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Geomorphological Assessment relating to Natural Character of the Manawatu District Coast

A report prepared for the Manawatu District Council

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GLOSSARY

Beach: Accumulation of unconsolidated materials (sand, gravels) along a coast, encompassing the inter-tidal area plus the area immediately landward that is affected by wave uprush (swash) and seaward affected by the wave backrush. This cross-sectional extent is also termed the **foreshore.**

Blowout: A trough excavated in foredunes by enhanced wind flow typically funneled through topographic constrictions or gap in vegetative cover which causes the dune crest to “blow out”. An advancing lobe of sand spills downwind.

Coastal progradation*:* Refers to the seaward displacement of the shoreline when the beach builds out in response to a surplus of sediment (a positive sediment budget). The Manawatu coast has a history of net progradation. Coastal accretion is part of the same process but strictly refers to the build-up in elevation of a beach or dune surface rather than to the outward movement of the shoreline.

Deflation area: A landform of varying size and shape (basin, plains or flats) that forms when sand is removed by wind action. Damp sand just above the watertable limits the vertical extent of a deflation surface.

Depression: An area, typically with saucer or trough shape, that is lower than the surrounding landscape and likely formed by wind erosion (deflation) or compaction in wet/swampy areas.

ENSO: El Nino Southern Oscillation is a quasi-regular (3 to 7 years) climate change caused by variation in sea-surface temperature in the tropics that causes change in mid latitude wind (and wave) conditions toward stronger winds from the westerly quarter, wetter on the NZ west coast and drier on the NZ east coast.

Foredune: A sand dune located immediately landward of the beach and aligned parallel to the shoreline at the time of formation. Pioneering sand grasses such as marram and spinifex are critical to foredune development as these trap sand blown from the beach and enable ongoing dune growth.

Holocene: The current warm period that began approximately 10,000 years ago. Prior to this the temperature was cooler (temperature 5-10 degrees cooler 20,000 years ago) and sea-level over 100 m lower due to extensive ice cover.

Incipient landforms: Landforms in the very early part of their evolution. They do not necessarily develop into larger, more permanent features as they are particularly susceptible to modification and destruction. For example, an incipient foredune may be removed by storm wave erosion, or a stream’s incipient valley may be captured by a larger expanding adjacent valley.

Littoral: A zone extending from the high tide mark to the offshore limit of wave and current-driven sediment transport.

Marine processes: Wave, wind and associated currents which drive change (sediment transport) in the tidal and subtidal zones.

Parabolic dune: A typically U, or V-shaped sand dune with an elevated convex nose, that may reach 10s of metres in height, with lower trailing arms, sometimes exceeding a kilometer in length, separated by an intervening basin from which and is eroded, funneled between the sidewalls (the throat) where it becomes airborne and deposits in the nose area. This landform often originates at the foredune, but then disassociates itself from the coast as it migrates inland, often for several kilometers, before being arrested by river/streams, or perhaps stabilizing during an extended period of low wind and high rainfall i.e. conditions constraining wind erosion while promoting vegetation growth. Anthropogenic intervention has resulted in stabilization during more recent times.

Post-glacial marine transgression (PGMT) The retreat and shrinking of Pleistocene ice sheets, ice caps, and mountain glaciers following the last glaciation (ice age) resulted in the addition of enormous quantities of water to the oceans; as a consequence global sea-level rose by over 100 m and shorelines retreated landward (transgressed) by several kilometres. This transgression lasted about 10,000 years

Pleistocene: A period lasting some 2.5 million years (up until the Holocene). The Pleistocene is characterized by repeat glaciations which caused sea-level to fluctuate over a range of about 120 m, more recently during 100,000 year cycles

Pliocene: That period of geological time from 2.5 to 5.3 million years ago. The Pliocene was preceded by the warmer Miocene and followed by the Pleistocene ice ages.

Regression modelling: Statistical techniques for investigating relationships between variables.

Relict coastal dunes*:* Dunes that developed in the past that are now stabilised by vegetation and no longer active.

Risk: The potential for losing something of value. In risk management it is expressed in terms of the combination of the likelihood of occurrence of a hazardous event with the consequence of the event.

Shoreline: The fringe of a water body. Where that water body is the ocean the shoreline is also called the coastline.

Shoreline indicators: Features used to define the shoreline such as an elevation (Mean Sea Level), the vegetation-front or base of a cliff. These indicators are not interchangeableand when identifying shoreline behavior it is critical to use the same indicator or reconcile differences if mixing indicators.

Sand dune: A mound or hill of sand that forms when sand, being transported by wind or water flow, is deposited as flow characteristics change. With coastal sand dunes, wind flow typically interacts with vegetation to cause deposition, with different types of vegetation having different aerodynamic properties and thus characteristic dune shapes. The valley or trough between dunes is referred to as a slack or swale.

Sand flat: a flat or gently undulating area where sand has been removed by deflation processes. Also referred to here as a *deflation plain or sand plain*, and sometimes referred to as *dune slacks*.

Stable dune: A sand dune that is able to resist wind erosion, typically one that has a continuous/uniform cover of vegetation.

Strata: Layers of sedimentary rock deposited horizontally underwater and subsequently lithified into rock. Strata may subsequently be tilted or otherwise deformed by internal or external forces such as those causing faulting and folding.

Surf zone: That coastal area affected by breaking wave processes.

Unstable dune: A sand dune that is affected by erosion. Such a dune typically has a lack of vegetation or discontinuous vegetation.

Transgressive dunes: Dunes that migrate downwind burying pre-existing vegetation and landforms.

Transgressive dune field: An assemblage of sand dunes migrating downwind. Several such fields occur along the west coast of the North Island with the *Waverly Dune Complex* (referred to in this report) being one such example.

Transverse dunes: These are transgressive dunes that, in contrast to parabolic dunes, are aligned at right angles to the *wind resultant* (see definition below). They are roughly shore-parallel in the Manawatu-Horowhenua districts and are largely relict dunes. They developed when there was limited vegetation and an abundant source of sand, and normally exhibit a relatively gentle windward slope and a steep leeward slope.

Wind resultant: A measure of the long-term effect of winds of varying strength, duration and direction upon the net direction of sand transport. Application of the wind resultant to the Manawatu District is provided in Appendix B.

1 INTRODUCTION

The Manawatu District Council is presently investigating a plan change to give effect to the Natural Character requirements of the New Zealand Coastal Policy Statement 2010 (Polices 1, 13 and 14). The Council has recently received a Natural Character Assessment from Hudson Associates Landscape Architects (Hudson 2015). That assessment used the Boffa Miskell interpretation of the coastal environment which is based on the following three zones:

- Zone A The Coastal Marine Area and Active Coastal Interface which is that area with sea and tidal dominance;
- Zone B The area of Coastal Dominance where coastal processes dominate or significantly influence abiotic, biotic and experiential characteristics of the area, and
- Zone C The area of Coastal Context where there is an influence or presence of active or remnant coastal processes.

Hudson (2015) notes that in a number of natural character assessments undertaken in New Zealand including the recent Boffa Miskell assessment of the Horowhenua District, the Coastal Environment is considered to consist only of Zone A and Zone B, and that was the approach used to define its extent for the Manawatu District Natural Character Assessment.

However, the NZCPS 2010 (Policy 1[1]) also recognises that the extent and characteristics of the coastal environment vary from region to region and locality to locality, and the issues that arise may have different effects in different locations.

The Manawatu District Council (MDC) subsequently decided that more specific expertise in coastal geomorphology was required so the council could be more confident in planning for the coastal environment (letter of introduction to Coastal Systems Ltd from MDC Planner, 5 October,2015).

Coastal Systems Ltd (CSL) was subsequently engaged to undertake such a geomorphological assessment. In particular, CSL were commissioned to carry out an assessment to identify geomorphological characteristics and qualities of the Manawatu Coastal Environment including:

1. Identify, with reference to Policy 1 of the NZCPS, natural features, landforms, processes and areas in the Manawatu District where coastal processes, influences or qualities are significant or contribute to natural character.
2. Identify whether these features, landforms, processes and areas are within the extent of the coastal environment identified in the Hudson (2015) report.
3. Identify any of the natural features, landforms, processes or areas identified above that are outstanding in terms of their geomorphological characteristics and qualities.

4. Describe the threats from human activities to the characteristics and qualities of each of the identified natural features, landforms, processes or areas.

The CSL assessment begins (Section 2) by describing geomorphological features and processes beginning at the seaward limit of morphological change and progressing inland. Throughout geological time, coastal landforms and processes can be identified across the entire Manawatu District so a decision was made to restrict the assessment to geomorphology that had been active since termination of the Holocene Post Glacial Marine Transgression (PGMT); this relates to the past c. 6500 years when sea-level had ceased its rise after the last glacial (Ice Age). Such features and inferred processes are well preserved over an extensive area of the coastal plain. Before beginning the description of the geomorphology, however, the broader setting is considered with a brief description of the background geology and PGMT environments. Section 3 ends with a consideration of the relative significance of the geomorphological features and processes with the two having greatest significance, the Rangitikei Inlet and the inland dune field, being considered in greater detail in Sections 3 and 4 respectively. The dune field is extensive and varies in age and landforms, including associated sand plains and water bodies, and this complexity required considerable analysis to define Geomorphological Character Units and to select Representative Dune Areas (Section 5). Section 5 also addresses the extent to which the Hudson (2015) boundary of the coastal environment encompasses the geomorphologies identified in this assessment. Management and protection considerations are provided in Section 6, and conclusions and recommendations made in Section 7.

Note that in our assessments *outstanding* geomorphologies are defined as having regional/national significance and their form and controlling processes are clearly evident, either contemporarily observable or inferred by relict form.

Note also that an extensive Glossary is provided to assist the reader with technical wording.

2 GEOMORPHOLOGICAL FEATURES

This section describes coastal geomorphological features beginning at the seaward extent and progressing inland. However, first the broader setting is established with a brief description of the Geology and early Holocene environments. Pertinent features are map-located in Figure 2.1 and located and illustrated in cross-section on a recent satellite image in Figure 2.2. Figure 2.2 also contains the corresponding 1958 image.

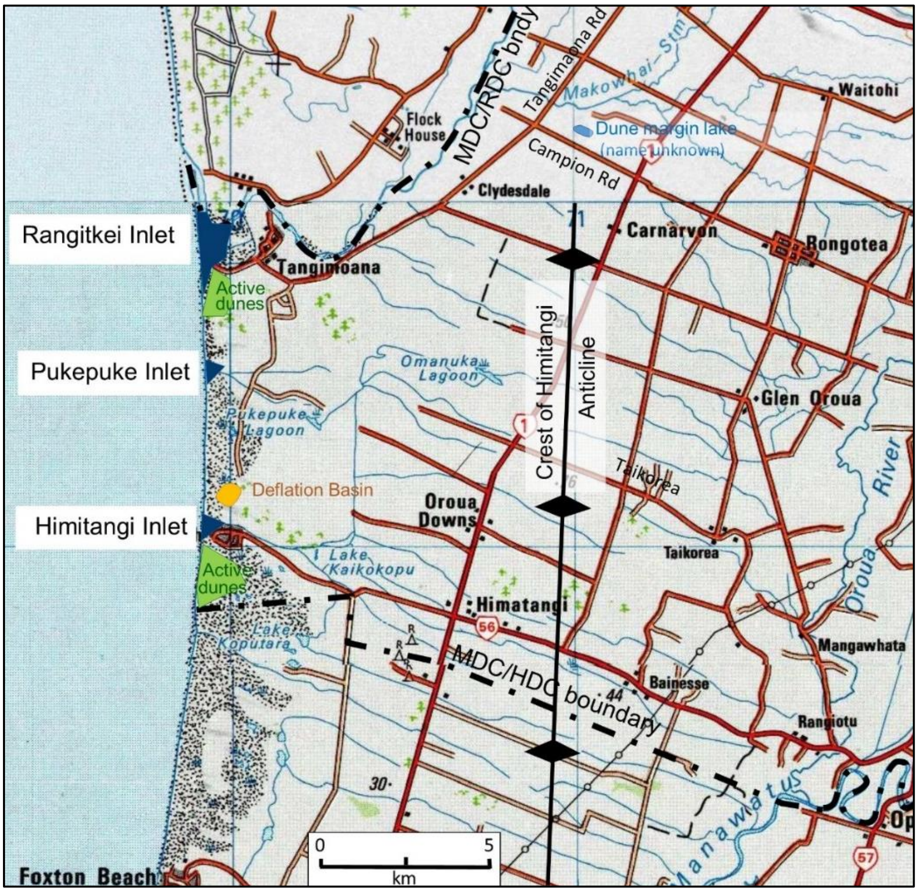

Figure 2.1 Place locations and geomorphological features within the Manawatu District referred to in the text.

2.1 Geological setting

The coastal processes operate within a wider geological context. Being located over a subducting plate margin, the Manawatu district is tectonically active, with rapidly uplifting ranges to the east, moderately uplifting hill country to the north, and active volcanoes located in Taranaki and the Central Plateau. All of these areas supply abundant sediment, largely via rivers, to the coast of South Taranaki Bight. The Bight forms a large coastal re-entrant that acts as a natural trap for sediment from rivers and eroding cliffs in Wanganui and Taranaki that is transported southeastward by waves and currents (Shepherd and Hesp 2003). Longshore transport decreases to the south where the waves crests arrive more parallel to the coastline, resulting in the deposition of a large quantity of sediment in the central part of the Bight. This deposition of sand-sized sediment has enabled the shoreline to advance seaward by approximately 4 kilometres (c. 0.6 m per year) between the Rangitikei and Manawatu Rivers during the past 6000-7000 years (Shepherd et al., 1986). Those rivers also add to the supply of sediment to the Manawatu District coast. Coastal progradation would have been even greater if large quantities of sediment had not been blown inland in the form of migrating sand dunes.

A further tectonic influence is the block-faulting of the basement rocks at depth to the west of the ranges; this has warped the younger overlying sedimentary beds, resulting in the formation of anticlines (hills) in Manawatu District. The crest of the Himatangi Anticline extends parallel to the coast near Highway 1 between Carnarvon and Foxton (Hesp and Shepherd 1978). The growth of the anticline not only diverted the courses of the Oroua and Manawatu Rivers southwards towards Foxton but also profoundly influenced coastal geomorphological development.

2.2 Early Holocene coastal environment

Sea-level rose by approximately 120 m in response to the melting of continental ice sheets that commenced about 18,000 years ago toward the end of the last ice age. This Post Glacial Marine Transgression (PGMT) ended approximately 6500 years ago when the sea reached its present level. By that time the rising Himatangi Anticline had reached a sufficiently high elevation to form a barrier that prevented the postglacial shoreline from encroaching any further inland than 4 km east of the present coastline (see Figure 2.1_1). To the east of the anticline the lower Manawatu Valley was flooded by the sea to form a large sheltered estuary that extended as far north as Opiki near the southern boundary of Manawatu District. The estuary has been largely infilled with sediment during the past 6500 years to form an extensive area of alluvial plains (Hesp and Shepherd 1978).

