ELF14201

4 September 2013

Tasman District Council
189 Queen Street
Richmond
Nelson 7050

Attention: Maxine Day

Dear Maxine

Mean High Water Spring (MHWS) levels including sea-level rise scenarios: Envirolink Small Advice Grant (1289-TSDC95)

Introduction

This letter report responds to your request to provide consistent Mean High Water Spring (MHWS) levels for the Tasman and Golden Bay coastlines within the jurisdiction of Tasman District Council (TDC). MHWS levels are provided for 13 locations referenced to the local vertical datum, along with a brief description of the methods used and the limitations of the results.

Ongoing sea-level rise will require updates of MHWS levels or for projecting MHWS levels into the future, whereby the appropriate sea-level rise is simply added to the 'present day' MHWS levels. A worked example is shown for sea-level rise magnitudes of 0.7 m and 1.0 m, which extend the equivalent tie-point values for the 2090s (0.5 m and 0.8 m) in the Ministry for the Environment (2008) guidance out to 2115 to cover at least a 100-year period.

Background

Mean High Water Spring (MHWS) is an important planning demarcation between the coastal marine area (CMA) and land. Specifically, it is used as the baseline for establishing esplanade reserves and strips and measuring set-back distance for locating dwellings, establishes the activity status of a range of resource-management activities (i.e., those within the CMA and those outside it) and is used as a baseline for measuring coastal erosion and calculating risks of inundation.

Providing a defensible and consistent "baseline" MHWS level at locations around Tasman and Golden Bays will deliver more certainty for TDC in developing planning maps and assessing changes in sea levels over time. Sea-level rise will gradually raise the MHWS level and therefore its landward extent, which will impact how future coastal activities are managed and planned for. It is important that TDC is using a reliable and consistent definition of MHWS that is also applicable and readily able to be revised for various sea-level rise scenarios.

National Institute of Water & Atmospheric Research Ltd, Gate 10, Silverdale Road, Hillcrest, Hamilton 3216
PO Box 11-115, Hillcrest, Hamilton 3251, New Zealand. Phone +64-7-856-7026, Fax +64-7-856-0151

Defining MHWS

A number of meteorological and astronomical phenomena control sea level:

- Astronomical tides.
- Monthly variability in sea level (MMSL) from climate cycles (seasonal, El Niño etc.).
- Mean Sea Level (MSL) which is an average of the MMSL over periods of a year or ideally longer.
- Storm surge (low-pressure systems) and set-down (anticyclones).
- Wave setup (and run-up) during storms.
- Climate-change effects including sea-level rise.

What is initially required is a MHWS level that provides a reasonable representation of the 'calm water' vertical elevation of the CMA boundary line relative to a fixed vertical datum, in this case Nelson Vertical Datum–1955 (NVD-55).

Both storm surge/set-down and monthly variability in sea level tend to be normally distributed above and below MSL with no net effect on MHWS. Besides tides and changes in MSL, the only other process that can contribute a net effect on upper-tide range levels is a persistent "background" wave climate that produces a regular wave setup at the coast. Inclusion of this additional component to MHWS will need to wait until the coastal inundation Medium Advice Grant project is completed.

Consequently, MSL and astronomical tides are the only components that will be used to define present-day MHWS levels, along with various sea-level rise offsets that could be selected from to represent MHWS levels under future climate change. These sea level components and the methods used to define them are detailed below.

Mean Sea Level (MSL)

The monthly mean sea level (MMSL) describes the variation of the non-tidal sea level over time periods ranging from months up to decades and is the result of climate variability, including the effects on sea level, winds and sea temperatures from:

- persistent patterns of storminess or fair weather conditions
- seasonal warming/cooling effects
- 2–4 year El Niño–Southern Oscillation (ENSO) cycles
- 20–30 year Inter-decadal Pacific Oscillation (IPO) cycles.

MSL is calculated by averaging MMSL over a fixed period in time, usually several years and is typically expressed relative to a fixed datum. Due to sea-level rise, MSL, when calculated over a sufficient period, is generally increasing with time e.g., the New Zealand average rise is 1.7 cm per decade (Hannah & Bell, 2012).[1]

Port Nelson Ltd. operates a sea-level gauge in the southern region of Tasman Bay (refer Appendix A – Figure 1). A digital gauge has been operating since 1984 and is surveyed relative to Chart Datum, whereas NVD-55 is 2.24 m above Chart Datum (Appendix A – Figure 2). Based on the sea level measurements from this gauge Land Information New Zealand (LINZ) have set the MSL from 1996-2012 to 2.32 m above Chart Datum (LINZ, 2013)[2], which is 0.08 m above NVD-55 (Figure 2).

