Public Interest Law and Science Initiative Inc.

Submission to the Kapiti Coast District Council by the Public Interest Law and Science Initiative inc.[1], by Sean Rush[2] on:

The Climate Advisory Panel Report- 20 June 2024

Thank you for the opportunity to make this submission regarding the "CAP report".

This submission makes the following key points:

1. There is no problem definition – there is no benchmarking analysis of how coastal inundation has affected Kapiti residents previously, and whether that has changed over time, as greenhouse gas emissions have increased. What problem are we solving?

   Pilsi has been unable to find evidence of repetitive coastal inundation.

2. A significant part of the Kapiti Coast, such as Otaki beach, continues to edge closer to Australia, reducing the coastal hazard. Until this slows and reverses, there is no need for action in these areas.

3. The use by CAP of high-end climate models, in line with MfE guidelines, is unfortunate and out of line with the latest science, Policy 24 and the Climate Change Adaptation Act 2002.

   The legislation provides a statutory test – to identify "likely' climate changes.

   The IPCC defines "likely" as between 50% and 66%.

   CAP uses SSP5-8.5 – the most extreme climate scenario that is described as "unlikely" both by the IPCC and by the SeaRise scientists.

   The IPCC defines "unlikely" as below 33% probability of occurrence.

4. Of more relevance is the impact of low-pressure systems (tropical cyclones) coinciding with King Tides, the latter are predictable and should be marked on every coastal dweller's calendar. We need to focus on other more important aspects of coastal hazard – not sea level rise.

5. I attach at Appendix 1, a paper published by the NZ Geoscience Society in March. Not one of the scientists involved in the SeaRise project, Jacobs or at CAP have accepted my open invitation to meet with me to explain where I have got it wrong.

Background to The Public Interest Law and Science Initiative inc

The Public Interest Law and Science Initiative inc ("PILSI") is a not-for-profit organisation with members made up from the legal and scientific community, including planners, economists, sea level experts, statisticians and other academics, as well as members of communities and

[1] Public Interest Law and Science Initiative Inc. (pilsi.org.nz)

[2] Sean has a Masters in Climate Change Science and Policy and was an Expert Reviewer for the Intergovernmental Panel on Climate Change;'s Sixcth Assessment Report, Working Group 1, The Physical Science Basis.

community groups concerned with the honest and robust application of science in law and policy making.

We are concerned about the use of false narratives, supposedly underpinned by science, to win support for what would be otherwise, unpopular policies.

Our mission is to be an honest broker and simply let science speak to power.

Sea Level Rise

Regarding sea-level rise, the most recent up to date scientific study on sea level rise in New Zealand (Denys et al 2020[3]) shows a somewhat pedestrian trend of rising seas at around 2 - 3 mm/year which is influenced heavily by oceanic effects, such as the Pacific Inter-Decadal Oscillation as well as atmospheric conditions, such as the ENSO.

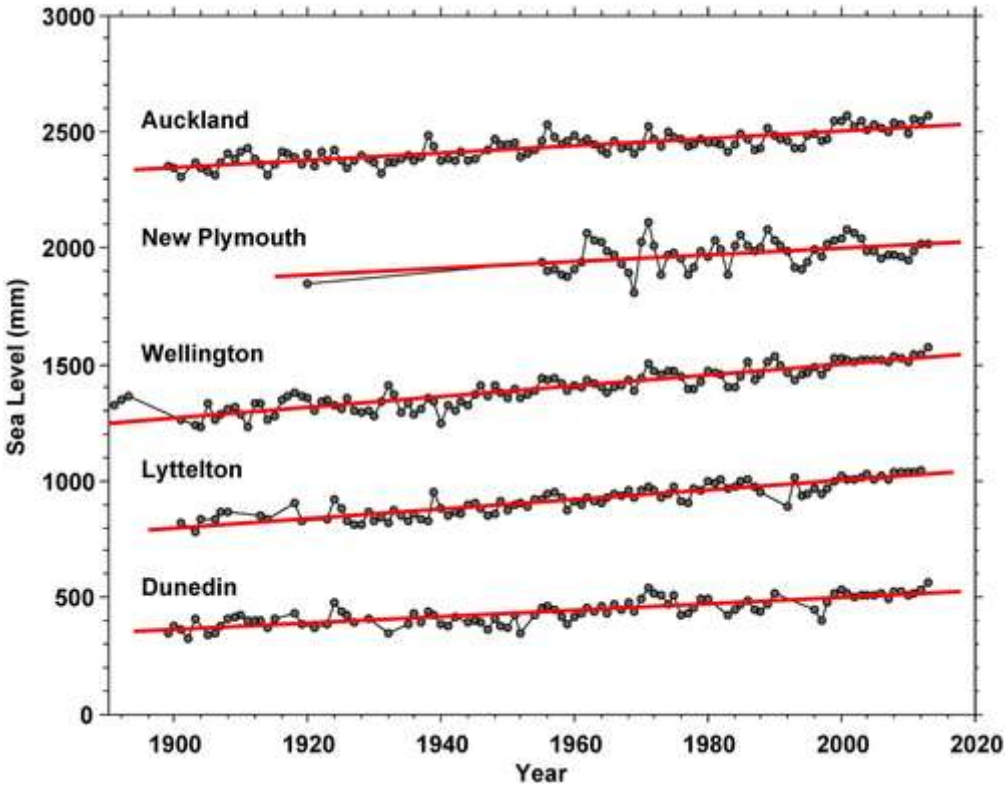

Figure 1: From Denys et al 2020

Of more relevance is the impact of earthquakes – the Kaikoura earthquake raised the coastal land by over 2 metres on the Kaikoura coast and affected the Wellington area with an overall uplift of 40 mm. As can be seen, sea level measured by the Wellington Harbour Tide gauge remains below the pre-Kaikoura earthquake peak in 2016.

[3] Denys et al (2020) "*Sea Level Rise in New Zealand: The Effect of Vertical Land Motion on Century-Long Tide Gauge Records in a Tectonically Active Region.*"

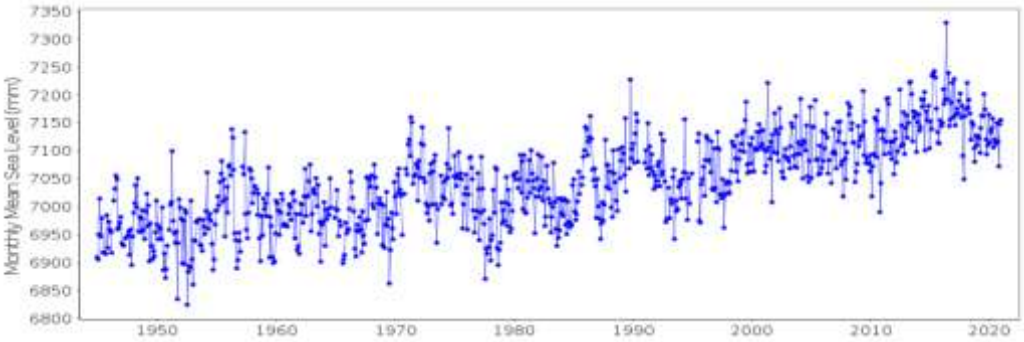

Figure 2: Relative Sea Level measured by the Queen's Wharf tidal gauge with current (May 2022) level extended back in time. *Source: PMSL web data* - 221_high.png (900×360) (psmsl.org)

The Big Danger – Low pressure systems - Tropical Cyclones

The pedestrian rate of sea level rise is comparatively unimportant to the threat posed by low pressure systems. For those who think Cyclone Gabrielle signals the emergence of climate change then it is worthwhile recalling what NIWA said in the October prior to its landing in its annual forecast for the 2022/23 tropical cyclone season.

Their Southwest Pacific Tropical Cyclone Outlook[4] is a collaboration with the MetService. It was issued in the prior October predicting that 6 to 10 named cyclones could occur. The report described an expected "near normal" season based on the average since 1969. In line with the IPCC conclusions, they saw no evidence of a changing climate that would put the expected weather outside what has been 'normal' since 1969.

Curiously, some scientists changed their view *after* Gabrielle hit, stating that climate change affected the amount of rain that fell (although could not accurately say by how much).[5] However, many of the automated weather stations lost power during the cyclone and only six stations recorded observations of rainfall during the cyclone. Of the six stations that were active during the cyclone, the earliest records begin in 1990, 2 years after Cyclone Bola, meaning comparisons to the most recent significant weather event in the area cannot be made.[6]

Building resilient weather stations along the Kapiti Coast would be a good first step in any adaptation plan.

