Environment Waikato Technical Report 02/06

Coromandel Beaches: Coastal Hazards and Development Setback Recommendations

Prepared by:
Jim Dahm
Adam Munro

For:
Environment Waikato
PO Box 4010
HAMILTON EAST

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Document prepared by Environment Waikato and Coastline Consultants.

Peer reviewed by Dr Terry Hume, National Institute of Water and Atmospheric Research, Hamilton, and Associate Professor Patrick Hesp, Massey University, Palmerston North.

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Executive Summary

Purpose of Report

This work analyses and reports investigations of Coromandel beaches conducted by Environment Waikato over the last decade, including investigations of Holocene beach development, shoreline change and coastal flooding.

The results of the work are used to review existing coastal development setbacks and to develop revised recommendations for both the eastern and western coast. Comments are also made in relation to design flood levels for coastal inundation.

Other management implications of the work are also briefly discussed.

Methods

The nature and pattern of Holocene beach and dune sedimentation along the eastern Coromandel coast was investigated by radiocarbon dating and examination of dune morphology. Previous work at other sites (e.g. Pauanui) was also reviewed.

Shoreline changes over the last 55-120 years were investigated at various sites along both the eastern and western Coromandel coasts using shoreline information from surveys, aerial photographs and beach profiling.

Investigations related to coastal flooding included compilation of newspaper reports on over 300 historical storm events dating from 1868, analysis of tide gauge records and review of previous work. These investigations particularly focused on the western Coromandel where there have been serious coastal flooding problems.

Eastern Coromandel

The beach and dune barrier systems of the eastern Coromandel can be classified into two distinct beach types: medium-large foredune barriers fronted by fine to medium-grained beaches, and pocket beaches with limited dune reserves and fronted by steep-faced, medium-coarse sand beaches.

- **Holocene Beach and Dune Sedimentation**

Holocene beach and dune development appears to have been initiated about 6400-7650 cal yr (calendar years) BP, about the time that sea level stabilised at or near present levels following the most recent post-glacial transgression.

The total extent and the rates of Holocene barrier development have varied markedly along the coast.

However, the major barrier systems (e.g. Whangamata, Pauanui, Cooks Beach and Whitianga) all show a very similar broad pattern – with initially slow sedimentation, followed by a period of rapid shoreline advance, and then (over the last 500-2000 years) a marked decrease in the rate of progradation.

This general pattern suggests that most of the beach and dune sands for the major barriers were derived from onshore movement of sediments from the adjacent continental shelf, with rate of net onshore transport falling off as an equilibrium shoreface profile was attained. There also appears to have been a lag between attainment of present sea level and rapid onshore movement of the sediments buried by the post-glacial marine transgression. This lag varied from site to site, being relatively short at some barriers (e.g. Whitianga) and very lengthy at others (e.g.

Whangapoua). It is not clear whether initial sedimentation during this period was primarily derived from erosion of pre-existing sediments (including Pleistocene barrier remnants), limited onshore supply or other sources.

While onshore supply from the continental shelf has been the dominant sediment source for the major barriers, modern fluvial supply may also be a limited factor at some sites, particularly Whitianga and Pauanui.

With the exception of Whangapoua, most of the pocket beaches appear to have been in place by about 4000-4500 cal yr BP, though the dunes have since continued to grow in height. The sediments for these barriers appear to have been primarily derived from the continental shelf and/or from erosion of pre-existing Pleistocene barrier systems.

Many of the pocket beaches have very limited dune sand reserves, typically only a single dune and this sometimes just a veneer of sand of varying thickness over pre-Holocene surfaces. However, larger sand reserves occur at Tairua and Whangapoua beaches.

The common occurrence of resistant, pre-Holocene materials within the envelope likely to be influenced by coastal erosion will limit the most severe erosion that can occur at many pocket beaches.

Overall, Holocene progradation along the eastern Coromandel now appears to have ceased at most beaches. At best, most beaches are either in or approaching a state of dynamic equilibrium. For management purposes, the beaches can be regarded as having all the sand they are likely to get.

- **Shoreline Changes**

Analysis of shoreline change over the last 60-100 years suggests that most eastern Coromandel beaches are in a state of dynamic equilibrium, with little trend for net shoreline advance or retreat. However, there is evidence of duneline recession at both Whiritoa and Kuaotunu beaches, pocket beaches that have historically been subject to significant sand extraction. Very slow, ongoing shoreline progradation (<0.1 m/yr) may also be occurring at one or two sites (e.g. Pauanui) with modern fluvial supply.

The most significant shoreline changes appear to be dynamic and primarily occur over periods of decades. These decadal variations appear to be related to both coastwise and local factors, with “cycles” of erosion and accretion typically occurring over periods of 30-50 years or more.

The coastwise trends may relate to variations in the frequency of erosive coastal storms, with accretion dominating during periods with a low frequency of coastal storms and erosion during periods with a higher frequency. However, it is also clear that local factors significantly influence or even determine the decadal variations at many sites (e.g. Buffalo and Cooks Beaches).

In areas away from the influence of estuary or stream entrances and other local factors, the maximum dynamic fluctuations generally appear to be less than 30 m.

However, much larger dynamic changes can occur on shorelines adjacent to ebb tidal deltas and in close proximity to estuary entrances (e.g. northern end of Pauanui Beach, eastern end of Cooks Beach), near stream entrances (e.g. Whiritoa, Kuaotunu West) or major stormwater outlets (e.g. Williamson Park, Whangamata).

One major barrier system (Kennedy Bay) is also vulnerable to spit breaching.

- **Coastal Flooding Along the Coromandel East Coast**

The only significant coastal flooding at ocean beaches occurs at Buffalo Beach and, to a much lesser extent, the eastern end of Cooks Beach. At both these sites, frontal foredunes have been eliminated or lowered by coastal subdivision. Whitianga has experienced at least 15 separate coastal flooding events since 1930.

Waves have been a significant factor in most flooding experienced in the last 70 years, over-topping shoreline areas as high as 2.5-3 m above mean high water springs. Storm surge effects also contribute significantly, with elevations up to 0.8 m noted in past events.

Coastal flooding has also occurred around estuarine margins, particularly the low-lying Manaia Road area at Tairua and parts of Whangamata. Swell waves propagating through harbour entrances and elevation of water levels due to storm surge effects both appear to be factors in this flooding.

Though four significant, distantly-generated tsunami have been recorded along the eastern Coromandel over the last 120 years (August, 1868, May 1877, August 1883, and May 1960), tsunami are not known to have caused any significant coastal flooding over the past century. However, newspaper reports indicate that the distantly-generated tsunami event of May 1960 caused some minor flooding at Whitianga and recent tidal analysis has identified Mercury Bay as a potential tsunami "hotspot." Further work is required to better define tsunami risk.

- **Potential Impact of Predicted Global Warming**

Existing vulnerability to coastal erosion and coastal flooding could be considerably exacerbated over the next 100 years as a consequence of the effects likely to accompany predicted global warming, including a predicted rise in mean sea level of 0.5 m (IPCC, 1996).

Western Coromandel

- **Coastal Flooding**

Investigation of historical coastal flooding has identified 6 major events since 1930 (Table 6) that have caused flooding of a similar or greater magnitude to the July 1995 and Cyclone Drena events. Therefore, despite only two events in the last 45 years, major coastal flooding appears to be relatively frequent.

The flooding arises from the combination of astronomical tides with wave and storm surge effects.

Available information on extreme sea levels arising from the combination of tides and storm surge alone, suggests that levels in excess of RL (Reduced Level) 2.3 m (with respect the Tararu mean sea level datum) are rare, despite the July 1995 event in which tides and storm surge effects resulted in water levels approaching RL 2.5 m.

However, wave effects (particularly associated with northerly ocean swell migrating into the Firth) appear to have been a significant component in most historical coastal flooding. Wave over-topping of coastal margins floods low-lying areas further inland and can also carry large volumes of rock and gravel more than 10-15 m landward.

The highest recorded coastal flood level (RL 3 m, noted during the flooding of May 1938, is presently adopted as the best estimate of the 1% AEP design flood level (that level with a 1% probability of being equalled or exceeded in any given year).

Available information tends to suggest this design level may be conservatively high for existing coastal processes, except in nearshore areas subject to wave run-up. However, until existing information can be substantially improved, we do not believe it is appropriate to recommend any changes. Particularly in view of predicted sea level rise of 0.5 m over the next 100 years – which would markedly increase both the frequency and severity of existing coastal flooding.

However, nor do we believe it is necessary in the interim to raise the design level to allow for predicted sea level rise. The existing figure is probably an adequately conservative estimate of the 1% AEP event for the expected 50-year life of any new buildings, even with the sea level rise likely to occur over this period.

The importance of wave effects suggests that extreme sea levels may vary around the Firth according to wave exposure. Further refinement of the existing design level will require more definitive information on wave effects.

Recent modelling of both distantly- and locally-generated tsunami tends to suggest that tsunami hazard in the Firth of Thames is low.

The Miranda Plains and the alluvial deltaic fans of the Thames Coast have extensive areas vulnerable to coastal flooding and this vulnerability would be significantly increased by predicted sea level rise of 0.5 m. Therefore, considerable caution should be exercised before any intensification of development in these areas.

- **Shoreline Changes**

Analysis of shoreline change indicates that the alluvial delta fans of the Thames Coast can undergo significant progressive shoreline change associated with movements of river entrances and channels. It appears that some of these features (e.g. Tapu and Waikawau) might even be substantially reworked by river channel changes over periods of 50-100 years or more. It is probable that similar scale changes may also occur at other sites over longer periods of time.

In addition, significant dynamic fluctuations (typically 25-35 m) can also occur in the vicinity of river entrances over periods of decades.

In areas removed from the river entrances, shorelines are generally less active - but can undergo dynamic shoreline changes of up to about 15 m.

Longer-term trends for progradation or recession are difficult to determine from the limited available data. However, it appears that any trends for long-term progradation are slow, probably only 1-5 m/century.

Implications for Hazard Management

The close proximity of development to the sea and the degradation of natural dune systems have resulted in coastal hazard problems at many Coromandel coastal settlements. There is also potential for hazard problems to be considerably aggravated over the next 50-100 years as a consequence of predicted sea level rise and intensification of existing nearshore development

Hazard management strategies addressing these issues emphasize the need to avoid risk in new areas of subdivision, reduce risk in areas of existing subdivision, live with some risk (especially to property) and to protect and restore natural coastal buffer zones.

Development setback recommendations have been designed which identify the areas at risk and provide for maintenance of a protective buffer zone even with worst likely erosion.

In areas of existing development, two setbacks are proposed.

The ***Primary Development Setback (PDS)*** includes the worst probable erosion likely to be associated with existing coastal processes **plus** an allowance of 10 m to ensure a protective buffer is maintained even under conditions of worst erosion. The PDS is recommended as the minimum setback for any coastal development and as a building avoidance area. Where this setback precludes reasonable exercise of existing rights, a site-specific hazard assessment should be required as a pre-requisite to any development.

The second setback, the ***Secondary Development Setback (SDS)****,* incorporates an allowance for the effects that may accompany predicted global warming over the next 100 years. It is recommended that no further intensification of subdivision or development be permitted within this area.

Along the eastern Coromandel coast, the PDS varies from 30-40 m, while the total SDS varies from 45-60 m. The equivalent setbacks along the western Coromandel are typically 25 m and 50 m, though a lesser setback (15 m) is recommended for Otautu Bay.

It is recommended that site specific provisions be determined for undeveloped areas and that these should be sufficient to provide for other coastal management objectives, including preservation of natural character. In the absence of site-specific provisions, a minimum setback of 100 m is proposed for the eastern Coromandel and 50 m for the western Coromandel, except in a few isolated sites where site-specific provisions are proposed.

The effect of natural, erosion resistant materials and any shoreline armouring works have generally been ignored in mapping the setbacks – except at those sites where adequate information was available to incorporate these effects.

Setbacks in the vicinity of river and stream entrances have been determined on the basis of site-specific information for each beach – estimating the likely magnitude of dynamic changes on the basis of historical changes shown on historic vertical and oblique aerial photography held by Environment Waikato, the limited available cadastral survey information and coastal morphology.

Recommended setbacks for all key sites are shown in Appendix D.

The setbacks along the western Coromandel will not provide protection from coastal flooding and it is recommended that a design flood level of RL 3 m also be adopted as the minimum floor level in areas potentially subject to inundation.

In view of various uncertainties, particularly in respect of projected global warming, ongoing review of the setbacks will be required once every 10 years.

1 Background

1.1 Purpose of Report

Environment Waikato has undertaken a variety of investigations related to coastal hazards over the last decade - particularly focused on the ocean beaches of the eastern Coromandel, though also including work on the western Coromandel coast and the west coast of the Waikato Region (Figure 1-1).

This information has formed the basis for various Council policies and programmes, including overview reports on both coastal erosion and coastal flooding hazard (Dahm, 1999a and b), and mitigation strategies developed for these hazards (Environment Waikato, 1999c and d). It has also placed a significant role in the initiation of the Council's Beachcare programme, management of sand extraction, site specific hazard management strategies and advice and various other matters (Dahm, 1994; Dahm et al., 1994; Dahm and Spence, 1994 & 1997; Dahm and Riddle, 2001).

However, to date, apart from various site-specific reports, there has been no detailed technical reporting of the work.

Coastline Consultants Ltd were engaged in April 2000 to prepare a technical report reviewing this unpublished data and information (detailed in section 2 below).

The report also synthesizes the technical information to review and revise existing development setbacks for priority sites on the eastern and western Coromandel.

Some limited work has also been undertaken on the West Coast of the Region (e.g. Mokau and Aotea). This and other limited information on Waikato West Coast sites has previously been discussed in Dahm (1999a) (and more recently in Dahm and Riddle, 2001). It is clear from the limited available information that nearshore (and particularly near-entrance) areas along the West Coast are potentially very unstable and should presently be avoided for further subdivision and development (Dahm, 1999a). Setback recommendations adopted by some councils along this coast (e.g. Waitomo and Otorohanga District Councils) reflect this.

However, understanding of the sediment dynamics of West Coast beaches is still poor. NIWA are presently undertaking investigations to better define sediment sources, storage and movement along this coast and Environment Waikato have also installed a computer-controlled video camera to better understand shoreline changes at the Mokau River entrance. Over time, this and other work will improve available information on the nature and magnitude of shoreline movements and coastal flooding along the West Coast.

Therefore, this report focuses solely on the work conducted along the eastern and western Coromandel coasts.

Figure 1-1: The Waikato Region and coastal locations.

1.2 Objectives

The brief for the report includes the following specific objectives:

- Analyse and report Holocene drilling and carbon dating conducted by Environment Waikato
- Analyse and report shoreline change data held by Environment Waikato – identifying as far as practical existing shoreline trends and the magnitude of dynamic shoreline changes on both eastern and western Coromandel coasts
- Summarise and report information collated in Environment Waikato's storm data base
- Develop and report a proposed hazard assessment process for the design of development set-backs on the eastern and western Coromandel Peninsula
- Integrate the above information to document and support development setback recommendations for priority Coromandel east and west coast sites
- Identify hazard management recommendations for these areas
- Highlight other coastal management implications of the work for Coromandel beaches.

1.3 Review Process for Coastal Development Setbacks

A review of the coastal development setbacks on Coromandel beaches was initiated in 1999.

The review was limited to developed beaches of the Thames Coromandel District, with the beaches included in the review agreed with TCDC staff in the 1999/2000 financial year. The one developed beach in the Hauraki District (Whiritoa) was also included because of site-specific investigations in the early 1990's. A coastal hazard management strategy, including development setbacks, was developed for Whiritoa Beach at that time (Dahm et. al., 1994) and has since been implemented.

The review process commenced with a detailed analysis of available scientific data and the development of draft recommendations, which were broadly discussed in various meetings with staff of Environment Waikato and TCDC. All parties agreed that a careful scientific review of the recommendations was critical.

The first draft of this report was produced in July 2000 and has since been scientifically peer-reviewed by Associate Professor Patrick Hesp of Massey University and by Dr Terry Hume of NIWA (Hesp, 2001; Hume, 2002). The latter of these 2 reviews was completed in late February 2002.

The peer reviews concluded that the proposed setbacks were not overly conservative on the basis of the present scientific data (Hesp, 2001; Hume, 2002). They also made a number of useful and constructive suggestions for further refinement of the report, which have largely been adopted.

The review has now refined the setback recommendations as far as is reasonably practical on the basis of available scientific information.

1.4 Statutory Requirements

It is important to appreciate that there a number of statutes (including the Resource Management Act and the Building Act) which require that regional and district councils (and to a lesser extent various other management agencies) manage natural hazards, including coastal erosion and flooding.

These statutes establish a requirement to identify the areas vulnerable to coastal hazards, a key purpose of this report.

The provisions in the various statutory documents will also significantly influence how future subdivision and development is managed within the identified hazard prone areas.

The management of natural hazards, including coastal erosion and flooding, is primarily conducted within the framework of the Resource Management Act 1991. As such, it must be undertaken in a manner that is consistent with the purpose and principles of the Act and with the policies and objectives of subsidiary documents, including the New Zealand Coastal Policy Statement (NZCPS), the Regional Policy Statement for the Waikato Region (RPS), the proposed Regional Coastal Plan (RCP) and the proposed District Plan for the Thames Coromandel district.

The RMA and the NZCPS are the key "big picture" documents that outline the principles and policies governing coastal management. The key provisions in these documents that are relevant to the management of coastal hazards are outlined in Appendix E. These provisions reinforce the wide range of considerations now relevant in coastal management, including the management of natural hazards.

The RPS, RCP and the District Plan add further detail to these provisions at regional and local level. The RPS is also fundamental to hazard management in the Waikato Region as it establishes the overall approach and relevant responsibilities.

In essence, the principles and policies in these various statutory documents require that the management of coastal hazards provide for the sustainable management of the coastal environment, including:

- Enabling people and communities to provide for their social, economic, and cultural well being and for their health and safety (s5, RMA);
- Sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations (s5, RMA);
- Safeguarding the life-supporting capacity of air, water, soil, and ecosystems (S5, RMA);
- Avoiding or mitigating adverse environmental effects (s5, RMA);
- Preservation of the natural character of the coastal environment (s6a, RMA);
- Maintenance and enhancement of public access to and along the coast (s6d, RMA);
- The continued functioning and, where appropriate, restoration and rehabilitation of natural coastal systems (Policy 1.1.4 and 1.1.5, NZCPS);
- Recognising and protecting the ability of natural features to protect subdivision, use and development and enhancing that ability where appropriate (Policy 3.4.3, NZCPS);
- The avoidance of significant adverse effects arising from cumulative use and development (Policy 3.2.2, NZCPS);
- Maintenance and enhancement of coastal amenity, including scenic and recreational values (s7d, RMA);
- Protection of historic areas and areas of spiritual or cultural significance (e.g. s6e, 7a, 7e and 8, RMA);
- Location and design of new subdivision, use and development so that the need for hazard protection works is avoided (Policy 3.4.5, NZCPS);
- Use of non-structural methods for the management of coastal hazards, unless structural solutions are the best practicable option (Policy 3.4.6, NZCPS);
- Where coastal protection works are the best practicable option, they should be located and designed so as to avoid adverse environmental effects to the extent practicable (Policy 3.4.6, NZCPS);
- Consideration of abandonment or relocation of existing structures (Policy 3.4.6, NZCPS);
- The adoption of a precautionary approach when providing for subdivision, use and development in the coastal environment where potentially significant adverse effects may arise (Policy 3.3.1, NZCPS);
- Recognising the potential for sea level rise and other changes which may accompany predicted global warming (Policy 3.4.2, NZCPS).

The various objectives summarised above are central considerations to coastal management, including the management of coastal hazards. Therefore, coastal hazard management now incorporates a very wide range of matters in addition to the protection of property.

Identification of the areas vulnerable to coastal hazards is critical to achieving these various objectives and appropriately managing the coastal margin.

1.5 Structure of Report

An executive summary is provided at the front of the report.

Chapter 2 outlines the data collected by Council over the last decade and the methods and procedures used to collect and analyse this information.

Chapters 3 and 4 report work along the eastern and western Coromandel, respectively.

In Chapter 5, the findings from this work are used to develop recommendations for coastal development setbacks.

2 Methods

Environment Waikato has undertaken a wide range of work related to the assessment and management of coastal hazards over the last decade, including investigations of holocene beach development, shoreline changes and coastal flooding.

2.1 Investigations of Holocene Beach Development

The nature and pattern of Holocene beach and dune sedimentation since cessation of the post glacial rise in sea level ca 6500-7000 yr BP (Gibb, 1986) can provide a wide range of information relevant to the assessment of coastal hazards – including information on shoreline trends over recent centuries, sources and rates of sediment supply, and the extent of Holocene deposition.

Most of the Holocene investigations undertaken by Council have focused on beach and dune systems of the eastern Coromandel, though the Holocene spit at Mokau on the West Coast has also been drilled and dated.

The work has primarily involved the drilling and dating of Holocene dunes and limited investigations of the surface morphology of the dune systems. In addition, field inspections were conducted at all sites listed in this report

2.1.1 Coring and radiocarbon dating of Holocene dunes

The pattern and extent of Holocene beach and dune sedimentation was investigated by coring and radiocarbon dating of Holocene dunes at 8 sites along the Coromandel east coast (Whiritoa, Whangamata, Opoutere, Tairua, Cooks Beach, Buffalo Beach, Matarangi and Whangapoua) (Figure 1-1).

Drilling was only conducted to depths sufficient to extract suitable shell material for radiocarbon dating. All shell samples were taken from beach sediments underlying the dune sands, typically at elevations 0.5-2 m below mean sea level – with the exception of two samples from Whiritoa (Whiri 7 and 8) which were taken from dune sands (and thus post-date the shorelines at these sites). At most sites, sediments above these levels contained relatively little coarse shell (i.e. fragments larger than 4 –5 mm). The elevation of the samples tends to suggest that the shell was originally deposited on the lower (seaward edge) of the beach-face – which can lie 20-40 m (sometimes more) seaward of the toe of dune.

The majority of samples were taken using various coring equipment, particularly a truck-mounted, Laskey hollow-stemmed auger and a portable vibro-corer. The full cores taken with the vibro-corer were retained for simple lab examination. With the truck-mounted auger overlying sediments were logged and sampled during drilling, though not always cored. However, coring was always used when drilling depths reached beach sands to facilitate sufficient shell retrieval for dating.

Some early samples were also taken with truck-mounted wash-drilling systems, though useful logging and shell retrieval proved difficult with these systems. They also tended to be somewhat messy, due to water and drilling mud requirements and were less suitable for many of the subdivided areas where drilling had to be conducted on private lawns.

All sites at Whitianga were surveyed and levelled. Holes at Whangamata sites were also levelled, though not positioned. At other Coromandel sites, the positions of the drill holes were identified on large scale, vertical aerial photographs (typically scales of 1:5000), using measurements to identifiable local features. For each barrier system, sample sites were translated along dune crests to a common shore-normal transect, with distances to the shoreline then measured along this transect for each core site. Distances from the present shoreline were also measured in the field for all sites located close to the sea.

All shell samples were submitted to the University of Waikato Radiocarbon Dating Laboratory for dating. The conventional radiocarbon ages obtained were calibrated to calendar years using the procedure (and the computer programme 'Calib') developed by Stuiver and Braziunas (1993).

A list of all sites, their dates (in radiocarbon and calendar years), and their distance from sea is provided in Appendix A. Conventional (i.e. radiocarbon) ages are referred to as "yr BP" (where BP = 1950) and calendar/solar years are reported as "cal yr BP". Calibrated ages are most properly regarded as a range, usually the range encompassed by the 95% confidence (2 sigma) interval. The maximum and minimum ages reported in Appendix A and the error limits shown on graphs in Chapter 3 represent the upper and lower ends of this range.

It is important to appreciate that the reported ages are of the shell and do not necessarily reflect the age of the associated depositional landforms – since the shellfish may have died some time before the shell was deposited. This issue of "inbuilt age" (Shepherd et al., 1997) raises potentially serious issues for dating of barrier development using shell dates – since the age of the shell might be considerably older than the age of the shoreline it is taken to represent.

This concern is particularly relevant in this study, where most samples were composed of broken rather than whole shell, suggesting the shell had been worked by the sea for some time (possibly decades, possibly more – it is difficult to estimate) before being deposited. Samples of broken shell may also be composed of pieces of shell of many different ages, potentially adding further complication.

In such circumstances, it is preferable to have other independent dating methods that can be used to provide some crosscheck on the shell ages.

There are some late Holocene tephras mantling parts of the Coromandel such as the Tuhua Tephra, Taupo Lapilli and Kaharoa Tephra (Hogg, 1979; Hogg and McCraw, 1983; Abrahamson, 1987) and these were able to be used in places. However, these tephras are often either limited in distribution (e.g. Tuhua) or are not of sufficient thickness to be readily identified in the field. The degree of human modification of Coromandel dunes also complicates identification of any air-fall tephra deposits. No peat deposits (e.g. in dune swales) of sufficient depth for useful dating were found, a limitation also noted also by previous workers (e.g. Marks and Nelson, 1979).

Therefore, inevitably, the dating of barrier development relies heavily on the radiocarbon dating of shell. Consequently, given the potential difficulties noted above, emphasis was placed on the use of repeated sampling to provide some crosscheck on the dates. This involved the coring and dating of some dunes in more than one location (preferably some considerable distance apart) and/or the submission of two or more samples from individual cores (usually from different levels in the core, where this was practical or appropriate).

This duplication of cores/samples was particularly emphasised in nearshore dune locations where dates were critical to better understanding shoreline progradation trends over recent centuries and/or millennia. It was also emphasised on the landward margins of some barriers to better confirm the date of barrier initiation and also better confirm the pattern of sedimentation in these early periods.

For example, at Whangamata, four separate sites were drilled and dated within or immediately behind the present frontal dune (sites Wgm 3, 4, 10 and 12 – Appendix A) and duplicate dates were also obtained from cores Wgm 6, 8 and 41 (Appendix A).

While the shells provide an indication of the maximum age of the ridge immediately *seaward,* it cannot be assumed that they necessarily provide a useful indication of the age of the ridge immediately *landward* (Shepherd et al*.,* 1997). However, they do provide a maximum age for the retreat of the sea from the beach in front of the landward ridge (Shepherd et al*.,* 1997). Therefore, in interpretation of shoreline progradation, the distance from the sample site to the present toe of dune has been assumed as the net progradation since the shell was deposited.

While the modern equivalent of the depositional environment in which the shell was deposited (i.e. toe of beach face) may lie 20-40 m further seaward of the present toe of dune, this shoreline cannot yet be regarded as having been abandoned.

2.1.2 Dune morphology

Coromandel coastal dunes have been extensively altered by human activities over the last 100-150 years, particularly urban subdivision since the 1960’s. However, useful information is available on dune morphology and pattern from historical aerial photographs that pre-date the extensive urban subdivision.

Environment Waikato has also surveyed a shore-normal transect across the Whitianga barrier system, where many of the older Holocene dune landforms have not yet been subdivided. Limited field measurements and observations of isolated dune remnants were also undertaken at other sites and by earlier work (e.g. Marks and Nelson, 1979).

2.2 Investigations of Shoreline Change

Analysis of shoreline changes over the last 50-100 years can provide useful information on the nature and magnitude of dynamic shoreline movements and on longer term trends for recession or progradation.

Available information on shoreline change along the coast of the Waikato Region is still limited but includes mapping of historical shoreline changes at a number of sites and beach profile monitoring. Other information held by Council includes an extensive collection of historical aerial photographs (vertical and oblique) dating from the 1940/50’s and a large collection of newspaper reports on historical coastal storms (the latter is discussed further in Section 2.3.1).

2.2.1 Terminology used for shoreline changes in this report

In this report, shoreline changes are generally referred to as long-term trends or dynamic shoreline changes.

The term *long term trend* is used only to refer to *net changes in shoreline position arising from a positive or negative sediment budget.* In other words a long-term trend for **(recession)** means that the beach system is, over time, losing more sand than it is gaining. A long term trend for accretion (referred to as **progradation**) means that the beach is, over time, gaining more sand than it is losing.

All other shoreline changes are referred to as *dynamic changes*. These changes (which may occur over periods from seconds to centuries) indicate nothing about the underlying status of the sediment budget of the sand system. In other words, when viewed over periods of several decades or more, these changes do not result in any net gain or loss of sediment – being associated simply with fluctuations in shoreline position or changes associated with other causes (e.g. river channel changes).

In most cases, long term trends for net recession or progradation are relatively slow and typically masked by dynamic changes over periods of several years to several decades. On the coast of the Waikato Region, most shoreline changes evident to human observers are probably dynamic changes (Dahm, 1999a). However, long-term trends can result in very significant shoreline changes over periods of several decades to centuries.

2.2.2 Mapping of historical shorelines

The nature and magnitude of historical shoreline changes have been investigated at various sites by previous workers, particularly along the eastern Coromandel (e.g. Healy et al*.,* 1981; Gibb and Aburn, 1986).

Over the past 10 years, Environment Waikato has extended this information with further shoreline mapping at selected sites along the eastern and western Coromandel coasts and at Mokau on the West Coast.

- **Eastern Coromandel**

Mapping of historical shoreline changes has been conducted at Whiritoa, Whangamata, Pauanui, Tairua, Cooks Beach and Whitianga (Figure 1-1). Most of this work has focused on the mapping of historical shorelines (usually toe of dune) from suitable aerial photographs dating from the 1940's. The existing toe of the dune was also re-surveyed for these analyses at Whangamata, Pauanui, Tairua and Whitianga.

The earliest work (at Cooks Beach and Whiritoa) was conducted by (then) DSIR Land Resources at Aokautere using a zoom transfer scope to superimpose mapped shorelines on a rectified image. They estimated the accuracy of the shoreline markers as $\pm$ 3 m (e.g. Letter of John Dymond, DSIR Land Resources dated 30 September 1991, reference 9223908). The later work at Whangamata and Whitianga was conducted by (then) Photosurvey Ltd of Auckland (now Precision Aerial) using a stereo-plotter. They estimated the accuracy of the shoreline markers as $\pm$ 1.5-2 m to (worst case – usually the 1940's imagery) $\pm$ 4 m (Letter from Keith Miller of Photosurvey Ltd, dated 7 September 1993). With all work, Mr J Dahm of Environment Waikato inspected the imagery with DSIR and Photosurvey staff prior to mapping, to confirm the shoreline features to be mapped.

The earlier analysis of shoreline change at Pauanui (Gibb and Aburn, 1986) was also updated with a re-survey of the toe of dune in 1996. This data was compiled with shorelines mapped from the earlier analysis and new maps produced – the work undertaken by (then) Works Consultancy Services Ltd (now Opus International Ltd) of Hamilton. This firm also undertook an analysis of shoreline change at Tairua Ocean

Beach – using shoreline information from a field survey conducted in November 1997 and from aerial photos dating from 1944, 1971, 1978 and 1983. The aerial photographs were typically 1:2000 scale, unrectified enlargements. As such, the error in absolute placement of the lines could be significant. Nonetheless, the work was carefully conducted (being repeated by the Company after earlier problems) and we believe the data does provide useful information on the magnitude of shoreline changes. However, due to potential limitations with this work, we have not emphasised this data in our reporting.

Gibb and Aburn (1986) were able to usefully incorporate a survey dating from 1895 in the original compilation of the Pauanui shoreline change maps – complementing the aerial photograph data (which dates from the 1940's at all sites). It was initially desired to also incorporate pre-1940's cadastral information in the compilation of shoreline change maps undertaken at Whiritoa, Whangamata, Cooks Beach and Whangamata. However, advice from the (then) Department of Survey and Land Information indicated that available cadastral information was generally unsuitable.

The work undertaken at Tairua allowed the 1895 shoreline to be plotted, taken from an earlier Hauraki Catchment Board plan. However, though the traverse book of survey control used along the beach at that time was able to be located, there were no offsets or references to the line itself (Letter from Mr I Watkins, Survey Technician, Opus Consultants Ltd, dated 18 June 1998, ref S1518D). This tends to reinforce the advice received earlier from the Department of Survey and Land Information.

In the compilation of the shoreline change maps at Whitianga, an attempt was made to incorporate a survey dating from 1852 (conducted by HMS Pandora under Commander Drury). Photosurvey Ltd advised that the latitude and longitude data on the 1852 chart was insufficiently accurate to allow direct comparison with later shorelines. Therefore, the shoreline was positioned by matching rocky parts of the shoreline with those mapped photogrammetrically from aerial photographs. In general, a reasonable fit was obtained, but Photosurvey Ltd advised that some parts of the 1852 survey appear to have been sketched in and are considerably out of position with more recent charts. Therefore, there is considerable uncertainty attached to the position of this shoreline. Approaches were made to the British Admiralty seeking further information on survey datums used during the Pandora survey but they were unable to locate useful information.

All shoreline change analyses along the eastern Coromandel used photography purpose-flown by the (then) Hauraki Catchment Board to record the impact of the July 1978 storm wave event, one of the most significant erosive events along this coast over the last 50 years.

Relevant plans for all shoreline change analyses reported here are held by Environment Waikato, excepting Whiritoa. This information was subsequently lost. However, the major details of this analysis are able to be discussed as the work was used in reports prepared for the Whiritoa Hazard Management Strategy (Dahm, et al., 1994). A plan prepared at that time showing the shoreline changes was also able to be located and is presented in Chapter 3. A list of Plan numbers for available work is included in Appendix B. All data for Whitianga is also held in Environment Waikato's GIS.

- **Western Coromandel**

Coastal flooding is generally a much more serious issue than coastal erosion along the relatively sheltered margin of the western Coromandel. Therefore, work on this coast has tended to focus on coastal flooding rather than erosion.

Nonetheless, there are some locally significant erosion hazard issues, particularly on some of the gravel deltas of the Thames Coast and at Koputauaki Bay to the north of

Coromandel (Dahm, 1999a). Investigations of shoreline change along the western Coromandel have particularly focused on these sites.

The limited available cadastral surveys for Tararu, Te Puru and Waikawau (Figure 1-1) were compiled and new toe of bank surveys completed for each of these alluvial gravel delta fans along the Thames Coast. The surveys at these sites also included shore-normal cross-sections to determine the elevation of the seaward margins.

Shoreline changes at Te Puru were also mapped from a series of registered, historical aerial photos dating from 1968-91 (O'Regan et al*,* 1995).

At Koputauaki Bay in the northern Coromandel (Figure 1-1), shoreline changes over the last 90 years were mapped from available aerial photos and surveys by J.M. Harris Ltd, Registered Surveyors, of Te Kuiti. A baseline survey of the toe of bank was also conducted at this site, together with spot depths and contouring of local onshore and offshore topography.

Relevant plan numbers are listed in Appendix B.

2.2.3 Beach profiling

Beach profile monitoring sites were initially established at many beaches along the eastern Coromandel coast in 1979 and 1981 (Healy et al*,* 1981), with further sites progressively added as required since that time.

The sites were only surveyed occasionally between 1979 and 1990, but since that date Environment Waikato has attempted to maintain semi-annual surveys at key sites. Many of the sites have also been periodically re-surveyed by NIWA staff.

Much of the older data inherited by Environment Waikato contained small errors that required checking and correcting, though this is gradually being resolved by environmental monitoring staff of Environment Waikato. An initial list of reliable data has been compiled (Stewart, 2001), though we noted some occasional remaining issues in the surveys we inspected.

The position and elevation of most of the beach profiling sites have not yet been surveyed due to the difficulty and cost of this work (most eastern Coromandel beaches do not yet have a mean sea level datum established). However, work is presently being initiated to position and level all of the sites over the next three to four years using GPS (D Stewart, Environment Waikato, *pers. comm.,* June 2000).

Despite the limited length and frequency of the record, the beach profile data does provide a useful overview of the general pattern of shoreline change along the eastern Coromandel over the last 20 years.

Beach profiling work has also been conducted in front of Te Puru School along the western Coromandel since the early 1990's. This location has been one of the most actively eroding areas around the margins of the Thames Coast gravel deltas over the last decade and the monitoring is designed to help estimate the nature and magnitude of dynamic fluctuations around the coastal margins of these features. The monitoring is still ongoing, though the recent placement of shoreline armouring works to protect the school foreshore has reduced the value of the work in terms of shoreline response.

2.2.4 Other information on shoreline change

Over the last decade, Environment Waikato has also collated an extensive collection of vertical and oblique aerial photographs of coastal sites around the Region, particularly along the eastern and western margins of the Coromandel. These photographs provide considerable useful information on the nature and magnitude of historical shoreline changes. Most of these photographs are held in geographically arranged dossiers at Environment Waikato.

There is also useful information on the impact of historical storm events in the extensive storm database compiled over the last 10 years (see section 2.3 below) and in historical files.

2.3 Coastal Flooding

Investigations related to coastal flooding have primarily focused on the western Coromandel, particularly around the southern Firth of Thames where there have been serious coastal flooding problems (Dahm, 1999b).

Work undertaken on coastal flooding has included compilation of information (particularly newspaper reports) on historical events and analysis of the Tararu tide gauge records.

2.3.1 Compilation of historical newspaper reports

An extensive list of over 300 storm events dating from 1868 was compiled (Appendix C). This work commenced with the list of (about 180) coastal storms compiled for the Bay of Plenty by Hay (1991), adding further dates from a variety of published (particularly Barnett, 1938; Kerr, 1976; Soil Conservation and Rivers Control Council, 1957; Revell, 1981; Thompson et al*.,* 1992) and unpublished sources (particularly council files and community information). Some storms were also identified by comparative references in newspaper reports of other events.

These dates were then checked for newspaper reports of the storm events using available newspaper archives. Searching focused on newspaper archives from the Coromandel area (the main area of interest) and the New Zealand Herald. Initially, both the New Zealand Herald and the Waikato Times (and its predecessor the Waikato Argus) were searched. However, comparison of results for storm events indicated that the Herald reports were generally more extensive – probably because of its location in a coastal city (where coastal storms tend to be recorded) and the wider (national) circulation of this daily paper.

A list of the papers searched is noted besides each storm event in Appendix C. The newspaper archives were primarily located in the Hamilton Public Library (Waikato Times and Waikato Argus), University of Waikato library (New Zealand Herald), Thames Library (Thames Advertiser, Evening Star, Thames Star and Hauraki Herald) and the (then) Paeroa Gazette offices (Coromandel and Mercury Bay Gazette, Hauraki Plains Gazette, Thames Valley Gazette and Waihi Gazette).

A standard searching process was developed to ensure most available information on any particular event was able to be located. Searching of newspapers began 2-3 days before the given storm date to allow for possible errors in the date and to identify storm warnings and other information. If no articles related to the storm were located, searching was conducted for a week after the storm date to ensure no articles were missed. Any information relating to the storm was copied – including meteorological information, flooding reports, shipping delays and wrecks and storm damage reports. The dates of the newspapers searched and all copied materials are contained in archives held by Environment Waikato. Ideally, these archives should ultimately be scanned. All copied materials have details of their source, date and newspaper page.

After compilation, all newspaper reports were reviewed, looking particularly for information on coastal erosion or flooding – especially around the Coromandel. In general, the reporting of coastal erosion and/or flooding in the Coromandel were spasmodic up until the 1930's. Therefore, discussion of coastal storms in Chapters 3 and 4 focuses on the period since 1930. The list of major storms for this period is believed to be reasonably comprehensive for the Coromandel west coast.

2.3.2 Other sources of information

Environment Waikato maintains a tide gauge at Tararu in the southern Firth of Thames and this recorder provided useful information on water levels during the coastal flooding events of July 1995 and Cyclone Drena (January 1997). Information on flood levels surveyed around coastal margins was also able to be obtained from various sources for these flooding events.

Some information on coastal storms and historical flooding was also able to be obtained from Council files, long-term residents or property owners and existing reports (e.g. Smith, 1980).

3 Eastern Coromandel

3.1 General Background

The eastern Coromandel coast extends approximately from Cape Colville to just north of Waihi Beach on the northeast coast of the North Island (Figure 1-1). The coast is a popular holiday destination - having high natural and amenity values and located close to major population centres in the Auckland, Waikato and Bay of Plenty regions. Holiday settlements are particularly common at beaches along the coast, with 75% of all eastern Coromandel beaches being either developed or partially developed as of 1996.

The coast is located on the tectonically active margin of the Australian and Pacific Plates and forms part of the Coromandel Peninsula, an uplifted horst block feature down-tilted to the east and composed on Tertiary volcanics overlying an indurated Jurassic sedimentary basement (Skinner, 1976). Pleistocene and late Quaternary tephra deposits also thinly mantle extensive areas of the Peninsula, largely originating from volcanic centres in the central North Island (Hogg, 1979; Hogg and McCraw, 1983).

The coastline is steep and rocky and indented by numerous small embayment and pocket beaches which front a relatively narrow continental shelf, approximately 20-30 km in width (Bradshaw et al., 1991). A number of small, shallow tidal estuaries also occur along the coast in drowned river valleys impounded by Holocene barrier systems.

Tides along the coast are essentially semi-diurnal and microtidal, with spring tide ranges typically 1.5 m on the open coast, though slightly amplified (1.62 m) in Mercury Bay (Harris, 1985; Smith, 1980).

The coast has a temperate climate, with high spasmodic rainfall (typically 1500-1800 mm per annum along the coast). Predominant winds are low speed west and south westerlies associated with the passage of mid-latitude anticyclones. High speed onshore-directed east and north-easterly winds occur during less frequent storm events (generally 10-20 per annum), typically occluded cyclones, Tasman depressions and, more rarely, decaying tropical cyclones (Harris, 1985).

Located on a lee shore in a mid-latitude zone of dominant westerly winds, the coast is sheltered from persistent waves and swells generated in the Tasman Sea (Harris, 1985; Hilton, 1990; Bradshaw, 1991). The wave climate is primarily a mixed storm and swell wave environment, swell waves generated by subtropical disturbances north of New Zealand and storm waves generated by onshore winds associated with local weather patterns (Pickrill and Mitchell, 1979). Predominant wave directions range from east to north (primarily from the northeast) with estimates of (deep water) significant wave height ranging from 1-1.44 m (Pickrill and Mitchell, 1979; Harris, 1985). Little is yet known of the storm wave climate, though Bradshaw (1991) suggests storms are dominated by significant wave heights of 1-5 m (more rarely up to 9 m) and wave periods of 4-10 (more rarely 12) seconds. More detailed wave monitoring is currently being undertaken by the Auckland Regional Council and NIWA by means of a wave-rider buoy stationed in deep water off the Mokohinau Islands (Goring, 1999).

Beach and shelf sedimentation processes are most significantly influenced by onshore winds and waves associated with storm events (Christopherson, 1977; Harray and Healy, 1978; Bradshaw, 1991; Bradshaw et al*.,* 1991 and 1994).

These local storm events are often characterised by both fetch- and duration-limited conditions (Harris, 1985). As such, the most severe coastal erosion generally arises during periods with a relatively high frequency of storm wave events rather than from isolated extreme events. Therefore, the coast tends to be characterised by decades in which erosion predominates (e.g. mid 1960's to late 1970's) and those in which accretion is dominant (e.g. 1980's and early 1990's) according to the magnitude and frequency of erosive storm events. Though these decadal variations are reasonably well known among coastal practitioners along the north east coast of New Zealand, the reasons for them are not yet well understood. However, it is widely suspected they are strongly linked to climatic shifts related to changes in the frequency and magnitude of ENSO events - with a higher frequency of erosive storm events more likely to occur during climate phases dominated by La Nina conditions.

The beach and dune barrier systems of the eastern Coromandel have been variously classified (Healy, et al*.,* 1981; Abrahamson, 1987; Bradshaw, 1991). However, as noted by Bradshaw (1991), they can essentially be subdivided into:

- ***Medium-large foredune barriers*** composed of foredune plains up to 2.8 km wide, attached to the mainland at their basal ends and enclosing moderate-sized estuary systems. These foredune plains are fronted by fine to medium-grained beaches, which have flatter beach gradients than the pocket beaches and tend to adopt a dissipative character during storm conditions (Bradshaw, 1991). These barrier systems, south to north, are Whangamata, Opoutere, Pauanui, Cooks Beach, Whitianga, Matarangi and Kennedy Bay.

- ***Pocket barrier beach systems,*** which occur in small embayments, on steep rocky coasts (Bradshaw, 1991). These systems are fronted by steep-faced, medium-coarse grained pocket beaches (Healy and Dell, 1987), which tend to be more reflective than dissipative beach systems. Sites with nearshore subdivision and development include Whiritoa, Onemana, Tairua, Hahei, Kuaotunu East and West, Rings and Whangapoua.

This simple subdivision is adopted for the discussion of eastern Coromandel beaches in this report. Figure 3-1 contrasts the offshore profiles of these two beach types.

3.2 Holocene Beach and Dune Sedimentation

This section discusses the development of the present eastern Coromandel beaches. Locations of the sites discussed are shown on.

3.2.1 Moderate-large barrier systems

Previous work on the development of these Holocene barrier systems has been reported by Marks and Nelson (1979) who studied the Omaru Spit at Matarangi, Gibb and Aburn (1986) who reported the age structure of the Pauanui barrier and Abrahamson (1987) who noted aspects related to Holocene barrier development at a number of sites.

The work reported here focuses largely on the pattern of Holocene dune development at Whangamata, Cooks Beach, Whitianga and Matarangi, though limited work was also conducted at Opoutere. A list of the sample sites is provided in Appendix A, together with the shell dates and the distance of the sites from the sea.

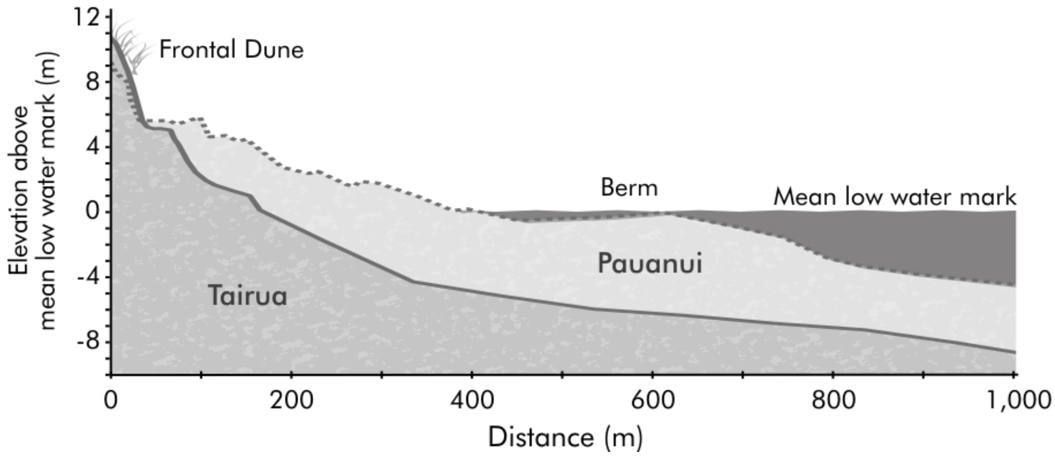


Figure 3-1: This diagram illustrates the difference in offshore beach gradients between a coarse-grained pocket beaches (Tairua Ocean Beach) and a fine-medium grained barrier system (Pauanui Ocean beach). Tairua beach has coarse sand and a steep beach face, reaching a water depth of 4 m about 300 m offshore. At Pauanui beach, with finer sand, the gradient is flatter, reaching a water depth of 4 m about 1000 m offshore.

3.2.1.1 Initiation of Holocene beach and dune sedimentation

Shell taken from the most landward cores at all sites returned conventional ages in the range of 6100-7100 yr BP (Appendix A), equivalent to a calibrated age range of about 6400-7650 cal yr BP (Appendix A).

The oldest ages were returned from sites on the landward margins of the Matarangi (Mat 29 and 39), Whangamata (Wgm 5 and 11) and Cooks Beach (Co 32) barrier systems - with conventional ages in the range of about 6500-7080 yr BP (Appendix A). Shell obtained from around the edge of a water well drilled on the landward margin of the Opoutere Spit (sample Opt A) also dated in this range (about 7040 yr BP) (Appendix A).

Therefore, it appears that beach sedimentation at most of the major barriers commenced around 6500-7100 yr BP, about the time that sea level stabilised at or near present levels following the most recent post-glacial transgression (Gibb, 1986).

The similarity of the various dates from different sites and their consistency with present best information on the initiation of the Holocene stillstand provides reasonable confidence in the dates. Shell from separate drill sites near the landward margin of the Whangamata barrier (sites Wgm 5 and 11, with Wgm 6 only slightly further seaward) also all returned similar dates (Appendix A).

The shell dates are also consistent with limited observations of tephra deposits within the older Holocene dunes. For instance, Abrahamson (1987) noted pumice (presumed to be from the Tuhua Tephra) incorporated in Holocene dune sands at Opoutere. Wave deposited pumice was also noted in Core Wgm 11 along the landward margin of the

Whangamata barrier. This pumice is also most probably from the Tuhua Tephra, which was erupted from Mayor Island and is widely distributed in the vicinity of Whangamata (Hogg, 1979; Hogg and McCraw, 1983). Clasts of sea-rafted pumice (about 3-8 cm diameter) were also noted incorporated in Holocene sediments near the back of the Whitianga barrier - in a drain cutting opposite the Mercury Bay Timber Mill. The fibrous appearance of the pumice tends to suggest it was probably also derived from the Tuhua Tephra (DJ Lowe, *pers. comm.,* 1991).

These observations suggest that Holocene sedimentation at these sites commenced prior to the eruption of the Tuhua Tephra - presently dated (error weighted mean from 10 determinations) at 6130 $\pm$ 30 yr BP (ca 7000 cal yr BP) (Froggatt and Lowe (1990)).

However, the oldest sediments at the Pauanui barrier were dated at 5060 $\pm$ 60 yr BP (about 5600 $\pm$ 60 cal yr BP) by Gibb and Aburn (1986). This shell was taken from a drill site very near the landward margin of the Pauanui barrier (Figure 5 on page 12 of Gibb and Aburn, 1986). This tends to suggest that Holocene barrier development may have commenced somewhat later at Pauanui.

3.2.1.2 Pattern of Holocene barrier development

This section briefly outlines the broad pattern of Holocene sedimentation at the sites investigated.

Whangamata

The Holocene barrier system at Whangamata (Figure 1-1; Figure 3-2, Appendix D) is approximately 1.15 km wide and averages about 3-3.2 km length.

The pattern of Holocene progradation suggested by radiocarbon dating of shell is shown in Figure 3-2 (dates are shown in calendar years).

