Coastal Inundation Tool Guidance

1 Overview

The Coastal Inundation Tool provides users with a tool to quickly understand the susceptibility of coastal areas to coastal inundation due to tides, storms and projected sea level rise at a regional scale. The tool is not intended to provide specific information that could be used to define actual coastal inundation hazards or minimum floor levels for specific properties.

Using the Coastal Inundation Tool consists of two components:
1. Choosing a sea level scenario,
2. Mapping the inundation that might occur.

The user can either choose a predefined sea level scenario, or choose to create their own.

The tool is intended to identify areas where further work should be undertaken, if required, to better quantify the coastal inundation hazard, both currently and in the future. The tool only shows 'static' water levels and does not include the effects of currents, friction, waves or other hydraulic processes that affect water movement or inundation.

The tool shows:
- **Connected inundation** (blue shaded areas), which represent areas where water could directly (or via waterways) flow to the sea for a chosen water level.
- **Disconnected inundation** (green areas), which represent areas that are at or below a chosen water level, but may have no direct flow path to the sea. Disconnected areas may still be affected by coastal inundation in some way, e.g. via groundwater.

The very first mapped sea level for all locations shows the area that is likely to be inundated with a high tide (generally 0.2 m below the MHWS water level). All higher mapped sea levels only show areas that would not normally be inundated by a high tide.

All sea levels and land elevations are provided relative to Moturiki Vertical Datum 1953, both in the Coastal Inundation Tool and also as referred to in the text and tables of this guidance document.

2 How do I use the Coastal Inundation Tool?

The Coastal Inundation Tool allows the user to choose a sea level scenario for a specific location. As sea levels vary around the WRC coastline, sea level values are required that best represent the specific location.

There are two ways to use the Coastal Inundation Tool:

1. Use sea level scenario information and the slider to match the sea level on the map to different pre-defined scenarios (or user-defined scenarios; refer to Section 2.2) (Refer to Figure 1):
    a. Click on the "Sea Level Scenario" icon
    b. Use the search bar in the side panel to search for your area of interest – the map will zoom to the area, and sea level scenario information will be displayed in a table in the side panel. Most coastal locations are searchable using this option, but not all.
    c. If a location is not coming up on the search results, simply click on the point on the map that is closest to your area of interest. This will bring up sea level scenario information that is most relevant to your area of interest, and you can then zoom to that area
    d. You can also search for your property using the address/property search bar
    e. Use the slider to match the sea level on the map to the sea level scenarios in the table
    f. If you move to a new area on the coast, make sure you update the sea level scenario information to match your new location, by using the search bar or clicking on the point.

2. Explore susceptibility to coastal inundation:
    a. Zoom to your area of interest on the map, or search for your property using the address/property search bar
    b. Move the slider up and down to explore susceptibility to coastal inundation at different levels
    c. You can also press the play button below the slider to watch inundation increase with sea level. This also allows all of the mapped water level layers to "load", which speeds up the performance of the tool once they've all cycled through.

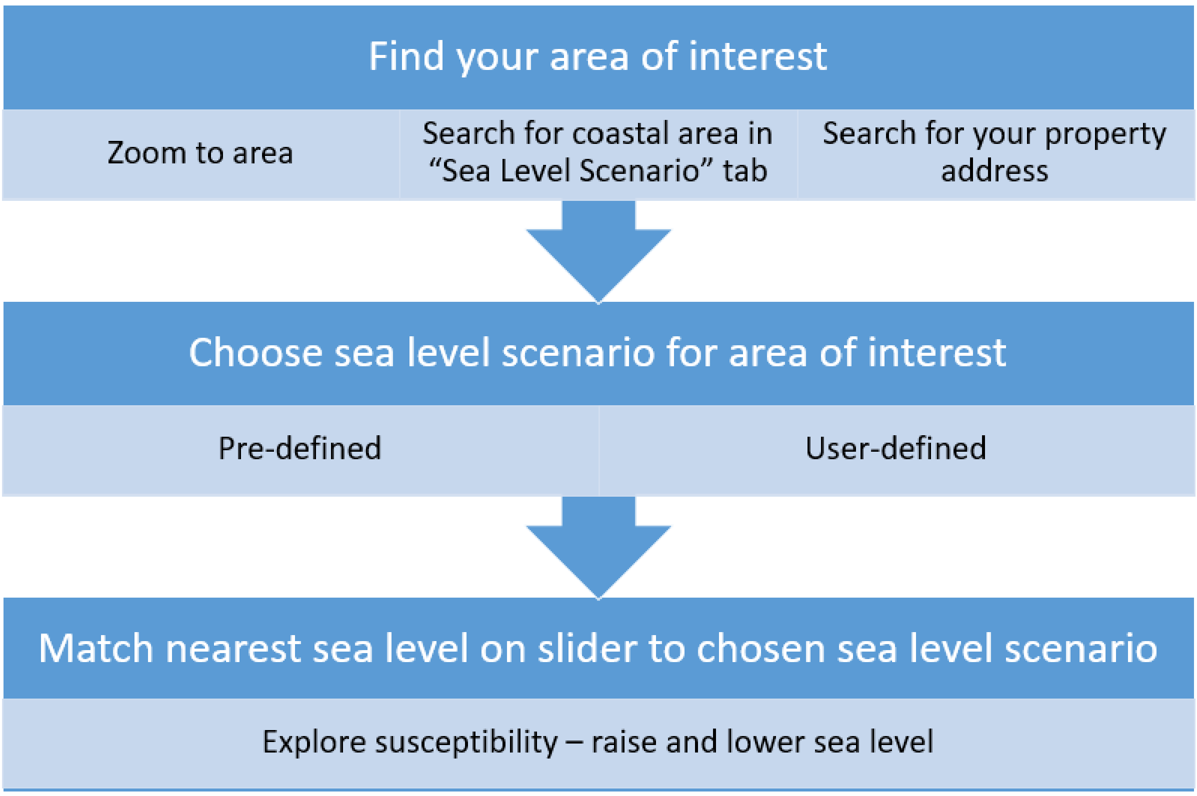


Figure 1 Coastal Inundation Tool process.

2.1 Pre-defined Sea Level Scenarios

The pre-defined sea level scenarios provide the user with a quick reference to commonly used sea levels. The user can also define their own sea level scenarios if required, refer to Section 2.2.

Sea level scenarios for specific areas around the Waikato region's coastline have been provided based on tide levels, storm tides and projected sea level rise.

The sea level scenarios provide sea level estimates for the present day and with future projected sea-level rise. The present day sea levels are valid for the next approximately five years representing:

- Mean High Water Spring Tide (MHWS)
- Maximum High Tide (Max Tide)
- Lower Storm Tide
- Upper Storm Tide

Refer to Section 3 for descriptions on how the values were derived.

Frequency information for the sea levels scenarios is not provided in the tables, as this information is only available for the WRC-managed Whitianga, Tararu and Kawhia tide gauges. Section 5.3 of this User Guide has tables containing sea levels for different storm tide frequencies for each of the tide gauges – this can be used to provide context around how frequently various storm tide sea levels may occur.

The pre-defined sea levels do not include Sea-Level Anomaly. The Future Projected sea levels simply include the addition of 0.5 m and 1.0 m to the Present Day levels. The tool also provides a link (at the bottom of each sea level scenario table) to relevant information from the latest MfE Guidance to provide context around the range of sea level rise that could be expected over the next 100 years.

