National Report of New Zealand

Prepared for
GLOSS Experts 16 Meeting

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1. Introduction

New Zealand does not have a formal, nationally administered, network of sea-level gauges. Instead, sea level gauges are mostly operated independently by various agencies, with some national coordination of daily downloads of data, post processing and archiving undertaken through voluntary partnerships with either Land Information New Zealand (LINZ) or National Institute of Water and Atmospheric Research Ltd (NIWA).

LINZ continues to regularly receive tide gauge data, maintain the national archive of sea level data and act as the primary national contact for the international archives held by the Permanent Service for Mean Sea Level (PSMSL) and the University of Hawaii Sea Level Center (UHSLC). As New Zealand's Hydrographic Authority, LINZ uses this data to produce official tide predictions and other tide-related information to meet its safety of life at sea obligations. LINZ is also responsible for overseeing the operation of the tsunami monitoring network (Section 2.3). LINZ also manages the operation of two gauges in the Ross Dependency, Antarctica, one of which (Scott Base) is a GLOSS Core Network station.

Quality assurance of NIWA sites up to the end of 2017 is almost complete and should be available to PSMSL later in 2019 (including Scott Base).

The following brief report outlines activities in New Zealand associated with sea level gauges, availability of data, some key events and results. The main developments or results since the last report have been:

a) The number of sea-level gauges around New Zealand has been relatively stable during 2018/19, with only a few changes: Waitangi (Chatham Islands) gauge has not been reinstated, the Opononi Wharf gauge in Hokianga Harbour has been re-instated by Northland Regional Council (from 15-Jun-2018), Manu Bay (Raglan) gauge has been re-commenced by Waikato Regional Council but their Raglan Harbour gauge has been out of operation since 25 March 2018.

b) High storm-tide levels and wave overtopping occurred in three closely-spaced summer-of-storms in January to February2018 – with the first two events coinciding with high perigean-spring tides.

c) A low-pressure system of subtropical origin (north Tasman Sea) deepened near New Zealand on 5-6 January 2018, generating strong north to north-east winds in the Upper North Island. Waves from long fetches, combined with storm surge and the highest high tide of the year, led to coastal flooding around the Firth of Thames, the town of Kaiaua and surrounding farms flooded, damage to shoreline structures in Auckland and severe damage to the Thames-Coromandel state highway. The storm-tide level at the Tararu gauge in the Firth of Thames (operated by Waikato Regional Council) reached its highest water level (2.86 m) on 5 January since the gauge was

commissioned in 1990, resulting in a 3.0 m water level at the shoreline (an average recurrence interval of 100 years).

d) Ex TC *Fehi* from 1-3 February 2018 impacted the northern part of the South Island and the West Coast with wave overtopping and coastal flooding. The joint probability of storm surge (0.43 m), wave setup/runup at the coast and a high perigean-spring tide produced a water level in the Nelson/Tasman area with an average recurrence interval of 110-170 years, while on the West Coast the Jackson Bay gauge (operated by Bureau of Meteorology with NIWA) recorded the largest ever recorded storm surge recorded on the open coast of 1.0 m.

e) Ex TC *Gita* impacted the western North Island and northern South Island on 20-22 February. North-westerly gales generated high waves along the Taranaki to Kāpiti coast, leading to overtopping of seawalls and damage to state highways.

f) LINZ has rescued more than 70,000 images of paper tide charts from film and improved their ease of discoverability and access. However, these data remain as TIF images – they have not been digitised.

2. Sea Level Stations

A large number of organisations own and operate sea level stations in New Zealand. These stations can be grouped into four categories:

a) Sites at major ports operated by the local port company or regional council.

b) An open coast network coordinated by NIWA (which includes some regional and local council owned sites).

c) A tsunami monitoring network established by LINZ in partnership with the Crown-owned research organisation GNS Science's GeoNet Project.

d) Other sites.