[1] Hannah, J., Bell, R.G. (2012) Regional sea level trends in New Zealand. *Journal of Geophysical Research–Oceans,* 117, C01004: doi:10.1029/2011JC007591 http://www.agu.org/pubs/crossref/2012/2011JC007591.shtml

[2] LINZ (2013) New Zealand nautical almanac 2013/14 edition, NZ 204. Published annually by Land Information NZ. Recent MSL values also available at: http://www.linz.govt.nz/hydro/tidal-info/tide-tables/tidal-levels

National Institute of Water & Atmospheric Research Ltd, Gate 10, Silverdale Road, Hillcrest, Hamilton 3216
PO Box 11115, Hillcrest, Hamilton 3251, New Zealand. Phone +64-7-856-7026, Fax +64-7-856-0151

MSL can vary along a coastline due to the interactions between the bathymetry and the processes that control sea level, particularly the tides, oceanographic currents and prevailing winds. Monthly MSL (MMSL) values were calculated relative to NVD-55 for both the Little Kaiteriteri and Tarakohe gauges using gauge-zero offsets supplied by TDC (Martin Doyle, pers com.). These MMSL time series were then compared to the Nelson gauge data relative to NVD-55 for the overlapping period (2006–2011) as shown in Figure 3 (Appendix A).

Amplitude and timing of variability in MMSL showed good agreement across all three gauges however a vertical offset between the gauges is present. Tarakohe MSL over the 2006–2011 period is above (+3.9 cm) and Little Kaiteriteri was significantly below (-16.3 cm) the Nelson gauge MSL relative to NVD-55. Given the lower accuracy of the Little Kaiteriteri Trig A datum (±0.2 m), the resulting survey confidence for the Little Kaiteriteri gauge levelling of ± 0.2 m means its MSL estimate has to be discounted at this stage. With only a minor difference in MSL between Tarakohe and Nelson and taking into account the Little Kaiteriteri Trig A survey accuracy, it is more appropriate to use the longer (1996–2012) MSL value of +0.08 m NVD-55 at Port Nelson to define the MSL over the entire TDC coastline (excluding the west coast section). MSL tends to be similar over wider areas of oceanographically similar regions, which we assume will also apply in Tasman and Golden Bays.

Astronomical tide height

Astronomical tides are caused by the gravitational attraction of solar-system bodies, primarily the Sun and the Earth's moon. Tidal forces acting on deep oceans cause forced long waves that then propagate into the shelf areas and amplify. The Collingwood area has the distinction of having the highest tide range in New Zealand, with ranges exceeding 4 m. arising from standing long wave generated to the west of Cook Strait. In New Zealand the astronomical tides have the largest influence on sea level, even considering storm-surge.

There are a variety of quantitative and qualitative definitions of what constitutes the astronomical tide component of MHWS, depending on its intended usage. NIWA has developed an approach (e.g., Bell, 2010; Stephens et al. 2012)[3] that involves the combination of: i) an algorithm, using high-tide predictions covering a 100-year period to include all possible tidal combinations (excluding sea-level rise and weather-related components); and, ii) a degree of judgement in selecting an appropriate percentile of all the high tides that would exceed a MHWS level. This technique was applied to the Tasman and Golden Bays as described below.

Thirteen (13) locations, shown in Figure 1, were selected from Google Earth imagery to cover settlements or towns at a reasonably consistent spacing around the coastline, which enables MHWS levels to be easily interpolated for sites in between.

Tide heights were predicted at each of the 13 locations using NIWA's EEZ tide forecaster model (Walters, 2001)[4] using 13 tidal constituents, which make up most of the tide observed around New Zealand. To correct for any bias (offset) in the tide model within the Tasman Bay Region, a comparison was made between the phase (timing) and amplitude (=half tidal range) of the tidal constituents from the model with those extracted from the measured sea level at Little Kaiteriteri and Tarakohe. Additional shorter records from previous deployments by NIWA were also used, with a short 70-day record from December 2001–to February 2002

[3] Bell, R.G. (2010) Tidal exceedances, storm tides and the effect of sea-level rise. Presentation to 17th Congress of the Asia and Pacific Division of the IAHR, Auckland, 21-24 February 2010: 10.
Stephens, S., Wadhwa, S. (2012) Development of an updated Coastal Marine Area boundary for the Auckland Region. *NIWA Client Report* HAM2012-111, prepared for Auckland Council.

[4] Walters, R.A., Goring, D.G., Bell, R.G. (2001) Ocean tides around New Zealand. *New Zealand Journal of Marine and Freshwater Research*, 35: 567–579. Same model used to drive the Tide Forecaster: http://www.niwa.co.nz/services/online-services/tide-forecaster

National Institute of Water & Atmospheric Research Ltd, Gate 10, Silverdale Road, Hillcrest, Hamilton 3216
PO Box 11115, Hillcrest, Hamilton 3251, New Zealand. Phone +64-7-856-7026, Fax +64-7-856-0151

off Collingwood and a mid-Golden Bay deployment from December 2001 to August 2002. A comparison of the three most dominant twice-daily tidal constituents (M_2, N_2 and S_2) showed good agreement in both phase and amplitude. To ensure the most accurate tidal predictions the small bias in the phases of the three constituents was applied to all 13 output locations.