Sea level scenarios are provided below for specific areas (all values relative to Moturiki Vertical Datum 1953):

Area				Coromandel East Coast					
Location				Whiritoa Beach	Opoutere Beach	Tairua and Pauanui	Hahei Beach	Mercury Bay	Matarangi and Whangapoua
Present Day		**MHWS (m)**		1.07	1.07	1.08	1.08	1.10	1.16
		Max Tide (m)		1.26	1.26	1.27	1.27	1.29	1.37
		Storm Tide Range (Estimate)	**Lower (m)**	1.37	1.37	1.38	1.38	1.40	1.46
			Upper (m)	2.07	2.07	2.08	2.08	2.10	2.18
Future Projected	***0.5 m projected Sea Level Rise***	***MHWS (m)***		*1.57*	*1.57*	*1.58*	*1.58*	*1.60*	*1.66*
		Max Tide (m)		*1.76*	*1.76*	*1.77*	*1.77*	*1.79*	*1.87*
		Storm Tide Range (Estimate)	***Lower (m)***	*1.87*	*1.87*	*1.88*	*1.88*	*1.90*	*1.96*
			Upper (m)	*2.57*	*2.57*	*2.58*	*2.58*	*2.60*	*2.68*
	1.0 m projected Sea Level Rise	***MHWS (m)***		*2.07*	*2.07*	*2.08*	*2.08*	*2.10*	*2.16*
		Max Tide (m)		*2.26*	*2.26*	*2.27*	*2.27*	*2.29*	*2.37*
		Storm Tide Range (Estimate)	***Lower (m)***	*2.37*	*2.37*	*2.38*	*2.38*	*2.40*	*2.46*
			Upper (m)	*3.07*	*3.07*	*3.08*	*3.08*	*3.10*	*3.18*

Area				Coromandel East Coast					
Location				Opito Bay	Whangamata	Onemana Beach	Hot Water Beach	Shakespeare Bay	Whitianga (Wharf)
Present Day		**MHWS (m)**		1.11	1.07	1.07	1.08	1.10	0.98
		Max Tide (m)		1.31	1.26	1.26	1.27	1.30	1.18
		Storm Tide Range (Estimate)	**Lower (m)**	1.41	1.37	1.37	1.38	1.40	1.28
			Upper (m)	2.12	2.07	2.07	2.08	2.11	1.99
Future Projected	***0.5 m projected Sea Level Rise***	***MHWS (m)***		*1.61*	*1.57*	*1.57*	*1.58*	*1.60*	*1.48*
		Max Tide (m)		*1.81*	*1.76*	*1.76*	*1.77*	*1.80*	*1.68*
		Storm Tide Range (Estimate)	***Lower (m)***	*1.91*	*1.87*	*1.87*	*1.88*	*1.90*	*1.78*
			Upper (m)	*2.62*	*2.57*	*2.57*	*2.58*	*2.61*	*2.49*
	1.0 m projected Sea Level Rise	***MHWS (m)***		*2.11*	*2.07*	*2.07*	*2.08*	*2.10*	*1.98*
		Max Tide (m)		*2.31*	*2.26*	*2.26*	*2.27*	*2.30*	*2.18*
		Storm Tide Range (Estimate)	***Lower (m)***	*2.41*	*2.37*	*2.37*	*2.38*	*2.40*	*2.28*
			Upper (m)	*3.12*	*3.07*	*3.07*	*3.08*	*3.11*	*2.99*

Area				Coromandel East Coast				
Location				Otama Beach	Kuaotunu	Kennedy Bay	Port Charles and Sandy Bay	Stony Bay
Present Day		**MHWS (m)**		1.13	1.15	1.17	1.24	1.26
		Max Tide (m)		1.33	1.36	1.38	1.46	1.48
		Storm Tide Range (Estimate)	**Lower (m)**	1.43	1.45	1.47	1.54	1.56
			Upper (m)	2.14	2.17	2.19	2.27	2.29
Future Projected	***0.5 m projected Sea Level Rise***	***MHWS (m)***		*1.63*	*1.65*	*1.67*	*1.74*	*1.76*
		Max Tide (m)		*1.83*	*1.86*	*1.88*	*1.96*	*1.98*
		Storm Tide Range (Estimate)	***Lower (m)***	*1.93*	*1.95*	*1.97*	*2.04*	*2.06*
			Upper (m)	*2.64*	*2.67*	*2.69*	*2.77*	*2.79*
	1.0 m projected Sea Level Rise	***MHWS (m)***		*2.13*	*2.15*	*2.17*	*2.24*	*2.26*
		Max Tide (m)		*2.33*	*2.36*	*2.38*	*2.46*	*2.48*
		Storm Tide Range (Estimate)	***Lower (m)***	*2.43*	*2.45*	*2.47*	*2.54*	*2.56*
			Upper (m)	*3.14*	*3.17*	*3.19*	*3.27*	*3.29*

Area				Coromandel West Coast					
Location				Coromandel Harbour	Amodeo Bay	Port Jackson	Port Jackson Road	Colville Bay	Te Kouma Harbour and Manaia Harbour
Present Day		**MHWS (m)**		1.58	1.53	1.39	1.48	1.51	1.60
		Max Tide (m)		1.86	1.80	1.63	1.72	1.78	1.88
		Storm Tide Range (Estimate)	**Lower (m)**	1.88	1.83	1.69	1.78	1.81	1.90
			Upper (m)	2.67	2.61	2.44	2.53	2.59	2.69
Future Projected	***0.5 m projected Sea Level Rise***	***MHWS (m)***		*2.08*	*2.03*	*1.89*	*1.98*	*2.01*	*2.10*
		Max Tide (m)		*2.36*	*2.30*	*2.13*	*2.22*	*2.28*	*2.38*
		Storm Tide Range (Estimate)	***Lower (m)***	*2.38*	*2.33*	*2.19*	*2.28*	*2.31*	*2.40*
			Upper (m)	*3.17*	*3.11*	*2.94*	*3.03*	*3.09*	*3.19*
	1.0 m projected Sea Level Rise	***MHWS (m)***		*2.58*	*2.53*	*2.39*	*2.48*	*2.51*	*2.60*
		Max Tide (m)		*2.86*	*2.80*	*2.63*	*2.72*	*2.78*	*2.88*
		Storm Tide Range (Estimate)	***Lower (m)***	*2.88*	*2.83*	*2.69*	*2.78*	*2.81*	*2.90*
			Upper (m)	*3.67*	*3.61*	*3.44*	*3.53*	*3.59*	*3.69*

Area				Firth of Thames							
Location				Miranda	Thames (Tararu)	Kaiaua	Wharekawa	Te Puru	Waikawau/Te Mata/Tapu	Kereta	Hauraki Plains
Present Day		**MHWS (m)**		1.80	1.79	1.77	1.73	1.75	1.71	1.66	1.80
		Max Tide (m)		2.12	2.11	2.09	2.04	2.06	2.02	1.95	2.12
		Storm Tide Range (Estimate)	**Lower (m)**	2.21	2.20	2.18	2.14	2.16	2.12	2.07	2.21
			Upper (m)	3.23	3.22	3.20	3.15	3.17	3.13	3.06	3.23
Future Projected	***0.5 m projected Sea Level Rise***	***MHWS (m)***		*2.30*	*2.29*	*2.27*	*2.23*	*2.25*	*2.21*	*2.16*	*2.30*
		Max Tide (m)		*2.62*	*2.61*	*2.59*	*2.54*	*2.56*	*2.52*	*2.45*	*2.62*
		Storm Tide Range (Estimate)	***Lower (m)***	*2.71*	*2.70*	*2.68*	*2.64*	*2.66*	*2.62*	*2.57*	*2.71*
			Upper (m)	*3.73*	*3.72*	*3.70*	*3.65*	*3.67*	*3.63*	*3.56*	*3.73*
	1.0 m projected Sea Level Rise	***MHWS (m)***		*2.80*	*2.79*	*2.77*	*2.73*	*2.75*	*2.71*	*2.66*	*2.80*
		Max Tide (m)		*3.12*	*3.11*	*3.09*	*3.04*	*3.06*	*3.02*	*2.95*	*3.12*
		Storm Tide Range (Estimate)	***Lower (m)***	*3.21*	*3.20*	*3.18*	*3.14*	*3.16*	*3.12*	*3.07*	*3.21*
			Upper (m)	*4.23*	*4.22*	*4.20*	*4.15*	*4.17*	*4.13*	*4.06*	*4.23*

