2021 Update to Methodology for Determining Minimum Floor Levels – Final

PREPARED FOR DUNEDIN CITY COUNCIL | APRIL 2022

Stantec

Revision Schedule

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2	14/10/21	Final Draft for Client Review	SL/RO	RO	JC	RO
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Executive Summary

Dunedin City Council is a territorial authority with responsibilities under the Building Act 2004, which includes responsibilities associated with minimum acceptable floor levels of buildings, and the Resource Management Act 1991, which includes responsibilities with respect to natural hazards.

This 2021 Update Report reviews a 2011 methodology to determine minimum acceptable floor levels for buildings in terms of the Building Regulations 1992 for buildings at coastal locations and potentially subject to coastal hazards. The approach taken to prepare this report is the same as in 2011. Credible information sources were reviewed, and their relevant conclusions used. No new research was undertaken.

A core assumption when using this report is that it is for Building Consent purposes only and that all land-use planning requirements are to hand. This is because the rules around land-use approvals may require minimum floor levels higher than the levels given in this report.

A core source of information is the 2017 Ministry for Environment document *"Coastal hazards and climate change: Guidance for local government".*

Sea Level Rise (SLR) will continue for hundreds of years. For rises in the order of 1m, sources reviewed make it clear that it is a matter of 'when, not if'. The 2014 IPCC 5th Assessment Report includes the following statement: 'It is virtually certain that global mean sea-level rise will continue for many centuries beyond 2100, with the amount of rise dependent on future emissions'. This sentiment is repeated in the first Working Group report on the physical science that will form part of the 2022 IPCC 6th Assessment Report.

This report projects results out to the year 2080. This is to meet the DCC's obligation under the Building Act to issue building consents for minimum of a 50-year duration, plus an allowance that the next update of this report is not until 2030.

The methodology defines:

- a 'Base Level', which is the mean level of the sea (MLOS) plus a storm surge height' plus tectonic settlement, and a freeboard height;
- a Climate Change Effects Factor (CCE Factor), which is a minimum allowance for climate change effects, including sea level rise and worsening storm surges; and
- a 'Local Adjustment Factor' (LA Factor), which includes a height adjustment relevant to the local and/or project specific matters such as topography, building usage, the design life of a building, and any mitigating circumstances.

The methodology is summarised graphically in Appendix A.

The level datum used for this update is New Zealand Vertical Datum 2016 (NZVD2016). This is a change from the use of Otago Metric Datum in 2011. This change is to follow best practice that Land Information NZ (LINZ) are promoting, and to recognise that new sea rise research in New Zealand tends to be in terms of NZVD.

Comparing the conclusions of the 2011 and 2021 Minimum Floor Levels reports:

Table 1: Comparison of Levels: 2011 to 2021 (in terms of NVD:2016)

	2011	2021
Mean Sea Level	negative 0.26m	negative 0.25m
Base Level	2.04m	2.34m
Base Level plus CCE factor	2.54m	3.13m

The increase of 590mm since the 2011 Report is comprised:

Increase in mean sea level 2011 -2021	10mm
Allowance for tectonic subsidence	90mm
Increase in freeboard allowance	200mm
Increase in future storm surge	100mm
Increase in sea level to extend prediction to 2080	190mm

For buildings with a design life up to 2080, the recommended minimum value of the Climate Change Effects Factor is 790mm, giving a minimum floor level of 3.13 metres. For buildings with a longer design life, this factor should be increased by at least 10 mm per year for every year the design life extends beyond 2080. This is to be consistent with the Council's Climate Change Policy 2011.

The use of Local Adjustment Factors (LA Factors) is proposed as a necessary refinement to the above values. These Factors recognise that at a specific location sea level influence can be greater or less than the general prediction. The LA Factor is determined by considering other matters, as outlined in this report. These matters include building design life, building classification, topographical effects, Tsunami effects, tidal bore effects, wave run-up, river flooding and backwater effects, settlement due to liquefaction, on-site effluent disposal, and any mitigating circumstances.

It is expected that there will be many circumstances where a LA Factor is required.

Where a LA Factor is not applicable, the Base Level plus the CCE Factor should be adopted as the minimum floor level.

While the review was commissioned specifically to address minimum floor levels in terms of the Building Regulations for areas subject to coastal hazards and particularly sea level inundation, much of the information is relevant more broadly to development that is exposed to coastal hazards.

This 2021 Update report has been prepared to provide DCC with a 10-year methodology, from 2021 to 2030, being the ten-year period this updated methodology will be relied upon by DCC. However, because of the uncertainty about the rate of sea level rise, it is recommended that the methodology is reviewed after each relevant government policy or guideline update, or at least every five years.

The purpose and scope of this 2021 Update report means it is not appropriate to be used directly for determining minimum ground levels, for example in developing a coastal subdivision. Ground levels are subject to further guidelines, such as the NZ Coastal Policy Statement, the City Plan and codes of practice for subdivision.

Abbreviations

AEP	Annual Exceedance Probability
CCE Factor	Climate Change Effects Factor
DCC	Dunedin City Council
IPCC	Intergovernmental Panel on Climate Change
LAF	Local Adjustment Factor
LINZ	Land Information New Zealand
MfE	Ministry for Environment
MHWS	Mean high water spring (refers to tides)
MLOS/MSL	Mean Level of Sea/Mean Sea Level. Synonymous in this report
NZVD:2016	NZ Vertical Datum 2016
ORC	Otago Regional Council
RCP	Representative Concentration Pathway (an IPCC term)
SLR	Sea Level Rise
VLM	Vertical Land Movement

1.0 INTRODUCTION

1.1 PURPOSE

This report provides Dunedin City Council (DCC) with an update to the 2011 Methodology for Determining Minimum Floor Levels. Its purpose is for determining minimum floor levels for building consent applications with respect to sea level.

DCC have requested this 2021 Update Report be prepared to provide a methodology that can be used until the next planned review is undertaken in 2030.

The Dunedin City Council is responsible for residential development at coastal and harbour locations between Waikouaiti and Taieri Mouth. DCC has responsibilities under the Building Act 2004, which includes responsibilities associated with minimum acceptable floor levels of buildings, and the Resource Management Act 1991, which includes responsibilities with respect to natural hazards.

The methodology is used for determining minimum acceptable floor levels for buildings in terms of the Building Regulations 1992 for buildings at coastal locations and potentially subject to coastal hazards.

It is to be applied to building consents after all land use approvals have been granted, i.e, the assumption is that all land use consents are already in place.

1.1.1 Precautionary Principal

The 'precautionary principle' requires an informed but cautious approach to decisions where full information on effects is not available, particularly when effects are potentially significantly adverse and/or where decisions are effectively irreversible.

A precautionary approach is also particularly relevant where effects are of low probability but high potential impact, such as infrequent but devastating storms impacting coastal locations. In this context, it will be necessary to consider the changing frequency of such events.

The 'precautionary principle' is implied in the Resource Management Act and set out in Policy 3 of the New Zealand Coastal Policy Statement (2010).

1.2 BACKGROUND

In 2011, DCC engaged MWH (now Stantec) to identify a methodology for determining suitable minimum floor levels for buildings in order that building consents could be granted. This was to update a process established in the early 1990's.

The methodology was specifically relevant to building consents for habitable spaces (dwellings) at locations where a single dwelling would be permitted without the need for a land use or subdivision consent.

At the time, it was also anticipated that, where a land use or subdivision consent would be required (e.g. within an undersized rural or non- complying residential zoned parcel of land), and the Council would require a site specific assessment of coastal hazards, that the information in the report would be relevant.

The process involved searching out and using the definitive publications on the various aspects relating to sea level and coastal hazard, eg guidelines from MfE on storm surge, DCC policy on sea level rise, etc. The data provided by these publications was then combined to build up a maximum credible sea level.

This 2021 Update follows a similar process.

1.3 LIMITATIONS

1.3.1 Assumption of Prior Land-use Approval

This Minimum Floor Levels report is focused on Building Act requirements and assumes that the land-use planning requirements under the RMA are already complete, as is necessary before gaining a building consent.

1.3.2 Ground Levels and Subdivision

The purpose and scope of this 2021 Update report means it is not appropriate to be used directly for determining minimum ground levels, for example in developing a coastal subdivision. Subdivision is also subject to other legislation and provisions, such as the Resource Management Act and NZS4404 – NZ Standard for Land Development and Subdivision Infrastructure.

There are other factors and guidance that must be taken into account to determine appropriate ground levels, not least, the need for contours and falls to ensure adequate drainage of stormwater and wastewater.

Further, the determination of ground levels will take into account a much longer timeframe than the 50-60 years considered in this report for building consent purposes.

Sections of this report highlight that the NZ Coastal Policy Statement requires consideration of 1.0m of sea level rise, and the DCC 2nd Generation District Plan 1.05m (Policy 2.2.1.4, risk from coastal hazards). These documents have a longer time-frame in mind than the 50 years for a building consent, but for all that, clearly reinforce that sea-level rise in the order of 10mm/year can be anticipated.

The provisions of the NZ Coastal Policy Statement (especially policies 24 and 25) effectively direct a 100-year horizon for land use redevelopment or change in land use, including intensification. In this regard, the MfE2017 document 'Coastal hazards and Climate Change' also recommends (Table 12) minimum SLR allowances.

1.3.3 Additional Allowance for Increased Design Life

The understanding, in preparing this report, is that in issuing a Building Consent the DCC is restricted by the Building Act to consider only a 50-year building life. Building lifespans in Dunedin are commonly longer than 50 years, and therefore become increasingly at risk of ongoing sea level rise.

The Building Act infers a minimum of a 50 yrs life for floor levels in the following provision:

> **B2.3.1** *Building elements* must, with only normal maintenance, continue to satisfy the performance requirements of this code for the lesser of the *specified intended life* of the *building*, if stated, or: (a) the life of the building, being not less than 50 years, if:… ii) Those building elements are difficult to access or replace,

On a building consent the 'Intended Life' is commonly noted as 'Indefinite, not less that 50 years'. This is different from limiting life to <u>no more than</u> 50 years.

If the life of a building is expected to extend beyond 50 years, then an additional allowance for the minimum floor level should be added. An additional allowance will need to be specifically determined on a case-by-case basis. The actual building life and its importance will be factors to take into account.

In the 2011 Minimum Floor Levels report it was noted that MfE (2008a, 2009) advise "*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 10 mm per year beyond 2100 is recommended*.......".

The rate of sea level rise deduced from the Council's Climate Change Policy 2011 is 10 mm per year.

More recent reports are suggesting rates higher than 10mm per year after 2080. For example, the rate given by the IPCC's RCP8.5 projections beyond 2080, are in the order of 12mm/year, as are SLR rates given by MfE (refer 2.2.4).

1.4 RISKS

A full risk assessment has not been undertaken as part of this report. However some key risks were apparent in preparing the report.

1.4.1 Longer Building Life

Under the Limitations section above, it is noted that in issuing a Building Consent DCC consider only a 50 year building life. Buildings frequently have a longer life, and when this is the case their floor level will become increasingly at risk of further (and inevitable) sea level rise.

It is recommended that DCC establish a method for mitigating the risk where there is a realistic expectation of a life greater than 50 years. Provisions might range from an addition to the minimum floor level through to a note on the title.

Both the International Panel for Climate Change (IPCC) and the Ministry for Environment (MfE) are clear that for sea level rises of the scale discussed in this Update Report, it is a matter of 'when, not if' they occur.

1.4.2 Uncertainties in Predictions

Predictions of sea level rise, and climate change effects (eg by IPCC and MfE) rely on information from models. These models have inherent uncertainty and lack sufficient real-life events to properly calibrate them. Predictions also make assumptions regarding how well the world moves to carbon neutrality. These same reports do not discount that sea level rise may be more rapid than predicted, ie low-likelihood, high-impact scenarios.

This report adopts relatively conservative assumptions. Beyond that, there is still a risk that worse-case outcomes eventuate.

1.4.3 Lack of Use of Local Adjustment Factors (LAFs)

This Minimum Floor Levels report allows for LAFs to be used on a case-by-case basis to add or subtract additional allowance for floor level, based on site specific conditions. Presently there is a shortage of information to support LAFs, leading to a tendency to use them less, rather than more. Some circumstances that might warrant a LAF may also change with time, such as building use.

1.5 UPDATING THE 2011 REPORT

The following steps have been undertaken to update the 2011 report and guidance:

a. Search and review relevant resources to identify where there are references that might affect the current assessment and methodology.
b. Determine the effect of these changes on the current estimates.
c. Make the best assessment possible on how this will impact current minimum floor levels and document the logic behind this assessment.
d. Meet with the DCC Building Services Manager to outline findings to date and, in particular, the likely changes to the current minimum floor level guidance.
e. Prepare a draft Update Report with revised guidance
f. Finalise updated report and guidance for subsequent DCC review and input.

The 2011 methodology developed a methodology for determining a minimum floor level in terms of three key components, and this is continued in this Update Report:

1. A 'Base Level', which is the mean level of the sea (MLOS) plus a storm surge height plus a freeboard height;
2. Adding a Climate Change Effects Factor (CCE Factor), which is a minimum allowance for climate change effects, including sea level rise; uncertainty in predictions and increasing storm surge.
3. 'Local Adjustment Factor' (LA Factor), to include height adjustments relevant to the local and/or project specific matters such as topography, building usage, the design life of a building, and any mitigating circumstances.

This 2021 Update continues the use of the same three groupings, with the addition of one further element to the 'Base Level' - Vertical Land Movement (VLM). Accumulation of satellite survey information, and its analysis over the last 10 years, has allowed a prediction to be included for the trend in tectonic settlement (or VLM) in Dunedin.

1.6 NZ SEARISE PROGRAMME

The NZ SeaRise Programme www.searise.nz has commenced in recent years and is a particular programme to keep aware of. It is collating a lot of the research and conclusions that are specific to New Zealand and potential overtake the MfE guidance documents as the first source of information. The program states:

> *NZ SeaRise brings together 30 local and international experts to improve predictions of sea-level rise in New Zealand. Our data will be incorporated into the next Ministry for the Environment report on coastal hazards and climate change. From 2021, we will share detailed maps and models, based on different global sea-level rise scenarios. This will provide more accurate and reliable information, crucial for council and government planners and be freely available to the public.*

2.0 RESEARCH

2.1 LEGISLATION

2.1.1 Building Act

Under Section 72 of the Building Act 2004, the Dunedin City Council (DCC) must issue building consents on land that is at risk from coastal hazards, or any other hazard, provided that the building complies with the Building Code and that the building itself does not accelerate, or worsen, or extend the hazard to another property (MfE, 2008a). (*Consent under Section 72 does require that an entry is to be made on the relevant certificate of title in accordance with Sections 73 and 74 of the Act*).

Section 71 of the Building Act requires the Council to refuse a building consent if the following applies: the land is subject to one or more natural hazards; or the building work is likely to accelerate, worsen or result in a natural hazard on that land or any other property – unless adequate provision has been or will be made to protect the land, the building work, or other property from the natural hazard (Building Act 2004).

The Second Generation District Plan (2GP, see policy 2.2.1.4) requires that the plan 'identifies areas at risk from coastal hazards' and provides a 'Hazard 3 (coastal) Overlay Zone'. In preparing this Update Report, no check has been made to see if the current 2GP overlay includes all areas at risk from Coastal Hazard.

2.1.2 Building Regulations

2.1.2.1 Surface Water and Freeboard

NZ Building Regulations (Clause E1 Surface Water) requires buildings and site work to be constructed to protect people and other property from the adverse effects of surface water.

Clause E1.3.2 states that*: "Surface water, resulting from an event having a 2% probability of occurring annually, shall not enter buildings"*. The associated clause E1/VM1 promotes a freeboard of 500mm, and this is largely consistent with NZS4404:2010 NZ Standard for Land Development and Subdivision Infrastructure.

<u>A 500mm freeboard is adopted in this report</u>. This has been confirmed by DCC and is based on the assessment of the Building Act and other requirements. A more detailed analysis is included in Appendix F.

We also note the Building Industry Authority Determination 99/005 (Appendix F) that referred to a 500mm freeboard above a 1% Annual Exceedance Probability (AEP) flood level. Researching the specific circumstances of this determination is outside of the scope of this report, other than to note that there are times when different freeboard values are appropriate.

2.1.2.2 Building Life

The Building Regulations (Clause B.2: Durability) require building elements to function for not less than 50 years.

2.1.3 Resource Management Act 1991

Subdivision and land use consent is dealt with under the Resource Management Act (1991).

Section 7 *Other matters* of the RMA includes that**:**

> *In achieving the purpose of this Act, all persons exercising functions and powers under it, in relation to managing the use, development, and protection of natural and physical resources, shall have particular regard to—*
>
> *(i) the effects of climate change*:

Section 106 of the RMA requires the Council to review natural hazards when assessing subdivision consent applications. It is consistent with s71 of Building Act. Subdivision applications at coastal (including harbour and estuarine) locations should therefore include a more detailed assessment of coastal hazards than will result from this review of minimum floor levels. Where a land use consent is required to build, then a more detailed hazard assessment may similarly be required.

2.1.3.1 New Zealand Coastal Policy Statement 2010

The provisions of the NZ Coastal Policy Statement (especially policies 24 and 25) effectively direct a 100-year horizon for land use redevelopment or change in land use, including intensification. It requires an assessment of hazards and risk, and encourages avoiding risks. While land-use consenting is not the same as a building consent, the guidance is worth noting.

With regard to building developments, policy 25(a-b) is particularly relevant:

> ***Subdivision, use, and development in areas of coastal hazard risk***
> *In areas potentially affected by coastal hazards over at least the next 100 years:*
> *(a) avoid increasing the risk of social, environmental and economic harm from coastal hazards;*
> *(b) avoid redevelopment, or change in land use, that would increase the risk of adverse effects from coastal hazards;*

Regional Policy Statements and Plans that arise from the NZCPS have not been reviewed.

2.1.3.2 Environment Court Decision

No research of Environment Court decisions has been undertaken, but it is noted an Environment Court decision on a zone change application (ref. W029/06) referred to a 100 year timeframe when considering coastal issues and the above BIA determination similarly identified that timeframe for hazard mitigation.

Thus, building elements should be designed to function for a period of greater than 50 years, and such a period may be 100 years or more.

2.1.3.3 DCC Second Generation District Plan

The DCC 2nd Generation District Plan, Policy 2.2.1.4, states:

> *Identify areas at risk from coastal hazards, and include these as follows:*
> *a. in the dune system mapped area, include undeveloped dune systems that may be vulnerable to, or buffer adjacent areas from, coastal processes including erosion, inundation from the sea and sea level rise.*
> *b. in the Hazard 3 (coastal) Overlay Zone, include areas where there may be ponding of water, including where it is from poor drainage caused by connectivity of groundwater with the sea and inundation from the sea. In these areas there is a low risk to property and to the safe and efficient operation of on-site wastewater disposal. This includes areas where the risk from these hazards will worsen over time due to the effects of climate change, taking into account a 1.05m sea level rise.*

The basis of this policy has not been investigation as part of the review.

2.2 RELEVANT POLICY AND GUIDELINES

2.2.1 Council Climate Change Predications Policy 2011

The Dunedin City Council adopted a Climate Change Predictions Policy in September 2011 (see Appendix I). There has been no update to this policy since that time.

As shown below, the 2011 policy includes sea level rise predictions of 0.3m from 2010 up to 2040, and 0.8 – 1.6m up to 2090. The range in later years is likely to take into account increasing uncertainty over the longer timeframe.

Projection	2040	2050	2090	2100
2011 policy	0.3m	-	0.8 – 1.6m	-

The sea level rise prediction trend in this policy is an increase of 10 mm each year, between 2040 and 2090 (taken at the lower end of the 2090 range).

For clarity, for the year 2080, the 2011 Policy predicts a rise of 300mm from 2010 to 2040, plus 40 years at 10mm per annum - a total of 700mm to 2080. From this can be deducted the 10mm rise of the mean level of the sea (MLOS) that LINZ has recorded in the Otago Harbour over the last 10 years. <u>This gives a sea rise projection of 690mm from the date of this Update report to 2080</u>.

The sections below discuss how DCC's policy of 10mm per annum compares with IPCC projections.

2.2.2 Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report (2014)

The IPCC was jointly established in 1988 by the World Meteorological Organisation (WMO) and the United Nations Environment Programme (UNEP). The IPCC undertakes regular assessments of the current state of knowledge about climate change. Research, including projections of global sea level rise. The 2011 methodology cited a recommendation of the IPCC to adopt a sea level rise number of 10mm per annum for planning beyond 2100.

The IPCC Fifth Assessment Report in 2014 (IPCC AR5) sets out long term emissions scenarios to assist governments to form appropriate adaptation and mitigation responses to the threat of human-induced climate change. The scenarios are not predictions of what the future will be; they are a plausible description of how the future might unfold, due to different types of uncertainty and in particular, the future global emissions pathway and emergence of polar ice sheet instabilities.

The projected rises in sea level that the IPCC assessed as 'likely' under the lowest and highest of these scenarios are shown in Figure 1. The purple band is projected rise in sea level under the 'Stringent mitigation' scenario (RCP2.6) and the orange band shows projected rise in sea level under the 'Very high greenhouse gas emissions' scenario (RCP8.5). The relationship to the two bands, relating to moderate emission-mitigation, are shown on the right of the graph.

A Representative Concentration Pathway (RCP) is a greenhouse gas concentration (not emissions) trajectory adopted by the IPCC. Four pathways were used for climate modelling and research in IPCC AR5 (see Figure 1). The pathways describe different climate futures, all of which are considered possible depending on the volume of greenhouse gases (GHG) emitted in the years to come. The RCPs – originally RCP2.6, RCP4.5, RCP6, and RCP8.5 – are named after a possible range of radiative forcing values in the year 2100 (2.6, 4.5, 6, and 8.5 W/m^2, respectively).

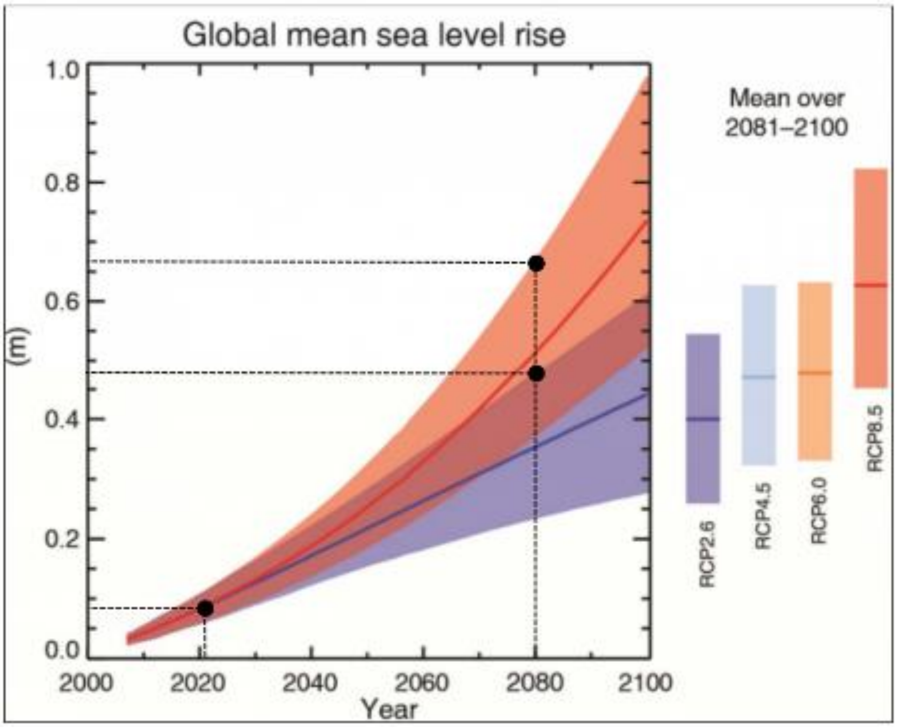


Figure 1: Intergovernmental Panel on Climate Change Fifth Assessment Report projections of global average mean sea level (MSL) rise (metres, relative to a base MSL of 1986–2005) covering the range of scenarios from RCP2.6 to RCP8.5

The above graph for RCP8.5 predicts a rise between 2021 and 2080 of between 0.39m and 0.57m. For the same period, DCC's sea level rise policy of 690mm (Appendix I) is conservative.

Sea level is not expected to rise uniformly over the globe - there are many factors, some which vary over time, that cause local variations. Discussing these factors is outside the scope of this Update Report.

2.2.3 IPCC 6th Assessment Report (2021)

The Sixth Assessment Report (AR6) of the United Nations ICCP was released in August 2021. Three working groups plan to publish reports, with the first of the three working groups publishing *The Physical Science Basis of Climate Change* on 9 August 2021. The other two are planned for 2022 and a final synthesis report is due to be finished by late 2022.

The general tone of first working report suggests that RCP8.5 is appropriate. It also comments that "In the longer term, sea level is committed to rise for centuries to millennia…"

Once the full IPCC 6th Assessment synthesis report is completed in 2022 it should be reviewed to see if any changes to DCC's Minimum Floor Levels are required.

The 6th report introduced a 'low likelihood, high impact storyline', as illustrated below, giving about 0.95m SLR between 2021 and 2080. This is a development of the 'H+' scenario in the IPCC 5th report, but with predictions of greater sea level rise. This value has not been used in this 2021 DCC Update for minimum floor levels, but highlights the risk of sea level rise greater than RCP8.5 due to the uncertainty in predictions.

