Heyward Point to Long Beach

Setting

The only permanent settlement along this stretch of coastline is Long Beach, which is located on flat, low-lying ground which is generally less than 3m above msl. Long Beach is bordered by coastal hills to the east, west and south which rise to between 200 and 350m (Figure 1). A series of low dune ridges, up to 5m in elevation, separate the northern edge of the settlement from the Pacific Ocean. Drivers and Mabel Creeks cross swampland before incising the coastal dunes as they convey runoff from the upstream catchment to the coast. The permanent population of Long Beach was 108 at the time of the 2013 census, up from 93 in 2006. Access is via Purakanui Road which connects to Port Chalmers and Waitati. Low-lying (but currently undeveloped) land is also located at Kaikai and Murdering (or Whareakeake) Beaches, as shown in Figure 6.

Figure 1. Topography of the Heyward Point to Long Beach area

Assessment of Risk

A number of residential dwellings in Long Beach are holiday houses and are therefore not occupied permanently (Statistics NZ, 2013). As a result, the overall exposure of the community to natural hazards is lower than if there was a larger and more permanent population, as the number of people exposed to natural hazards is generally small. The township is a popular holiday and weekend destination however, particularly during the summer months.

Characteristics of mapped hazard area affecting Long Beach

The location and topography of Long Beach expose it to two broad categories of natural hazards: inundation (either from the sea, or heavy rainfall events), and land instability (including coastal erosion, rock-fall, and the effects of seismic shaking):

❖ Direct Inundation from the Pacific Ocean

Two categories of lower-lying land in Long Beach have been identified using the methodology outlined in Part 1 of this report. These are described below, and shown in Figure 2 (low-lying land at nearby Kaikai and Murdering beaches has been mapped using the same methodology, and is shown in Figure 6).

It is noted that the coastal dunes to the north of Long Beach currently provide some protection against direct inundation from the Pacific Ocean during periods of elevated sea level (Figure 2 and Figure 5). However, water could enter the township if the dunes were eroded or overtopped, or infiltration (piping) occurred during storm surge or tsunami events. The buffering effect is more limited where Drivers and Mabel Creeks cut through the coastal dunes, providing a more direct passage between the ocean and the Long Beach community.

Area A: Land which is below the height identified as the 1:100 year storm surge level (Table 1). If water was to reach this height, a number of residential properties in Long Beach would be inundated to a depth of up to 0.5m, particularly on Beach Road, and the lower (eastern) end of Mihawaka Road. This area is also vulnerable to other coastal hazards such as tsunami and surface ponding due to heavy rainfall. Low-lying land in this area has been affected by surface ponding (i.e. not direct inundation from the sea) in recent times (Figure 3).

Area B: Land which is below the combined height of the 1:100 year storm surge level and an additional 1m (as described in Part 1 of this report, and listed in Table 1). Although higher than Area A, this area may still be affected by high magnitude, low frequency tsunami and storm surge events, where these have the ability to overtop or penetrate the dunes or road embankments which separate Area B from the coast. As sea level rises, the likelihood that inundation resulting from these hazards will reach a level where it can affect people and assets in this area will increase. At current sea level, surface ponding is less likely to affect this area than lower-lying land in Area A.

Beyond Area B: High magnitude, low frequency tsunami events (as described in Table 2) may affect land which is higher than that mapped as Area B, irrespective of sea-level rise. Although such events may occur rarely, they could affect much of the coastal terrace upon which Long Beach is situated. The actual extent of inundation (along with other characteristics such as velocity and depth) during the largest credible tsunami events are not possible to map accurately, given the current level of information available.

❖ Other Natural Hazards

Surface ponding: The relatively low elevation and flat topography of the Long Beach settlement, a shallow water table,[1] and normal astronomical tides can combine to impede the natural drainage of water during prolonged or heavy rainfall events. This can contribute to extensive surface ponding in low-lying parts of the settlement. Prolonged inundation can occur under current conditions (Figure 3), and this can damage buildings and vehicles, and cause major inconvenience to residents.

[1] Groundwater is generally shallow at the coast, as this is where groundwater discharges to the sea. Heavy rainfall events will cause the water table to rise resulting in ponding in low lying areas/depressions (R. Morris, ORC, pers. comm., 10 December 2013).

Any increase in mean sea level and the upper range of the normal tidal cycle will likely exacerbate the problems associated with surface ponding, and may influence the depth of inundation, the frequency of events, and the duration of ponding. Changes in climate may also lead to increases in the intensity and frequency of storm events (MfE, 2008). The combined effects of more frequent and intense heavy rainfall events and a higher base sea-level may further exacerbate the effects of ponding.

Surface ponding hazard has not been mapped as part this investigation, and the extent of inundation will depend on the duration and intensity of each rainfall event, and the ability of water to drain away (which is partly controlled by sea level). Lower-lying land which will be more prone to this hazard will generally lie within Area A.

Flood hazard: The channel and margins of Drivers and Mabel Creeks are mapped on Figure 2 as a flood hazard area, as they are regularly affected by inundation during heavy rainfall events, and may be affected by fast-moving water and debris during storm surge or tsunami events. Low-lying land to the south of Long Beach can also be affected by flooding for extended periods, due to runoff from the surrounding hill catchments being unable to drain rapidly to the Pacific Ocean (Figure 4).

Rockfall and landslide: Land immediately below the steep coastal cliffs to the west of Long Beach can be affected by falling boulders and debris. Rockfall and cliff collapse may be initiated during extreme rainfall or seismic events. Rockfall could cause localised but severe damage to buildings and roads in this area, and present a risk to safety.

The coastal hills near Long Beach are susceptible to shallow landslides, and although no larger landslides have been mapped on the surrounding slopes (GNS, 2012), they remain a possibility, especially during extreme rainfall events. A small (15m) landslip blocked Mihiwaka Rd in April 2010, cutting off access to the Long beach community (ODT, 2010)

Seismic shaking: Ground shaking at Long Beach with a return period of 100 years is likely to displace objects and crack large windows (Opus 2005). The maximum intensity ground shaking modelled by Opus (2005) for Long Beach is associated with a magnitude 7 earthquake on the Akatore Fault. This would make it difficult for people to stand, and cause moderate damage to chimneys and un-reinforced stone and brick walls.

Ground subsidence or liquefaction as a result of seismic shaking has the potential to damage roads, power lines, underground pipes and building foundations. GNS (2014b) describes the hazard associated with liquefaction in the Long Beach area further, and describes the coastal terrace upon which the township is situated as being composed of materials which have a moderate to high likelihood of being susceptible to liquefaction.

❖ Other Coastal Areas

Sand dunes: The sand dunes to the north of Long Beach act as a buffer to help protect it against the effects of erosion and direct inundation from the sea during tsunami and storm surge events. Activities that disturb the form of the dunes (such as excavation or the placement of structures) or its vegetation cover may compromise their stability. Any increase in mean sea level may mean that wave action would increasingly affect the stability of these sand dunes. However, there would need to be sustained erosion of the dunes before residential properties were directly affected by the Pacific Ocean (either from direct inundation or coastal erosion). Figure 5 shows that the vegetated foredune accreted (moved seaward) between 1956 and 2013. This aggradation is likely to have increased the ‘buffering’ ability of the dune system against coastal hazards.

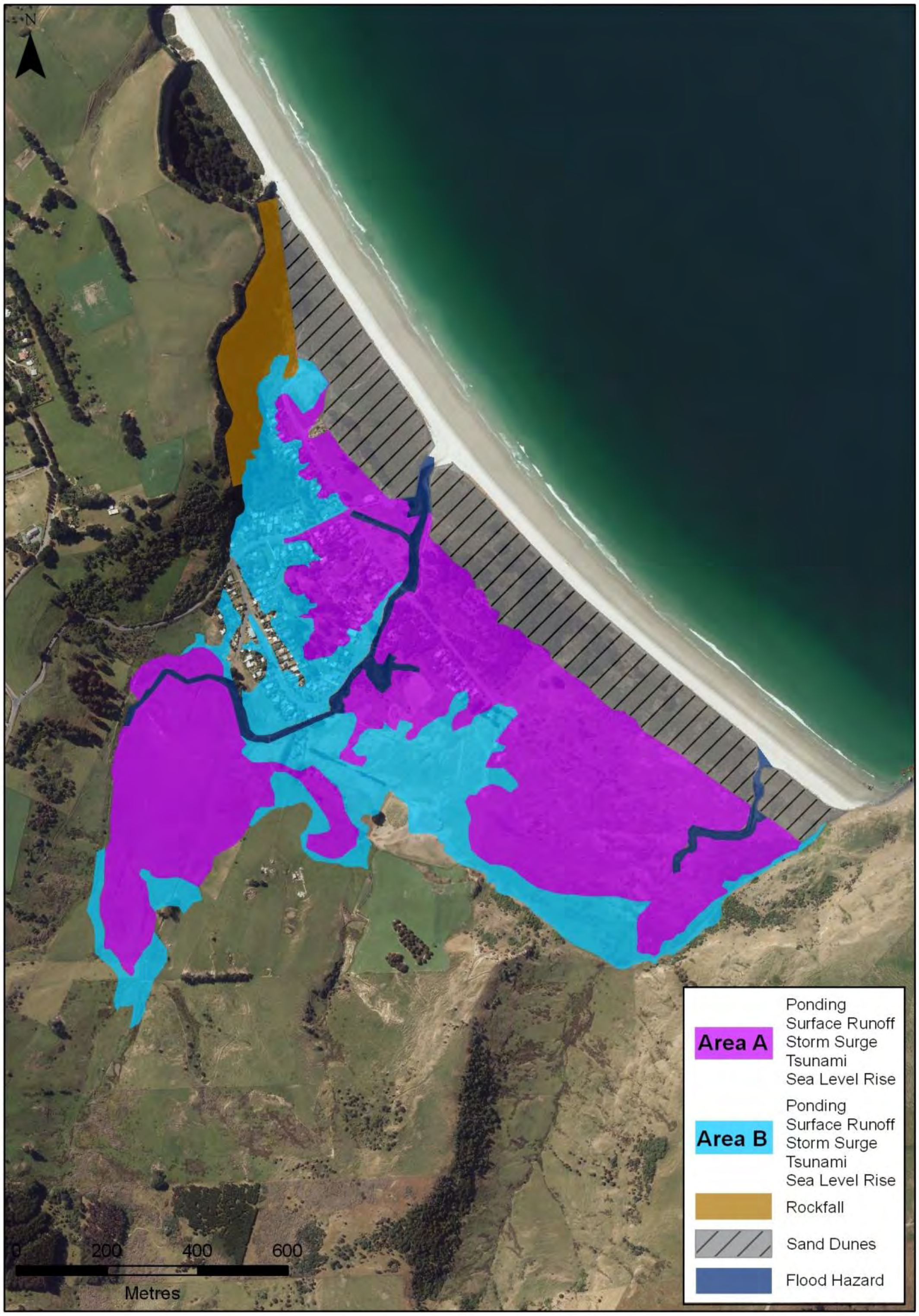

Figure 2: Mapped natural hazards areas in Long Beach

Figure 3. Water ponding on a property at Long Beach after heavy rainfall in May 2010 (Source: ODT)

Figure 4. Long Beach during a heavy rainfall event in June 2013. The steep cliffs to the west of the settlement, and the low-lying, flood-prone area to the south can both be seen in this image.

Figure 5. Changes in the location of the vegetated foredune at Long Beach between 1956 and 2013, overlaid on an aerial photograph collected in 2013 (Source: DCC)

Figure 6. Mapped natural hazards areas in Murdering Beach (left) and Kaikai Beach (right)

Purakanui

The settlement of Purakanui is located on the eastern margin of Purakanui Inlet. Most residential sections are located on more elevated slopes, although some development does exist close to the margins of the inlet. The margins of the inlet are clearly defined by roads, or rocky headlands (Figure 7). As such, the effects of coastal hazards such as storm surge, tsunami and coastal erosion on existing development is limited.

The permanent population of Purakanui was 66 at the time of the 2013 census, down from 75 in 2006. Access is via Purakanui Road which connects to Port Chalmers and Waitati (Figure 1).

❖ Low-lying land

Lower-lying land around the margins of Purakanui Inlet has been identified using the methodology outlined in Part 1 of this report. This includes roads, boat ramps and boat sheds (**Error! Reference source not found.**Figure 7), some low-lying land on the western side of the inlet, and the raised coastal terrace which lies between the estuary outlet and Osborne Road.

Figure 7. View of Purakanui from Bay Road (Source: Google Street View)

Area A: Land which is below the height identified as the 1:100 year storm surge level (Table 1). This area may also be vulnerable to inundation during tsunami events (ORC, 2012a). As sea level rises, the likelihood that inundation resulting from these hazards will reach a level where it can affect people and assets in this area will increase.

Area B: Land which is below the combined height of the 1:100 year storm surge level, and an additional 1m (as described in the introduction, and listed in Table 1). Although higher than Area A, this area currently has some vulnerability to high magnitude, low frequency storm surge and tsunami events. As sea level rises, the likelihood that inundation resulting from these hazards will reach a level where it can affect people and assets in this area will increase.

- Flood hazard: Several steep gullies and ephemeral streams pass through the residential part of Purakanui. The location of the thalweg (or deepest part) of these waterways is shown on Figure 8, although the area which could be affected by flooding during a heavy rainfall event has not been mapped.

Figure 8. Mapped natural hazard areas in Purakanui

Waitati

Setting

Waitati is located in the south-west corner of Blueskin Bay (Figure 9) and much of the settlement lies at low elevation, less than 5m above msl. The township is flanked by coastal hills to the west, south and east, with several peaks over 600m. The Waitati River flows through Waitati from west to east, and Orokonui Creek borders the eastern edge of the township. Both rivers discharge into Blueskin Bay estuary at the east of the settlement.

The Waitati settlement (including Orokonui, and south to Donald's Hill / Shortcut Roads) had a population of 315 at the time of the 2013 Census, compared to 303 in 2006. Most dwellings are permanently occupied, with many residents commuting to Dunedin for work or school. The small settlement boasts a community hall, library, primary school, and volunteer fire brigade, and has a number of small businesses. In addition to local roads, some key links in the lower South Island transport network pass through Waitati, including State Highway 1 and the South Island Main Trunk Railway Line. The railway embankment which separates Waitati from Blueskin Bay acts as a buffer against the force of breaking waves, but can also inhibit the drainage of floodwater from the Waitati River.

Figure 9. Topography of Waitati and the surrounding area

Previous flood events in Waitati

The Waitati River catchment is short and steep, dropping from 739m at Swampy Summit to sea level over a distance of just 9km. Heavy rainfall in the headwaters drains rapidly and with little warning to the lowland river flats that surround the Waitati Township (ORC, 1993). Natural drainage to the Pacific Ocean is via the Blueskin Bay estuary, and can therefore be restricted when water level in the estuary is high, due to normal astronomical tides, or any additional storm surge component.

Parts of Waitati were affected by high flows in the Waitati River in May 1957, March 1968, June 1980, February 1991 and in April 2006 (ORC, 2013). The largest event since European settlement is likely to have occurred in the 1920's, when "the meandering Waitati became one sheet of water from one side of the valley to the other" (ORC, 1993). The main channel of the Waitati River changed its course below the Harvey Street Bridge during a large flood in the 1880's.

Figure 10. Waitati River close to overtopping the true left bank, downstream of the Harvey Street Bridge, April 2006

Figure 11. Waitati River overtopping at Killarney Street, Waitati, Feb 1991

Assessment of Risk

The current level of development within the Waitati settlement is generally low density residential with relatively old housing stock, and some small-scale commercial activity. The township is exposed to a range of natural hazards, and, like many coastal communities, is vulnerable to the effects of climate change, through increasing sea level and the potential for larger, and more frequent heavy rainfall events and floods. Although the town's population has only increased slowly in recent years, any increase in the level of development will add to the risk associated with natural hazards.

Characteristics of mapped hazard areas in Waitati

The location and topography of Waitati expose it to two broad types of natural hazard: land instability (including coastal erosion and the effects of seismic shaking, including liquefaction), and inundation (either from the sea, or flooding during heavy rainfall events). The interaction of different processes (e.g. coastal storm surge coinciding with high river flows and surface runoff) can also increase the level of hazard faced by the Waitati community. Buildings and other structures may exacerbate the hazard associated with flood or coastal hazard events, by contributing debris, or by restricting, amplifying or re-directing the flow of water. The characteristics and effects of natural hazards in Waitati are described below, and these have been used to map the hazard areas shown in Figure 12.

❖ Direct Inundation from the Pacific Ocean

Two categories of lower-lying land have been identified using the methodology outlined in Part 1 of this report. These are described below, and shown in Figure 12. Elevated sea levels may result in water entering the township from Blueskin Bay, as backflow up the Waitati River and/or by overtopping the railway embankment (Figure 12). The overall effects of direct inundation from the Pacific Ocean may create a threat life/safety, could result in damage to buildings and create difficulties when evacuating people. These effects are likely to be greatest in areas which are low-lying, and/or immediately adjacent to the ocean.

Area A: Land which is below the height identified as the 1:100 year storm surge level (Table 1). This area is also vulnerable to other coastal hazards such as tsunami, and inundation resulting from heavy rainfall events and high flows in the Waitati River or Orokonui Creek. As sea level rises, the likelihood that inundation resulting from these hazards will reach a level where it can affect people and assets in this area will increase.

Area B: Land which is below the combined height of the 1:100 year storm surge level, and an additional 1m (as described in the introduction, and listed in Table 1). Although higher than Area A, this area currently has some vulnerability to high magnitude, low frequency tsunami, storm surge, and flood events (as described in ORC (2012a), and shown in Figure 11). As sea level rises, the likelihood that inundation resulting from these hazards will reach a level where it can affect people and assets in this area will increase.

Beyond Area B: High magnitude, low frequency tsunami events (as described in Table 2) may affect land which is higher than that mapped as Area B, irrespective of sea-level rise. Although such events may occur rarely, they could affect much of the low-lying area in and around Waitati. The actual extent of inundation (along with other characteristics such as velocity and depth) during the largest credible tsunami events are not possible to map accurately, given the current level of information available.

❖ Other Natural Hazards

Flood and alluvial hazard: The lower Waitati River floodplain is prone to flood hazard (i.e. high river flows) and alluvial fan activity (water-borne sediment). The overall effects of inundation due to river flooding (including duration, depth and velocity) could create a risk to public safety, result in damage to buildings, and create stress for residents who were required to evacuate. There is potential for the river to create a different course in its lower reaches due to lateral migration of the active channel (caused either by the erosive power of floodwaters, or the accumulation of sediment in the channel). Both the current channel and the channel that existed prior to a flood event in the 1880's are shown in Figure 12.