Area				West Coast					
Location				Mokau River	Waikato River	Raglan Harbour	Marakopa River	Kawhia Harbour	Aotea Harbour
Present Day		**MHWS (m)**		1.82	1.69	1.72	1.76	1.74	1.73
		Max Tide (m)		2.17	2.02	2.06	2.10	2.08	2.07
		Storm Tide Range (Estimate)	**Lower (m)**	2.36	2.23	2.26	2.30	2.28	2.27
			Upper (m)	3.23	3.08	3.12	3.16	3.14	3.13
Future Projected	***0.5 m projected Sea Level Rise***	***MHWS (m)***		*2.32*	*2.19*	*2.22*	*2.26*	*2.24*	*2.23*
		Max Tide (m)		*2.67*	*2.52*	*2.56*	*2.60*	*2.58*	*2.57*
		Storm Tide Range (Estimate)	***Lower (m)***	*2.86*	*2.73*	*2.76*	*2.80*	*2.78*	*2.77*
			Upper (m)	*3.73*	*3.58*	*3.62*	*3.66*	*3.64*	*3.63*
	1.0 m projected Sea Level Rise	***MHWS (m)***		*2.82*	*2.69*	*2.72*	*2.76*	*2.74*	*2.73*
		Max Tide (m)		*3.17*	*3.02*	*3.06*	*3.10*	*3.08*	*3.07*
		Storm Tide Range (Estimate)	***Lower (m)***	*3.36*	*3.23*	*3.26*	*3.30*	*3.28*	*3.27*
			Upper (m)	*4.23*	*4.08*	*4.12*	*4.16*	*4.14*	*4.13*

2.2 User Defined Sea Level Scenario

The simplest way of determining a user defined sea level scenario is to use the 'building block' approach. Starting with a base sea level, various components can be added to provide an indicative water level. The basic components or 'blocks' to use are:

- Tide Level -varies along the WRC coastline
- Sea Level Anomaly – varies over time
- Storm surge (added to Tide level) or Storm Tide – varies along the WRC coastline
- Projected Sea Level Rise – constant along the WRC coastline, but there are different Sea Level Rise Scenarios

A combination of the above components will derive a specific sea level scenario.
Here are some water level scenario examples:

Present day tide levels = *Tide Level*

Present day storm-tide sea level *= Tide Level + Storm Surge*
= Storm Tide level

Future tide level with 1.0 m sea level rise *= Tide Level + Projected Sea level Rise (1.0 m)*

Future Storm tide sea level with 1.0 m sea level rise *= Storm Tide level + Projected Sea level Rise (1.0 m).*

If in doubt on what water level scenario to use for a particular application, it is suggested to consult WRC or a coastal expert.

3 Sea level Components

3.1 Tide Levels

Tide levels vary around the Waikato Region's coasts. NIWA has provided tide levels for the Waikato region based on a national tide model, which have been adjusted with local tide gauge readings where available. The tide levels supplied for the Coastal Inundation Tool are:

- Mean High Water Springs (MHWS)
- Maximum Tide (MaxHT).

There are various definitions of MHWS, we have used a level that the highest 10% of all tides exceed, called MHWS10. The maximum tide level is the maximum tide level predicted over a 100 year period (not including projected sea level rise). Refer to Table 7 in Section 5.2 for other tide markers.

All tide levels provided for the Coastal Inundation Tool are for open coast areas. Tide levels and ranges can vary inland up rivers and estuaries/harbours and therefore, the tide levels provided may not be applicable.

All tide levels and ground elevations are relative to Moturiki Vertical Datum 1953. Refer to Section 5.1 for datum offsets.

3.2 Sea Level Anomaly

The sea-level ‘anomaly’ describes the variation of the non-tidal sea level on time scales ranging from month to month, through an annual sea-level cycle, up to decades due to climate variability. The variations in sea level along the coast are due primarily to changes in water temperature and wind patterns.

As water gets warmer it expands and sea levels rise. Persistent winds can also ‘push’ water towards the coast (increasing sea levels) or away from the coast (decreasing sea levels). The sea level variations occur at time periods over a year (seasonal changes), several years (El Niño and La Nina Climate Cycles) and over decades (Pacific Decadal Oscillation).

Therefore, while tide levels can be accurately predicted, the actual sea level at any given location is likely to differ from the predicted tide.

The sea-level anomaly is not provided for in the pre-defined water level scenarios in the coastal inundation tool. The range of sea level anomaly at all tide gauge sites is generally up to +/- 0.2 m (NIWA 2015). To account for the effects of sea-level anomaly on a water level scenario, a sensitivity assessment is suggested by increasing/decreasing the water level by a 0.2 m increment.

Figure 2 below shows the monthly sea-level anomaly for three tide gauges at Whitianga Wharf, Tararu on the Firth of Thames and at Kawhia Wharf.

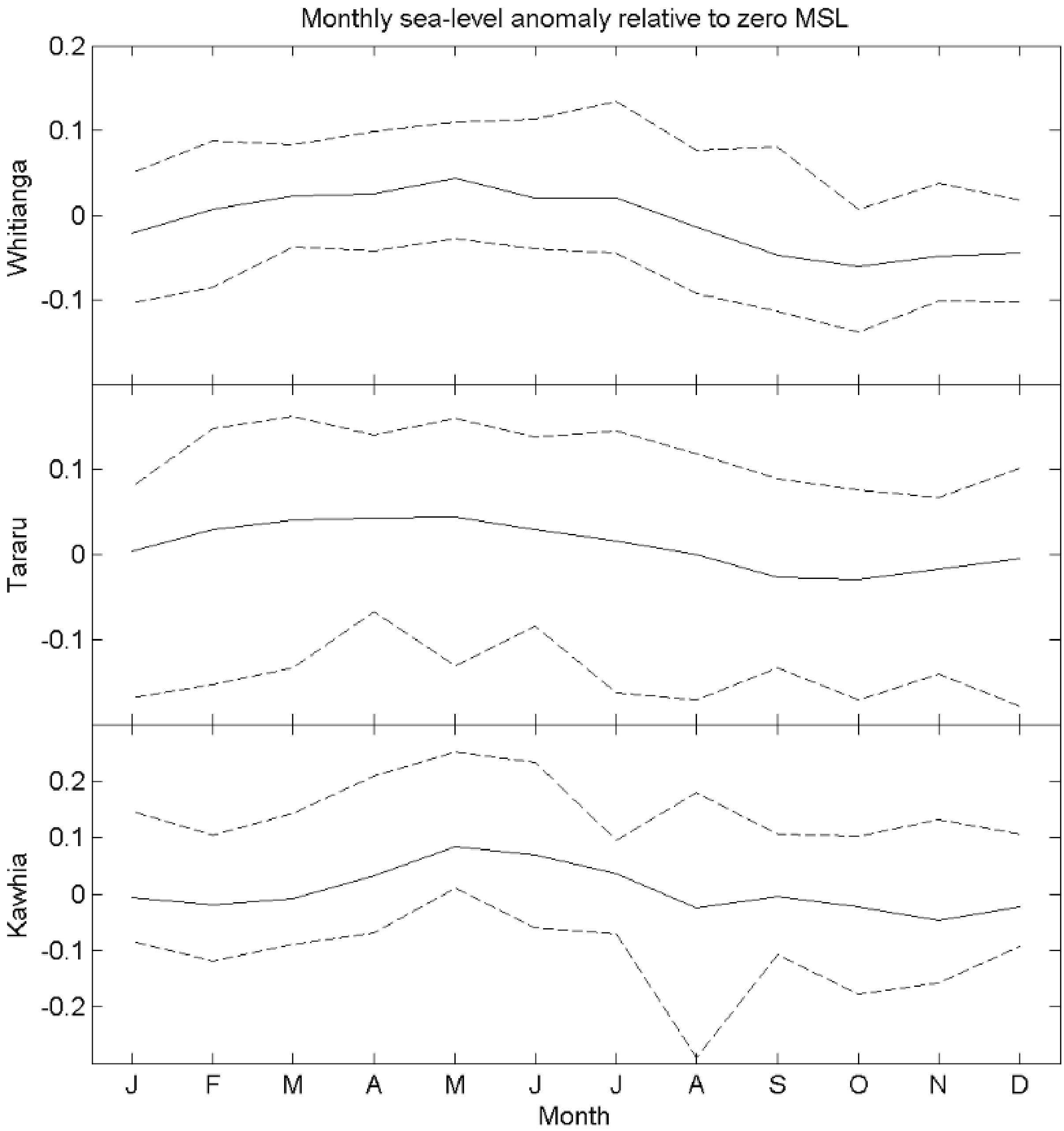


Figure 2 **Monthly Sea level Anomaly for three tides gauges. For each tide gauge the dashed top and bottom lines are the maximum and minimum values respectively. The solid middle line is the mean value. (Source: NIWA 2015)**

3.3 Storms

Storms affect the sea level along coasts in a number of ways. Figure 3 below shows the components that cause sea levels to increase due to storm effects.