Using the 13 bias-corrected tidal constituents, a time series of tide levels spanning 100 years was calculated and the height of each high-tide peak relative to a zero MSL extracted. All the high-tide values for each site were then sorted in descending order of height and a frequency of occurrence calculated before producing a high-tide exceedance curve. A 6% exceedance level (the level equalled or exceeded by the highest 6% of all predicted high tides) or MHWS-6 has been selected to represent the MHWS mark in Tasman Bay. Example high-tide exceedance plots are shown in Figure 4 for Collingwood (site 11) and Port Nelson, with the latter also showing the MHWS-C marker, for Port Nelson, of 4.26 m above Chart Datum or 2.02 m NVD-55 calculated by LINZ over a 19-year prediction period for cadastral and engineering applications (Figure 2).[5] The MHWS-6 was chosen for three reasons, firstly, it matches closely with, and is consistent with the MHWS-C level produced by LINZ for the Standard Port of Nelson, secondly the exceedance approach provides a regionally-consistent and transparent estimate of the MHWS vertical level that takes into account regional changes in individual tidal harmonic constituents, and thirdly it covers most (94%) of all high tides (excluding weather effects).

A 10% exceedance MHWS-10 has been used elsewhere in New Zealand (e.g., in Auckland Stephens, et al. 2012), but in the Tasman District, the higher tide range and combination of the tidal constituents mean a MHWS-6 level is a more applicable MHWS marker that also matches more closely with the LINZ MHWS-C marker at Port Nelson. However, the MHWS-C marker is not easily amenable to spatial extrapolation away from a Standard Port, hence the versatility of the MHWS-6 approach.

It should be noted that some very high perigean-spring tides (e.g., "king tides") can still significantly exceed the MHWS-6 level. For example, the Highest Astronomical Tide (HAT) at Jackett Island (site 3) and Collingwood (site 11) is about 0.32 m above the MHWS-6 level locally (see also Figure 4). This is expected, as most definitions of a MHWS level for the demarcation of the CMA seldom use the Highest Astronomical Tide.

Overall, the MHWS-6 level provides a regionally-consistent approach to defining MHWS, with a transparent 6% of all predicted high tides exceeding this level.

Climate Change

Climate change is causing the MSL to gradually rise, which means MHWS will rise accordingly. Over the last century, sea level around New Zealand has risen at an average long-term rate of ~1.7 cm/decade based on long term sea level measurements around New Zealand. Projections are for sea levels to reach 0.5 to 1.0 m or more by 2100 (relative to a 1980–99 MSL) and will continue to rise for several centuries due to a lagged ocean response to climate-change.[6]

Ongoing sea-level rise will require updates of MHWS levels or for projecting MHWS levels into the future for coastal-hazard planning purposes under the NZ Coastal Policy Statement (e.g., out to at least 100 years including climate-change effects). Until future research shows otherwise, the appropriate mean sea-level rise can simply be added to the 'present day' MHWS levels.

5 http://www.linz.govt.nz/geodetic/datums-projections-heights/vertical-datums/tidal-level-information-for-surveyors

6 Royal Society of NZ (2010). Sea level rise – Emerging issues. September 2010, 4p.

National Institute of Water & Atmospheric Research Ltd, Gate 10, Silverdale Road, Hillcrest, Hamilton 3216
PO Box 11115, Hillcrest, Hamilton 3251, New Zealand. Phone +64-7-856-7026, Fax +64-7-856-0151

As for credible sea-level rise values to use, the Ministry for the Environment–MfE (2008) guidance[7] provides a risk-based approach for assessing future coastal hazards, recommending the consequences for an activity or project should be assessed for a range of higher sea-level rises. In particular the guidance states:

> *For planning and decision timeframes out to the 2090s (2090–2099):*
>
> 1) *a base value sea-level rise of 0.5 m relative to the 1980–1999 average should be used, along with*
> 2) *an assessment of the potential consequences from a range of possible higher sea-level rises (particularly where impacts are likely to have high consequence or where additional future adaptation options are limited). At the very least, all assessments should consider the consequences of a mean sea-level rise of at least 0.8 m relative to the 1980–1999 average. Guidance on potential sea-level rise uncertainties and values at the time (2008) is provided within the Guidance Manual to aid this assessment.*
>
> *For planning and decision timeframes beyond the 2090s 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 (in addition to the above recommendation)".*

Since the MfE guidance was published in 2008, the NZ Coastal Policy Statement has been updated, requiring identification of areas in the coastal environment that are potentially affected by coastal hazards over at least 100 years, taking into account the effects of climate change (Policy 24). The two values of sea-level rise to be considered as a minimum number of rises for assessing risk of 0.5 m and 0.8 m by the 2090s in the 2008 MfE guidance are equivalent to rises of 0.7 m and 1.0 m extended out to 2115, which is "at least 100 years" from the present.[8]

Different allowances for sea-level rise should be considered, depending on both the consequences (= risk) of sea-level rise and other effects of climate change on particular development or infrastructure and the ease (or otherwise) for implementing future adaptation measures once the adopted sea-level rise is exceeded. This approach was suggested in an Envirolink report to Nelson City Council by NIWA[9] in 2009 recommending different sea-level rise values to accommodate for different levels of consequences (low, medium and high). However, this report pre-dates the 2010 NZ Coastal Policy Statement, which now stipulates a longer timeframe of "at least 100 years" to use for risk assessments.

