# Section 32 Report Appendix 5: Coastal inundation

## 1. Introduction

This appendix details how coastal inundation and sea-level rise has been considered in relation to low-lying coastal sites included in Plan Change 79.

## 2. Legislative Requirements

### *2.1 Resource Management Act 1991 and coastal hazard management*

The Resource Management Act 1991 (RMA 1991) Sections 61, 66, and 74 specify a number of matters to be considered by councils when preparing or changing their regional policy statements and regional and district plans. These requirements are relevant to Plan Change 79, specifically in relation to assessing the impacts from relative sea-level rise and coastal storms for coastal areas facing irreversible and ongoing sea-level rise. Policy statements or plans are to be prepared or changed:

(a) In accordance with the **New Zealand Coastal Policy Statement 2010 (NZCPS)**. One of the NZCPS's goals is to manage coastal hazards and climate change risks to avoid increasing the risk of adverse effects. The risk from coastal hazards over at least 100 years must be identified. Objective 5 seeks to ensure that coastal hazard risks, taking account of climate change, are managed including by locating new development away from areas prone to such risks. Key NZCPS policies are:

- Policy 3 Precautionary Approach
- Policy 24 Identification of coastal hazards
- Policy 25 Subdivision, use, and development in areas of coastal hazard risk
- Policy 26 Natural defences against coastal hazards
- Policy 27 Strategies for protecting significant existing development from coastal hazard risk

(b) Having regard to the **National Adaptation Plan 2022**. The first national adaptation plan (2022 NAP) contains Government-led strategies, policies and proposals that will help New Zealanders adapt to the changing climate and its effects.

The 2022 NAP states that when making or changing policy statements or plans under the Resource Management Act 1991, councils should use recommended climate change scenarios (as a minimum) to identify and assess risk from coastal hazards and the effects of climate change. Councils should screen for hazards and risks in coastal areas using the SSP5-8.5 scenario, and use at least two IPCC scenarios[1] (SSP2-4.5 and SSP5-8.5) for detailed hazard and risk assessments, adding the relevant rate of vertical land movement (VLM) locally. Additionally, the 2022 NAP recommends councils should stress-test plans, policies and strategies using a range of scenarios as relevant to the circumstances.

[1] The Intergovernmental Panel on Climate Change (IPCC) have developed five climate change scenarios, being SSP1-1.9, SSP2-2.6 M, SSP2-4.5 M, SSP3-7.0, and SSP5-8.5. The scenarios span a wide range of plausible futures, from 1.5 degrees Celsius 'best-case' low-emissions scenario (SSP1-1.9) to over 4 degrees Celsius warming scenario (SSP5-8.5) by 2100 (2024 Guidance).

## 2.2 Coastal Hazards and Climate Change Guidance 2024

NZCPS Policy 24 Identification of Coastal Hazards requires councils to 'take into account national guidance and the best available information on the likely effects of climate change on the region or district'. Of relevance are the Ministry for the Environment's Coastal Hazards and Climate Change Guidance (February 2024), in conjunction with the NZ SeaRise: Te Tai Pari O Aotearoa programme (launched 2022).

Since the early 2000s, the Ministry for the Environment has provided guidance to councils on adapting to coastal hazards and the risks presented from climate change, particularly sea-level rise. The 2017 Coastal Hazards and Climate Change Guidance introduced a 10-step decision making process for councils to work with their communities to develop long-term adaptive planning strategies to respond to coastal hazards and sea-level rise. The 2024 Guidance revises the 2017 publication with a number of updates, including advances in sea-level rise science and global projections[2] and the application of vertical land movement (VLM) – as displayed on the NZ SeaRise online platform.

Through the Council's 'Coastal Management Project' staff have progressed initial work to help inform the development of an adaptive planning strategy following the 2017 Guidance (and going forward, the 2024 Guidance). This has included release of an online coastal hazards map viewer (2019), coastal hazards risk assessment (2020), and educational engagement on high-level coastal management options (2021). However, the work programme was paused in 2022 for reasons including the uncertainty around the resource management system reform. A 'community adaptation planning' work programme is budgeted for in the draft 2024 Long Term Plan which will take an all-hazards approach and incorporate best practice from the 2024 Guidance.