We would expect more rain and associated damage in the Hawke's Bay and Gisborne areas from Gabrielle, as opposed to Bola, due to the relative proximity of Gabrielle's storm track to both areas. Despite it being the most costly, tropical cyclone season, 2022-23 was a 'below average' cyclone season.[7] In fact most of the tropical cyclone seasons recorded over the last 10 years have been below average in terms of storms achieving tropical cyclone status with the record high being in 1997-98.[8]

What is clear from the below storm tracks is that the effect a tropical cyclone has is not dependent on sea level rise but how close it comes to a major urban area, such as Napier/Hastings – a seemingly random walk dictates how strong the impacts are felt.

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[4] https://niwa.co.nz/climate/southwest-pacific-tropical-cyclone-outlook/southwest-pacific-tropical-cyclone-outlook-october-2022.
[5] This might be contrasted with a NIWA scientists after the event claim https://www.rnz.co.nz/news/national/485990/niwa-scientist-in-no-doubt-climate-change-behind-cyclone-gabrielle-s-intensity.
[6] Source: https://www.carbonbrief.org/heavy-rainfall-from-new-zealands-cyclone-gabrielle-more-common-on-warmer-planet/.
[7] Sourced: https://en.wikipedia.org/wiki/2022%E2%80%9323_South_Pacific_cyclone_season
[8] Source::BOM's Seasonal Outlooks for Tropical Cyclones available at https://en.wikipedia.org/wiki/2023%E2%80%9324_South_Pacific_cyclone_season

Storm tracks for Tropical Cyclone Bola (left) and Gabrielle (source: Wikipedia)

Adaptation planning needs to focus strongly on predicting when a storm track will pass close to New Zealand's coast and warnings from Niwa should be taken seriously.

Sea level inundation will not occur because of the ~2 – 3 mm/yr rise in sea level. Sea level rises and subsides with the tide by metres each day. Sometimes the planets align, literally, to enhance the standard gravitational tug and produce a King tide. These above-normal tides can trigger high tide flooding, disrupting coastal communities. This flooding is exacerbated if high tides coincide with low pressure systems that release pressure on the sea surface and allow it to rise tens of centimetres for a short period.[9] This is known as the inverted barometer effect. When wind set up, which is where wind blows the sea towards the coast causing it to pile up, is added then the sea level rise is significantly greater than the 2 – 3 mm/yr increase we see annually.

We can plan for King tides – we know when the Moon will be full. These days should be embedded on the calendar of every coastal homeowner. We should then develop a sound system to rapidly warn communities of an inverted barometer effect and wind set up should they develop.

Coastal dwellers should know what the result in their community is should such events coincide, with or without, a King tide.

Climate risk and response information-sharing

With climate being the average of weather across a minimum of 30 years, a simple method to predict what's coming is to extrapolate out trends that are emerging over the last 30 – 50 years as a reasonable steer towards what is likely to arise in the next 10 or more years.

We can do this with the Wellington Harbour Tide Gauge (figure 3 below) where we can extrapolate forward from 2005 to 2030 based on the prior trends:

[9] See https://www.linz.govt.nz/guidance/marine-information/tides/meteorological-effects-tides

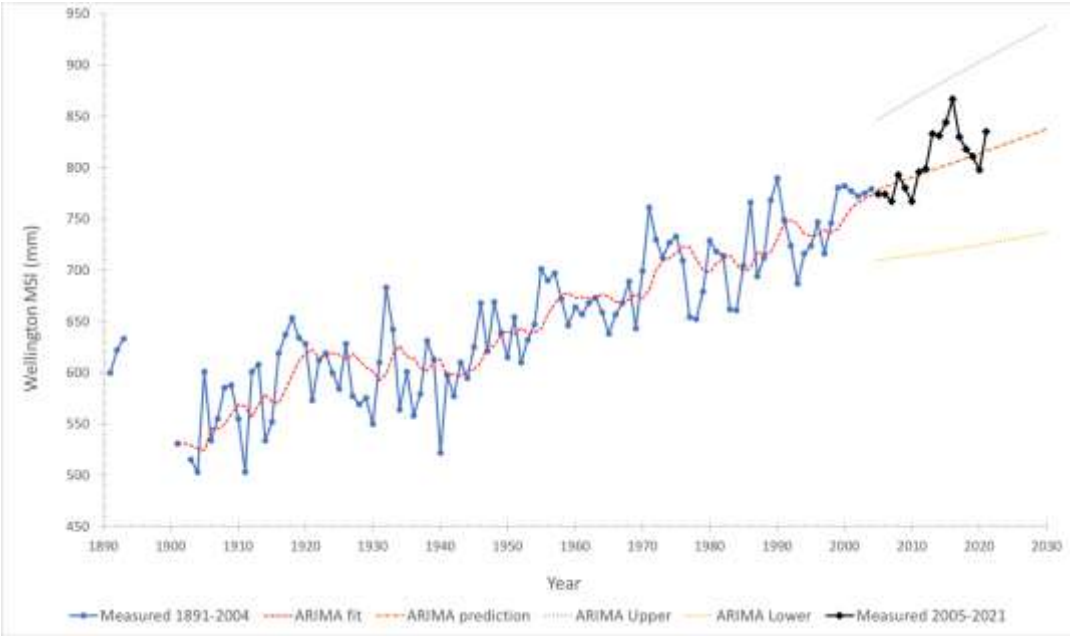

Figure 3 – Annual mean relative sea level at Wellington from 1891 to 2021 using data from Bell & Hannah (2012) updated with data from the Permanent Service for Mean Sea Level (PSMSL) and LINZ tide gauge site WLGT sensors 40 & 41. An ARIMA model was fitted using R functions *auto.arima* and *forecast* provided by the package *forecast*. The upper and lower bounds for the forecast correspond to 95% confidence limits.

Were we to take the Wellington region rain gauges, we would find no trend in rainfall changes. Niwa reported in 2020 "there are no obvious consistent temporal trends within or between the sites."[10]

The approach of using the past as a guide to the future, for the identification of likely effects of future climate change, is different to that advocated for by the Ministry for the Environment ("MfE").

The MfE advocates for the use of high-end models that the IPCC modelling community now categorise as part the 'The Emissions World Avoided.'

This submission proposes that the Government (including MfE) use the SSP4-6.0 model that is consistent with current trajectories.

However, RCP 8.5/SSP5-8.5 has been embedded into the National Climate Change Assessment (NCCA) and it needs to be pulled out for the following reasons.

1. The NCCA is meant to inform the development of the National Adaptation Plan (Ministry for the Environment. 2022.Aotearoa New Zealand's first national adaptation plan. Wellington. Ministry for the Environment. ("NAP") for use by Councils.

   The embrace of RCP8.5 / SSP5-8.5 was premature and its ongoing presence is unfortunate. Section 5ZQ(3)(f) of the Climate Change Response Act 2002 requires the Minister to take into account the "current effects and likely future effects of climate change." (emphasis added).

[10] NIWA CLIENT REPORT No: 2020089AK "Historic climate extremes analysis for the Wellington Region" December 2020.

But the IPCC Working Group 1 in its Sixth Assessment Report ("AR6") stated in respect to high emission scenarios:

a. *"… However, the likelihood of high emission scenarios such as ... SSP5-8.5 is considered low in light of recent developments in the energy sector ..."* [IPCC AR6 WG1 Section 1.6.1.4]

b. *"The high-end scenarios RCP8.5 or SSP5-8.5 have recently been argued to be implausible to unfold (e.g., Hausfather and Peters, 2020; see Chapter 3 of the AR6 WGIII).* [IPCC AR6 WG1 Section 4.2.2]

2. The Hausfather and Peters (2020) paper, cited by the IPCC, is entitled: "Emissions – the 'business as usual' story is misleading". Its sub-heading says, conclusively:

> "**Stop using the worst-case scenario for climate warming as the most likely outcome — more-realistic baselines make for better policy**." (emphasis added)

I set out some extracts that are relevant to the statutory test:

a. "RCP8.5 was intended to explore an unlikely high-risk future. But it has been widely used by some experts, policymakers and the media as something else entirely: as a likely 'business as usual' outcome."

b. "Happily — and that's a word we climatologists rarely get to use — the world imagined in RCP8.5 is one that, in our view, becomes increasingly implausible with every passing year."

c. "Emission pathways to get to RCP8.5 generally require an unprecedented fivefold increase in coal use by the end of the century, an amount larger than some estimates of recoverable coal reserves. It is thought that global coal use peaked in 2013, and although increases are still possible, many energy forecasts expect it to flatline over the next few decades. Furthermore, the falling cost of clean energy sources is a trend that is unlikely to reverse, even in the absence of new climate policies."

d. "we suggest that climate-impact studies using models developed for AR6 should include scenarios that reflect more-plausible outcomes, such as SSP2-4.5, SSP4-6.0 and SSP3-7.0 (see 'Possible futures'). When RCP8.5 or its successor SSP5-8.5 are deployed, they should be clearly labelled as unlikely worst cases rather than as business as usual."

e. They include the below diagram with references showing how the high end scenarios are now deemed "highly unlikely' and "unlikely." An unlikely scenario will fail the statutory test here in New Zealand.