The Waitati River and its tributary streams also convey entrained sediment (generally fine silts and sands) from the surrounding hills to the low-lying floodplain during times of intense rainfall. The deposition of this sediment on the floodplain may influence runoff patterns, and affect assets such as roads and buildings. Material entrained in floodwaters can cause additional damage to buildings and other assets (i.e. beyond that of flooding due to water only). The deposition of sediment within the main channel of the Waitati River can reduce its capacity, causing the river to avulse and overflow onto adjacent areas.

The lower reaches of the Orokonui Stream catchment have been mapped as an alluvial fan (Barrell et.al 1998, Opus 2009), which have been subject to active floodwater-dominated alluvial fan activity in the past.

Seismic hazard: Ground shaking at Waitati with a return period of 100 years is likely to displace objects and crack large windows (Opus 2005). The maximum intensity ground shaking modelled by Opus (2005) for Waitati is associated with a magnitude 7 earthquake on the Akatore Fault. This level of shaking would make it difficult for people to stand, and cause moderate damage to chimneys and un-reinforced stone and brick walls.

Ground subsidence or liquefaction as a result of seismic shaking has the potential to damage roads, power lines, underground pipes and building foundations. GNS (2014b) describes the hazard associated with liquefaction in the Waitati area further. The lower part of the Waitati River floodplain (including the Waitati township) is identified as being composed of materials which have a moderate to high likelihood of being susceptible to liquefaction.

Landslide hazard: Although approximately 34% of the Waitati River catchment has been mapped as comprising historic landslide features, none have been identified within or directly above the Waitati Township.

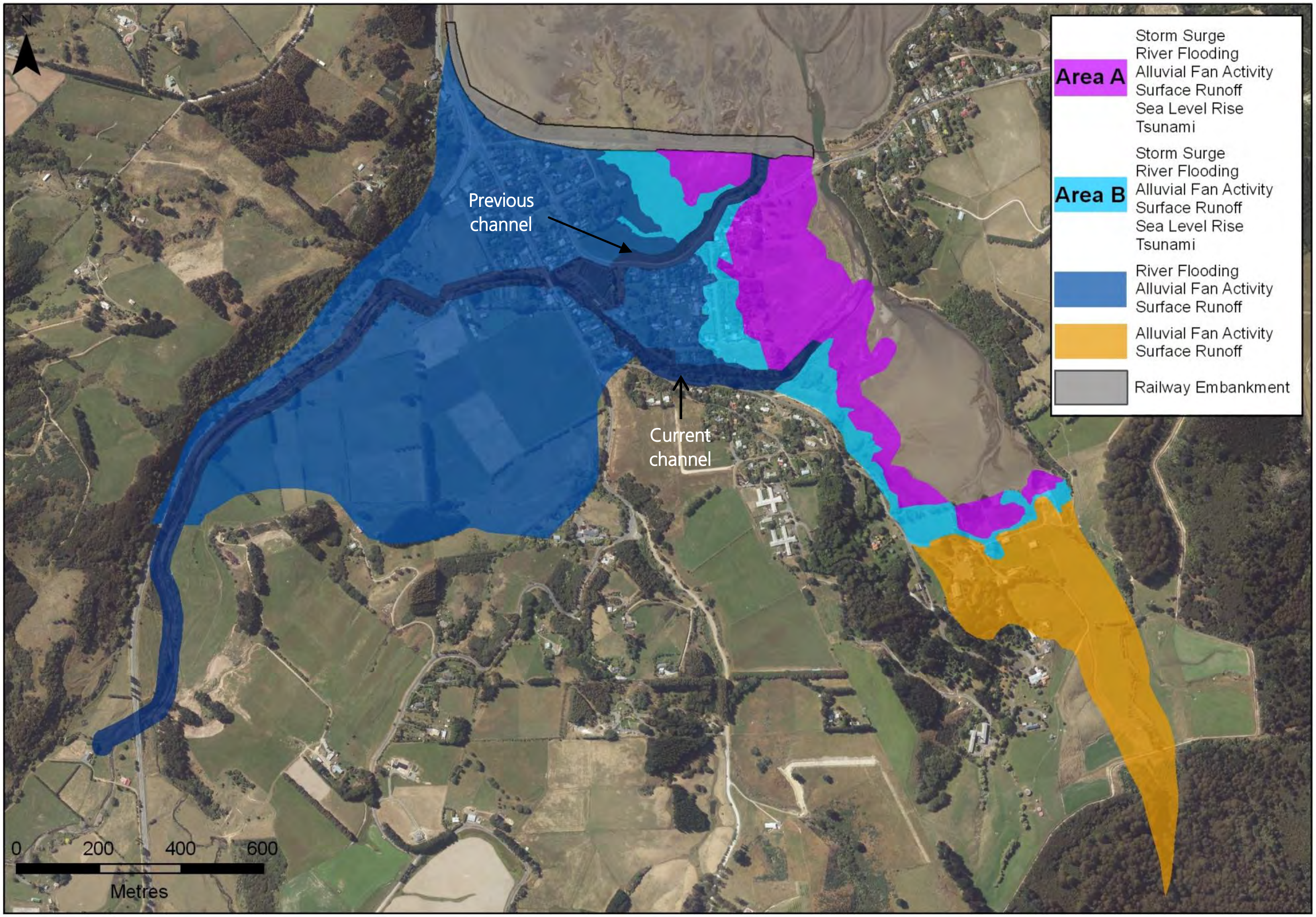

Figure 12: Mapped natural hazard areas in Waitati. The current channel of the Waitati River and the channel that existed prior to a flood event in the 1880's are shown as a darker blue.

Warrington and Evansdale

Setting

The settlement of Warrington is situated on land which is elevated 8m or more above msl, in the north-east corner of Blueskin Bay (Figure 13). Coastal hills rise to an elevation of 400m to the north and west of the township, and a sand-spit extends approximately 2.2km to the south, separating Blueskin Bay from the open coast. Warrington had a population of 450 at the time of the 2013 census, increasing from 426 in 2006 and 399 in 2001(Statistics NZ, 2013).

Evansdale is located 1.5km to the west, at the base of the Kilmog Hill on State Highway 1, with a population of approximately 45 people. Although the wider Evansdale area is low-lying, most of the residential activity is centred on areas of slightly higher elevation (Figure 14).

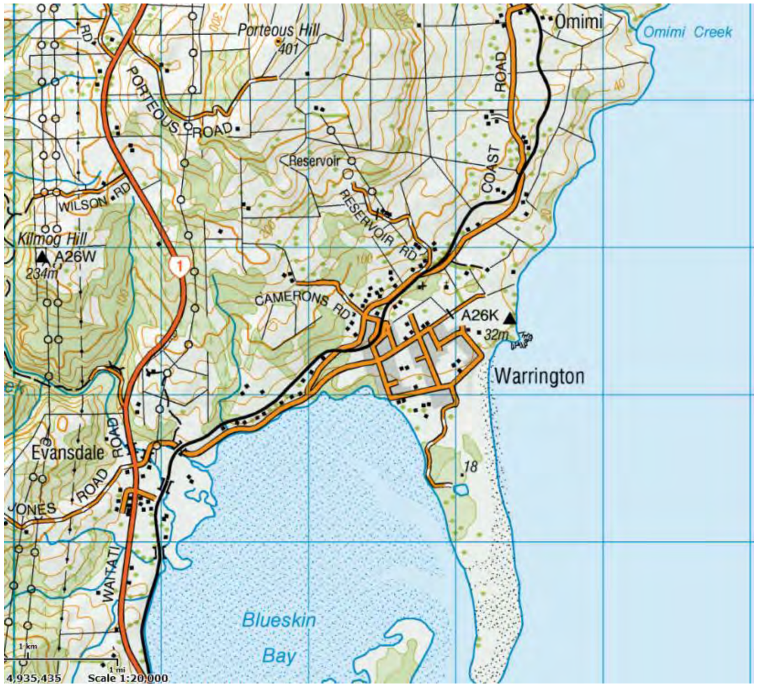

Figure 13. Topography of Warrington, Evansdale and the surrounding area

Figure 14. View of Evansdale from SH1, looking south (Source: Google Maps)

Assessment of risk

The overall exposure of the Warrington and Evansdale communities to natural hazards is currently relatively low, due to the small population, and because most development has occurred on land which is moderately elevated - beyond the normal influence of the sea, and outside the area most affected by land instability. The risk to the community could increase however, if additional development occurred in lower-lying areas or on steeper slopes to the north of Warrington.

Characteristics of mapped natural hazard areas in Warrington and Evansdale

The location and topography of these communities expose them to two broad types of hazard; inundation (either from the sea, or from heavy rainfall / flood events), and land instability (including coastal erosion, landslides, and the effects of seismic shaking). The characteristics and effects of these hazards are described below. Mapped hazard areas are shown in Figure 15, along with other areas which play an important role in protecting these coastal communities.

❖ Direct Inundation from the Pacific Ocean

The elevation of Warrington means that storm surge is unlikely to affect residential parts of the township (there are only 2-3 houses situated on land which is less than 6m above msl). Although Evansdale is protected to some extent by the Warrington sand spit, parts of the community are low-lying, and are vulnerable to extreme tides, storm surge and tsunami. The effects of these events (including velocity, depth and duration) could create a threat to life/safety, result in damage to buildings, and would create difficulties when evacuating people. These effects are likely to be greatest in areas which are low-lying, and/or immediately adjacent to the ocean.

Area A: Land which is below the height identified as the 1:100 year storm surge level (Table 1). This area is also vulnerable to tsunami, and inundation resulting from high flows in Careys Creek. As sea level rises, the likelihood that inundation resulting from these hazards will reach a level where it can affect people and assets in this area will increase.

Area B: Land which is below the combined height of the 1:100 year storm surge level, and an additional 1m (as described in Part 1 and listed in Table 1). Although higher than Area A, this area currently still has some vulnerability to high magnitude, low frequency tsunami, storm surge, and flood events. As sea level rises, the likelihood that inundation resulting from these hazards will reach a level where it can affect people and assets in this area will increase.

Beyond Area B: High magnitude, low frequency events (as described in Table 2) may affect land which is higher than that mapped as Area B, irrespective of sea-level rise. Although such events may occur rarely, they could affect much of the alluvial fan area which forms the floodplain of Careys Creek, and much of the Warrington sand spit. The actual extent of inundation (along with other characteristics such as velocity and depth) during the largest credible tsunami events are not possible to map accurately, given the current level of information available.

❖ Other Natural Hazards

Flood and alluvial fan hazard: The low-lying area around Evansdale can be affected by flood events in Careys Creek (ORC, 2009a), and the current channel location is mapped as 'Flood Hazard' in Figure 15. The channel lies within a wider floodplain, which has been mapped as a floodwater-dominated alluvial fan (Barrell et.al 1998, Opus 2009), and has been subject to active floodwater dominated alluvial fan activity in the past. During extreme rainfall events, the velocity and depth of water draining the upper catchment can carry sediment and debris. The velocity of these flood flows will decrease as they arrive on the flatter, low-lying floodplain, causing entrained sediment and debris to be deposited. The deposition of sediment (usually fine silts and sands) can alter the form of the fan surface, and may affect roads and buildings. Material entrained in floodwaters can cause additional damage to buildings and other assets (i.e. beyond that of flooding due to water only.

Seismic hazard: Ground shaking at Warrington with a return period of 100 years is likely to result in ground shaking which would displace objects and crack large windows (Opus 2005). The maximum intensity ground shaking modelled by Opus (2005) for Warrington is associated with a magnitude 7 earthquake on the Akatore Fault. This would likely make it difficult for people to stand, and would cause moderate damage to chimneys and un-reinforced stone and brick walls.

Ground subsidence or liquefaction as a result of seismic shaking has the potential to damage roads, power lines, underground pipes and building foundations. GNS (2014b) describes the hazard associated with liquefaction in the Warrington area further. The lower reaches of Careys Creek and the sand spit to the south of Warrington are identified as being composed of materials which have a moderate to high likelihood of being susceptible to liquefaction. Landslide activity on the hills above Warrington and Evansdale may also be initiated or re-commence due to seismic shaking.

Landslides: The most prominent natural hazard affecting the Warrington area is land instability, in the form of landslides. Like most of the coastal hills of the area, a thin loess cover overlies basalt and alluvial conglomerates that were weathered from the volcanic rock. Even on low-angle slopes (10-20 degrees) these conditions have led to a number of landslides, and mapping by GNS, 2014a shows the slopes of Porteous Hill as far down as Coast Road (Figure 13) being affected. Landslides in the area tend to be triggered by heavy or prolonged rainfall and seismic shaking.

The Coastal Scenic Highway and South Island main trunk line are constantly being displaced at a number of locations and have to be realigned regularly (GNS, 2014a). Future movement is likely to continue to be very slow, and while failure will not have catastrophic effects on infrastructure, ongoing damage is likely. The majority of landslides in this area are considered very sensitive to environmental or human-induced modifications which may result in reactivation.

GNS (2014a) describes the hazard associated with mapped landslides in the Warrington area further.

❖ Other Coastal Areas

Sand spit: The Warrington sand spit, which acts as a buffer to protect against the effects of erosion and direct inundation from the sea. Activities that disturb the form of this sand spit and its vegetation cover (such as excavation or the removal of vegetation) may compromise it natural buffering ability. Changes in the morphology of the sand spit may also influence how storm surge and tsunami events affect the Evansdale area in the future. The line of the vegetated foredune at the northern end of the sand spit (closest to Warrington) moved seaward by up to 230m between 1958 and 2013 (Figure 16). This is likely to have increased the buffering effect this feature would have against coastal hazards, for communities on the margins of Blueskin Bay.

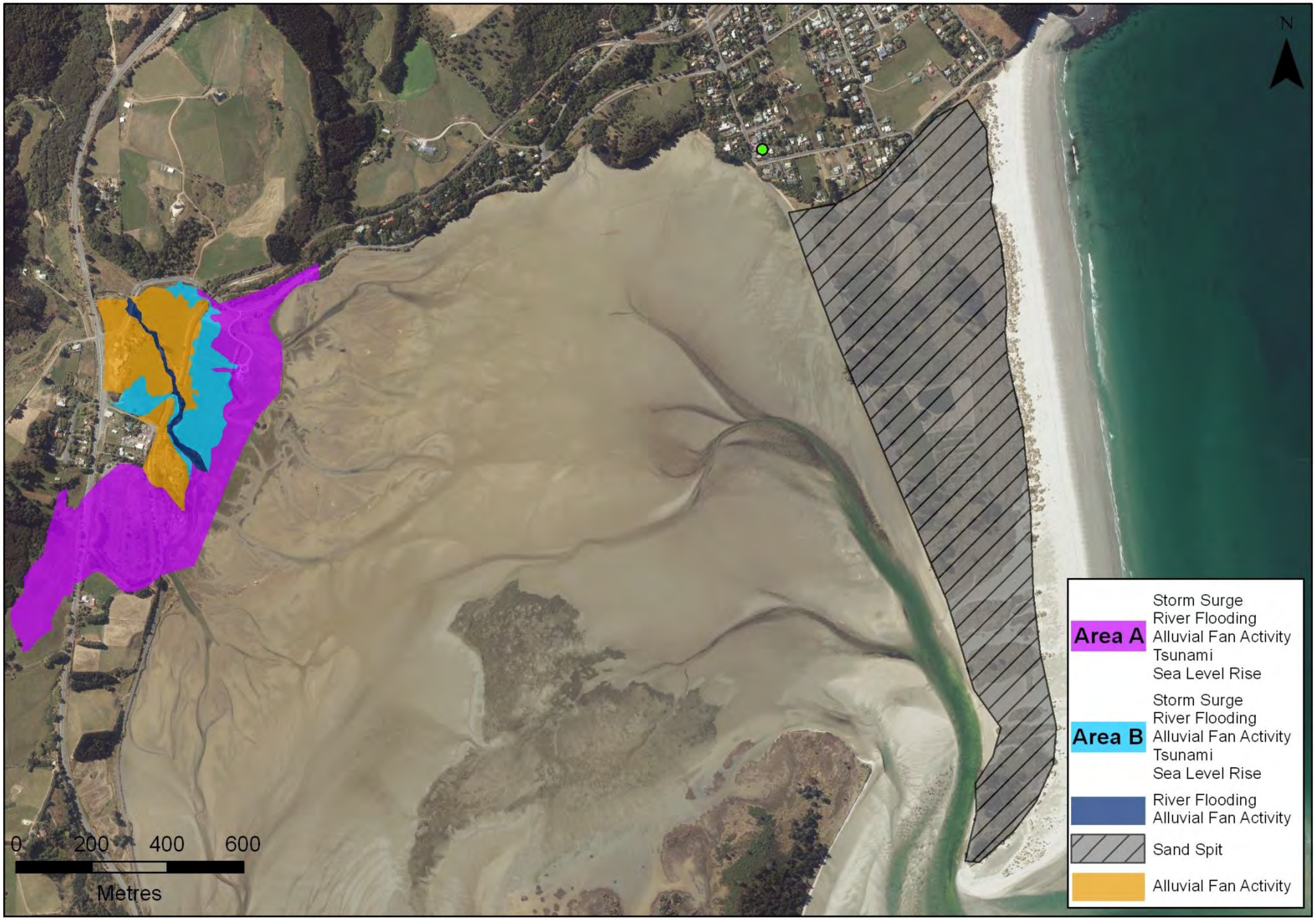

Figure 15. Mapped natural hazard areas in Warrington and Evansdale

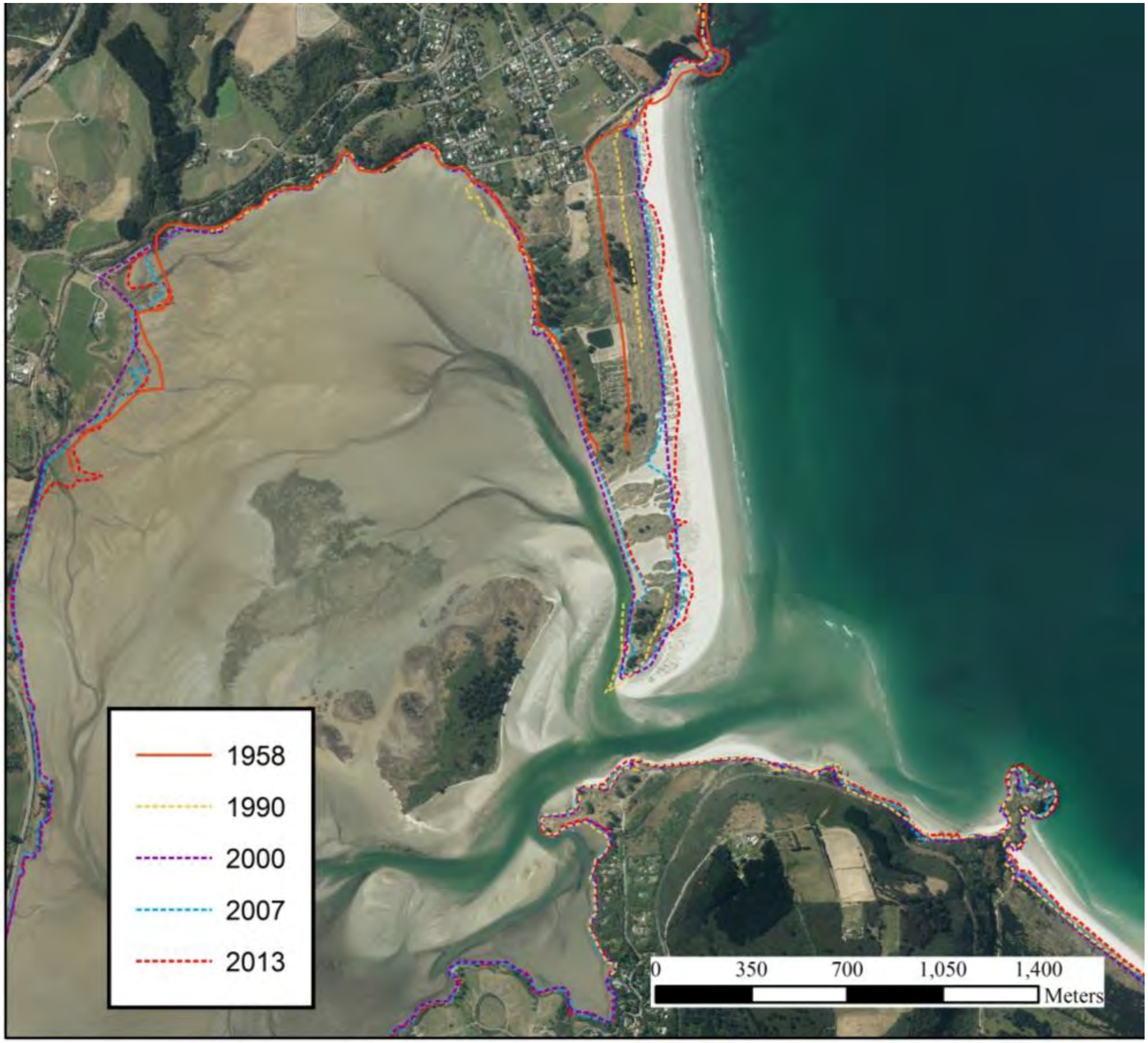

Figure 16. Changes in the northern Blueskin Bay coastline between 1958 and 2013, overlaid on an aerial photograph collected in 2013 (Source: DCC)

