QUEEN ELIZABETH PARK

COASTAL DUNES MANAGEMENT

DISCUSSION DOCUMENT

Prepared for
Wellington Regional Council

by

Boffa Miskell Ltd

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EXECUTIVE SUMMARY

The objectives of this report are to:

- Outline the overall erosion processes that are occurring in the coastal dune area of Queen Elizabeth Park, after reviewing the physical and natural history background
- Examine current Park coastal dune management
- Develop options for management strategies and specific projects in the coastal dune area

It provides background material and scopes options for future management directions and projects, that can be used in the forthcoming review of the Park Management Plan.

Coastal processes

The Queen Elizabeth Park coastline, characterised by a flat sandy beach backed by a significant sand dune system, is very vulnerable to the effects of wave action. The various components that can contribute to extreme sea levels could combine to produce an extreme high water level of 3.56 metres in a 50 year return period or 4.25 meters in a 100 year return period. Historically, there has been a retreat of the coastline in the northern part of the Park that has averaged 0.8 metre per year for the last 25 years, beginning with the severe storm of December 1976. This historical average can be compared to a prediction of a theoretical maximum retreat of 30.5 m in a 50-yr return period extreme storm event or 48.7 m in a 100-yr return period extreme storm event. Many parts of the coastal foredune are actively eroding at present and beach retreat continues near the northern boundary of the Park. Towards the southern end of the Park, the shoreline appears to have been more stable.

Biota

The vegetation of the coastal dune area is a complex mosaic of several communities in which both indigenous and introduced plants are prominent. All the communities show a considerable amount of disturbance. There are three main communities which cover more than 90% of the total dune area:

- Shrubland dominated by taupata, boneseed, flax and lupin, over spinifex and marram
- Vineland dominated by blackberry and bracken, with scattered boneseed, toetoe, pampas, mahoe and taupata
- Low forest dominated by taupata, mahoe, boneseed and karo.

A large number of the adventive plants occurring in the Park have become or are becoming persistent and troublesome weeds of the coastal dune area. Examples are boneseed, blackberry, Italian buckthorn, boxwood, and pampas. The first two especially are dominant in large areas. Some of the weedy species are however valuable in retarding retreat of the foredune. Any weed control which results in bare ground or a sparse plant cover has the potential to enhance the further spread of weeds. Some relatively rare plants in the coastal dunes may be threatened by the spread of weeds. There are a number of New Zealand native species, not native to the Park or to the district, which are or have the potential to be invasive and troublesome weeds which could irreversibly alter the composition and nature of coastal dune communities. A large area of the coastal dune is designated to be managed for conservation purposes. Without either or grazing and active management of this area, weed infestation is likely to increase.

Native animal communities are little known but appear to be impoverished. A number of animal pests are likely to be having significant effects on natural processes in this area, of which the most significant are likely to be mustelid and rat species. Weeds are well surveyed but there is little systematic knowledge of the impacts of animal pests.

Values

The coastal dune area has been recognised for some time as having significant natural and cultural values. A large number of archaeological sites and other sites of significance to Maori are found in the area and these are concentrated in the coastal dune area. Natural processes will continue to threaten some of these sites. The Park is subject to several Waitangi Tribunal claims. The coastal dunes are recognised as a Recommended Area for Protection in the Protected Natural Programme Survey of the Foxton Ecological District. However, it appears that, compared to the time of assessment for the PNA survey there is now less dominance by native plant species and greater dominance by the most widespread weed species. Management intervention to reduce the weed threat and restore appropriate plant cover is urgently needed to maintain the important natural values of the coastal dune area.

Recreation management

Queen Elizabeth Park is managed under a Management Plan (prepared in 1993), which aims to provide for the sustainable management and development of the Park for outdoor recreational use while preserving its natural, historical and cultural values. The Park is an important recreational area, and visitors expect good access to the beach. Access from the coastal track (including walking with dogs) is essentially uncontrolled and in some places, is causing damage to the foredune or beach edge. Horse riding has a long history in the Park but has very severe impacts on unconsolidated dunes and the coastal track. Horse riding on the inland track is also opening up local points on the track to erosion which has the potential to become worse.

Principles for management

Two of the central questions running through much of the preceding summary of issues are:

- To what extent can or should the coastal dune area within Queen Elizabeth Park be stabilised, restored, or otherwise managed?
- Does management of the area for conservation and cultural values conflict with management for recreational potential?

Some principles that could guide reaching answers to these and other fundamental questions are:

Erosion processes issues

- There should be no change to the “allow natural processes” principle in the present Management Plan.
- Pedestrian access to the beach from the coastal dune area needs to be controlled and channelled to a reasonable extent, in order to protect the foredune and its biota, and archaeological sites.
- Plant cover on the coastal dune area should be maintained to the greatest extent compatible with natural processes.

Recreation and access issues

- Recreational use has a primary right in the Park to be provided for, consistent with preservation of the Park's natural, historical and cultural values.

Pests and restoration

- Pest control needs to be prioritised according to the risks to conservation values.
- Ongoing control of weeds and management of non-natives plant species will be required, within an overall weeds control strategy for the Park.
- Plant pest control should usually be accompanied by replanting of new desired plant cover
- All restoration and amenity planting should be done using eco-sourced plants native to the local district (with the possible exception of the Wainui Development Area).

Archaeological and cultural values

- Archaeological sites require active protection
- Protection of the archaeological sites and Maori cultural values is best achieved through kaitiakitanga of the tangata whenua, in association with professional care from Park and other organisations' staff, and respect and understanding from the public.
- In general, the best physical protection of archaeological sites in the coastal dune area will be achieved by maintaining as complete vegetation cover as possible, and siting tracks and other infrastructure away from archaeological sites.

Knowledge and awareness

- A well-informed public are most likely to be sympathetic to conservation management.
- Changes in management, and the state of the environment within the Park, should be monitored.

Options for future management of the coastal dune area

Some options for overall management of the coastal foredunes were examined. Beach nourishment and structural protection works options are not favoured because they are inappropriate and far too expensive. The two principal options that appear to be feasible for responsible management of the coastal dune area are "Do nothing" or "Dune management and conservation". The "Dune management and conservation" is the preferred option of the consultant team, because this option:

- is compatible with the "natural processes" principle but attempts to maintain plant and animal communities as well;
- increases the chances of success of an ecological restoration programme by maintaining vegetation cover; and
- should succeed in slowing the rate of foredune erosion in the short-term, and hence enhancing the security of Park infrastructure without compromising the natural character of the coastal dune area.

However, this strategy will not change the long-term rate of erosion.

Specific projects and recommendations

Some specific short and long term projects are briefly discussed. These cover:

- Provision of secure (hardened) points of access between the coastal foredunes and the beach
- Foredune habitat restoration

- Foredune and other revegetation;
- Track development
- Weed and pest control
- Archaeological sites management
- Interpretation and education
- Further studies and monitoring.

The most specific and urgent of these projects are covered by the following recommendations:

Pest control

1. Carry out focussed short-term studies on animal pest densities and impacts over next 12 months, in conjunction with WRC Biosecurity Department and possibly with post-graduate Victoria University student projects.

2. Complete a comprehensive animal and plant pest strategy for the Park by the end of 2002, as part of the revision of the Management Plan

3. Immediate pest control priorities:
   - Complete pampas control
   - Trials of complete weed control and replanting in small areas
   - Contain spread (include surveillance monitoring) of currently restricted aggressive weed species, especially brush wattle and Italian buckthorn
   - Continue current animal pest control

Beach access

4. Undertake more detailed consideration of hardened beach access points. This should include construction of one “high use” and one ”low use” structure before summer 2001 season on a trial basis, pending firm policy on beach access in the revised Management Plan.

Restoration

5. Undertake detailed consideration of one specific area restoration project, alongside Management Plan revision.
6. Gather resource material about coastal restoration projects.

Education and interpretation

7. Plan a specific programme for public education and interpretation about the ecological, cultural and archaeological values of the coastal dune area, if possible in conjunction with the area restoration project.

TABLE OF CONTENTS

Photos 1-10 and Maps 1 and 2 follow the Recommendations (p35).

W01034-10 (PB), Final report to WRC 12.09.01

1 INTRODUCTION

1.1 Background to project

Queen Elizabeth Park is located on the Kapiti Coast between Paekakariki and Raumati, 40 kilometres north of Wellington. Access to the Park is at the northern and southern ends through Raumati and Paekakariki, and from State Highway 1 at MacKays Crossing. The Park is Crown Land, managed as a regional park by the Parks and Forests Group, Landcare Division, of the Wellington Regional Council "in order to provide recreational access to the Kapiti Coast for residents and visitors to the Wellington Region, and to preserve a representative example of the natural landscape of the Kapiti Coastal plain for recreational and educational purposes"[1]. The Park is managed as a Recreation Reserve under the Reserves Act 1977.

Of the total Park area of 638 hectares, about 200 ha of coastal dunes are managed in their natural state for recreation and conservation purposes. The Park foredunes are identified as being the last relatively unmodified dunes on the Kapiti Coast. Most of the remaining area of the Park is leased by the Wellington Regional Council for farming. The Park is covered by a Management Plan which was prepared in 1993[2]. While the objectives and policies of the Management Plan recognise that the dunes are a very important conservation zone, it is also recognised that they are heavily invaded by a some serious and persistent weed species, and also have a number of other issues involved with their management for both conservation and recreation species.

Through the review of the Wellington Regional Council's 10 year plan (Long-term Financial Strategy) in 2000, funding was approved for 3 biodiversity projects at Queen Elizabeth Park:

- Remnant forest restoration
- Mackays Crossing wetland restoration
- Coastal dune area restoration

1.2 Scope and objectives of this report

In early 2001 Wellington Regional Council sought the assistance of Boffa Miskell Ltd towards the above projects. This report is concerned with the third of the projects.

The objectives of this report are to:

- Outline the overall erosion processes that are occurring after reviewing the physical and natural history background

[1] Wellington Regional Council 1993: Queen Elizabeth Park Management Plan. (2 vols: Part 1: Aims, Objectives and Policies; Part 2: Resource Statement). WRC Publication No WRC/REC-G-93/58.
[2] Queen Elizabeth Park Management Plan 1993. See footnote 1.

- Look at the current Park Coastal Dune management and discuss with relevant organisations and community groups
- Develop options for management strategies and specific projects.

The results of this work will then feed into subsequent work on foredune restoration, as well as a review of the Management Plan, which is planned to commence in 2002. The current work is not intended to replace or pre-empt revision of any aspects of the Management Plan, rather to provide background material and scope options for future management directions and projects. It also provides limited details of possible specific projects that could proceed immediately, again without pre-empting revision of the Management Plan.

1.3 Acknowledgements

This report was prepared by Paul Blaschke (Project Leader), Boffa Miskell Ltd, and John Lumsden, coastal management consultant. We acknowledge with thanks assistance from the following:

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Residents of Paekakariki and Raumati, for participating in an informal “focus group” discussion.

2 PHYSICAL AND NATURAL HISTORY BACKGROUND

2.1 Climate

The Park area as a whole is subject to west to north west, relatively frequent gales, annual rainfall of about 900-1250mm, and has warm summers and mild winters. One of the most significant climatic features is the occurrence of frequent gales from the west and northwest. These gales affect the coastal dune area in particular as it has no protection against weather coming from the west. The climate has a significant influence on the Park environment, determining the type and quality of the vegetation and affecting landform. Changes in climatic trends may change this influence of climate (see below).

2.2 Topography

The landscape of the Park is characterised by a series of landform zones that run the length of the Park and lie parallel with the coast, reflecting their original from coastal processes. Aspects of the topography and landscape of the coastal dune area are shown in Photos 1-10 and Map 1.

Since the local sea level stabilised at its present level, about 6000 years ago, the Kapiti and Manawatu coastline has been generally advancing seawards as a result of deposition of sediments. This material has given rise to a series of dune formations that lie parallel to the coast through the length of the Park and occupy approximately half of the Park area.

Along the eastern side of the Park between the dunelands and the hills to the east is an area of level, low-lying peat land. The whole coastal dune area comprises more or less consolidated sand dunes rising from a sandy beach (Photos 1-6), orientated in a west northwest-east southeast direction, parallel to the coastline. The physiography and geomorphology of the dunes are described in detail in the Park Management Plan[3]. Most of the Park's coastal dunes are derived from the Taupo phase of dune building formed from sea-rafted pumice and pumice sand washed out to the Manawatu and Horowhenua coasts following the Taupo volcanic eruption about 1900 years ago. The resulting dunes are steep-sided, rising to nearly 30m above sea level within only a few hundred metres of the shoreline. Soils developed on these dunes are generally poorly-developed and excessively-drained yellow-brown sands (Waitarere and Foxton series soils).

Along the eastern side of the Park between the dunelands and the hills to the east is an area of level, low-lying peat land.

There are other quite high dunes within the coastal dune area but behind the foredune. These are dunes of the Taupo dune-building phase which occurred about 1900 years ago. These dunes rise up to 29m at the Whareraoa trig. They are relatively stable compared to the coastal foredune, but have the potential for severe wind erosion if their vegetation is

[3]Queen Elizabeth Park Management Plan 1993 (Part 2, pp 20 – 22).

disturbed (Photo 7). Where the Whareroa Stream flows past the southern end of the Whareroa trig dune, relatively high sand cliffs are formed as a result of erosion.

There are only very small areas of "unconsolidated dunes" or "unstable foredune complex", the two other main physiographic units recognised in the southwestern North Island sand country. These are mainly at the northern end of the Park (Photos 2 and 8). However, between the high dunes there are relatively large inter-dune hollows, which are lower and in height, have more gentle concave topography and therefore collect moisture and more well-developed and slightly peaty soils (Photos 7 and 8). Most of the woody vegetation remaining in the coastal dune area is found in these inter-dune hollows. The presence of the hollows coastal dune area also means that not all the coastal edge is high above ground level; some of the fringe has appearance of a low (<1m) and flat narrow coastal terrace (Photos 4 and 10).

At the southern end and near the centre of the Park where the Wainui and Whareroa streams reach the coast, movement of the stream up and down the coast has resulted in a much wider and more open beach area.

At the northern end of the Park, erosion and dune retreat immediately south of the Raumati sea-wall has similarly resulted in a larger beach area. These three areas have a more open coastal character than the rest of the Park, particularly at the mouth of the Whareroa Stream where there is a break of about 150 metres between the foredunes.