2.1 Stations at Major Ports

Station	Latitude	Longitude
Marsden Point	35° 50' S	174° 30' E
Auckland	36° 51' S	174° 46' E
Onehunga	36° 56' S	174° 47' E
Tauranga	37° 39' S	176° 11' E
Gisborne	38° 40' S	178° 02' E
Port Taranaki	39° 03' S	174° 02' E
Napier	39° 29' S	176° 55' E
Nelson	41° 16' S	173° 16' E
Wellington	41° 17' S	174° 47' E
Picton	41° 17' S	174° 00' E
Westport	41° 45' S	171° 36' E
Lyttelton	43° 36' S	172° 43' E
Timaru	44° 23' S	171° 15' E
Port Chalmers	45° 49' S	170° 39' E
Dunedin	45° 53' S	170° 30' E
Bluff	46° 36' S	168° 21' E

Table 1
Sea level stations whose data is used to produce daily tide predictions

2.2 Open Coast Network

NIWA coordinates an informal nation-wide network of open-coast sea level gauges in partnership with some port companies (counted above), regional and local councils and, for one installation, the National Tidal Unit, Bureau of Meteorology (Australia). There are 14 gauges coordinated and/or archived by NIWA, (excluding those stations counted above in Section 2.1), five of which are operated by NIWA. This network of stations complements the gauges operated by individual ports (Section 2.1) and other local/regional councils (Section 2.4). Details on sites and the characteristics of the 14 stations in the open-coast network are listed in Table 2.

Station (Agency)	Latitude	Longitude	Start date of NIWA archive	Record interval (min)	Gauge Type
Moturiki Is. [NIWA]	37° 38’ S	176° 12’ E	27-May-1971	1, 5	B+SW
Tararu [WRC]	37° 08’ S	175° 31’ E	1-Nov-1992	5	US
Sumner Head [NIWA, ECan]	43° 34’ S	172° 46’ E	3-Jun-1994	1	B
Jackson Bay* [NTU, NIWA]	43° 58’ S	168° 37’ E	13-Dec-1996	1, 6	SEAFR
Dog Island [NIWA]	46° 39’ S	168° 25’ E	2-Feb-1997	1	B
Whitianga [WRC]	36° 50’ S	175° 43’ E	13-Jul-1999	5	R
Little Kaiteriteri [TDC]	41° 03’ S	173° 02’ E	17-Jun-2000	1	B
Scott Base [Antarctica NZ, LINZ]	77° 51’ S	166° 46’ E	15-Jan-2001	5	B
Poutu Point [NRC]	36° 22’ S	174° 11’ E	21-Apr-2002	5	B
Green Is. [NIWA, ORC]	45° 57’ S	170° 23’ E	4-Dec-2002	1	B
Tarakohe [TDC]	40° 49’ S	172° 54’ E	28-Jan-2005	1	B
Kawhia Harbour [WRC]	38° 04’ S	174° 49’ E	29-Aug-2008	1	B
Manu Bay [WRC]	37° 49’ S	174° 49’ E	16-Mar-2018	5	B
Raglan Wharf** [WRC]	37° 48’ S	174° 53’ E	1-Jul-2008	1	R
Porirua Harbour (Mana) [GWRC]	41° 06’ S	174° 52’ E		1	SW

* Fire damaged gauge in January 2012 – new installation in September 2014

** Fire destroyed gauge in 2011, and re-instated in September 2012 – non-operational since 25 March 2018

Table 2

Sea level gauges in an open-coast network (excluding Standard Port Stations)

Gauge type abbreviations: B = gas bubbler with ParoScientific PS2 pressure sensor; SW = still-well float/counter weight + digital logger; US = ultrasonic in air; SEAFR = SEAFRAME acoustic gauge; R = radar.

Agency abbreviations: WRC [Waikato Regional Council]; ECan [Environment Canterbury]; NTU [National Tidal Unit, Bureau of Meteorology, Australia]; NRC [Northland Regional Council]; TDC [Tasman District Council]; ORC [Otago Regional Council]; GWRC [Greater Wellington Regional Council].