It appears that initial seaward progradation (ca 6000-7000 cal yr BP) was relatively slow (perhaps less than 0.05 m/yr) but thereafter increased rapidly - being about 0.15 m/yr by about 5500-6000 cal yr BP and approximately 0.2 m/yr by about 4000 cal yr BP (Figure 3-2). This relatively rapid seaward progradation was sustained until about 1000-1200 cal yr BP, after which rates of seaward progradation decreased significantly. Rates of seaward progradation appear to have averaged only about 0.04 m/yr over the last 1000 years (Figure 3-2).

Dune morphology, as determined from historical aerial photos and field inspection of isolated dune remnants, also supports the pattern of slow initial progradation followed by more rapid seaward advance. The oldest dunes (in the vicinity of sites Wgm 5, 6 and 11) are generally distinct and continuous, with dune heights of 1.5 m to in excess of 2 m elevation above swales and wavelengths of 90-100 m. Remnants of the oldest dune (observed along the estuary margin in the vicinity of Mayfair Avenue) appear to have been up to 3.5 m above original dune swale levels and in excess of 6 m above MHWS. In contrast, dunes further seaward near the centre of the barrier are considerably less distinct and continuous (e.g. Whangamata Golf Course), with wavelengths (as measured off historical aerial photograph SN 292/985/38 flown 17.5.44) typically only 20-30 m – consistent with more rapid progradation. Remnants of these dunes (e.g. in golf course) suggest heights are variable but most commonly less than 1.2 m.

Interpretation of the most seaward dune morphology is more difficult due to significant modification of these dunes by serious wind erosion of the frontal dunes over the last 100 years. Sheets of inland migrating sands are evident up to 150-200 m inland of the shore in some historical aerial photographs dating from the 1940’s and 50’s. More recent modification of dune morphology associated with extensive subdivision and development has also occurred. However, the frontal dunes are much higher and more distinct and continuous than those observed near the centre of the barrier, consistent with relatively slow rates of seaward progradation in recent centuries. There is also a very strong consistency in the dates from drill sites on or behind the present frontal foredune (sites 3, 4 10 and 12). Shell from these sites generally dated in the range of 950-1250 cal yr BP, with the exception of site 3 which dated in the range 570-700 cal yr BP (Appendix A).

An interesting feature of the development of the Whangamata barrier is the significant influence of wave refraction and diffraction around headlands and offshore islands. In particular, the converging longshore flows in the lee of the islands located immediately offshore from Whangamata have had a very significant influence on the shape of the barrier. The foreland formed in the lee of these islands has essentially resulted in the formation of two distinct ocean beaches, oriented almost at right angles to each other (Figure 3-2, Map2a & 2b).

Information on the depth of the Whangamata sands indicates that depth generally increases seaward, with depths of 6-7 m near the landward margin (near Beverly Crescent), to 8-9 m in the vicinity of the Whangamata Golf Course and in excess of 15 m near Sea-View Road towards the ocean margin (Dewhurst, 1982). If these sands are primarily Holocene dune, beach and nearshore sands then it would appear that very significant volumes of sand were available for barrier formation. Assuming an average depth of 10 m of Holocene barrier sands over the area (approximately 3.5 km^2), approximately 35-40 million cubic metres of Holocene sands has probably accumulated in the barrier system over the last 7000 years. Together with an estimated 4-6 million cubic metres in the beach system to depths of 4 to 5 m below mean sea level, suggests that approximately 40-45 million cubic metres of sands have been deposited in the beach and barrier system over the last 7000 years.

The tendency for sand depth to increase seaward also suggests that greater volumes of sand were probably required per unit of progradation as the barrier advanced seaward. This may have helped slow progradation rates as the barrier advanced seaward. However, the rapid slowing of progradation over a relatively short time period (about 1500 years) and distance (about 150 m) (Figure 3-2) tends to suggest that other factors (discussed later) were a more dominant influence.

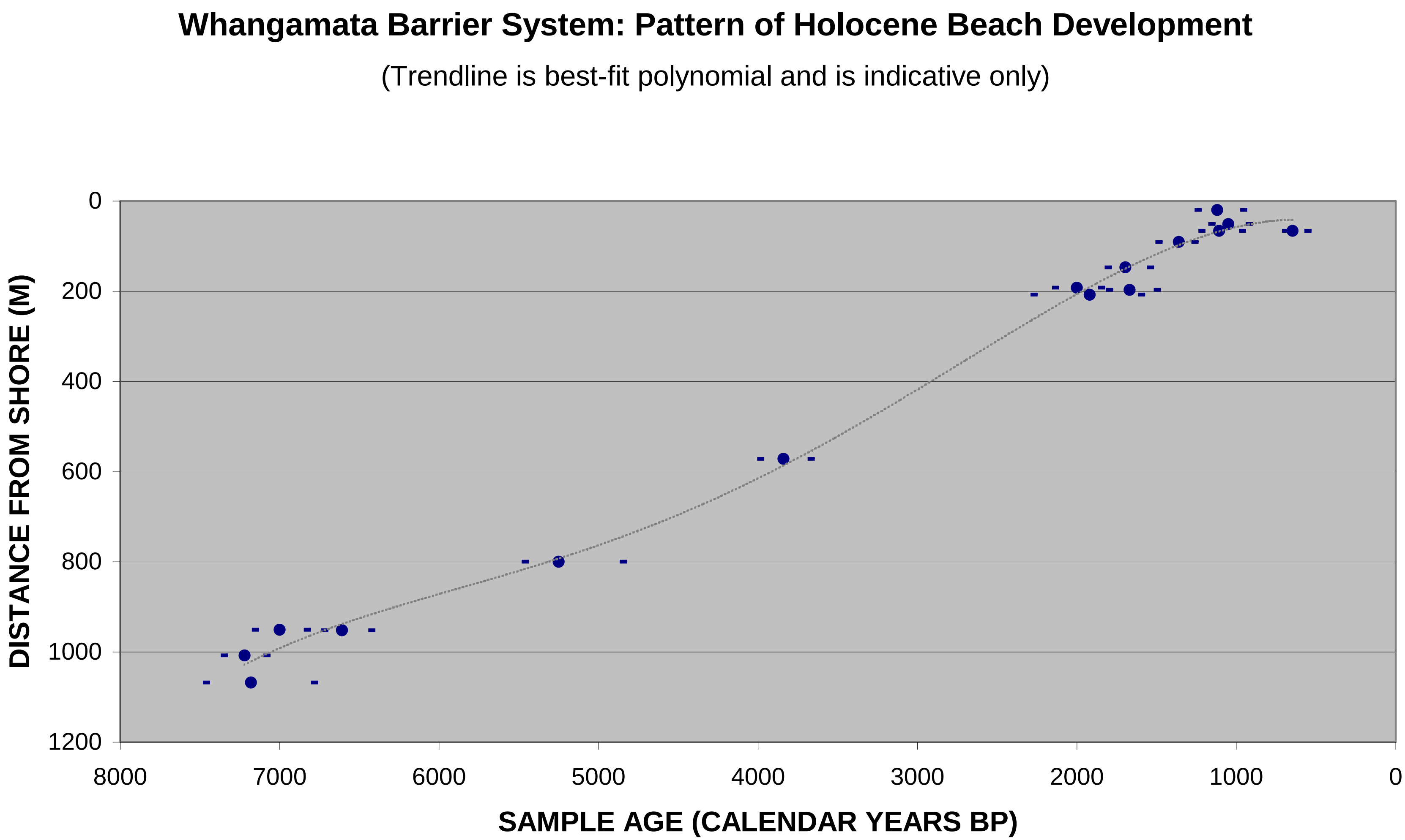


Figure 3-2: The age structure of Whangamata barrier from radiocarbon dating.

Cooks Beach

The Holocene barrier of Cooks Beach (Figure 1-1, Figure 3-3, Map 7a & 7b) is approximately 2800-2900 m long and varies in width from 200 m at the western end to 675 m at the eastern end.

The pattern of Holocene progradation indicated by the carbon dating is shown in Figure 3-3.

Development of the barrier commenced in a triangular embayment at the southeast corner of the present barrier. The oldest dune lies seaward of core site Co 33 and is larger and more distinct feature than those further seaward. Unfortunately, this core did not contain useful quantities of shell and so the oldest shoreline was unable to be dated.

However, shell dates from site Co 32 (about 225 m from the landward margin of the Holocene sediments), suggests that Holocene sedimentation had commenced by about 7400-7650 cal yr BP (Appendix A).

The three dunes landward of site Co 31 are all fairly large composite features with heights of 2-3 m and wavelengths of about 80-90 m, though maximum heights gradually decrease seaward. These features increasingly give way further seaward (about midway between sites Co 30 and 31) to much smaller dunes – with heights of 0.3-0.5 m and wavelengths (seaward of site 30) of 20-40 m.

This suggests that the rate of progradation was gradually accelerating in this period (between about 5240 and 4410 cal yr BP (Appendix A), reaching about 0.08-0.09 m/yr by 4410 cal yr BP. The south-eastern embayment in which barrier development had commenced had been infilled with sediment by about this time – with sedimentation now occurring along lengths broadly equivalent to the length of the present barrier.

This acceleration is masked to some extent in Figure 3-3, which shows rates of seaward progradation rather than areal or volumetric change over time. In early stages of barrier development, sedimentation was occurring over total shoreline lengths of less than 1000 m - compared to lengths of 2600-2800 m once sedimentation commenced along the full length of Cooks Beach. Therefore, much larger dune volumes were arriving into the Cooks Beach embayment by 4410 cal yr BP than had occurred previously. We estimate that the peak rate of sediment supply was about 5-6 times higher than the rate of sediment supply during the earliest barrier progradation able to be dated. (These estimates are based only on considerations of area and progradation rate; the figure might be higher if there were sufficient sub-surface information to enable volumes to be estimated).

This rapid progradation began slowing about 3000 cal yr BP, with only very slow seaward progradation (about 0.03 m/yr) prevailing over the last 1500-2000 years (Figure 3-3).

Shell from sites Co 1 and Co 5 drilled on the immediate landward side of the present foredune both returned similar ages (Appendix A). Older aerial photographs indicate that this foredune gave way to a complex of smaller foredunes towards the eastern end of the barrier. Sample 6 taken from near the landward margin of this complex also returned a similar date (Appendix A). This consistency provides some confidence in the dates.

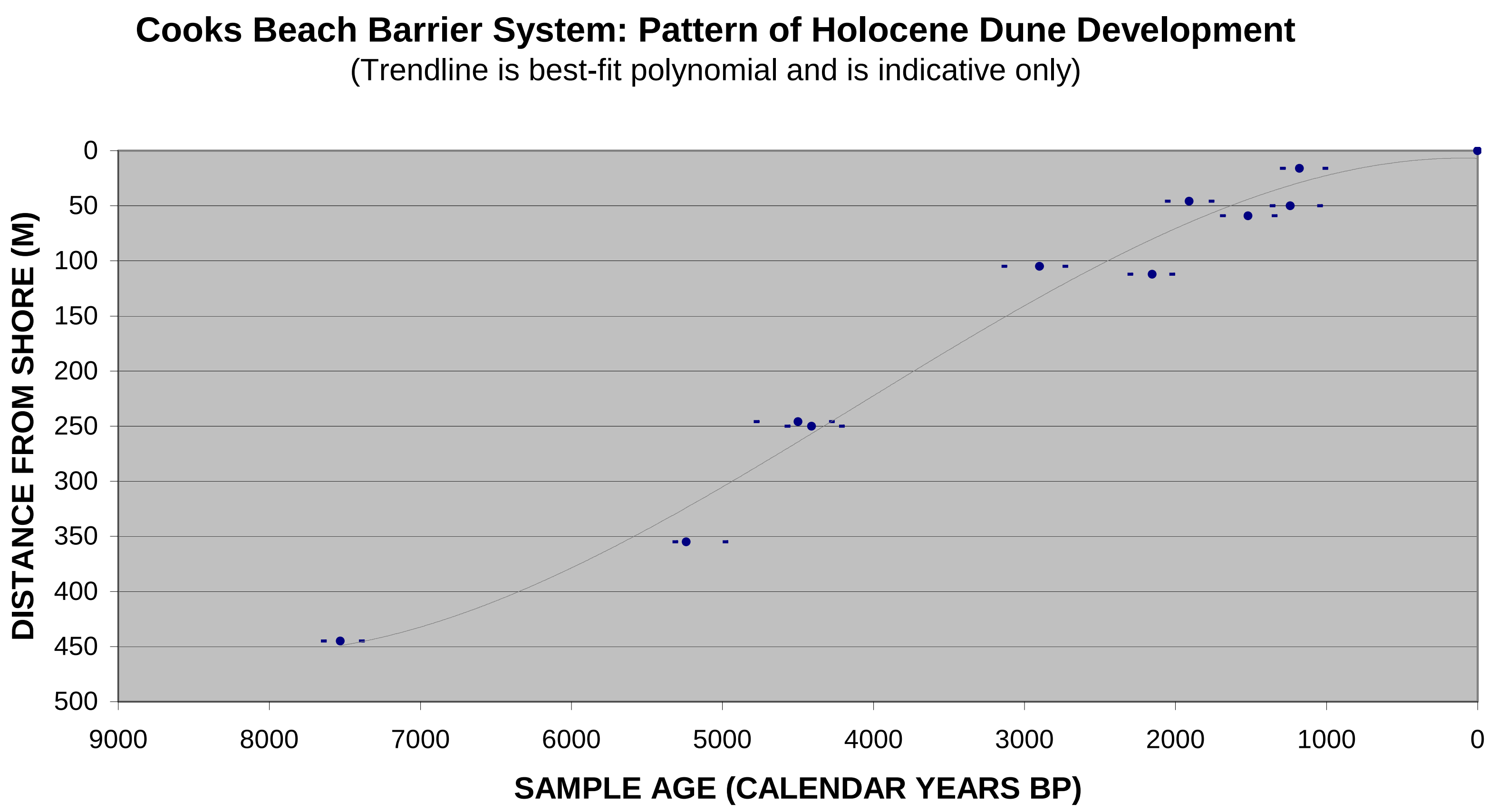


Figure 3-3: Age structure of Cooks Beach barrier system from radiocarbon dating.

Shell from site Co 3 drilled on the seaward side of the present foredune (in the swale between the foredune and the incipient foredune) dated at 1021-1301 cal yr BP (Appendix A), also suggesting limited seaward progradation over the last 1000 years.

An interesting aspect of the barrier progradation at Cooks Beach is the east-west difference in both barrier width and dune morphology.

The greater barrier width at the eastern end reflects not only the deeper nature of the original re-entrant but also the pattern of wave refraction and diffraction into this re-entrant. The barrier width fronting individual dunes shown on historical photos (e.g. Photo SN292/967/43, flown 22/5/44, NZ Aerial Mapping Ltd) increases from west to east. This indicates that a slightly higher rate of progradation has been required at the eastern end to adjust to the pattern of wave refraction and diffraction into the embayment.

However, this slightly higher rate of progradation is not sufficient to explain the quite significant apparent difference in dune morphology between the eastern end of the barrier and central/western regions. Historical aerial photos indicate that dune ridges at the eastern end are more numerous and have a lesser wavelength (typically about 15 m) than central (typically 20-25 m) and western (typically 30-40 m) areas of the barrier. There is also very clear evidence of significant truncation and narrowing of many of the ridges at the eastern end and a widening of others.

The smaller wavelength suggests the dunes at the eastern end were formed during periods of fairly rapid shoreline progradation, while the truncation and narrowing of the ridges tends to suggest periods of erosion.

In other words, the pattern of dune morphology tends to suggest periods of relatively rapid progradation interspersed with periods of erosion. This may indicate that the seaward progradation during the Holocene was occasionally interrupted by periods of erosion at the eastern end of the beach.

Similarly, there is some evidence that the area has previously been subject to erosion, subsequent to the cessation of Holocene seaward progradation. The pattern of the most seaward foredunes in 1944 (Photo SN292/967/43, flown 22/5/44, NZ Aerial Mapping Ltd), indicates the single frontal foredune evident in western and central areas gave way at the eastern end to a complex of 3-4 smaller foredunes. This “pod” of dunes suggests that the shoreline in this area has fluctuated over time.

Therefore, the recent erosion may be associated with major shoreline fluctuations that occur in this area over periods of several decades. Such complex decadal trends are commonly observed on shorelines adjacent to ebb tidal deltas (Dahm, 1983; Hicks and Hume, 1996; Hicks et al., 1999).

However, the 1944 aerial photographic evidence is suggestive rather than conclusive. Moreover, as the dunes have since been destroyed by subdivision, it was not possible to examine this matter further in the field.

Whitianga

The Holocene barrier at Whitianga (Figure 1-1) is the widest in the Coromandel, with a width of about 280 m.

The pattern of Holocene barrier development suggested by the radiocarbon dating is shown in Figure 3-4.

As with both Cooks Beach and Whangamata, the initial pattern of shoreline progradation evidences a period of relatively slow progradation (about 0.08 m/yr) gradually accelerating to very rapid seaward growth – with maximum rates of 0.5-0.6 m/yr prevailing by about 4500 cal yr BP (Figure 3-4).

The dune morphology is also consistent with this pattern, with the most landward dunes having a higher elevation than those further seaward (Figure 3-5). Field inspection indicated that the most landward dunes are also more distinct and continuous, again consistent with a slower rate of progradation.

The maximum rates of progradation indicated by the radiocarbon dates are similar to those estimated for the last 2000 years (0.5 m/yr) by Abrahamson (1987), based on the occurrence of large pieces of sea-rafted pumice (presumed to be derived from the Taupo Eruption of ca 1800 yr BP) about 1 km inland.

The period of rapid shoreline progradation almost certainly reflects large volumes of sand drowned by the Holocene transgression being moved onshore. However, the higher rates of progradation noted at this site (during both the period of rapid progradation and the earlier sedimentation) may indicate that local fluvial supply is also a factor contributing to barrier progradation at this site. The Whitianga Estuary has the largest catchment of any estuary in the Coromandel and includes a number of large rivers.

The shoreline trend over recent centuries is less clear. The shell date of 519-779 cal yr BP at the most seaward site (Whit 6) (Appendix A) suggests that rates of seaward progradation may have slowed markedly, averaging only about 0.1-0.15 m/yr over the last 500-800 years.

However, the sediments at this site have been reworked historically by longshore migration of the Taputapuatea Stream, which now discharges into the middle of Buffalo Beach. This reworking, widely evident in the most seaward regions of the barrier, is strongly reflected in the core stratigraphy. This stratigraphy (composed of layers of fine sand alternating with very shelly sediments) was markedly different from other more landward sites at Whitianga (typically fine sands with little shell until depths below mean sea level).

The reworking introduces the possibility that the sediments at this site have been contaminated by the incorporation of shell that is either older or younger than the original sediments.

This considerably complicates interpretation of the data. For instance, if the shell deposited at this site had an inbuilt age of only 300-500 years (i.e. the shoreline at Whit 6 was 300-500 years younger than dated), the rate of shoreline progradation over the last few hundred years would be similar to that observed historically.

While dune morphology in the most seaward area of the barrier has been largely disrupted by earthworks (Figure 3-5) associated with subdivision and development and by longshore migration of the Taputapuatea Stream, remnants of dune features up to about 0.75 m high are noted in this area. These are larger than the small wavelength dunes that characterise areas further landward (which are typically less than 0.35 m high and barely discernible) and may indicate a slowing in the rate of progradation. However, the data is not conclusive as isolated dunes of higher relief also occur in the area of known rapid progradation.

Therefore, while the data tends to suggest a slowing of progradation in recent centuries, shoreline trends over the last few hundred years cannot be conclusively determined from the Holocene data.

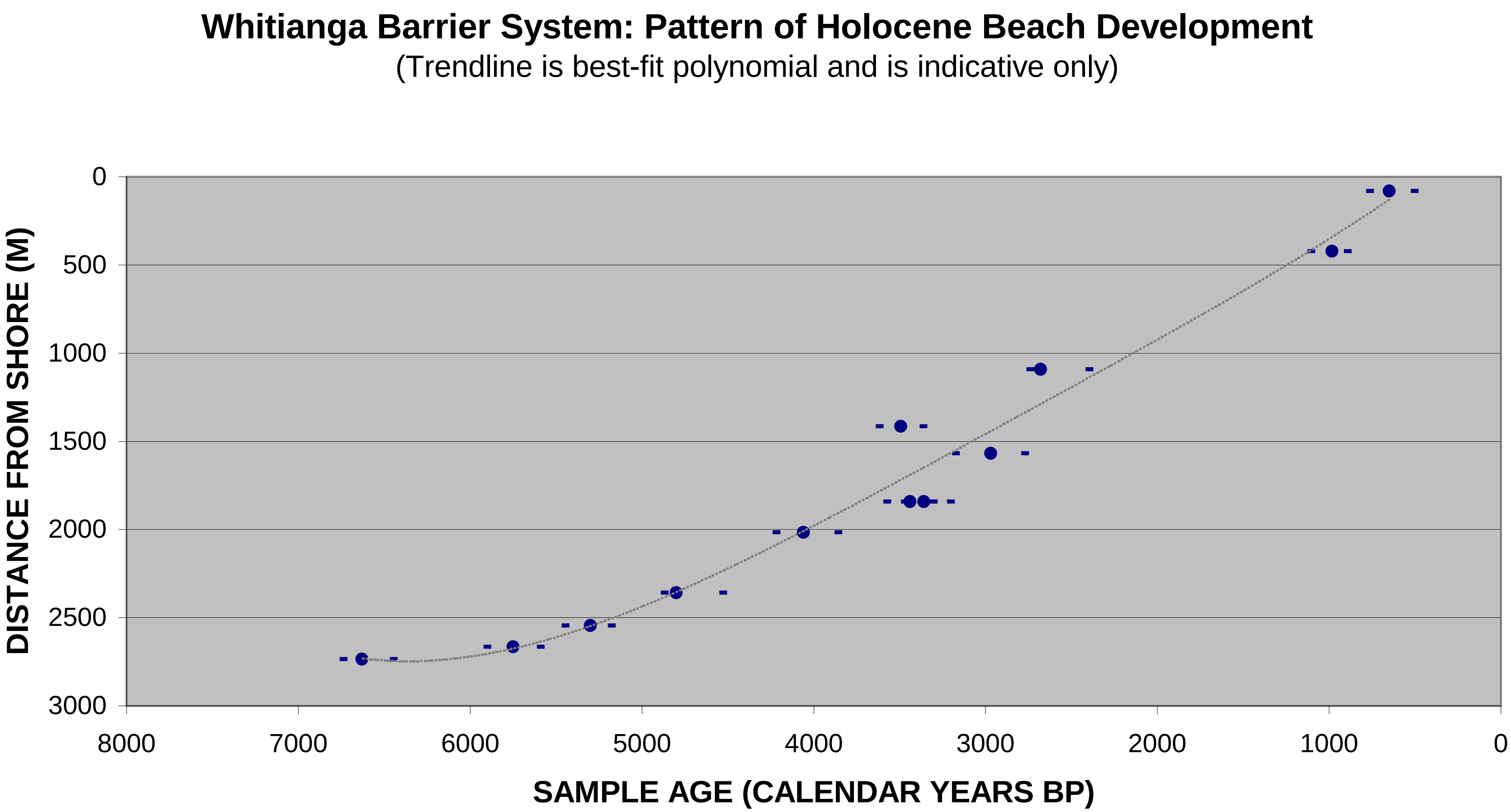


Figure 3-4: Age structure of Whitianga barrier from radiocarbon dating.

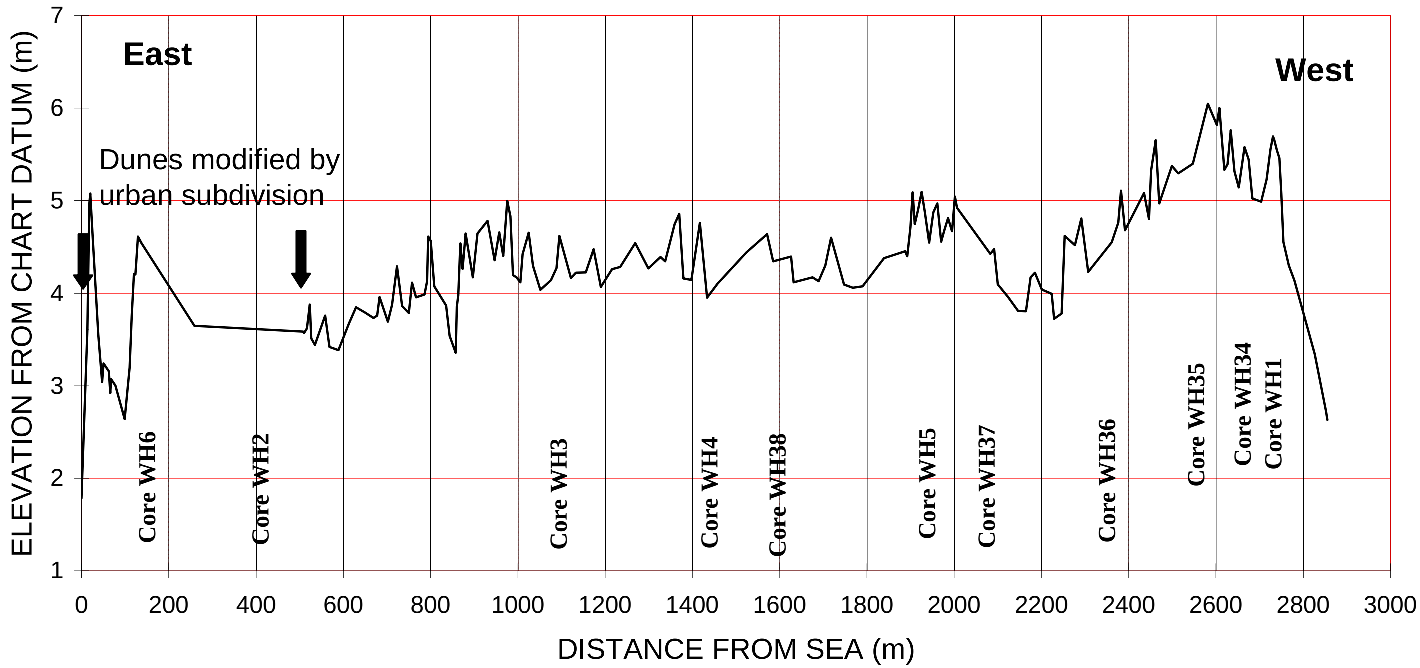


Figure 3-5: Shore perpendicular transect surveyed across the Whitianga barrier system.

Matarangi

The barrier system at Matarangi encloses Whangapoua Harbour (Figure 1-1) and is composed of a series of Holocene dune ridges backed by wide back-barrier flats (Marks and Nelson, 1979). The spit is approximately 4200 m long and has a total width of 975-1175 m, about 400-450 m being the seaward band of Holocene dunes.

The pattern of Holocene barrier dune progradation suggested by the radiocarbon dating is shown in Figure 3-6.

The most landward core sites (Mat 24, 29 and 39) all suggest that Holocene beach and dune sedimentation at Matarangi commenced about 7000-7500 cal yr BP (Appendix A; Figure 3-6). These sites were either located on (Mat 29 or 30) or behind (Mat 24) the most landward dune - a large complex feature with a width of about 150-200 m. The dates suggest fairly rapid emplacement of this initial, relatively wide shoreline. If these dates correctly reflect the placement of the initial barrier, they would tend to suggest that the initial shoreline might have been derived from a transgressive barrier pushed ahead of the rising sea-level.

A cross-section surveyed by the Hauraki Catchment Board in 1976 suggests this dune rises to about 8 m above MHWS, with the more seaward dunes typically only 4-5 m above this datum (Section 2A, Hauraki Catchment Board Plan 1499).

The large height and width of this landward dune suggests that the shoreline was in this vicinity for a lengthy period before prograding further seaward. This is also suggested by the date of 4840-5244 cal yr BP from the swale on the immediate seaward side of this dune (site Mat 28, Appendix A).

The dates from sites further seaward tend to suggest that very rapid progradation occurred in the period 4000-5000 cal yr BP (Figure 3-6). The dates from the most seaward sites (Mat 25 from the seaward face of the foredune and Mat 27 from immediately behind the frontal foredune) suggest that the existing barrier was largely in place by about 3800-4200 cal yr BP (Figure 3-6).

This pattern of rapid seaward progradation followed by a marked slowing in the rate of seaward advance is also broadly consistent with dune morphology. Dune cross-sections conducted before dune morphology was destroyed by coastal subdivision suggest relatively low dune ridges characterise the most seaward portion of the barrier (e.g. Figure 6 of Marks and Nelson, 1979; also Section 2A on HCB Plan 1499). Similarly, the much higher foredune shown on some cross-sections reported by Marks and Nelson (1979) tends to suggest a marked slowing in progradation in recent centuries or millennia (e.g. see Marks and Nelson, 1979, Transect 3 on Figure 6, page 353). Remnants of this dune are also still evident, though Marks and Nelson (1979) report that the feature was modified in places by early subdivision.

However, although the pattern of progradation suggested by the carbon dates is broadly consistent with dune morphology, there is also strong evidence that the shell from the most seaward cores is much older than the shorelines in these areas – suggesting contamination from older shell. This evidence includes:

- ***Inconsistency between radiocarbon ages of the most seaward dunes and the degree of weathering evident in dune soils:*** The degree of iron-staining and weathering noted in the topsoil at site Mat 28 was significantly more advanced than noted at sites further seaward, suggesting an age gap of greater than 1000 years in the age of these sands. Marks and Nelson (1979) also recorded significant differences in the degree of diffuse iron-staining and pan development over this area (see Figure 19, page 368 of Marks and Nelson, 1979).

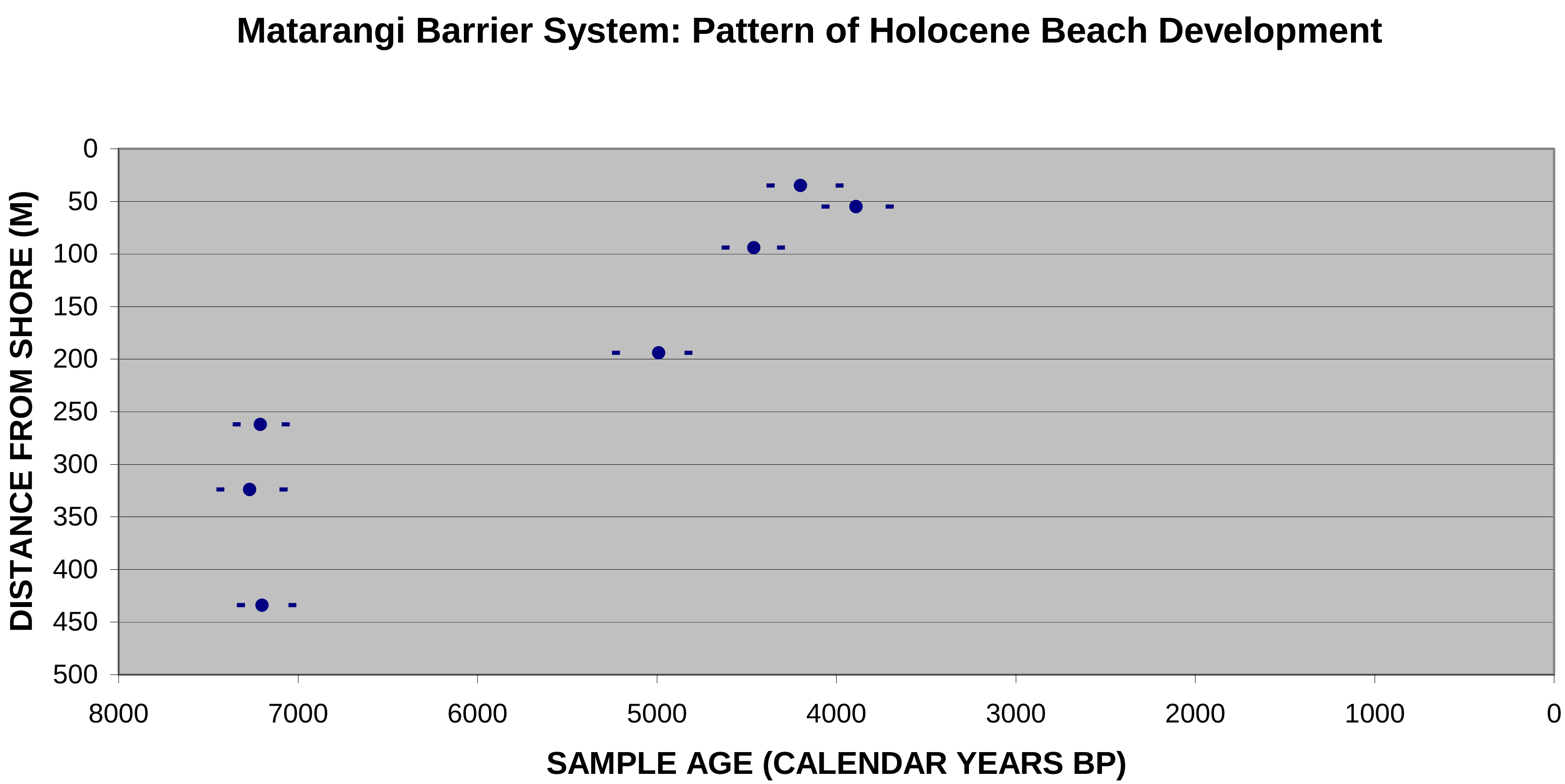


Figure 3-6: Age structure of Matarangi barrier from radiocarbon dating. There are some errors associated with this data – please see the text.

- ***Possible occurrence of sea-rafted Taupo pumice in the dunes:*** Marks and Nelson (1979) noted sea-rafted pumice incorporated in dune sediments about 180 m inland from the toe of the dune. This could be sea-rafted pumice from the Taupo Eruption of ca 1800 yr BP, as noted at Whitianga by Abrahamson (1987). If so, this would suggest that seaward progradation of the barrier was still continuing at that time.

- ***The size of the present frontal foredune*** is not as large as would be expected had the shoreline been in its present position for nearly 3000 years - considering the size of the foredune which formed in about 2000 years along the back of the barrier. While Marks and Nelson (1979) reported an "abnormally high frontal dune ridge" on some sections of the beach (Marks and Nelson, 1979, page 369 - see also their Figures 4 and 6 on pages 351 and 353 respectively), the dune dimensions are considerably less than the most landward relict foredune.

Overall, further work is required to better define the pattern of shoreline progradation at Matarangi. However, as noted above, the available evidence does suggest a broadly similar pattern of Holocene barrier sedimentation to other sites, including:

- an initial period of relatively slow seaward progradation (following initial barrier emplacement which appears rapid) – as evidenced by the considerable height and width of the most landward dune
- Commencement of more rapid seaward progradation about 5000 cal yr BP, broadly consistent with other sites
- evidence from frontal dune morphology that suggests the shoreline has prograded relatively slowly in recent centuries or millennia.

Other Moderate to Large Barriers

Gibb and Aburn (1986) reported data on the age structure of the Pauanui barrier system from three cores drilled across this feature. Their data indicate fairly rapid progradation (0.39 m/yr) commenced at this site ca 5000 yr BP, progressively decreasing to about 0.06 m/yr over the last 2000 years (see Gibb and Aburn, 1986, Table 2, page 13).

This pattern is broadly similar to that noted at the above sites, though the early period of relatively slow progradation is not evident. However, interestingly, there are remnants of a high, wide dune along the landward margins of the Pauanui barrier. This may indicate that the initial barrier experienced relatively slow rates of sedimentation. However, as noted earlier, the oldest date recorded by Gibb and Aburn (1986) also tends to suggest that initial barrier sedimentation may have commenced later at Pauanui than other barrier systems.

Limited dates from Opoutere, including a site behind the frontal foredune (Opt 19) suggest this barrier may have largely been in place by about 4500-4836 cal yr BP (Appendix A). However, as with Matarangi, these dates do not correspond well with either the degree of weathering and iron staining noted at the site or with the height of the present foredune. Therefore, the radiocarbon dates are inconclusive for this site and further work is required to more conclusively define the pattern of barrier sedimentation at this site.

3.2.2 Pocket beaches

Investigations of pocket beaches along the eastern Coromandel were primarily limited to field inspections and examination of historical aerial photos pre-dating recent subdivision.

This work indicated that pocket beaches along the eastern Coromandel generally have only limited dune deposits. Most typically, they are beaches with no dune deposits (e.g.

Te Karo Bay), a limited veneer of dune sands over older materials (e.g. Hahei), large single dunes (e.g. Waikawau, Hotwater and Tairua beaches) or a mixture of these situations along the beach length (e.g. Opito). Only one site (Whangapoua) has multiple dune ridges.

More detailed investigations of the nature and pattern of Holocene deposition were also undertaken by drilling and coring at Whiritoa, Tairua and Whangapoua.

3.2.2.1 Whiritoa

Whiritoa Beach, located towards the southern limit of the Coromandel East Coast (Figure 1-1; Map 1) is an embayed pocket beach backed by a single foredune.

The depths of Holocene dune sands at Whiritoa were investigated by drilling at a number of sites along the full length of the beach. Holes were levelled to a local datum with an approximate relationship to mean sea level (no reliable mean sea level datum has yet been established at most Coromandel beaches, though there are fairly good approximations at the major centres). The results are summarised in Table 3-1 below.

Table 3-1: Elevations and thickness of Holocene dune sands measured at Whiritoa Beach drill sites. Elevations are in terms of a local datum, where MHWS is approximately RL 6.7-6.8 m.

Site	Approx. surface elevation (m)	Thickness of Holocene dune and beach sands (m)	Approximate elevation of base of sands (m)	Comments
1	14.5	2.3	12.2	
2	12.4	9	3.4	
3	12*	9	3	
4	11.9	10.5	1.4	Sea rafted pumice in iron-stained sands noted at 5 m depth.
5	10.6	6.5	4.1	
6	9*	-	-	
7	9*	4.6	4.5	
8	9.35	3.7	5.7	Sea rafted pumice in iron-stained sands near base of hole.
9	12.1	12.5	-0.5	Sea rafted pumice in iron-stained sands near base of hole.
10	8.8	6.8+	Below 2 m	Sea rafted pumice in iron-stained sands near base of hole.

Generally, drill holes revealed that the present, single dune is often just a veneer of sand over pre-Holocene materials, with greatest depths at the northern end of the beach adjacent to the Whiritoa Stream (site 9).

Depths of sand gradually increase from Pohutukawa Reserve (largely composed of pre-Holocene materials, with a narrow prism of dune sands along the seaward face) south to the Surf Club (holes 4 and 5, about centre beach) and thereafter decrease in depth and thickness further south to the urupa. Along the landward margins of the urupa, hand auguring indicated that sands are often less than 1-2 m thick. Rock is also exposed on the dune face at the southern end of the urupa and long-term residents report that more extensive exposures of rock were exposed in this area after a major storm in July 1978.

As would be expected, the depths of Holocene sands also increase northward from Pohutukawa Reserve to Whiritoa Stream. Shell taken from near the base of the Holocene sands at site 9 (drilled on Holocene dunes immediately south of Whiritoa Stream) dated at 6811-7323 cal yr BP, suggesting that beach development commenced soon after the cessation of the Holocene transgression – similar to the larger barrier systems discussed above.

The occurrence of sea-rafted pumice at or near the base of the Holocene sands in sites 8, 9 and 10 is probably from the Tuhua Tephra dated at approximately 6130 $\pm$ 30 yr BP (calibrated age of ca 7000 cal yr BP) (Froggatt and Lowe, 1990). This suggests initiation of sedimentation at or about the time of this eruption – consistent with the shell date. Wave deposited pumice (also probably Tuhua Tephra) higher in the Holocene sands (at a level equivalent to about the present toe of dune) was also noted at site 4. The incorporation of Tuhua Tephra in strand level deposits at this site (located only 8 m from top edge of the present seaward dune face in front of the surf club) suggests that initial beach deposition may also have been fairly rapid.

Shell taken from shallow dune sands at sites 7 (about 3 m depth) and 8 (about 2 m depth) both dated reasonably recently (less than 2000 cal yr BP) and are indicative of slow ongoing dune development.

The limited nature of the dune deposits indicates that there is little surplus sand in this beach system to accommodate any future erosion.

In some areas (e.g. at the southern end of the beach, behind the urupa) the elevation of the more resistant underlying materials is well above present sea levels and will act to limit future erosion. However, in many other areas (e.g. from just north of the surf club south to Moray Place) the elevation of the underlying materials is below present beach levels (about RL 6-7 m) and will not limit erosion.

The source of the Whiritoa Beach sands has always been something of an enigma as the mineralogy shows little resemblance to local cliff or stream sediments (McLean, 1979). Similar coarse sands are noted some distance offshore but are separated from the present beach system by a wide band of fine and very fine sands quite distinctly different from the beach sands (McLean, 1979; Willoughby, 1981; Bradshaw, 1991).

Bradshaw (1991) suggested that the Whiritoa Beach sands may have been largely derived from erosion of Pleistocene beach and dune sands deposited during the last Holocene stillstand ca 120,000 yr BP. Bradshaw noted that such deposits are exposed behind present Holocene barriers at Whiritoa and many other sites along the eastern Coromandel.

It is also possible that the beach sands were in part or wholly derived from coarse sands exposed on the shelf shortly after the Holocene transgression. The band of fine and very fine sands which presently separates coarse offshore sands from the beach system have largely been derived from the sorting and preferential onshore movement of fine sediments from offshore sands (Dahm and Healy, 1980 and 1985; Bradshaw, 1991) and from modern fluvial sources (Bradshaw, 1991). Therefore, coarser sands may have been among the sediments initially exposed in the beach-nearshore area immediately following the post-glacial transgression, only subsequently being buried by preferential onshore movement of fine and very fine sands derived from wave re-working of offshore sands.

Whatever the original source of the sands, it is quite clear that the only present occurrence source of similar sediments is located well offshore from the seaward edge of the beach system. It is very unlikely that significant volumes of these sediments find their way across the intervening fine and very fine sands to the present beach system.

Therefore, for management purposes, this beach system has all the sand it is going to get. This, together with the very limited volumes of dune reserves, emphasises the importance of taking all practical steps to protect existing sand reserves (Dahm et al., 1994).

3.2.2.2 Tairua

Tairua Ocean Beach (Figure 1-1; Map 5) is a tombolo approximately 1300 m long and backed by a single, high foredune ranging from 140-250 m wide.

Holes were drilled on both the landward and seaward ends of the barrier to investigate the age structure of the barrier.

Shell from site T1, drilled at the northern end of the barrier on the landward margin, dated at 6588-6945 cal yr BP (Appendix A), suggesting that development of this barrier was also initiated at or soon after the commencement of the present Holocene stillstand.

Shell from site T2, drilled at the southern end of the barrier on the seaward side (about 20-30 m from the seaward toe of the present foredune) dated at 4509-4882 cal yr BP (Appendix A). This date suggests that progradation of the original barrier beach occurred relatively quickly – with most of the existing barrier width in place by this time. There would appear to have been no more than about 20-30 m progradation since this period (i.e. less than 0.004-0.006 m/yr). This suggests that the beach has essentially received all the sand it is going to get and is, at best, in dynamic equilibrium.

The early emplacement of the beach probably explains the large, high foredune that has developed on this and similar sites – with dune building occurring along the shoreline for at least 4500-5000 years.

Unlike Whiritoa Beach, Holocene sands were encountered to the base of the drill holes. As the drill sites were located at opposite ends of the barrier system and on both the landward and seaward margins, this tends to suggest that the entire barrier is composed of Holocene sands – though more detailed investigations of sub-surface conditions (e.g. using ground radar) would be required to confirm this.

The larger volume of Holocene sands available for barrier progradation at this site probably reflects its close proximity to a major river system. Abrahamson (1987) previously noted that all large barrier systems along the eastern Coromandel occur at the entrance of drowned river valley systems. Work by Bradshaw (1991) indicated that these drowned river systems tend to have more extensive offshore sediment deposits, associated with infilled valleys incised on the continental shelf. Abrahamson also noted extensive Pleistocene beach and dune deposits inland of the present barrier. Erosion of these features may also have contributed to initial barrier formation.

The depth of Holocene sands also suggests that there are unlikely to be any geological surfaces at an elevation likely to significant impede any future coastal erosion.

3.2.2.3 Whangapoua

Whangapoua is a pocket beach approximately 1650 m long (Map 18), located on the northern side of the entrance to Whangapoua Harbour (Figure 1-1).
The beach is unique among the eastern Coromandel pocket beaches in that it is backed by a series of semi-parallel dunes ridges rather than a single large dune. The dune ridges were drilled at dated at 3 sites (Appendix A) from the landward margin of the barrier system (Wpa 21) to the swale behind the present frontal dune (Wpa 23). The pattern of barrier development derived from the shell dates is shown in Figure 3-7.

Shell from beach sands at site Wpa 21, drilled on the landward side of the most landward dune ridge, dated at 7500-7750 cal yr BP (Appendix A). As with most barrier systems along the eastern Coromandel, it appears that barrier development was initiated at or very near the time that sea level reached present levels following the most recent post-glacial transgression.

Initial progradation was very slow, averaging only 0.01 m/yr between about 7600 and 2340 BP (Figure 3-7). However, relatively rapid progradation (about 0.06 m/yr) characterised the subsequent period to about 1150 cal yr BP (Figure 3-7). Subsequently, rates of seaward advance reduced, averaging only 0.02 m/yr.

This pattern of barrier development differs markedly from both Tairua and Whiritoa barrier systems, which appear to have been in place by about 4500-5000 cal yr BP. Rather, the broad pattern is very similar to that observed for the major barrier systems – with initially slow progradation, followed by rapid progradation, decreasing rapidly over the last 1000-1500 years.

The date of onset of more rapid progradation is difficult to estimate with accuracy, due to the wide sample spacing between sites Wpa 21 and 22. However, it is unlikely to have commenced much before 3000-3500 cal yr BP.

As with the drill sites at Tairua, no pre-Holocene materials were encountered to the base of the drill holes – indicating that there are unlikely to be any geological impediments to future erosion of this barrier. As with Tairua, it appears there were also abundant sediments available for barrier formation.

The pattern of barrier formation has strong implications for the source of the barrier sands. The period of rapid progradation and subsequent slowing is consistent with onshore supply of sediments from the continental shelf (slowing as the shelf equilibrated and the supply of suitable sand sizes decreased), rather than erosion of local Pleistocene barrier deposits. However, the initial barrier formation may have been in large part derived from pre-existing Pleistocene barrier deposits – with significant Pleistocene barrier deposits evident landward of the present barrier.

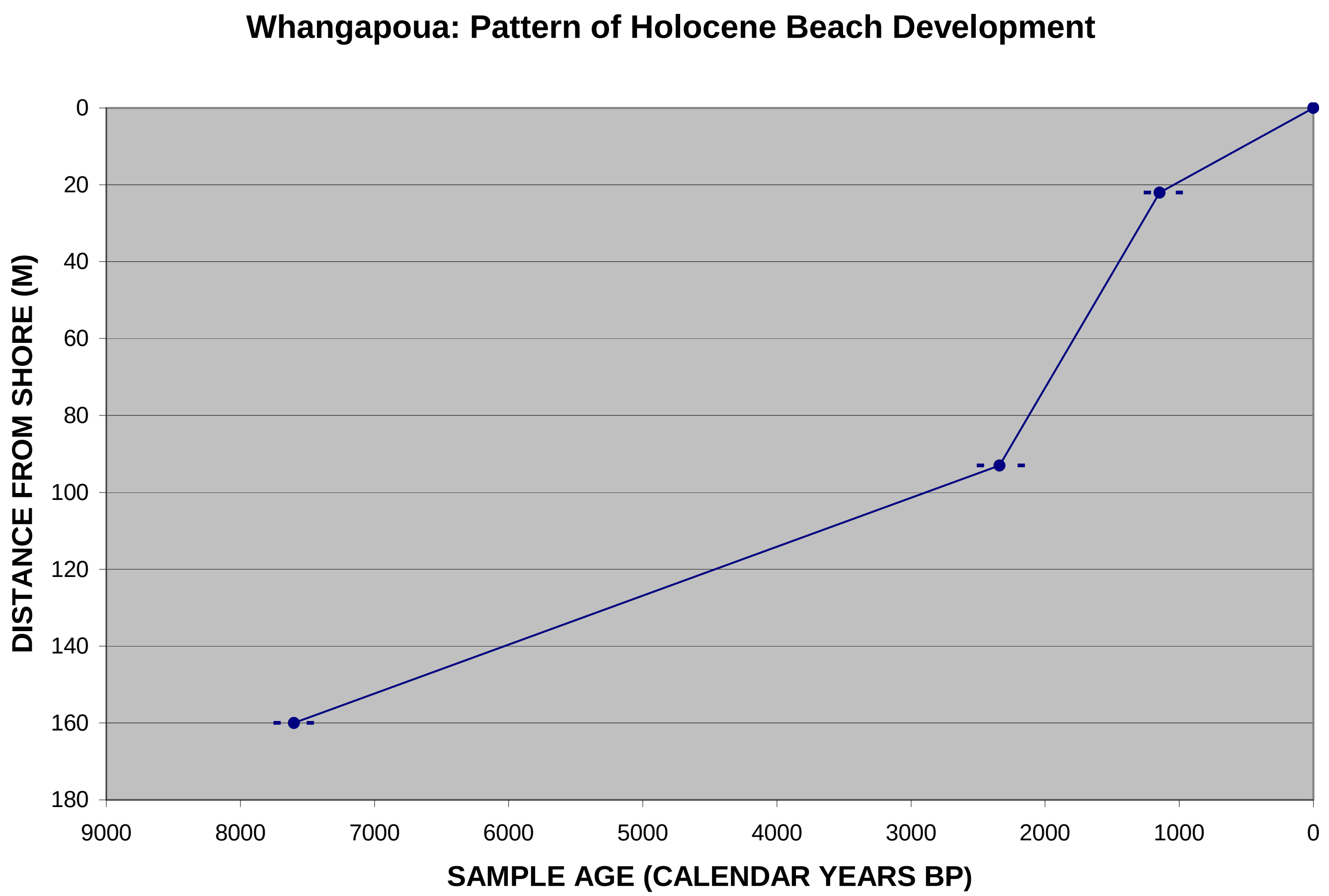


Figure 3-7: Age structure of Whangapoua barrier from radiocarbon dating. The trendline links data points and is indicative only.

3.2.2.4 Other Pocket Beaches

It is clear from field inspections and information from residents and other sources that many of the pocket beaches of the eastern Coromandel have very limited beach and dune sand reserves.