Karitane

Setting

Karitane is located on the southern (true right) bank of the Waikouaiti River, stretching from the mouth to 2.5km upstream (Figure 17). A narrow (100 – 200m wide) sand spit separates the lower reaches of the river from the open coast. The southern part of Karitane lies at the base of the Huriawa headland, where the Waikouaiti River is diverted sharply to the east as it enters the Pacific Ocean. The town is exposed to the open coast on its southern side (from Roneval Street, along the coast to the southwest).

Most of Karitane has been built on land which is elevated 8m or more above msl, with the exception of the low-lying isthmus that connects the Huriawa headland to the mainland, and parts of Stornoway Street.

Figure 17. Aerial photograph of Karitane (dated 2006), showing main features of the town and surrounding area

Karitane had a population of 360 at the time of the 2013 Census, compared to 348 in 2006 and 399 in 2001. Approximately half of the dwellings are permanently occupied, and the town is a popular holiday retreat (Statistics NZ, 2013). The settlement has a primary school and a number of small businesses.

Previous flood events in the Waikouaiti River:

The Waikouaiti catchment covers an area of 425km^2 and surrounding peaks range in elevation from 400-700m (ORC, 2008b). Large flood events in this catchment are relatively infrequent, but when they do occur, can have a significant effect on development located on the lower floodplain, including parts of Karitane. The low gradient of the river and the minimal elevation of the floodplain area cause flood flows to spill across a wide area, inundating farmland, residential dwellings and parts of SH1.

The largest flood in recent history was that in June 1980 and Figure 18 shows the extent of floodwaters during this event. The depth, velocity and duration of inundation across this flood hazard area will vary, but floodwaters have the potential to damage buildings and pose a risk to life/safety (Figure 19). Localised effects due to surface runoff from the hills to the south, including re-mobilisation and deposition of sediment, can also occur.

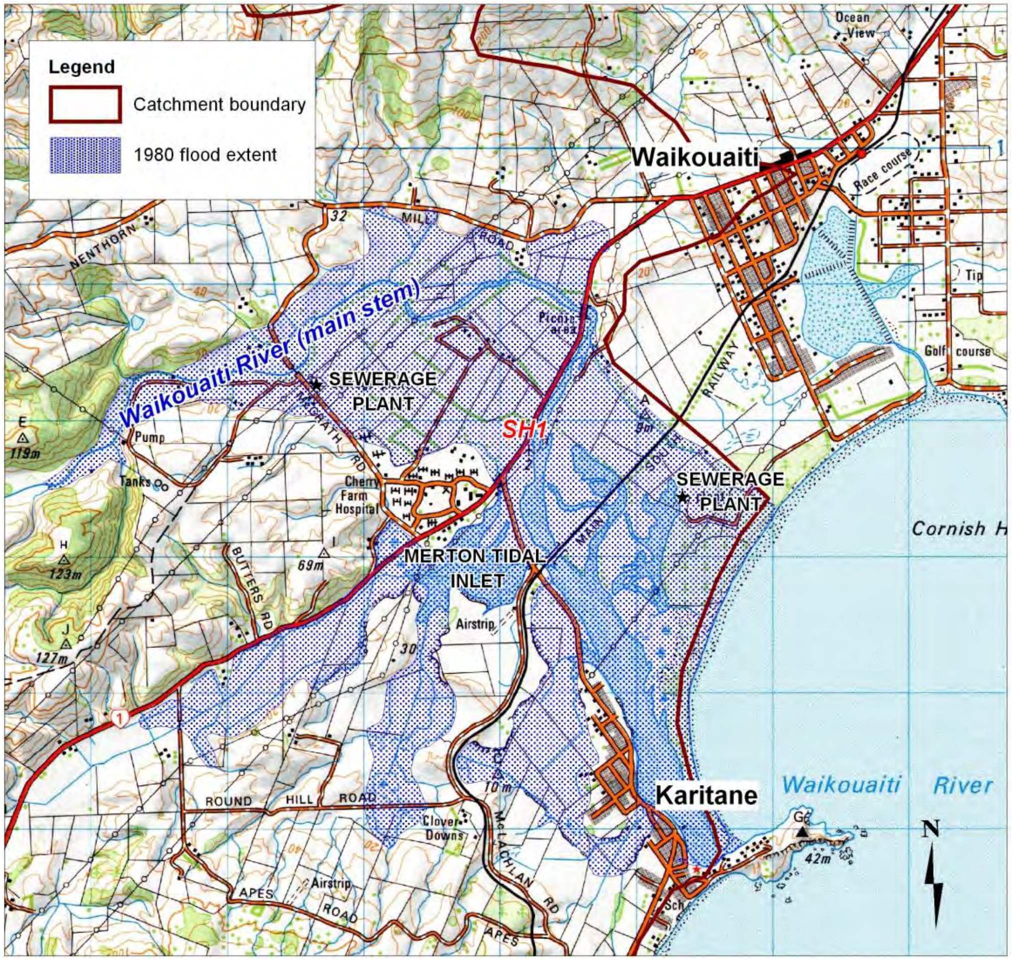

Figure 18. Extent of flooding on the Waikouaiti River during the largest event in recent history, in June 1980 (Source: ORC, 2008b)

 

Figure 19. Images taken during the June 1980 flood. Karitane church and adjacent house on Stornoway Street (left), and Coast Road (right).

A secondary flow path of the Waikouaiti River carries flow to the west of Karitane during flood events, re-entering the main channel at Stornoway Street and creating a temporary 'island' upon which the northern half of the settlement has been built (Figure 20).

The lower 5 km of the Waikouaiti River is influenced by the tide under low-flow conditions, and when high water levels in the river coincide with elevated sea levels at the coast, the extent, depth and duration of inundation in Karitane may be exacerbated (Figure 20).

Figure 20. View of Karitane, Waikouaiti Beach and the lower Waikouaiti River floodplain, at a flow of approximately 450m^3/s at 11am on 17 July 2013. The river peaked at 512m^3/s earlier in the day, a flow which has an estimated return period of between 10 and 15 years (ORC, 2008b). Stornoway Street (where a secondary flow path re-enters the Waikouaiti River) is at centre-left of the image.

Assessment of risk

The overall exposure of the Karitane community to natural hazards is currently relatively low, as most development has occurred on land which is moderately elevated - beyond the normal influence of the sea or the Waikouaiti River, and outside the area most likely to be affected by land instability. The risk to the community could increase however, if additional development occurred in lower-lying areas.

Characteristics of mapped natural hazards areas in Karitane

Karitane and the surrounding area is subject to natural coastal and river processes, and the interaction of these during storm events can influence the depth and extent of inundation, water velocity and sedimentation. The settlement is predominantly built on Late Pleistocene shoreline deposits, consisting of weathered sand with pebbles and shells overlain by loess (GNS, 2001). The lower-lying land (which has generally not been settled, and forms the wider floodplain) consists of more recent Holocene river deposits of gravel, sand and mud. The area is therefore subject to land instability (including coastal erosion, sedimentation during flood events, and the effects of seismic shaking, including liquefaction and subsidence). The characteristics and effects of these hazards are described broadly below, and have been used to map the hazard areas in Figure 21.

❖ Direct Inundation from the Pacific Ocean

Two categories of lower-lying land have been identified using the methodology outlined in Part 1 of this report. These are described below, and shown in Figure 21. The overall effects of direct inundation from the Pacific Ocean (including velocity, depth and duration) may create a threat to life/safety, could result in damage to buildings, and would create difficulties when evacuating people. These effects are likely to be greatest in areas which are low-lying, and/or immediately adjacent to the ocean. It is noted that the Waikouaiti River mouth provides a passage through which storm waves and elevated sea levels can move into the lower reaches of the estuary.

Area A: Land which is below the height identified as the 1:100 year storm surge level (Table 1). This area is also vulnerable to other coastal hazards such as tsunami and coastal erosion, and inundation resulting from heavy rainfall events and high flows in the Waikouaiti River. As sea level rises, the likelihood that inundation resulting from these hazards will reach a level where it can affect people and assets in this area will increase.

Area B: Land which is below the combined height of the 1:100 year storm surge level, and an additional 1m (as described in the introduction, and listed in Table 1). Although higher than Area A, this area currently has some vulnerability to high magnitude, low frequency tsunami, storm surge, and flood events. As sea level rises, the likelihood that inundation resulting from these hazards will reach a level where it can affect people and assets in this area will increase.

Beyond Area B: High magnitude, low frequency storm surge and tsunami events (as described in Table 2) may affect land which is higher than that mapped as Area B, irrespective of sea-level rise. Events such as these would affect much of the lower Waikouaiti River floodplain, and could also affect land adjacent to Karitane's south beach. The actual extent of inundation (along with other characteristics such as velocity and depth) during the largest credible tsunami events are not possible to map accurately, given the current level of information available.

Apart from a small number of houses located on the isthmus connecting the Huriawa headland to the mainland, most residential properties within Karitane are outside of Areas A and B. However, the northern part of the town would likely become isolated during a 1:100 year storm surge event (particularly if the Waikouaiti River was also high), and access to the north would be affected by inundation and erosion of local roads and bridges.

❖ Other Natural Hazards

Flood hazard: Land which is vulnerable to river flooding, as well as storm surge and tsunami, or a combination of these hazards. The flood hazard area shown in Figure 21 is derived from ORC (2008b). The depth, velocity and duration of inundation across this area will vary, but floodwaters have the potential to damage buildings, pose a risk to life/safety (Figure 19), and create difficulties when evacuating people. Localised effects due to surface runoff from the hills to the south, including re-mobilisation and deposition of sediment, can also occur.

Some of the land mapped within the 'Flood Hazard' area on Figure 21 is also vulnerable to direct inundation from the Pacific Ocean, as it lies below the 1:100 year storm surge level. The effects of inundation are likely to be exacerbated by sea-level rise. Any buildings in this area may exacerbate the hazard associated with flood or coastal hazard events, by contributing debris, or by restricting, amplifying or re-directing the flow of water.

Alluvial fan hazard: The southern part of Karitane is exposed to alluvial fan hazard, as mapped by Barrell *et al.* (1998), and shown in Figure 21. During extreme rainfall events, this active alluvial fan can convey sediment from the hill catchments to the south towards Karitane. The velocity of these flood flows will decrease as they approach the Waikouaiti River floodplain, causing entrained sediment and debris to be deposited. The deposition of large volumes of sediment can alter the form of the fan surface, affect roads and buildings, and may interact with high flows in the Waikouaiti River.

Land instability: A landslide feature to the south of Karitane at Puketeraki has a history of ongoing movement, and is considered very sensitive to environmental or human-induced modifications which may result in reactivation. GNS (2014a) describes the hazard associated with landslides in the Karitane area further.

Seismic hazard: Ground shaking at Karitane with a return period of 100 years is likely to result in ground shaking which would displace objects and crack large windows (Opus 2005). The maximum intensity ground shaking modelled by Opus (2005) for Karitane is associated with a magnitude 7 earthquake on the Akatore Fault. This would likely make it difficult for people to stand, and would cause moderate damage to chimneys and un-reinforced stone and brick walls.

In addition to the effects of ground shaking, the presence of unconsolidated sediment (silts and sands) mean the land in and around Karitane is susceptible to subsidence and liquefaction during earthquakes. Ground subsidence or liquefaction has the potential to damage roads, power lines, underground pipes and building foundations.

GNS (2014b) describes the hazard associated with liquefaction in the Karitane area.

❖ Other Coastal Areas

Sand spit: The narrow sand spit to the east of the Waikouaiti River currently provides some protection for Karitane from the effects of breaking waves (Figure 20 and Figure 22). However the low elevation and unconsolidated sand which makes up this barrier means seawater may erode or overtop the spit during storm surge or tsunami events, increasing the potential for storm waves to affect the shoreline on the southern margin of the estuary. Changes to the coastline between 1958 and 2013 are illustrated in Figure 23. The most significant changes during this time occurred at the mouth of Waikouaiti River, with erosion occurring at the southern tip of the sand spit. Activities that disturb the natural form of the spit (such as excavation or the placement of structures) or its vegetation cover may compromise its stability.

Figure 21. Mapped natural hazard areas in the vicinity of Karitane, and at the mouth of the Waikouaiti River (inset)


Figure 22. Mouth of the Waikouaiti River, showing the sand spit which separates the river and town from the coast (December 2013)

Figure 23. Changes in the Karitane coastline between 1958 and 2013, overlaid on an aerial photograph collected in 2013 (Source: DCC)

Waikouaiti

Setting

The town of Waikouaiti is located at the northern end of the unnamed bay which lies between Cornish Head and the Huriawa headland, and approximately 3km north of the Waikouaiti River Mouth (Figure 24).[2] The town is bordered by a flat, relatively low-lying terrace and the Waikouaiti River to the west, and the Hawksbury Lagoon to the east. A causeway and a series of culverts separate the western part of this lagoon from the uncontrolled eastern portion (which has a direct connection to the Pacific Ocean via the outlet) (Wildland Consultants, 2009). These structures may influence the effects of storm surge, tsunami or flood events, although this has not been modelled as part of this report.

A 300-400m wide strip of raised Holocene sand deposits, 2-5m high, separate the town from the coastline, with a narrow outlet linking the south-east corner of the Hawksbury lagoon to the open coast.

At the time of the 2013 census, about 1,122 people lived in Waikouaiti (up slightly from 1,095 in 2006), and roughly a third of those live within 1.2km of the coast (ORC, 2012a). Most of the dwellings (approximately 85%) are permanently occupied (Statistics NZ, 2013).

Figure 24. Topography of Waikouaiti, Karitane and the surrounding area

The dwellings situated closest to the shoreline are located at the southern end of Beach Street, and also on Stewart Street, some 350m back from the beach. Stewart Street is the lowest-lying part of the town, with residential properties situated on land that is less than 2m above msl. The rest of Waikouaiti lies further back from the ocean on land that is at least 5m above msl.

Assessment of risk

Although Waikouaiti is one of the larger settlements situated along the coastline of the Dunedin district, most of the township is sufficiently elevated, and set back from the current shoreline, so as to have a relatively low vulnerability to natural hazards. The

[2] The town is sufficiently elevated not to be affected by flood flows in the Waikouaiti River (ORC, 1993).

relatively slow rate of population growth also means that there has been limited demand for intensive development on more hazard-prone land.

However, parts of the town are vulnerable to a range of hazards (as described below), and are vulnerable to the effects of climate change, through increasing sea level and the potential for larger, and more frequent heavy rainfall events. Any increase in the level of development in these areas will add to the risk associated with natural hazards.

Characteristics of mapped hazard areas in Waikouaiti

The location and topography of Waikouaiti expose it to two broad types of hazards: inundation (either from the sea or as a result of heavy rainfall events), and land instability (including coastal erosion and the effects of seismic shaking, including liquefaction). Changes in climate and sea-level rise over the next 100 years will likely accentuate the effects of inundation and coastal erosion. The characteristics and effects of these hazards are described below, and these have been used to map the hazard areas shown in Figure 25.

❖ Direct Inundation from the Pacific Ocean

Two categories of lower-lying land have been identified using the methodology outlined in Part 1 of this report. These are described below, and shown in Figure 25. The overall effects of direct inundation from the Pacific Ocean (including velocity, depth and duration) may create a threat to life/safety, could result in damage to buildings, and would create difficulties when evacuating people. These effects are likely to be greatest in areas which are low-lying, and/or immediately adjacent to the ocean.

Area A: Land which is below the height identified as the 1:100 year storm surge level (Table 1). This area may also be vulnerable to other coastal hazards such as tsunami, and inundation resulting from heavy rainfall events and high water levels in the Hawksbury Lagoon. As sea level rises, the likelihood that inundation resulting from these hazards will reach a level where it can affect people and assets in this area will increase.

Area B: Land which is below the combined height of the 1:100 year storm surge level, and an additional 1m (as described in Part 1 of this report, and listed in Table 1). Although higher than Area A, this area currently has some vulnerability to high magnitude, low frequency tsunami, storm surge, and flood events. As sea level rises, the likelihood that inundation resulting from these hazards will reach a level where it can affect people and assets in this area will increase.