Consequently, the Council is yet to prepare an adaptive planning strategy or local community adaptation plans. In these circumstances, the 2024 Guidance provides recommended relative sea-level rise[3] (RSLR) allowances for councils to use in decision-making processes (e.g., plan making and land-use decisions) in the interim until such time that a council and their community have developed an adaptive planning strategy. These RSLR allowances form a precautionary initial planning and design response and is consistent with the precautionary approach set out in the NZCPS Policy 3[4].

The 2024 Guidance (page 51) states "*For making interim decisions on new coastal development or infrastructure and change in land use, such as intensification and upzoning, the precautionary interim allowance recommended (before an adaptive planning strategy is developed) is to use the SSP5-8.5 H+ based RSLR projection to identify areas 'potentially affected'*[5] *by coastal hazards and*

[2] Based on the 2021 Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report sea level data, downscaled to Aotearoa New Zealand.

[3] The 2024 Guidance (page 42) describes relative sea level rise as the net rise in mean sea level from both: i) the absolute rise in height of sea level; and ii) local vertical land movement. It is therefore the net rise in sea level relative to the local land surface or sea-bed elevation on which assets and people are placed.

[4] NZCPS Policy 3 Precautionary Approach:

(1) Adopt a precautionary approach towards proposed activities whose effects on the coastal environment are uncertain, unknown, or little understood, but potentially significantly adverse.
(2) In particular, adopt a precautionary approach to use and management of coastal resources potentially vulnerable to effects from climate change, so that:
    (a) Avoidable social and economic loss and harm to communities does not occur;
    (b) Natural adjustments for coastal processes, natural defences, ecosystems, habitat and species are allowed to occur; and
    (c) The natural character, public access, amenity and other values of the coastal environment meet the needs of future generations.

[5] As referenced in the New Zealand Coastal Policy Statement Policy 24: Identification of coastal hazards.

*climate change. Timeframes are also informed by the risk of being affected by coastal hazards, with greater or longer-term investments, such as infrastructure or new suburbs, needing assessment over at least a 100-year period out to 2130."*

Table 1 below shows the recommended precautionary RSLR projections to use as interim allowances, sourced from the 2024 Guidance.

**Table 1:** Interim precautionary relative sea-level rise allowances recommended to use for coastal planning and policy before undertaking a dynamic adaptive pathways planning approach for a precinct, district or region (Source: Table 8, pages 52-53 of the 2024 Guidance).

| Planning category | Recommended interim precautionary RSLR allowances |
|---|---|
| **A. Coastal subdivision, greenfield developments and major new infrastructure** | Using a **timeframe** out to **2130** (≥100 years), apply the *medium confidence* **SSP5-8.5 H+** based RSLR projection* that includes the relevant VLM rate for the local and/or regional area.<br>(Note: approximately 1.6 metre rise in MSL, before including VLM.) |
| **B. Changes in land use and redevelopment (intensification and upzoning)** | Using a **timeframe** out to **2130** (≥100 years), apply the *medium confidence* **SSP5-8.5 H+** based RSLR projection* that includes the relevant VLM rate for the local and/or regional area.<br>(Note: approximately 1.6 metre rise in MSL, before including VLM.) |
| **C. Land-use planning controls for existing coastal uses and assets (building additions)** | Using a **timeframe** out to **2130** (≥100 years), apply the *medium confidence* **SSP5-8.5 M** based RSLR projection that includes the relevant VLM rate for the local and/or regional area.<br>(Note: approximately 1.2 metre rise in MSL, before including VLM. |
| **D. Non-habitable, short-lived assets with a functional need to be at the coast, which are either low consequences or readily adaptable (including services)** | Using a **timeframe** out to **2075** (≥50 years), apply the *medium confidence* **SSP5-8.5 M** based RSLR projection that includes the relevant VLM rate for the local and/or regional area.<br>(Note: approximately 0.5 metre rise in MSL, before including VLM.) |

Notes:

* H+ is the 83rd percentile (or p83 at the top of the likely range on graphs in the NZ SeaRise platform).

i) Relative sea-level rise (SLR) projections that include satellite-derived vertical land movement (VLM) are available from the NZ SeaRise platform. Alternatively, locally monitored VLM can be applied to the SLR projections.

ii) M = median or p50 (50th percentile); MSL = mean sea level; RSLR = relative sea-level rise; SSP = shared socio-economic pathway used by the Intergovernmental Panel on Climate Change; VLM = vertical land movement.