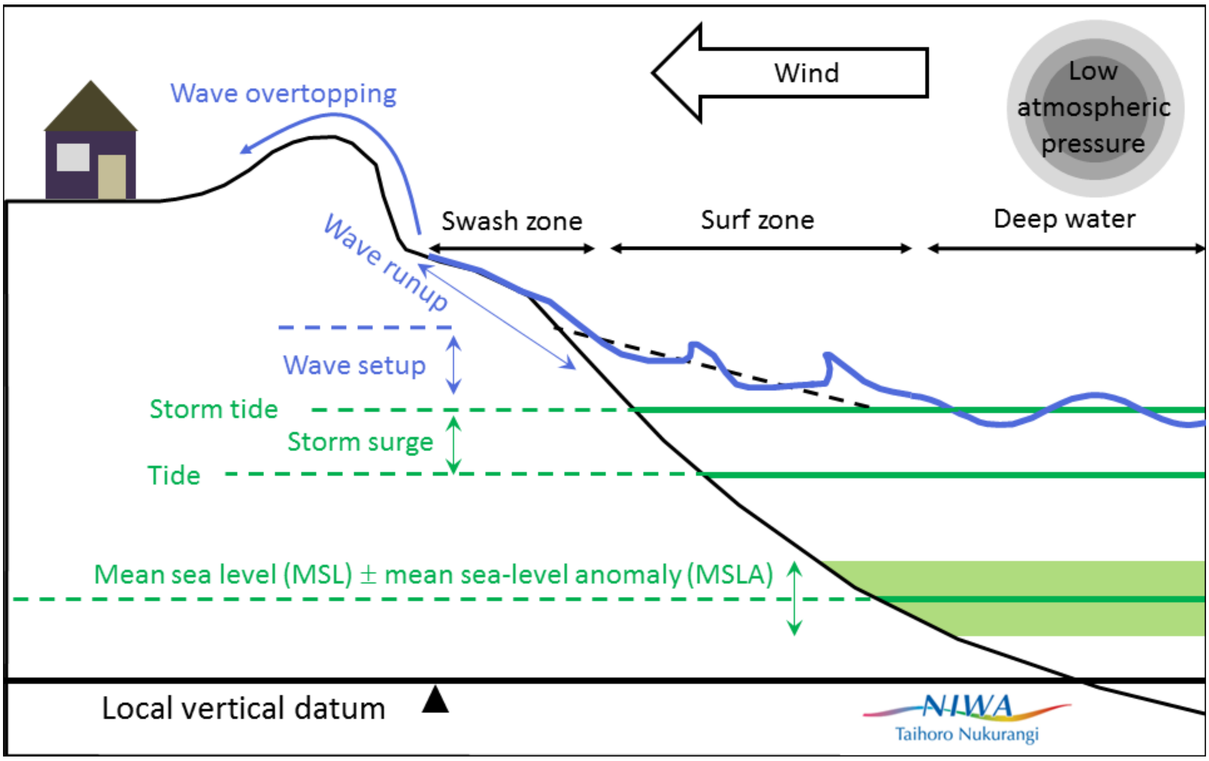


Figure 3 Components causing increased sea levels along the coast during a storm event.

An explanation of the components is provided below:

- Storm Tide includes the following components:
  - Tides –astronomical tides (largest storm tides generally occur during a spring tide)
  - Storm Surge:
    - Inverted Barometer - a decrease in atmospheric pressure causes the water to rise (approximately 1 cm water level for every 1hPa drop in pressure)
    - Onshore winds 'push' water from deep water towards the coastline
- Monthly Mean Sea Level Variation = Sea Level Anomaly
- Wave 'setup' along the surf zone **(no information on wave set up provided for in the Coastal Inundation Tool)**
- Wave 'run up' along the shoreline **(no information on wave run up provided for in the Coastal Inundation Tool)**

The characteristics of storm surge, the tide height, and the resulting storm tide level varies along the Waikato coastline.

For the Coastal Inundation Tool, a lower and upper storm tide level for each location is provided in the pre-defined water level scenarios. The storm tide ranges for each location are indicative only, but are based on storm-tide analysis of sea levels recorded by WRC tide gauges (NIWA 2015, refer to Section 5 of this document for summaries).

For each tide gauge, storm surge levels were calculated from the difference between the tide value and storm tide value. The lower storm surge value is the difference between the MHWS10 tide value and the 39% AEP storm tide value (which represents a "biannual" event. The upper storm surge value is the difference between the maximum high tide value and the maximum storm tide value.

As the largest component of a storm tide is the astronomical tide (refer to Section 6.3), which varies around the Waikato region in a known way, the storm surge component derived from the nearest tide gauge was added to the tide at each location.

The lower storm tide value is the lower storm-surge value added to the MHWS value at each location. The upper storm tide value is the upper storm surge value added to the maximum high tide value at each location.

Table 1 below shows the lower and upper storm-surge components for each tide gauge, which were added to the tide values of the representative areas.

	Tararu Tide Guage	Whitianga (open coast) Model point	Kawhia Harbour Tide Gauge
MHWS (m – MVD-53)	1.79	1.11	1.74
Maximum Tide (m– MVD-53)	2.10	1.32	2.07
39% AEP Storm Tide (m– MVD-53)	2.20	1.41	2.28
Maximum Storm tide (m– MVD-53)	3.21	2.13	3.13
Lower SS component (m)	0.41	0.30	0.54
Upper SS component (m)	1.11	0.81	1.06
Areas SS components used	Firth of Thames	Coromandel East and West Coast	West Coast

Table 1 Lower and upper storm surge components and the areas they are applied to

There is no reliable available information on long term sea levels for the Coromandel West Coast (which we took to extend as far south as Te Kouma and Manaia Harbours). Therefore, the Whitianga tide gauge was used to provide an estimate on storm surge. South of Te Kouma and Mania Harbour is regarded as the Firth of Thames.

Further information on tides and storm tides based on analysis of tide gauges at Whitianga Wharf, Tararu and Kawhia Harbour can be found in Section 5.

3.3.1 Waves

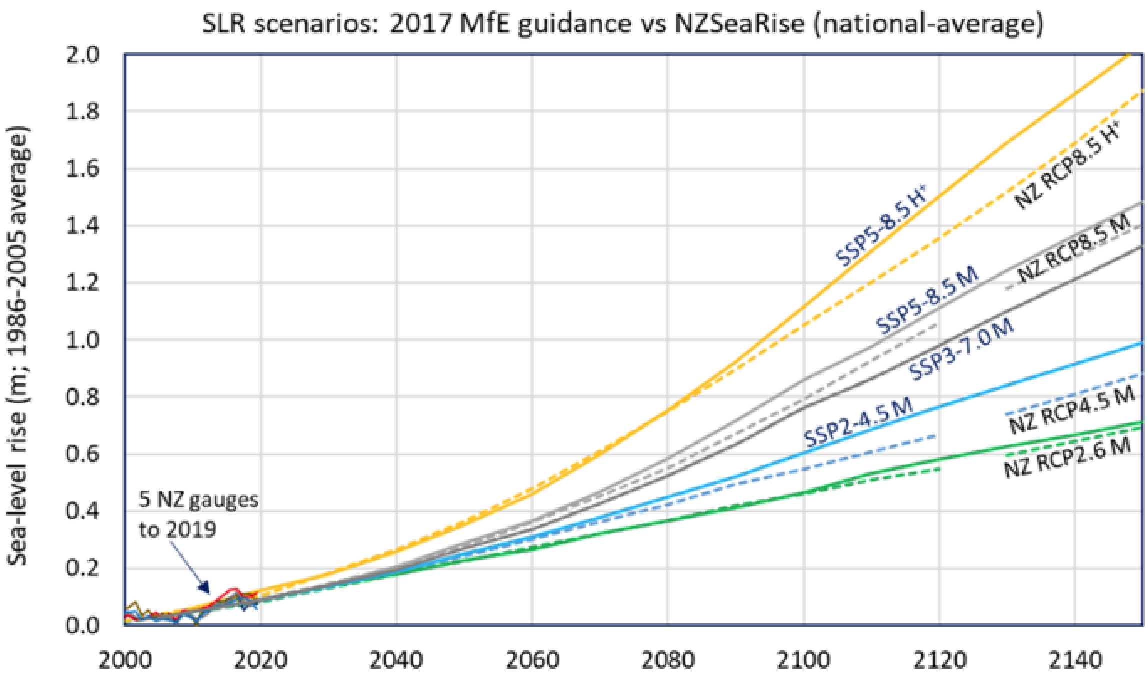
The pre-defined sea level scenarios do not make any allowances for wave (wind and/or swell) effects. However, if a property is adjacent to either the open coast or within an estuary or harbour, a comprehensive coastal hazard assessment would need to include wave effects.

