POLICY TO MANAGE IMPACTS OF CLIMATE CHANGE IN MANUKAU CITY

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Abstract

Manukau City Council, under the Resource Management Act 1991 and the Local Government Act 2002, has the responsibility to promote the sustainable management of natural and physical resources, to avoid or mitigate natural hazards and to have particular regard to the effects of climate change.

Under the Manukau Operative District Plan 2002, Council develops and maintains a set of Engineering Quality Standards (EQS) that outlines the functional requirements and design standards for land development within the city has to comply with. The EQS requires specifically the minimum elevations of finished building site along the coastline to avoid possible coastal inundation.

With the Intergovernmental Panel for Climate Change (IPCC) releasing its Forth Assessment Report in April 2007, confirming that "Warming of the climate system is unequivocal", that sea level rise would continue throughout the 21st century, Council decided to review the current standards on minimum elevations of finished building site to ensure that buildings constructed today can cope with the effects of climate change and sea level rise within their expected useful lives which generally in the spectrum of 50 to 100 years.

Detailed assessment on the variability in astronomical tide levels and storm surge were made along both the Manukau Harbour and Waitemata Harbour coasts. Climate change impacts on Mean High Water Spring and 1% Annual Exceedance Probability water levels were determined for the 2050's and 2080's relative to the present day. For planning purposes a sea-level rise allowance towards the upper end of the IPCC Fourth Assessment Report sea-level rise projections has been adopted.

Key Words:

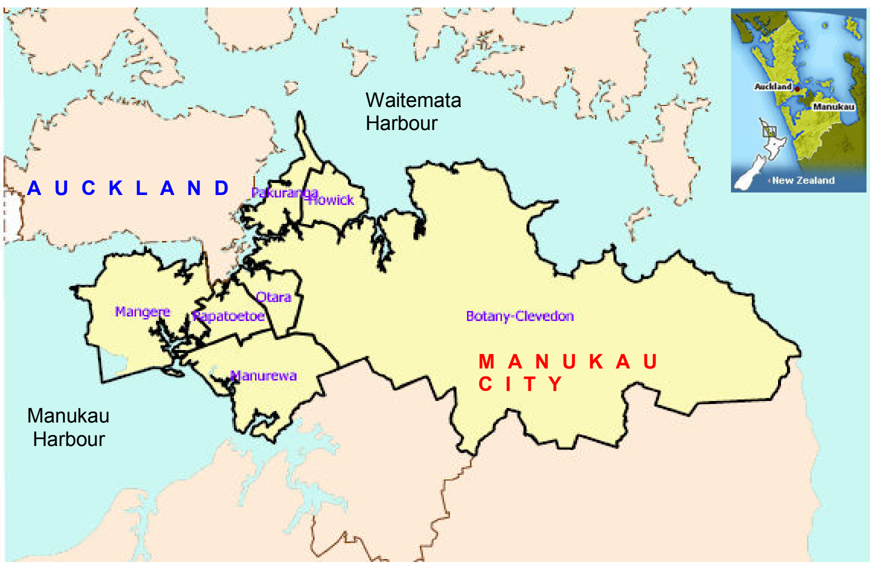
Sea Level - Manukau Harbour - Waitemata Harbour - Engineering Quality Standards – District Plan

1.0 INTRODUCTION

1.1 Background

Manukau City has a population of around 330,000 and is located within the Auckland Region in the North Island of New Zealand. This city has a total area of around 550sq km of which 145sq km has been urbanised and the remainder is rural with several small residential communities located mainly along the coastline.

Manukau is bounded by 320 km of coastline with the Waitemata Harbour to the east and Manukau Harbour to the south (refer to Figure 1 for location)



.Ç North

Figure 1: Manukau City Location Plan

The city has had rapid growth over the last 15 years and there is continued pressure to develop low-lying lands along its coastlines. This is exacerbated due to the high desirability for living along coastlines and increased property prices as key drivers for development. This demand is increasing with migrants from Europe (particularly Britain) who prefer to settle along the coast.