Beyond Area B: High magnitude, low frequency events (as described in Table 2) may affect land which is higher than that mapped as Area B, irrespective of sea-level rise. Although such events may occur rarely, they could affect much of the raised coastal terrace that lies between Waikouaiti and the coast, and the margins of the Hawksbury Lagoon. The actual extent of inundation (along with other characteristics such as velocity and depth) during the largest credible tsunami events are not possible to map accurately, given the current level of information available.

❖ Other Natural Hazards

Flood hazard: The Office Creek catchment upstream of SH1 and the area around the racecourse is low-lying relative to the surrounding area, and is therefore vulnerable to the effects of flooding and sedimentation (Figure 25 and Figure 27). The velocity of flood water in this area would generally not be high. However, the overall effects of inundation (including frequency, duration and depth) would result in damage to buildings, and create difficulties and stress when evacuating people.

The outlet of the Hawksbury Lagoon is also mapped as a flood hazard area, and the ability of floodwaters to drain through this outlet can be affected by conditions at the mouth. The morphology of this outlet also plays a role in determining the level of inundation further inland, due to coastal storm surge and tsunami events.

Alluvial fan hazard: During times of very heavy rainfall, ephemeral streams and overland flow may convey entrained sediment (generally fine silts and sands) from the surrounding hills to the low-lying floodplain beside Waikouaiti. A number of composite alluvial fans are mapped to the north and east of Waikouaiti (Opus, 2009). The deposition of this sediment on the lower slopes may influence runoff patterns, and affect assets such as roads and buildings

Landslide hazard: A report by GNS (2014a) shows that much of Waikouaiti is located on a feature which is a possible landslide. Any landslide activity which may have occurred in this location is thought to be old (more than 12,000 years ago), and the likelihood of this feature moving further as a result of environmental and/or human induced modifications is also thought to be very low.

Seismic hazard: Ground shaking at Waikouaiti with a return period of 100 years is likely to displace objects and crack large windows (Opus 2005). The maximum intensity ground shaking modelled by Opus (2005) for Waikouaiti is associated with a magnitude 7 earthquake on the Akatore Fault. This would likely make it difficult for people to stand, and would cause moderate damage to chimneys and un-reinforced stone and brick walls.

In addition to the effects of ground shaking, unconsolidated sediment (silts and sands) and a shallow water table means that some land on the margins of Waikouaiti is susceptible to subsidence, liquefaction and lateral spreading during earthquakes. These processes have the potential to damage roads, power lines, underground pipes and building foundations.

GNS (2014b) describes the hazard associated with liquefaction in the Waikouaiti area further. The low-lying area to the north-east corner of the town, and the coastal terrace to the south are identified as being composed of materials which have a moderate to high likelihood of being susceptible to liquefaction.

❖ Other Coastal Areas

Raised coastal terrace: A raised coastal terrace and dune system is mapped on Figure 25. This acts as a buffer to protect lower-lying areas further inland against the effects of erosion and direct inundation from the sea. Activities that disturb the form of this foreshore area and its vegetation cover (such as excavation or the removal of vegetation) may compromise its stability. This buffer area may be affected by future changes in sea level or large storm events. Changes to the coastline between 1958 and 2013 are illustrated in Figure 28, and this shows limited (but consistent) erosion of the vegetation line, by up to 34m, at the north-eastern end of the beach over this time. Evidence of recent erosion at this location is shown in Figure 26

In addition, the erosive power of breaking waves (generated by either a storm surge or tsunami event), combined with long-term shoreline retreat and sea-level rise, may mean that the 'buffering' capacity of the raised coastal terrace is reduced over time.

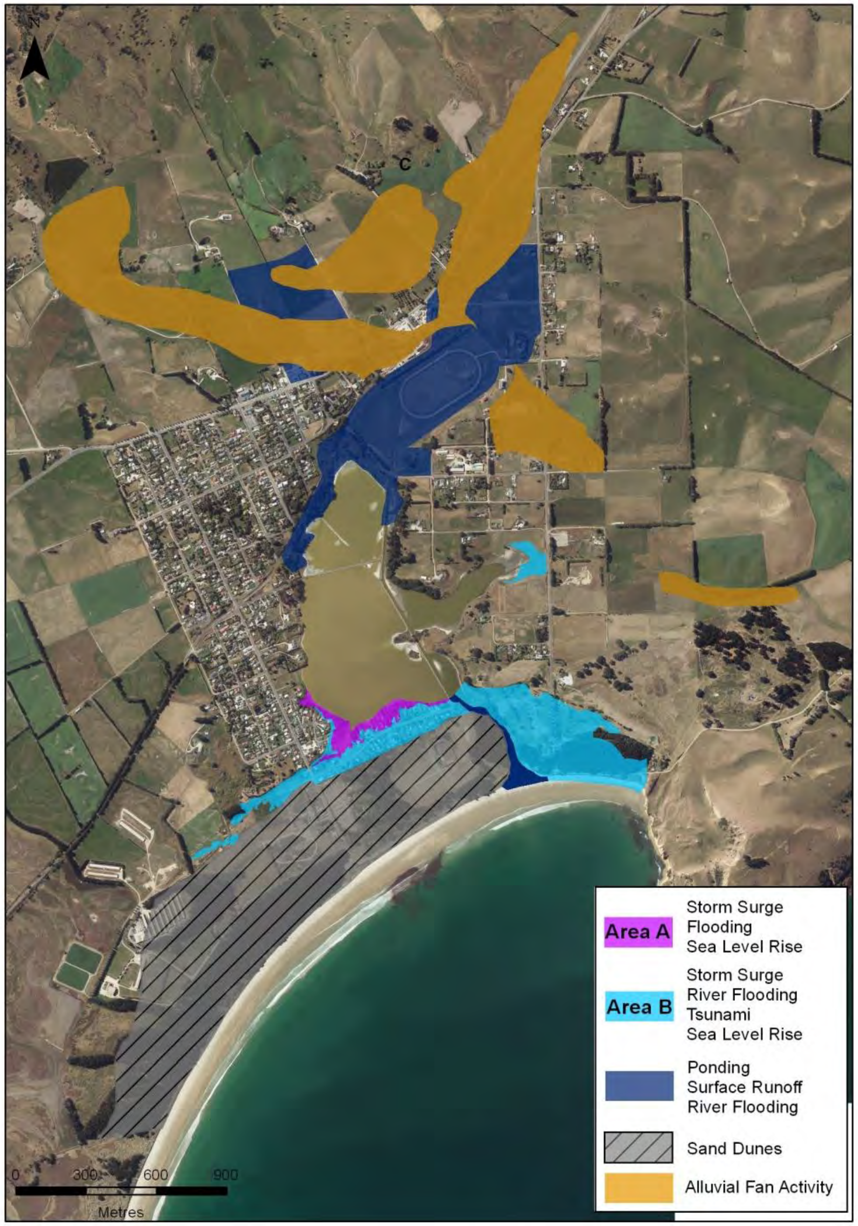

Figure 25. Mapped natural hazard areas in the Waikouaiti area

Figure 26. Evidence of recent erosion of Holocene beach deposits at the north-eastern end of Waikouaiti Beach, alongside Matanaka Drive (December 2013)

Figure 27. Surface flooding at the north-eastern corner of Waikouaiti, following a prolonged rainfall event in August 2012. The Hawksbury Lagoon can be seen to the right of the image, and the Waikouaiti racecourse is to the left.

Figure 28. Changes in the Waikouaiti coastline between 1958 and 2013, overlaid on an aerial photograph collected in 2013 (Source: DCC)

Pleasant River mouth

Setting

The Pleasant River catchment has an area of 130km^2 and varies in altitude from 616m above msl (Mt Watkin) to sea level (ORC, 1993). Below Goodwood and State Highway 1 the channel opens out onto tidal estuarine mudflats which extend for about 3km along the river for a width of 300m (Figure 29).

Only the lower part of the Pleasant River catchment lies within the Dunedin City District, with the remainder lying within the Waitaki District. Currently there is no development on the mapped hazard areas shown on Figure 30.

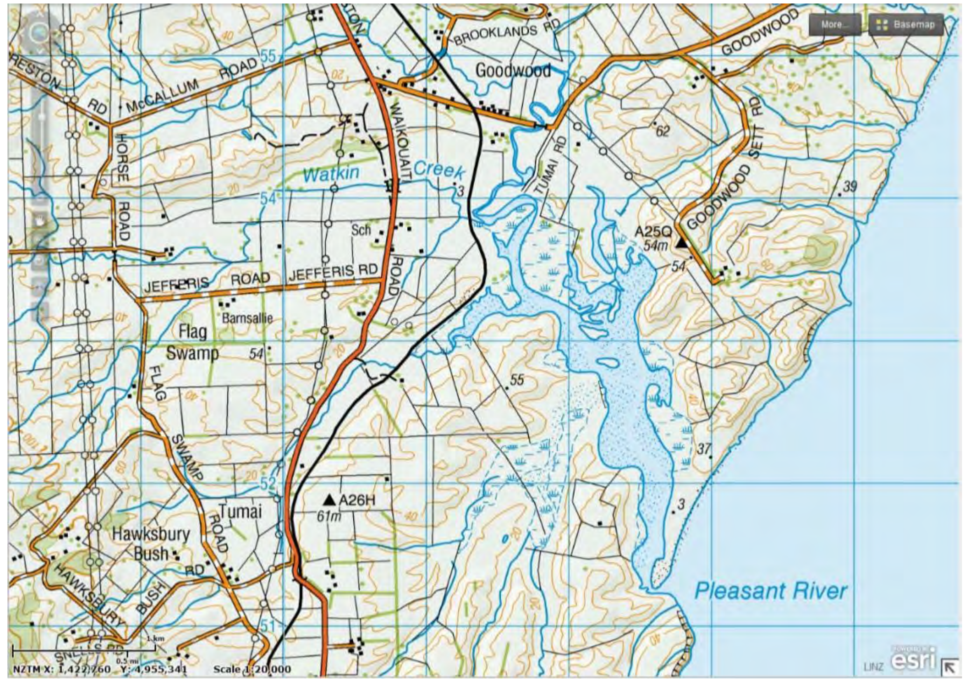

Figure 29. Topography of the lower Pleasant River catchment, including Goodwood

Characteristics of mapped hazard areas in the lower reaches of the Pleasant River

❖ Low-lying land

Lower-lying land around the margins of the Pleasant River estuary has been mapped and is shown in Figure 30.

Area A: Land which is below the height identified as the 1:100 year storm surge level for Waikouaiti (Table 1). This area may also be vulnerable to inundation during tsunami events (GNS, 2013). As sea level rises, the likelihood that inundation resulting from these hazards will reach a level where it can affect people and assets in this area will increase.

Area B: Land which is below the combined height of the 1:100 year storm surge level for Waikouaiti, and an additional 1m (as described in the introduction, and listed in Table 1). Although higher than Area A, this area currently has some vulnerability to high magnitude, low frequency storm surge and tsunami events. As sea level rises, the likelihood that inundation resulting from these hazards will reach a level where it can affect people and assets in this area will increase.

Floodplain: The accurate topographic data (LiDAR) used to map Areas A and B only extends 2km upstream of the mouth, and low-lying land upstream of this point could therefore not be mapped using the method outlined in Part 1. Instead, the approximate extent of the low-lying land which may be affected by flooding or storm surge has been mapped using aerial photos collected in 2013, and verified using historical flood photos and field observations. This is mapped on Figure 30 as 'Floodplain', and has been extended for approximately 300m upstream of the Waitaki District / Dunedin City boundary.

- Other Natural Hazards

Seismic hazard: Ground shaking due to remote or nearby earthquake activity could result in subsidence, liquefaction and lateral spreading during earthquakes. These processes have the potential to damage roads, power lines, underground pipes and building foundations. These effects are may be larger where the land is underlain by unconsolidated sediment (silts and sands) and a shallow water table. Opus (2005) identified that the Pleasant River floodplain is 'possibly susceptible' to liquefaction.

- Other Coastal Areas

Sand Spit: A sand spit / dune system is mapped on Figure 30. This acts as a buffer to protect lower-lying areas within the estuary against the effects of direct inundation from the sea. Activities that disturb the form of this foreshore area and its vegetation cover (such as excavation or the removal of vegetation) may compromise its stability. This buffer area may be affected by future changes in sea level or large storm events.

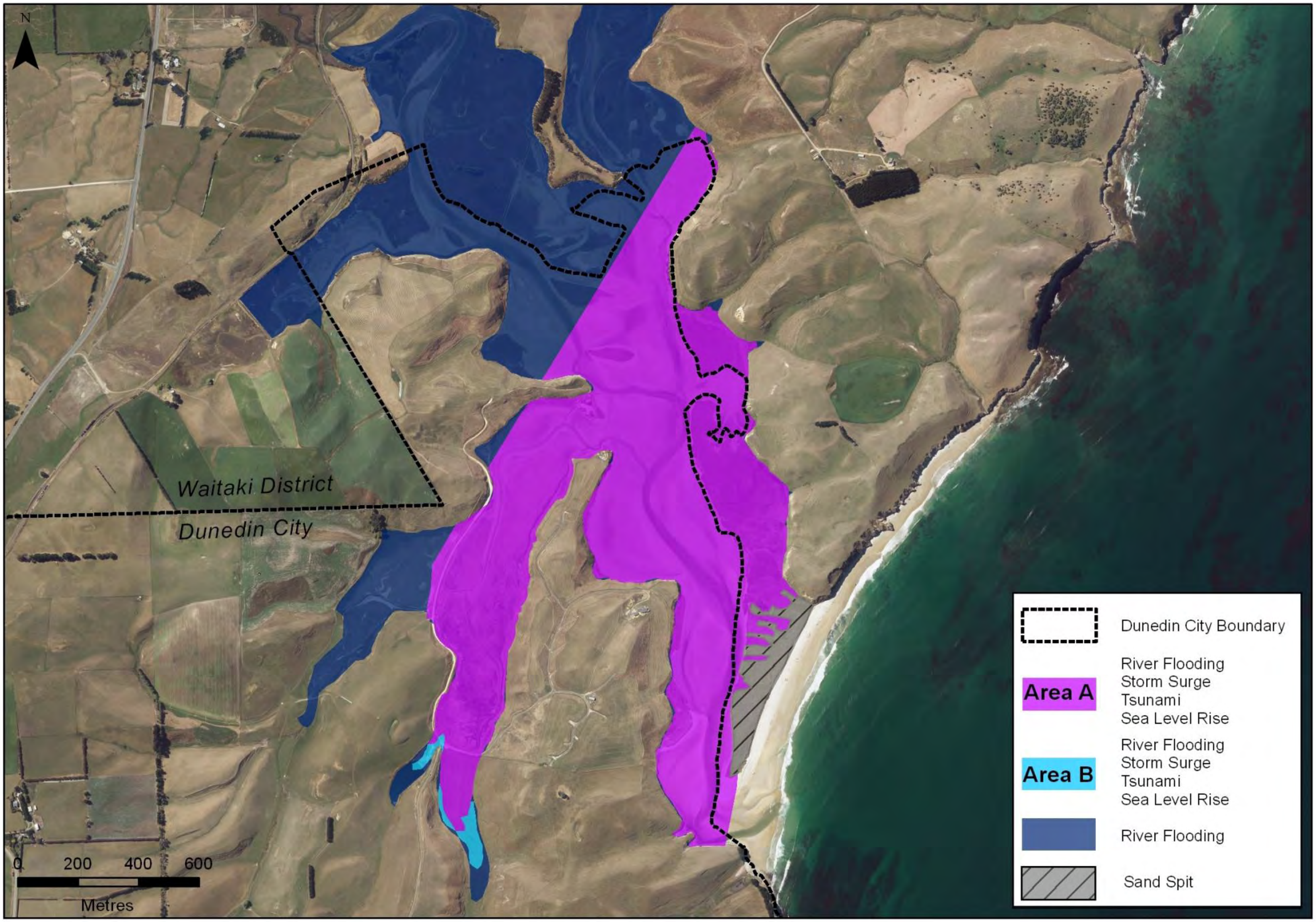

Figure 30. Mapped natural hazard areas in the lower Pleasant River

Figure 31. Inundation of low-lying land adjacent to the lower reaches of the Pleasant River, following a period of heavy rainfall in August 2012

Glossary

Avulsion: The abandonment of a river channel and the establishment of a new channel at a lower elevation on its floodplain as a result of floodplain / channel aggradation.

Holocene: A geological epoch which began at the end of the Pleistocene (at about 11,700 calendar years ago) and continues to the present. The Holocene is part of the Quaternary period.

Pleistocene: The geological epoch which lasted from about 2,588,000 to 11,700 years ago, spanning the world's recent period of repeated glaciations.

Regolith: A layer of loose, heterogeneous material covering solid rock. It includes dust, soil, broken rock, and other related materials.

References

Australian Geographic, March 8, 2012. Floods: 10 of the deadliest in Australian history.

Barrell, D. J. A., McIntosh, P. D., Forsyth, P. J., Litchfield, N. J., Eden, D. N., Glassey, P. J., Brown, L. J., Froggatt, P. C., Morrison, B., Smith Lyttle, B., Turnbull. I. M. 1998. 'Quaternary fans and terraces of coastal Otago, New Zealand' Institute of Geological and Nuclear Sciences science report 98/11.

Bell, 2013. A submission on the proposed Northland Regional Policy Statement. Evidence of Dr. Robert Gordon Bell for Director-General of Conservation.

Dunedin City Council 2009. Dunedin City Residential Capacity Study.

Dunedin City Council 2011a. Climate Change Predictions Policy 201, Corporate Policy, DCC, 6 September 2011

Dunedin City Council, 2011b. Integrated Catchment Management Plan documents. Accessed online at http://www.dunedin.govt.nz/your-council/council-projects/3waters/icmpdocuments

Fitzharris, B. 2010. Climate change impacts on Dunedin. Climate Management Ltd. Unpublished report for Dunedin City Council. March 2010.

GNS Science, 1996. Geology of the Dunedin Area.

GNS Science, 2001. Geology of the Waitaki Area.

GNS Science, 2012. Attributing and reconciling source of landslide data within the Dunedin City Council area. Report prepared for the Otago Regional Council.

GNS Science, 2013. Review of tsunami hazard in New Zealand.

GNS Science 2014a. The hazard significance of landslides in and around Dunedin City. Report prepared for the Otago Regional Council.

GNS Science 2014b. Assessment of liquefaction hazards in the Dunedin City District. Report prepared for the Otago Regional Council.

Hannah, J. and Bell, R.G. 2012 'Regional sea level trends in New Zealand' Journal of Geophysical Research, vol. 117.

IPCC, 2007: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp.

IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

Ministry for the Environment, 2008a. Coastal Hazards and Climate Change. A Guidance Manual for Local Government in New Zealand. 2nd edition. Revised by Ramsay, D, and Bell R. (NIWA). Prepared for Ministry for the Environment.