One of the most notable systems in this respect is Hahei Beach (Map 6), an embayed beach of approximately 1200 m length located to the immediate south of Mercury Bay (Figure 1-1). A major storm in July 1978 stripped the sand from this beach, exposing an underlying wave-cut platform. While there are dunes along much of the length of the beach, erosion scarps evident in photos taken after the July 1978 storm show that the dune sands are also largely a veneer over older materials.

The resistant materials underlying the dune sands typically extend to about 1.8 m above MHWS over much (if not all) of the length of the beach, acting to significantly limit erosion during severe storm events.

Field inspections of other beaches also indicate the presence of erosion resistant materials along some parts of the immediate backshore. This includes sections of Wharekaho Beach and Opito Bay, though both these beaches also contain significant lengths of foreshore backed by coastal dunes.

The common occurrence of resistant materials along the backshore of pocket beaches, often within the envelope likely to be influenced by coastal erosion, complicates the assessment of potential coastal erosion at these sites. Rigorous assessment of the risk of coastal erosion at many of these sites would require significant sub-surface investigations/mapping. However, until such information is available, it is more appropriate to adopt a precautionary approach and assume that back-beach areas are erodible.

The limited beach and dune sediments at many eastern Coromandel pocket beach systems emphasises the need to protect these sand reserves – particularly through effective dune management and the avoidance of sand extraction.

3.3 Shoreline Changes

This section reviews available information on shoreline changes along the eastern Coromandel to assess any existing long-term trends and the nature and scale of coastal erosion associated with dynamic shoreline changes and fluctuations.

3.3.1 Long-term trends and dynamic equilibrium

Long-term shoreline trends are essentially determined by the sediment budget of a beach system.

If a beach has a positive sediment budget (i.e. over time, it receives more sediment than it loses), the whole beach system will exhibit a trend for net seaward advance (**progradation**). Similarly, if a beach is losing more sediment than it gains, there will be a landward movement of the whole beach system with time –referred to in this report as **recession**.

Recession can also occur as a consequence of net offshore sediment transfers within a beach system as a consequence of sea level rise (Bruun, 1962).

If the beach system is neither gaining nor losing sand over time, the beach is in dynamic equilibrium. In this state, the instantaneous form and shoreline position will fluctuate about an average.

The assessment of long-term trends is difficult as they can be masked by dynamic shoreline changes, including periods of erosion and accretion occurring over time scales of years to decades. These dynamic changes can be related to a wide variety of controlling processes including episodic storm erosion and subsequent beach and dune recovery, decadal variations in the magnitude and frequency of storm events, El Nino Southern Oscillation (ENSO) cycles, interactions between shorelines and adjacent tidal entrances and ebb tidal deltas and many other factors.

Over time-frames of up to several decades, often the limit of available data, dynamic shoreline changes are frequently of a much larger magnitude than any long-term trends.

Considerable experience and judgement are usually required to adequately discern between long-term shoreline trends and dynamic shoreline changes.

3.3.2 Shoreline mapping

3.3.2.1 Data Analysis

Historical shoreline changes mapped at Whiritoa, Whangamata, Pauanui, Cooks Beach and Whitianga (see section 2.2.1 and Appendix B) were analysed by measuring distances from each mapped shoreline to a baseline, using shore normal transects. These transects were variously spaced at 25 m (Cooks, Whangamata and Whitianga), 30 m (Pauanui) and 50 m (Whiritoa).

For each mapped shoreline, transect offsets were averaged alongshore to determine a spatially-averaged position for each mapped shoreline. These average shoreline positions were then plotted against time for each site to provide a broad indication of trends in shoreline position.

The maximum shoreline change measured at each transect over time was also quantified – i.e. the difference between the most prograded and eroded shorelines on that transect. This provides an approximate measure of the scale of dynamic shoreline fluctuations occurring, with adjustment for any identified longer-term trends.

Clearly, the various mapped shorelines represent “snap-shots” of shoreline position. With the exception of the 1978 photography purpose-flown after a major erosive storm, the dates of the photography and surveys are essentially “accidental” in regard to shoreline movements. i.e. It cannot be assumed that the mapped shorelines adequately define the magnitude of shoreline changes that occur at any particular site. They simply reflect the shoreline positions at the time of the relevant survey or photography.

Therefore, considerable caution has to be observed in interpreting such data. This is particularly so in regard to dynamic shoreline variations. Therefore, to estimate the largest shoreline fluctuation that can occur at any particular beach, we have tended to adopt the largest fluctuation evident within the available data set - except where this was clearly related to local factors that do not apply along the remainder of the beach length.

Results for each of the sites where shoreline changes were mapped are discussed below.

3.3.2.2 Whiritoa Beach

Previous analysis indicated that the variation in average shoreline position with time suggests a consistent trend for net duneline recession along the main beach over the period 1948-1987, averaging about 0.19 m/yr (Dahm et al., 1994). The general dominance of duneline erosion for each period is also evident in Figure 3-8.

The average rate of retreat during this period varied from 0.1-0.3 m/yr, with the highest rate (0.31 m/yr) observed in the period 1963-1978. This probably reflects a combination of both shoreline recession and the significant short-term dune erosion associated with the July 1978 storm. The July 1978 event caused significant erosion at the eastern end of Whiritoa Beach (Dell, 1981).

The average net recession within each period is well within the error of the shoreline mapping (estimated at $\pm$ 3 m for each shoreline). However, the consistency of the trend and the average duneline recession over the entire period (about 7.25 m) tend to suggest that the apparent trend for recession is probably real. This is also suggested by the overall changes in shoreline position over the period (Figure 3-8).

There is also isolated evidence of serious dune scarping at isolated points along the beach suggestive of dune recession. This is particularly severe in front of Pohutukawa Reserve towards the northern end of the beach where *Meulenbeckia complexa* (a species occurring landward of the primary sand grass zone dominated by species such as spinifex and pingao) is noted draped over the erosion scarp.

The duneline is also relatively irregular (Map 1), suggestive of recession. Duneline recession can frequently tend to be quite localised in initial stages, particularly at either end of the beach where the dunes are more susceptible to wave attack and stream entrance effects. However, over time, it would be expected that the duneline along the beach will tend to equilibrate and become smoother.

If the trend for dune recession is real, it probably relates to past sand extraction from this beach system. Sand was extracted from the beach over the period from at least 1947 until cessation in 1995/96, removing an estimated total of about 180,000 m^3 over this period (Dahm, et al., 1994). This sand was largely removed from a back-beach pit at the southern end of the beach, the pit being replenished by sands washed over the berm and into the pit by wave action.

As available evidence strongly suggests that the beach is no longer receiving any significant net sand supply (McLean, 1979; Bradshaw, 1991; section 3.1 above), the sand extraction almost certainly represented a net sediment loss from the beach system. In this relatively small beach it could be expected that such losses would be compensated for by erosion of the dune reserves. These impacts could take some time to become fully evident, as severe dune erosion is relatively infrequent. The irregular duneline noted above may indicate the process of adjustment to the sand losses is still continuing.

The maximum shoreline changes measured at each transect ranged up to 31 m, though most were less than 15 m.

The largest duneline changes (up to 31 m) were observed at the northern end of the beach (Figure 3-8) and these changes were particularly influenced by longshore migration of the adjacent Ramarama Stream entrance in the early 1980's. The exposure of underlying bedrock near the toe of the dune at the southern end of the beach (see section 3.2.2 above) probably limits shoreline fluctuations in the vicinity of the Whiritoa Stream entrance.

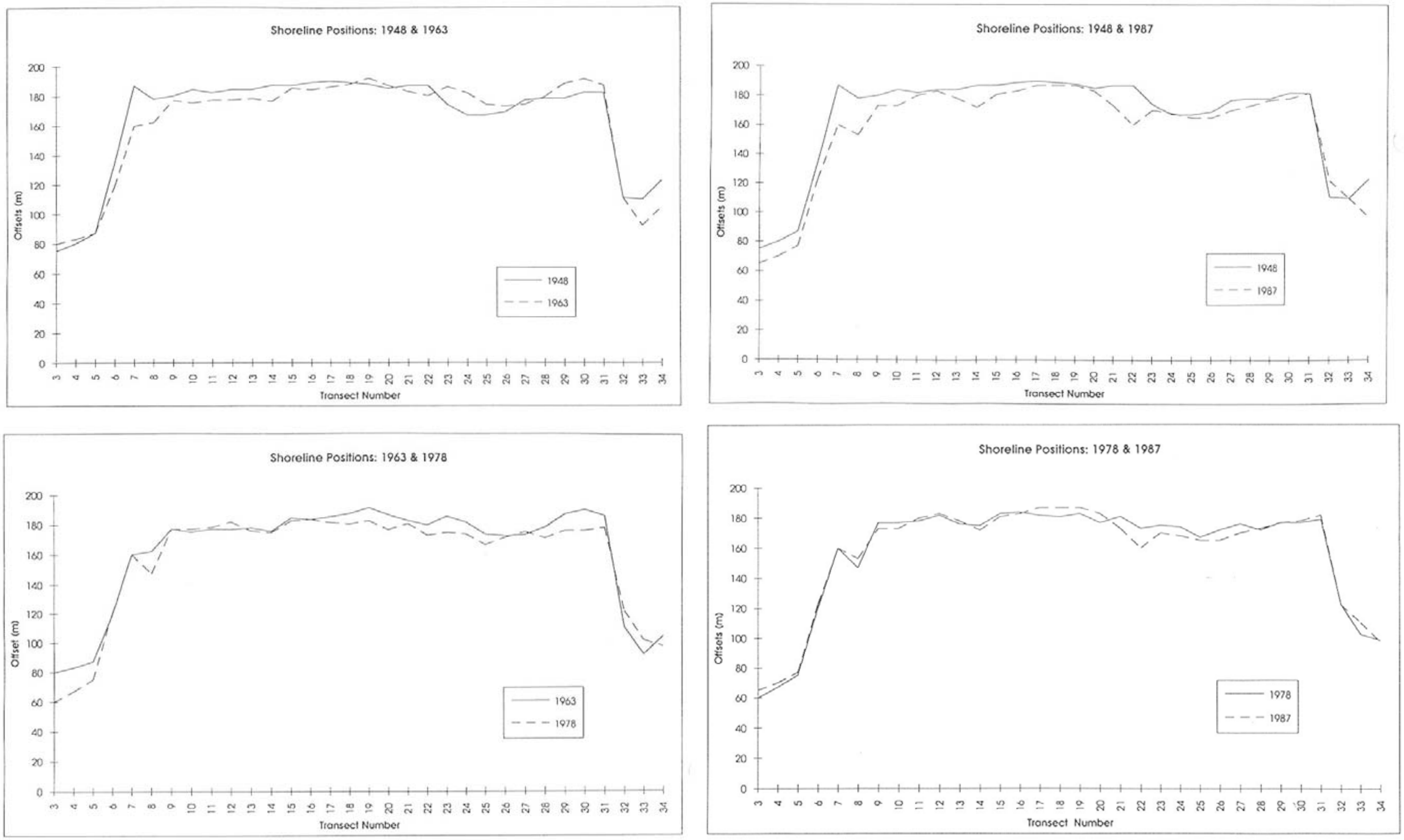


Figure 3-8: Duneline changes at Whiritoa Beach

Significant changes (typically 11-16 m, but up to 27 m) were also noted on the main beach, towards the southern end and removed from stream influences. Therefore, while maximum duneline erosion along the main beach was typically less than 10-15 m, it appears that maximum shoreline fluctuations of up to 15-20 m (and more rarely up to 27 m) can also occur on the main beach. However, as noted above, the shoreline changes probably also incorporate an element of duneline recession.

3.3.2.3 Whangamata

Whangamata essentially has two ocean beaches, the eastward facing main Whangamata Ocean Beach and the southwards facing Otahu Beach (Map 2a & 2b).

The five "snapshots" of average shoreline position over the 50 year period from 1944 to 1994 show no discernible trend for net accretion or erosion over the period – with the most prograded shoreline positions (1944 and 1987) being almost identical (Figure 3-9). Rather, the major changes in shoreline position appear to relate to shoreline fluctuations (Figure 3-9).

Both the main ocean beach (Whangamata Beach) and Otahu Beach show a trend to erode during the 1960's and 70's, with the most landward position of both beaches recorded following the 1978 storm (Figure 3-9). Similarly, both sites show a trend to accrete in the subsequent period to 1987.

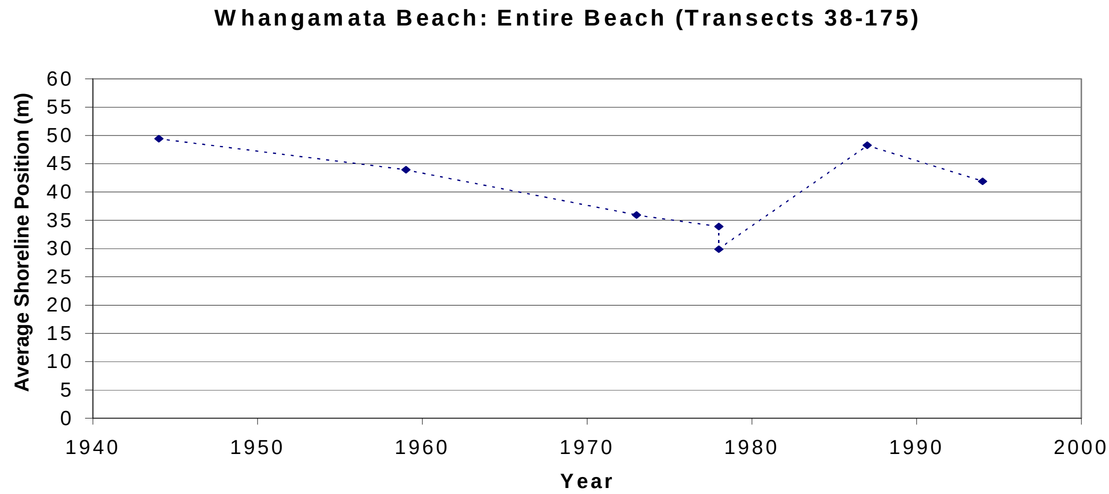
While caution has to be exercised in interpolating between the "snapshots," examination of other data for the intervening periods (e.g. various oblique aerial photographs from the Whites Aviation collection and beach profile data for the period since 1981) tends to suggest the trends shown in Figure 3-9 are broadly representative of these periods. Therefore, we have shown a dashed line linking the various "snapshots" to better illustrate the broad overall trends in shoreline change. These lines (also shown for other sites presented later) are indicative of broad trends only. They do not show the exact position of the shoreline at any point in time between the dates of the mapped shorelines. Nor, of course do the dates of the mapped shorelines show the exact dates that periods of accretion gave way to periods dominated by erosion or vice versa.

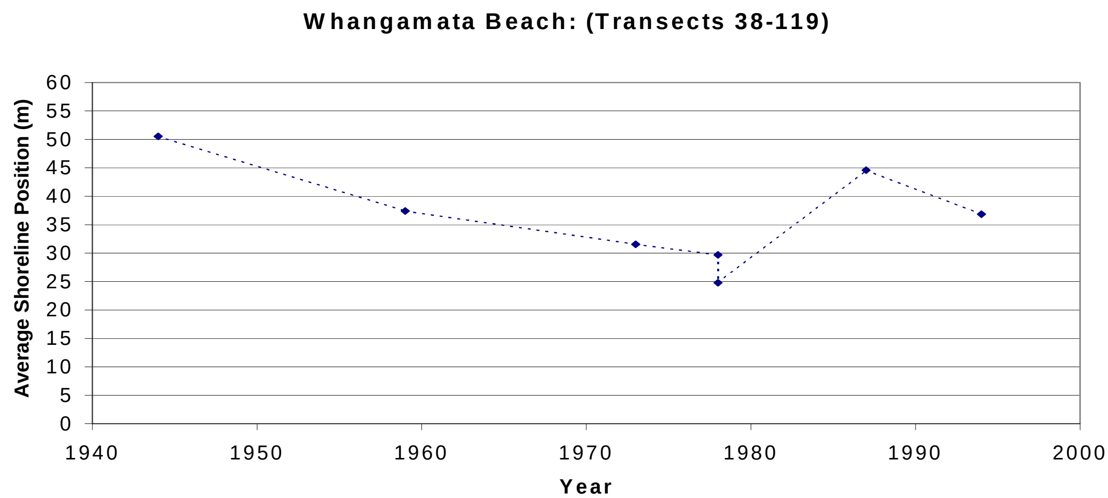
These general trends for erosion or accretion over substantial periods of time tend to suggest that the position of the Whangamata shoreline may be more strongly influenced by decadal trends than annual or inter-annual variations or individual storm events.

The apparently significant influence of decadal trends illustrates the danger of extrapolating long-term trends from limited data sets. For instance, analyses based only on records from 1944 to 1978 would probably have concluded there was a long-term trend for recession at Whangamata. Similarly, extrapolation of the overall trend for the period from 1978 to 1995 would tend to suggest a long-term trend for net progradation. This emphasises the dangers of extrapolating short-term databases to predict longer-term trends.

If the "snapshots" <u>broadly illustrate the general trends</u> in shoreline position over this 50-year interval (as we believe), it would appear that there was probably only one full "cycle" from an accreted shoreline through a significantly eroded shoreline back to an accreted duneline. This apparent "cycle" occurring over about 30 years at Otahu Beach and over a period of up to 45 years on the main ocean beach (Figure 3-9).

The dominant influence of decadal trends in overall shoreline movement is further supported by the relatively minor (about 3-4 m) landward movement on the main ocean beach in response to the July 1978 event (Figure 3-9). This tends to suggest that the impact of the July 1978 event may relate more to the progressive landward movement during earlier storm events than to the severity of this particular event.





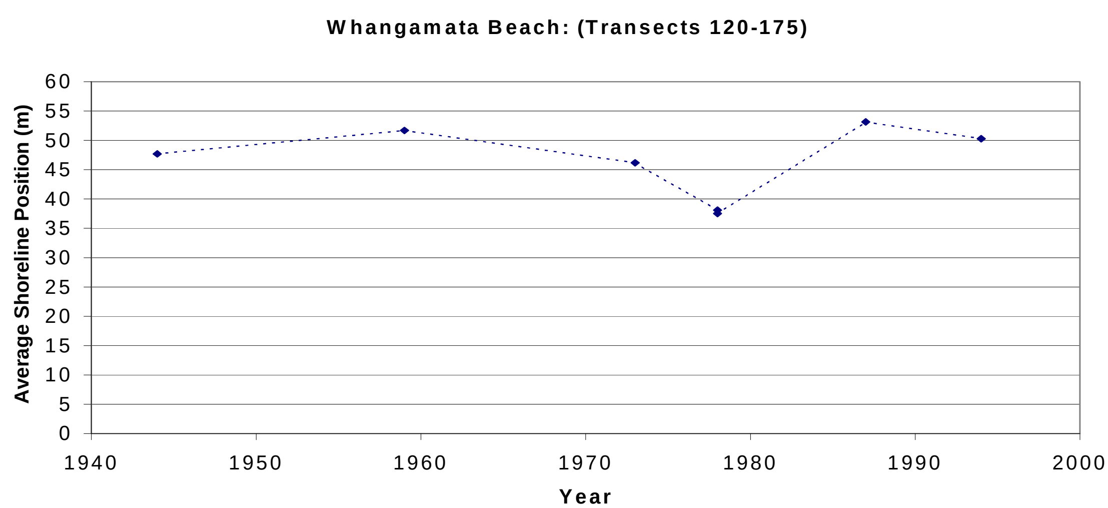


Figure 3-9: Changes in average shoreline position a Whangamata and Otahu beaches.

In this respect, it is notable that the average shoreline position of Otahu Beach did not change significantly between the January 1978 and July 1978 shorelines (Figure 3-9). This is consistent with post-storm observations, which noted “a foredune erosion scarp” along the main beach, but “no erosion scarp was to be seen on the length of the beach leading to the Otahu River Mouth” (Report of post storm observations by R W Harris, Chief Engineer, 9 August, 1978).

The scale of maximum shoreline change recorded shows considerable variation along the total length of the Whangamata and Otahu shorelines (Figure 3-10). The transects noted are spaced at 25 m and number north to south.

Particularly significant are the large duneline changes (up to about 60 m) recorded in the vicinity of the Williamson Park stormwater outlet (Figure 3-10). This outlet discharges from a large storage pond and flows can appear like a small stream during major rainfalls. Historically, uncontrolled discharges from this outlet have nearly undermined an adjacent bach (since replaced). A relatively large duneline fluctuation was also recorded at transect 70 (Figure 3-10) located near Ranfurly Avenue. This reflects severe wind erosion of the dune due to vegetation disturbance associated with pedestrian beach access off Ranfurly Avenue.

The only other sites where maximum-recorded changes exceed 30 m occur along the southern end of the main ocean beach in the lee of Clark Island (transects 109-121 inclusive), where strongly refracting waves often break at considerable angles to the shoreline. It would appear that the significant longshore transport generated in this area could lead to larger shoreline fluctuations than noted on other shoreline areas on this beach.

Apart from these areas, where the large duneline fluctuations clearly relate to local factors, the maximum duneline fluctuation along both Whangamata and Otahu beaches is generally less than 30 m, though often not much less (Figure 3-10).

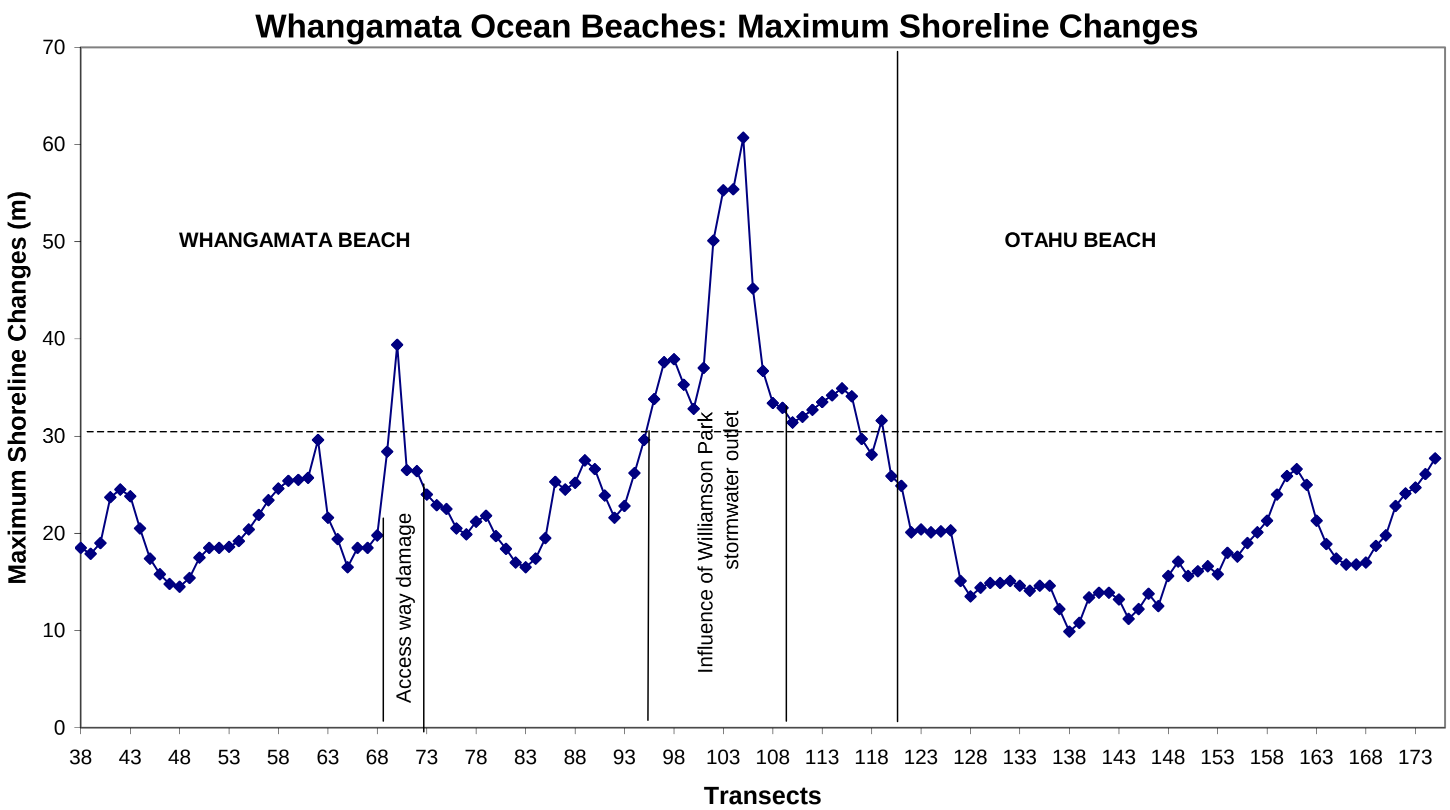


Figure 3-10: Maximum shoreline changes measured at Whangamata ocean beaches between mapped shorelines (1944, 1959, 1973, 1978, 1993 - see appendix B).

3.3.2.4 Pauanui Ocean Beach

The “snapshots” of shoreline position at Pauanui tend to suggest both decadal fluctuations in shoreline position and a possible long-term trend for continued net progradation (Figure 3-11).

Over the period 1895 to 1995, there appears to be a very slow ongoing trend for progradation, of the order of 5-10 m per century based on the average position of the entire beach (Figure 3-11).

This trend is consistent with the average rate of progradation (about 0.06 m/yr) noted by Gibb and Aburn (1986) for the last 2000 years and tends to suggest ongoing net sediment supply to the Pauanui Ocean Beach. If so, this ongoing sediment supply is most probably derived from the Tairua River – since there is clear evidence from the pattern of Holocene progradation at this and other sites that supply of sediment from the continental shelf has markedly decreased over the last 2000 years (see earlier discussion in section 3.2.1). This is supported by work conducted by Gibb (1983), who argued for the dominance of fluvial supply to the modern ocean beach on the basis of mineralogical investigations of beach and estuarine sands.

The decadal trends are similar to those noted at Whangamata for the period from 1967 – with erosion dominating until 1978, with accretion tending to dominate thereafter (Figure 3-11). However, in 1944 the Pauanui shoreline appears to have generally been in an eroded state (Figure 3-11) while the Whangamata shoreline at this time was generally in a relatively prograded state (Figure 3-9). Therefore, the decadal trends appear to have both local and coastwise elements.

The trend of maximum shoreline changes over the period 1944-1995 is shown in Figure 3-12 (the transects noted are spaced at 30 m and number from the southern end of the beach). These results tend to suggest that the beach can be broadly subdivided into two main regions:

- **The areas north of transect 60, where the shoreline appears to be significantly influenced by the adjacent ebb tidal delta**. Dynamic shoreline changes in this area show a trend to increase in magnitude towards the entrance of Tairua Estuary, where shoreline fluctuations of up to 78 m have been observed in the period since 1944 (Figure 3-12). The full length of the shoreline area influenced by the ebb tidal delta becomes most evident when the 1895 shoreline data is also included in the estimation of maximum shoreline changes (Figure 3-12).

- **South of transect 60, where dynamic shoreline changes are generally less than 30 m.** Larger shoreline changes (34-44 m) are noted in the vicinity of transects 40-44 when the 1895 data is included in the shoreline change analysis (Figure 3-12), but these probably incorporate an element of long-term progradation. If the 1895 shoreline is excluded from the analysis, the changes exceed 30 m (36 m) at only one of these transects.

Therefore, in areas removed from the influence of the ebb tidal delta, the maximum scale of dynamic shoreline fluctuations is very similar to those generally noted at Whangamata. The larger changes noted along the shoreline adjacent to the ebb tidal delta are typical of such environments (Dahm, 1983; Hume and Hicks, 1996; Hicks et al., 1999) and emphasise the need for site-specific consideration of shoreline change in these areas.

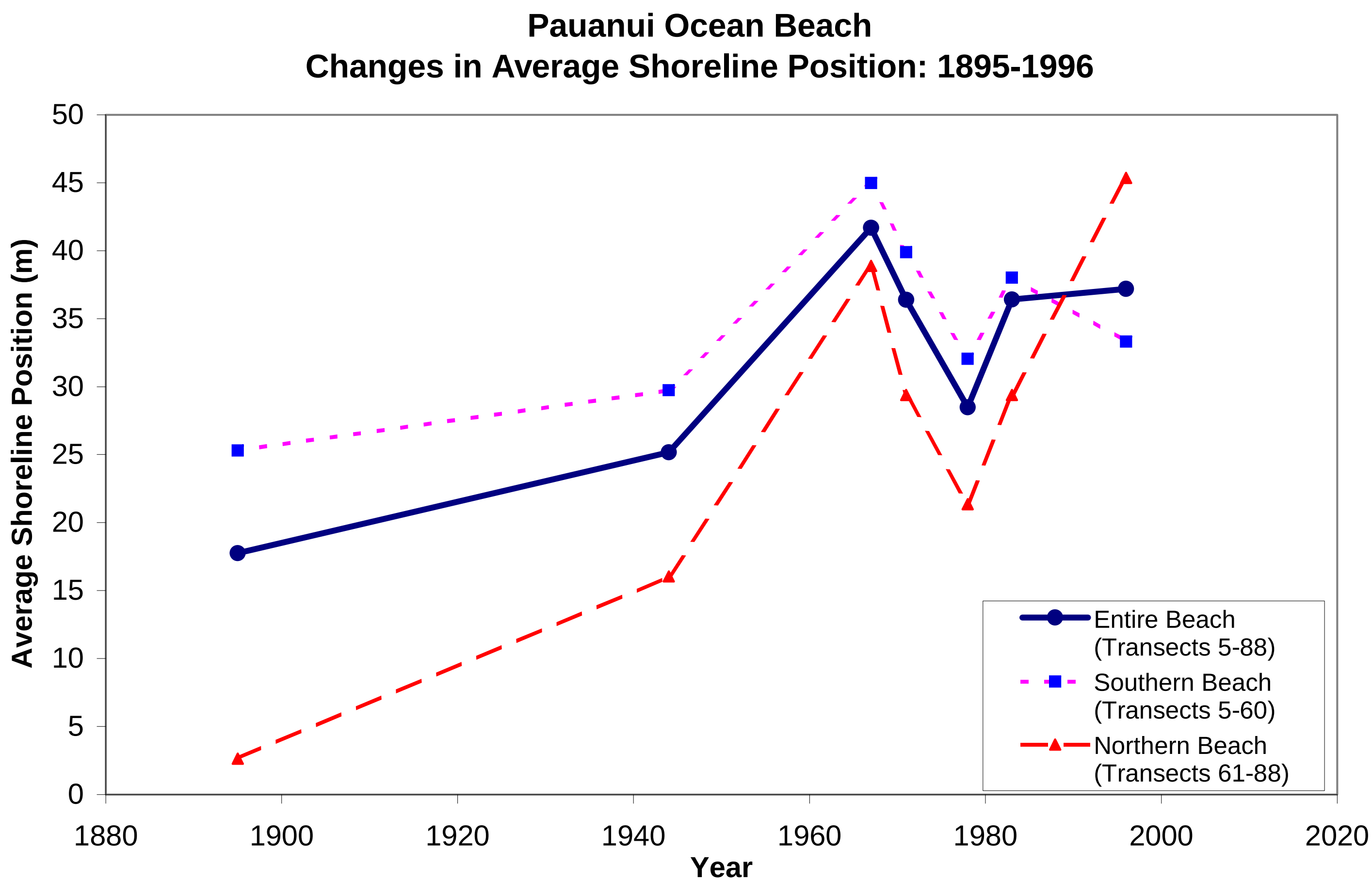


Figure 3-11: Changes in average duneline position at Pauanui – the dashed line is broadly representative of shoreline changes since 1944 but not for 1895-1944.

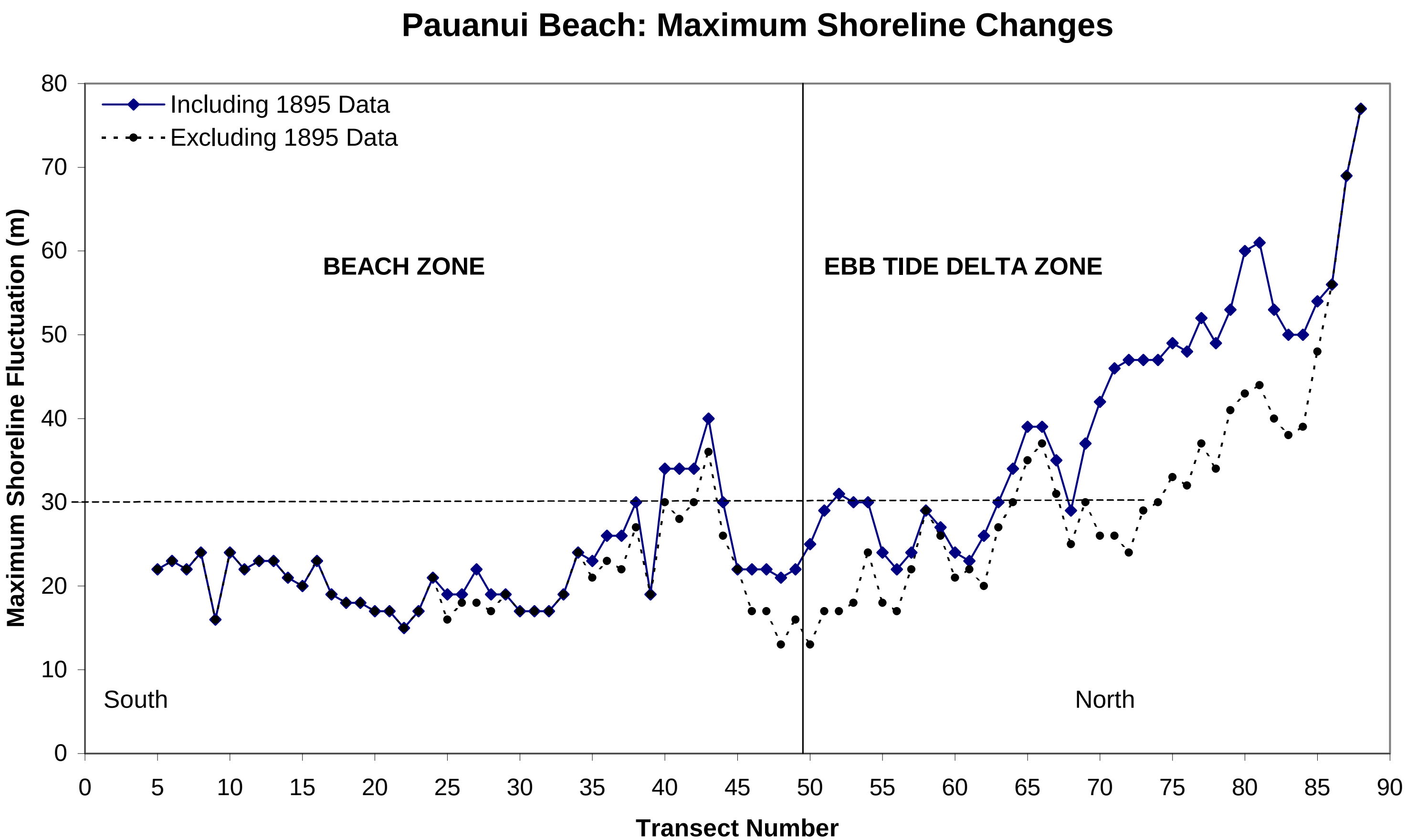


Figure 3-12: Maximum shoreline fluctuations recorded at Pauanui between dates of mapped shorelines. The inclusion of the 1895 data probably incorporates some long-term progradation.

3.3.2.5 Tairua Ocean Beach

The analysis of shoreline change at Tairua Ocean Beach suggests the shoreline has no long-term trend for recession or progradation but is dominated by decadal fluctuations as observed at other sites (Figure 3-13).

The decadal trends are broadly similar to those noted at Pauanui. The shoreline was in a similarly eroded state in 1944, showed an overall accretion to 1971, erosion until 1983 and then subsequent accretion to 1997 (Figure 3-13). It is possible that some erosion had already commenced by the end of the 1944-1971 period, given major coastal storms in 1968 – though this was difficult to determine from other available photography.

The broad similarity of the trends tends to suggest that the shoreline mapping has a reasonable accuracy, despite the use of non-rectified photography.

Maximum shoreline fluctuations were typically in the range of 15-20 m, with 22 m being the maximum shoreline fluctuation noted (Figure 3-14). As with the Whiritoa, the other medium-coarse sand pocket beach investigated, it appears that the maximum duneline fluctuations are slightly less than those observed on the finer grained beaches of the moderate to large barrier systems.

3.3.2.6 Cooks Beach

This beach, though a single interconnected sediment system, has demonstrated quite different shoreline trends over the last 50-60 years – with an overall trend for erosion at the eastern end of the beach and a similar overall trend for accretion in central and western beach regions (Figure 3-15).

These changes are briefly discussed below.

Erosion at Eastern End of Cooks Beach

The easternmost 900-1000m of the beach has shown a trend for marked erosion, particularly in the 1970's (Figure 3-16).

Information from long-term residents and property owners suggest that the erosion trend probably began in the late 1960's. Large dunes at the very eastern end of the beach (near the Cook Memorial, east of existing development) were completely eroded in the "Waihine" storm of April 1968 and a subsequent storm event about three months later (Mr Graeme Newitt, *pers. comm*., 1991; Mr Roy Redshaw, *pers. comm.,* 1991). Long-term property owners advise that this dune was about 4-6 m high near the Cook Memorial, though frontal dunes were much lower (generally 1-2 m high) along the property frontages immediately to the east (Mr G Newitt, *pers. comm.,* 1991; Mr R Nash, *pers. comm.,* 1991). There is also correspondence from the (then) Coromandel County Council indicating awareness of erosion at the eastern end of Cooks Beach in 1968 (e.g. Letter from Coromandel County Council to Mr G Newitt of Matamata, dated 23-7-68).

Residents began placing protection works in the early 1970's. Initially, these were largely brush and post works, though the first rocks were dumped as early as 1970 (Mr G Newitt, *pers. comm.,* 1991 and various others).

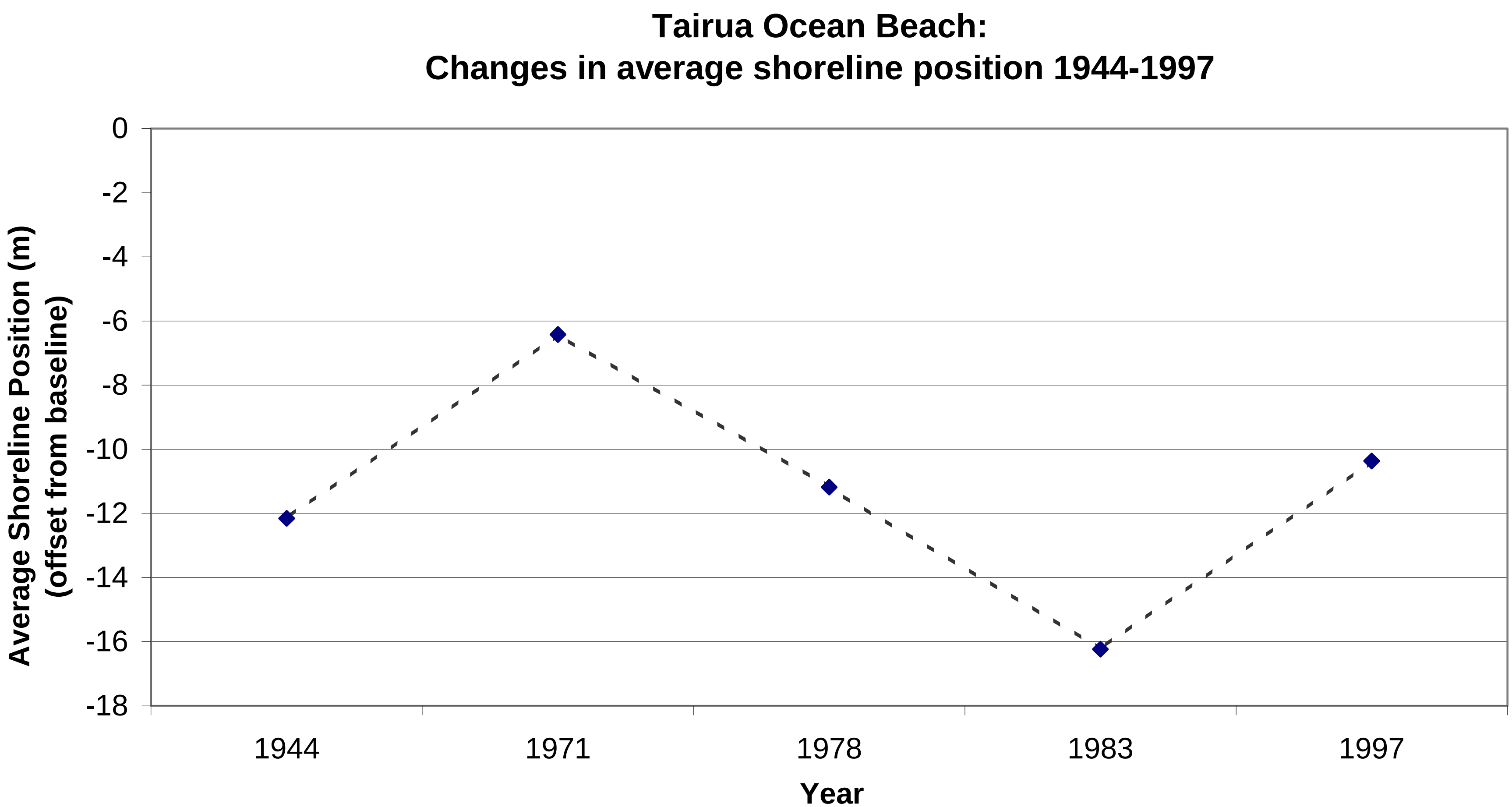


Figure 3-13: Changes in average shoreline position at Tairua Ocean Beach

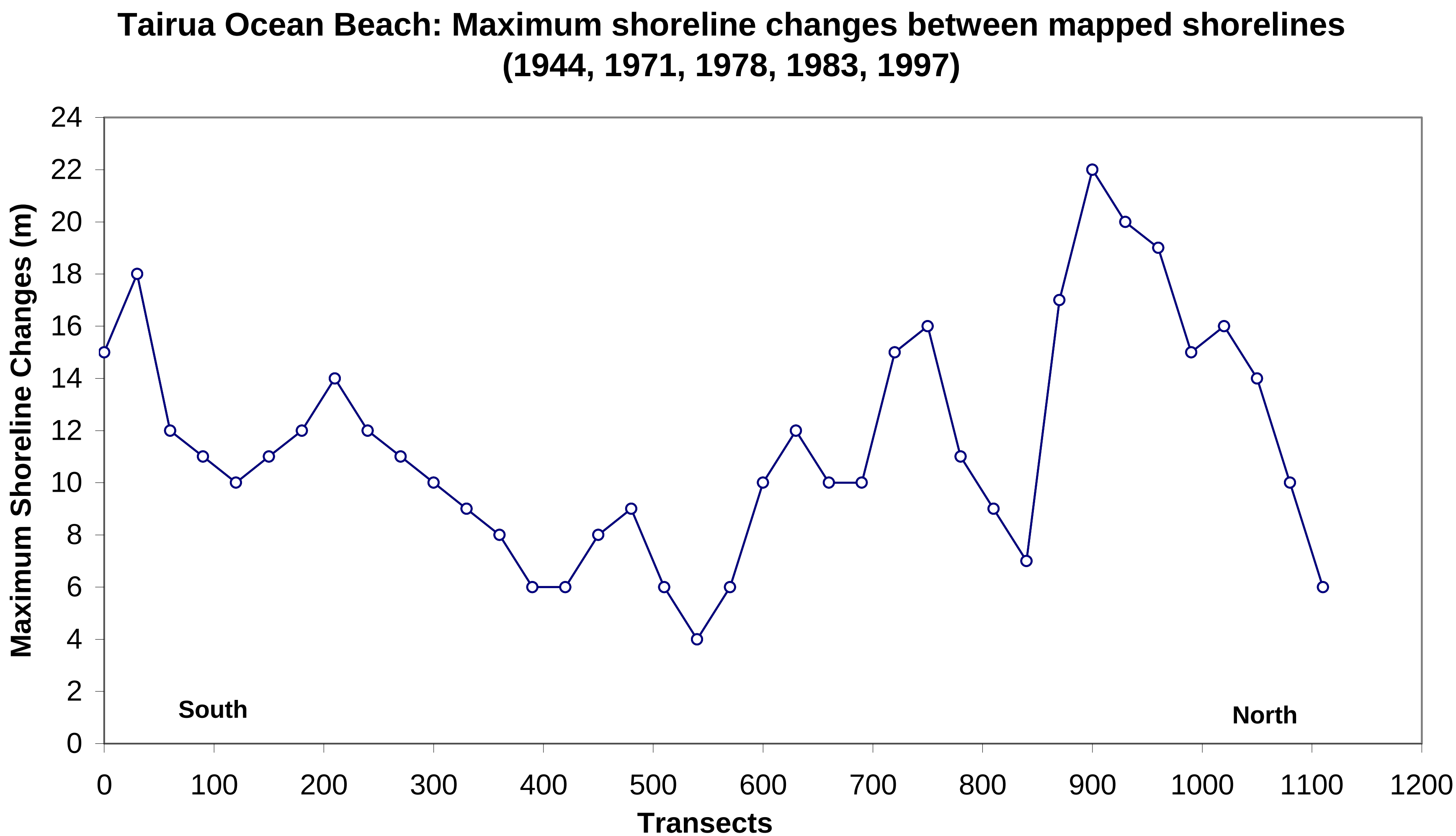


Figure 3-14: Maximum shoreline changes at Tairua Ocean Beach.

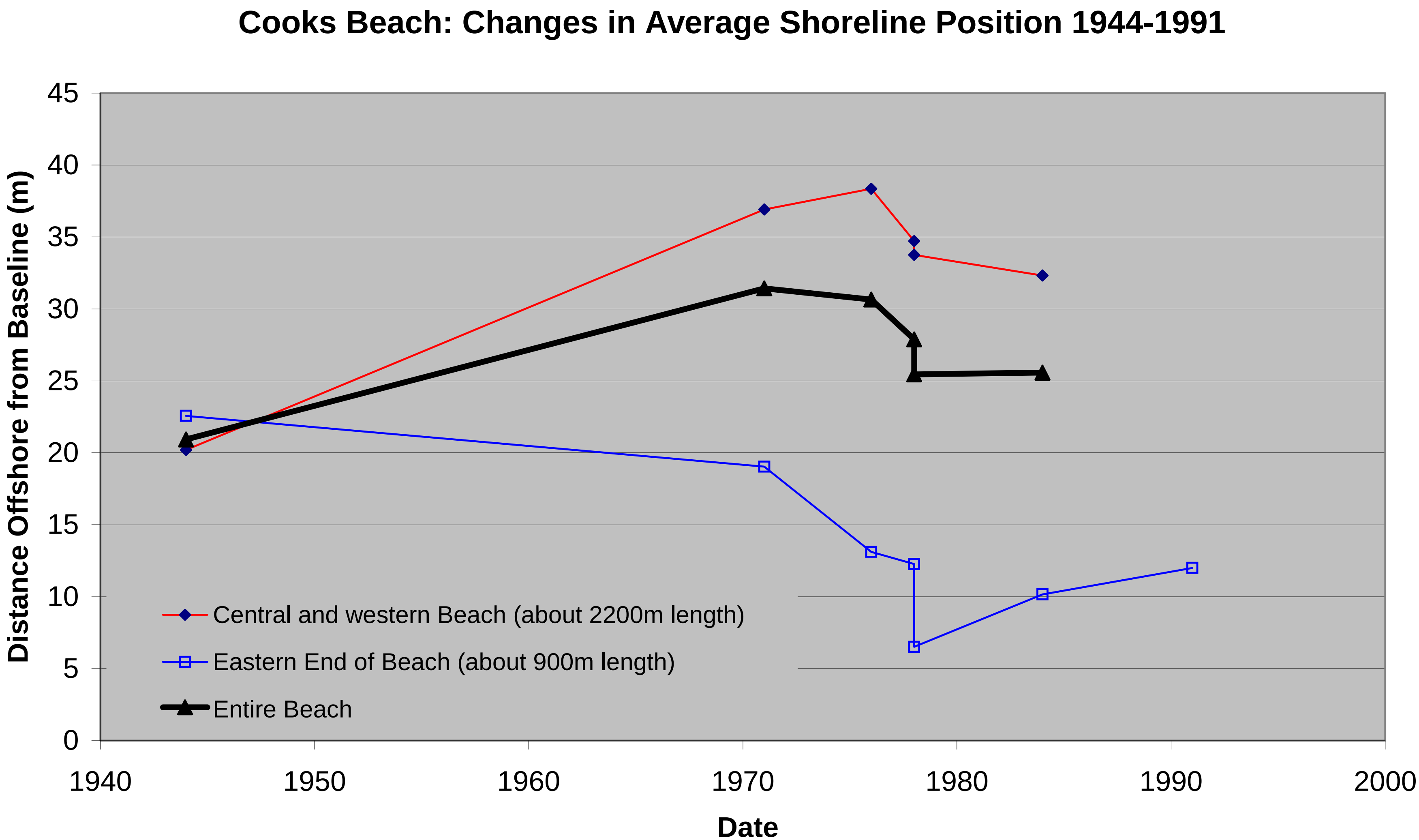


Figure 3-15: Changes in average shoreline position at Cooks Beach.