Wave effects are very site specific and require detailed assessments to quantify localised inundation.

3.4 Projected Sea level Rise

Current guidance on Projected Sea Level Rise for New Zealand is provided by NIWA and Ministry for the Environment, in the 2017 publication, “Coastal hazards and climate change: Guidance for local government” (‘the guidance’) and, in the 2022 publication, “Interim guidance on the use of new sea-level rise projections” (‘the interim guidance’). The interim guidance outlines updates to parts of the guidance to reflect the latest sea-level rise scenarios from the Intergovernmental Panel on Climate Change and NZSeaRise.
The guidance: https://environment.govt.nz/publications/coastal-hazards-and-climate-change-guidance-for-local-government/
The interim guidance: https://environment.govt.nz/publications/interim-guidance-on-the-use-of-new-sea-level-rise-projections/

The interim guidance includes figures and tables which provide information on the sea level rise we could expect to see over the next 100+ years, under different scenarios (refer to Figure 4 and Tables 2 to 4). These tables are also provided in the Coastal Inundation Tool via a link at the bottom of each sea level scenario table. The guidance and interim guidance also provides information to support councils to manage and adapt to the increased coastal hazard risks posed by climate change and sea-level rise.



Note for figure 1: Comparison of the new nationally averaged NZSeaRise projections (excluding VLM) (solid lines) with the matching equivalent suite of four sea-level rise (SLR) projections in the 2017 coastal hazards guidance (dashed lines), all to a common zero baseline period used previously (1986–2005). *Source*: Ministry for the Environment, 2017; NZSeaRise/Takiwā platform (averaging six locations north to south) and tide-gauge data from the Ministry for the Environment and StatsNZ (https://www.stats.govt.nz/indicators/coastal-sea-level-rise).

Figure 4 **(Figure 1 in the guidance) Comparison of new NZSeaRise projections with 2017 coastal hazards guidance projections from 2000 to 2150.**

Year	SSP1–2.6 M (median) [m]	SSP2–4.5 M (median) [m]	SSP3–7.0 M (median) [m]	SSP5–8.5 M (median) [m]	SSP5–8.5 H+ (83rd percentile) [m]
2005	0	0	0	0	0
2020	0.06	0.06	0.06	0.06	0.09
2030	0.11	0.11	0.11	0.11	0.15
2040	0.15	0.16	0.16	0.18	0.23
2050	0.20	0.22	0.24	0.26	0.32
2060	0.24	0.28	0.31	0.34	0.43
2070	0.29	0.35	0.40	0.44	0.57
2080	0.34	0.42	0.50	0.56	0.72
2090	0.38	0.49	0.61	0.69	0.90
2100	0.44	0.57	0.73	0.83	1.09
2110	0.50	0.66	0.83	0.95	1.28
2120	0.55	0.74	0.95	1.08	1.47
2130	0.60	0.81	1.07	1.21	1.66
2140	0.64	0.89	1.19	1.34	1.84
2150	0.68	0.96	1.30	1.46	2.01

Notes for table 1: Decadal increments for average[11] "medium confidence" projections of sea-level rise (metres above 1995–2014 baseline) applied nationally and excluding any regional and local factors including VLM. For local or regional scale sea-level rise projections, use the NZSeaRise maps in Takiwā[12] and downloaded datasets to create a similar table.

Table 2 **(Table 1 in the guidance) Decadal increments for averaged "medium confidence" projections of SLR applied nationally.**

Table 2: Approximate years when various national sea-level rise increments could be reached

SLR (m)	Year achieved for SSP5-8.5 H$^+$ (83rd percentile)	Year achieved for SSP5-8.5 (median)	Year achieved for SSP3-7.0 (median)	Year achieved for SSP2-4.5 (median)	Year achieved for SSP1-2.6 (median)
0.3	2050	2055	2060	2060	2070
0.4	2060	2065	2070	2080	2090
0.5	2065	2075	2080	2090	2110
0.6	2070	2080	2090	2100	2130
0.7	2080	2090	2100	2115	2150
0.8	2085	2100	2110	2130	2180
0.9	2090	2105	2115	2140	2200
1.0	2095	2115	2125	2155	>2200

SLR (m)	Year achieved for SSP5-8.5 H$^+$ (83rd percentile)	Year achieved for SSP5-8.5 (median)	Year achieved for SSP3-7.0 (median)	Year achieved for SSP2-4.5 (median)	Year achieved for SSP1-2.6 (median)
1.2	2105	2130	2140	2185	>2200
1.4	2115	2145	2160	>2200	>2200
1.6	2130	2160	2175	>2200	>2200
1.8	2140	2180	2200	>2200	>2200
2.0	2150	2195	>2200	>2200	>2200

Notes for Table 2: Approximate year (to the nearest five-year value) when each national sea-level rise increment could be reached, under the "medium confidence" sea-level rise projections, with increments relative to a 1995–2014 baseline (midpoint 2005). Excludes any regional and local factors including VLM and the "low confidence" projections. Where VLM is significant, use the Takiwā maps and downloaded datasets to create a similar table.

Table 3 (Table 2 in the guidance) Approximate years when various national sea-level increments could be reached.

Category	Description	Transitional allowances in the 2017 coastal hazards guidance (s. 5.7.3) or table 2 of the Summary (Ministry for the Environment, 2017a)	Transitional allowances to use now, until the refresh of the coastal guidance
A	Coastal subdivision, greenfield developments, and major new infrastructure	*Avoid hazard risk by using sea-level rise over more than 100 years and the H+ scenario*	Avoid new hazard risk by using "medium confidence" sea-level rise out to **2130** for the SSP5-8.5 H+ (*83rd percentile SSP5-8.5 or p83)* scenario that includes the relevant VLM for the local/regional area (from table 1; typically 1.7 m rise in regional MSL before including VLM). Also, check the lifetime and utility of new developments using the median RSLR projections for the "low confidence" SSP scenarios out to 2150 and beyond.
B	Changes in land use and redevelopment (intensification)	*Adapt to hazards by conducting a risk assessment using the range of scenarios and the pathways approach*	Adapt to hazards by conducting a risk assessment using the range of updated "medium confidence" RSLR scenarios (including VLM) out to **2130** with the dynamic adaptive pathways planning approach; or if a more immediate decision is needed: • avoid new and increased hazard risk by using "medium confidence" sea-level rise out to

Category	Description	Transitional allowances in the 2017 coastal hazards guidance (s. 5.7.3) or table 2 of the Summary (Ministry for the Environment, 2017a)	Transitional allowances to use now, until the refresh of the coastal guidance
			2130 and the SSP5-8.5 H+ (*83rd percentile SSP5-8.5 or p83*) scenario that includes the relevant VLM for the local/regional area (from table 1; typically 1.7 m rise in regional MSL before including VLM).
C	Land-use planning controls for existing coastal development and assets planning. Use of single values at local/district scale transitional until dynamic adaptive pathways planning is undertaken	*1.0 m sea-level rise*	Use the SSP5-8.5 M scenario out to **2130**, which includes the relevant VLM for the local/regional area (from table 1; typically 1.2 m rise in regional MSL before including VLM).
D	Non-habitable, short-lived assets with a functional need to be at the coast, and either low-consequences or readily adaptable (including services)	*0.65 m sea-level rise*	Use the SSP5-8.5 M scenario out to **2090** that includes the relevant VLM for the local/regional area (from table 1; typically 0.7 m rise in regional MSL before including VLM).