The council through its district plan has previously adopted minimum building floor levels both for the east and west coastlines and developments are required to comply with these to ensure that they have adequate protection against inundation and sea level rise.

The council's current requirements were based on the first IPCC report prepared in 1990 and therefore a review of the sea level rise projections was initiated based on the 2007 IPCC fourth assessment report (AR4). The review was undertaken by the National Institute of Water and Atmospheric Research Ltd (NIWA) on behalf of the Council.

1.2 Purpose and Scope of Study

The purpose of this study was to ensure that the effects of climate change on long-term sea-level rise is adequately incorporated into Council's design procedures and the District Plan requirements.

The terms of reference for the project required the following aspects to be conducted:

- Define key coastal locations in the City and review historical mean sea level, mean high water springs (MHWS) and highest recorded tide for each of the locations.
- Project the sea levels of each key location for year 2050 and 2080. Three scenarios were analysed and sea levels projected for each of the scenarios:
    - Scenario 1: low temperature rise
    - Scenario 2: moderate temperature rise
    - Scenario 3: extreme temperature rise
- Recommend the most appropriate scenario and the minimum floor levels that can be adopted by Council's Engineering Quality Standards.
- Produce maps showing possible future coastal inundation areas of the city that can feed into Council's GIS system.

It should be noted that the study only considered coastal inundation and does not consider flood effects from streams and waterways.

1.3 Council's Existing Requirements

Manukau City's Operative District Plan in Chapter 9 specifies that finished building site levels shall not be less than 0.5m above the following reduced levels (Lands and Survey Datum).

- 3.39m in catchments draining to the Manukau Harbour and
- 2.90m in catchments draining to the Waitemata Harbour.

In addition, minimum freeboard to surface water is required for building floor levels to avoid flooding of properties.

1.4 Components of Sea Level

The main component of sea level is the astronomical tide, which can be predicted accurately many years in advance.

Increasing global sea levels are well linked to global climate change. Measurements of sea-level changes over the last two centuries have primarily come from long-term data from tide gauges mounted on land, supplemented since around 1993 by measurements made by satellites. The longest records suggest that the rate of rise of global sea levels began to increase from around the early to mid-1800's compared with a relatively stable sea level in the preceding century.

Over the 20th century global sea levels have increased by on average 170mm ±50mm. In New Zealand, tide gauge records from four main ports average out to a linear rise in relative mean sea level with respect to the land surface of 1.6 mm/yr (160mm per century) over the 20th century, (Hannah, 2004, and updated to 2006 by NIWA). Figure 1 shows mean annual sea levels recorded at the Port of Auckland (Waitemata) tide gauge since 1900. It is the longest record in New Zealand, with the linear trend of around 1.4 mm/yr up to 2006.

