GOSFORD CITY COUNCIL
SEA LEVEL RISE BENCHMARKS
DISCUSSION PAPER

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FOREWORD

This discussion paper has been prepared by Coastal Environment Pty. Ltd. and Whitehead and Associates Pty. Ltd. for the Gosford City Council (the Client) in accordance with the requirements of the agreed brief. It remains the property of the Client.

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Cover photo: Large waves and elevated ocean levels at Wamberal Beach, Gosford NSW.
Photo: Coastal Environment Pty Ltd, 15th October 2014

ACKNOWLEDGEMENTS

This project was undertaken for the Gosford City Council by Coastal Environment Pty. Ltd. and Whitehead and Associates Pty. Ltd. The brief and content of the report were agreed with Council staff prior to commencement. Background information relevant to the review has been provided to the consultants by Council staff within the Sustainable Corporate & City Planning unit and we acknowledge that input.

DISCLAIMER

The findings and conclusions included in this report are those of the authors and do not purport to represent any particular position or updated policy of the Gosford City Council. The objectives are to summarise the background to Council's present policy and to review more recent information relevant to that position for discussion by Council. In preparing this report, the consultants relied upon the available published information and on their personal knowledge and experience relating to sea levels and coastal processes.

Within the available time for preparation of the paper, no new analyses of data or modelling of beach response have been undertaken. These were not required for the purpose of this review.

The information provided has been prepared in good faith by Coastal Environment Pty. Ltd. and Whitehead & Associates Pty. Ltd. on the basis of available information and inquiry as described in this advice. It is provided for the client in accordance with their brief and our proposal, and is for that purpose only. While all care has been used in preparing this information, the authors accept no responsibility for information or data that may affect this advice and of which we could not reasonably have been expected to be aware at the time the advice was provided. The information contained herein must not be used other than by the Client for the purpose of this engagement and should not be passed on to any other person without our permission. Coastal Environment Pty. Ltd. and Whitehead & Associates Pty. Ltd. accept no liability or responsibility for any use of this advice which does not accord with this disclaimer.

SUMMARY

This discussion paper has been prepared by Coastal Environment Pty. Ltd. In conjunction with Whitehead & Associates Pty. Ltd. to facilitate consideration by Gosford City Council of the relevance and currency of their sea level rise benchmarks for coastal planning and development assessment.

Scientific data relating to climate change is published on a regular basis and there is always pressure on Local Government, which now has responsibility for selecting the appropriate allowances, to review their current position. This report looks at the development of the current benchmarks used by Gosford City Council in the light of the most recent IPCC assessment report (AR5). This report, draws significantly from a detailed review undertaken in late 2014 by the authors for Shoalhaven and Eurobodalla Councils, but also considers more recent relevant local research publications.

Sea level rise has been recognised as a significant concern for future coastal landuse and management and has been incorporated in coastal zone management planning in NSW for at least the past 25 years. Gosford City Council has always taken a proactive role in incorporating sea level rise allowance in coastal and flood studies even prior to the issue of the NSW Government sea level policy in 2009. Subsequent to the withdrawal of that policy and the associated benchmarks in 2012, Council has reconsidered their adopted sea level rise benchmarks, ultimately adopting benchmarks that are broadly in line with both their original values and the values specified in the now withdrawn state government benchmarks.

Globally, the allowances recommended for sea level rise have remained similar to the values first recommended by the US National Research Council in 1987. Subsequent intensive research and review through the IPCC and others has refined our understanding, but not fundamentally altered the scale of expected sea level rise. More recently, at a local level, the NSW Government has returned responsibility to Local Government for determining appropriate values to be incorporated in forward planning. Part of the justification for this is the perceived need for “locally relevant” values to be used.

In reviewing the likely effects of location along the NSW coast, it is our conclusion that sea level rise applicable to Gosford will not vary significantly from that occurring at Sydney (or along the NSW South Coast) and so the Fort Denison tide gauge in Sydney Harbour provides an accessible and accurate long term record for monitoring changes to mean sea level. At a particular beach or estuary scale, water levels will continually vary around the offshore mean sea level in response to waves, tides, floods and atmospheric pressure. These other components need to be considered, along with sea level rise in order to determine appropriate “design” values for development, such as the setting of floor levels or the determination of coastal setback lines. This report only considers relevant changes to mean sea level offshore of the Gosford LGA. More detailed, local studies are required to establish these design values An example is the hazard study which underpins the draft Beaches Coastal Zone Management Study recently exhibited by Gosford City Council.

It is important that these studies are translated into management actions so that the potential adverse impacts of future hazards arising from all causes, including climate change, may be addressed.

We have reviewed the benchmark values presently adopted by Gosford City Council. While the recent legislative changes give the Council the opportunity to alter the allowances adopted we see no strong rationale for this to be done. The values currently being used are still reasonably close to the most recent IPCC report and to other widely accepted scientific information. They are consistent with the ongoing values being used by most LGAs in NSW and with the benchmarks applied in other states of Australia where specified by the corresponding state government. They provide a sound basis for future planning at this time. While Council has the opportunity to make minor changes to the benchmark values adopted, what is more important is the manner in which these are applied – the management framework. This process is well progressed in Gosford City and the benchmarks used are appropriate for the current Coastal Zone and Flood Risk Management Plans to be finalised.

Council should prepare for the need to reconsider and adjust benchmark values in future. We recommend that this should occur, in future, following the release of new IPCC projections and prior to the actions which will ultimately result in changes to the CZMP, as the CZMP is reviewed. This would typically occur every 5-6 years. We expect that reconsideration of the benchmark values at the present time may be impractical, particularly given the standing directive of the Minister for the Environment to submit CZMP's for ratification by June 30 of this year.

We are aware of conflicting opinions among some scientists and groups within the broader community relating to the detail of climate change and, in more extreme cases, the well-established and basic principles of the underlying science. We have reviewed the latest IPCC report and subsequent scientific literature relevant to sea level rise along the NSW coast. We have included in this discussion paper, reference to recent publications by government and independent organisations, professional organisations and industry leaders all of whom accept and incorporate the IPCC findings in their forward planning. It is our opinion that the information published by the IPCC represents the most widely accepted scientific literature and the prevailing scientific opinion in respect of climate change and sea level rise.

Research into climate change will continue and adjustments will be made to future projections as the science progresses. The current understanding is adequate if not perfect, to allow forward planning to proceed. It is appropriate for Council to keep in touch with any changes in the science and if necessary to adjust their management framework in the future, in the same manner they have done in the recent past. The science underpinning climate change and sea level rise is compelling and cannot be ignored. The guidance provided by government, legal advice and insurance perspectives are overwhelmingly advising Local Government to recognise that sea level rise poses a genuine threat and to plan for the future accordingly.

CONTENTS

1. SCOPE OF THIS ASSESSMENT

Coastal Environment Pty. Ltd. in conjunction with Whitehead & Associates, was engaged by Gosford City Council to prepare a discussion paper relating to the development and currency of the sea level rise benchmarks currently used by Council for coastal planning and development assessment.

The advice has been prepared by Doug Lord of Coastal Environment Pty. Ltd. and by Dr David Wainwright from Whitehead & Associates Pty. Ltd. The assessment draws on a recent comprehensive review of sea level rise allowances suitable for coastal planning undertaken for Shoalhaven City Council and Eurobodalla Council in 2014 (Whitehead & Associates and Coastal Environment, 2014) and on other relevant and widely accepted scientific data as referenced.

The agreed purpose of this discussion paper is:

- To review the development and adoption of the existing Gosford City Council sea level rise benchmarks.
- To comment on more recent information relating to the future sea level rise projections including the most recent published IPCC reports, the Whitehead & Associates report on the NSW south coast sea level rise framework, recent publications by the Climate Change Council and the Australian Academy of Science, and other relevant issues relating to the current sea level rise allowances as raised by Council.
- To advise Gosford City Council of the suitability or otherwise of their current sea level rise allowances.
- To advise an appropriate framework for ongoing review of the adopted benchmarks.

The review was undertaken over a short time period in February 2015 and as such relies on the available published information relating to sea level relevant to the NSW Coast. Detailed assessments of the science underpinning sea level rise projections have been published elsewhere and continue to be released as more information becomes available. As appropriate these publications have been referenced.

In undertaking this review, it should be understood that consideration of sea level rise is limited to deep water sea levels and does not account for shoreline changes in morphology or localised storm effects which considerably impact the level of inundation and wave activity at the coast and within estuaries. The offshore sea level is the primary input to more detailed coastal process and hazard definition studies which then define the water levels and extent of hazard at a particular location. These detailed local studies remain essential for coastal management, planning and development assessment. This process, including allowance for future sea level rise, has been applied in NSW for the past 25 years.

2. Background to the NSW Sea Level Benchmarks

2.1 NSW Benchmarks

Consideration of future sea level rise has been an integral part of coastal management in NSW for the past 25 years. With the introduction of the Coastal Hazards Policy and the Coastline Management Manual (NSW Government, 1990), Local Government was formally advised to incorporate allowance for future climate change and sea level rise into their Coastal Zone Management Plans.

Amendments to the NSW Coastal Protection Act in 2002 introduced significant changes, including that completed Coastal Zone Management Plans (CZMPs) must be submitted and approved by the relevant Minister and gazetted by Local Government upon completion. This amendment was introduced to give stronger, statutory power to the plans, with amendments to the plans to be permitted only through revision and re-gazettal of an updated plan.

With a growing concern at the implications of sea-level rise, the Government embarked on a review of the coastal management approach in NSW. In 2009, the Sea Level Rise Policy Statement (New South Wales Government, 2009) was adopted advocating sea-level rise planning benchmarks of 0.4 and 0.9m above 1990 mean sea levels by 2050 and 2100 respectively. At the time that policy also abolished the existing Coastal Hazards Policy which underpinned the Coastline Management Manual and formally abolished both that Manual and the Estuary Management Manual, which were to be replaced by a series of Guidelines to be published on the Departmental web site from time to time. The government grant programs for coast and estuaries were combined in a single program and guidelines covering the preparation of Coastal Zone Management Plans (CZMPs) and emergency protection works were introduced. Further changes to the Coastal Protection Act were gazetted in early 2009 which formally put these changes in place.

Following a change of State Government at the NSW election in March 2011, the new Government decided to revisit the changes and approach to coastal management in NSW. In particular, concerns were expressed at the fixed sea-level rise benchmarks enshrined in the policy and also with the constraints placed on individual property owners when constructing emergency protection works.

The legislative amendments (Coastal Protection Amendment Act 2012) associated with **Stage One** of the NSW Government's coastal reforms commenced on 21 January 2013. They include amongst other things:

- simplification of the procedures for implementing temporary protection works (formerly called emergency protection works);
- clarification of the information that local councils must place on Section 149 certificates relating to land affected by future sea-level rise;
- withdrawal of the state-wide sea-level rise benchmarks included in the *NSW Sea Level Rise Policy Statement*, giving Councils flexibility to consider coastal hazards in the context of their own local circumstances;
- developing a guide for coastal erosion hazard mapping by councils;

- an extra 12 months for Local Government to prepare their CZMPs with their communities and for councils to determine the potential future coastal hazards which reflect local conditions; and

- deferment by the Minister of certification of any further CZMPs while the Government undertakes further Stage 2 reforms and determines how these plans can better link with other legislation.

