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Bank Street Commercial Wharf

5-11 Bank Street, Pyrmont NSW

Section 75W Application

Climate Change and Sea Level Rise Report

Report Number 610.10676-R08

22 May 2017

Urban Growth NSW

Level 12, 19 Martin Place

SYDNEY NSW 2000

Version: v1.0

Bank Street Commercial Wharf

5-11 Bank Street, Pyrmont NSW

Section 75W Application

Climate Change and Sea Level Rise Report

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DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
610.10676-R08-v1.0	22 May 2017	Dr Peter Georgiou		

Executive Summary

UrbanGrowth NSW is preparing a modification application in relation to the earlier Part 3A approval for Sydney Heritage Fleet facilities at 5 Bank Street, Pyrmont (MP 11_0001). The proposal involves the relocation of an RMS-licensed Commercial Operator from Pyrmont Bridge Road, Glebe to the Bank Street, Pyrmont site to enable the development of the New Sydney Fish Market. The proposal is in effect a decanting of water-based operations within Blackwattle Bay and allows a working harbour use to continue in generally the same location with similar operational parameters to its current use.

This report is an updated assessment by SLR of the Mod 3 proposal specifically addressing the recently released NSW Planning & Environment SEARs (Secretary's Environmental Assessment Requirements) applying to the project in the area of climate change and sea level rise – refer SEAR extracts below:

Key Issues	The Environmental Assessment (EA) shall address the following: **16. Climate Change and Sea Level Rise** • An assessment of the risks associated with sea level rise on the proposal in accordance with current NSW Government guidelines
Plans and Documents	The following plans and relevant documentation shall be submitted; **18. Climate Change and Sea Level Rise Assessment**

In this report, in order to address the above requirements, SLR has …

- reviewed NSW Government guidelines in relation to climate change-induced sea level rise
- updated the previous sea level rise projections in line with the latest Climate Change data;
- examined the proposed Mod 3 development RL's (elevations) in relation to these projections; and
- provided recommendations and adaptation measures as required in relation to sea level rise.

Summary of Findings

There have been no significant changes to NSW Government guidelines in relation to climate change-induced sea level rise, although greater reliance has been placed on a risk-based approach rather than a proscribed, deterministic approach.

There have however been significant refinements in the development and presentation of global and local projections of climate change-induced impacts on temperature, rainfall, sea levels, ocean temperature, etc.

These changes – documented in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (2013) and accompanying Fifth Climate Model Intercomparison Project (CMIP5, 2013) have been examined in this report and climate change projections updated from SLR original report on this development (2012).

The revised climate change projections of design water level in this report take into account both:

- climate change-induced sea level rise
- climate change-induced catchment flooding increase, associated with climate change-induced peak rainfall event intensity increases

Executive Summary

Future Scenario Projections

The proposed facility has a design life of just over 10 years, and accordingly, the "2030" climate change scenario projections apply. All of the recommendations below would therefore have to be re-visited in the case of any future design for the site with a permanent (eg 50-year+) design lifetime.

The development currently has its lowest RL's, along the water's edge, above the 100-year ARI event design water level. By 2030, projected sea level rise and rainfall intensity increases suggest that the lowest RL's within the facility will lie just below the 5-year ARI event design water level. This can be interpreted as the event that has a 20% chance of exceedance in any one year. This is beyond the normal level of 5% engineering risk usually applied to environmental-related design factors.

It is noted that the higher levels within the facility, which is where all infrastructure is to be located (offices, stacking and car parking areas, etc) will be well above the 100-ARI event even for the more extreme "2090" / "RCP8.5" climate change scenario. Risk issues therefore are associated only with the facility's waterfront areas.

Design Factors

The project's sea wall provides the primary defence for the development site against climate change-induced sea level rise and increased peak catchment flooding. Accordingly, the following recommendations are made:

- Develop and construct a "flexible design" whereby in the future the ground RL of the sea wall and immediate foreshore areas at water's edge can be raised above their current +1.5 m AHD level. An increase of 0.2 m would provide a predicted 5% exceedance risk level.
- Ensure, as much as is practicable, that all services (particularly electricity) are located above predicted inundation levels throughout the site. Ensure that they also can be re-located to higher levels in the event of confirmed increases in the design water level.

Operational Factors

- On an Annual Basis, review available sea level records in Sydney Harbour to ascertain how actual sea level rise and peak rainfall intensity are tracking against the various climate change "RCP" scenarios discussed in this report. In recent times, the NSW Government, through NSW Public Works, has been publishing annual reports on NSW harbour and estuary sea levels – the latest report available is October 2016.
    - **Accordingly, develop a Climate Change Adaptation Plan for the proposal to include such ongoing review.**
- As part of the Climate Change Adaptation Plan, ensure that the entity responsible for the site maintains a continuous watch on Bureau of Meteorology severe storm warnings, particularly as time advances towards 2030, to be ready to shut down the facility (at least the low lying water's edge areas) to the Public in the event of an extreme storm and/or rainfall event.
- As the development's sea wall is the primary defence against the climate change-induced sea level rise and catchment flooding increase, it is recommended that the entity responsible for the site monitors the integrity of the sea wall at regular intervals and carries out maintenance to ensure its ongoing defence-related function.
    - **Accordingly, the responsible entity should develop a Sea Wall Maintenance and Management Plan to ensure ongoing risk management of the facility's main inundation feature for actual future sea level rise, any future movements and/or erosion of the seawall, etc.**

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1 INTRODUCTION

UrbanGrowth NSW is preparing a modification application in relation to the earlier Part 3A approval for Sydney Heritage Fleet facilities at 5 Bank Street, Pyrmont (MP 11_0001). The proposal involves the relocation of an RMS-licensed Commercial Operator from Pyrmont Bridge Road, Glebe to the Bank Street, Pyrmont site to enable the development of the New Sydney Fish Market. The proposal is in effect a decanting of water-based operations within Blackwattle Bay and allows a working harbour use to continue in generally the same location with similar operational parameters to its current use.

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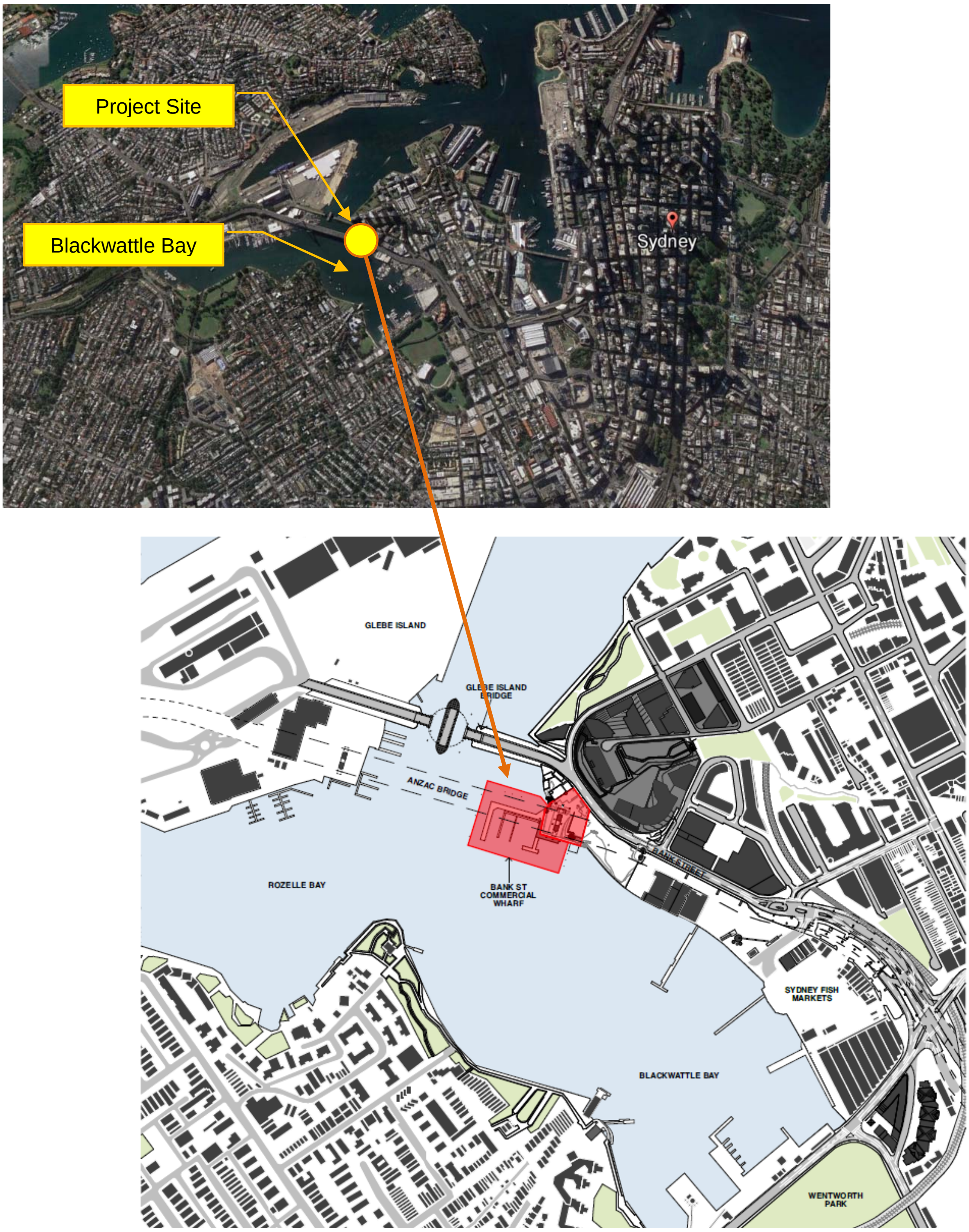
2 SITE AND PROJECT DESCRIPTION