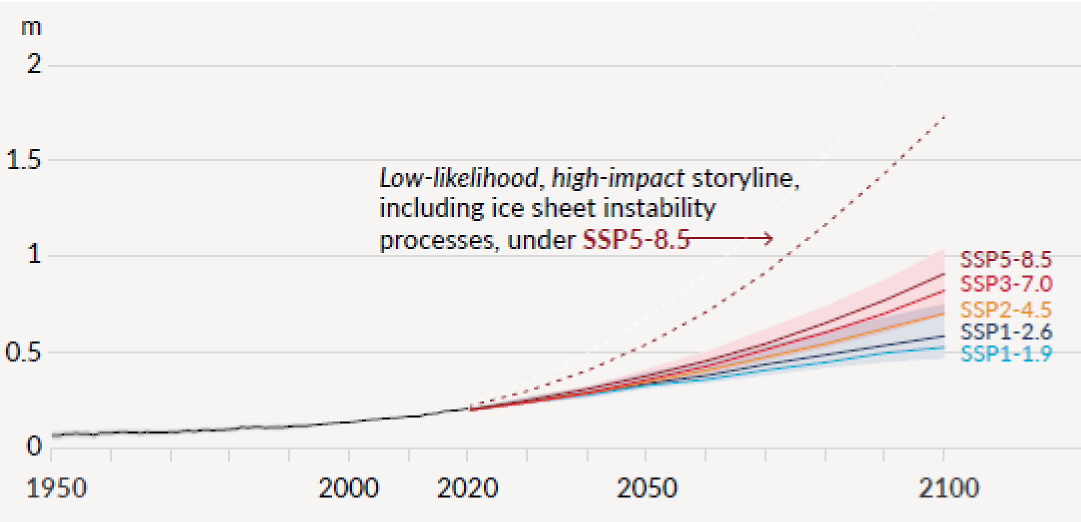


Figure 2: Global mean sea level change relative to 1900 (IPCC Physical Science Basis for 6th report 2021, page 29)

2.2.4 Coastal azards and climate change: Guidance for local government, Ministry for the Environment (2017)

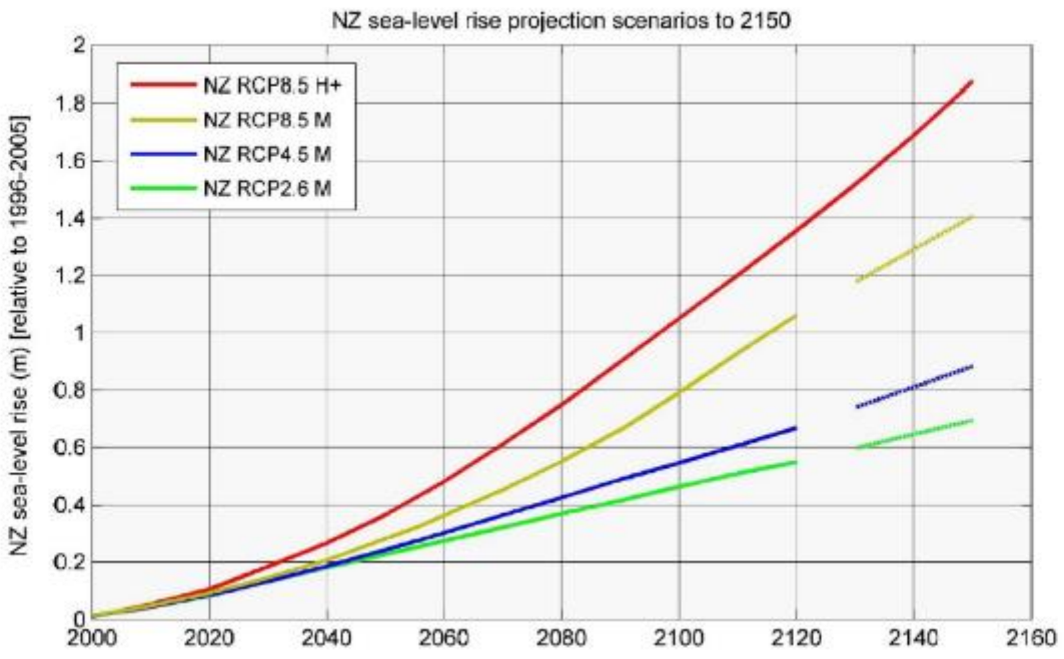
The Ministry for the Environment (MfE) undertook a major revision of its 2008/09 guidance, to include the findings and projections of the IPCC Fifth Assessment Report. Previous guidance (Ministry for the Environment, 2008a) adopted a risk-based approach, advising users to start assessments of a range of higher sea levels at a base level of 0.5 metres and at least consider 0.8 metres by the 2090s, with an extension beyond 2100 applying a rate of 10 mm/yr.

MfE's *Coastal hazards and climate change: Guidance for local government (2017)* is the current New Zealand guidance. The 2017 guidance takes a different approach because of the uncertainty about future changes in climate.

In line with IPCC Fifth Assessment Report, four scenarios have been developed for New Zealand to cover a range of possible sea-level futures:

1. a low to eventual net-zero emission scenario (RCP2.6)
2. an intermediate-low scenario based on the RCP4.5 median projections
3. a scenario with continuing high emissions, based on the RCP8.5 median projections

4. a higher H+ scenario, taking into account possible instabilities in polar ice sheets, based on the RCP8.5 (upper end of "likely range" or 83rd percentile, used by IPCC) projections (provided primarily for stress-testing where risk tolerance is low and/or future adaptation options are limited).



New Zealand scenario trajectories are out to 2120 (covering a minimum planning timeframe of at least 100 years), and the NZ H^+ scenario trajectory is out to 2150 from Kopp et al (2014) (K14). No further extrapolation of the Intergovernmental Panel on Climate Change-based scenarios beyond 2120 was possible, hence the rate of rise for K14 median projections for RCP2.6, RCP4.5 and RCP8.5 are shown as dashed lines from 2130, to provide extended projections to 2150. Note: all scenarios include a small sea-level rise (SLR) offset from the global mean SLR for the regional sea around New Zealand.

Figure 3: Four scenarios of New Zealand-wide regional sea-level rise projections (with extensions to 2150 based on Kopp et al, 2014) (Source: MfE 2017, page 105)

NZ SLR scenario Year	NZ RCP2.6 M (median) [m]	NZ RCP4.5 M (median) [m]	NZ RCP8.5 M (median) [m]	NZ RCP8.5 H+ (83rd percentile) [m]
1986–2005	0	0	0	0
2020	0.08	0.08	0.09	0.11
2030	0.13	0.13	0.15	0.18
2040	0.18	0.19	0.21	0.27
2050	0.23	0.24	0.28	0.37
2060	0.27	0.30	0.36	0.48
2070	0.32	0.36	0.45	0.61
2080	0.37	0.42	0.55	0.75
2090	0.42	0.49	0.67	0.90
2100	0.46	0.55	0.79	1.05
2110	0.51	0.61	0.93	1.20
2120	0.55	0.67	1.06	1.36
2130	0.60*	0.74*	1.18*	1.52
2140	0.65*	0.81*	1.29*	1.69
2150	0.69*	0.88*	1.41*	1.88

* Extended set 2130–50 based on applying the same rate of rise of the relevant representative concentration pathway (RCP) median trajectories from Kopp et al, 2014 (K14) to the end values of the Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC AR5) projections. Columns 2, 3, 4: based on IPCC AR5 (Church et al, 2013a); and column 5: New Zealand RCP8.5 H+ scenario (83rd percentile, from Kopp et al, 2014). Note: M = median; m = metres; NZ = New Zealand; SLR = sea-level rise. To determine the local SLR, a further component for persistent vertical land movement may need to be added (subsidence) or subtracted (uplift).

Figure 4: Decadal increments for projections of sea-level rise (metres above 1986–2005 baseline) for the wider New Zealand region (Source: MfE 2017, page 106)

MfE reinforces the point made by IPCC in their 5th (2014) and 6th (2021) Reports that SLR will continue for hundreds of years. The reports make it clear that, for rises in the order of 1m, it is a matter of ‘when’ not ‘if’. Figure 5 is from the MfE 2017 report (Table 11, page 07). It indicated the earliest and latest likely timeframes for a given SLR to occur.

SLR (metres)	Year achieved for RCP8.5 H+ (83%ile)	Year achieved for RCP8.5 (median)	Year achieved for RCP4.5 (median)	Year achieved for RCP2.6 (median)
0.3	2045	2050	2060	2070
0.4	2055	2065	2075	2090
0.5	2060	2075	2090	2110
0.6	2070	2085	2110	2130
0.7	2075	2090	2125	2155
0.8	2085	2100	2140	2175
0.9	2090	2110	2155	2200
1.0	2100	2115	2170	>2200
1.2	2110	2130	2200	>2200
1.5	2130	2160	>2200	>2200
1.8	2145	2180	>2200	>2200
1.9	2150	2195	>2200	>2200

The earliest year listed is based on the RCP8.5 (83rd percentile) or H+ projection and the next three columns are based on the New Zealand median scenarios in figure 27, with the latest possible year assumed to be from a scenario following RCP2.6 (median). Note: the year for achieving the sea-level rise is listed to the nearest five-year value.

Figure 5: Approximate years, from possible earliest to latest, when specific sea-level rise increments (metres above 1986–2005 baseline) could be reached for various projection scenarios of sea-level rise for the wider New Zealand region

MfE notes the difficultly of deriving a single value for SLR to apply nationally, given the wide range of sea-level trajectories into next century and the risk that this can lead to a rigid predetermination of the future if planning is based solely on a single value. For use in land use planning processes, the MfE guidance (s5.6) does provide a minimum transitional sea level rise allowance (table 12, page 108) for four categories of activities or types of development. *Category C* generally covers existing development, which the MfE guidance notes is the most challenging for adaptation.

The minimum transitional NZ wide SLR allowance for land use planning controls for existing coastal development and asset planning is 1.0 m SLR in 100 years. This corresponds to equivalent values in the MfE2008 guidance. The continued use of 1 metre SLR in 100 years in risk assessments (equivalent to 0.8 metres by 2090s from Ministry for the Environment (2008a) reflects coastal hazard risk typically peaking above a mid-range, or the ‘most likely’ SLR, and positioned more towards the higher end of the SLR projection range between NZ RCP4.5 M and NZ RCP8.5 M. The application of a sea-level rise of 1 metre over a 100-year planning timeframe for existing development is also consistent with other international coastal planning guidelines

DCC’s current 2011 sea level rise policy gives a lower bound of a 1m rise over 100 years, as a linear progression of 10mm per year.

2.3 APPLIED RESEARCH

2.3.1 Otago Regional Council Storm Surge Modelling Study (NIWA 2008)

This study was commissioned by the Otago Regional Council. It considered nine locations within Dunedin's territory, at risk due to extreme sea levels with a combination of tide, storm surge, wave set-up and wave run-up.

The report noted the significant range in storm surge levels predicted along the Otago coast and the significant added effect of wave run-up at some locations. Karitane, Purakanui, Long Beach, and Taieri Mouth were identified as low lying and at greater risk from the overall effects of storm surges. Unlike tsunami events, storm surges were not likely to have sufficient energy to travel up river or overland to any extent.

The report tabulated storm surge values for 100 and 500 year return period events at the specified locations as well as the average and maximum wave run-up values at the same locations.

	Return Period			
Location	20 Years	50 Years	100 Years	500 Years
Tautuku	1.85	1.91	1.95	2.06
Papatowai	1.78	1.84	1.89	2.00
Catlins	1.77	1.83	1.87	1.99
Kaka Point	1.75	1.81	1.86	1.97
Clutha	2.01	2.08	2.14	2.25
Toko Mouth	2.36	2.45	2.50	2.63
Taieri Mouth	1.79	1.86	1.90	2.01
Brighton	1.87	1.94	1.98	2.09
Kaikorai	1.82	1.88	1.93	2.04
South Dunedin	1.83	1.90	1.94	2.05
Dunedin Harbour	1.66	1.73	1.79	1.91
Long Beach	1.57	1.63	1.68	1.80
Purakanui	1.58	1.64	1.69	1.80
Warrington	1.55	1.61	1.66	1.78
Karitane	1.64	1.71	1.75	1.86
Moeraki	1.60	1.67	1.71	1.83
Hampden	1.84	1.91	1.96	2.07
Kakanui	1.96	2.03	2.08	2.20
Oamaru	2.01	2.08	2.14	2.26

Figure 6: Predicted extreme sea levels (m above MLOS) for four return periods (Source: NIWA 2008, table 3.1, page 23)

This 2021 Update Report adopts a storm surge height of 2.0m. This is for a surge that could happen at any time and is unchanged from the 2011 Minimum Floor Levels Report. An allowance for worsening storm surge is discussed in section 5.3.

Included in the NIWA report are figures for the nine locations within the Dunedin City boundary (refer Figure 6) showing for various return periods the extent of inundation.

The NIWA report noted that it did not include for potential dune erosion when considering the risk of inundation in South Dunedin.

Local Adjustment Factors separately account for wave run-up, and values range from 0.22 metres north of the Dunedin Peninsula to 0.47 metres south of the Peninsula. For inclusion in the Local Adjustment Factor we recommend using the geographically closest NIWA figure unless specific topographical features warrant a more detailed assessment of this factor.

2.3.2 Vertical Land Movement

Vertical Land Movement (VLM) is the rise or settlement of land.

Vertical land movement is discussed in MfE's *Coastal hazards and climate change: Guidance for local government (2017)*. The information is provided to support users of the guidance with knowledge on why and how local sea-level rise around New Zealand is affected by vertical land movement. The Guidance notes the presence of significant ongoing subsidence of the landmass, which will exacerbate the absolute ocean sea-level rise and suggests that future projections of sea-level rise at some locations or regions in New Zealand may also need to factor in estimates of ongoing vertical land movement.

Paul Denys of the Otago University Survey School provided information regarding the latest research into Vertical Land Movement. The principal paper that provides information for the Dunedin area is *"Sea Level Rise in New Zealand: The Effect of Vertical Land Motion on Century-Long Tide Gauge Records in a Tectonically Active Region"* (2019), authored by Paul H. Denys[1], R. John Beavan[2], John Hannah[1], Chris F. Pearson[1], Neville Palmer[2] Mike Denham[1], and Sigrun Hreinsdottir[2].

This paper concludes that in the Dunedin area, tectonic settlement is generally occurring. It varies depending upon location, generally in the region of 1 – 2mm per year. Paul Denys, of the Otago University Survey School comments (email 29 July to Stantec):

> *The current rates, which will be different compared to the paper [referenced above] due to a combination of longer time series plus the Kaikoura 2016 earthquake event will result in different vertical rates. My current estimates are:*
>
> *DUND -2.5 mm/yr (site on Otago Peninsular, close to radio towers)*
> *OUSD -1.5 mm/yr (School Surveying, corner Frederick and Castle streets)*
> *DUNT -0.85 mm/yr (Port Chalmers harbor)*
>
> *Without doing an error analysis etc, I would suggest subsidence in the range of 1-2 mm/yr.*

This 2021 Update Report adopts a VLM of minus 1.5mm per annum (ie the land is settling, not rising).

[1] 1School of Surveying, University of Otago, Dunedin, New Zealand
[2] GNS Science, Lower Hutt, New Zealand

2.4 OTHER RESEARCH

2.4.1 Otago Climate Change Risk Assessment (Tonkin and Taylor, 2021)

This report outlines the findings of the first Otago Climate Change Risk Assessment (OCCRA) that has been developed by Otago Regional Council (ORC). It provides a wide-ranging regional snapshot of the effects on the region and its infrastructure of current and future climate scenarios and details the highest ranked climate change related risks for the region.

The report discusses IPCC's RCP8.5 as a 'high end' or in some cases, a 'business as usual' emissions scenario, with global greenhouse gas emissions continuing at current rates and if a significant reduction in emissions does not occur.

The report notes that changes in the marine environment under the RCP8.5 scenario include increasing mean sea level and larger storm surges. The report predicts that storm surges, waves, wind, and the frequency and intensity of storms will all be affected by climate change. These, combined with sea level rise, will generate increasing extreme high water levels along the coast of Otago.

The report also notes that sea level rise will worsen the effect of flooding in some areas (eg the Taieri Plains), reinforcing the need for the Local Adjustment Factors proposed in this Minimum Floor Levels Report.

2.4.2 Climate Change Projections for Otago (NIWA, 2019)

This Otago Regional Council commissioned report analyses projected climate changes for the Otago Region. This report addresses expected changes for various climate variables out to 2100, drawing heavily on climate model simulations from the IPCC Fifth Assessment Report. Hydrological impacts of climate change are also assessed, and key findings focus on temperature change, extreme rainfall, and annual flow rates and floods.

The report does not present data directly useable for this Minimum Floor Levels Report.

2.4.3 NIWA Zone 5 (2019)[3]

This report presents a regional snapshot of projected climate changes and hazards. Zone 5 comprises of eastern South Island from Kaikōura to Owaka (South Otago) and includes Central Otago and the MacKenzie Basin including Lakes Tekapo to Ōhau to the east of the Southern Alps. Includes the West Coast, inland Otago and Southland

The report provides coastal and estuarine flooding: increasing persistence, frequency and magnitude, 2040 & 2090 for RCP 4.5 and RCP8.5 scenarios. The data used is a compilation of reviews of existing scientific papers and reports to provide a high-level snapshot of the projected changes for the National Climate Change Risk Assessment (NCCRA). The seventeen hazards are those selected in the NCCRA, and do not present an exhaustive list of climate change hazards.

The report does not present data directly useable for this Minimum Floor Levels Report.

2.4.4 Natural Hazards of South Dunedin (ORC, 2016)

Report discusses a wide range of factors which can influence flood hazard in South Dunedin, and that future changes in mean sea level, climate and groundwater level are the processes most likely to exacerbate the effects of this hazard. The report mainly provides a description of the environmental and community setting of South Dunedin and does not present data directly useable for this Minimum Floor Levels Report.

However, the report does discuss changes in land surface elevation and research lead by Paul Denys from the University of Otago School of Surveying. The most up-to-date research available on Changes in land surface elevation, from University of Otago School of Surveying is referenced in 2.3.2 above.

[3] Available at: https://niwa.co.nz/adaptationtoolbox/regionalprojections/zone5

2.4.5 Preparing New Zealand for Rising Seas: Certainty and Uncertainty (PCE, 2015)

This Parliamentary Commissioner for the Environment report is written in the context of certainty that the sea is rising and uncertain of how rapidly it will rise, how different coastal areas will be affected, and how New Zealand should prepare. It follows on from a 2014 PCE report, 'Changing climate and rising seas: Understanding the science' which was written to make the science of climate change, and specifically sea level rise, accessible and relevant for New Zealanders.

This 2015 report identifies problems with, and gaps in, the direction and guidance provided by central government for councils and calls for a major review. It focuses on adaptation planning and is a direct driver for the MfE 2017 guidance, concluding with a number of direct recommendations to Minister for the Environment to update direction and guidance.

The report does not present data directly useable for this Minimum Floor Levels Report.

2.4.6 Community vulnerability to elevated sea level and coastal tsunami events in Otago (ORC, 2012)

This report describes the varying degrees of vulnerability to elevated sea level and tsunami hazard along the Otago coastline. It assesses the vulnerability (rather than the risk) of Otago's coastal communities to these hazards. It draws on tsunami and storm surge modelling undertaken by NIWA for ORC in 2008, coastal topography data and local knowledge of each community. This information is used to assess how people, and the communities in which they live, would be affected during credible, high magnitude tsunami and elevated sea level events.

The likelihood of a water level of a certain height occurring in the next 100 years was assessed, based on the maximum predicted levels for all the modelled tsunami and storm surge scenarios provided by NIWA (2007, 2008).

The level of vulnerability was assessed under three modelled return-period events (or scenarios). While these events are unlikely to occur frequently, they may have significant consequences if they do. The scenarios were selected as they represent credible high magnitude (but not 'worst case') scenarios.

These assessments do not change the assessment for storm surge determined elsewhere in this report.

2.4.7 Otago Regional Council Tsunami Inundation Study (NIWA 2008)

This report has not been updated since the 2011 Minimum Floor Levels report. Therefore, the commentary below is unchanged since 2011.

The tsunami report identified near-field sources (in particular the Puysegur Fault) and far-field sources (South America) with the former likely to produce the greater wave height but the latter source providing the greater frequency of events (100 year return period). Also considered were less active faults (Akatore) and tsunami generated by submarine landslide events. The report provided a single height prediction for the near field events and both 100 and 500 year return period predictions for the far-field events. Because of the shielding effect of the Otago Peninsula the maximum heights for near-field events were significantly higher south of the Otago Peninsula than north of it.

Wave amplitudes were tabulated for the three predictions noted above. To determine a total wave height, the amplitudes should be added to a typical mean high water spring (MHWS) tide level of 0.9 metres. However, for the purposes of this review and any future calculation of minimum floor levels, care should be taken not to add the total wave height to the 'base level' as this would be too conservative.

Tsunami events particularly at river mouths and upstream reaches of the rivers represented a much greater risk due to the 'tidal bore' effect. Taieri Mouth, the Lower Taieri Plain, Green Island adjacent to the Kaikorai Estuary, and State Highway 1 in the vicinity of the Waikouaiti River would be at risk of inundation and wave damage.

The Otago Harbour was however identified as at low risk from tsunami events, the harbour entrance providing significant damping of waves from near or far-field sources. Predicted wave heights were 0.150 metres for near field and 0.5 metres for far field events (an event in mid-19th century apparently lifted boats onto land).

The report identified six regions within Dunedin for the purposes of the report. Figures were generated showing the extent of inundation at each location for the three predicted events. The sequence of wave fronts and associated times of arrival were stated for each event. The maximum heights were noted for the near-field and the far-field events with a 500 year return period. For locations outside the harbour the far-field 500 year predictions were in the range 2.1 to 2.5 metres above the MLOS, being generally lower north of the Peninsula.

3.0 METHODOLOGY

Appendix A graphically summarises the output of the 2021 Update methodology. This chart presents the sea level components as follows:

1. A level datum.
2. The current Mean level of the sea (MLOS), relative to the datum. MLOS is increasing owing to global warming.
3. Storm surge, which is the increase in sea level (excluding the effects of waves) due to low barometric pressure and winds blowing either onshore or alongshore over the ocean (with the coast on left).
4. An allowance for ongoing tectonic subsidence.
5. A freeboard height consistent with the interpretation of the Building Act, including a safety margin.
6. A 'Base Level' derived from the present day MLOS plus the allowance for storm surge, tectonic subsidence, and the freeboard.
7. A Climate Change Effects (CCE) Factor. A height that allows for predicted sea level rise, uncertainty in predictions, and the increase in other effects (eg. storm surge) that are predicted as a result of climate change. This factor requires continual review as global and local trends become apparent.
8. 'Local Adjustment Factors' (LAFs) which may be relevant, to mitigate local effects that include: wave run-up during storm events; site specific tsunami exposure; 'tidal bore' effects in rivers; and any lifelines importance factor applying to the specific building.

Where subdivision or land use consent is required, the Council may require a more detailed site specific assessment of natural (coastal) hazards, and may subsequently grant consent subject to mitigation measures relevant to the location, which may include the specific siting of a dwelling within the lot and a 'site specific' minimum floor level.

3.1 LEVEL DATUM – NZVD 2016

The first step in this 2021 Update was to reconfirm the level datum. A Datum Level is an arbitrary surface used as a reference point against which vertical dimensions are measured. It is used to highlight differentials between vertical heights.

There have been a number of datum levels used for Dunedin. The 2011 report adopted the Otago Metric Datum (OMD). OMD is linked to Tide Chart Datum. These and other historically used datum are described in Appendix C.

The level datum used for this Update is New Zealand Vertical Datum 2016 (NZVD2016). NZVD2016 is the current national vertical datum. It is being promoted by Land information New Zealand to establish a standardised system across New Zealand and increasingly adopted by DCC. This datum ensures a nationally consistent height reference surface for New Zealand and allows for direct comparison with nationally provided data and policy (see appendix).

NZVD2016 is also linked to Tide Chart Datum and provided the same base comparison as the 2011 methodology.

4.0 BASE LEVEL

The 2011 Base Level was determined from mean level of the sea and storm surge height (excluding local wave run-up effects). These components were compared to tidal reference points (see 3.1). A Freeboard height was added to these 'natural world' conditions to establish the 2011 'Base Level'.

The 2021 Update adds an additional factor relating to Vertical Land Movement (VLM).

The 2021 Update methodology, based on NZVD:2016, has been determined from the following components:

- Present day MLOS
- Storm Surge height (excluding local wave run-up effects)
- Vertical land movement
- Freeboard.

These components are discussed below.

4.1 MEAN SEA LEVEL (MSL)

The mean sea level (sometimes called the mean level of the sea) is the surface level of the ocean at a point averaged over an extended period usually 18–20 years. The measurement is relative to a fixed reference level, or vertical datum, and is often used as a level to which heights on land are referred. Mean sea level continues to rise due to climate change.

In 2011 the number used for mean level of the sea (MLOS) was provided by the University of Otago School of Surveying.

This 2021 update has drawn information from the same source, as well as the Land Information NZ website that monitors the level at a variety of ports around New Zealand (see Appendix D). The number has been provided relative to NZVD:2016. It is presented in Appendix C relative to Chart Datum, to enable a simple comparison with the 2011 methodology

The present day MLOS number used in this 2021 Update is -0.25m in terms of NZVD:2016.

4.2 STORM SURGE

Storm surges are temporary increases in regional sea and estuary water levels. Low barometric (air) pressure combined with strong onshore winds cause storm conditions and higher than predicted tide levels that can last from hours to days. (see Appendix G – fact sheet)

These surges are of greater duration than the tidal cycle. As is common, when referring to a storm surge height it is the level elevation due to a storm being superimposed onto a high tide. That is, the general elevation of sea level due to the storm, plus the height of the normal tide.

A storm surge value for this 2021 Update Report has been determined using the Otago Region Storm Surge Modelling Study (NIWA, June 2008). This 2008 study was also used in the 2011 Minimum Floor Levels report. NIWA and ORC advise that there has been no update to this study.