Ministry for the Environment, 2008b. Preparing for climate change. A guide for local government in New Zealand.

New Zealand Coastal Policy Statement, 2010. Published by the Department of Conservation, P.O. Box 10420, The Terrace, Wellington 6143.

NIWA, 2008. Client Report CHC 2008-047. Otago Regional Council Storm Surge Modelling Study.

NIWA, 2007. Client Report CHC 2007-030. Otago region hazards management investigation: tsunami modelling study.

New Zealand Standard 9401: 2006. Managing Flood Risk – A Process Standard. Standards New Zealand.

Otago Regional Council 1993. Floodplain Management report: Dunedin District – Rural Areas.

Otago Regional Council 2002. Waitaki District Floodplain Report (Draft).

Otago Regional Council 2008a. Te Rauone Beach – Wave, Tide and Current Monitoring. Report to Council 2008/415.

Otago Regional Council 2008b. The Water Resources of the Waikouaiti River.

Otago Regional Council 2009a. The Water Resources of the Waitati River and Careys Creek.

Otago Regional Council 2009b. South Dunedin Groundwater Monitoring – Initial Data November 2009. Report prepared for the Chief Executive ORC.

Otago Regional Council 2012a. Community vulnerability to elevated sea level and coastal tsunami events in Otago.

Otago Regional Council 2012b. 100 year ARI levels for DCC communities. Memorandum prepared in response to a request from Dunedin City Council.

Otago Regional Council 2012c. Milton 2060. Flood Risk Management Strategy for Milton and the Tokomairiro Plain.

Otago Regional Council 2012d. The South Dunedin Coastal Aquifer & Effect of Sea Level Fluctuations.

Otago Regional Council 2013. Natural hazards information for mediation session Nov 15, 2013. File Note prepared for resource consent application SUB 2012-104 and LUC 2012-571.

Otago Regional Council, 2014a. Review of Dunedin City District Plan – Natural Hazards. Project Overview

Otago Regional Council, 2014b. Flood Hazard of the Taieri Plain and Strath Taieri.

Otago Regional Council, 2014c. Flood Hazard of Dunedin's urban streams.

Opus International Consultants 2009. Otago Alluvial Fans Project. Report # 1205 – Version 2, prepared for Otago Regional Council.

Opus International Consultants 2005. Seismic Risk in Otago.

Opus International Consultants 2012. Dunedin 3 Waters Strategy Appendix A: ICMP Summaries, prepared for the Dunedin City Council.

Statistics New Zealand, 2013. 2013 Census population and dwelling map tool. Accessed online January 2013 at http://www.stats.govt.nz/StatsMaps/Home/Maps/2013-census-population-dwelling-map.aspx

Statistics New Zealand, 2006. 2006 Census population and dwelling map tool. Accessed online January 2013 at http://www.stats.govt.nz/StatsMaps/Home/Maps/2006-census-quickstats-about-a-place-map.aspx

Tonkin & Taylor, 2011. Ocean Beach Domain Reserve Management Plan. Coastal issues and options. Report prepared for Dunedin City Council.

Wildland Consultants, 2009. Ecological Management Plan for Hawksbury Lagoon, Waikouaiti.

Appendix 1. Summary of the methods used to map hazard areas for coastal communities

Community	Hazard Area	Methods used to map area
Brighton and Ocean View	A	Land which is below the height identified as the 1:100 year storm surge level for Brighton.
	B	Land which is below the combined height of the 1:100 year storm surge level for Brighton, and an additional 1m.
	Flood	Main channel and floodplain of Otokia and Taylors creeks.
	Raised coastal terrace	Beach platform / dunes that act as a buffer against the effects of erosion and direct inundation from the sea.
Waldronville and Westwood	A	Land which is below the height identified as the 1:100 year storm surge level for Kaikorai.
	B	Land which is below the combined height of the 1:100 year storm surge level for Kaikorai, and an additional 1m.
	Flood	The current extent of the Kaikorai Stream channel and estuary, downstream of the Brighton Road Bridge.
	Raised coastal terrace	Beach platform / dunes that act as a buffer against the effects of erosion and direct inundation from the sea.
South Dunedin and the upper Otago Harbour	A	Land which is below the height identified as the 1:100 year storm surge level for St Kilda / St Clair (South Dunedin). Land which is below the height identified as the 1:100 year storm surge level for the upper Otago Harbour (upper harbour).
	B	Land which is below the combined height of the 1:100 year storm surge level for St Kilda / St Clair, and an additional 1m.
Ocean Grove	A	Land which is below the height identified as the 1:100 year storm surge level for St Kilda / St Clair.
	B	Land which is below the combined height of the 1:100 year storm surge level for St Kilda / St Clair, and an additional 1m.
	Raised coastal terrace	Dunes which act as a buffer against the effects of erosion and direct inundation from the sea
South coast of the Otago Peninsula	A	Land which is below the height identified as the 1:100 year storm surge level for St Kilda / St Clair.
	B	Land which is below the combined height of the 1:100 year storm surge level for St Kilda / St Clair, and an additional 1m.
	Raised coastal terrace	Dunes which act as a buffer against the effects of erosion and direct inundation from the sea.
Mid Harbour	A	Land which is below the height identified as the 1:100 year storm surge level for the upper Otago Harbour.
	B	Land which is below the combined height of the 1:100 year storm surge level for the upper Otago Harbour, and an additional 1m.
Harwood	A	Land which is below the height identified as the 1:100 year storm surge level for Long Beach and Purakanui.

	B	Land which is below the combined height of the 1:100 year storm surge level for Long Beach and Purakanui, and an additional 1m.
Aramoana	A	Land which is below the height identified as the 1:100 year storm surge level for Long Beach.
	B	Land which is below the combined height of the 1:100 year storm surge level for Long Beach, and an additional 1m.
	Sand Dunes / Sand Spit	Beach platform / dunes / Sand Spits that act as a buffer against the effects of erosion and direct inundation from the sea.
	Rockfall	Land subject to rockfall.
Heyward Point to Long Beach	A	Land which is below the height identified as the 1:100 year storm surge level for Long Beach.
	B	Land which is below the combined height of the 1:100 year storm surge level for Long Beach, and an additional 1m.
	Sand Dunes	Beach platform / dunes that act as a buffer against the effects of erosion and direct inundation from the sea.
	Flood	Main channel and floodplain of Drivers Creek and Mabel Creek.
Purakanui	A	Land which is below the height identified as the 1:100 year storm surge level for Purakanui.
	B	Land which is below the combined height of the 1:100 year storm surge level for Purakanui, and an additional 1m.
Waitati	A	Land which is below the height identified as the 1:100 year storm surge level for Warrington.
	B	Land which is below the combined height of the 1:100 year storm surge level for Warrington, and an additional 1m.
	Flood	The current and former channels of the Waitati River. The lower Waitati River floodplain.
	Alluvial fan	Land mapped as an alluvial fan by Opus, 2009.
Warrington and Evansdale	A	Land which is below the height identified as the 1:100 year storm surge level for Warrington.
	B	Land which is below the combined height of the 1:100 year storm surge level for Warrington, and an additional 1m.
	Flood	Main channel and floodplain of Careys Creek.
	Alluvial fan	Land mapped as an alluvial fan by Opus, 2009.
	Sand spit	Sand spit that acts as a buffer against the effects of erosion and direct inundation from the sea.
Karitane	A	Land which is below the height identified as the 1:100 year storm surge level for Karitane.
	B	Land which is below the combined height of the 1:100 year storm surge level for Karitane, and an additional 1m.
	Floodplain	Waikouaiti River main channel and floodplain.
	Alluvial fan	Land mapped as an alluvial fan by Opus, 2009.
	Sand Spit	Sand spit that acts as a buffer against the effects of erosion and direct inundation from the sea.
Waikouaiti	A	Land which is below the height identified as the 1:100 year storm surge level for Karitane.
	B	Land which is below the combined height of the 1:100 year storm surge level for Karitane, and an

		additional 1m.
	Flood hazard	Outlet of the Hawksbury Lagoon.
	Alluvial fan	Lower-lying area, prone to flooding and sedimentation.
	Raised coastal terrace	Beach platform / dunes that act as a buffer against the effects of erosion and direct inundation from the sea.
Pleasant River mouth	A	Land which is below the height identified as the 1:100 year storm surge level for Karitane.
	B	Land which is below the combined height of the 1:100 year storm surge level for Karitane, and an additional 1m.

Appendix 2. Cross-section maps

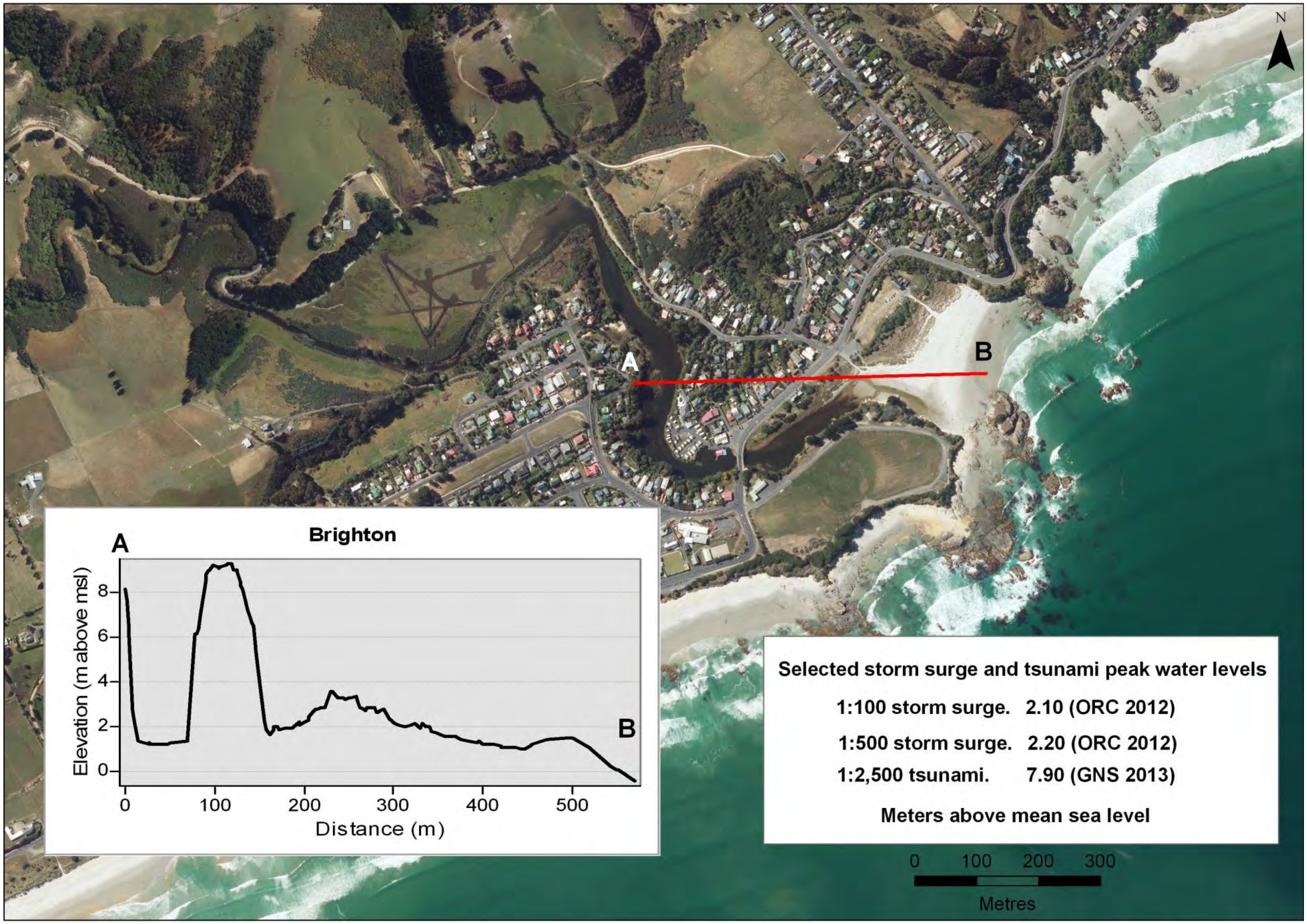

Figure 32. Cross section A-B through Brighton, and peak water levels associated with selected high magnitude storm surge and tsunami events

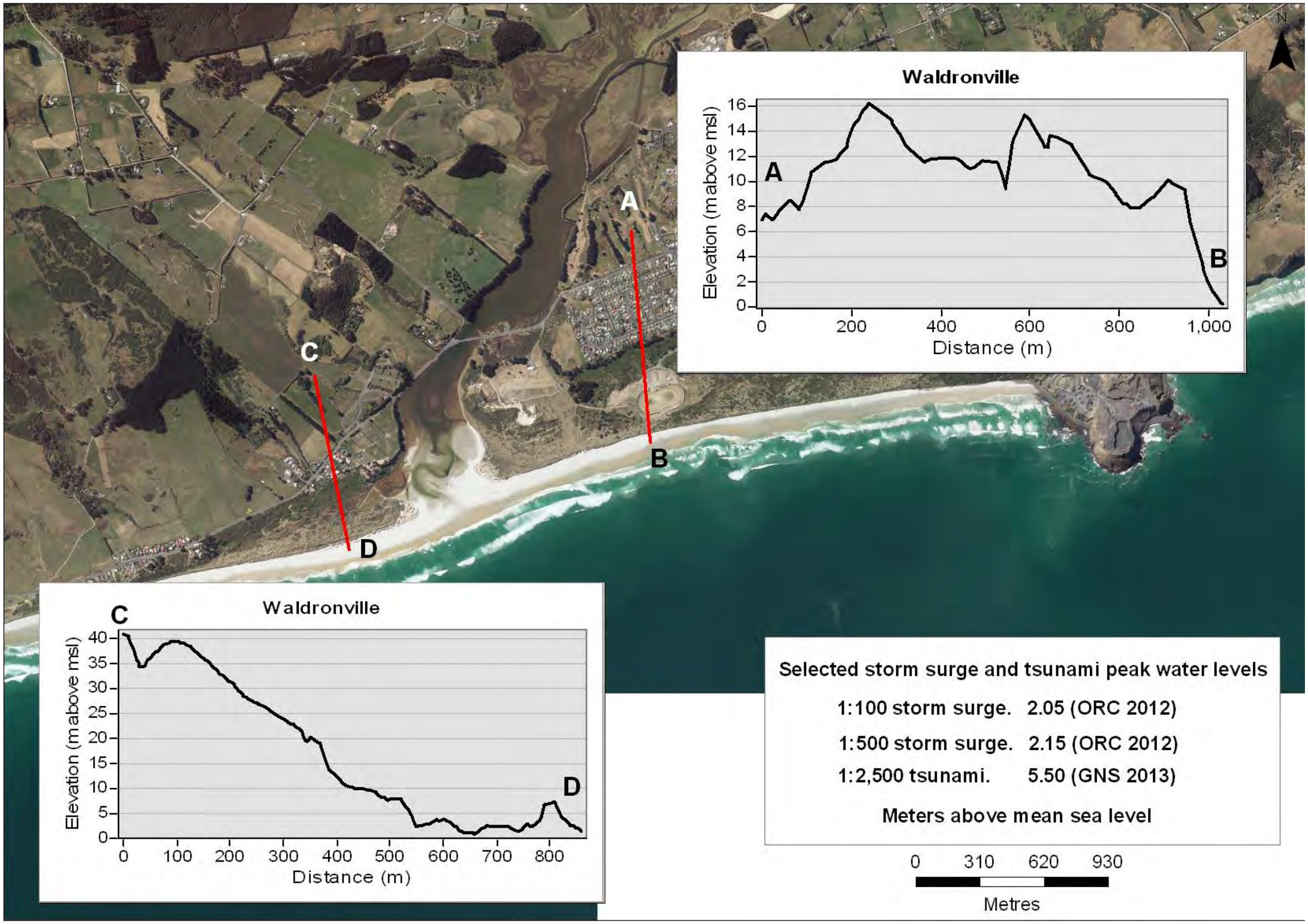

Figure 33. Cross section A-B and C-D through Waldronville, and peak water levels associated with selected high magnitude storm surge and tsunami events

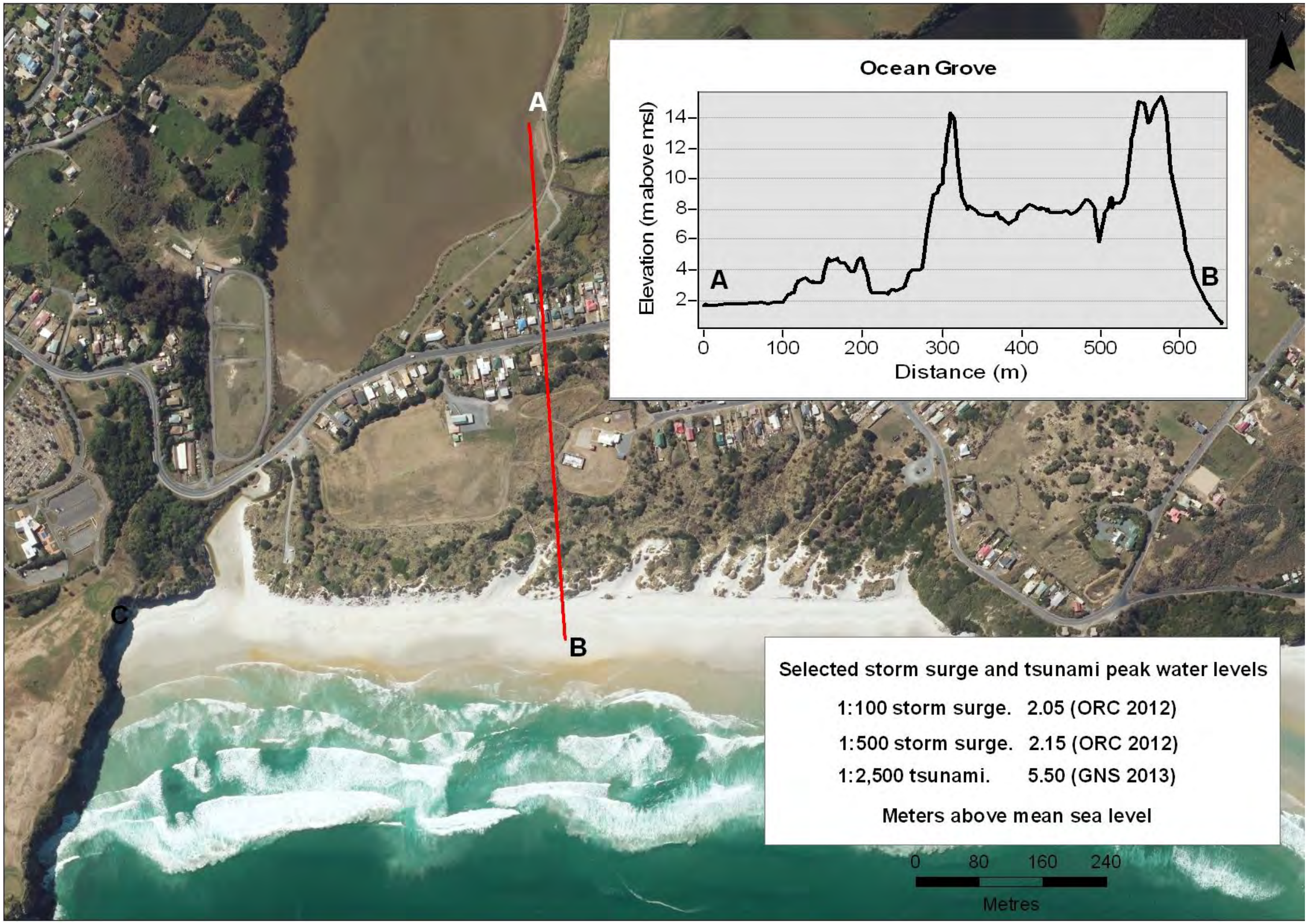

Figure 34. Cross section A-B through Ocean Grove, and peak water levels associated with selected high magnitude storm surge and tsunami events