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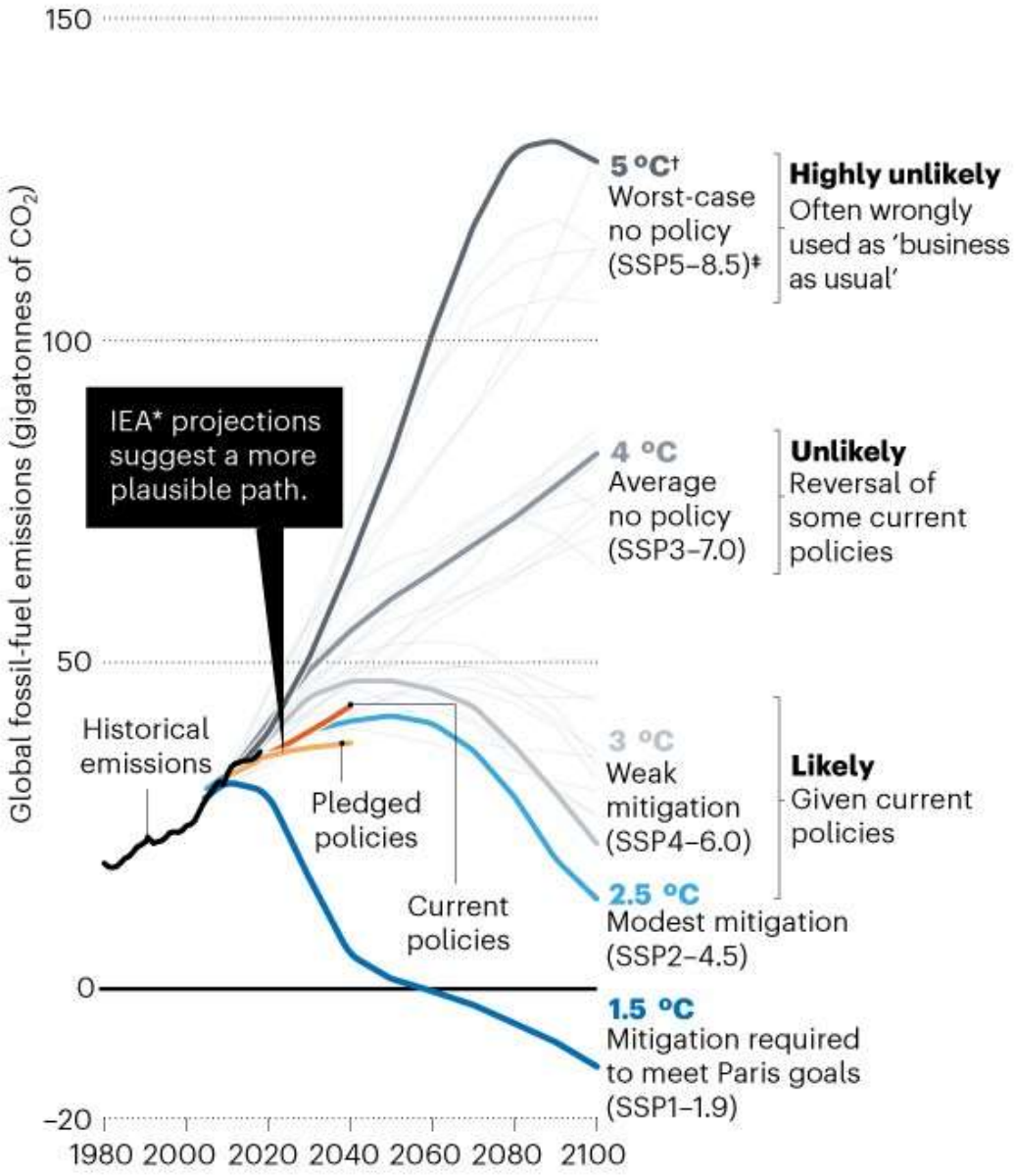
POSSIBLE FUTURES

The Intergovernmental Panel on Climate Change (IPCC) uses scenarios called pathways to explore possible changes in future energy use, greenhouse-gas emissions and temperature. These depend on which policies are enacted, where and when. In the upcoming IPCC Sixth Assessment Report, the new pathways (SSPs) must not be misused as previous pathways (RCPs) were. Business-as-usual emissions are unlikely to result in the worst-case scenario. More-plausible trajectories make better baselines for the huge policy push needed to keep global temperature rise below 1.5 °C.



*The International Energy Agency (IEA) maps out different energy-policy and investment choices. Estimated emissions are shown for its Current Policies Scenario and for its Stated Policies Scenario (includes countries' current policy pledges and targets). To be comparable with scenarios for the Shared Socioeconomic Pathways (SSPs), IEA scenarios were modified to include constant non-fossil-fuel emissions from industry in 2018.
†Approximate global mean temperature rise by 2100 relative to pre-industrial levels.
‡SSP5–8.5 replaces Representative Concentration Pathway (RCP) 8.5.

Sources: Historical data: Global Carbon Budget (2019); SSP data: ref. 19/J. Rogelj *et al. Nature Clim. Change 8*, 325–332 (2018)/SSP Database (v2); IEA data: Ref. 7

3. Hausfather and Peters are not alone in declaring RCP8.5/SSP5-8.5 'implausible.' Others come to similar conclusions:
    a. Pielke and Ritchie (2021),

    "The original basis for the scenarios supporting RCP8.5 are extreme: they project a future that is characterized by high population, little technological advancement, extremely high carbon dioxide emissions and apocalyptic levels of climate change."

    "The influence of this implausible scenario on public and policy discussion of climate change is pervasive and consequential."

    b. Burgess et al (2021)

    "Our analysis supports the conclusions drawn by previous studies (Hausfather and Peters 2020, Pielke and Ritchie 2020) that high-emission AR5 (RCP8.5) and high-emission AR6 (i.e. SSP3-7.0 and SSP5-8.5) baselines should not be utilized as reference scenarios in climate research."

    c. Huard et al (2022): "the high-emission scenario SSP5-8.5 becomes unlikely as we reach the second half of the century.

4. IPCC Professor Dave Frame, at Canterbury University, was reported by Newsroom saying in regard to Auckland planning decisions based on RCP 8.5:

    "If they build in a safety margin that's actually contingent on a scenario that nobody really believes, then it's bad policy practice. **And I also think it opens the door to legal challenge**." (emphasis added).

5. Meinshausen et al 2023, - resulted from the IPCC Expert Workshop held in Bangkok, April 2023. The paper involves 41 co-authors from the IPCC climate modelling community and addresses the next generation of framing pathways for use in IPCC AR7.

    The coauthors similarly ruled out the plausibility of the high-end scenarios. Their Table 1 (below) shows that the high-end scenarios (red circle) are now consigned to "The Emissions World Avoided" with the more likely scenarios based on current trends circled green.

    The authors state that the higher end warming pathway category could be mistaken as a 'business as-usual' scenario and they consider it would be beneficial to separate high forcing pathways for scientific purposes, from the more policy-oriented framing pathway categories.

Table 1 - Overview of suggested pathway categories to inform the design of specific representative emission pathways for Earth system model runs. Categories of emission pathways identified in the IPCC AR6 WGIII (compare Table SPM.1) and selected WGI core SSP-RCP scenarios are provided for comparison. For each category, we provide an indicative 'priority' suggestion, recognizing that there are limited resources to run a large set of scenarios across all ESMs.