As in 2011, the method for selecting a representative height for inclusion in the 'Base Level' was by inspection of the 2008 NIWA predicted extreme sea levels (see table in 2.3.1) and selecting a level that represented a reasonable upper bound figure within the 50 to 100 year return periods.

A storm surge height of 2.0 metres above the MLOS has been adopted. This is exclusive of wave height and run-up. This same value was adopted in the 2011 methodology.

A 2.0m height produces a storm surge level of 1.75m in terms of NZVD:2016.

4.3 VERTICAL LAND MOVEMENT

Vertical Land Movement (VLM) is the one further element added to the base level for this 2021 Update.

Vertical Land Movement (VLM) can mitigate or worsen the effects of sea level rise. Accumulation of satellite survey information, and its analysis over the last 10 years, has allowed a prediction to be included for the trend in tectonic settlement in Dunedin.

A VLM subsidence figure of 1.5mm per year has been adopted in this 2021 Update report (see section 2.3.2).

4.4 FREEBOARD HEIGHT

A freeboard height mitigates the risk of damage to underground services and floor elements (particularly timber floors) and provides a safety margin against intrusion of water.

Freeboard comprises two elements:

- A minimum requirement. For protection against secondary flood flows (which is similar to flooding from the sea), the Building Act requirement is that freeboard is to always be at least 150mm. This minimum value only applies in limited circumstances.
- The addition of a factor of safety.

There is not a specific value in the Building Code that must be used as a factor of safety in relation to sea level. However, there are provisions for comparable circumstances, and other planning documents also give guidance on freeboard.

The approach with this Update Report has been to look at the various documents and interpret a freeboard allowance that is consistent with them.

For this 2021 Update, the 150mm absolute minimum has been increased by a factor of safety of 350mm. **A freeboard height of 500 mm is adopted.**

A full description of the logic, and regulatory requirements, for adopting a freeboard of 500mm is given in Appendix F.

4.5 SUMMARY OF BASE LEVEL COMPONENTS

In terms of New Zealand Vertical Datum 2016 the Base Level comprises:

• Mean Level of the Sea 2021	minus 0.25m
• Storm Surge	2.0m
• Vertical Land Movement to 2080	90mm
• Freeboard	500mm
Base Level:	**2.34m NZVD:2016**

4.6 TESTING THE BASE LEVEL

The following tidal ranges are included to provide a reference point against which the Base Level can be tested. Tides are controlled by the gravitational forces of the Moon and the Sun pulling the Earth's water towards them. Relatively high 'spring tides' occur about every two weeks when there is a full or new moon. King tides are particularly high spring tides that occur about twice a year when the Earth, the Sun, and the Moon are aligned, and the Moon is closest to the Earth (PCE, 2015).

4.6.1 High Tides

The Mean High Water Spring (MHWS) is the highest level to which spring tides reach on average over a period of time. This level is generally close to being the ‘high water mark’ where debris accumulates on the shore.

The mean high water springs level (MHWS) for Dunedin is 2.21 metres above chart datum (ref. LINZ 2021) and therefore 0.85 metres above NZVD2016

From data provided by LINZ for records from 1905 (refer Appendix D), the highest tide (ie a site without any wave run-up but influenced by storm surge) for Dunedin, was **1.392m above NZVD:2016**, and this occurred on two dates, 16 March 1980 and 15 June 1999. The Dunedin site is in the harbour by the Birch St wharf.

4.6.2 Predicted Astronomical Tide

LINZ 2021 show the highest astronomical tides (HATs) predicted during the 19 year astronomical cycle will **exceed the MHWS by 0.22 metres**. This extreme figure has not been used to determine a minimum floor level. This is because it is considered an unreasonable double jeopardy to assume that the maximum predicted storm surge event will happen at the same time as a maximum astronomical tide event.

The tidal ranges elsewhere along the Dunedin coastline vary from those at the Dunedin Inner Harbour gauge site. For example, the MHWS range is plus 200mm near Taieri Mouth and minus 200mm near Waikouaiti (NIWA Storm Surge Study, 2008). Storm surge and tsunami heights reported by NIWA are, however, relative to a single MLOS height.

5.0 CLIMATE CHANGE EFFECTS (CCE) FACTOR

The Climate Change Effects Factor (CCE factor) is the allowance for predicted sea level rise, and the increase in other effects (eg. storm surge) that are predicted as a result of climate change. The CCE factor is an allowance that is added to the Base Level.

The 2011 report investigated three CCEs, but increased intensity of rainfall events was disregarded early. In this report, increased intensity of rainfall events is discussed in relation to Local Adjustment Factors.

The Climate Change Effects included in this 2021 Update are:

- Increase in Sea level
- Allowance for uncertainty in modelling
- Allowance for increased storm surge.

These CCE are discussed below.

5.1 INCREASE IN SEA LEVEL

The 2011 methodology applied a sea level rise number for Dunedin of 0.5 metres by 2060. This was reached by comparing MfE's 2008 recommended minimum predicted increase and DCC Climate Change Predictions Policy (2011)

The DCC policy includes sea level rise predictions of 0.3m up to 2040, and 0.8 – 1.6m up to 2090

The Building Regulations have a requirement that certain building elements, including floors, function for not less than 50 years. However, DCC intend this 2021 Update to apply for 50 years over the full lifetime of this Update ie from 2021-31. Therefore, A '60 year' allowance for sea level rise (to 2080) is applied to this 2021 Update.

The **sea level rise number for Dunedin is 0.69 m to 2080** being:

- 300 mm from 2010-2040
- 400mm, being 10 mm per year from 2040 to 2080
- Less 10mm observed increase in the MLOS by LINZ in the period 2011 – 2021.

5.2 ALLOWANCE FOR UNCERTAINTY IN MODELLING

Predictions of sea level rise, and climate change effects (eg by IPCC and MfE) rely on information from models. These models have inherent uncertainty, and lack sufficient real-life events to properly calibrate them. Predictions also make assumptions regarding how well the world moves to carbon neutrality.

This report adopts relatively conservative assumptions. The DCC SLR policy that is adopted in this report gives 2080 SLR that is at the upper bound of the IPCC predictions, refer 2.2.2. **For this reason, the allowance for uncertainty in modelling for this Update Report is set at zero.**

Beyond that, there remains a risk that beyond 2080 higher SLR eventuates.

5.3 ALLOWANCE FOR INCREASED STORM SURGE

This is an allowance for storm surge to increase over time, principally due to weather events being becoming more extreme. The 2011 methodology cited MfE's assumption at the time that storm-tide levels would rise *"only due to an increase in mean sea level rise".* Accordingly, the 2011 methodology did not include a number for increased storm surge. This guidance has since changed. Section 5.9 of MfE 2017 provides '**Guidance: storm surges, waves and winds':**

Specifically, the following guidance is provided based on more recent IPCC AR5- and New Zealand-based studies.

> • *Undertake sensitivity testing for coastal engineering projects and for defining coastal hazard exposure areas out to 2100, using:*
>
> *− a range of possible future increases across New Zealand of 0–10 per cent for storm surge out to 2100*
>
> *− a range of possible future increases across New Zealand of 0–10 per cent for extreme waves and swell out to 2100*
>
> *− changes in 99th percentile wind speeds by 2100 and incorporating these for the relevant RCP scenario from Ministry for the Environment (2016) on climate change projections, to assess waves in limited-fetch situations, such as semi-enclosed harbours, sounds, fjords and estuaries.*

MfE was asked to confirm with regard to the "0-10 per cent for storm surge" what the 0-10% is added to, to clarify whether it is 10% of the total storm surge, or the difference between high tide and storm surge high tide. The response via email of 1 September 2021 was:

I have checked with Rob Bell, who authored chapter 5 of the guidance, and received the following response:

Most regions have available (regional/unitary council) a set of extreme storm-tide levels (made up of tide, sea-level and storm surge components) and possibly have wave/swell setup and/or runup heights, all based on past observations and processed to provide say 2% and 1% AEP (1/50 and 1/100 yr) levels to design or plan for (this is for the current level of risk).

What the guidance is saying for coastal engineering projects is to explore the sensitivity of the option or design by adding a few possibilities of up to 10% more in the storm-surge component and same for the wave component to these recent-past extreme sea levels, to see if that makes any substantial difference to the option or design chosen.

One of those components for extreme levels is sea level rise added to MSL, which is given in section 5.7 of the Guidance (relative to the 1986-2005 MSL).

This Minimum Floors report adopts a storm surge height, at 2021, of 2.0m. We interpret the above advice as recommending consideration of an additional 10% or 200mm. However, it is not unequivocal in saying the extra 10% should be adopted.

An allowance of 100mm is adopted, on no greater logic than it is halfway between zero and the maximum.

5.4 SUMMARY OF CLIMATE CHANGE EFFECTS

The minimum allowance for the Climate Change Effects Factor is:

• Increase in Sea level	690mm
• Allowance for uncertainty in modelling	zero
• Allowance for increased storm surge	100mm
Total	**790mm**

6.0 LOCAL ADJUSTMENT FACTOR

The Local Adjustment Factor (LAF) is proposed as the third and final Factor that enables the minimum floor level at any particular site to be determined.

Local Adjustment (LA) Factors takes account of local and/or project specific matters that would be inappropriate to apply generally. A 'Local Adjustment Factor' is a height adjustment relevant to local conditions such as topography, tsunami effects, tidal bore effects, wave run-up, river flooding and backwater effects, settlement due to liquefaction, on-site effluent disposal, building usage, the design life of a building, and any mitigating circumstances.

As in the 2011 methodology, the scope of this 2021 Update requires comment on any factors that should be included for consideration as a result of the research undertaken as part of this review. For example, increased rainfall events that were discussed under CCE in the 2011 report are now discussed here.

It is beyond the scope of this review to assess LA Factor in any great detail. Therefore, the comments below are not comprehensive, and there may be further factors that should be considered when determining Local Adjustment Factor.

The commentary below related to LAFs has remained relatively unchanged since 2011.

The DCC Climate Change Policy (2011) is provided in Appendix I. It includes a projected SLR of between 0.8 and 1.6m for the year 2090. To be consistent with this policy it is proposed that an allowance for sea level rise of greater than 0.8m beyond 2090 should be considered as part of the Local Adjustment Factor. It is considered that such an allowance would be applicable when considering Building Classification and Risk (refer 6.2). For example, a more conservative allowance for sea level rise would be used for a building/project where the consequences of a sea level rise greater than the Climate Change Effect Factor would be unacceptably severe.

As discussed previously, where subdivision or land use consent is required, the Council may require a more detailed site specific assessment of natural (coastal) hazards, and may subsequently grant consent subject to mitigation measures relevant to the location eg the specific siting of a dwelling within the lot and a 'site specific' minimum floor level.

A negative LA Factor may apply in situations where hazard prevention or mitigation works exist. For example South Dunedin is low lying and ground level is below the identified Base Level plus the CCE Factor. Higher ground between the low-lying area and the harbour and sea, and pumped drainage mitigates coastal hazards including sea level. As a consequence, in applying the methodology to South Dunedin and considering the mitigating provisions, the Council may consider a negative LA Factor is applicable.

A negative LA Factor may apply in situations where surface water inundation is of less consequence, such as with domestic garages and storage yards.

6.1 SPECIAL ZONES

Special Zones may be created where higher (or lower) levels of protection against the effects of sea level rise and other coastal hazards can be considered. This may be because specific protection works are in place. Conversely, it may be because the consequences of inundation are greater or less than average.

For example, South Dunedin has in place a system to convey stormwater to the open sea or to harbour outlets. We predict there will be greater difficulty with time in controlling groundwater levels throughout South Dunedin but understand DCC is reviewing groundwater and stormwater management measures required in the future.

A LA Factor may be adopted accordingly for such zones.

6.2 BUILDING CLASSIFICATION AND RISK

A number of building types, including domestic garages and commercial workshops, have been and may in the future be constructed at locations subject to a risk of inundation. For future consent applications, DCC may again accept a lower floor level (negative LA Factor) or may grant a waiver of any minimum floor level requirement.

Buildings containing 'lifelines' facilities, such as communications equipment, hospitals, water treatment plants and other essential services and infrastructure, should be identified and the LA Factor specifically assessed.

Should the consequences of inundation adversely affect such buildings or the functions within them (eg the plant and equipment), a higher allowance for sea level rise than that provided by the Climate Change Factor should be applied as a component of the Local Adjustment Factor.

6.3 TOPOGRAPHICAL EFFECTS

Topographical effects, including exposure to wave run-up at open sea beach locations during storm surge or tsunami events, and exposure to 'tidal bore' effects in rivers during tsunami events, require specific assessment.

Reference should be made to the ORC commissioned Tsunami and Storm Surge reports (NIWA 2008) for detailed hazard maps and an appropriate LA Factor determined[4]. In the NIWA report wave run-up values range from 0.22 metres north of the Dunedin Peninsula to 0.47 metres south of the Peninsula. For inclusion in the LA Factor we recommend using the geographically closest NIWA figure unless specific topographical features warrant a more detailed assessment of this factor.

6.4 DIFFERENT FREEBOARD

The Environment Court has favoured freeboard heights in flood plains as great as 0.5 metres, although the circumstances for this have not been researched. Further, there may be local circumstances where a reduction of freeboard from the recommended 500mm for the Base Level, can be made.

It is conceivable that a situation may arise where coastal defences are occasionally overtopped by waves. Additional freeboard or specific drainage provisions for buildings protected by such seawall or coastal defence may be required.

6.5 DWELLINGS AND ON-SITE EFFLUENT DISPOSAL

Development at a number of coastal communities, for example Long Beach and Harwood, has hinged upon the feasibility of on-site effluent disposal systems. Concerns have been with the potential impact on the disposal systems of raised groundwater levels likely to result from the effects of sea level rise.

Where new dwellings cannot be connected to reticulated foul sewerage systems, site specific assessments should be made. The viability of residential development at such locations may be in doubt depending upon SLR and present day ground levels so determination of a minimum floor levels could be irrelevant.

6.6 TSUNAMI EFFECTS

The Otago Regional Council (ORC) commissioned Tsunami Inundation Study identified individual wave amplitudes to be in the range 2.4 to 2.5 metres above MLOS south of the Otago Peninsula and 2.2 metres above MLOS north of the Otago Peninsula in a 500 year AEP, 'far field', seismic event. The study also provided predictions for 'near field' events but made clear the 'far field' events were of higher probability.

Although these 500 year AEP tsunami heights are greater than for the 100 year AEP storm surge predictions we have for determination of the 'Base Level' recommended adoption of the more likely upper bound storm surge value. In other words, Tsunami is no worse than storm surge.

There may be places where the local tsunami hazard is greater than the standard allowance described above. This may be due to the local topography, both above and below the waterline. Identification of such areas can be included as a component of the LA Factor.

Therefore tsunami, in general, is considered no greater a threat than storm surge. However the ORC tsunami study identified locations including the Taieri River and lower Taieri Gorge where the energy from a tsunami event could be sufficient to send a 'tidal bore' through the gorge, affecting West Taieri settlements such as

[4] Otago Regional Council Storm Surge Modelling Study by NIWA available at https://maps.orc.govt.nz/hazards/NHDBDocuments/Storm%20surge%20modelling%20study%20(2008).pdf

Henley. Provision should be made to review development and appropriate minimum floor levels, although in many sites the 1% AEP flood level may well govern floor levels in such areas.

As and when any other such locations are identified, an appropriate LA Factor should be introduced.

6.7 WAVE RUN-UP

Storm surge wave run-up heights range from 0.25 metres at Waikouaiti up to 0.45 metres at Taieri Mouth. The LA Factor should therefore be adjusted accordingly. These values should be applied where wave run-up exposure exists.

Table 2: Hazards and Local Adjustmentsprovides guidance on the locations most at risk, where wave run-up should be considered as a component of the LA Factor.

6.8 COASTAL EROSION

The Otago coastline includes areas prone to rapid erosion. They include areas of raised beach terrace (ref. Geology of the Dunedin Area, IGNS 1996), sand spits within the Otago Harbour (e.g. Harwood), open sea locations (e.g. Warrington), and rocky shorelines capped with loess soil deposits (e.g. alongside Brighton Taieri Mouth Road).

Also, localised areas of sedimentary and metamorphic rock formations are at risk of relatively high rates of coastal erosion and similarly these should be identified as part of any site-specific hazard assessment.

6.9 BACKWATER

In some locations such as the examples listed below, minimum floor levels will be affected by a combination of flooding due to storm, and tide. There will be a backwater curve from stormwater draining off the land that will add to the sea level. Potential locations are the lower reaches of the Waikouaiti, Waitati, and Taieri Rivers, Kaikorai Stream and Otokia Creek.

In these location there is potential for the appropriate minimum floor level to be higher than the Base Level plus CCE Factor.

For floor level assessments at these locations the flood level should be determined either by using historical data or by calculation of catchment characteristics. Much of 'at risk' Taieri Mouth is situated outside The Council's territory, but Henley is within Dunedin and could be at risk as it is tidal and therefore the drainage of flood waters is affected by higher sea levels. The Momona Airport is within the West Taieri flood protection scheme so not directly at risk from coastal events.

6.10 SETTLEMENT DUE TO LIQUEFACTION

The DCC Hazard Register identifies some areas subject to liquefaction. These are generally low lying, meaning that any settlement could be significant with respect to minimum floor levels.

Experience from the Christchurch earthquake has shown that where liquefaction occurs, settlement will also occur. Such settlement can be significant. Resurveying of Christchurch revealing the magnitude of settlement may enable a Local Adjustment Factor for Dunedin to be determined.

Recent investigations (eg GNS 2014: Assessment of liquefaction hazards in the Dunedin City district) have determined that liquefaction settlement risk is not as widespread as might be expected (eg in South Dunedin) and might be in the order of 70mm.

6.11 INCREASED RAIN FALL

While climate change is predicted to increase the maximum intensity of rainfall events, this will not have an effect on sea level in general.

However, there may be an effect on tidally-affected flood zones such as at Henley, which should be accounted for as a Local Adjustment Factor.

6.12 ASSESSMENT OF LA FACTOR

Quantifying the LA Factor is beyond the scope of this review. However, Table 2 suggests a methodology for an initial check as to whether a LA Factor may be applicable and, therefore, should be quantified.

Table 2: Hazards and Local Adjustments

Location	Extent of Development at Risk	Storm Surge Wave Run-up Hazard	Tsunami 'Tidal Bore' Hazard	Erosion Hazard
Waikouaiti Beach	large	high	low	low
Karitane Estuary	large	moderate	low	low
Karitane Beach	large	high	high	high
Waikouaiti River	large	low	low	low
Warrington/ Evansdale	moderate	low	moderate / low	low
Waitati Township	large	low	low	low
Purakanui	small	low	low	low
Long Beach	large	high	high	moderate
Aramoana	large	moderate	low	low
Te Ngaru to Careys Bay	large	low	low	moderate
Harwood to Harington Point	large	low	low	high
Papanui Inlet	small	low	low	moderate
Hoopers Inlet	small	low	low	moderate
Tomahawk	high	moderate	high	moderate
St Kilda to St Clair	high	high	low	high
Waldronville	small	moderate	low	moderate
Kaikorai Estuary	small	low	low	low
Westwood to Ocean View	large	high	low	moderate
Brighton / Otokia Creek	large	low	low	low
Brighton to Taieri Mouth	small	moderate	low	moderate
Henley	moderate	low	moderate	low

The Council may require a building consent application to include a site specific assessment of coastal hazards in order that an appropriate LA Factor can be calculated.

7.0 SUMMARY AND CONCLUSIONS

This 2021 Update of the 2021 Update to Methodology for Determining Minimum Floor Levels has resulted in a recommended methodology for DCC to use for the period 2021- 2030.

The review has recommended use of New Zealand Vertical Datum 2016 (NZVD2016) and all levels in this 2021 Update are with reference to NZVD2016.

A minimum floor level is determined as the sum of a Base Level and Climate Change Effects Factors.

The review has established that the present day mean level of the sea (MLOS) in terms of New Zealand Vertical Datum 2016 (NZVD2016) is negative 0.25 metres. The recommended Base Level is 2.34m, comprising an allowance of 2.0m for storm surge, vertical land movement of 90mm and a freeboard height of 500mm. The recommended Climate Change Effects Factor is 790mm for a building with a design life up to 2080, with at least an additional 10mm for every year thereafter, where the life of a building extends beyond 2080.

A number of Local Adjustment Factors are identified and should be considered to take into account matters that are specific to the local physical setting, to the life and use of the building, the design life of a building, and any mitigating circumstances.

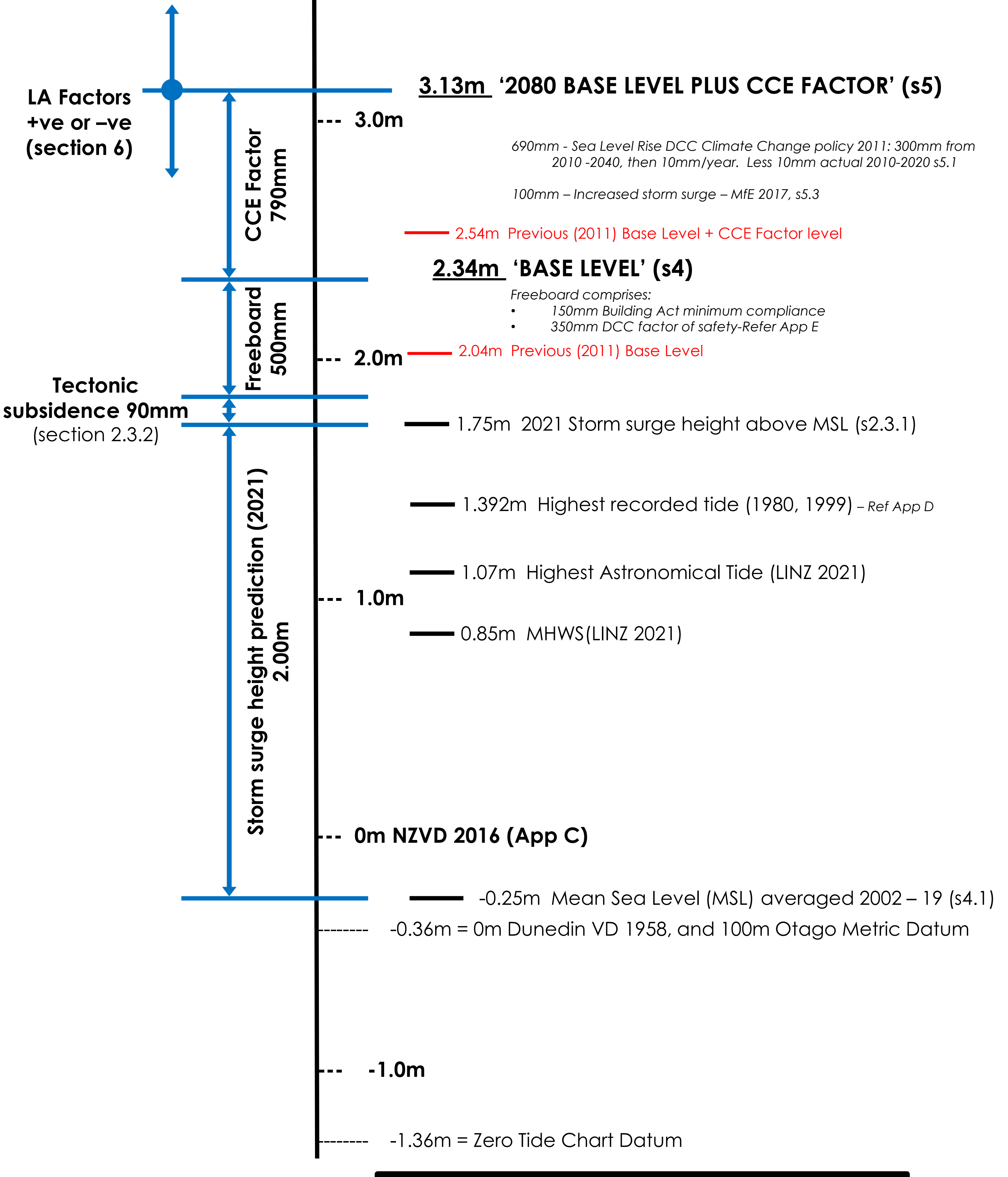
In the absence of a LA Factor, the minimum acceptable floor level is the Base Level plus the Climate Change Effects Factor. The resulting minimum acceptable floor level for a building with a life less than or equal to 2080 is 3.13m NZVD:2016.

Because of the uncertainty about the rate of sea level rise, Stantec recommend that the methodology, and particularly the Climate Change Effects factor, be reviewed after relevant government policy or guideline updates, or at least every five years. This is because the science behind the CCE Factor is subject to an enormous amount of ongoing research.