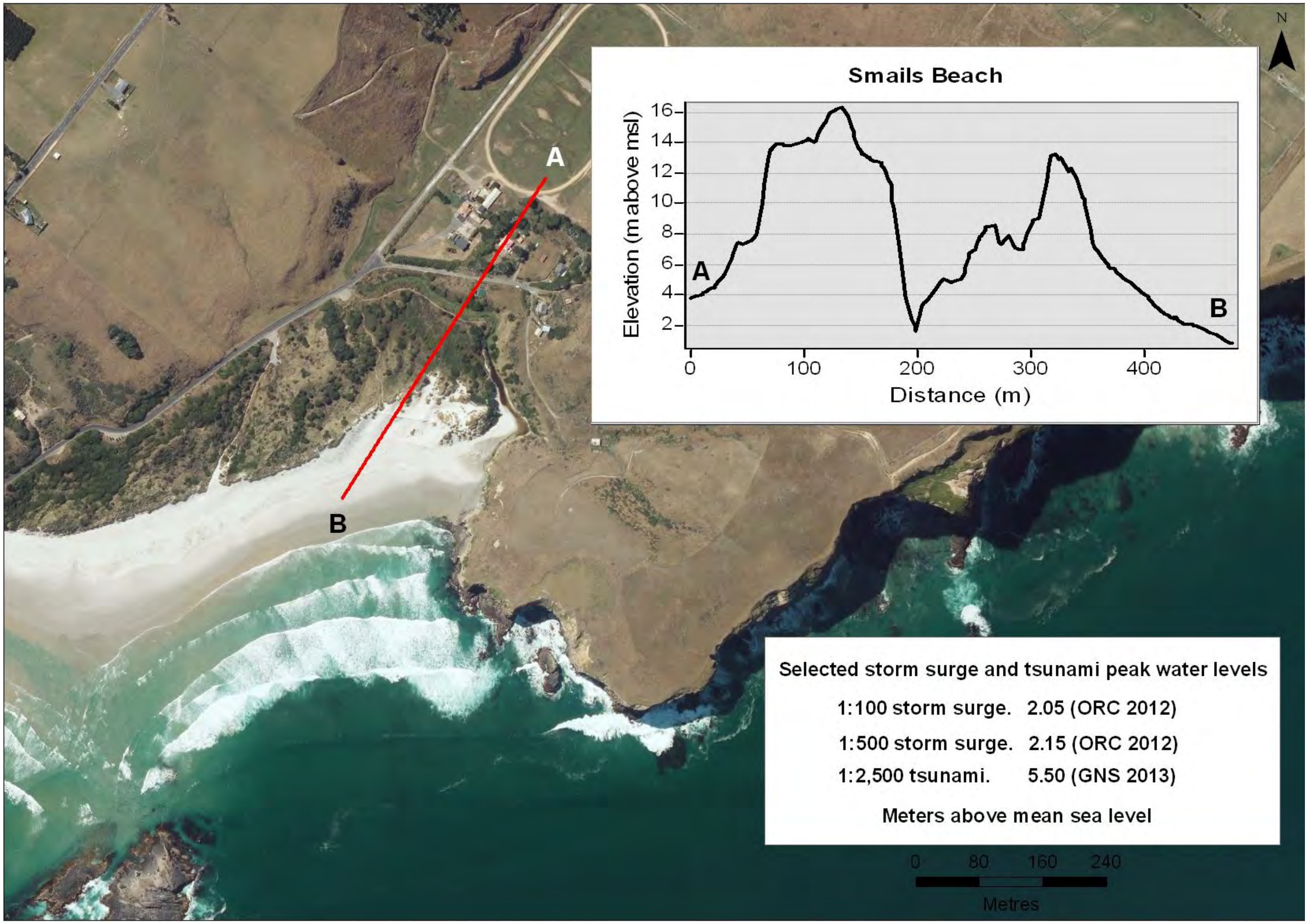

Figure 35. Cross section A-B through Smails Beach, and peak water levels associated with selected high magnitude storm surge and tsunami events

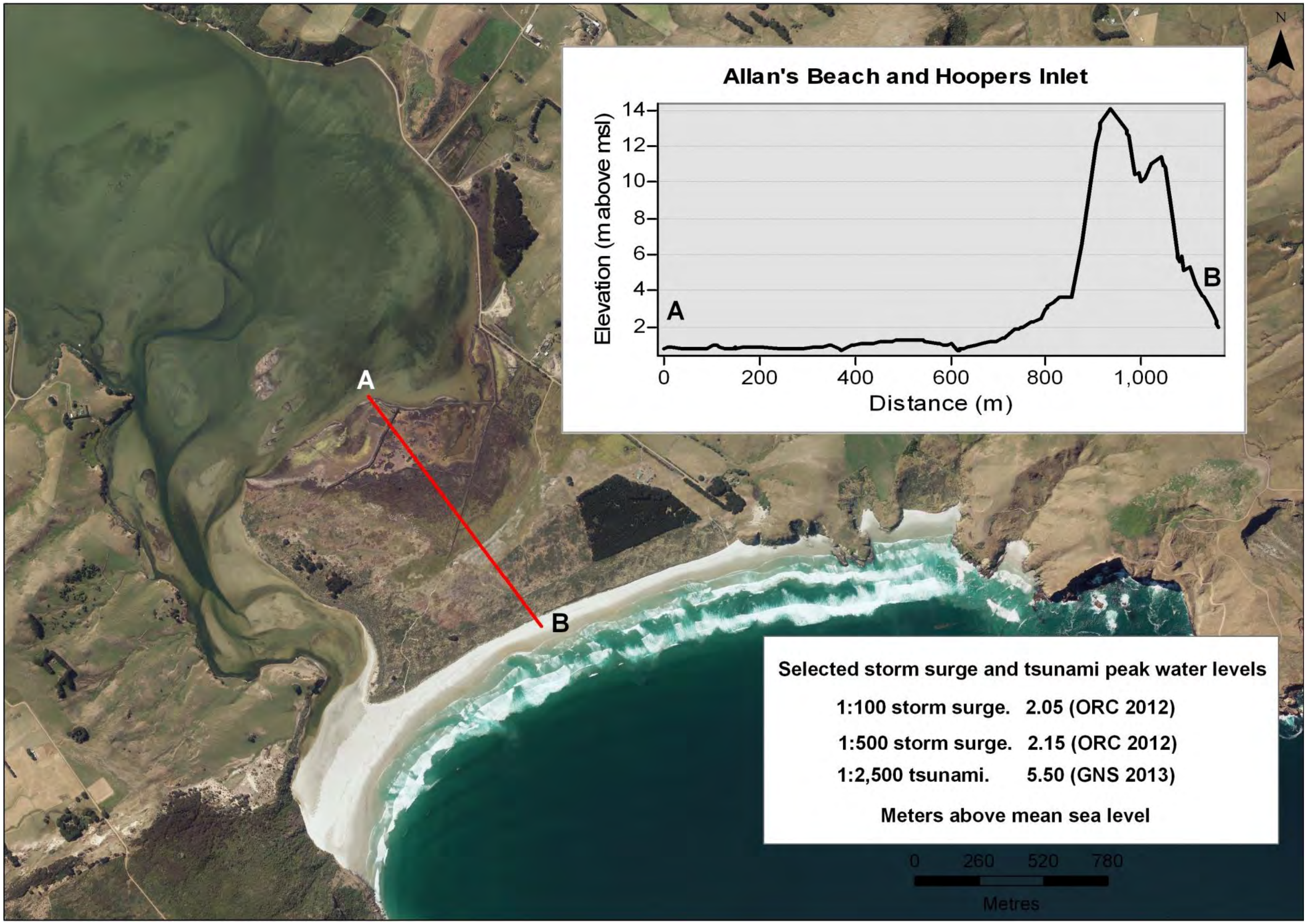

Figure 36. Cross section A-B through Allan's beach and Hoopers Inlet, and peak water levels associated with selected high magnitude storm surge and tsunami events

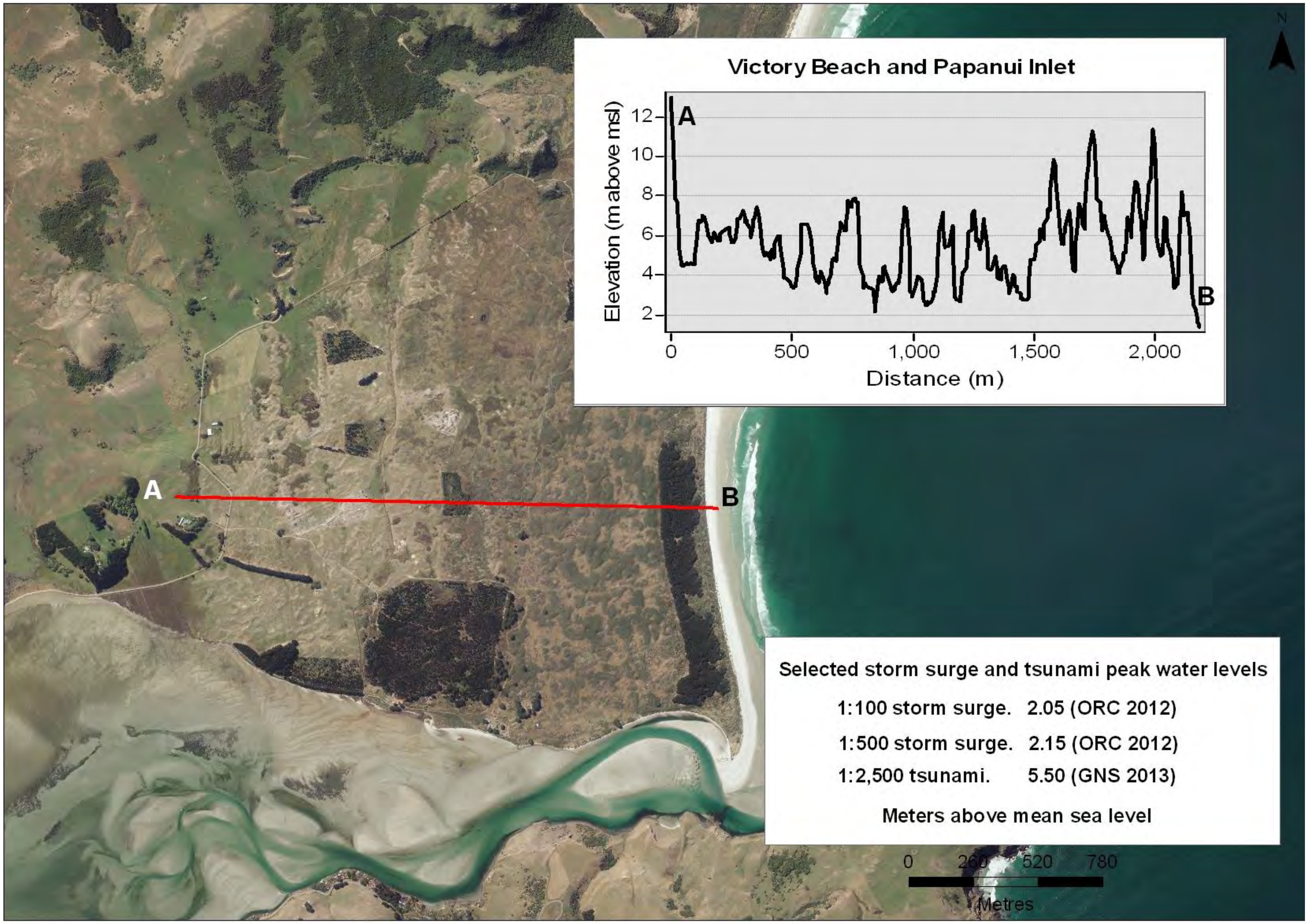

Figure 37. Cross section A-B through Victory Beach and Papanui Inlet, and peak water levels associated with selected high magnitude storm surge and tsunami events

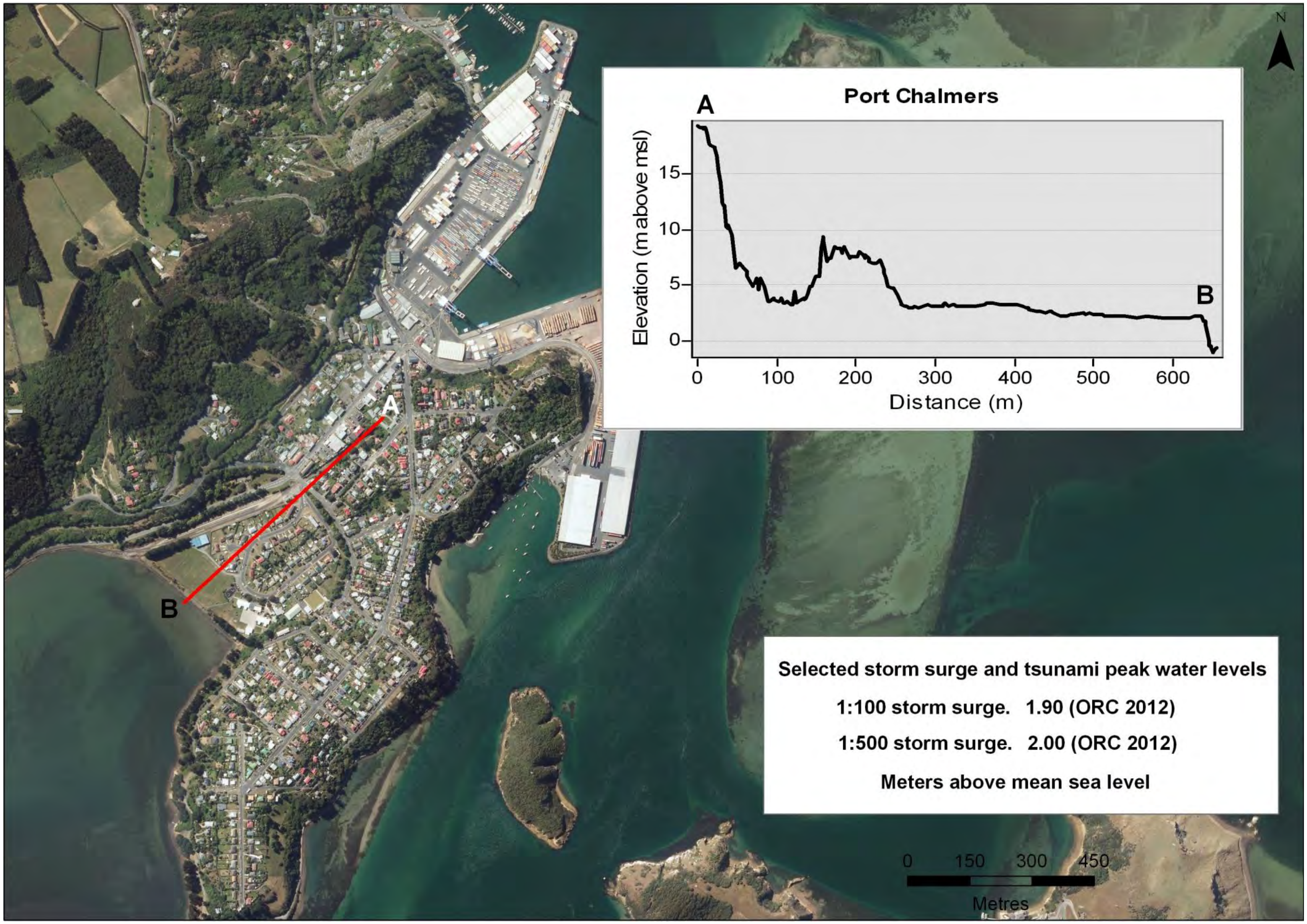

Figure 38. Cross section A-B through Port Chalmers, and peak water levels associated with selected high magnitude storm surge and tsunami events