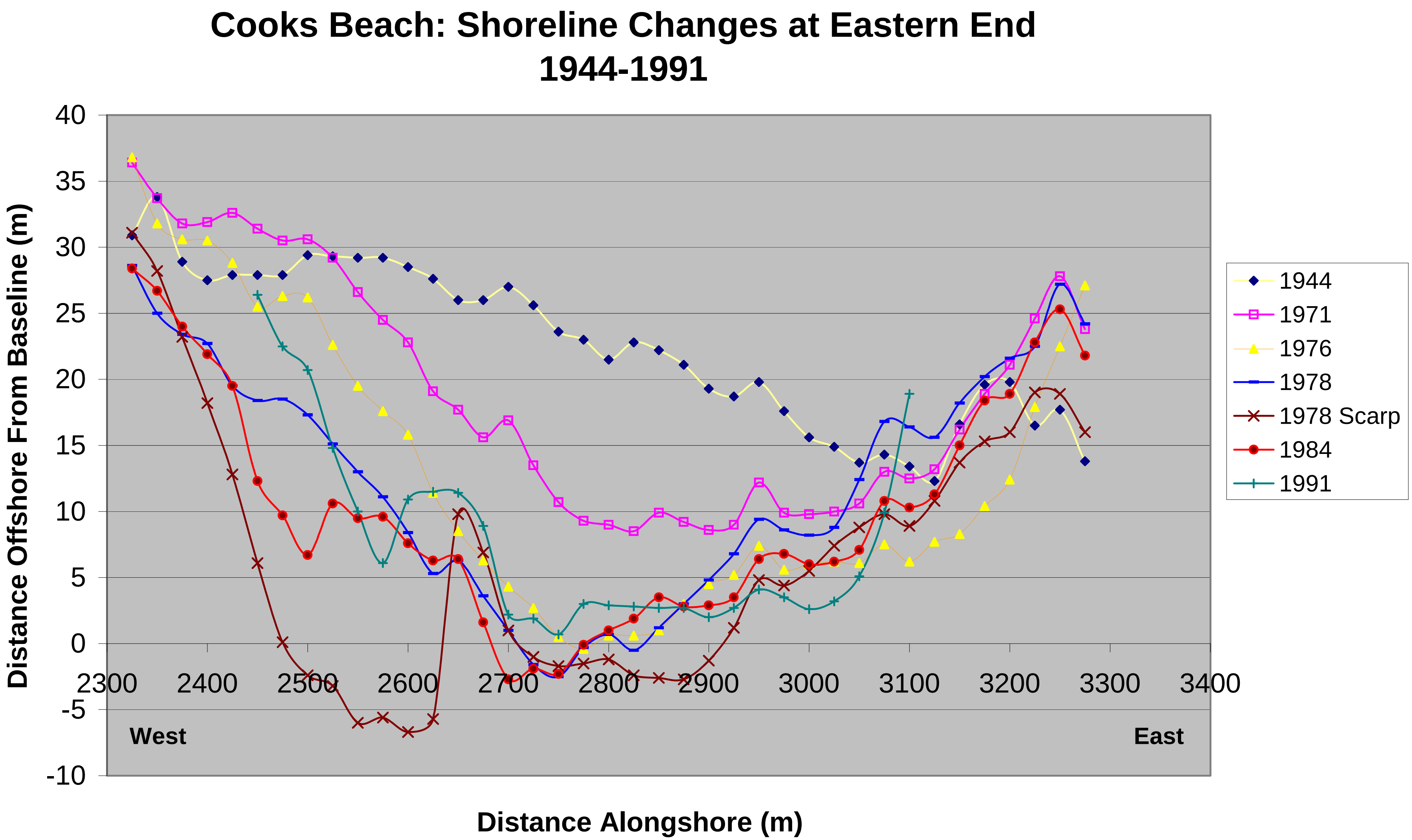


Figure 3-16: Pattern of coastal erosion at eastern end of Cooks Beach.

It appears from resident reports that the erosion began to impact on some properties in the early 1970's. Various long-term property owners independently report that the last foreshore subdivision at the most eastern end of the beach (DPS 15943, surveyed 1971) was severely impacted by erosion and wave flooding before the first house had been built. Many property owners also advise that waves washed completely over this area to Captain Cook Road before the first house was built. They note that this wave flooding was aided by bulldozing of the area associated with the development, which removed the small frontal dune along the foreshore (Mr G Newitt and Mr G Sharland, *pers. comm*., 1991). Others also noted erosion. For instance, one long-term property owner reported that the area had been sprayed with "instant grass" after bulldozing and that erosion shortly after saw instant grass layers "jutting out into the air for several feet and collapsing in other areas" (Mr G Sharland, *pers. comm.,* 1991). The Ministry of Works also advised the Coromandel County in the early 1970's to consider setting aside further reserve along this subdivision due to erosion hazard (letter from MWD Hamilton to Coromandel County Council dated 2-10-73, MWD Ref. 40/12). Concern with the development appears to have been widespread. One long-term property owner advised that the development was widely regarded at the time as being of the "rough quick buck" type.

Property owner reports indicate that erosion was very serious from about 1973 onwards and various works were placed and destroyed in the following years, particularly in the period 1975-78. In Easter of 1978, erosion washed back some metres in places despite the fact that the seas were relatively calm (Mr R Nash and others, *pers. comm*., 1991). This tends to suggest that the erosion was primarily related to changes on the adjacent ebb tidal delta and not solely related to storm events.

The most serious erosion occurred shortly afterwards in the storm of July 1978, which severely eroded several properties (some to a depth of more than 15 m) and affected about eight dwellings including partial undermining of some. Post storm observations record that the storm produced "an immediate threat to about eight residences. Foundations were beginning to be undermined on one of these buildings. Quite large quantities of rock were being placed on the beach at the time of inspection (July 21 and 22) … Most of the length concerned has now been faced with dumped rock" (Report on July 1978 event, R W Harris, Chief Engineer, Hauraki Catchment Board, 9 August, 1978).

The pattern of erosion at the eastern end of the beach is broadly evident from the various "snapshots" of shoreline position provided by shoreline mapping (Figure 3-16).

This figure indicates that the erosion tended to progress both westwards and landwards in the period up to 1978 (Figure 3-16). It can also be seen from this diagram that maximum erosion exceeded 30-35 m in some areas.

Interestingly, there is also evidence that "end effects" may have contributed to the July 1978 erosion in some areas. Heavy rock protection was placed along the frontage of a property to the immediate east of Iti Lane after loss of previous shoreline armouring the preceding Easter (Mr R Nash, *pers. comm.,* 1991). These works (located between 2650m and 2680m on Figure 3-16) were not affected by the July 1978 storm (Figure 3-16), even though this event destroyed a number of lesser armouring works to both the east and west of this area. However, the most severe erosion occurred immediately to the west of these works (Figure 3-16). Properties immediately to the west (e.g. 129 and 127 Captain Cook Road) experienced up to 15 m erosion, with a depth of cut in excess of 2 m (Mr R Clarke, owner of property at 127 Captain Cook Road, *pers. comm.,* 1991). Thereafter, it is reported that the erosion scarp decreased in height and dwindled away to nothing about 8 houses further westward (115 Captain Cook Road) (Mr R Redshaw, *pers. comm.,* 1991). This pattern is strongly suggestive of "end effects," though it is also clear that the erosion was progressively moving westward up to and including 1978 (Figure 3-16).

There was some shoreline recovery at the eastern end of the beach between 1978 and 1984 (Figure 3-16), though much of this apparent recovery is also related to the extensive rock armour and foreshore reinstatement undertaken by property owners after the July 1978 event. Many of the properties most seriously eroded in July 1978 now have large volumes of rock armour underlying their lawns and extending from under their houses to their front property boundaries (Mr R Clarke and others, *pers. comm.*, 1991).

Subsequent to 1984, there has been some further erosion damage – associated with storm events in July 1987 and in August and September 1989.

Property owner reports suggest that the event in July 1987 largely affected properties to the east of Iti Lane, particularly in the area from 137-155 Captain Cook Road. The event removed a timber wall fronting some properties (e.g. 147 Captain Cook Road) and eroded 3-6 m inside property boundaries – though various owners believe the erosion would have been more serious but for rock placement during the storm (Mr S Scott, *pers. comm.,* 1991). A timber wall backed by ply and rocks was placed along the frontage of the properties from 143-153 Captain Cook Road after this event (Mr A Telfour, *pers. comm.,* 1991).

The events in 1989 damaged properties in much the same area as the 1987 event, particularly 137-141 Captain Cook Road, though resident reports suggest areas further east would also have been affected but for a timber wall installed after the 1987 event (Mrs E M Keys and others, *pers. comm*., 1991). Further armouring works were placed following these events, including gabions along the frontage of 139 and 141. These works are still in place.

The fact that the events of 1987 and 1989 appear to have largely impacted properties to the east of Iti Lane may be due to the extensive protection now existing along the frontages of properties further west. Various property owner reports suggest rock armour now exists along (and, apparently, within) virtually all property boundaries from 135 Captain Cook Road west to at least 109 Captain Cook Road. However, the works at the more western end are presently buried and not visible. The works from 131 to 109 Captain Cook Road were all placed in the period shortly after the July 1978 event.

Beach profiling sites at the eastern end of the beach (including two additional sites established in early 1991 to monitor shoreline trends in this area) suggests little to no net shoreline recovery has occurred over the last 10 years.

The erosion at the eastern end of the beach is consistent with the pattern of Holocene dunes at this end of the beach. As noted in section 3.2.1 above, the pattern of Holocene dunes strongly suggests that the eastern shoreline adjacent to the ebb tidal delta is punctuated by periods of significant erosion and accretion.

The reason for these dynamic shoreline changes is uncertain but they appear to relate strongly to changes on the ebb tidal delta. In 1944, when the eastern shoreline was in a prograded state, the main ebb channel discharging from Purangi Estuary turned markedly westward across the ebb tidal delta. However, in the 1970's the channel turned progressively more northward, resulting in an easterly shift of the body of the ebb tidal delta. The main ebb channel now turns markedly northwards and the bulk of the ebb tidal delta lies considerably further eastwards than in 1944.

Therefore, it is possible that the shoreline accretion tends to be associated with a westerly discharge of the main ebb channel. On these occasions, the main body of the ebb tidal delta lies more westward and the shoreline probably progrades in the lee of this feature – possibly as a consequence both of wave refraction over the delta and sediment supply from onshore migration of sediment from the delta. Similarly, erosion appears to be associated with an eastward movement of the ebb tidal delta.

If this is correct, it appears that a period of accretion is unlikely to occur in the near future – given the present northerly orientation of the main ebb channel and the more easterly location of the body of the ebb tidal delta.

Accretion in Central and Western Areas of Cooks Beach

In contrast to the eastern end of the beach adjacent to the ebb tidal delta, the remainder of the beach was characterised by significant accretion over the period 1944 to 1976 (Figure 3-17). The most significant accretion (typically 20-25 m) has tended to occur at the western end of the beach though significant accretion (typically 12-20 m) has also occurred in central areas (Figure 3-17).

However, overall, the entire beach system shows only relatively minor (<5 m) seaward movement over the period 1944-84 (Figure 3-15) – tending to suggest the erosion and accretion largely balance. Therefore, the accretion in western and central areas may simply prove to be dynamic change associated with shoreline fluctuations operating over periods of decades.

This is also suggested by the duneline erosion between 1976 and 1984 (Figure 3-17). Beach profile data from sites in the central (ccs 30) and western (ccs 29) parts of the beach show overall accretion from 1979 to about 1995, with a trend for beach lowering and erosion (the dune toe retreating by about 7m) in the period from 1996-98, returning the duneline to about the 1979 position.

As the beach is a single, interconnected sediment system it is possible that the accretion in central and western areas of the beach relates in part to the erosion at the eastern end – i.e. a transfer of sediment from the eastern end of the beach to central and western areas. However, as the total area of accretion is considerably in excess of the area of erosion, it seems likely that other factors are also responsible.

For instance, it could be argued that the accretion in central and western areas also indicates some ongoing, long term progradation. However, this seems unlikely given the relatively low rates of net progradation that have prevailed over the last 1500-2000 years (see discussion in section 3.2.1 above). Moreover, the overall accretion along the full length of the beach between 1944 and 1984 is relatively minor (Figure 3-15) and if the erosion trend noted from 1996 continues, this minor net accretion may be eliminated in coming years.

Overall, the weight of presently available evidence tends to suggest that shoreline changes at Cooks Beach are largely dynamic, associated with meso-scale shoreline fluctuations operating over periods of several decades.

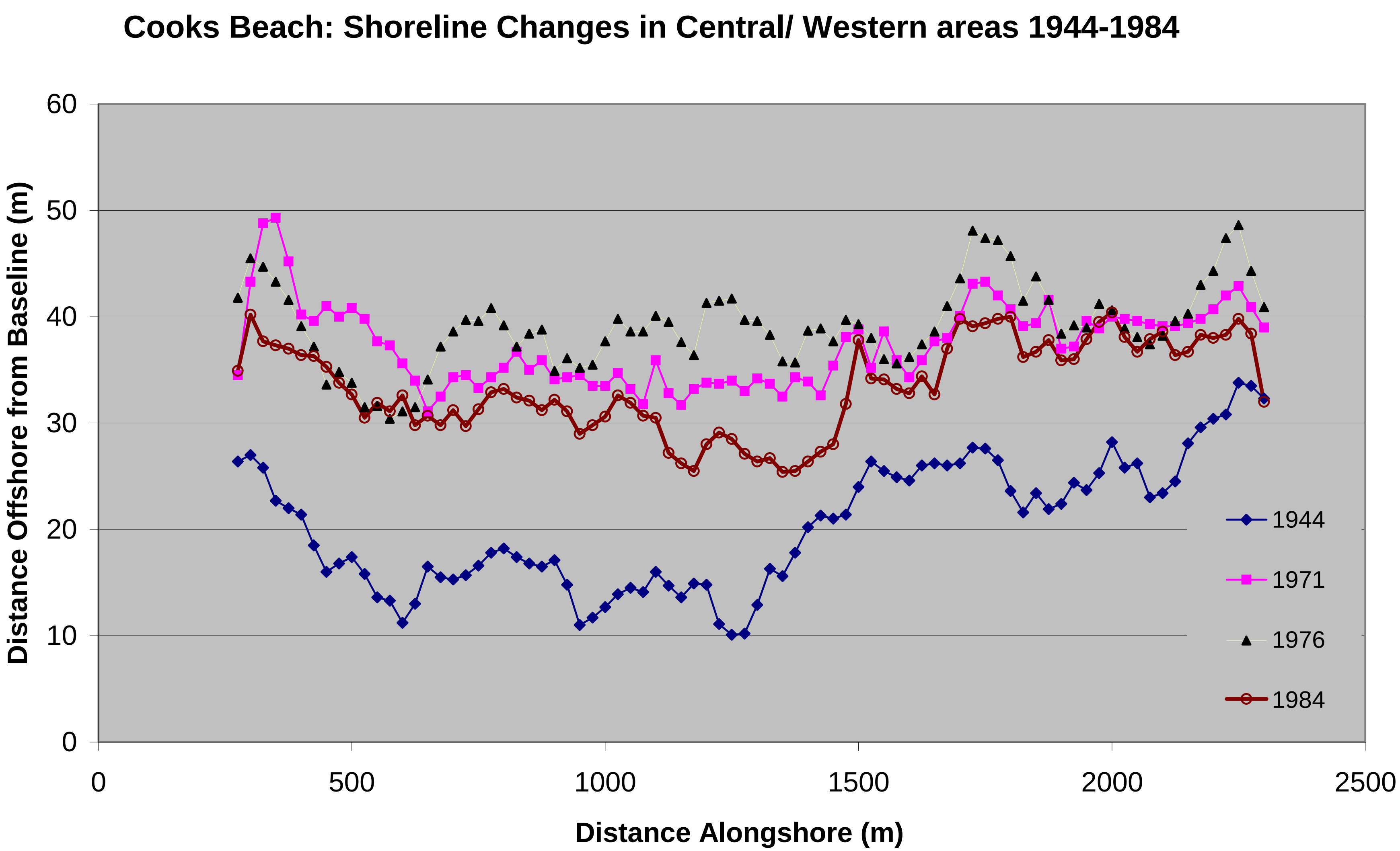


Figure 3-17: Shoreline change in central and western areas of Cooks Beach.

3.3.2.7 Whitianga

Only minor changes in average shoreline position are evident in the five “snapshots” of Buffalo Beach between 1944 and 1993 (Figure 3-18). This tends to suggest that, overall the beach may be in dynamic equilibrium. The placement of the 1865 shoreline on plans held by Environment Waikato suggests net progradation (typically of 50-70 m) has occurred along most of the Buffalo Beach shoreline since this time. However, there are concerns with the accuracy to which the 1865 shoreline has been able to be plotted (see discussion in section 2.2.1). Therefore, at this stage, it is appropriate to place more emphasis on the aerial photography data.

Despite the relatively minor changes in average shoreline position, quite significant dynamic changes are evident within individual segments of the beach (Figure 3-18 and Figure 3-19).

At Ohuka Beach (perpendicular to the north-eastern end of Buffalo Beach), the average shoreline position has fluctuated by up to 13-14 m (Figure 3-18). Maximum shoreline changes at individual transects typically range from 10-20 m, with a maximum change of just under 23 m (Figure 3-19). While the “snapshots” tend to suggest a trend for net accretion along this segment (Figure 3-18), beach profile information (site ccs 24) indicates that the toe of dune has retreated by more than 10 m since 1995. Therefore, it is more probable that the observed changes are primarily dynamic fluctuations.

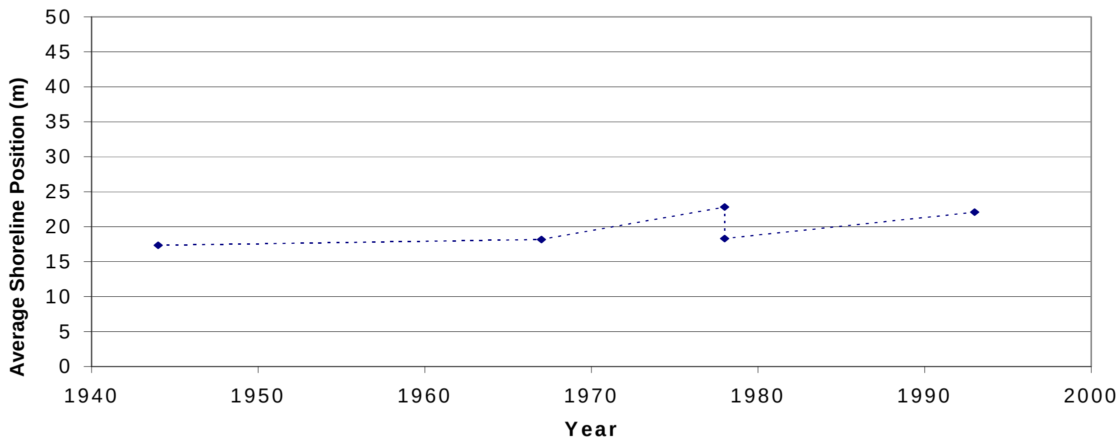
Along the frontage of coastal subdivision at the north end of Buffalo Beach, there appears to have been a general trend for net accretion (averaging about 12 m) over the period from 1944-93 (Figure 3-18). Information from long-term property owners and aerial photography also indicates a general trend for net accretion between about 1960 and 1995, with up to 15 m duneline accretion in some areas.

Despite the overall trend for accretion, there were also periods of erosion. For instance, there is some evidence of a period of erosion in the late 1950’s, giving rise to a slightly larger setback for the latter stage of the subdivision at the northern end of the beach. Nonetheless, the overall trend through the period was for accretion.

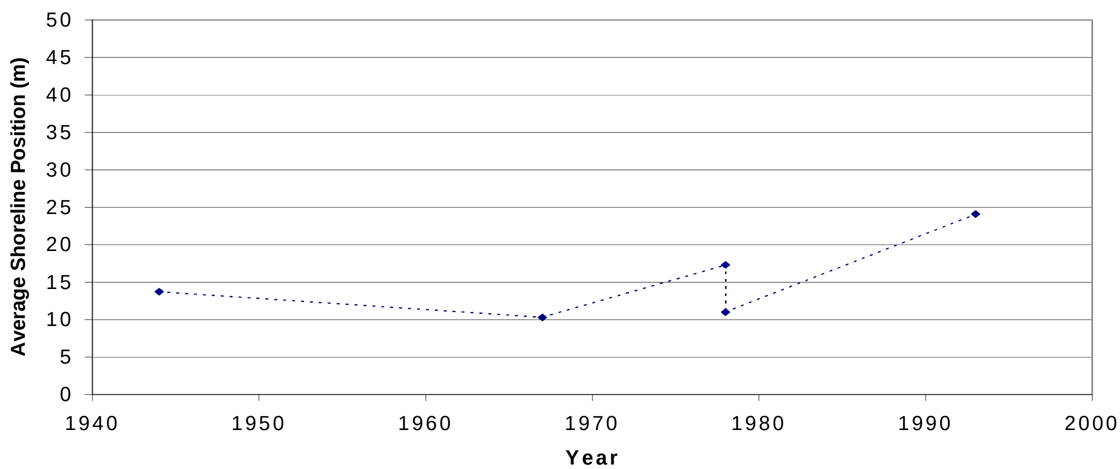
The trend for accretion through the late 1960’s and the 1970’s is notable, given evidence from other sites (e.g. Whangamata and Pauanui) of a general trend for erosion through this period, probably associated with a higher frequency of erosive storm events. Moreover, the trend for accretion appears to have been affected in only a minor way by the storm event of July 1978 (Figure 3-18). This tends to suggest that the trend for accretion was largely governed by local factors.

Since 1995/96, the trend for accretion has reversed and there has been marked erosion in this area – with field measurements and advice from property owners suggesting that the toe of the dune has retreated by up to 12-15 m in places. The most significant erosion has occurred near the centre of the housing development and was still ongoing in this area in June 2000. Beach profile data indicates that the erosion has been slightly less (about 10 m duneline retreat) at sites ccs 24 and ccs 25/1 - located at the northern and southern ends of the area, respectively.

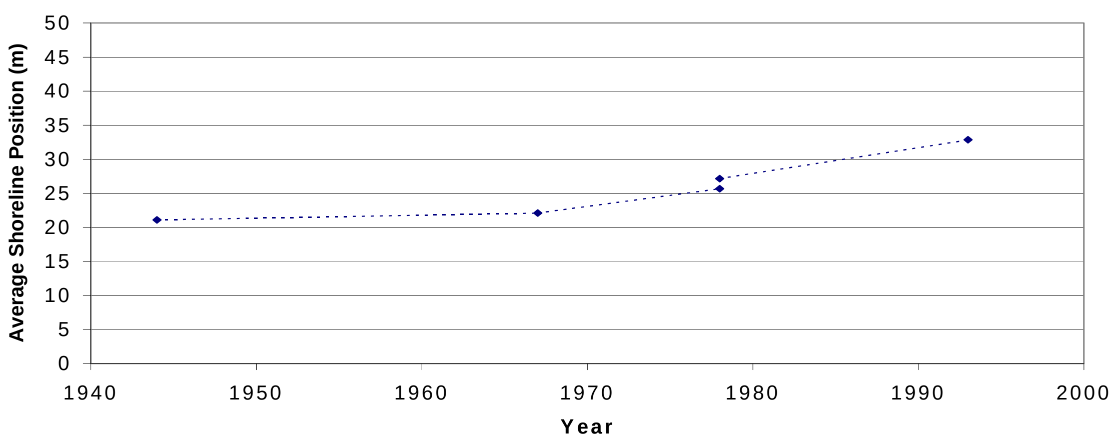
Ohuka and Buffalo Beaches: Entire Beach (Transects 17-161)

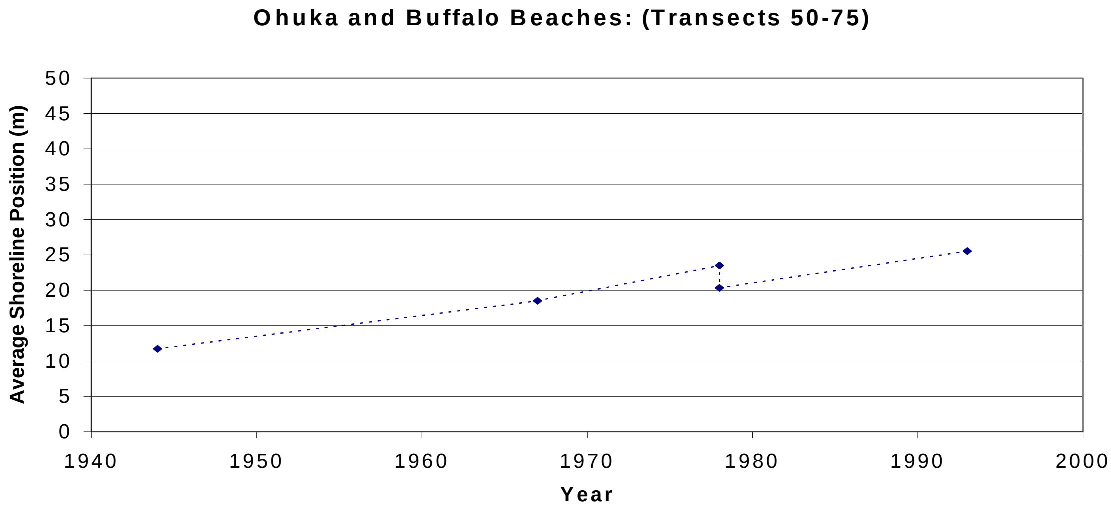


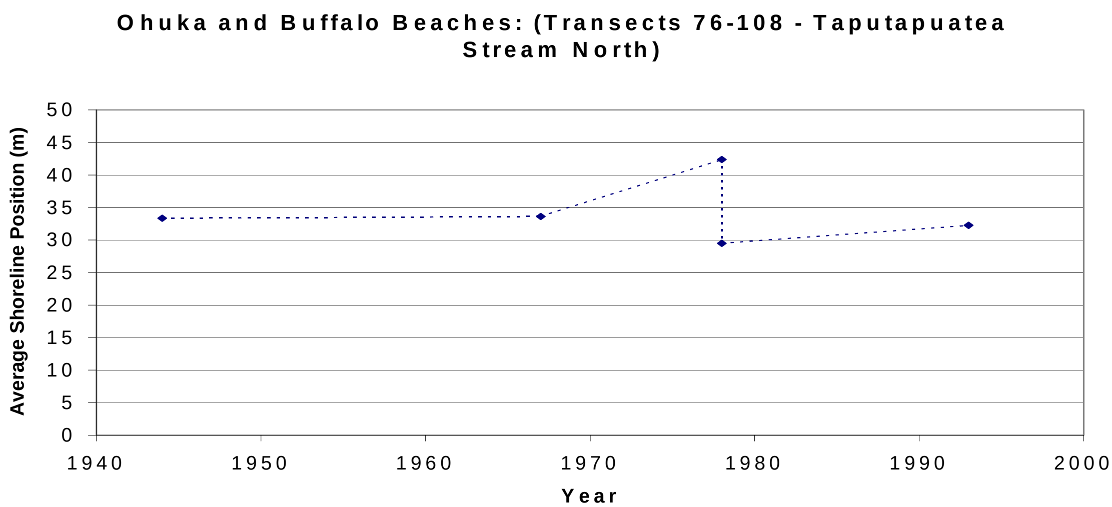
Ohuka and Buffalo Beach: (Transects 17-40)



Ohuka and Buffalo Beaches: (Transects 43-49)







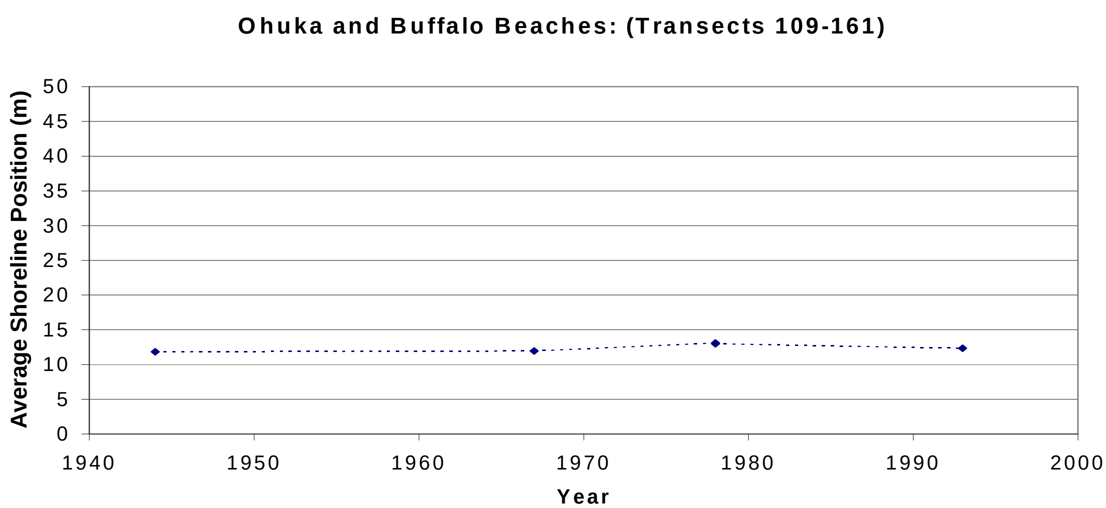


Figure 3-18: Changes in average shoreline position, Ohuka and Buffalo Beach.

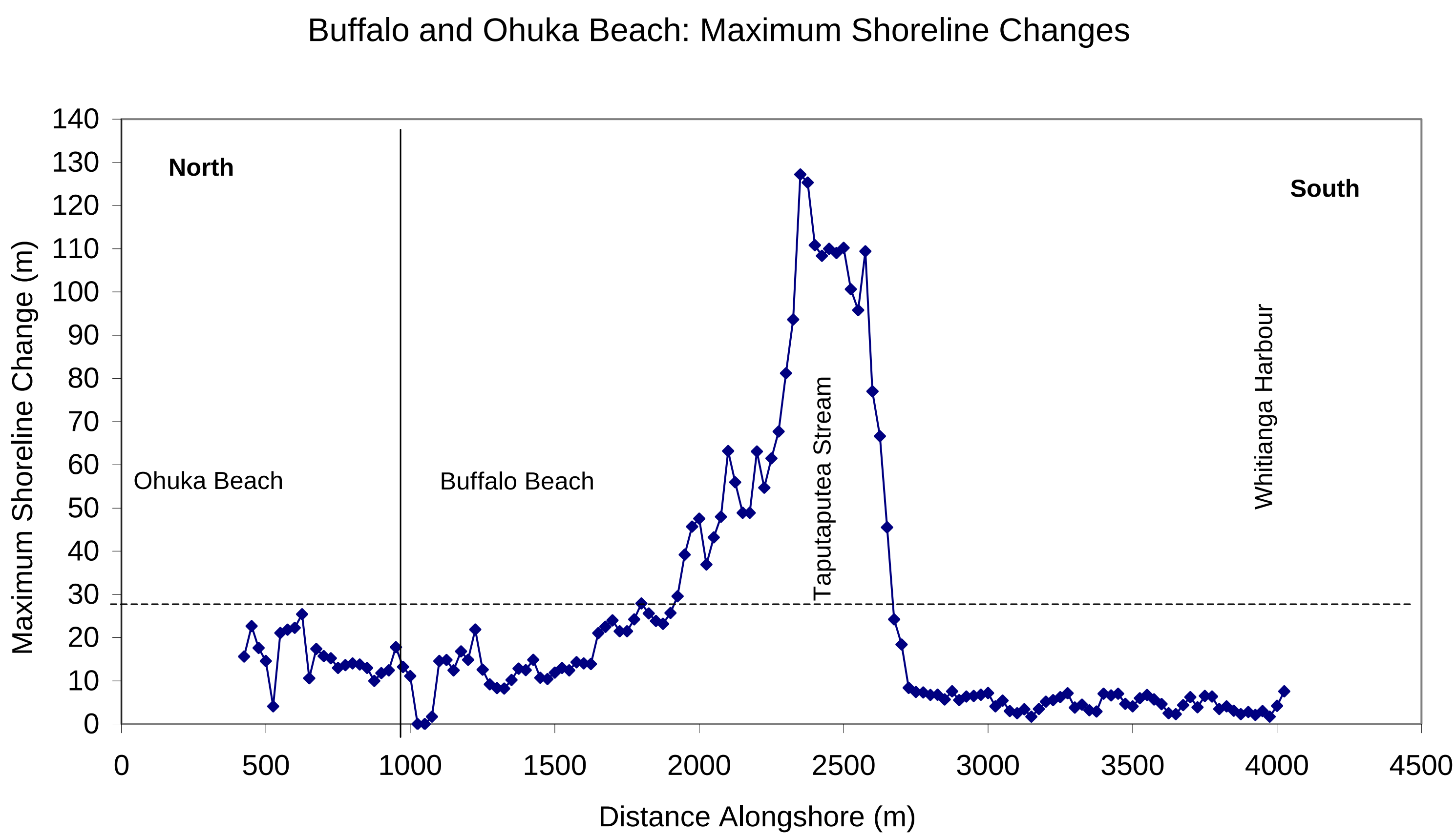


Figure 3-19: Buffalo and Ohuka Beach: Maximum Shoreline Changes between Mapped Shorelines (1944, 1967, 1/1978, 9/1978, 1993)

The recent trend for erosion tends to suggest that both the accretion and the erosion are dynamic changes, rather than long-term trends for net progradation or recession. It is interesting that this single “cycle” of accretion and erosion has occurred over a period in excess of 4 decades. At July 2000, the erosion was continuing. A notable aspect of this decadal “cycle” is the rapidity of the erosion in comparison to the slow, gradual accretion that preceded it. This latter aspect will probably tend to characterise most decadal variations.

The evidence from this site tends to further reinforce the dominant influence of decadal trends on duneline movements along eastern Coromandel beaches – over periods up to at least 3-5 decades.

The evidence also suggests that the impact of an individual storm event may be significantly influenced by the decadal trends occurring at the time. For instance, at the time of the July 1978 storm, this area of Buffalo Beach appears to have been in a relatively prograded state due most likely to local processes promoting beach accretion at that time. Therefore, although severe erosion occurred, the storm did not impact landward properties to the extent of far less significant events since 1996.

However, at many other Coromandel beaches, the 1978 storm appears to have occurred near the end of an erosional period, when the beaches were already in an eroded state. Therefore, this event caused quite severe damage at such sites, including Cooks Beach and the southern end of Hahei Beach.

The dominant influence of decadal trends over individual storm events probably reflects the duration-limited nature of most coastal storms (Section 3.1). Individual events are generally not of sufficient duration to achieve maximum potential storm cut and offshore bar formation. It is possible that some decadal variations are primarily driven by factors that influence the frequency of erosive coastal storms i.e. periods of accretion occur when the frequency of coastal storms is low, enabling the slow onshore movements and beach recovery to dominate over erosion and offshore sediment transport. Conversely, erosive periods may occur when the frequency of coastal storms is sufficient to ensure the dominance of offshore transport, i.e. beaches do not fully recover before the next erosive event. However, there is also evidence that local factors are more important in the decadal trends at this site (see discussion below).

In the central area of Buffalo Beach, changes are more complex due to the influence of the Taputaputea Stream entrance. Large shoreline changes, commonly in excess of 100 m, have occurred in this area associated with stream entrance movements (Figure 3-19). Shoreline armouring placed along the southern margin of the stream in the early 1970’s has now stopped the prior, slow southward migration of the stream entrance. However, significant changes are still observed in this area, with meandering of the stream channel causing significant erosion of the duneline along the northern side of the entrance in recent years.

The southern end of Buffalo Beach shows little change in average position in the various “snapshots” of shoreline location mapped for the period 1944 to 1993 (Figure 3-18). Similarly, maximum shoreline changes observed at each transect appear to have been less than 10 m (Figure 3-19).

However, this data does not provide an entirely accurate picture of this area. In particular, severe erosion occurred over central-southern parts part of the area in the 1960’s – leading to the placement of shoreline armouring to protect the immediately adjacent State Highway. This shoreline area had been affected by erosion prior to the 1960’s but not threatened to the same extent.

Historic photographs indicate that a wide high tide dry beach often prevailed in this area up prior to the 1960’s (Environment Waikato, 1999). As the shoreline receded in the 1960’s, the high tide dry beach was eliminated along the front of the armouring

(Environment Waikato 1999). This loss of high tide beach is a significant example of the “passive erosion” effects commonly noted along the face of armouring structures.

Estimates based on historic photographs and field measurements suggest that the high tide dry beach typically extended at least 10-15 m seaward of the State Highway prior to the erosion. Estimates of the maximum erosion that would have occurred in the absence of the shoreline armouring suggest there have been times when re-establishment of a high tide dry beach would probably have required erosion at least 12-15 m landward of the armouring. In all probability, even more significant erosion would have occurred during extreme storm events. Therefore, shoreline erosion of at least 20 m (and possibly 30 m) could have been experienced in this area if the armouring had not been placed.

In more recent years, there has been some evidence of beach recovery along the front of the shoreline armouring – with a narrow high tide dry beach often noted in the period 1998-2000. This could indicate that the erosion noted in the 1960’s was part of a dynamic shoreline fluctuation, occurring over a period of decades, rather than net recession.

However, the area of southern Buffalo Beach to the north of the shoreline armouring has shown a trend for erosion since 1995. Shoreline profile data (sites ccs 26 and 27) and other field measurements indicate landward erosion of the dune toe ranging from 8-15 m. The beach profile sites in this area (sites ccs 26 and 27) indicate that the shoreline now typically lies 3-4 m landward of the position surveyed at the time of the earliest surveys in 1979. Slight duneline accretion dominated the period from 1979 to 1995.

These various lines of evidence indicate that larger scale shoreline changes occur over the southern beach than suggested by Figure 3-19.

Overall, it appears that the Buffalo Beach shoreline is in dynamic equilibrium (though there is still some uncertainty in this regard), with dynamic fluctuations of up to 20-30 m occurring over periods of decades in areas removed from the Taputapuatea Stream entrance. These decadal changes appear to be significantly influenced by local factors.

The local factors that determine the nature and scale of the dynamic changes are not well understood but are almost certainly related to the large, low ebb tidal delta complex immediately offshore.

This ebb tidal delta, extending seaward more than 1700 m off the centre of the beach (ccs 25/1) (Figure 3-20), is dynamically linked to the beach-dune system by an anti-clockwise net sediment transport loop. Sandy sediments from the lower harbour are transported out and deposited on the ebb tidal delta by discharging ebb flows. The sediments are then moved gradually landwards from the ebb tidal delta to the beach by wave action. Similarly, over time, beach sediments show a net southward drift towards and into the harbour entrance.

The close relationship between changes on the ebb tidal delta and the shoreline is well illustrated in Figure 3-20, which compares offshore surveys conducted when the beach was in prograded (January 91) and eroded (July 1999) states. It can be seen that the recent period of beach erosion was accompanied by a significant width of bed lowering/deepening, extending offshore to distances of at least 600-700 m (Figure 3-20). Therefore, these surveys suggest that the recent erosion has been strongly influenced (if not primarily determined) by changes over the ebb tidal delta.

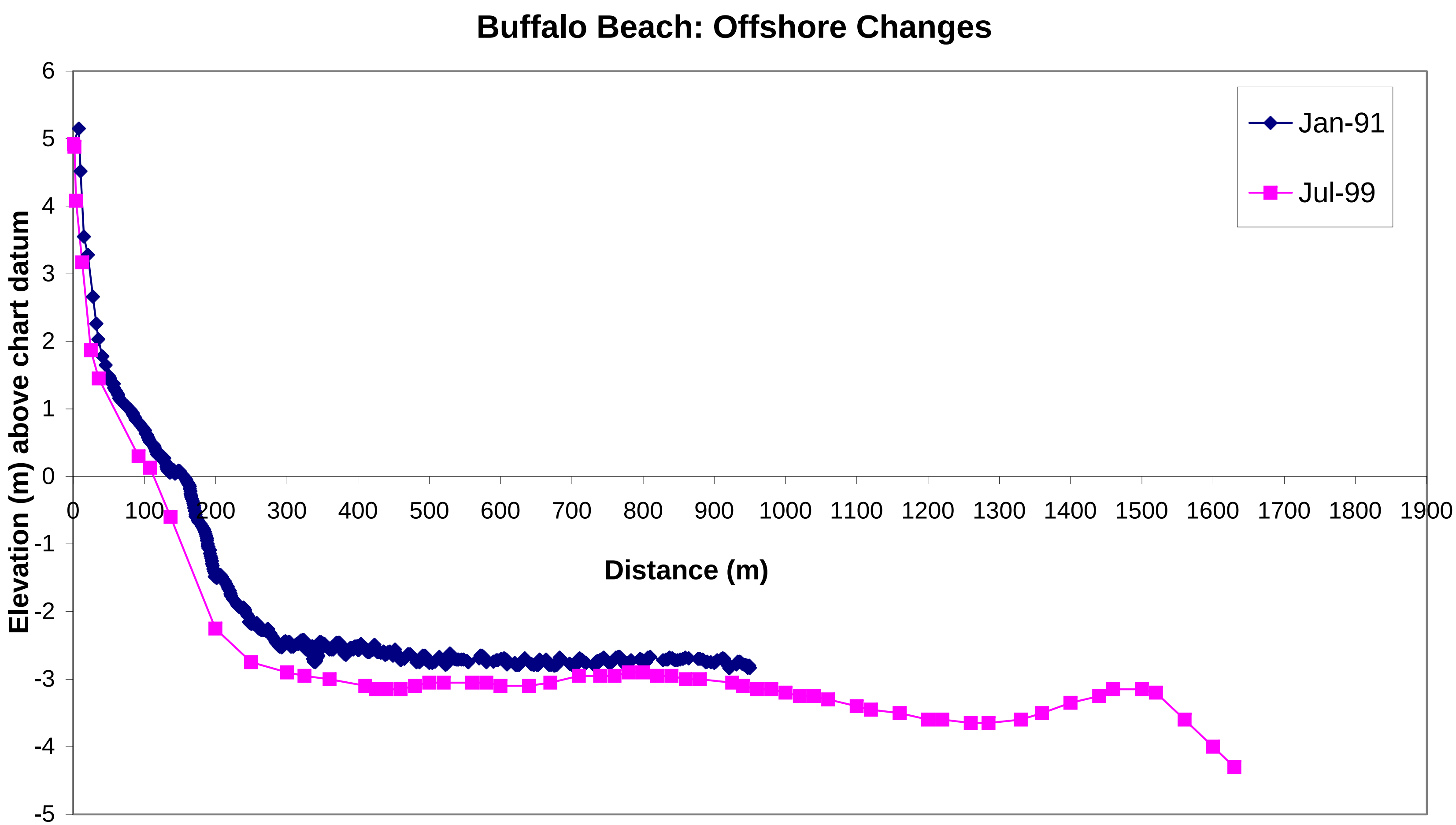


Figure 3-20: Buffalo Beach: Offshore changes accompanying erosion: 1991-1999 (Site ccs 25/1 near centre of Buffalo Beach)

The pattern of change shown in Figure 3-20 contrasts with the pattern observed when beach-dune erosion is primarily related to storm wave action. On such occasions, sands eroded from the beach-dune system are deposited on offshore bars, resulting in the shallowing of offshore areas.

It is interesting to note that the width of bed lowering offshore (i.e. below RL 0.00 m, essentially lowest low tide) considerably exceeds the width of shoreline retreat (Figure 3-20) - the toe of dune is about RL 3 m). Moreover, while the offshore deepening occurs over considerable widths, the actual change in elevation is generally only 0.3-0.4 m. This suggests that the beach is very sensitive to changes on the offshore delta.

Given the large width of bed lowering offshore (Figure 3-20), it may be some time before extensive beach recovery occurs. This also tends to be borne out by historical experience - with the last period of accretion occurring over a period of at least 35-40 years, while the erosion of this accumulation largely occurred in a period of less than 5 years.

3.3.2.8 Matarangi

Analysis of shoreline changes at Matarangi Beach by Carter (1976) indicated little difference between MHWM surveys of 1893 and 1976, the latter survey generally close to, or seaward of the 1893 survey. A survey in 1967 also located pegs used in the 1893 survey at the southern end of the beach, indicating little erosion in this area since 1893 (von Sturmer, 1976).

Carter (1976) also noted shoreline changes in excess of 320 m at the tip of the spit, adjacent to the entrance of Whangapoua Harbour. These dynamic fluctuations are the largest shoreline changes observed on the eastern Coromandel.

Field measurements of the width of the incipient dune fronting the faceted, main frontal foredune suggest shoreline fluctuations of 20-25 m are relatively common over periods of decades.

Therefore, the limited available information for this site tends to suggest the beach is in dynamic equilibrium, with maximum shoreline fluctuations of less than 30 m in areas well removed from the harbour entrance and ebb tidal delta – similar to other sites investigated.

3.3.3 Beach Profile Data

Available beach profiling data for selected (Whangapoua, Matarangi, Buffalo, Cooks, Hahei, Tairua, Pauanui, Whangamata and Whiritoa) beaches was plotted and examined to estimate the general pattern of change over the period of record.

In general, most sites demonstrated an overall trend for accretion or relatively little change between 1979 and 1995 – even though periods of erosion were also evident (particularly between 1979-81 and 1988-90).

In the period since 1995, a number of sites have demonstrated a trend for dune toe erosion. These include Whangapoua (especially at the northern and central areas), Matarangi, Buffalo and Cooks beaches. This included quite significant duneline erosion at Whangapoua (e.g. about 10-15 m at sites ccs 11 and ccs 12) and Buffalo (often 10-15 m as discussed above). Field inspections also indicate that quite severe dune erosion has occurred at the northern end of Tairua Ocean Beach and to a lesser extent along the northern end of Whiritoa Beach (particularly in front of Pohutukawa Reserve).

It is not yet clear whether these trends signal the commencement of a further period of coastwise duneline erosion, as appears to have occurred in the period from 1967-81. However, as noted above, we believe that the erosion at Buffalo was also significantly influenced by local factors. Little data subsequent to 1998 was available at the time of our analysis.

The shoreline fluctuations noted in the beach profile record to date (late 1999/early 2000) are generally less than the maximum fluctuations observed from the photogrammetric mapping of shoreline change (discussed further above).

At this stage, we believe it is appropriate to place greater emphasis on the photogrammetric mapping because:

- **The beach profile record is relatively short (post 1979/81):** As discussed above, available evidence suggests that significant shoreline fluctuations generally only occur over periods of several decades on Coromandel beaches. Therefore, a reasonably long record is required to demonstrate the full magnitude of the changes that can occur.
- **The period of the beach profile record to date has been dominated interannual ENSO and interdecadal IPO conditions that are believed to be more conducive to accretion and beach recovery than to erosion.** For instance, El Nino conditions have tended to dominate over La Nina phases in the ENSO cycles of the last two decades. This suggests that the beach profile record is unlikely to be representative of the full range of beach changes which occur over longer periods of time.
- **Beach profile data only records changes at isolated points on a beach.** It is by no means certain that the maximum beach changes possible will occur at these locations. The photogrammetric mapping enables shoreline changes between the various mapped shorelines to be determined for every point on the beach.
- **Photogrammetric mapping is a standard and widely accepted technique in mapping shoreline changes.** The mapping in this work was also conducted by appropriately trained and experienced practitioners using accepted techniques and equipment (see section 2.2). The results from different sites all tended to be relatively consistent in indicating potential for changes in excess of those observe from the more temporally and spatially limited beach profile record.

In this study, we are primarily interested in assessing the maximum scale of dynamic fluctuations that can occur over periods of several decades and also any long-term trends for erosion or accretion. We believe that neither of these factors can be usefully determined from the available beach profile record at the present time (i.e. April 2002). Therefore, a more detailed analysis of the beach profile data was not justified for this study and we have tended rather to emphasize the longer term shoreline change data from the photogrammetric analyses of shoreline changes.

This approach is also most consistent with the statutory requirement (Policy 3.3.1, NZCPS) to adopt a precautionary approach towards uncertainty.

This is in no way a criticism of the beach profile data. We believe this record is extremely valuable for a wide variety of purposes and will become increasingly useful for hazard assessment as the available record becomes more representative of longer term shoreline variability. However, as noted in section 5.6, we believe emphasis should also be given to complementing the beach profile monitoring with other techniques (e.g. LIDAR mapping) over the next few years.

3.3.4 Other information on shoreline change

The pattern of shoreline change at various other Coromandel sites was not extensively investigated. However, useful information was obtained by examination of historical aerial photographs (including oblique aerials from the Whites Aviation collection) for each site, field inspection and information from previous reports and long-term property owners.

In general, most sites also appear to be in dynamic equilibrium – with little evidence of long-term recession or (in areas removed from stream or estuary entrances) shoreline fluctuations in excess of 30 m.

The only apparent exceptions are Kuaotunu West, Wharekaho and Kennedy Bay beaches. These sites are briefly discussed below.

3.3.4.1 Kuaotunu West

Kuaotunu West (Figure 1-1) is an embayed pocket beach approximately 1200 m long and backed in central and western areas by a large frontal foredune. Severe faceting of the large frontal foredune and the exposure of old Maori occupation layers and old orange-stained sands strongly suggest some net recession has occurred at this site.

Interestingly, the site is the only other eastern Coromandel pocket beach besides Whiritoa to have been subject to extensive sand extraction, though lesser extraction operations have been conducted at various other beaches. The evidence of long-term recession at Whiritoa and Kuaotunu West strongly suggests that these pocket beach systems are quite vulnerable to sand extraction. The extraction at Kuaotunu was ceased in the early 1980's, but it is not clear whether or not the apparent net recession is continuing.

Kuaotunu West also shows the significant effect that longshore migrating stream entrances can have on eastern Coromandel beaches. Historical aerial photographs indicate that the stream discharging into the centre of this embayment (Map 15) used to slowly migrate eastwards, eroding the beach over a width of over 100 m. This acted to prevent the development of extensive dune deposits at the eastern end of the beach (e.g. Photo 70520, Flown 25/8/72, Whites Aviation Ltd). This natural process has probably occurred throughout the Holocene as available historical photos suggest that large dunes have only ever been evident to the west of the stream entrance.

The trend for net eastwards movement of the stream entrance may also indicate a general trend for net eastwards sediment transport within the beach – i.e. towards Kuaotunu East beach, with which it is probably littorally interconnected. The fixing of the stream outlet in the centre beach by regular clearing of the stream entrance over the last 15-20 years is now resulting in a wide band of dunes accumulating at the southern end of the beach system.

3.3.4.2 Wharekaho Beach

Healy et al. (1981) suggested that Wharekaho Beach (Figure 1-1) might be undergoing net recession – based on extensive concentrations of iron sands in central and western beach areas. They note that these sediments tend to concentrate in sediment-starved situations. Many of the existing property boundaries are also at or near present MHWM, while the original subdivision surveys (dating from the early 1950's) suggest that there was once a public reserve fronting these sections. This again could be indicative of some net recession – though further investigation would be required to better assess this.

3.3.4.3 Kennedy Bay

The Kennedy Bay (Figure 1-1) barrier spit, a medium to large barrier system, encloses the Harataunga River Estuary at its northern end (Map 19). The main river/estuary channel erodes into the back of the barrier in this area and the combined action of river floods and high seas have caused breaching of the spit in the past. While this breach has since been repaired by human action, the spit remains vulnerable to further breaching in the future.

3.4 Coastal Flooding

3.4.1 General

To date, coastal flooding of coastal settlements has been relatively limited along the eastern Coromandel.

The only open coastal sites where houses have experienced coastal flooding have been at Buffalo Beach and the eastern end of Cooks Beach (Dahm, 1999b), the natural dunes at both these sites having been eliminated or lowered by coastal subdivision.