Notes for table 3: Recommended updates (last column) to the minimum transitional procedures or RSLR allowances, are for use in planning instruments while in transition towards a DAPP strategy. *VLM = vertical land movement; p83= 83rd percentile (top of shaded likely range).*

Table 4 (Table 3 in the guidance) Recommended updates to the minimum transitional procedures or RSLR allowances.

NZ Sea Rise: Te Tai Pari O Aotearoa programme provide maps showing location specific sea-level rise projections for every 2 km of the coast of Aotearoa New Zealand. Refer to the interim guidance and NZSeaRise, for how to include vertical land movement into sea-level rise projections. **Do not use the vertical land movement predictions** displayed on the NZSeaRise maps, as these predictions are not accurate at the property scale level.
https://www.searise.nz/

NIWA provide extreme coastal flood maps for Aotearoa New Zealand. The maps include a modelled representation of New Zealand's 1% annual exceedance probability (AEP) extreme sea level flooding under current climatic sea conditions, plus relative sea level rise up to 2 m above present-day mean sea level.
https://niwa.co.nz/natural-hazards/our-services/extreme-coastal-flood-maps-for-aotearoa-new-zealand

Thames Coromandel District Council provide maps as part of the Shoreline Management Pathways Project, which include the 'Coastal Inundation Hazard – 1% AEP' for coastal areas within the district.

https://www.tcdc.govt.nz/Our-Community/Council-Projects/Current-Projects/Coastal-Management/Shoreline-Management-Pathways-Project

4 Ground Elevations

All ground levels used to map the sea level scenario have been measured using LiDAR aerial surveys and compiled into a Digital Elevation Model (DEM), relative to Moturiki Vertical Datum 1953 (MVD-53). The LiDAR information is generally accurate to around ±0.2 m vertically; some areas are less or more accurate.

The LiDAR information is a 'snapshot' of the ground elevation at the time of the survey, so any changes to ground elevation since the LiDAR survey will not be captured. The DEM ground elevations are the most up to date currently available from WRC. Table 5 shows the year when LiDAR was captured.

Area	DEM grid cell size	Year of LiDAR capture
Coromandel Peninsula (West and East coast)	1 m	2012
Hauraki Plains	2 m	2007/2015
Kaiaua/Miranda	2 m	2007/2010
Port Waikato	1 m	2010
Raglan, Aotea and Kawhia Harbours	1 m	2007/2008
Other West Coast areas	1 m	2015

Table 5 LiDAR survey year and horizontal resolution of DEM

The LiDAR survey does not identify all features that either allows water to flow through, such as culverts, or barriers to water flow such as flood walls or sheet piling.

Therefore, manual modification of the DEM for specific areas was undertaken to ensure the DEM generally represented the hydraulic regime, especially for areas with flood protection, such as the Hauraki Plains.

Therefore, the green disconnected inundation areas may or may not be 'real' and could actually be connected inundation areas. The disconnected inundation areas should still be regarded as areas that could be affected by coastal inundation.

Flood protection assets such as stop banks or flood walls are provided as a layer in the tool. Therefore, disconnected (green) areas behind identified stop banks/flood walls are assumed to be protected from coastal inundation up to the design crest level. Connected inundation (blue) areas behind identified stop banks/flood walls show that the flood protection has been overtopped.

5 Tide Gauge Analysis for Whitianga Wharf, Tararu and Kawhia Wharf

All sea-level data used in the Coastal Inundation Tool is based on analysis of tide gauges at Whitianga Wharf (Coromandel East Coast), Tararu (Firth of Thames) and Kawhia Wharf (West Coast). The tide-gauge analyses are strictly only accurate at the specific location of the tide gauge. However, the sea-level data provides the best available coastal water level information, and a tide model was used to transfer information from the tide gauges to other areas.

An analysis of sea levels for the three tide gauges was undertaken by NIWA in 2015.

The following sections contain information used to calculate the sea levels used in the pre-defined sea level scenarios and provides information for the user to derive their own sea level scenario. The full tide gauge analysis report is here and in DM#3460508.

5.1 Mean sea level offsets to Moturiki Vertical Datum 1953 (MVD-53)

Location	Mean sea-level offset relative to MVD-53 (m)		
	MSL Averaging Period 2008–2014 (Kawhia record duration)	MSL Averaging Period 1999-2014 (Whitianga record duration)	MSL Averaging Period 2005-2014 (Recent decade)
Auckland	0.16	0.14	0.15
Moturiki	0.12	0.11	0.11
Whitianga	0.14	0.11	0.13
Tararu	0.18	0.19	0.18
Kawhia	0.13		

Table 6 MSL offsets to MVD-53 datum at Auckland, Moturiki, Whitianga, Tararu and Kawhia. MSL epoch averages were calculated from annual means. The highlighted values have been adopted by WRC.

5.2 Tide markers

Tide Marker	Whitianga		Kawhia	Tararu
	Wharf	Open coast		
Minimum high water (m)	0.51	0.64	0.69	0.91
MHWPS (m)	1.00	1.13	1.85	1.88
MHWS–6 (m)	1.01	1.14	1.81	1.85
MHWS–10 (m)	0.98	1.11	1.74	1.79
Maximum water (m)	1.19	1.32	2.07	2.10

Table 7 Analysis of high waters at Whitianga (wharf and open coast), Kawhia and Tararu relative to MVD-53. MHWS–6 = mean high water spring height exceeded by 6% of all tides, MHWS–10 = mean high water spring height exceeded by 10% of all tides, MHWPS = mean high water perigean spring (M2 +S2 + N2). The MHWS elevations presented here are given in meters relative to MVD-53.

Note: The Whitianga tide gauge is located at the wharf inside the harbour entrance. Based on a comparison of water levels between the wharf and offshore, the tide gauge at Whitianga Wharf is recording water levels 0.13 m lower than outside the entrance. The reduced water levels are due to attenuation of the tidal wave as it moves into Whitianga Harbour.

5.3 Storm Tides

Tables 8 to 11 summarise extreme storm tide distributions for each tide gauge based on a Monte Carlo joint-probability analysis.

The probability is represented in both Annual Exceedance Probability (AEP) and Annual Return Interval (ARI).

5.3.1 Tararu tide gauge extreme storm-tide distribution

AEP (%)	ARI (years)	Median (mm)	Lower 95% C.I (mm)	Upper 95% C.I (mm)
39	2	2.196	2.193	2.198
18	5	2.275	2.269	2.28
10	10	2.348	2.34	2.359
5	20	2.431	2.417	2.446
2	50	2.538	2.519	2.561
1	100	2.62	2.589	2.658
0.5	200	2.706	2.662	2.759

Table 8 Extreme storm-tide distribution at Tararu. Elevations for the median and 95% confidence bounds are based on a Monte Carlo joint-probability analysis of sea level data at Tararu. The storm-tide elevations presented here are given relative to MVD-53.

5.3.2 Whitianga Wharf tide gauge and Open Coast extreme storm-tide distribution

AEP (%)	ARI (years)	Median (mm)	Lower 95% C.I (mm)	Upper 95% C.I (mm)
39	2	1.282	1.28	1.285
18	5	1.345	1.34	1.35
10	10	1.396	1.389	1.403
5	20	1.452	1.442	1.462
2	50	1.532	1.514	1.547
1	100	1.601	1.575	1.636
0.5	200	1.685	1.639	1.737

Table 9 Extreme storm-tide distribution at Whitianga WHARF. Elevations for the median and 95% confidence bounds are based on a Monte Carlo joint-probability analysis of sea level data at Whitianga Wharf. The storm-tide elevations presented here are given relative to MVD-53.