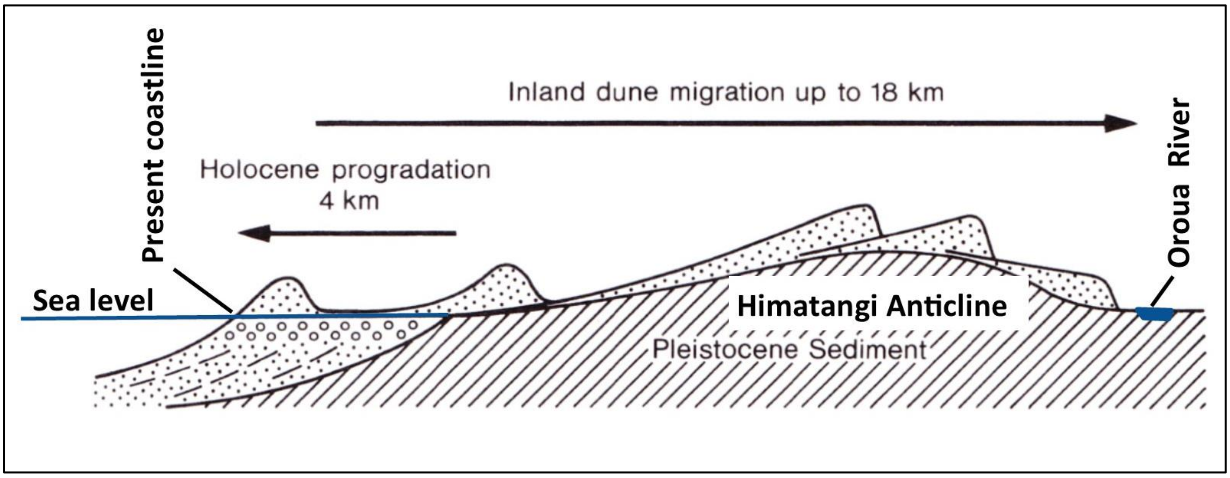

Figure 2.1_1 Holocene geomorphological evolution in the Manawatu District.

Adapted from Shepherd and Hesp (2003)

2.3 Beach and surf zone

Wave energy is the predominant geomorphological driver of sediment transport along the coast line of the South Taranaki Bight – which includes the 12 km section administered by the MWD. No published wave information is available for Himatangi Beach, but results for Wanganui and Otaki provide an indication of the contemporary wave climate on the MDC-administered coast. At Wanganui, 13 months of non-directional wave data (January 1986 to February 1987) at the 20 m depth contour found the average (significant) height was 1.05 m and the 1% excedence value was 3.2 m (Macky et. al., 1988). Note, a waverider buoy was also located off the Himatangi coast during this time period but it appears that these data were never analysed. A 20 year directional hindcast numerical model for Otaki at the 10 m depth contour and calibrated with 49 days of instrumented data (MetOceans, 2012) found the median significant wave height was 0.93 m and 1% excedence value was also 3.4 m. The numerical output found the wave climate was dominated by shorter period (sea) waves with 80% less than 10 seconds. Furthermore, 71% approached from the W to NW sectors and 18% from the southwesterly quarter. Waves lift sand by turbulence and an oblique approach to the shoreline enables such sediment to be swept alongshore within the breaker and beach zones. The MDC coast is therefore dominated by locally generated wave energy approaching obliquely from the west-northwest thus likely resulting in net NW to SE longshore current and sediment transport (littoral drift).

Further evidence for net NW to SE sediment transport comes from sediment characteristics. Regionally, grain size systematically decreases southward (Burgess 1971) indicating increasing distances from the source. Minerologically, there is a southward decrease in the proportion of magnetics from the major Taranaki Volcanic Region indicating long-term net southward littoral drift, as does hypersthene from the Central Volcanic Region being traced south to Raumati (Gibb 1979).

Local waves are generated by the regional wind regime which matches the dominance of W to NW winds and lesser S to SE component. However, longshore currents are also enhanced directly by surface wind shear with studies indicating alongshore directed wind can be a primary forcing agent of the longshore current. However, tidal streams and other oceanic longshore currents (e.g. the D'Urville Ocean Current) are of secondary importance.

Estimates of net littoral drift at Wanganui range between 300,000 to 600,000 m^3/year based on a variety of measured wave data (Shand, 2000). By contrast, an estimate for Otaki based on MetOceans (2012) numerical model data found net northward transport of ~5,000 m^3/year. While the NE/SW trending shoreline at Otaki offers some explanation, it appears in the present wind regime may not be representative of the longer-term regime as the geological/sediment characteristics indicate net N to S drift at Otaki, Gibb, (1979). Nonetheless, it is most likely a net N to S transport occurs along the MDC coast; however, site specific investigation is required to provide a reliable estimate.

While the longshore tidal currents are not influential in terms of coastal geomorphology, such processes are very much influenced by the tidal range which the LINZ website gives as 2.2 m for mean high water springs (MHWS) and 0.9 m for 2015 mean neap water springs

(MNWS). This spring range put it in the so called meso-tidal range which, coupled with the short period and energetic wave regime results in wide uniform (dissipative) beaches with occasional rip channels and multiple (2 in this location) subtidal sand bars (Short and Agaard 1992). On storm-dominated coasts such as the South Taranaki Bight, beach and surf zone morphologies are dominated by an underlying process of net offshore bar migration in which new bars are generated on the lower inter-tidal beach, systematically migrate seaward and disappear several years later in the outer surf zone (Shand et al., 1999).

Based on CSL bathymetric data and Digital Globe satellite images, the outer bar on the mid MDC coast has been located up to 500 m seaward of the foredune toe, the inner bar up to 300 m and the seaward limit of the foreshore up to 180 m from the foredune. Note the foreshore encompasses the inter-tidal area plus additional areas to seaward and landward where wave uprush and downrush occur and is typically that area referred to as the beach. The foreshore width at Himatangi Beach ranges between 54 and 142 m (mean 96 m). These features are illustrated in Figure 2.2 (upper image).

Finally, shoreline change over time (erosional, stable or depositional) is a fundamental descriptor in terms of indicating future geomorphological behaviour. Analysis of shorelines in the Himatangi Beach area (detailed in Appendix A) show an average (linear) rate of seaward advance of 0.94 m/year between 1889 and 2015. Overall, the relationship appears to be non-linear and better represented by a linear fits to the 1889 to 1963 period (0.63 m/year) and to the 1963 to 2015 period (1.28 m/year). The apparent increase in annual rate of change may be associated with European settlement that released hinterland sediment into rivers and hence to the coast, eventually to become part of the upper beach system. While these rates of shoreline change are possibly representative of the central/southern MDW coastline, the northern shoreline is likely to have been affected by Rangitikei River Mouth dynamics described in some detail in Section 3.

2.4 Inlets

Three inlets occur along the Manawatu District’s 12 km stretch of coast: the Rangitikei near the northern boundary with the Rangitikei District Council, the Pukepuke some 5 km to the south, and the Kaikokupu at Himatangi Beach some 2.5 km from the southern boundary with the Horowhenua District Council and 12 km from the Manawatu Rivermouth.

Rangitikei Inlet

The Rangitikei Inlet is boarded by duneland closer to the coast along with plantation and lake and wetland to the rear. The inlet size is approximately 100 ha and comprises a variety of configurations which usually incorporate a spit that, historically, has extended up to 3 km and projected alongshore in both directions. The Rangitikei Inlet is the largest natural inlet on the South Taranaki Bight from Cape Egmont to Wellington. Earlier in the Holocene evidence suggests the inlet was located further north with Holocene sand dune migration forcing its relocation southward (see Section 4). The inlet contains a large estuary some 150 ha in size of which 50 ha of saltmarsh is a (proposed?) Protected Natural Area (Priority 2) under the Department of Conservations Protected natural Area Programme(DOC, 1992).

The river itself is 241 km long, making it the 3rd longest in the North Island, and has a natural annual mean flow of 88 m^3/s which is the 6th largest in the North Island. The natural annual low flow is 14.7 m^3/s, and natural annual flood flow is 830 m^3/s.

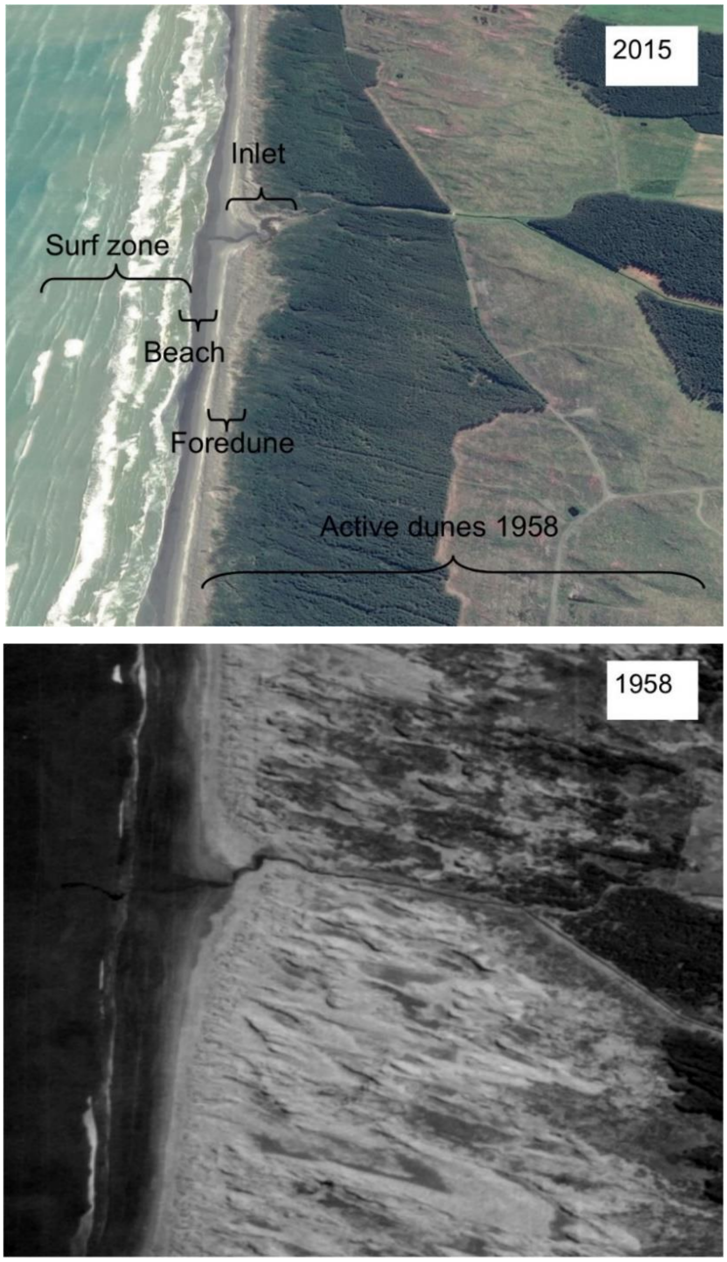

Figure 2.2 Upper 2015 satellite (Digital Globe) image shows an oblique view of the central section of the Manawatu District's coast including the Pukepuke Inlet . Geomorphological features described in the text are marked. The lower image was derived from a NZAM aerial photo and shows (approximately) the corresponding scene in 1958. Of note is the depth of active dunes (about 700 m) extending landward of the foredune.

The hill country catchment provides much of the river's finer sediments while the Ruahine Ranges and Kaimanawa Mountain headwaters provide the river's substantial (gravel) bed-load. The Rangitkei River provides most of the metal (gravel) for the Rangitikei and Wanganui regions with 210 000 m^3 being extracted in 2003.

Regarding river management that could impact inlet processes: in the late 1970s, part of the Rangitikei headwaters were diverted into Lake Taupo as part of the Tongariro Power Development (TPD) Eastern Diversion. In the lower river flood flows have decreased by 0.4%, the mean flow by 11% and the low flow by 16%. Water allocation has reduced flows by a further 2.6 m^3/s. A river diversion 1 km inland from the mouth was carried out in 1966 for flood control. However, the only management further seaward is very occasional and minor/localised dedging for recreational boat access to the sea.

The hydrological and morphological characteristics of the inlet result in it having considerable effect on the adjacent surf zone, beach and dune processes.

Pukepuke Inlet

The Pukepuke Inlet is boarded by plantation and stretches inland approximately 150 m (Figure 2.2). The inlet area can range between 1.3 ha and 2.8 ha and its effect on beach and foredune processes can extend some 250 m northward and 350 m southward. The Pukepuki Stream extends inland some 11 km to the crest of the Horowhenua Anticline. The catchment is some 4,900 ha and comprises sand dunes and sand flats, lakes and wetlands. Significant artificial drainage is evident within the catchment and a 50 m stream diversion within the back of the inlet has contributed to the inlet area's reduction over time.

Kaikokupu Inlet

The Kaikokupu Inlet is similar to the Pukepuke in that it backs onto the Himatangi Anticline and drains sand dunes and sand flats, lakes and wetland impounded behind the more seaward sand dunes. The Kaikokupu Inlet boaders the Himatangi Beach Settlement on the left (southern) side but the inlet is in a natural state on the northern side. The inlet extends inland approximately 190 m, its current area is 162 ha compared with its 1942 area of 210 ha and its effect on beach and foredune processes can extend some 350 m northward and 700 m southward. The Kaikokupu Stream extends inland some 11.5 km to the crest of the Himatangi Anticline. The catchment area is 5,380 ha and as with the Pukepuke this comprises sand dunes and flats, swamps and lakes, pasture and plantation. Again, significant artificial drainage is evident within the catchment. A 150 m training wall along the left side of the inlet constrains southern migration by the channel and associated dune erosion; behavioural modification has also contributed to the reduction of the inlet area over time.

2.5 Foredune

Between inlets, the Manawatu District coast is characterised by a foredune. Foredunes commonly occur landward of the beach and its controlling wave processes, and at the time of formation are typically aligned parallel to the shoreline. The MDC foredune has been able to establish and extend seaward because of the prograding shoreline which, as it advances, creates new land surface beyond the reach of marine processes upon which sand can accumulate and an incipient dune begin to develop. Establishment and growth of such a dune also depend on the presence of sand grasses such as marram and spinifex to trap sand blown from the beach.

The MDC foredune is also characterised by localised erosion where foredune vegetation has been destroyed and wind funnelling has resulted in erosional gaps with wind carrying sand eastward (inland) to form lobes. This landform is referred to as a *blowout* and can develop further to form a parabolic dune which can lose its connection with the beach and migrate as an entity across the landscape (see Section 4). The foredune dimensions vary considerably along the coast depending on local rates of accretion which control the seaward extension of the dune, and foredune wind erosion that can reduce the dune volume in places whilst adding to volume elsewhere where associated deposition has occurred. Available data indicates the Manawatu District's coastal foredune can range in height from 5 m to 12 m high and in width from 30 m to over 100 m.

Such blowouts and parabolic dunes characterise west coast dune systems and presently active examples are particularly notable immediately south of the Rangitkei Rivermouth and about the Himatangi Beach Settlement. Prior to stabilization projects, the entire Manawatu District coast was characterised by a such dune forms extending landward for several hundred metres from the foredune (see Figure 2.2 lower image)

2.6 Dunes landward of the foredune

Stabilized or relict sand dunes extend inland from the MDC foredune for up to 18 km and form part of a dune belt extending from Paekakariki to Patea, a distance of nearly 200 km and cover an area of 85,000 ha with continuity broken only by rivers (Fleming 1953, Cowie 1963, DOC 1993). The entire coastal dune field could be considered to be a large-scale coastal landform because the dunes were generated at or near the coastline relatively recently and are characteristic coastal landforms. The dune field probably developed episodically during the past 6500 years, so is geologically youthful, well-preserved and clearly expressed in the present landscape. However, the processes and landforms are not uniform throughout the region and considerable and significant variation exists. The range of landforms and time-transgressive aspects of their development has resulted in some authors referring to the dune field as comprising of several dune complexes.

