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Titahi Bay Coastal Processes and Geomorphology

Dr Iain Dawe

FOR FURTHER INFORMATION

Dr Iain Dawe Hazards Analyst Environmental Policy Environment Management		Greater Wellington Regional Council Wellington PO Box 11646		T 04 801 1031 F 04 385 6960 Web www.gw.govt.nz				ENV/23/13/05 WGN_DOCS-#673723 August 2009

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1. Introduction

Titahi Bay is the only safe surfing and swimming beach that is easily accessible from Porirua. As such, it is a prime recreational asset and a significant natural feature heavily used by locals and visitors to the city. Like other beaches adjacent urban areas in New Zealand, this popularity means that Titahi Bay faces pressures from use and development very close to the shoreline.

Over the years this use and development has resulted in a range of structures being placed on the beach and in the backshore sand dunes that have adversely affected and interfered with the natural processes operating in the beach. Nevertheless, there is the potential for Titahi Bay to be partially restored to reclaim some of this ‘naturalness’ whilst recognising the cultural heritage of the beach and its place within an urban setting.

Despite the importance of Titahi Bay to Porirua City and the management issues that have arisen over the many years that people have been using and enjoying the beach, there have very few studies of the natural processes operating within the Bay.

This report outlines and summarises the natural processes and geomorphology of Titahi Bay and provides some comment on potential natural systems management.

2. Titahi Bay Geology and Geomorphology

Situated on the western coastline of Porirua City, Titahi Bay is a textbook horseshoe shaped pocket beach, wholly contained between two rocky headlands that are fronted by broad rock shore platforms. However, the Bay hasn’t always looked this way, having experienced a long geological evolution over the past several hundred thousand years, during a period known as the Quaternary. A major driver of this development has been sea level.

On a geological timescale, sea levels have fluctuated dramatically on a scale of 10s to100s of metres in response to long term variations in the global climate. Cold periods or ice ages are associated with lower sea levels, whilst warmer periods are associated with higher sea levels. Since the height of the last ice age, about 20 000 years ago, global mean sea level has risen by more than 100 m due to melting ice sheets, causing a marine transgression. Most the rise occurred between 12 000-8000 BP, with a period of semi-stabilisation since 6500 BP. In the past 1000 years, sea level is estimated to have been rising at a rate of around 0.2 mm/yr, although there are many regional variations to this figure. More recently, this rate of rise has increased dramatically, by a whole order of magnitude, to 1.8 mm/yr.

2.1 Geological development

Titahi Bay has formed in recent geological history, attaining its current form *ca.* 6500 yrs BP, after sea levels stabilised, following the last post-glacial marine transgression. This marine transgression has seen sea levels rise some 100-120 m since their lowest point *ca.* 20,000 yrs BP. The bay is backed by a cliff at its southern end (in front of which the boat sheds have been built) and another toward the northern end of the beach adjacent the Bay Drive access point. The southern cliff is composed of marine derived sandstone and probably contains old sand dune deposits. The northern cliff is composed of older alluvial derived gravels and loess deposited during an earlier glacial period (Fig. 1).

At the height of the last inter-glacial warm period, *ca.* 125,000 yrs BP, sea levels were 5-6 m higher than present and the area from the western end of Onepoto Park to Titahi bay was connected to the open sea, effectively making it another entrance to the Harbour (Fig. 1). In fact, Onepoto Park, next to Main Road, is a reclamation and was until recently part of Porirua Harbour. Through a combination of tectonic uplift and dropping sea levels in the last glacial period, this connection was closed off and the shallow seabed of Titahi Bay and the area behind Mana Island, known as ‘The Bridge’, became dry land. At the height of this period, the shoreline was some 7 km west of Titahi Bay, placing it beyond Mana Island.

Around 12,000 years ago sea levels began to rise rapidly, cutting back the coast and creating a new shoreline. Titahi Bay has formed during this process through differential erosion between hard and soft geological units. The rocky headlands encapsulating Titahi Bay are composed of more resistant greywacke units, whilst the material behind the beach is a mixture of alluvial gravels and marine sands and silts (Fig. 1.). The Bay has partly formed in the low area that was once an open inlet to the Harbour. The soft sediments deposited in here were eroded more easily to create an embayment. Over time wave activity has distributed these sediments and created the crescent shaped beach, now known as Titahi Bay.