A worked example is shown in Table 1 (Appendix B) for a sea-level rise magnitude of 0.7 m and 1.0 m, which extend the equivalent tie-points for the 2090s (0.5 m and 0.8 m) in the Ministry for the Environment (2008) guidance out to 2115 to cover at least a 100-year period.

In addition to defining 'present day' MHWS levels, it is also instructive to add a sea-level rise (SLR) component for different sea-level rise scenarios to demonstrate the potential effects of climate change and the associated landward progression of the CMA boundary with time (leaving aside any coastal defences that may impede that).

---

[7] Ministry for the Environment (2008). Coastal Hazards and Climate Change: A Guidance Manual for Local Government in New Zealand. http://www.mfe.govt.nz/publications/climate/coastal-hazards-climate-change-guidance-manual

[8] Britton, R., Dahm, J., Rouse, H., Bell, R., Blackett, P. (2011) Coastal adaptation to climate change: Pathways to change. Externally peer-reviewed report prepared as part of the Coastal adaptation to climate change, NIWA publication: 106 – see Section 2 http://www.niwa.co.nz/sites/default/files/pathways_to_change_nov2011.pdf

[9] Stephens, S.A., Bell, R.G. (2009) Review of Nelson City minimum ground level requirements in relation to coastal inundation and sea-level rise. *NIWA Client Report* HAM2009–124, prepared for Nelson City Council and the Envirolink Fund (FRST – now MBIE). http://www.envirolink.govt.nz/Envirolink-reports/

National Institute of Water & Atmospheric Research Ltd, Gate 10, Silverdale Road, Hillcrest, Hamilton 3216
PO Box 11115, Hillcrest, Hamilton 3251, New Zealand. Phone +64-7-856-7026, Fax +64-7-856-0151

MHWS levels

Present-day MHWS-6 levels vary by 0.1 m across the 13 sites within Tasman and Golden Bays due to variations in the tidal amplitudes of the main tidal constituents. Table 1 (Appendix B) contains these elevations referenced to NVD-55 and includes worked examples for two sea-level rise scenarios. Any other appropriate sea-level rise can be easily added to the present-day MHWS-6 levels in Column 6 of Table 1 (Appendix B).

<u>It is recommended</u> that the defined MHWS-6 levels are ground-truthed with field surveys at two or three locations having differing morphology and exposure, before they are put into practice or incorporated officially in any planning documents. These field surveys, following a higher spring tide, would establish where on the upper-beach profile the MHWS-6 line sits in relation to other natural indicators of the upper tide zone such as debris drift lines, the previous high-tide wet line, shape of the back-beach and the edge of vegetation.

The landward horizontal extent of the MHWS-6 vertical levels (developed under this Small Advice Grant) is left to TDC to map in GIS, intersecting the MHWS levels horizontally with LiDAR or other topographic elevations to the same datum (NVD-55).

Usage and limitations of the MHWS-6 levels

The MHWS-6 levels provided in this letter report have certain limitations that should be understood before applying them to the Tasman and Golden Bay coastal margins. These limitations and some advice on the application of these levels are summarised below:

- The method of using a percentage exceedance value (in this case 6%) is designed to provide a regionally consistent approach to defining MHWS for the purpose of broad-scale planning and measuring changes in sea level over time. A transparent 6% exceedance frequency shows good agreement with observed water levels at the three regional tide-gauge sites and the MHWS-C level calculated by LINZ for the Port of Nelson. As discussed above, the MHWS-6 levels should first be ground-truthed to ensure it generally ties into the beach geomorphology of the region and the regular wave exposure.

- The line of MHWS-6 provides a more accurate land/CMA boundary for mapping and general planning purposes than that currently shown in Council's TRMP maps. For specific development projects adjacent to the coast, the definition of an appropriate local MHWS line, besides using MHWS-6 as an initial starting position, also needs to consider other relevant factors, including beach elevation, natural shoreline indicators and an assessment of, and provision for, the effects of local coastal dynamics.

- Under different sea-level rise scenarios, similar to the worked examples in Appendix B (Table 1) or any other appropriate value that is adopted, simply adding the sea-level rise to the MHWS-6 level assumes that there will be no change in tidal amplitude as the sea level rises. However, with time there may well be relative changes in water depth minus sedimentation or erosion from various coastal processes influenced by climate change.