The approximate rise in MSL can be considered broadly representative across Aotearoa New Zealand, because the absolute SLR from north to south only varies by ± 0.025 metres by 2150 (relative to the central location).

## 3. Climate Change Scenario Applied

IPCC's five shared socio-economic pathways (SSPs) each present a different scenario of how future societal choices, demographics, and economics will influence greenhouse gas emissions. The emissions under each SSP will in turn influence the amount of energy that is trapped in the atmosphere by greenhouse gasses, a process referred to as radiative forcing.

The best way to minimise and reduce long-term coastal hazard risk is to avoid areas that are, or will become, exposed to coastal hazards and sea-level rise. This will avoid costly and avoidable risk which the Council and community would otherwise have to address in the future. To inform Plan Change 79, the Council has screened for hazards and risks in coastal areas using the SSP5-8.5 climate change scenario – both the M (medium, 50th percentile or *p50*) and the upper-bound H+ (83rd percentile or *p83*) (see Table 2).

**Table 2:** Climate Change Scenarios

| Year | Scenario | Confidence Level |
|---|---|---|
| **2130** | • SSP5-8.5 M including VLM<br>• **SSP5-8.5 H+ including VLM** | Medium |

SSP5-8.5 is a very high emissions scenario in which the global economy grows rapidly on the back of $CO_2$ emissions that double by 2050 and triple by 2100. SSP5-8.5 projects a radiative forcing of 8.5 W $m^{-2}$ at the end of the century, with a consequently large temperature increase of over 4°C by 2100. The warming of the Earth system under the scenarios results in sea-level rise due to changes in terrestrial water storage, the melting of land-based ice, and the thermal expansion of ocean water (Figure 4). The 2024 Guidance recommends the use of this high-end emissions scenario in coastal planning. This is to reflect that the world has been on a high emissions trajectory in the past few decades, combined with the very long timeframes for sea-level rise to respond to released emissions and the deep uncertainty about future emissions and tipping points[6].

Sea-level rise projections under each of the climate change scenarios have been produced by the NZ SeaRise programme (e.g., Levy et. al, 2020). Use of these projections is supported by NZCPS Policy 24 which recommends the use of best available information on the likely effects of climate change.

