to account for uncertainty. Freeboards for levees need to include the factors outlined in Section 5.1. Earthen levees also need to consider the following issues:

- post construction settlement that can occur. This effectively reduces the long term crest level of the levee;
- surface erosion due to vehicle, animal or pedestrian crossing can reduce the level of the levee crest;
- there is significant potential for surface shrinkage cracking and associated additional risk of failure where good grass cover and an appropriate moisture content cannot be maintained in earthen levees;
- the performance of earthen levees when they overtop is characterised by relatively quick vertical erosion resulting in an embankment breach. This can allow more water in quickly which can result in relatively fast rising flooding and difficult evacuation; and
- levees can be designed to include an allowance for climate change.

E2. Voluntary purchase removes development and occupants from particularly hazardous parts of the floodplain which cannot be effectively protected by other means. This solution can be adaptive as areas of voluntary purchase can increase as necessary. However, extension of voluntary purchase could have enormous cost and social implications.

E3. Voluntary house raising (VHR) involves the raising of house floor levels to a level derived from a particular design level (generally the 1% AEP flood level) plus a freeboard. This solution is only adaptive where VHR decisions and raised floor levels consider the impacts of climate change. This has associated cost implications. A further consideration is that VHR can result in evacuation problems, as people tend to not want to evacuate until their floors are overtopped. Therefore, more regular and deeper over ground flooding (that may result from climate change) may lead to increased exposure of residents to flood hazard in evacuating raised premises.

E4. Flow capacity increase options are generally not adaptive as they provide a set additional capacity for a particular design solution.

E5. Flood warning and emergency management generally target the larger scale flood events (ie) extreme or probable maximum floods and therefore cover the full range of potential flooding. These strategies, by their nature need to be robust to cater for widely varying flood behaviour. A key issue in emergency response planning is the timing of events (available warning time, time for cutting evacuation routes etc). Additional requirements for management studies (Ref 11) have been developed by DNR in consultation with the State Emergency Service to improve knowledge in this area to provide for more robust emergency response planning.
5.3 Overall

Management decisions and strategies that relate to the full range of flood risk, i.e., consider the upper limit of flood behaviour and its impacts, generally relate to emergency response or management. Emergency management planning by its nature has to account for natural variation between events and, therefore, strategies tend to be flexible and robust. Emergency management planning can therefore be considered adaptive with climate change if managed with knowledge of the altered range of risks and associated community flood awareness and readiness.

However, decisions that relate to a specific AEP event, where the recurrence interval of this event may change due to climate change, do not necessarily have adaptive capacity unless this is specifically built in.

6. Improving Adaptive Capacity of Flood Risk Management Decisions

Improving the adaptive capacity of flood risk management decision making needs to concentrate on decisions that relate to specific AEP events rather than the full range of events. These decisions generally relate to protection of existing and future development for a particular frequency of flood event. There are a number of ways in which additional adaptive capacity can be built into these decisions.

- Considering the potential for new floodways to form under various climate change scenarios. These new floodways may not exist in the design floods currently used for management decisions. Completing this task may identify areas which need to be set aside for this function or developed with the knowledge that they may perform this function in the future, and are therefore compatible with this function. This may have an impact on appropriate future land uses in limited circumstances.

- Considering the potential for significant changes in flood hazard in particular areas. Where areas are particularly sensitive to climate change, consideration could be given to directing future development types to those areas more compatible with the changing hazard. The result would be the steering of more vulnerable developments to less exposed areas.

- Considering the potential for changes in flood behaviour or hazard to impact upon the type of management option appropriate for a particular location. Considering the implications of climate change on flood behaviour when considering management options should ensure that the types of management options selected are robust enough to manage associated changes.

- Allowing an additional freeboard in FPLs (specifically for climate change) when setting fill levels and floor level controls for new development or for the construction of works, such as levees. Examination of the potential climate change implications (sensitivity analysis) for a specific location would enable assessment of an additional freeboard to allow for climate change impacts.

- Building flexibility into decision making to enable future works to allow for climate change. For new development this could involve setting aside land as part of new release areas to incorporate potential flood protection for future climate change. For a works project this may mean building flexibility into the design to enable upgrading in future. This could involve setting additional land aside for the raising of an earthen levee now or designing a concrete levee so that it can readily be raised in the future.

Decisions on the management options to consider will depend upon the practicality and feasibility (including financial) now and in the future at the particular location. However, it is important to remember the potential costs, both economic and social, of not considering climate change, as outlined in Section 2 of this paper.
7. Impacts on Management Plan Development, Review and Implementation

The floodplain risk management process culminates in the development and implementation of a floodplain risk management plan for a particular area. These plans provide the basis for managing flood risk to the existing and future community and the associated decision making.

This paper indicates the significant nature of potential impacts of climate change on flood damages and the resultant potential for exposure of the community to increased flood hazard. It highlights the need to consider climate change to ensure that management decisions are robust and appropriate in the long term. It is therefore essential that climate change be considered in the preparation and implementation of management plans and in associated decision making as outlined below.

7.1 Review of Completed Studies, Plans, Works and Existing Development Controls

Management plans outline the direction taken in managing flood risk in a particular area. Section 2.7 of the Floodplain Development Manual highlights the triggers for the review of management plans. These triggers include time (review regularly around every 5 years), after significant flood events, where significant changes occur that influence the decisions in plans, where impediments to implementation warrant review to examine ways to overcome these impediments, and where changes to future land use outside trends considered in the management plan are proposed.

Climate change ramifications for existing studies and plans should be examined as part of any review of management plans. Therefore the ramifications of climate change should be considered in all existing plans across NSW as they are reviewed. This would generally be expected to occur within the next 5 years.