Appendices

We design with community in mind

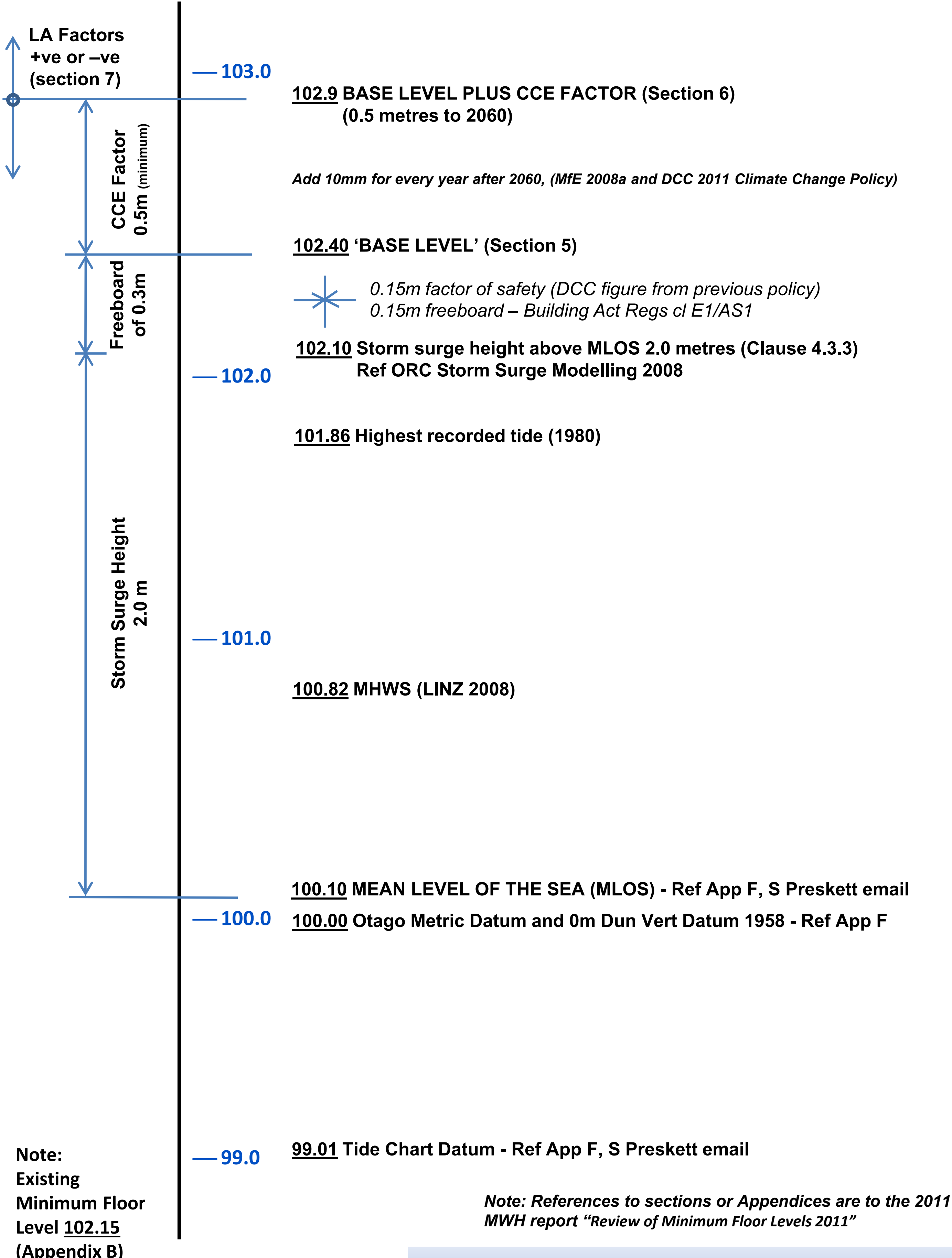
Appendix A DETERMINATION OF MINIMUM FLOOR LEVELS 2021



DUNEDIN CITY COUNCIL
Determination of Minimum Floor Levels to 2080

All levels in terms of NZVD2016
October 2021

Appendix B PREVIOUS MINIMUM FLOOR LEVEL CHART –2011


LA Factors
+ve or –ve
(section 7)
CCE Factor
0.5m (minimum)
Freeboard
of 0.3m
Storm Surge Height
2.0 m
103.0
102.0
101.0
100.0
99.0
102.9 BASE LEVEL PLUS CCE FACTOR (Section 6)
(0.5 metres to 2060)
Add 10mm for every year after 2060, (MfE 2008a and DCC 2011 Climate Change Policy)
102.40 'BASE LEVEL' (Section 5)
0.15m factor of safety (DCC figure from previous policy)
0.15m freeboard – Building Act Regs cl E1/AS1
102.10 Storm surge height above MLOS 2.0 metres (Clause 4.3.3)
Ref ORC Storm Surge Modelling 2008
101.86 Highest recorded tide (1980)
100.82 MHWS (LINZ 2008)
100.10 MEAN LEVEL OF THE SEA (MLOS) - Ref App F, S Preskett email
100.00 Otago Metric Datum and 0m Dun Vert Datum 1958 - Ref App F
99.01 Tide Chart Datum - Ref App F, S Preskett email
Note:
Existing
Minimum Floor
Level 102.15
(Appendix B)
Note: References to sections or Appendices are to the 2011
MWH report "Review of Minimum Floor Levels 2011"

Appendix C LEVEL DATUMS

- Reference, S Preskett, chart datum to Dunedin vertical datum
- Comparison of Datums to NZVD:2016
- Nationally consistent datums factsheet

Roger Oakley

From: Scott Preskett [scott.preskett@otago.ac.nz]
Sent: Friday, 15 July 2011 3:39 p.m.
To: Roger Oakley
Cc: pmarshal@dcc.govt.nz
Subject: RE: Level Datums

Hi Roger and Phil

The connection between Dunedin 1958 and Chart Datum (CD - zero point for tide predictions and charted depth values) can be determined through the connecting official benchmark for CD. Dunedin is a Standard Port, meaning that the permanent tide records have been established over a long period of time.

The value for MSL above Chart Datum can be found here:

http://www.linz.govt.nz/hydro/tidal-info/tide-tables/tidal-levels

From the table we see that MSL is 1.09m above CD (as of 2011 – this gets regularly updated as required), which means that therefore CD lies 1.09m below MSL. This may be useful for various purposes – but has been separately (more recently) calculated to the other various vertical datums, so MSL here is not directly equivalent to Dunedin 1958 (for example). Note also that the MSL-CD relationship at Pt Chalmers is different – this value specifically refers to Dunedin.

The connection of CD (Dunedin) to a physical benchmark is defined here:

http://www.linz.govt.nz/hydro/tidal-info/tide-tables/datum-descriptions

This states that CD at Dunedin lies **3.728m** below BM WW83 (LINZ code AFEQ) – the stainless steel pin down by the sheds, near the original tide pole. Looking at the LINZ Geodetic Database for AFEQ, we find that this has an orthometric height of **2.7366m (Dunedin Vertical Datum 1958).** Therefore, CD is (3.728 – 2.7366) **0.991m below Dunedin 1958**.

From speaking to some of the more land minded people here, the Otago Metric Datum is simply 100.00m below Dunedin 1958. If so, then the CD value will be simply (100-0.991) **99.009m ODM.**

I hope this clarifies things (including my understanding of the Otago Datum!)

Regards,

Scott Preskett

Professional Practice Fellow
Hydrographic Surveying
School of Surveying, University of Otago

Tel: +64 3 479 7587
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scott.preskett@surveying.otago.ac.nz
Surveying at the University of Otago

Sea levels : AFEQ

Figure 1 illustrates the relationship between the various height surfaces for the LINZ benchmark AFEQ. AFEQ is a tide gauge reference benchmark located in steamer basin (Wharf Street). These heights can be summarised as follows:

Orthometric heights: AFEQ

- [1] above chart datum 3.73 m
- [2] above Dunedin VD1958 2.73 m
- [3] above NZVD2016 2.37 m
- [4] above MSL (mean 2011) 1.11 m

Ellipsoid height: AFEQ

- Above GRS80 ellipsoid 8.01 m

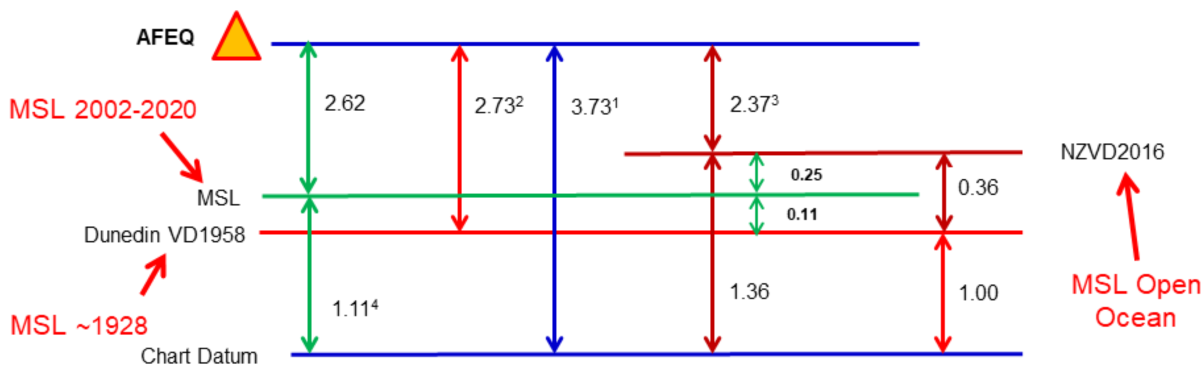


Figure 1: Sea levels relative to the tide gauge reference benchmark AFEQ.

Dunedin VD1958: Dunedin VD1958 is based on sea level data observed between the period 1918 – 1937, (mean 1928). This is represented as the red horizontal line in Figure 1.

MSL: MSL is based on the "*Standard Port periods of observation*" Currently, Dunedin MSL is based on 19 years of data for the period 2002-2019. (mean 2011).

MSL is 1.11 metres above chart datum.

Using current the current SLR estimate of 1.3 mm/yr (e.g. Denys *et al*. 2020) for the period of time since the definition of Dunedin VD1958 gives:

$$
\begin{aligned}
SLR &= 84 \text{ years } \times 1.3 \text{ mm/yr} \\
&= 109 \text{ mm } (0.11 \text{ m})
\end{aligned}
$$

which is close to the current estimate of MSL above Dunedin VD1958 of 0.11 m.

NZVD2016: NZVD2016 is the current national vertical datum and is 0.36 metres above Dunedin VD1958. Note that this offset is not constant and varies spatially. The range of offsets across South Dunedin is approximately 1-2 cm.

NZVD2016 can be thought of as the open ocean sea level (not confined to the Otago harbour).

Modernising height data

Land Information New Zealand
Toitū te whenua

The New Zealand Vertical Datum 2016 provides a nationally consistent height reference surface. Standardised heights are an important tool for planning, consenting and infrastructure works.

NZVD2016 is New Zealand's official height system. It allows for the consistent collection and seamless exchange of heights across New Zealand. Heights used in GIS, infrastructure, planning, consents and works can now be nationally standardised. This provides better support for regional and national projects.

NZVD2016 is compatible with technologies such as GPS and levelling and NZVD2016 heights can be provided for all existing benchmarks. This allows accurate height measurements anywhere in the country.

The ability to integrate elevation information is critical in the assessment of water flow in coastal and low lying areas.

Traditional sea level datums

Traditionally a tide gauge has been used as the basis for a height system. However, these heights are misleading as they do not represent local sea level; the sea varies around the country and the height is not updated over time; these are historic reference points.

These systems are becoming less economic to use and maintain and are susceptible to movement, such as caused by earthquakes and geothermal activity.

Each local authority has determined their own sea level height reference, which means that heights are difficult to share with others. This can result in duplicated effort and errors.

How can LINZ help you?

LINZ is happy to work with you to understand your needs and how NZVD2016 could be best implemented in your area.

For more information contact Rachelle Winefield at crm_geodetic@linz.govt.nz

Case Study: Nelson City and Tasman District

Before NZVD2016 was developed, Tasman District and Nelson City Councils each used independent height datums. The difference between the two was more than 12 metres.

This led to problems, and in one example a building site was within the Nelson City Council boundary, while the infrastructure was supplied via Tasman District Council.

Two sets of plans, with two different heights had to be prepared. This caused duplication of effort and risked confusion on site.

LINZ was able to provide tools and advice which allowed local height datasets such as contours, LiDAR and benchmark heights, to be provided in terms of NZVD2016.

In July 2017, both councils successfully adopted NZVD2016 as the standard for all new height data, removing the risk of duplication and improving efficiency across both regions.

Image showing the distribution of NZVD2016 Benchmarks across the Tasman District and Nelson City Council boundaries

September 2017

Appendix D LINZ TIDE AND SEA LEVELS 2021

STANDARD PORT TIDAL LEVELS

Extract from LINZ Website - July 2021

[Standard port tidal levels | Toitū Te Whenua Land Information New Zealand (linz.govt.nz)]

The following table shows the standard tidal levels for tides around New Zealand.

Tidal levels table

For help understanding column headings used in this table see Definitions of Tidal Terms.

Standard Port	MHWS	MHWN	MLWN	MLWS	Spring Range	Neap Range	MSL	HAT	LAT
Auckland	3.36	2.83	1.03	0.48	2.88	1.80	1.91	3.72	0.06
Bluff	2.81	2.42	1.06	0.59	2.22	1.36	1.75	3.09	0.31
Dunedin	2.21	1.82	0.40	0.06	2.15	1.42	1.11	2.43	-0.13
Gisborne	2.12	1.74	0.79	0.40	1.72	0.95	1.26	2.22	0.28
Lyttelton	2.58	2.04	0.78	0.31	2.27	1.26	1.43	2.72	0.16
Marsden Point	2.73	2.31	0.92	0.47	2.26	1.39	1.60	3.01	0.14
Napier	1.89	1.48	0.44	0.08	1.81	1.04	0.97	2.00	-0.02
Nelson	4.28	3.25	1.47	0.53	3.75	1.78	2.36	4.68	0.11
Onehunga	4.21	3.39	1.40	0.53	3.68	1.99	2.43	4.55	0.13
Picton	1.60	1.08	0.57	0.12	1.48	0.51	0.85	1.73	0.01
Port Chalmers	2.19	1.80	0.46	0.15	2.04	1.34	1.13	2.38	-0.05
Port Taranaki	3.56	2.75	1.15	0.34	3.22	1.60	1.96	3.91	-0.03
Tauranga	1.96	1.65	0.52	0.21	1.75	1.13	1.10	2.15	-0.06
Timaru	2.51	2.12	0.83	0.46	2.05	1.29	1.48	2.71	0.28
Wellington	1.83	1.49	0.75	0.46	1.37	0.74	1.13	1.93	0.39
Westport	3.21	2.54	0.96	0.28	2.93	1.58	1.75	3.55	-0.06

1. The above levels, in metres, are referred to Chart Datum, which is the same as the zero of the tidal predictions in all cases.
2. The values for the MHWS, MHWN, MLWN and MLWS tidal levels given in the table are the averages of the levels of all spring and neap tides predicted for the period 1 July 2021 - 30 June 2022 using the harmonic constituents derived from the analysis of the observations made at that port during the period given on the Standard Port Periods of Observation page. The average annual value of MHWS etc. varies from year to year in a cycle of approximately 19 years. This variation is in the order of up to 0.1 - 0.15 metres.

3. The values for the spring and neap ranges have been deduced from the spring and neap tidal level values. As a consequence of the annual variation of the tidal levels, the variation in the ranges of the spring and neap tides over the 19 year cycle is twice that of the levels.
4. The value of MSL for each port has been derived from the analysis of tidal observations made at the port during the period given in the table on the Standard Port Periods of Observation page.
5. The values for HAT and LAT given in the table above are the highest and lowest tidal levels that are predicted to occur under average meteorological conditions during the period 1 January 2000 - 31 December 2018 using the harmonic constituents derived from the analysis of the observations made at that port during the period given in the table on the Standard Port Periods of Observation page.
6. This table is not intended to be used for the determination of cadastral or administrative boundaries. A table of standard port values for cadastral purposes is available on this website see Related Content below.

Last Updated: 1 July 2021

Definitions Given on the LINZ Website

Standard Ports

Standard Ports are those for which tidal predictions are provided in the form of daily tables giving the times and heights of high and low waters. All times in these tables are in New Zealand Standard Time. Predicted heights are in metres and are based on the Chart Datum of the largest scale chart of the place.

Secondary Ports

Secondary Ports are those for which daily predictions are not provided. Data sufficient for calculating times and heights at these ports and places are given after the Standard Port predictions in this book. Secondary Ports are grouped under Standard Ports with a similar tidal pattern.

Mean Sea Level (MSL)

The average level of the sea surface over a long period or the average level which would exist in the absence of tides.

Mean High Water Springs (MHWS) & Mean Low Water Springs (MLWS)

The average of the levels of each pair of successive high waters, and of each pair of successive low waters, during that period of about 24 hours in each semi-lunation (approximately every 14 days), when the range of the tide is greatest (Spring Range).

Mean High Water Neaps (MHWN) & Mean Low Water Neaps (MLWN)

The average of the levels of each pair of successive high waters, and of each pair of successive low waters, during that period of about 24 hours in each semi-lunation (approximately every 14 days), when the range of the tide is least (Neap Range).

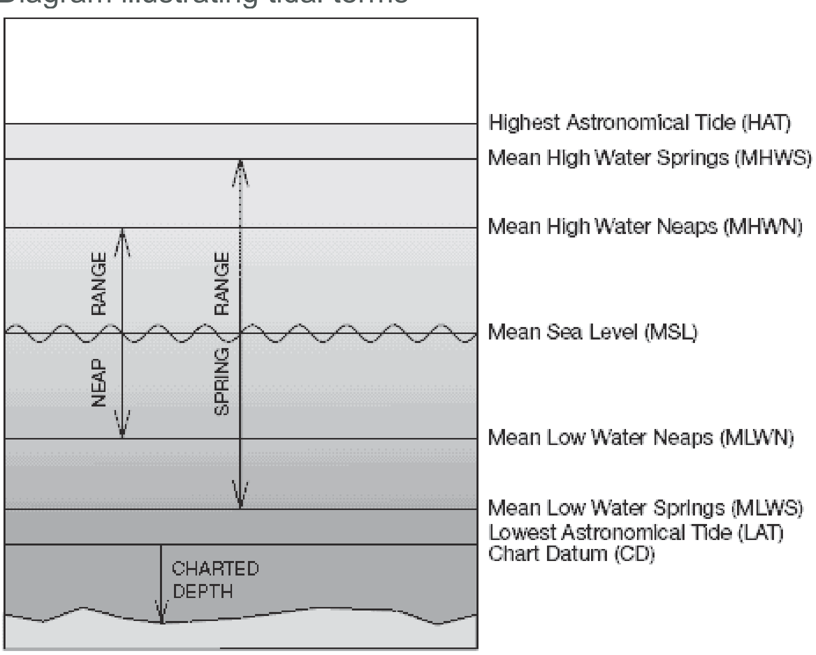
Chart Datum (CD)

A water level so low that the tide will but seldom fall below it. When meteorological conditions are such that sea level is lowered, the tide will fall below the predicted low water heights, and at a place where Chart Datum is at a comparatively high level, the actual depths at or near low water may be considerably less than charted.

Highest & Lowest Astronomical Tide (HAT & LAT)

The highest and lowest tidal levels which can be predicted to occur under average meteorological conditions over 18 years. Modern chart datums are set at the approximate level of Lowest Astronomical Tide (LAT) and Tide Tables list the predicted height of tide above Chart Datum. It should be noted that water level may fall below the level of LAT if abnormal meteorological conditions are experienced.

Diagram illustrating tidal terms



HIGHEST RECORDED TIDES IN DUNEDIN HARBOUR

Email from LINZ Hydrographical services 7 October 2021. hydro@linz.govt.nz

> For **Dunedin**, we have tidal records from 1905-01-01 to 2021-10-01. The highest tide we have recorded at this site is 2.750m, which occurred on two dates:
> 16-Mar-1980 16:00
> 15-Jun-1999 17:00
> This level is referenced to Chart Datum.
> At Dunedin, CD is 3.728m below benchmark AFEQ, and AFEQ has an NZVD2016 height of 2.37m.
> By my calculations, the maximum tide is therefore 1.392m above NZVD2016.
>
> I also checked nearby **Port Chalmers** (records 1985-06-11 to 2021-10-01).
> Here, we have the maximum as being 2.703m on 12-Apr-2020.
> CD is 3.816 below DR0F, but unfortunately, we don't have an NZVD measurement on this benchmark.
>
> For your reference:
> LINZ geodetic database https://www.geodesy.linz.govt.nz/gdb/
> Standard port datum descriptions https://www.linz.govt.nz/sea/tides/tide-predictions/standard-port-datum-descriptions

From the above 'Standard port datum descriptions', the location for Dunedin measurement point is:

> **Dunedin**
> 3.728m below B.M. WW 83 (LINZ code AFEQ), a stainless steel pin set into the concrete base at the north western corner of G Shed, Birch Street Wharf.

Appendix E BUILDING ACT S71-74

Building Act 2004 Sec 71 – 74. Reprint as at 8 June 2021

Part 2 Building

Subpart 3—Building work—Project information memoranda and building consents

Limitations and restrictions on building consents: Construction of building on land subject to natural hazards

71 Building on land subject to natural hazards

(1) A building consent authority must refuse to grant a building consent for construction of a building, or major alterations to a building, if—

(a) the land on which the building work is to be carried out is subject or is likely to be subject to 1 or more natural hazards; or

(b) the building work is likely to accelerate, worsen, or result in a natural hazard on that land or any other property.

(2) Subsection (1) does not apply if the building consent authority is satisfied that adequate provision has been or will be made to—

(a) protect the land, building work, or other property referred to in that subsection from the natural hazard or hazards; or

(b) restore any damage to that land or other property as a result of the building work.

(3) In this section and sections 72 to 74, **natural hazard** means any of the following:

(a) erosion (including coastal erosion, bank erosion, and sheet erosion):

(b) falling debris (including soil, rock, snow, and ice):

(c) subsidence:

(d) inundation (including flooding, overland flow, storm surge, tidal effects, and ponding):

(e) slippage.

Compare: 1991 No 150 s 36(1)

72 Building consent for building on land subject to natural hazards must be granted in certain cases

Despite section 71, a building consent authority that is a territorial authority must grant a building consent if the building consent authority considers that—

(a) the building work to which an application for a building consent relates will not accelerate, worsen, or result in a natural hazard on the land on which the building work is to be carried out or any other property; and

(b) the land is subject or is likely to be subject to 1 or more natural hazards; and

(c) it is reasonable to grant a waiver or modification of the building code in respect of the natural hazard concerned.

Compare: 1991 No 150 s 36(2)

Section 72: amended, on 15 March 2008, by section 13 of the Building Amendment Act 2008 (2008 No 4).

73 Conditions on building consents granted under section 72

(1) A building consent authority that is a territorial authority that grants a building consent under section 72 must include, as a condition of the consent, that the building consent authority will, on issuing the consent, notify the consent to,—

(a) in the case of an application made by, or on behalf of, the Crown, the appropriate Minister and the Surveyor-General; and

(b) in the case of an application made by, or on behalf of, the owners of Māori land, the Registrar of the Maori Land Court; and

(c) in any other case, the Registrar-General of Land.

(2) The notification under subsection (1)(a) or (b) must be accompanied by a copy of any project information memorandum that has been issued and that relates to the building consent in question.

(3) The notification under subsection (1)(c) must identify the natural hazard concerned.

Compare: 1991 No 150 s 36(2), (3)

Section 73(1): amended, on 15 March 2008, by section 14 of the Building Amendment Act 2008 (2008 No 4).

Section 73(2): amended, on 1 February 2010, by section 20 of the Building Amendment Act 2009 (2009 No 25).

74 Steps after notification

(1) On receiving a notification under section 73,—

(a) the Surveyor-General or the Registrar of the Maori Land Court, as the case may be, must enter in his or her records the particulars of the notification together with a copy of any project information memorandum that accompanied the notification:

(b) the Registrar-General of Land must record, as an entry on the record of title to the land on which the building work is carried out,—

(i) that a building consent has been granted under section 72; and

(ii) particulars that identify the natural hazard concerned.

(2) If an entry has been recorded on a duplicate of the record of title referred to in subsection (1)(b) under section 641A of the Local Government Act 1974 or section 36 of the former Act, the Registrar-General of Land does not need to record another entry on the duplicate.

(3) Subsection (4) applies if a building consent authority determines that any of the following entries is no longer required:

(a) an entry referred to in subsection (1)(b):

(b) an entry under section 641A of the Local Government Act 1974:

(c) an entry under section 36 of the former Act.

(4) The building consent authority must notify the Surveyor-General, the Registrar of the Maori Land Court, or the Registrar-General of Land, as the case may be, who must amend his or her records or remove the entry from the record of title.

Compare: 1991 No 150 s 36(5), (6), (7)

Section 74(1)(a): amended, on 1 February 2010, by section 21 of the Building Amendment Act 2009 (2009 No 25).

Section 74(1)(b): amended, on 12 November 2018, by section 250 of the Land Transfer Act 2017 (2017 No 30).

Section 74(2): amended, on 12 November 2018, by section 250 of the Land Transfer Act 2017 (2017 No 30).

Section 74(4): amended, on 12 November 2018, by section 250 of the Land Transfer Act 2017 (2017 No 30).

Appendix F FREEBOARD DETERMINATION 2021

2021 DCC Minimum Floor Levels Report
Determination of Freeboard

1.0 CONFIRMATION

The following approach was confirmed by DCC on 27 August 2021, in an email from Neil McLeod (DCC) to Roger Oakley (Stantec).

2.0 FREEBOARD DETERMINATION

2.1 BUILDING ACT 2004

In the assessment below, words in italics are defined terms in the Building Act.

The Building Act 2004 gives effect to the Building Code, via Part 2. There are a variety of clauses in the Building Act relating to the Building Code but attention is drawn to:

- Section 15(1)(a): In general terms, this Part provides — (a) that all building work must comply with the building code to the extent required by this Act:
- Section 16: The building code prescribes function requirements for building and the performance criteria with which building must comply in their intended use.
- **Section 17: All building work must comply with the building code to the extent required by this Act, whether or not a building consent is required in respect of that building work.**

2.1.1 BUILDING CODE MAIN REQUIREMENTS

The building code can be found in Schedule 1 of the Building Regulations 1992, and is in force. See regulation 8 of the Building (Forms) Regulations 2004 for information about the revocation of the rest of these regulations.

The Building Code is given standing pursuant to Regulation 3 of the above Building Regulations 1992, which remain in effect, despite the Building Act 1991 being replaced by the Building Act 2004. See regulation 8(1) of the Building (Forms) Regulations 2004 (SR 2004/385).