Category to be represented	Key characteristics of the representative pathway	Advantages	Potential drawbacks	Closest category (and selected pathways) in IPCC AR6[a]
High emissions: "TEWA" - The emission world avoided	• High end emissions • Departing from historical emissions in the past, i.e., 2015. • Three main options are SSP5-8.5, SSP3-7.0 or a new pathway that retrospectively reflects 'no-further climate action' (NFA) starting in, e.g., 1992, 2010 or 2015, each with their respective advantages and challenges (aerosols, comparability to CMIP6 and possibly CMIP5, representativeness of previous reference scenarios, etc.) • Lower priority	• Allows depiction of the world that could have unfolded without climate policies. • Allows to learn about high tail warming possibilities of lower scenarios. • Allows direct comparison of new generation of ESMs with previous ones, if a CMIP6 high end pathway is repeated (SSP5-8.5 or SSP3-7.0). • High signal-to-noise for projected changes in climate	• Could be mistaken as a reference case pathway. • Could lead to the false impression that the difference with this avoided scenario is the exclusive result of successful climate policies, and therefore that we have already achieved the biggest part of the challenge and what is left requires a smaller effort in comparison.	AR6 WGIII category C7-C8 SSP3-7.0 or SSP5-8.5 or RCP8.5.
"Medium" or "No further action (NFA)"	• A medium-high category that approximately reflects the median of "current policies as of 2023" or "current trends" estimates. • Approximately flat global GHG emissions from 2025 towards the end of century. • Approximately resulting in a 2.5-3.0°C world by the end of the	• An approximate depiction of future emissions in the absence of further climate policy action and assuming continuation of "current trends" as of the early 2020s. • Reflective of 2°C crossing up to approximately 2.5-3°C warming by 2100.	• The longer-term evolution of emissions under current policies is highly uncertain. Together with the DASMT this category spans the range of future policy outcomes (as of 2023)	AR6 WGIII category C6 SSP2-4.5, RCP4.5.

6. Professor Roger Pielke Jr, an expert in this area, restated the Fuss et al 2014 diagram that appears as Figure 8 in MfE's "A guide to local climate change risk assessments" as below, to account for Table 1 above from Meinshausen.

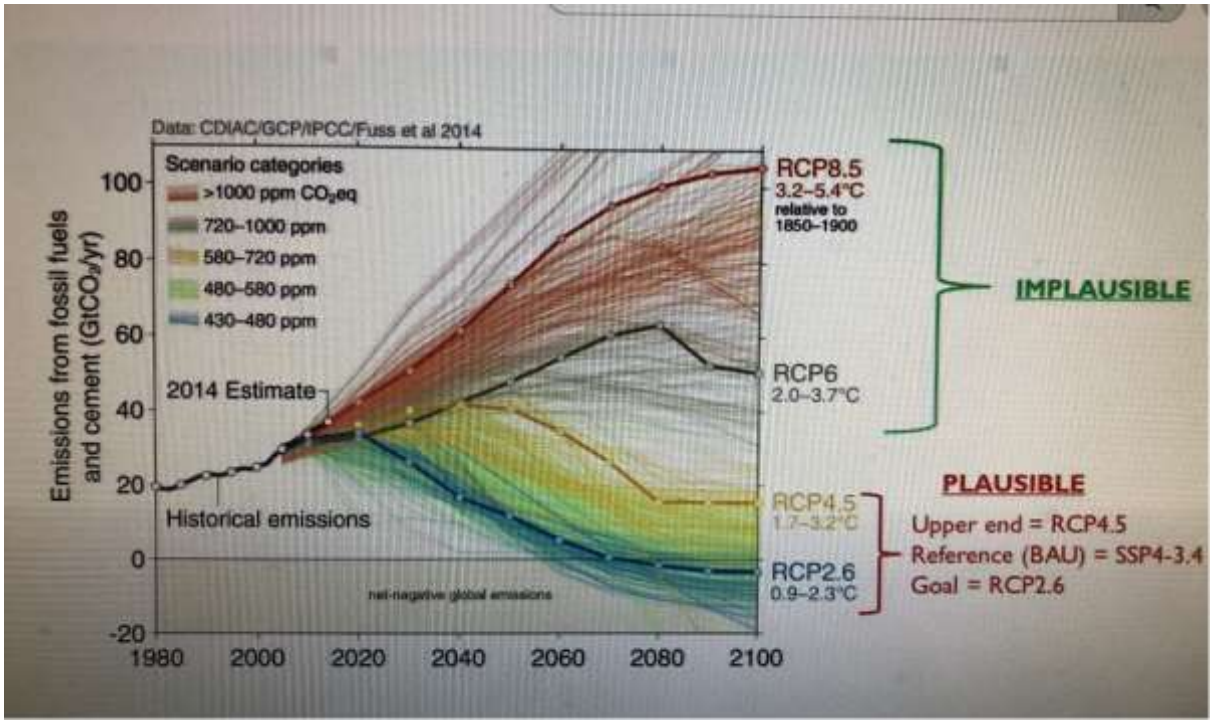


Figure 4 - Source: Roger Pielke Jr – used with permission

The SeaRise Project

For coastal adaptation the MfE relies heavily on a sea level study from a group known as the "SeaRise Project."

The team used novel satellite technology over a short six to seven-year period that showed large areas of coastal New Zealand subject to subsidence. This, they said, exacerbated the sea level rising trend assessed by the IPCC – doubling it in some parts of New Zealand.

The short-term data set used is inadequate to make long term projections of vertical land movement and has accordingly been received with some controversy by numerous academics at Victoria, Canterbury and Waikato Universities as well as GNS and independent scientists. Two papers have been published by the Geoscience Society of New Zealand on the subject: one by the author Is Wellington Sinking? (see Appendix 1)and one by long-standing geoscientist, Bruce Hayward, Is Auckland Sinking? Both ask questions of the SeaRise analysis that have never been addressed.

The forward projections of relative sea level rise, starting in 2005, show an overestimate of sea level rise of some 550% when compared to the Wellington tide gauge. The study's output should never have been fast-tracked into policy for decision makers in MfE's Coastal hazards and climate change guidance.

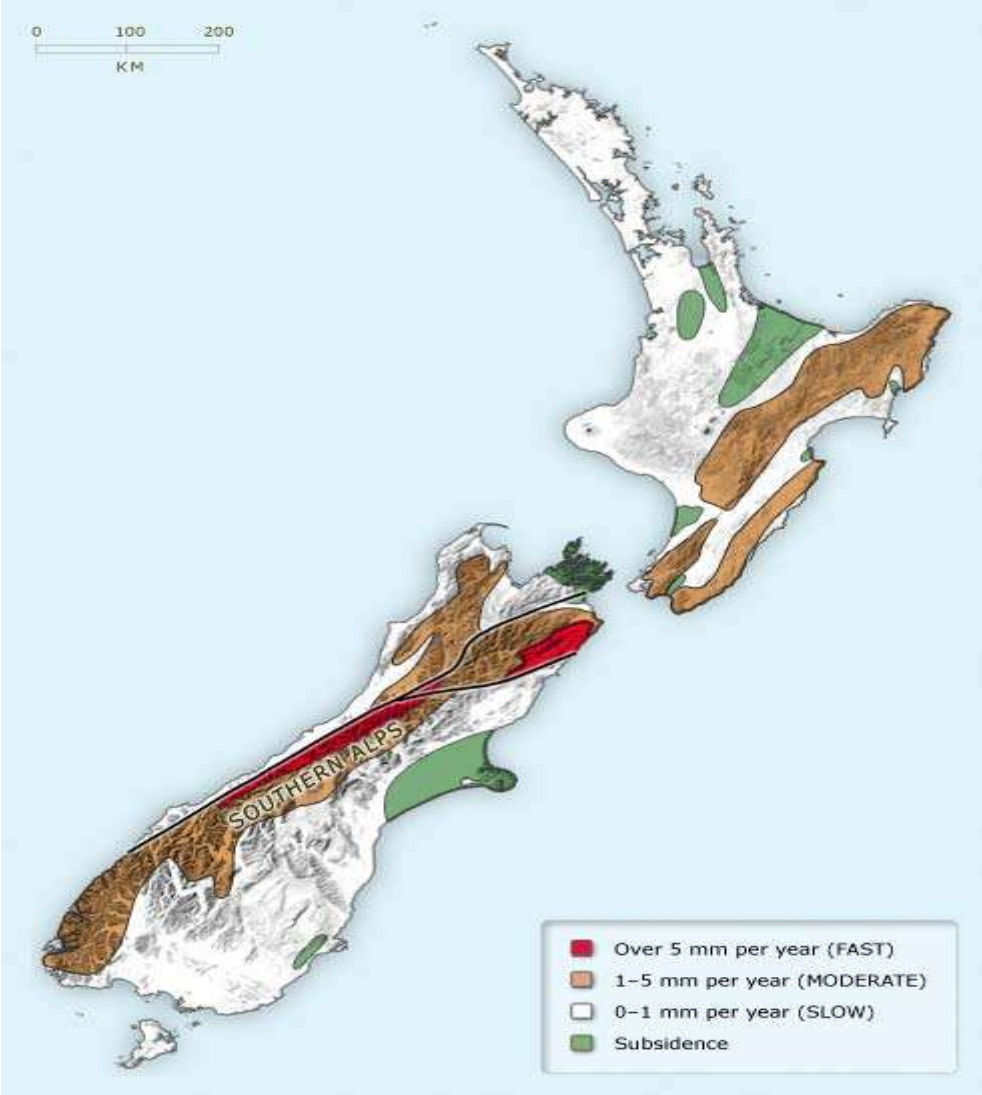
It is not 'best available' science. The best measurements of sea level come from long term tide gauges. New Zealand has four that have been the cornerstone of coastal planning since at least the 1950s.