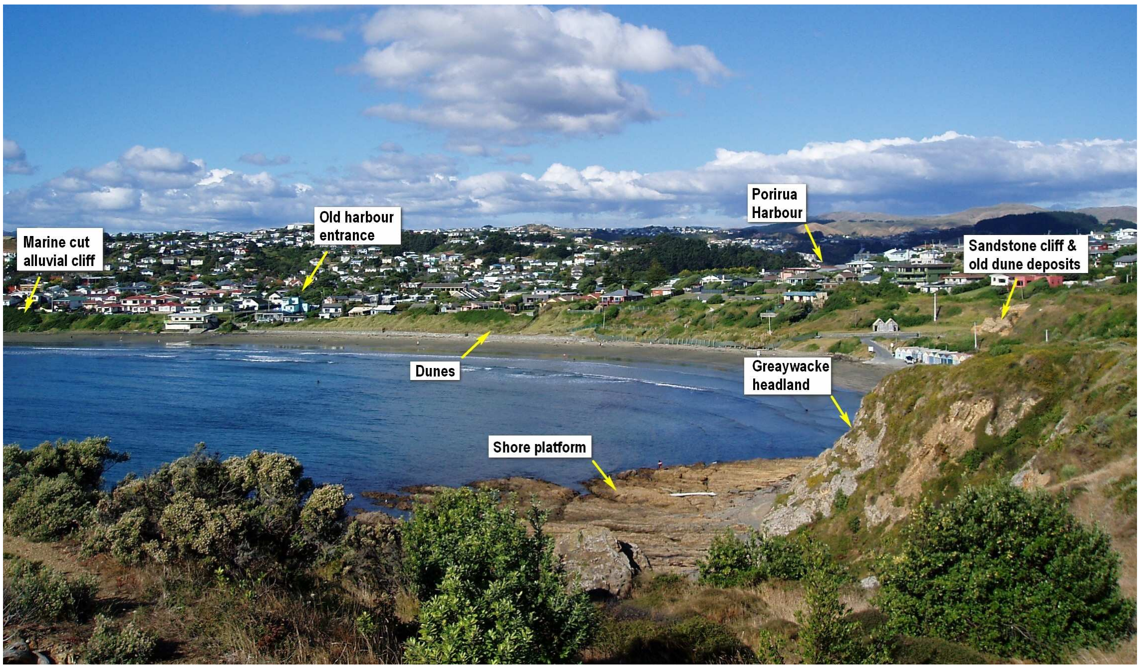

Figure 1. Contemporary photograph of Titahi Bay illustrating the geological and geomorphological units described in the text. The beach has formed in an area of soft sedimentary and unconsolidated sediments between more resistant greywacke headlands. During the last interglacial period ca. 125,000 years BP, when sea levels were 4-6 higher than present, the sea flowed through a channel cut in old fluvial deposits and into Porirua Harbour. Whitireia Peninsula would have been an island.

2.2 Sediments

Titahi Bay is now a semi-closed system with limited fluvial input of sediment and low quantities of sediment supplied from off-shore sources. Much of the sediment has been derived in-situ or from relict sources during the post-glacial marine transgression.

The beach is composed of medium to fine sands derived offshore from the continental and nearshore shelf and from shoreline erosion through the geomorphic evolution of the Bay over the past 10,000 years. It is underlain by a deeper deposit of marine and alluvial greywacke gravels derived from erosion of the headlands and the cliffs at the back of the beach. The shore platforms are the eroded base of these headlands and indicate the extent of the former cliff line. Gravels formed in this process were deposited on the seabed of the Bay. Some of this material has been transported landward onto the beach. The former opening to the harbour, has been entirely cut through an old alluvial fan deposit. The gravel derived from this erosion now underlie the nearshore and foreshore. These gravels are commonly exposed in significant quantities in the foreshore*, particularly following stormy periods when sand is scoured from the beach face, leaving a lag deposit of the coarser sediments (Fig. 2.). The shape and appearance of the gravels, the degree of rounding and smoothness, all indicates they have been re-worked in the marine environment over a long period of time.

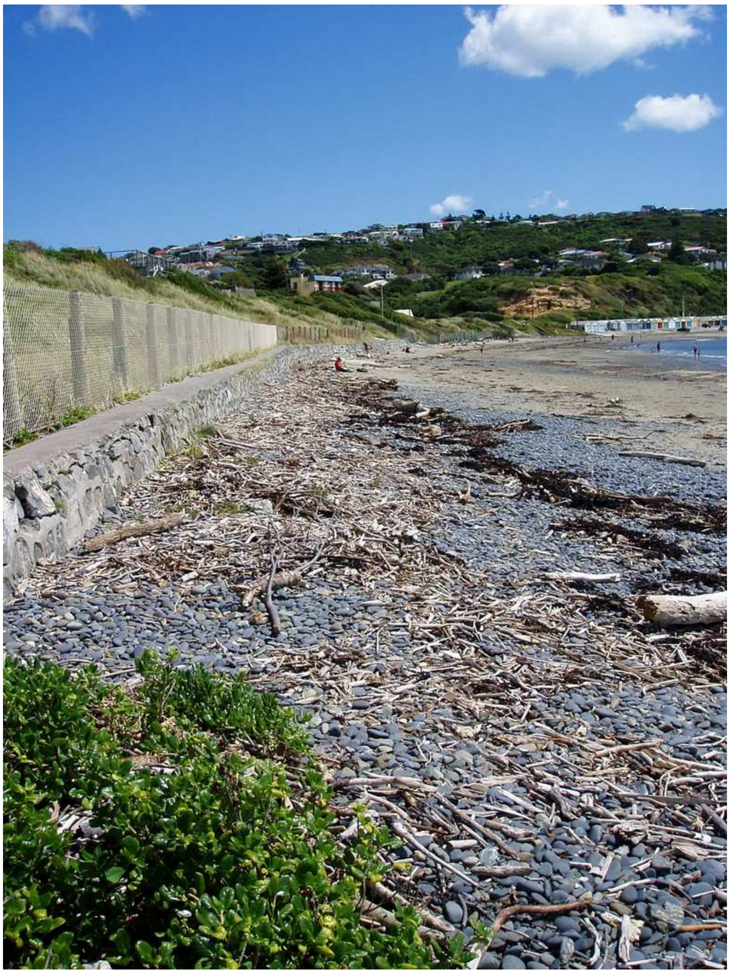

Figure 2. Marine abraded greywacke gravels are commonly exposed in the foreshore of Titahi Bay. They are uncovered after storm events scour sand from the beach face, leaving a lag of the coarser material in place. Wave action has pushed some of the gravel into a storm berm that is sometimes present at the back of the beach.

2.3 Geomorphology

Titahi Bay is a moderate sized pocket beach. The sandy foreshore is around 1.0 km in length, whilst the bay itself (out to the heads) covers an area of approximately 0.25 km^2.