2.1.1.1 E1 – Surface Water

The main requirement of the Building Code in relation to the DCC Minimum Floor Levels project appears to be Clause E1 – Surface Water

- Clause E1.2 – Functional Requirement, states '*Buildings* and *sitework* shall be constructed in a way that protects people and *other property* from the adverse effects of *surface water*.
- Performance subclause E1.3.2 states; "*Surface water*, resulting from an event having a 2% probability of occurring annually, shall not enter *buildings*.
- The Codes' stated 'Limits on application' of E1.3.2 are: Performance E1.3.2 shall apply only to *housing*, *communal residential* and *communal non-residential buildings*.

2.1.1.2 Verification Method E1/VM1

DCC's assessment of appropriate freeboard for Minimum Floor Levels is adapted from Clause 4.3 - Secondary flow from site to downstream drainage system. This clause states:

> 4.3.1 The secondary flow estimated to arrive on the site shall be directed into the surface water drainage system designed for the site. The height of the secondary flow shall be used as a basis

> for determining the building floor level necessary to comply with the requirements of NZBC E1.3.2.
> The level of the floor shall be set at the height of the secondary flow plus an allowance for freeboard. The freeboard shall be:
> – 500 mm where surface water has a depth of 100 mm or more and extends from the building directly to a road or car park, other than a car park for a single dwelling.
> – 150 mm for all other cases.
> COMMENT: The 500 mm freeboard allows for waves generated by vehicles. Such waves will not be sustained unless there is at least 100 mm depth of water and an unobstructed path from the point where the wave is generated to the building.

DCC consider that the flooding associated with secondary flow paths to be very similar to flooding from the sea. **Therefore DCC's position is that a freeboard of 500mm shall be used for minimum floor levels associated with sea level.** DCC's own experience from South Dunedin flooding is that a 500mm freeboard is appropriate.

2.1.1.3 Building Code Acceptable Solution E1/AS1

Clause 2.0 of this Acceptable Solution proposes a floor level a minimum of 150mm above the surrounding land, but clause 1.0.1 limits its application:

> 1.0.1 This Acceptable Solution is limited to buildings and sitework having a catchment area of no more than 0.25 hectares and which are:
> a) Free from a history of flooding,
> b) Not adjacent to a watercourse,
> c) Not located in low lying area, and
> d) Not located in a secondary flow path.

DCC's position is that this limitation means the clause is not suitable for use in situations relating to sea level exposure.

2.2 NZS4404:2010. NZ STANDARD FOR LAND DEVELOPMENT AND SUBDIVISION INFRASTRUCTURE

Section 4 of NZS4404 covers stormwater, with s4.3 being for Stormwater Design. Section 4.3.52 covers Freeboard, and uses a 1% AEP (Annual Exceedance Probability). This varies from the 2% AEP in the Building Code, but it is noted that 4404's focus on land development vs building development. It states:

4.3.5.2 Freeboard

The minimum freeboard height additional to the computed top water flood level of the 1% AEP design storm should be as follows or as specified in the district or regional plan:

Freeboard	Minimum height
Habitable dwellings (including attached garages)	0.5 m
Commercial and industrial buildings	0.3 m
Non-habitable residential buildings and detached garages	0.2 m

The minimum freeboard shall be measured from the top water level to the building platform level or the underside of the floor joists or underside of the floor slab, whichever is applicable.

Freeboard is defined in NZS4404 as:

Freeboard	A provision for flood level design estimate imprecision, construction tolerances, and natural phenomena (such as waves, debris, aggradations, channel transition, and bend effects) not explicitly included in the calculations

2.3 DCC CODE OF PRACTICE FOR SUBDIVISION AND DEVELOPMENT 2010

This Code adds additional requirements to 4404. In its introduction in Part 4: Stormwater Drainage, states: Under normal circumstances design and construction of stormwater systems shall be undertaken in accordance with the requirements of Part 4, Stormwater of NZS440 :2004, except as amended for DCC requirements in the clauses below. There is no amendment in relation to freeboard, other than in cl4.2.1 where it states 'Careful design of secondary flow paths will reduce potential for damage in flood conditions. Such designs should include provision of measures to restrict damage by flood such as locating dwellings to provide freeboard, …'.

3.0 CONCLUSION

DCC's position is that for the purposes of minimum floor levels associated with sea level, a freeboard of 500mm should be added to the calculated water level to allow for wave action and other uncertainties. This is consistent with clause 4.3.1 of E1/AS1 of the Building Code, NZS4404:2010 and DCC's observed experience.

Determination No 99/005

Floor level for a house on a flood-prone site

1 THE MATTER TO BE DETERMINED

1.1 The matter before the Authority is a dispute as to whether building consent should be granted for a house on a flood-prone site with proposed floor levels lower than is required in the territorial authority's catchment management plan.

1.2 The Authority takes the view that it is being asked in effect to determine whether the proposed building complies with clause E1.3.2 of the building code (the First Schedule to the Building Regulations).

1.3 In making its determination the Authority has not considered whether the proposed building work will comply with any other provisions of the building code or of the Building Act.

1.4 The Authority has also not considered whether the floor level required by the catchment management plan is a legitimate requirement under the Resource Management Act or any other Act except the Building Act. The Authority reads section 34(3) of the Building Act as a positive obligation on a territorial authority to grant building consent if satisfied on reasonable grounds as to compliance with the building code irrespective of requirements under other Acts. Section 35(3) makes it clear that issuing a building consent under the Building Act will not prevent the enforcement of any other Act.

2 THE BUILDING

2.1 The proposed building is a new detached house on an almost level site (ground levels varying from approximately RL 53.7 to 54.2 m). Habitable rooms on the ground floor are shown as having a finished floor level of RL 54.6 m and the garage as having a finished floor level of RL 54.3 m.

3 THE PARTIES AND THEIR SUBMISSIONS

3.1 The applicant was the owner. The other party was the territorial authority.

3.2 The applicant submitted a report by a consulting engineer. The report recommended a floor level for habitable rooms of RL 54.6 m on the basis that:

(a) The flood level in a storm having a 2% probability of occurring annually ("the 50 year flood", also referred to as the 2% AEP event) would be RL 54.3 m.

The consulting engineer arrived at that level from consideration of the 100 year flood level of RL 54.4 m shown in the catchment management plan for a point about 50 m upstream from the proposed house.

(b) A freeboard of 300 mm would be adequate for the site concerned.

The consulting engineer arrived at that freeboard from a site survey which led him to conclude that flood waters in the RL 54.2 to 54.4 m range can spread over a significantly greater area than is shown in the catchment management plan and that there was no risk of backwater effects.

The consulting engineer also considered that because the area was comparatively flat lesser freeboard was required than in a narrow steep-sided valley.

3.3 The territorial authority's submission was in effect that the catchment management plan specified that floor levels for habitable rooms were to be 600 mm above the 100 year flood level shown in the catchment management plan. That equated to a minimum floor level for habitable rooms of RL 55.0 m. The territorial authority said:

> We see the 2% AEP floor level requirement of the Building Act as minimum guidelines which we enhance to 1% to apply to [our local] conditions well proven by detailed analysis and many years of practical stormwater management.

The catchment management plan also specified floor levels for non-habitable rooms, which are presumably intended to apply to the garage, see 5.2 below.

3.4 The Authority drew the attention of the parties to the draft revision of its Approved Document E1, which had been made available for public comment towards the end of 1998, and in particular to the following proposal with respect to freeboard:

> The level of the floor shall be set at the height of the secondary flow plus an allowance for freeboard. The freeboard shall be:
>
> - 500 mm where surface water ponds to a depth of 100 mm or more and extends from the building to a road or car park, other than a car park for a single dwelling.
> - 150 mm for all other cases.

The Authority also sought the views of an engineer whom it had engaged as an adviser in respect of that draft. That advice was given orally, and the Authority repeated it to the parties in the following words:

> We understood [the Authority's adviser] to explain that:
>
> (a) Freeboard allows for both:
>
> (i) Uncertainties in determining flood level, and
>
> (ii) Wave action.
>
> See also Determination 98/003.
>
> (b) The 500 mm freeboard mentioned in the draft is made up of:
>
> (i) 150 mm for uncertainties in determining flood level.
>
> That is considered a reasonable allowance for the general case of a 100 hectare catchment to which the draft is limited, and it is also considered appropriate for the much bigger [catchment concerned] on the basis that the Catchment Management Plan was no doubt the result of sophisticated modelling and calculation.
>
> (ii) 350 mm for a wave generated by a vehicle. This in turn is made up of 200 mm wave height plus 150 mm run-up when the wave hits the building.
>
> A 200 mm wave will be sustained so long as there is a minimum 100 mm depth of water, and will travel a considerable distance. A reduction in the depth of 100 mm between the source and the building will cause the wave to break.

3.5 The territorial authority responded by saying:

(a) Finished floor level of any habitable room should be at the 100 year flood level plus 600 mm freeboard as indicated in the catchment management plan.

(b) "Freeboard is the design margin to allow for factors omitted in the overall designs such as wave action and settlement of foundations and uncertainties in the estimation of flood levels. Should freeboard criteria be considered for amendment we would expect more intensive review of the [catchment management plan] model based on newly acquired and appropriate data."

3.6 The applicant's consulting engineer responded by saying:

(a) "Given the wide flowpath downstream from [the house concerned] . . . an allowance of 150 mm for uncertainties is reasonable".

(b) "[The house] is about 30 m from the road carriageway. Fencing can be expected to limit wave action."

(c) ". . . in terms of the 100 mm flood depth criteria:

"50 year (2% AEP) flood level	RL 54.30 m
"Driveway level at road boundary	RL 54.19 m

"This gives a floodway depth of 110 mm at the road boundary of the property. The client can provide a 170 mm hump in the driveway and front yard, if necessary, to ensure that wave action cannot affect [the house].

"in view of the above factors, the proposed floor level of RL 54.60 m (2% AEP flood level plus 300 mm) is considered adequate."

3.7 Neither party wished the Authority to hold a hearing at which it could speak and call evidence.

4 THE BUILDING CODE

4.1. The relevant provision of the building code in respect of floor levels, in clause E1 "Surface water", is:

Provision	**Limits on application**
E1.3.2 *Surface water*, resulting from a storm having a 2% probability of occurring annually, shall not enter *buildings*.	Performance E1.3.2 shall apply only to *Housing*, *Communal Residential* and *Communal Non-residential buildings*.

5 DISCUSSION AND CONCLUSIONS

5.1 The Authority takes the view that section 34(3) of the Building Act prevents a territorial authority from refusing a building consent for work which complies with the building code even if it does not comply with requirements under any other Act. Such a requirement is to be enforced under the Act concerned, not by the refusal of a building consent under the Building Act. Thus the catchment management plan, issued under the Resource Management Act, is irrelevant to this determination, which is not to say that the catchment management plan cannot be enforced under the Resource Management Act.

5.2 The floor levels for non-habitable rooms specified in the catchment management plan are not discussed below because clause E1.3.2 of the building code applies only to the classified uses Housing, Communal Residential, and Communal Non-residential as defined in clause A1 of the building code (see 4.1 above) and a domestic garage does not come within any of those classified uses, but within the classified use Outbuildings. Thus the building code has no requirement for the floor level of the garage and the proposed floor level of RL 54.3 m must be accepted.

5.3 The territorial authority was unwilling to consider any freeboard other than as specified in the catchment management plan.

5.4 The applicant's consulting engineer was of the opinion that the freeboard appropriate for comparatively flat land is less than the freeboard appropriate for a narrow steep-sided valley. That opinion appears to relate to uncertainties in the estimate of surface water level and not to wave-type effects.

5.5 The applicant's consulting engineer estimated the 50 year flood level at RL 54.30 m on the basis of the 100 year flood level specified in the catchment management plan. That estimated flood level was not disputed by the territorial authority, and therefore the Authority is prepared to accept it for the purposes of this determination.

5.6 The applicant's consulting engineer suggested that fencing might limit wave action. However, the house is served by a straight drive to the road, approximately 30 m long. The Authority does not consider that fences beside the drive will have a significant effect on wave action along the drive. The Authority therefore considers that wave action must be allowed for so that 500 mm freeboard is appropriate. The Authority therefore considers that the house will comply with clause E1.3.2 of the building code if the finished floor level of habitable rooms in the house is at or above RL 54.80 m.

5.7 The Authority recognises that the allowance for wave action will not be necessary if the house will not be exposed to wave action. That will be the case if the depth of water at some point in the path of any waves is less than 100 mm or if there is an effective barrier to prevent the passage of waves. The applicant suggested a "170 mm hump" on the drive, and the Authority considers that the suggested hump having its top at or above RL 54.36 m would be effective to prevent wave action along the line of the drive. However, the Authority does not have sufficient information to determine whether similar provisions would need to be made to prevent wave action along different stretches of flood water between adjacent roads and the house concerned. Such precautions might include the provision of fences sufficiently solid to prevent the passage of waves. All necessary provisions would need to be specified in the building consent. If all necessary provisions were made to prevent waves reaching the house then an appropriate freeboard is 150 mm above the 50 year flood level of RL 54.30 m, so that the finished floor level of habitable rooms in the house could be RL 54.45 m.

6 THE AUTHORITY'S DECISION

6.1 In accordance with section 20(a) of the Building Act the Authority hereby determines:

(a) That the house will comply with clause E1.3.2 of the building code if either:

(i) The finished floor level of habitable rooms is at or above RL 54.80 m; or

(ii) The plans submitted to the Authority are amended to incorporate, to the satisfaction of the territorial authority, provisions to prevent waves reaching the house as discussed in 5.7 above, and the finished floor level of habitable rooms is at or above RL 54.45 m; and

(b) Clause E1.3.2 does not apply to the garage, so that the proposed garage floor level of RL 54.3 m is to be accepted.

Signed for and on behalf of the Building Industry Authority on this 15th day of June 1999

W A Porteous
Chief Executive

Appendix G MFE FACTSHEETS 1-6, 2009

FACT SHEET 1

This is one of a series of fact sheets developed to accompany *Preparing for coastal change*, and provide further information on elements of coastal processes.

Coastal erosion

This fact sheet provides information on **coastal erosion**, *which will be affected by climate change and sea-level rise.*

A natural process

Coastal erosion is a natural process. In its natural state, the coast recedes or advances depending on sediment supply, climate and ocean conditions. Coastal *accretion* is where the shoreline builds out. Coastal *erosion* is when the shoreline retreats, either temporarily or permanently. Erosion becomes a hazard when it threatens people's activities or settlements or other things they value.

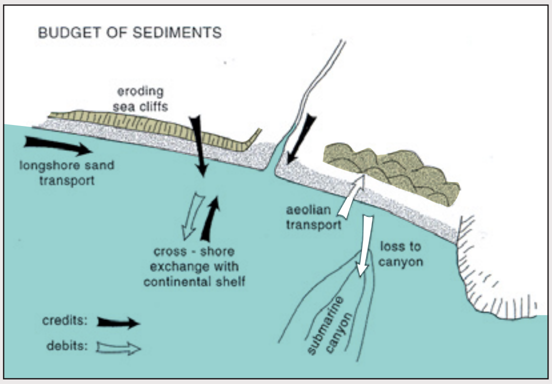


Figure 1: Elements of a typical sediment budget

Typical sediment **sources** to nearshore coastal systems:

- longshore transport – sediment moves into the area along the coast
- onshore transport – sediment is brought to the coast from further out at sea
- input from rivers – sediment flows down rivers and is deposited along the coast
- sediment is transported onto beach by the wind (aeolian transport)
- eroding sea cliffs deposit sediment on the coast
- beach nourishment – sediment lost through longshore drift or erosion is replaced from outside sources
- dune vegetation traps sand.

Typical sediment **losses** from nearshore coastal systems:

- longshore drift moves sediment out of the area
- wind blows sediment away from beach
- sediment is transported offshore by storms, swell, currents, etc
- abrasion – rock surfaces are ground away by other rock or sand particles carried by the wind
- sand is extracted
- waves bouncing off hard defences (eg, structures such as sea walls) carry sediment away
- dams and reservoirs trap river sediments, preventing them from reaching the coast.

Source: Derived from Komar P. 1998. Beach Processes and Sedimentation. New Jersey: Prentice-Hall Inc.

Coastal change has many causes

Changes to coastlines are caused by many different and interconnected factors:

- *hydrodynamic driving processes* – are the forces of moving water. These include swell, sea waves, tides, storm surge, currents and the effects of climatic variability – for example, the El Niño-Southern Oscillation and the Interdecadal Pacific Oscillation. Climate change may affect each of these processes
- *geomorphology* – the coast's physical features (such as beaches, barriers and the types of sediment present), and its geological features (such as headlands and islands) and how these interact with the *hydrodynamic driving processes* described above. An example is sand spits, which are often unstable and prone to large and long-lived changes
- *sediment budget* – the rate at which sediment comes and goes from the coast, and whether this is balanced (see figure 1)

- *vertical land movement* – whether the coast is rising or subsiding
- *sea-level rise*.

Predicting coastal change is difficult

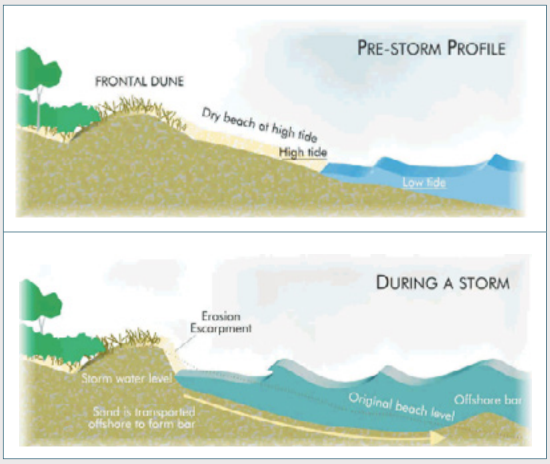
Because many factors are involved in coastal erosion, and they are not all present all of the time, shoreline change in any particular location is *not* consistent year after year.

Erosion and accretion can occur in cycles, particularly on sandy coastlines. Changes can happen seasonally, annually, or over several decades. Erosion and accretion can also be caused by particular events such as storms (figure 2) – there may be little change for many years until a storm (or a sequence of storms) causes rapid erosion.

Even over short distances of coast, patterns of erosion and accretion can vary, producing erosion hotspots, for example linked to the occurrence and movements of nearshore sandbars.

Because of this variability, coastal erosion is typically divided into two timescales: *short-term fluctuations* (days to a few months) and *long-term trends* (from seasonal, to decades or centuries).

The variability in when and how coastal erosion happens makes it very difficult to estimate what may occur at a specific place. Data and historic information about shoreline changes and sediment budgets are needed, along with an understanding of how vulnerable the coast is to climate change.



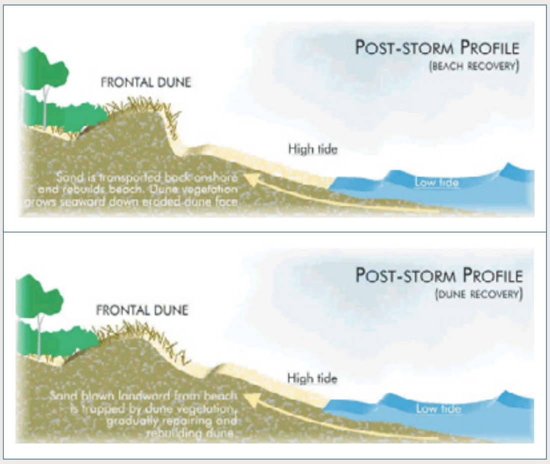


Figure 2: Typical response of a natural sand beach–dune system to erosion during a storm, and how the beach and dunes build up again over the following months (and even years).

Source: Dune Restoration Trust of New Zealand.

People's influence on the coast

What we do can have a big impact on that natural ebb and flow of coastal sediments. Our impacts can markedly alter or control natural processes by:

- changing how sediment flows from catchments to the coast, via rivers and streams. For example, by our land-use practices, urbanisation, building dams and extracting water for irrigation
- dredging tidal entrances and harbour channels, which affects how sediment moves
- removing sand or gravel from nearshore areas
- building coastal protection, such as groynes, breakwaters, artificial reefs and seawalls. This affects the natural buffering, movement and distribution of sediments on beaches and in shallow coastal waters
- adding sediment to beaches and shallow coastal waters (beach nourishment)
- permanently modifying the coast in ways that affect the natural movement of beach and nearshore sediments. This includes removing dunes, removing or changing vegetation, reclaiming land, and building wharves and marinas.

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Ministry for the Environment
Manatū Mō Te Taiao

FACT SHEET 2

This is one of a series of fact sheets developed to accompany *Preparing for coastal change*, and provide further information on elements of coastal processes.

Coastal flooding due to storms

This fact sheet outlines the process of **coastal flooding** *caused by storms, a hazard that will be affected by climate change and sea-level rise.*

Storms, tides and sea level

Coastal flooding is a natural event that happens when extreme weather causes low-lying coastal land to be inundated with water.

Flooding may occur when high tides (mostly spring or *perigean*[1] tides) combine with:

- a storm surge – when strong onshore winds accompany low barometric (air) pressure, causing a temporary rise in sea level above the predicted tide height. A storm surge may last for hours or days. Fact sheet 5 in this series explains storm surges in more detail.
- larger than normal waves and/or swell – seawater may spill over low coastal barriers when the average level of seawater inside the surf zone is higher than the sea level offshore from the breakers (*wave set-up*), or when waves run higher up the beach than normal (*wave run-up*). In some cases, distant storms may cause the damaging waves or swell.
- higher than average monthly mean sea level caused by regular climate cycles and unpredictable variability.

The total sea level formed from this combination of high tides, month-to-month variability in mean sea level and storm surges is called a *storm tide*. Whether coastal flooding occurs during a storm or not, and just how severe it is, depends on timing. For example, if the peak of the storm surge does not coincide with the highest wave conditions and the time of a high spring tide, inundation may not occur.

1 A spring tide happens every two weeks, when the Earth, sun and moon are nearly aligned. A 'perigean' spring tide, sometimes called a 'king tide', occurs three or four times a year when a spring tide coincides with when the moon is at its closest point to Earth.

Figure 1: Hauraki Plains inundated (May 1938)

Source: RNZAF

The biggest storm tides last century occurred in 1936 and 1938. Auckland suffered a similar-sized event on 23 January 2011.

The Great Cyclone of 1 – 2 February 1936, with barometric pressures down to 970 hPa and ferocious winds and waves, came on the back of a very high perigean-spring tide. Widespread coastal flooding caused damage along the east coast of the North Island. Coastal roads were washed away, a house fell into the sea at Te Kaha, and houses 100 metres inland at Castlepoint were swamped when the sea breached the coastal dunes. A month later, on 25 – 26 March, an easterly gale produced by a low depression combined with extremely high perigean-spring tides to cause damage and sea flooding in the Auckland region.

Two years later, on 4 – 5 May 1938, more than 1600 hectares of the lower Hauraki Plains were flooded at depths of 0.5–1.3 metres (figure 1). Spring tides and north-east gales combined to create a large storm surge with accompanying waves, all exacerbated by heavy rain. The shoreline stopbank from Waitakarau to Kopu was breached in several places.

More recently, on 23 January 2011, Auckland experienced a storm of similar magnitude. Flooding was 0.11 metres deeper and more extensive than in 1936, with houses inundated and roads closed. Most of the difference in peak water levels for these similarly-sized storms can be attributed to a sea-level rise of 0.12 metres since 1936.

Sources: Brenstrum E. 1998. The New Zealand Weather Book. Nelson: Craig Potton Publishing: Nelson; www.ohinemuri.org.nz/journals *(Sept 2009); Stephens et al. 2013. Coastal inundation by storm-tides and waves in the Auckland Region. Prepared for the Auckland Council by NIWA. Auckland: Auckland Council.*

Landforms play a part

Just how big and deep a flood is also depends on the coast's physical characteristics and topography. Typically, flood waters follow the pathways described below.

- Direct inundation – where the storm tide, plus the wave set-up level, exceed the elevation of the land. This typically occurs when there is no coastal barrier, or the barrier has been reduced, sometimes because people have modified it. Areas with no coastal barrier often include estuaries, sheltered coastlines and river margins.
- Breach flooding – when a natural barrier (such as a gravel ridge or narrow dune field) or a human-made defence (such as a stopbank) is breached. Breach flooding is more likely to occur on open sections of coast that are exposed to larger waves and swell.
- Wave splash and spray – when a natural or artificial barrier is over-topped. This typically occurs when wave or swell conditions coincide with a high tide or storm tide. Again, the volume of floodwater is greater on more exposed, open sections of coast.

Flooding of the coast, estuaries and low-lying areas by rivers and storm water can be made worse by high tides or storm tides (figure 2). Following an extreme event, land in relatively flat, low-lying coastal margins can stay inundated by seawater for several days – places such as Christchurch's Lower Heathcote River, the South Canterbury plains, the Hauraki Plains, and Ahuriri in Napier. Beside the damage caused to buildings, infrastructure and electrical services, inundation by seawater drastically affects vegetation and pasture production for several months.

Figure 2: Coastal inundation at East Clive, south of Napier, on 16 August 1974, was caused by persistent heavy swell coinciding with high tides. This resulted in the gravel barrier being overtopped, and the low-lying land behind being inundated. Two hundred homes were affected.

Source: Ministry of Works and Development, Napier (now the National Institute of Water and Atmospheric Research (NIWA)).

Our actions can increase the hazards from flooding

What we do can also exacerbate coastal storm flooding hazards.

- River training works, such as straightening and stopbanks, can raise river levels at the coast.
- Poorly designed coastal protection structures, such as seawalls, can cause the beach to erode, or increase its exposure to wave run-up and overtopping.
- Developing coastal property in areas prone to flooding (low-lying land around estuaries or shorefront areas without an adequate buffer).
- Building roads or other infrastructure can block the flow of water over land.