In most other open coastal areas, the dunes are generally of sufficient elevation to prevent wave over-topping – maximum wave run-up probably being of the order of 5-6 m above MSL and usually less.

Limited coastal flooding issues have been experienced around estuarine margins of Tairua Harbour and to a lesser extent at Whangamata and Whitianga (Dahm, 1999b).

Minor tsunami-induced inundation also occurred at Whitianga in May 1960 (Dahm, 1999b).

This section briefly reviews available information on coastal flooding at the above sites, including the potential for existing flooding to be aggravated by sea level rise. A brief discussion of the potential for tsunami flooding is also presented.

The majority of information on coastal flooding has been derived from the compilation of historical newspaper reports on coastal flooding (Section 2.3.1) and existing reports.

3.4.2 Historical coastal flooding

Available information on coastal flooding along the eastern Coromandel since 1930 is summarised in Table 2. This table, primarily derived from historic newspaper reports, probably under-estimates the frequency of historical coastal flooding – since newspaper reports of storm damage along the eastern Coromandel were generally limited prior to the 1970's and many existing settlements were also not in place prior to the 1950's and 60's.

It can be seen that reported coastal flooding has most frequently occurred at Whitianga - though the settlements of Cooks Beach, Tairua and (to a much lesser extent) Whangamata have also been moderately affected.

Minor coastal flooding (e.g. limited over-topping of some low dunes with water flowing onto roads behind) has also occurred at some other sites, such as the southern end of Tairua Ocean beach and Whiritoa Beach. The dunes at Kennedy Bay have also been over-topped at the northern end, associated with past breaching of the spit at this site.

Flooding at Whitianga, Cooks Beach, Tairua and Whangamata are discussed below.

3.4.2.1 Whitianga

Whitianga has experienced reasonably frequent coastal flooding with at least 15 separate events since 1930 (Table 3-2).

Table 3-2: Significant coastal flooding events along the eastern Coromandel since 1930.

Date of Storm	Settlements Impacted by Coastal Flooding	Estimated Severity of Flooding
10 Sept 1933	Whitianga	Moderate
3 May 1934	Whitianga	Moderate
1-2 Feb 1936	Whitianga	Extensive
25-26 Mar 1936	Whitianga	Extensive
6 Mar 1954	Whitianga	Moderate
24 May 1962	Whitianga	Moderate
10 April 1968	Whitianga?	Moderate?
23 Jan 1972	Whitianga	Extensive
18 July 1978	Whitianga; Cooks Beach; Tairua; Whiritoa.	Extensive
15 Mar 1980	Whitianga	Moderate
12 Apr 1981	Whitianga	Moderate
12-13 May 1985	Whitianga	Moderate
14-15 Jul 1987	Whitianga	Moderate
23 Aug 1989	Whitianga	Moderate
10 Mar 1997	Whitianga; Tairua; Whangamata.	Moderate

Flooding has generally occurred along the foreshore, particularly at the south end of the beach near Albert Street and Esplanade Road. Other foreshore areas also frequently affected include areas near Halligan's Road and the hospital, along the margins of the Taputapuatea Stream (upstream of the state highway bridge) and at Ohuka Beach at the northern end of Buffalo Beach. Coastal flooding has also occasionally occurred in the vicinity of Victoria Street along the estuarine margin.

The following summaries of newspaper reports from the more significant events indicate typical damage:

- ***February 1936:*** Waterfront road (state highway) under water, Albert Street flooded to a depth of 2 feet (0.6m). Considerable flooding of properties, some houses flooded, the tide almost covering the "green" at the south end of Victoria Street, and the local beaches were described as littered with launches, dinghies and wreckage of all kinds.
- ***March 1936:*** Conditions were reported as similar to the February 1936 storm but with "higher tidal water," "shops" were inundated (though no location was given) and "... Forsters Store was entirely surrounded by water."
- ***May 1962:*** The sea was reported to have crossed the road in "many places along the waterfront," flooding properties on the other side and leaving the state highway littered with debris. The highway was blocked at Brophy's Beach (Ohuka Beach) by "huge logs ... tossed across the road."
- ***January 1972:*** Waves over-flowed parts of the state highway and reportedly sent water "streaming inland" for almost 200 m, flooding properties (some to a depth of 0.6 m) and the ground floors of some beaches and houses - even though extensive sand-bagging was undertaken.
- ***July 1978:*** A Civil Defence report indicated severe coastal flooding in the area of the hospital and Albert Street and noted that only sandbag protection avoided far more serious consequences (Report on Civil Defence Emergency, 19-21 July 1978, L.J. Braddock, Sub-area controller. Held by Civil Defence office, TCDC, Thames). Newspapers reported waves breaking on Buffalo Beach Road and Esplanade Road and substantial overflows across much of the highway along Buffalo Beach.

It is clear from these reports of past events that waves have been a significant factor in most flooding experienced in the last 70 years – excepting the minor flooding associated with the May 1960 tsunami. In the 1978 event, Civil Defence reports noted that road overwash exceeded 1.2 m depth in surges, with large rocks from the rip-rap protection carried completely across the road.

During extreme events, waves have over-topped shoreline areas as high as 2.5-3 m above mean high water springs.

Storm surge effects also appear to contribute significantly, with Smith (1980) noting a storm surge elevation of 0.8 m at the Whitianga Wharf during the July 1978 event. A number of newspaper reports of other events also note abnormally high tides.

The number of events noted over the last 70 years suggests that the highest risk properties (e.g. Esplanade Road, Ohuka Beach) have an annual probability of being flooded of more than 10%. Other areas vulnerable to flooding probably have an annual probability of flooding ranging from 2-10%.

This vulnerability to coastal flooding could be considerably exacerbated over the next 100 years as a consequence of changes likely to accompany predicted global warming. As noted by Hume (2002, p11), there is now a much higher level of certainty in regard to climate change projections "*it's no longer if, it's when and how much!*". Therefore, the effects of such changes have to be given careful consideration in planning for future management and use of the coastal margin. For instance, best present estimates suggest a rise in mean sea level of 0.3-0.49 m by 2100 AD and continuing to rise beyond that time (IPCC, 2001; Bell et al., 2001). This estimate is very little changed from the previous IPCC best estimate projections (IPCC, 1995), reflecting the increased certainty noted by Dr Hume.

A rise in mean sea level of this magnitude would significantly exacerbate existing vulnerability and result in serious and frequent flooding, particularly at the southern end of the beach. The close proximity of foreshore development at the southern end of the beach also considerably complicates the provision of effective protection in this area.

Given the vulnerability of Whitianga to coastal flooding and the potential for this hazard to be exacerbated by projected sea level rise, further work on coastal flooding in this area is warranted. Reasonable estimates of extreme sea levels arising from the combined effects of tides and storm surge are available for Moturiki (near Mount Maunganui) and it is probable that the extreme sea levels at Whitianga will be of similar amplitude – though possibly slightly elevated by seiche effects. Therefore, further work should probably focus on quantifying wave effects and how these may be influenced by sea level rise. Improved information on ground levels around the coastal margin and the wider township would also be useful to better assess the potential impacts of major storm events and projected sea level rise.

As discussed further below, there is also some evidence that Whitianga may be particularly susceptible to tsunami flooding.

3.4.2.2 Cooks Beach

According to long-term residents the most significant flooding in recent history occurred during the July 1978 storm, affecting many foreshore properties east of Endeavour Place. Wave over-topping east of Iti Lane also occurred during the 1960's - after the bulldozing of the dunes in this area, but prior to the building of most present houses. On both occasions, waves extended inland almost as far as Captain Cook Road, particularly east of Iti Lane.

Despite the low nature of the foreshore at the eastern end of the beach, the information on coastal floods suggests that coastal inundation is infrequent. Flooding events probably have an annual probability of 2-5% or less. However, present best estimates of mean sea level rise (0.3-0.5 m, as noted above) would very considerably exacerbate coastal inundation at this site unless a protective, natural dune buffer is able to be re-established.

3.4.2.3 Tairua

Coastal flooding at Tairua is primarily limited to land and properties around the estuary, particularly the low-lying Manaia Road area directly opposite the estuary entrance. However, storm waves have also over-topped low dune areas at the south end of the ocean beach and flowed landward through Hemi Place to the estuary (e.g. the storms of March 1954 and July 1978).

The most serious flooding of properties to date occurred in July 1978 when 40 properties and many houses along the estuarine margin of Manaia Road were affected by elevated storm surge water levels. Wave effects associated with swell waves propagating through the harbour entrance were also a significant factor in over-topping the coastal margin and flooding the lower lying areas behind.

Subsequently, flooding has been restricted by a protective earth bund built after the 1978 flooding. This bund has a crest elevation of 2 above mean sea level - based on maximum flooding levels measured after the July 1978 event and an allowance of 0.3 m for freeboard. The bund has not been over-topped by storm events since construction, but wave run-up associated with Cyclone Gavin (March 1997) did leave salt water effects (e.g. dead grass, debris) very near to the crest.

The level of protection provided by the bund is unknown.

At present a design level equivalent to about 2.6 m above present mean sea-level, is recommended by Environment Waikato for minimum floor levels in this area. The annual probability of this level is also unknown.

3.4.2.4 Other Areas

Some limited flooding has occurred in developed areas around Whangamata Harbour. During Cyclone Gavin in March 1997, at least 4 properties at the bottom end of Beach Road (opposite the site of the proposed marina) were flooded. Though no houses were flooded, observers noted that one house was "within one or two millimetres of being swamped" and some garages and sheds suffered minor flood damage.

The static water level arising from tides and storm surge effects was surveyed at 400 mm above normal high water springs (Don Airey, Whangamata, *pers. comm.,* June 2000). There were also wave effects associated with swell waves that propagated through the harbour entrance and these probably lifted water levels above this elevation in places (Don Airey, *pers. comm.,* July 2000).

The annual probability of the elevated water levels is unknown though locals described the flooding as the worst noted on over 40 years, suggesting they could be infrequent – possibly having an annual probability of 2-4% at most.

The issues observed in Tairua and Whangamata Estuary indicate the potential for flooding issues around Coromandel east coast estuaries – particularly in low lying areas and/or areas exposed to swell wave effects propagating through the estuary entrances.

A recent tide gauge installation at Whangamata has established that tide levels at this site correlate closely with the Moturiki Tide Gauge near Mount Maunganui. Therefore, extreme sea levels arising from the combinations of tides and storm surge at Moturiki may well also be applicable for Coromandel sites. However, allowance would also have to be provided for wave effects in deriving any design water levels for Coromandel locations.

3.4.3 Tsunami-induced coastal flooding

To date, tsunamis are not known to have caused any significant coastal flooding along the Coromandel coast over the past century – though newspaper reports indicate that the distantly-generated tsunami event of May 1960 caused some minor flooding at Whitianga (particularly in low lying areas upstream of the wharf, near Monk Street and along the upstream margins of the Taputapuatea Stream).

This section briefly discusses potential tsunami risk based on existing information.

3.4.3.1 Distantly-Generated Tsunamis

Distantly-generated tsunami are those generated some distance from New Zealand, with a particularly common source being the western coast of South America.

Recently de Lange and Hull (1994) have suggested that distantly generated events could potentially cause reasonably frequent and significant coastal flooding. They estimate that tsunami events, mostly generated off South America and with an average height of 0.5-3 m at the NZ shore, have an annual probability of occurrence in excess of 1%.

Events at the lower end of this range would probably have limited impact, but the higher end of the range (e.g. 2-3 m) could cause significant flooding at some sites.

Given the potential impact of larger, distantly generated events it is important that further work is undertaken to better quantity the risk from such events. Council should assist in promoting and advocating such work.

At least four, significant, distantly generated tsunami have been recorded along the eastern Coromandel over the last 120 years (August, 1868, May 1877, August 1883, and May 1960). Little information is available about flooding associated with the three earliest of these events, though the 1883 event was reported as having nearly caused the capsize of a vessel tied to Whitianga Wharf (NZ Herald, August 1883, page 5). As noted above, the May 1960 event resulted in minor flooding of parts of Whitianga. More significant impacts may have occurred if the earliest waves had coincided with high tide and/or had occurred when there was some significant wave action.

Environment Waikato have recently installed a tide recorder at Whitianga to improve understanding on the susceptibility of this area to coastal flooding. Preliminary analysis of records from this gauge shows a broad band of energy at high frequency that indicates seiching in Mercury Bay (Goring, 1999). These seiches have a period of about 1 hr and an amplitude that is typically less than 100 mm. The presence of these seiches is significant as they designate Mercury Bay as a potential tsunami “hotspot” (Goring, 1999). A tsunami containing energy at this period entering Mercury Bay could cause the bay to resonate at its natural period, possibly amplifying the waves by 10- or even 100-fold in size (Goring, 1999). This could occur with locally- or distantly generated tsunami. Research presently underway by NIWA and due to be completed by June 2000 will clarify the susceptibility of Mercury Bay to tsunami attack (Goring 1999).

Distantly-generated tsunamis take at least 4 hours to reach New Zealand and there are well established warning systems that detect and distribute information on such events (de Lange and Hull, 1994). Those sites that are identified as being vulnerable to tsunami should have local response plans linked to these warning systems.

3.4.3.2 Locally-Generated Events

The risk from locally-generated tsunamis, which could potentially have a catastrophic impact on any particular locality, is difficult to assess from available information. De Lange (1995) estimates a 2% annual probability of a serious or catastrophic local tsunami (i.e. shore height in excess of 3 m) occurring *somewhere* on the New Zealand coast. However, the risk at any specific locality is likely to be considerably less and as yet there is no data to permit adequate assessment of the risk along the eastern Coromandel.

Therefore, Council should help promote management relevant research on locally generated events as opportunity rises. The potential risk posed to the eastern Coromandel (or other parts of the Region) by locally- or distantly generated events is possibly best assessed by investigating the occurrence of such events over the last 6000-7000 years (i.e. since sea level arrived at or near present levels). Council supported a proposal for such work submitted for FoRST funding in 1998. However, the application was not successful. Nonetheless, Council should continue to help promote and advocate such work as appropriate opportunities arise.

As the travel time to the coast from any local tsunami source region is too short to permit a planned response (de Lange, 1995), raising community awareness of warning signs (e.g. rapidly retreating water levels) will need emphasis in any work to raise community preparedness for such events (Dahm, 1999).

If Mercury Bay is identified as a potentially vulnerable location, the development of appropriate local response plans may be warranted (Dahm, 1999). One option that might also assist with both locally- and distantly-generated tsunami could be the relocation of the existing tide gauge to offshore Islands in outer Mercury Bay (Goring, 1999). A gauge located on Ohinau Island would provide nearly 20 minutes warning of a tsunami reaching Whitianga (Goring, 1999).

4 Firth of Thames

4.1 General Introduction

The coast of the Firth of Thames typically consists of sand and gravel beaches and rocky coast, with wide inter-tidal flats also fronting the southern and south-western shorelines.

Most beaches along the western margin are narrow with limited sediment reserves, though occasional, small stream-mouth alluvial gravel fans prograde into the Firth along the Thames Coast (Figure 4-1). The southern margin is backed by the low-lying Firth of Thames and generally fronted by a band of mangroves several hundred metres wide. The western shoreline is a chenier plain up to 2 kilometres in width, composed of shell, sand and gravel ridges overlying intertidal muds.

Beach sediments are primarily derived from local streams and rivers, with some contribution also from cliff erosion (Dravitski, 1988). Net sediment transport is southward along both eastern and western margins of the Firth.

The surrounding coast is often low-lying and has suffered extensively from coastal flooding. Therefore, most work on coastal hazards in this area has focused on improving understanding of coastal flooding. However, limited work has also been conducted on coastal erosion, particularly along the more populated western Coromandel Coast.

4.2 Coastal Flooding

Flooding from the sea of low lying areas around the margin of the Firth of Thames results from the combination of astronomical tides with wave action and storm surge effects. Elevated sea levels arising from tide and storm surge effects are usually distributed over a large area. However, wave effects are typically localised and can vary significantly dependent on wave exposure of the site. Natural buffers such as mangroves can also significantly damp wave effects.

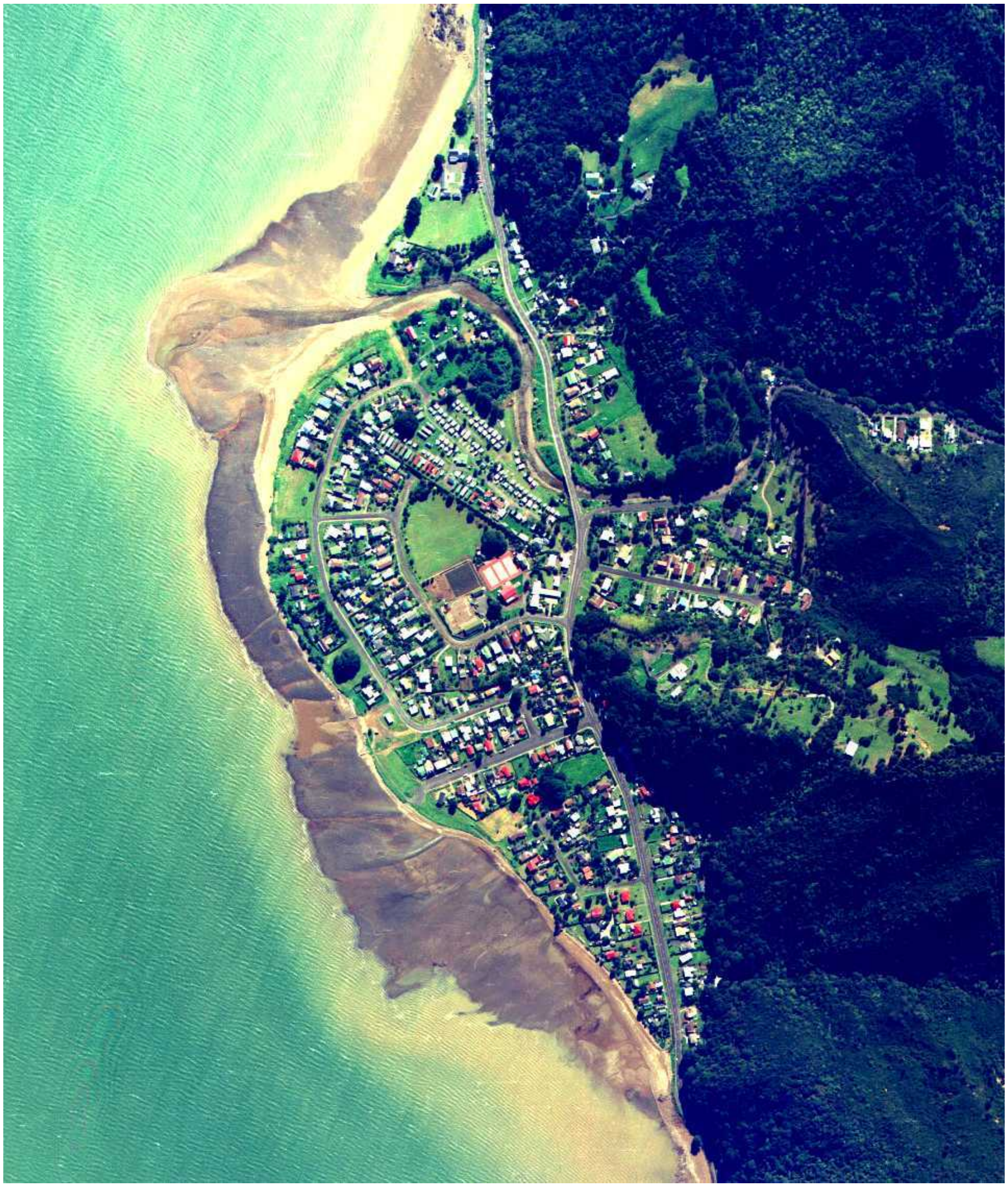


Figure 4-1: Te Puru township. Where rivers meet the coast on the western Coromandel Peninsula, large deposits of sand and gravel from flood deposits have accumulated (deltaic fans). Like many settlements on the western Coromandel Peninsula, Te Puru township is built on a deltaic fan. The processe that formed these areas continue today and they are vulnerable to both river and coastal flooding (Photo: Air Maps, Tauranga).

At present, design coastal flood levels are based on the highest recorded extreme sea level (3 m above the Tararu MSL datum), measured during a storm of May 1938 (Environment Waikato 1995; 1999). The annual probability of this extreme sea level is unknown.

Environment Waikato has undertaken various work aimed at improving understanding of coastal flooding in the southern Firth. To date this work has focused on:

- Analysis of the sea level record from the Tararu tide gauge
- Collation of information (particularly newspaper reports) on historical coastal flooding events.

This section briefly reviews this work, together with available information on sea level rise.

Implications for design flood levels and coastal flooding are then discussed.

Information on the risk of tsunami flooding is also briefly discussed – based largely on work undertaken by the University of Waikato under Dr Willem de Lange.

4.2.1 Analyses of Tararu tide gauge records

The Tararu tide gauge is situated in the southern Firth of Thames, located on an old beacon structure several hundred metres offshore from the northern end of Thames township.

Data collection commenced on May 15, 1990 and the site has a fairly continuous record since this date with only a few gaps. Most gaps are of short duration (1-3 days) but there is a significant gap of 27.32 days in 1992, which essentially eliminates that year for tidal analysis (Goring, 1995). The importance of minimising gaps, particularly for more than a few days has been emphasised by NIWA (Goring, 1995).

To date, Environment Waikato have commissioned analyses to identify the major tidal constituents and to develop preliminary estimates of extreme sea levels likely to arise from the combinations of tides and storm surge (Goring, 1995, Goring et al. 1997; Bell and Hill, 1997). NIWA were also commissioned to hindcast tide levels for major historic coastal flood events and to provide wave and other data for the two most recent (July 1995 and Cyclone Drena) events (Bell and Hill, 1997).

4.2.1.1 Analysis of Sea level Record

Goring (1995) identified the main tidal constituents for Tararu, enabling tidal predictions to be developed for the southern Firth of Thames.

This analysis indicated that semi-diurnal tides (especially the lunar, M_2, solar, S_2, and elliptical, N_2, tides) are by the far most important factors in the variation of sea level at Tararu, representing 98% of the variance of the signal (Goring, 1995; Goring et al. 1997).

With identification of the key tidal constituents, various tidal parameters were also calculated for the Tararu site (Table 4-1) (Bell and Hill, 1997).

Table 4-1: Tide level benchmarks for Tararu relative to the Tararu MSL datum.

Tide Benchmark Level	Height Above Datum
MHWPS (Perigean + Spring)	+1.72
MHWP (Perigean)	+1.53
MHWS (Spring)	+1.47
MHWN (Neap)	+1.08
MSL Datum (Tararu)	0.00
MSL (1990-95)	-0.016
MLWN (Neap)	-1.08
MLWS (Spring)	-1.47
MLWP (Perigean)	-1.53

The most significant high tides are typically those associated with perigean spring tides, which occur every 221 days (approximately every 7 months) due to the combination of the three major semi-diurnal tidal constituents. These high tides are times when the margins of the Firth are particularly vulnerable to coastal flooding if they coincide with storm surge and/or significant wave effects.

Goring (1995) also provided a table of the dates and elevations of the highest predicted tides to the end of 2000.

Tidal analyses have also determined the maximum, extreme sea level that can arise from astronomical tides alone (RL 1.917 m). Tides of this elevation will occur every 18.6 years (Bell and Hill, 1997).

Comparison with tidal records from the Moturiki Island tide gauge on the open coast in the Bay of Plenty indicated much larger tidal amplitudes at Tararu (tides are about 1.5 times higher at Tararu), indicating that the Firth of Thames considerably amplifies the tidal signal (Goring, 1995).

The 2% of the variation in the signal not accounted for by semi-diurnal tides is evenly split between storm surge, diurnal tides, compound tides and long period effects, with the effect of seiche being much smaller (Goring et al., 1997).

With regard to storm surge, it was noted that sea level at Tararu responds to barometric pressure at Auckland Airport essentially as an inverted barometer (i.e. a rise of 1 hPa in pressure produces a drop of 10 mm in sea level and vice versa). As a result, 80% of the variation in sea level could be explained by barometric pressure (Goring, 1995).

The diurnal tide component results in alternate high tides differing in amplitude by up to 150 mm (Goring et al*.,* 1997).

Compound- and over-tides are common, arising from non-linear interaction between the three major semi-diurnal tides d
ue to the propagation of these tides over the shallow waters of the Firth of Thames (Goring, 1995). However, these compound and overtides are generally less than 19 mm amplitude (Goring et al. 1997).

Little useful comment is yet possible on long period (>18 hrs) effects as the record is too short (Goring, 1995).

4.2.1.4 Extreme Sea Levels arising from Tides and Storm Surge

In 1997, NIWA was commissioned to report on the annual exceedance probability of various extreme sea levels arising from the combination of astronomical tides and storm surge effects.

The results from the analysis are detailed in Table 4-2.

Table 4-2: Estimates of annual exceedance probabilities of extreme sea levels for Tararu with standard errors. Levels are those arising from the combined effect of waves and storm surge and do not include wave effects. Levels are with respect to MSL at Tararu.

Exceedance Probability	Extreme Sea Level (mm)	Standard Errors
0.2000	2010	20
0.1000	2090	20
0.0500	2160	30
0.0200	2250	40
0.0100	2320	50
0.0050	2390	60
0.0020	2480	70
0.0010	2540	80
0.0005	2610	90
0.0002	2700	110
0.0001	2770	120

The estimates of the extreme levels were determined using available sea level (including tides) and storm surge time series data derived from what is a relatively short record at the Tararu gauge. Therefore, while the deterministic sea level time series is reasonable, NIWA caution that they expect the stochastic storm surge statistics "will change markedly for every extra year of data that is acquired" (Goring et al., 1997, p2). They recommend the analysis should be repeated periodically "as additional data becomes available for Tararu" (Goring, 1997, page 14).

NIWA also caution that the extreme sea levels extrapolated beyond the 1% annual exceedance probability should be used as indicative only given the short record at the Tararu site (Goring et al. 1997).

These initial results estimate the 1% annual exceedance probability sea level for Tararu at 2320 $\pm$ 50 mm (Table 4-2).

It is important to appreciate that this1% AEP extreme sea level *cannot* be equated with the 1% AEP design flood level - as it does not include wave effects. Wave effects (e.g. wave set-up and wave run-up) are discussed further below.

4.2.2 Historical coastal flooding events

Work was undertaken to identify the major coastal flooding events over the last 70 years and obtain information on the nature and extent of flooding during these events. The methods used for this work are outlined in section 2.3.1.

4.2.2.1 Major Coastal Flooding Events

The significant coastal flooding events identified since 1930 are listed in Table 4-3.

The events listed as "extensive" are those for which available information suggests were of similar or greater severity to the recent July 1995 and Cyclone Drena (January 1997) events. "Moderate" events are those that tended to result in less widespread and severe flooding, often being localised to one or two sites.

The magnitude of the 1951 and earlier events were largely judged on the basis of damage reports from newspapers and from information provided by long-term residents. These sources were also important for the two more recent events (July 1995 and January 1997), though much other useful information was also obtained for these events from field investigations, surveyed flood levels (from various organisations), resident reports, tide gauge data and various other sources.

This list is not exhaustive for ‘moderate’ events but probably includes all the major (“extensive”) events - given the very extensive list of storms that were compiled and checked (see section 2.3.1 and Appendix C). The list also includes all the major events that various long-term residents were able to recall dating back to the 1930’s and 1940’s.

The list of settlements and areas impacted is almost certainly not exhaustive. For instance, land and settlements along the western margins of the Firth (e.g. Kaiaua and Miranda) were probably flooded in the events of 1936, 1938 and 1951, even though these sites were not specifically discussed in the newspaper reports checked. The list of areas impacted by early events also excludes many existing settlements (e.g. on the alluvial gravel fans of the Thames Coast) that were either not in existence (e.g. Waikawau) or were relatively sparse (e.g. Tararu, Te Puru) at the time of some early events. Conversely, flood protection works now provide a much higher level of protection to some areas (e.g. the Hauraki Plains) than was in place at the time of some earlier events (e.g. May 1938 and June 1947). Events of similar magnitude now would be very unlikely to affect most areas of the Hauraki Plains.

Table 4-3: Significant coastal flooding events around the margin of the Firth of Thames since 1930.

Date of Storm	Settlements and Areas Impacted by Coastal Flooding	Estimated Severity Of Flooding
25-26 Mar 1936	Flood plains south of Thames; Thames; SH25 (Thames Coast); Tararu; Thornton’s Bay; Waiomu; Tapu; Coromandel.	Extensive
4 May 1938	Coastal plains along western margin; Hauraki Plains; Pipiroa; Thames.	Extensive
20-21 Jun 1947	Hauraki Plains; flood plains south of Thames; SH25 (Thames Coast); Tararu.	Extensive
1 Mar 1951	Thames; SH25 (Thames Coast); Tararu; Whakatete and Ngarimu Bays; Thornton’s Bay; Te Mata	Extensive
6 Mar 1954	Thames; Manaia.	Moderate
2-3 Mar 1962	Tararu	Moderate
20 Aug 1970	Tararu	Moderate
14-15 Jul 1987	Moanatairi	Moderate
14 Jul 1995	Kaiaua; Coastal plains along western margin; Thames; Moanatairi; SH25 (Thames Coast); Tararu; Te Puru; Waikawau.	Extensive
11 Jan 1997 (Cyclone Drena)	Kaiaua; Coastal plains along western margin; SH25 (Thames Coast); Moanatairi; Tararu; Te Puru; Waiomu; Tapu; Te Mata; Waikawau.	Extensive

4.2.2.2 Frequency of Major Flooding Events

The information in Table 4-3 indicates there have been 6 events since 1930 that have caused flooding of a similar or greater magnitude to the July 1995 and Cyclone Drena events. Therefore, despite there being only two events in the last 45 years, major coastal flooding events appear to be relatively frequent.

While it is not possible to comment *definitively* on the “return period” of flooding similar to the recent (July 1995 and Cyclone Drena) coastal flooding events, the data suggests such flooding could have an annual probability in excess of 5%.

It is notable that the historical events have been irregularly distributed over time. Four events occurred within a period of 15 years (1936-51), followed by a period of nearly three times this length (1951-95) with no significant events (Table 4-3). It is possible there are decadal trends that may influence the probability of these events, though further work would be required to assess this.

4.2.2.3 Significance of Wave Effects

Newspaper reports and field observations suggest that wave effects associated with northerly swell waves have significantly contributed to many of the major events – particularly the flooding of 1936, 1947, 1951 and 1997.

The flooding during Cyclone Drena was primarily related to northerly, storm-generated swell waves propagating into the Firth. A wave rider buoy in the outer Hauraki Gulf noted average wave periods of 7-8s and significant and maximum wave heights of 3.2 m and 5-5.5 m respectively (Goring, 1997). Maximum observed wave heights noted in the Firth were typically about 1 m (rarely 1.5 m) prior to breaking, reflecting wave refraction and other modification as the waves migrated into the shallow Firth.

The high-energy swell waves commonly over-topped exposed coastal margins, flooding lower lying areas further inland. Levels surveyed along natural shorelines indicate that maximum wave run-up elevations were typically RL 2.6-2.8 m. However, higher elevations (sometimes in excess of RL 3 m) were over-topped in some areas, particularly where there were more abrupt coastal transitions. These sites included armoured shorelines around the edge of the Moanatairi Reclamation and at the seaward end of Robert St at Tararu. At these sites, the shoreline is held seaward of natural shoreline positions by armouring and water depths in excess of 2 m often occur immediately adjacent, providing less dissipation of wave energy than occurs at natural shorelines fronted by beaches.

Typical flood levels of RL 2.6-2.65 m were measured inside houses on the Moanatairi Reclamation at Thames (F Millington, Surveyor, Thames, *pers. comm.,* 1997). At this site, waves significantly over-topped the surrounding embankment and partly filled the “basin” enclosed by the rock wall. Photos from the storm event also show breaking wave bores migrating across the reclamation after over-topping the surrounding embankment.

The significance of nearshore wave effects is evident in that a maximum water level of only RL 2.05 m was measured at the Tararu tide gauge, located a few hundred metres immediately offshore from Moanatairi. Similarly in Grahamstown, a suburb of Thames sheltered from northerly wave action by the Moanatairi Reclamation, flood levels indicated by residents were estimated by the authors to be about RL 2.25 m – well below those noted in areas more exposed to the northerly swell action.

In the areas exposed to wave action, waves over-topping the coastal margins also carried large volumes of rocks and debris. In some areas, rocks of up to 0.2 m diameter were sometimes carried up to15 m inland, indicating high velocity wave effects in the areas of significant wave over-topping.

Newspaper reports of historical events also suggest the influence of northerly swell waves in the events of 1936, 1947 and 1951. Newspaper reports of both the 1936 and 1947 events refer to northerly waves “pounding” the Thames Coast road and causing severe erosion and flooding. Photos from the event of 1951 also indicate rock debris along SH 25 similar to that noted after Cyclone Drena.

Maximum flooding levels in these events are unknown. However, newspaper reports and information from long-term residents tend to suggest that flooding levels were probably similar to the events of July 1995 and January 1997, with the exception of the 1951 event which was probably more severe (at least along the Thames Coast).

Long-term residents who lived at Thornton’s Bay during the 1951 event indicate that waves came right to the steps of their family home (316 SH 25, still standing in the same location) - at least 10 m further landward than during Cyclone Drena (Mr C Brokenshire, Thames and Mr B Brokenshire, Thornton's Bay, pers. comms., 1997). Another long-term resident who took extensive photographs of the 1951 event also believes it involved more severe flooding than Cyclone Drena (Mr B McMann, Whitianga).

Hindcast tide levels indicate that predicted high tides at the time of the 1951 event were not very high (RL 1.37-41 m, Table 1, Goring, 1997). Therefore, flooding would probably not have occurred in the absence of the significant wave effects. That this flooding appears to have been more severe than Cyclone Drena (which had a predicted high tide level of about RL 1.8 m) suggests waves may have been more severe than observed during Cyclone Drena – though the contribution of storm surge effects is unknown.

May 1938 Event

The May 1938 storm is significant in that the highest known flood levels in the southern Firth of Thames were recorded during this event.

The foreshore stop-banks then fronting the Hauraki Plains were breached in 15 separate areas, most significantly in the vicinity of Pipiroa on the eastern Hauraki Plains near the Piako River. Newspapers recorded that "extraordinary tides coupled with NE gales topped the stopbanks by 2ft," noting the event as the worst flooding in the history of the Hauraki Plains. The Grahamstown area in Thames was also flooded and damage to the Thames Coast road noted.

A note on aerial photographs taken shortly after this flood records "highest known tide recorded RL 102.5 ft at Pipiroa 4.5.38," which corrected for Tararu datum (minus 92.64 ft) reduces to 9.86 ft (3.0053 m) above MSL (Kevin Campbell, Environment Waikato – memo dated 4 May 2000, file 82 00 09). A level of RL 3.0 m is also widely recorded for this event in various files and reports held by Environment Waikato.

This extreme water level is currently adopted as the best present estimate of the 1% AEP extreme water level around the southern Firth of Thames, though the annual probability of the level is unknown (Environment Waikato, 1995; 1999). However, as the extreme sea level measured during this event is the highest on record the annual probability could well be considerably less than 1%.

Hindcast tide levels indicate a predicted high tide of RL 1.67 m (at 2246 hrs) for the evening of May 4 1938 (Bell and Hill, 1997). Therefore, the maximum-recorded flooding level was of the order of 1.33 m above the predicted tide level – a very significant difference.

The general assumption appears to be that this maximum flood level was a widely pervasive water level, though there is very little information in available newspaper reports or files on this aspect. However, it is commonly reported in more recent information that water levels in the 1938 event came to the window sills of the Lady Bowen Hotel in Thames, which apparently lie at about RL3 m (e.g. Cross, 1995). Newspaper reports in 1938 also record that a car left at the Park Hotel was submerged to the top of its radiator. While these reports do tend to imply that this maximum flood level was widely distributed, more information is required on the event before definitive conclusions can be drawn. This will probably require searching of any relevant archived files that date from this period.

The difficulty with the assumption of a widely pervasive flood level of this elevation is that this would tend to suggest a significant contribution from the combination of astronomical tides and storm surge. This is especially so for the wave-sheltered area of Grahamstown (where the aforementioned Lady Bowen Hotel is located), which is in the lee of the Moanatairi Reclamation – though this reclamation was not as extensive in

1938 and Grahamstown may then have been more exposed. However, the best present information on the extreme sea levels arising from storm surge and tide effects alone suggests that extreme water levels above RL 2.3 m are rare (an annual probability of < 1%) (Table 4-2).

Therefore, it seems likely that the 1938 event included significant wave effects – assuming that the extreme sea level estimates in Table 4-2 are reasonably accurate (which may not be able to be assumed, given the relatively short record from which they have been derived).

This is also suggested by the limited information available on coastal flooding levels associated with other major events. In all of these storm events, it appears that flood levels approaching RL 3 m have only been rarely achieved - usually in areas along coastal margins where wave run-up has been a significant factor. In areas further inland, more removed from the immediate effects of wave run-up and over-topping, maximum coastal flooding levels appear typically to have ranged from RL 2.4-2.7 m.

Newspaper reports indicate that the event was accompanied by gale force winds, which are likely to have generated significant swell waves. However, newspaper reports in the papers searched (Appendix C) do not provide details of waves. Reporting of such details was complicated by the fact that it occurred late at night.

The significance of the May 1938 event in terms of existing design levels warrants further investigation of this event, including collation of information from any relevant, archived files dating from this period.

July 1995 Event

The July 1995 event varies somewhat from other major coastal flooding events in that tides and storm surge were the major factors contributing to the extreme sea level of RL 2.48 m measured at the Tararu gauge.

The event appears to have been relatively rare and unusual, as the peak of the storm surge occurred precisely at the time of high tide (Figure 11, page 5, Goring, 1995). Moreover, the high tide was also a perigean tide, with one of the highest predicted tides for 1995 (1.895 m). Had the peak of the storm occurred one tidal cycle before or after there would have been no flooding, as maximum water levels would barely have exceeded 2 m above MSL.

The unusual nature of the event is further emphasised by best present information on extreme sea levels (Table 4-2). This information suggests that an extreme sea level of this elevation *arising from tides and storm surge alone* (i.e. excluding wave effects) has an annual probability of only 0.2% (Table 4).

Nonetheless, the occurrence of an extreme water level of this elevation relating primarily to tides and storm surge emphasises the need for further data before placing too much reliance on the extreme sea levels in Table 4-2. As noted earlier, NIWA caution that the stochastic storm surge component of these levels may change markedly as further data comes available.

While the elevated levels measured at the Tararu gauge primarily relate to tides and storm surge, there is also evidence that wave effects may have contributed to flooding in some coastal margins during the event.

Data from a wave rider buoy in the outer Hauraki Gulf indicates that there were northerly-directed swell waves during the July 1995 event (Goring, 1997). Significant wave heights of 2 m, maximum wave heights of about 3.8 m and typical periods of 6-8 s were measured at the wave buoy site (Goring, 1997). The wave heights in the Firth could not be ascertained from observers as the flooding occurred at night. However, most observers suggest they were generally about 0.5 m in height, much lower than during Cyclone Drena.

In relatively wave-sheltered areas (such as Grahamstown), levelling of well-defined flood marks indicate that flood levels were typically in the range of 2.4-2.5 m above MSL. These are similar to the levels noted at the gauge. However, in some parts of Tararu, well-defined flood marks were levelled at 2.55-2.6 m above MSL, suggesting some minor contribution also from wave effects.

In areas along the foreshore of Kaiaua township (western side of the Firth), debris deposits and resident reports indicate that waves overtopped coastal margins levelled at 2.7-3 m above MSL. Similar elevations were also levelled along the seaward front of some houses in northern Kaiaua. These houses were on the immediate landward side of the road and the levels appear to relate to occasional surges of water across the road. One resident in this area reported that the water level was up and gone in less than 20 s, suggesting an isolated surge of water. Flood levels of RL 2.6-2.7 m were levelled in some places further landward. Therefore, waves appear to have been quite a significant additional influence in flooding along this side of the coast.

Debris levels of about RL 2.8 m were also commonly noted at various points on the coast (G Walder, Surveyor, Environment Waikato, *pers. comm.,* 1995; Cross, 1995), suggesting the influence of wave run-up.

Residents at Kaiaua and Tararu commonly reported the influence of waves, noting that waves contributed to flooding by “pulsing” or “pumping” water across elevated coastal margins to lower lying areas further landward.

Waves were also reported to have also deposited rock debris on isolated, low-lying areas of SH 25 along the Thames Coast. Rocks up to 0.3 m diameter were noted on the southern side of Ngarimu Bay in the vicinity of Springfield Terrace (J Robertson, Engineer, Thames Coromandel District Council (TCDC), *pers. comm.,* 1995). However, this effect was far less significant than that which occurred along SH 25 in Cyclone Drena.

Therefore, while the contribution of tides and storm surge to extreme sea levels was unusually significant in the July 1995 event, it appears that wave effects from northerly swell waves were also relevant in some areas.

4.2.3 Sea level rise

Recent investigations of long-term tide gauge records around New Zealand suggest that there has been historical sea level rise of 1.3-2.3 mm/yr (Bell, 1999). Similar trends have also been noted in a variety of other countries.

It has also been suggested that the rate of sea level rise could be accelerated as a consequence of predicted global warming. While this is a matter of considerable uncertainty and debate, the most recent report by the Intergovernmental Panel on Climate Change suggests a scientific consensus that such effects are likely to occur (IPCC, 1996; 2001). Using “best estimate” model parameters for a range of scenarios, the IPCC presently estimates a rise in mean sea level of 0.3-0.49 m by 2100 AD (IPCC, 2001; Bell et al., 2001), little changed from their previous best estimates of 0.38-0.55 m (IPCC, 1996). Such a rise in mean sea level would have a very significant impact on coastal flooding, increasing both the frequency and severity of flooding.

While there is uncertainty in regard to these predictions, a precautionary approach would seem to be warranted given the present scientific consensus. The implications for individual sites are discussed in more detail in Chapter 5.

4.2.4 Tsunami

The Hauraki Gulf has experienced at least 11 tsunami and one meteorological tsunami since 1840 (Chick and de Lange, 1999). While most of these were small events, 4 had amplitudes up to 2 m (Chick and de Lange, 1999). Moreover, modelling suggests that the Firth of Thames amplifies distantly generated tsunami wave heights by about 50% of their amplitude in the outer Hauraki Gulf, so they will be more hazardous in the Firth (Chick and de Lange, 1999).

However, recent modelling of both distantly and locally generated tsunami tends to suggest that tsunami hazard in the Firth of Thames is low (Chick, 1999; Chick and de Lange, 1999).

4.2.5 Implications for design flood levels

The above information suggests that:

- Wave effects are a significant component in most coastal flooding events around the Firth of Thames. These effects appear to be particularly associated with northerly ocean swell waves migrating into the Firth. The importance of wave effects in coastal flooding suggests that extreme sea levels may vary around the Firth according to wave exposure.

- *In the absence of significant wave effects*, analysis by NIWA suggests that extreme sea levels with an annual probability of less than 1% are unlikely to exceed RL 2.3 m. However, this information is based on analysis of a relatively short sea level record. Further analysis should be conducted as additional data become available from the Tararu gauge.

- Flooding events of similar magnitude to Cyclone Drena and the July 1995 events appear to be relatively common – probably having an annual probability of about 5% or higher.

- During such events, wave effects (including wave run-up) in exposed areas can overtop natural coastal margins with elevations of RL 2.6-3 m. More rarely, elevations in excess of RL 3 m can be over-topped, particularly locations with abrupt coastal transitions (e.g. armoured shorelines not fronted by a natural beach to dissipate wave energy).

- Wave over-topping of coastal margins is commonly associated with turbulent, high velocity flows that can carry large volumes of rock and gravel more than 10-15 m inland.

- Limited information on the May 1938 event suggests that some rare coastal flooding events may also have widely pervasive extreme sea levels of up to RL 3 m, but more investigation is required to confirm this. The annual probability of such events is unknown, but may be considerably less than 1%.

- Existing vulnerability to coastal flooding could be significantly increased by predicted sea level rise of 0.5 m over the next 100 years. This would markedly increase both the frequency and severity of existing coastal flooding.

These findings have significant implications for design flood levels around the Firth. In particular, the significance of wave effects suggests that design flood levels may vary markedly according to wave exposure.

Refining of the existing design levels will require improved information on wave effects. The Tararu tide gauge has now has a wave-sampling programme designed to collect information for future analysis. This data collection is complemented by the Auckland Regional Council wave rider buoy in the outer Hauraki Gulf (NIWA, 1999). Ultimately, it should be possible to define and model the swell wave climate to identify the variation in wave effects around the Firth. However, we believe that neither the existing data nor existing wave models are adequate for this task at present.

Once the variation in wave effects around the margins of the Firth can be better defined, this information can be combined with tide and storm surge data to develop appropriate design flood levels for different locations.

Existing information, though ambiguous, tends to suggest that a design level of RL 3 m is probably a conservatively high estimate of the 1% AEP design flood level *for existing coastal processes*. This extreme water level appears to have an annual probability of much less than 1% - except in nearshore areas subject to wave run-up (such as the stopbanks along the margin of the southern Firth of Thames).

However, until existing information is able to be substantially improved, we do not believe it is appropriate to recommend any changes to this level - particularly in view of predicted sea level rise. However, nor do we believe it is necessary in the interim to raise the design level to allow for predicted sea level rise. The figure is probably an adequately conservative estimate of the 1% AEP event for the expected 50-year life of any new buildings, even with the sea level rise likely to occur over this period. However, it will be important to review this recommendation once improved information comes available.

Therefore, until better information is available, we recommend the existing design level of RL 3 m should be retained for minimum floor levels.

Similarly, the present 1% AEP level of RL 3.5 m should continue to be adopted for flood embankments and other structures along the coastal margin – to allow for wave run-up. This elevation may even need to be higher in areas that are particularly exposed – such as the Moanatairi Reclamation, which extends seaward into the Firth and is almost certainly subject to more severe wave effects than naturally grading shorelines. The recent flood protection works in this area included a 0.6 m timber parapet wall (raising embankment elevation to RL 4.1 m) to provide additional protection against wave runup over the sea wall crest (set at RL 3.5 m).

4.2.6 Vulnerability to flooding

4.2.6.1 Western Margin of the Firth of Thames

Average ground levels over the chenier plain in the vicinity of Miranda (Figure 1-1) typically range from 1.5-2.4 m above MSL (Tararu datum). Elevations can exceed RL 2.7-2.9 m on some of the rare, higher ridges. There are also extensive areas less than RL 1.7 m (some with elevations down to 1.3 m in places), well below maximum tide levels (Table 4-1).

The area is therefore extremely vulnerable to coastal flooding and can be extensively inundated by major coastal storms of similar or greater magnitude to Cyclone Drena and the July 1995 event. Therefore, flooding of this area could have an annual probability of about 5% or more. Very serious flooding would occur with any events with water levels of RL 3 m.

Predicted sea level rise of 0.5 m by 2100 AD would considerably aggravate coastal flooding in this area. This rise in sea level would lift the highest astronomical tides (Table 4-1) to elevations of RL 2-2.3 m – well above the elevation of much of the Miranda plains. Relatively frequent events similar to Cyclone Drena would result in very severe flooding. During such events, it is probable that high-energy swell waves would propagate across the plains - once the foreshore ridge had been breached. This would significantly aggravate flooding in this area. The high-energy waves could also seriously damage any development they encountered.

As the chenier ridges are wave built features, the elevation of the beach and the most seaward ridge will tend to rise with sea level - as waves and wave over-topping build up the elevation of these features. However, this very narrow band is unlikely to provide significant protection to the existing low-lying areas further landward that will not be raised. Extensive flooding will readily occur once the features on the coastal margin have been breached.

The high existing vulnerability and the potential for this to be significantly increased with sea level rise, suggest that considerable caution should be exercised before any intensification of development of this area. Given the severity of wave over-topping, development should also be well setback from the coast.

4.2.6.2 Thames Coast

Ground levels over the deltaic alluvial gravel fans of the Thames Coast (Figure 4-1 typically range from RL 2-3.5 m or higher, though areas of lower elevation also occur. The coastal margins tend to be raised slightly, commonly having elevations of RL 2.5-3.5 m or higher.

Coastal margins were commonly over-topped during the Cyclone Drena and July 1995 events, particularly at Tararu, Te Puru, Waikawau and Waiomu – flooding low-lying areas and dwellings further inland. Tararu was less significantly impacted during Cyclone Drena as a flood embankment was constructed along the low-lying, southern coastal margin after the July 1995 event. Significant flooding of the Moanatairi subdivision also occurred during the July 1985 and Cyclone Drena events, though extensive flood protection works have since been completed. Grahamstown in Thames was also flooded during the July 1995 event.

Considerably more serious flooding would be experienced in all of these settlements in the event of a major event with widely pervasive levels of about RL 3 m. Moreover, in the absence of major flood protection works, most of these settlements would experience frequent and severe coastal flooding with a rise in mean sea level of 0.5 m.

The ability to construct adequate flood protection embankments is constrained at many sites by the close proximity of subdivision and development to the sea. The need to maintain flood channels and low-lying coastal margins to assist in the release of river floods also constrains coastal flood protection options at some sites, notably Te Puru.

4.2.6.3 Hauraki Plains

The Hauraki Plains, a former deltaic swamp that has now largely been drained and developed, is the lowest lying area around the southern Firth of Thames.

In its natural state, both the Piako and Waihou Rivers discharged their floodwaters into one contiguous ponding area covering the Hauraki Plains. After prolonged rain, the rivers would overtop their banks and the Plains would become a vast inland sea stretching from one side of the Thames Valley to the other (Environment Waikato, 1999). Early reports indicate that boats would frequently cross the Plains and not keep to the rivers (Environment Waikato, 1999b).

Since flood protection and drainage (which commenced in the early 1900's), much of the shallow peat in the area has disappeared and deeper peats have settled appreciably. The Piako River in this area has almost non-existent gradients and large areas of land are now only 1-2 m above mean sea level (Environment Waikato, 1999b).

However, the area is now extensively protected by flood protection works, including foreshore stopbanking along the foreshore of the Firth of Thames between the Waihou River and Waitakaruru River mouths. The stop-banks have been built to an elevation of RL 3.5 m. These works provide protection from coastal inundation to a total area of about 20,000 hectares. Without the protection works, over 11,600 hectares would be inundated or isolated twice per month by astronomical tides alone (Environment Waikato, 1999b).

Mangroves have expanded along the foreshore over the last 50 years and now extend several hundred metres into the Firth. These mangroves provide significant wave attenuation and have probably increased the level of protection provided by the banks. Farmers along this area report significant wave attenuation by the mangroves during Cyclone Drena.