Within the larger picture of dune formation described above, the coastal foredune within most of the Park is clearly in a phase of erosion at present, with front slopes largely bare of vegetation, some front slopes oversteepened, and clear signs of undermining of vegetation at the top of some foredunes. These features are illustrated in Photos 1-6 and Figs 1-2[4].

At the inland edge of the coastal dune area, the coastal dunes grade into older dunes (from the Foxton phase of dune building, thought to be 2000-4000 years ago). These dunes are generally slightly lower than those near the coast, and are interspersed with flatter, more peaty areas. The exact inland boundary between the Taupo and Foxton – phase dunes would be extremely hard to determine accurately. Therefore, for this project the inland boundary of the study area has been arbitrarily set at the current fence line between farming and conservation/recreation land uses within the Park, as shown on the maps.

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[4] Erosion and beach retreat over the last 30 years have been described in several reports, viz.:
Gibb, J.G. (1978). The problem of coastal erosion along the "Golden Coast", Western Wellington, New Zealand. *Water and Soil Technical Publication No 10*, Water and Soil Division, Ministry of Works and Development, Wellington. 19pp.
Hastie, W. 1989. *Coastal erosion: Queen Elizabeth Park.* Technical Note LN1989/7. Land Information Department, Wellington Regional Council.
Palmer, R. 1997. Queen Elizabeth Park Erosion Assessment. Unpublished status report for Wellington Regional Council (attachment to Council Report 97.68)

2.3 Coastal erosion

2.3.1 Natural processes affecting coastal erosion

Natural processes affecting coastal erosion are described in detail in Appendix 1. There are three main factors which have a bearing on coastal erosion:

- Sea-level variability
- Climate variability
- Tsunami risk

The following section summarises the principal conclusions of Appendix 1 concerning these three factors.

Sea-level Variability: Sea-level variations have an important role in determining the "background" sea level, or vulnerability to storm activity, present in any given month. The trend in sea level rise for the past 100-150 years is small, with a global mean of +1.8 mm/yr. Over the last century, this equates to an increase in sea level of 0.18 m. This on-going rise gradually increases the probability of exceedance of any specified hazard datum (relative to the landmass) from coastal inundation events. Sea-level rise should thus be factored into any long-term plans for the coast.

Climate Variability: Although much of the focus of global research is on sea-level rise, it must also be noted that changes in weather patterns may, potentially, have much greater effect on coastlines, particularly in the shorter term. For the one hundred year period 1980s to 2080s, all general circulation models (GCMs) show a strengthening (or at least no weakening) in typical westerly wind circulation over New Zealand. Averaged over all GCMs, the strength of the background westerly circulation over central New Zealand is predicted to increase by around 15% over the next 50 years, and by another 15% during the subsequent 50 years. However, such predictions are subject to enormous variations. For example, a recent WRC policy publication quotes a NIWA prediction of a 5% increase in rainfall over the western part of the Wellington region over the next 70 years, but this prediction is subject to a variation of ± 25%, i.e. the actual change could be anywhere from a 30% increase to a 20% decrease[5]. The last 25 years have been dominated by El Niño conditions, that have resulted in an average increase in westerly winds over central and southern New Zealand, compared to the previous 30 years.

Despite the GCM predictions, it is possible that another oscillation, the "Interdecadal Pacific Oscillation" (IPO, see Appendix 1), may reverse over the next 2-5 years, which could bring in two or more decades of somewhat lighter westerlies and more La Niña episodes than have been experienced during the last two decades. Such decadal-scale variability in the wind climate of New Zealand must also be taken into account. It is also important to distinguish the difference between weather (e.g., a particular storm event) and climate, which provides the background or context in which adverse weather-related events occur. Severe storms can occur during any climate phase.

[5] "Climate Change - a brief review". Wellington Regional Council Policy Department, 2000.

Tsunami Risk: A recent report to Wellington Regional Council (See Appendix 1) has suggested that the west coast of Wellington should be considered to be potentially at risk from a locally generated tsunami. According to this report, the return period for waves higher than 10 m is about one in 400 years. However, specific actions to avoid the hazard or reduce the level of risk, as far as Queen Elizabeth Park is concerned, are not considered feasible at this time. From the point of view of Park management, it is suggested that it will be sufficient to note in the plan that a potential tsunami risk, which in an extreme case could inundate the park, has been identified and that any future development options consider the implications of this risk.

2.3.2 Extreme sea levels

Appendix 1 sets out the factors taken into account in deriving an estimate for extreme sea levels at Queen Elizabeth Park. Combining all possible various factors, proposed design high water levels for a 1% and 2% annual exceedance probability (AEP), relative to the tide range at the Park, are shown in Table 1 below.

Water Level Factor	2% AEP (m) (50 year return period)	1% AEP (m) (100 year return period)
Storm surge set-up	0.75	0.85
High tide	0.80	0.90
ENSO (La Niña)	0.10	0.10
Wave set-up	0.75	0.90
Wave run-up	0.96	1.05
Sea level rise (Climate change)	0.20	0.45
TOTAL (total extreme event sea-level rise)	**3.56 meters**	**4.25 meters**

Table 1: Design high water levels comprising set-up components

2.3.3 Coastal Erosion features

The erosion of coastal land occurs when elevated water levels combine with storm induced wave action to attack beaches, and dunes or cliffs backing beaches. The extent to which property and land is lost depends principally on the elevation of the water relative to the level of the beach. It will also depend on the energy remaining in the impacting wave, which affects run-up, as well as the duration of the storm event although it is worth noting that erosion of sandy coastlines can occur, albeit at a less spectacular rate, even during times of super-elevated water levels but only modest wave action.

On ocean coastlines, the water level, as noted above, depends on astronomical tides and the many oceanographic and atmospheric processes, such as El Niño events, that may alter predicted water levels. In addition there may also be a rise in water level produced by waves including the setup that elevates mean shoreline position and the runup swash of individual waves beyond that mean level.

A further factor that is relevant to coastal erosion is the morphology and shape of the beach and dune system, and its capacity to act as a buffer between the attacking waves and coastal assets. Important factors are sediment size and supply, beach slope and elevation, dune volume and wave characteristics. The Queen Elizabeth Park coastline, characterised as it is by a flat sandy beach backed by a significant sand dune system, is classical in terms of its vulnerability to the effects of wave action.

Historic change

Gibb (1978, see footnote 4) reported on shoreline displacements over the century prior to 1977 from information obtained from cadastral plans (1874-1968) and aerial photographs (1943-1977). Although significant erosion occurred during this period, both to the south at Paekakariki (18-60 m), and to the north at Raumati (24-37 m), net accretion of 20-25 m was recorded at Queen Elizabeth Park.

As part of the present study, aerial photographs of the Park taken in August 1942, June 1976 and June 2000 have been compared to show changes in the position of the coastline that have taken place during these periods. The photos were scanned and brought together to show a continuous strip of the Park coastline at the same scale in each case. Within the limits imposed by photo quality and distortion it has been possible to provide a measurement of the erosion at several locations along the shoreline between August 1942 – June 2000 and between June 1976 – June 2000. The photo montages, showing the measured recession of the shoreline, are shown in Figs 1 and 2. The numbers at the left of the 2000 photos represent measured and scales distances (in metres) from identified fixed points on land (shown as white intersection points). The seaward limit has been taken as the boundary between vegetation and the beach.

Although the measured amounts of erosion carry a possible error of ±5.0 m, trends are nevertheless apparent. Significantly, the June 1976 photos show the position of the shoreline just prior to the severe storms in September of that year and also prior to the construction of the Raumati seawall, which has been blamed for causing erosion at Queen Elizabeth Park.

While it is uncertain how much erosion occurred during the 1976 storms, it is clear that the rate of erosion along the Park shoreline has increased significantly since 1976. It is also apparent that the erosion along the shoreline is much higher at the northern end, manifested by particularly noticeable loss immediately south of the Raumati seawall (Photos 1 and 2). Towards the southern (Paekakariki) end of the park, the shoreline appears to have been more or less stable, most probably because of an adequate supply of sand from the eroding shoreline to the north.

The measurements suggest that approximately two thirds of the erosion since 1942 has occurred since 1976, the effects being far more noticeable north of the Whareroa Stream and beginning to taper off from a point around 500 m south of the stream to very little apparent erosion at the southern end of the park. *The erosion since 1976 equates to an average, as high as 0.8 m per year and, in the absence of better information, this is an appropriate figure to use for design purposes.*

Predicting future change

This projected long-term average rate of erosion over the past 25 years suggested for design purposes is 0.8 m per year, as derived above. If this is extrapolated into the future, over 50 years, about 40 m of erosion might be expected and the equivalent for 100 years is 80 m. This figure can be compared with mathematical calculations of the maximum expected dune erosion (coastal retreat) during a single extreme storm (Appendix 1). This figure has been calculated as:

30.5 m ……….. (50-yr return period)
48.7 m ……….. (100-yr return period)

These latter figures represent the theoretical maximum erosion during a sustained event and are useful when considering setback distances. In reality, the park dune system represents a significant store of sand. Because of the probable formation of off-shore bars that tend to limit the effects of a storm, and at least partial recovery following the storm, the actual probable maximum events are more likely to be of the order of 50% of these figures, with possible localised additional effects should rip currents eventuate as off-shore bars form. There is, of course, a significant element of speculation in making such erosion predictions for irregular natural events, especially given that the park coastline reportedly[6] underwent net accretion during much of the 100 years prior to 1977. But the two sets of figures above emphasise the fact that coastal erosion does not occur continuously but in discrete extreme events.

Streambank erosion:

There is localised streambank and slump erosion along the westward end of the Whareroa Stream, where the banks are up to 4m high. This erosion has caused some disruption of fences, as well as to farming activities where the stream marks the boundary between the farmed area and the coastal dunes area.

[6] Gibb (1978), see footnote 4.

2.4 Natural vegetation and fauna

2.4.1 Vegetation

The vegetation of the coastal dune area is a complex mosaic of several communities in which both indigenous and introduced plants are prominent. All the communities show a considerable amount of disturbance, as do most 'natural areas' on the Kapiti Coast. The Foxton Ecological District Protected Natural Areas Report[7] suggests that prior to European disturbance, sand dune communities would have been dominated by spinifex and pingao (see Appendix 2 for all scientific names), with shrubs such as sand coprosma and tauhinu on more stable dune areas behind, and forest areas close to the coast with prominent ngaio, akeake, rewarewa, titoki, mahoe, kohekohe and wharangi. Of these species, pingao, rewarewa, titoki and kohekohe are now absent from the areas and several others are rare, but the current flora includes some notable and relatively rare native plant species, notably the shrubs sand coprosma, and native broom and the very restricted coastal wharangi tree. The species pingao, spinifex and sand coprosma have recently been selected as representative native species of coastal dune vegetation in Wellington conservancy[8]. The full species list of the coastal dune area is extensive, and is given in full in Appendix 2.

There are three main communities which occur throughout the coastal dune area and cover more than 90% of the total area, and five much more restricted communities occurring in specific parts only. They have not been mapped in this project as they are very closely inter-digitated (especially the first two). They are briefly described below.

A. Taupata-boneseed-flax-lupin over spinifex-marram shrubland

This is a very varied community occurring on the whole of the foredune. It is dominated by individual plants or small clumps of taupata, flax, toetoe, and some of the taller introduced weeds such as boneseed, Italian buckthorn, boxthorn, and pampas (northern part only). The canopy of these plants is between 3-6m high and occupies between 25-75% of the ground area. All these plants are also growing in the middle storey. Ground cover is similarly varied, with the sand-dunes binders and marram dominant over more open parts, as well as ice plant, introduced grasses, and seedlings of the canopy species, (although taupata regeneration is poor). Pohuehue and climbing dock are common scrambling plants over the whole of this community.

B. (Boneseed-Cortaderia-Mahoe-Taupata) over blackberry-bracken vineland

Over the largest part of the coastal dune area inland from the foredune, blackberry is the dominant plant, with bracken common in places, but apparently not competing with blackberry. Other plants competing with blackberry in places are boxthorn and boneseed, gorse, pampas and toetoe, lupin, and occasional emergent mahoe, taupata and cabbage trees. Introduced herbaceous weed such as black and velvety nightshade, sheep's sorrel

[7] Ravine, D.A. 1992. *Foxton Ecological District. Survey Report for the Protected Natural Areas Programme.* NZ PNA Programme Report No 10. Department of Conservation, Wanganui.

[8] Milne, R. and Sawyer, J.W. (in prep). *Coastal dune vegetation in Wellington Conservancy: current status and future management.* Department of Conservation, Wellington.

and thistles are common, particularly on the edges of tracks and cleared areas. Knobby clubrush is common in some moister parts of the southern area. In the southern section there are a few of the regionally rare sand coprosma. Sheep's sorrel and pohuehue are common scramblers.

C. Taupata – Mahoe – Boneseed- Karo low forest
Areas of closed-canopy low forest occur mainly in the moister hollows inland of the foredunes and on the more sheltered inland edges of the coastal dunes. The canopy is generally between 5-8m high. The main dominants are taupata and mahoe, which could be considered as 'natural vegetation' on the dunes, but introduced plants such as boneseed and karo (a native New Zealand but not naturally occurring in the Wellington region) are becoming very prominent in many of the stands. All these plants are regenerating, but boneseed and karo tend to be more prolific in the understorey and as seedlings than the native trees. In one stand in the northern section a single mature tree and seedlings of the regionally rare tree wharangi have been found.

D. Marram – Spinifex – Iceplant Grassland
This community grows in a narrow strip on the coastal side of the foredune. It is discontinuous as the foredune undergoes erosion (see below). Occasional small lupin are the only woody plant to establish.
E. Planted trees and shrubs
At the southern end of the Park and around the Whareroa Stream entrance, a number of native and introduced trees and shrubs have been planted over the last 30 years, resulting in a quite different vegetation character to the rest of the coastal dune area. This is particularly noticeable at the southern end (the Wainui Development Area), where trees such as pohukatawa and Norfolk pine are dominant, together with widespread planted smaller trees and shrubs such as boobialla (Tasmanian ngaio), Chatham Island tree daisy, karo, camellias, proteas, etc. At the Whareroa Stream mouth, the canopy is not dominant to that extent, but planted karo, boobialla, pohutukawa and Chatham Island tree daisy are common.