To the north the dominant winds and parabolic dune ridges are at a lower angle to the coastline and the dunes encroached less than 6 km inland. Dune ridges were able to influence the initiation of relief and also block existing valleys causing the formation of elongate lakes, for example Virginia Lake in Wanganui. In some locations, the coast became cliffed subsequent to early dune field development, preventing further dune encroachment.

The central part of the field, which includes the Manawatu District, comprises topography that forms less of a barrier to dune encroachment with dunes more freely migrating across the hinterland and crossing the gentle crest of the Himatangi Anticline to eventually be stopped by the Oroua and Manawatu Rivers. This represents the greatest landward extent of cross-country dune migration within the entire dune field. This achievement was facilitated by sediment supply probably being at a maximum in this coastal sector and winds blowing more directly onshore, resulting in parabolic dune ridges at a higher angle to the shoreline. When the sea reached its present level c.6500 years ago the coastal plain prograded rapidly seaward while dunes simultaneously migrated far inland, often leaving extensive deflation plains in their wake. Drainage was impounded by dunes on the seaward side of the Himatangi Anticline later in the development of the dune field to produce extensive (c.f. elongate) swamps and lakes.

To the south of Foxton, the coastal plain narrows as the Tararua Range becomes progressively closer to the coast: this causes a decline in wind energy and consequently dunes migrated smaller distances inland. Sometimes the dunes formed parallel to the shore and in places more stable shorelines allowed dune growth to reached higher elevations. Lakes often formed where streams were impounded at the inner margin of the field.

2.7 Geomorphological significance

The surf zone, beach, shoreline and foredune characteristics for the MDC coastal reach are dramatic and important geomorphological features and processes that are useful in explaining the coastal environment. However, they are typical of the wider regional environment so are of local significance only.

The three inlets of the MDC coast are all important geomorphological features worthy of recognition. The smaller Pukepuke and Kaikokupu Inlets are somewhat similar to each other as well as to other inlets along the adjacent coast so have local significance. By contrast, the Rangitikei Inlet is large and differs in characteristics from other inlets along the entire South Taranaki Bight thereby giving it greater geomorphological significance.

The Paekakariki to Patea dune field is the largest in New Zealand and comprises a range of geomorphological expressions making compelling geomorphological reasons for regarding the entire regional dune belt as a particularly significant coastal landform. As the dune field crosses territory administered by several district councils, each needs to recognise the particular dune field geomorphology in their area and take some protect measures.

Given their relative significance, the Rangitikei Inlet and the Regional Dune Field, these are now described in greater detail in Sections 3 and 4 respectively.

3 RANGITIKEI INLET

3.1 Historical behaviour (1870s to 1960s)

The dynamic nature of the Rangitikei Inlet is best illustrated chronologically using historical information: survey plans, aerial photographs and satellite imagery. Figure 3.1 is a survey plan comparing the mouth and channel extending well upstream in 1881 (red lines) and 1916 (blue). Of note in Figure 3.1 are the upstream changes in river channel pattern with meanders migrating downstream. The inlet itself has a very symmetrical configuration with the channel appearing to enter the sea at right angles in 1881 and having a slight northerly offset in 1916. The 1941 aerial photo (Figure 3.2) shows the channel approaching the coast from the south with a well-developed south spit and no north spit; this configuration was associated with the river's developing meander that migrated up to the township of Tangimoana where a small port and recreational boating facilities were establishing.

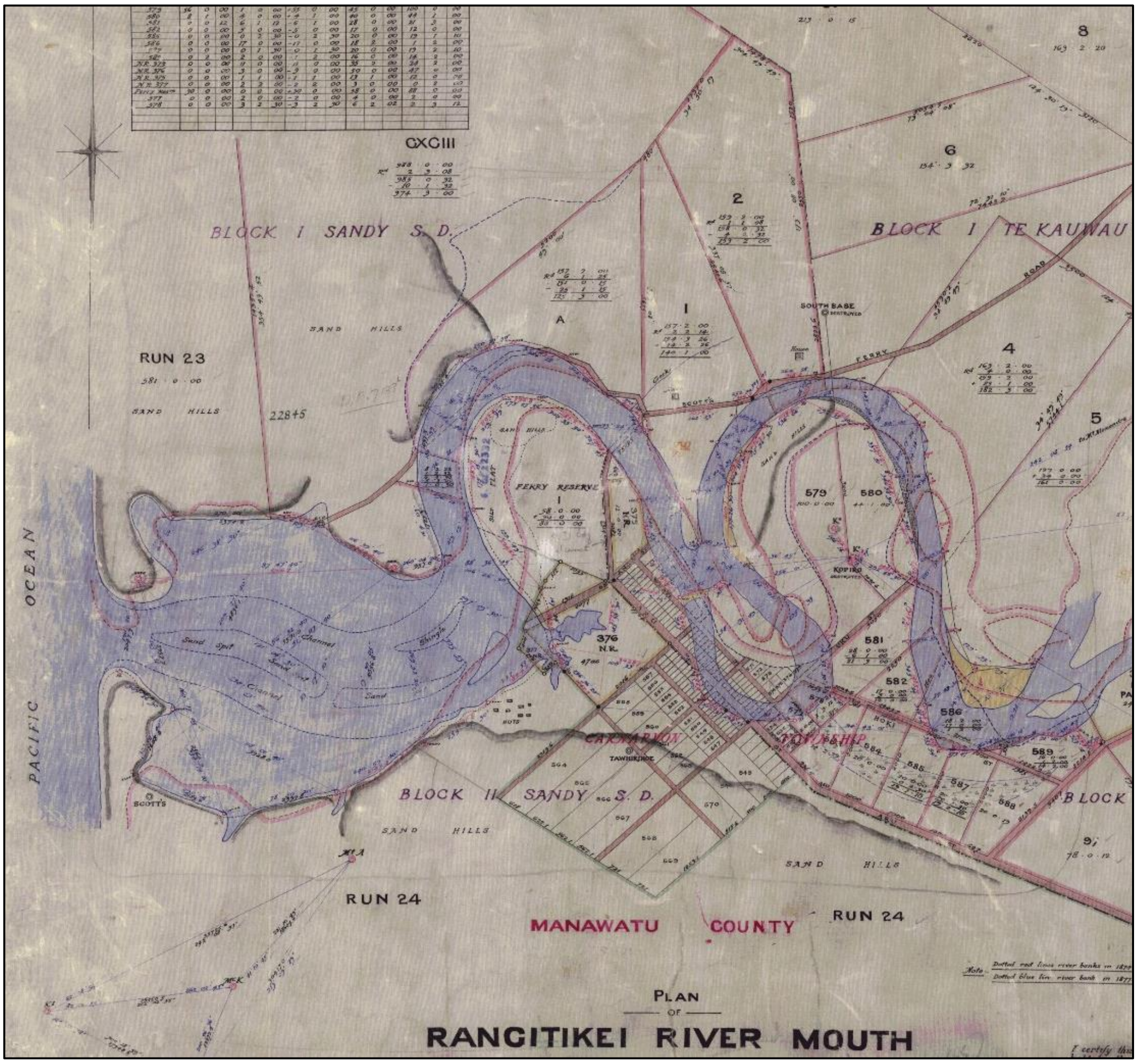

Figure 3.1 Rangitikei Rivermouth, estuary and lower river stretching some 4 km inland as depicted by survey plan SO 17293 with the 1881 features shown by the red lines and 1916 features in blue.

Figure 3.2 Rangitikei River Mouth, estuary and lower river as depicted in the first available vertical aerial photograph taken in 1941 Photo NZAM

3.2 Systematic change (late 1960s to early 2000s)

This northern offset-based configuration, however, was to change with the 1966 river diversion known as the Okanagan Cut, which cut out the entire loop that passed Tangimoana. This work was carried out as part of the Lower Rangitikei Flood Control Scheme by the Rangitikei Wanganui Catchment Board (early predecessor of Horizons Regional Council), and the diversion also relieved bank erosion that had been occurring at Tangimoana because of the ongoing migration of the meander loop . Fig 3.3 shows both the natural channels and the Okanagan Cut operating in 1971; however, it was not long before the full river flow occurred through the cut with only flood flows using the pre-diversion channel. Similar diversions were carried out in many other parts of New Zealand for flood control purposes, including the Whirokino Cut on the lower Manawatu River.

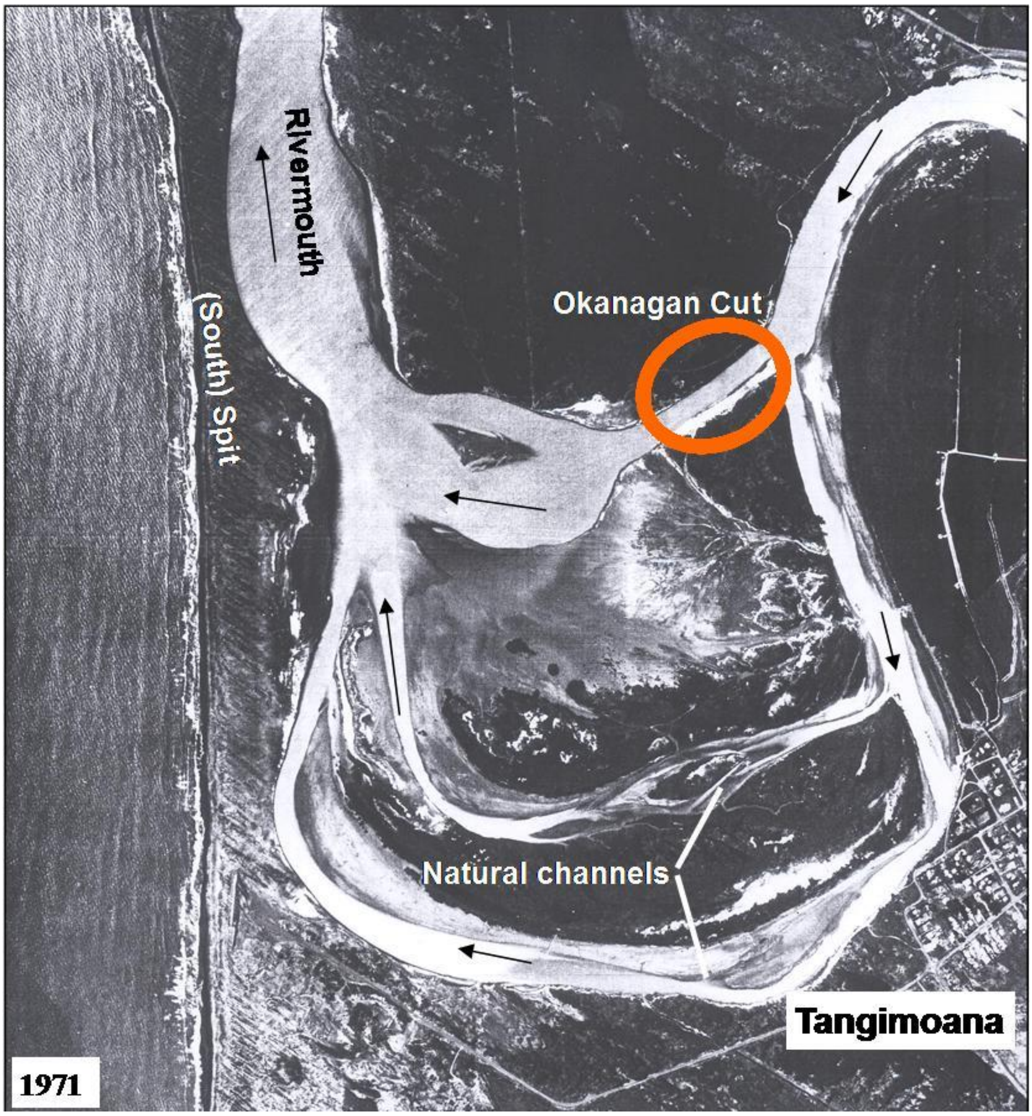

Figure 3.3 Lower river simultaneously flowing through the natural channel at the base of this 1971 photo and through the Okanagan Cut made in 1966.

Photo NZ Aerial Surveys

Following the "Okanagan Cut", a second phase of inlet behaviour occurred with the downstream end of the diversion effectively becoming the upstream limit of the inlet (the inlet throat) and the channel systematically migrating from a northward approach to the shoreline, with the configuration dominated by a south spit, to a southward offset and spit attached at its northern end. This process is portrayed in Fig 3.4 which plots the left (southern) side of the channel.

A further morphological change that occurred after the diversion was the ongoing development of a shoal downstream of the Okanagan Cut (Figure 3.5). Shoals often occur downstream of a flow constriction as deposition accompanies the drop in velocity. The flow can then bifurcate, i.e. spit to each side of the shoal with channels running along each bank. While different water levels at the time of photography mean that these data only provide an indication of shoal dimensions, the spatial extent appeared to be increasing over time.

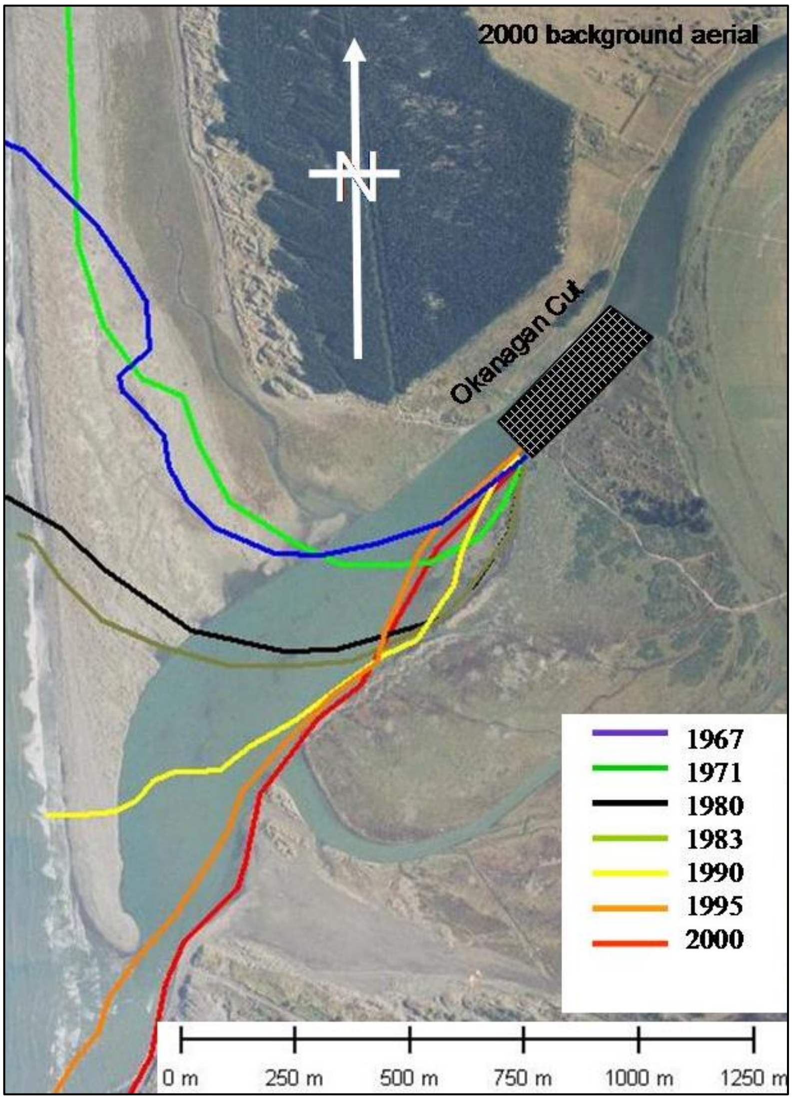

Figure 3.4 Systematic southward migration of the channel's southern bank between 1967 and 2000. Note the Okanagan Cut opened in 1966. Photo Lawrie Carins

3.3 Natural dynamic phase (mid 2000s to present)

By 2003 the spit (above high tide level) was some 700 m long and over 200 m wide at its widest point. However, the shoal-induced western branch of the inlet channel was orientating more directly seaward and at this point the high tide spit was only about 10 m wide (Figure 3.6 upper photo). In February 2004 a significant flood occurred (return period 40 to 50 yrs, Tate, 2004), and the spit breached (Figure 3.6 lower photo). With the main river flow now through the new channel, wave overwash processes began moving the detached spit landward as depicted by the blue arrows in Figure 3.6.