Subsequent to the abolition of the benchmarks, the NSW Government determined to permit local government to once again assess and adopt their own allowances for sea level rise in preparing their CZMPs. Section 55D of the Coastal Protection Act 1979 states that: "*A council is to prepare a draft coastal zone management plan in accordance with the Minister's guidelines*".

This reference is to the 2013 "Guidelines for Preparing Coastal Zone Management Plans" (OEH, 2013c) which at Section 3.1 advises on sea level rise that a draft CZMP should include "*projected climate change impacts on risks from coastal hazards (section 55C(f) of the Coastal Protection Act 1979), based on council's adopted sea level rise projections or range of projections. Councils should consider adopting projections that are widely accepted by competent scientific opinion*."

There was no requirement for Local Government to alter their benchmarks from the previous State Government policy values. Further, there is no suggestion that sea-level rise can be ignored, and it is clear that the effects of climate change need to be considered in adopting future sea level projections.

The **Stage 2** reforms are currently under consideration by the NSW Coastal Ministerial Taskforce, supported by the Coastal Expert Panel appointed by the Government. These reforms have a strategic focus and are closely linked to the current planning reforms and local government reviews. The Coastal Ministerial Taskforce has approved the scope of the **Stage 2** reforms, which are intended to deliver longer term improvements in the management of erosion risks by councils and landowners. Announcements by the Minister in November 2014 indicate that the reforms will include amongst other things the preparation of a new Coastal Management Manual and the reconstitution of the NSW Coastal Council.

2.2 NSW Chief Scientist Review

Prior to the release of the NSW Sea Level Rise Policy Statement in 2009, which advocated sea-level rise benchmark levels for use in preparing CZMPs, councils relied on guidance from recognised technical and Government sources, generally based on findings of the Intergovernmental Panel on Climate Change (IPCC). Each council was then able to interpret this information and incorporate appropriate allowances into their CZMPs. When the policy was released, the NSW Government's intention at the time was to ensure that all councils were dealing with sea-level rise appropriately and that planning and development responses were consistent with the best available scientific information and applied consistently across local government boundaries.

The benchmark values advocated within the policy were based on the best scientific information available at that time and were somewhat higher than the most commonly applied values being used by local government over the preceding 20 years. The publicity associated with the release of the policy, together with a requirement that yet to be completed CZMPs must be revised to

accommodate the new benchmark values, resulted in a backlash from some sections of the community that saw the incorporation of the projected 50 and 100 year hazard lines into the planning process as unfair and unnecessary. The notification of the future hazards on Section 149 Planning certificates (under the *Environmental Planning and Assessment Act, 1979* (NSW) was also contentious.

In 2011, the then newly elected NSW Government called for an assessment of the policy and the benchmarks by the NSW Chief Scientist and Engineer (Professor Mary O'Kane). Professor O'Kane's report (NSW Chief Scientist and Engineer, 2012) advised, amongst other things, that:

"The way the science has been used to date to determine benchmarks for sea level rise in NSW is adequate, in light of the evolving understanding of the complex issues surrounding future sea levels."

The report continued to include within its recommendations that:

"The NSW Government could look toward more regionally specific calculations that take into account specific sea level, topography, flood risk and other conditions along the NSW coast. This would allow factors such as probability of extreme events (e.g. severe storms and surges) and impacts to be incorporated into local planning."

This recommendation was subsequently used as part of the rationale for removing the policy and benchmarks in 2012, again returning that responsibility to Local Government.

2.3 Gosford City Council Benchmarks

Gosford City Council has taken an active role in assessing climate change impacts throughout the city area. This commitment is ongoing.

Based on the Council report "Sea Level Rise Options", on January 29th 2009, Council, by resolution (Min# 2009/55), adopted sea level rise planning benchmarks. These were based on the NSW Department of Environment and Climate Change's projected upper sea level rise figure between 1990 and 2100 of 0.91m with an assumed linear increase from present day levels. This provided the basis for Council staff to proceed with risk assessment, policy development, and planning and development decisions.

These were superceded in October 2009 by the release of the NSW Sea Level Rise Policy (New South Wales Government, 2009) based on information included in the IPCC fourth assessment report. These sea level rise benchmarks from 1990 to 2050 (0.4m AHD) and from 1990 to 2100 (0.9 m AHD) were to be adopted by all Councils in NSW.

Gosford City Council adopted a broader Climate Change Policy on 4th May 2010 (minute number 2010/352) which was subsequently applicable to all Council activities. The objectives as set out in this policy are:

- To provide a strategic framework, that is consistent with a whole of government, and whole of Council approach, that will assist Council prepare for**,** and assist the community and environment to become more resilient and adaptable to, the impacts of Climate Change.

- To undertake adaptation and mitigation actions as a sustainable response to climate change. These actions would support the known environmental, economic, social and cultural values of the local community.

- To review climate change risks and impacts (for example, sea level rise, carbon footprint, temperature increase, embodied carbon, precipitation change, and storm, bushfire, drought and flood events) as further reliable information becomes available.

- To provide Council and the public with objective information that will assist in understanding the problem, alternatives, opportunities and/or solutions.

- To continue to undertake research and to participate in opportunities that will improve climate change management capacity.

- To comply with applicable legal requirements and implement any relevant state government policies, guidelines and/or directives.

- To recognise Gosford's proportionate contribution to Australia's historic emissions and associated moral obligations.

In 2011 following the introduction of the State Government sea level rise benchmarks, Gosford City Council prepared an internal report "Managing Climate Change Adaptation A Business Case for Gosford City Council 2011" (Gosford City Council, 2011). This report addressed likely issues and adaptation strategies over a five year plan to commence the process of managing climate change and sea level rise.

In 2012, the NSW Government announced that they would be introducing a range of coastal management reforms including the withdrawal of the 2009 NSW Sea Level Rise Policy Statement. Some three years after their introduction and following on from the NSW Chief Scientist report, the State Government withdrew the mandatory sea level rise benchmarks, leaving Councils to determine the appropriate allowances for their Council area.

At the Council meeting of 20th August 2013, Gosford City Council considered and passed a motion of Council that "*the recommendation of the Director Environment and Planning be adopted*". This recommendation was supported by report titled "Endorsement of Climate Change Scenarios for Gosford IR 14093208" (Gosford City Council, 2013). The recommendations in the report which were adopted were:

- "*Council endorse the climate change scenarios for Gosford as they are described within Table 1 of this report.*

- *A report be presented to Council reviewing the climate change scenarios for Gosford within 12 months of the release of the next IPCC report.*"

Section 1 of the tabulation (originally Table 1) from the Council report is reproduced below and shows the current allowance for climate change as applied by Gosford City Council. The allowances at Section 1 - Sea level and storm surge - as defined in that report are a continuation of the allowances in the previous Council Policy and subsequent State Government benchmarks. These are

consistent with the most recent projections in the IPCC 5th Assessment report and remain applicable as part of an overall planning framework. They are consistent with the current allowances adopted by most Councils in NSW.

Table 2.1: Climate Change Scenarios for Gosford (HCCREMS, 2010 -Sourced from: Blackmore & Goodwin, 2009, 2010; CSIRO, 2007; Macadam, McInnes and O'Grady, 2007; CSIRO, 2007b)

Climate Variable	Current[1] (indicative)	Indicative change[2] (relative to current)		Comments
		2050	2100	
1. Sea level rise and storm surge				
Sea level		↑ 0.4m	↑ 0.9m	Latest projections indicate SLR of up to 1.4m by 2100
Storm tide – max height, 1:100 ARI (average recurrence interval)	1.4m	1.8m	2.3m	Based on NSW design still water levels - excludes wave setup
Storm tide – ARI (1.4 m)	1:100	1:1	na	Limited regional modelling of recurrence intervals has been undertaken to date

Key

↑ increase; ↑↑ greater increase

↓ decrease, ↓↓ greater decrease

na - not available

1. Current - average 1977-2007
2. Indicative change - based on 'most likely' projections

In determining coastal inundation and recession for the Broken Bay and Open Coast Beaches Coastal Processes and Hazard Definition Study, the consultants engaged by Council to prepare that study (Worley Parsons, 2014) reduced the sea level allowance to 2050 and 2100 to account for the sea level rise that had occurred above the average values between 1980 and 2007 (see Table 2.1). This effectively reduced the sea level rise allowances applied to 0.4 minus 0.06, that is 0.34m (2050), and 0.9 minus 0.06, that is 0.84m (2100). That approach was ratified by Council in accepting the findings of the Worley Parsons report in March 2014.

Council is also preparing a floodplain risk management plan for the Brisbane Water estuary. The Council advises that preparation of the flood study (which informs the plan under development) has determined flood levels based on the current sea level rise at the time of the study (i.e. measured increases to sea level have been incorporated into the assessment.

3. CLIMATE CHANGE SCIENCE

3.1 INTRODUCTION

It is not our purpose in preparing this document to try and provide a detailed summary of the climate change science and in particular projections for future sea level rise. This information is well published by a range of technical experts specialising in the field. For a more detailed understanding of the science the reader is directed to those publications, the most relevant of which are included in the reference list to this report.

Over the past thirty years, there has been an enormous effort internationally by the scientific community to improve the understanding of climate science and the likely future impacts on various global physical and ecological systems. Results of new studies are published almost daily, focussing on specific processes or locations, meaning that any review is open to criticism for not having incorporated all the latest literature.

There are two key sources of uncertainty associated with future sea level rise:

- What will be the future rates of global greenhouse gas emissions (relating to human behaviour and economics); and
- How will the climate warm in response, and what will be the impact on sea levels (relating to our understanding of the science).

In 2014 the authors undertook a detailed review of available climate change information as part of a study into sea levels for a South Coast Sea Level Rise Policy and Planning Framework (Whitehead & Associates and Coastal Environment, 2014). Based on that review we have concluded that the broad theory of anthropogenic climate change presented by the Intergovernmental Panel on Climate Change (IPCC) represents the view held by an overwhelming majority of scientists that are suitably qualified in this area. Nevertheless, there remains a vocal minority claiming that the underlying scientific principles are flawed. We recommend Council take special care in checking the veracity of any advice they receive in contradiction of the IPCC position which are often based on negative reviews, designed to confuse and contradict.

Accepting that the prevailing scientific understanding of the mechanisms that are presently effecting climate change are sound, the uncertainty associated with future human behaviour is of at least equal significance as that related to the uncertainty associated with science over multi-decadal time frames.

Part of the uncertainty arises from expected variation in the way that sea levels will rise around the globe. Accordingly, there has been some focus on adopting “locally relevant information” in determining appropriate projection for different locations along the NSW coast.

The remainder of this chapter examines these sources of uncertainty as follows:

- Section 3.2 looks at how sea levels have varied historically off the New South Wales coast, this is limited to our previous analysis of the South Coast; and
- Section 3.3 examines the available future projections, considering both scientific and economic uncertainties.

The chapter closes with a summary of the position being taken by a number of professional organisations and Government Instrumentalities in Australia at present.

Sections 3.2 and 3.3 are derived primarily from our study undertaken for the South Coast (Whitehead & Associates and Coastal Environment, 2014). While Sydney is the northernmost extent of those analyses, it is perfectly reasonable to assume that the observed offshore mean sea level trends are equally relevant to the Gosford LGA.