- The MHWS-6 levels presented are based on 'calm conditions' and do not include any effects of persistent or regular wave processes on the water level at MHWS. Wave setup is one process which increases in mean sea level at the coast inside the surf zone from the release of wave energy as waves break in shallow water. While not including wave setup is a reasonable assumption in a low wave-energy environment such as Tasman and Golden Bays, it is likely that wave setup, could, during average conditions, contribute a small component to a 'practical' definition of the MHWS level

National Institute of Water & Atmospheric Research Ltd, Gate 10, Silverdale Road, Hillcrest, Hamilton 3216
PO Box 11115, Hillcrest, Hamilton 3251, New Zealand. Phone +64-7-856-7026, Fax +64-7-856-0151

that is observed around the Tasman Bay and Golden Bay coastline. Note: debris-drift lines on the upper slopes of beaches can be more indicative of wave run-up either for a recent event or a previous larger storm, so care is needed in interpreting debris lines as a surrogate MHWS.

Note: Effects of wave setup on water levels in Tasman Bay will be assessed in an upcoming Medium Advice Grant study for TDC when defining coastal inundation frequency and magnitude levels. If the result of this study shows that average wave set up is a significant component in Tasman Bay, then a wave setup offset could be provided to adjust the MHWS-6 levels.

Acknowledgement

This advice was funded by the Ministry of Science and Innovation (Envirolink Small Advice Grant, Regional Council Advice number 1289-TSDC95).

Disclaimer

NIWA shall not be liable for any loss, damage or cost howsoever caused (whether direct or indirect) incurred by any person through the use of, or reliance on, the data contained in this letter.

Yours sincerely

Nigel Goodhue (signed on his behalf by Dr Bell)
Coastal & Estuarine Processes Group

Reviewed by:

Dr R.G. Bell
Programme Leader: Hazards & Risk

Appendix A: Site map, mean level of the sea graph and tidal exceedance curves.

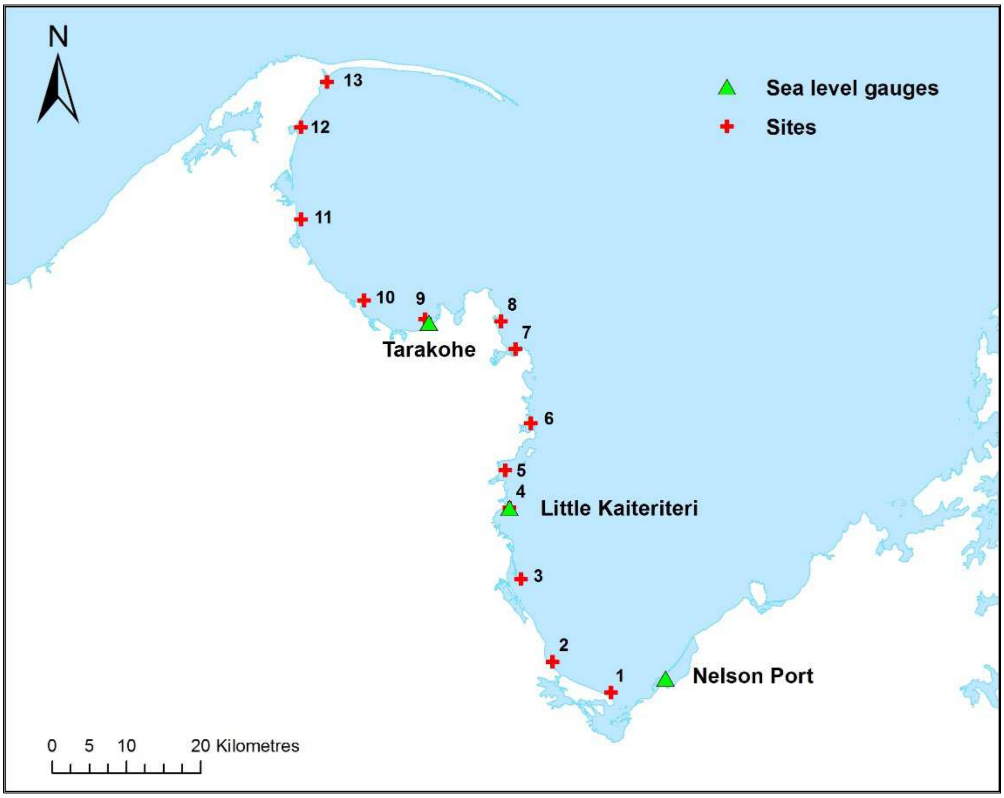


Figure 1. Site map illustrating the Tasman Bay coastline, three sea level gauges used in this study and the 13 sites where MHWS levels have been defined.