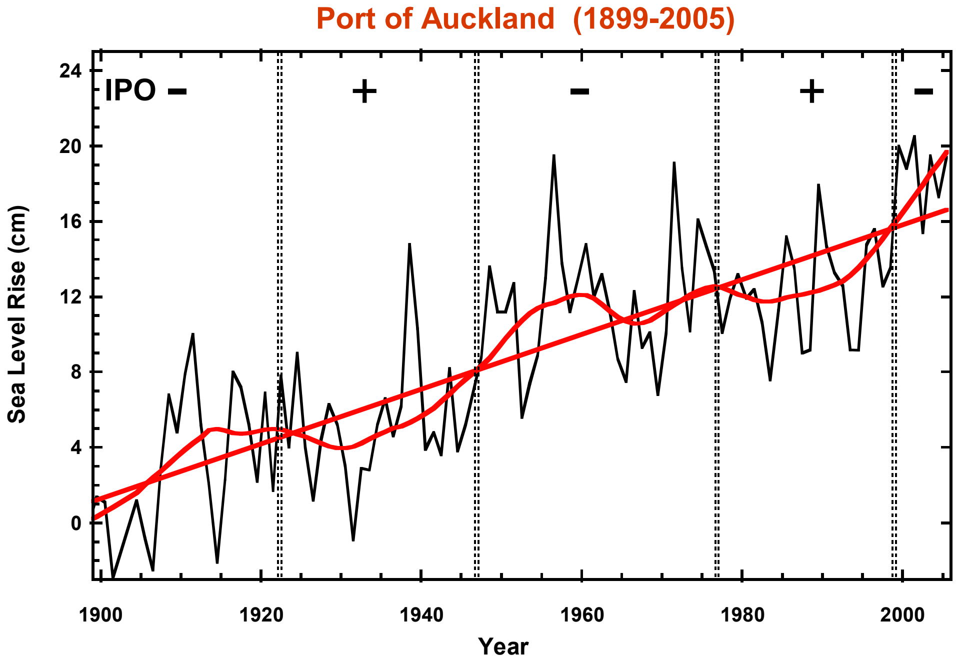


Figure 2: Measured Sea level Data at Port of Auckland.

The rise in annual mean sea level (black line) was recorded at the Port of Auckland gauge over the period 1899 to 2005 relative to the mean level around 1900. The curved line is a weighted running mean showing the influence of the phase of the Interdecadal Pacific Oscillation (IPO) on the average rate of sea-level rise. The long term linear trend of 1.4 mm/yr is shown by the straight red line.

Sea levels will continue to rise over the 21st century and beyond primarily because of thermal expansion within the oceans and loss of ice sheets and glaciers on land. The basic range of projected global sea-level rise estimated in the AR4 is for a rise of 0.18 m to 0.59 m by the decade 2090-2099 (mid 2090's) relative to the average sea level over the period 1980 to 1999, Figure 3. This is based on projections from 17 different Global Climate Models (GCMs) for six different future emission scenarios. The ranges for each emission scenario are 5 to 95% intervals characterising the spread of GCM results (bars on the right-hand side of Figure 3). However, these projections exclude uncertainties in carbon cycle feedbacks and the possibility of faster ice melt from Greenland and West Antarctica ice sheets.

The basic set of projections (light blue shading in Figure 3) include sea-level contributions due to ice flow from Greenland and Antarctica at the rates observed between 1993 to 2003 but it is expected that these rates will increase in the future particularly if greenhouse gas emissions are not reduced. An additional 0.1 to 0.2 m rise in the upper ranges of the emission scenario projections (dark blue shading) would be expected if these ice sheet contributions were to grow linearly with global temperature change. An even larger contribution from these ice sheets, especially from Greenland, over this century cannot be ruled out.

It is important to note that the range of uncertainty in future sea-level rise projections is largely related to different future scenarios of greenhouse gas emissions (based on scenarios of different future socio-economic profiles, energy use, population growth etc) and the differences in projections from the various climate models used for each emission scenario.

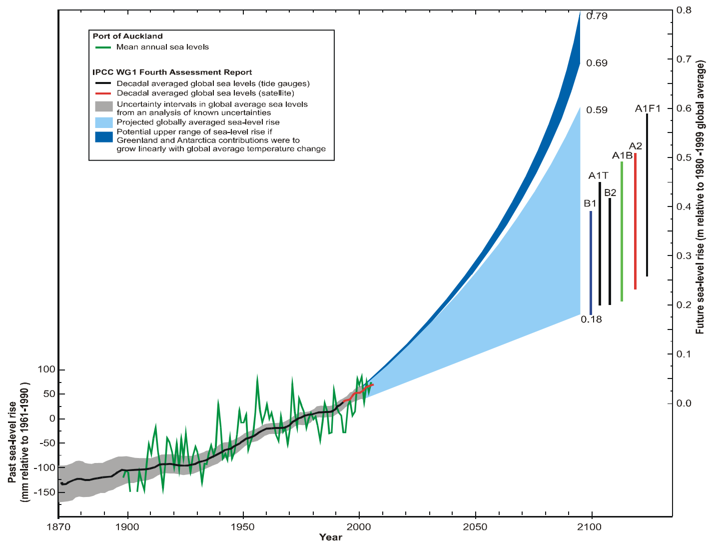


Figure 3: Global mean sea-level rise projections to the mid 2090's and historical sea-level measurements back to 1870.