By 2005 the new North Spit had extended some 450 m and wave overwash and wind-blown sand processes were now welding the detached spit onto to the previous inside bank of the inlet (Figure 3.7 upper photo). Of note is the red dashed line indicating sand from the welding spit was able to be blown landward to contribute to dune instability.

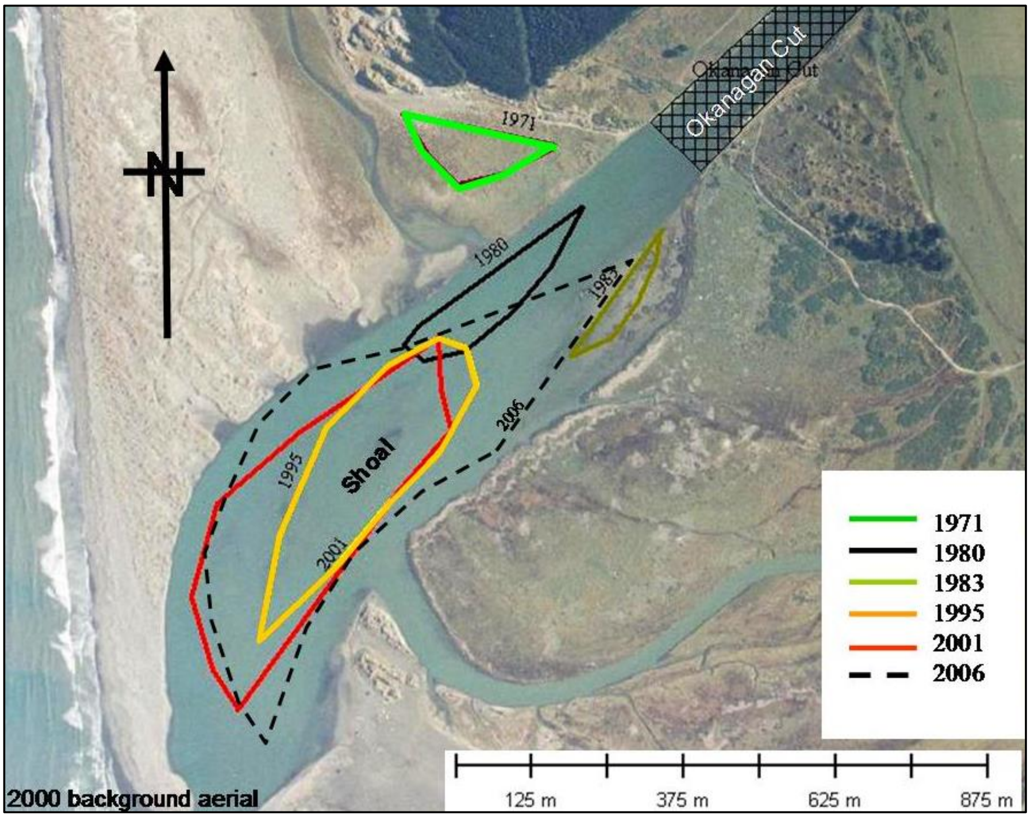

Figure 3.5 Development of the shoal downstream of the Okanagan Cut based on aerial photographs. Location of shoal margins are approximate as they are dependent on the tide and river level at the time of photography

Photo Lawrie Carins

By 2007 the spit had extended up to 650 m (high tide boundary) and the channel had been forced southward to take on its pre-breach alignment (Figure 3.7 central photo). Of note are the yellow arrows in the central and lower photos of Figure 3.7 which illustrates a 200 m migration of wind-blown sand across existing vegetation since the 2004 breach (58 m/year). This migration was being enhanced by sand from the detached and welded spit. It is noted that the destabilization of sand dunes had initiated prior to the spit breach in 2004 due to the river flow eroding/undercutting the inside bank (which comprised vegetated sand and some silt), with wind then eroding the exposed sand to form blowouts, destroying further vegetation and causing inland sand drifts.

However, shortly after reestablishment of the pre-breach northern spit/single outlet configuration, the spit again breached (Figure 3.8 upper photo). It is common for re-breaching to occur after a stable spit has been breached as the reforming spit has a relatively low surface elevation and volume so is overtopped and eroded by less extreme conditions than were required for the initial breach. Such breach/recovery cycles are now ongoing (Figure 3.8 centre and lower photos) and will likely continue until a sustained period of lesser flow/tide and waves enable the spit to accumulate a more substantial and resistant volume of sediment. Of course, should the future climate become characterised by more frequent storms then breaking the present behavioural state, at least in the shorter-term, will become less likely, and instability/mobility of the adjacent dune field will become more evident.

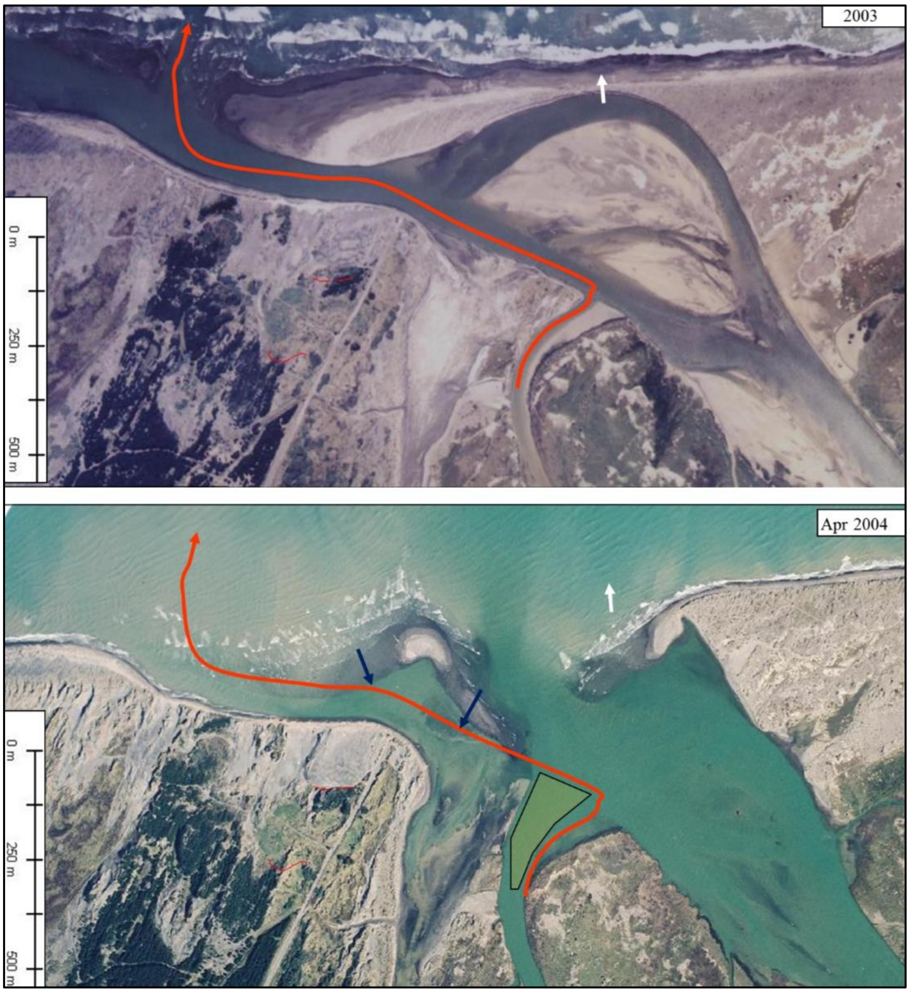

Figure 3.6 Upper photo, 2003 pre-breach inlet configuration with the navigation route depicted by the red arrow and the subsequent breach location (February 2004) marked by white arrow. Lower photo shows post-breach configuration after 2 months with navigation and breach arrows from the upper photo superimposed for comparison. The shaded orange area defines an area of old sand dune that was quickly eroded by wave penetration through the breach. Note North Spit redevelopment is already occurring. Photos Lawrie Cairns

The Rangitikei Inlet has undergone several phases of behaviour during the historical period, some natural, some anthropogenically induced, some slow, and some (such as the present phase) exhibiting particularly rapid, and spectacularly dramatic, change. Such behaviour is more than a scientific curiosity, rather it provides a basis for scientific investigation into the most dynamical of coastal systems (inlets) – environments which are a focus of human activity yet presently lacking in scientific understanding.

Indeed, the information presented in this brief description of the Rangitikei Inlet is strongly suggestive of an answer to a most basic question on inlet behaviour (Gibb, 1979, p35): why are some inlets orientated against the direction of net littoral drift? It is well established that the direction of net littoral drift is a control of inlet offset (i.e. the spit extends in the direction of net littoral drift). However, the longshore variation in spit direction experienced in the long-term Rangitikei data set suggests the approach direction of the channel relative to the coastline can override net littoral drift and quantification of such a relationship is an area worthy of further research.

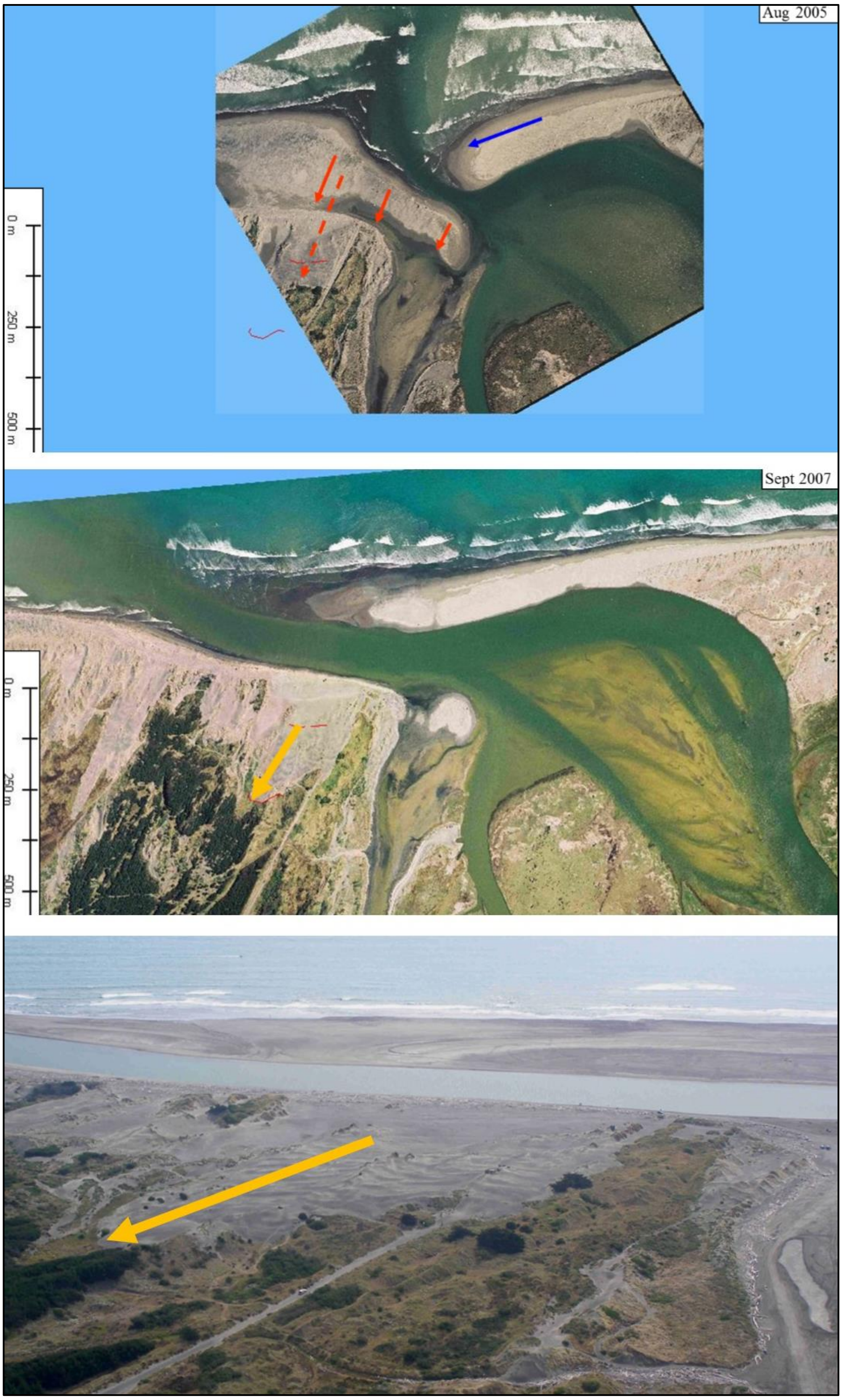

Figure 3.7 Upper photo, 18 months after the breach with detached spit merging with previous landward inlet channel (red arrows) and detached spit sand able to blow inland (dashed red arrow). New spit extension marked by blue arrow. Central vertical photo and lower oblique photo were taken 3.5 years after the breach, with yellow arrows defining the inland progression of destabilised sand.