The nearshore[†] is shallow and gently sloping; falling an average 1.0 m vertical for every 100 m. At the heads the water depth is only 5.0 m and at 1.0 km the depth is 10.0 m.

This has an important bearing on the dissipation and refraction of wave energy into the Bay. In wave process terms this means that waves start to feel the bottom of the sea bed a significant distance offshore. This also causes waves to break further offshore, making the beach dissipative thereby giving it a tendency to accumulate sediment.

As the sea levels stabilised around 6500 years ago, a renewed phase of sand dune development ensued around the coast, including Titahi Bay. Sand dunes formed along the back of the beach and in front of the cliffs. These dunes formed when dry sand from the foreshore was blown inland, particularly from northwest winds or strong sea breezes, a process that continues to this day.

*Foreshore: area of beach that lies approximately between low water springs and high water springs

[†] Nearshore: area of beach below low water springs that experiences modification from wave activity

2.4 Fossil forest

There are times during low tide, particularly during the spring when northwest storm events have scoured sand from the beach, when fossil trees are visible in the nearshore (Fig. 3). These tree stumps are *in situ* (*i.e.* have not been transported there by other means) remnants of an old forest that grew in a swampy environment over 100,000 years ago during the last warm Inter-glacial period (100-125 ka.). Sea level rise between 12-6,000 BP has eroded the coastline, and uncovered the fossil beds in the floor of Titahi Bay. The size of the stumps indicates the trees grew to a large size and includes species of Rimu, Totara and Matai (Begg & Mazengarb, 1996). The fossil trees sit in old gravelly, silt and peat beds, that are around 10 m deep and are underlain by a deeper greywacke basement – the same rock unit of the headlands.

Figure 3. Fossil tree stumps are sometimes exposed in the lower foreshore of the Bay

3. Coastal Process

3.1 Tides

Tides vary in height due to the position and distance of the moon as it orbits earth that operate on a daily, fortnightly and monthly cycle. Tides are generally highest (and lowest) on the new and full moon - known as the spring tides. The average elevation of these tides above a chart datum is referred to as the mean high water springs.

Titahi Bay is located adjacent the northern end of the powerful and complex Cook Strait tidal stream. Despite this, tides play a relatively small role in the processes operating in the Bay. This is because the tidal amplitude or range (from high to low water) is small, at around 1.70 m on the highest spring tides. Thus, the Bay can be classified as micro-tidal. The tidal flow is clockwise around the Bay on the flood tide and anti-clockwise back out on the ebb tide. The water level ranges from 0.85 m below the mean sea level to 0.85 m above mean sea level during the largest spring tides. The mean high water springs (*i.e.* the average), rises to around 0.70 m above mean water level. It has been generally observed that in places where the tidal range is less than 2.0 m, waves will be the dominating coastal process influence.

3.2 Wave climate

Titahi Bay is a moderate wave energy environment, sheltered to swell from all directions except the northwest. It is sheltered by Mana Island and the top of the South Island to the west. For much of the time, the Bay is subject to small, low energy wind-waves generated by sea breezes and weather systems blowing from the northern and western quadrants. It is also subject to low rolling, heavily refracted southerly swell from Cook Strait. It has been calculated that less than 15% of the wave energy from southerly swells in Cook Strait makes it through to this coast (Laing *et al.*, 2003). The main driver of wave and current activity within the Bay is from northwest generated waves.

There is only a narrow window approximately 50^o wide, from $310\text{-}360^o$ north and northwest from which waves with unrestricted fetch (i.e. the water distance over which the wind blows) are able to enter the Bay. The focus for this opening is the middle and southern end of the beach.

There are no significant measured wave records for this section of coast. The closest study of the deepwater wave climate was made for the Kapiti Coast by Laing *et al.* (2003). Using a 20 year weather record, the significant wave heights (highest $1/3^{rd}$ of waves) were hindcast to produce a distribution of their occurrence. It was found that almost 60% of the significant wave heights were under 1.0 m, around 35% were between 1-2 m and around 5% were between 2-3 m, with only a small fraction (0.3%) larger than 3.0 m. The highest significant wave height was 4.5 m. The September 1976 storm was found to have produced significant wave heights of 3.6 m. Whilst there are limitations to applying this record to the Porirua Coast, it will be broadly similar.

A wave hindcast analysis was conducted for this study using a range of weather event scenarios. Waves were modelled from the northwest, based on the exposure of Titahi Bay to the unrestricted fetch from this direction. The results can be viewed in Table 1. It can be seen that they are in line with the much larger scale results for the Kapiti Coast, discussed above. It highlights that the largest deepwater wave heights that can be expected for the area, are in the order of 4.0 m.

Table 1. Deepwater wave hindcast conditions for Titahi Bay coast from the northwest quadrant for 6 event scenarios, using ACES wave modelling software.

Wind NW	**Mod Breeze**	**Fresh Breeze**	**Strong Breeze**	**Near Gale**	**Gale**	**Strong Gale**
Wind (knots)	15	20	25	30	40	45
Wind (Kph)	25	35	45	55	75	85
Event Duration (hr)	6.0	6.0	8.0	8.0	12.0	12.0
Wave Period (s)	4.75	5.20	5.80	6.20	7.20	7.50
Wave Height (m)	1.00	1.30	1.80	2.20	3.50	4.00

3.3 Wave currents and sediment transport

The geomorphology, shape and orientation of the coast exert a major control on the wave and sediment transport processes operating within Titahi Bay. In areas where there is a broad, shallow nearshore, waves can be forced to break many hundreds of metres offshore. It is not uncommon to observe waves breaking outside the heads at Titahi Bay where the water depth is 5.0 m. This dissipates the wave energy and reduces the impact of breaking waves on the beach face. For this reason, beaches with wide, shallow surf zones, such as Titahi Bay, are commonly referred to as dissipative beaches. On these shore types, waves 3.0-3.5 m high will break in water depths around 5.0 m. The wave hindcast analysis indicated that waves of this height were capable of being generated from the northwest and agrees with known observations of wave activity in the Bay. Thus, while Titahi Bay is exposed to energetic waves from the northwest, the geomorphology of the seabed acts to modify those waves by dissipating much of their energy before it reaches the shoreline.