2.1 Site Description

The project site is located at Bank Street, Pyrmont, beneath the Anzac Bridge on Blackwattle Bay, west of the Sydney CBD area – refer location map in **Figure 1**.

Figure 1 Location Map of the Bank Street Maritime Facility, Pyrmont

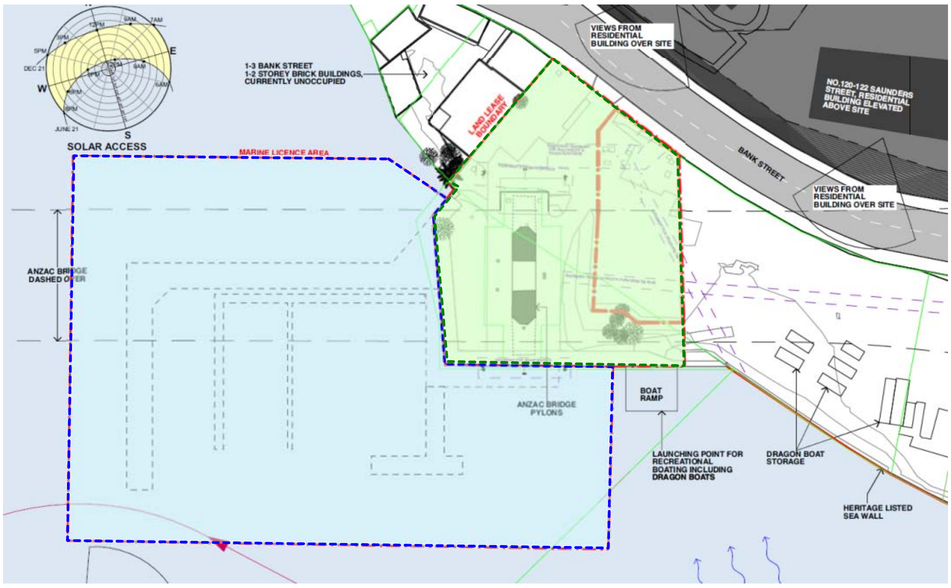


2.2 Project Description

The project site – refer **Figure 2 -** consists of two components:

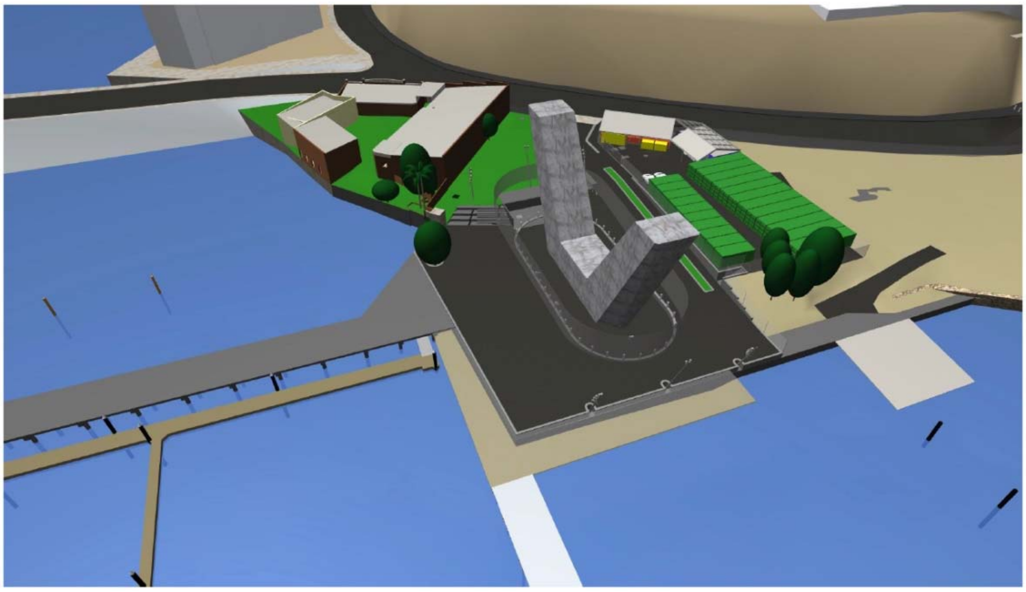
- Marine Licence Area (~13,000 m^2)
- Land Lease Area (~4,500 m^2) which "fits" around the eastern main pylons of the Anzac Bridge and comprises common (public) spaces, an Administration Building, limited on-site parking, a shipping container location and temporary storage and waste facilities.

Figure 2 Project Site Showing Marine (blue) and Land (green) Lease Areas



An architectural perspective of the facility is shown in **Figure 3**. Only the lower (below deck) sections of the Anzac Bridge are shown.

Figure 3 Project Site 3D View from the South



3 LEGISLATION AND GUIDANCE – HISTORICAL PERSPECTIVE

The NSW Planning & Environment SEARs (Secretary's Environmental Assessment Requirements) applying to the project state the following in relation to climate change and sea level rise:

> The Environmental Assessment (EA) shall address the following:
>
> - **16. Climate Change and Sea Level Rise**
>   An assessment of the risks associated with sea level rise on the proposal in accordance with current NSW Government guidelines

3.1 NSW Government Guidelines

NSW Government Guidelines reviewed in this report include:

- NSW Government (1990) Coastline Management Manual
- NSW Government (1997) NSW Coastal Policy
- NSW Government (2009) Reforms to coastal erosion management in NSW
- NSW Government (2009) NSW Sea Level Rise Policy Statement
- NSW Department of Planning (2010) NSW Coastal Planning guideline: Adapting to Sea Level Rise
- DECCW (2009) Derivation of the NSW Government's sea level rise planning benchmarks
- DECCW (2010a) Coastal Risk Management Guide: Incorporating sea level rise benchmarks in coastal risk assessments
- DECCW (2010b) Flood Risk Management Guide: Incorporating sea level rise benchmarks in flood risk assessments
- NSW Office of Environment & Heritage (2015) Floodplain Risk Management Guide

3.2 NSW Government (2009) NSW Sea Level Rise Policy Statement

This guideline states the following:

- Sea level rise is an incremental process and will have medium- to long-term impacts.
- The best national and international projections of sea level rise along the NSW coast are for a rise relative to 1990 mean sea levels of …
  - 40 cm by 2050 and
  - 90 cm by 2100.
- The Intergovernmental Panel on Climate Change (IPCC) in 2007 also acknowledged that higher rates of sea level rise are possible.

The reader is referred to the following two documents for the background to the above:

- NSW DECCW (2009) *Technical Note: Derivation of the NSW Government's Sea Level Rise Planning Benchmarks*
- NSW DECCW (2012) *Assessment of the Science behind the NSW Government's Sea Level Rise Planning Benchmarks*

The latter document shows the components that comprised the projected sea level rise recommendations for 2050 and 2100 – these are detailed in **Table 1**.