The black line and grey shading on the left hand side show the decadal averaged global sea levels and associated uncertainty respectively, as measured by tide gauges throughout the world. The red line is the decadal averaged sea levels as measured by satellites since 1993. The green line is the mean annual relative sea level as measured at the Port of Auckland since 1899 (Figure 2). The light blue shading shows the range in projected mean sea level out to the 2090's. The dark blue line shows the potential additional contribution from Greenland and West Antarctica Ice Sheets if contributions to sea-level rise were to grow linearly with global average temperature change. The vertical colour lines on the right-hand side show the range in projections from the various GCM's for six emission scenarios.
The allowance for sea-level rise adopted in the Manukau study followed the recommendations provided by Ministry for Environment (MfE) (2007b), with there being good argument to continue to adopt the global projections provided by the IPCC AR4. For New Zealand the recommendation provided by MfE (2007b) is that:

1. For planning and decision timeframes out to the 2090's (2090-2099) that a minimum sea-level rise of **0.5m relative to the 1980-1999 average** is used along with an assessment of the sensitivity to a possible higher sea-level of up to **0.8m relative to the 1980-1999 average** (to account for a possible high emission scenario and uncertainties associated with increased contribution from Greenland and Antarctica Ice sheets, and possible differences from the global average sea-level rise in the New Zealand region).

2. For planning and decision timeframes beyond 2100 where, as a result of the particular decision, future adaptation options will be limited, an allowance for sea-level rise of **10mm/year beyond 2100** is recommended (in addition to the above recommendation).

    - The timeframes adopted in this study was the 2050's (2040-2060) and 2080's (2070-2090). MfE (2007a) advocates a precautionary approach for incorporating the uncertainty surrounding sea-level rise considerations within development and infrastructure planning.

2.0 ASSESSMENT METHODOLGY

2.1 Introduction

Extreme sea levels were assessed for the both the Manukau Harbour and Waitemata Harbour coasts. This assessment was used to help highlight areas of the Manukau City coastal margins at potential risk from future coastal inundation.

Any assessment of extreme sea levels depends on the availability of long term digital sea-level records with the accuracy of the assessment depending on

1. The quality of the input data, including: (a) the accuracy of the measured or simulated sea-level maxima; and (b) suitable historic coverage—the longer the available record the more reliable the estimates. and
2. The degree of fit between the "true" distribution of the sea levels, and the fitted statistical distribution used to extrapolate to the extreme values.

For the Waitemata Harbour, a high-quality digital dataset was available from the Port of Auckland, from 1974 to present. This 33-year record was sufficiently long to reliably estimate expected 1% AEP levels at that site; and classical extreme-value methods were applied to this dataset in the study. However, for the Manukau Harbour coast, only 4 years of suitable data (2001-2005) was available for the Port of Onehunga (from Ports of Auckland Ltd) which was of insufficient length to reliably extrapolate estimates out to 1% AEP (or 1 in 100 year event), requiring a different type of approach.

Analysis of the sea-level data measured at the two sea-level gauges were analysed to provide extreme sea level estimates at that particular location. However, extreme sea levels do vary along a coastline, particularly in a harbour / estuarine environment such as along both east and west coasts of Manukau City. This is due to both:

- Changes in the tidal amplitude (i.e. in the upper reaches of estuaries and harbours the tide range is higher (amplified) than along the more open sections of coast), and
- Changes in the relative contribution of the storm surge components, particularly related to the wind set-up component of storm surge.

2.2 Port of Auckland Tide Gauge Site

Based of the analysis of the 33 years of digital data from the sea level gauge at the Port of Auckland, and incorporating noted historical measurements during extreme storm tide events back to 1925, Table 1 summarises predicted extreme water levels for the Port of Auckland location for the present day and for the 2050's and 2080's.