F. Willows
Around the Whareroa Stream the dominant species is crack willow. Understorey and ground species are sparse under the dense canopy, except for large patches of wandering willie. There are small areas of indigenous wetland species such as rautahi and raupo.

G. Grassland
There are many areas of mown exotic grass scattered along the track system throughout the coastal dune area.

2.4.2 Fauna
Birdlife: Birdlife associated with the varied coastal environment is said to be a feature of the Park[9]. The seaward dunes provide shelter and food for gulls and terns. Wading birds

[9] Queen Elizabeth Park Management Plan 1993, Vol 2, p35. Also noted in the Foxton Ecological District PNA Survey Report (see footnote 7), p17.

such as pied stilt and variable oystercatcher frequent the shore at low tide looking for food, and banded stilt are thought to have started nesting in parts of the dunes. However, this species diversity is mainly associated with the beach and seaward dunes. At the time of field work for this project (May and June 2001), birdlife was noticeably sparse, especially away from the beach. In particular, native birds common in small forest remnants, such as fantail and waxeye, were absent from all the small forest remnants throughout the coastal dune area. (Fantails are not recorded in the bird list for the Park in the Management Plan Resource Statement).

Other fauna: The Management Plan Resource Statement summarises information to 1992. A number of common native and introduced freshwater fish have been recorded in the Whareroa Stream. There is virtually no information available about amphibians, reptiles and invertebrates in the Park as a whole.

2.4.3 Ecological District and Ecodomain

The coastal dune area is part of the Foxton Ecological District (see footnote 6). Within the Ecodomain framework developed for the Wellington Regional Council, they form part of the duneland Ecodomain[10].

2.5 Pests

2.5.1 Animal pests

A number of animal pests are present in the coastal dune area of the Park and are likely to be having significant effects on natural processes in this area, as summarised below. However there appears to be no systematic knowledge of the density and impacts of the various pests.

Mustelids (particularly stoats and ferrets) and feral cats: These are likely to be present in significant number in these habitats, and to be having a significant negative impact on birdlife.

Hares and rabbits: They are very common in the coastal dune area, especially on the more open areas. Hares in particular would be having a significant effect on the vegetation by eating seedlings, and burrowing.

Rats and mice: Rats are significant predators of invertebrates and bird chicks. Mice would be having some effect on seeds and germination of some vegetation species.

Possums: Possums are likely to be having an effect on palatable vegetation species, including the canopy dominant mahoe. However, the coastal dune area offers less favourable habitat to possums than other parts of the Park, especially the bush remnant.

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[10] See descriptions in: Wellington Regional Council 1999. *Wellington Regional Native Plant Guide.* Wellington Regional Council; and Natural Textures 1999. *A Guide to Growing Native Plants in Kapiti.* Kapiti Coast District Council.

Feral or uncontrolled dogs: Have an impact by disturbing vegetation and birds.

Magpies: Aggressive towards native birds and may scare them away from some sites.

2.5.2 Plant pests (weeds)

A large number of the adventive plants listed in Appendix 2 are weedy. Some have become or are becoming persistent and troublesome plant pests of the coastal dune area. There are several types of troublesome plant pests. As noted in the previous section, some exotic species are dominant in several communities or are present throughout the Park, and are likely to be persistent. Examples are boneseed, blackberry, Italian buckthorn, boxwood, and pampas. The first two especially are dominant in large areas and the coastal dune area is host to many large and old boneseed trees.

Other weeds have the potential to become more troublesome in the future, including Italian buckthorn and brush wattle. Boneseed, pampas, German ivy and wandering willie are on the list of priority pest plants in the Wellington conservancy[11]. Italian buckthorn is noted as a controlled plant in the Proposed Regional Pest Management Strategy (April 2001).

2.6 Archaeological sites and cultural and historic values

A large number of archaeological sites and other sites of significance to Maori are found in the coastal dune area. Tangata Whenua for the Park are Te Ati Awa ki Whakarongotai, Ngati Toa Rangatira, and Ngati Haumia. Some of the most important and prominent sites are in the vicinity of the Whareroa trig, and Wainui Trig, which were both pa sites. In the former case there were significant cultivation areas around the pa, where there are now midden and oven sites. This area also contains a site where paru (a rare black mud used for dying flax etc) was extracted. Apart from these areas there are numerous midden sites, especially near the coast. Some of the above sites, only a few of which are on the New Zealand Archaeological Association database, are described in recent archaeological reports[12]. There are also other significant archaeological sites in other parts of Queen Elizabeth Park, such as a large pa site (Tipapa) and military camp sites close to Mackays crossing.

The Whareroa Stream has traditionally been recognised as the tribal boundary between Te Ati Awa ki Whakarongotai and Ngati Toa Rangatira. Queen Elizabeth Park is subject to several Waitangi Tribunal claims.

[11] Howell, C., Hughes, P.G and Sawyer, J. 2000. Plant Pest Atlas, Wellington Conservancy excluding the Chatham Islands. Department of Conservation, Wellington.

[12] Kapakapanui, 1998. Queen Elizabeth Park, Paekakariki: Archaeological Report for Wellington Regional Council.

2.7 Significance of natural and cultural values

The coastal dune area of Queen Elizabeth Park have been recognised for sometime as having significant natural values. In 1992 it was recognised as one of the largest of 46 Recommended Areas for Protection (RAPs) in the Protected Natural Programme Survey of the Foxton Ecological District (refer footnote 7). In that survey report eight indigenous-dominated ecological units were described (as well as the remnant hardwood forest stand further inland). The fauna was not described.

The coastal dune area was designated as a RAP on criteria such as 'indication of the original ecological character of this part of this coast… high diversity of communities … unique communities in the ecological district … very large area … fully fenced, sufficient seed source to recover from disturbed state … good [viability] prospects with improved management'. The report also noted clearance and 'insensitive' plantings affecting the naturalness of the area, as well as several weeds present in large amounts, notably boneseed, pampas, blackberry, gorse, boxthorn, and marram. However, the ecological units as described were all dominated by native species, unlike the descriptions used in the current report. It thus appears that, compared to 1989/90 (date of fieldwork for the PNA survey) there is now less dominance by flax, bracken and pohuehue, and greater dominance by the most widespread weed species, especially boneseed and blackberry. *In other words, management intervention to reduce the weed threat and restore appropriate plant cover is urgently needed to maintain the important natural values of the coastal dune area.*

The northern sand dunes in the Park are also recognised as a significant geomorphic feature in the New Zealand Landform Inventory[13].

[13]Joint Earth Sciences Working Group on Geopreservation 1989. *New Zealand Landform Inventory. First Approximation.* VUW Research School of Earth Sciences. Occasional Paper No 4.

3 MANAGEMENT CONTEXT

3.1 Recent and current management approaches

Queen Elizabeth Park is managed under a Management Plan, operative since 1993. The aim of management under the Plan is 'To provide for the sustainable management and development of QEP for outdoor recreational use while preserving its natural, historical and cultural values'. There are 18 objectives under the headings 'Park Management and Development', 'Conservation', 'Recreation', and 'Promotion and Education'. There are a large number of detailed policies under each of these headings, divided into policies for specific zones (areas) recognised with the Park (see below).

Twelve management / land use areas are recognized, of which four occur in the foredune area (Map 2): The Wainui Development Area, the southern coastal dunes, the Whareroa Development Area and the northern dunes.

3.2 Specific features of foredune management

3.2.1 Recreation:

Infrastructure: The only roads which extend into the foredune area are the central access roads into Whareroa Development Area, and the road off it leading to the car park south of Whareroa Development Area. The main coastal and inland tracks are maintained to a standard that permits 4-wheel drive vehicles to be driven over them to enable emergency access or access for track maintenance. There is a track network, consisting principally of a coastal track and an inland track, meeting together at the northern and southern ends of the Park and at the Whareroa Development Area. Infrastructure at the Whareroa and Wainui Development areas includes a toilet block, car parking areas, grassed areas for picnics, water supply, signage, and, at the Whareroa Development Area, the junction of the Park tramway. The developed area at the southern end of the Park (Wainui Development Area) also includes a motor camp and picnic areas.

Recreation Activities: There are a lot of mainly passive recreation activities taking place in the dunes, such as walking and picnicking. Walking with dogs is very popular; (see comment on policies below). Horse riding is a long-established activity on the Park and is provided for in the Management Plan, with designated horse trails etc. Bike riding is also popular.

There is strong pressure from groups of current park users to continue to maintain extensive mown grass areas in the southern and central dunes.

3.2.2 Conservation Activities:

The principal conservation activities in the foredunes is weed and pest control, and weed surveillance. The seriousness of weed invasions (section 2.5.2 above) has been realised for some time and confirmed by current surveys and monitoring of weed distribution (see Appendix 3). Weed control has been more active in the last few years and has been concentrated on pampas and brush wattle in the northern block. Pampas has been sprayed. This has been effective and has nearly eliminated pampas from the northern zone.

Pampas is one of the most prevalent weeds in the southern coastal zone. The current weed control operator has a good knowledge of weed problems and has picked up several new weed arrivals or further infestations.

Animal pest control has been low-key, in the light of inadequate knowledge of what the main pest threats are, the main activity has been night shooting of rabbits and hares on the inland fringe of the dunes. There is more intensive control in other parts of the Park, especially of possums in the forest remnant.

Work has commenced on a realignment of the coastal and inland tracks linkage in the Whareroa area, in order to avoid damage to the many archaeological sites and sites of significance to Maori in this area.

3.3 Summary of current issues and constraints to foredune management

3.3.1 Erosion processes issues

- Ongoing coastal erosion from wave action is occurring over the whole coastal section of Queen Elizabeth Park, except possibly the southernmost 1 kilometre. It is most pronounced near the northern boundary, immediately south of the Raumati sea wall (Photos 1-6).
- This trend has been probably been occurring for several decades, but has been more pronounced in the last 25 years.
- Coastal erosion on this part of the coast is a natural process. It may be slightly less pronounced at the northern boundary of the Park if the Raumati seawall were not present, but would still occur.
- There is no cost-effective way to prevent this erosion, and under the current Management Plan prevention or stabilisation should not be attempted.
- "Restoration" policies for the coastal dune area should be principally confined to enhancing appropriate plant cover where possible, and some degree control of access between the coastal dune area and the beach (see below).
- Because of the ongoing coastal erosion, the above restoration actions will not *prevent erosion* (in major storms), but they could be expected to *retard attrition of the coastal foredune* in normal conditions (i.e. other than major storms).
- Coastal erosion will threaten some of the Park's infrastructure in the next decade. Infrastructure at risk includes parts of the coastal track, the Whareroa parking area, mown lawns and picnic areas in several other parts of the Park, and sections of the sealed driveways and parking bays in the Wainui Development Area (Photo 6). In an extreme event the new toilet block in the Whareroa Development Area could be at risk during its expected lifetime.
- Streambank erosion on the Whareroa Stream is also likely to occur on an ongoing and unpredictable basis. This erosion will caused localised disruption to Park

infrastructure (principally fences) from time to time. Removal of the willow trees from the lower Whareroa Stream would exacerbate streambank erosion in the short term.

3.3.2 Recreation and access issues

- Access from the coastal track is essentially uncontrolled. In a number of places, uncontrolled pedestrian access is causing some damage to the foredune or beach edge (Photo 9).
- The Park is an important recreational area with high numbers and a diverse range of visitors. Visitors expect good access to the beach, and a proportion of them expect unlimited access.
- Walking with dogs is an important recreational activity in the coastal dune area. Dog impacts on beach access points are roughly comparable to human ones and under Park policy all dogs should be under the control of Park users.
- Any tensions that arise on occasion between dog walkers and other Park users are essentially an amenity issue between different types of users, not a resource issue.
- Horse riding is also an important recreational activity. Horse impacts on unconsolidated dunes are very severe. Horses are not permitted on the beach or the coastal track, but some riders ignore this ban and are causing damage to tracks and beach access points.
- Horse riding on the inland track is also opening up local points on the track to erosion which has the potential to become worse (Photo 7).
- The impact of recreational use of the coastal dune area and its boundary with the beach can set up a conflict between the Management Plan aims of "providing for the sustainable management and development of Queen Elizabeth Park for outdoor recreational use while preserving its natural historical and cultural values".

3.3.3 Natural values

- The coastal dune area has very high natural values. They are not unique in the Wellington region, and they are not the most important from a conservation viewpoint, but they are relatively few comparable areas within Wellington Regional Council regional parks, and none within Kapiti Coast.
- The size of the coastal dune area and its location close to the population centres of the Wellington region gives extra importance to these natural values. Further population growth and economic development on the Kapiti Coast and the region generally will enhance the natural values of the Park in its relatively undeveloped state.
- The coastal dune area contains some distinctive plant species and vegetative associations which warrant active management for protection.
- The native fauna of the Park is very poorly known but appears to be rather impoverished.

3.3.4 Pests and weeds

- There are several introduced weed species currently present in the Park which present a severe threat to the native communities of the coastal dune.
- It is likely that weed infestation in the coastal dune area has increased markedly in recent times.

- Some of the weedy species are of value in retarding retreat of the foredune (in the short, not the long term).
- At present, weed control is done in a way which does not enhance the further spread of weeds. However, any weed control which results in bare ground or a sparse plant cover has the potential to enhance the further spread of weeds.
- Weed control is being undertaken in a fairly *ad hoc* way, without clear priorities having been established. Weed control does not appear to be linked to a plan for replanting and restoration of areas being controlled.
- Recent surveys of native plant distributions indicate that some relatively rare plants in the coastal dunes (both in the northern and southern sections) may be threatened by the spread of weeds.
- There are a number of New Zealand native species, not native to the Park or to the Foxton Ecological District, which are or have the potential to be invasive and troublesome weeds that could irreversibly alter the composition and nature of coastal dune communities.
- There is poor knowledge of animal pests and the risks posed by them.

3.3.5 Archaeological and cultural values

- There are many archaeological sites and other sites of significance to Maori in Queen Elizabeth Park and these are concentrated in the coastal dune area.
- Natural processes will continue to threaten some of these sites.
- Under the Historic Places Act, protection of archaeological sites from known disruption is a responsibility of the Wellington Regional Council as the agency responsible for the Park's management. Current policy in the Management Plan is not consistent with this responsibility.

3.3.6 Cost issues

- Resources available for spending on Park development and facilities are limited and need to be carefully prioritised.
- None of the options and specific management options raised later in this report have been costed. Many of them have significant cost implications and in total are well beyond current resources available for Park management. Therefore all management options will need to be carefully prioritised.