Table 1 Component of the NSW Planning Sea Level Rise Benchmarks

Component	Year 2050	Year 2100
Sea level rise (global mean)	30 cm *IPCC TAR 2001*	59 cm *IPCC AR4 2007*
Accelerated ice melt (global mean)	(included in above value)	20 cm *IPCC AR4 2007*
Regional Variation in sea level rise	10 cm *Interpolated from* McInnes *et al* (2007)	14 cm *Extrapolated from* McInnes *et al* (2007)
Rounding	-	-3 cm *Rounding to the nearest 10 cm*
Total	**40 cm**	**90 cm**

The above sea level rise adjustments were used in SLR's previous 2012 assessment of the Maritime Facility. They are reviewed in **Section 4** of this report.

3.3 References Used in Relation to Design Water Levels

At the time of writing of the SLR 2012 assessment of the proposal, no detailed current sea level information pertaining to Blackwattle Bay was available. Contact was made with the City of Sydney, regarding a Blackwattle Bay Flood Study that was in progress. However, they were unable to release any sea level data from this study.

Accordingly, a sea level rise vulnerability study, completed at Fort Denison was identified as the most relevant and contemporary reference available:

- NSW Coastal Unit (2008), Fort Denison Sea Level Rise Vulnerability Study

Fort Denison lies approximately 4 km north-east of the site, and the above study was a detailed quantitative assessment of historical tidal data recorded at Fort Denison over a 100-year period.

The design (still water) levels (reference to AHD, Australian Height Datum) obtained from this study are presented in **Table 2** versus Average Reoccurrence Interval (ARI) over a 100 year period. They represent a statistical combination of tide plus non-tidal influences (eg water level changes associated with major storms impacting the coastline such as "East Coast Lows"). The ARI 100-year event represents a design water level for a 1 in 100-year occurrence of probability, ie the event that occurs, *on average*, once every 100 years. Alternatively, this event can be interpreted as having a 1% chance of exceedance in any one year. The 20-year ARI event will occur, *on average*, once every 20 years and has a 5% chance of occurring in any one year.

Table 2 Sydney Harbour Design Water Levels (excerpt from Fort Denison Study)

ARI (years)	Design Level (AHD)	ARI (years)	Design Level (AHD)
1	1.235	10	1.345
2	1.275	20	1.375
5	1.315	50	1.415
10	1.345	100	1.435

Reference: *Fort Denison Sea Level Rise Vulnerability Study* (Coastal Unit, October 2008)

4 LEGISLATION AND GUIDANCE – UPDATE

4.1 Review of Most Recent Sea Level Rise Recommendations

To SLR's knowledge, no changes have been made to the NSW Guidelines discussed in **Section 3.1** with regard to sea level rise recommendations.

However, significant updating has occurred within both the global and Australian scientific community with regard to climate change and associated sea level rise. These are described below.

Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (2013)

IPCC 2013 unequivocally concluded that:

- Greenhouse gas (GHG) emissions have markedly increased in recent times as a result of human activities. This increase has influenced a warming of the atmosphere and the ocean (especially since the 1950s), changes in the global water cycle, reductions in overall snow and ice, a **global rise in mean sea level**, and changes in some climate extremes.
    - Each of the three most recent decades has been successively warmer at the Earth's surface than any preceding decade since 1850. In the Northern Hemisphere, 1983-2012 was likely the warmest 30-year period of the last 1400 years (**medium confidence**).
    - Over the last two decades, the Greenland and Antarctic ice sheets have been losing mass, glaciers have continued to shrink almost worldwide, and Arctic sea ice and Northern Hemisphere spring snow cover have continued to decrease in extent (**high confidence**)
    - The rate of sea level rise since the mid-19th century has been larger than the mean rate during the previous two millennia (**high confidence**).
- Continued warming and changes in all components of the global climate system are projected.

In terms of further specific details …

1. It is **very likely** that anthropogenic influence (ie human activity), particularly in relation to greenhouse gases and stratospheric ozone depletion, has led to a detectable observed pattern of tropospheric warming and a corresponding cooling in the lower stratosphere since 1961.
2. It is **very likely** that anthropogenic forcing has made a substantial contribution to increases in global upper ocean heat content (0-700 m) observed since the 1970s.
3. It is **likely** that anthropogenic influence has affected the global water cycle since 1960, including:
    - observed increases in atmospheric moisture content in the atmosphere (**medium confidence**)
    - global-scale changes in precipitation patterns over land (**medium confidence**)
    - intensification of heavy precipitation over land regions (**medium confidence**), and
    - changes in surface and sub-surface ocean salinity (**very likely**).
4. It is now **very likely** that human influence has contributed to observed global scale changes in the frequency and intensity of daily temperature extremes since the mid-20th century, and **likely** that human influence has more than doubled the probability of occurrence of heat waves in some locations.
5. Anthropogenic influences have **very likely** contributed to Arctic sea ice loss since 1979 and **likely** contributed to the retreat of glaciers since the 1960s and to the increased surface mass loss of the Greenland ice sheet since 1993. It is also **likely** that there has been an anthropogenic contribution to observed reductions in Northern Hemisphere spring snow cover since 1970.
6. It is **very likely** that there is a substantial anthropogenic contribution to the global mean sea level rise since the 1970s.

Climate Change Impacts in Australia – Updated CSIRO-BOM Assessment

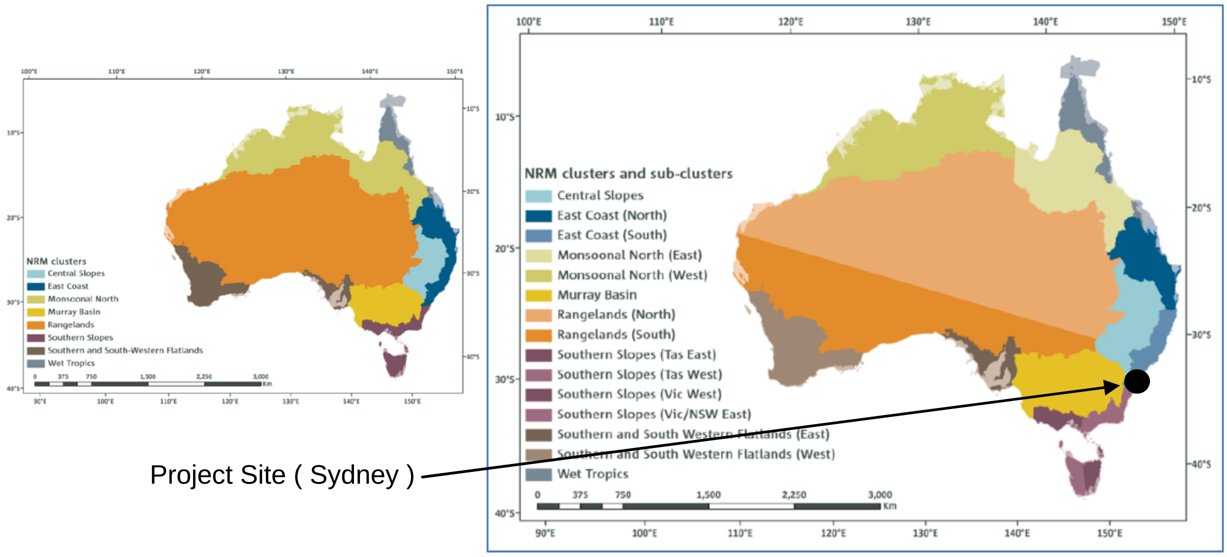
Australia has already experienced increasing temperatures, shifting rainfall patterns, surrounding ocean acidification and a rise in sea level associated with the impacts of a warming global climate.

In recognition of the impact of climate change on the management of Australia's natural resources, the Australian Government developed the **Regional Natural Resource Management (NRM) Planning for Climate Change Fund**, to provide projections of the likely impact of climate change on Australia's natural resources. The Fund (which operates within the Commonwealth Department of Environment) has also been reviewing adaptation opportunities for protecting and managing our land, soil, water, plants and animals.