A far better option to assess coastal sea level changes would be to install an array of tide gauges at multiple, strategic points around the coast. After a relatively short period e.g. 5-years, the measurements could be matched to the long term tide gauge records (and cGPS and paleo records) to extend the new tide gauge trends back in time.

Vertical Land Movement

The article, "Is Wellington Sinking?" published by the NZ Geoscience Society, in March 2024, (Appendix 1) sets out the problems of relying on a short-term data set for long term planning and how over planning timeframes the subsidence is reversed, eliminated and reversed. The MfE now advise planners to adopt local measurements of VLM, where available.

GNS has published data showing parts of the Kapiti coast rising at 1 – 5 mm/yr. This can be contrasted with Jacobs' advice of -1 mm/yr. We suggest ignoring VLM in the analysis or going with the long term trend.

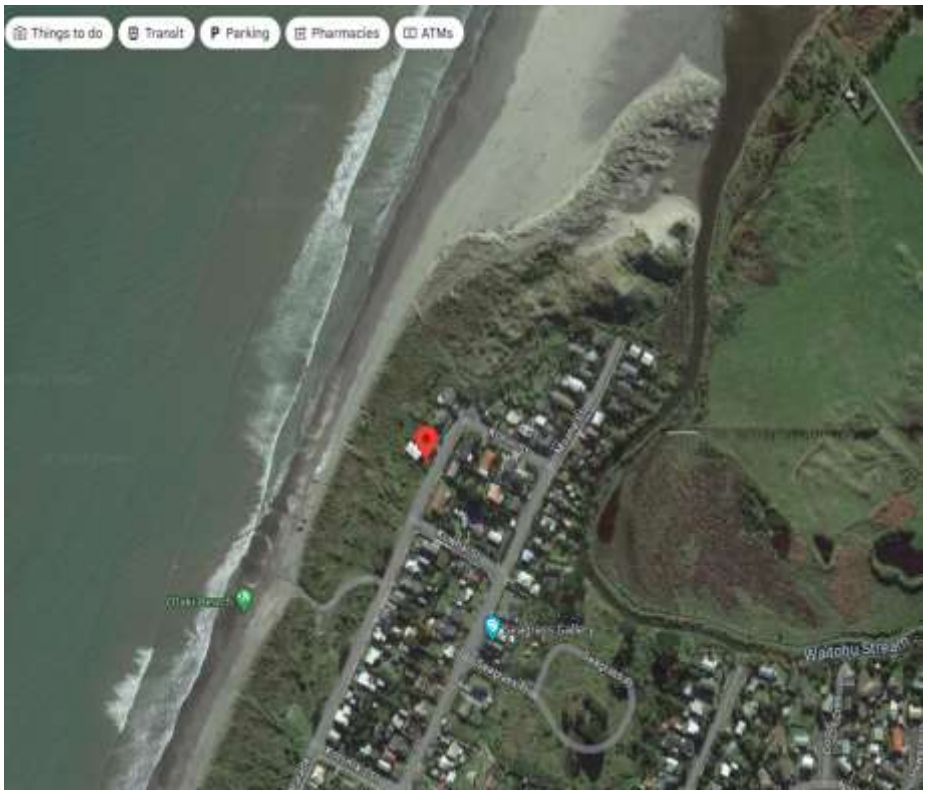


Source: Cartography by Carolyn Hume, GNS Science, based on maps by Harold Wellman (South Island) and Brad Pillans (North Island), with some generalisation. From The Encyclopaedia of New Zealand.

The Northern Adaptation Area

As far as the Otaki beach is concerned, there is a clear and well understood accretion trend.

The 'X" marks the location of 7 Mariner Parade 1958. Courtesy of the National Archives Reference: WA-48515 ; Description. Aerial photograph taken by Whites Aviation.



7 Marine Parade Otaki, from google maps 2023

Surveyor's mark at 7 Marine Parade Otaki Beach showing the land being 6 metres above mean sea level.

Conclusion

This submission concludes:

1. The observational evidence for sea level rise discloses a less alarming trend of around 2 – 3 mm/yrs over the prior 100 years and more. This trend is routinely offset by earthquakes and slow slip events.

2. Modern technological advancements should be employed to ensure early warning systems are robust to bad weather and effects on sea level, and their observations can be readily communicated to vulnerable communities.

3. Funding should be directed to the installation of an array of tide gauges, deployed along the Kapiti coastline to give real time data on relative sea level changes.

4. Vertical land movements should be either ignored or the long-term trend be adopted.

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5. It is clear the scientific community has now moved well away from the high-end scenarios, described in AR6 as “unlikely”, and since then by the modelling community itself. The ongoing use of these scenarios for planning will add cost to developers and unnecessarily constrain private property rights. They do not provide policy relevant data.

6. Otaki beach continues to edge closer to Australia, reducing the coastal hazard. Until this slows and reverses, there is no need for action.

7. All hazard warnings on LIM reports should be removed.

Kind Regards

Sean Rush
President
Public Interest Law and Science Initiative inc.

Public Interest Law and Science Initiative Inc.

Appendix 1: Published by the Geoscience Society of New Zealand, March 2024 edition.

Is Wellington Sinking?

Sean Rush*

Bruce Hayward's well referenced article "Is Auckland Sinking?" (Geoscientist Aotearoa/New Zealand Issue 4, November 2023) seeks an explanation of an apparent mismatch between the well-established tectonic stability around Auckland, and satellite observations of subsidence publicised by a government-funded research team known as the "SeaRise Project" in May 2022 (see Box 1).

Box 1: The NZ SeaRise Project was a $7.1 million, five-year (2018–23) research programme funded by the Ministry of Business Innovation and Employment-administered Endeavour Fund, involving a team of scientists from several institutions and led by Tim Naish and Richard Levy of the Antarctic Research Centre, Victoria University of Wellington. In 2022 the team received a further five-year grant of $13 million to extend its work. The peak deliverable for the original SeaRise programme was an online tool providing projections of relative sea level rise at 2 km intervals around New Zealand's entire coast, out to 2150, with decadal milestones highlighted. The method utilised summed global projections for global (absolute) sea level rise from the Intergovernmental Panel on Climate Change (IPCC), with the team's estimates of local (tectonic, sediment compaction, etc.) vertical land motion. The latter has been primarily informed by an historic (2003–11) InSAR data set, with lesser reference to continuous GPS and tide gauge records. The results were fast-tracked into the Ministry for the Environment's (MfE) 2022 "Interim guidance on the use of new sea-level rise projections" and the final version (MfE 2024) was issued in February 2024.[11] It also featured in literature associated with the MfE's coastal adaptation ("managed retreat") consultation.[12]

Wellingtonians have been asking the same question as Bruce Hayward. As with Auckland, there is a plethora of science showing that, contrary to the SeaRise modelling, parts of the Wellington region have been rising out of the water throughout the late Quaternary, due to episodic seismic and aseismic processes (e.g., Pillans et al 1995[13]; Ninis et al, 2022[14]; Beaven and Litchfield 2012[15]). However, the SeaRise news coverage [16], and the online 'tool' (Figure 1),

[11] Ministry for the Environment. 2024. Coastal hazards and climate change guidance. Wellington: Ministry for the Environment.