3.3.7 Land use issues

- In the present Management Plan, the northern and southern dunes occur in separate management zones, but the available information about natural values no longer appears to provide a strong rationale for this separation.
- The inland boundary of the coastal dune area (in practical terms the fence between grazed and ungrazed land, shown in Map 1) is somewhat arbitrary. It results in a large area of the coastal dune being designated to be managed for conservation purposes, compared to the resources available to manage this area. Without grazing and active management of this area, weed infestation is likely to increase. On the other hand, the size of this area provides many opportunities for further conservation (and recreational) potential in the future.

3.3.8 Knowledge and awareness

- Public knowledge and awareness of the special nature of the coastal dunes in Queen Elizabeth Park is likely to be very low.
- There is a lack of interpretation material available at the Park or from the Wellington Regional Council, which exacerbates the low public knowledge and awareness of the special nature of the coastal dunes in the Park.
- The importance of the natural values of the Park and its unique characteristics in the region (see above) mean that there is some responsibility on the Wellington Regional Council as Park managers to present and interpret the Park's natural values.
- The planned new entrance to the Park in conjunction with changes to the SH1 route in the vicinity) are likely to give the Park a higher profile to the passing public.

3.4 Principles for coastal dune management and restoration

To what extent can or should the coastal dune area within Queen Elizabeth Park be stabilised, restored, or otherwise managed? Does management of the area for conservation and cultural values conflict with management for recreational potential? These seem to be two of the central questions running through much of the preceding summary of issues. These questions are not directly answered in this report: they are properly addressed through revision of the Management Plan. However, the background information and current management summary presented above suggests some principles that could guide reaching answers to these and other fundamental questions. These principles are as follows:

3.4.1 Erosion processes issues

- There should be no change to the "allow natural processes" principle in the present Management Plan.
- Pedestrian access to the beach from the coastal dune area needs to be controlled and channelled to a reasonable extent, in order to protect the foredune and its biota, and archaeological sites.
- Such protection cannot be absolute.
- Plant cover on the coastal dune area should be maintained to the greatest extent compatible with natural processes.

3.4.2 Recreation and access issues

- Recreational use has a primary right in the Park to be provided for, consistent with preservation of the Park's natural, historical and cultural values.

3.4.3 Pests and restoration

- Pest control needs to be prioritised according to the risks posed by pest species, principally risks to conservation values.
- Ongoing control of weeds and management of non-natives plant species will be required, within an overall weeds control strategy for the Park.
- Plant pest control should usually be accompanied by replanting of new desired plant cover.

- All restoration and amenity planting should be done using eco-sourced plants native to the local district (with the possible exception of the Wainui Development Area).

3.4.4 Archaeological and cultural values

- Archaeological sites require active protection.
- Protection of the archaeological sites and Maori cultural values is best achieved through kaitiakitanga of the tangata whenua, in association with professional care from Park and other organisations' staff, and respect and understanding from the public.
- In general, appropriate physical protection of most archaeological sites in the coastal dune area will be achieved by maintaining as complete vegetation cover as possible, and siting tracks and other infrastructure away from archaeological sites.

3.4.5 Land status issues

- Land use issues other than control of access to beach are not addressed by this report.
- Revision of the Park Management Plan should not be pre-empted by this report.
- The northern and southern dunes are essentially similar in terms of significance; therefore they should be treated equally in zoning and planning work.

3.4.6 Knowledge and awareness

- A well-informed public are most likely to be sympathetic to conservation management.
- Changes in management, and the state of the environment within the Park, should be monitored as an integral part of Park management. Monitoring information need to be recorded in a systematic way.

4 TOWARDS A MANAGEMENT STRATEGY FOR THE QUEEN ELIZABETH PARK COASTAL DUNES

4.1 Options for future management of the coastal dune area

Some of the principal options available are summarised in Table 2. These options are presented in a format consistent with the Kapiti Coast District Council Coastal Management Strategy[14].

4.2 A preferred option

It can be seen from the Table that the "Beach nourishment" and "Structural protection works" options are not favoured. Beach nourishment, while unlikely to affect natural character, could not be justified on grounds of capital cost ($1500+ per lineal metre of coast) and probable on-going maintenance costs. Similarly, structural protection is not appropriate in this environment, and even if appropriate, is too expensive to consider seriously. Structural protection would be unlikely to receive a resource consent.

This means that the two principal options that appear to be feasible for responsible management of the coastal dune area are "Do nothing" or "Dune management and conservation". The rest of this report explores some aspects of the latter option. This does not seek to discount the "Do nothing" option. It is a valid option that should be explored further in the Management Plan revision. However while doing nothing may be feasible or even advisable as a strategy for coastal erosion management, it is not favoured by the consultants as a strategy for the management of the coastal foredune area generally. It would result in a significant decline in the natural (ecological) values of the area, from weed infestation, and it would not enable the conservation and recreational policies of current Park management to be reconciled.

Therefore the "Dune management and conservation" is the preferred option of the consultants. This option:

- is compatible with the "natural processes" principle but attempts to maintain plant and animal communities as well;
- increases the chances of success of an ecological restoration programme by maintaining vegetation cover; and
- should succeed in slowing the rate of foredune erosion in the short-term, and hence enhancing the security of Park infrastructure without compromising the natural character of the coastal dune area.

Note however that this strategy will not change the *long-term rate of erosion*: severe storms will still affect the foredune. Nor will it be easy to monitor and evaluate the

[14] Kapiti Coast District Council are presently reviewing their coastal management strategy. This has involved new surveys of the beach and off-shore zone, as well as studies of waves, climate change and storm effects, erosion studies and development of options for coastal managemement.

success of such a strategy in quantifiable terms, therefore objective setting for this strategy will not be straightforward.

Table 2. Summary of coastline erosion issues and management options for Queen Elizabeth Park

Management Zone	Coastline Characteristics	Coastline Issues	Management Options
Queen Elizabeth Park – *From north end of Paekakariki to southern end of Raumati seawall at Raumati South)*	1. An eroding coastline consisting of foredunes of varying height to 10 metres. 2. Beach and its hinterland have important recreational, ecological and amenity values. 3. Essentially unmodified and retains a high level of natural character.	1. Beach has amenity and recreational values that should be maintained if possible. 2. Although it has been reported that the QE park coastline has a long term history of accretion, erosion has been occurring at least since construction of the Raumati seawall following the 1976 storms. Measurements indicate that since 1942 around 50% of the coastline has receded 23 (±5) metres. Although precise measurements have not been possible, it is likely that 60-70% of this erosion has occurred since 1976, and this equates to an average rate of up to 0.8 metre per year since that time. 3. Erosion along the southern third of the QE park coastline is less and there appears to have been little change nearer the Paekakariki end. 4. Localised erosion at the Raumati end has caused recession of the order of up to 80 metres along the northernmost 100 metres of the park shoreline. 5. The beach is presently poorly supplied with sediment and there is insufficient information to determine the likelihood of a reversal in the present erosion trend. 6. It is probable that the eroded sand from the park coastline is helping to maintain the beach further south at Paekakariki. Efforts to limit the erosion at QE Park may well lead to problems along The Parade at Paekakariki. 7. Although no buildings are presently at risk the erosion threatens coastal tracks and other infrastructure in places and the high scarp tends to make access difficult to and from the beach.	1. **Do nothing** – Doing nothing is a realistic option as long as present erosion rates are acceptable. It is noted that this option is compatible with present park management policy. While any loss of park land may be a cause of some concern, no significant public assets are presently at risk. The costs of any mitigation proposals have to be weighed against any potential benefits from enhancing the characteristic values of the coastline. 2. **Dune management and conservation** – The principle behind this is to encourage dune growth by appropriate fencing and planting so as to limit the impact of erosive events. A secondary benefit is that the amount of sand blown inland is likely to be reduced. This would involve possible dune reconstruction at blowouts and planting on the foredune. It may also include provision of public access ways and some fencing to minimise foot traffic on the exposed dunes. Beach Care groups may also be established to facilitate and enhance a dune conservation programme. 3. **Beach renourishment** – This involves raising beach levels by importing sand from elsewhere. This method is used where maintaining the beach, while protecting shoreline assets, is a prime consideration. The capital cost and on-going maintenance costs are unlikely to be justified at QE Park, except possibly to offset the localised erosion at the northern end. 4. **Structural protection works** – Construction of protection works, which may include: seawalls, revetments, groynes, and off-shore breakwaters, cannot be justified at QE Park, because of cost and incompatibility with Park policies.

5 OPTIONS FOR SPECIFIC PROJECTS

In this final section some suggestions for more specific management options and projects are made. These are not outlined in detail as that task should be developed as part of the planned revision of the Park Management Plan. However the group of options below, as a whole, should give some idea of the scope of possible projects consistent with the preferred strategy outlined in the previous section. Some of the location-specific projects are shown on Map 1.

5.1 Park zoning

In revision if the Management Plan some thought needs to be given to the zoning for the coastal dune area. Because of the past disturbance pattern and the distribution of both weeds and notable plant species, there seems to be little justification to splitting the northern and southern dunes into separate management units as at present. It would seem more logical to recognise the Wainui and Whareroa Development Zones as at present (especially recognising the special, less indigenous, ecological character of the former), but to regard all the rest of the coastal dune area as one unit (Map 2). Perhaps there would be justification to recognise the lower Whareroa Stream as a separate unit, in view of its significant archaeological and cultural values, and the unique stream and wetland environments within it. If it stays as one unit, however, the Whareroa Zone should not be regarded as a "development zone" (although it contains important infrastructure developments), because of these important natural and cultural values.

5.2 Access to the beach

The free access of people between the coastal dune area and the beach is damaging the feature and coastal fringe in places. There is a good case for building wooden step or other structures in places to allow safe access without damaging the ground surfaces, and also for 'channelling' access to these points by blocking nearby potential access with plantings of relatively tall or rough-textured vegetation such as flax. Access points need to be reasonably frequent, otherwise people will use other places (see map 1 for some suggested points in the northern half). Not all places need to be constructed to the same standard, access points from the Wainui road end and the Whareroa Car Park probably needing the highest standard to take heavy foot traffic.

Access by horses and any type of wheel vehicle onto the beach can cause significant adverse impacts. Under present policies horses and vehicles are not permitted to go onto the beach, and this should be stringently policed.

5.3 Foredune restoration and revegetation

Restoration and revegetation of the whole 200 ha coastal dune area, while desirable, is not a feasible option in the near future. It is more feasible to choose a discrete area to focus efforts and learn techniques for eventual extension to larger area. Such a project would lend itself well as a focus for a local community or iwi group. There are several 'Beachcare' or 'Dunecare' groups around the country who would be able to share experiences with a similar group working in Queen Elizabeth Park, and technical resources for dune restoration work[15]. The main elements of a programme in the coastal dune area would be:

- Choice of area and goals for a programme. This needs to be done very carefully, including factors such as ease of access, proximity to residential areas, size and natural boundaries of area, deciding what 'natural' or previous state to aim for, etc.
- Pest control: requires a decision on whether to try and eliminate all plant pests or non-native species, or to target only key ones. See below for further notes on animal and plant pests.
- Revegetation: requires detailed planning work required in advance regarding choice of species, propagation of species, timing of revegetation in relation to weed control, etc. If a foredune area were chosen for revegetation the native grasses sand tussock (*Astrofestuca littoralis*, currently absent), pingao (very rare in the Park) or spinifex would seem sensible plants to choose, with sand coprosma and sand daphne (*Pimelia arenaria,* currently absent) in appropriate areas. For forest remnants, a long-term goal might be restoration of a more extensive and healthy canopy including species such as mahoe, taupata and ngaio (already present but not regenerating well), and kohekohe and wharangi (not present or very rare).
- Routeing access past (and possibly through) the area without causing damage to it.
- Possible use of sand fencing (low fences to trap sand behind which planting takes place; the fence eventually disappears beneath sand and plant cover).

A possible restoration area at the northern end of the coastal zone is shown in Map 1 and Photo 8. There would also be a case for siting a restoration project in other parts opf the coastal dune area. For example, at the mouth of the Whareroa Stream, where there are important cultural as well as natural values, or near the southern end, in proximity to southern end residents, and in a more stable part of the coastline. No specific recommendations are made for which, if any, of these areas should be chosen, as this decision would be dependent on many factors beyond the biophysical ones discussed in this report. However, the resources required to successfully complete a restoration project such as this, suggest that it would be preferable to concentrate efforts on one well-planned and integrated restoration project, at least initially, rather than dissipate effort on a number of projects. Planning of a restoration project in the coastal dune area should be coordinated with restoration and conservation management in other parts of the Park.

5.4 Track development

The inland route should be completed, and then promoted as a round trip and as an alternative walking route to the coastal track. If horse traffic is to continue on this track, it will need hardening in some places, especially where it crosses to the coast near the Whareroa Trig (Photo 7).

[15] For example, useful guidelines for seed collection, propogation and establishment of spinifex and pingao developed by the Forest Research Institute for the Coastal Dune Vegetation Network (CDVN Technical Bulletins Nos 1 and 2).

5.5 Other revegetation opportunities

If there is a propagation programme for pingao and spinifex, then it is possible that there would in time be sufficient stock to revegetate bare sand areas. Other possibilities for replanting include:

- Planting flax and shrubby species to discourage pedestrian access to the beach at fragile points.
- Trial of techniques for enhancement of remnant forest areas e.g. clearance of blackberry around edges, followed by planting of kanuka or manuka into cleared areas.
- Replacement of non-native ornamental plants e.g. boobialla (Tasmanian ngaio). This could possibly include New Zealand natives not naturally occurring in the local area (see below).
- For the long term, the possibility of a natural vegetation "mountain-to-sea" linkage between the coastal communities of Queen Elizabeth Park and the Akatarawa Forest Park in the vicinity of Mt Wainui should be considered. This is relatively close link by distance[16], and the possibility of construction of the Transmission Gully motorway would offer both a mechanism for facilitating land tenure arrangements and a potential corridor route that would provide a magnificent gateway to Wellington for road travellers.

All revegetation work should be consistent with natural biotic distributions as described in Ecological District and Ecodomains work (see footnote 9). The references cited list suitable plants of all growth forms for the dune environment on the Kapiti Coast.