In the absence of significant sea level rise, these banks probably provide a very high level of protection from coastal flooding, provided they are adequately maintained.

4.3 Shoreline Changes

To date, investigations of shoreline change along the western Coromandel have largely been limited to the alluvial gravel fans of the Thames Coast and to Koputauaki Bay in the Northern Coromandel. This section briefly discusses available information on shoreline change in these environments – proceeding from south (Thames) to north (Koputauaki Bay).

4.3.1.1 Thames

The vast majority of the Thames foreshore is reclaimed and well seaward (usually by 150 m or more) of the original shoreline. Much of this reclamation was undertaken in the late 1800's and early 1900's in association with the disposal of tailings from gold mining, though some has continued until relatively recently. For instance, the most seaward portion of the Moanatairi Reclamation (now a residential subdivision) was completed in the late 1960's.

In most places this reclaimed foreshore is armoured, though the adequacy and standard of this armouring varies considerably. In the absence of shoreline armouring the shoreline would erode towards pre-reclamation positions.

The only "natural" shoreline occurs at Kuranui Bay on the immediate northern side of Thames township. This sandy beach is slowly prograding due to the accumulation of sediment transported in a net southwards direction along the Thames Coast. The net southwards transport along the coast essentially ends at Kuranui Bay due to the groyne effect of the Moanatairi Reclamation, which extends seaward at the south end of this beach.

4.3.1.2 Tararu

This alluvial fan, located immediately north of Thames (Figure 1-1) has an approximate area of 252,000 m^2 a seaward shoreline length of about 1420 m. The feature extends seaward about 300 m at its widest point.

There is very limited cadastral survey information available for the site, though an old undated MHWM line was able to be located and plotted with the shoreline (toe of bank) survey conducted for Environment Waikato in 1998 (FW Millington Surveys Ltd, Plan Ref 1661, sheets 1-6). In addition, shoreline changes could be assessed from various available aerial photographs dating from 1944 to 1995, resident information and field inspections.

These sources of information indicate very little change in shoreline position over the last 60-70 years, typically less than 5-10 m around most of the edge of the delta. This limited change is probably related at least in part to a concrete sea wall, which once existed around much of the edge of the delta from the Tararu Stream entrance southwards. While much of this seawall is still largely in place, extensive lengths have been undermined and have recently failed between Wilson and Rennie Streets.

The date of installation of the seawall is unknown. However, it is shown on photos dating from the 1940's and older, long-term residents advise that it has been there as long as they can recall – since at least the mid 1930's. The reason for the original construction of the wall is unknown as historic aerial photographs indicate that it pre-dated most subdivision and development of the seaward margin.

In the area between Robert and Wilson Streets, the seawall holds the shoreline seaward of its natural position by up to 10-12 m (these distances estimated by comparing cross-section information for this area with adjacent beach areas). The wall appears to have been built seaward of the beach, an oblique aerial photograph dating from 1959 clearly showing the wall to be some distance seaward of part of the beach, then still evident behind the wall (Photo 49364, Flown 4/5/59, Whites Aviation Ltd).

In most other areas, the present natural shoreline is close to the position of the wall. Therefore, in most places it appears that the natural shoreline would simply have fluctuated in position (probably by less than 10-12 m) in the absence of the wall.

In areas of natural shoreline along the southern region of the delta there appears to have been some minor shoreline fluctuations over time, certainly less than 10 m and in most cases probably less than 5 m.

The only significant shoreline change is noted in the immediate vicinity of the stream entrance, where there have been changes of 20-30 m associated with dynamic stream changes. For instance, the present true left bank (Map 27) presently lies at least 20-25 m seaward of the most landward position noted at the time of the undated, historic MHWM position. Similarly, the promontory along the true right hand side (northern) bank grew seaward by 25-30 m between aerial photographs flown in 1944 (SN 292/980/2, flown 17/5/44, NZ Aerial Mapping) and 1995 (Photo 182368, flown 27/4/95, Air Maps Ltd). These changes indicate that, in its natural state the stream entrance swung from side to side – these changes resulting in shoreline movements of at least 25-30 m either side of the entrance. These are normal and expected occurrences in such a locality. The entrance is presently held in its existing position by regular dredging/clearance associated with flood protection works. However, should this dredging cease at some future date, ongoing natural fluctuations of at least 25-30 m can be expected to occur over periods of decades.

Cross-sections indicate that, in its natural state the elevations of the coastal margin were typically RL 2.3-2.7 m – though various protection works have now raised many areas. The protection works include a bund installed along the southern margin following the July 1995 event. This bund, with a top elevation of RL 3 m prevented over-topping in most areas during Cyclone Drena, though some areas were overtopped towards the southern end. Other protection works include a wide variety of ad hoc measures installed over time by various parties from Wilson Street to just south of Robert Street. These measures typically have elevations ranging from RL 2.6 m to above RL 3.5 m (e.g. dumped rock and gabion works at the end of Robert Street and immediately either side).

The coastal margins were overtopped in various places from just north of Wilson Street southwards – though less extensive over-topping occurred during Cyclone Drena due to the various raising of coastal elevations that occurred between these events. Some of these areas still remain vulnerable to overtopping with the events of Cyclone Drena magnitude or greater. Extensive flooding is likely to accompany extreme events like that of May 1938 (presuming the RL 3 m elevation reported during that event to have been widely pervasive).

There are also limited options for flood protection in some areas (particularly between Robert and Wilson Streets), due to the close proximity of coastal development to the sea. A recent pilot study has experimented with groynes and beach nourishment in an attempt to establish a beach in this area – to increase wave energy dissipation before the wall and thus reduce over-topping. A raised wall has also been built further landward to reduce wave over-topping – though this is limited in elevation due to concerns related to sea views. These measures (if extended over the full length between Robert and Wilson Streets) will probably assist to reduce flooding during moderate events (e.g. Cyclone Drena) but will not provide an effective solution for the more severe events.

With a rise in mean sea level of 0.5 m, existing flooding problems would be seriously aggravated.

Therefore, notwithstanding various recent, useful initiatives, the settlement remains vulnerable to significant wave over-topping and flooding – particularly during the more extreme storms and/or in the event of significant sea level rise.

4.3.1.3 Te Puru

The Te Puru deltaic fan (Figure 1-1; Map 26) is the largest of these alluvial features on the Thames Coast, with a total area of about 422,000 m^2, a seaward shoreline length of 1760 m and extends seaward about 400 m at its maximum width.

Available cadastral surveys have been compiled for this site, together with a re-survey of the coastal margin (toe of bank) in 1995 (FW Millington Ltd, Plan 1344, Sheets 1-13). Additional information on shoreline change is also provided by a wide range of vertical and oblique aerial photographs dating from 1944, beach profiling (in front of the Te Puru School), field inspections and resident reports. Shoreline changes evident on aerial photos since 1968 were also mapped by O'Regan et al., 1995).

Maximum shoreline variations shown by cadastral surveys were mapped at transects spaced 50 m apart, with additional transects placed where necessary to pick up significant changes. Results are shown in Figure 4-2.

It can be seen that the maximum shoreline changes at each transect are typically less than 2 m, except in the vicinity of transects 0-200 and 700-1100 (Figure 4-2).

The large changes between transects 0-200 (Figure 4-2) are associated with the present river entrance and immediate vicinity (Map 26). The large shoreline changes in this area arise from progressive north-eastwards migration of the river channel over the last 100 years and dynamic changes associated with variation in the alignment and position of the river entrance.

The progressive element of the river entrance change has tended to result in accretion along the true left (southern) bank and erosion of the true right (northern) bank.

Changes associated with dynamic variations in the alignment and location of the river entrance have resulted in periods of both accretion and erosion along both banks. These shoreline movements typically have magnitudes of 20-35 m. These movements caused severe erosion of the true left bank in the mid-late 1950's and threatened adjacent subdivision. This lead to the installation of rock armour over a length of approximately 225 m (Photo 56862, Flown 29/12/61, Whites Aviation Ltd). Residents report that this area has also been subject to at least one further period of erosion since. In more recent years the bank in this area has significantly accreted. This is due in part to regular dredging/clearance of the river entrance for flood protection purposes, which has also maintained the outlet along its present alignment and prevented dynamic changes. However, continuation of the dynamic changes will occur if the dredging is ever ceased. The adequacy of the protection provided by the rock armour along the true left bank is unknown.

The significant changes in the vicinity of transects 700-1100 appear to relate primarily to accretion following progressive reduction in flow through a secondary river channel which discharges near this area. Historic surveys dating from 1868 (ML 1412) and

1869 (ML 1197) indicate that a significant secondary river channel discharged in this area at that time (FW Millington Surveys Ltd, Plan 1344, Sheet 3). This channel now only carries flood flows and the outlet is also fixed in location via a culvert.

Over most of the remainder of the delta shoreline, changes appear to be primarily associated with dynamic shoreline fluctuations. Analysis of aerial photos since 1968 also indicated that shoreline movements are largely characterised by dynamic shoreline changes (O'Regan et al., 1995).

The maximum fluctuations evident are of the order of 15-20 m (Figure 4-2), though there was limited available data at most transects west of the entrance (usually three surveys) to estimate the magnitude of shoreline fluctuations.

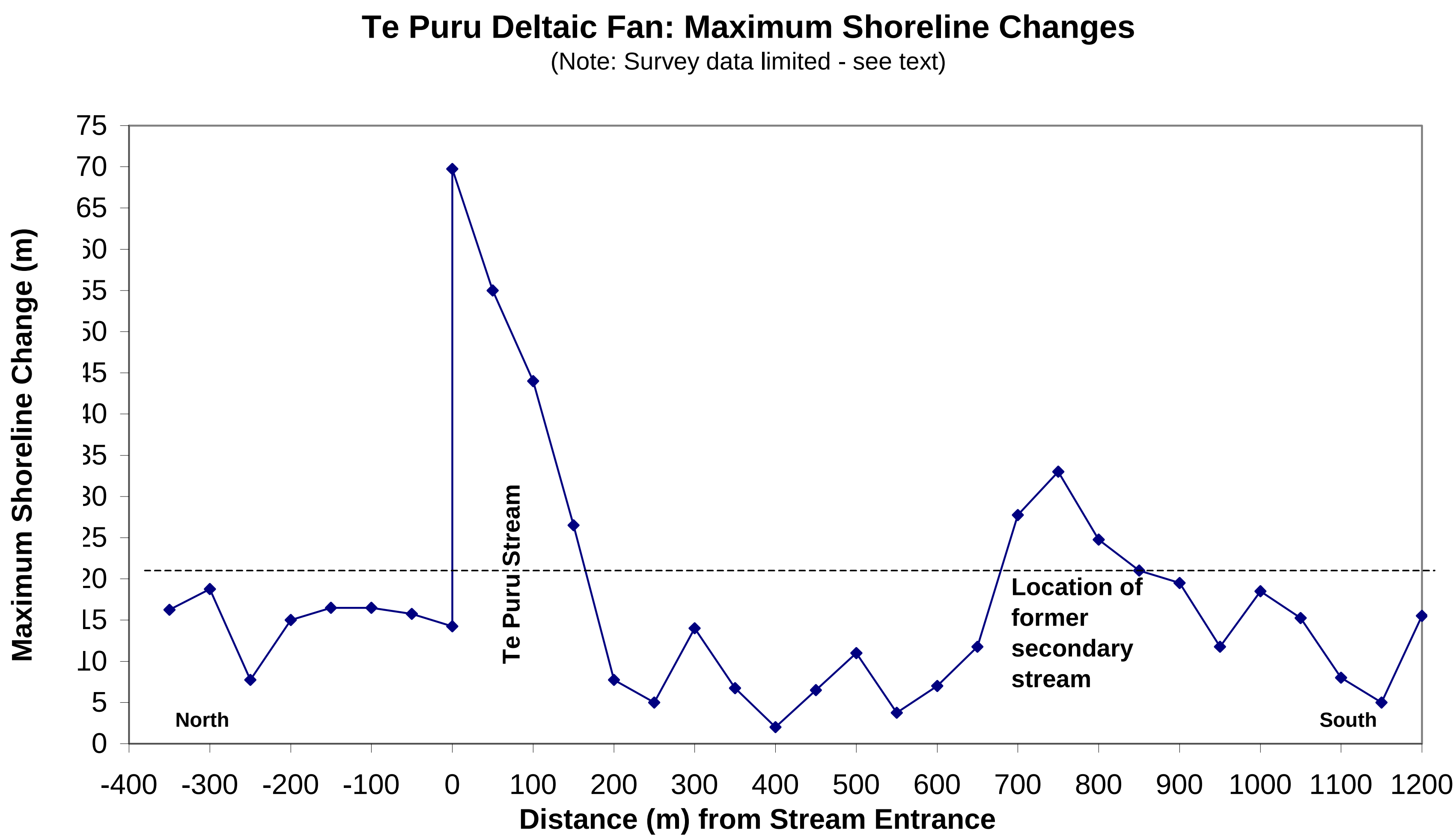


Figure 4-2: Maximum shoreline changes noted around edge of Te Puru Stream delta fan.

The most extensive data set is available for the foreshore to the east of the present river channel (transects 0 to –450), with partial surveys of this area available for eight separate dates from 1869. There are also a number of vertical and oblique aerial photographs of this area taken between 1944 and 1996 and regular beach profiling has been conducted since the early 1990's.

This data suggests that significant shoreline (toe of bank) fluctuations occur in his area. During the latest phase of erosion, which has characterised the area since about 1990, available data suggests a total of about 15 m shoreline retreat up to the period after Cyclone Drena (erosion protection was placed after cyclone Drena). Aerial photographs and available cadastral surveys indicate that similar erosion has also occurred in this area in the past.

The last occasion was in the 1950's, when available aerial photos (Whites Aviation photos 40852 and 63622, dated 20/3/56 and 21/2/65 respectively) indicate that a house at the western end of the area had to be relocated landward. A concrete seawall built at that time was buried by a subsequent period of accretion and local residents only became aware of the structure in the early 1990's, after it was exposed by the present period of erosion. Since that time, the wall has largely been destroyed by erosion.

Therefore, the latest "cycle" of erosion, accretion and further erosion appears to have occurred over 40-50 years. The decadal nature of these dynamic changes is also emphasised by the persistence of the latest trend for erosion for a period of at least 7-10 years. Therefore, as with the East Coast beaches, it appears that the most significant dynamic shoreline changes occur over periods of decades, i.e. decadal trends are primarily responsible for the most significant shoreline changes.

The progressive changes associated with the river entrance movement may also be dynamic over periods of many decades or 1-3 centuries – as suggested by data from the Tapu and Waikawau deltas considered below.

It is difficult to estimate any trend for long-term accretion or growth of the delta, given the limited data and the large scale of the dynamic and progressive changes that occur.

However, approximate estimates can be made assuming constant rates of aerial expansion over the last 6000-7000 years that sea level has been at or near present levels - assuming that rates of sediment supply and removal have not changed markedly in recent decades. Estimates based on the present delta area and seaward shoreline length suggest that the Te Puru delta fan is unlikely to be experiencing more than 3-4 m net progradation per century. Similar estimates for the other deltas suggest that any long-term trend for progradation is unlikely to exceed 1-3 m/century. It is also possible that these features are now largely in dynamic equilibrium - with sediment supply and removal largely balanced over lengthy periods of time.

4.3.1.4 Waiomu

The Waiomu deltaic fan is a relatively small feature (Map 25) located to the north of Te Puru (Figure 1-1). Comparison of photographs flown in 1944 (Photo SN292/976/1, Flown 22/5/44, NZ Aerial Mapping Ltd) and 1995 (Photo 182375, Flown 27/4/95, Air Maps Ltd) suggests that the shoreline is characterised by dynamic changes of less than 15 m. Front beach property owners report a consistent trend for foreshore erosion over the last 10 years (Mr F Tomsett, *pers. comm.,* 1997; Mrs M Pye, *pers. comm.,* 1997), with loss of at least 8-10 m over this period.

Larger changes have occurred along the margin of the Waiomu stream, with accretion of up to 25 m evident along the true left bank in the period between 1944 and 1995. It is probable that this area comes and goes over periods of decades, associated with dynamic changes around the Waiomu Stream entrance, similar to the changes noted around the Tararu and Te Mata River entrances.

4.3.1.5 Tapu

Changes of the Tapu deltaic fan over the last 60-70 years have been identified using aerial photos since 1944 and the observations of long-term residents.

These sources of data indicate that the last 50-60 years have been characterised by significant accretion over the area south of the Tapu Stream. In particular, the infilling of a large embayment in the centre of the delta since the mid 1960's (Figure 4-3, Figure 4-4), with the shoreline in this area prograding by up to 120 m.

This area of accretion is still very low-lying and areas further landward are at least 1-1.3 m higher. The area further landward is faced with a rock wall, suggesting a period of erosion prior to the recent accretion.

Resident reports and aerial photographs suggest that the shoreline south of Wharf Road (Figure 4-4) has also prograded by up to about 20 m over the last 50-60 years. A long-term resident in this area, Mr C Russock, showed us the location of a rock wall placed by his father to protect against sea erosion about 60 years ago. This wall is now buried and about 20 m from the existing shoreline.

The accretion appears to be a progressive trend associated with north-westward movement of the Tapu Stream. Some erosion of the true right (northern) bank has also occurred in outer areas over this period – with about 35-40 m retreat noted between photos of 1944 and 1995.

The scale of these changes suggests that significant areas of the Thames Coast deltas can be reworked by progressive river channel changes over periods of 50-150 years or more. The rate of these progressive changes does however appear to vary between sites.

Figure 4-3: Tapu Stream delta showing embayment (arrowed) on southern side of stream channel. (Whites Aviation photo, Air Logistics Ltd, Auckland, Photo 63615, flown 16/2/65).

Figure 4-4: Tapu Stream deltaic fan in 1994, showing infilled embayment (accreted area). The maximum width of the accreted area is about 120 m. Wharf Road (referred to in text) is the branch road running seaward from SH25. In the early 1900's, this road led to a wharf located on the southern side edge of the embayment shown in Figure 4-3. The area south of Wharf Road (behind the trams and houses shown) has also accreted, by about 20 m over the last 60-70 years. (Photo 49348, Maps Ltd, Tauranga, flown 1/6/94).

4.3.1.6 Waikawau

This deltaic fan, the most northern of the major features along the Thames Coast shows very significant shoreline changes over the last 75 years (Figure 4-5).

There has been a progressive trend for accretion of the shoreline on the southern side of the Waikawau River over this period. In places the shoreline has prograded by more than 120 m over this period.

This accretion has been associated with a general trend for the river channel to move north-westwards over this period. The area of the deltaic fan on the northern side evident in various historic photos (Figure 4-6) has now been completely eroded and removed by the progressive change.

The change at this site emphasises that the Thames Coast deltas can be very dynamic features over periods of 50-150 years or more, due to progressive changes in river channel and entrance positions.

The longer-term progressive changes have also been accompanied by shorter-term dynamic changes, though available photographs tend to suggest these changes are typically less than 10-15 m.

4.3.1.7 Koputauaki Bay

This coastal embayment, located to the north of Coromandel township (Figure 1-1) consists of broad alluvial flats fronted by a wide inter-tidal area similar to those of the Thames Coast deltaic fans. The Waiwhango Stream discharges into the centre of the embayment.

The alluvial flats on the true left (southern) side of the stream have demonstrated a consistent trend for erosion since at least 1909 (Figure 4-7). Over this period, erosion along the 450 m length of the foreshore has typically averaged about 0.2-0.3 m/yr, with maximum shoreline retreat of 30-50 m.

The river flats are undeveloped but the erosion now poses a serious threat to urupa located in the area, particularly the southernmost urupa (Figure 4-7).

The consistent trend for erosion over this lengthy period further illustrates the potential for significant progressive shoreline change in alluvial environments along the western Coromandel coastline.

4.3.1.8 Summary

The evidence from the above sites suggests that alluvial features on the western Coromandel coastline can undergo significant progressive changes associated with movements of river entrances and channels. It appears that some of these features (e.g. Tapu and Waikawau) might even be substantially reworked by river channel changes over periods of 50-100 years or more. It is probable that similar scale changes may also occur at many other sites over longer periods of time.

There are also significant dynamic fluctuations (typically 25-35 m) in the vicinity of river entrances over periods of decades associated with changes in the position and orientation of the river channels. In areas removed from the immediate river entrances it appears that the shorelines are generally less active over periods of decades – but can undergo dynamic shoreline changes of up to about 15 m.

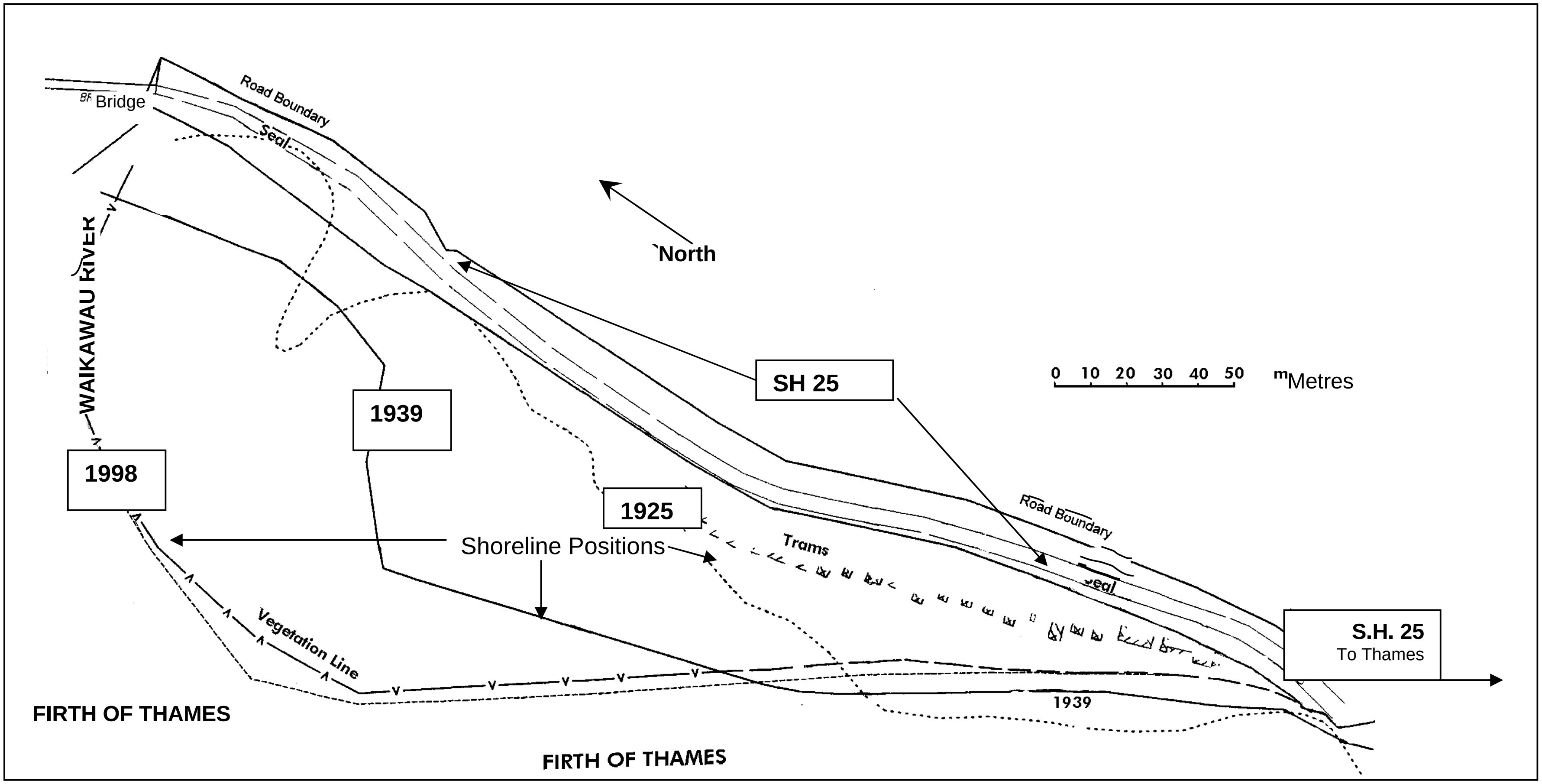


Figure 4-5: Surveyed shoreline positions (1925, 1939 and 1998) for the southern portion of the Waikawau Stream Delta, Western Coromandel. The surveys show consistent northward growth of this portion of the delta shoreline. As this change occurred, the delta area on the northern side of the river (Figure 4-6) was progressively eroded and is now entirely gone.

Figure 4-6: Waikawau River delta March 1959. Note the delta area on the northern side of the river (arrowed) that thas now been entirely eroded, associated with growth of the delta area on the southern side. (Whites Aviation photo, Air Logistics Ltd, Photo 49405, flown 4/3/59).

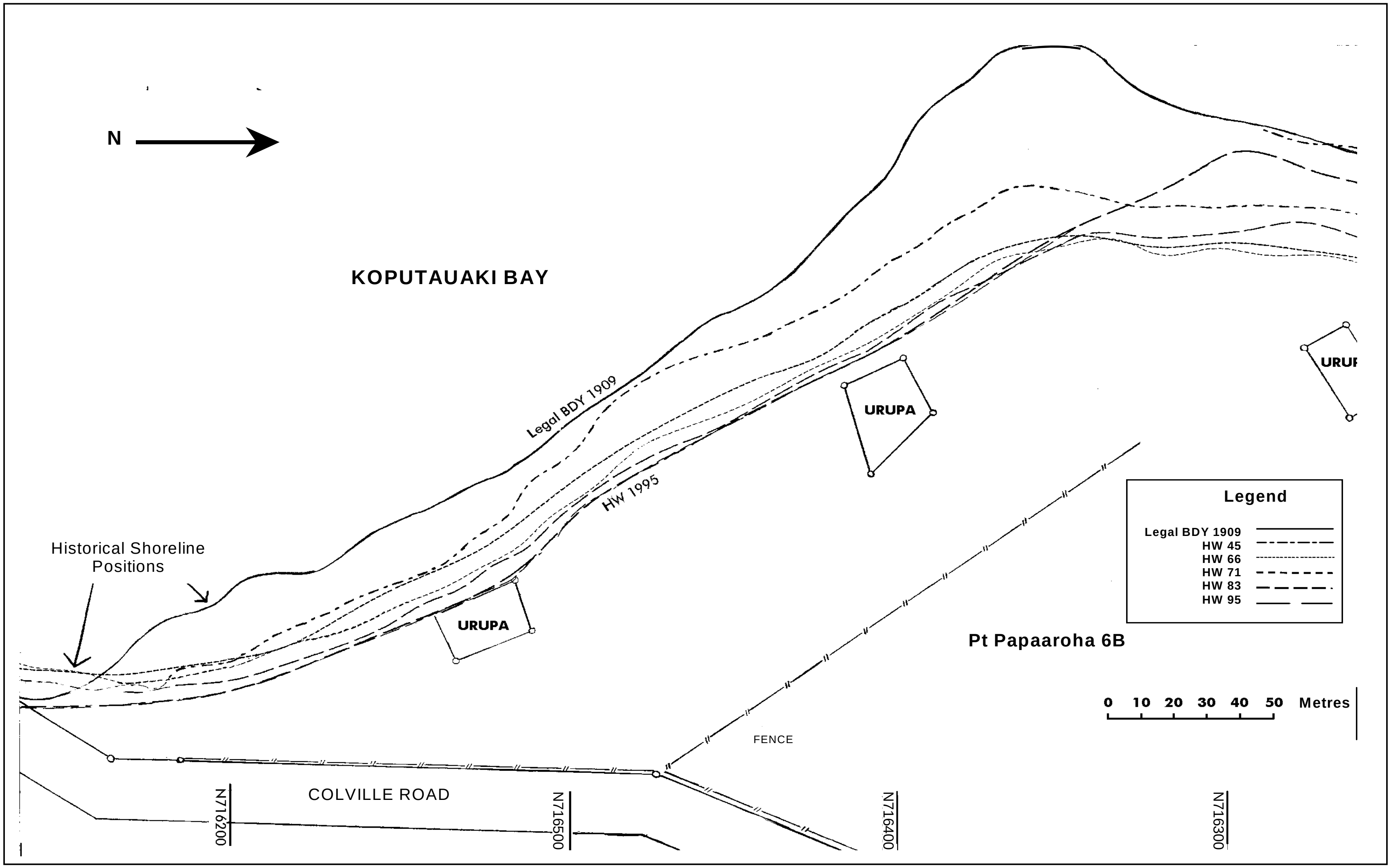


Figure 4-7: Shoreline changes at Koputauaki Bay, western Coromandel, 1909 to 1995. Note the consistent trend for landward retreat along most of this length of shoreline.

5 Implications for Hazard Management

This chapter discusses the implications of the previous chapters for coastal hazard management around the Coromandel Peninsula.

In particular:

- the coastal development setbacks currently in use along the eastern Coromandel are reviewed and revised;
- coastal development setbacks are developed for the deltaic alluvial fans of the western Coromandel.

5.1 Coastal Hazards on the Coromandel Peninsula

5.1.1 Coastal hazards as a management issue

The Coromandel Peninsula contains some of New Zealand's premier coastal heritage and is a popular holiday destination. Located in close proximity to major population centres in Auckland and the Waikato, the Peninsula has been subject to heavy development pressure over the last 40 years as roading access has improved.

Subdivision has particularly targeted sandy beaches, with over 75% of all Coromandel beaches (east and west coasts) now developed or partially developed (Dahm, 1999a). Much of this development has occurred in close proximity to the sea, with over 70% of beachfront houses located within 100 m of the toe of dune on the eastern Coromandel coast and 50 m on the west coast (Dahm 1999a). Many houses are also much closer (Figure 5-1, Figure 5-2).

The conversion of the natural beach-dune systems to built landscapes and the proximity of the development to the sea has significantly reduced the natural character of the coast. In many cases, bulldozing and grassing have also significantly modified the natural dune areas remaining between development and the sea.

The close proximity of development to the sea and the degradation of natural dune systems have also resulted in many existing and potential coastal hazard problems - with houses and property vulnerable to coastal erosion and/or flooding.

A recent review of coastal erosion and flooding in the Waikato Region identified 15-18 Coromandel settlements that appear to have buildings and/or private property presently vulnerable to coastal erosion and/or flooding (Dahm, 1999a and b).

The reports also note the potential for these problems to be considerably aggravated over the next 50-100 years as a consequence of:

- increased coastal erosion and flooding associated with predicted sea level rise and other changes that may accompany predicted global warming
- ongoing subdivision and development, particularly intensification of existing nearshore development

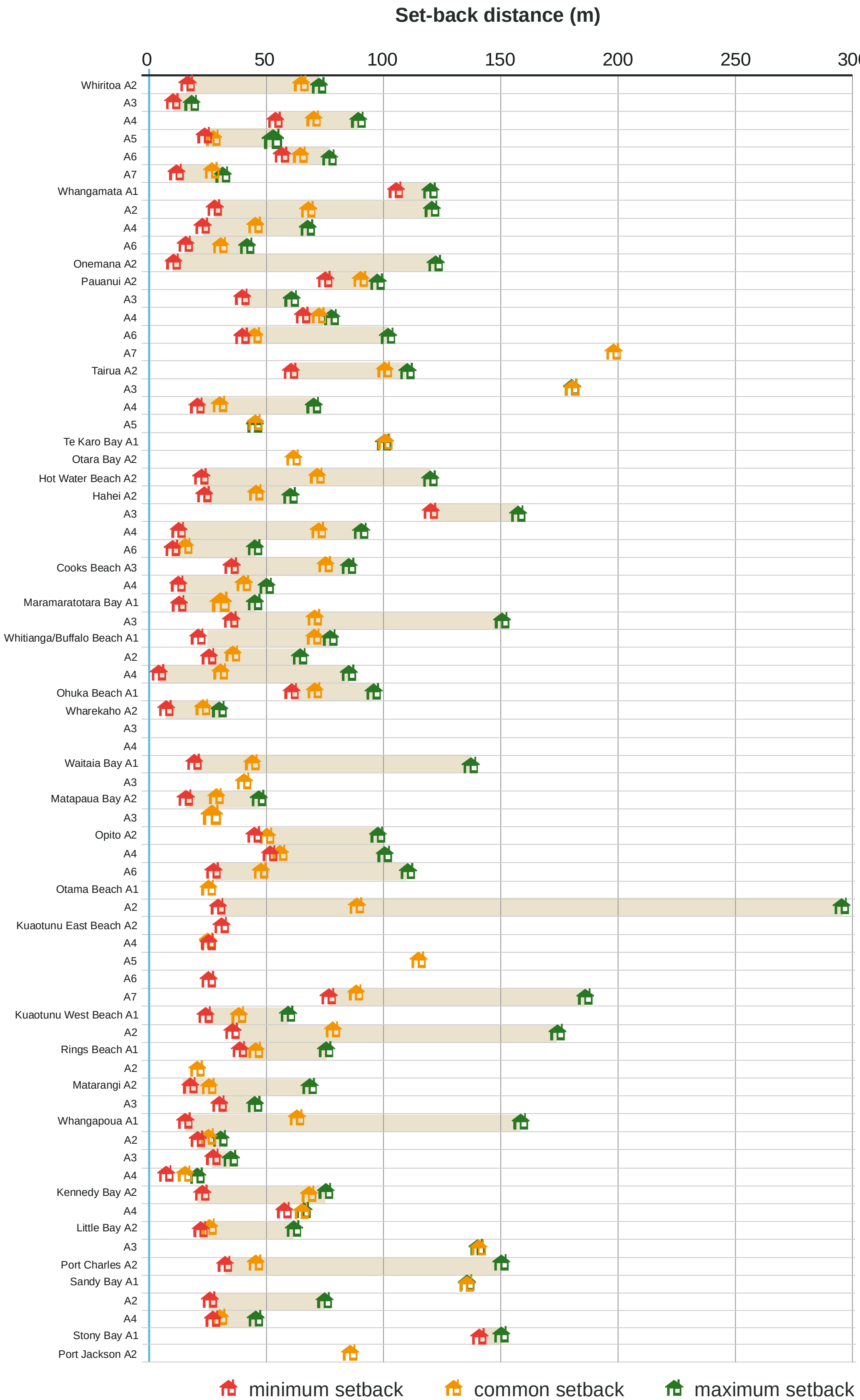


Figure 5-1: Proximity of beachfront dwellings to shoreline (toe of dune) along the eastern Coromandel Peninsula. Most houses are setback less than 100 m, with many less than 50 m and some less than 15-25 m. (See text of Figure 5-2 for more detail on plots).

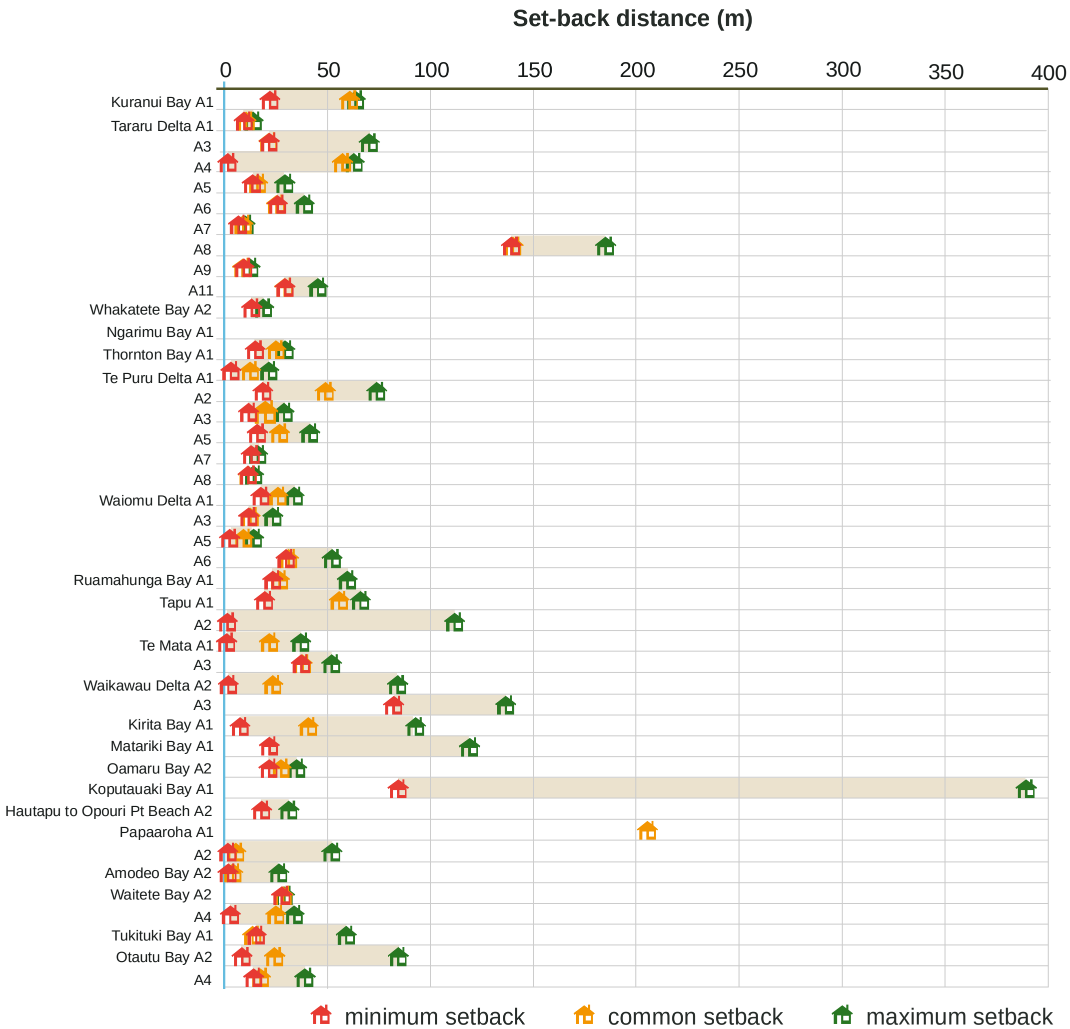


Figure 5-2: Proximity of beachfront dwellings to shoreline (edge of vegetation) along the western Coromandel. The setbacks are based on measurements from aerial photography flown in 1995/96. Each settlement was subdivided into blocks of dwellings of broadly similar setback (labelled A1, A2, etc). Within each of these blocks of dwellings, the minimum, average and maximum setbacks were measured. It can be seen that most beachfront dwellings along the western Coromandel are closer than 50 m to the sea, with many dwellings setback less than half that distance. The closest dwellings are sometimes less than 10 m.

The reports conclude that most existing and potential problems relate to the pattern of human use and development and to human-induced changes in natural coastal processes – rather than to natural changes in coastal processes (Dahm, 1999a). In general, it is evident that the Coromandel beachfront subdivision and development has been placed too close to the sea to accommodate the natural processes and shoreline changes that occur in these dynamic systems.

5.1.2 Hazard management strategies

Environment Waikato has recently developed and adopted hazard mitigation strategies for both coastal erosion and coastal flooding hazard, in consultation with coastal district councils (Environment Waikato, 1999c and d). These strategies are non-statutory documents and are aimed at developing guidelines for the implementation of hazard management policies in relevant regional and district planning documents (e.g. Regional Policy Statement, Regional Coastal Plan, District Plans).

Emphasis is placed on managing human use to accommodate natural coastal processes, rather than managing natural processes to accommodate human use.

The management of natural processes is not precluded. However, the strategies conclude that, in general, such management options are unlikely to provide appropriate and sustainable long-term solutions at most sites – even though they may have a limited role as short-medium term options at some sites. In particular, the strategies identify significant environmental and other issues associated with the use of engineering structures, particularly shoreline armouring (Environment Waikato, 1999a and c).

The strategies emphasise avoiding risk in areas of new subdivision, reducing risk in areas of existing development, living with some risk (especially to existing property) and the protection and restoration of natural coastal buffer zones such as coastal dunes (Environment Waikato, 1999c and d). Community information and participation are identified as being critical if this approach is to succeed.

The strategies recognise that additional measures will also be required at various identified settlements where there are serious existing hazard issues (e.g. eastern end of Cooks Beach). It is recommended that site-specific strategies be developed for such areas.

The avoidance and reduction of risk within hazard areas requires that these areas be identified and appropriately managed. This is primarily achieved through the use of coastal setbacks and design flood levels. These measures are discussed below.

5.2 Coastal Setbacks

As noted by Healy (2001, p9) the term setback is generally used to mean:

That zone measured as a linear distance landwards from a reference feature, usually taken as the toe of the frontal dune, to a line on the ground, which is subject to hazards from the coastal marine environment, and within which, on the balance of evidence and in the light of the scientific knowledge of the moment, it would be prudent to restrict development.

Ideally, coastal setbacks should be multi-purpose and provide for a variety of coastal management objectives in addition to the avoidance or mitigation of hazard risk – including preservation of natural character, protection of public access to and along the coast, the maintenance and enhancement of amenity values and many others (see Section 1.4 and Appendix E).

Therefore, the above definition of a coastal setback could be modified to:

That zone measured as a linear distance landwards from a reference feature, usually taken as the toe of the frontal dune, within which, on the balance of evidence and in the light of the scientific knowledge of the moment, it would be prudent to restrict development in order to achieve desired coastal management outcomes.

The definition of such multi-purpose setbacks is beyond the scope of this report. At developed beaches, the proximity of existing coastal subdivision and development to the sea (Figure 5-1, Figure 5-2) also constrains the setback that is reasonably practical.

Therefore, in this report, a different approach has been adopted for the definition of setbacks in developed and undeveloped areas, as discussed below.

5.2.1 Setbacks in developed areas

The development setbacks defined in this report for developed areas are designed to protect from coastal hazards.

It is also important to note that a development setback *does not of itself constitute a "magical" safety zone immediately on one side... and a zone of ... "impending destruction" on the other* (Healy, 2001, p9). Rather, as Healy notes it is a line on the ground, which, on the balance of evidence, and in the light of the scientific knowledge of the moment, it would be prudent to restrict development.

In this study, the development setbacks define the area that might reasonably be expected to be subject to coastal hazards within the next 100 years, defined on the basis of existing knowledge, with an allowance also for remaining uncertainties.

Ideally, a single development setback should be adopted, sufficient to provide for the hazard associated with existing coastal processes and projected global warming, together with existing uncertainties (e.g. Healy, 2001).

However, this is simply not practical along developed shorelines of the eastern and western Coromandel due to the close proximity of beachfront subdivision and development in this area (see Figure 5-1, Figure 5-2).

Therefore, on both the eastern and western Coromandel beaches, we have adopted two separate setbacks for developed areas – a primary development setback and a secondary development setback.

We believe this dual setback approach provides the most effective and practicable approach for coastal hazard management in developed areas, providing for natural coastal processes and the human dimension of the hazard at these sites.

The two setbacks are briefly outlined in the following sections.

5.2.1.1 Primary Development Setback (PDS)

This setback defines the area that has to be managed to provide <u>reasonable</u> protection from coastal hazards associated with existing coastal processes.

It is determined on the basis of:

- the worst probable recession likely to occur within a 100-year period with existing coastal processes (i.e. no allowance for changes that may occur predicted global warming); **plus**
- an additional buffer zone.

Assessment of worst likely coastal erosion

The assessment of the maximum erosion likely to be associated with existing coastal processes incorporates consideration of the erosion associated with both dynamic changes (including those which occur over periods of decades) and any existing longer-term trends for shoreline change (recession or progradation).

The assessment for eastern and western Coromandel beaches is discussed in detail in sections 5.4 and 5.5, respectively. However, in general terms, the assessments are reasonable estimates of the worst likely erosion based on the existing information discussed in Chapters 3 and 4. Where appropriate, we have also used a numerical procedure to ensure a systematic approach and facilitate updating of the setbacks with improved information.

Additional buffer zone

The second element of the primary development setback is concerned with ensuring that an adequate natural buffer zone remains between development and the sea, even with the worst likely erosion.

This natural buffer zone serves a number of important purposes:

- **Protects natural dune function and integrity.** It is critical that natural dune building and repair is maintained, even after severe erosion. This requires a dune buffer with appropriate native sand binding species (e.g. spinifex and pingao) to facilitate the sand trapping critical to natural dune building and repair.

- **Allows for the collapse of near vertical erosion scarps formed after severe storm erosion.** After severe storm erosion, dunes typically develop a steep erosion scarp, which will normally slump. Allowance for this normal slope adjustment is usually based on a <u>safe</u> angle of dune face repose of about 25 degrees (e.g. Gosford City Council, 1990) (in practice the dune face is likely to adopt a steeper angle of repose, around 35 degrees). It is also wise practice to make some further allowance for reduced bearing capacity behind the adjusted dune face (Gosford City Council, 1990; see also relevant note on pages 11 & 12 of Hume, 2002). Otherwise, buildings located in this area may be subject to foundation failure, particularly on elevated dunes.

- **Provides sufficient space to allow restoration of natural dune function where dunes have previously been damaged or degraded**. Many frontal foredunes have been severely degraded along the developed foreshores of many eastern Coromandel beaches, often bulldozed, covered with spoil and grassed (Environment Waikato, 2001). Sufficient setback of development is required to enable future restoration of natural dune function where it has been disrupted. If houses are placed too close to the sea, effective dune management will be severely restricted.

- **Protection of lower lying areas further landward from coastal flooding**. The maintenance of a remnant dune buffer is critical at many sites to protect lower lying inland areas from coastal inundation. For instance, the coastal flooding problems noted at Cooks and Buffalo beaches result largely from the loss and/or lowering of frontal foredunes associated with subdivision and development.

- **Provides a factor of safety in the estimates of erosion**. The prediction of erosion hazard is not a precise science and it is important to incorporate an appropriate factor of safety to ensure buildings are protected. This aspect was reinforced by one of the reviewers, who notes that a factor of safety is fundamental to estimation of an appropriate setback distance (Hesp, 2001).

- **Minimise the need for shoreline armouring works.** It is common experience that property owners tend to place shoreline armouring works once erosion approaches within 10-15 m of their dwellings, often regardless of controls or regulations relating to these devices. These measures can degrade the natural and amenity values of beaches. Ensuring an adequate dune buffer remains after worst probable erosion reduces both the pressure and need for the placement of such works.

- **Enable the relocation of threatened houses should this be necessary**. It can prove difficult to relocate houses when they too close to the edge of a vertical erosion scarp and therefore it is wise to ensure a buffer of 5-10 m remains even under conditions of worst erosion. As noted above, this buffer also helps ensure the house is not damaged as a consequence of dune slumping.

Along the western Coromandel coast, the buffer zone has an additional purpose – protection from high velocity wave effects and rock debris associated with wave over-topping of coastal margins (see section 5.4).

The buffer zone can also be viewed as providing some provision for other coastal management objectives such as preservation of natural character.

The desirable width of buffer zone required for the above objectives varies according to many local factors. However, at most developed beaches on the Coromandel, the close proximity of existing coastal subdivision to the sea seriously limits the width of additional buffer zone that is practical.

The buffer zone widths adopted on the eastern and western Coromandel are discussed in sections 5.4 and 5.5, respectively. The figures are in most cases the absolute minimum that is appropriate. We have adopted this approach (i.e. minimum appropriate buffer zone) purely to minimise constraints on nearshore properties.

Comment on primary development setback

The setback estimates are designed to provide reasonable protection from the worst likely erosion with existing coastal processes, based on the understanding of coastal processes developed in preceding chapters, rather than estimates that are sufficiently precautionary to provide absolute or total hazard protection for every conceivable eventuality.

We have deliberately adopted this approach to minimise, as far as reasonably practicable, serious constraints on the use of existing property. It is possible that rare erosion events (e.g. massive storms or tsunami), not evident in existing information, may occur with existing coastal processes and exceed the maximum erosion allowed for in the setback. However, it is not possible on the basis of existing information to make any reasonable estimate of the magnitude or frequency of such events.

It is recommended that the PDS should be adopted as the minimum setback for any coastal development and should be a building avoidance area. In this manner, the setback will avoid the placement of new houses within the area of highest hazard risk and will also steadily reduce existing vulnerability in this area as existing houses are replaced with new dwellings further landward.

Where the setback precludes the reasonable exercise of existing property rights, a site-specific hazard assessment should be conducted to see if the blanket setback can be safely reduced at that location. If the setback cannot be reasonably reduced, a site-specific hazard management strategy will be required to provide for property owner rights while also ensuring appropriate and sustainable management of hazard risk.

Along the east coast, the protection and restoration of a naturally functioning frontal foredune should also be actively encouraged along the seaward margin of beachfront properties within this setback. This is probably best achieved by providing information and appropriate support (e.g. through the existing Beachcare programme).

5.2.1.2 Secondary Development Setback (SDS)

This setback encompasses the primary development setback **and** the additional area that might be impacted by coastal hazards given the effects likely to accompany predicted global warming.

There are considerable uncertainties in regard to the potential impact of projected climate change over the next 100 years and the additional setback is intended to provide a reasonable allowance for the additional hazard that may arise over the next 100 years.

The means by which this additional setback has been determined for the beaches of the eastern and western Coromandel coasts are outlined in sections 5.4 and 5.5, respectively. However, generally speaking, the estimates are based on reasonable best present estimates of projected sea level rise by 2100 AD.

This is clearly a lower risk area than the PDS, as hazard impact is conditional on best present estimates of sea level rise and other assumptions (see discussion in sections 3.4.2.1, 4.2.3 and 5.4.3.3). The scientific information presently available (discussed in earlier chapters), suggests that the area landward of the PDS is unlikely to be impacted by the continuation of existing coastal processes.

Nonetheless, it is appropriate to identify the potential for hazard risk, given the scientific consensus that a rise in mean sea level and other changes which may aggravate coastal hazards are likely to occur within the next century (IPCC, 2001; Bell et al., 2001). There are also statutory requirements to allow for the potential impact of such changes (e.g. Policies 3.4.2 and 3.4.4 of the NZCPS, Appendix E).

This zone may be subject to controls similar to the existing 30-60 m zone and, in addition, further intensification of subdivision or development should be carefully managed within this area.

These measures will not eliminate the additional, potential hazard associated with a rise in mean sea level. Rather, the emphasis is on avoiding any intensification of development within this risk area - ensuring that future hazard problems are not aggravated by present-day subdivision and development decisions. To attempt to prevent any development within this area is simply not reasonable or practicable given the existing pattern of subdivision and development and associated property and development rights. However, the development setbacks will signal to present and future owners that the properties may have a “design life” of less than 100 years.

5.2.2 Setbacks in undeveloped areas

In all undeveloped areas, it is recommended that site-specific setbacks be determined that provide not only for existing and potential coastal hazards, but also for the wide range of other coastal management objectives that are relevant to such areas (see section 1.4 and appendix E).