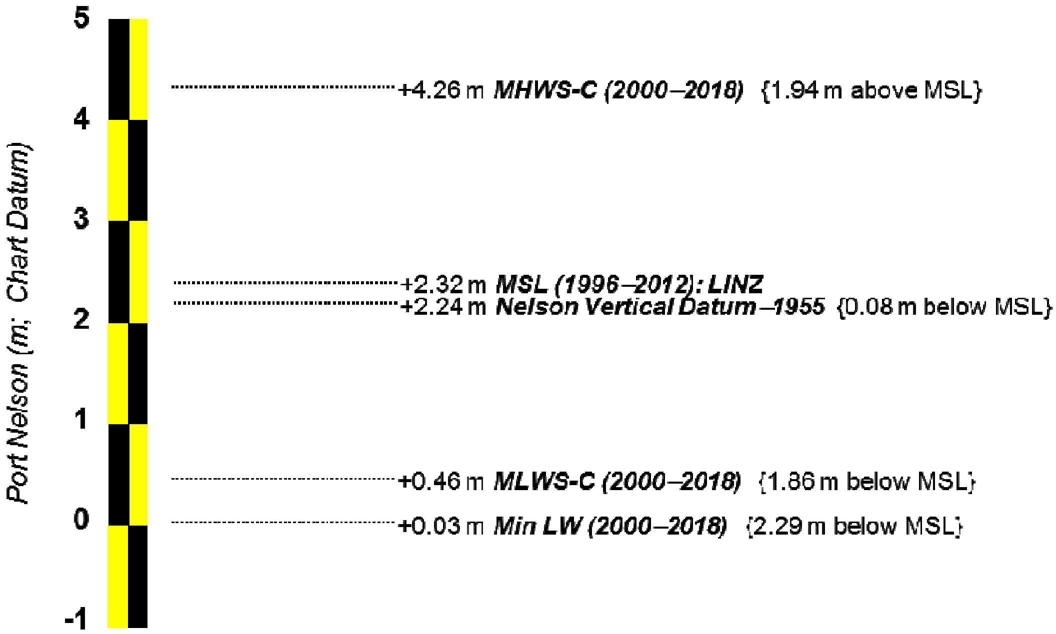


Figure 2. Relativity of Nelson Vertical Datum–1955 to Chart Datum at Port Nelson plus LINZ spring-tide cadastral (MHWS-C, MLWS-C), minimum Low Water (Min LW) and MSL levels.

National Institute of Water & Atmospheric Research Ltd, Gate 10, Silverdale Road, Hillcrest, Hamilton 3216
PO Box 11115, Hillcrest, Hamilton 3251, New Zealand. Phone +64-7-856-7026, Fax +64-7-856-0151

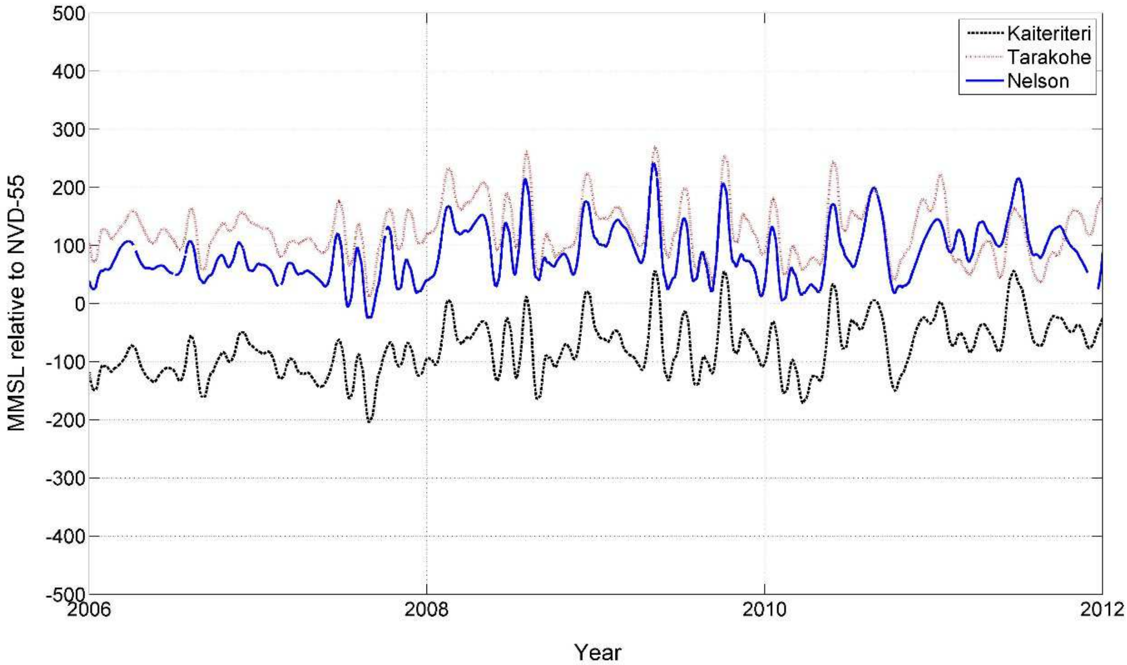


Figure 3. Comparison of Monthly MSL (MMSL) relative to NVD-55 from three sea-level gauges located in Tasman Bay (2006-2011). Refer to Figure 1 for the locations. Gauge zero for Little Kaiteriteri, Tarakohe and Nelson are -2.898, -3.08 and -2.24 metres below NVD-55 respectively. The offsets for Little Kaiteriteri and Tarakohe were supplied by the TDC and for Nelson by LINZ, and have been used to convert the MMSL from gauge zero to NVD-55.