Australia has **54 NRM regions**, defined by catchments and bioregions. Many aspects of the activities of both human activity and ecosystems within these regions are vulnerable to impacts of climate change.

- For the purposes of climate change impacts, NRM regions have been grouped into so-called **"clusters"**, which essentially correspond to the broad-scale climate and biophysical regions of Australia – refer left-hand diagram in **Figure 4**. Each cluster is broadly consistent in terms of its own history, population, resource base, geography and climate, and therefore has a unique set of priorities for responding to climate change
- Recent studies suggested that further sub-division was needed in some cases to better capture the important patterns of projected change for specific climatic variables. In light of this, five of the eight clusters were sub-divided into so-called **"sub-clusters"**, more useful for impact assessment and adaptation planning - refer right-hand diagram in **Figure 4**.
- The location of the Bank Street, Pyrmont, Maritime Facility is shown in the sub-cluster diagram – it lies within the East Coast South sub-cluster.

Figure 4 Australia's Natural Resource Management (NRM) Clusters & Sub-Clusters



Australia's CSIRO and Bureau of Meteorology (BOM) have prepared tailored climate change projections for each of Australia's eight NRM clusters (as well as their sub-clusters) to be considered in planning and adaptation option assessments.

Most Recent CMIP5 Modelling Methodology Used for Climate Change Predictions

The future of anthropogenic greenhouse gas and aerosol emissions (and hence their resultant radiative forcing) is highly uncertain, encompassing substantial unknowns in population and economic growth, technological developments and transfer, and in particular, **political and social changes**. The recent Paris Climate Change global gathering for example resulted in an evident enthusiasm to tackle the impacts of climate change. Commitments were made in terms of both mitigation and adaptation strategies and targets. How these commitments will be delivered over coming years and decades however would appear to have considerable uncertainty.

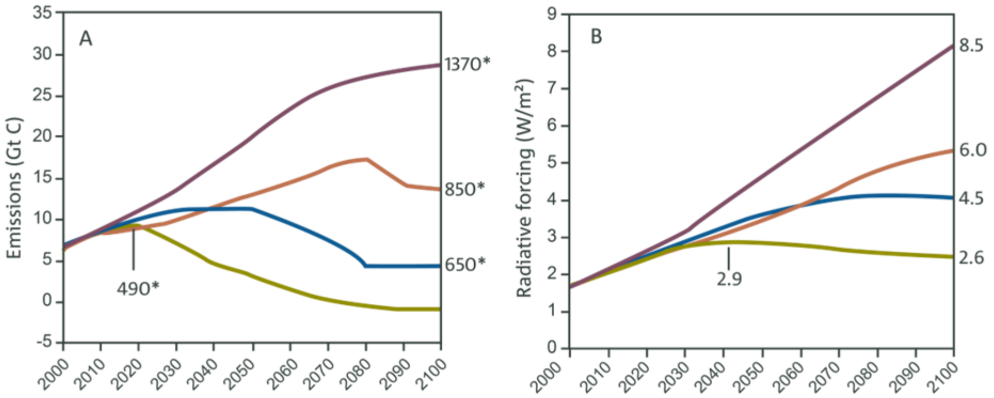
The climate modelling community has therefore developed **"Representative Concentration Pathways"** (RCPs) to explore credible future options, expressed in terms of future carbon emissions and associated radiative forcing.

- Each RCP prescribes internally self-consistent 'representative' concentrations of greenhouse gases and aerosols, as well as land use changes. RCPs were developed by a group of experts in areas spanning atmospheric modelling, chemistry and the carbon cycle and social scientists working in economics, policy and impacts [Moss et al. 2010].
- Four standard RCPs have since been commonly adopted in most global climate studies (**and used in the Australian context**). They represent the distillation of a much larger number of potential futures discussed in the literature [van Vuuren et al. 2011, Meinshausen et al. 2011].
- These RCPs were used in the **Fifth Climate Model Intercomparison Project (CMIP5)** and the latest **IPCC Assessment Report (2013)**. They span the range of plausible global warming scenarios and provide a range of options for the world's governments and other institutions for decision making.

The (projected) carbon emissions and the corresponding radiative forcing for the four standard RCPs are shown in **Figure 5**. No particular scenario is deemed more likely than the others, although it is fair to say that the lowest radiative forcing scenario, RCP2.6, would require major and rapid change in carbon emissions patterns on a global scale.

- **RCP8.5** represents a future with little curbing of emissions, with CO_2 concentrations continuing to rapidly rise, reaching 940 ppm by 2100 (we are currently just over 400 ppm).
- **RCP6.0** represents lower emissions, achieved by application of some mitigation strategies and technologies. CO_2 concentrations rise less rapidly than RCP8.5, but still reach 660 ppm by 2100 with total radiative forcing stabilising shortly after 2100.
- **RCP4.5** concentrations are slightly above those of RCP6.0 until after mid-century, but emissions peak earlier (around 2040). CO_2 concentrations reach 540 ppm by 2100.
- **RCP2.6** represents the most ambitious mitigation scenario, with emissions peaking very soon (around 2020), then rapidly declining. Such a pathway would require early and aggressive carbon emission controls from all emitters, including developing countries, combined with advanced technologies for actively removing carbon dioxide from the atmosphere.

Figure 5 RCP Emission Scenarios – Carbon Emissions & Associated Radiative Forcing



4.2 East Coast (South) Cluster – SEA LEVEL RISE

Changes in sea level are caused primarily by (i) changes in ocean density ("thermal expansion") and (ii) changes in ocean mass due to the exchange of water with the terrestrial environment, including from glaciers and ice sheets (eg Church et al., 2014).

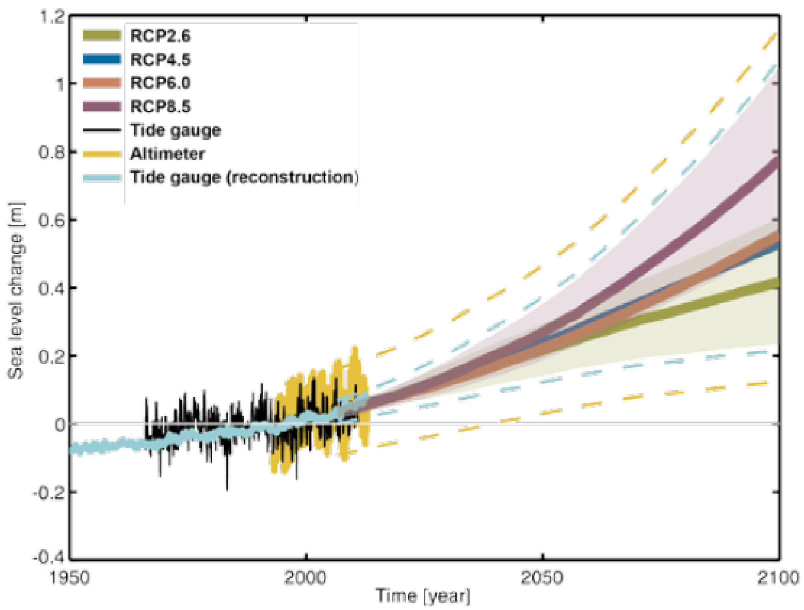
Historical observations in the period 1966-2009 indicate the following:

- The average relative tide gauge trend around Australia showed a rise of 1.4 ± 0.2 mm/yr.
- When the influence of the El Niño Southern Oscillation (ENSO) on sea level is removed, the average trend becomes 1.6 ± 0.2 mm/yr.
- After accounting for and removing the effects of vertical land movements due to glacial rebound and the effects of natural climate variability and changes in atmospheric pressure, sea levels have risen around the Australian coastline at an average rate of 2.1 mm/yr over 1966-2009 and 3.1 mm/yr over 1993-2009.
- The above observed rates of rise for Australia are consistent with (albeit slightly higher than) global average values (White et al., 2014).

Projections of future sea level changes using CMIP5 Global Circulation Models (GCMs) are shown for Sydney in **Figure 6**. The median prediction for each RCP is shown as a thick, bold line. The variation (lighter shade colouring) either side shows the 5% and 95% percentile predictions for each RCP.