5.6 Other pest control

Plant pest control will need to be carefully prioritised, and timed in conjunction with any replanting and restoration. A 10-year Strategic Plan for pest control is needed, but first some further basic baseline information about animal pest densities and impacts is required, to set realistic animal pest control goals. The current weed surveys will provide a good baseline for plant pest control planning. In the meantime, work on pampas control could continue, which does not leave bare ground for re-growth of weeds. Also, a sensible short-term policy would be to contain the further spread of clearly troublesome but presently restricted weeds such as buckthorn and brush wattle. A policy for management of 'weedy' natives from outside the local area, eg karo, pohutukawa – is also needed. Also a policy is required for vegetation management in the Wainui Development Area, which has much more planted vegetation, both native and non-native species, and the plantings have some cultural and historic significance.

[16] Closer and more direct, for example, than the Waikanae mountain-to sea restoration concept promoted by Philip Simpson (Simpson, P G 1997. *Ecological Restoration in the Wellington Conservancy.* Department of Conservation, Wellington.)

5.7 Archaeological sites management

In general archaeological sites are best protected by provision of a complete plant cover[17]. This means, for example, that plant pest control on or near archaeological sites need to be done cautiously so as to avoid erosion of those sites. Further investigation of specific sites in the coastal dune area may suggest specific management needs for those sites.

5.8 Bird habitat

An alternative focus to revegetation of plant cover in restoration area is the restoration of animal habitat. A bird species that naturally may have been expected in a dune habitat but is now absent or rare from it can provide an inspiring focus for restoration. The choice of bird would obviously depend on the specific area chosen for restoration, in particular whether it was a forest or a more open one. Choosing a bird or other animal species as an 'icon' for restoration efforts would also require a focus on animal pests and the development of a policy toward stray domestic pets.

5.9 Interpretation and education

All the above possibilities would require an educated and sympathetic public audience, both Park users and local residents. This aspect has also been discussed in recent work on restoration of the forest remnant in the centre of Queen Elizabeth Park[18]. The special ecological characters of the coastal dune area needs much more emphasis than at present.

Elements of interpretation and education include:

- Attractive and informative interpretation signs and material
- Signs and written material explaining conservation policies e.g the need to channel/restrict access etc.
- A dune theme for public events or programmes such as Arbor Day

An important and receptive audience for interpretation and education is school children. This can also have excellent spin-offs for support for restoration programmes. Schools often make excellent sites for plant propagation nurseries!

5.10 Further studies and monitoring

Many knowledge gaps have been highlighted in this report. The most glaring are regarding animals of the coastal dune area both native animals and pests. There is scope for many useful and interesting research topics in these gaps. Other gaps mainly concern monitoring of ecological/natural process trends, including:

- Monitoring of beach profiles: Kapiti Coast District Council presently has a programme of beach profile surveying to enable changes at the more critical sections of the Kapiti coast to be monitored. Given the lack of quantitative data for the Park, similar monitoring should be considered, at least annually and following any major

[17] As shown by several examples in Jones, K.L. and Simpson, P.G. 1995. Archaeological site stabilisation and vegetation management. Case studies II: Auckland and Northland, Otago and Canterbury, and Wellington. Department of Conservation Science and Research Series No 90.

[18] Boffa Miskell, 2001. Restoration of Native Forest Remnant, Queen Elizabeth Park, Paekakariki. Report to Wellington Regional Council.

events, in order to better understand coastal processes and to assist future decision-making concerning management of the Queen Elizabeth Park coast. Monitoring should complement the KCDC monitoring programme.
- Monitoring of individual storm effects on vegetation cover on the foredune
- Monitoring of weed trends, using the 2001 survey as a baseline (if no other earlier studies are available as a baseline)
- Monitoring of success of canopy tree regeneration (mahoe and taupata, compared with the dominant weed species)
- Monitoring of animal pest densities

6 RECOMMENDATIONS

The recommendations below are intended to focus on the most urgent and specific aspects of the various suggestions made in this report. It should be emphasized once again that all suggestions and recommendations in this report should not replace or pre-empt revision of any aspects of the projected Park Management Plan.

Pest control

1. Carry out focussed short-term studies on animal pest densities and impacts over next 12 months, in conjunction with WRC Biosecurity Department and possibly with post-graduate Victoria University student projects.

2. Complete a comprehensive animal and plant pest strategy for the Park by the end of 2002, as part of the revision of the Management Plan

3. Immediate pest control priorities:
   - Complete pampas control
   - Trials of complete weed control and replanting in small areas
   - Contain spread (include surveillance monitoring) of currently restricted aggressive weed species, especially brush wattle and Italian buckthorn
   - Continue current animal pest control

Beach access

4. Undertake more detailed consideration of hardened beach access points. This should include construction of one “high use” and one ”low use” structure before summer 2001 season on a trial basis, pending firm policy on beach access in the revised Management Plan.

Restoration

5. Undertake detailed consideration of one specific area restoration project, alongside Management Plan revision.
6. Gather resource material about coastal restoration projects.

Education and interpretation

7. Plan a specific programme for public education and interpretation about the ecological, cultural and archaeological values of the coastal dune area, if possible in conjunction with the area restoration project.

PHOTOGRAPH 1: Erosion on high foredune, northern end of beach.

PHOTOGRAPH 2: Beach retreat, Raumati end. Note however that dune is relatively low and vegetation cover complete.

BOFFA MISKELL
planning design ecology

QUEEN ELIZABETH PARK
Coastal Foredune Area

Date: July 2001
Reference: W01018

PHOTOGRAPH 3: Active foredune, south of Whareroa Stream. Note exposed midden and "rafted" vegetation on and at the bottom of the dune.

PHOTOGRAPH 4: Eroding inter-dune terrace, between Raumati and Whareroa Stream. Erosion at these points is very difficult to stop and can move the dune edge inland rapidly.

PHOTOGRAPH 5: Undercutting vegetation at top of dune, south of Whareroa Stream.

PHOTOGRAPH 6: Semiactive dune edge (right), within a few metres of edge of parking area (left), Wainui area. Even with slower rates of erosion at this end of the park, such areas can be expected to be at risk

PHOTOGRAPH 7: Connecting track between coastal and inland tracks, northern side of Whareroa Trig. Note significant track erosion.

PHOTOGRAPH 8: Inland edge of foredune migrating inland, near Raumati end. Much of deep green canopy is boneseed.

PHOTOGRAPH 9: Foredune erosion, exacebated by access from coastal track, between Raumati and Whareroa Stream. Access could be discouraged by flax planting at top picture.

PHOTOGRAPH 10: Simple wooden stepped access could be provided here to avoid erosion at nick-point (behind log) which is present step down point.

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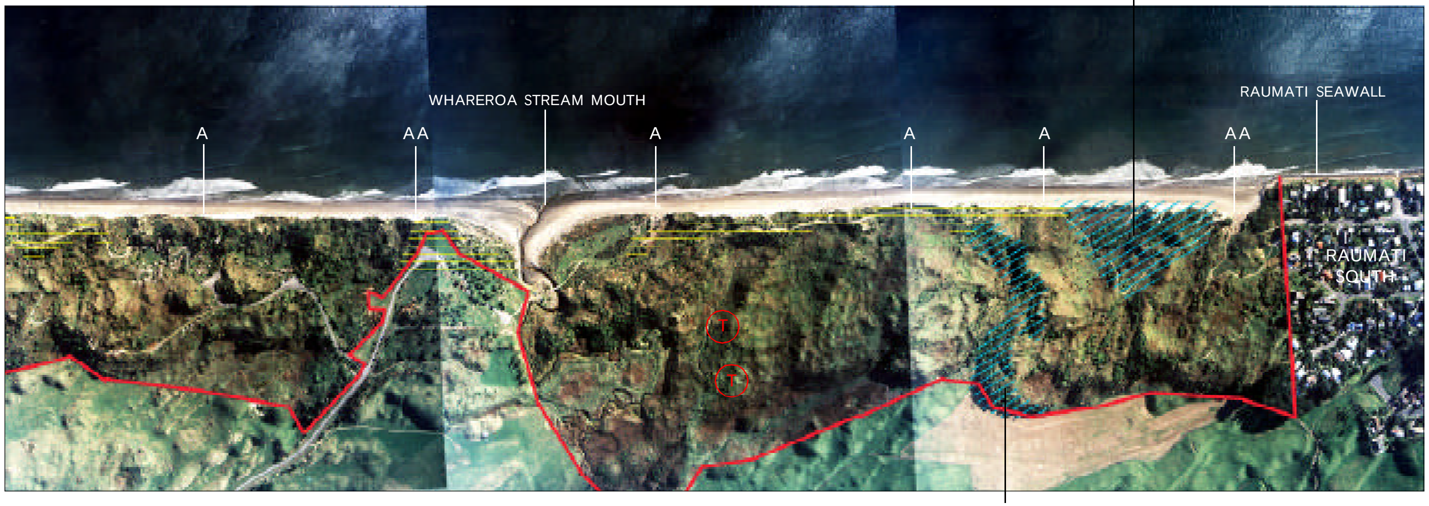
planning design ecology

QUEEN ELIZABETH PARK
Coastal Foredune Area

Date: July 2001
Reference: W01018

PROPOSED RAUMATI DUNES
RESTORATION SITE



BEST NATURAL FOREST
REGENERATION (wharangi present)

KEY:

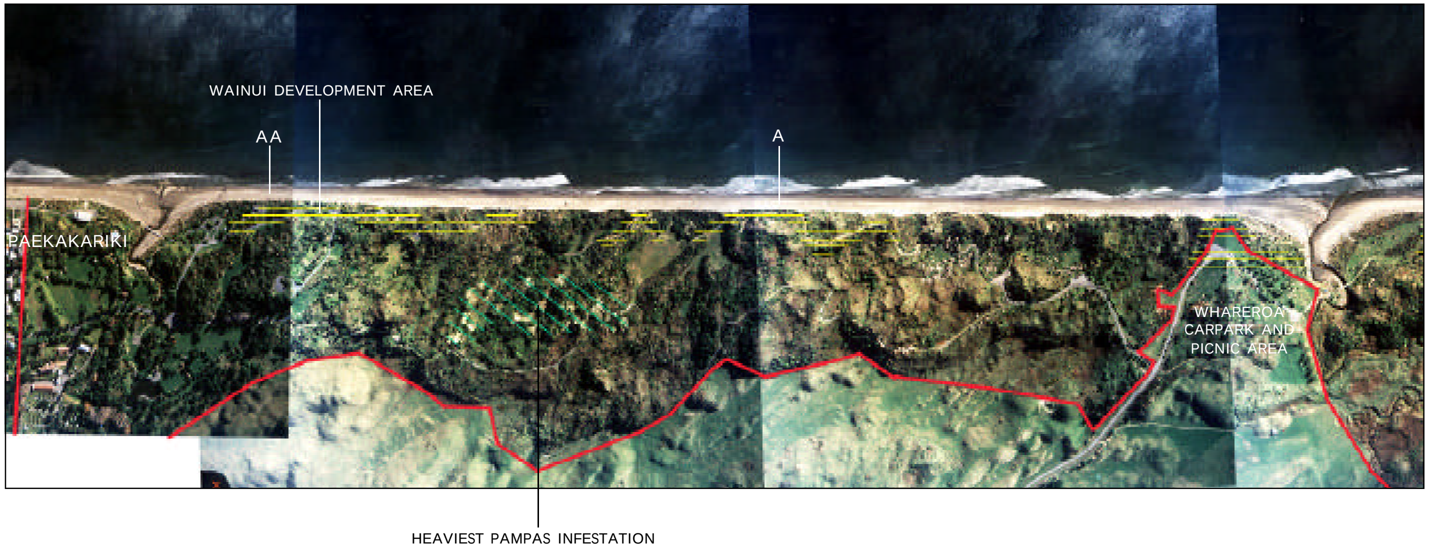
- Fenceline marking inland Boundary of coastal dune area. (excluding Whareroa carpark and picnic area)
- Coastal track sections and other infrastructure potentially at risk from coastal erosion.
- Proposed restoration project
- A — Possible access point - heavy traffic
- AA — Possible access point - light traffic

MAP 1

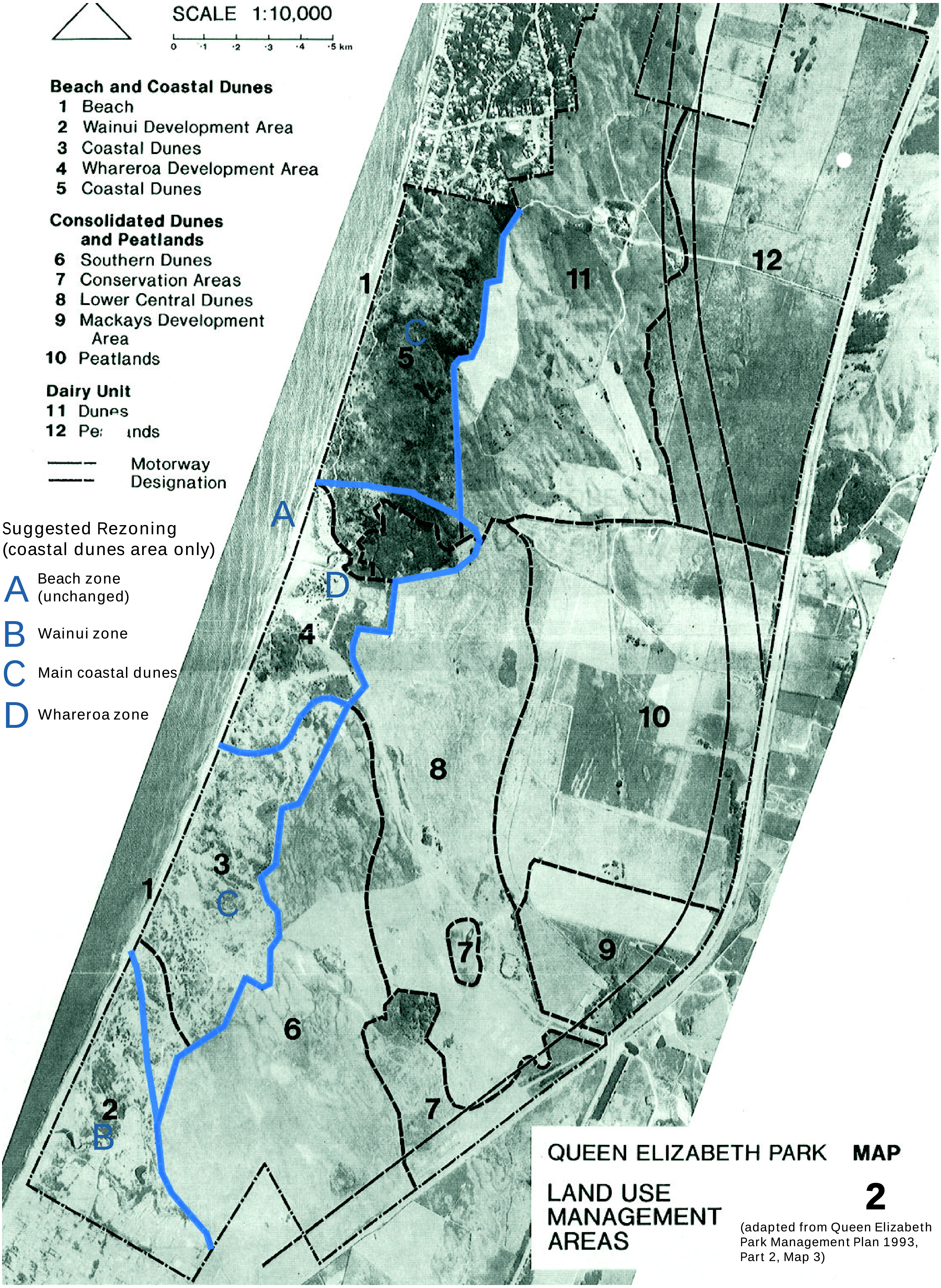
Date: July 2001
Reference: W01018
Scale: 1:6400 approx (A3)