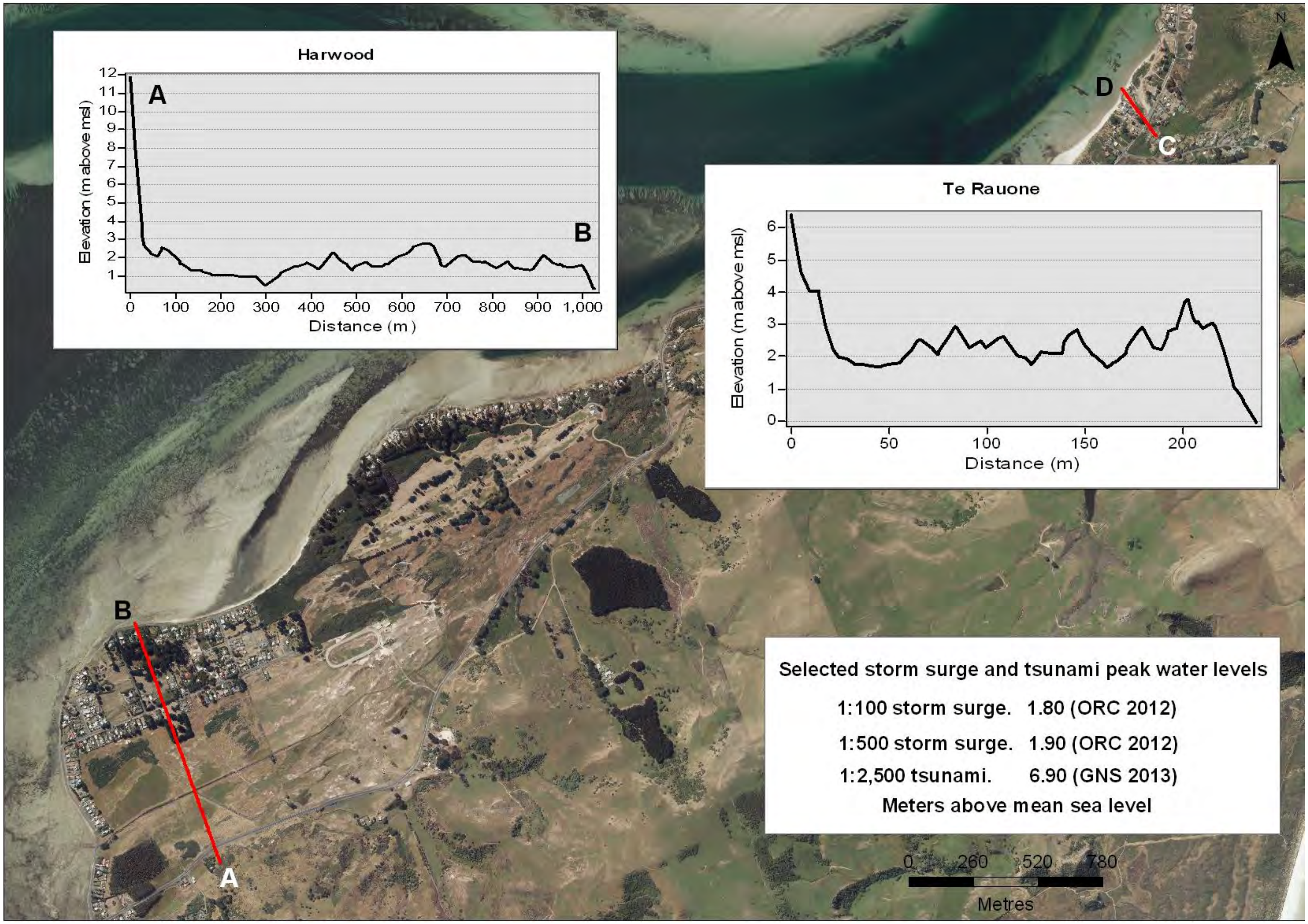

Figure 39. Cross section A-B through Harwood and C-D through Te Rauone, and peak water levels associated with selected high magnitude storm surge and tsunami events

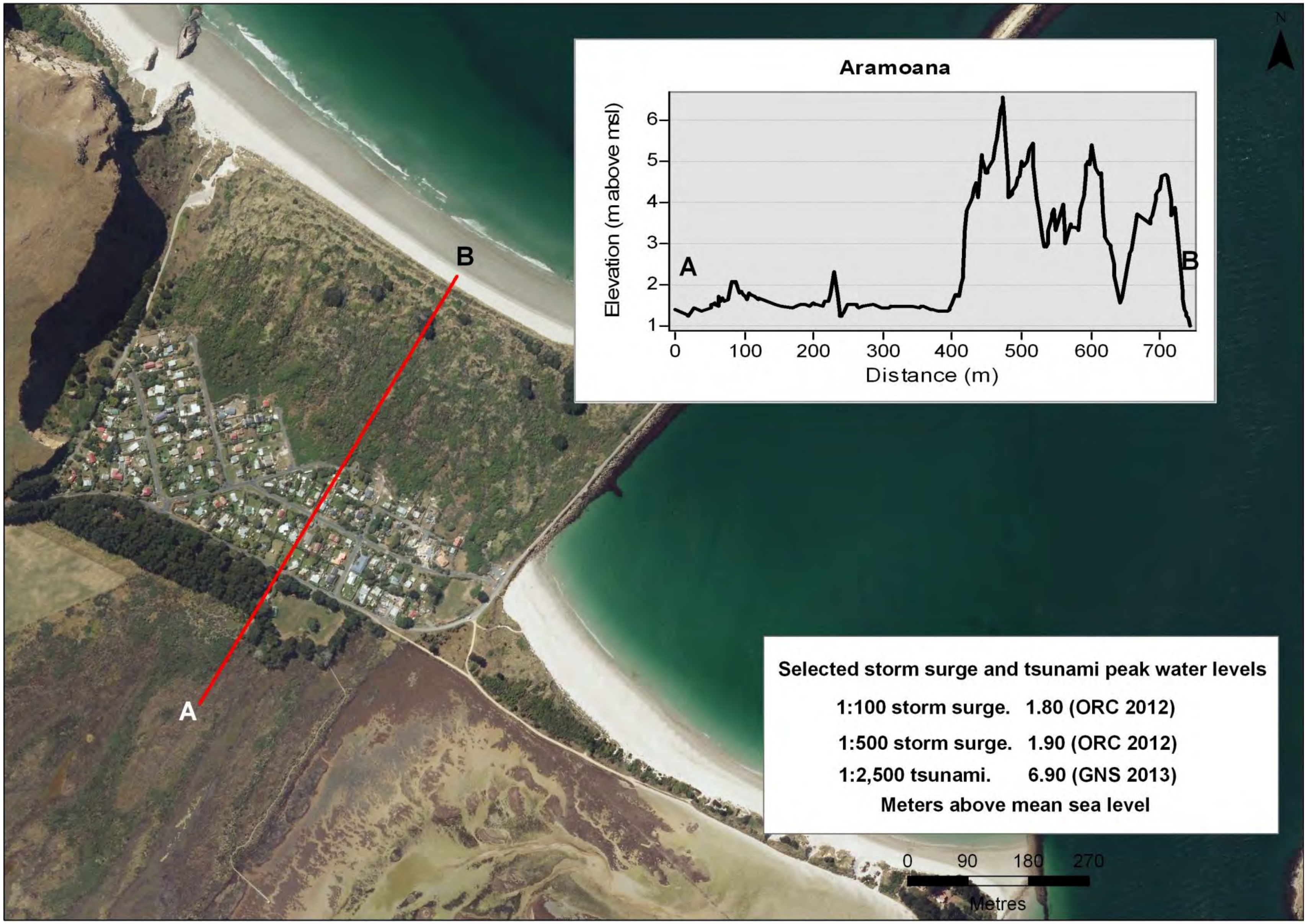

Figure 40. Cross section A-B through Aramoana, and peak water levels associated with selected high magnitude storm surge and tsunami events

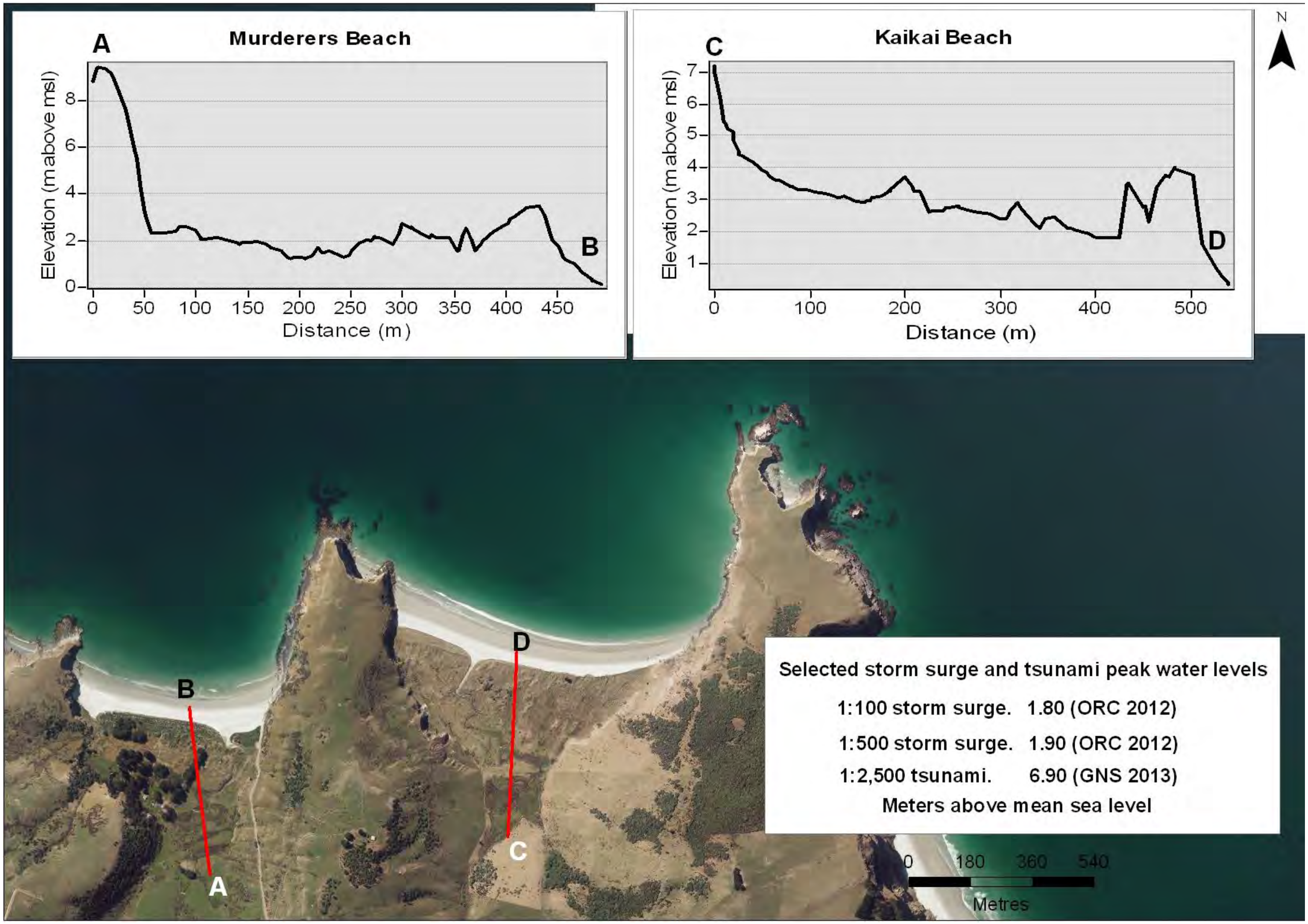

Figure 41. Cross sections A-B through Murdering Beach and C-D through Kaikai Beach, and peak water levels associated with selected high magnitude storm surge and tsunami events

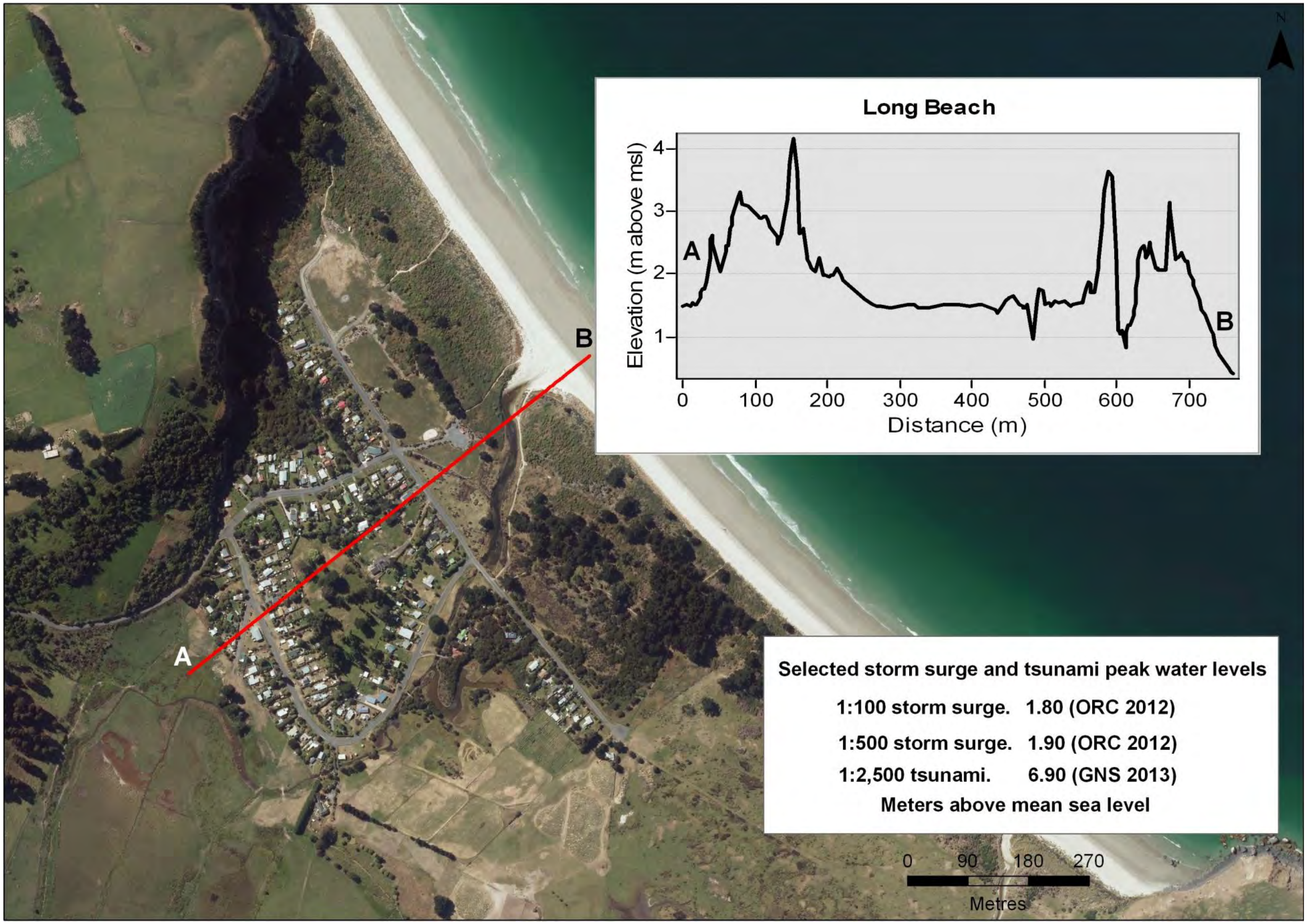

Figure 42. Cross section A-B through Long Beach, and peak water levels associated with selected high magnitude storm surge and tsunami events

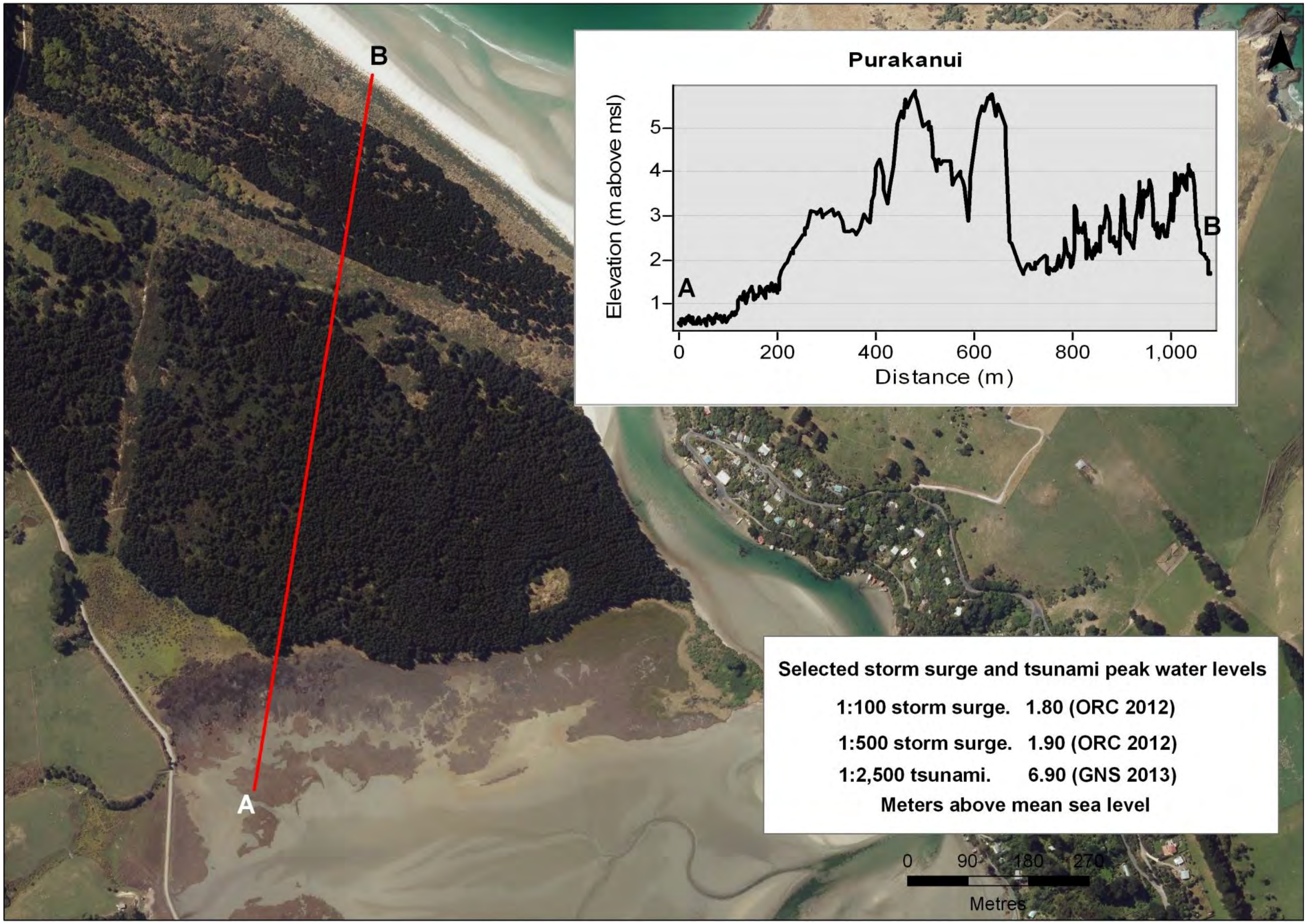

Figure 43. Cross section A-B through Purakanui, and peak water levels associated with selected high magnitude storm surge and tsunami events