[12] Expert Working Group on Managed Retreat. 2023. Report of the Expert Working Group on Managed Retreat: A Proposed System for Te Hekenga Rauora/Planned Relocation. Wellington: Expert Working Group on Managed Retreat.

[13] Pillans B, Huber P (1995). Interpreting coseismic deformation using Holocene coastal deposits, Wellington, New Zealand. Quaternary International 26: 87–95.

[14] Ninis D, Little T, Litchfield NJ, Wang N, Jacobs K, Henderson CM 2022. Pleistocene marine terraces of the Wellington south coast – their distribution across multiple active faults at the southern Hikurangi subduction margin, Aotearoa New Zealand. New Zealand Journal of Geology and Geophysics 65: 242–263.

[15] Beaven RJ and Litchfield NJ 2012 Vertical land movement around the New Zealand coastline: implications for sea-level rise. GNS Science Report 2012/29. 41 p.

[16] Image and commentary available at https://www.searise.nz/maps-2 last visited 25 January 2024.

suggested that parts of Wellington, such as Petone and Owhiro Bay, could be subject to sea level rise of 30 cm by 2040. Land subsidence, known as "Vertical Land Movement" or "VLM", is driving this accelerated rate, doubling the rate of relative sea level (RSL) rise.[17] As Bruce Hayward found, the SeaRise claims appeared inconsistent with peer reviewed research and observations from around the region and warrant closer examination.

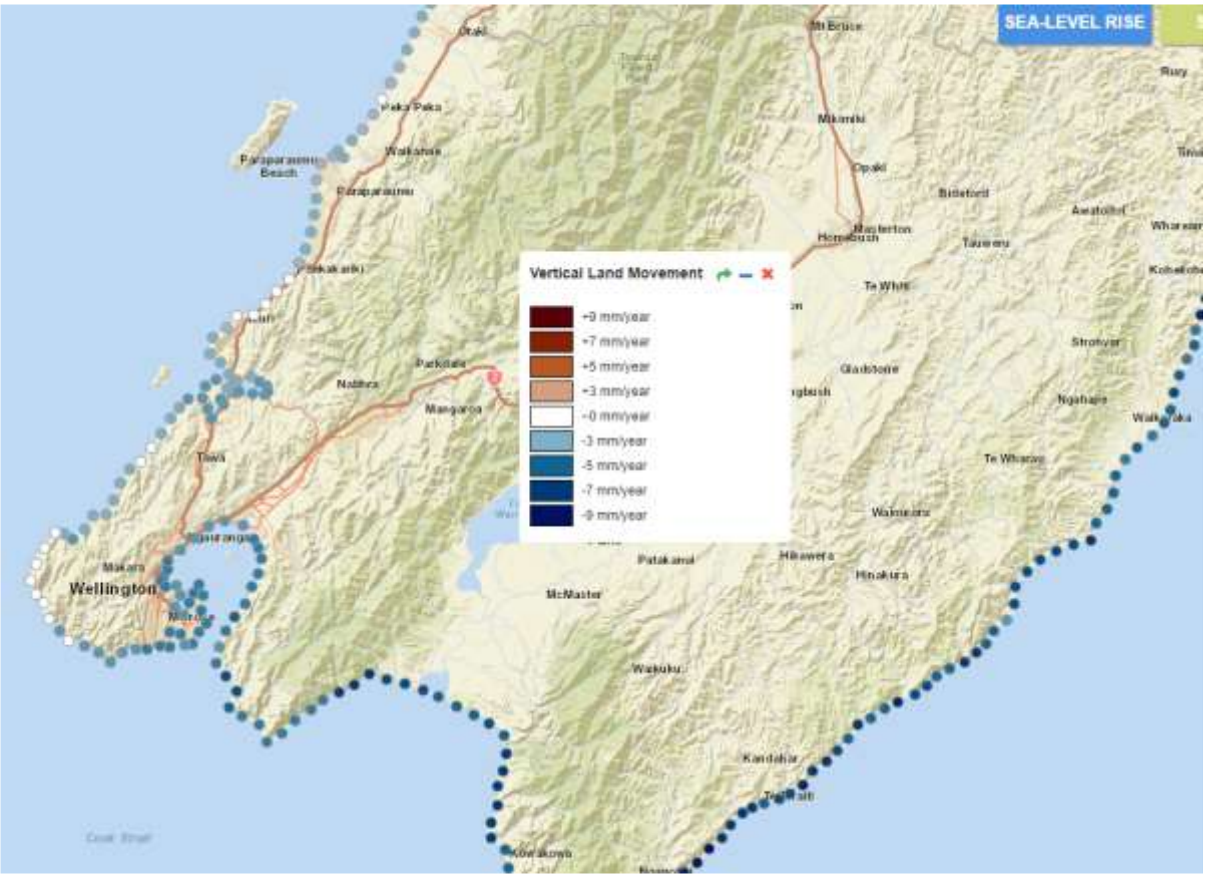

Figure 1: Screen capture of NZ SeaRise map of Vertical Land Movement for Wellington Region, 2003–2011. From https://searise.takiwa.co/map/6233f47872b8190018373db9/embed

Queen's Wharf Wellington

Subsidence

Location 2502 on the SeaRise 'tool' is at Queen's Wharf Wellington, about 10 km from both Petone and Owhiro Bay. It is also the location of the Wellington Harbour Tide Gauge for which measurements are available online from 1944 courtesy of the Permanent Service for Mean Sea Level (PSMSL; Figure 2). Analysis of the tide gauge data indicate that the average increase in monthly RSL observed by the tide gauge from 1944 to 2020 is 24.6 cm.

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[17] Reported by Radio New Zealand, 1 May 2022 at https://www.rnz.co.nz/news/national/466262/sea-levels-rising-twice-as-fast-as-thought-in-new-zealand last visited 25 January 2024.

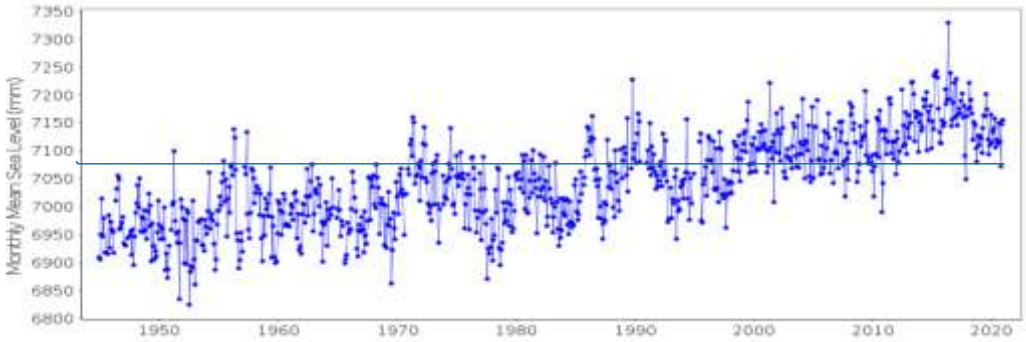

Figure 2: Monthly Mean Sea Level measured by the Queen's Wharf tide gauge in May 2022 with the level extended back in time. *Source: PMSL web data* - 221_high.png (900×360) (psmsl.org)

SeaRise record a 3.09 mm/yr subsidence rate between 2003 and 2011. This is consistent with the findings of Denys et al. (2020)[18] of an average interseismic subsidence rate in Wellington of ~3 mm/yr. But extrapolating that back to 1944 would suggest the VLM component of RSL alone would be 23.5 cm to 2021 across the 76-year data set. This leaves only 1.1 cm of sea level rise from the documented increase in absolute sea level (the height of the ocean surface above the centre of the Earth). Such a rate is well below established trends documented across the tide gauge record (e.g. Denys et al 2020) suggesting SeaRise's VLM component is far too high.

In reconciliation of the apparent mismatch, Denys et al. (2020) explain that slow slip events (SSEs) have been responsible for an average of 0.8 mm/yr of uplift from 1997 through to the end of their data set in 2013. They conclude: "*subsidence is not steady state and to understand the VLM, it is the average rate for the duration of the TG* [tide gauge] *data (subduction plus uplift) rather than the actual subduction rate that we need to determine."*

Adopting a longer data set to determine land movement trends, relevant for RSL projections, is recommended by Beaven and Litchfield (2012). They note that *"SSEs modulate the interseismic vertical motion so that a measurement of land elevation change between two SSEs may be quite different from the rate averaged through many events (which is the rate of most interest for RSL predictions)".* This modulation, when coupled with other sources of uplift, may result in the cancellation or even the reverse of the subsidence predicted by the SeaRise modelling.