- Providing inadequate drainage behind coastal berms, seawalls or roads.
- Physically removing, reducing or damaging natural coastal barriers, such as sand dunes and gravel barriers. For example, lowering access ways, removing vegetation, and trimming or removing dunes.
- Permanently modifying coastal margins by creating structures such as waterways, canals, marinas and boat ramps, or reclaiming land.

'Red alert' tide days ('king tides')

'King tides' raise the likelihood of exposed low-lying coastal areas being flooded, even if only modest storm surges or wave conditions occur.

Upcoming dates when high tides are predicted to reach the highest levels can be found at: www.niwa.co.nz/our-science/coasts/tools-and-resources/tide-resources.

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FACT SHEET 3

This is one of a series of fact sheets developed to accompany *Preparing for coastal change*, and provide further information on elements of coastal processes.

Components of coastal sea level

This fact sheet outlines* the components which make up sea level *at the coast.

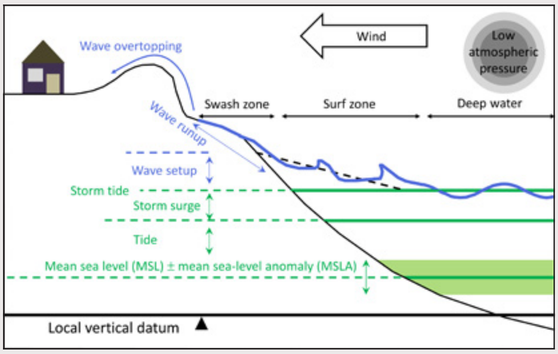

Figure 1: Components of coastal sea level.

Source: NIWA

The elevation that the sea reaches at a shoreline is determined by the following components (also shown in figure 1).

- *Mean sea level* (MSL) – the average level of the sea over a defined period, usually 18–20 years. The measurements are relative to a fixed reference level, known as a *vertical datum* (see supplementary information sheet 10 on Datums in the guidance). MSL continues to rise due to climate change.
- *Mean sea-level anomaly* (MSLA) – this is the difference between actual sea level and the mean sea level (MSL), on time scales ranging from months to several years. Anomalies between the two can be due to short-term climate variability or longer-term fluctuations caused by seasonal effects (annual cycle), the El Niño-Southern Oscillation and the Interdecadal Pacific Oscillation (IPO). For example, sea levels are a few centimetres higher in late summer and early autumn, and a few centimetres lower in winter and early spring. During the longer-term El Niño phases, sea levels tend to be lower, and during La Niña phases, sea levels tend to be higher. And, when the IPO is in its negative phase, which it has been since 1999, sea levels can increase by up to 5 centimetres.
- *Astronomical tide* – this is the largest contributor to variations in sea levels. Tides result from the gravitational attraction of the moon and sun, and can be forecast well ahead. They oscillate above and below the combined MSL and MSLA for any given month. More information about tides is provided in fact sheet 4 in this series.
- *Storm surge* – the temporary increase in regional sea level due to low barometric (air) pressure combined with strong onshore winds. Conversely, high pressure and winds blowing offshore tend to lower the sea level below the predicted tide. Storm surges are described in fact sheet 5 of this series.
- *Storm tide* – this term describes the temporary rise in sea level offshore of the zone where waves break. Storm tide is the combination of the four components described above (MSL + MSLA + tide + storm surge).
- *Wave set-up* and *run-up* – at the shoreline, the maximum vertical height reached by the sea is a combination of the wave set-up (the height of seawater landward of the zone where waves break), and the wave run-up (or *swash*; the waves running up the beach). These act on top of the storm tide. Both wave set-up and run-up can vary a great deal, even over a short length of coast, depending on the type of beach, its slope, the backshore features and whether coastal defence structures are present or not.

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FACT SHEET 4

This is one of a series of fact sheets developed to accompany *Preparing for coastal change*, and provide further information on elements of coastal processes.

Tides around New Zealand

This fact sheet discusses ***tides*** *around New Zealand, and how they influence sea level.*

The sun, the moon and the sea

Tides are generated by gravitational forces exerted by the sun and moon on the oceans. Once the open ocean tides reach estuaries and harbours, they are modified by:

- *wave shoaling*, where shallower water causes the wave to slow down and increases the tide range
- friction from the seabed and constrictions such as estuary entrances, river mouths and straits.

New Zealand's tides are *semi-diurnal*. That is, on most days, two high and two low tides will occur. One complete cycle of a high and a low tide happens on average every 12 hours and 25 minutes. Tides can be predicted for many years in advance.

The greatest differences between high and low waters happen around full and new moons, and are known as spring tides. A *spring tide* happens every two weeks, when the Earth, sun and moon are nearly aligned. A perigean spring tide occurs three or four times a year when a spring tide coincides with the moon being at its closest point in its orbit around the Earth.

The size of spring tides varies around New Zealand, reaching 3.5–4 metres on the west coast, but only 1–2 metres on the east coast (figures 1 and 2).

The smallest difference between high and low tides happens just after the first and third quarters of the moon, and are known as *neap tides*. The Foxton tide, in figure 2, shows the spring-neap-spring tide cycle that occurs approximately every fortnight.

Mean high water spring

Mean high water spring (MHWS) describes the highest level that spring tides reach, on average, over a long timescale – often 18–20 years. The highest visible line of seaweed, driftwood and other marine debris that gathers on a shoreline over a year is generally a good indicator of MHWS.

While MHWS sets the boundary for coastal planning, defining just where it lies can be complicated, as there are a number of

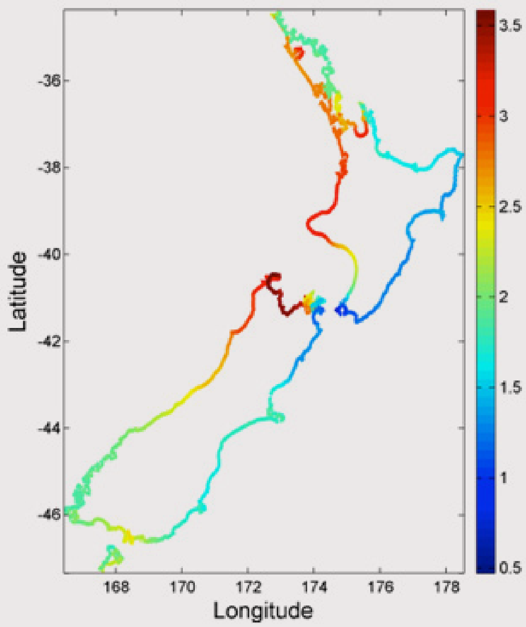

Figure 1: Spring tide range (in metres) around the coast of New Zealand.

Source: NIWA

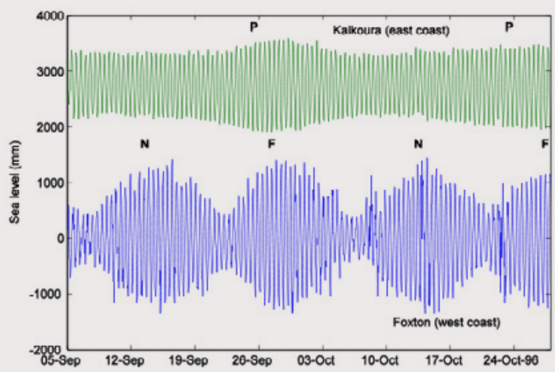

Figure 2: Comparison of tide characteristics between Kaikoura (east coast) and Foxton (west coast). P= perigee, N= new moon and F= full moon.

Source: NIWA

different ways to do so. A commonly used nautical definition calculates MHWS as, 'the long-term average of the highest spring tides that occur around every new and full moon'. Normally, only about 10–15 per cent of all high tides exceed the nautical definition for MHWS. One exception is those along New Zealand's central–eastern coasts. For example, at Kaikoura (see figure 2), nearly 43 per cent of high tides exceed the nautical MHWS level.

This is because the sun's influence on tides along the central and eastern coasts is relatively weak, and creates only a small difference between their fortnightly neap and spring tides. The higher tides peak just once a month (about every 27.5 days), when the moon's elliptical orbit is closest to the Earth – known as the *lunar perigee*.

King tides

The largest of the high tides cluster around dates when a full or new moon coincides with the moon in its perigee. These peak approximately every seven months and are known as perigean-spring tides, or *king tides*. They can be predicted and publicised well ahead of time. If bad weather coincides with these red alert days, the likelihood of coastal flooding in low-lying areas greatly increases. This is described in more detail in fact sheet 2 of this series, which covers coastal flooding due to storms.

Tide prediction resources

Official tide predictions at standard and secondary ports in New Zealand are available at: www.linz.govt.nz/sea/tides/tide-predictions.

Open coast and exclusive economic zone tide predictions for up to one month at any location around New Zealand, for any time period since 1830, are available at: www.niwa.co.nz/services/online-services/tide-forecaster.

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FACT SHEET 5

This is one of a series of fact sheets developed to accompany *Preparing for coastal change*, and provide further information on elements of coastal processes.

Storm surge

This fact sheet outlines the processes that create **storm surge**, *which can contribute to flooding at the coast.*

Processes that create storm surge

Storm surges are temporary increases in ocean and estuary water levels caused by storm conditions that last from hours to days. Storm surge is a combination of two weather and ocean processes:

- low barometric (air) pressure allows sea levels over a large area (100 square kilometres or more) to rise above the pre-storm sea level. This is known as the *inverted barometer effect*, and results in approximately a 1-centimetre rise in sea level for every 1 hPa drop in barometric pressure below normal
- strong, persistent winds blowing onshore cause water to 'pile up' against the coast, raising water levels (figure 1). Because of the Coriolis effect[1], winds that blow along New Zealand's shores in an anticlockwise direction (that is, with the coast on the left) also cause water to pile up. Similarly, both onshore and anticlockwise winds can 'hold up' water levels in estuaries.

Wind and air pressure effects

The combination of the wind and air pressure effects can vary greatly, depending on the type of weather system. During low-pressure systems that arrive from the tropics, which rotate clockwise, the effect of air pressure generally contributes at least half of the height of a storm surge hitting New Zealand's east coast.

In the case of a low-pressure trough that is blocked by a stationary or slow-moving area of high pressure, prolonged winds blow over large distances (large *fetch*[2]). These winds can drive large surges that have a relatively small air pressure component. One example is the storm that hit Tararu (in the Firth of Thames) on 12 June 2006. A cold front brought heavy rain and severe north-westerly gales, with wind speeds of up to 23 metres per second around the time the storm surge peaked, contributing a wind surge of 0.8 metres to the total storm surge height of 0.97 metres.

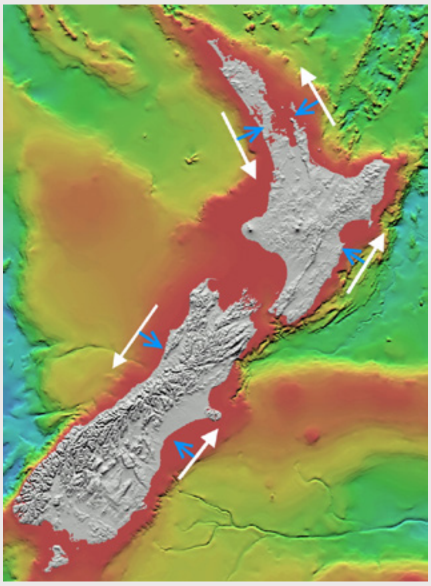


Figure 1: Alongshore wind directions (white arrows) around New Zealand that contribute onshore water level set-up (blue arrows) to storm surge.

Source: NIWA

1 The Coriolis effect occurs when a mass moving in a rotating system experiences a force (the Coriolis force) acting perpendicular (at 90 degrees) to the direction of motion and to the axis of rotation. On the Earth, this means that moving objects in the southern hemisphere tend to be deflected to the left, and to the right in the northern hemisphere.

2. The distance of continuous open water.

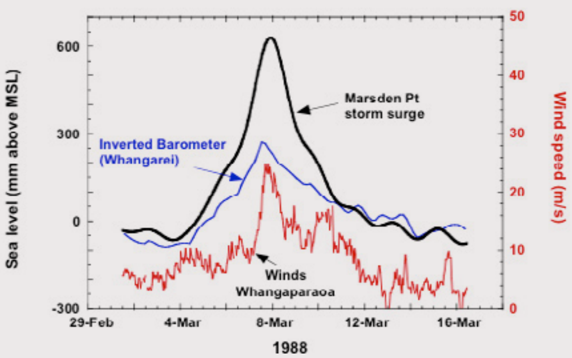
Different coasts, different surges

Storm surge height rarely exceeds 0.6 metres on open coasts around New Zealand, and is usually much smaller. However, they can be higher in some estuaries and harbours. The largest recorded is a 0.90 metre storm surge in Kawhia Harbour on 6 May 2013, followed closely by a 0.88 metre surge in Tauranga Harbour during Cyclone *Giselle* in April 1968.

The main factor that determines whether a high storm surge will cause flooding on low-lying land is whether it coincides with high spring or perigean tides.

Figure 2: Cyclone *Bola*, one of the most damaging cyclones to hit New Zealand in recent decades, tracked southwards over New Zealand in early March 1988.

At Marsden Point, the storm surge measured over 0.6 metres (black line). At its peak, approximately 50 per cent was due to the inverted barometer effect (blue line), with the remainder due to the influence of the strong east-north-east winds (red line).



Storm tide and storm surge monitoring

Data on tides and storm surges is captured at 16 sea level monitoring sites around the New Zealand coast. Data for the previous 5 days is available from: www.niwa.co.nz/our-services/online-services/sea-levels.

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FACT SHEET 6

This is one of a series of fact sheets developed to accompany *Preparing for coastal change*, and provide further information on elements of coastal processes.

Ministry for the Environment
Manatū Mō Te Taiao

Waves

*This fact sheet provides additional information on **waves** around New Zealand.*

What makes a wave?

Waves around New Zealand's open coast are generated from two sources (that often coexist):

- locally generated waves are caused by winds blowing over open water – from tens to hundreds of kilometres. The distance of continuous open water is known as the *fetch*. Long fetches allow the wind to build up larger waves
- distantly generated waves (swell), formed in the Pacific Ocean or Southern Ocean.

Waves are defined by three things:

- *significant wave height* (H_s) – the average height of the highest 33 per cent of waves over a certain period, measured in metres (m). See figure 1
- *wave period* (T_m) – the average time between successive waves, measured in seconds (s)
- *wave direction* – south (S), north (N), east (E) or west (W), or combinations of these – for example, W–SW

Different waves for different coasts

The ocean around New Zealand can be divided into four major zones, each with different wave conditions. Each zone exposes New Zealand's open coasts to different waves:

- *south-facing coasts (Fiordland to Catlins, South Island):* an extremely high energy wave zone (mean H_s = 3–4 m; T_m = 10–12 s; SW–W). Waves are typically steep, indicating a zone of active wave generation, but also contain a sizeable swell component from the Southern Ocean
- *western New Zealand coasts*: a high energy wave zone (mean H_s = 2–3 m; T_m = 6–8 s; SW–W). The waves are steep and respond to the regular passage of weather systems across the Tasman Sea
- *eastern New Zealand, up to East Cape*: a moderate to high energy wave zone (mean H_s = 1.5–3 m; T_m = 6–9 s; S). Sheltered from prevailing westerly winds by the New Zealand land mass, but exposed to southerly winds and swell. Wave steepness is variable, indicating a mixture of swell and wind sea[1].
- north-eastern North Island (East Cape to North Cape): a low energy lee shore (mean Hs = 1–2 m; Tm = 5–7 s, N–E). Wave steepness is variable. Highest waves occur during extropical cyclones, or as swell that is generated by distant Pacific cyclones to the north-east of the North Island.

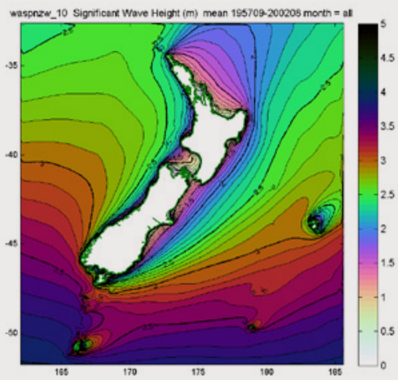

Figure 1: The 45-year average of the significant wave height (Hs) in metres around New Zealand, based on a deep water wave model. *Source: NIWA*

In estuaries and harbours, waves are mostly generated by local winds, and their height is limited by the fetch and the depth of water. Wind waves in estuaries and harbours can still cause erosion and flooding hazards, particularly during very high tides or storm tides.

1 Regional wave conditions which result from recent winds and are generated mainly in the direction of the wind, in contrast to swell.

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FACT SHEET 7

This is one of a series of fact sheets developed to accompany *Preparing for coastal change*, and provide further information on elements of coastal processes.

Sea-level rise

This fact sheet provides additional information on sea-level rise*: what has happened so far, and what may happen in future.*

Sea level has changed in the past

Global sea level has fluctuated considerably over many thousands of years. When the climate was warmer about 125,000 years ago, it was a few metres higher than today's sea level. During the last *glacial maximum*, when the ice sheets were at their greatest extent (about 20,000 years ago), the sea's level was more than 120 metres lower than today.

After at least a thousand years of little change, sea level around the world began to rise around the latter half of the 19th century, and increased at a rate of around 1.7 millimetres a year during the 20th century. Since satellite measurements began in 1993, the global average sea level has risen more quickly, at 3.3 millimetres a year. The increase is due partly to natural climate variability, and partly to warming of the atmosphere and oceans.

There are two main drivers of the global rise in sea level:

- rising temperatures, which warm ocean waters and make them expand
- more water is being added to the oceans from melting of land-based ice in glaciers and ice sheets, as well as increased runoff of freshwater.

Global may be different to local

Local sea-level change may be different from the global average, because winds and currents may change, and because the meltwater added to the oceans is not distributed evenly around the world.

If the land is rising or falling, this also changes the sea level in that place. The term *relative sea-level* change describes the combined movement of both water and land. That is, even if sea level was constant there could still be changes in relative sea levels – rising land would produce a relative fall in sea level, while sinking land would produce a relative rise in sea level.

The New Zealand story

Across New Zealand, over the 100 years up to 2015, the average relative sea-level rise was around 1.8 millimetres a year (see figure 1). This is based on 10 sites around the coast where sea level is measured. It differs from the global average.

What we do to adapt to sea-level rise needs to be based on what will happen here – not the global average rate. For New Zealand, that means using sea-level rise projections for the south-west Pacific (which indicate about an additional 0.05 metres above the global average by the 2090s), plus any local uplift or subsidence of the land, which can be measured by continuous GPS recorders.

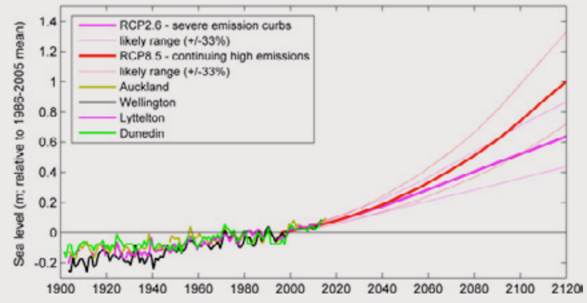

Figure 1: Relative sea-level rise for New Zealand's four main ports since 1900. Also included are sea-level rise projections from two scenarios adopted by the Intergovernmental Panel on Climate Change (IPCC) to describe possible climate futures, depending on how much greenhouse gas is emitted in the years to come. RCP2.6 represents severe emissions curbs, and RCP8.5 represents a scenario of continuing high emissions (IPCC, AR5).

The global story

In its most recent report released in 2014, the Intergovernmental Panel on Climate Change[1] (IPCC) projects that global sea-level rise by 2100 will be between around 0.3 metres and 1.0 metre above the 1995 level, depending on the amount of future greenhouse gas emissions. Over a shorter time frame, up to 2060, there is less uncertainty, and the IPCC projects a narrower range of sea-level rise – 0.2–0.4 metres.

In the more distant future, it is virtually certain that sea-level rise will continue for many centuries, well beyond 2100, as rising temperatures warm the oceans and make them expand. Sustained global warming of 2–4°C could lead to the near complete loss of the Greenland ice sheet over a thousand years or more, causing a global average sea-level rise of about 7 metres. It is also possible that sustained global warming may cause ice sheets in Antarctica to irreversibly collapse, raising sea levels.

1 The Intergovernmental Panel on Climate Change (IPCC) is the international body for assessing the science related to climate change. It was set up in 1988 to provide policymakers with regular assessments of the scientific basis of climate change, its impacts and future risks, and options for adapting to it and reducing its severity (mitigation).

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Appendix H DUNEDIN CITY COUNCIL, CLIMATE CHANGE PREDICTIONS POLICY, 2006

Policy Report

TO:	Planning and Environment Committee
FROM:	General Manager City Environment
MEETING DATE:	2 October 2006
SUBJECT:	**CLIMATE CHANGE PREDICTIONS POLICY**

SUMMARY

In order to undertake planning for the future of the City over the next 50-100 years, it is important that the Council adopt some kind of prediction about the effects of climate change into the future. Current predictions are that rainfall frequency and intensity, temperature variability and associated sea level rise will all impact on Dunedin. Given that many of the City's plans, particularly in terms of its infrastructure extend into the 50-100 year timeframe, it is prudent to start factoring in such changes. It is recommended that the predictions from the Intergovernmental Panel on Climate Change (IPCC) be adopted for planning purposes.

POLICY IMPLICATIONS:	Yes, adopting the predictions will have an effect across the entire Council.
OTHER IMPLICATIONS:	
(i) **Approved Annual Budget:**	No.
(ii) **LTCCP/ Funding Policy:**	Possibly, this will depend on the outcomes of the planning process.
(iii) **Community Boards:**	Yes.

RECOMMENDATIONS

1 That the Committee adopt the **Climate Change Predictions Policy** set out in Attachment One as a new Council Policy.

2 That the Committee note that the Policy is based on the predictions of the Intergovernmental Panel on Climate Change.

3 That any changes to the predictions by the Intergovernmental Panel on Climate Change are brought back to the Committee for consideration and adoption.

4 That the Committee note that an Interdepartmental working party will be established to develop a work programme to ensure that climate change effects are taken into account in all Council activities.

BACKGROUND

There are a variety of predictions about whether or not climate change is occurring in the world, and if it is occurring, the impact of such change in terms of temperature, rainfall and associated sea level rise brought about by ice melt, etc. At the same time the Dunedin City Council is making decisions on infrastructural replacements and renewals that in many cases have a greater than 50-year life. Examples of these would be the Roading network, many community assets and wastewater, storm water and water pipe networks. There are also potential impacts on water availability for supply purposes, potential impacts on coastal conservation works and the potential for areas of low lying land to be inundated with sea level rise which raises important planning issues.

In order to plan appropriately into the future, it is prudent to adopt international best predictors of the effects of climate change so that future potential changes can be taken account of in our current planning.

Current Predictions

Recognising the problem of potential global climate change, the World Meteorological Organisation (WMO) and the United Nations Environment Programme (UNEP) established the Intergovernmental Panel on Climate Change (IPCC) in 1988.

The role of the IPCC is to assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation. The IPCC does not carry out research nor does it monitor climate related data or other relevant parameters. It bases its assessment mainly on peer reviewed and published scientific/technical literature. A main activity of the IPCC is to provide at regular intervals an assessment of the state of knowledge on climate change.

The First IPCC Assessment Report was completed in 1990 while the Third Assessment Report, being the latest, was completed in 2001. The IPCC has decided to continue to prepare comprehensive assessment reports and is scheduled to complete its Fourth Assessment Report in 2007.

The IPCC has predicted global temperature increases of between 1.4 and 5.8 degrees Celsius by 2100. While temperature increases for New Zealand are expected to be less than the global average (due to a lag in warming of the oceans around New Zealand) there is still expected to be changes including:

- ⇒ increased temperatures
- ⇒ decreased frost risk but increased risk of very high temperatures
- ⇒ stronger west – east rainfall gradient (wetter in the west and dryer in the east)
- ⇒ increased frequency in extreme daily rainfalls
- ⇒ increased sea level
- ⇒ increased westerly winds.

In terms of more specific predicted climate change effect, the following table shows the range of change predicted for Otago and Dunedin in terms of temperature changes and rainfall.

Climate Changes

Temperature Changes (°C)		**Summer**	**Autumn**	**Winter**	**Spring**	**Annual**
1990 – 2030's		-0.2 to 1.2	0.0 to 1.1	0.2 to 1.8	0.0 to 1.2	0.1 to 1.3
1990 – 2080's		-0.1 to 2.7	0.4 to 3.3	0.7 to 3.5	0.2. to 3.0	0.4 to 3.1
Rainfall Changes (%)						
Dunedin	2030's	-7 to +8	-2 to +3	-7 to +15	-4 to +11	-2 to +6
	2080's	+1 to +34	-9 to +46	-5 to +30	-2 to +16	+2 to +14

Sea Level Rise

In terms of sea level rise predictions, New Zealand studies have predicted increases in a range of 5 – 7 mm per year. Taking that into account the recommended planning values for sea level rise are as follows:

Sea Level Rise	2050	2100
Mean sea level increase	+0.33 metres	+0.66 metres

There are a wide range of assumptions that have gone into the above predictions. Rather than try and understand all of the assumptions, the predictions from the IPCC and the subsequent work done in New Zealand that has given rise to the above predictions are the best scientific predictors of the potential effects of climate change that we currently have.

The IPCC is shortly going to be bringing out a revised prediction about climate change and sea level rise based on further modelling and verification of work that they have undertaken. It is to be expected that the IPCC will firm up on their view of the potential impact with each subsequent prediction. Any planning will need to take account of this.