Continued increase in sea level for the East Coast cluster is projected with **very high confidence**. The rate of sea level rise during the 21st century will be larger than the average rate during the 20th century as greenhouse gas emissions grow. For higher greenhouse gas emissions, particularly for RCP8.5, the rate of rise continues to increase and results in a sea level rise of about 30% higher than the RCP4.5 level by 2090. Significant inter-annual variability will continue through the 21st century.

Figure 6 Sea Level Change for Sydney (relative to 1986-2005) using CMIP5 GCMS



The median and 5% and 95% percentile predictions for the "near future", 2030, and "late in the century", 2090, timescales are given in **Table 3**.

- The future averaging periods are 2020-2040 and 2080-2100, for the 2030 and 2090 simulation period years respectively.
- The variables are relative to the 1986-2005 reference period.
- The ranges of sea level rise and sea allowance in **Table 3** are considered likely (minimum 66% probability). However, should a collapse in marine based sectors of the Antarctic ice sheet be initiated, these projections could be several tenths of a metre higher by late in the century (Church et al., 2014).

In addition to **Sea Level Rise**, **Table 3** also shows a variable labelled the "**Sea Allowance**".

- Using the method of Hunter (2012), a Sea Allowance has been calculated based on the mean sea level rise, the uncertainty surrounding the rise, and taking into account the nature of extreme sea levels along the East Coast coastline (Haigh et al., 2014).
- The Sea Allowance is the minimum distance required to raise an asset to maintain current frequency of breaches under projected sea level rise. When uncertainty in mean sea level rise is high (eg in 2090), sea allowance approaches the upper end of the range of projected mean sea level rise.

Table 3 Sea Level Rise and Sea Allowance Projections for Sydney

Simulation Period Year	Variable	RCP Simulation Scenario		
		RCP2.6	RCP4.5	RCP8.5
2030	Sea Level Rise	0.13 (0.09 - 0.18)	0.13 (0.09 - 0.18)	0.14 (0.10 - 0.19)
	Sea Allowance	0.14	0.14	0.15
2090	Sea Level Rise	0.38 (0.22 - 0.54)	0.47 (0.30 - 0.65)	0.66 (0.45 - 0.88)
	Sea Allowance	0.48	0.59	0.84

Note: bracketed figures for Sea Level Rise are the 5% and 95% confidence level projections

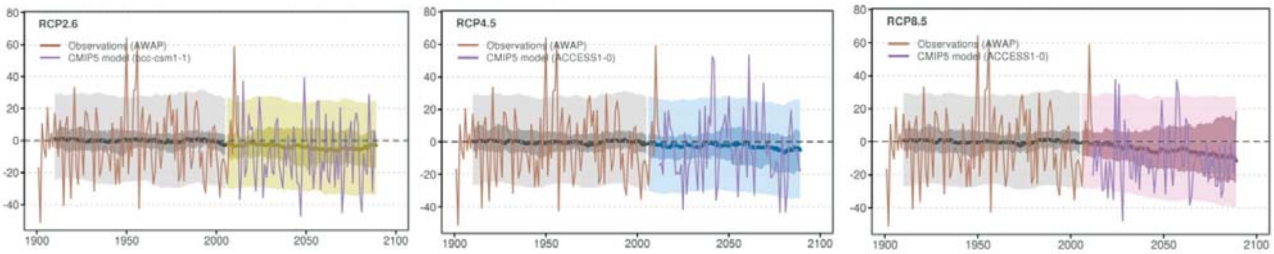
It can be seen that the previously referenced NSW Government Sea Level Rise Planning Benchmarks shown in **Table 1** are comparable to the Sea Allowance projections given in **Table 3** for the RCP8.5 simulation scenario.

4.3 East Coast Cluster – AVERAGE RAINFALL

During the 20th century (relative to a 1986-2005 baseline average), a definitive long-term trend was not evident in East Coast rainfall with intermittent periods of wetter and drier conditions. The 21st century commenced with the so-called Millennium drought followed by above-average rainfall. The highest annual rainfall on record within the East Coast Cluster occurred in 2010 within the North sub-cluster, relating to the formation of a strong La Niña event. While the rainfall in 2010 for the East Coast South sub-cluster was above average, it was not close to being a record high amount, consistent with previous studies showing that rainfall in this part of the Eastern Seaboard is less influenced by La Niña and El Niño conditions than other parts of Eastern Australia.

CMIP5 projections for rainfall under the various RCP scenarios - refer **Figure 7** - do not provide a definitive overall trend for RCP2.6 and RCP4.5. The RCP8.5 scenario suggests a small decrease in median annual rainfall by 2090, however, overall the inter-model changes are comparable to natural variability.

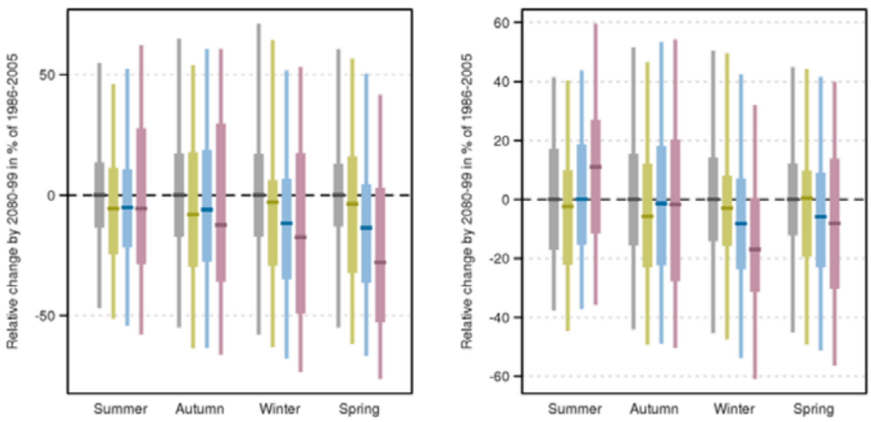
Figure 7 CMIP5 Projections for East Coast Annual Rainfall
(shown as %age change relative to the 1950-2005 mean)



The “mixed” response seen in annual rainfall is similarly evident in the seasonal projections shown in **Figure 8**. By late in the 21st century under RCP4.5 and RCP8.5 in East Coast South, a decrease in winter rainfall is projected with medium confidence (driven by fewer winter storms). A range of changes is projected in the other seasons, with a tendency for increase in summer. Seasonal changes compared to 1986-2005 range from around -25% to +20% under RCP4.5 and -30% to +25% under RCP8.5.

Figure 8 Projected Seasonal Rainfall Changes for the East Coast Clusters
(shown as %age change relative to the 1950-2005 mean)

North Sub-Cluster **South Sub-Cluster**



In summary, there is high confidence that natural climate variability will remain the major driver of East Coast rainfall changes in the next few decades, highlighting the need to consider the risk of both a drier and wetter climate in impact assessments.

4.4 East Coast Cluster – HEAVY RAINFALL EVENTS

In a warming climate, heavy rainfall extremes are expected to increase in magnitude mainly due to a warmer atmosphere being able to hold more moisture [Sherwood et al., 2010].