QUEEN ELIZABETH PARK

Coastal Foredune Area



Zonation in 1993 Management Plan



Appendix 1 Coastal Erosion at Queen Elizabeth Park

Report Prepared for Boffa Miskell Ltd
J L Lumsden

1.1 Sea-level Variability

Sea-level variations at seasonal, inter-annual (year-to-year) and decadal time-scales have an important role in determining the "background" sea level, or vulnerability to storm activity, present in any given month. Whereas recent research has raised the level of understanding of seasonal, inter-annual (year-to-year) and decadal variability in sea level around New Zealand (e.g., Bell and Goring, 1997; Bell et al., 2000), there remains a serious lack of long-term open coast sea-level data, and the Kapiti coast is no exception. In general, researchers have to rely on tide gauges located in various ports.

Generally, the annual cycle in sea level is small around the New Zealand coast. The mean variation from the 3-year record obtained from the Kapiti Island tide gauge is just under ±0.04 m, generally peaking in February.

The year-to-year variation is greater than the seasonal cycle as it is more closely associated with the El Niño-Southern Oscillation (ENSO) system. Around the North Island, sea level is elevated above normal during La Niña episodes (e.g., 1989 and 1998-99). Conversely, El Niño events tend to suppress sea level. At Kapiti the inter-annual elevation of background sea level at Kapiti could be up to 0.15 m for a few months during strong La Niña episodes (Bell et al, 2000).

The trend in sea level rise for the past 100-150 years is small, with a global mean of +1.8 mm/yr. Over the last century, this equates to an increase in sea level of 0.18 m and the on-going rise gradually increases the probability of exceedance of any specified hazard datum (relative to the landmass) from coastal inundation events. Sea-level rise should, thus, be factored into any long-term plans for the coast.

An analysis by Hannah (1990) of sea-level trends from 1990-1988 from tide-gauge data at New Zealand's four main ports produced a national average rise in sea level of +1.7 mm/yr. This is similar to the global average and, so far, there has been no apparent acceleration in the rate of rise (Bell et al., 2000).

Predictions of future sea-level rise, within the context of climate change in response to human-induced changes in atmospheric composition (i.e. "greenhouse gases" and sulphate aerosols), are regularly addressed by the Intergovernmental Panel on Climate Change (IPCC). In the latest IPCC predictions (March 2001) two scenarios and a worst-case are proposed. Projections for global sea-level rise by 2100 are 38 cm for scenario 1 and 29 cm for scenario 2, but considerable uncertainties are attached to these estimates. The worst-case scenario considered by the IPCC would result in a sea-level rise of up to 88 cm by 2100.

Long-term projections of sea-level rise and its impacts for New Zealand are complicated by two additional factors. These concern the rising New Zealand land mass (about 4 cm per century) and tectonic plate movements (potentially of the order 0.5-1.0 m), which can have a much larger impact on relative sea-levels. Major tectonic changes tend to occur in discrete and localised jumps and, thus, their effect on long-term relative sea levels is difficult to generalise.

Although the Wellington-Kapiti region contains complex faulting structures and recent evidence of an active off-shore fault running north of Kapiti Island, estimates of uplift (0.5-0.4 mm/yr) remain somewhat uncertain and the conservative approach is to ignore such phenomena when considering the effects of sea-level rise until such time as further quantitative information becomes available.

1.2 Climate Variability

Although much of the focus is on sea-level rise, it must also be noted that changes in weather patterns may, potentially, have much greater effect on coastlines, particularly in the shorter term.

The IPCC provides climate simulation results for a number of coupled atmosphere-ocean general circulation models (GCMs). Outputs from these models have been analysed for the present-day climate and for projected future changes over the next century (Mullan et al., 2000). All models simulate most of the broad scale features of the observed present-day climate, although only four of the six produce realistic El Niño-Southern Oscillation (ENSO) patterns in the New Zealand region.

For the one hundred year period 1980s to 2080s, all models show a strengthening (or at least no weakening) in typical westerly wind circulation over New Zealand associated with an increase in mean Equator to Pole temperature difference (i.e., the polar regions are not expected to warm to the same extent as the equatorial regions). It should be noted, however, that the magnitude of predicted change does vary from model to model.

Averaged over all GCMs, the strength of the background westerly circulation over central New Zealand is predicted to increase by around 15% over the next 50 years, and by another 15% during the subsequent 50 years.

More particularly, there is little agreement between the models on the projected changes in El Niño-Southern Oscillation (ENSO) behaviour (Mullan et al., 2000). At present there is no strong evidence of significant changes in ENSO, at least over the coming 50-100 years.

Research suggests that the behaviour of ENSO is modulated on the 20-30 year time scale by what has become known as the “Interdecadal Pacific Oscillation” (IPO). The IPO conditions the tropical Pacific towards extended periods of predominantly El

Niño conditions, followed by periods of more evenly balanced La Niña and El Niño events.

Of more direct interest to the Kapiti region and QE Park in particular, is the fact that the last 25 years have been dominated by El Niño conditions, that have resulted in an average increase in westerly winds over central and southern New Zealand, compared to the previous 30 years. Similarly, the 1950s was also a period of enhanced westerly wind activity that coincided with a spate of erosion along the Kapiti coast (Donnelly, 1959).

Despite the GCM predictions, it is possible that the IPO may reverse over the next 2-5 years, which could bring in two or more decades of somewhat lighter westerlies and more La Niña episodes than have been experienced during the last two decades. Such decadal-scale variability in the wind climate of New Zealand must be taken into account and should be seen as overlaid on the greenhouse gas changes discussed above. It is also important to distinguish the difference between weather (e.g., a particular storm event) and climate, which provides the background or context in which adverse weather-related events occur. Severe storms can occur during any ENSO episode.

1.3 Tsunami Risk

A recent report to Wellington Regional Council (GeoEnvironmental Consultants, 2001) has suggested that, contrary to general opinion, the west coast of the Wellington region is a relatively high tsunami risk area. The report notes that, off the Horowhenua coast, prominent faults have been identified, associated with a zone of faulting that extends off-shore from Kapiti Island to onshore Manawatu. Because of this, the west coast of Wellington should be considered to be potentially at risk from a locally generated tsunami (the most hazardous distant sources lie to the east of New Zealand).

According to the WRC report, the return period for waves higher than 10 m is about one in 400 years. This, and the characteristics of the likely tsunami waves, has serious implications for the Kapiti coast, all urban areas along the west coast being at relatively high risk from inundation.

The authors argue that some mitigation measures fall within the Regional Council's jurisdiction and they note that three types of approaches can be used:

- Policy and management measures that reduce the likelihood of damage.
- Preparedness and response planning to deal with consequences of an event.
- Engineering design measures that reduce vulnerability.

From the point of view of QE Park management, it is suggested that it will be sufficient to note in the plan that a potential tsunami risk, that in an extreme case could inundate the park, has been identified and that any future development options consider the implications of this risk. Specific actions to avoid the hazard or reduce the level of risk, as far as QE Park is concerned, are not considered feasible at this time.

1.4 Design Storm Set-up and Tide Levels

The various components that can contribute to extreme sea levels along the Kapiti coast have been discussed above. There is a paucity of long-term sea level and wave information for the coast, making quantitative estimation of extreme sea levels, and their return periods, difficult. The various components (highest tide, biggest storm surge, La Niña conditions plus heavy seas) that contribute to sea level cannot simply be added together to form a "worst case" scenario as the probability of occurrence is so small as to have no practical significance.

In the recent study of waves, tides, storm surge and sea level rise on the Kapiti coast, carried out by NIWA for the writer and Kapiti Coast District Council in 2000, a more realistic extreme sea level was produced for Waikanae Beach to which projected climate change factors (sea-level rise and windiness) can be added. From this, an estimate for extreme sea levels at QE Park can be made after making due allowance for tide range differences and wave run-up exposure.

Storm surge

Storm surge is the raising of the sea level that results from a lowered barometric level (as occurs in storms). In the last 50 years, the September 1976 event stands out as the highest known storm surge along the Kapiti coast, estimated at ~0.7 m (Gibb, 1978). Minimum daily barometric pressures, at or below 975 hPa have occurred 4 times at Paraparaumu Airport since 1962. Such events produce an inverted barometer set-up of just over 0.4 m in sea level. If such low pressures coincided with strong on-shore winds similar to those experienced in 1976, an additional set-up of 0.2 to 0.25 m, imposed by wind stress, could be expected.

Historic analysis of other, lesser events, suggests that a storm surge of 0.7 metres would have a reasonably low annual exceedance probability (AEP) of around 2% for the Kapiti coast. This is not dissimilar to other parts of the New Zealand coast where the upper limit for storm surges is considered to be ~1 m, with an AEP of less than 1%. The NIWA report suggests that, until a longer sea-level record is obtained, a storm surge set-up of 0.85 m (excluding wave set-up and run-up) provides a suitably conservative estimate of a 1% AEP, and 0.75 m for a 2% AEP, for Kapiti.

High Tide Levels

Mean high water spring (MHWS) tide level for the Kapiti Island sea-level recorder is 0.9 m above MSL (10% exceedance). The highest astronomical tide (HAT), exceeded by only 1% of tides is 1.0 m. The corresponding figures for Paekakariki are 0.8 m and 0.9 m respectively (NIWA, 2000).

Wave set-up and Run-up

Wave set-up is the periodic rise in sea level caused by the forward motion of waves approaching the shore. Wave run-up is the swash that runs up the beach to reach a certain elevation before retreating. The only known estimate of the combined wave set-up and final run-up (across the beach), is the observation by Gibb (1978) of an average of 2.6 m vertical movement in the driftwood line during the September 1976 storm.

Wave set-up is dependent on the breaking wave height, wave period, and also the slope of the beach and nearshore zone and will, generally, be 8-15% of the incident breaking wave height. For example, consider regular breaking waves with a 10 second period approaching normal to the Kapiti coast with a typical nearshore slope of 0.02 (1 in 50). Estimated deepwater significant wave heights of 5 m and 6 m (for 50 and 100 year return periods) could produce wave set-ups of 0.75 m and 0.90 m, respectively, at the shoreline, based on the method outlined in CERC (1984).

Wave run-up is more difficult to generalise for a particular stretch of coast, as it is strongly dependent on the site-specific beach and foredune profiles, and the associated substrate (e.g., walls, rocks, gravel, sand) at each site. Therefore, a site-by-site appraisal is needed for each different section of the coastline. There is considerable literature derived from studies of wave run-up, but the method that has found favour on the wide dissipative beaches of the American west coast, and used here, is based mainly on the work of Holman (1986) derived from his analysis of field data to evaluate extreme run-up elevations.

Holman analysed run-up in terms of the mean run-up level, the significant level (elevation of the highest one third), the 2% exceedance level, and the absolute maximum run-up achieved during a 20-minute measurement record. In this case it is appropriate to use the 2% exceedance, denoted by $R_{2\%}$, since extreme run-up elevations are the main focus. Holman (1986) found that the run-up elevation can be predicted by the relationship:

$R_{2\%}/H_s = C\xi$ (1)

Where H_s is the deep-water significant wave height, C is an empirical constant established by measurement, and ξ is the dimensionless Iribarren "surf similarity" number, defined as:

$\xi = S/(H_s/L_o)^{0.5}$ (2)

where S is the slope of the beach face and L_o is the deepwater wave length given by $L_o = (g/2\pi)T^2$, where g is the acceleration of gravity and T is the wave period. Combining these equations yields:

$R_{2\%} = CS(H_sL_o)^{0.5} = C(g/2\pi)^{0.5}.S(H_s)^{0.5}.T$ (3)

for the run-up elevation as a function of the deep-water significant wave height and period, and of the beach slope. Equation (3) accounts for the total run-up elevation due to the presence of waves, that is, it combines the wave-induced set-up, which raises the elevation of the mean shoreline, and the swash elevation of individual waves beyond that mean shoreline. The value of C depends, in part, on the grain size of the beach sediment which affects the frictional drag and porosity.

Holman (1986) found that, when run-up elevation is expressed as the 2% exceedance value of run-up maxima, $R_{2\%}$, that C = 0.9 was an appropriate value to use on relatively wide sandy beaches. From Figure 3, the slope of the beach (Tan β) = 0.038. During the September 1976 storm, the significant wave height H_S reached 3.6 m with a peak period of 9.4 secs. Using these figures in equation yields:

$R_{2\%}$ = 0.81 m

Similarly, this model can be run to provide values of $R_{2\%}$ for 50-year and 100-year return periods for significant wave height and period of 0.96 m and 1.05 m, respectively.

Sea-level variability
The inter-annual elevation of background sea level at Kapiti could peak at +0.15 m for a month or so during strong La Niña episodes and in warm summer months. For design purposes it is sufficient to add a nominal +0.1 m set-up to both the 1% and 2% AEP design levels to account for elevated seasonal and La Niña sea levels.