Upper/central photos Lawrie Cairns, lower photo CSL

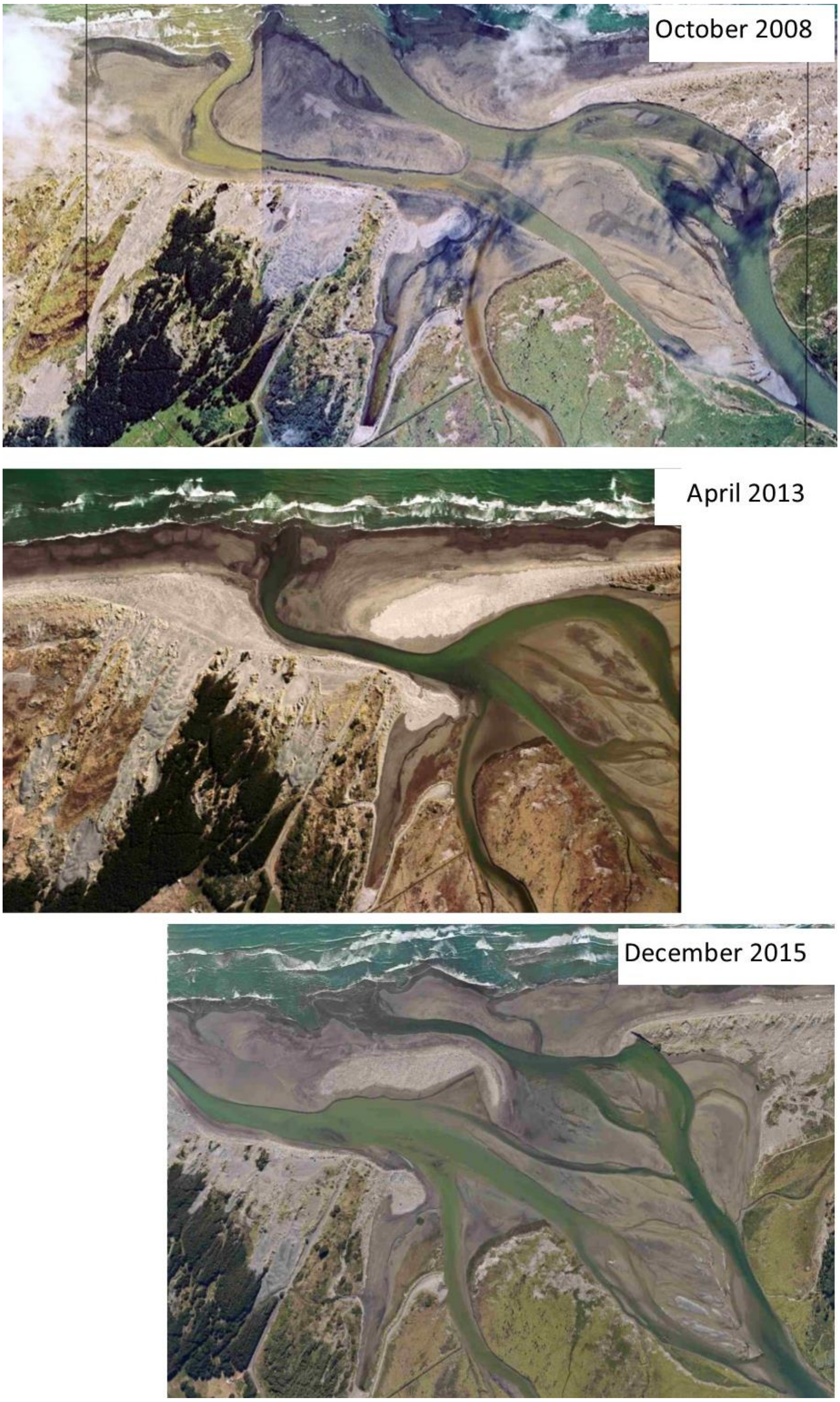

Figure 3.8 Aerial photos taken 2008, 2013 and 2015 depicting contrasting (single and double mouth) inlet configurations. Photos Lawrie Cairns

4 THE DUNE FIELD

This section brings together information on the morphology of the dune field within the Manawatu District as well as the age of the dunes and how they were formed. This information then enables a classification of the Manawatu Dune Field into four *Geomorphological Character Areas*. Such a framework provides a good start to assess the geomorphological importance and value of the Manawatu Dune Field which is fundamental to the development and implementation of management strategies. It is noted that the dune field also has other attributes in terms of its cultural, landscape, aesthetic and economic values, which could be taken into account when developing management strategies and policies.

4.1 Age

It is generally accepted that the dune field is of Holocene age and probably commenced forming when the sea rose to its present level about 6500 years ago, i.e. at the end of the Post Glacial Marine Transgression, following the last glacial period. At that time, the shoreline near Tangimoana was c. 4 km inland from its present location (Shepherd et al., 1986) but since then has extended seaward at an average rate of about 0.6 metres per year, although the progradation may have been episodic

The landforms of most coastal plains become progressively older with distance inland from the coastline but this is complicated by the fact that some dunes in this district migrated inland to their present position – a process that took thousands of years, probably in stages or phases. The further inland that the dunes of a single phase migrated, the more recent the age of their final stabilisation by vegetation. As a result, the oldest (Foxton Phase) dunes have been dated in excess of 5000 years old in locations where they did not migrate far from the coast and as young as 2000 years at the innermost margin of the field. These dunes have been identified as ‘time-transgressive’ landforms by Muckersie and Shepherd (1995), who obtained a number of carbon dates from the dune field, but far more research is needed before a detailed history of dune migration can be established. A further complication is the fact that some dunes that initially formed several thousand years ago were reactivated more recently following human settlement (Cowie 1963, Cowie et al. 1967). Only about 30 radiocarbon ages have been obtained to date dune migration and far more are required before an accurate chronology is established that would help in identifying the causes of major dune migration episodes: research is discussed further in Appendix C.

Within Manawatu District, soil maps provide an approximate guide to the relative age of the dunes based upon their degree of soil development. Cowie (1963) recognised and mapped three major phases of dune migration that he named Foxton, Motuiti, and Waitarere; his results are reproduced as Figure 4.1. However, it is noted that the ages of the Cowie’s stated dune phases have been updated by subsequent radiocarbon dating and more accurate dates are provided in this section.

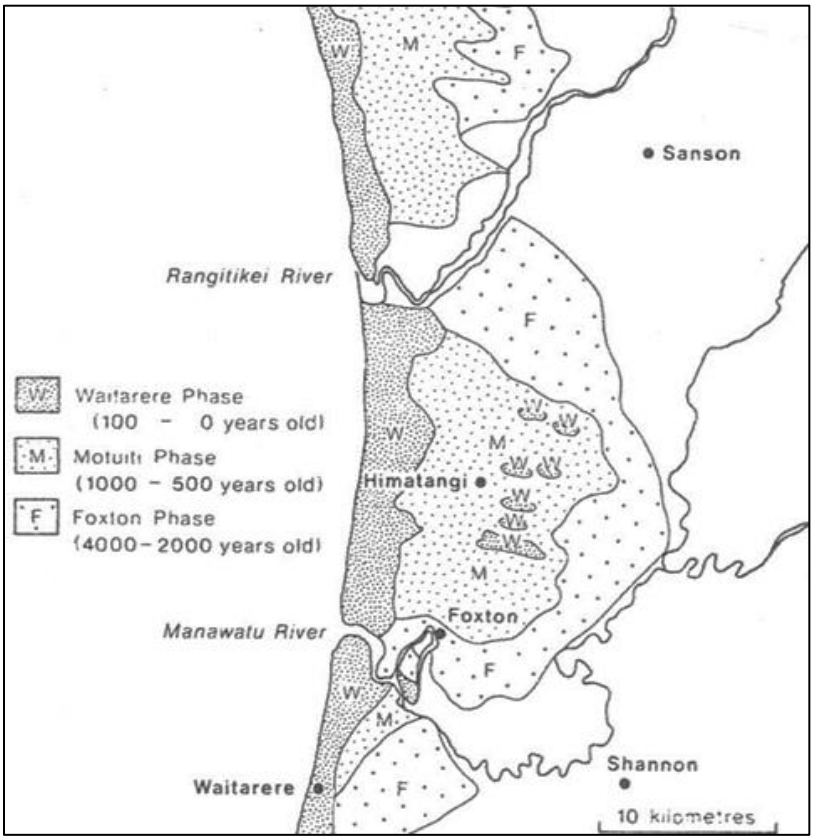

Figure 4.1 Manawatu dune-building phases based on soil types. Cowie (1963)

4.1.1 Foxton Phase Dunes

The dunes of the Foxton Phase developed following the major post-glacial sea-level rise about 6500 years ago. At that time the coastline was about 4 km inland from its present position. Between the Manawatu and Rangitikei Rivers some Foxton phase dunes continued migrating inland for up to 4500 years, reaching 18 km from the present coastline near Rangiotu about 2000 years ago (Shepherd and Lees, 1987). Globally, it is very unusual for coastal dunes to migrate so far inland. Undisturbed Foxton phase dunes are sufficiently old to have developed thicker black or grey soils that, with careful maintenance, protect them from wind erosion and enable more productive farming.

Foxton Phase dunes near the Rangitikei River are closer to the coast and more extensive than further south in the District. This is because approximately 5000 years ago the Rangitikei River entered the sea up to 11 km north of its present estuary, thereby enabling Foxton phase dunes to migrate directly inland from the WNW to their present location within the District. By 2000-3000 years ago, the river had migrated to the south, providing a barrier that prevented migration of Motuiti Phase dunes over the northernmost Foxton Phase dunes to the south of the river. This geomorphological history provides support for Cowie's soil-based chronology as it indicates a significant time interval between the Foxton and Motuiti dune phases.

4.1.2 Motuiti Phase Dunes

These dunes are of intermediate age, with some having been initiated near the coastline between 2000 and 3000 years ago, and probably continued migrating inland over older Foxton phase dunes until about 700 years ago (Muckersie and Shepherd 1995). They are absent from the northernmost part of the Manawatu Dune Field for the reason stated above.

4.1.3 Waitarere Phase Dunes

These dunes are the youngest and only extend two to three kilometres inland from the coastline. Waitarere Phase dunes are thought to have been initiated after Maori settlement about 600 years ago and were very active following European settlement. Their poorly developed soils limit their value for agriculture but they are suitable for forestry. The soil map of Cowie et al. (1967) indicates that many Motuiti phase dunes, particularly those extending up to 7 km to the east of Highway 1, south of Taikorea Road, were remobilised more recently. This probably followed forest burning during both Maori and European settlement for by 1860 the sand country was largely scrub covered (Esler 1978).

Age-based dune classification: Cowie (1963) and Cowie et al. (1967) classified the dune field according to the relative degree of soil development. However, given the time-transgressive nature of the dunes, the paucity of absolute dune ages and remobilisation of some older dunes more recently, a purely age-based classification of dunes within the Manawatu District is probably premature.

4.2 Processes

The Manawatu coast provides optimum conditions for aeolian processes and dune development because of the abundant longshore sand supply, wide beach, fine sand size and strong onshore winds (see Appendix B). Active dunes and older relict dunes are now discussed

4.2.1 Active dunes

Active dunes are now largely confined to a narrow zone adjacent to the coastline. A fundamental distinction may be made between the *foredune*, that is fixed in position by the vegetation covering it, and *transgressive* dunes that lack a vegetation cover and migrate inland, primarily as *blowout lobes* and *parabolic dunes.* See Figure 4.2 for an illustration of the dune type continuum.

As noted earlier in Section 2.4, the *foredune* is the most seaward of the dunes and consists of a shore-parallel ridge that is fixed in position and accretes upwards when pioneering sand-binding plants trap sand that is blown onshore from the beach. The foredune provides a store of sand that reduces the rate of shore retreat during erosion by storm waves. The morphology of the foredune may vary according to the dominance of either the native sand-binding plants spinifex and pingao or marram (introduced), with the native plants growing dunes with a smoother appearance while marram grows into a more hummocky form. As the plants grow they continue to trap wind-blown sand, thereby enabling the foredune accretes upwards.

The foredune adjacent to the mouth of the Rangitikei River (about 1 km in length) is unstable and this area, along with the adjacent 1.5 km stretch of more stable foredune, is part of the Department of Conservations (proposed?) Protected Natural Area 27 (DOC, 1992). Much of the remaining foredune along to Himatangi Beach is now relatively stable, it is currently breached by about 30 widely spaced *blowouts*. As noted in Section 2.4, these are erosional gaps that form when the foredune vegetation cover is breached and the underlying sand deflated by wind erosion. The vegetation cover may be disturbed naturally e.g. by strong winds or storm waves, or by human-related activities such as grazing by introduced animals or off-road vehicles. Even a well vegetated and maintained foredune may become prone to wind erosion if it builds up to an unstable height where it is exposed to higher velocity winds.

South of Himatangi Beach the foredune is dissected by larger and more closely spaced blowouts than occur to the north of Himatangi Beach. Page (2003) studied the development from foredune to blowouts and parabolic dunes near this southern boundary of the district. The 2 km of foredune within the MDC coast (along with 6 km in the adjacent HDC coast) are protected as the Department of Conservation’s (proposed?) Protected Natural Area 24 (DOC, 1992).

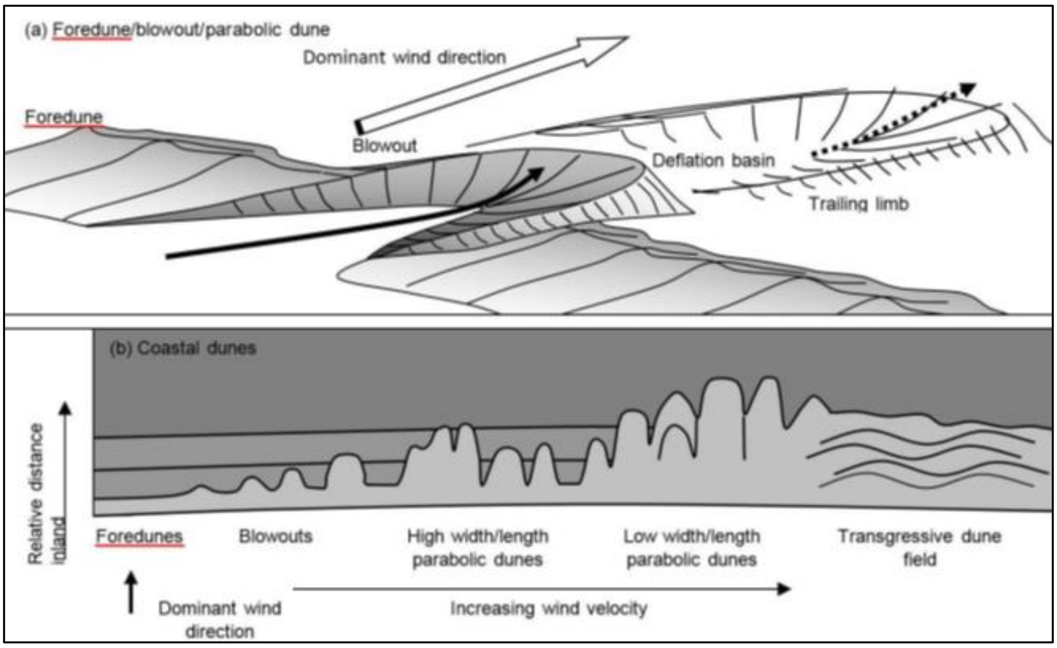

Figure 4.2 Upper diagram: foredune blowout developing into a parabolic dune. Lower diagram: progression from foredunes and relict foredunes in areas with low wind energy to parabolic and more extensive transgressive with higher wind energy dunes and transverse dunes where vegetation impedes migration). Sourced from Bird (2000) and Sloss, Shepherd and Hesp (2012).