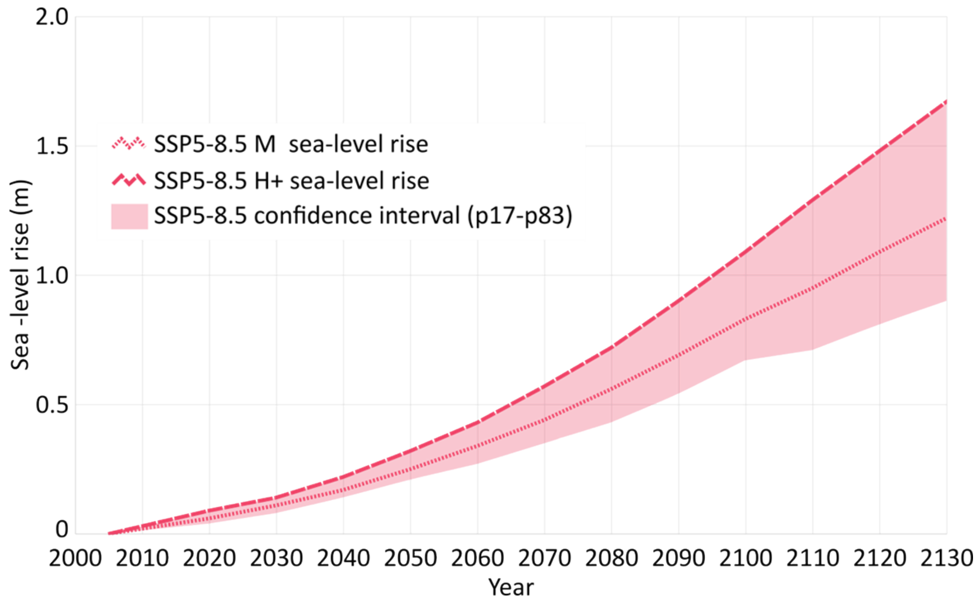


**Figure 1:** Example for Separation Point (NZ SeaRise site 6361) of SLR under SSP5-8.5. The H+ scenario for SSP5-8.5 corresponds to the upper margin of the red-shaded confidence interval (p17-p83).

[6] For more information, refer to 'Box 3: Should the high-end SSP5-8.5 scenario be used in coastal planning?' on page 41 of the 2024 Guidance.

Council's screening process has been used to identify localities at high risk of being affected over the next 100 years (as required by NZCPS Policy 24), considering both long-term and more imminent areas at high risk. To determine the landward boundary for each location for assessing the impacts from relative sea-level rise and coastal storms the SSP5-8.5 H+ scenario has been applied (using the precautionary approach supported by NZCPS Policy 3). In doing so, Council has given regard to the 2022 NAP and taken into account the 2024 Guidance.

## 4. Bathtub modelling

Council has used 'bathtub' modelling to visualise the areas susceptible to coastal inundation from sea-level rise and coastal storms under the SSP5-8.5 climate change scenario (Table 1). Bathtub modelling is so named because it treats the ocean like a bathtub that fills up when water is added. Bathtub modelling maps areas as susceptible to inundation where land elevations are at or below the inundation level that is being mapped. Land elevations are derived from LiDAR surveys of the coast, where land elevations are measured by laser pulses from a plane. Different inundation levels can be mapped for different amounts of relative sea-level rise and/or storm events of different magnitudes. Areas mapped as susceptible to inundation may be either directly connected to the ocean (e.g., via drains or other waterways), or may be disconnected, being at a low elevation but not directly connected to the ocean (Figure 2). Disconnected areas may still be susceptible to inundation as relative sea-level rises despite not being directly connected to the ocean, due to difficulties in evacuating stormwater from these areas. In the same way that water that fills a bathtub is still and does not have waves, bathtub mapping is for a 'static' water level that does not include factors that can dynamically change water levels such as waves and currents.

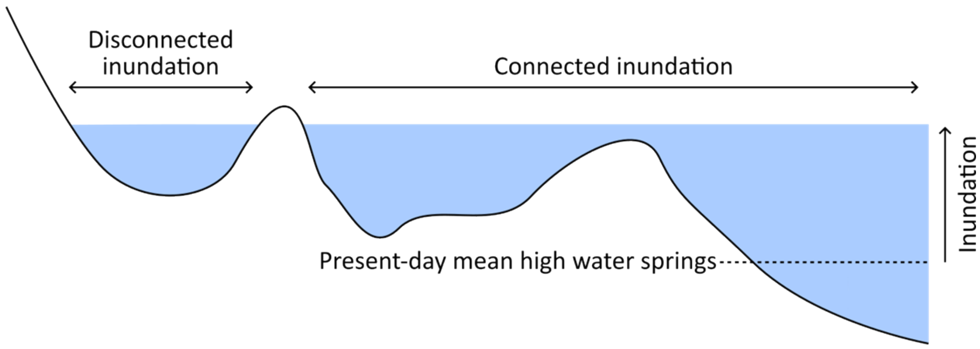


**Figure 2:** A conceptual illustration of an elevation cross-section of a coastal location where bathtub modelling has been used to identify areas susceptible to inundation due to relative sea-level rise. Areas of connected inundation are directly connected to the present-day coast, while areas of disconnected inundation are not directly connected but are at or below the elevation that may be inundated.

Council's bathtub modelling displays relative sea-leave rise in 0.5m increments on the [online coastal hazards map viewer].

## 5. Assessment

For each site the assessment of potential impacts of coastal inundation from sea-level rise and coastal storms has involved consideration of the following elements:

(1) relative sea-level rise (due to future climate change using SSP5-8.5 M and H+ scenarios, and vertical land movement).