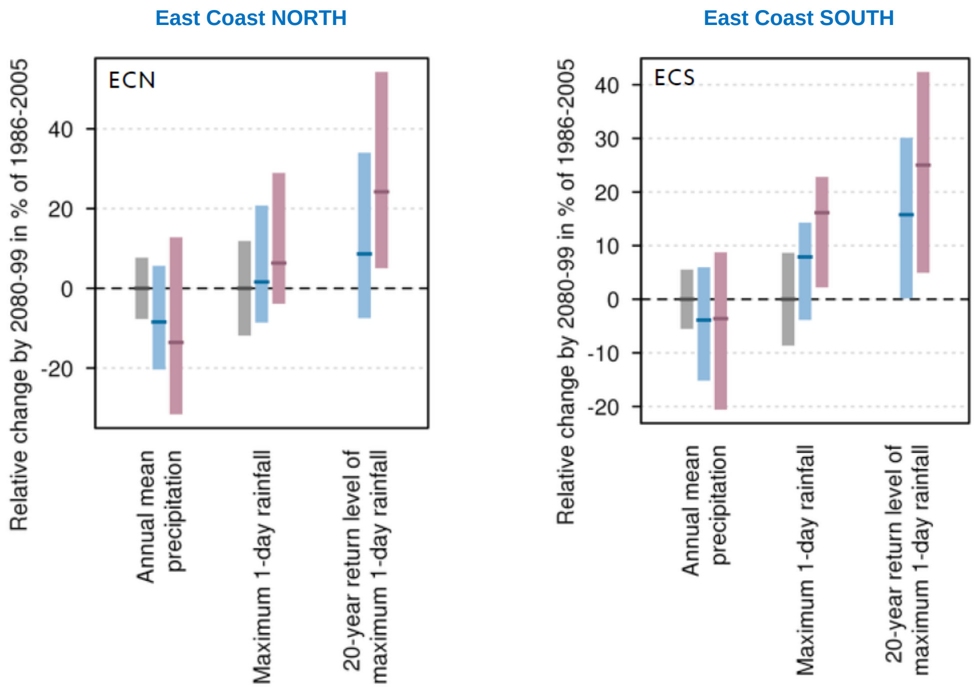
Daily rainfall amounts from the CMIP5 simulations have been analysed and the maximum values determined in each year and within 20-year periods. For both East Coast North and South, the models project an increase in the magnitude of the annual maximum 1-day rainfall and the magnitude of the 20-year return value of maximum 1-day rainfall by 2090 – refer **Figure 9**, where a 20-year return value is equivalent to a 5 % chance of occurrence within any one year.

Comparing the trend in the two extreme indices with that of the annual mean rainfall clearly shows that while the projection for mean rainfall is tending towards a decrease in the cluster, the extremes are projected to increase. For example, based on the median change for RCP8.5, the extreme daily rainfall amount at a location within a 20-year period by 2090 could be expected to be around 20% larger than the extreme from a recent 20-year period. Actual values at individual locations may vary, of course. It may be noted that this pattern (change in mean relative to extremes) is found in all other Australian NRM clusters.

The magnitudes of the simulated changes in extreme rainfall indices are strongly dependent on emission scenario and the future time period. Furthermore, the magnitude of the change simulated by GCMs is somewhat uncertain because many of the weather systems that generate extreme rainfall are not well resolved by GCMs (such as tropical cyclones, East Coast Lows, intense frontal systems and severe thunderstorms).

Thus in summary, there is high confidence that the intensity of heavy rainfall extremes will increase in the East Coast South cluster, but the magnitude of change contains significant uncertainty.

Figure 9 Projected Change in Annual Mean and Peak 1-day Rainfall Events
(shown as %age change relative to the 1950-2005 mean)



4.5 Project Site – Design Storm Tide Level

In **Section 3.2**, it was noted that the previous SLR 2012 assessment of the proposal used the 2008 Fort Denison study to estimate design water levels for the project site area:

- NSW Coastal Unit (2008), *Fort Denison Sea Level Rise Vulnerability Study*

Since that time, a major flooding study was completed for the City of Sydney for the Blackwattle Bay area:

- WMAwater (September 2015) *Blackwattle Bay Catchment – Flood Study*

Detailed flood mapping was undertaken for a range of design events: ARI's of 2, 5, 10, 20, 50 and 100 years as well as the Probable Maximum Flood event. The study also looked the impact of climate change involving an increase in rainfall and increase in sea level.

Although the Blackwattle Bay study was published in 2015, the incorporation of climate change into the flood modelling did not take into account the most recent CSIRO-BOM climate change scenario recommendations (based on IPCC5), but instead relied upon the fourth IPCC report (2007), as well as CSIRO recommendations made in 2007 and the NSW DECC *Floodplain Risk Management Guideline: Practical Consideration of Climate Change* (October 2007).

Accordingly, the Blackwattle Bay climate change scenarios analysed were:

- a rise in tailwater level in Blackwattle Bay of 0.4 m and 0.9 m
- increases in design rainfall intensity of 10%, 20% and 30%

It can be seen that …

- The sea level rise values used in the Blackwattle Bay study are the same as those given in **Table 1**.
- The design rainfall increases used in the Blackwattle Bay study lie within the range of peak 1-day rainfall intensities shown in **Figure 9** which vary from 5% to over 40%.

The results of the Blackwattle Bay modelling suggest the following:

Sea Level Rise:

- Sea level rise largely affects only low lying areas adjacent to Blackwattle Bay
- A 0.4 m sea level rise is unlikely to have any effects on the peak flood levels whereas a 0.9 m sea level rise may have minor implications, of the order of 1-2 cm, on peak flood levels in the vicinity of seawalls as well as Wentworth Park.

Rainfall Increase:

The results indicate that the average increase in the 1% AEP flood event is:

- +0.1 m for a low level rainfall increase of 10%
- +0.2 m for a medium level rainfall increase of 20%
- +0.2 m for a high level rainfall increase of 30%

The 2015 Blackwattle Bay study focussed (as was its objective) on catchment flood levels in the area and did not re-visit the design water levels that had been established in the 2008 Fort Denison study. It is noted that in NSW Public Works Report MHL2475 (October 2016) *NSW Ocean and River Entrance Tidal Levels Annual Summary 2015-2016*, the Fort Denison design water levels were unchanged.

5 SLR RECOMMENDATIONS REGARDING CLIMATE CHANGE IMPACTS

The factors which ultimately influence the Design Water Level for the Maritime Facility proposal are:

- Tidal variations and in particular, tidal extremes
- Additional seaward side non-tidal water level factors, in particular the influence of major storm events such as East Coast Lows which can generate water build-up in addition of tidal water level variations
- Land-side factors, namely the influence of major flooding events on local water levels, which for obvious reasons are associated with peak rainfall events.

Climate change affects all of the above:

- Sea Level Rise superimposes an additional component on both tidal and non-tidal water level variations
- Rainfall Intensity Increase has the potential to augment land-side flooding.

An important consideration in assessing how the above factors interact is an understanding of the likelihood that all three factors might produce a peak event at exactly the same time, ie what is the probability that a peak tide might occur right at the point when a major storm (eg East Coast Low) was having its greatest impact along the local coastline and local flooding (caused by an intense rainfall event) was generating peak local water levels at the same location.

Much work has been done along the Australian coastline to determine the joint probability of occurrence statistics of tidal, non-tidal and rainfall events (eg McLuckie et al., 2010).

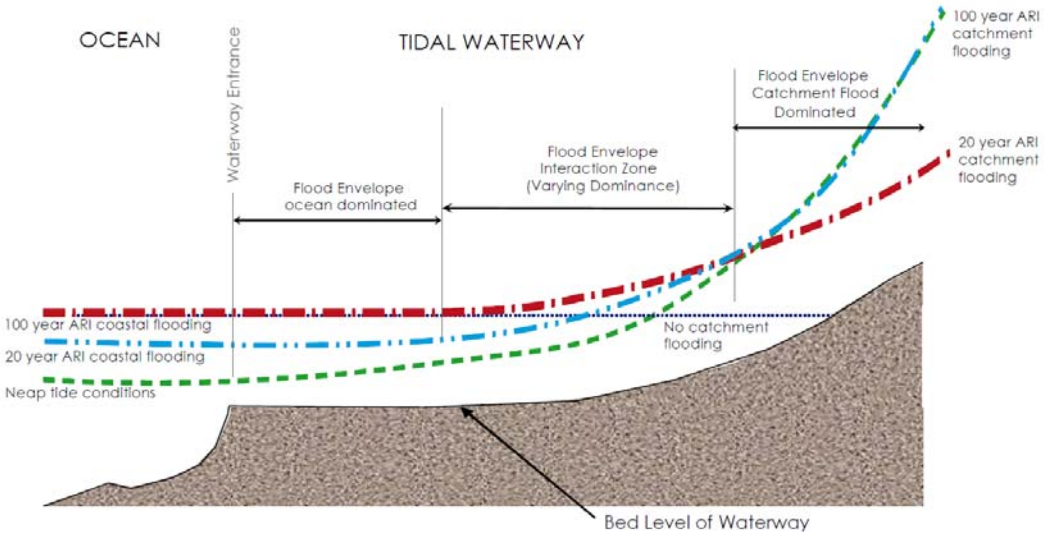
Using these joint probability studies, Collins et al. (2012) describe a general approach to the determination of 100-year design water levels that involves a combination of events to capture critical joint events. This approach has gained acceptance in NSW (and other States) and has the benefit of providing a substitute for a detailed modelling site-specific assessment. The combinations are shown in **Table 4**, and are expressed in terms of AEP likelihood (eg the 1% AEP event, 5% AEP event, etc).