When waves approach a shoreline and enter shallow water, the base of the wave begins to ‘feel’ the seabed and undergoes a process of shoaling and refraction. Wave speed is partly controlled by the water depth. Those sections of the wave that enter shallow water first, slow down relative to the rest of the wave. This changes the wave direction by bending the crests toward the coast and forces the wave crests to break more closely parallel to the shoreline. Thus, the shape and depth of the nearshore seabed plays a major role in controlling the way in which waves break along a beach. As waves break into Titahi Bay, they undergo divergence and fan out across the Bay, breaking more or less parallel to each stretch of the beach. Visually, waves break within the Bay as a curve, following the contours of the nearshore seabed (Fig. 4.). This is important because it controls the critical process of sediment transport within the Bay.

Figure 4. Wave refraction into Titahi Bay forces waves to break more or less parallel to each section of shoreline. As the wave crests enter the heads, they fan out or diffract, across the Bay following the contours of the nearshore seabed. This process has helped distribute sand around the foreshore to create the distinct crescent shaped beach we see today.

There are two main processes by which sediment transport is initiated in a shoreline. The first is known as mass sediment transport and occurs during the process of wave shoaling. As a wave enters shallow water, it interacts with the seabed, which produces turbulence and bottom friction that sets sand in motion. This process can transport sand in either a dominantly onshore or offshore direction depending on the wave conditions. Storm waves tend to cause sand to be transported offshore, whilst gentler more rolling swell tends to bring sand onshore. Through this process, sand can be brought into Titahi Bay from the seabed outside the heads. It has been suggested that the balance of this on-off shore transport for Titahi Bay is negative, and that sand is slowly leaking out of the system (Barrow, 2000). However, a field study and sediment budget analysis would be required to confirm this hypothesis.

The second main process that transports sand in a shoreline is a system of nearshore currents that are generated during wave shoaling and breaking. These currents are strong enough to both, put sand in motion and, to transport sand that has been stirred up through wave breaking. Most of this current and sediment transport activity occurs forward of the breaking wave, in an area known as the surf zone. These currents can transport sediments either parallel or perpendicular to the shore.

Perhaps the more widely understood current than forms in a surf zone is the longshore current. Longshore currents develop when waves break at an oblique angle to the shore (Figure 5). The greater the angle between the wave crest and the shoreline, the stronger the longshore current and the greater its capacity to transport sand. This current is unidirectional and can operate over long distances of the shoreline. Longshore currents are able to transport sand from one area of a beach to another or permanently out of a beach system. Sand can be transported back and forward along a beach by this current, with the net direction determined by the prevailing wave conditions.

During strong northerly conditions, waves can be seen to break slightly obliquely to the shore in Titahi Bay. Aerial photographs reveal that in these conditions, wave activity is concentrated in the southern half of the Bay. It can be deduced that during these conditions a southward directed longshore current could operate from about the middle of Bay, transporting sand in the southern section of the Bay. Evidence for this is drawn from the fact that there is a slightly larger accumulation of sand in the southern half of the beach. This is also supported by the greater sand dune development along this section of the Bay. However, the sand within the Bay is reasonably evenly distributed along the shoreline, and this current does not appear to be a dominant process acting in the shoreline. Part of the reason for this is due to wave diffraction. As discussed above, waves breaking within Titahi Bay, tend to break more-or-less parallel to the shore, rather than on an angle, thereby reducing the capacity of the longshore current. Furthermore, because Titahi Bay is a pocket beach, longshore currents will only operate over short sections of the shore before terminating near the end of the beach. Thus, longshore currents are not able to remove sand permanently from the Bay. In this way, it is a reasonably self-contained system.

Another important longshore directed current forms as part of a rip cell circulation system. It forms when waves break more perpendicular to a shoreline and results from a complex interaction of waves in the nearshore zone (Figure 5). This system of nearshore rip and feeder currents are capable of moving sediment alongshore for short distances, before they are carried seaward in a rip current. Rip currents only operate to the edge of the surf zone. During storm conditions, sand is commonly scoured from the foreshore and deposited via these currents in the surf zone in the form of a sand bar. During periods of more settled weather, this bar is transported back onshore through the process of mass sediment transport discussed above. This transport system is cyclical, operating in response to storm wave activity, and recycles sand between the foreshore and nearshore. One important difference between this current system and the oblique wave generated longshore current, is that sand remains within the system, it is not permanently lost from the beach. Due to wave diffraction, these currents are probably the dominant process responsible for sediment transport in Titahi Bay.

It may be expected that Titahi Bay will undergo cyclical phases of erosion and accretion, in response to the prevailing weather and wave conditions. These cyclical phases can operate over a seasonal time frame or longer annual periods in response to larger scale climatic events such as El Nino/La Nina. During more stormy periods, for example during the spring northwesterlies, the beach is commonly scoured, revealing the underlying gravels in the beach. The scoured sand is deposited on the nearshore seabed. Over the ensuing summer months, when the wind and waves are more settled, this sand is transported back onshore, building up the foreshore beach and covering up the gravels.