3.2 Historical Sea Levels Offshore of New South Wales

It is important to understand how sea levels are behaving (e.g. how they have been rising historically; the present sea level elevation). We have analysed mean sea level trends along the south coast of New South Wales. In terms of planning and engineering design, mean sea level is used as a basis for calculating suitable elevations (planning floor elevations, maritime facilities, seawall crest elevations), by adding local components including astronomical tide, catchment flooding, storm surge, runup and the like.

The variation of mean sea level was examined over a period of 18 years (from 1996 – 2013) using a variety of data sources, including primary tidal gauge stations operated by the National Tidal Facility (Fort Denison and Port Kembla), ocean tide gauges operated by Manly Hydraulics Laboratory (Middle Head in Sydney, Jervis Bay, Princess Jetty in Batemans Bay and Bermagui) and satellite altimeter data offshore of the study area, as provided by CSIRO.

The period 1996-2013 was chosen as this is the period over which reasonably complete data sets were available for all gauges and satellite altimetry data considered. Many gauges were installed by Manly Hydraulics Laboratory (MHL) along the south coast in the 1990's, and the limiting site was Princess Jetty, which began recording around mid-1995. Satellite altimetry data is commonly considered reliable from 1993 onwards. It is important to make sure that the periods used are consistent, as variability relating to broad scale climate patterns such as ENSO can significantly affect calculated trends over very short periods. Trends covering different periods from different sites cannot be directly compared.

The available data for each site was processed by (i) removing data flagged as erroneous; (ii) averaging the recorded values for each year at each site; (iii) assembling an annual series of mean sea level for each site considered; (iv) performing an ordinary least squares regression on each time series and (v) determining a representative trend over the 18 year period considered.

At this point, it is important to highlight that ***we do not consider these historical linear trends as representative of either long term historical, or future behaviour***. Far more sophisticated means of removing the impact of ENSO and other sources of "noise" from the record are available, but were not considered necessary here. In particular, 1997, near the start of the period considered was a notable El-Nino (high air pressure and relatively lower water level) year, and years near the end of the period (2010, 2011) contain significant La-Nina events (low air pressure and relatively higher water levels). As noted above, the period chosen can significantly affect calculated rates of rise. However, ***the key aim of this analysis was to determine whether there was any geographic variation in ocean water level trends***. The linear trends calculated are presented in Figure 3.1. Notably, all gauges showed similar trends, responding in a similar way to variations in climate (i.e. all

gauges tend to show comparable rises and falls from one year to the next). The rates of rise at each of the gauges used were between 3.3 and 4.2 mm/yr. Notably, the altimeter data tended to show higher rates of rise (4.1-4.5 mm/yr) and not all of these differences can be accounted for by, for example, the effects of ongoing isostatic adjustment of the Earth's crust as it continues to rebound following the end of the last glacial period some 15,000 to 20,000 years before present.

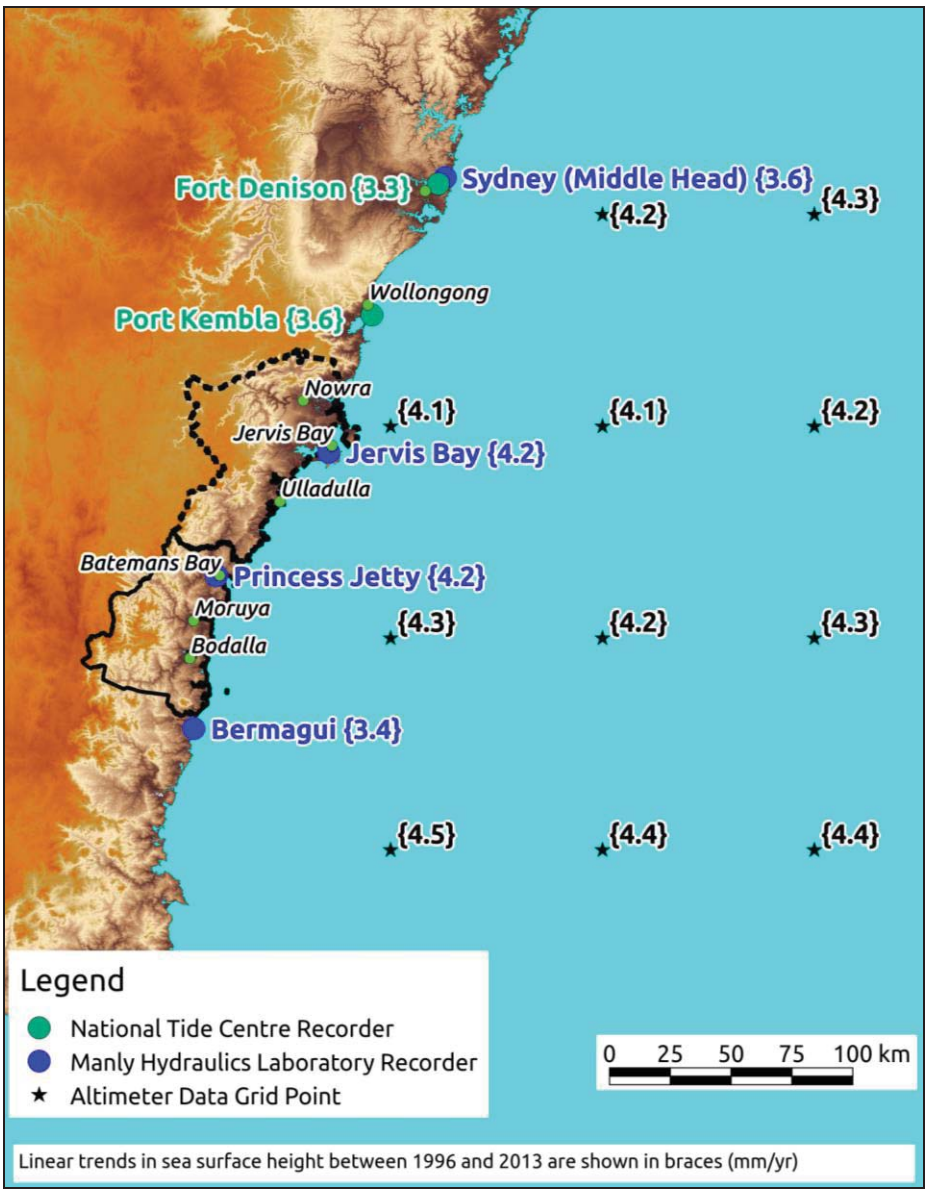

Figure 3.1 Linear sea level trends between 1996-2013 (mm/yr) at a variety of sites, South Coast NSW.

We were unable to find a specific geographic variation in the trends and patterns of mean sea level variation between Sydney and Bermagui. Furthermore, the rates calculated along this part of the coastline were similar to the global average estimated in Assessment Report 5 of the Intergovernmental Panel on Climate Change (IPCC AR5) over the same period. The analysis strongly indicates that future sea-level rise offshore of the South Coast of New South Wales will be more or less the same as that experienced at Sydney. ***Given that Gosford is a relatively small distance north***

of Sydney, it is reasonable to assume that the mean sea level offshore of the Gosford LGA will vary in an almost identical fashion to the corresponding levels at Sydney.

Having established a lack of geographical variation, ***we conclude that the long tidal record at Fort Denison is the most useful for monitoring future sea level rise***, in order to estimate what the present mean sea level is offshore of the Gosford LGA. By monitoring these levels year by year, it will be possible to determine when particular management action "triggers" are reached in future. The full record of annually averaged mean sea levels extends from 1886 and is provided in Figure 3.2. Also shown is a filtered (or "smoothed") mean sea level trend, using the Hodrick-Prescott method (with lambda = 400) to remove the effects of variations less than around a decade that are largely attributable to cycles of El Nino/La Nina (ENSO).

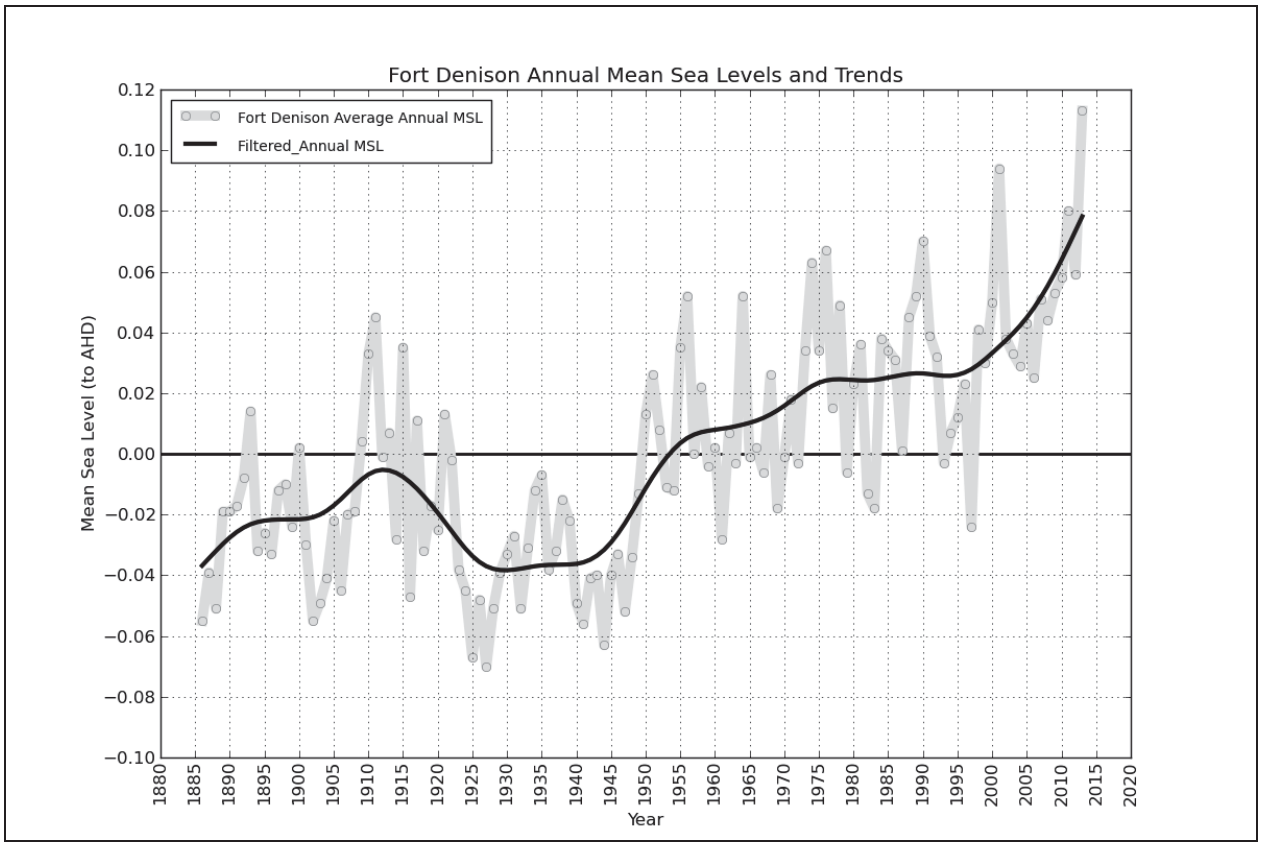

Figure 3.2 Fort Denison Raw Annual Mean Sea Level time Series, Including Hodrick Prescott Filter (1886-2013).