Climate change (windiness and sea-level rise)
There is a 50% chance that sea level around New Zealand will rise by +0.20 m by 2050 and by +0.45 m by 2100 according to the 1995 IPCC estimates. While the 2001 estimates vary depending on the scenario adopted, the level of uncertainty remains high and the 1995 estimates are considered sufficient for design purposes at this stage.

Design high water levels
Combining the above estimates, proposed design high water levels for a 1% and 2% annual exceedance probability, relative to the tide range at Queen Elizabeth Park, are shown in Table 1.

Water Level Factor	**2% AEP (m) (50 year return period)**	**1% AEP (m) (100 year return period)**
Storm surge set-up	0.75	0.85
High tide	0.80	0.90
ENSO (La Niña)	0.10	0.10
Wave set-up	0.75	0.90
Wave run-up	0.96	1.05
Sea level rise (Climate change)	0.20	0.45
TOTAL	**3.56**	**4.25**

Table 1: Design high water levels comprising set-up components

1.5 Coastal Erosion

The erosion of coastal land occurs when elevated water levels combine with storm-induced wave action to attack beaches, and dunes or cliffs backing beaches. The extent to which property (land) is lost depends principally on the elevation of the water relative to the level of the beach. It will also depend on the energy remaining in the impacting wave, which affects run-up, as well as the duration of the storm event although it is worth noting that erosion of sandy coastlines can occur, albeit at a less spectacular rate, even during times of super-elevated water levels but only modest wave action.

On ocean coastlines, the water level, as noted above, depends on astronomical tides and the many oceanographic and atmospheric processes, such as El Niño events, that may alter predicted water levels. In addition there may also be a rise in water level produced by waves including the setup that elevates mean shoreline position and the runup swash of individual waves beyond that mean level.

A further factor that is relevant to coastal erosion is the morphology and shape of the beach and dune system, and its capacity to act as a buffer between the attacking waves and coastal assets. Important factors are sediment size and supply, beach slope and elevation, dune volume and wave characteristics. The QE Park coastline, characterised as it is by a flat sandy beach backed by a significant sand dune system, is classical in terms of its vulnerability to the effects of wave action.

Historic change

Gibb (1978) reported on shoreline displacements over the century prior to 1977 from information obtained from cadastral plans (1874-1968) and aerial photographs (1943-1977). Although significant erosion occurred during this period, both to the south at Paekakariki (18-60 m), and to the north at Raumati (24-37 m), net accretion of 20-25 m was recorded at QE Park.

As part of the present study, aerial photographs of QE Park taken in August 1942, June 1976 and June 2000 have been compared to show changes in the position of the coastline that have taken place during these periods. The photos were scanned and brought together to show a continuous strip of the Park coastline at the same scale in each case. Within the limits imposed by photo quality and distortion it has been possible to provide a measurement of the erosion at several locations along the shoreline between August 1942 – June 2000 and between June 1976 – June 2000. The photo montages, showing the measured recession of the shoreline, are appended to this report. Although the measured amounts of erosion carry a possible error of ±5 m, trends are nevertheless apparent.

Significantly, the June 1976 photos show the position of the shoreline just prior to the severe storms in September of that year and also prior to the construction of the Raumati seawall, which has been blamed for causing erosion at QE park.

While it is uncertain how much erosion occurred during the 1976 storms, it is clear that the rate of erosion along the QE Park shoreline has increased significantly since 1976. It is also apparent that the erosion along the shoreline is much higher at the northern end, manifested by particularly noticeable loss immediately south of the Raumati seawall. Towards the southern (Pakakariki) end of the park, the shoreline appears to have been more or less stable, most probably because of an adequate supply of sand from the eroding shoreline to the north.

The measurements suggest that approximately 2/3 of the erosion since 1942 has occurred since 1976, the effects being far more noticeable north of the Whareroa Stream and beginning to taper off from a point around 500 m south of the stream to very little apparent erosion at the southern end of the park. The erosion since1976 equates to an average, as high as 0.8 m per year and, in the absence of better information, this is an appropriate figure to use for design purposes.

Predicting future change

In recent decades there have been considerable advances in the understanding of coastal processes, including the mechanics of sediment movement, prediction of storm wave characteristics and the effects of such waves on beaches. Many of these processes have been integrated into numerical models that predict changes in beach morphology enabling assessments to be made of beach profile evolution in response to tides and storms.

Recent research in Oregon (Komar et al., 1999) has focused on analyses of extreme water levels that result from unusually high tides that combine with runup from storm waves. As shown in Figure 1, of interest is the total water level produced by these combined processes, relative to the elevation of the junction between the beach and the base of the foredune. Clearly, dune erosion can only occur if the total water level reaches or exceeds the elevation of the beach/dune junction.

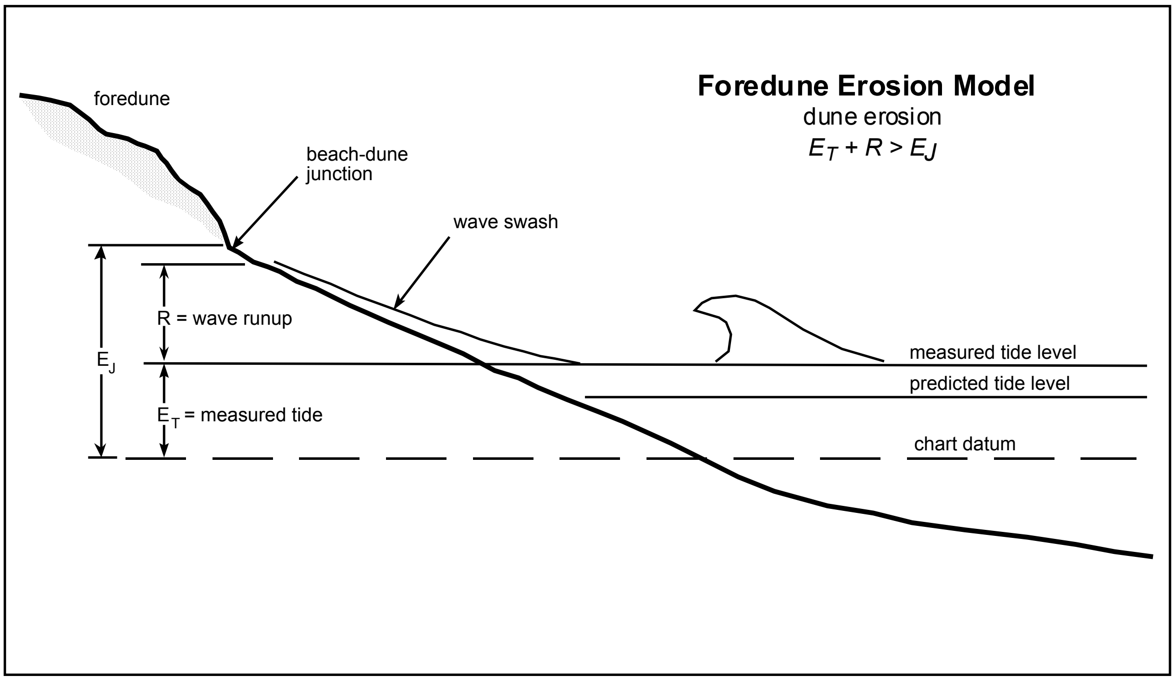


Figure 1. Total water level compared with elevation of the toe of the dunes.

Much of the Oregon research was directed towards testing models developed for the assessment of dune erosion when attacked by storm waves superimposed on elevated water levels. Two broad approaches were considered. Those representing geometric models, which assess the maximum possible dune retreat for extreme conditions, and process-based models (such as SBEACH and COSMOS) that evaluate waves and currents, the processes important in causing cross-shore transport of sediment that results in beach and dune erosion. With their ability to account for the lag of actual erosion behind the causative waves and currents, process-based models generally predict smaller rates of erosion than do the geometric models (Komar et al, 1999). However, Komar found, that on the low sloping dissipative beaches of Oregon, the process-based models tended to under-predict erosion during extreme events because of their inability to account for such features as rip currents and long-period infragravity motions that effect run-up on such beaches. This led to the conclusion that, for the purposes of establishing setback distances, it was appropriate to use the more conservative figures given by the geometric models.

The QE Park coastline is similarly configured with a relatively low sloping dissipative beach and the use of a geometric model is considered appropriate.

These models are considered "geometric" in the sense that the analysis involves the upward and landward shift of a triangle, one leg of which corresponds to the elevated water level, and then the landward transition of that triangle and beach profile to account for the extent of erosion and total possible retreat of the dunes.

The geometric model developed for use in Oregon is depicted in Figure 2. The model also includes an assessment of the lowered elevation of the beach due to the presence of a rip current, a phenomenon known to occur along the Paekakariki coast.

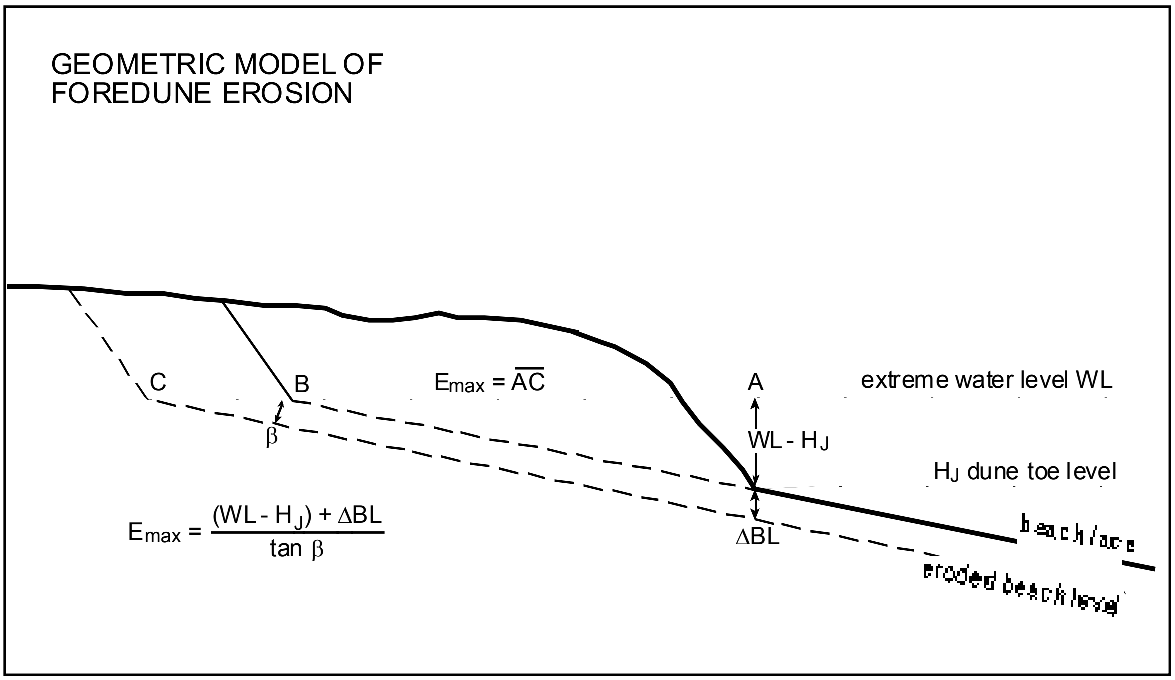


Figure 2. Geometric model used to evaluate max. potential erosion during a storm.

Elevations are given with respect to Mean Sea Level. Important is the total water level, WL, which is the combined tidal elevation and storm-wave run-up. The erosion of the foredune is dependent on the water-level elevation compared with the elevation of the toe of the foredune, E_J, the junction with the beach face (Figure 1). At QE Park, where there is a relatively high energy coast, at any particular location the beach face dominated by wave swash is wide with a typical uniform slope angle, β (Figure 2). The model assumes that this slope is maintained as the dunes are eroded back so the analysis focuses on the right triangle depicted in Figure 2 where erosion due to high water alone cuts back the foredune to point B. Additional erosion could result from the lowering of the beach due to the presence of a rip current or general beach erosion during the storm. This vertical shift in the profile is represented by the beach-level change ΔBL, which results in a further retreat of the dunes to point C in Figure 2.

The total retreat of the foredune is now given by the line segment AC, which is taken as the equivalent to E_{max} (the maximum expected dune erosion (coastal retreat) during a single extreme storm). From the right triangle formed by this erosion, Figure 2:

$E_{max} = \{(WL – H_J) + \Delta BL\}/\tan\beta$ (4)

For the purposes of this exercise, the beach profile obtained from survey work carried out for Kapiti Coast District Council on 12 July 2000 will be used to represent a typical profile at Queen Elizabeth Park. The actual profile is adjacent to the Whareroa driveway roadend in the Park. This is shown in Figure 3.

The toe of the dunes is nominally at elevation H_J = 2.4 metres. From Table 1, WL = 3.56 m and 4.25 m represent extreme water levels respectively for 50-year and 100-year return periods. This indicates that these foredunes should be highly susceptible to erosion during times of elevated water levels and storm waves. Tan β = 0.038.