2.3 Tsunami Monitoring Network

LINZ has partnered with GeoNet to improve the system of sea level recorders around New Zealand and its off-shore islands to allow better detection and confirmation of tsunamis.

The data from these sites is transmitted to GeoNet which is responsible for monitoring New Zealand's geophysical hazards (earthquakes, volcanoes, landslides and tsunamis). Real time data from this network is available via the Global Telecommunications System (GTS) and plots of the observed and de-tided data are updated every 5 minutes on the GeoNet web-site http://www.geonet.org.nz/tsunami. Data is also archived and made freely available from the GeoNet and LINZ web-sites.

Station	Latitude	Longitude	Start date
Wellington	41° 17' S	174° 47' E	23-Mar-2007
Napier	39° 29' S	176° 55' E	20-Sept-2007
Owenga (Chatham Island)	44° 02' S	176° 22' W	7-Dec-2007
Gisborne	38° 40' S	178° 02' E	11-Mar-2008
Tauranga	37° 39' S	176° 11' E	6-Jul-2008
Lottin Point	37° 33' S	178° 10' E	10-Oct-2008
North Cape	34° 25' S	173° 03' E	24-Dec-2008
Devonport	36° 50' S	174° 47' E	26-Mar-2009
Boat Cove (Raoul Island)	29° 17' S	177° 54' W	29-May-2009
Fishing Rock (Raoul Island)	29° 55' S	177° 55' W	29-May-2009
Castlepoint	40° 55' S	176° 13' E	7-Oct-2009
Puysegur	46° 05' S	166° 35' E	14-Dec-2009
Port Chalmers	45° 49' S	170° 39' E	25-Feb-2010
Kaikoura	42° 25' S	173° 42' E	27-May-2010
Manukau	37° 03' S	174° 31' E	28-Jul-2010
Korotiti Bay (Great Barrier Is)	36° 11' S	175° 29' E	31-Jul-2010
Sumner	43° 34' S	172° 34' E	11-Aug-2010
Charleston	41° 54' S	171° 26' E	14-Jul-2015

Table 3

Operational sea level stations in the tsunami monitoring network

Dates indicate when the LINZ/GeoNet sites commenced operation.

2.4 Other Sea Level Gauge Sites

In addition to the sites described above, continuous sea level measurements are also taken at sites at minor ports, supplementary gauges at major ports and several estuaries. Most of these stations are owned and operated by either local/regional councils or port companies.

LINZ operates a sea level station in Antarctica at Cape Roberts.

Station	Latitude	Longitude
Rangaunu Harbour (Awanui) [NRC]	35° 00' S	173° 15' E
Whangaroa [NRC]	35° 03' S	173° 45' E
Opua (Bay of Islands) [NRC]	35° 19' S	174° 07' E
Opononi – Hokianga Harbour [NRC]	35° 30' S	173° 23' E
Dargaville [NRC]	35° 56' S	173° 52' E
Hoods Landing (Port Waikato) [WRC]	37° 20' S	174° 45' E

Tauranga Harbour (Omokoroa) [BRC]	37° 40’ S	176° 03' E
Tauranga Harbour (Sulphur Pt.) [POT]	37° 41’ S	176° 10' E
Tauranga Harbour (Oruamatua) [TCC/BRC]	37° 42’ S	176° 13' E
Tauranga Harbour (Hairini Bridge) [TCC/BRC]	37° 43’ S	176° 10' E
Kaituna [BRC]	37° 45’ S	176° 25' E
Rangitaiki [BRC]	37° 55’ S	176° 52' E
Whakatane Town Wharf [BRC]	37° 57’ S	177° 00' E
Ohiwa Harbour (Ohope Wharf) [BRC]	37° 59’ S	177° 06' E
Opotiki Wharf [BRC]	38° 02’ S	177° 14' E
Bridge Street (Christchurch) [CCC]	43° 31’ S	172° 43’ E
Avon/Heathcote (Ferrymead) [CCC]	43° 33’ S	172° 43' E
Milford Sound [Environment Southland]	44° 40’ S	167° 56' E
Spit Wharf (Otago Harbour) [POL]	45° 47’ S	170° 43' E
Cape Roberts (Antarctica) [LINZ]	77° 02’ S	163° 12' E

Table 4

Other sea level gauge sites

Agency abbreviations: CCC [Christchurch City Council]; BRC [Bay of Plenty Regional Council]; NRC [Northland Regional Council]; POT [Port of Tauranga]; POL [Port Otago Ltd.]; TCC [Tauranga City Council]; WRC [Waikato Regional Council].