AEP (%)	ARI (years)	Median (m)	Lower 95% C.I (m)	Upper 95% C.I (m)
39	2	1.41	1.406	1.411
18	5	1.471	1.466	1.476
10	10	1.522	1.515	1.529
5	20	1.578	1.568	1.588
2	50	1.658	1.64	1.673
1	100	1.727	1.701	1.762
0.5	200	1.811	1.765	1.863

Table 10 Extreme storm-tide distribution at Whitianga OPEN COAST. Elevations for the median and 95% confidence bounds are based on a Monte Carlo joint-probability analysis of sea level data at Whitianga Wharf. An offset of 0.13 m is added to account for tide attenuation at the tide gauge. The storm-tide elevations presented here are given relative to MVD-53.

As mentioned in Section 6.2, the Whitianga Tide gauge is located inside the harbour, and the tide attenuates as it passes through the harbour entrance; the tide elevation is about 0.13 m lower than outside the harbour. Similarly, storm-tide levels are also likely to be reduced compared to the open coast areas with Mercury Bay.

To account for the tide attenuation at Whitianga WHARF, extreme storm-tide distribution values for the Whitianga OPEN COAST have simply had 0.13 m added. Considering astronomical tides are the largest component of storm tides, the additional 0.13 m is a reasonable approximation to account for the attenuation. However, the exact amount of storm tide attenuation through the harbour entrance is unknown.

5.3.3 Kawhia Wharf tide gauge extreme storm-tide distribution

AEP (%)	ARI (years)	Median (m)	Lower 95% C.I (m)	Upper 95% C.I (m)
39	2	2.271	2.267	2.276
18	5	2.374	2.366	2.382
10	10	2.458	2.447	2.47
5	20	2.548	2.533	2.565
2	50	2.665	2.643	2.692
1	100	2.757	2.719	2.803
0.5	200	2.864	2.802	2.957

Table 11 Extreme storm-tide distribution at Kawhia Wharf. Elevations for the median and 95% confidence bounds are based on a Monte Carlo joint-probability analysis of sea level data at Kawhia Wharf. The storm-tide elevations presented here are given relative to MVD-53.

The Kawhia wharf is situated inside Kawhia Harbour, so the tide gauge measurements do not represent the open coast tide and storm tide regime. Storm-tide levels measured at Kawhia might be amplified relative to the open coast, due to tidal amplification and wind set up effects within the harbour. Importantly the tide gauge does not measure the effect of the energetic west-coast wave climate.

5.3.4 Storm tide composition

Figures 5 to 7 show the composition of the largest 20 storm tides for each tide gauge.