Table 4 Probabilistic Combinations to Determine Design Water Levels at Coastal Locations

Event Combination	Coastal Flooding Event (tidal and non-tidal)	Catchment Flooding Event (land-side)
1	1% AEP	5% AEP
2	5% AEP	1% AEP
3	1% AEP	-
4	Neap tide conditions	1% AEP

As they are applied to locations adjacent to the coastline, different combinations tend to provide the critical design event. This can be seen in **Figure 10**, which provides a simplistic illustration of the individual events given in **Table 4** and the design envelope they produce going from sea-side to land-side at a coastal location.

Figure 10 Interaction of Coastal and Catchment Flooding



Source: McLuckie D., Babister M., Dewar R. (2010) *Considering the Impacts of Climate Change on Flood Risk*. Engineers Australia – First Practical Responses to Climate Change National Conference Melbourne, 29 September to 1 October 2010.

Once the four event combination scenarios have been examined, a judgement needs to be made on the appropriate flood level (ie return period) to adopt. This needs to consider the distance from the coast, the significance of the infrastructure involved and the risk profile.

In the present instance the following is relevant

- The Bank Street, Pyrmont, Maritime Facility is located right at the shoreline of Blackwattle Bay.
- Its design water levels will be dominated by sea-side factors (tidal and non-tidal) with only a small contribution from land-side catchment flooding.
- The Facility has been designed for “temporary” usage and will not house personnel on site permanently, suggesting that there may be some cause to relax slightly the normal 100-year return period objective for the design water level – especially if design features can be built into critical engineering elements, ie the facility’s seawall, that can be augmented in future years.

6 MARITIME FACILITY RECOMMENDED DESIGN WATER LEVEL

Table 5 presents the key and most up-to-date data relevant to the selection of design water level for the proposed development.

Table 5 Maritime Facility Recommended Design Water Level

Fort Denison Study Design Water Level (includes peak tidal and storm surge effects)			
ARI (years)	**Design Level (AHD)**	**ARI (years)**	**Design Level (AHD)**
1	1.235	10	1.345
2	1.275	20	1.375
5	1.315	50	1.415
10	1.345	100	1.435

CSIRO-BOM Climate Change-Induced Sea Level Rise – determined as “Sea Allowance”			
Design Year	**RCP2.6**	**RCP4.5**	**RCP8.5**
2030 (applies to 2020-2040 period)	0.14	0.14	0.15
2090 (applies to 2080-2100 period)	0.48	0.59	0.84

Blackwattle Bay Catchment Flood Study – Climate Change Rainfall Increase			
Design Year	**RCP2.6**	**RCP4.5**	**RCP8.5**
2030 (applies to 2020-2040 period)	-	+0.05 m	+0.05 m
2090 (applies to 2080-2100 period)	+0.1 m	+0.15 m	+0.2 m

COMBINATION OF ALL FACTORS (using 2030 sea level rise and 2030 rainfall intensity increases)			
ARI (years)	**Design Level (AHD)**	**ARI (years)**	**Design Level (AHD)**
1	1.425 (1.435)	10	1.535 (1.545)
2	1.465 (1.475)	20	1.565 (1.575)
5	1.505 (1.515)	50	1.605 (1.615)
10	1.535 (1.545)	100	1.625 (1.635)

Note: First figure shown for each ARI is for the RCP 4.5 scenario
The bracketed figure shown for each ARI is for the RCP 8.scenario
(RCP2.6 scenario figures are not shown)

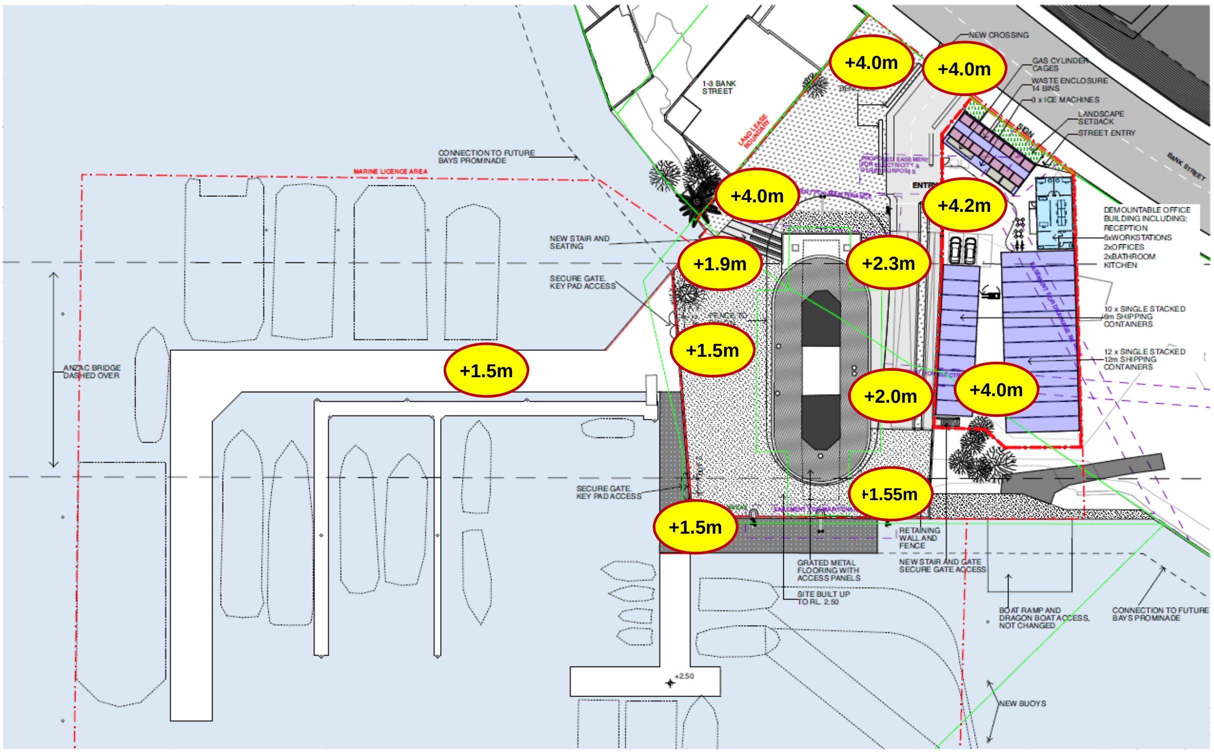
In the above, it bears recalling that neither the RCP4.5 nor the RCP8.5 climate change scenarios allow for the possibility of a collapse in any of the marine-based sectors of the Antarctic ice sheet. Should this occur, the above recommended design water levels could increase in by several tenths of a metre.

7 IMPACT ASSESSMENT

Figure 11 shows RLs (relative to AHD) for key locations within the proposal, including along the development's waterfront areas.

- Areas within the proposal away from the waterfront, along Bank Street, are at around 4.0 m AHD; this extends to the shipping container stacking area and carpark.
- Areas midway between Bank Street and the water's edge are at around 2.0 m AHD.
- All areas along the waterfront of the proposal, which will include the development's seawall, waterfront promenade and seaside fixed aprons, will remain at the current level of 1.5 m AHD.

Figure 11 Key Development Area RLs Within the Maritime Facility Proposal



On the basis of the above:

Currently, the lowest (fixed) RLs within the proposed Maritime Facility, +1.5 m AHD, (excluding floating pontoons which move up and down with water level) lie just above the 100-year ARI +1.435 m AHD design water level.