AEP (%)	**0.5 (50%)**	**0.2 (20%)**	**0.1 (10%)**	**0.05 (5%)**	**0.02 (2%)**	**0.01 (1%)**	**0.005 (0.5%)**
Present day (m AVD-46)	1.95	2.04	2.09	2.13	2.18	2.23	2.25
2050's (m AVD-46)	2.28	2.37	2.42	2.46	2.51	2.56	2.58
2080's (m AVD-46)	2.61	2.70	2.75	2.79	2.84	2.89	2.91

Table 1: Predicted extreme water levels (excluding waves) associated with a given Annual Exceedance Probability (AEP) at the Port of Auckland AEP

2.3 Manukau Harbour Coast

For the Manukau Harbour due to a short 4 year record the Extreme Value method could not be reliably used. Therefore the unique approach of Monte Carlo modelling was used to simulate annual maxima data.

Table 2 summarises these storm-tide levels for the present day and for the 2050's and 2080's for Ports of Onehunga.

Table 2: Predicted Extreme Water Levels associated with a Given Annual Exceedance Probability at the Port of Onehunga

AEP (%)	**0.5 (50%)**	**0.2 (20%)**	**0.1 (10%)**	**0.05 (5%)**	**0.02 (2%)**	**0.01 (1%)**	**0.005 (0.5%)**
Present day (m AVD-46)	2.57	2.68	2.75	2.81	2.88	2.92	2.97
2050's (m AVD-46)	2.90	3.01	3.08	3.14	3.21	3.25	3.30
2080's (m AVD-46)	3.23	3.34	3.41	3.47	3.54	3.58	3.63

The existing Regional Harbour Model (RHM, DHI, MIKE 21 system) was used by NIWA to provide predictions of water surface elevations along the coastlines of Manukau for each of the climate change scenarios considered. The model was calibrated and was used to simulate for different wind speeds and directions for the three sea levels rise for present, 2050's and 2080's.

3.0 RESULTS AND ANALYSIS

3.1 Predicted Sea levels

From the data sets generated by the harbour model 1% AEP storm-tide level along the coastlines for present, 2050's and 2080's at selected locations could be plotted to check for variability. Figures 4, 5 and 6 show this data and the sea level variability along the Manukau Harbour coastline.

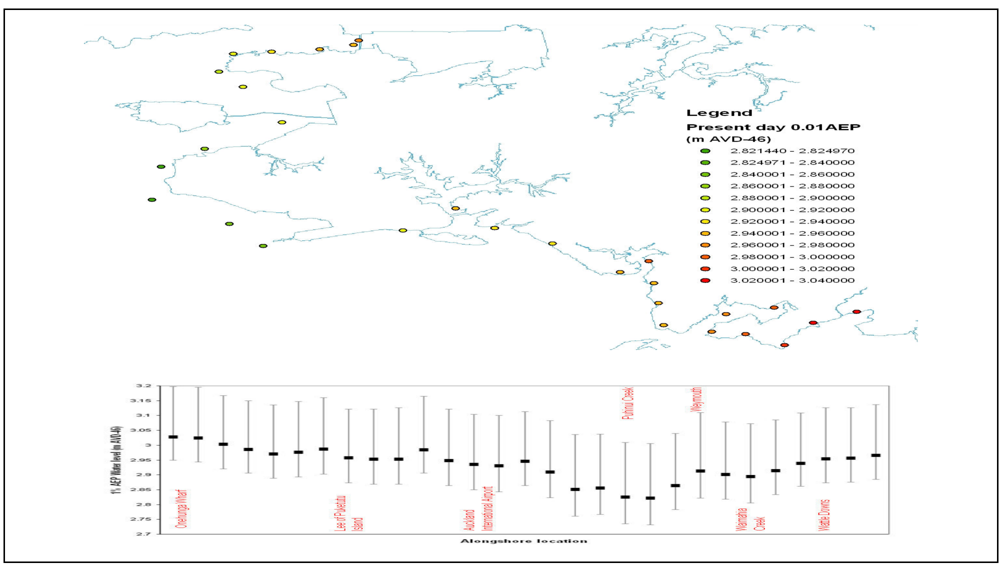


Figure 4: Variation in 1% AEP storm-tide level along the Manukau Harbour coast - present day

