National Report of New Zealand

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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) which has recently had a new station added. LINZ also manages the operation of two gauges in the Ross Dependency, Antarctica, one of which (Scott Base) is a GLOSS Core Network station.

NIWA's overall budget for a wide range of environmental monitoring (climate, water, coastal, satellite) from core research funding (Ministry of Business, Innovation and Employment) has been significantly stretched in recent years. This resulted in the closure of a number of gauges, including five NIWA sea-level stations in 2012/13 but no further closures have occurred or are envisaged. Quality assurance of NIWA sites up to the end of 2014 is almost complete and should be available to PSMSL by early 2016.

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) One former NIWA sea level station (Charleston – West Coast, South Island) that was closed in July 2012 has since been re-occupied by GeoNet with the installation of a tsunami sea level station (CHST) in July 2015, plugging a gap in the tsunami gauge network coverage on the West Coast;

b) A contractual arrangement between National Tidal Unit, Bureau of Meteorology (Australia) and NIWA has led to the replacement of the Jackson Bay gauge that was damaged by fire in January 2012. The new gauge became operational in September 2014 with an FTP data-feed to NIWA from the Bureau.

c) The highest storm-tide level in New Zealand for 2014 was at Christchurch (Sumner Head) on 4 March which reached 0.6 m above the local mean high-water perigean-

spring tide level, generated by a deep-low offshore accompanied by gale-force southerly winds and coincided with flooding in Christchurch.[1]

d) The M8.3 earthquake off central Chile at 2254 UTC on September 16, 2015 generated tsunami waves in New Zealand that peaked at an amplitude of 0.1 – 0.3 m on the eastern seaboard and up to 0.5 m in the Chatham Islands (Owenga gauge).

e) The annual mean sea level for 2013 and 2014 is the highest on record for a number of long-term gauge sites, at 1 – 3 cm above the 1999 – 2000 peak (after the Inter-decadal Pacific Oscillation regime shift), despite the El Niño-Southern Oscillation being in a neutral phase (higher than normal MSL occurs during La Niña episodes).

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

1 Natural Hazards 2014, p. 39. Annual summary report by the Natural Hazards Research Platform. http://www.naturalhazards.org.nz/NHRP/Publications/Natural-Hazards-issues .

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 13 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 13 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 [AntarcticaNZ, 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
Raglan Wharf** [WRC]	37° 48' S	174° 53' E	1-Jul-2008	1	R

* Fire damaged gauge in January 2012 – new installation in September 2014
** Fire destroyed gauge in 2011, and re-instated in September 2012

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].

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 establishment of the main network of 17 sea level recorder stations was completed mid – 2010. In 2015, a further station was established at Charleston (West Coast, South Island) to plug a wide gap in coverage of the western coastline, occupying the same site used by NIWA for 15 years (1997 – 2012).

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.

The Pacific Tsunami Warning Center (PTWC) has a tsunami monitoring station at Waitangi on Chatham Island.

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
Waitangi (Chatham Island)	43° 57' S	166° 33' W	

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
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
Mana (Porirua Harbour) [GWRC]	41° 06’ S	174° 52’ 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]; GWRC [Greater Wellington 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, station 128 is included in Table 3 and station 134 is part of 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

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 by GNS Science.

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. It appears that this stance is unlikely to change – it may be time to remove Auckland from the GLOSS Core Network and include Moturiki (Table 2).

c) Chatham Island (128):
Near real-time data is provided through Pacific Tsunami Warning Center.

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 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 has nearly completed QA of the records from the five NIWA-operated stations (Table 2) up to the end of 2012 – which will be supplied to PSMSL early in 2016 when final checks are completed. A set of metadata for these sites has also been complied. QA for the 2013 – 2015 data will commence shortly.

Station	Data submitted to PSMSL, UHSLC	
	From	To
Marsden Point	January 2013	December 2014
Tauranga	January 2013	December 2014
Gisborne	January 2013	December 2014
Napier	January 2013	December 2014
Port Taranaki	January 2013	December 2014
Wellington	January 2013	December 2014
Nelson	January 2013	December 2014
Lyttelton	January 2010	December 2014
Timaru	January 2013	December 2014
Dunedin	January 2013	December 2014
Port Chalmers	January 2013	December 2014
Bluff	January 2013	December 2014

Table 6

Stations for which hourly, monthly and annual mean sea level data has been submitted to PSMSL and UHSLC since the GE 13 meeting in 2013

5.3 Open Coast Network

The open-coast network data (Table 2) is processed nightly and uploaded 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 are listed at: http://gcmd.nasa.gov/KeywordSearch/Home.do?Portal=amd_nz&MetadataType=0 under the Oceans and Tide Gauges sub-sections.