(2) extreme storm events (1% AEP), including the effects of storm tide and wave setup.

Additionally, to determine the landward boundary of the area susceptible to inundation for planning purposes (e.g. the application of planning objectives, policies and rules), a third consideration was also included:

(3) a 'factor of safety', to account for unknown factors and potential uncertainties.

This is summarised as the following:

| Year | Screening Assessment | Landward Boundary of area susceptible to coastal inundation for Planning Purposes |
|---|---|---|
| **2130** | • Relative sea level rise (SSP5-8.5 M including VLM), and 1% AEP coastal storm (storm tide and wave setup)<br>• Relative sea level rise (SSP5-8.5H+ including VLM), and 1% AEP coastal storm (storm tide and wave setup) | Relative sea level rise (SSP5-8.5H+ including VLM), 1% AEP coastal storm (storm tide and wave setup), and 'factor of safety' |

Each of the elements used in the screening assessment and to determine the landward boundary for planning purposes are explained in the next sections.

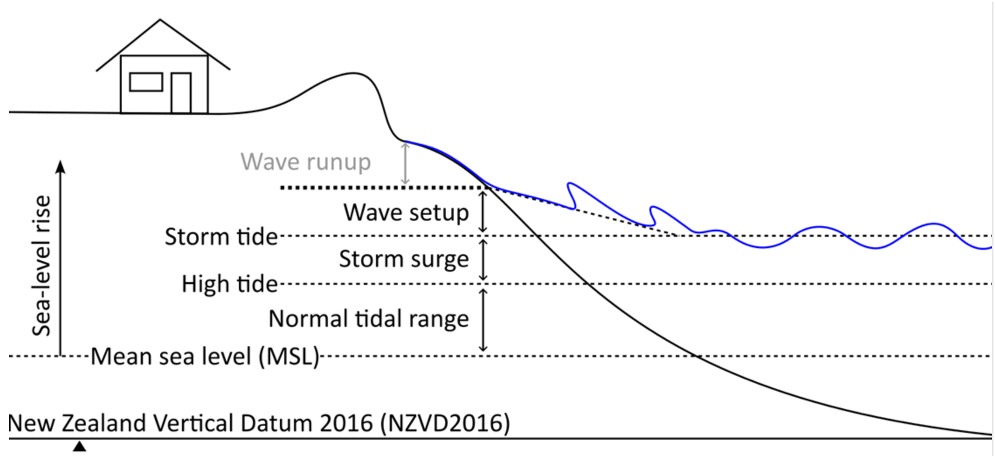


**Figure 3:** Conceptual illustration of the elements of coastal inundation included within the bathtub modelling and screening assessments. Wave runup is shown in light grey as while this is a component of coastal inundation it is not included within the bathtub modelling and screening assessment.

## *4.3 Relative sea-level rise*

Relative sea-level rise includes both the effects of sea-level rise due to projected future climate change and the effects of vertical land movement.

### Future climate and sea-level rise

The landward boundary of the area susceptible to inundation considers relative sea-level rise under the SSP5-8.5 H+ scenario, while the screening assessment considers sea-level rise under both SSP5-8.5 M and SSP5-8.5 H+. Both have been undertaken for the year 2130.

For Tasman, at 2130 the median sea-level rise projection for SSP5-8.5 it is 1.21-1.22 m, while the projected H+ (*p83*) sea-level rise for SSP5-8.5 is 1.66-1.67 m. There is some very minor spatial variability in SSP5-8.5 sea-level rise projections across the district, with values increasing by one-centimetre in the very north of the district compared to the south.