2.5 GLOSS Stations

Five stations in the GLOSS Core Network are located within New Zealand.

GLOSS stations 101, 127 and 129 appear in Table 1 and station 134 is in Table 2.

GLOSS ID	Station
101	Wellington
127	Auckland
~~128~~	~~Waitangi (Chatham Island) *~~
129	Bluff
134	Scott Base (Antarctica)

Table 5

New Zealand’s GLOSS Core Network stations

* See 5.1(c) for further comment about GLOSS ID 128.

3. Sea Level Measurement Technologies

3.1 Stations at Major Ports

Sea level data at all major ports (Table 1) is recorded digitally.

A variety of sea level measurement technologies are used, including sub-surface pressure transducers, float and stilling well, downward-looking radar and ultrasonic systems.

Data is recorded once every minute at half of the sites with the balance producing data at intervals of either 5 or 10 minutes.

3.2 Open Coast Network

As listed in Table 2, most of the sites operated by NIWA use a bubbler gauge technology (with shrouds over the orifice head to reduce wave effects) with PS2 ParoScientific pressure sensors, while other installations use either radar, acoustic, ultrasonic or float/counter weight systems.

All sites record data in digital form, mostly at 1 minute recording intervals, with the remaining gauges recording at 5 minute intervals.

3.3 Tsunami Monitoring Network

Each of the LINZ/GeoNet tsunami monitoring sites listed in Table 3 incorporates a pair of Druck PTX 1830 pressure sensors. The vented sensors have a range of 0 – 20 metres and output a 4 – 20mA signal. Sea level is measured at a rate of 10Hz and a record is output at 1 minute intervals.

3.4 Other Sea Level Gauge Sites

Details of equipment used at these sites has not been collated, however pressure sensors, ultrasonic, bubbler and float/counter weight technologies would be most likely.

4. Continuous GPS (CGPS)

CGPS observations have been made at the major ports (Wellington, Lyttelton and Dunedin since late 1999 and Auckland since 2009). These stations are operated either by GNS Science or the University of Otago.

Discussions continue amongst interested parties to increase the number of GNSS sites co-located at tides gauges, with an initial aim of six more sites.

5. Data Availability

5.1 Hourly Data for GLOSS Core Network stations:

a) Wellington (101) and Bluff (129):
Fast delivery of data for these GLOSS stations is forwarded to UHSLC each month.

b) Auckland (127):
The port company operating this site refuses to make this data available to the international community free of charge. Auckland Council are in discussions with the port company, but if the stance doesn't change it may be time to remove Auckland from the GLOSS Core Network and include Moturiki (Table 2).

c) Chatham Island (128):
This site stopped recording 15 February 2016 when wharf redevelopment commenced. No organisation has been found to re-instate this station.

d) Scott Base (134):
The entire dataset up to the start of 2007 was quality-assured by PSMSL after receipt of data from NIWA and also submitted to UHSLC. Subsequent data for calendar years 2007 to 2010 have been provided to PSMSL, while quality-assurance of the next batch up to 2018 is being undertaken by NIWA.

5.2 Hourly Data, Monthly and Annual Means

Once each year LINZ provides data for other New Zealand stations to PSMSL and UHSLC. Data supplied since the last GE meeting are summarised in the following table.

NIWA will supply data from the five NIWA-operated stations (Table 2) and Scott Base up to 2015 to PSMSL by July 2019.