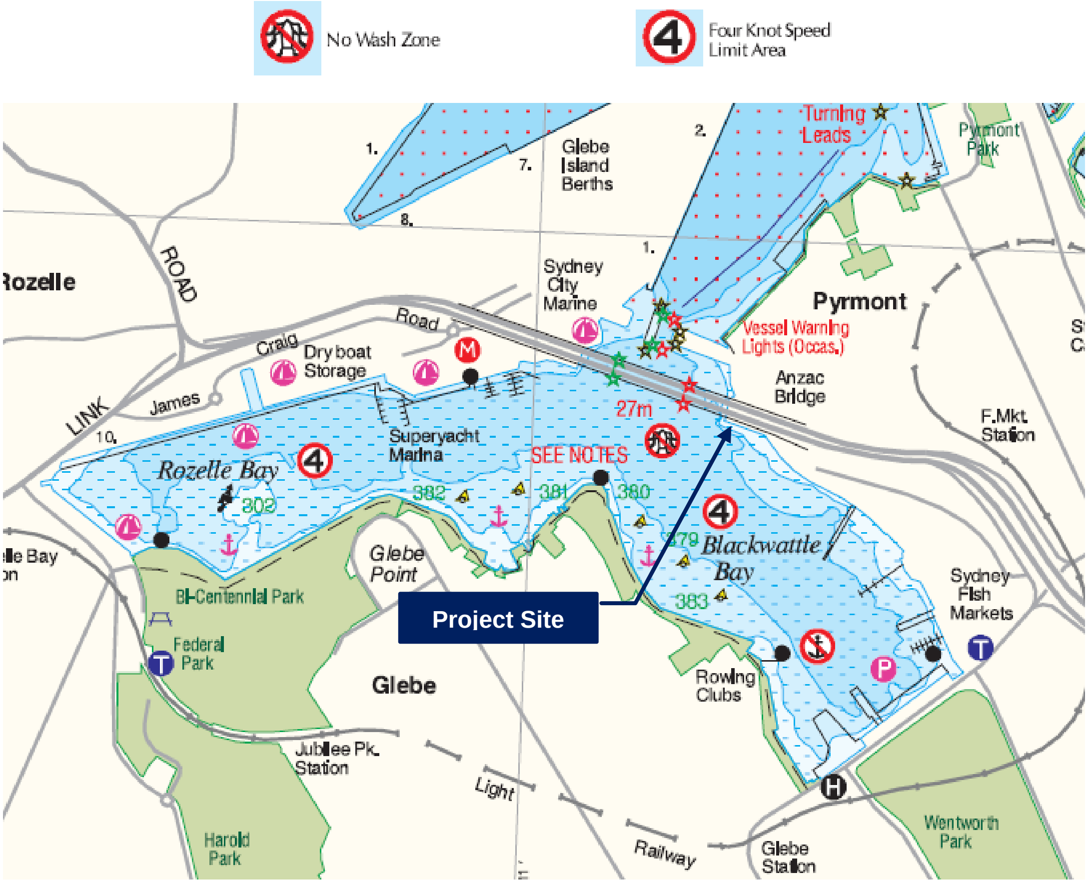
By 2030, the lowest (fixed) RLs within the proposed Maritime Facility, +1.5 m AHD, (excluding floating pontoons which move up and down with water level) will be just below the 5-year ARI +1.505 m and +1.525 m AHD design water level given in Table 5 for the 2030 RCP4.5 and RCP8.5 scenarios respectively. The higher levels with the proposed facility, +4.0 m AHD, will be well above the 100-year ARI / 2090 RCP8.5 scenario level.

Table 6 represents potential climate change-related environmental impacts using a format outlined within the *NSW Coastal Planning Guideline: Adapting to Sea Level Rise*, along with an assessment as to whether these generic impacts might affect the site and associated proposed development.

Table 6 Potential Sea Level Rise Risks

Impact	Applicable YES	Applicable NO	Assessment and/or Comment
Sea level and increased tidal range	■		The results presented in the previous section indicate the most exposed areas at the site waterfront are slightly above the more severe climate change projection for the "2090" / "RCP8.5" scenario. There remain uncertainties in future sea levels due to factors such as increased Antarctic Marine-based Ice Sheet melting which suggests the need for a future adaptation strategy should current sea level rise projections end up being conservative (ie too low).
Soft coast erosion	□ in 2030	□ now	Due to the height and presence of the sea wall (and given that it is maintained) it is unlikely that the predicted sea level rise will cause soft coast erosion.
Beach and foredune loss and/or migration and bluffs		■	Not relevant to present proposal.
Shoreline recession		■	This site does not contain beach or dunes; if the project sea wall integrity is maintained, shoreline recession will not become a risk for the site.
Beach realignment		■	Not relevant to present proposal.
Coastal flooding	□ in 2030	□ now	The most exposed areas at the site waterfront are slightly above the more severe climate change projection for the "2090" / "RCP8.5" scenario, which includes an allowance for flooding impact from climate change-induced increased rainfall intensity.
Slope instability		■	The previous Water Sensitive Urban Design Report (SLR 2010) indicates that risks to slope instability are unlikely.
Groundwater elevation and/or salinisation	?	?	Due to sea level rise and increased catchment flooding associated with climate change-induced rainfall intensity increase, there is potential for elevated groundwater and salinization. SLR is unaware of the information currently available on the depth or quality of groundwater beneath the site. Therefore it is not possible to tell the effect that sea level rise may have on the site's groundwater levels, and thus what the risk to site might be.
Wave Run-up		■	Wave run-up is defined as the vertical height above the still water level to which water from an incident wave will run up the face of a structure. Wave activity from water craft in the immediate vicinity of the project site has the potential to augment water levels beyond those discussed in this report. The entire Blackwattle Bay (and adjoining Rozelle Bay) has a 4-knot speed and "No Wash Zone" restriction placed on it, to assist in managing interactions between a 600-berth dry stack storage facility located in the bay as well as super yacht marina, other large powered vessels and local dragon boat and rowing fleets. As a result wave run-up should be minimal. Refer **Figure 12**.

Figure 12 Maritime Speed Limits Imposed by NSW RMS in Blackwattle Bay



8 MITIGATION / ADAPTATION

8.1 Risk Approach

The development currently has its lowest RL's, along the water's edge, above the 100-year ARI event design water level.

By 2030, projected sea level rise and rainfall intensity impact on catchment flooding suggest that the lowest RL's within the facility will lie just below the 5-year ARI event design water level. This can be interpreted as the event that has a 20% chance of exceedance in any one year. This is beyond the normal level of engineering risk usually applied to environmental-related design factors, ie 5%.

It is noted that the higher levels within the facility, which is where all infrastructure (offices, stacking and car parking areas, etc) is located, will be well above the 100-ARI event even for the 2090 climate change scenarios. Risk issues therefore are associated only with the facility's waterfront areas.

The development's design and operation will need to take into consideration the projections for sea level rise and increased peak catchment flooding identified in this report and that appropriate mitigation and/or adaptation measures are implemented.

8.2 Design Factors

The project's sea wall provides the primary defence for the development site against climate change-induced sea level rise and increased peak catchment flooding. Accordingly, the following recommendations are made:

- Develop and construct a "flexible design" whereby in the future the ground RL of the sea wall and immediate foreshore areas at water's edge can be raised above their current +1.5 m AHD level. An increase of 0.2 m would provide a predicted 5% exceedance risk level.
- Ensure, as much as is practicable, that all services (particularly electricity) are located above predicted inundation levels throughout the site. Where these lie below such levels, ensure that they, along with the lower level foreshore areas, can be re-located to higher levels.

8.3 Operational Factors

- On an Annual Basis, review available sea level records in Sydney Harbour to ascertain how actual sea level rise and rainfall intensity is tracking against the various climate change "RCP" scenarios discussed in this report. In recent times, the NSW Government, through NSW Public Works, has been publishing annual reports on NSW harbour and estuary sea levels – the latest report available is October 2016.
    - **Accordingly, develop a Climate Change Adaptation Plan for the proposal to include such ongoing review.**
- As part of the Climate Change Adaptation Plan, ensure that the entity responsible for the site maintains a continuous watch on Bureau of Meteorology severe storm warnings, particularly as time advances towards 2030, to be ready to shut down the facility (at least the low lying water's edge areas) to the Public in the event of an extreme storm and/or rainfall event.
- As the development's sea wall is the primary defence against the climate change-induced sea level rise and catchment flooding increase, it is recommended that the entity responsible for the site monitors the integrity of the sea wall at regular intervals and carries out maintenance to ensure its ongoing defence-related function.
    - **Accordingly, the responsible entity should develop a Sea Wall Maintenance and Management Plan to ensure ongoing risk management of the facility's main inundation feature for actual future sea level rise, any future movements and/or erosion of the seawall, etc.**

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