Implications of Predicted Change

The Ministry for the Environment New Zealand Climate Change Office has also produced a number of guidance manuals to assist in assessing and planning for the effects of climate change, including some specifically for Local Government. Arising from those reports are the following sorts of tables that assist the thinking that is needed to deal with the potential climate change. These are examples only and will need significant investigation and input by Council and external stakeholders.

Impacts of Climate Change on Council Functions

Function	Climate Change Mechanism	Potential Impacts
Planning	Increase in high intensity rainfall effects	▪ Increased flood risks may require planning restrictions on flood plains etc.
	Increased sea level	▪ Planning restrictions in at risk coastal areas.
Roading	Increase in high intensity rainfall events	▪ Increase in road washouts and landslips onto roads. ▪ Increased maintenance required for water tables.
	Increased sea level	▪ Erosion of coastal roads/roadbeds. ▪ Increased closures due to sea inundation. ▪ May require road levels raised.
Stormwater	Increase in high intensity rainfall events	▪ Increased stormwater surcharging. ▪ Possible property damage.
	Increased sea level	▪ Greater reliance on pumping. ▪ Higher groundwater level impacts on underground pipe networks.
Water	Reduced annual rainfall	▪ Less secure raw water supply.
	Increased seal level	▪ Possible salt-water invasion of aquifers. ▪ Higher groundwater level impacts on underground pipe networks.

Impacts of Climate Change on Non-Council Functions

Function	Climate Change Mechanism	Potential Impacts
Electricity	Reduced annual rainfall	▪ Lower storage in hydro lakes – higher power prices, power shortages.
	Increased average temperatures	▪ Increased electricity usage for air conditioning in summer. ▪ Reduced consumption for heating in winter.

There are already a number of activities that have begun at the Council which are aimed at looking at the implications of climate change as follows:

- There is a sea level rise study underway which will look at the impact of sea level rise on our planning scenarios. This will need to look at such things as:
    - Potential District Plan changes to take account of climatic changes and potential inundation and increased coastal erosion associated with sea level rise;
    - Infrastructural assets which may need to be altered to take account of sea level rise, such as roads and related infrastructure and water pipes;
    - Coastal reserves and the impact of increased sea levels and storm related events

- Water and Waste Services will be producing water, wastewater and stormwater strategies, which will have to deal with the issues of climate change and the impact on water availability and the likely increased intensity of weather events

- Flood risk management is continually being looked at in response to events such as the floods on 26 April 2006.

These items were included in a report to the 26 June 2006 Finance and Strategy Committee which also considered the issue of peak oil. That report also noted a number of other activities that were either being undertaken or were being looked at to address the issues of greenhouse gas emissions and possible ways of dealing with future oil shortages. That list is as follows:

- For emission reduction at the landfill, we currently have a project looking at landfill gas recovery for which funding is provided in the LTCCP.
- What we do with sludge at the Tahuna Wastewater Plant upgrade will be an important issue in terms of methane production.
- The Resource Recovery and Waste Management Strategy identifies ways of trying to reduce the amount of organic materials that finds its way into the landfill. Further on we might be able to deal with some issues such as dealing with plastics to turn them into diesel, etc.
- The Dunedin City Council Energy Manager will directly help to reduce our green house gas emissions in part through the Communities for Climate Protection programme.
- It is possible that the Dunedin City Council owned companies could investigate the use of waste as alternative heating sources, both commercially and residentially.
- The Transportation Strategy encourages a shift away from single occupancy vehicles. It promotes cycleways, walking and public transport.
- The joint Dunedin City Council / Otago Regional Council Public Transport Working Party is looking into alternatives to cars.
- Work will be done on the mission critical hierarchy for the Dunedin City Council lifelines.
- The Dunedin City Council's pilot programme for Cosy Homes may help to reduce the use of oil.

DISCUSSION

Adopting predictions of climate change will enable the Dunedin City Council to incorporate appropriate variables into its long term planning. The best estimates of climate change worldwide are those that come from the Intergovernmental Panel on Climate Change and it is recommended that they be adopted.

These predictions, if adopted as Council Policy, would then be used in all future planning. Renewal of existing assets, constructions of new assets or facilities, all work programmes and all planning initiatives would take these predictions into account. Any significant implications resulting from the impact of our climate change would then be reported to the relevant Committee for full consideration.

In order to progress this work across the Council, an Interdepartmental Working Party will be established to understand the implications of the adoption of the predictions and to develop a work programme to ensure that the predictions are taken into account within the appropriate activities.

Climate Change predictions are likely to change over time as new information becomes available. It is recommended that the Council Policy is updated, through consideration by this Committee, of any future IPCC predictions.

Prepared by:

Tony Avery
GENERAL MANAGER CITY ENVIRONMENT

Approved for submission by:

Jim Harland
CHIEF EXECUTIVE

Date report prepared: 26 September 2006

Policy Manual details that will apply if adopted:	
Title of the position, which is the key contact for the administration and review of this Policy or Policy Statement	*Climate Change Predictions Policy*
Outcome(s) to which this Policy or Policy Statement contributes	*Wealthy Community* *Accessible City* *Safe and healthy people* *Sustainable City and environment*
Sub-outcomes to which this Policy or Policy Statement contributes	*A city that encourages sustainable economic development.* *A city that encourages strategic investment in people and businesses.* *A local transport system that is integrated with the wider needs of the community.* *Dunedin is connected to the global transport nodes.* *A place where people are safe in their homes, work and public spaces.* *Our services, infrastructure, and environment enhance quality of life.* *We enhance our place through quality developments.* *We value the natural environment, biodiversity and landscapes.* *We actively promote sustainability.*
Review date	*At release of revised predictions from the IPCC or 30 October 2009, whichever is sooner*
Office Use Only: New Policy Number, if applicable. Committee Code /mm/yy/Agenda Item No. *(Codes: PE, CDC, ISCOM, EDC,FS, CL)*	____/____/____/__

Attachment

Attachment One - Policy - **(Climate Change Predictions Policy)**

ATTACHMENT ONE

Climate Change Predictions Policy

On 30 October 2006, the Dunedin City Council adopted the following predictions of climate change from the Intergovernmental Panel on Climate Change (IPCC). These predictions are to be used, where relevant, in all planning processes and activities undertaken by the Council, which would result in decisions, which have an effective life of greater than 50 years. Such decisions would include decisions around the renewals of existing assets, construction of new assets or facilities, all work programmes and all planning initiatives.

Any significant implications resulting from the impact of any climate change will need to be reported to the relevant Committee for full consideration.

The climate change predictions to be used are as follows:

Temperature Changes (°C)		**Summer**	**Autumn**	**Winter**	**Spring**	**Annual**
1990 – 2030's		-0.2 to 1.2	0.0 to 1.1	0.2 to 1.8	0.0 to 1.2	0.1 to 1.3
1990 – 2080's		-0.1 to 2.7	0.4 to 3.3	0.7 to 3.5	0.2. to 3.0	0.4 to 3.1
Rainfall Changes (%)						
Dunedin	2030's	-7 to +8	-2 to +3	-7 to +15	-4 to +11	-2 to +6
	2080's	+1 to +34	-9 to +46	-5 to +30	-2 to +16	+2 to +14

Sea Level Rise	**2050**	**2100**
Mean sea level increase	+0.33 metres	+0.66 metres

Examples of the sorts of consideration that will need to be given in decisions that have an effective life of greater than 50 years are as follows. Note that these are examples only and there are likely to be a wide range of potential effects that will need to be considered.

Function	**Climate Change Mechanism**	**Potential impacts**
Planning	Increase in high intensity rainfall effects	▪ Increased flood risks may require planning restrictions on flood plains etc.
	Increased sea level	▪ Planning restrictions in at risk coastal areas.
Roading	Increase in high intensity rainfall events	▪ Increase in road washouts and landslips onto roads. ▪ Increased maintenance required for water tables.
	Increased sea level	▪ Erosion of coastal roads/roadbeds. ▪ Increased closures due to sea inundation. ▪ May require road levels raised.
Stormwater	Increase in high intensity rainfall events	▪ Increased stormwater surcharging. ▪ Possible property damage.
	Increased sea level	▪ Greater reliance on pumping. ▪ Higher groundwater level impacts on underground pipe networks.
Water	Reduced annual rainfall	▪ Less secure raw water supply.
	Increased seal level	▪ Possible salt-water invasion of aquifers. ▪ Higher groundwater level impacts on underground pipe networks.

Climate change predictions are likely to change over time as new information becomes available. As any new IPCC prediction becomes available, the Council will need to consider whether this policy is updated.

Appendix I DCC CLIMATE CHANGE PROJECTIONS 2011

Climate Change Predictions Policy 2011

Corporate Policy - Sustainability Advisor
Approval date: 6 September 2011

Dunedin City Council – Climate Change Projections (2011)

This document provides updated climate change projections for Dunedin. Table 1 provides a summary of the projections, with further details provided in the following pages.

CLIMATE CHANGE PROJECTIONS SUMMARY

The Council's "Climate Change Predictions Policy" adopted in 2006 was based on projections from the Intergovernmental Panel on Climate Change (IPCC) Third Assessment report published in 2001. More recent projections and information are now available in the IPCC Fourth Assessment Report (IPCC, 2007) and at the regional level by the Ministry for the Environment (MFE, 2008) and the National Institute of Water and Atmospheric Research (NIWA, Reisinger et al, 2010). Recently the Council commissioned a report from the University of Otago (Fitzharris, 2010) to provide an assessment of the Climate Change impacts on Dunedin, to enable effective planning and decision making by the Council in the long term. This recent report forms the basis for these updated projections set out in this document.

Table 1 – Climate change projections for Dunedin (relative to 1990 levels)

Climate Variable	Projected change in Dunedin	
	2040	2090
Mean Temperature Change	+1.1 °C	+2.5 °C
Sea Level Rise	+0.3 m	+0.8 to +1.6 m
Annual Rainfall Change [min, max]	-5 to +5 %	-5 to +15 %
Daily Temperature Extremes	Fewer frosts, increasing very hot days	
Extreme Rainfall	+9%	+20%
Drought	Drought incidence will be largely the same over large areas of the city, slight increase for urban area of Dunedin city and expected to increase for coastal areas north of Waitati	
Waves and storm surge	Storm surge level likely to rise at least in line with sea-level and to be greater when combined with ENSO events and increased storm intensity	
Average wind	Increased annual mean westerly component	
Strong wind	Increased possibility of severe winds	
Snow	Snow level rising with decreased annual mean snowfall	

CLIMATE VARIABLES

A summary of the rationale for each of the climate variables in Table 1 is outlined below. Appendix 1 provides further information of the variables including past observational data.

Mean Temperature Change

The numbers specified in Table 1 have been derived from the upper bound estimates from the *Climate Change Impacts on Dunedin* report (Fitzharris 2010). These projections have come from a report done by NIWA (Reisinger et al 2010), who statistically downscaled IPCC global climate change projections to provide local information for New Zealand regions.

Sea Level Rise

All climate models indicate that sea level rise will accelerate in a warmer world; however there is considerable uncertainty with the timing and rate, due to our incomplete understanding of the processes leading to loss of polar ice sheets (Fitzharris 2010).

IPCC (2007) projections of sea level rise indicate a range of 0.18 – 0.59m by the end of the 21st century, depending on the emission scenario used. However, IPCC estimates were hampered by a lack of understanding of the future rate of loss of polar ice. The Ministry for the Environment (MFE) has recommended that all assessments should consider the consequences of a mean sea-level rise of at least 0.8 metres relative to the 1980–1999 average. However, there is now strong argument emerging that future sea level rise may be considerably higher. Research on Greenland and Antarctic ice sheets that has been published since the IPCC Fourth Assessment Report suggests that ice loss from polar ice sheets could increase total sea level rise by 2090 to between +0.7 to +1.6m, with the recently commissioned *Climate Change Impacts on Dunedin* report (Fitzharris 2010) recommended that Dunedin City should plan for +1.6m sea level rise by 2090. Therefore the Council has decided to plan for a minimum of +0.8m and a maximum of +1.6m sea level rise by 2090 considering the recommendations from both central government and more recently the scientific community. The Council will review these numbers when the IPCC release their Fifth Assessment report in 2014 or earlier if necessary.

It should also be emphasised that further rapid increases in the rate of sea level rise of several metres over century time scales cannot be excluded with progressive melting of Greenland or West Antarctic ice sheets.

Annual Rainfall Change

The numbers specified in Table 1 have been derived from the *Climate Change Impacts on Dunedin* report (Fitzharris 2010). The report also states that there is a tendency for rainfall increases to be greater for inland and southern areas of Dunedin City. North from Waitati, the period about 2040 may be drier than present. Coastal areas will be 5% wetter in spring/winter and 5% drier in summer/autumn. Inland areas will be 5% wetter in all seasons, except for 2090 when spring/winter precipitation increases by 15% above present values. The periodicities in rainfall, which are a feature of the current climate, are likely to continue and therefore groups of years, possibly extending up to a decade in length, will continue to be wetter or drier than usual.

Due to the different climatic zones of Dunedin overlaid with the complexity of other phenomena affecting rainfall such as El Nino, La Nina, the Pacific Decadal Oscillation, the Southern Annular Mode, the Quasi-Biennial Oscillation, solar activity and sea surface temperature, it can be difficult to project a number for the average rainfall change for Dunedin. As the current observations of rainfall in some areas of Dunedin are showing a decreasing trend and other areas a positive trend, it is critical that rainfall is continually monitored for the different climatic zones of Dunedin.

Extreme rainfall events

The intensity of extreme rainfalls is associated with temperature increases and so a consideration of future temperature change is also necessary. As a result of climate change, heavier and/or more frequent extreme rainfalls are expected over New Zealand, especially where the mean rainfall is predicted to increase. The percentage increase in extreme rainfall depths is expected to be approximately 8% per degree Celsius of temperature increase (MFE 2008).

Storm Surge Events
NIWA provided detailed modelling to the Otago Regional Council, in 2008, and hazard maps on extreme storm surge and wave events for the whole Otago coast. Their results suggested that extreme storm and wave events in the Otago region may in the future temporarily raise sea level by up to 2.63m above present mean level of sea (MLOS). Clearly sea level rises of several tens of centimetres will have significant effects on the predicted sea levels from current storm surge and wave events. They predict that a sea level rise of 0.5m would increase the 100-year return period predictions by 20-30%.

A number of low-lying areas in Dunedin City are at risk of extensive inundation from storm events even in the present climate, especially Long Beach, Purakanui and Karitane. Future climate change and sea level rise will increase that risk, extend it to other coastal communities and threaten to breach the protective dune systems of South Dunedin.

Droughts
Drought magnitude and frequency are expected to increase in a warmer climate as evapotranspiration increases. It has been detailed in the Fitzharris report that current 1-in-20 year drought could occur at lease twice as often in eastern parts of New Zealand under a warming of about 2°C. If average rainfall increases (which it is projected to for inland and southern areas of Dunedin City) then this will help offset the higher temperatures and prevent a drought from occurring in these areas, but if the projections are not correct then there could be an increase in droughts. Drought is expected to increase for coastal areas north of Waitati.

Fires
The likelihood of fires will increase with hotter, drier conditions. Fire risks will increase for eastern parts of New Zealand (Fitzharris 2010).

Extreme Winds
Unfortunately there is little information currently available for New Zealand on frequency of strong winds under global warming. However, it is suggested that as climate models show an increase in the frequency and strength of the westerly wind belt over this century, the incidence of gales over the area of Dunedin City will be expected to increase.

BACKGROUND TO PROJECTIONS

IPCC Emission Scenarios
Projections of climate change depend heavily upon future human activity and so the IPCC has developed 40 different scenarios, each making different assumptions for future greenhouse gas emissions, land-use and other driving forces such as global population, economic growth, technology, energy availability, and national and international policies. The IPCC scenarios have been grouped into four scenario families, A1, A2, B1, and B2 (Table 2), which emphasise globalised vs. regionalised development on the A,B axis and economic growth vs. environmental stewardship on the 1,2 axis (IPCC, 2000). Three variants of the A1 (globalised, economically oriented) scenario lead to different emissions trajectories: A1FI (intensive dependence on fossil fuels), A1T (alternative technologies largely replace fossil fuels), and A1B (balanced energy supply between fossil fuels and alternatives). Appendix 2 details further these scenarios.

Table 2 – Description of IPCC Emission Scenarios

	More economic focus	More environmental focus
Globalisation	**A1** Rapid economic growth Groups: **A1F1, A1B, A1T**	**B1** Global environmental sustainability
Regionalisation	**A2** Regionally oriented economic development	**B2** Local environmental sustainability

The emissions scenarios span a range of plausible futures and formed the basis of much of the climate projection work done for the IPCC's Third and Fourth Assessments, where they used general circulation model (GCM) experiments to provide future climate change projections. GCMs are numerical models of the planet that simulate physical processes in the ocean, atmosphere, cryosphere and at the surface. The IPCC is unable to indicate whether any one emission scenario is more likely than another. However, the global emissions growth rate since 2000 has been greater than for the most fossil-fuel intensive of the IPCC emissions scenarios, A1F1. Emissions since 2000 were also far above the mean stabilization trajectories for both 450 and 650 ppm $CO_{2,eq}$ (Figure 1).

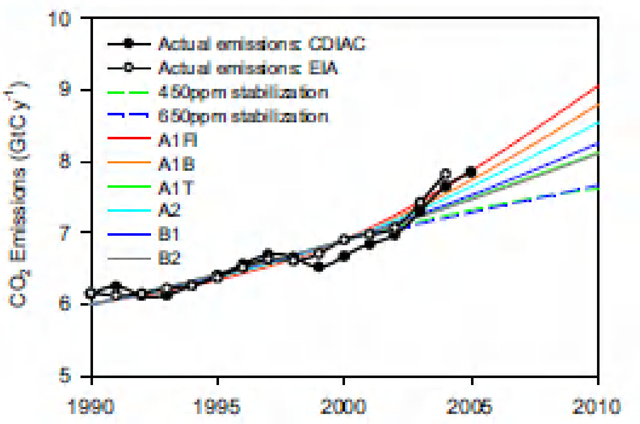


Figure 1 - Observed global CO_2 emissions from the US Department of Energy: Energy Information Administration (EIA) and Carbon Dioxide Information and Analysis Centre (CDIAC) data, compared with IPCC emissions scenarios and stabilization trajectories (Raupach et al 2007).

Therefore reducing greenhouse gas emissions and carbon sequestration (i.e. climate change mitigation work) is as essential as adaptation work and therefore the Council will be developing mitigation goals in line with scientific recommendations and work with other governmental organisations, business and the community to ensure catastrophic Climate Change is avoided.

Climate Change Projections for Dunedin

The climate change projections for Dunedin have primarily been derived from the Fitzharris report, which came from a report done by NIWA (Reisinger et al 2010). NIWA statistically downscaled IPCC global climate change projections to provide local information for New Zealand regions. The other source for the projections has been the Ministry for the Environment (MFE, 2008). They presented information on climate change projections for Otago that also utilised the IPCC emission scenarios. The projections are given for 2040 and 2090 timeframes (relative to 1990 levels), however the effects of global warming and sea level rise will continue after 2090 for centuries even if greenhouse gas concentrations are to be stabilised.

It is not only important that future projections for the Dunedin climate are derived from peer-reviewed science but they must also be compared to historical and current local climate data to provide better accuracy. Appendix 1 presents historical to current data for key climate variables for the urban area of Dunedin (mean temperature change, annual rainfall and sea level rise), from the NIWA Climate database (http://cliflo.niwa.co.nz/), and these have been compared to the projections.

Lastly it is important to take into consideration the complexity of the topography of Dunedin. This topography creates five distinct climate zones, of which their current climate conditions are described in Appendix 3. Historical to current localised climatic information for these distinct zones can be found through the NIWA Climate database. To develop a better understanding of the effects of Climate Change on these five distinct areas of Dunedin, it would be useful to compare local climate monitoring, on a periodic basis, to the projections. As projections available at present cover the Otago region, there may be scope at a later date to work with NIWA to develop better resolution and climate projections for the distinctive climatic zones of Dunedin.

LEGISLATIVE CONTEXT

Key legislation that provides local government with the powers and responsibilities to manage the risks associated with climate change and consider climate change adaptation are:-

- The Resource Management Act 1991 (RMA)
- Local Government Act 2002 (LGA)
- Building Act 2004
- Civil Defence Emergency Management Act 2002 (CDEMA)

Therefore many of the functions of local government relate to, or can be affected, by climate change.

DEFINITIONS

Projections

Projections are used in this policy rather than predictions due to the level of uncertainty involved in determining them. A projection is a potential future evolution of a quantity or set of quantities, often computed with the aid of a model. Projections are distinguished from predictions in order to emphasize that projections involve assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realised, and are therefore subject to substantial uncertainty. Projection is used instead of prediction in this document because the numbers are based on IPCC emission scenarios which are not predictions but are based on different plausible estimates of future social and economic development (e.g., economic growth, population level) (Solomon et al 2007).

The Climate Change projections for Dunedin detailed in this document will provide the necessary guidance for the Council to fulfil its adaptation objectives.

Climate Change Mitigation and Adaptation

Rational responses to the threat of climate change can be grouped into two sets of actions: mitigation and adaptation. Mitigation involves actions to produce less greenhouse gas pollution and therefore limit the extent of global warming and climate change. Adaptation involves investing in ways to help the community manage the impacts of global warming. Mitigation and adaptation differ in terms of their respective goals as can been seen in Table 3 but are interrelated as mitigation efforts in the long term will ultimately lessen the Climate Change impacts that will need to be adapted to.

Table 3 - Objectives and definitions of climate change mitigation and adaptation

	Objectives	Definitions
Climate change mitigation	• Stabilising greenhouse gas concentrations • Reducing greenhouse gas emissions • Promoting greenhouse gas sinks • Halting dangerous anthropogenic climate change	'Technological change and substitution that reduce resource inputs and emissions per unit of output. Although several social, economic and technological policies would produce an emission reduction, with respect to climate change, mitigation means implementing policies to reduce greenhouse gas emissions and enhance sinks' (IPCC, 2007)
Climate change adaptation	• Reducing climate change related harm to natural and human systems • Reducing the vulnerability of natural and human systems to the impacts of climate change	'Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects' (IPCC, 2007)

Sudden versus Slow Impacts
Climatic impacts can also be distinguished by their speed of onset: i.e., those that happen suddenly; and slow-onset impacts that follow a pattern of gradual change (Figure 2). Gaining a better understanding of the specific onset and duration of climatic impacts can help clarify the type of adaptation response necessary, as well as point towards the most adequate planning process. For sudden, short-term events such as storms and flooding, adaptation efforts may need to focus on improved disaster prevention, establishing early warning systems, and effective disaster response which fall into Civil Defence responsibilities. For slow-onset, continuous impacts such as sea-level rise, however, strategic forward planning is critical, and existing planning instruments such as land use planning may need to be altered to take gradual changes in climatic stressors into account. Clarification of the onset of impacts is useful to help focus adaptation goal setting and prioritisation activities.

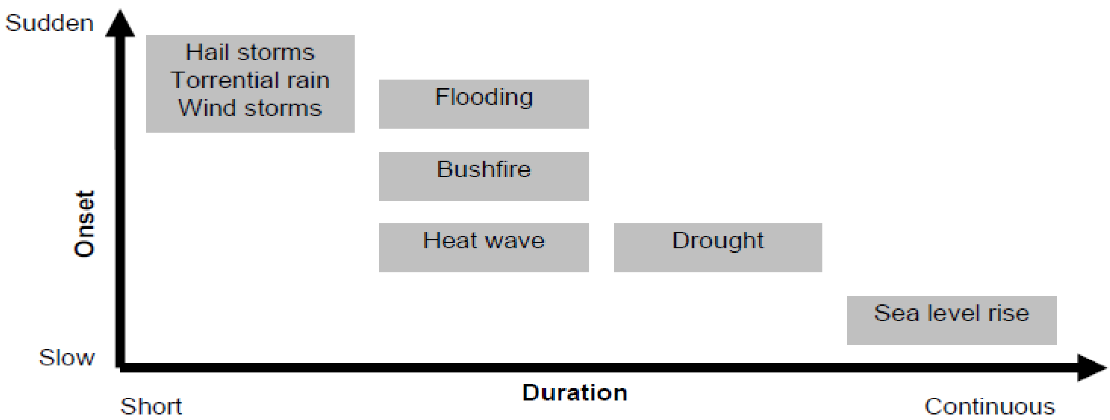
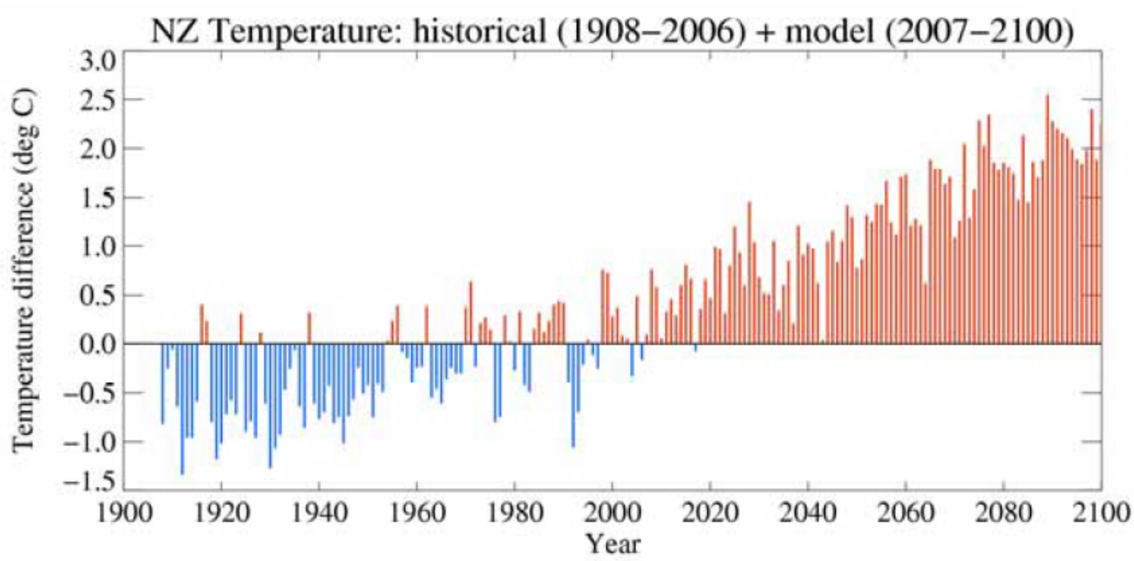


Figure 2 – Typical onset and duration of climatic impacts (Funfgeld and McEvoy 2011)

APPENDICES

Appendix 1 – Climate variables - Historical and current data and MFE projections

Mean Temperature Change (°C)
Current observations and historical data of the temperature in NZ can be seen in Figures 3a and 3b. These figures show a time series of NZ average temperature as observed for 1908 to 2006. Otago Regional Council (2007) appended a future simulation derived from a single climate model for the period 2007 to 2099 for comparison in Figure 3b. As can be seen from Fig 3a and 3b, the temperature in NZ has been rising. Figure 4 is a smaller dataset and is the measured temperature for Dunedin, with predictions for future change based on MFE estimates.