Thus, it is important to distinguish between short term erosion events, caused by storm activity and longer term erosion caused by an alteration in the hydrodynamic process or a sediment deficit. This has important implications for the foreshore management plan, because it informs the type of strategies that can be employed to manage the beach.

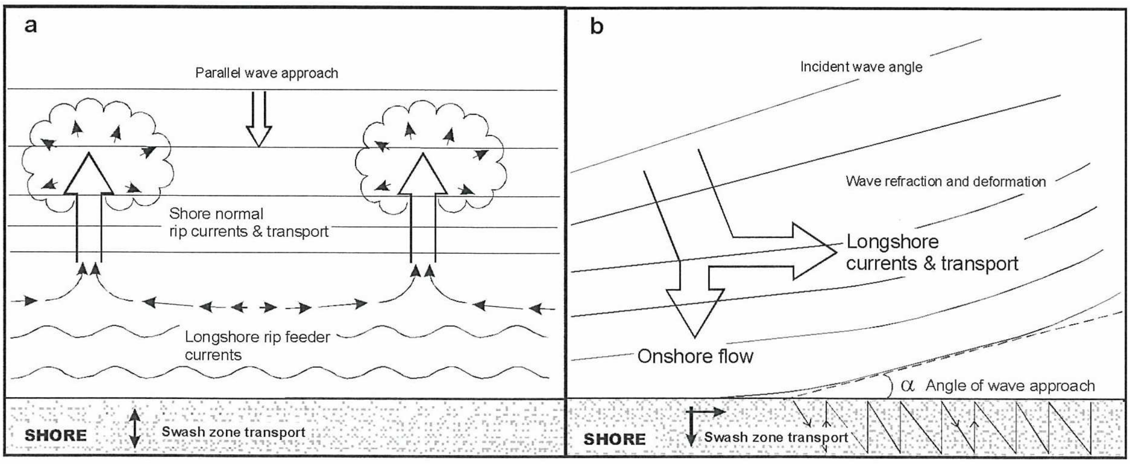

Figure 5. The two main types of current systems that can develop in the nearshore zone forward of the breaking waves. The first is a cell circulation system that develops when waves approach parallel to a shoreline (a). The second is a longshore current that forms when waves approach a shoreline at an oblique angle (b). A great deal of sand can be transported in these currents. Sediment transport in Titahi Bay is probably dominated by the first process, as wave diffraction within the bay reduces the capacity of the longshore current to transport sediment.

3.4 Shoreline change

Despite the importance of Titahi Bay as a place to live and as a recreational asset, there have been very few scientific studies or field measurements of shoreline change. Any analysis of long term changes in the shoreline has to rely on aerial photographs. A report entitled “Erosion assessment and management options at selected sites in Porirua City” by Beca in 2003, made an analysis of shoreline change using aerial photographs between 1973 and 1995. Only two points were able to be identified in the photo sets to allow an accurate measurement of the changes in shoreline position. In the period from 1973 to 1980 the shoreline advanced at the two locations seaward by 0.50 & 1.75 m (+0.07 & 0.25 m/yr); then retreated by 2.25 & 2.50 m from 1980-1987 (-0.32 & 0.36 m/yr); followed by another retreat from 1987-1995 of 0.75 & 2.00 m (-0.11 & 0.25 m/yr). It was found that over this 22 year period the mean trend was for slight erosion in the order of 10 cm per year. In coastal process terms, this magnitude of erosion is considered low scale.

However, it was acknowledged in the report that it was difficult to draw any firm conclusions from the aerial photographs because of the lack of fixed markers (only two) to measure advances and retreats across the whole Bay and because of the high degree of modification of the beach. It was noted that, some of the change reflected short to medium term shifts in dunes rather than net long term changes and that for the period 1987-1995, much of the erosion probably occurred in the 1980s.

In addition, there were two significant El Nino events in the 1980s, one in 1982-83 and the other in 1988, that were associated with strong northwesterly events causing storm surges and coastal erosion. Indeed, the seawall in Titahi Bay was built in the mid-1980s, partly in response to a period of erosion caused by these events. The changes that were experienced over this period are consistent with those that might be expected in any sandy shoreline, as discussed in the preceding section.

An important contributor to this erosion has been the state of the dune system. Aerial photographs from 1962 and 1973 reveal that the dunes in the southern half of the beach were semi-mobile, vegetated with marram and contained blowouts. As a sand binding grass, Marram is effective at trapping sand, but it is not resilient to erosion. Marram builds steep dunes that are easily undermined by storm wave events or strong winds, that the Marram subsequently struggles to re-vegetate. Thus, in this state the beach was susceptible to erosion from storm events (Fig. 6).

Figure 6. Titahi Bay in the mid 1980s. The dunes were in a poor state at this time, heavily degraded and eroded by wind and wave activity. This was exacerbated by Marram grass, that creates steep dune faces susceptible to erosion and wind scour. Unlike the native sand binding species, Marram is not effective at recolonising eroded dunes faces.

The dunes were present in the 1942 aerial photograph, when the beach was in a less modified state (Fig. 7). It is also evident that there was slightly more sand in the southern half of the Bay in the 1940s. However, even at this stage human impacts were starting to bear on the beach (Fig. 8). By the 1920s vegetation had been cleared and by the 1940s subdivision development was well under way.