In the absence of such site-specific determinations, a single, minimum setback of 100 m is proposed as a general rule. At most sites, this setback will ensure a minimum buffer zone of at least 40-50 m in the event of even the most serious recession likely over the next 100 years. This should ensure that a full-undeveloped frontal dune would remain at all of these sites, even in the event of serious erosion.

This large setback reflects the fact that coastal management considerations additional to hazard management (e.g. preservation of natural character, biodiversity, amenity values, sometimes cultural heritage) will be important factors at these sites.

For instance, the preservation of natural character is a Matter of National Importance in the Resource Management Act and central to the principles and policies of the New

Zealand Coastal Policy Statement (Appendix E). Case law has established a high duty to provide for this matter and emphasises that coastal environments free from built elements retain the highest degree of natural character and have the highest priority for absolute protection and preservation (Maplesden and Boffa Miskell, 2000).

This is likely to be a particularly important consideration at any undeveloped sites along the eastern Coromandel, given the seriously diminishing nature of coastal open space along the margins of Coromandel sandy beaches. At many undeveloped sites, considerations such as natural character may require an even larger setback or dictate that no development can occur at all.

The 100 m setback is based on the decision of the Town and Country Planning Appeal Board for the Matarangi subdivision, which held in 1978 that ocean front subdivision and building should be prohibited in the strip 100 m wide inland from the seaward toe of the outer foredune. This decision was based primarily on the need to preserve natural character.

A larger setback is recommended in some specific areas. For instance, the northern end of the Kennedy Bay barrier – excluding the entire spit end from development in view of the vulnerability of the access to this area to spit breaching.

5.3 Design Flood Levels

A design flood level (DFL) identifies the extreme water level that may occur during defined rare events.

In urban areas, the design standard adopted is usually the 1% AEP extreme water level. The Building Act identifies a lesser standard (the 2% AEP event) as the statutory minimum protection for new residential dwellings. However, adoption of this standard in urban areas could result in serious losses during more extreme events and give rise to the need for expensive flood mitigation works (e.g. embankments, lifting houses). In some cases, the lesser standard may be appropriate for rural areas.

The design water levels are used to fix minimum floor levels in new dwellings within the flood prone area – usually with an additional allowance (commonly 0.5 m) for wave effects.

Identification of the flood prone area is typically based on the relatively crude assumption that all areas below the design flood level are potentially vulnerable to inundation. However, in reality this is not always so. For instance, if wave effects are a significant element in the design level, then it may be that the extreme water level will only be experienced in nearshore coastal margins. Similarly, some areas below the design flood level may be adequately protected by higher-level areas further seaward, which provide a barrier to inundation.

However, identification of such subtleties requires numerical modelling and a sophisticated understanding of both the coastal flood events and local topography that is well beyond the present level of information available for Coromandel coastal margins. Therefore, in the interim, there is little alternative to adoption of the simpler approach to designation of flood risk areas.

A design flood level of RL 3 m (wrt the Tararu MSL datum) is presently adopted for the Western Coromandel. As discussed in Sections 4.2.2 and 4.2.5, there are a number of uncertainties that relate to this design figure. However, in our opinion, available information is presently too ambiguous to usefully refine this important figure. Nonetheless, as the limited available information tends to suggest the present design level contains an element of conservatism, we believe it is not necessary at this point in time to incorporate a further allowance for predicted sea level rise.

Therefore, this report adopts a design flood level of RL 3 m for the margin of the southern Firth of Thames.

It is very important that work continues to better refine this design level, particularly to identify the swell wave climate for the margin of the Firth of Thames and associated wave effects.

No design flood levels are available for ocean beaches of the eastern Coromandel, though it is probable that design levels used in the southern Bay of Plenty will be usefully indicative for many sites.

As noted above, most coastal flooding problems along ocean beaches of the eastern Coromandel relate to loss or lowering of natural dune buffer zones. Therefore, local hazard management strategies that focus on restoring natural buffer zones in affected areas are probably the most effective and appropriate action in the interim. In those areas where it is not reasonably practical to eliminate coastal flooding through the restoration of natural buffer zones, more detailed assessment of the risk from coastal flooding could be undertaken to better assess most appropriate action. This is particularly likely to be required for the southern end of Buffalo Beach. Possibly, also the eastern end of Cooks Beach. However, the latter site is probably amenable to restoration of a natural buffer zone – though other additional measures will probably also be required.

As noted in Section 3.4.3, the shoreline of Mercury Bay (particularly Whitianga) may also be vulnerable to tsunami risk and further information on this vulnerability is required.

5.4 Review of Setbacks for the Eastern Coromandel Coast

5.4.1 Existing setbacks

Within the Thames Coromandel District Council (TCDC) area, eastern Coromandel beaches have had coastal development setbacks in place since the early 1980's.

These 30 m and 60 m setbacks (measured from the seaward toe of the most seaward foredune) are applied and enforced under the Building Act at all developed sandy beaches along the eastern Coromandel. No buildings, structures or septic tanks and their disposal fields are permitted within the 30 m setback, unless a site specific hazard assessment indicates that a lesser standard is appropriate at that site or the hazard risk is appropriately mitigated. Relocatable buildings may be situated between the 30 m and 60 m setbacks, subject to certain conditions.

The Hauraki District Council also adopted these setbacks and similar rules for Whiritoa Beach in the early 1990's. The primary development setback at this site was fixed on the basis of hazard assessment investigations conducted in associated with the development of a hazard management strategy for this site (Dahm et. al., 1993).

The rationale for the existing setbacks is not outlined in available information, though Dell (1981) provides a useful summary of earlier 60 m and 100 m blanket setback recommendations issued by the (then) Hauraki Catchment Board. This report is also the first reference to the 30 m setback in the information we were able to locate, though no background was provided on the origin of the figure.

However, in practice it has been assumed that:

- The 30 m setback defines the area likely to be at risk from erosion associated with existing coastal processes (except in areas near estuary or stream entrances or major stormwater outlets where erosion hazard can be considerably aggravated)
- The 60 m setback identifies the additional area that might be impacted in the event of changes likely to accompany predicted global warming.

The present setbacks move with the toe of the dune and this can lead to concerns. For instance, houses consented when the duneline is in a prograded state can be permitted further forward than adjacent houses consented when the shoreline is eroded (Diagram 2). This raises issues in respect of equity and sea views for the owners. Similarly, such houses can have quite different levels of protection from hazard events.

Therefore, a further objective of the present review is to develop setbacks that are fixed in position with regard to property boundaries. i.e. The setbacks recommended in this report do not move as the shoreline moves – they are spatially fixed (Figure 5-3). In this way, adjacent properties are treated equally and everyone is working to the same building line.

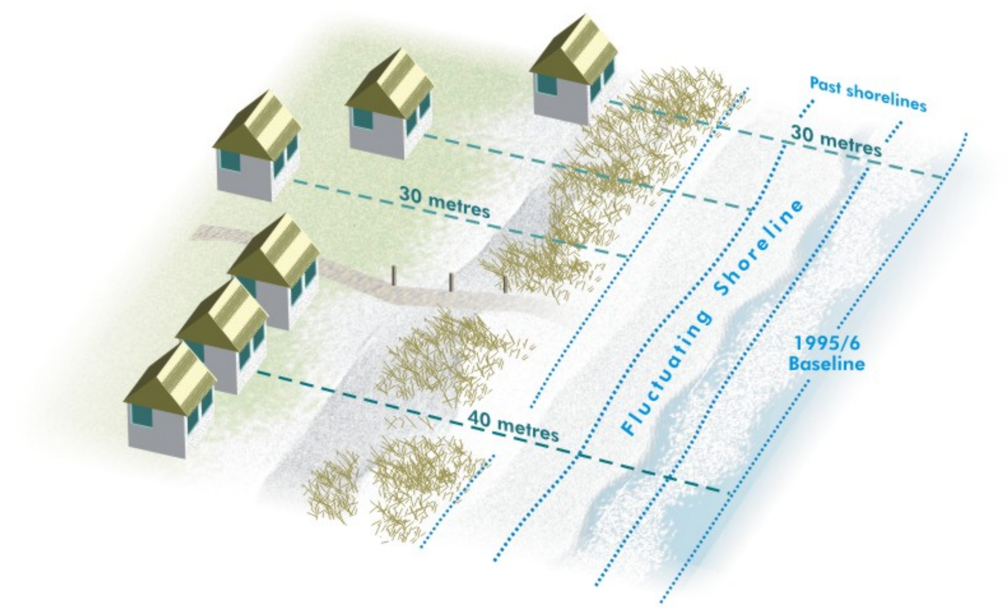


Figure 5-3: Two different approaches to development setbacks. Where the setback controls move with the shoreline, houses built or renovated at different times can receive different levels of protection. By measuring the revised setbacks from a line that doesn't move with shoreline fluctuations, all building activities are given adequate protection without being over conservative.

5.4.2 Estimation of revised setbacks for developed areas

The assessment of appropriate coastal development setbacks for eastern Coromandel beaches requires consideration of a number of factors, including:

- The maximum dynamic shoreline fluctuation associated with existing coastal processes over the next 100 years
- Any long term trends for shoreline recession or progradation
- The potential of changes likely to accompany predicted global warming
- Maintenance of an additional buffer zone reasonably sufficient to provide for the factors discussed in section 5.2.1.1

The required widths of the setbacks can be expressed numerically in terms of the formulae:

$$\mathbf{PDS} = (R \times T) + S + F \qquad \text{i}$$

$$\mathbf{SDS} = (R \times T) + S + F + X \quad (\text{i.e. } SDS = PDS + X) \qquad \text{ii}$$

Where:

PDS = Primary Development Setback (see section 5.2.1.1)

SDS = Secondary Development Setback (see section 5.2.1.2)

R = Long term rate of shoreline recession or progradation

S = The maximum shoreline fluctuation likely to occur within the defined planning period (100 years in this study)

X = Dune line retreat in response to sea level rise

T = Planning period – taken as 100 years for our study

F = Additional buffer zone safety factor to provide for the matters discussed in section 5.2.1.1)

These setbacks are illustrated in Figure 5-4.

These equations are very similar to the formulae commonly used for east coast beaches. Work by Professor Terry Healy and Dr Jeremy Gibb has, over a number of years, developed and refined useful numerical approaches which can be used to reduce the complex coastal behaviour along east coast beaches to simple numerical relationships (e.g. Gibb, 1998; Auckland Regional Council, 2000; Healy, 2001).

The use of a numerical approach to quantify the development setbacks helps ensure a systematic and transparent approach to hazard assessment and also enables setbacks to be readily updated with new information.

However, it is important that the development setbacks are also based on an understanding of the coastal processes and dynamics of the particular site (Kirk et al., 1999; Auckland Regional Council, 2000),

Therefore, the values adopted for the parameters in the above equation have been based on the understanding of coastal processes developed in preceding chapters. These considerations are detailed further below.

There are also some parts of the east coast beaches where the complex sand systems cannot be adequately described by the simple empirical models above – in particular, areas close to stream and estuary entrances. In such areas, we have made site-specific determinations of the setbacks based on field inspections, morphology, changes evident on historical photos and other lines of evidence.

In regard to undeveloped sites, the above formulae are not appropriate for development setbacks as they only consider coastal hazards. As discussed in section 5.2.2, setbacks in such areas will almost certainly have to be composite setbacks sufficient to provide for a wide variety of other coastal management concerns (see section 1.4 and Appendix E). Setbacks in these areas have been determined on the basis outlined in section 5.2.2.

The following sections outline estimates of various parameters used in estimation of the setbacks for the developed beaches of the eastern Coromandel.

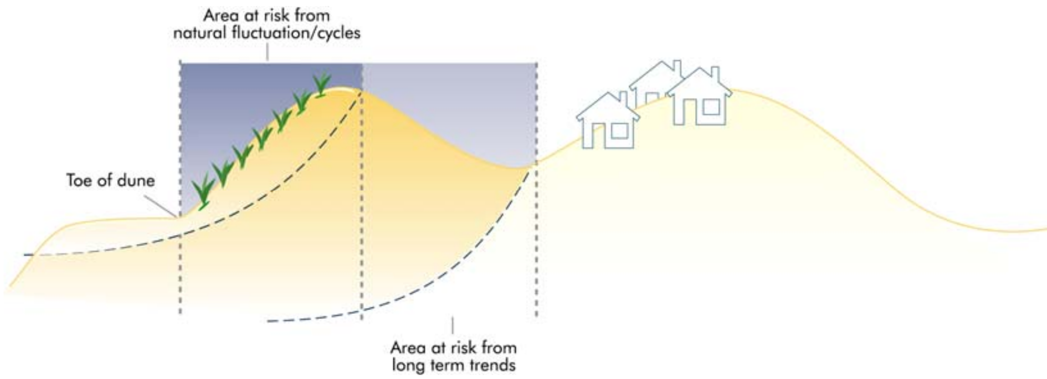


Figure 5-4: Setbacks proposed for eastern Coromandel Beaches (see text for discussion).

5.4.2.1 Long-term Shoreline Trends (R)

The analysis of existing shoreline changes outlined in Chapter 3 considered trends in Holocene progradation and shoreline changes over the last 50-100 years. Results suggest that most eastern Coromandel beaches are either in or approaching dynamic equilibrium - with no consistent evidence of long-term trends for either progradation or recession at most sites.

For instance, the long-term trend data from the Holocene cores indicates that net seaward progradation of the beaches has gradually been decreasing over time. The average rates for the last 500-1500 years are generally very low and have probably followed the historical trend to gradually decrease further over this time (i.e. the existing rate is probably lower than the average).

As discussed in Chapter 3, there may be some ongoing progradation at one or two sites (e.g. Pauanui or Whitianga), though available data is ambiguous and also tends to suggest that any such change is negligible.

There is also a danger in incorporating long-term trends for progradation into the calculation of development setbacks. For instance, if a beach had a long-term rate of progradation of 0.1 m/yr, then the numerical procedures used to define the development setbacks (see above equations) would reduce the width of the setback zone by 10 m (i.e. R x 100). However, this assumes that the 10 m is already in place, when in fact it will be several decades before this is true. Consequently, if a major erosive period occurs within the next few years, before the long term progradation has occurred, the development setback may prove to be insufficient to protect properties.

Therefore, no long-term trends for recession or progradation have been assumed in placing the development setbacks (i.e. a value of R=0 has been adopted for the calculations). We believe this is most appropriate approach, both in terms of the available data and the statutory requirement to adopt a precautionary approach to remaining uncertainties.

5.4.2.2 Maximum shoreline fluctuation (S)

Available data suggests that the beaches of the eastern Coromandel are characterised by dynamic shoreline fluctuations occurring over periods of several decades.

At most sites, it appears that the maximum shoreline fluctuation occurring over periods of several decades is about 30 m.

There is also some limited evidence that the maximum shoreline fluctuations at pocket beaches may be slightly less than those observed at the finer-grained, more dissipative barrier spit beaches. The largest shoreline change noted at either Whiritoa or Tairua was 22 m, excepting areas at Whiritoa near stream entrances.

Ideally, more data on shoreline change at pocket beaches is required. However, given the 10 m dune buffer adopted in addition to the development setbacks, we are inclined to adopt 25 m as the maximum shoreline fluctuation likely for pocket beaches – excepting areas near streams, where larger setbacks may be necessary depending on site specific characteristics.

Therefore, a figure of 30 m is adopted for maximum shoreline fluctuations on the fine-grained barrier dune systems and 25 m for the coarser-grained pocket beaches.

In general, the only larger fluctuations noted occurred in areas adjacent to ebb tidal deltas or close to stream or estuary entrances (e.g. Figure 3-12), in the immediate vicinity of large stormwater outlets (e.g. Figure 3-10), and at the south end of Whangamata Ocean Beach where wave refraction around Clark Island appears to result in slightly larger fluctuations (Figure 3-10). Site-specific estimates of shoreline fluctuations were incorporated into setbacks in areas near stream and estuary entrances.

5.4.2.3 Potential Impact of Predicted Global Warming (X)

There are a number of effects likely to accompany predicted global warming that may exacerbate coastal erosion. Hicks (1990) noted that these effects include:

- a rise in mean sea level (more accurately, an increase in the rate of rise – since available information tends to suggest that sea level around New Zealand has generally been rising at a rate of 1.3-2.3 mm/yr over the past 100 years).
- a possible increase in the frequency and intensity of coastal storms on north-east exposed coasts of the North Island
- possible reorientation of shorelines in response to changes in littoral drift.

The scale of any such effects and their timing are, like global warming, matters of considerable uncertainty and ongoing scientific enquiry and debate. Nonetheless, there is presently a broad scientific consensus that global warming is likely to occur and to be accompanied by effects such as a rise in mean sea level (IPCC, 2001). There is also a requirement in the NZCPS for policy statements and plans to " … *recognise the possibility of a rise in mean sea level, and … identify areas which would as a consequence be subject to erosion or inundation* …" (Policy 3.4.2).

Moreover, when considering shoreline changes over periods of several decades, macro-scale processes such as sea level rise can become important factors (Sherman and Bauer, 1993).

Therefore, it is important to estimate the potential impact of global warming in considering the hazard posed by coastal erosion.

However, apart from sea level rise, it is not presently possible to make any useful quantitative estimates of the effects likely to accompany predicted global warming or their impact on coastal erosion. Therefore, in this report, comment on the possible effect of predicted global warming is restricted to the potential impact of associated sea level rise.

Projections of future changes in sea level as a consequence of global warming have been made by IPCC (2001). In essence, global mean sea level is projected to rise by 0.09-0.88 m by 2100 AD, with the most likely range being 0.3-0.49 m (IPCC, 2001; Bell et al., 2001).

This figure is a global average and will almost certainly vary around the globe. However, at this point in time, there is no site-specific information available for the Coromandel (or New Zealand) coastline.

A rise of 0.5 m by 2100 AD has been adopted for the estimates of erosion made in this report, though clearly the actual change could lie in the range of 0.08-0.88 m. We believe that the estimate of 0.5 m is consistent with a precautionary approach without being unduly conservative.

There have been a large number of discussions of the implications of sea level rise for coastal systems, especially considering increased coastal erosion and shoreline retreat (Dubois, 1992; Dolotov, 1992).

In general, assessments of erosion are based on the assumption that, for coastal systems in short-term equilibrium, inundation by sea level rise will cause a landwards translation of beach profiles as described by the Bruun Rule (Bruun, 1962; 1983).

This rule argues that as sea level rises against a shore profile in equilibrium, beach erosion takes place to provide sediments to the nearshore so that the seabed can elevate in direct proportion to the rate of sea level rise.

Bruun proposed the following simple equation to estimate the extent of shoreline retreat:

$$X = al/h$$

where X is the shoreline retreat, a is the rise in mean sea level, l is the horizontal distance between the foredune crest and the seaward limit of profile adjustment (a depth known as the closure depth, a critical factor in the estimates and not always easy to determine) and h is the elevation between these two points.

Dubois (1992) assessed the validity of Bruun's model in several coastal environments and found the model provides a reasonable representation of the migration of shoreface morphologies. However, Dubois (1992) also noted that Bruun's model becomes unrealistic when the entire shoreface is considered, where there are strong lithological controls or where systems are strongly three-dimensional with significant longshore transport in and/or out of the beach system (Sherman and Bauer, 1993).

Strong lithological controls are generally not relevant for most Coromandel beaches out to the seaward edge of the nearshore beach systems (typically depths of less than 7 m below MSL), with mobile sands tending to characterise these areas (McLean, 1979; Bradshaw, 1991; Bradshaw et al., 1991). Within these areas, it is probable that the nearshore profiles are in dynamic equilibrium, fluctuating about an average. Many beaches also demonstrate significant morphological and/or sediment changes at this point (e.g. McLean, 1979) – suggesting it is probably the most appropriate point to adopt for the closure depth, rather than shoreface areas further offshore.

It has long been recognised that the two-dimensional Bruun Rule is inappropriate where there are significant rates of longshore transport. In these situations, the sediment volumes required for profile adjustment can be supplied by transport into the beach system and not require any net transfers from subaerial parts of the beach-dune system. However, most Coromandel beaches are embayed and appear to be relatively discrete sediment systems (McLean, 1979; Healy et al., 1981; Bradshaw, 1991), with little longshore transport between beaches and no significant, net sediment supply from outside the beach system. This is also supported by the Holocene data discussed in this study.

Overall, we believe the assumptions underlying application of the Bruun Rule generally apply to Coromandel beaches and that estimates of potential erosion obtained using this method will be relevant.

Moreover, from a pragmatic point of view, the only simple alternatives to the Bruun rule are either to guess the impact of predicted global warming or to ignore these effects completely. The latter is incompatible with clear policy directions contained in the NZCPS. We also believe that to ignore the potential impact of predicted global warming, despite the broad scientific consensus in regard to these changes (IPCC, 2001; Bell et al., 2001; Hume, 2002), is not consistent with the adoption of a precautionary approach.

Estimates of the additional erosion that could be associated with a rise in sea level were made using the Bruun Rule for two barrier spit beaches (Pauanui and Buffalo) and two pocket beaches (Whiritoa and Tairua) (Table 5-1).

Table 5-1: Estimates of additional erosion that could be associated with predicted sea level rise at Pauanui and Buffalo Beaches

	Pauanui	**Buffalo**	**Whiritoa**	**Tairua**
Elevation difference (H)	15m	8m	18	23
Distance (L)	500m	350m	500	545
Sea level change (a)	0.5m	0.5m	0.5	0.5 m
Potential Erosion (aL/H)	**17**	**22**	**14**	**12**

The parameters used in these calculations for Buffalo and Whiritoa beaches were based on dune and offshore surveys conducted by Environment Waikato (at ccs 25/1 for Buffalo and ccs 61 for Whiritoa). The Tairua calculations were based on offshore data from Hydrographic Survey 534 (using original sounder sheets provided by the Hydrographic Office) and beach-dune data from ccs 36/1 located in the centre of the beach. The Pauanui calculations were based on the lower order estimates reported in Appendix 11 of Gibb and Aburn (1986).

The seaward edges of the nearshore-beach systems were adopted as the seaward edge of the profile of adjustment (“closure depth”). At these four sites, the seaward edge of the nearshore-beach systems are usually marked by fairly sharp changes in offshore slope and, in some cases (e.g. Whiritoa), by significant changes in sediment characteristics (McLean, 1979; Gibb and Aburn, 1986; Bradshaw, 1991). For these beaches, the seaward edge of the nearshore beach system typically lies in water depths of approximately 3 m (Buffalo) to 6-7 m (Pauanui, Whiritoa and Tairua) below chart datum.

Dunes were included in the profile of adjustment at all sites.

Results for these sites are shown in Table 5-1.

These results suggest a figure of about 15 m for medium-coarse grained pocket beach systems and about 20 m for the more dissipative beaches, which characterise the fine-grained barriers.

Other offshore survey information is also available (e.g. Healy et al., 1981; Hydrographic charts) but it is difficult to estimate closure depth from this data without additional information on this surveys. However, approximate estimates of erosion were made using survey data from Healy et al. (1981) and these typically ranged from 15-20 m.

Gibb (1994) reports that estimates for ocean beaches in the Bay of Plenty have typically ranged from 20-35 m. This tends to suggest that our estimates are not unduly conservative and tend to be lower- rather than upper-level estimates.

Therefore, on the basis of existing information we believe that the figures of 15 m and 20 m respectively are probably adequate as blanket estimates for the Coromandel pocket beaches and barrier spit systems, respectively.

5.4.2.4 Additional Buffer Zone/Safety Factor (F)

The setback estimates include an allowance to ensure the maintenance of a dune buffer, even in the event of serious coastal erosion (Figure 5-4; see also discussion in section 5.2.1.1).

We have been constrained in the safety factor adopted by a desire to minimise constraints on the very valuable nearshore properties.

After detailed consideration, we have adopted a figure of 10 m for eastern Coromandel beaches. On the basis of present knowledge, outlined in Chapter 3, it should be adequate for most conditions likely to be experienced.

In other words, it is a <u>reasonable</u> bare minimum to adopt at developed sites for the factors outlined in section 5.2.1.1, excepting the preservation of natural character. It cannot be guaranteed that the safety factor will be adequate to provide for all conceivable events. As noted by Healy (2001) and many others, there is always the possibility that extraordinary hazard events may occur that result in far more serious erosion or flooding than is evident in the available historical data.

If either the councils or other parties require more “cast iron” guarantees, then a larger safety factor will need to be adopted. However, our view is that, at many developed sites, this would place such severe constraints on reasonable property use that it would undermine rather than assist effective hazard management.

5.4.2.5 Setback Estimates

Setbacks estimated from the above considerations are shown in Table 5-2.

Table 5-2: Development setback recommendations for eastern Coromandel beaches.

	Maximum likely shoreline fluctuation (m)	Long-term shoreline trend (m)	Dune Buffer Zone Allowance (m)	Primary Development Setback (PDS) (m)	Additional erosion that may accompany projected sea level rise (m)	Secondary Development Setback (SDS) (m)
Developed Barrier Spits	30	0	10	**40**	20	**60**
Developed Pocket Beaches	25	0	10	**35**	15	**50**
Un-developed Beach areas						**100 Minimum**

These setbacks are very close to the existing 30 m and 60 m setbacks – the major difference arising from the allowance for a dune buffer zone. We believe the minimal allowance for a dune buffer zone is important for the reasons outlined above in Section 5.2.1.1.

Therefore, it is proposed that the existing blanket setbacks for developed Coromandel beaches be adjusted as per Table 5-2, except for those regions in close proximity to stream or estuary entrances and other limited localities (e.g. major stormwater outlets) where higher setbacks are likely to be required. We have estimated the latter on a site-specific basis during the setback mapping process – using historical photos and morphologic evidence.

5.4.3 Mapping of recommended setbacks

The recommended setbacks have been plotted on rectified images for all developed eastern Coromandel beaches and are stored on Environment Waikato's GIS system. While not ideal, it was the best GIS framework available to us at the time the work was completed.

The plotting procedure involved mapping the seaward edge of vegetation from vertical colour aerial photography flown in 1995/96, with the required setbacks then measured from this baseline.

In mapping the toe of dune from the 1995/96 aerial photography, considerable care was taken to keep this line reasonably smooth. This was necessary to minimise irregularities in location of the setback boundary, which could potentially disadvantage some properties in relation to adjacent areas.

Field checks of the plotted dunelines were also conducted prior to plotting the setbacks at all sites - except those from Kennedy Bay (Figure 1-1) north. These field checks included examination of all significant irregularities in the duneline and measurements of the duneline in relation to property boundaries. The latter measurements were particularly designed to ensure that the mapped edge of vegetation adequately coincided with the seaward dune toe (after periods of sustained beach and dune accretion, it is not unusual for spinifex runners to extend seaward of the dune toe).

The photography used for the setback mapping was flown after a long period of sustained beach and dune recovery, possibly related to the longest period of El Nino conditions for many years. Evidence from beach profiles indicates that most Coromandel beaches were in a fairly prograded state at this time, probably towards the seaward rather than the landward edge of the dynamic envelope. Therefore, we believe that adopting the 1995/96 duneline as a baseline is unlikely to have introduced significant additional conservatism into the development setbacks. This could arise if the baseline adopted for mapping had followed a period of sustained erosion and lay towards the landward margin of the dynamic envelope, since much of the width of the dynamic envelope would then be "double-counted."

It should be noted that the recommended setbacks are relatively narrow compared to setbacks adopted at many beaches further south in the Bay of Plenty. The latter sites include Waihi Beach, just beyond the southern end of the Coromandel coast, where a hazard management setback of up to 135m was recently affirmed by the Environment Court as being appropriate for that site and not unduly conservative on the basis of existing information.

Therefore, while there may be some scope for minor adjustment in the future, it is unlikely that setbacks are unduly conservative in most areas. This was also the view of the scientific reviewers (Hesp, 2001; Hume, 2002).

5.4.4 Effect of erosion resistant materials and shoreline armouring

It was noted in Section 3.2.2 that many pocket beaches have a veneer of dune sands over older, more erosion resistant materials. These underlying materials will severely limit maximum possible erosion at many sites – such as parts of Wharekaho, Opito and Hahei beaches.

There is generally insufficient information on the location and extent of such resistant materials to incorporate consideration of these effects in the development setbacks. Therefore, most of the mapped setbacks do not take this potential effect into account. I.e. The development setbacks have generally been mapped as if erosion resistant materials did not exist.

However, following field inspections and community information, the primary development setback at Hahei, Maramaratotara and parts of Wharekaho and Opito was reduced to 30 m to partially allow for these effects. These changes have only been made where it was very clear from field inspections that the reduced setback was appropriate.

Setback reductions may also be possible at other sites, and will be considered as new information comes to hand. The secondary development setback will not be relevant in many areas because of erosion resistant materials.

In some areas, shoreline protection structures have been placed along the frontages of existing properties. This is particularly the case at Buffalo, Cooks and Hahei beaches. However, none of these works have been consented as appropriate long-term solutions to erosion hazard and most lack proper engineering design and construction. Many also do not have relevant authorisation. Therefore, any effect of these structures on coastal erosion has been ignored in fixing the development setbacks (i.e. the lines have been placed as if the structures did not exist).

5.5 Hazard Management Coromandel West Coast

5.5.1 Existing coastal hazard management provisions

At present, there are two separate hazard management provisions used along the western Coromandel coast – a 15 m development setback and a design coastal flood level of RL 3 m.

As noted in Section 4.2, there is some uncertainty with respect to the existing design flood level but existing information does not allow any useful revision of this figure.

The 15 m setback was adopted as an interim measure on the recommendation of Environment Waikato, following problems with coastal erosion at various points around the margin of several Thames Coast alluvial deltaic fans, particularly fronting Te Puru School.

Problems were especially being experienced in areas where there was little to no width of esplanade reserve landward of the shoreline. It was also noted that new houses were tending to be built as far seaward as possible and were often large and non-relocatable. Prior to the interim setback recommendation, the only setback required along the margin of most coastal settlements was a 7.5 m setback from the front property boundary.

A 25 m setback was initially proposed but District Council staff were reluctant to accept this in the absence of hard information that coastal erosion of this magnitude could occur along this coast in areas away from the entrance of local streams. The interim setback of 15 m was proposed based on a conservative estimate of the maximum shoreline fluctuation along the frontage of Te Puru School *prior to Cyclone Drena.* The 15 m setback is a building exclusion zone.

5.5.2 Coastal hazards on Western Coromandel

The considerations in Chapter 4 have revealed that the western Coromandel coast is susceptible to a number of quite different and complex coastal hazards – particularly alluvial deltaic fans such as those of the Thames Coast.

The coastal hazards affecting the alluvial deltaic fans of the Thames Coast are summarised in the schematic illustration shown in Figure 5-5.

The margins of the delta are affected by:

- coastal erosion associated with shoreline fluctuations, with these changes usually the most significant in the vicinity of stream and river entrances

- high velocity wave effects where the coastal margin is over-topped, including the landward transport of significant volumes of rock debris where this material exists on the local shoreline ("V" zone, Figure 5-5).

Some of the deltaic fans also exhibit significant instability over periods of several decades associated with changes in position of the river entrance. The Waikawau and Tapu deltas appear particularly significant in this regard, though large changes are also evident at Te Puru. It appears that, under natural conditions, these changes could result in very significant shoreline changes over periods of 50-100 years. As noted in Chapter 4, it is possible that some of the deltaic fans may have been completely reworked by such changes over periods of 100-200 years or more.

Large areas of the deltaic fans also lie below the present coastal design flood level and some deltas (e.g. Te Puru, Tararu and Waikawau) have also been significantly flooded by more common events such as the July 1995 and Cyclone Drena events.

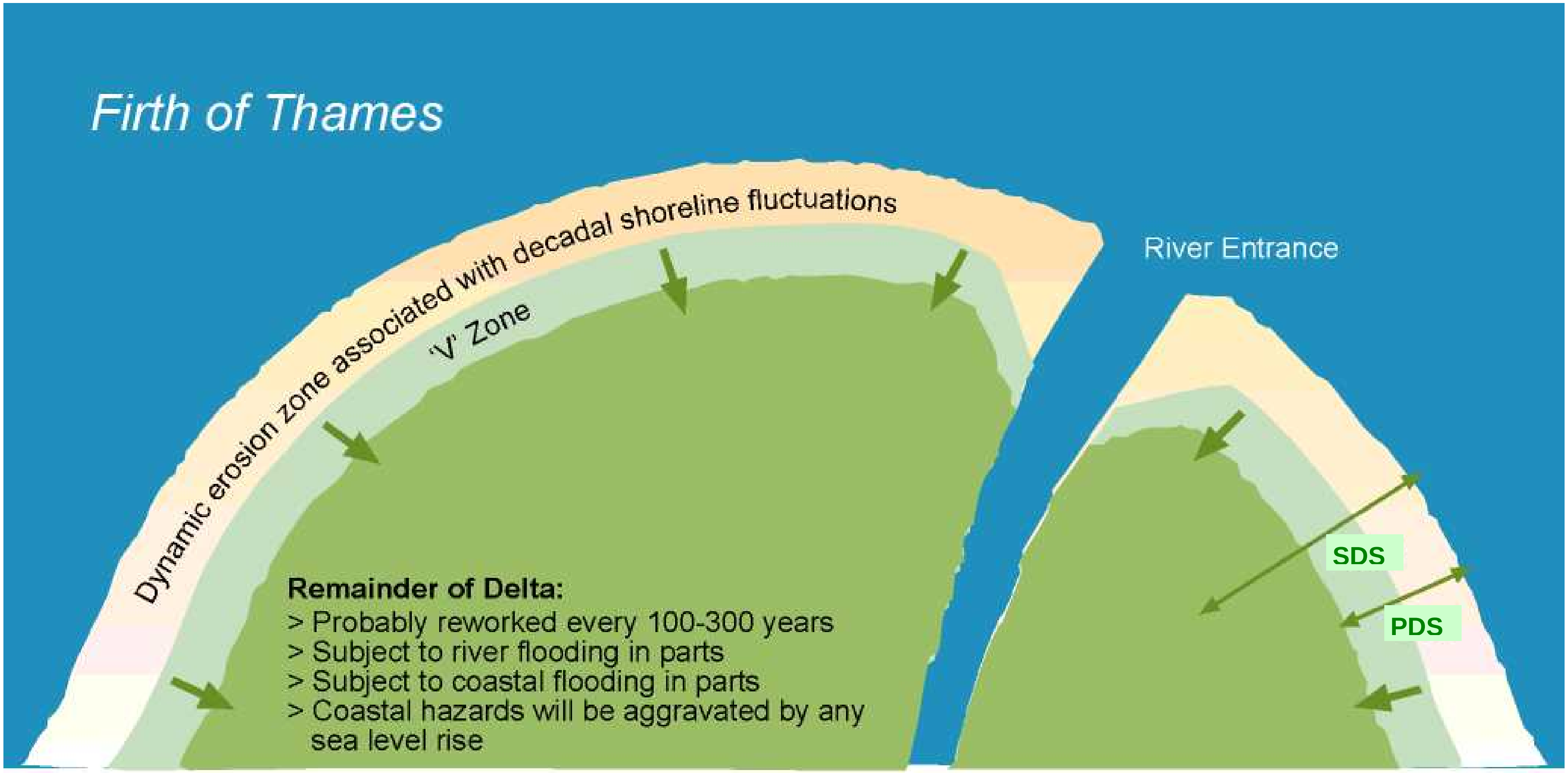
A rise in mean sea level is likely to considerably exacerbate all of these hazards.

In addition to the wide variety of coastal hazards, some of the deltas are also significantly vulnerable to river flooding, particularly Te Puru.

Therefore, despite being located in a relatively sheltered environment, the deltaic fans of the Thames Coast appear to be vulnerable to a surprising range of natural hazards.

Many other low-lying coastal environments around the Firth of Thames are also vulnerable to many of these hazards, particularly coastal flooding, wave overtopping and erosion associated with shoreline fluctuations. At least one other coastal alluvial environment (Koputauaki Bay) has also exhibited large-scale shoreline changes similar to Waikawau and Tapu (Figure 4-7).

Most of these settlements have largely been developed since the mid-late 1950's. Like the Coromandel east coast, development has generally been placed very close to the sea – with most beachfront development less than 50 mfrom the shoreline, much of this closer than 25 m (Figure 5-2).



PDS: Primary Development Setback to avoid risk associated with dynamic shoreline fluctuations and an additional buffer zone (about 10 m) to allow for high velocity effects and rock debris accompanying wave overtopping of coastal margins.
SDS: Secondary Development Setback plus an additional setback to provide for the potential impact of predicted sea level rise on coastal hazards.

Figure 5-5: Schematic picture of a typical Thames Coast delta – showing the various coastal hazards the deltas are exposed to and the proposed hazard setbacks (see text for more discussion).

The 40-50 year period since this development appears to have had a much lower than average occurrence of significant coastal flooding events (Table 4-3). On average, coastal flooding of similar or greater magnitude to Cyclone Drena may be almost twice as frequent as has been experienced in this period (Table 4-3).

The range of hazards faced by these settlements, particularly the deltaic fans of the Thames Coast, raises serious questions about their long-term sustainability – particularly in the event of a significant rise in mean sea level. These issues should be explored in detail before any significant intensification of existing development (as might for example arise from sewage reticulation).

5.5.3 Proposed Development Setbacks

5.5.3.1 Developed Areas

In areas of existing development, the following setbacks are proposed:

Primary Development Setback

This setback is designed to provide for dynamic shoreline changes ***plus*** a suitable buffer to allow for the reduction or dissipation of high velocity effects during periods of wave overtopping. As with the existing 15m setback, it is recommended this should be a building exclusion zone.

Information presented in Chapter 4 suggests that the maximum, dynamic shoreline fluctuations are typically less than 10-15 m in areas removed from the influence of stream or river mouths, though fluctuations as high as 20 m have probably occurred in some exposed areas (e.g. along the front of Te Puru School). Similarly, the most significant gravel overwash effects tend to be observed within 10-15 m of the shoreline, though lesser effects also occur further inland.

Therefore, we have adopted a primary development setback of 25 m for most developed areas, except those in the vicinity of stream or river entrances. Setbacks in these latter areas were determined on the basis of site-specific information – estimating the magnitude of possible decadal changes on the basis of field examinations, coastal morphology and historical changes shown on vertical and oblique aerial photography (held by Environment Waikato) and the limited available cadastral survey information.

The 25 m setback will provide reasonable protection from coastal erosion and high velocity wave effects without too severely constraining the use of most properties.

The setback is not adequate to protect the properties from coastal flooding. It does provide a useful width of coastal margin free from development that can be raised, where appropriate, to help alleviate flooding. However, in some areas (e.g. parts of Te Puru), raising the coastal margin to provide protection from coastal flooding will hinder the release of river floods through secondary flood channels and may aggravate river flooding. Therefore, to provide improved protection against coastal flooding, it is recommended that a minimum floor level also be adopted (see discussion further below).

As with the Coromandel east coast, the setbacks have been determined as if existing shoreline armouring works were not present. For example, there is extensive rock protection (currently buried) along the coastal margin south of Te Puru Stream and this lies well seaward of the PDS. At Tararu, from Wilson Street to just south of Robert Street, the present shoreline is held artificially seaward by shoreline armouring structures. In this area we have estimated the shoreline adjustment that would occur in the absence of the shoreline armouring structures and added this width to the setback. This adjustment has been calculated by comparing surveyed cross-sections with adjacent beach areas.

The only other exception to the blanket setback of 25 m occurs at Otautu Bay in the northern Coromandel (Map 21), where a setback of 15 m has been recommended. The existing developed area at this site is elevated well above existing or potential coastal flooding and is subject only to coastal erosion. Historical photographs show little shoreline change at this site and we believe the lesser setback offers adequate protection to dwellings.

There are some areas where the proposed primary development setback and associated management provisions are unlikely to be practical as they impact too severely to enable reasonable use of many existing properties. This is particularly the case for some properties at Te Puru (particularly Te Puru School from Tatahi Street south) and at Tararu (particularly near Robert and Wilson Streets and immediately south of Tararu Stream) (Map 26 & 27).

The hazard issues at both of these sites are complex and it is probable that site-specific hazard management strategies will also be required to fully address the issues. Site-specific strategies will also be required at any other sites where the setback precludes reasonable use of existing properties and cannot be adequately reduced on the basis of further information from the community.

As the alluvial fans of the Thames Coast are complex features subject to both coastal and river flooding and to both coastal and river erosion (Figure 5-5), it will generally be necessary to develop a site-specific hazard management strategy for all affected properties rather than treat individual sites in isolation. The strategies will also need to consider all hazards, rather than being based around any particular hazard. Otherwise, there is a danger that action taken to mitigate one hazard may aggravate another.

Secondary Development Setback (SDS)

This setback provides an allowance for the aggravation of existing coastal hazards likely to accompany a projected rise in mean sea level of 0.5 m over the next 100 years.

The effect of the rise in sea level on erosion of the Thames Coast deltaic fans is difficult to estimate, though it is probable that there would be some landward erosion. If the profile adjustment was limited to the narrow “fillet” beach fronting most shorelines, then erosion would probably only be of the order of 5-7 m. However, a wide inter-tidal zone also fronts the beaches. If this area was raised in elevation by 0.5 m during the gradual sea level rise, as would seem probable, significant sediment volumes would be required. This could promote more significant beach erosion, depending on the effect of this sediment sink on the sediment budget of the beach.

More significantly, the rise in mean sea level would seriously aggravate both coastal flooding and wave over-topping issues. It is unlikely that settlement would be sustainable on many areas of the alluvial fans under these conditions – particularly not in coastal margin areas that would be subject to very significant wave effects.

It is difficult to estimate these effects and setback requirements. However, we propose a minimum 50 m setback to allow for the impacts of predicted sea level rise.

We recommend that there should be no intensification of existing subdivision or development permitted within this area.

We do not believe this setback alone will be sufficient to mitigate the increased flooding and wave effects. However, we believe it probably would be sufficient to accommodate the worst likely additional erosion **and** provide sufficient remaining width for the construction of a wave and flood protection embankment.

It is our judgement that flood protection embankments will be required at many Coromandel west coast sites in the event of a rise in mean sea level of 0.5 m. Coastal flood protection embankments may even be required at many sites with existing coastal processes, as has already proved to be the case at Tararu.

However, as noted further above, there will be cases where flood protection embankments may not be practicable, since they would seriously reduce flood release during stream flooding. This has already proved to be the situation along some areas of the Te Puru foreshore which drain secondary channels operative during stream floods.

We have also adopted the 50 m setback as the recommended minimum setback for most undeveloped areas. As well as providing for longer-term hazard implications, we believe this setback is the minimum likely to be required to provide for other coastal management objectives, including the preservation of natural character. It is recommended that subdivision and development not be permitted within this setback at undeveloped sites.

We have recommended a larger setback for some undeveloped areas, such as those at Tapu and Waikawau. This setback at Tapu is designed to preclude use of the recent accretion at Tapu, which is very low-lying and which will probably continue to come and go over time scales of several decades. (As a general rule of thumb, we would argue that no development should occur on any recent accretion along the western Coromandel, since such areas are almost certainly dynamic over periods of decades). The larger setback at Waikawau is adopted in view of the considerable instability of this feature.

The larger setbacks at both Tapu and Waikawau only affect land already designated as reserve or otherwise in public ownership.

A rise in mean sea level of 0.5 m would raise serious issues about the sustainability of settlements on the alluvial fans, markedly increasing the frequency and severity of flooding and exposing coastal margins to very severe wave effects (see discussion in section 4.2). Therefore, we believe that serious consideration should be given to future implications before any further development or intensification of existing settlements on these alluvial fans. An expectation of reasonable use obviously applies to areas in which subdivision and development rights have already been granted. However, we recommend against any further designation of land for new or more intense subdivision or development, unless the long-term hazard implications have been fully considered and resolved to the satisfaction of both councils.

Mapping of setbacks

The recommended setbacks have been mapped on rectified images as per the process adopted for the eastern Coromandel (see Section 5.4.7 above).

Setback maps for all key sites are shown in Appendix D.

Minimum floor level of RL 3 m

We recommend that the present 1% AEP design coastal flood level be adopted as the minimum floor level in all areas potentially subject to coastal inundation. As noted above, a minimum floor level is required because the recommended primary development setback does not provide protection from coastal flooding.

Available information suggests this minimum floor level will provide a standard of flood protection at least equal to the 2% AEP standard required by the Building Act. Present information on extreme coastal flood levels (see section 4.3) suggests that this minimum floor level will also maintain a similar standard of flood protection to at least 2050, even with best present estimates of sea level rise over that period (<0.2 m).

This recommendation is not in any way intended to propose a lowering of any existing minimum floor level standards or recommendations developed on the basis of site-specific considerations. A higher standard may well be appropriate in some areas. Rather, the intent of the recommendation is to ensure that a basic minimum standard of coastal flood protection is achieved in all areas.

It is important not to ignore the potential for coastal flooding simply because of the relatively low frequency of such events over the last 40 years. We reiterate earlier findings (Dahm, 1999b; see also section 4.2 of this report) that severe coastal flooding events (i.e. of similar or greater severity than Cyclone Drena) appear to have a much higher frequency than suggested by the occurrence of such events over the last 40 years. We also believe that coastal flooding with an annual probability of 2% or less may well be more severe than that experienced during the recent July 1995 or Cyclone Drena events.

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Appendix A: Holocene Sample Sites and Radiocarbon Dates

Site	Site Number	Sample Reference Number	Age in Radiocarbon years	Maximum Calibrated Age (Years)	Calibrated Age (Years)	Minimum Calibrated Age (Years)r	Distance from Shore (m)
Whitianga	WH1	WK2114	6160BP ± 60	6754	6630	6461	2735
	WH2	WK2115	1440BP ± 50	1120	984	907	421
	WH3	WK2116	2840BP ± 60	2756	2680	2413	1092
	WH4	WK2117	3600BP ± 50	3633	3493	3378	1414
	WH5	WK2118	3470BP ± 60	3485	3360	3218	1841
	WH5B	WK2267	3540BP ± 60	3589	3440	3319	1842
	WH6	WK2119	1070BP ± 80	779	650	519	80
	WHIT34	WK4436	5380BP ± 70	5916	5750	5606	2665
	WHIT35	WK4437	4960BP ± 60	5461	5300	5192	2545
	WHIT36	WK4438	4540BP ± 70	4884	4800	4544	2359
	WHIT37	WK4439	4020BP ± 60	4233	4060	3873	2016
	WHIT38	WK4440	3170BP ± 70	3189	2970	2786	1568
Matarangi	MAT24	WK4450	6690BP ± 70	7335	7200	7048	434
	MAT25	WK4449	4120BP ± 60	4383	4200	3998	35
	MAT26	WK4448	4330BP ± 60	4634	4460	4324	94
	MAT27	WK4447	3910BP ± 60	4077	3890	3719	55
	MAT28	WK4446	4750BP ± 70	5244	4990	4840	194
	MAT29	WK4445	6710BP ± 100	7359	7210	7085	262
	MAT39	WK4444	6780BP ± 70	7449	7270	7097	324
Tairua	T1A	WK2120	6290BP ± 80	6945	6760	6588	
	T2	WK2121	4520BP ± 80	4882	4790	4508	
Opoutere	OPT A	WK2266	7040BP ± 70	7618	7510	7378	
	OPT 18	WK4452	4650BP ± 60	5035	4860	4793	
	OPT 19	WK4451	4490BP ± 60	4836	2760	4493	
Whangapoua	WPA21	WK4453	7170BP ± 70	7747	7600	7498	160
	WPA22	WK4454	2650BP ± 60	2502	2340	2197	93
	WPA23	WK4455	1570BP ± 50	1257	1147	1018	22

Site	Site Number	Sample Reference Number	Age in Radiocarbon years	Maximum Calibrated Age (Years)	Calibrated Age (Years)	Minimum Calibrated Age (Years)r	Distance from Shore (m)
Whangamata	WGM1	WK2286	3870BP ± 60	3999	3840	3682	572
	WGM2	WK2287	2070BP ± 60	1812	1670	1512	197
	WGM3	WK2288	1070BP ± 40	708	647	566	66
	WGM4	WK2289	1540BP ± 50	1231	1107	977	66
	WGM5	WK2290	6720BP ± 70	7364	7220	7095	1008
	WGM6A	WK2291	6500BP ± 70	7168	7000	6842	951
	WGM6B	WK2296	6140BP ± 60	6734	6610	6438	952
	WGM8A	WK4435	2300BP ± 130	2285	1920	1610	208
	WGM8A+B	WK4434	2770BP ± 100	2751	2490	2288	
	WGM9	WK4433	1820BP ± 50	1501	1361	1276	91
	WGM10	WK4432	1490BP ± 50	1170	1050	935	51
	WGM11	WK4431	6670BP ± 170	7476	7180	6797	1068
	WGM12	WK4430	1550BP ± 60	1256	1120	969	20
	WGM13	WK4429	2100BP ± 50	1820	1695	1554	147
	WGM14	WK4428	2370BP ± 60	2149	2000	1861	192
	WGM41A+B	WK4427	4880BP ± 110	5476	5250	4861	800
	WGM41B	WK4426	5320BP ± 200	6170	5700	5278	
Whiritoa	WHIRI7	WK2122	780BP ± 70	530	450	287	
	WHIRI8	WK2123	1850BP ± 50	1523	1395	1950657	
	WHIRI9	WK2124	6580BP ± 120	7323	7120	6811	
Cooks	CO1	WK2052	1960BP ± 70	1699	1520	1355	59
	CO2	WK2053	3120BP ± 80	3145	2900	2742	105
	CO3	WK2054	1610BP ± 70	1301	1180	1021	16
	CO4	WK2055	4350BP ± 80	4786	4500	4288	246
	CO5	WK2056	2290BP ± 60	2064	1910	1774	46
	CO6	WK2057	1660BP ± 80	1369	1240	1055	50
	CO7	WK2058	2500BP ± 50	2312	2154	2034	112
	CO30	WK4442	4280BP ± 70	4581	4410	4221	250
	CO31	WK4443	4870BP ± 60	5324	5240	4992	355
	CO32	WK4441	7080BP ± 70	7651	7530	7399	445

Appendix B: List of Shoreline Change Plans

Location	Years	Plan Numbers	Company
Whangamata	1944 1959 1973 1978 1993	3107/1000/A1/793 Sheets 1-7	Photosurvey Ltd Auckland
Pauanui	1895 1944 1967 1971 1978 1983 1996	7204 Sheets 1-6	Works Consultancy Services Hamilton
Cooks Beach	1944 1971 1976 1/1978 9/1978 1984	3276/2000/A1/495 Sheets 1-3	Photosurvey Ltd Auckland
Buffalo Beach	1944 1967 1/1978 9/1978 1993	3240/1000/A1/395 Sheets 1-7	Photosurvey Ltd Auckland
Tararu	"Old MHWM" 1952 1998	1661 Sheets 1-6	FW Millington Ltd Thames
Te Puru	1869/70 1898 1913 1921 1927 1942 1946/47 1955 1995	1344 Sheets 1-13	FW Millington Ltd Thames
Waikawau	1925 1939 1998	1661B Sheets 1-5	FW Millington Ltd Thames
Koputauaki Bay	1909 1945 1966 1971 1983 1995	"Koputauaki Bay Foreshore" File 3237	JM Harris Ltd Te Kuiti

Table B1: Sites for which maps of historical shoreline change were compiled – showing years for which shorelines were mapped, relevant plan numbers and firms responsible for plan preparation.