Transgressive dunes migrated inland episodically for thousands of years along this coast but relatively few are currently active. The process was boosted during the past few hundred years following disturbance to the vegetation, particularly that stabilising the foredune, firstly by Maori and more recently by European settlers and their introduced animals. However, subsidised dune restoration schemes and pine plantations led to the stabilisation of 81% of the bare dunes between the 1950s and 1990s and a greater decline in the area of active dunes (see Figure 4.3) than elsewhere in New Zealand (Hilton, 2006). Whereas large mobile transverse dunes were present in the past, the presently active transgressive dunes are less extensive and consist almost entirely of blowout lobes and parabolic dunes, together with the deflation troughs and hollows associated with them.

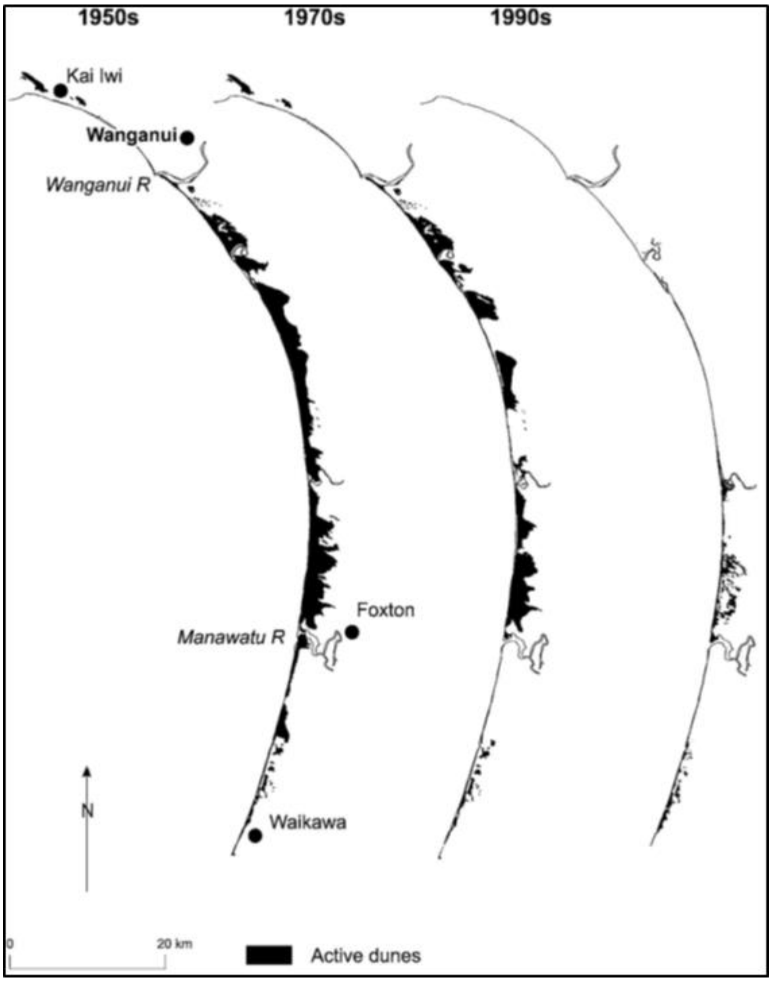

Figure 4.3 Diagram showing the progressive loss of active dunes since the 1950s (from Hilton 2006).

Active transgressive dunes occur along the 8 km Himatangi to Foxton coastline; this area of dunes is referred to as Foxtangi dunes in DOC (1992). The active dunes in the northernmost 2 km of the Foxtangi dunes are in the Manawatu District, and these active transgressive dunes (and active foredune), are particularly impressive (see Figure 4.4). An area of active parabolic dunes also occurs just north of Himitangi Beach Settlement, although these are partially covered with plantation

Some 150 ha of active transgressive dunes also occur adjacent to, and south of, the Rangitikei River mouth (NB Figures 3.6 to 3.8). These dunes are contained within the Department of Conservation (proposed?) Protected Natural Area (Priority 1). The Himitangi and Rangitikei Rivermouth dunes are the largest remaining areas of active dunes along the coast of South Taranaki Bight. These dunes consist mainly of active *parabolic dunes* with an advancing nose, trailing arms (sand ridges) and a central trough or basin. These parabolic dunes are aligned in the direction of the prevailing WNW onshore wind and the distinctly parallel alignment of dune ridges is particularly noticeable from the air. As noted in Section 3, the active Rangitikei Rivermouth dunes are highly dynamic due to the inlet behaviour. The southward offset channel erodes the dunes along the riverbank, thereby initiating blowout development, while detached spits weld to the shore and their sediment blowing landward buries vegetation and supplements landward migration of the active dunes.

Figure 4.4 Active dunes in the Manawatu District immediately south of Himatangi Beach Settlement . Photo CSL, 2004

Blowout initiation and dune migration are also associated with sustained periods of strong westerly winds, conditions usually associated with El Nino conditions (see Figure 4.5). During the 2007 event, CSL carried out repeat aerial surveys of the Rangitiki Rivermouth dune system between 28 September and 10 November that recorded dune-front migration of 34 m, i.e. an average rate of 0.8 m/day.

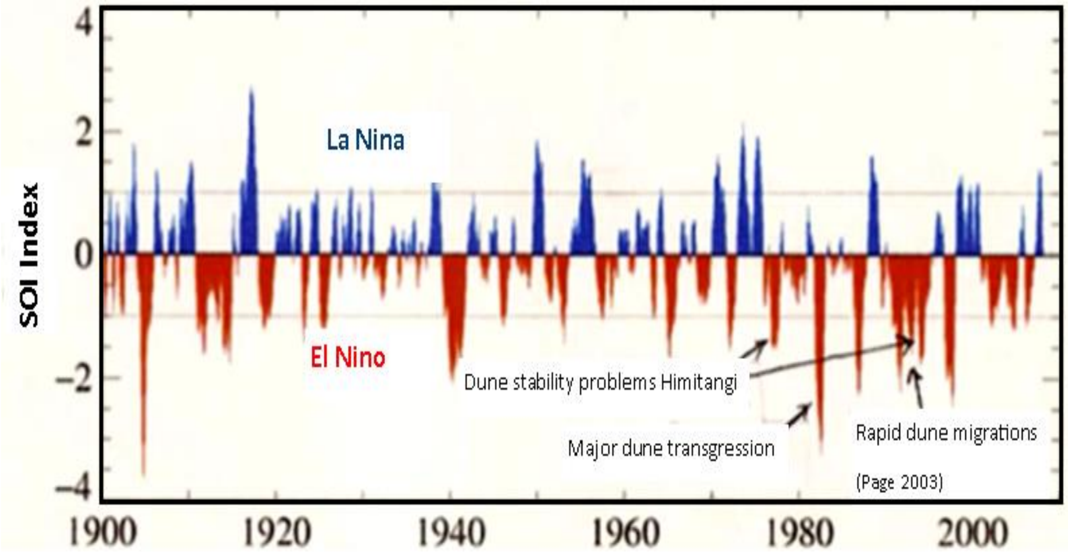

Figure 4.5 Plot of the Southern Oscillation Index (NIWA) showing El Nino and La Nino events. Periods with enhanced dune activity in the Manawatu have been marked

4.2.2 Relict dunes

Most of the dune field consists of stable vegetated dunes (relict dunes) and sand flats that are used mainly for farming and forestry, activities which can remove vegetation and lead to wind erosion, deflation and wind drifts that required stabilization. However, the morphology of the dunes provides evidence for the nature of past processes (see Morphology section below). The dune ridges and associated deflation plains together form a very distinctive landscape, sometimes termed 'the sand country'. Although the original native forest cover has been replaced by pasture and plantations, the natural dune forms are not modified and grassland cover is of benefit in that even relatively small dune landforms that would be invisible under a forest cover are clearly expressed in the landscape (Figure 4.6).

Figure 4.6 V- and U-shaped parabolic dunes inland near the southern boundary of the Manawatu District. The dune ridges run WNW-ESE, parallel with the wind resultant.

A process-based dune classification is of some value for dunes that are currently active, but by far the largest part of the dune field consists of older relict dunes. The exact cause(s) and nature of large-scale migration of Motuiti and Foxton Phase dunes in the past is still largely unknown. However, the fine sand size, wide beach and prevailing strong westerly winds would have provided optimal conditions for the initiation of dune phases. Foxton Phase dune migration was probably initiated by major onshore sand transport by waves following the postglacial sea-level rise, while seismic events that increased the sand supply (via rivers or uplift of the nearshore sea floor) or generated tsunamis may have influenced all three phases.

The reason for widespread dune stabilisation is unknown but we speculate that it would require conditions that encouraged vegetation growth while inhibiting wind-blown sand activity, conditions such as an extended period (decades?) of lighter wind accompanied by higher rainfall.

4.3 Morphology

Detailed classification of the dunes on morphological grounds is difficult because sufficiently detailed three-dimensional data has not been available and many dunes are not simple ‘text-book’ examples. Indeed, many of the dunes are composite landforms, where several parabolic dunes have merged together, and/or formed nested features where dunes of younger age have encroached within, or piled up over, older dunes. Furthermore, the elevation of dunes is influenced to some degree by the nature of the landscape over which the dunes transgressed. For instance, dunes in the vicinity of Highway 1 between Himatangi Junction and Carnarvon are more elevated (above sea level) than those to the east or west: this is because they ascended over the crest of the Himatangi Anticline (Hesp and Shepherd, 1978) that runs near and approximately parallel to the highway, before descending towards the Oroua River.

At the broadest scale, a geomorphological distinction may be made between the dune hillocks/ridges and the intervening sand (deflation) flats. While the dune ridges dominate the landscape, a larger area is occupied by the relatively flat sand plains that developed in the wake of the migrating dunes as bare sand surfaces behind them were deflated down to the elevation of damp sand just above the level of the water-table. Most sand plains slope gently towards the coast to the west of the crest of the Himatangi Anticline, consistent with the slope of the regional water-table, whereas in the eastern part of the dune field they slope eastward towards the Manawatu and Oroua Rivers, consistent with the slope of the eastern flank of the underlying anticline.

Most relict dunes consist of the noses and trailing arms of parabolic dunes, and these are particularly well developed in Manawatu District where the dune field is widest. The dune ridges are mostly linear features that run parallel to the WNW resultant wind direction (NB Figure 4.6). The dunes generally range between approximately 5m and 30m in height. However ridges less than 5m in height may still dominate relatively flat rural landscapes.

A morphological-based dune classification would distinguish between the contemporary foredune that is a shore-parallel feature, and parabolic dunes with arms aligned WNW-ESE.

Most parabolic dunes are relict features but near the coastline some parabolic dunes are still active or only partially stabilised by vegetation**.** Parabolic dunes develop where the vegetation stabilising pre-existing dunes, and particularly the foredune, is breached. Where the vegetation cover was more completely removed, parabolic dunes coalesced to form larger transverse dunes (see Glossary), and geomorphological evidence suggests that those dune types may have been more prevalent in the past. However, when their migration slowed or ceased, the transverse dunes became partially vegetated, resulting in the renewed formation of parabolic dunes that form the final observable landforms.

4.4 Geomorphological character units

4.4.1 The dune areas

An attempt is now made to distinguish (classify) the dune-field based on the age-process-morphological characteristics described in the previous sections. However, the boundaries between the resulting 4 units or classes (see Figure 4.7) are not always very distinct as changes may be gradual.

- Unit 1 is the area containing the youngest dunes and forms a distinct unit where the dunes are generally higher and more closely spaced than in other units. The other remaining three units are less clearly defined and all contain dunes that migrated long distances.
- Unit 2 is an area over which dunes migrated leaving large deflation plains in their wake,
- Unit 3 is an area where the dunes ceased migrating and stabilised.
- Unit 4 is an area where the sand supply was cut off after only the oldest dunes had formed. Boundaries between Units 2, 3, and 4 are not always distinct.

4.4.2 Unit 1 – Seaward dune area

This unit comprises the youngest and seaward-most dunes that lie along the Manawatu District coast. The unit extends up to 4 km inland and includes the contemporary foredune, blowout lobes and mainly smaller parabolic dunes that lie adjacent to the coastline and are closely spaced. Sand plains are relatively small except near Tangimoana where they are underlain by gravel and are up to 1.5 km in length. Most dunes in this area were active relatively recently during the later Waitarere Dune Phase (NB Figure 2.2), but were stabilised during the past 60 years.

4.4.3 Unit 2 – Western Dune area

This area lies to the east of the Seaward Dune Area (Unit 1). It contains the most extensive sand plains in Manawatu District, which developed to the rear of migrating Motuiti Phase dunes where sand was deflated to a level near the water-table. The parabolic dunes that rise above the plains mostly formed during the Motuiti Phase. A line of shallow lakes that extends southwards into Horowhenua District is located at the seaward margin of this unit (see Figure 4.7).

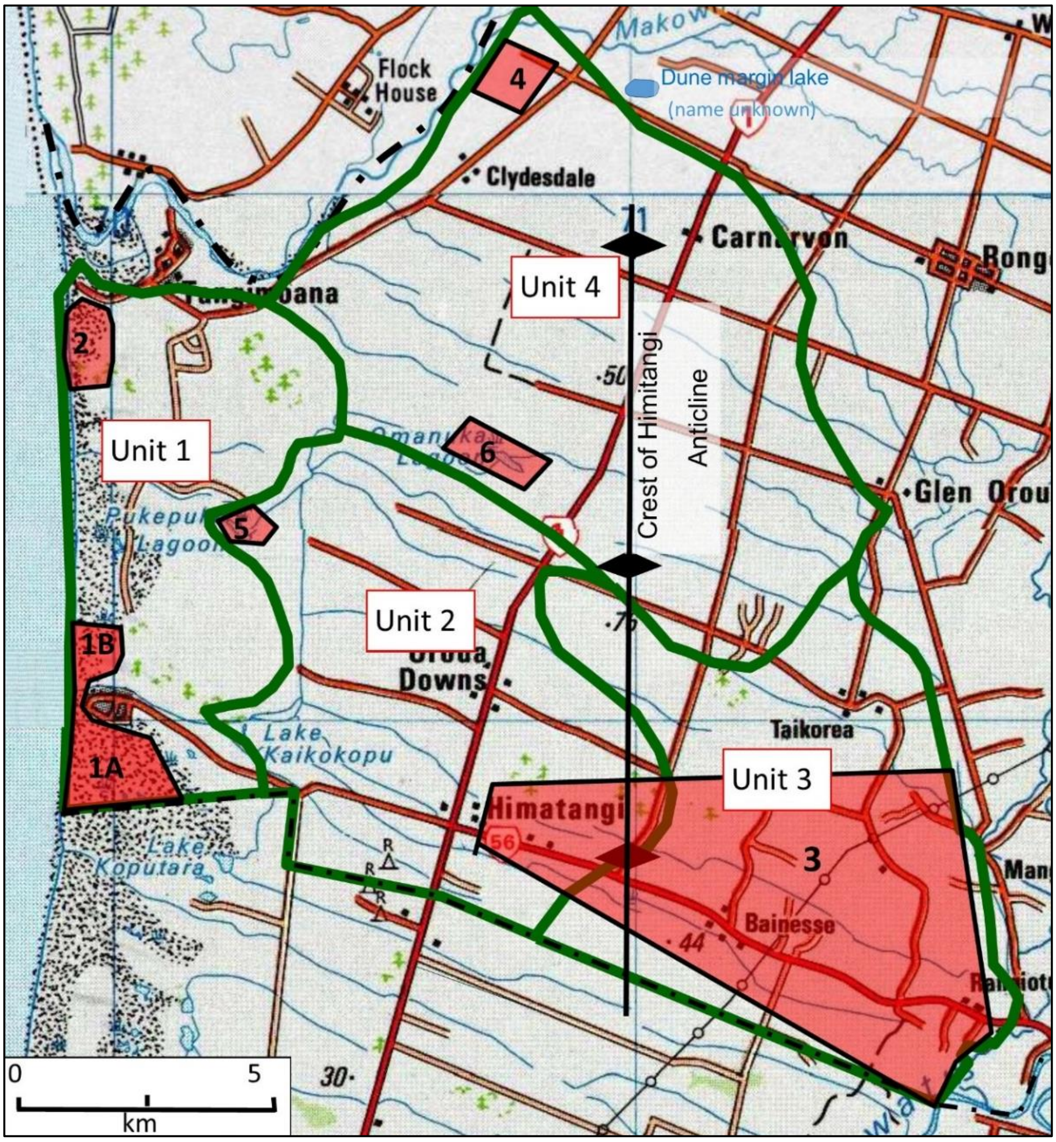

Figure 4.7 Diagram depicting the four *Geomorphological Character Units* outlined by bold green lines, as well as six *Representative Dune Areas* shaded in red with black boarders.