### Vertical land movement

Relative sea-level change can be driven by a change in the level of the ocean or vertical movement of the land. Where the land is subsiding, this increases rates of relative sea-level rise (Figure 3). Following the 2022 NAP and 2024 Guidance, VLM is added onto the projected future sea-level rise for both the screening assessment and to determine the landward boundary of the area susceptible to coastal inundation. For the bathtub mapping at the district-scale the rates of VLM produced by the NZ SeaRise programme for sites every 2 km along the coastline have been averaged across sections of the coast. These sections correspond to areas of the coastline that have broadly similar shoreline characteristics and storm inundation levels (see below), as well as similar rates of VLM, and are largely similar to the coastal cells used in the recent Coastal Hazards Assessment in Tasman Bay/Te Tai o Aorere and Golden Bay/Mohua (Tasman District Council, 2019). Subsidence is experienced across the district, with the averaged rates of VLM ranging from -4.00 mm $yr^{-1}$ near Richmond to -0.41 mm $yr^{-1}$ at Patons Rock. These rates of subsidence have the effect of increasing the rates sea-level rise experienced along the coast (Figures 4 and 5).

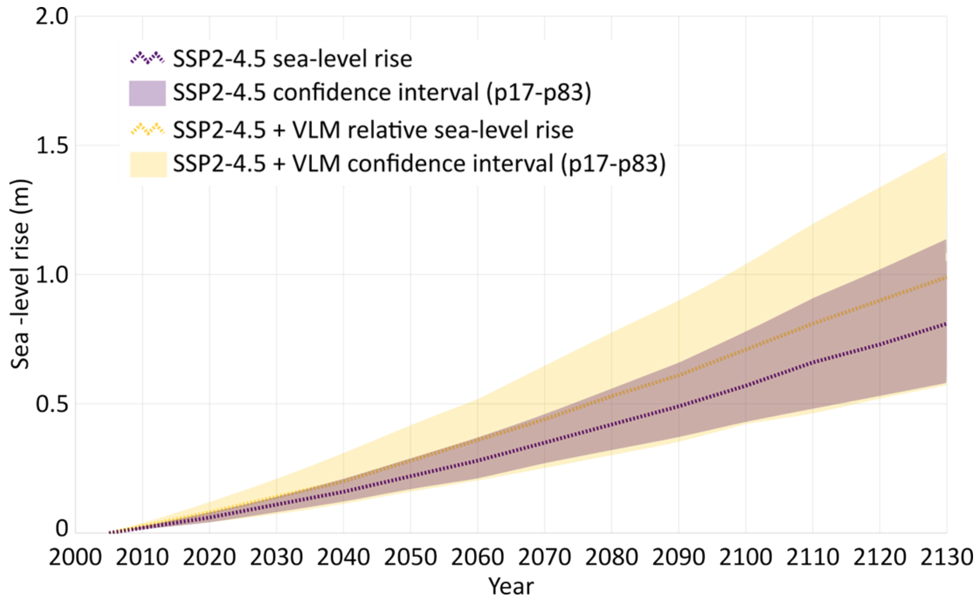


**Figure 4:** Example for Separation Point (NZ SeaRise site 6361) site showing the effect that subsidence (VLM) has on the rate of relative sea-level rise projected for the site under SSP2-4.5.

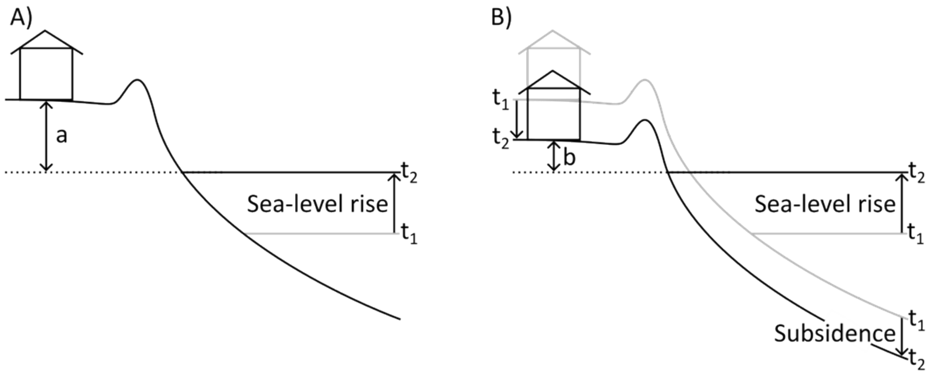


**Figure 5:** Conceptual illustration showing the effect of subsidence on relative sea-level rise. (A) Sea-level rises between two points in time $t_1$ and $t_2$ without any vertical land movement. (B) Sea-level rises the same amount between the same two points in time, while at the same time the land subsides. From the point of view of someone on the land, the sea-level has risen much more in (B) compared to (A)—this can be seen by comparing the difference in the height of the sea at $t_2$ with respect to the house, distance (a) compared to distance (b).