National Institute of Water & Atmospheric Research Ltd, Gate 10, Silverdale Road, Hillcrest, Hamilton 3216
PO Box 11115, Hillcrest, Hamilton 3251, New Zealand. Phone +64-7-856-7026, Fax +64-7-856-0151

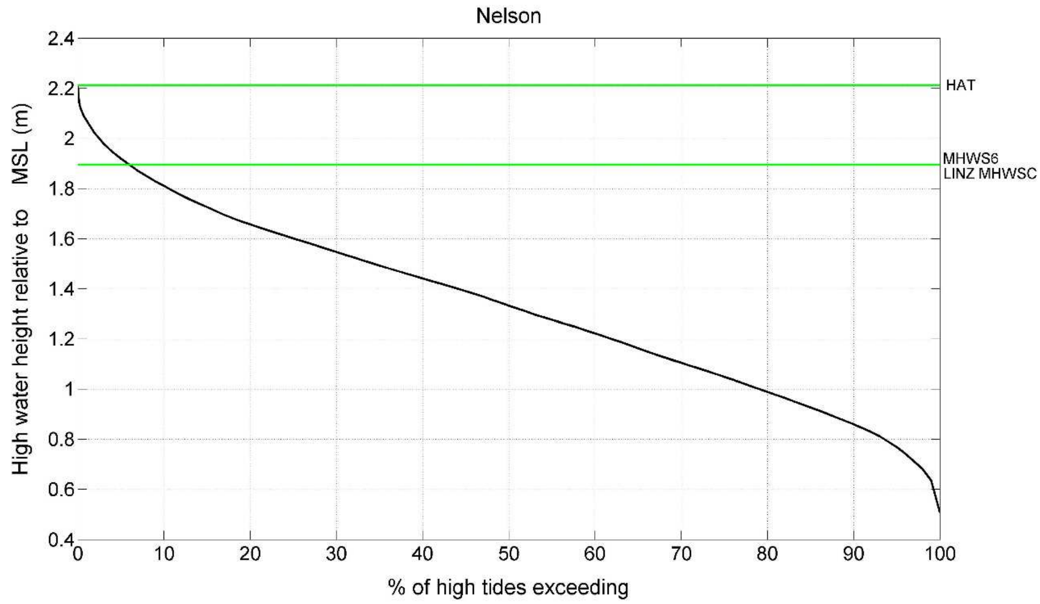


Figure 4a. High-tide exceedance curve for Port Nelson based on next 100-years of predicted high tides relative to MSL (excluding all other sea-level components and sea-level rise). HAT = highest astronomical tide. MHWS6 = level which is exceeded by only 6% of all high tides at Nelson and is the approach used to define MHWS for the Tasman Bay and Golden Bay coastline. LINZ MHWSC = the cadastral MHWS level for Port Nelson as defined by Land Information New Zealand.