Wainwright et al. (2014) trialled a number of different filters and found the Hodrick-Prescott filter to be reasonably representative of the better performing filters for this time series. Of particular interest is that the trend shown by the filter indicates that mean sea level (with ENSO removed) has not fallen since 1930 (over 80 years). Notable periods with increased rate of rise were during the 1940's and 1950's and since 1995.

With this type of filtering to remove a "mean sea level value", a number of subsequent years need to pass before the mean sea level for a particular year can be assessed with high accuracy (i.e. to within 1mm). However, analysis of the Fort Denison record has shown that filtering such as this is unlikely

to under or overestimate mean sea level by more than 1-2 cm during any given year (Lord et al, 2014).

Filters such as these can be utilised to help understand both the underlying "natural" variability and the impact of sea level rise from anthropogenic sources. The pragmatism of utilising the historical information to estimate the present day mean sea level, and thus determine when various management triggers are realised, is explored in more detail in (Lord et al. 2014).

3.3 Projecting Into the Future: IPCC Fifth Assessment Report

The present NSW Government CZMP Guidelines state:

> *"Councils should consider adopting projections that are widely accepted by competent scientific opinion"*

There are three key terms:

- Projections: Meaning that estimates of future climatic conditions, including any anthropogenic effects, should be considered in planning for sea-level rise.
- Widely Accepted: Opinions vary on the future of regional sea levels and it is not expected that a complete consensus will be achieved in the near future. However, we consider that the above statement prompts Councils to accept the prevailing scientific view.
- Competent: The processes contributing to changes in local mean sea level are complicated and our review of recent developments in this field illustrates that the level of understanding required is substantial. Council should source information from competent individuals and organisations.

Following consideration of the latest IPCC assessment report (AR5 of the IPCC), the methods adopted in distilling available science, the transparent nature of the IPCC's review process and a variety of other literature sources surveying the opinions of scientists active in climate change research, we agree that the conclusions presented by the IPCC are reasonable and represent the views most widely accepted by the international climate change science community.

AR5 quantifies the uncertainty associated with future sea level rise given a particular projection of greenhouse gas emissions (or "radiative forcing"). This means that the decision of a local council to select a particular sea level rise projection should be largely influenced by a balance of the perceived risks associated with adopting a particular greenhouse gas emissions projection, and a highly qualitative assessment of what the future behaviour of the global population will be. The IPCC offer no guidance regarding the probability of each projection, other than that all are "possible".

While we have found no evidence to suggest that sea level rise will occur in a non-uniform way along the South Coast of New South Wales, it is highly likely that local conditions relating to factors other than the physics of thermal expansion and melting ice, and an individual council's appetite for risk will have some bearing in the decision making. The existing legislation, policies and overall planning framework in New South Wales presently direct Councils towards a more risk averse (i.e. higher) sea level rise projection. Planning and design practice and common sense lead to the same conclusion.

AR5 presents four projections, which are known as *Representative Concentration Pathway* (RCP) scenarios. These are prescribed pathways for atmospheric greenhouse gas and aerosol concentrations, together with land use changes and are characterised by the radiative forcing, or warming effect of those changes. While consistent and plausible, the RCPs are not based on any given socio-economic scenario in the way that the four SRES were. (the SRES scenarios were used in the previous IPCC report from 2007: AR4).

The four RCPs were characterised by Jubb et al (2013) and these are described in Table 3.1.

Table 3.1 Characterisation of RCP's adopted in AR5 (adapted from Jubb et al. (2013)

RCP	Radiative Forcing end of 21st Century	Equivalent Peak $C0_2$ (ppm)	Description	Comparable SRES Scenario
RCP 8.5	8.5	>1370	Very high baseline scenario. Little effort to reduce emissions and warming not curbed by 2100	A1FI
RCP6.0	6.0	850	Medium Scenario. Stabilises soon after 2100	A1B
RCP4.5	4.5	650	Medium Scenario. Stabilises soon after 2100	B1 (at 2100)
RCP2.6	2.6	490	Very Low "Ambitious" scenario. Emissions peak early at 3.0 W/m^2 then fall due to active removal of $C0_2$. Also known as RCP3PD	Lower than all SRES scenarios considered in AR4

In using their discretion, we understand that Councils are effectively being asked to make a judgement on the likelihood of these four RCP's and are called upon to select that projection which is most appropriate and defensible from a legal and planning perspective.

Even so, greenhouse gas concentration pathways do not provide us information on local mean sea levels. The four RCP's were used as inputs to many different Atmospheric Ocean Global Circulation Models (AOGCM's) as part of Phase 5 Coupled Model Intercomparison Project (CMIP5), the results of which are used in AR5.

A projected global mean sea level rise was calculated for each model, and the range containing 90% of the modelled projections (5-95%) is reported for each of the RCPs. However, although 90% of the modelled results fall within that range, the IPCC describes that range as only being *likely* to occur. This means in the standard nomenclature of the IPCC, that the IPCC considers there to be a 66% likelihood that the global mean sea level rise will fall within that range, if the RCP in question actually arises.

Therefore, the 5-95% model spread range is actually transformed to a likelihood range of 17-83%. In effect, each of the four RCP's can be represented by three lines: a "High" line, which has a 17% chance of being exceeded, a "Middle" line, which has a 50% chance of being exceeded, and a "Low" line which has an 83% chance of being exceeded if that RCP occurs.

These global average lines need to be transformed to local conditions. The following effects are considered to have some effect on the local mean sea level rise:

- Glacial Isostatic Adjustment, Present understanding is that the coastline around Sydney is expected to account for a few centimetres of relative sea level fall by 2100;
- Gravitational Effects relating to changes in the gravitational field of the earth following redistribution of ice mass around the globe as it melts and flows into the ocean. The effect of this offshore of New South Wales is expected to be small (~1% of total sea level rise by 2100);
- Due to changes in global circulation, there are expected to be changes in sea level along the east coast of Australia, largely related to changes in the dynamics of the East Australia Current. Overall, these changes are expected to increase mean sea level along the coast of NSW relative to the global average, but by less than 10% of the global average mean sea level rise.

All of these adjustments were made to the four global projections of mean sea level rise to derive mean sea level projections that are locally relevant for Sydney. The resulting "High" lines for all four RCP's are presented in Figure 3.3. To make the projections relevant to present day conditions, they have all been zeroed to 2015. It is also important to note that there is still a significant estimated chance (around 1 in 6) that these "High" lines would be exceeded, if the RCP in question is precisely realised.

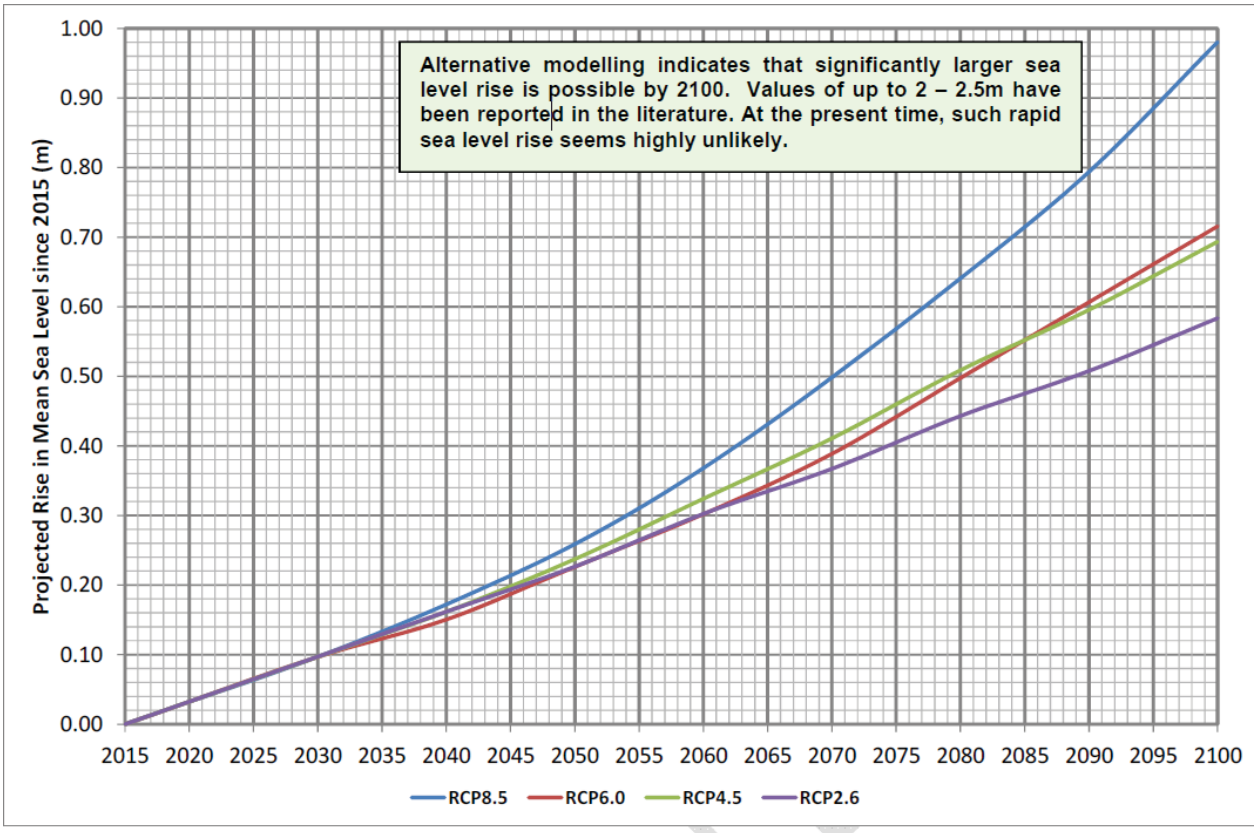

Figure 3.3 Adjusted NSW South Coast Sea Level Rise Projection "High" Lines for AR5 RCP's

Perhaps the most important feature of Figure 3.3 is the notable absence of any significant difference between projections by 2050 (less than 40mm). The projections diverge somewhat in subsequent decades.

Councils need to choose between the four projections. In providing a recommendation, we have taken information into account considering the existing legal, planning and risk management environment; the responsibilities of Councils and context within which they need to make decisions; and the present state of uncertainty relating to the science and the future intensity of global fossil fuel use. Aspects of this were discussed as part of risk management workshops held on the South Coast of New South Wales, and it should be noted that the risk profile may vary from LGA to LGA along the coast. This is a point that Council needs to deliberate. For the South Coast, the process led to the following conclusions:

- That RCP2.6 is not as plausible as the other projections and should not be used for coastal management and planning at this time;
- Attendees at the risk assessment workshops undertook a consequences assessment which indicated that the future adverse consequences of adopting a sea-level rise projection that is too low are more severe than through adopting a projection that is too high. Importantly this does not rule out the potential for negative consequences from adopting a projection that is too high;
- That planning guidelines, legislation and legal advice encourage a cautious approach that promotes the selection of a higher sea-level rise projection; and
- That, following AR4, there was a tendency both in Australia, and globally, to adopt projection based on the fossil fuel intensive scenario (A1FI) for planning purposes. That scenario is most similar to RCP8.5 in the most recent IPCC assessment and there are apparently no widely supported arguments for a change from this approach.