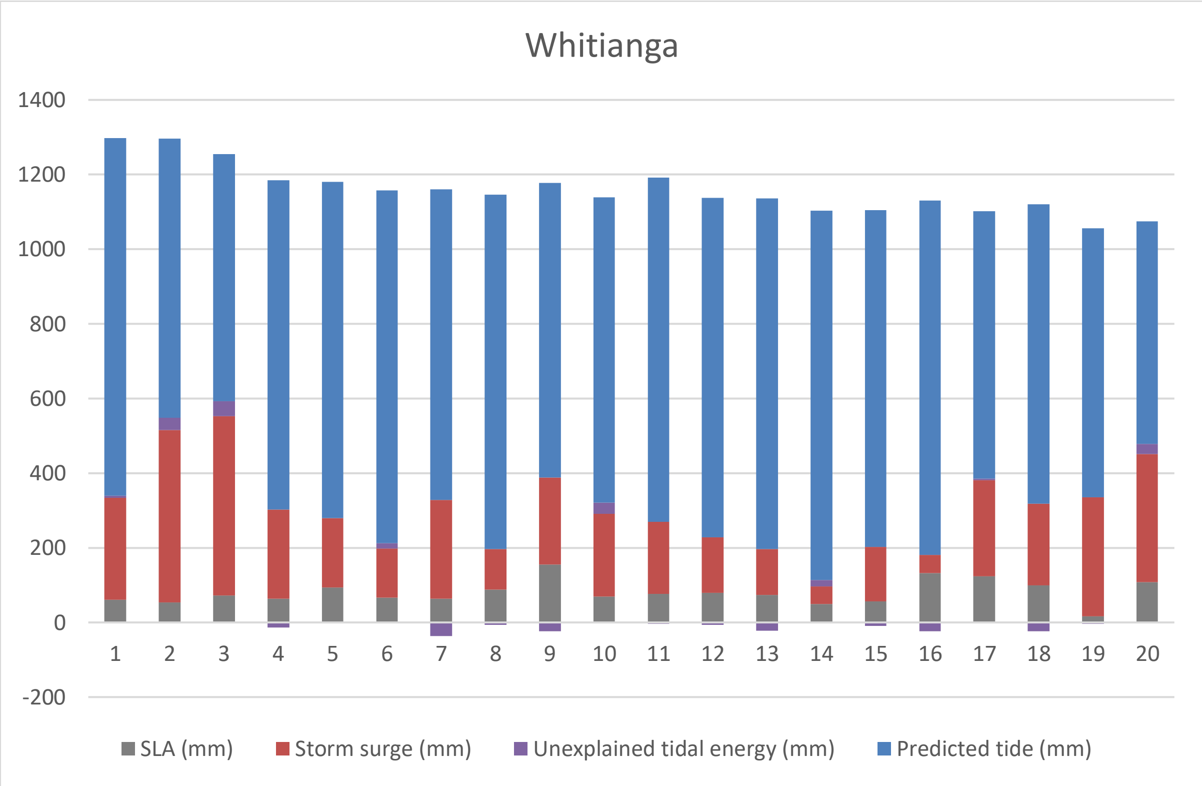


Figure 5 Storm tide composition for Whitianga Tide Gauge

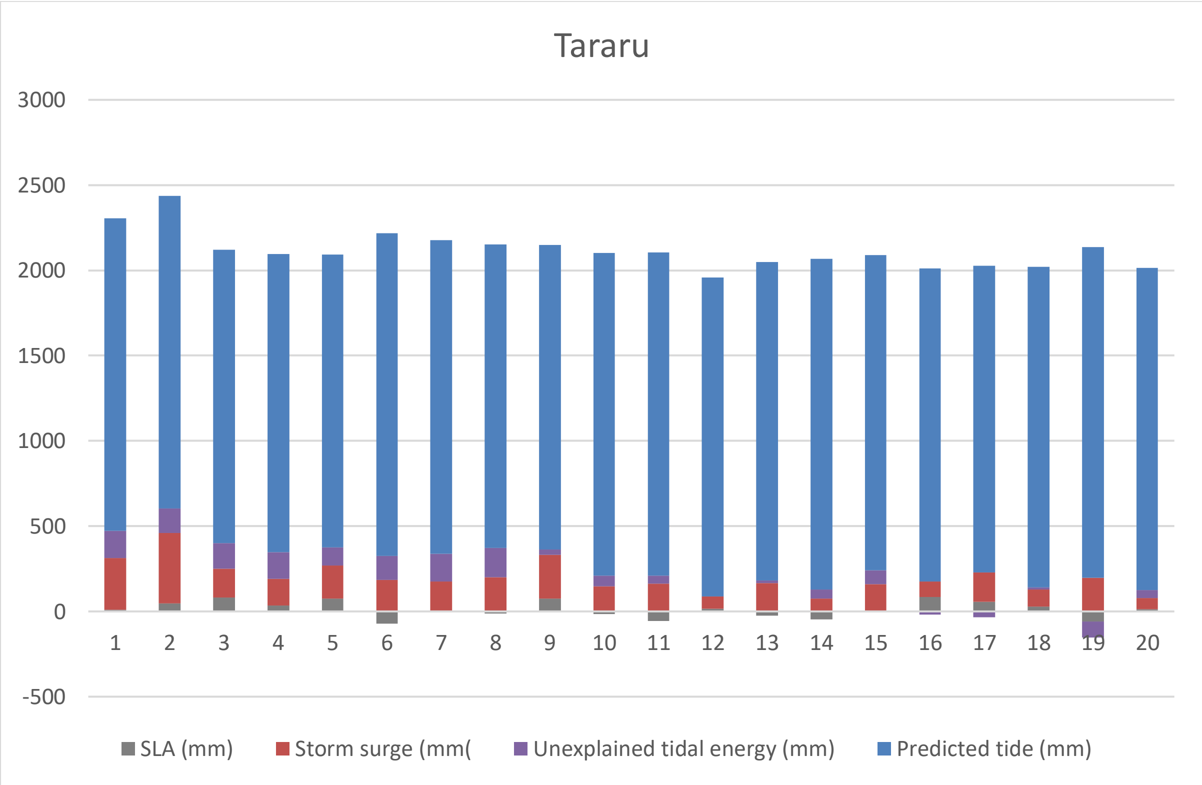


Figure 6 Storm tide composition for Tararu Tide Gauge

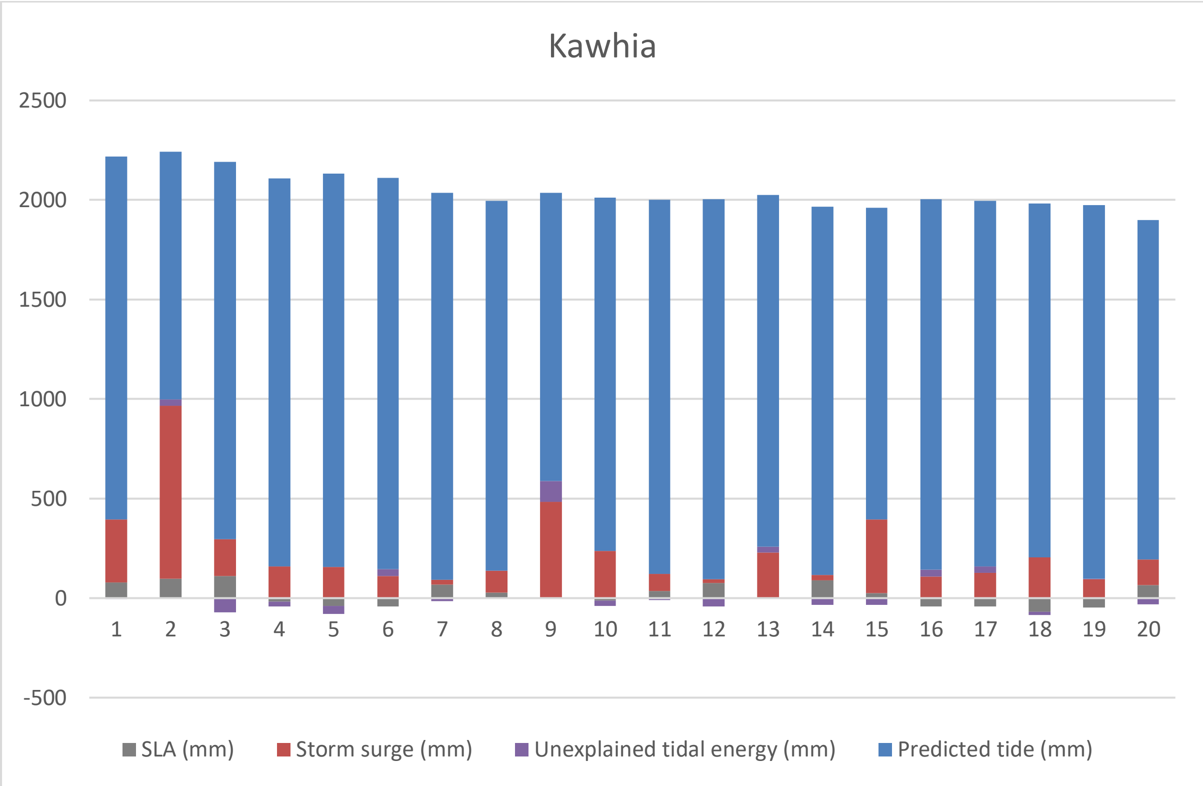


Figure 7 Storm tide composition for Kawhia Tide Gauge

5.3.5 Maximum Storm Tide Estimates

Table 12 provides estimates of a 'worst case' storm tide scenario where maximum water level components coincide. The probability of such an event occurring is unknown and extremely low, but possible.

Location	Tide	Storm surge	SLA	Sum
Whitianga Wharf	1.19	0.63	0.18	2.00
Whitianga Open Coast	1.32	0.63	0.18	2.13
Tararu	2.10	0.97	0.14	3.21
Kawhia	2.07	0.90	0.16	3.13

Table 12 Maximum Storm tide estimates for the 3 tide gauges.

6 Further information

The following links provide further information:

Coastal Storm Inundation - NIWA
https://www.niwa.co.nz/natural-hazards/hazards/coastal-storm-inundation

Coastal Hazards and Climate Change: Guidance for Local Government – Ministry for the Environment, 2017
https://www.mfe.govt.nz/publications/climate-change/coastal-hazards-and-climate-change-guidance-local-government

NIWA (Stephens et al.) 2015: Analysis of Whitianga, Tararu and Kawhia sea-level records to 2014. NIWA Client Report to Waikato Regional Council HAM2015-046, 98p. http://www.waikatoregion.govt.nz/assets/PageFiles/41257/3460508%20NIWA%20report.pdf

7 Frequently Asked Questions

How accurate is this inundation mapping information?

The Coastal Inundation tool is intended to provide an indicative estimate of the inundation extent for a particular sea level scenario. The mapping tool does not include all the components (i.e. wave effects) that contribute to coastal inundation, and does not substitute for a coastal hazard assessment by a qualified specialist. The tool is designed to alert people of a property's susceptibility to coastal inundation. There are two factors that affect the accuracy of mapping coastal inundation extent.

Firstly, the accuracy of the sea level scenario. The sea level scenarios are based on work undertaken by NIWA (2015) that used the best-available sea level information and models, and are accurate to within a few centimetres.

Secondly, the accuracy of the ground elevations used to map the sea level scenarios. All ground levels used to map the sea level scenarios have been measured using LiDAR aerial surveys. The LiDAR information is generally accurate to around ±0.2 m vertically relative to Moturiki vertical datum. However, the LiDAR information is a 'snapshot' of the ground elevation at the time of the survey, so any changes to ground elevation since the LiDAR survey will not be captured (refer to Table 5 for LiDAR capture dates).

The effect of these uncertainties on coastal inundation can be explored, by adjusting the water-level slider within the coastal-inundation tool.

The mapping of the MHWS10 level shows inundation of areas that I know do not get inundated during even a king tide, is the information wrong?

All MHWS10 values are based on a tide model (NIWA) along the open coast. As the tides enter an enclosed water body such as an estuary or enclosed harbour, the tide range and high-tide levels can change. In areas where the MHWS value is overestimating the tide, it is suggested that the sea level that best matches the expected tide inundation on the map is used as the starting sea level elevation.

Will the coastal inundation tool devalue my property?

The coastal inundation tool does not provide a coastal hazard assessment. Therefore, the tool itself is unlikely to and unintended to devalue a property. The tool can alert people that a property is more or less susceptible to coastal inundation and where further investigation could be undertaken as part of due diligence for a property purchase.

As the information used in the coastal inundation tool has been available for some time, a proper due diligence process would likely include similar information whether this tool existed or not.

Will showing this coastal inundation extent cause issues for my insurance?

Insurance companies should not be using this tool to ascertain coastal-inundation risk for any specific property, although they may use the tool to identify areas that should require further assessment.

I own a property that is inundated using a sea level scenario, what should I do now?
If the property is shown to be inundated with a present day scenario, then ensuring that you and your family are prepared for an emergency, including having an evacuation plan, is important. Get Ready and the Waikato Region Emergency Management Group website are great online resources to assist with this.

Additionally, if you are looking to develop or sell the property then you or another party may need to provide/seek further information as to the risk of coastal inundation. Any further information would likely to have been required whether the coastline inundation tool was used or not.

Can I use the coastal inundation tool as part of information for a consent application?
No. A site-specific assessment on coastal hazards is likely to be required. However, the tool can be used as a ‘first cut’ assessment to ascertain if a site-specific coastal hazard assessment is required, prior to lodging consent.