## 4.4 *Extreme storm events*

Extreme storm events inundate low-lying areas of the coast, with sea-level rise progressively increasing the height reached by storm surge and wave setup processes (Figure 3). Storm surge is the elevation in ocean water levels along the coast produced by the low air pressure and strong onshore winds that accompany storms. The height reached by the storm surge above the predicted tide level is referred to as the storm tide (Figure 3). Wave setup is a component of storm inundation that is caused by water being pushed up along the shoreline by the transfer and release of energy from waves breaking at the coast.

For open coast sites storm tide and wave setup values have been taken from the NIWA Coastal Calculator. For sheltered estuary sites storm tide values have been taken from the NIWA Coastal Calculator and correspond to the storm tide value for the open coast adjacent to the estuary, while wave setup values follow the methodology applied in the 2019 TDC report Coastal Hazards Assessment in Tasman Bay / Te Tai o Aorere and Golden Bay / Mohua. The 1% AEP storm tide elevation is approximately 2.36 m NZVD2016[7] in Golden Bay (approximately 0.62 m above mean high water springs, MHWS), and approximately 2.27 m NZVD2016 in Tasman Bay (approximately 0.59 m above MHWS). Wave setup varies from 0.2 m in sheltered estuary locations across Golden and Tasman Bays, to a maximum of 0.71 m at Tata Beach.

Wave runup is not included in the static inundation levels used for the bathtub modelling as runup is a dynamic wave effect that is highly site-specific.

## 4.5 *Factor of safety*

A factor of safety of 0.50 m has also been added above the projected 2130 static inundation level to account for unknown factors and potential uncertainties:

- ***Uncertainties and variations in the rates of VLM***. The NZ SeaRise Programme has published rates of VLM for locations every 2 km around the New Zealand coastline. These rates of VLM

[7] New Zealand Vertical Datum 2016.

are averages of all the VLM estimates within 5 km of the averaging location. Error estimates and the maximum and minimum VLM estimate are provided for each average VLM rate. In Tasman and Golden Bays the error estimates range from 0.62 mm $a^{-1}$ near Puponga, to a maximum of 2.86 mm $a^{-1}$ near Tamatea Point. Over 100 years, these rates compound to an uncertainty of between 0.06-0.29 m. VLM rates have been averaged for sections of the coastline with broadly similar shoreline characteristics, storm inundation levels, and rates of VLM. However, in some areas local rates of VLM may be higher than the average rate used for the bathtub modelling.

- ***Vertical uncertainties with the land elevations represented by the LiDAR elevation surface***. This vertical uncertainty is typically ~0.15-0.20 m (e.g., LINZ 2020, 2022).
- ***Uncertainties with projections of storm-tide and wave setup elevation***. Storm-tide and wave setup values have been derived from the NIWA Coastal Calculator for Tasman and Nelson Districts for sections of the coast that have broadly similar shoreline characteristics and wave climate. The Coastal Calculator presents the central (best) estimate of storm-tide plus wave setup. The upper 95% confidence interval of the extreme wave analysis is typically 0.02-0.04 m greater than the central (best) estimate. Wave setup is calculated using an empirical relationship between beach slope and offshore significant wave height—wave setup is therefore highly sensitive to beach slope. For localities where the local beach slope is steeper than the representative beach slope used for that section of the coast local wave setup will be underestimated.
- ***Omission of dynamic components of inundation from storms such as wave runup***. The bathtub modelling approach deliberately does not include dynamic components of inundation from storms such as wave runup. Wave runup is principally of concern to locations close to the coastline. However, when considering a 100-year timeframe out to the year 2130, it is not clear where the coastline may be at 2130. For areas close to the coastline at 2130, the static bathtub water level will therefore underestimate susceptibility to inundation during coastal storms.

## 6. Trigger for retreat *(yet to be finalised and will be subject to separate consultation)*

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