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 for the four main ports in New Zealand, plotted relative to the local vertical datum for the region the gauge is located. These datums were generally established on sea level measurements from the 1920s and early 1930s, hence annual MSL averages around zero for these decades. This analysis was undertaken by Emeritus Professor John Hannah (formerly Otago University) and NIWA. The annual mean sea level for 2013 and 2014 is the highest on record for several long-term gauge sites, being 1 – 3 cm above the 1999 – 2000 peak (after the Inter-decadal Pacific Oscillation regime shift) as shown in Figure 1. This is despite the El Niño-Southern Oscillation (ENSO) being in a neutral phase, with higher than normal MSL usually occurring during La Niña episodes. Definitive assessments of recent acceleration in sea level rise will require several more years of data due to the climate variability.

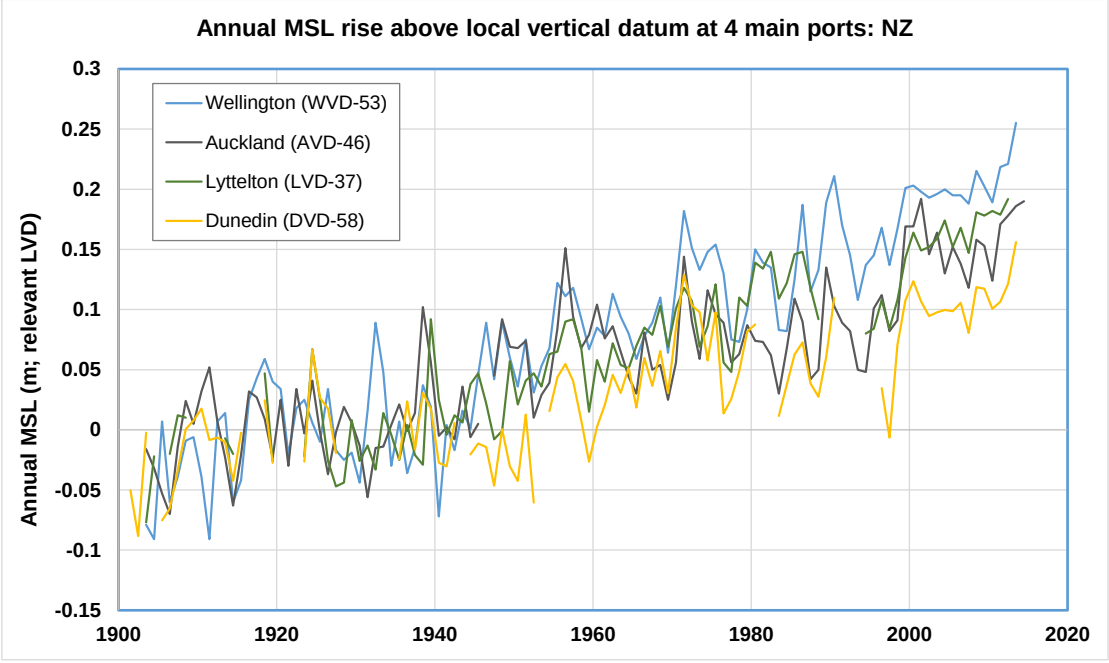

Figure 1

Time series of annual MSL from the four main ports of New Zealand, relative to the relevant local vertical datum (LVD) as shown in the legend

Each LVD was established from tide gauge measurements in the earlier part of last century for years listed in Table 1 of Hannah and Bell (2012) [2].

Research at NIWA continues on improving the 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 is underway to build MSL anomaly forecasts for NZ gauge sites out 1 – 3 months ahead into the red-alert calendar system, in tandem with ongoing collaboration with NOAA, Australia's Commonwealth Scientific and Industrial Research Organisation and the University of Hawaii in developing an operational methodology for forecasting MSL anomaly in the Pacific.

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.

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.

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