Due to these points, RCP 8.5 was recommended as a suitable and defensible basis for sea level rise projection at the present time. In conclusion, we note that recent research indicates global emissions from recent years are tracking on top of the RCP8.5 projection (Fuss et al. 2014), as shown in Figure 3.4. Of course, there is a long time to go until 2100 for significant changes in this trend to occur.

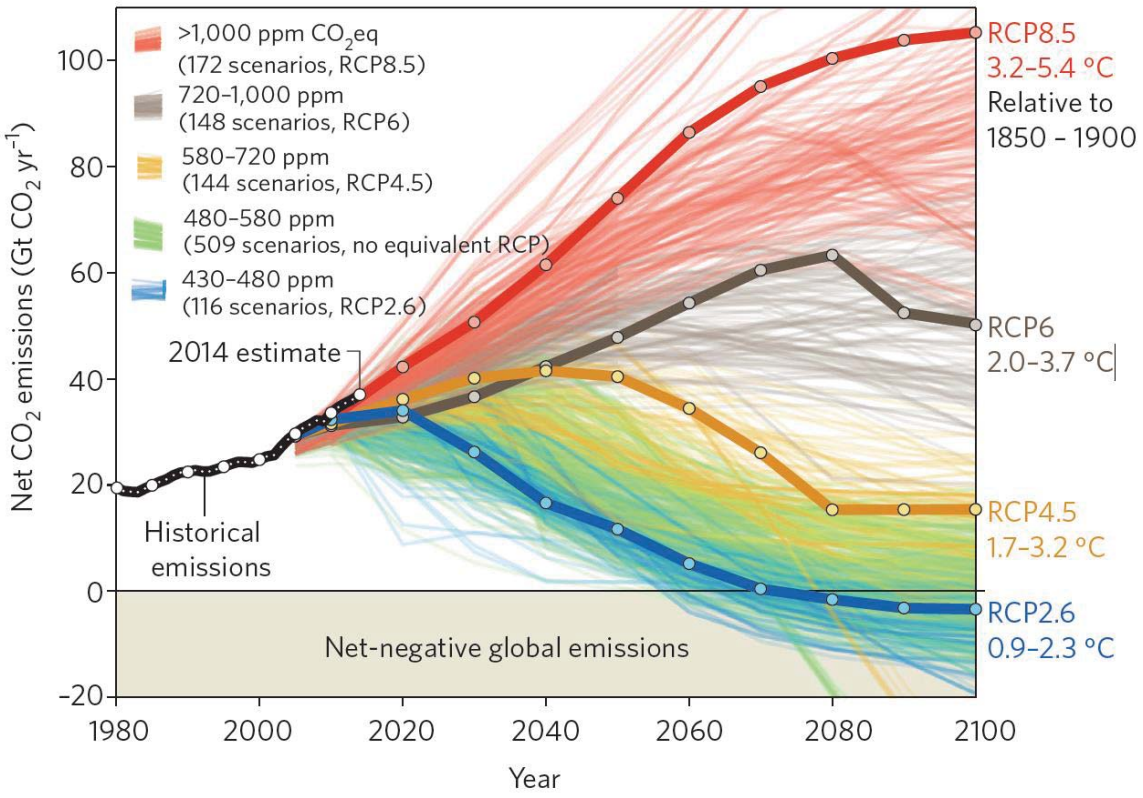

Figure 3.4 Figure 1(a) from Fuss et al, (2014), Illustrating the Present Emissions Pathway.tracking RCP8.5

3.4 The position Taken by Others

It has been nearly 18 months since the release of the IPCC's AR5. In that time a number of Australian organisations have reformulated or adopted policies and positions that reflect the updated summary of scientific understanding. The positions of others are of relevance to Council in making a decision, as they reflect the importance that other institutions place on sea level rise and climate change in general.

3.4.1 Academy of Science

In February 2015, The Australian Academy of Sciences issued an updated version of a 2010 report, which aimed to simply answer a number of questions about climate change (AAS, 2015). The report states that:

"*Along with its sister Academies, the Australian Academy of Science has played an active role in assessing the science of climate change since the 1970s. The Academy recognises the role of the Intergovernmental Panel on Climate Change (IPCC) as the mechanism for the international scientific assessment of climate change science, impacts and response strategies. However, it believes that it is important that Australian climate scientists explain the science, including its uncertainties and implications, to the Australian community in simpler terms than can be found in most of the IPCC reports*."

The report poses nine key questions relating to climate change and then provides succinct answers to those questions as agreed by a cross section of the scientific community within Australia.

The Academy recognises that:

"*As in all areas of active science, uncertainties remain. However, enormous scientific progress has been made in our understanding of climate change and its causes and implications. Since 2010, the IPCC has prepared a new international assessment with the active involvement of many Australian researchers, including several members of the Academy Working Group. This Q&A update is thus well informed by recent international developments in the science as well as the most recent work by our own scientists on peculiarly Australian aspects of the climate change problem*."

In considering sea level rise the Academy advises that:

- In past warmer climates, sea level was higher than today.
- Globally, sea levels are currently rising.
- Australian sea levels are rising.
- Sea levels are projected to rise at a faster rate during the 21st century than during the20th century.
- Rising sea levels result in a greater coastal flood and erosion risk.
- Sea levels will continue to rise for centuries.

With respect to the rate of future sea level rise, the Academy presents a range of sea level rise scenarios based on future greenhouse gas emissions (low and high pathway). For each scenario, they include a range of uncertainty above and below the mid projection. The plotted curves of projected sea level rise for a high and low scenario are measured above the average sea level from 1986 to 2005 (consistent with the most recent coastal hazard report prepared for GCC). The spread of the projections to 2100 are from 0.3m rise to 1.0m rise and are based on the 5th IPCC assessment report.

While advising an increase in coastal flood and erosion risks from sea level rise, the Academy states:

"*This effect will continue with more than a ten-fold increase in the frequency of extreme sea levels by 2100 at many locations and a much increased risk of coastal flooding and erosion, even for a low emissions pathway*".

It is clear that the Academy takes the position of the IPCC as the most authoritative source of advice on climate change, and that impacts are likely to be significant.

3.4.2 Engineers Australia

In November, 2014, Engineers Australia released their Climate Change Policy statement (Engineers Australia, 2014). That Policy states:

"Engineers Australia accepts the comprehensive scientific basis regarding climate change, the influence of anthropogenic global warming and that climate change can have very serious community consequences" ; and

"*Engineers Australia policy position is that increasing atmospheric greenhouse gas concentrations, including from the combustion of fossil fuels, are contributing to anthropogenic global warming and adverse changes to Earth's climate systems"*

Further, Engineers Australia advocates that:

"Engineers must act proactively to address climate change as an ecological, social and economic risk"

Within the details of the statement, it is noted that:

"Engineers Australia considers Australia is particularly vulnerable to climate change impacts…(including)….Increased loss and damage to natural and built environments in coastal and riparian environs from: sea-level rise, storm surge, wave action, inundation, groundwater change and saline intrusion"

Both primary authors of this discussion paper are members of Engineers Australia. The policy statement presents a very strong agreement with the IPCC's theory of Anthropogenic Climate Change and acknowledges that the impacts of that climate change will be significant and needs to be considered seriously.

3.4.3. CSIRO

http://www.climatechangeinaustralia.gov.au/en/

The CSIRO maintain and update a web site (above) that provides current information about observed and projected climate change. They advise that the information

> *"found on this site is the most comprehensive ever released for Australia, and has been prepared with an emphasis on informing impact assessment and planning in the natural resource management sector. Material has been drawn from observations and from simulations based on up to 40 global climate models and four scenarios of greenhouse gas and aerosol emissions during the 21st century."*

The site hosts the most recent assessment of the impacts of climate change on regional Australia (CSIRO and Bureau of Meteorology, 2015). In this report at Chapter 8 "*Projections (and Recent Trends) Marine and Coasts*" the CSIRO provide a detailed discussion of all aspect of climate change and its impact on the oceans. Their projections for sea level rise at various locations around the Australian coast (including Sydney and Newcastle) are also presented and are in line with the projections outlined earlier in this discussion paper.

CSIRO at Section 8.1.7 of their report advises:

> *"At the end of the 21st century, sea level is continuing to rise in all scenarios, with the rate in the high emission scenario equivalent to the average rate experienced during the deglaciation of the Earth following the last glacial maximum. Global mean and Australian sea levels will continue to increase beyond 2100, with thermal expansion contributions continuing to rise for many centuries proportional to the degree of warming."*

3.4.4 Antarctic Climate & Ecosystems Cooperative Research Centre: ACE-CRC

On their web page, in a discussion on AR5 (http://www.acecrc.org.au/Research/IPCC%20AR5) the ACE-CRC state:

"The IPCC is the international body responsible for providing governments with the largest and most comprehensive summary of the latest scientific information on climate change. This work depends on voluntary input from scientists around the world and ACE researchers have been involved as coordinating lead authors, lead authors, contributing authors and as reviewers of the first, second and final drafts of chapters, both as scientific expert reviewers and on behalf of the Australian Government"

3.4.5 Professor Ian Chubb: Chief Scientist of Australia

On the 24th of September, 2014, Professor Chubb delivered the Richard Selby Smith Oration at the University of Tasmania in Hobart. The transcript is available online at:

http://www.chiefscientist.gov.au/2014/09/speech-2014-richard-selby-smith-oration/

"When I think not just of me – and many of you – I come to some big things, like the climate. How will we manage, or mitigate or even adapt to the effects of a greenhouse gas which we ***through our activities*** *release into the atmosphere at a rate many, many times faster than the fastest measured in ice-core samples dating back 850,000 years? And given that our activities have already released some 2 trillion tonnes of CO_2 in the past 150 or so years, the question needs an answer – not some trivialising of an important and complex matter by impugning the integrity of the scientists, or by dismissing the science as a new religion, or as a delusion."* (Emphasis as presented on web page)

3.4.6 Geoscience Australia

http://www.asx.com.au/asxpdf/20140925/pdf/42sflpkzv9t42m.pdf

Geosciences Australian in an article published in AUSGeo News March 2011 Issue 101 in an article titled "Australia's coastline: adapting to climate change" states:

"All of Australia's major cities (except Canberra) will potentially be affected by rising sea-levels, higher tides and more frequent storms. Perth, Adelaide, Melbourne, Sydney, Brisbane, Darwin and Cairns all include low-lying areas and critically important commercial precincts, infrastructure, and very large numbers of residential properties."

3.4.7 Australian Bureau of Meteorology (BoM)

On BoM's Web Page, at the following address,

http://www.bom.gov.au/climate/change/#tabs=About-climate-change

and under the sub-title "What is causing the warming", it states:

"Over the last 100 years, global mean temperature has increased by around 0.74 °C. This rapid rate of warming is very unusual in the context of natural climate variability.

In the first half of the 20th century, increasing greenhouse gases, increasing solar radiation and a relative lack of volcanic activity all contributed to a rise in globally averaged temperature. During the

1950s and 1960s, global temperatures levelled off. This is most likely due to an increase in reflective particles in the atmosphere, known as aerosols, from increased industrialisation and the volcanic eruption of Mt. Agung in 1963. Since the 1970s, increases in greenhouse gases have dominated over all other factors, and there has been a period of sustained warming. It is very unlikely that 20th century warming can be explained by natural causes alone.