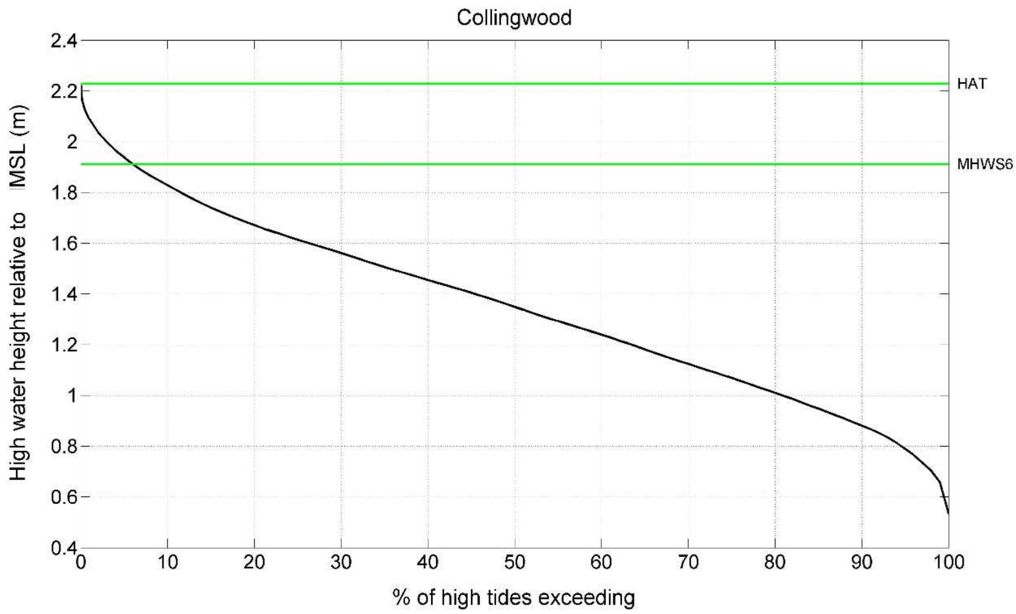


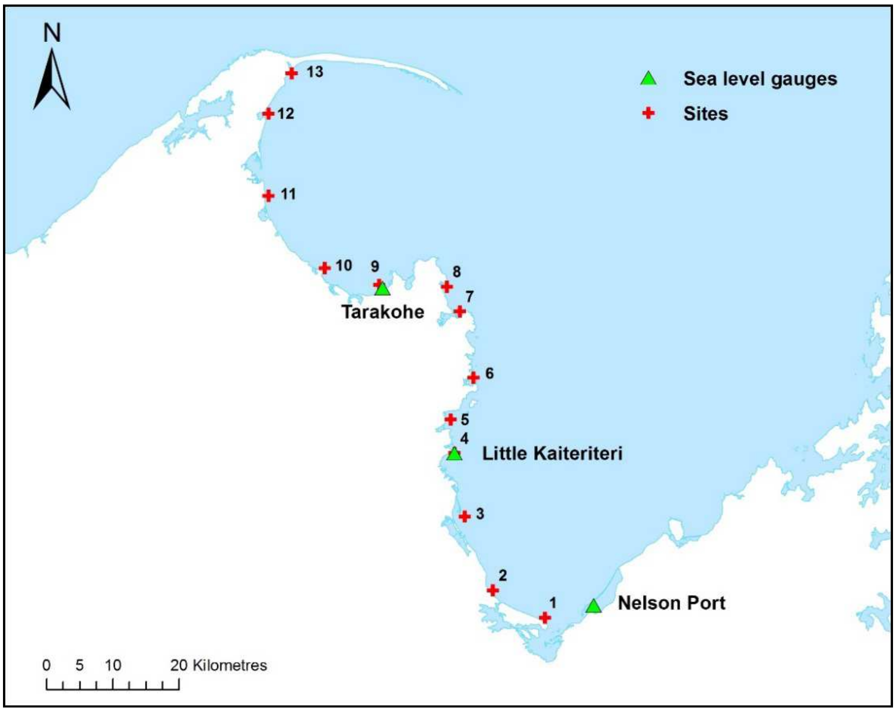
Figure 4b. High-tide exceedance curve for Collingwood based on 100-years of predicted high tides relative to MSL (excluding all other sea-level components and sea-level rise). Refer to the caption of Figure 3 for definition of the various tide levels. *<u>Note</u>: tide prediction based on tidal constituents from a short 70-day record (24 Nov 2001 to 3 Feb 2002)*.

National Institute of Water & Atmospheric Research Ltd, Gate 10, Silverdale Road, Hillcrest, Hamilton 3216
PO Box 11115, Hillcrest, Hamilton 3251, New Zealand. Phone +64-7-856-7026, Fax +64-7-856-0151

Appendix B: Table of Mean High Water Spring (MHWS-6) levels.

Table 1. Mean High Water Spring (MHWS-6) elevations (based on MHWS exceeded by 6% of all high tides), including two worked examples in italics for sea-level rise (SLR) scenarios of 0.7 m and 1.0 m by 2115, all referenced to NVD-55 (blue shading) for 13 sites within Tasman and Golden Bays. Assumes MSL is everywhere the same as at Port Nelson i.e., 0.08 m above NVD-55.

				(Relative to NVD-55)			
Site	**Longitude (°WSG84)**	**Latitude (°WSG84)**	**MHWS-6 (m) (relative to MSL)**	**MSL (m) (1996-2012)**	**MHWS-6 (m)**	***MHWS-6 + 0.7 m SLR (m)***	***MHWS-6 + 1 m SLR (m)***
1	173.190	-41.272	1.90	0.08	1.98	*2.68*	*2.98*
2	173.096	-41.234	1.90	0.08	1.98	*2.68*	*2.98*
3	173.046	-41.134	1.88	0.08	1.96	*2.66*	*2.96*
4	173.027	-41.048	1.87	0.08	1.95	*2.65*	*2.95*
5	173.020	-41.002	1.86	0.08	1.94	*2.64*	*2.94*
6	173.061	-40.946	1.84	0.08	1.92	*2.62*	*2.92*
7	173.037	-40.855	1.83	0.08	1.91	*2.61*	*2.91*
8	173.014	-40.822	1.83	0.08	1.91	*2.61*	*2.91*
9	172.892	-40.819	1.88	0.08	1.96	*2.66*	*2.96*
10	172.795	-40.796	1.90	0.08	1.98	*2.68*	*2.98*
11	172.694	-40.697	1.91	0.08	1.99	*2.69*	*2.99*
12	172.695	-40.586	1.93	0.08	2.01	*2.71*	*3.01*
13	172.736	-40.531	1.93	0.08	2.01	*2.71*	*3.01*



National Institute of Water & Atmospheric Research Ltd, Gate 10, Silverdale Road, Hillcrest, Hamilton 3216
PO Box 11115, Hillcrest, Hamilton 3251, New Zealand. Phone +64-7-856-7026, Fax +64-7-856-0151