Notes:

Pauanui: This work used the shoreline maps produced for the earlier work by Gibb and Aburn (1986) – adding only a 1996 survey commissioned by Environment Waikato.

Cooks Beach: The shoreline change mapping for this site was undertaken by (then) DSIR Land Resources at Aokautere. These lines were digitised by Photosurvey Ltd to secure the data and produce the above plans after earlier work at Whiritoa was lost.

Buffalo Beach: As discussed in the report text, a survey from the 1860's was also mapped and is shown on plans held by Environment Waikato – but there are doubts about the accuracy of placement of this shoreline and further information is required before this early survey can be reliably compared to recent shorelines. (See text for further discussion).

Te Puru: The only year listed for which a full shoreline survey was available was 1995 (survey commissioned by Environment Waikato). Most of the other years listed involve surveys of only short portions of the Te Puru foreshore, though at least 3 surveys were available for most parts of the foreshore.

Tararu: Only the 1998 shoreline survey (commissioned by Environment Waikato) was available for most of the shoreline length. The "old MHWM" (scaled onto the plan) covers most of the area north of Robert Street. The 1952 survey is a legal boundary survey covering much of the shoreline south of Robert Street.

Appendix C: List of Coastal Storms and Newspapers Searched

YEAR	APPROXIMATE DATE	PAPERS SEARCHED
1868	15 August	NZH
1873	20 April	NZH
1873	12 August	NZH, WT
1874	7 February	NZH
1874	14 March	NZH
1875	3 November	NZH, WT, TA
1876	20 January	NZH, WT
1876	23 July	NZH, WT, TA
1877	11 May	NZH, TA
1879	5 June	NZH, TA
1882	18 October	NZH, TA
1883	10 March	NZH, WT,
1883	24 July	NZH, TA
1883	3 November	NZH
1885	14 March	NZH, WT, TA
1886	4 June	NZH, TA
1886	26 June	NZH, WT, TA
1886	7 August	NZH, WT, TA
1886	12 September	NZH, WT, TA
1886	17 October	NZH, WT, TA
1886	10 November	NZH
1887	14 May	NZH, TS
1887	12 September	NZH, TA
1888	31 August	NZH, TA
1890	7 April	NZH, WT, TA
1890	11 September	NZH, WT, TA
1891	14 May	NZH, WT, TA
1892	5 August	NZH, WT, TA
1892	21 August	NZH, WT, TA
1893	23 February	NZH, WT, TA
1893	2 May	NZH, WT, TA
1893	15 May	NZH, WT
1893	31 May	NZH
1893	17 July	NZH, WT
1893	27 October	NZH, WT
1894	16 June	NZH, WT, TS
1894	26 November	NZH, WT
1895	2 January	NZH, TA
1895	21 May	NZH, TS
1895	7 June	NZH
1895	2 July	NZH, TA
1895	23 September	NZH, WT, TA
1895	31 October	NZH, WT, TA
1896	11 May	NZH, TA, OG
1896	22 July	NZH, TA, OG
1897	29 January	NZH, WA, TA, OG
1897	17 April	NZH, TA, OG
1897	15 May	NZH, WA, OG
1897	13 October	NZH, TA, OG

YEAR	APPROXIMATE DATE	PAPERS SEARCHED
1898	8 May	NZH, WA, TA, OG
1898	19 May	NZH, WA, TA, OG
1898	22 June	NZH, WA, TA, OG
1898	11 August	NZH, WA TA, OG
1898	26 October	NZH, WA, TA, OG
1899	26 March	NZH, WA, TA, OG
1899	30 December	NZH, WA, OG
1900	21 May	NZH, OG
1900	6 August	NZH, WA, TS, OG
1900	12 September	NZH, WA, TS, OG
1900	16 October	NZH, WA, TS, OG
1900	23 October	NZH, TS, OG
1900	31 October	NZH, TS, OG
1900	17 December	NZH, WA, OG
1900	26 December	NZH, WA, TS, OG
1901	20 May	NZH, OG
1901	19 June	NZH, WA, OG
1901	29-30 June	NZH, WA, TS, OG
1901	1 November	NZH, WA, OG
1901	12 December	NZH, WA, TS, OG
1902	13 May	NZH, WA, TS, OG
1903	5 September	NZH, WA, TS, OG
1903	21 September	NZH, TS, OG
1903	5 October	NZH, WA, TS, OG
1903	16 November	NZH, WA, OG
1904	18 February	NZH, WA, WT, OG
1905	23 June	NZH, WA, WT, TS, OG
1905	5 July	NZH, WA, WT, OG
1905	28 July	NZH, WA, WT, TS, OG
1905	1–2 August	NZH, WA, WT, TS, OG
1906	24 March	NZH, TS, OG
1906	10-11 July	NZH, TS, OG
1906	17 July	NZH, TS, OG
1907	14 January	NZH, TS, OG
1907	19 July	NZH, TS, OG
1908	8 March	NZH, TS, OG
1908	10 June	NZH, TS, OG
1909	4 January	NZH, TS, OG
1909	3 July	NZH, TS, OG
1909	3 July	NZH, TS, OG
1909	30 August	NZH, TS, OG
1909	28 December	NZH, TS, OG
1910	30 March	NZH, OG
1910	13 June	NZH, OG
1910	1-2 July	NZH
1910	21 November	NZH, OG
1911	6 February	NZH, OG
1911	24-26 February	NZH
1911	21 July	NZH, TS, OG
1912	24 April	NZH, TS, OG
1912	20 June	NZH, TS, OG
1914	17 May	NZH, TS, OG
1916	4 February	NZH, TS, OG
1916	15 July	NZH, TS, OG
1916	2 August	NZH, TS, OG
1917	21 February	NZH

YEAR	APPROXIMATE DATE	PAPERS SEARCHED
1918	14-15 February	NZH, TS, OG
1918	4 March	NZH, TS, OG
1918	20 March	NZH, TS, OG
1918	15 July	NZH, TS, OG
1920	26 March	NZH, TS, OG
1920	5 June	NZH, TS, OG
1920	19 June	NZH, TS, OG
1920	15 December	NZH, TS, OG
1921	15 January	NZH, TS, OG
1922	26 January	NZH, TS, OG
1922	25 February	NZH, TS, OG
1922	26 May	NZH, TS, OG
1923	31 January to 2 February	NZH
1923	19 April	NZH, TS, HPG
1924	11 March	NZH, TS, HPG
1924	3 April	NZH, TS, HPG
1924	16-17 May	NZH, TS, HPG
1924	24 May	NZH, TS, HPG
1926	22 January	NZH, TS, HPG
1926	3 May	NZH, TS, HPG
1926	20 May	NZH, TS, HPG
1926	11 July	NZH, TS, HPG
1926	25 December	NZH, TS, HPG
1927	25 July	NZH, TS, HPG
1928	30 April	NZH, TS, HPG
1928	26 May	NZH, TS, HPG
1928	22 July	NZH, TS, HPG
1928	28 December	NZH, HPG
1929	18 March	NZH, TS, HPG
1929	12 May	NZH, TS, HPG
1929	9 November	NZH, TS, HPG
1930	6 July	NZH, TS, HPG
1931	8 May	NZH, TS, CMBG
1931	1 August	NZH, TS, CMBG
1933	3 February	NZH, TS, CMBG
1933	22 July	NZH, TS, CMBG
1933	10 September	NZH, TS, CMBG
1934	12 February	NZH, TS, CMBG
1934	3 May	NZH, TS, CMBG
1934	19 June	NZH, TS, CMBG
1934	8 July	NZH, TS, CMBG
1934	4 September	NZH, TS, CMBG
1934	24 September	NZH, TS, CMBG
1934	2 October	NZH, TS, CMBG
1935	14 March	NZH, TS, CMBG
1935	5 July	NZH, TS, CMBG
1936	1-2 February	NZH, WT, TS, CMBG
1936	25-26 March	NZH, WT, TS, CMBG
1936	1 May	NZH, TS, CMBG
1937	14-16 May	NZH, TS, CMBG
1937	4 August	NZH, TS, CMBG
1938	5 February	NZH, TS, CMBG
1938	4 May	NZH, WT, TS, HPG
1938	26 July	NZH, TS, CMBG
1940	13-14 January	NZH, TS, CMBG
1940	3 February	NZH, TS, CMBG

YEAR	APPROXIMATE DATE	PAPERS SEARCHED
1940	26 July	NZH, TS, CMBG
1940	14 December	NZH, TS, CMBG
1941	26-27 February	NZH
1941	7-8 April	NZH
1942	15 May	NZH, TS, HPG
1942	26 August	NZH, TS, HPG
1943	5-6 January	NZH
1943	11-12 January	NZH
1943	22 September	NZH, TS, HPG
1944	23-24 March	NZH
1944	27 May	NZH, TS, HPG
1945	27 May	NZH, TS
1945	3 October	NZH, TS, HPG
1946	26 July	NZH, HPG
1946	5 August	NZH, TS, HPG
1947	14-15 January	NZH
1947	23 March	NZH, TS, HPG
1947	26 March	NZH, TS, HPG
1947	19 April	NZH, TS, HPG
1947	20-21 June	NZH, TS, HPG
1947	27 June	NZH, TS, HPG
1947	2 July	NZH, TS, HPG
1947	21 July	NZH, TS, HPG
1948	13 March	NZH, TS, HPG
1948	23 September	NZH, TS, HPG
1948	2 October	NZH, TS, HPG
1948	19 November	NZH, TS, HPG
1949	13-14 December	NZH
1950	19 May	NZH, TS, HPG
1950	4 July	NZH, TS, HPG
1950	19 November	NZH, TS, HPG
1951	22 January	NZH
1951	1 March	NZH, WT
1951	2-3 April	NZH
1951	4 July	NZH, TS, WG, HPG
1951	11 July	NZH, TS, WG, HPG
1951	22 August	NZH, TS, WG, HPG
1952	20 December	NZH, TS, WG, HPG
1953	1 April	NZH, TS, WG, HPG
1953	5 July	NZH, TS, WG, HPG
1953	18 August	NZH, TS, WG, HPG
1953	1 September	NZH, TS, WG, HPG
1954	19-20 January	NZH
1954	6 March	NZH, TS, WG, HPG
1954	17-19 May	NZH, TS, WG, HPG
1954	14 August	NZH, TS, HPG
1955	24 October	NZH, TS
1956	3-4 February	NZH
1956	9-10 March	NZH
1956	8 April	NZH, TS, WG, HPG
1959	28-29 January	NZH
1959	14-16 March	NZH, WT, TS, CMBG
1960	23 February	NZH, WT, TS, WG, CMBG
1960	3 March	NZH, TS, WG, CMBG
1960	10-11 April	NZH
1960	15 May	NZH, TS, WG, CMBG

YEAR	APPROXIMATE DATE	PAPERS SEARCHED
1960	23 May	NZH, TS, WG, CMBG
1960	19 July	NZH
1961	13-17 January	NZH
1961	11-12 February	NZH
1962	2-3 March	NZH, WT, TS, WG, CMBG
1962	15 April	NZH, WT, TS, WG, CMBG
1962	24 May	NZH, TS, WG, CMBG
1962	31 May	NZH, WT, TS, WG, CMBG
1962	6 June	NZH, TS, WG, CMBG
1962	8 October	NZH, TS, WG, CMBG
1963	20-21 February	NZH
1963	6-7 February	NZH
1964	8-11 April	NZH
1964	22-23 December	NZH
1965	12-13 February	NZH
1966	28 February	NZH, TS, WG, CMBG
1966	16-17 March	NZH
1966	2 April	NZH, WT, TS, WG, CMBG
1966	18 July	NZH, WT, TS, WG, CMBG
1967	5 January	NZH, WT, TS, WG, CMBG
1967	3 February	NZH, TS, WG, CMBG
1967	1 August	NZH, WG, CMBG
1967	10 October	NZH, WT, TS, WG, CMBG
1968	6-9 March	NZH
1968	10 April	NZH, WT, TS, WG, CMBG
1968	28 May	NZH, WT, WG, CMBG
1968	23 July	NZH, WT, WG, CMBG
1968	20 November	NZH, TS, WG, CMBG
1968	15-16 December	NZH
1969	5-7 February	NZH
1969	16 April	NZH, TS, WG, CMBG
1970	20 August	NZH, WT, TS, WG, CMBG
1971	4 January	NZH
1971	21-22 March	NZH
1972	23 January	NZH, TS, WG, CMBG
1972	15-16 May	NZH, WT, TS, WG, CMBG
1972	12 August	NZH, WT, TS, WG, CMBG
1974	21-22 January	NZH
1974	18-19 March	NZH
1975	6 February	NZH, WT, TS, WG, TPG
1975	10 March	NZH, WT, TS, WG, TPG
1975	14 June	NZH, WT, TS, WG, TPG
1976	30 April	NZH
1977	23-24 March	NZH
1977	18 May	NZH, WG, TVG
1978	17-20 April	NZH
1978	18 July	NZH, WT, TS, WG, TVG
1979	4 February	NZH, TS, WG, TVG
1979	12 April	NZH, TS, WG, TVG
1979	30 June	NZH, TS, WG, TVG
1979	9 July	TS, WG, TVG
1980	15 March	NZH, TS, WG, TVG
1980	18 October	NZH, WG, TVG
1981	8-9 March	NZH
1981	12 April	NZH, TS, WG, HH, TVG
1982	9 April	NZH, TS, WG, HH, TVG

YEAR	APPROXIMATE DATE	PAPERS SEARCHED
1982	28 July	NZH, TS, WG, HH, TVG
1983	2 March	NZH
1983	8 June	NZH, TS, WG, TVG
1983	6 December	NZH, TS, WG, TVG
1984	1 May	NZH, TS, WG, TVG
1984	2 August	NZH, TS, WG, TVG
1985	12-13 May	NZH, TS, WG, HH, TVG
1985	22 June	NZH, TS, WG, HH, TVG
1986	25 January	NZH, TS, WG, HH, TVG
1986	11 July	NZH, TS, WG, TVG
1986	21 December	NZH, TS, WG, TVG
1987	14-15 July	NZH, TS, WG, HH, TVG
1987	25 July	NZH, TS, WG, TVG
1987	2 October	NZH, TS, WG, HH, TVG
1988	8 March	NZH, TS, WG, HH, TVG
1988	16-17 April	NZH
1988	1 September	NZH, TS, WG, HH, PG
1988	3 October	NZH, TS, WG, HH, PG
1988	28 December	NZH, TS, WG, HH, PG
1989	4 January	NZH, TS, WG, HH, PG
1989	23 August	NZH, TS, WG, HH, PG, MBS
1989	8 September	NZH, TS, WG, HH, PG
1989	24 November	NZH, TS, WG, PG
1990	8-9 March	NZH
1992	20-21 February	NZH
1994	2-7 June	NZH
1995	14 July	NZH, WT, HH
1996	11-17 March	NZH
1996	23 March to 2 April	NZH
1996	25 June	NZH, WG
1996	30 December	NZH, WT
1997	11 January	NZH, WT, WG, TS, HH
1997	10 March	NZH, WT, WG, MBS
1997	1-2 June	NZH

List of storm dates searched for information on coastal flooding in the Waikato region.

The major (known) storms on the Coromandel east and west coasts since 1930 are listed in the main report in Table 2 (section 3.4) and Table 5 (section 4.2.2).

<u>KEY TO PAPERS</u>

NZH	New Zealand Herald	TVG	Thames Valley Gazette
WT	Waikato Times	PG	Paeroa Gazette
WA	Waikato Argus	CMBG	Cormomandel and Mercury Bay Gazette
TA	Thames Advertiser		
TS	Thames Star	WG	Waihi Gazette
OG	Ohinemuri Gazette	HH	Hauraki Herald
HPG	Hauraki Plains Gazette	MBS	Mercury Bay Sun

Appendix D: Development Setback Maps

Map 1: Whiritoa

0.0 0.1 0.2 0.3 km

N

Request No 7612

Legend

- Coastal Toe of Vegetation
- Primary Development Setback (PDS)
- Secondary Development Setback (SDS)
- Setback for Undeveloped Areas
- Parcel Boundary (DCDB)

Environment Waikato REGIONAL COUNCIL

Map 2a: Whangamata

0.0 0.1 0.2 0.3 km

N

Request No 7612

Legend

- Coastal Toe of Vegetation
- Primary Development Setback (PDS)
- Secondary Development Setback (SDS)
- Setback for Undeveloped Areas
- Parcel Boundary (DCDB)

Environment Waikato
REGIONAL COUNCIL

Map 2b: Whangamata

0.0 0.1 0.2 0.3 km

N

Request No 7612

Legend

- Coastal Toe of Vegetation
- Primary Development Setback (PDS)
- Secondary Development Setback (SDS)
- Setback for Undeveloped Areas
- Parcel Boundary (DCDB)

Environment Waikato
REGIONAL COUNCIL

Pacific Ocean
Bambury Pl
Onemana Dr
Onemana Dr
Oratia Pl
Map 3: Onemana
0.0
0.1
0.2
0.3 km
N
Request No 7612
Legend
Coastal Toe of Vegetation
Primary Development Setback (PDS)
Secondary Development Setback (SDS)
Setback for Undeveloped Areas
Parcel Boundary (DCDB)
Environment Waikato
REGIONAL COUNCIL

Map 4a: Pauanui

0.0 0.1 0.2 0.3 km

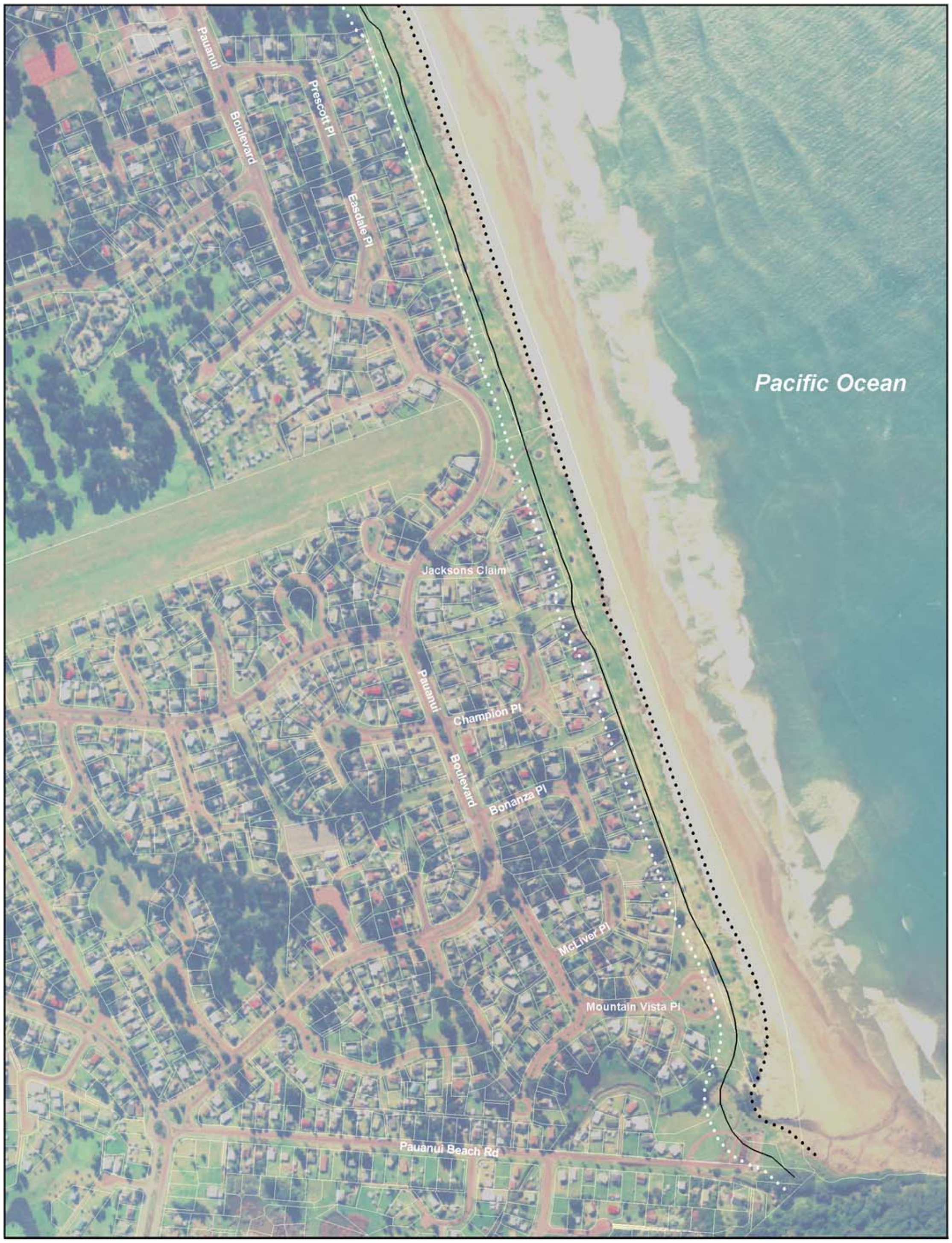
N

Legend

- Coastal Toe of Vegetation
- Primary Development Setback (PDS)
- Secondary Development Setback (SDS)
- Setback for Undeveloped Areas
- Parcel Boundary (DCDB)

Environment Waikato REGIONAL COUNCIL

Request No 7612



Map 4b: Pauanui

0.0 0.1 0.2 0.3 km

N

Request No 7612

Legend

- Coastal Toe of Vegetation
- Primary Development Setback (PDS)
- Secondary Development Setback (SDS)
- Setback for Undeveloped Areas
- Parcel Boundary (DCDB)

Environment Waikato REGIONAL COUNCIL

Map 5: Tairua

0.0 0.1 0.2 0.3 km

N

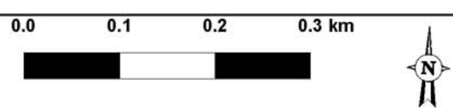
Legend

- Coastal Toe of Vegetation
- Primary Development Setback (PDS)
- Secondary Development Setback (SDS)
- Setback for Undeveloped Areas
- Parcel Boundary (DCDB)

Environment Waikato REGIONAL COUNCIL

Request No 7612

Map 6: Hahei

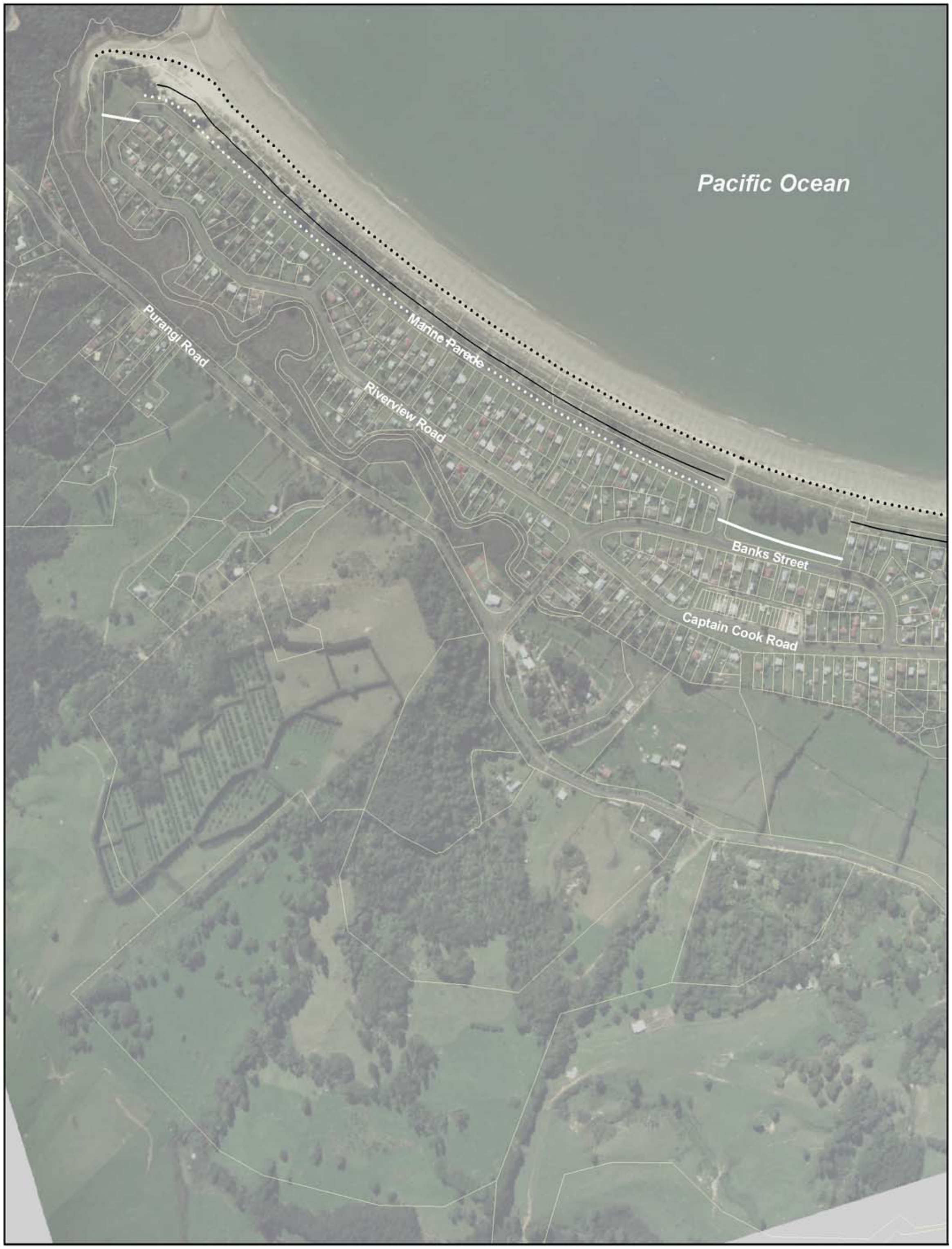


Request No 7612

Legend

- Coastal Toe of Vegetation
- Primary Development Setback (PDS)
- Secondary Development Setback (SDS)
- Setback for Undeveloped Areas
- Parcel Boundary (DCDB)

Environment Waikato REGIONAL COUNCIL



Map 7a: Cooks Beach

0.0 0.1 0.2 0.3 km

N

Request No 7612

Legend

- Coastal Toe of Vegetation
- Primary Development Setback (PDS)
- Secondary Development Setback (SDS)
- Setback for Undeveloped Areas
- Parcel Boundary (DCDB)

Environment Waikato REGIONAL COUNCIL

Map 7b: Cooks Beach

0.0 0.1 0.2 0.3 km

N

Legend

- Coastal Toe of Vegetation
- Primary Development Setback (PDS)
- Secondary Development Setback (SDS)
- Setback for Undeveloped Areas
- Parcel Boundary (DCDB)

Environment Waikato
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Map 8: Maramaratotara

0.0 0.1 0.2 0.3 km

N

Legend

- Coastal Toe of Vegetation
- Primary Development Setback (PDS)
- Secondary Development Setback (SDS)
- Setback for Undeveloped Areas
- Parcel Boundary (DCDB)

Environment Waikato REGIONAL COUNCIL

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Map 9a: Buffalo Beach

0.0 0.1 0.2 0.3 km

N

Request No 7612

Legend

- Coastal Toe of Vegetation
- Primary Development Setback (PDS)
- Secondary Development Setback (SDS)
- Setback for Undeveloped Areas
- Parcel Boundary (DCDB)

Environment Waikato REGIONAL COUNCIL

Map 9b: Buffalo Beach

0.0 0.1 0.2 0.3 km

N

Request No 7612

Legend

- Coastal Toe of Vegetation
- Primary Development Setback (PDS)
- Secondary Development Setback (SDS)
- Setback for Undeveloped Areas
- Parcel Boundary (DCDB)

Environment Waikato REGIONAL COUNCIL

Map 10: Ohuka

0.0 0.1 0.2 0.3 km

N

Request No 7612

Legend

- Coastal Toe of Vegetation
- Primary Development Setback (PDS)
- Secondary Development Setback (SDS)
- Setback for Undeveloped Areas
- Parcel Boundary (DCDB)

Environment Waikato REGIONAL COUNCIL

Map 11: Wharekaho

0.0 0.1 0.2 0.3 km

N

Request No 7612

Legend

Coastal Toe of Vegetation

Primary Development Setback (PDS)

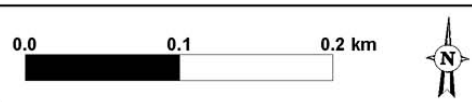
Secondary Development Setback (SDS)

Setback for Undeveloped Areas

Parcel Boundary (DCDB)

Environment Waikato REGIONAL COUNCIL

Map 12: Waitaia



Request No 7612

Legend

- Coastal Toe of Vegetation
- Primary Development Setback (PDS)
- Secondary Development Setback (SDS)
- Setback for Undeveloped Areas
- Parcel Boundary (DCDB)

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Map 13a: Opito Bay

0.0 0.1 0.2 0.3 km

N

Legend

Coastal Toe of Vegetation

Primary Development Setback (PDS)

Secondary Development Setback (SDS)

Setback for Undeveloped Areas

Parcel Boundary (DCDB)

Environment Waikato REGIONAL COUNCIL

Request No 7612

Map 13b: Opito Bay

0.0 0.1 0.2 0.3 km

N

Legend

- Coastal Toe of Vegetation
- Primary Development Setback (PDS)
- Secondary Development Setback (SDS)
- Setback for Undeveloped Areas
- Parcel Boundary (DCDB)

Environment Waikato REGIONAL COUNCIL

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Map 14: Kuaotunu East

0.0 0.1 0.2 0.3 km

N

Legend

- Coastal Toe of Vegetation
- Primary Development Setback (PDS)
- Secondary Development Setback (SDS)
- Setback for Undeveloped Areas
- Parcel Boundary (DCDB)

Environment Waikato REGIONAL COUNCIL

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Map 15: Kuaotunu West

0.0 0.1 0.2 0.3 km

N

Request No 7612

Legend

- Coastal Toe of Vegetation
- Primary Development Setback (PDS)
- Secondary Development Setback (SDS)
- Setback for Undeveloped Areas
- Parcel Boundary (DCDB)

Environment Waikato REGIONAL COUNCIL

Map 16: Rings Beach

0.0 0.1 0.2 0.3 km

N

Legend

- Coastal Toe of Vegetation
- Primary Development Setback (PDS)
- Secondary Development Setback (SDS)
- Setback for Undeveloped Areas
- Parcel Boundary (DCDB)

Environment Waikato REGIONAL COUNCIL

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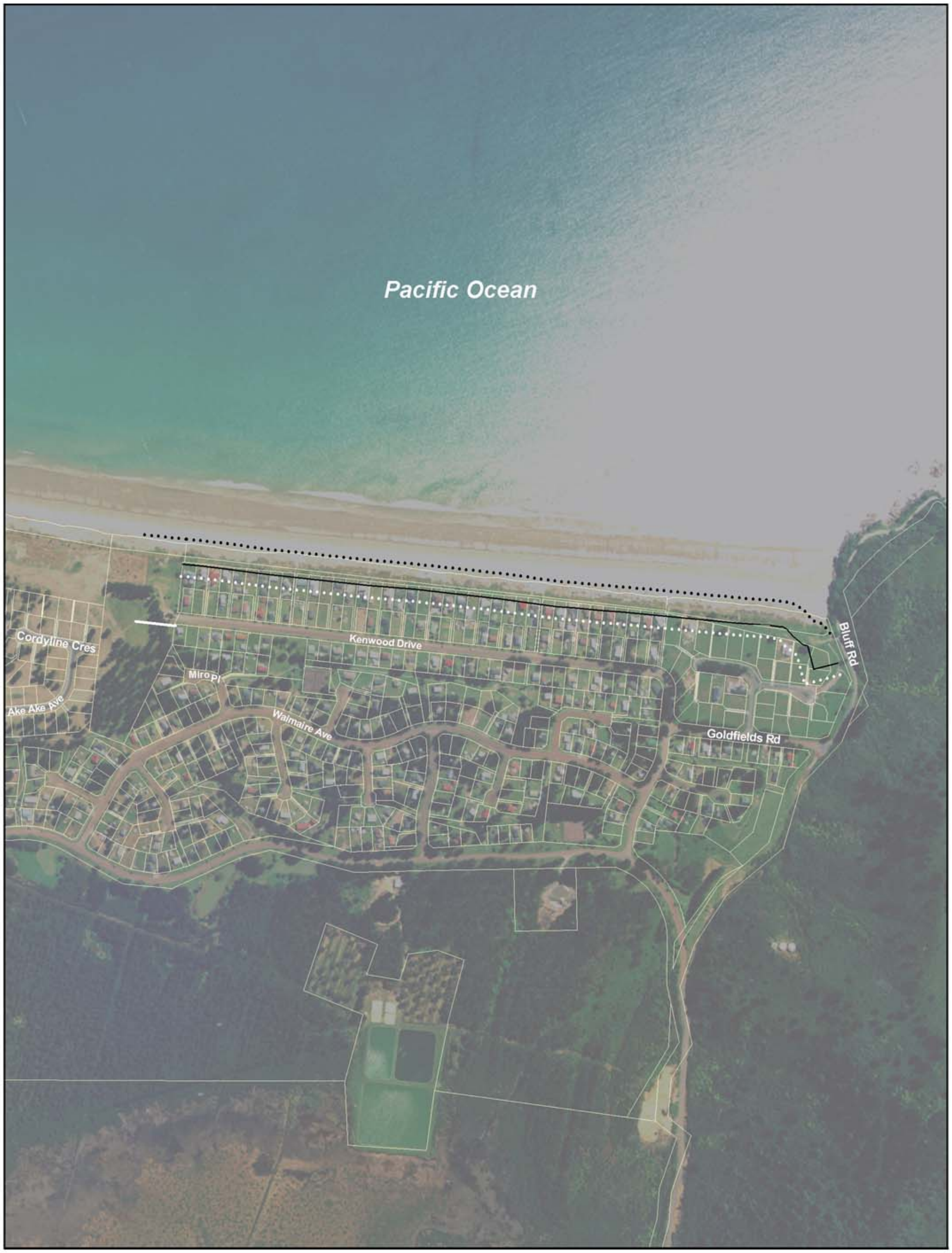


Map 17: Matarangi

0.0 0.1 0.2 0.3 km

Request No 7612

Legend

- Coastal Toe of Vegetation
- Primary Development Setback (PDS)
- Secondary Development Setback (SDS)
- Setback for Undeveloped Areas
- Parcel Boundary (DCDB)

Environment Waikato REGIONAL COUNCIL

Map 18: Whangapoua

0.0 0.1 0.2 0.3 km

N

Request No 7612

Legend

- Coastal Toe of Vegetation
- Primary Development Setback (PDS)
- Secondary Development Setback (SDS)
- Setback for Undeveloped Areas
- Parcel Boundary (DCDB)

Environment Waikato REGIONAL COUNCIL

Map 19a: Kennedy Bay

0.0 0.1 0.2 0.3 km

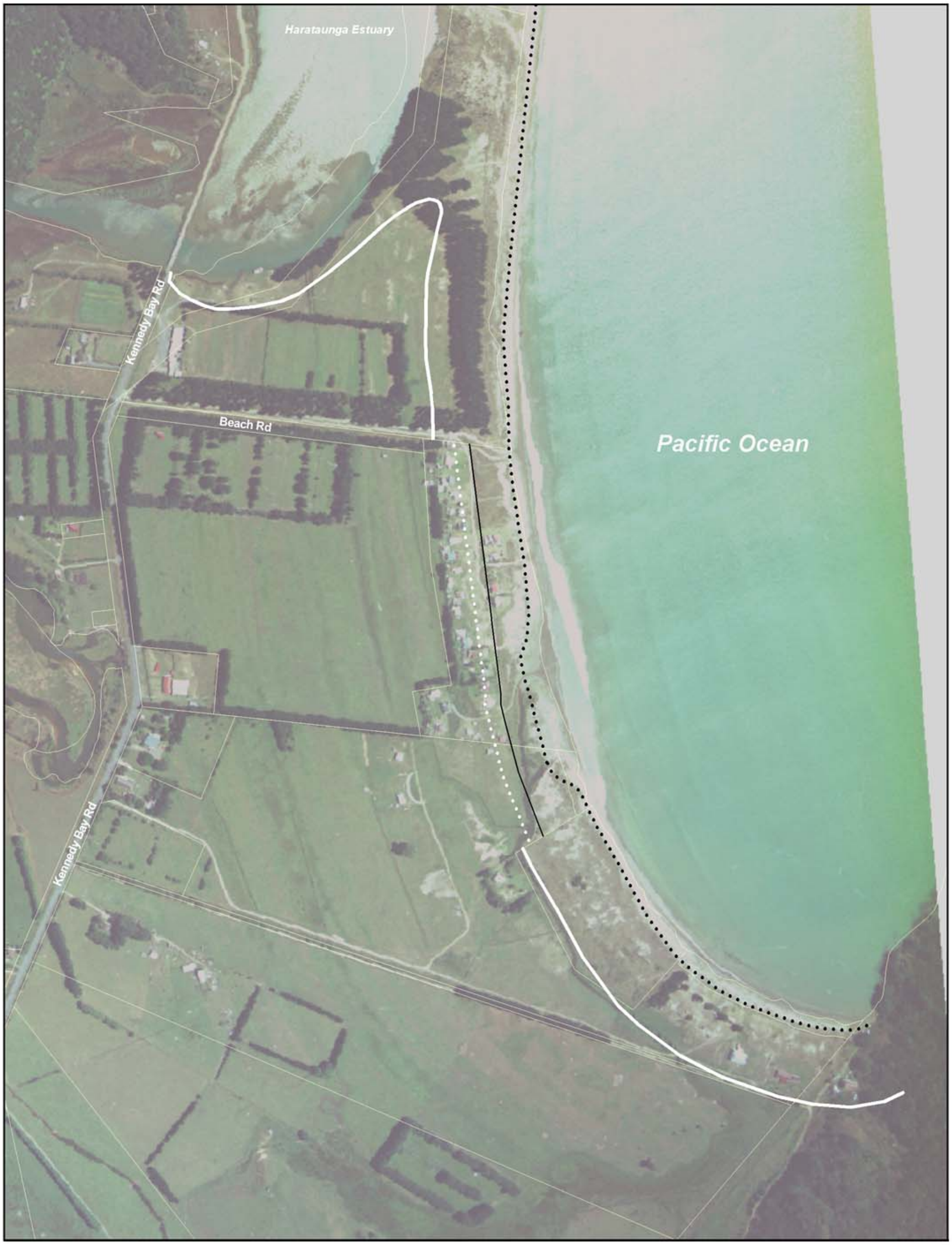
N

Request No 7612

Legend

- Coastal Toe of Vegetation
- Primary Development Setback (PDS)
- Secondary Development Setback (SDS)
- Setback for Undeveloped Areas
- Parcel Boundary (DCDB)

Environment Waikato REGIONAL COUNCIL



Map 19b: Kennedy Bay

0.0 0.1 0.2 0.3 km

N

Request No 7612

Legend

- Coastal Toe of Vegetation
- Primary Development Setback (PDS)
- Secondary Development Setback (SDS)
- Setback for Undeveloped Areas
- Parcel Boundary (DCDB)

Environment Waikato
REGIONAL COUNCIL

Map 20: Sandy Bay

0.0 0.1 0.2 0.3 km

N

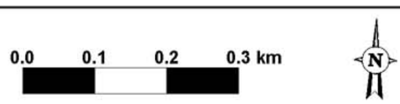
Request No 7612

Legend

- Coastal Toe of Vegetation
- Primary Development Setback (PDS)
- Secondary Development Setback (SDS)
- Setback for Undeveloped Areas
- Parcel Boundary (DCDB)

Environment Waikato REGIONAL COUNCIL

Map 21: Otautu Bay



Legend

- Coastal Toe of Vegetation
- Primary Development Setback (PDS)
- Secondary Development Setback (SDS)
- Setback for Undeveloped Areas
- Parcel Boundary (DCDB)

Environment Waikato REGIONAL COUNCIL

Request No 7612

Map 22: Papa Aroha

0.0 0.1 0.2 0.3 km

N

Request No 7612

Legend

- Coastal Toe of Vegetation
- Primary Development Setback (PDS)
- Secondary Development Setback (SDS)
- Setback for Undeveloped Areas
- Parcel Boundary (DCDB)

Environment Waikato REGIONAL COUNCIL

Map 23: Waikawau Delta

0.0 0.1 0.2 0.3 km

N

Legend

Coastal Toe of Vegetation

Primary Development Setback (PDS)

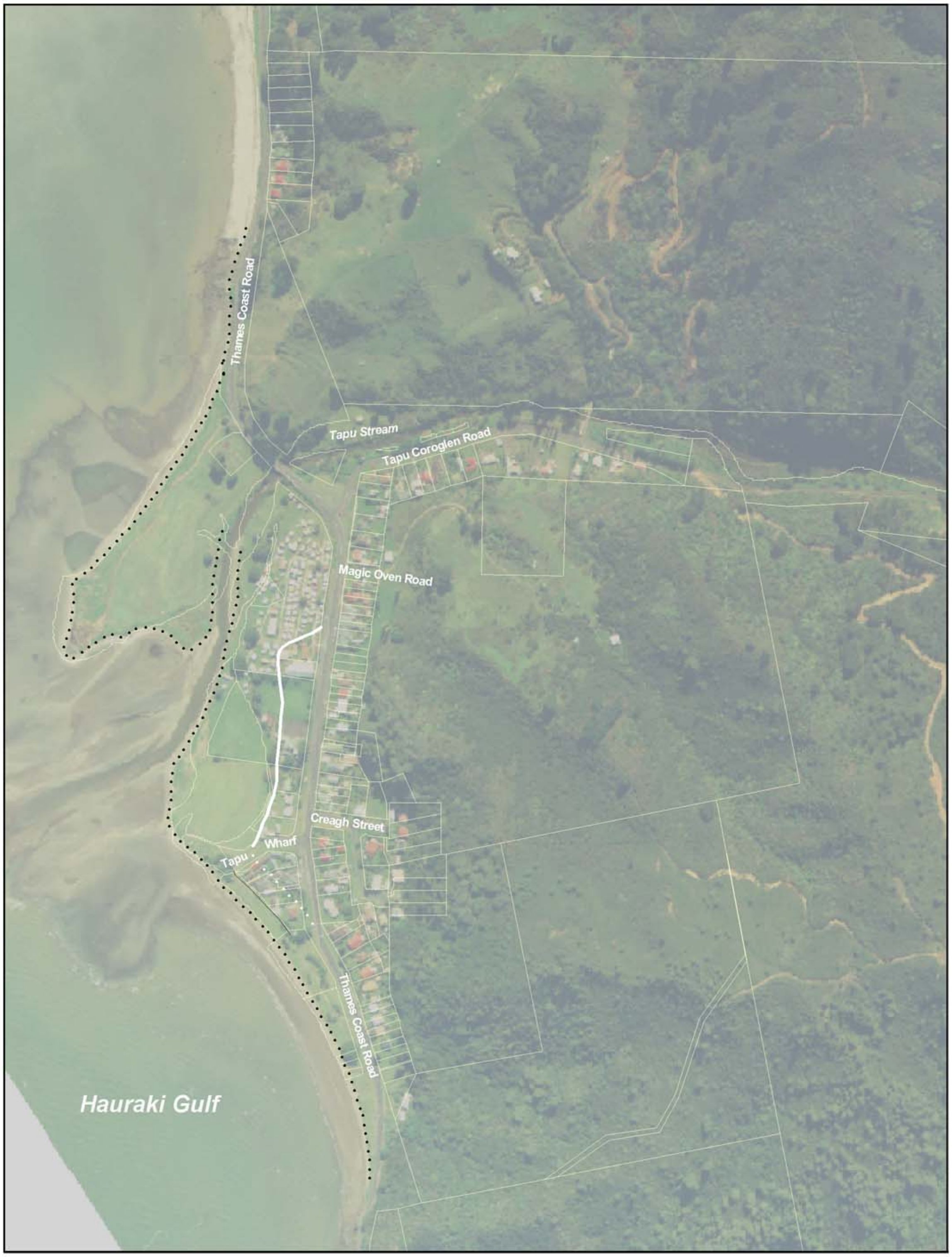
Secondary Development Setback (SDS)

Setback for Undeveloped Areas

Parcel Boundary (DCDB)

Environment Waikato
REGIONAL COUNCIL

Request No 7612



Map 24: Tapu

0.0 0.1 0.2 0.3 km

N

Request No 7612

Legend

- Coastal Toe of Vegetation
- Primary Development Setback (PDS)
- Secondary Development Setback (SDS)
- Setback for Undeveloped Areas
- Parcel Boundary (DCDB)

Environment Waikato
REGIONAL COUNCIL

Map 25: Waiomu

0.0 0.1 0.2 0.3 km

N

Request No 7612

Legend

- Coastal Toe of Vegetation
- Primary Development Setback (PDS)
- Secondary Development Setback (SDS)
- Setback for Undeveloped Areas
- Parcel Boundary (DCDB)

Environment Waikato REGIONAL COUNCIL

Map 26: Te Puru

0.0 0.1 0.2 0.3 km

N

Request No 7612

Legend

- Coastal Toe of Vegetation
- Primary Development Setback (PDS)
- Secondary Development Setback (SDS)
- Setback for Undeveloped Areas
- Parcel Boundary (DCDB)

Environment Waikato REGIONAL COUNCIL

Map 27: Tararu

0.0 0.1 0.2 0.3 km

N

Request No 7612

Legend

- Coastal Toe of Vegetation
- Primary Development Setback (PDS)
- Secondary Development Setback (SDS)
- Setback for Undeveloped Areas
- Parcel Boundary (DCDB)

Environment Waikato REGIONAL COUNCIL

Appendix E: Relevant Statutory Provisions

Resource Management Act 1991

The purpose of the Resource Management Act is set out in Section 5 of the Act, which states:

(1) The purpose of this Act is to promote the sustainable management of natural and physical resources.

(2) In this Act, 'sustainable management' means managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural well-being and for their health and safety while:

(a) Sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations;

(b) safeguarding the life-supporting capacity of air, water, soil, and ecosystems; and

(c) avoiding, remedying, or mitigating any adverse effects of activities on the environment.

6. Matters of National Importance

In achieving the purpose of this Act, all persons exercising functions and powers under it, in relation to managing the use, development, and protection of natural and physical resources, shall recognise and provide for the following matters of national importance:

(a) The preservation of the natural character of the coastal environment (including the coastal marine area), wetlands, and lakes and rivers and their margins, and the protection of them from inappropriate subdivision, use, and development;

(b) The protection of outstanding natural features and landscapes from inappropriate subdivision, use, and development;

(d) The maintenance and enhancement of public access to and along the coastal marine area, lakes, and rivers; and

7. Other Matters

In achieving the purpose of this Act, all persons exercising functions and powers under it, in relation to managing the use, development, and protection of natural and physical resources, shall have particular regard to:

(b) the efficient use and development of natural and physical resources;

(c) the maintenance and enhancement of amenity values;

(d) intrinsic values of ecosystems;

(f) maintenance and enhancement of the quality of the environment;

(g) any finite characteristics of natural and physical resources; and

New Zealand Coastal Policy Statement

General Principles

10. It is important to maintain biological and physical processes in the coastal environment in as natural a condition as possible, and to recognise their dynamic, complex and interdependent nature.

Policies

Policy 1.1.1

It is a national priority to preserve the natural character of the coastal environment by:

(a) encouraging appropriate subdivision, use or development in areas where the natural character has already been compromised and avoiding sprawling or sporadic subdivision, use or development in the coastal environment;

(b) taking into account the potential effects of subdivision, use, or development on the values relating to the natural character of the coastal environment, both within and outside the immediate location; and

(c) avoiding cumulative adverse effects of subdivision, use and development in the coastal environment.

Policy 1.1.3

It is a national priority to protect the following features, which in themselves or in combination, are essential or important elements of the natural character of the coastal environment:

(a) landscapes, seascapes and landforms, including:

significant representative examples of each landform, which provide the variety in each region;

(iii) the collective characteristics which give the coastal environment its natural character including wild and scenic areas;

Policy 1.1.4

It is a national priority for the preservation of natural character of the coastal environment to protect the integrity, functioning, and resilience of the coastal environment in terms of.-

(a) the dynamic processes and features arising from the natural movement of sediments, water and air;

(f) intrinsic values of ecosystems.

Policy 1.1.5

It is a national priority to restore and rehabilitate the natural character of the coastal environment where appropriate.

Policy 3.1.1

Use of the coast by the public should not be allowed to have significant adverse effects on the coastal environment, amenity values, nor on the safety of the public nor on the enjoyment of the coast by the public.

Policy 3.1.2

Policy statements and plans should identify (in the coastal environment) those scenic, recreational and historic areas, areas of spiritual or cultural significance, and those scientific and landscape features, which are important to the region or district and which should therefore be given special protection; and that policy statements and plans should give them appropriate protection.

Policy 3.2.4

Provision should be made to ensure that the cumulative effects of activities, collectively, in the coastal environment are not adverse to a significant degree.

Policy 3.4.3

The ability of natural features such as beaches, sand dunes, mangroves, wetlands and barrier islands, to protect subdivision, use, or development should be recognised and maintained, and where appropriate, steps should be required to enhance that ability.

Policy 3.4.4

In relation to future subdivision, use and development, policy statements and plans should recognise that some natural features may migrate inland as the result of dynamic coastal processes (including sea level rise).

Policy 3.4.5

New subdivision, use and development should be so located and designed that the need for hazard protection works is avoided.

Policy 3.4.6

Where existing subdivision, use or development is threatened by a coastal hazard, coastal protection works should be permitted only where they are the best practicable option for the future. The abandonment or relocation of existing structures should be considered among the options. Where coastal protection works are the best practicable option, they should be located and designed so as to avoid adverse environmental effects to the extent practicable.