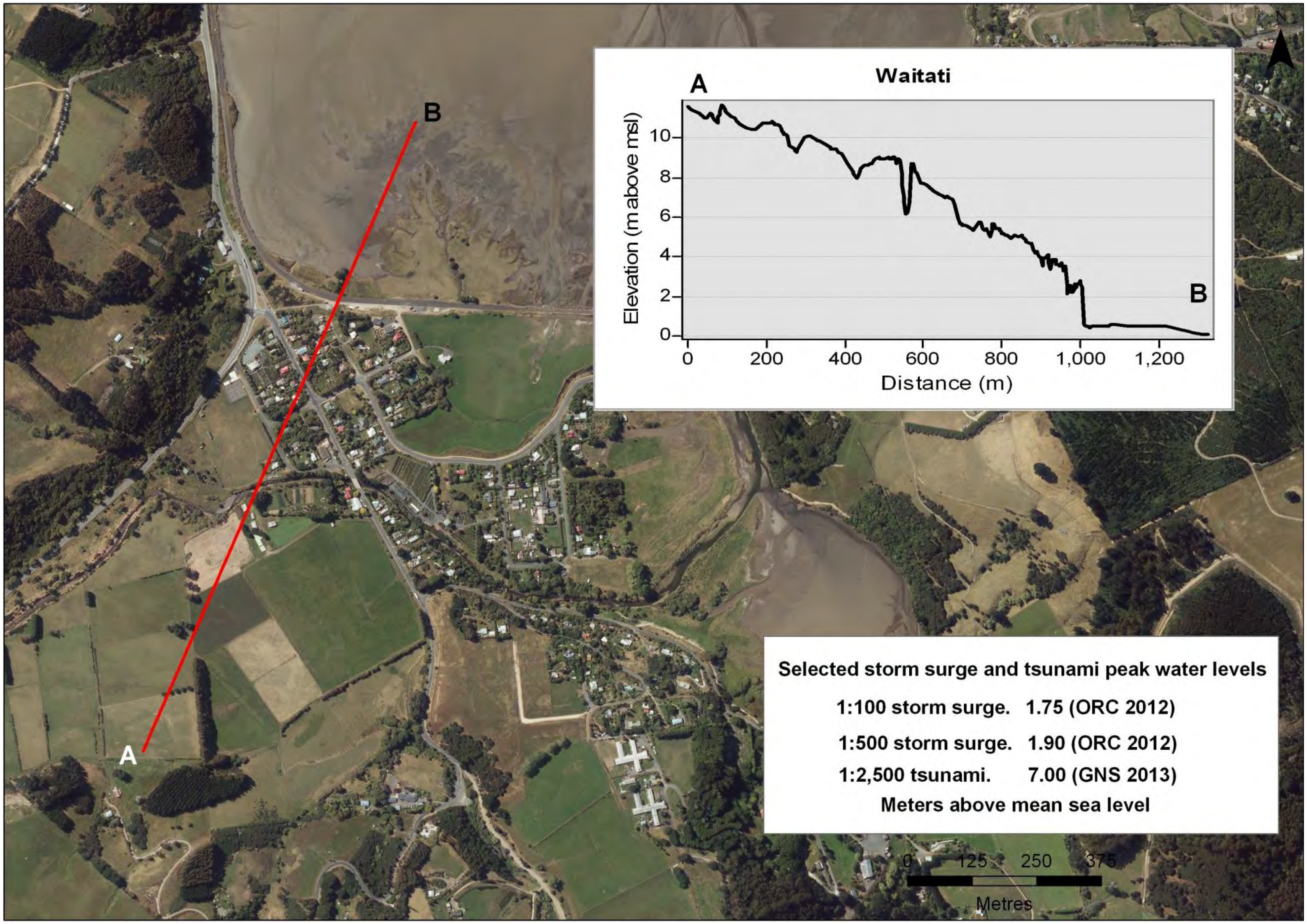

Figure 44. Cross section A-B through Waitati, and peak water levels associated with selected high magnitude storm surge and tsunami events

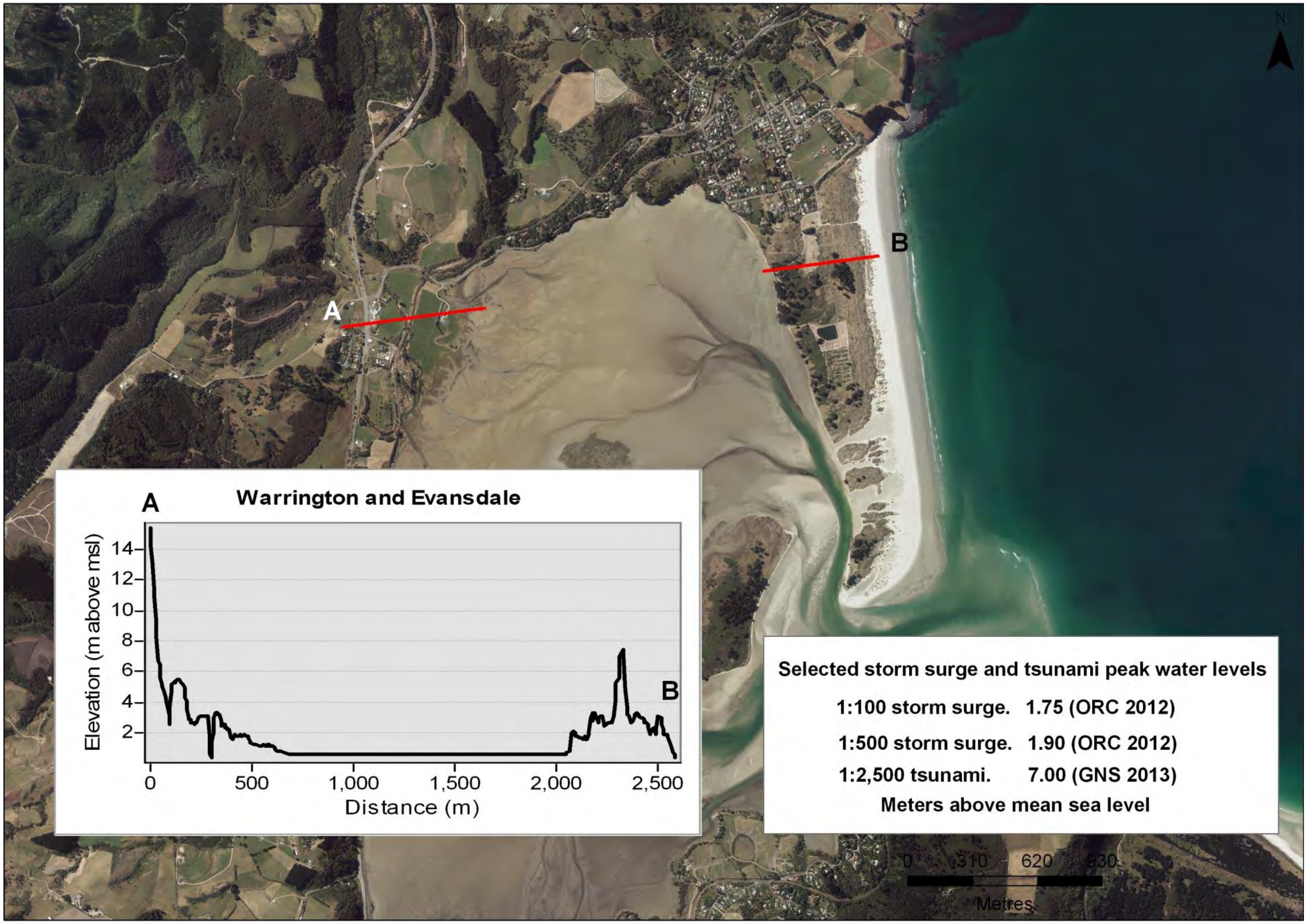

Figure 45. Cross section A-B through Warrington and Evansdale, and peak water levels associated with selected high magnitude storm surge and tsunami events

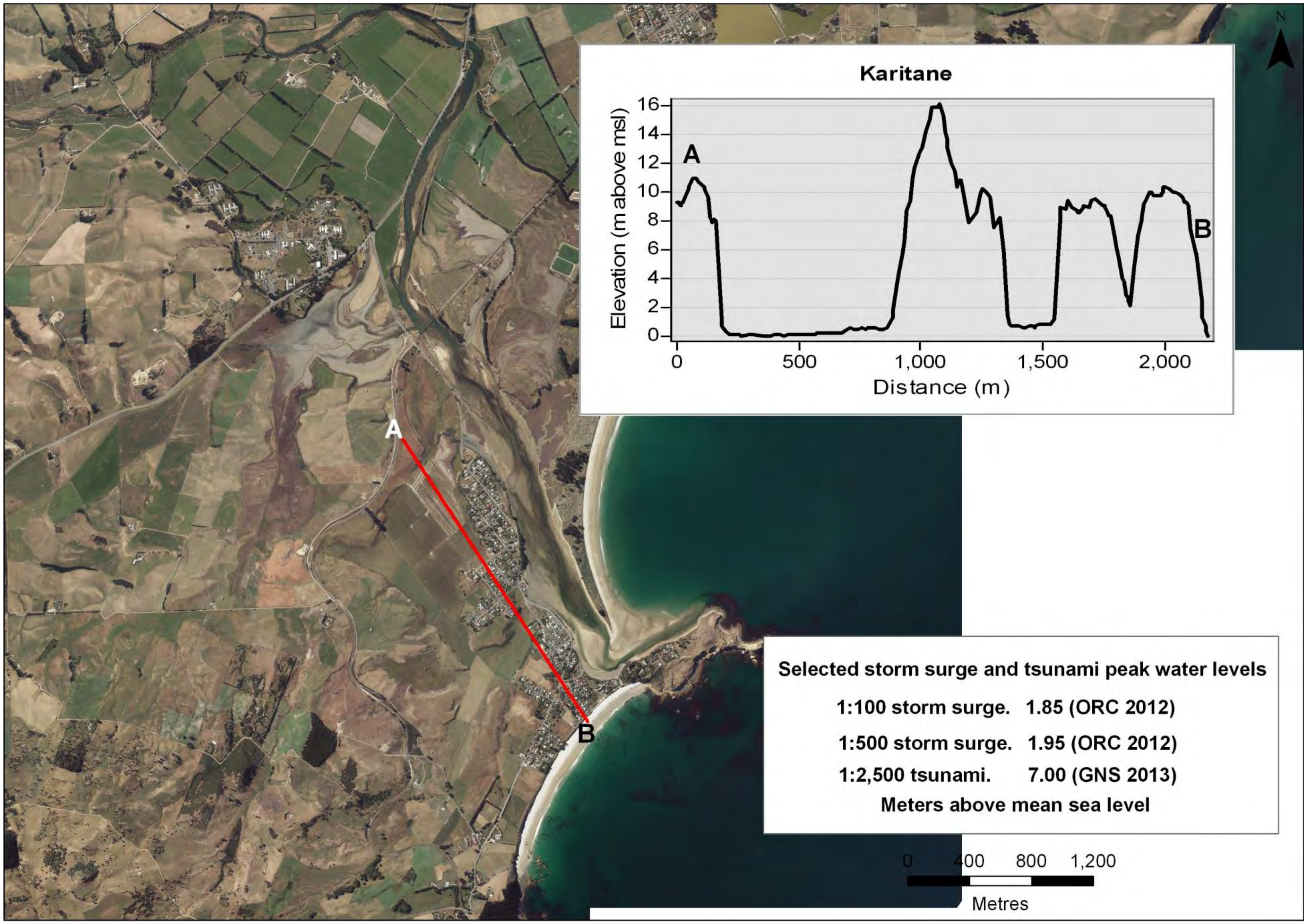

Figure 46. Cross section A-B through Karitane, and peak water levels associated with selected high magnitude storm surge and tsunami events

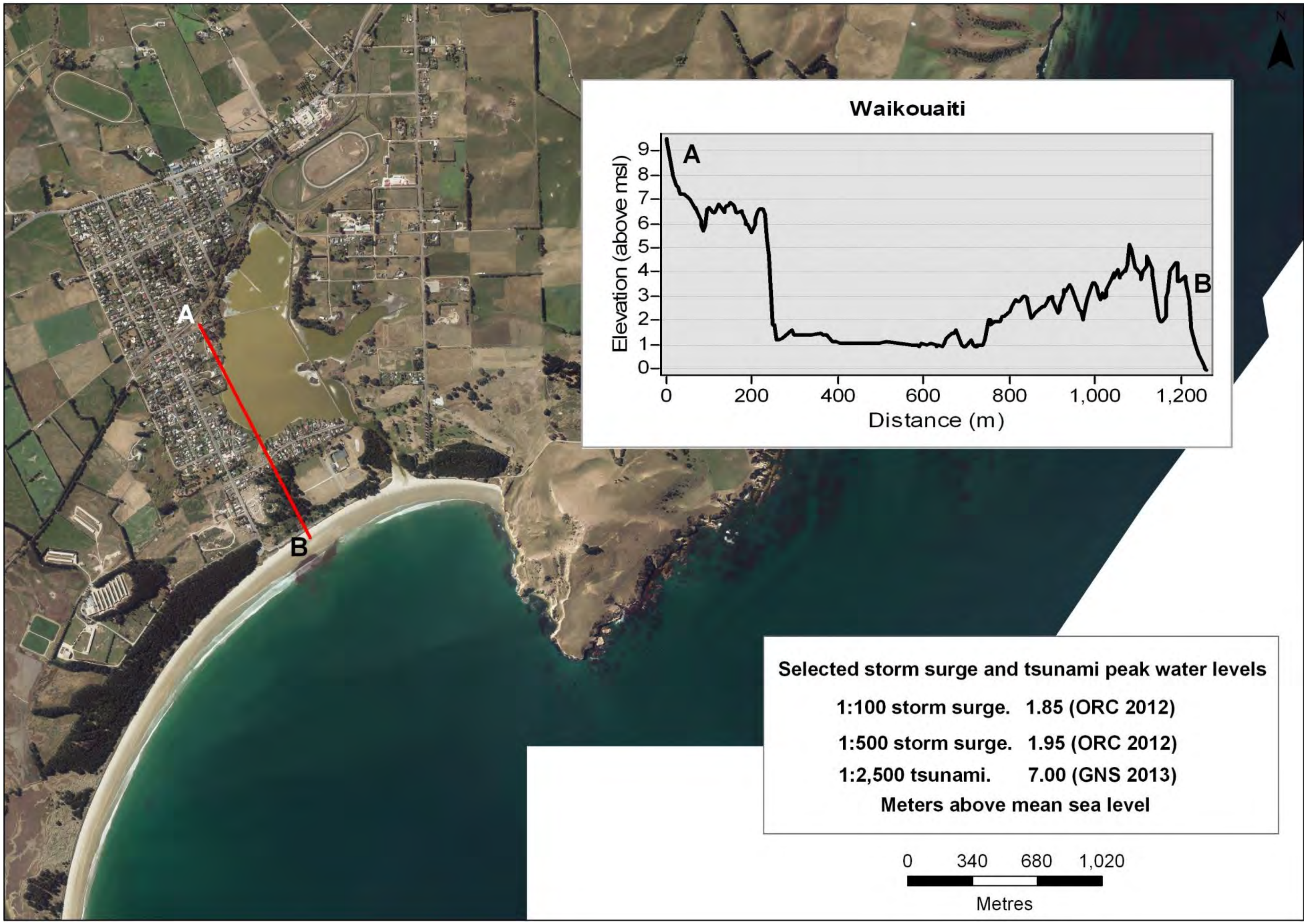

Figure 47. Cross section A-B through Waikouaiti, and peak water levels associated with selected high magnitude storm surge and tsunami events

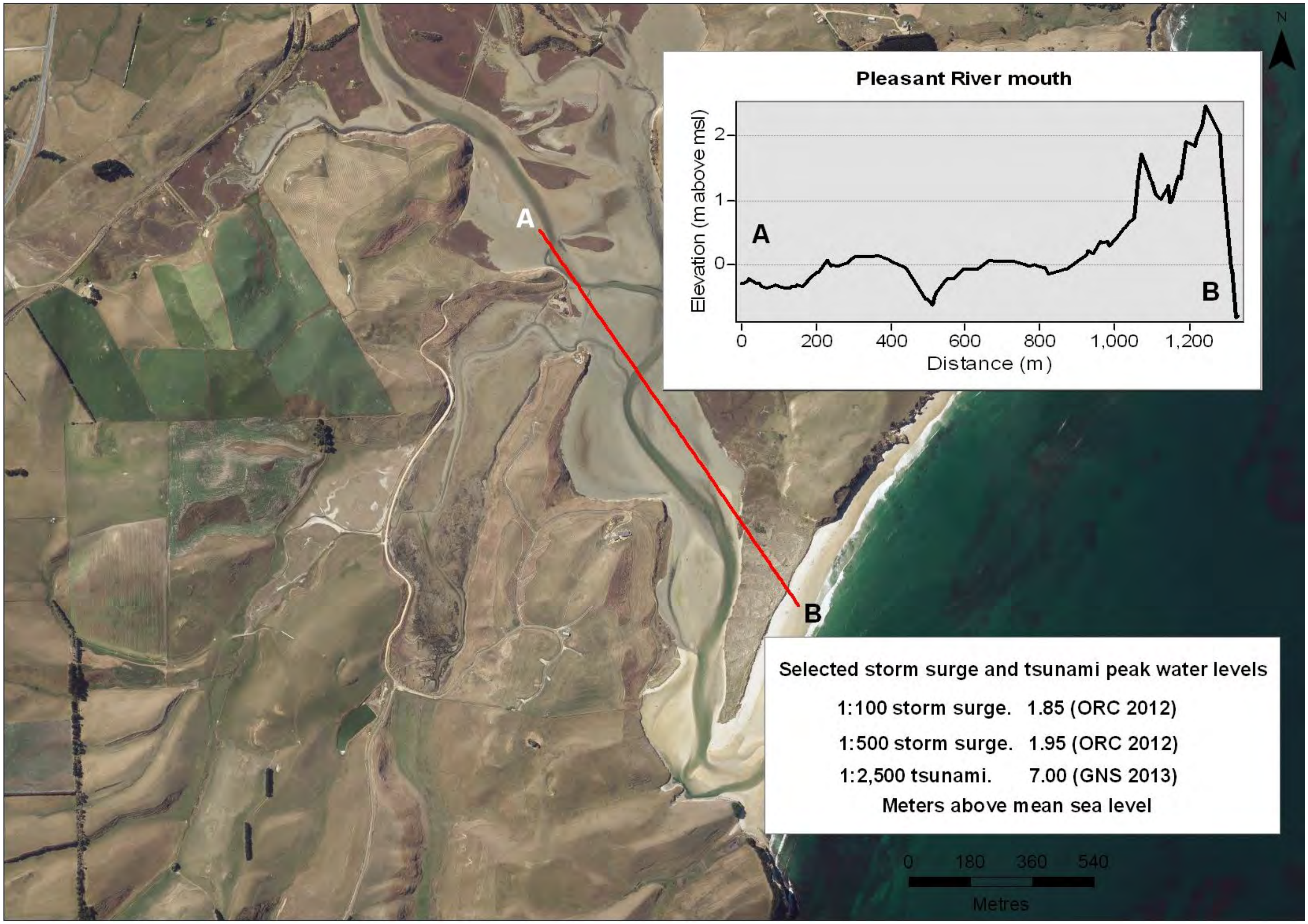

Figure 48. Cross section A-B through the Pleasant River mouth, and peak water levels associated with selected high magnitude storm surge and tsunami events