For example, more recent work has been undertaken by NIWA, amongst others (e.g., Wallace 2020[19]) , on the nature and return times of SSEs as well as observations of uplift from other sources.

[18] Denys P, Beaven RJ, Hannah J, Pearson CF, Palmer N, Denham M, Hreinsdottir S (2020) "*Sea Level Rise in New Zealand: The Effect of Vertical Land Motion on Century-Long Tide Gauge Records in a Tectonically Active Region.*"

[19] Wallace LM 2020. Slow Slip Events in New Zealand. Annual Review of Earth and Planetary Sciences 48(1): 175–203.

NIWA advised the Greater Wellington Regional Council regarding RSL in a 2018 client report.[20] Like Denys et al. (2020), the authors were cautious about estimating VLM based solely on transitory subsidence. Their data sets were from 23 GNSS sites around the region between 2008 and 2018, and from 1998 to 2018 for three sites, including Queen's Wharf. Relevant to the SeaRise modelled subsiding trend, they state:

"*The net effect is that the subsidence due to the subduction of the Pacific plate under the Australian plate and coseismic displacement to date was mostly cancelled out by the current day Kaikoura earthquake postseismic deformation and the upwards ratcheting effect of the SSEs*."

Figure 3 is a chart showing VLM at the GPS site at the Wellington airport, 5 km from the Queen's Wharf tide gauge, where uplift from Kaikō ura and other sources clearly prove NIWA are right. Wallace (2020) documents similar uplift on the Kapiti Coast with GNS Science reporting that the Kapiti Coast had been subject to uplift of up to 1 cm in the first half of 2023 alone.[21]

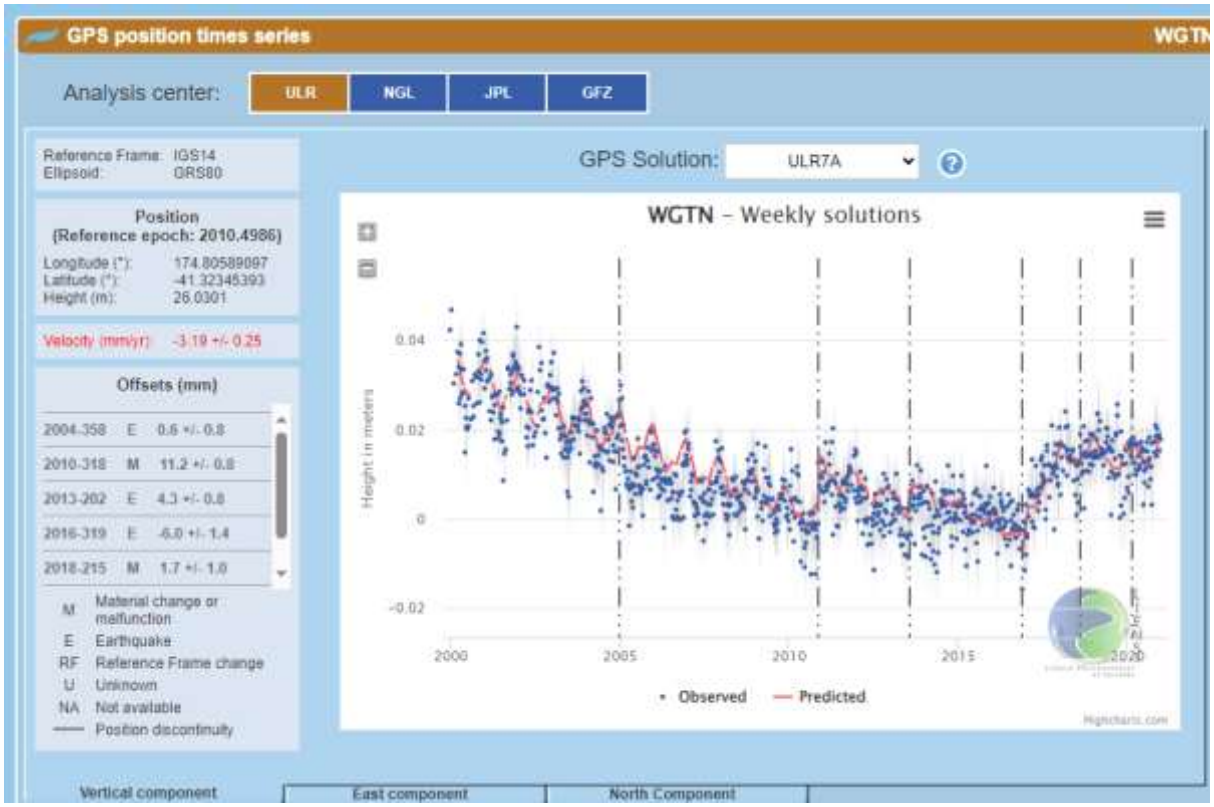

Figure 3: Screen capture of GPS measurements located at Wellington airport. Source: https://www.sonel.org/spip.php?page=gps&idStation=898

These sources of uplift have likely occurred previously and are likely to recur. But they were not observed in the short-term inter-seismic SeaRise dataset and accordingly are not modelled in their projections. Consequently, the SeaRise projections of future VLM are biased towards subsidence in the Wellington area.

[20] NIWA CLIENT REPORT No: 2019007HN. Report date: December 2018 NIWA Project: WRC19201.

[21] See https://www.geonet.org.nz/news/6vAA6FVHI9ojGmkONfsoOi last visited 6 June 2023.

Projections

The SeaRise projections of RSL rise at the Wellington Harbour Tide Gauge, Queen's Wharf (Figure 4), are similarly erroneous when compared to observations. The SeaRise online tool projects RSL rise from 2005 through to 2150, with decadal milestones, based on the IPCC's analysis of the response of absolute sea level to various emission pathways: from the lower pathway known as SSP1-1.9 through to the 'very unlikely'[22] highest pathway of SSP5-8.5. To these estimates are added the local VLM component projected by SeaRise.

The first milestone is 2020, where we now have measured data to test the model. At site 2502, which is at Queen's Wharf, using a realistic emission pathway, SSP2-4.5, SeaRise estimate with 'medium confidence' an overall rise in relative sea level of 11 cm, which without the VLM component, reduces to 6 cm, inferring a VLM component of −5 cm (P50 values).

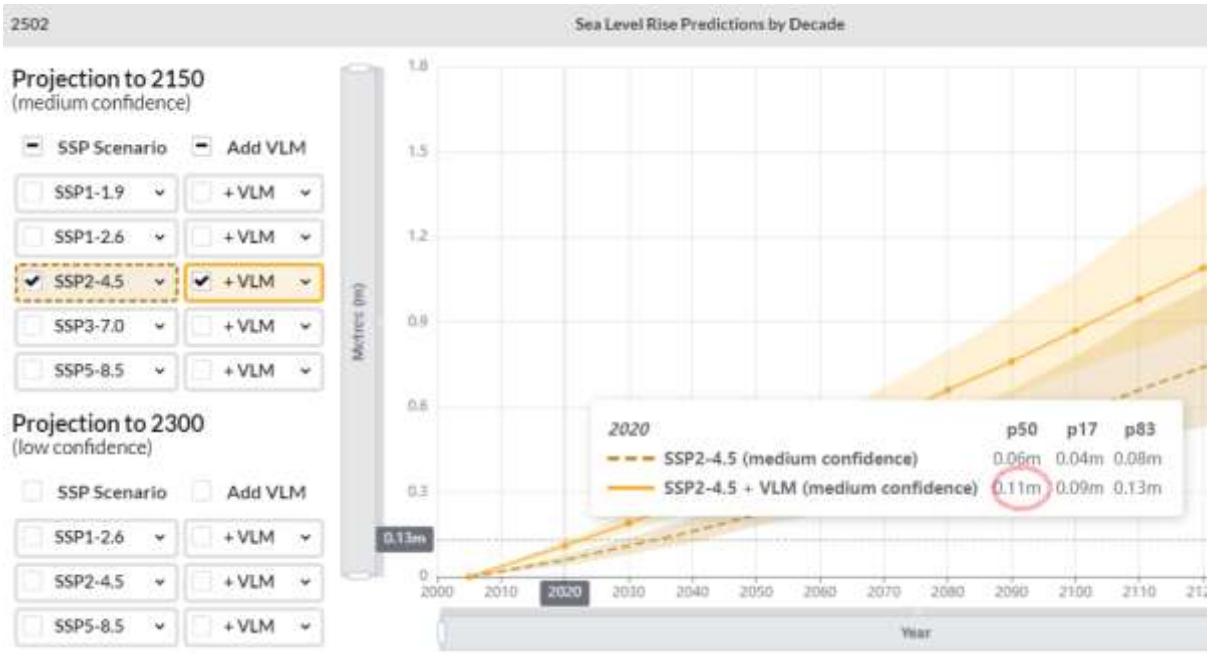

Figure 4: Screen capture of the SeaRise online tool for site 2502 highlighting the 11 cm projected RSL at 2005 – 2020 which reduces to only 6 cm without the VLM component (as at 25 January 2024 available at https://searise.takiwa.co/map/6233f47872b8190018373db9/embed).