4.4.4 Unit 3 – Eastern Dune area

This area lies adjacent and landward of the Western Dune Area (Unit 2) and contains dunes that migrated furthest inland from the coastline. It contains larger parabolic dunes with long trailing arms that formed during the Motuiti and Foxton dune phases. The southern part of this unit extends eastward to be truncated by Oruoa and Manawatu Rivers.

4.4.5 Unit 4 – Northern Dune area

This area lies across the north of the Manawatu District Dune Field and abuts each of the other units. The Northern Area is dominated by sand plains with relatively low parabolic dunes except near its western and southern boundaries. In this area Foxton Phase dunes reach their greatest extent because they were not covered by migrating Motuiti Phase dunes, probably because the Rangitikei River mouth had migrated southwards and deprived this area of a coastal sand source – possibly even before the end of the Foxton Dune Phase.

4.5 Classification of dune lakes and wetlands

Lakes and wetlands are associated with the dune processes and form an integral component of the dune field landscape; they should be incorporated within any assessment of dune field values as a whole.

4.5.1 Dune field margin lakes

To the north and south of Manawatu District, i.e. in Rangitikei and Horowhenua Districts, many elongate lakes occupy stream valleys along the eastern margin of the dune field where seaward-flowing streams were impeded by encroaching Foxton Phase dunes. However, only one stream in the north of the District, located 1 km east of the Tangimoana Rd - Campion Rd junction and marked in Figure 2.1, was blocked in this manner. It resulted in an elongate area extending some 800 m and is occupied by three small lakes (the largest being 270 m in length) separated by wetland. To the south, the inner margin of the dune field lies on the eastward-sloping flank of the Himatangi Anticline. As the streams in that area flow eastward towards the Oruoa and Manawatu Rivers, the drainage was not impeded by encroaching Foxton Phase dunes and therefore dune-margin lakes are entirely absent.

4.5.2 Intra-dune field lakes

Between the Manawatu and Rangitikei Rivers, a line of seven larger lakes/lagoons, together with several smaller lakes and wetlands, are located parallel to the coast, approximately 3 km inland. These extend from Pukepuke Lagoon towards Foxton Beach (see Figure 2.1) and are all relatively shallow. The two largest of this line of water bodies, Lake Kaikokopu and Pukepuke Lagoon, lie within Manawatu District. These lakes and lagoons developed within the dune field when the encroaching Waitarere Phase dunes impeded drainage from the seaward-sloping sand plain and, together with continuing coastal progradation, resulted in rising water tables.

Elsewhere, there are a number of very small lakes scattered within the dune field, occupying deflation hollows or locations where the drainage was impeded by continuing dune migration. The only significant lake within the older part of the dune field is Omanuka Lagoon that is a kilometre in length and associated with an area of smaller lakes and wetlands to the northwest. Radiocarbon dating of peat infilling the lagoon (Muckersie and Shepherd 1995) indicates that it formed about 3000 years ago.

4.5.3 Wetlands

There are few remaining wetlands in the Manawatu District Dune Field. Some wetlands occur where smaller lakes have been largely or completely infilled with sediment or peat, and others where coastal progradation caused rising water tables. Many wetlands were drained following European occupation. Wetlands usually adjoin the margins of lakes and vary from a narrow reed fringe to the more extensive swamps adjoining Pukepuke and Omanuka Lagoons. Ephemeral lakes appear at times of higher rainfall in the lowest parts of the deflation basins of active and recently active dunes in the Seaward Dune Area (Unit 1); such features are evident in Figure 4.8. These temporary water bodies are capable of breaching the foredune (Figure 4.9) albeit temporarily.

Figure 4.8 Ephemeral lakes occupying deflation basins within the Seaward Dune Area (Unit 1) following winter rains in August 2004. (Photo CSL)

Figure 4.9 Foredune breach during winter of 2015 by landward ephemeral waterbody, South Himatangi Beach. (Photo CSL, January 2016)

5 COASTAL ENVIRONMENT AND REPERSENTATIVE DUNE AREAS

5.1 Comparison

The Hudson (2015) Coastal Sector Boundary (CSB) is shown in Figure 5.1. This sector encompasses the surf zone, beach, foredune and inlet geomorphology. However, we note that the landward boundary is often uneven, reflecting the presence of current or recent dune instability. As these characteristics will change over time a geomorphologically-based approach would somewhat refine this boundary

In addition, the proposed CSB broadly encompasses the areas of active dunes noted above in Section 4, namely immediately south of the Rangitikei Rivermouth and immediately north (the deflation basin area) and south of Himatangi Beach Settlement. Again some final adjustment to the proposed CSBs are recommended.

However, as can be seen in Figure 5.1, large areas of Geomorphological Character Unit 1, the Seaward Dune Area, are excluded from the proposed CSB with the more landward Units 2, 3 and 4 therefore excluded entirely. Given the regional and national significance of these *relict dune environments* we have further addressed the matter of how to incorporate these geomorphologies into the Natural Character assessment soas to enable the council to identify and protect these features; in particular, we propose *several Representative Dune Areas (RDAs)* and these are spatially located in Figure 4.7 and depicted in more detail in Figure 5.2 to 5.5. However, we stress that these boundaries are proposed and open to refinement, particularly the very large RDA 3 which could be partitioned.

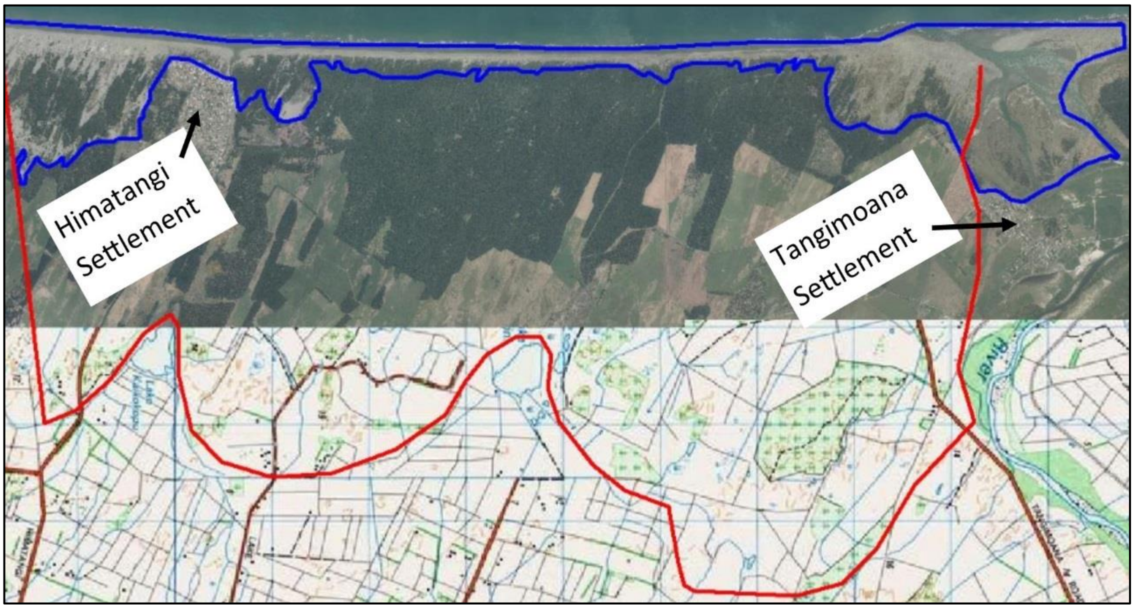

Figure 5.1 Hudson (2015) proposed Coastal Sector Boundary (blue line) and Geomorphological Character Unit 1 (red line).

5.2 Active dunes representation

- Representative Dune Area 1 contains currently active dunes and is located immediately north and south of the Himatangi Beach Settlement in Geomorphological Character Unit 1. The dunes to the south of the settlement (Unit 1A) are a particularly active part of the Foxtangi system and was illustrated earlier by Figure 4.4. On the northern side of the settlement are several active dunes including the exceptionally large parabolic containing the deflation basin described earlier as well as a contrasting narrow parabolic dune and others in differing stages of development (Figure 5.2). The dunes in RDA 1 are outstanding examples of active parabolic dunes and appear to be large enough to remain active dispite being partially vegetated.

- Representative Area 2 contains currently active dune and is located at and to the south of the Rangitikei Rivermouth in Geomorphological Character Unit 1. These dunes were illustrated earlier in Section 3 (Figures 3.6 to 3.8) where it was noted that these dunes are likely to remain unstable and possible increase in activity because of the Rangitkei Rivermouth/Inlet dynamics.

Comment These remaining active areas are significant because examples of the processes that produced the much larger dune field during the past 6000 years can no longer be observed in the District. These two areas provide distinctive active dune landscapes. They also have scientific value as they provide sites where aeolian processes and the rate of active transgressive dune movement can be studied, measured and related to variables such as windiness e.g. Page (2003). Sizeable areas of active dunes are becoming rare in the larger dune field because of sand stabilisation schemes, so remaining locations such as these also provide an opportunity for students of all ages to visit and appreciate the active erosional and depositional processes. These dynamic areas also contain some contrasting vegetation and hydrology and hence some variation in dune processes and form as well as providing distinct and dynamic ecological niches.

5.3 Relict dune representation

- Representative Dune Area 3 contains relict dune assemblages of both the Foxton and Motuiti Dune Phases and stretches almost from the State Highway at Himatange to Rangiotu at the Ohura River thereby spanning parts of Geomorphological Character Units 2 and 3. Figure 5.3 depicts a possible RDA 3 boundary.

Comment This site contains the best examples of well-defined parabolic dunes that formed during the Foxton and Motuiti Dune Phases. Dunes located near Rangiotu migrated further inland (c.18 km from the present coastline) than dunes in any other part of the Paekakariki to Patea Dune Field and during this migration climbed

Figure 5.2 Large parabolic dune and deflation basin in RDA 1B just north of Himatangi Beach Settlement. Photo CLS

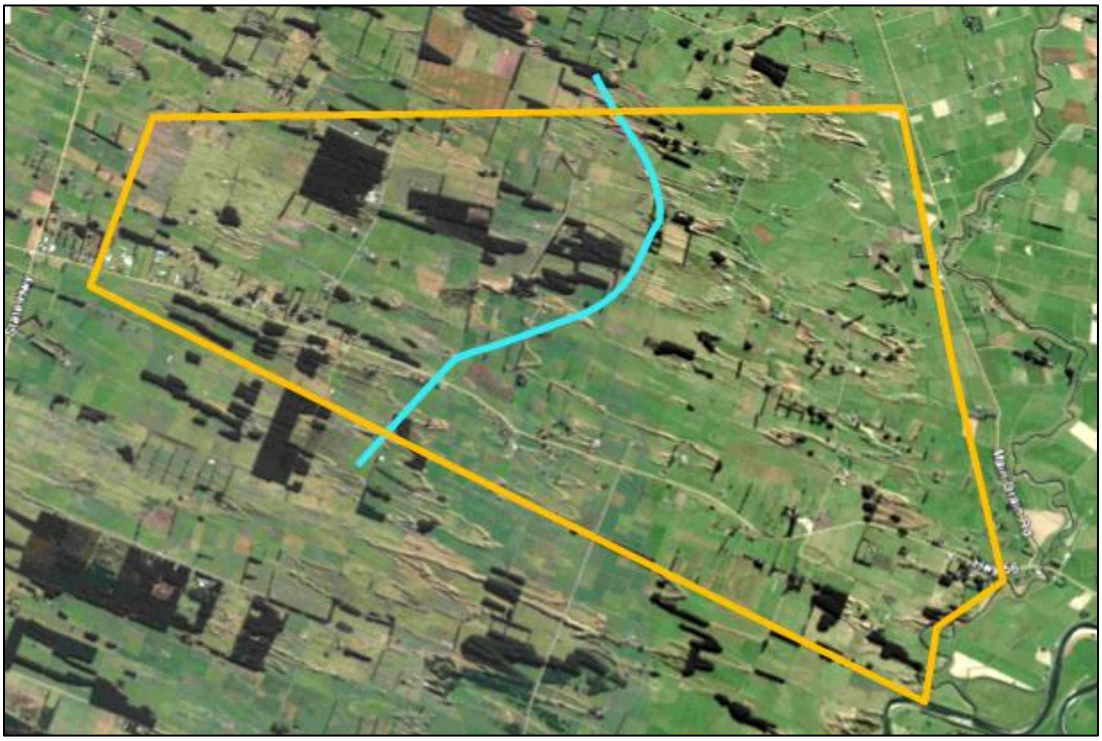

Figure 5.3 Representative Dune Area 3 within the proposed yellow boundary line that extends almost from the State Highway at left to Manawatu and Oroua Rivers on right side of image. Relict Foxton phase dunes are on the right of the blue line and relict Motuiti Phase dunes on the left of the blue line.

over the broad crest of the Himatangi Anticline before descending towards the Oruoa River. There are good examples of ‘textbook’ parabolic dunes but many others are nested or composite in form, while several dune ridges formed as the advancing edge of transverse dunes (see Glossary). The landscape is dominated by the trailing ridges as parabolic dunes advance (hence the size of RDA 3) and these are aligned to the WNW dominant wind direction and are separated by sand plains and deflation troughs. Of particular scientific interest is the exposure of the innermost dunes along the banks of the Oruoa River approximately 800 m southwest of Rangiotu. This site enabled vegetation buried by two advances of Foxton Phase dunes to be radiocarbon dated at younger than 2000 years old, providing the first evidence for the time-transgressive nature of the dunes (Shepherd and Lees, 1987).

- Representative Dune Area 4 contains the northernmost Foxton Phase dunes near the junction of Campions Road and Tangimoana Road and at the northern extremity of Geomorphological Character Unit 4. The dunes and proposed RDA 4 boundary are shown in Figure 5.4.