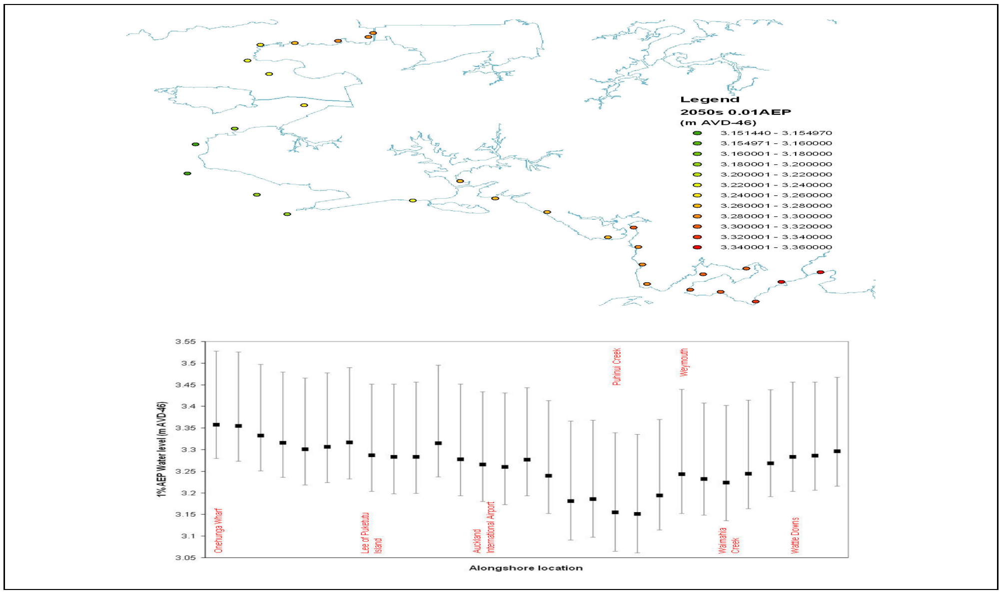


Figure 5: Variation in 1% AEP storm-tide level along the Manukau Harbour coast - 2050's.

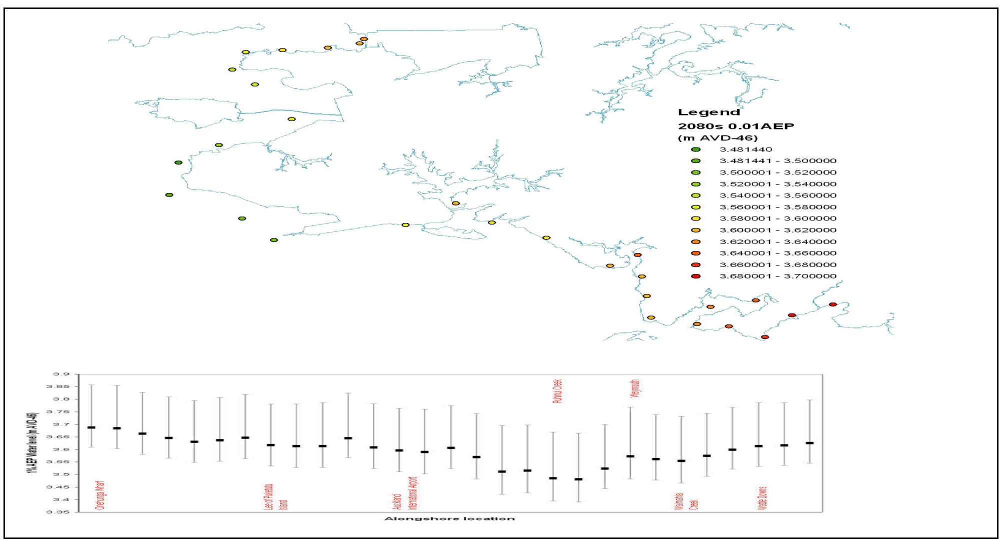


Figure 6: Variation in 1% AEP storm-tide level along the Manukau Harbour coast - 2080's.