The inclusion of climate change involves revisiting existing decisions for managing flood hazard to both existing and future development. It is likely to require remodelling of flood behaviour and management options where relevant sensitivity analyses have not been completed. This involves:

- an assessment of the performance of existing and proposed management works. This should include an examination of the potential performance of works under the range of climate change scenarios. Where the ramifications are significant this may involve:
  - examining the potential to improve or upgrade existing works;
  - examining the appropriateness of current management strategies; and
  - changing the design of proposed works.

This would involve both flood and damages modelling and an assessment of the potential costs implications for management options;

- an assessment of the current development limit and controls from a strategic perspective. The review should extend to examine the ability of these controls to manage the implications of climate change. Options to alter controls to allow for any significant impacts of climate change which become apparent in the medium to long term should be examined; and

- updating the management plan to outline the potential impacts of climate change and how these have been considered in decision making.

7.2 Current and Proposed Management Plans and Background Studies

Current and proposed flood investigations need to consider climate change by:
incorporating appropriate sensitivity analyses (as discussed in Section 4) into modelling of flood behaviour, damages and management options. Modelling would generally include some sensitivity analyses, however additional runs and associated interpretation may be required;

- considering the specific ramifications of changes in flood behaviour on existing and future development (people, property and infrastructure); and

- examining options to manage these ramifications, including associated benefits and costs.

This assessment will provide advice to decision makers on the management options available and the ramifications of both adopting and not adopting these options. The management plan needs to outline the potential impacts of climate change and how these have been considered in decision making.

7.3 Proposed Works Projects

Where work projects are proposed or under investigation and sensitivity to climate change has not been assessed during the preparation of the management plan, it is recommended that climate change be considered as part of preliminary design. The results of these investigations and the reasons for associated decisions should be fully documented for inclusion in the management plan, when next reviewed.

Dependent on the ramifications of climate change for the specific location and project, it may be necessary to consider:

- ensuring that the type of management options selected are robust enough to manage the ramifications of climate change; and

- accepting the level of protection provided and proceeding on the basis that protection will reduce in the future; or

- modifying the design to build in an allowance for climate change now, where the modification can cost effectively be built into the proposed project; or

- incorporating the ability to readily modify the work in the future to manage climate change implications. For example land could be set aside so that earthen levees could practically be raised in future, and concrete levees could be designed to be raised in the future.

7.4 Strategic Planning

Where strategic planning is being undertaken and sensitivity to climate change has not been assessed during the preparation of the management plan, it is recommended that climate change is considered to ensure that decisions on future land use consider the ramifications of climate change. The results of these investigations and the reasons for associated decisions should be fully documented for inclusion in the management plan, when next reviewed.

Depending upon the ramifications of climate change for the specific location it may be necessary to consider:

- that the impacts of climate change on flood behaviour or hazard may impact upon the decision to develop a particular area and the type of development appropriate for a particular location. Considering the implications of climate change on flood behaviour should ensure that development limits and controls are robust enough to consider potential climate change ramifications; and
accepting the level of protection provided and proceed on the basis that protection will reduce in the future; or

providing a level of protection based upon an agreed climate change scenario (this may provide a higher standard of protection at present) where the opportunity costs are relatively low; or

incorporating the ability to readily provide protection to the development to manage future climate change implications. For example, land could be set aside as part of subdivisions so that earthen levees could be built in the future. Careful consideration needs to be given to the associated emergency response and cost implications.

8. Conclusions

Consideration of climate change based upon the best available information is a fundamental part of informed flood risk management decision making now and into the future. It therefore needs to be incorporated into:

- new management plans as they are developed;
- existing management plans as they are reviewed;
- strategic floodplain risk management decisions in relation to development; and
- decisions on mitigation works as they are made or designs as they are produced.

Improvements in the adaptive capacity of floodplain risk management decisions for climate change (section 6) are necessary in line with the policy direction of the Australian Greenhouse Office and NSW Government. This adaptive capacity should reflect the very real risk that climate change presents. The floodplain risk management process is sufficiently robust and flexible to allow consideration provides an appropriate process for considering climate change by enabling:

- assessment of the potential climate change implications for the specific locations and associated ramifications for exposure to hazard and flood damages. This can be achieved through sensitivity analyses as outlined in Section 4;
- assessment of the ramifications of these changes on decisions on management measures and siting of development. In some cases a management measure or development type that may be appropriate with current hazards and exposure may not be effective or appropriate with changed conditions. This may lead to the need to revise management options; and
- examination of the ability of management measures and development decisions to enable (now or in the future) additional protection to be provided for climate change implications in the future. This may involve asking questions such as: Should freeboards be increased? Can allowance be made to put protection works in place in future? Can allowance be made to upgrade proposed or existing works in future?

Our knowledge of the extent of climate change and the associated ramifications is improving. However, we cannot afford to wait for finite work on climate change to be finished nor significant climate change to occur before we decide to manage the impacts.

Importantly, we cannot ignore climate change and the potential significant impacts which may occur at particular locations with the associated large increases in potential flood damages and risk to life. Appropriate mitigation measures and sound planning, adopted now at minimal cost, will provide enormous benefits for future generations.
As such the Department of Natural Resources is preparing a Technical Guideline to address the consideration of climate change through the floodplain risk management process.

9. References


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Presenters Biography

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He has a particular interest in floodplain risk management and has completed a wide range of studies into flood risk in both mainstream and major urban drainage areas as a consultant and with Coffs Harbour City Council as Flooding and Drainage Engineer, where he also developed Council’s floodplain management policy. Duncan is one of the main authors of the NSW Government’s Floodplain Development Manual and is currently working on a range of flood policy issues at both a State and National level.

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