An aerial photograph analysis was conducted in this study for the period 1942-2008, allowing a much longer time period to be examined and from which to draw conclusions about the longer term stability state of Titahi Bay. The photos were georectified in ArcMap GIS and the shorelines were plotted for each successive year. Since 1942, there have been slight inter-decadal variations in the shoreline, but no overall trend of erosion is apparent (Appendix 1). In fact, the shoreline has remained remarkably stable, despite the degree of human modification that has occurred in the shoreline. The fluctuations are in the order of 1-2 m, similar to those found in the Beca (2003) report.

Figure 7. 1942 aerial photograph of Titahi Bay. It can also be seen that, like today, there was slightly more sand in the middle and southern half of the shoreline. The dunes can be easily identified in this area, having formed behind this slight sand surplus. It can also be seen that subdivision development was well advanced by this time.

Figure 8. Titahi Bay circa 1920. Vegetation had been cleared from the back and foredunes. What appears to be Marram can be seen in the foreground behind the boat sheds. Buildings had been constructed on the top of the foredunes. Even at this stage, vehicles played a prominent role in recreation on the beach.

It can be concluded that the erosion that occurred in the 1980s was a medium term occurrence, rather than the start of a net long term trend. The erosion was exacerbated by the poor state of the dunes and the proximity of housing development in the back dune area, that locks up sand from the beach, thereby preventing it from nourishing the foreshore and increasing the impacts from wave run-up at the toe of the dune.

4. Sea Level & Climate Change

Whilst there may be debate surrounding some of the finer points of climate change, there is no question that there has been a measureable rise in global mean temperature and sea level over the past 100 years. These effects are already starting to be felt by our communities and so it is important that we are aware and plan for the impacts this will have on our environment.

Titahi Bay will face pressures from increasing sea level, which has been rising in New Zealand at a rate of 1.8 mm/yr over the past century (i.e. ~20 cm since 1900) (Hannah, 2004). Recent measurements suggest that this rate has increased to 3.1 mm/yr (Church *et al*., 2004; Holgate & Woodworth, 2004). One of the impacts of sea level rise is the ability for wave activity to reach higher up the beach and for longer periods of time. This is especially critical during times of storm surge when beaches can be subject to severe erosion. Overtime, beaches that have a low natural supply of sediment can move into a state of long term retreat as they adjust to a rising sea level.

Sea level rise is a certainty, it has already been occurring for over 100 years, and will continue to rise over the coming century. There is more uncertainty around the effects on local climate. It is thought by NIWA climate scientists that there will be an increase in the magnitude of storm events, but there is less confidence about a potential for an increase in the frequency of these events. What this means for Titahi Bay, is that extreme storm events may become slightly larger, but not necessarily more frequent. Thus, a 1:50 year storm event, may become a 1:25 year event. Overtime, this may place increased pressure on Titahi Bay to recover from storm events, as the wave energy exceeds the ability of the sediments to provide a buffer from erosion.

The fact there has been a sea level rise of 0.18 m over the past 100 years without significant erosion indicates that the beach is reasonably robust in the medium term (i.e. decades). Nevertheless, the beach will become more vulnerable in the long term if sea level rises attain the those forecast in the upper range of the IPPC 4AR (2007), i.e. 0.59 m by 2100, equivalent to a tripling of the sea level rise experienced over the past 100 years. There is a wide acceptance in the scientific community that sea level rise will be in the upper range of current estimates and may even reach 1.0 m by 2100.

4.1 Medium term controls on sea level

There is also annual and inter-decadal variability in the mean level of the sea around New Zealand, that can contribute to cyclical periods of erosion and accretion (Bell, *et al*., 2000). There are three main climatic effects:

- Annual seasonal heating and cooling of the sea surface from solar radiation. This occurs because water expands as it warms and contracts as it cools. The sea surface is typically around 0.04 m higher in the summer and any given year the variation can be as much as ±0.08 m.

- El Nino/La Nina cycles (Southern Oscillation) that can alter sea levels by up to ±0.12 m.

- The Interdecadal Pacific Oscillation (IPO) that occurs on a 20-30 year cycle and can alter sea levels by up to ±0.05 m.

The combination of these factors means that local sea level can vary annually by as much as ±0.25 m from the long term mean (Bell, *et al*., 2001). This has implications for the coast during storm surge events because there are periods of time when local sea level is elevated above the longer term mean. Furthermore, there are indications that the southern oscillation is associated with inter-decadal cycles of stormy and quiescent periods, that produce marked variations in the frequency of storm surges (de Lange & Gibb, 2000).

There have been a number of El Nino and La Nina events in the past 30 years that have affected the western Porirua-Kapiti coastline. As discussed in section 3.4, it was a series of El Nino events in the 1980s that partly led to the construction of the seawall in Titahi Bay.

5. Management Issues and Options

Titahi Bay has had significant modification and human impact from development over the years from the building of the Boat sheds, vehicle access on the beach, the surf club, storm water drainage onto the foreshore, housing in the back dunes, the construction of the seawall and other miscellaneous concrete structures that have been placed along the back of the beach. These structures all interfere with the natural ability of the dunes and the foreshore to respond to storm erosion, effectively making the beach less resilient or inflexible to change. Old photographs show that these activities were well underway as early as the 1920s (Fig. 8). It can be seen in the photographs that native vegetation had been largely cleared from the dunes and replaced with exotic grasses and Marram. Houses had been built in the backdunes and some of the first boat sheds had been placed on the foreshore. Notably, cars were a prominent feature of the recreational activities of the beach from the early days.