  Comment Parabolic dunes are generally less distinctive in the northeastern dune area (Unit 4) but this example is well developed. Dunes in this area are significant in that they could only have migrated into their present location when the Rangitikei River flowed sufficiently north of its present position to enable them to move inland from the coast south of the river mouth in an ESE direction. North of this site the early Rangitikei River, as now, would have been able to prevent dunes migrating into the Manawatu District.

Figure 5.4 Representative Dune Area 4 within the proposed (yellow) boundary line. These Foxton Phase parabolic dunes that migrated inland before the Rangitikei River (at left of image) shifted southwards to its present location.

5.4 Dunes associated with dune lakes

The formation of lakes within the dune field is directly related to the history of dune migration. There are only three sizeable dune lakes in the District but they have different ages and modes of formation. They are significant features from both a geomorphological and ecological point of view.

- Representative Dune Area 5 contains Pukepuke Lagoon midway between Himatangi and Tangimoana and just inside the Geomorphological Character Unit 2 boundary (Figure 4.7). The lagoon and proposed RDA 5 boundary is shown in Figure 5.5.

  Comment This lake is the northernmost of the line of lakes described in Section 4.5.2. Pukepuke Lagoon is the best example in the District of this type of lake and is fringed by extensive wetlands. Their ecological value has long been recognised but the dunes adjoining the lake to the west are not included in the Pukepuke Conservation Area. The dunes are also significant because they provide a good example of a *transverse dune* (see Glossary) that developed smaller parabolic dunes at its leading edge when it became partially stabilised by vegetation.

Figure 5.5 Representative dune area 5 within the proposed (yellow) boundary line: Pukepuke Lagoon and associated dunes and wetland.

- Representative Dune Area 6 contains Omanuka Lagoon midway between Omanuka Road and Whale Road and about 1 km seaward of the State highway. It lies on the southern side of Geomorphological Character Unit 4. This lagoon, associated dunes and wetlands to the northwest, and proposed RDA 6 boundary are depicted in Figure 5.6.

Comment Omanuka Lagoon is significant because it is the only sizeable lake that developed within the older part of the dune field. It appears to have formed when younger Foxton Phase dunes blocked an incipient stream valley that was developing on an older sand plain that sloped westward from the crest of the Himatangi Anticline. As it occupies a stream valley, the lake is more elongate than Pukepuke Lagoon. This lagoon is considerably older than Pukepuke Lagoon and more sediment has been deposited on its bed, with one sample of peat having been radiocarbon dated at c.3000 years old. Two wood samples from stumps of trees in growth position within the lake were radiocarbon dated at between 1000 and 1500 years, suggesting that the lake must have dried up around that time for a period sufficiently long for forest to have developed. Further research into the lake's history is warranted and a scientific study of the lake sediment could prove particularly fruitful. Appendix C discusses dune research including some methods and projects.

Figure 5.6 Representative Dune Area 6: Omanuka Lagoon and associated dunes and swamp

6. MANAGEMENT AND PROTECTION CONSIDERATIONS

6.1 Surf zone and beach

The surf zone and beach are subject to high energy and associated processes and operate independently of human activities. No threat is anticipated or management required

6.2 Inlets

Inlets are high interaction zones between marine and fluvial processes and tend to be the areas where human settlement and use concentrate – as happens at the Rangitikei and Himatangi Inlets. Unlike the open coast, inlets can be controlled relatively easily with structures and other measures (diversions and dredging) and this has been the case at the Manawatu District Inlets.

At the Rangitikei, the diversion at the landward end of the inlet has had an effect on the configuration; however, the resulting form and processes still reflect the natural (primary or first order) processes. Navigation may be affected at times depending on ever-changing channel and bar alignments determined by the primary processes. Water abstraction and climate change may also affect inlet processes and have consequences for navigation but these are anticipated to be secondary effects, for the time being at least, and any management should consist of soft options (rather than engineering structures) such as dredging.

The Pukepuke Inlet appears to have had a channel realignment carried out in the past, possibly to mitigate flooding. Given the lack of adjacent and hinterland development it is anticipated that the inlet processes are able to adjust to this level of human intervention.

The Kaikokopu Inlet at Himatangi Beach Settlement has been affected by a river training wall apparently constructed to control lateral migration of the channel to the south where it would otherwise have threated residences with shoreline erosion. The orientation of the training wall appears to have directed the channel northward away from the southern settlement seaward margin. The training wall is likely to require maintenance from time to time and eventually a more robust structure will be required should predicted climate change effects occur. The inlet may thus become further constrained (limiting lateral migration) in the future.

6.3 Foredune

The contemporary foredune is the most vulnerable of all dune landforms in the region because it lacks soil development, is vegetated, often sparsely, by low pioneering vegetation, and is exposed to strong winds directly from the sea. The foredune is the first line of defence against coastal erosion, but is a fragile landform vulnerable to destruction if anything interferes with its vegetation cover. Consequently, it is a natural feature that requires protection and vigilance by managers, especially if the regime changes (increased windiness and wave energy) associated with climate change predictions.

6.4 Transgressive dunes

Active transgressive dunes have been present in the district for more than 6000 years but, because they may encroach upon farmland, forests, buildings and infrastructure, active dunes been largely stabilised during the past 75 years with the result that very few examples remain. Those active dunes that survive are significant because they dramatically demonstrate the processes that have resulted in the development of the huge area of relict dunes that extend across most of the coastal plain to form part of New Zealand’s largest dune field. As such, they are a valuable scientific resource that enables the present active processes to be studied, but are threatened by continuing stabilization schemes. Some unvegetated deflation basins and dune lobes, such as those just north of Himitangi Beach, or plantation-covered relict dunes may provide a suitable playground for off-road vehicle enthusiasts and takes pressure off more fragile vegetated dunes, such as the foredune

6.5 Dune ridges

Dune ridges dominate the dune field landscape but are easily modified by earth-moving equipment and are therefore particularly vulnerable to removal or modification. The higher ridges are more prominent but even small ridges may dominate a landscape with low relief. While the expression of the dune forms in the landscape is most evident where there is pasture cover and few trees, the overall character and pattern of the dunes is most striking from the air.

6.6 Dune-field landscape

The foredune, transgressive dunes and dune ridges are positive relief features that form the most striking component of the dune field landscape and dominate skylines wherever the Tararua Range is not visible. To maintain the integrity of the dune field landscape, one or more of the following approaches could be considered. Note that they have also been suggested to the Horowhenua District Council. These options could be applied to the entire dune field or just to the smaller RDAs described in Section 5.

- Restricting any major modification to the natural form of dunes above a selected dune height, together with restriction of the erection of buildings on dune crests in particular locations. This should require accurate spatial delineation to provide clarity and certainty.
- Preserving the longitudinal continuity of major dune ridges because in this globally significant parabolic dune field, New Zealand’s largest dune field, the long parallel dune ridges are the most distinctive landscape features associated with dunes that have migrated long distances.
- Protecting particularly striking examples of dune forms.
- Preventing any major modification to the dunes within one or more carefully chosen strips of land that extend from the coastline to the inner margin of the dunes. These

strips could be 1 km in width. In addition to protecting representative cross sections of the dunes, including those of smaller sizes, they would preserve the dune forms, the dune stratigraphy and substrate for future scientific studies of the age and development of the dune field. Despite of the fact that this is New Zealand's largest dune field relatively little is known about the absolute age of the dunes or the reasons for periods of episodic dune .

The measures listed above need not affect existing farmers or land use unless landowners intend to remove dune ridges in order to produce flat land suitable for modern irrigation practices. The impact of conversion to forestry would also need to be considered. The dunes have always been susceptible to deflation if the vegetation cover is damaged or destroyed by over-grazing, but existing farms are generally well-managed and this is rarely a problem.

Although forest clearance, wetland drainage and exotic forestry have greatly modified the natural landscape, the dune landforms have survived largely unscathed, apart from small-scale earthworks associated with traditional farming practices and site works for coastal subdivision. The removal of dunes to facilitate irrigation on farms is very limited at present but, with the efficacy of modern earth-moving machinery and increased dairy farming, is likely to provide the main future threat to the natural physical landscape.

6.7 Dune flats

Dune flats (deflation plains) occupy a significant proportion of the dune field and provide the most suitable terrain for intensive irrigated dairy and crop farming. This is reflected in existing patterns of land use. If further intensification of agriculture is concentrated on the dune flats this would minimise any impact on the qualities of the dune field landscape.

6.8 Dune lakes and wetlands

As lakes and wetlands are relatively sparse in Manawatu District, their ecological and scientific values are particularly significant. The lakes are part of the dune field and should be included within any assessment of dune field values.

7. CONCLUSIONS and RECOMMENDATIONS

- The surf zone, beach and foreshore are dynamic and significant geomorphological units that are significant at a local level and they are largely encompassed by the Hudson (2015) Coastal Sector Boundary

- The two smaller inlets (the Pukepuke and Kaikokopu) are similarly dynamic and significant at the local level with the third, the Rangitikei having regional and possibly national geomorphological significance. Once again, the Hudson (2015) Coastal Sector Boundary largely encompasses these features.

- While the Hudson (2015) Coastal Sector Boundary contains the beach, inlet and foredune units as well as the two main active dune units, we recommend the final locations undergo (minor) alteration in places to more broadly represent the geomorphology.

- The landward dunes form part of New Zealand's largest dune field stretching 200 km from Paekakariki to Patea with geomorphological expression changing along the coast in accord with local variation in wind regime, relief and sediment supply. The dune field is nationally significant both in its varying parts and as a whole. The main active dune areas are encompassed by the Hudson (2015) Coastal Sector Boundary; however, a vast areas of relict dunes with accompanying sand flats and water bodies (about 23,000 ha) lie landward of the boundary. This study has explained the age/sequence, processes and morphological characteristics of these dunes, classified them into 4 Geomorphological Character Units and from these several Representative Dune Areas were selected to illustrate areas of active dunes, areas of old relict dunes and two area that include lagoons. Possible boundaries for the representative areas are suggested, but may require adjustment, especially the large RDA number 3. We recommend such RDAs be acceptably defined and incorporated into the Natural Character aspects of the District Plan.

- The Rangitikei Inlet and the Holocene Dune Field are considered to be *outstanding geomorphologies* as they each have regional/national significance and their form and controlling processes are clearly evident, either contemporarily observable or inferred by relict forms.

- The present geomorphological assessment includes a range of management and protection considerations

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APPENDICES

Appendix A Shoreline change

Himatangi shoreline change was calculated at sites north (NZMG 2699182.7 E and 6089519.5 N) and south (NZMG 2699182.70 E and 6089519.5 N) of Himatangi Beach using the 1889 survey plan, vertical aerial photos from 1942, 1963, 1979 and 1995 and satellite images from 2005 and 2015. The data set spanned 126 years. The shoreline was the toe of the foredune, with the 1889 spring high water mark being adjusted landward some 20 m, this being the contemporary difference, and the edge of dune vegetation identified in the aerial and satellite images being assumed to define the dune toe (this being normal practice). The site co-ordinates given above define the adjusted 1889 shoreline and other shorelines are located on the shore-normal transect extending seaward from this point. The data from the two sites were averaged and the analysis was carried out using linear regression modelling. The final time-series is depicted below with the change in slope at 1963 (year 74) being evident. In each case the correlation co-efficient (r) was greater than 0.997 (highly significant association).

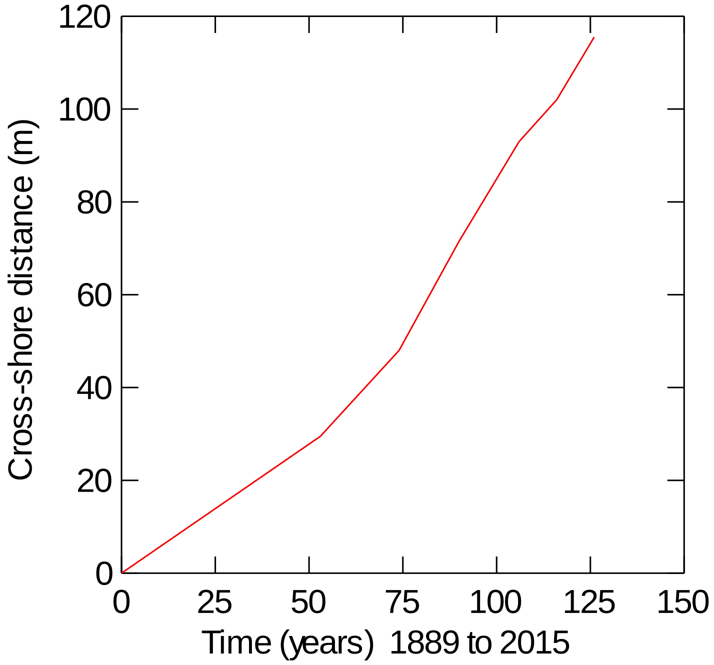

Figure caption Shoreline change at Himatangi between 1889 and 2015 (see text for explanation)

Appendix B. Wind resultant

When discussing sand and dune movement in this report we have referred to the ‘resultant for sand moving winds’. This resultant is computed from wind records by including only winds exceeding 10 knots, as lower velocities do not initiate sand movement, and by cubing the wind speeds as sand transport is proportional to the cube of the wind velocity. This resultant may differ from the predominant wind direction, butthetwo directions are similar in the Manawatu. Most coastal dune research uses a resultant computed from only onshore wind directions, as dune sand is normally sourced from the beach.

The resultant referred to in this report was computed by Muckersie (1989) from wind data recorded at Ohakea Airport, using the Freyberger method (1979). The onshore wind resultant derived in this manner was 291º. This is consistent with the observed direction of present dune migration and the alignment of inland dune ridges in the Manawatu District.

Total onshore sand-moving wind energy may be measured by calculating the drift potential (Freyberger, 1979). The value for Ohakea is classified as medium but is likely to be higher at the coastline as Wanganui Airport, which is located adjacent to the coastline, is **classified as high**.

Appendix C. Future research

Although the dune field is of considerable scientific interest, very little is known about it. Understanding could be improved with research in the following areas:

a) Material should be dated by C-14 and (generally less accurate) thermoluminescence methods to determine the absolute age of the dunes. The former technique would require the recovery of material for dating mainly from boreholes. Some radiocarbon dating has been carried out (e.g. Shepherd and Lees, 1987; Muckersie and Shepherd, 1995) but more would enable the start and finish of dune-migration episodes to be determined with greater precision, and establish whether the various dune phases were synchronous throughout the larger region. This may shed some light upon the causes of the episodes and enable their timing to be correlated with climatic history or possibly volcanic or seismic/tsunami events. It would also assist in determining the representativeness of the various dunes.

b) Dune morphology has never been studied in detail and no systematic classification of the dune forms has ever been attempted. This would need to precede any explanation for the variety of dune forms present in the district. An explanation would also require assessment of areal variation within the district of such factors as wind climate, sediment supply, coastal progradation rates and the nature of the landscape over which the dunes migrated.

There is little information about contemporary dune processes such as the speed of transgressive dune migration, the rate of blowout development and how these vary with time, and the rate of dune development on extensive bare surfaces such as river mouth bars. Study of the Rangitikei River mouth area would also enable models to be developed and tested with respect to the effect of the cyclic migration and shifting of river mouths upon dune development and coastal evolution. Such information, including research into inlet behaviour and configurations as mentioned at the end of Section 3, would assist coastal planning.