Importantly, almost all of the climate indicators show that climate change during the late 20th century is consistent with greenhouse gas increases. For instance, increases in solar radiation would cause warming in the troposphere and stratosphere. However, cooling in the stratosphere is what is actually observed, which is consistent with greenhouse gas increases."

3.4.8 Climate Council of Australia

A report published by the Climate Council (Steffen et al, 2014) aimed to explore the consequences of rising sea levels emphasised a number of key findings, including:

- Sea level has already risen and continues to rise due to climate change. Climate change exacerbates coastal flooding from a storm surge as the storm rides on higher sea levels;
- Australia is highly vulnerable to increasing coastal flooding because our cities, towns and critical infrastructure are mainly located on the coast. Australia's infrastructure has been built for the climate of the 20th century and is unprepared for rising sea level; and
- Coastal flooding is a sleeping giant. If the threat of sea level rise is ignored, the projected increases in economic damage caused by coastal flooding are massive.

The report goes on to urge deep cuts in greenhouse gas emissions to mitigate against these risks. Clearly, the Climate Council consider sea level rise to be a significant future threat

3.4.9 Insurance Industry

Although the Insurance Council of Australia (ICA) does not have a defined public policy on climate change science, it is apparent that they take the potential future risk seriously. (ICA, 2010). The ICA is primarily concerned with the present ability of Australia's building stock to withstand extreme weather under the existing climate.

However, their concerns also extend to ensuring that properties are not built in areas where they will be exposed to future hazards. At the present time the risks of storm surge, coastal erosion and gradual sea level rise are excluded by most insurance policies in Australia (ICA, 2015). Therefore, it appears that the insurance council's interest in avoiding development in areas where it will eventually be at risk in a future climate is to ensure that there is a larger pool of potential customers in future and that people aren't excluded from obtaining insurance.

Of particular interest to Council is the position of the insurer Statewide Mutual, expressed to its local government clients based on legal advice to them in March 2013 that:

"…Councils not move away from the benchmarks set out in the NSW Sea Level Rise Policy Statement until further guidance is given by OEH as to what new approach for sea level rise planning is to be adopted."

A variety of legal opinions reviewed by the authors approximately one year ago indicated that this view was expressed by a majority of those lawyers that had provided advice.

Under present political circumstances, it appears unlikely that the State Government is going to provide specific guidance, although, subsequent to the Statewide Mutual Advice, the State Government modified its Guidelines for the Preparation Coastal Zone Management Plans (OEH, 2013) to remove reference to the previous benchmark values and insert text reading:

"Councils should consider adopting projections that are widely accepted by competent scientific opinion"

3.4.10 Planning Institute of Australia

http://www.planning.org.au/documents/item/4881

The Planning Institute of Australia in their published "Climate Change Unit – Certified Practising Planner Program" state at page 4:

"the mainstream scientific consensus is that the World's climate is changing and that human activities that emit greenhouse gases are contributing to this change. It is important that we begin thinking about the planning response to climate change. But planning for climate change is complex. This complexity arises from a number of factors including the uncertainties inherent in climate change science, and society's response to it"

3.4.11 Australian Industry

BHP Billiton

BHP Billiton in their recent letter to shareholders dated 25th September 2014 (http://www.asx.com.au/asxpdf/20140925/pdf/42sflpkzv9t42m.pdf) on page 3 under the heading Climate Change state:

"BHP has a robust corporate planning process. That planning process, and the Board's assessment of strategy, business portfolio and future investments, is underpinned by scenario planning. Scenario planning gives us the ability to evaluate a wide range of global uncertainties through to 2035 including climate change, geotechnical and technological developments. At the core of our corporate planning is our acceptance of the most recent assessment of the Intergovernmental Panel on Climate Change (IPCC). The IPCC's latest report found that warming of the climate is unequivocal, human influence is clear and physical impacts are unavoidable. We incorporate the IPCC's assessment in our strategy as the base case for climate change science."

Westpac

In their "Climate Change Position Statement" in relation to the science on page 4 https://www.westpac.com.au/docs/pdf/aw/Transit_to_low_carbon_econo1.pdf, Westpac states:

"In February 2007 the Intergovernmental Panel on Climate Change (IPCC) released its Fourth Assessment Report. Its key conclusions were that:

- Global warming is 'unequivocal', and average temperatures have risen by 0.74^{0}C in the last century - the probability that this has been caused by natural processes is less than 5%.

- World temperatures will rise by 1.1 to 6.4°C and sea levels will probably rise by 18 to 59cm over the 21st century.

"This and earlier IPCC reports present the scientific consensus (we also monitor what other international and national expert bodies are saying) on human-induced climate change as well as the potential impacts - and options for mitigation and adaptation. The logical conclusion to this firming consensus is that all businesses should at least adopt a precautionary approach and manage climate change as a potential risk. Our situation is that we accept that many of the areas where we operate will be amongst the most adversely affected"

3.4.12 Summary

Aside from legal, planning and economic reasons to take climate change and sea level rise seriously, it is clear that those scientific and government organisations best qualified to form an opinion on the veracity of the science adopt a position that is consistent with the findings of the IPCC. The projections put forward by the IPCC are the ones most widely accepted by competent scientists in Australia.

This fact has been recognised by a number of professional and commercial organisations, who have subsequently adopted policies that reflect the findings of the IPCC. Also running through these position statements is a sense of urgency that there is a genuine threat which needs to be appropriately managed.

4. DISCUSSION

4.1 PROJECTIONS VS PREDICTIONS

There is widespread confusion within communities that sea level rise projections are in fact sea level rise predictions. A prediction is a best estimate of what value will occur at a particular time in the future. It is frequently based on some statistical analysis of historical data which is assumed to be representative and which is then extrapolated forward in time. If that extrapolation is valid, then the prediction may have a fifty percent chance of being exceeded at the nominated time and an approximately equal chance of not being reached. A common and often repeated misconception is that this linear extrapolation of historical records is the valid approach to setting sea level rise benchmarks at 2050 and 2100. It is not.

One difficulty with sea level rise is that the ongoing changes are not linear; the rate of change clearly varies with time (see Figure 3.2 for an illustration) and the overwhelming majority of scientific research tells us that rates of sea level rise will increase as atmospheric CO_2 levels increase. The sea level rise over the past 50 years will not equal the sea level rise over the next fifty years. The IPCC projections indicate that the rate of rise may be many times larger than historically averaged rates.

The final extent of climate change impacts in the future is dependent amongst other things on the action taken to reduce carbon emissions and the precise rate at which temperature, sea level expansion and ice melting responds to those emission levels. Scientists handle this by testing the impact of a range of social and economic emissions scenarios which are considered plausible. Coastal managers and engineers adapt these by selecting benchmark levels based on conservative, yet feasible scenario outcomes.

The benchmark levels should not be treated as accurate predictions. They are selected as acceptable risk "testing" values for decision making and are appropriately based on conservative assumptions. In the same way that we would not design a structural beam in a building for the average wind velocity over its planning life, it is not appropriate to assess the impact of coastal management decisions in the future on the basis of a sea level rise that has an unacceptably high probability of being exceeded.

The broad scientific consensus is in place, the detailed research to better understand and to refine the processes and rates at which they occur will continue indefinitely. However there is sufficient understanding of the processes and outcomes to move forward and to plan for future landuse and development with an acceptable degree of risk. It is the role of the engineer or the coastal manager, to take the available science and to then apply that with an appropriate level of risk. In so doing, it is not the intention to sterilise land or to remove all risk. Rather the objective is to identify an acceptable level of future risk and to implement strategies that address those risks as and when they eventuate. Such decision making is routine and commonly based on imperfect knowledge of the future.

4.2 CURRENT CLIMATE CHANGE PROJECTIONS

Determination of an appropriate projection still results in some confusion. For each projection (i.e. each RCP) there is a spread of model predictions reported by the IPCC in AR5, resulting in three lines being presented in AR5 (for 17%, 50% and 83% exceedance probabilities, respectively the "high",

"mid" and "low" lines as discussed in Section 3.3 and presented in table 3.1). It is erroneous to consider each of these lines as individual "projections" in themselves. Instead, they represent the spread of modelled sea level rise from a range of different models simulating the selected RCP. Review of the technical detail in AR5 indicates that the model results are approximately normally distributed, meaning that model results tend to cluster around the Mean/Median or 50% values. However, having adopted a particular RCP as appropriate, selection of the median value for planning is effectively planning for a 50% chance of failure.

We see two ways forward with this:

1. Select the "high" line as an appropriate, conservative default value; or.
2. Undertaking a full risk assessment which looks at the distribution of results (effectively uses all three lines, or by statistically synthesising potential sea level rise projections from the distribution represented by these three lines) and execute a statistical simulation of the resulting consequences and risk.

The first approach represents a more traditional engineering or planning approach that would normally be adopted, to assure an acceptably high level of protection against failure over the design life of development. This reasonably conservative value is then used to assess or design adaptation measures, rather than a blank tool used to refuse development or sterilise land which is unlikely to experience sea level rise hazards for many years. In the same way we do not use the average daily rainfall to design drainage structures that may fail if subjected to a deluge, we should avoid using non-conservative allowances for future sea level rise that will magnify future losses. It is worth remembering that scientific research indicates that sea levels will continue to rise for hundreds of years as a result of the increase in greenhouse gasses that has already occurred.

There are examples which have adopted the second approach, a more complete risk analysis. Thus far, these limited research efforts have provided further support for the adoption of the "high" line as the basis for planning, although these methods are still evolving. However, local circumstances, relating to the value of particular development will cause a change in the results from location to location.

Firstly, Hunter et al. (2013) calculated an appropriate "allowance", at a number of sites globally, for sea level rise by 2100, where the allowance was a vertical distance by which an asset would need to be raised under a rising sea level so that the present likelihood of flooding would not have increased at 2100. The calculation was based on AR4's A1FI (a fossil fuel intensive) scenario. For Fort Denison, an allowance of 0.88m (between 1990 and 2100) was calculated, directly comparable to the previous NSW sea-level rise policy value of 0.90, which in turn was based on the comparable "high" line of A1FI from AR4. Accordingly, a probabilistic assessment based on oceanic inundation indicated that the 'high' line is appropriate in the context of the NSW Coast (for which Fort Denison is a reasonable proxy).

Secondly, Woodroffe et al. (2012) utilised the statistical sampling of sea level rise projections in simplified beach erosion modelling software. When compared to the deterministic approach (straight adoption of the previous NSW sea-level rise policy values) the statistical approach returned erosion distances for the 95% exceedance level that were comparable but less than (around 80% of)

the calculated deterministic recession distance at 2100. This study suggests that, to provide a suitably high level of protection against failure (say 95% over a design life extending out to 2100), the high line can be adopted but may err on the conservative side in terms of coastal erosion.

These types of analyses can be complex, are specific to each particular site and the methods are still evolving. A clear accepted "standard" approach is not yet available.

In summary, selection of the most fossil fuel intensive projection (RCP8.5) is guided by present legislation, legal advice and the planning documentation. Selection of the "high" line of uncertainty representing the AR5 model results spread is a function of good cautious engineering and planning practice which aims to defend development against failure during its design life. These two selections are different, and we suggest that selection of the projection is the aspect over which Council should exercise discretion. However, on the basis of legal advice, the existing planning framework, the responsibilities of councils in New South Wales and recent information which indicates that the world is closely tracking RCP8.5 in terms of carbon emissions, we recommended that RCP8.5 be adopted as the basis for sea-level rise planning by Local Government in NSW at the present time.