5.1 Stormwater outfalls

A common contributor to coastal erosion is the placement of stormwater outfalls on the foreshore. There are three main outfalls on the beach, at the northern and southern vehicle access ways and one adjacent the surf club building. Outfalls have the effect of not only scouring sediment during rainfall events, but also of saturating the sands and making them extremely vulnerable to erosion by wave activity (Fig. 9). Effectively, the sand looses its ability to absorb wave run-up, because the pore spaces are filled with water. This is why there is always a characteristic notch around stormwater outfalls, because the beach experiences enhanced erosion around these points. Long term, it may be necessary to remove stormwater outfalls from the foreshore, in a process known as beach de-watering. But, in the medium term they could be extended slightly, where appropriate, so that they do not drain at the toe of the dune, thereby maintaining the health of the foredune.

Figure 9. Stormwater outfalls, like this one at the northern end of Titahi Bay, have an adverse effect on sandy beaches, causing scouring and making the beach extremely vulnerable to erosion from wave run-up.

5.2 Public access

Access ways through the dunes need to be carefully thought out. Paved access ways through the dunes seriously reduces their capacity to respond to storm events and erosion. It may be best in the medium to long term to restructure the access ways along more soft engineering lines and limit paved access to the north and south ends of the beach.

Continued access by cars along the foreshore reduces the resilience of the beach to erosion by compacting the sand and reducing its capacity to absorb wave run-up. This allows waves to run higher and faster up the beach face, increasing scouring and erosion of the backshore. In addition, it brings the water table closer to surface, keeping the sand moist and limiting the potential for sand dune development.

As sea levels continue to rise, it may be necessary in the medium to long term to restrict vehicle access to the foreshore, thereby allowing the beach to re-establish a more natural foreshore that is better able to cope with sea level rise and storm activity. One option would be to move the vehicle access points to the very ends of the Bay, so that vehicles are not compacting the important foreshore area in the middle of the Bay.

5.3 Effects of the seawall and built structures

The seawall in Titahi Bay was built in 1985 in response to a period of erosion that had been occurring through the earlier part of the decade. The close proximity of property built in the backdunes, heightened the concern of property owners, leading to a decision to build a seawall.

There are three main effects that seawalls can have on a beach:

1. It can act as a groyne and trap sand nourishing the beach from longshore sediment transport and cause erosion on the downcoast side – a process known as impoundment.

2. It can withhold sand from the beach system by locking it up and making it inaccessible to wave activity (especially during times of storm) – also called placement loss.

3. It can cause scouring in front of and at the ends of the wall due to wave reflection and enhanced turbulence.

There will be some scouring in front wall during storm events, but since its construction, the beach has not displayed a tendency for this to be a permanent effect. Likewise, it is not acting as a groyne. This is because the seawall is located at the back of the beach and for most of the time, out of the zone of nearshore currents. Furthermore, because the longshore currents are only weakly developed with the Bay, this effect is minimised.

The main effect the seawall has, is the withholding of sand from the beach. This prevents the natural process of dune development and sediment exchange between foreshore and backshore. This is exactly the same effect that other structures, such as buildings, exert on a beach.

Seawalls are not the most effective means of managing erosion in small, well contained pocket beaches like Titahi Bay, where the sediments are moved on and off shore in cycles of erosion and accretion. In the long term, and particularly under a rising sea level, the seawall will contribute to the loss of sand from the foreshore as it increasing interferes with wave run-up, increasing turbulence on the foreshore and preventing sand from depositing on the beach face. A seawall will hold the shoreline position, but ultimately it will result in the loss of the beach.

5.4 Coastal erosion

The coastal erosion in Titahi Bay is a natural process, exacerbated by human activities. It was shown in section 3.4 that the beach undergoes natural seasonal and inter-decal fluctuations, but the long term trend was stability. This is a classic example of a dynamic equilibrium shoreline, that fluctuates around a long term mean position.

It was acknowledged in the Beca (2003) report that the rate of erosion was low. Nevertheless, it was suggested in the that the seawall be extended by 150 m from its southern end at a cost of around $1000-$1250 per lineal metre.

The two biggest impacts that humans have had on Titahi Bay has been, the destruction of the native vegetative and the building of hard structures on the foreshore and dunes. Removing the native sand binders, Spinifex and Pingao, and replacing them with exotic grasses, destabilised the dunes and made them vulnerable to erosion by wind and wave activity. This problem was exacerbated by hard structures that locked up the remaining sand and prevented the natural exchanges of sediments between the nearshore, foreshore and dune system (Fig. 10).

Figure 10. Hard structures, such as these steps from the 1980s, interfere with the natural exchange of sediments between the nearshore and foreshore and are best avoided on sandy beaches.

One of the best and most cost effective means of remedying this problem, is to replace the exotic vegetation with native sand binders as part of dune and beach restoration programme. In fact, many of the human impacts can be remedied or reduced with a programme of soft-engineering or non-structural management initiatives.

As the seawall comes to the end of its engineering life, it may be possible to remove part of it without replacement. This will depend on the extent and success of a dune restoration project and on the rate of sea level rise at the time. If it is felt that the beach is able to respond to erosion events with a healthy dune system, rather than a seawall, it may be possible to put in place a soft engineered replacement.

Sea level rise is a gradual process that can be dealt with over a period time in a series managed stages, dealing with the issues as they arise. With a good programme of dune restoration it is possible that sea level rise can be accommodated by the beach for the next 30-40 years. Even if the beach does begin to experience increased pressure from climate change, dunes can still form on a beach with a slight negative sediment budget (Psuty, 1992).