Station	Data submitted to PSMSL, UHSLC	
	From	To
Marsden Point	January 2017	December 2017
Tauranga	January 2017	December 2017
Gisborne	January 2017	December 2017
Napier	January 2017	December 2017
Port Taranaki	January 2017	December 2017
Wellington	January 2017	December 2017
Nelson	January 2017	December 2017
Lyttelton	January 2017	December 2017
Timaru	January 2017	December 2017
Dunedin	January 2017	December 2017
Port Chalmers	January 2017	December 2017
Bluff	January 2017	December 2017

Table 6

Stations for which hourly, monthly and annual mean sea level data has been submitted to PSMSL and UHSLC since the GE 15 meeting in 2017

5.3 Open Coast Network

The open-coast network data (Table 2) is uploaded, for most sites, 3 to 6-hourly to the internet in the form of plots from tide, storm surge and long-wave/tsunami analyses. The web site is: http://www.niwa.co.nz/our-services/online-services/sea-levels.

Processed and quality-assured datasets for the NIWA-operated gauges (five active sites and six closed sites) are available by email request to sealevels@niwa.co.nz.

Requests for information or data from this network not covered above can be made to the first author of this report – contact details shown on the first page.

5.4 Tsunami Monitoring Network

Data recorded by the tsunami monitoring sites is available for free download in the form of daily files. Metadata about the sites and the data can be accessed at the following web site: http://www.linz.govt.nz/hydro/tidal-info/gauges/sea-level-data-downloads/index.aspx.

5.5 Other requests

Metadata for Antarctica gauges at Scott Base and Cape Roberts and the data can be accessed at the following web site: http://www.linz.govt.nz/hydro/tidal-info/gauges/sea-level-data-downloads/index.aspx.

Requests for information or data not covered above can be made to the authors of this report – contact details shown on the first page.

6.0 Research applications

Figure 1 shows the updated trajectories of the annual MSL up to 2017–2018 for the four main ports in New Zealand, and the record from the next longest record at Moturiki Island (Mt Maunganui) since 1973. Annual MSL is normalised to the average MSL over the period 1986-2005 (the baseline period used by the Intergovernmental Panel on Climate Change for sea-level rise projections in the 5th Assessment Report). This analysis was undertaken by Emeritus Professor John Hannah (formerly Otago University) and NIWA, with then annual MSL series available up to 2015 as a national statistic with an update pending[1]. The annual mean sea level for 2015 and 2016 is the highest on record for several long-term gauge sites, being 2 – 4 cm above the 1999 – 2000 peak (after the Inter-decadal Pacific Oscillation regime shift) as shown in Figure 1. This is despite the occurrence of an El Niño episode in the last two years, which normally would depress sea level lower than normal. Definitive assessments of recent acceleration in sea-level rise will require several more years of data due to the climate variability.