4.3 Applying Sea Level Rise Benchmarks

There is ongoing confusion in communities and promulgated by some inaccurate media reports, that sea level rise benchmarks are definitive predictions of mean sea level in 2050 and 2100. Likewise, when translated to coastal hazard lines the community may believe that these represent a best prediction of the shoreline location at those times. Neither of these are true and indicate our failure in communicating the purpose and use of these tools for coastal management planning.

More plausibly explained, they represent a statistically acceptable worst case that may occur at some locations (not at all locations simultaneously) and for some conditions (usually coincident with an event that would occur on average, about once every 100 years.). In the same way as we adopt a maximum wind velocity for design of structures or maximum rainfall intensity for design of drainage, these benchmark conditions are treated as appropriate assessment levels for potential sea level rise and adaptation design. In the same way that it is unlikely that the design wind velocity or the design rainfall will occur at any particular point in time at all locations, so it is also unlikely (but possible) that a benchmark value will be realised at the particular timeframe to which it refers. It represents a sound, risk based approach to addressing future hazards.

Significantly, sea level rise is expected to continue for several hundred years and eventually, to significantly exceed benchmark levels that have been historically adopted for the 2100 timeframe in NSW. It is also possible for a given scenario adopted by council, that the benchmark levels could be exceeded by the nominated time.

The benchmarks and hazard lines are a part of a coastal management framework, not the final answer. They should not be seen as an attempt to sterilise property but rather as a logical approach to identify likely future hazards and to ensure that those hazards are, where practical, identified and addressed allowing development to proceed where it is appropriate, and the risks are either acceptably small, or can be appropriately managed. The Gosford City Council Climate Change Policy commitment statement clearly advises Council's intent: *"to prepare, implement and review plans*

and strategies inclusive of consideration of risk from future SLR, and address the issue of, how to beneficially use coastal areas while recognising the long term need to protect, redesign, rebuild, elevate, relocate or retreat as sea levels rise." This is the process that Gosford City Council is currently following through the development and adoption of a Coastal Zone Management Plan for the open coast and Broken Bay beaches.

There is little to be gained in continually revisiting this issue. When and if the science or measurements are available that warrant reassessment of the overall management framework then this should be done. The current values adopted by Gosford City Council for sea level rise are consistent with the values presently adopted in most jurisdictions along the NSW coast and in other states of Australia. The South Australian state government in 1991, for example, adopted a policy as part of an overall coastal management framework administered through the SA Coast Protection Board which requires new development to accommodate a sea level rise of 0.3m above 1990 sea levels by 2050 and to demonstrate how they would accommodate a sea level rise of 1.0m (a further 0.7m) above 1990 levels to 2100. This policy has remained largely unquestioned and is accepted in SA as a component of coastal planning. It has not changed since it was introduced and precious resources have not been allocated to continually reviewing the appropriate benchmark levels which apply right around the SA coast. Another example of the relative strength of the sea level rise projections is that the US National Research Council in their report on sea levels (US National Research Council, 1987) put forward three cases when considering decisions for future coastal management. These were for a sea level rise of 0.5m (low), 1.0m (mid) and 1.5 (high) measured above the 1985 mean ocean level, to be used in assessing future impacts. The mid level of 1.0m is of similar magnitude to the current 2100 benchmark adopted by Council and to our recommendations based on the 15% exceedance projections included in the RCP 8.5 scenario of the IPCC 5th assessment report issued in 2014.

In our report prepared for Shoalhaven and Eurobodalla Councils (Whitehead & Associates and Coastal Environment, 2014) we recommended the adoption of sea level rise benchmarks to be used in an overall coastal management framework with time periods of 2030, 2050, 2070 and 2100, with different conditions applying to different land use proposed over those time periods. The levels were to be measured above the 2015 average ocean level and are presented in the table below which is taken from that report. They are based on the RCP8.5 projections and the high (15% exceedance) curve from the IPPCC 5th Assessment report. Again the levels recommended to 2050 and 2100 (right hand column) are similar to the withdrawn NSW benchmarks and the current Gosford City Council benchmarks.

Source: Whitehead & Associates and Coastal Environment, 2014. Table 1 Comparison of Recommended Projection against Previous Policy Values

Time	Local Sea-level Rise Projection Based on RCP 8.5 (in (metres)[2,3]			Previous State Policy (approx.)[3]
	Low[2]	Medium[2]	High[2]	
2015	0.00	0.00	0.00	0.0[1]
2030	0.06	0.07	0.10	
2050	0.16	0.20	0.26	0.35[1]
2070	0.29	0.39	0.50	
2100	0.53	0.74	0.98	0.85[1]

[1]Values adjusted by subtracting 50mm to account for apparent rise at Fort Denison between 1990 and the beginning of 2014.

[2]In the absence of detailed, rigorous and justifiable site specific risk assessment which uses all three sets of values, the "High" projection values (with ~ 15% probability of exceedance) are recommended for coastal management and planning, providing that ongoing review of available science and water level data is undertaken to enable adaptation of the approach in future.

[3]To obtain the absolute projected mean sea level elevation relative to AHD, a further 0.08 metres would need to be added to these values.

4.4 Misinformation and Misunderstanding

4.4.1 About Straight Lines

We have encountered a view in the community that the only "local information" of relevance is historical sea levels as measured at local tidal gauges. This is incorrect. Models can also make local predictions. Indeed, in a changing climate, complex models that include a wide range of atmospheric, oceanic and ice-melt processes while aiming to replicate the influence of greenhouse gases on the heat captured by the earth, are more suitable than trying to project forward from an historical base line. To project forward based only on existing historical data without trying to understand and account for the processes underlying the patterns in that historical data, is prone to significant error.

With this point in mind, we note that many researchers have reported "average sea level rises" at the Fort Denison tide gauge of between around 1 and 4mm/yr. The reasons for this variety should be clear by examining the black line in Figure 4.1 (which is the same as previous Figure 3.2).

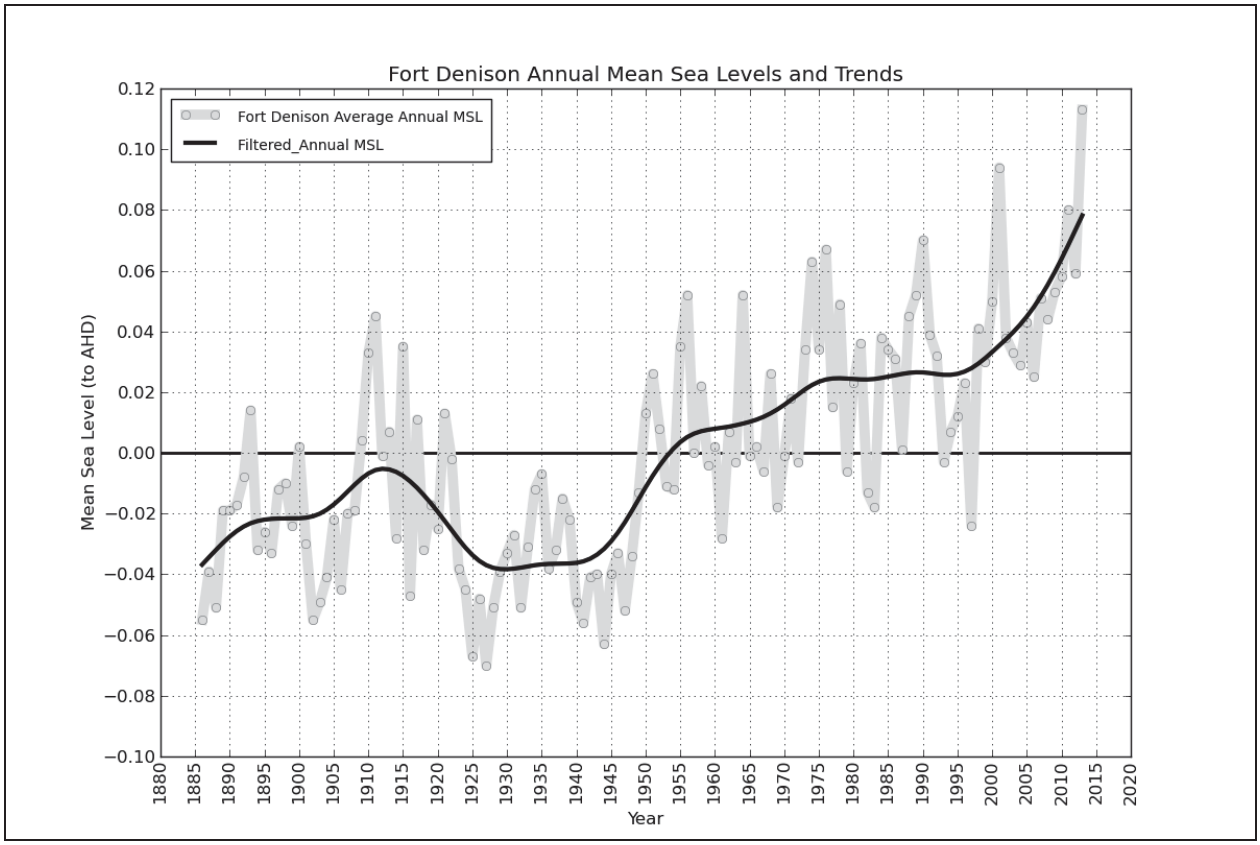

Figure 4.1 Fort Denison Raw Annual Mean Sea Level time Series,
Including Hodrick Prescott Filter (1886-2013).

It should be clear from that figure that a straight line (e.g. giving a result in mm/year) does not explain the patterns present in the data. Indeed, if you analyse between 1980 and 1995, the black "trend" line is almost flat. However, if you analyse from 1995 onwards, there is a clear rising trend.

Accordingly, rates of rise will depend on the time period analysed, and there can be significant variation. With this in mind, the rates of rise determined between 1996 and 2013 (inclusive) and reported in Section 3.2 can be seen to be relatively high (between 3.0 and 4.5 mm/yr) compared to the historical long term "average" value from the historical record (1886 to 2013). We don't consider that the rates we have derived (using straight lines) are representative of the long term (historical or future) sea level rise rates. That analysis was only presented to demonstrate that there was no significant difference along the NSW coast between Sydney and the Eurobodalla LGA.

Again, straight line fits of historical data are not an appropriate way of estimating future sea level rise in a changing climate.

4.4.2 About Satellite (Altimeter) Data

There is a point of view in the community that the satellite data is erroneous and should not be used for projecting future sea levels.

We agree that the satellite data should not be used as the primary basis for making future projections, for the reasons outlined in the preceding section. We advocate the use of model based projections as applied by the IPCC.

In terms of errors, it is instructive to examine the tide gauge analysis from Figure 3.1 (3.3 to 4.2mm/yr) and the altimeter analysis (4.1 to 4.5mm/yr). Bearing in mind that there is an ongoing component of "isostatic uplift" following the end of the last glacial period, the relative tide gauge rates can be adjusted by around 0.2mm per year, based on Peltier (2004), resulting in a range of 3.5 to 4.4 mm/yr).

Doubtless, there are errors in measurement associated with satellite altimeter data collection and reporting. Offshore of New South Wales it appears that the altimeter rates (4.1 – 4.5mm/yr) are sufficiently similar to the corresponding gauge rates (3.5-4.4mm/yr) for that data to be considered useful. Statements that indicate the satellite data is fundamentally flawed are not borne out by our analysis and do not provide a substantial argument against taking sea level rise seriously.