Similarly predicted sea level along Waitemata Harbour was also determined for present, 2050's and 2080's.

3.2 Coastal Inundation Areas along the Manukau City Coast

There are a number of areas along the Manukau City coast where coastal inundation occurs at present, typically when a storm surge coincides with a high spring tide.

There are also a number of other low lying areas where coastal inundation is occasionally an issue at present, and may become more of an issue in the future due to sea-level rise. To derive these areas, selection of a representative 1% AEP static water level for both the Waitemata Harbour and Manukau Harbour coasts for the present day, 2050's and 2080's (see Table 4) was made.

Table 4: Representative 1% AEP storm-tide values derived for the Manukau Harbour and Waitemata Harbour coasts of Manukau City.

Period	Manukau Harbour Coast		Waitemata Harbour Coast	
	Alongshore range (m AVD-46)	**Representative value (m AVD-46)**	**Alongshore range (m AVD-46)**	**Representative value (m AVD-46)**
Present day	2.82 – 3.03	3.05	2.18 – 2.40	2.40
2050's	3.15 – 3.36	3.40	2.53 – 2.82	2.85
2080's	3.48 – 3.69	3.70	2.85 – 3.13	3.15

Using the LIDAR data contours corresponding to these levels were plotted. Figures 7, 8 and 9 shows the position of the present day, 2050's and 2080's 1% AEP storm-tide contours for some of the coastal areas of the city.

Figure 7: 1% AEP storm-tide contours for the present day (red), 2050's (green) and 2080's (orange) for the Mangere Bridge area on the Manukau Harbour coast.

Figure 8: 1% AEP storm-tide contours for the present day (red), 2050's (green) and 2080's (orange) for the Bucklands Beach (southern part (left) and northern part (right)).

Figure 9: 1% AEP storm-tide contours for the present day (red), 2050's (green) and 2080's (orange) for Eastern Beach.

3.3 Comparison between Existing EQS Requirements and 1% AEP Storm-tide Predictions

The extreme storm tide levels were used to redefine the requirements for minimum building site levels and freeboard allowances within their Engineering Quality Standards.

The comparison between the existing minimum building site levels and the 1% AEP storm-tide estimates derived for the present day, 2050's and 2080's is shown in Figure 10. This suggests that the generic minimum building site allowance in the Council's existing EQS for both the Waitemata and Manukau Harbour coasts have previously been set with a considerable amount of foresight, with the minimum building site level (without any freeboard) comparable to the static 1% AEP storm tide levels likely to be experienced within the 2050's.