6. Conclusion

Titahi Bay is well suited to a dune restoration project. It is wide, dissipative beach with a low to moderate wave energy environment. It undergoes seasonal changes of erosion and accretion in response to storm wave activity. During these phases sediment is transferred between the nearshore and foreshore, it is not lost permanently from the system. The small shoreline fluctuations are a response to this process. However, it was shown that certain human activities have interfered with this natural process and reduced the flexibility of the beach to withstand and recover from erosion episodes. Removing native vegetation, building hard structures on the foreshore and in the dunes and draining water onto the beach, all reduce its ability to cope with natural erosion cycles. Furthermore, these effects will worsen under a rising sea level.

Many of these issues can be partly addressed by a programme of soft-engineering and dune restoration. Reducing the effects of stormwater on the beach, removing exotic vegetation and replacing it with native sand binders, and minimising hard structures on the shore will all act to lessen the effects of erosion and allow beach processes operate naturally. This will also increase the natural amenity values of the beach.

The dunes will be able withstand and recover from the episodic erosion events without wholesale loss. However, it must be stressed, that dunes will not prevent erosion, rather the beach will recover more efficiently if it has a healthy dune system, with a stock of native sand binders that can regrow and 'heal' the dune after an event.

It may be that in the future the dune will come under pressure from sea level rise, and require some additional toe protection, but this may be decades away. In the interim, there is an opportunity to establish a healthy operating dune that is better able to cope with additional pressures from climate change.

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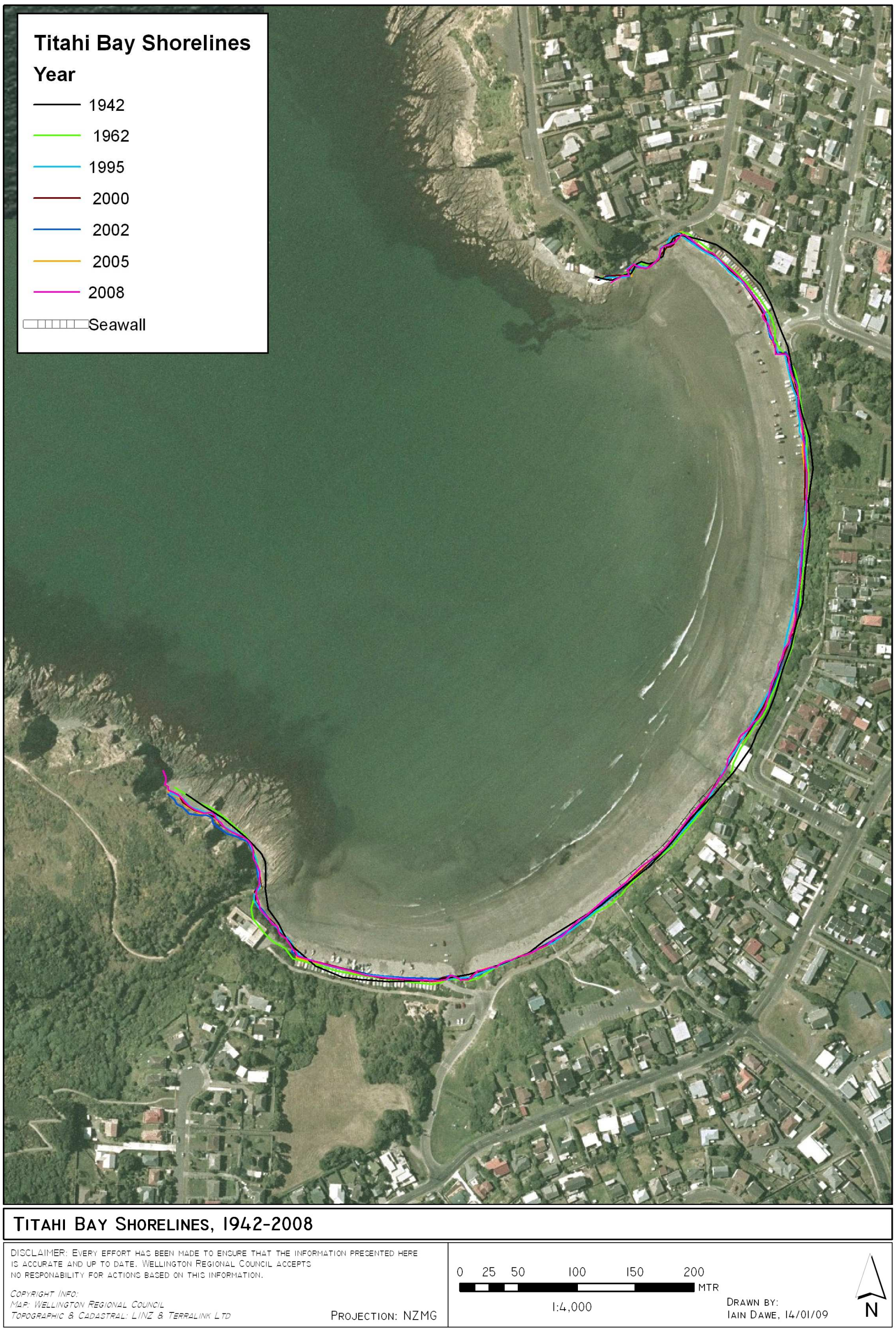
8. Appendix 1. Titahi Bay Shorelines, 1942-2008

Aerial photographs were geo-rectified in ArcMap GIS and the shoreline was plotted following the vegetated edge of the upper foreshore. This corresponds to the active part of the beach that experiences regular wave run-up. The analysis reveals that the shoreline position has been reasonably stable over this period, with only slight fluctuations associated with storm events. The shoreline has established a dynamic equilibrium between the sediment supply and wave activity.



TITAHI BAY SHORELINES, 1942-2008

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