4.4.3 About "Local Effects"

There are still ongoing arguments at some locations along the coast that their beach, or estuary is "special" in some way and therefore unlikely to be impacted by projected sea level rise. This is somewhat encouraged by use of the term "local information" from some quarters.

As discussed in Section 1, the offshore mean sea level forms a primary input to more detailed coastal process and hazard definition studies that will derive design values for particular estuaries, embayments and beaches. However, this change in offshore mean sea level will be almost identical along the region offshore of the Gosford LGA.

The only local variation that should be legitimately considered by Council is the nature, exposure and criticality of infrastructure at different locations along the coast, and the desires of the community in managing any threats that may arise from changes to sea level. Expressed in typical risk management nomenclature, the *Consequences* of sea level rise will vary from location to location in the Gosford LGA, but not the magnitude.

4.4.4 About Projections Derived from IPCC's AR5

Some reports indicate that the projections we have derived from IPCC's AR5 for the south coast are around 15cm lower than the previous Gosford Council benchmarks. This is not the case and the confusion appears to arise from comparing derived 2050 value of 26cm (between 2015 and 2050) with the previous benchmark value of 40cm (between 1990 and 2050). There has been around 5cm of mean sea level rise at Fort Denison since 1990. Either one value or the other needs to be adjusted for this start date. With reference to a 2015 starting year, the comparable values are 26cm and 35cm, a lowering of 9cm. The same projection also indicates slight increase in the sea level rise to 2100.

4.4.5 About Insurance Premiums

There is confusion in communities relating to the perceived role of insurers pressuring local councils to adopt high sea level rise predictions and thus forcing property premiums and company profits up. These assertions have been confused and exaggerated within the media. They involve two separate issues which are intermingled.

Firstly, Council is an insured body, relying on their insurance cover to address any claims arising from their normal operations. These may include amongst other things, claims for negligence or liability

arising from actions taken or actions not undertaken by Council. Australian insurers are under pressure from international re-insurers to make sure that insured parties (including local government) are meeting their responsibilities with respect to planning for climate change. This requires nothing more than that Councils act on the basis of widely accepted expert advice in considering and planning for the implications of climate change. Without being able to demonstrate their commitment the local insurers may not be able to obtain necessary re-insurance and their customers (including the Council) may not be able to insure their risks. The insurers are encouraging Councils to plan for climate change and sea level rise so they might minimise future payouts relating to unwise development.

The second issue relates to household insurance premiums which are increasing. Having experienced a range of unprecedented natural disasters (Brisbane floods, cyclones, bushfires etc) insurance companies are increasing premiums to recoup their losses. Where properties are exposed to flooding, then insurance premiums that include flood cover are increasing at above average rates for high risk properties. The option exists on many policies to not include flood insurance. In respect of beachfront properties, the majority of home insurance policies include exemptions from losses caused by inundation from the ocean (wave runup, storm surge or sea level rise) and damage caused by undermining of the building foundations (coastal erosion or slippage). Such properties have not been and are not covered by insurance for the major likely impacts resulting from sea level rise and so their premiums are not affected. In general, insurers providing individual property insurance base their premiums on the past claims that occurred in a particular locality and do not base the premiums on sea level rise projections. For the insurance industry to keep providing home insurance, premiums need to remain affordable and the maximum number of properties need to be insured. Premiums are and have increased in recent years but this is in response to claims received, not climate change projections.

4.4.6 About "Scientific Consensus"

Some individuals that are sceptical of the opinion of climate change science expressed by the IPCC, even though it represents the considered opinion of a clear majority of climate scientists, make the statement that "A consensus in science is irrelevant".

We thoroughly agree that scientific theories, even those agreed upon by an overwhelming majority, should be continually challenged and hope that this continues with climate change research. The theories should not be considered as "set in stone".

However, when making decisions that are defensible on behalf of the community, a consensus is entirely relevant. We believe that this is the reason why the present CZMP guidelines (OEH, 2013) require Councils to adopt information that is "*widely accepted* by competent scientific opinion" (our emphasis). As Engineers, the authors of this report are particularly concerned about making sure that available scientific information is utilised in a defensible manner that enables decisions to be made. Coastal managers and engineers don't have the luxury of waiting for absolute certainty before action is taken. Councils must continue to determine development applications.

We understand that there are differences in opinion between scientists, but don't believe that it is defensible to selectively highlight and be influenced by the opinions of a minority of scientists in the process of making decisions about how to plan for sea level rise.

5. CONCLUSIONS

5.1 GOSFORD CITY COUNCIL SEA LEVEL BENCHMARKS

- Consideration of future sea level rise has been an integral part of coastal management in NSW for the past 25 years. (section 2.1)
- Gosford City Council has taken an active role in assessing climate change impacts throughout the city area. This commitment is ongoing. (section 2.3)
- In reviewing the NSW Sea level rise benchmarks, the NSW Chief Scientist and Engineer advised that *"The way the science has been used to date to determine benchmarks for sea level rise in NSW is adequate, in light of the evolving understanding of the complex issues surrounding future sea levels."* (section 2.2)
- Subsequent to the abolition of the state-wide benchmarks in 2012, the NSW Government determined to permit local government to once again assess and adopt their own allowances for sea level rise. (section 2.1)
- In withdrawing the state-wide sea level rise benchmarks in 2012 the NSW Government made no requirement for Local Government to alter their benchmarks from the previous State Government policy values. Further, there was no suggestion that sea level rise can be ignored, and it is clear that the effects of climate change need to be considered in adopting future sea level projections. (section 2.1)
- The OEH 2013 Guidelines for Preparing Coastal Zone Management Plans advise that "*Councils should consider adopting projections that are widely accepted by competent scientific opinion*." (section 2.1)
- Gosford City Council on 20th August 2013 adopted new sea level rise benchmarks for the City of 0.4m to 2050 and 0.9m to 2100 measured above 1990 sea levels. (section 2.3)

5.2 MOST RECENT SCIENTIFIC ADVICE

- Accepting that the prevailing scientific understanding of the mechanisms that are presently effecting climate change are sound, the uncertainty associated with future human behaviour is of at least equal significance as that related to the uncertainty associated with science over multi-decadal time frames. (section 3.1)
- Following consideration of the latest IPCC assessment report (AR5 of the IPCC), the methods adopted in distilling available science, the transparent nature of the IPCC's review process and a variety of other literature sources surveying the opinions of scientists active in climate change research, we agree that the conclusions presented by the IPCC are reasonable and represent the views most widely accepted by the international climate change science community. (section 3.2)
- In our assessment of sea level changes along the NSW coast south of Sydney, we were unable to find a specific geographic variation in the trends and patterns of mean sea level variation between Sydney and Bermagui. Given that Gosford is a relatively small distance north of Sydney, it is reasonable to assume that the mean sea level offshore of the Gosford LGA will vary in an almost identical fashion to the corresponding levels at Sydney. (section 3.2)
- Aside from legal, planning and economic reasons to take climate change and sea level rise seriously, it is clear that those scientific and government organisations best qualified to form

an opinion on the veracity of the science adopt a position that is consistent with the findings of the IPCC. The projections put forward by the IPCC are the ones most widely accepted by competent scientists in Australia. This fact has been recognised by a number of professional and commercial organisations, who have subsequently adopted policies that reflect the findings of the IPCC. Also running through these position statements is a sense of urgency that there is a genuine threat which needs to be appropriately managed. (section 3.4)

- The existing legislation, policies and overall planning framework in New South Wales presently direct Councils towards a more risk averse (i.e. higher) sea level rise projection. Planning and design practice and common sense lead to the same conclusion. (section 3.3)
- The Australian Academy of Science in 2015 advise in relation to future sea level rise that "*This effect will continue with more than a ten-fold increase in the frequency of extreme sea levels by 2100 at many locations and a much increased risk of coastal flooding and erosion, even for a low emissions pathway*". (section 3.4.1)

- Engineers Australia in their Climate change policy statement released in late 2014 state that: *"Engineers Australia accepts the comprehensive scientific basis regarding climate change, the influence of anthropogenic global warming and that climate change can have very serious community consequences"* They further caution that*: "Engineers Australia considers Australia is particularly vulnerable to climate change impacts…(including)….Increased loss and damage to natural and built environments in coastal and riparian environs from: sea-level rise, storm surge, wave action, inundation, groundwater change and saline intrusion".* (section 3.4.2)

- BHP Billiton advised there shareholders in late 2014 that: *"At the core of our corporate planning is our acceptance of the most recent assessment of the Intergovernmental Panel on Climate Change (IPCC). The IPCC's latest report found that warming of the climate is unequivocal, human influence is clear and physical impacts are unavoidable. We incorporate the IPCC's assessment in our strategy as the base case for climate change science.*" (section 3.4.11)

5.3 Suitability of current GCC Sea Level Benchmarks

- The benchmark levels should not be treated as accurate predictions. They are selected as acceptable risk "testing" values for decision making and are appropriately based on conservative assumptions. (section 4.1)
- RCP 8.5 is recommended as a suitable and defensible basis for sea level rise projection at the present time. We note that recent research indicates global emissions from recent years are tracking on top of the RCP8.5 projection (section 3,3 and figure 3.4)
- On the basis of legal advice, the existing planning framework, the responsibilities of councils in New South Wales and recent information which indicates that the world is closely tracking RCP8.5 in terms of carbon emissions, we consider that RCP8.5 could be adopted as the basis for sea-level rise planning by Gosford City Council at the present time. (section 4.2)
- While the recent legislative changes give the Council the opportunity to alter the allowances adopted we see no strong rationale for this to be done. The values currently being used are still reasonably close to the most recent IPCC report and to other widely accepted scientific information. They are consistent with the ongoing values being used by most LGAs in NSW

and with the benchmarks applied in other states of Australia where specified by the corresponding state government. They provide a sound basis for future planning at this time. (summary)

- One difficulty with sea level rise is that the ongoing changes are not linear; the rate of change clearly varies with time (see Figure 3.2 for an illustration) and the overwhelming majority of scientific research tells us that rates of sea level rise will increase as atmospheric CO_2 levels increase. The sea level rise over the past 50 years will not equal the sea level rise over the next fifty years. The IPCC projections indicate that the rate of rise may be many times larger than historically averaged rates. (section 4.1)
- It is the role of the engineer or the coastal manager, to take the available science and to then apply that with an appropriate level of risk. In so doing, it is not the intention to sterilise land or to remove all risk. Rather the objective is to identify an acceptable level of future risk and to implement strategies that address those risks as and when they eventuate. Such decision making is routine and commonly based on imperfect knowledge of the future. (section 4.1)

5.4 Ongoing Review of the Benchmarks.

- Significantly, sea level rise is expected to continue for several hundred years and eventually, to significantly exceed benchmark levels that have been historically adopted for the 2100 timeframe in NSW. It is also possible for a given scenario adopted by Council, that the benchmark levels could be exceeded by the nominated time. (section 4.3)
- Council should consider putting a mechanism in place for reviewing projections on a regular basis. We suggest that this could occur when the IPCC releases its reports (every 5-6 years or so) and that modification of the CZMP and associated planning controls could occur subsequent to that review, if warranted. (summary)

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