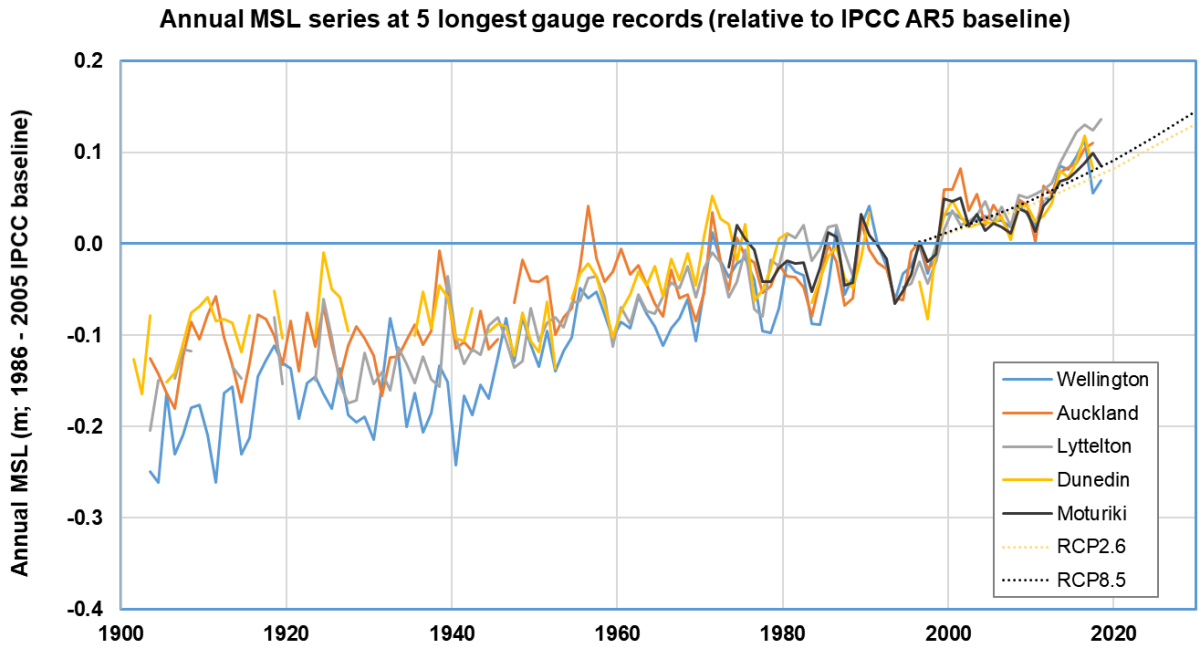

Figure 1

Time series of annual MSL from the five longest gauge records for New Zealand relative to the average MSL over the period 1986-2005, with a low and high emissions median projection for sea-level rise (RCP2.6, RCP8.5).

MSL trends established from 10 sets of tide gauge measurements are presented in Hannah and Bell (2012) [2] and updated to 2015 as a national statistic.[1]

[1] http://archive.stats.govt.nz/browse_for_stats/environment/environmental-reporting-series/environmental-indicators/Home/Marine/coastal-sea-level-rise.aspx

[2] Hannah, J., Bell, R.G. (2012). Regional sea level trends in New Zealand. Journal of Geophysical Research–Oceans 117, C01004: doi:10.1029/2011JC007591

Research at NIWA continues on improving the storm-tide red-alert tide days calendars, which NIWA publishes annually on web site: https://www.niwa.co.nz/our-science/coasts/tools-and-resources/tide-resources. These are dates of higher predicted perigean-spring high tides when small to moderate storms could lead to coastal inundation. There is a similar calendar system used in Kosrae (http://kosraecoast.com/december-to-february-tide-tables/). A recent journal paper provides the basis for these re-alert calendars and the improvement when adding in forecasts of MSL anomalies (Stephens et al., 2014 [3]). A NIWA research project led to operational MSL anomaly forecasts for NZ gauge sites (3 months ahead) into the red-alert calendar system.[4] In tandem with ongoing collaboration with NOAA, Australia's Commonwealth Scientific and Industrial Research Organisation and the University of Hawaii, an operational forecast of MSL anomaly is available for several sites in the Pacific.[5]

[3] Stephens, S.A., Bell, R.G., Ramsay, D, Goodhue, N. (2014). High-water alerts from coinciding high astronomical tide and high Mean Sea Level anomaly in the Pacific Islands region. *Journal of Atmospheric and Oceanic Technology, 31(12)*: 2829–2843. doi: 10.1175/JTECH-D-14-00027.1.

[4] https://www.niwa.co.nz/natural-hazards/physical-hazards-affecting-coastal-margins-and-the-continental-shelf/High-tide-red-alert-calendar

[5] http://uhslc.soest.hawaii.edu/products/slforecasts/

SEA LEVEL SITES IN NEW ZEALAND

Major port sites (Table 1) are shown in **red**
Open coast sites (Table 2) are shown in **green**
Tsunami monitoring sites (Table 3) are shown in **brown**
Other sites (Table 4, except the Tauranga Harbour sites) are shown in **blue**

Names of GLOSS Core Network stations are appended with their GLOSS ID number