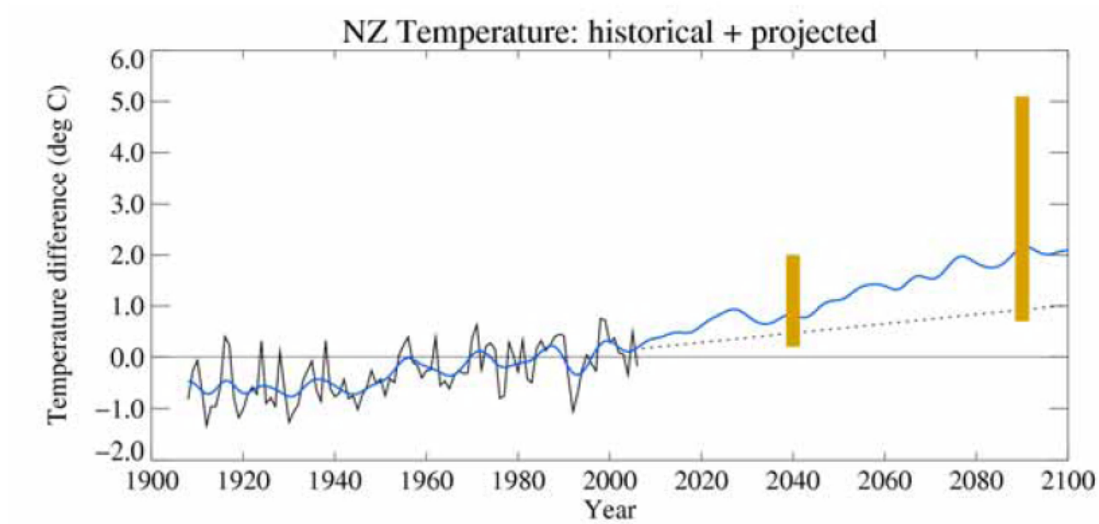


Figure 3a and 3b – New Zealand temperature (in °C) – historical record and schematic projections illustrating an example of future year-to-year variability. (Source MFE, 2008)

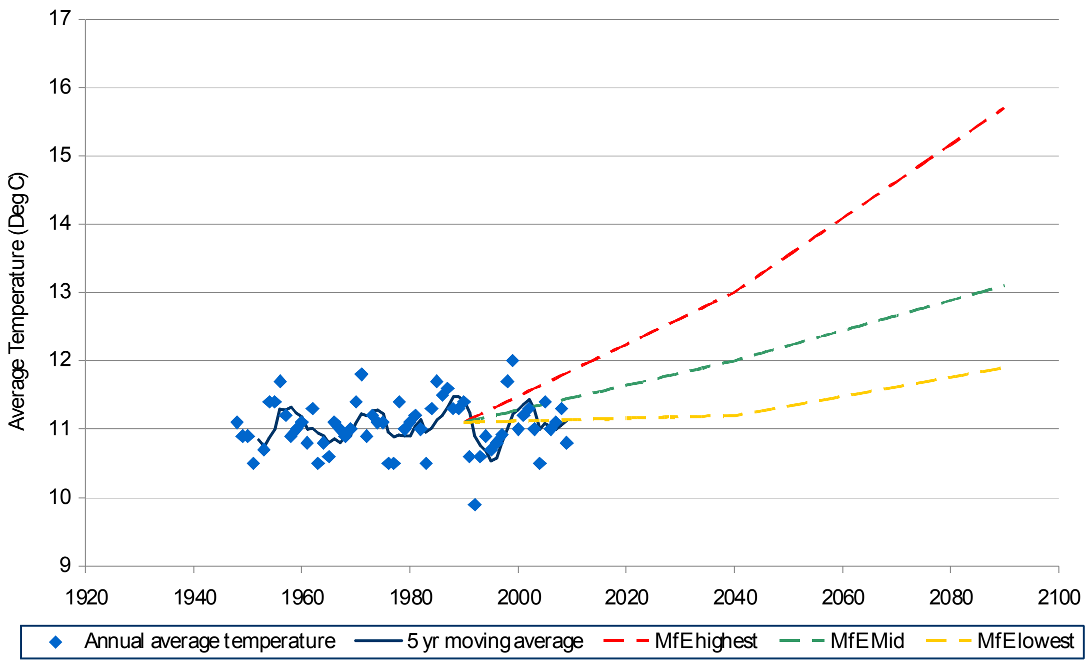


Figure 4 – Observed Dunedin temperature data (ORC)

The Ministry for the Environment (2008) also produced annual mean temperature projections for Otago which came from downscaled projections based on all of the IPCC emission scenarios (Table 4).

Table 4 – Projected changes in seasonal and annual mean temperature (in °C) from 1990 to *2040 and 2090* for Otago relative to 1990. The average change and the lower and upper limits [in brackets] are given (MFE, 2008).

Year	Summer	Autumn	Winter	Spring	Annual
2040	0.9 [0, 2.4]	0.9 [0.1,1.9]	1.0[0.3,2.1]	0.7[0.0,1.8]	0.9[0.1,1.9]
2090	2.0 [0.7,4.8]	2.0 [0.8,4.6]	2.2 [0.8,4.8]	1.7[0.5,4.3]	2.0[0.8,4.6]

Sea Level Rise

Sea-level increased by approximately 120 metres since the end of the last ice age and was relatively stable from about 2-3000 years ago through to about 100 years ago. During the 20th century global average sea level has increased by about 1.7mm/yr. In Dunedin, the tidal gauges have measured the sea level rise to be on average 1.3mm/yr.

During the 21st century sea level is virtually certain (more than 99% probability) to rise (NIWA, 2006). However, the exact amount of sea-level rise by the end of this century cannot be well defined. Sea level rise will continue for centuries even if greenhouse gas concentrations are to be stabilised. The lag between atmospheric and ocean warming, the time required for ice sheets to melt, and the momentum in the climate system, mean that sea levels will continue to rise for several centuries, even after atmospheric greenhouse gas concentrations are limited or stabilised. The timeframe of hundreds of years is relevant to the lifespan of some major pieces of infrastructure and to decisions on the location of major urban areas.

Figures 5 and 6 provide understanding as to how the projections for sea level rise have been changing since the last IPCC Fourth Assessment Report (2007).

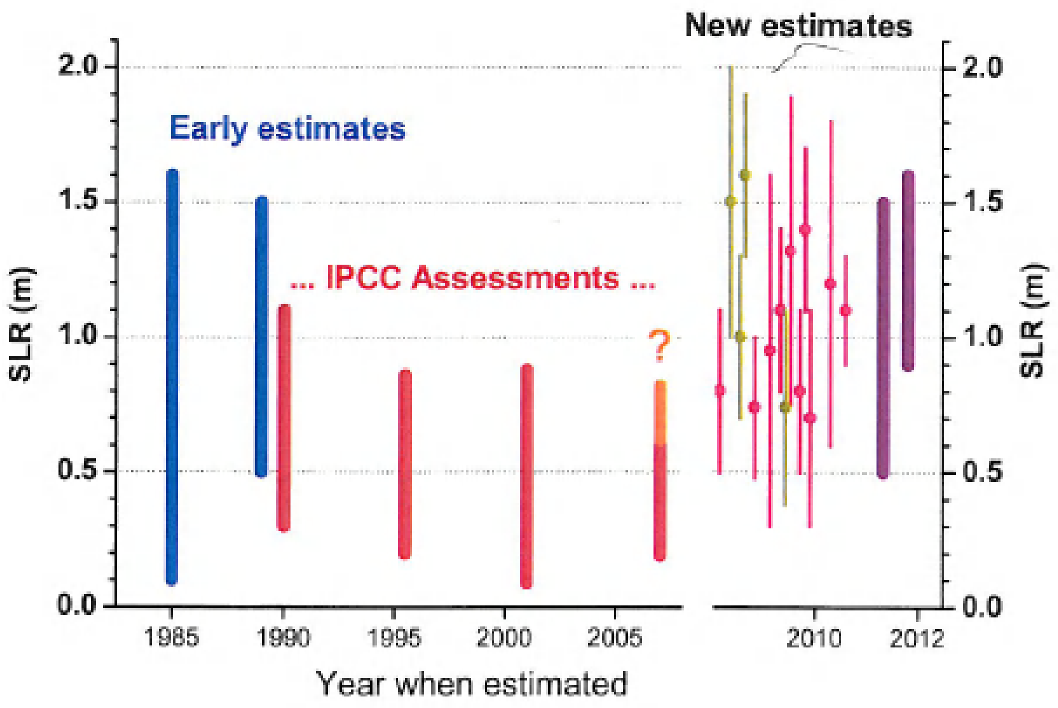


Figure 5 – A summary of scientific estimates for sea level rise by year 2100 that have been made since 1985. The two blue vertical bars are from a US Department of Energy report in 1985 and a major review paper in 1989. The four red bars summarise results from the last four IPCC Assessment reports with the question mark representing the lack of an upper bound mentioned in the Fourth Assessment. The narrow bars on the right show estimates from recent peer-reviewed scientific papers, with dark yellow showing estimates based on the last ice age and pink showing projections from the recent observed trends. The thicker purple bars show the range of 0.5-1.5m given in recent reviews and the range 0.9-1.6m given in a very recent statement from the Arctic Monitoring and Assessment Programme meeting in May 2011.

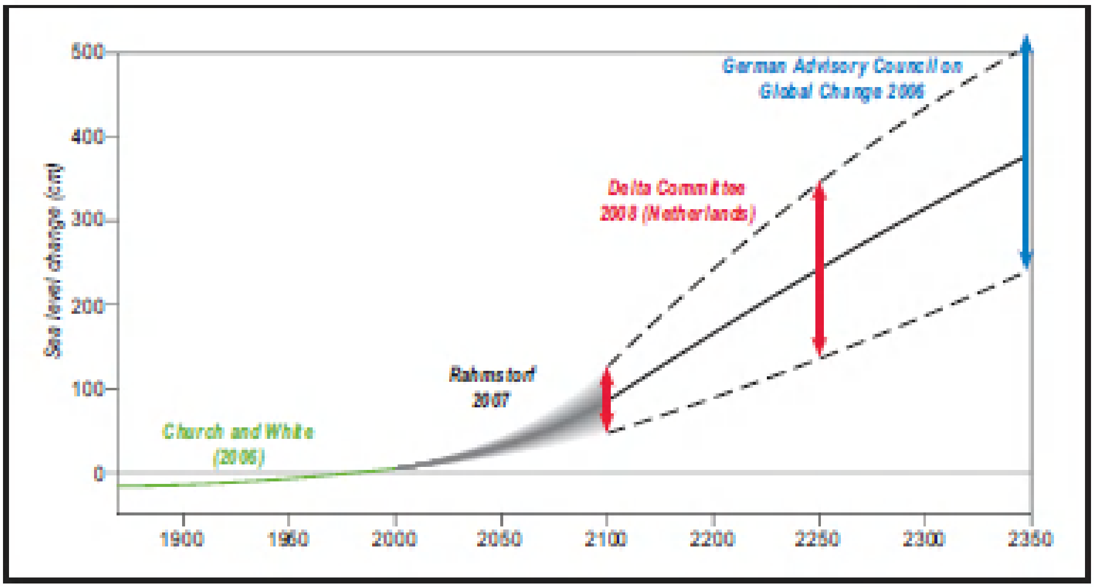


Figure 6 - Recent estimates of future sea-level rise relative to the 1990s. Source: German Advisory Council on Global Change 2009.

Annual Rainfall Change
The actual trend in annual rainfall at Dunedin in recent years (Figure 7) shows that totals have been generally much lower than the predictions shown in Table 4, and are presenting well outside the lower limit of IPCC predictions. A number of wet years would be required to push the 5 year moving average back within the range of IPCC predictions.

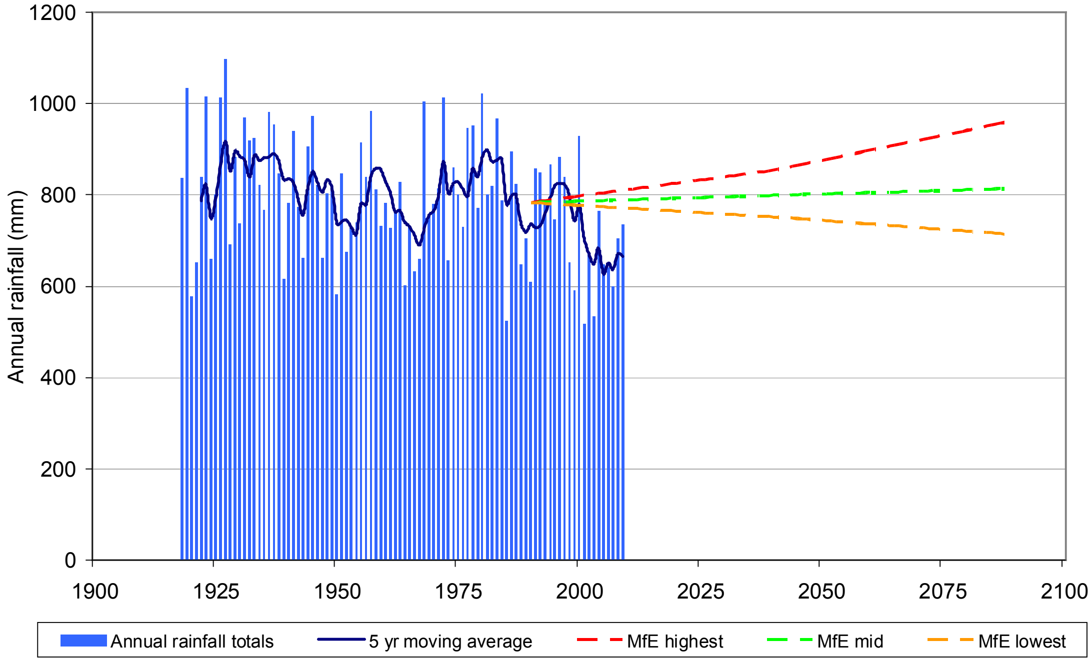


Figure 7 – Observed annual rainfall totals at Dunedin from 1918 to 2008 (blue bars), over-plotted by a 5 yr running average (solid blue line). The dashed red and orange lines indicate the highest and lowest IPCC projections, while the dashed green line shows the most likely projected change out to 2090. (Source, Otago Regional Council, 2008).

The Ministry for the Environment (2008) produced annual rainfall change for Otago (Table 5) which came from downscaled projections based on all of the IPCC emission scenarios.

Table 5 - Projected Annual Rainfall Change (in %) relative to 1990 (source MFE 2008)

Decade	Summer	Autumn	Winter	Spring	Annual
2040	1[-11,13]	2[-9,10]	3[-10,13]	2[-5,11]	2[-4,9]
2090	0[-29,19]	2[-11,16]	7[-16,24]	6[-1,32]	4[-9,23]

As the current observations of rainfall are showing a decrease, which is not in line with the projections, it is important that the Council continue to monitor this key climate variable for all the different climatic zones of Dunedin.

APPENDIX 2 - IPCC Emission Scenarios

A1. The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil-intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B, where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies).

A2. The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.

B1. The B1 storyline and scenario family describes a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.

B2. The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels. The scenarios do not include additional climate initiatives, which means that no scenarios are included that explicitly assume implementation of the United Nations Framework Convention on Climate Change or the emissions targets of the Kyoto Protocol.

APPENDIX 3 – Climate Regions of Dunedin City

F1 North Otago Climate (eg around Waikouaiti)
Annual rainfall is low, ranging between 500 mm to 800 mm. There tends to be more in winter than in other seasons. There are less than 100 rain days and severe droughts can occur. Summers are warm, with occasional hot northwesterlies giving temperatures above 30°C. Cool winters with frequent frosts and occasional snow. Prevailing winds are south-westerly and north-easterly.

F2 Hill Climate (eg Maungatuas, Flagstaff, Silver Peaks)
These areas are cooler, cloudier and wetter than F1. Rainfalls average 800 mm to 1500 mm annually. Southwesterlies predominate, with occasional very strong northwesterlies gales. Snow may lie for weeks in winter.

F3 Transitional Central Otago Climate (eg Strath Taieri)
Tending towards a semi-arid, semi-continental climate. Annual rainfall is below 500 mm, with less than 80 rain days. Drought is endemic. Warm and sunny summers and cold frosty winters. Foggy in autumn and early winter.

G1 Eastern Otago Climate (eg Dunedin urban area, Otago Peninsula)
Moderate to warm summers and cool winters. Rainfall is 500 mm to 900 mm and evenly distributed throughout the year, but with a slight winter minimum. Rather cloudy. Winds tend to be from the southwest, or from the northeast along the coast. The Taieri Plain is a variant climate of this region in that it is frostier and sunnier.

M Mountain Climate (eg Rock and Pillar Range)
Climate varies substantially depending on elevation. Annual precipitation is at least 1200 mm. Much of winter precipitation falls as snow and may lie on the ground for many months. Temperatures cool off with elevation at about 0.7°C/100 m.

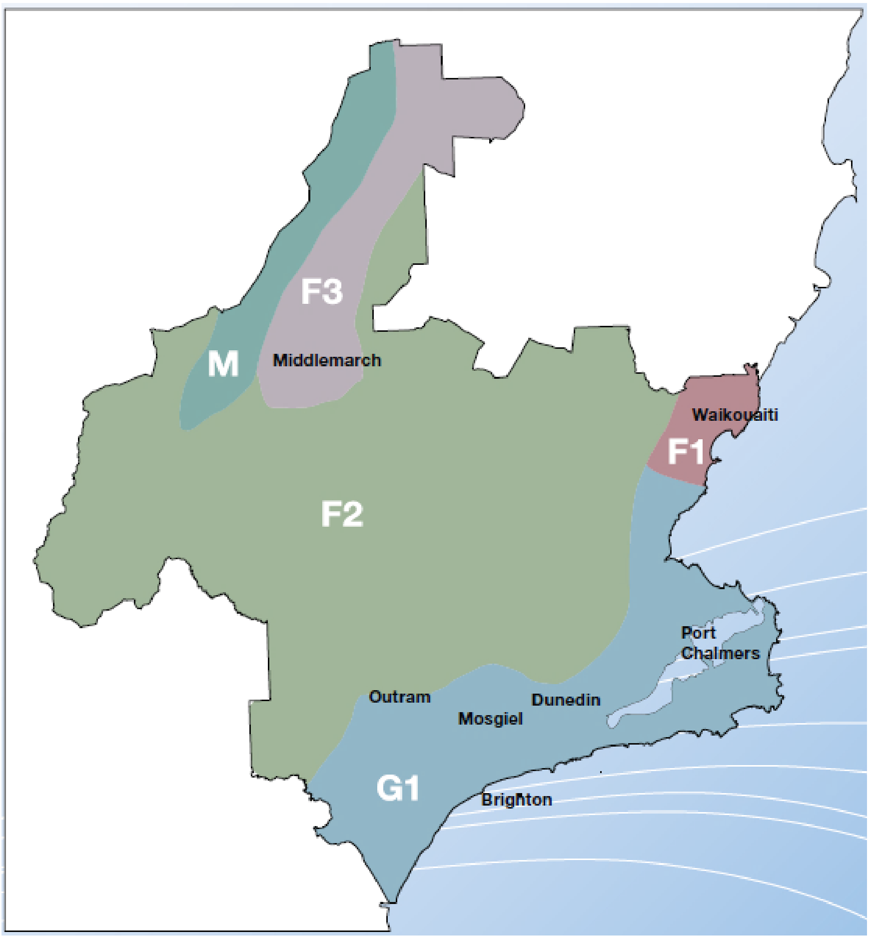


Figure 8 – Climatic regions of Dunedin City (Fitzharris, 2010)

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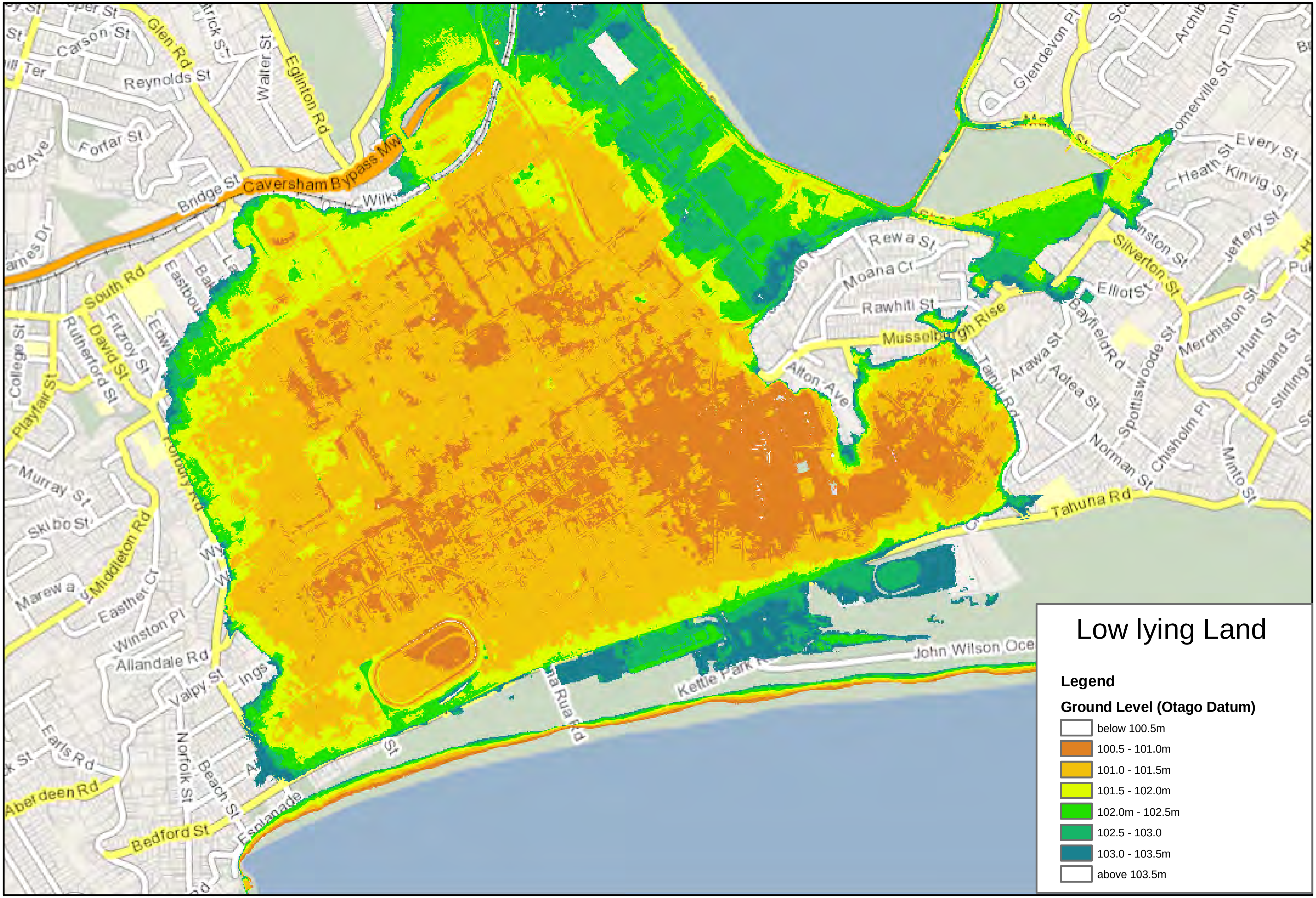
Appendix J SOUTH DUNEDIN LEVELS 2011


Low lying Land
Legend
Ground Level (Otago Datum)
below 100.5m
100.5 - 101.0m
101.0 - 101.5m
101.5 - 102.0m
102.0m - 102.5m
102.5 - 103.0
103.0 - 103.5m
above 103.5m
Carson St
Glen Rd
Reynolds St
Walter St
Eglinton Rd
Forfar St
Caversham Bypass Mw
Bridge St
South Rd
Rutherford St
David St
Fitzroy St
College St
Playfair St
Murray St
Middleton Rd
Easther Cr
Winston Pl
Allandale Rd
Valpy St
Norfolk St
Beach St
Aberdeen Rd
Bedford St
Esplanade
John Wilson Oce
Kettle Park
Tahuna Rd
Musselburgh Rise
Rewa St
Moana Cr
Rawhiti St
Alton Ave
Arawa St
Aotea St
Tainui Rd
Bayfield Rd
Norman St
Spottiswoode St
Chisholm Pl
Elliot St
Silverton St
Merchiston St
Hunt St
Oakland St
Minto St
Jeffery St
Kinvig St
Heath St
Every St
Somerville St
Glendevon Pl

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