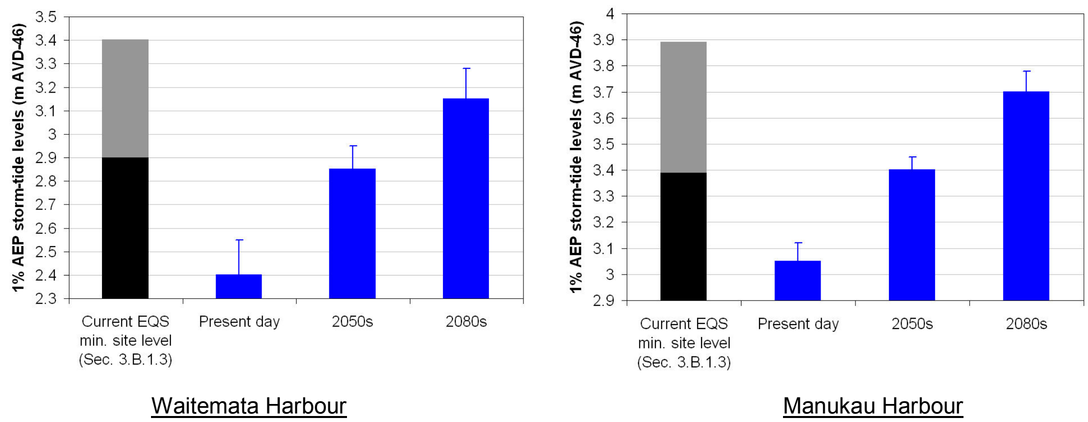


Figure 10: Comparison between existing EQS minimum building site levels with 1% AEP storm tide levels for the present day, 2050's and 2080's

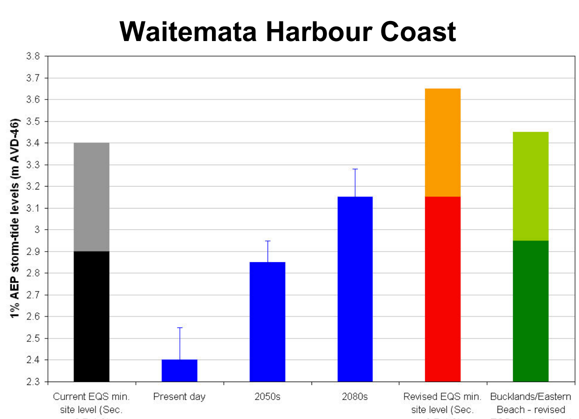
The minimum freeboard specified within the EQS above these levels (0.5m) (grey shading). The error bars on the storm tide predictions show the maximum upper 95% tolerance level anywhere along the respective coasts.

4.0 RECOMMENDED ENGINEERING QUALITY REQUIREMENTS

Based on the consideration of the 1% AEP storm-tide estimates it was recommended the EQS be revised to outline the building site level requirements as follows:

- *The finished building site level shall not be less than 0.5 metres above the following Reduced Levels (Auckland Vertical Datum-46):*
    1. *3.70 m along the Manukau Harbour coastline or catchments draining in to it.*
    2. *3.15 m along the Waitemata Harbour coastline or catchments draining to it with the exception of the Bucklands Beach and Eastern Beach areas where the finished building site level may be reduced to no less than 0.5 m above 2.95 m AVD-46.*
- *Where the design life of the building will not extend beyond 2050 these finished building site levels may be reduced to no less than 0.5 m above the Reduced Levels of 2.85m AVD-46 along the Waitemata Harbour coastline (2.65 m AVD at Bucklands and Eastern Beach), and 3.4 m AVD-46 along the Manukau Harbour coast.*

Figure 11 shows how this compares to the various levels shown in Figure 10. In the context of coastal inundation alone, it is suggested that adequate freeboard is incorporated in the above requirements.



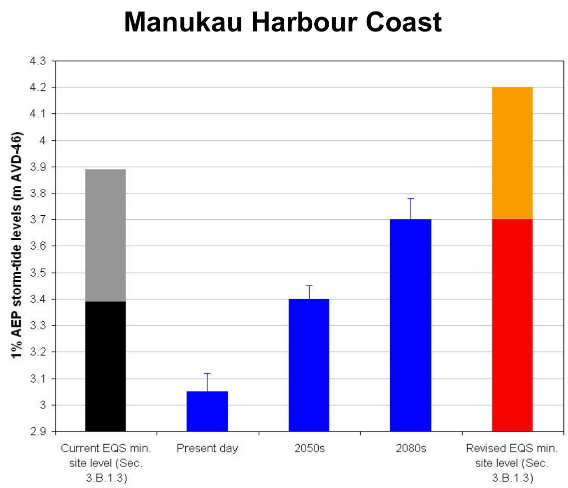


Figure 11: Comparison between existing and the proposed EQS minimum building site levels

5.0 REFERENCES

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