Ministry for the Environment
Manatū Mō Te Taiao

FACT SHEET 2

This is one of a series of fact sheets developed to accompany *Preparing for coastal change*, and provide further information on elements of coastal processes.

Coastal flooding due to storms

This fact sheet outlines the process of **coastal flooding** *caused by storms, a hazard that will be affected by climate change and sea-level rise.*

Storms, tides and sea level

Coastal flooding is a natural event that happens when extreme weather causes low-lying coastal land to be inundated with water.

Flooding may occur when high tides (mostly spring or *perigean*[1] tides) combine with:

- a storm surge – when strong onshore winds accompany low barometric (air) pressure, causing a temporary rise in sea level above the predicted tide height. A storm surge may last for hours or days. Fact sheet 5 in this series explains storm surges in more detail.
- larger than normal waves and/or swell – seawater may spill over low coastal barriers when the average level of seawater inside the surf zone is higher than the sea level offshore from the breakers (*wave set-up*), or when waves run higher up the beach than normal (*wave run-up*). In some cases, distant storms may cause the damaging waves or swell.
- higher than average monthly mean sea level caused by regular climate cycles and unpredictable variability.

The total sea level formed from this combination of high tides, month-to-month variability in mean sea level and storm surges is called a *storm tide*. Whether coastal flooding occurs during a storm or not, and just how severe it is, depends on timing. For example, if the peak of the storm surge does not coincide with the highest wave conditions and the time of a high spring tide, inundation may not occur.

1 A spring tide happens every two weeks, when the Earth, sun and moon are nearly aligned. A 'perigean' spring tide, sometimes called a 'king tide', occurs three or four times a year when a spring tide coincides with when the moon is at its closest point to Earth.

Figure 1: Hauraki Plains inundated (May 1938)

Source: RNZAF

The biggest storm tides last century occurred in 1936 and 1938. Auckland suffered a similar-sized event on 23 January 2011.

The Great Cyclone of 1 – 2 February 1936, with barometric pressures down to 970 hPa and ferocious winds and waves, came on the back of a very high perigean-spring tide. Widespread coastal flooding caused damage along the east coast of the North Island. Coastal roads were washed away, a house fell into the sea at Te Kaha, and houses 100 metres inland at Castlepoint were swamped when the sea breached the coastal dunes. A month later, on 25 – 26 March, an easterly gale produced by a low depression combined with extremely high perigean-spring tides to cause damage and sea flooding in the Auckland region.

Two years later, on 4 – 5 May 1938, more than 1600 hectares of the lower Hauraki Plains were flooded at depths of 0.5–1.3 metres (figure 1). Spring tides and north-east gales combined to create a large storm surge with accompanying waves, all exacerbated by heavy rain. The shoreline stopbank from Waitakarau to Kopu was breached in several places.

More recently, on 23 January 2011, Auckland experienced a storm of similar magnitude. Flooding was 0.11 metres deeper and more extensive than in 1936, with houses inundated and roads closed. Most of the difference in peak water levels for these similarly-sized storms can be attributed to a sea-level rise of 0.12 metres since 1936.

Sources: Brenstrum E. 1998. The New Zealand Weather Book. Nelson: Craig Potton Publishing: Nelson; www.ohinemuri.org.nz/journals (Sept 2009); Stephens et al. 2013. Coastal inundation by storm-tides and waves in the Auckland Region. Prepared for the Auckland Council by NIWA. Auckland: Auckland Council.

Landforms play a part

Just how big and deep a flood is also depends on the coast's physical characteristics and topography. Typically, flood waters follow the pathways described below.

- Direct inundation – where the storm tide, plus the wave set-up level, exceed the elevation of the land. This typically occurs when there is no coastal barrier, or the barrier has been reduced, sometimes because people have modified it. Areas with no coastal barrier often include estuaries, sheltered coastlines and river margins.
- Breach flooding – when a natural barrier (such as a gravel ridge or narrow dune field) or a human-made defence (such as a stopbank) is breached. Breach flooding is more likely to occur on open sections of coast that are exposed to larger waves and swell.
- Wave splash and spray – when a natural or artificial barrier is over-topped. This typically occurs when wave or swell conditions coincide with a high tide or storm tide. Again, the volume of floodwater is greater on more exposed, open sections of coast.

Flooding of the coast, estuaries and low-lying areas by rivers and storm water can be made worse by high tides or storm tides (figure 2). Following an extreme event, land in relatively flat, low-lying coastal margins can stay inundated by seawater for several days – places such as Christchurch's Lower Heathcote River, the South Canterbury plains, the Hauraki Plains, and Ahuriri in Napier. Beside the damage caused to buildings, infrastructure and electrical services, inundation by seawater drastically affects vegetation and pasture production for several months.

Figure 2: Coastal inundation at East Clive, south of Napier, on 16 August 1974, was caused by persistent heavy swell coinciding with high tides. This resulted in the gravel barrier being overtopped, and the low-lying land behind being inundated. Two hundred homes were affected.

Source: Ministry of Works and Development, Napier (now the National Institute of Water and Atmospheric Research (NIWA)).

Our actions can increase the hazards from flooding

What we do can also exacerbate coastal storm flooding hazards.

- River training works, such as straightening and stopbanks, can raise river levels at the coast.
- Poorly designed coastal protection structures, such as seawalls, can cause the beach to erode, or increase its exposure to wave run-up and overtopping.
- Developing coastal property in areas prone to flooding (low-lying land around estuaries or shorefront areas without an adequate buffer).
- Building roads or other infrastructure can block the flow of water over land.

- Providing inadequate drainage behind coastal berms, seawalls or roads.
- Physically removing, reducing or damaging natural coastal barriers, such as sand dunes and gravel barriers. For example, lowering access ways, removing vegetation, and trimming or removing dunes.
- Permanently modifying coastal margins by creating structures such as waterways, canals, marinas and boat ramps, or reclaiming land.

'Red alert' tide days ('king tides')

'King tides' raise the likelihood of exposed low-lying coastal areas being flooded, even if only modest storm surges or wave conditions occur.

Upcoming dates when high tides are predicted to reach the highest levels can be found at: www.niwa.co.nz/our-science/coasts/tools-and-resources/tide-resources.

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