During the same 15-year period the tide gauge recorded an increase of RSL of only 2 cm, which includes VLM (Source: https://psmsl.org/data/obtaining/rlr.monthly.data/221.rlrdata). The SeaRise methodology of adding IPCC estimates of absolute sea level rise to local rates of subsidence results in an over-estimation of around 550% for this site. This exaggerated rate is replicated around the region.

[22] Hausfather Z, Peters GP 2020a. Emissions – the 'business as usual' story is misleading. Nature577(7792): 618–620.
Hausfather Z, Peters GP 2020b. RCP8.5 is a problematic scenario for near-term emissions. Proceedings of the National Academy of Science 117(45): 27791-27792.
Pielke Jr R, Ritchie J 2021. Distorting the view of our climate future: The misuse and abuse of climate pathways and scenarios. Energy Research and Social Science 72: 101890.
Burgess MG, Ritchie J, Shapland J, Pielke Jr R, 2021. IPSS baseline scenarios have over-projected emissions and economic growth. Environmental Research Letters 16: 014016.

The adoption of this novel methodology adds complexity to an otherwise simple analysis. For example, an alternative straightforward method of predicting future RSL is to fit a statistical model to the long-term relative sea level records and extrapolate the model into the future to provide a forecast. Figure 5 shows an Autoregressive Integrated Moving Average (ARIMA) model that accounts for the serial autocorrelation of sea level data and non-stationarity due to an underlying acceleration of sea level rise. The ARIMA model was fitted to the data from 1901 to 2004 (red dashed line), and used to forecast sea level rise from 2005 to 2030 with 95% confidence limits (upper limit black dotted line, lower limit orange dotted line). The observed RSL for 2005 –2021 are also plotted (black line), and it is evident that the ARIMA forecast has predicted annual sea levels reasonably well up to 2021. The expanding separation of the confidence limits with time also restricts the utility of longer duration extrapolations.

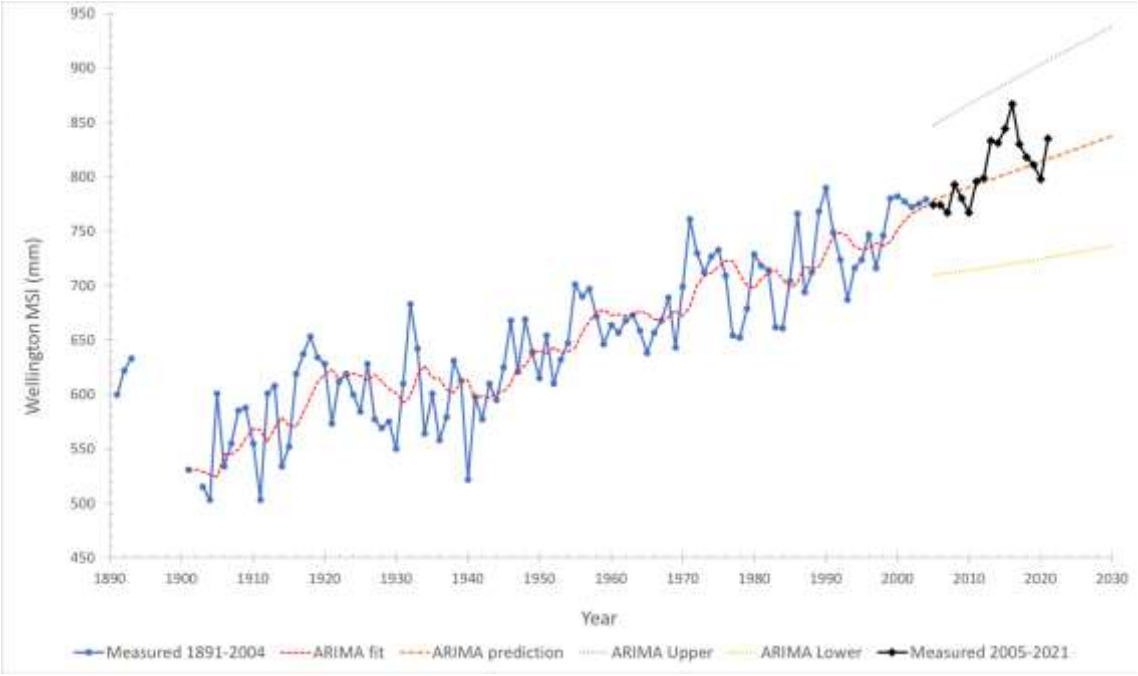

Figure 5 . Annual mean relative sea level at Wellington from 1891 to 2021 using data from Bell & Hannah (2012)[23], updated with data from the Permanent Service for Mean Sea Level (PSMSL) and LINZ tide gauge site WLGT sensors 40 and 41. An ARIMA model was fitted using R functions *auto.arima* and *forecast* provided by the package *forecast*. The upper and lower bounds for the forecast correspond to 95% confidence limits.

Conclusion

Bruce Hayward's piece concludes by offering possible explanations for why the SeaRise modelling is at odds with established Holocene records pertaining to Auckland. For Wellington, the explanation is clear: SeaRise's short-term, inter-seismic, data set has not recorded the episodic uplift associated with near and far earthquakes or slow slip events—both of which have recurred periodically. Over the medium term (>30– 100 yrs) these can cancel out the predicted subsidence. Over geologic time frames they result in net uplift.

[23] Bell RG, Hannah J, 2012. Sea level variability and trends: Wellington Region - Prepared for Greater Wellington Regional Council. Hamilton. (NIWA Client Report HAM2012- 043).

More recent research, presented at the GSNZ 2023 Conference (Stern et al. 2023) [24], suggests that satellite measurements may be biased towards subsidence. They advise using the tide gauge to test GNSS measurements. I agree.

The SeaRise model, (Naish et al 2022, submitted)[25] has not yet passed peer review but has been embraced by the Ministry of the Environment and is being adopted by coastal City and District Councils for town planning purposes. But with question marks around the model's accuracy for Auckland and now, Wellington, perhaps it is time to revert to the tried and trusted tide gauges as our best approach to measure medium-term RSL and estimate forward rates.

Meanwhile, I'd be interested to hear from other members who have similar concerns about the seeming inconsistency of the SeaRise VLM rates or projections with established trends in your region.

Acknowledgements

The author is grateful for the assistance and encouragement of Bruce Hayward, Mac Beggs, Andy Nicol, and Willem DeLange who also assisted with the ARIMA model analysis and SeaRise projections in Figure 4.

* Sean Rush (sean@seanrush.co.nz) is a Wellington-based lawyer. He holds a Masters in Climate Change Science and Policy and an LLM in Petroleum Law and Policy. He was an Expert Reviewer for the IPCC's Sixth Assessment Report—the Physical Sciences and appeared as an expert witness for a coastal ratepayer's group in a Kapiti Coast District Council coastal planning hearing. From 2019 to 2022 he was a Wellington City Councillor.

[24] Stern T, Lamb S, Denys P 2023. Forecasting relative sea level change within an active plate-boundary zone: New Zealand tide gauge and GNSS time series. In: Frontin-Rollet GE, Nodder SD ed. Geosciences '23. Wellington, New Zealand, Geoscience Society of New Zealand. Pp. 232.
[25] Naish T, et al. Submitted. The significance of vertical land movements at a convergent plate boundary for probabilistic sea-level projections for AR6 scenarios: The New Zealand case. Submitted to Earth's Future. Working paper available at https://www.searise.nz/publications and https://www.essoar.org/doi/abs/10.1002/essoar.10511878.1