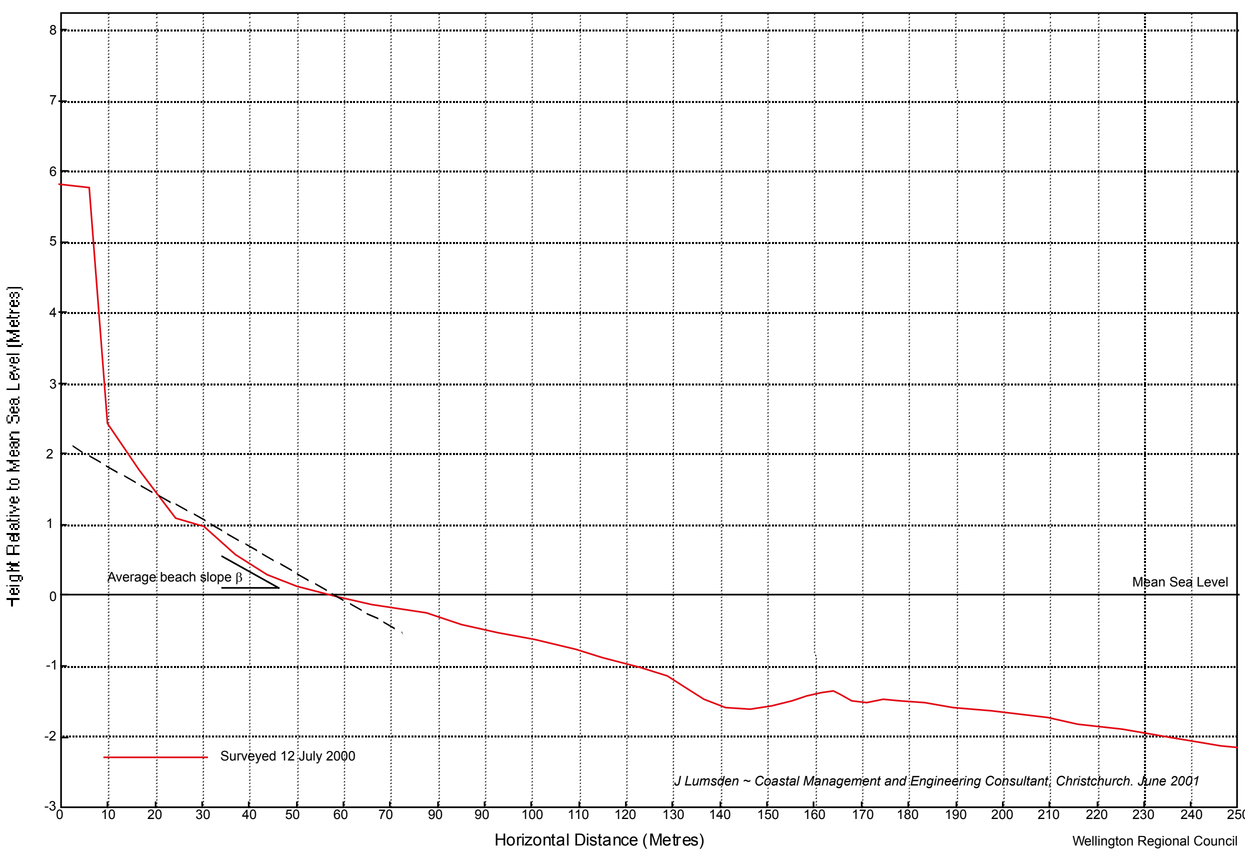


Figure 3: Beach Profile at QE Park Driveway

From Equation 4, ignoring the localised presence of rip currents for long-term analysis, values for E_{max} can be calculated:
E_{max} = 30.5 m ……….. (50-yr return period)
E_{max} = 48.7 m ……….. (100-yr return period)

These figures represent the theoretical maximum erosion during a sustained event and are useful when considering setback distances. In reality, the park dune system represents a significant store of sand and because of the probable formation of off-shore bars that tend to limit the effects of a storm, and at least partial recovery following the storm, the actual probable maximum events are more likely to be of the order of 50% of these figures, with possible localised additional effects should rip currents eventuate as off-shore bars form.

E_{max} can be compared to the projected long-term average rate of erosion over the past 25 years suggested for design purposes (0.8 m per year). Over 50 years, 40 m of erosion might be expected and the equivalent for 100 years is 80 m. There is, of course, a significant element of speculation in making such erosion predictions for irregular natural events, especially given that the park coastline reportedly (Gibb, 1978) underwent net accretion during much of the 100 years prior to 1977.

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Appendix 2. Plant species lists of the coastal dune area

LIST 1: SOME INDIGENOUS VASCULAR PLANTS IN THE NORTH BLOCK OF QUEEN ELIZABETH PARK, MACKAYS CROSSING, PAEKAKARIKI, BETWEEN WHAREROA STREAM AND RAUMATI SOUTH, CENTRED ON NZMS 260 R26 PARAPARAUMU, G.R. 761266, COMPILED ON 23 AND 29 MAY 2001, DURING VISITS TOTALLING 14.5 HOURS BY BJ MITCALFE AND JC HORNE.

NOTE: (1) Plants marked * are *EITHER, indigenous but adventive to Foxton Ecological District, OR, are indigenous cultivars*.
(2) Plants marked (P) are thought to have been planted.

BOTANICAL NAME	MAAORI NAME	COMMON NAME
MONOCOT TREES		
Cordyline australis	tii koouka	cabbage tree
DICOT TREES/SHRUBS		
Brachyglottis repanda	rangiora	rangiora
Carmichaelia australis	maakaakaa	NZ broom
Coprosma propinqua		
Coprosma repens	taupata	taupata
Coprosma robusta	karamu	karamu
Corynocarpus laevigatus (P)	karaka	karaka
Geniostoma rupestre var. ligustrifolium	hangehange	hangehange
Hebe stricta var. atkinsonii	koromiko	koromiko
Kunzea ericoides	kaanuka	kanuka
Leucopogon fasciculatus	mingimingi	mingimingi
Macropiper excelsum	kawakawa	kawakawa
Melicope ternata	wharangi	wharangi
Melicytus ramiflorus	maahoe	mahoe
Metrosideros excelsa*	poohutukawa	pohutukawa
Myoporum laetum	ngaio	ngaio
Myrsine australis	maapou	mapou
Olearia traversii (P) *		Chatham Is. tree daisy
Ozothamnus leptophyllus	tauhinu	tauhinu
Pennantia corymbosa	kaikoomako	kaikomako
Pittosporum crassifolium *	karo	karo
Pittosporum tenuifolium	kohuhu	kohuhu
Pseudopanax arboreus	whauwhaupaku	five-finger
Solanum sp.	poroporo	poroporo
DICOT LIANES		

Calystegia soldanella	panahi	shore bindweed
Calystegia tuguriorum	poowhiwhi	climbing convolvulus
Clematis forsteri	pikiarero	small white clematis
Muehlenbeckia australis	poohuehue	pohuehue
Muehlenbeckia complexa	"	"
Muehlenbeckia australis X M. complexa		
Parsonsia heterophylla	kaihua	parsonsia
FERNS		
Asplenium flaccidum	makawe o Raukatauri	hanging spleenwort
Asplenium oblongifolium	huruhuruwhenua	shining spleenwort
Asplenium polyodon	petako	sickle spleenwort
Microsorum pustulatum	koowaowao	hound's tongue
Pellaea rotundifolia	tarawera	button fern
Polystichum richardii	pikopiko	common shield fern
Pteridium esculentum	raarahu	bracken
Pteris tremula	turawera	shaking brake
GRASSES		
Cortaderia toetoe	toetoe	toetoe
Poa anceps		broad-leaved poa
SEDGES		
Carex flagellifera	maanaia	Glen Murray tussock
Carex geminata	rautahi	cutty grass
Carex testacea		speckled sedge
Cyperus ustulatus	upoko tangata	giant umbrella sedge
Isolepis nodosa	wii	leafless sedge
Isolepis prolifer		three square
Uncinia uncinata	matau a Maaui	hooked sedge
MONOCOT HERBS		
Lemna minor	kaarearea	common duckweed
Phormium cookianum	wharariki	coastal flax
Phormium tenax	harakeke	swamp flax
Typha orientalis	raupoo	raupo
DICOT HERBS		
Apium prostratum	tuutae kooau	shore celery
Euchiton audax		creeping cudweed
Parietaria debilis		NZ pellitory
Senecio minimus		fireweed
Tetragonia implexicoma	kookihi	NZ climbing spinach

LIST 2: SOME ADVENTIVE VASCULAR PLANTS IN THE NORTH BLOCK OF QUEEN ELIZABETH PARK, MACKAYS CROSSING, PAEKAKARIKI, BETWEEN WHAREROA STREAM AND RAUMATI SOUTH, CENTRED ON NZMS 260 R26 PARAPARAUMU, G.R. 761266, COMPILED ON 23 AND 29 MAY 2001, DURING VISITS TOTALLING 14.5 HOURS BY BJ MITCALFE AND JC HORNE.

BOTANICAL NAME	COMMON NAME
GYMNOSPERM TREES	
Cupressus macrocarpa	macrocarpa
Pinus sp.	pine
DICOT TREES/SHRUBS	
Acacia melanoxylon	Tasmanian blackwood
Chamaecytisus palmensis	tree lucerne
Chrysanthemoides monilifera	boneseed
Lupinus arboreus	tree lupin
Lycium ferocissimum	boxthorn
Myoporum insulare	boobialla
Phytolacca octandra	inkweed
Rhamnus alaternus	evergreen buckthorn
Rubus fruticosus agg.	blackberry
Salix fragilis	crack willow
Sambucus nigra	elderberry
Ulex europaeus	gorse
DICOT LIANES	
Calystegia silvatica	greater bindweed
Hedera helix	English ivy
Senecio angulatus	Cape ivy
GRASSES	
Arenaria ammophila	marram grass
Bromus willdenowii	prairie grass
Cortaderia selloana	pampas grass
Cynodon dactylon	Indian doab
Dactylis glomerata	cocksfoot
Ehrharta erecta	veld grass
Festuca arundinacea	tall fescue
Glyceria fluitans	floating sweet grass
Holcus lanatus	Yorkshire fog
Lagurus ovatus	hare's-tail
Paspalum dilatatum	paspalum
Pennesitum clandestinum	Kikuyu grass

Sporobolus africanus	rat's-tail
SEDGES	
Carex lurida	sallow sedge
MONOCOT HERBS	
Agapanthus praecox	African lily
DICOT HERBS	
Achillea millefolium	common yarrow
Anthemis cotula	stinking mayweed
Apium nodiflorum	water celery
Arctotheca calendula	Capeweed
Atriplex prostrata	orache
Brassica rapa	wild turnip
Capsella bursa-pastoris	shepherd's purse
Carpobrotus edulis	ice plant
Cerastium fontanum	mouse-ear chickweed
Chenopodium album	fathen
Cirsium arvense	Californian thistle
Cirsium vulgare	Scotch thistle
Conium maculatum	hemlock
Conyza bilboana	Canadian fleabane
Dimorphotheca pluvialis	rain daisy
Foeniculum vulgare	fennel
Fumaria muralis	scrambling fumitory
Galium aparine	cleavers
Geranium molle	dove's-foot
Lavatera arborea	tree mallow
Modiola caroliniana	creeping mallow
Myosotis sylvatica	garden forget-me-not
Physalis peruviana	Cape gooseberry
Plantago coronopus	buck's-horn plantain
Plantago lanceolata	narrow-leaved plantain
Polycarpon tetraphyllum	allseed
seudognaphalium luteum	cudweed
Ranunculus repens	creeping buttercup
Raphanus raphanistrum	wild radish
Rumex acetosella	sheep's sorrel
Rumex conglomeratus	clustered dock
Rumex sagittatus	climbing dock
Senecio elegans	purple groundsel
Senecio jacobaea	ragwort
Silene gallica	catchfly
Silybum marianum	variegated thistle
Solanum chenopodioides	velvety nightshade

Solanum nigrum	black nightshade
Solvia sessilis	Onehunga weed
Sonchus asper	rough sow thistle
Sonchus oleraceus	sow thistle
Spergula arvensis	corn spurrey
Stellaria media	chickweed
Tradescantia fluminensis	wandering willie
Trifolium repens	white clover
Vicia hirsuta	hairy vetch

LIST 3: SOME INDIGENOUS VASCULAR PLANTS IN THE SOUTH BLOCK OF QUEEN ELIZABETH PARK, MACKAYS CROSSING, PAEKAKARIKI, BETWEEN WHAREROA STREAM AND PAEKAKARIKI, CENTRED ON NZMS 260 R26 PARAPARAUMU, G.R. 754250, COMPILED ON 30 MAY, 8 AND 15 JUNE 2001, DURING VISITS TOTALLING 19 HOURS BY BJ MITCALFE AND JC HORNE.

NOTE: (1) Plants marked * are *EITHER, indigenous but adventive to Foxton Ecological District, OR, are indigenous cultivars.*

(2) Plants marked ** are indigenous to NZ but adventive to the mainland. (3) Plants marked (P) are thought to have been planted. (4) Plants marked (C) are in the cemetery.

BOTANICAL NAME	MAAORI NAME	COMMON NAME
GYMNOSPERM TREES		
Podocarpus totara (P)	tootara	totara
Podocarpus totara (P) *	tootara	golden totara
MONOCOT TREES		
Cordyline australis	tii koouka	cabbage tree
Cordyline kaspar (P) **	tii tawhiti	3 Kings cabbage tree
DICOT TREES/SHRUBS		
Brachyglottis repanda	rangiora	rangiora
Coprosma acerosa	taataraheke	sand coprosma
Coprosma repens	taupata	taupata
Coprosma rhamnoides		
Coprosma robusta	karamu	karamu
Corokia cotoneaster (P)	korokio	korokia
Corynocarpus laevigatus	karaka	karaka
Dodonea viscosa (P ?)	akeake	akeake
Entelea arborescens (P)	whau	whau
Geniostoma rupestre		

var. ligustrifolium	hangehange	hangehange
Griselinia littoralis	papauma	broadleaf
Griselinia lucida	puka	puka
Hoheria populnea (P) *	houhere	lacebark
Kunzea ericoides	kaanuka	kanuka
Leptospermum scoparium	maanuka	manuka
Macropiper excelsum	kawakawa	kawakawa
Melicytus ramiflorus	maahoe	mahoe
Meryta sinclairii (P) *	puka	puka
Metrosideros excelsa (P) *	poohutukawa	pohutukawa
Metrosideros kermadecensis (P) **	Kermadec pohutukawa	
Metrosideros excelsa		
X M. kermadecensis (P) *		
Myoporum laetum	ngaio	ngaio
Olearia paniculata	akiraho	golden akeake
Olearia traversii (P) *		Chatham Is. tree daisy
Ozothamnus leptophyllus	tauhinu	tauhinu
Pennantia corymbosa	kaikoomako	kaikomako
Pittosporum crassifolium (P) * karo	karo	
Pittosporum eugenioides (P ?) tarata	lemonwood	
Pittosporum ralphii (P) *		
Pittosporum tenuifolium	kohuhu	kohuhu
Pseudopanax arboreus	whauwhaupaku	five-finger
Pseudopanax hybrid (P ?)		
Sophora tetraptera (P) *	koowhai	kowhai

DICOT LIANES

Calystegia soldanella	panahi	shore bindweed
Calystegia tuguriorum	poowhiwhi	climbing convolvulus
Clematis forsteri	pikiarero	small white clematis
Muehlenbeckia australis	poohuehue	pohuehue
Muehlenbeckia complexa	"	"
Muehlenbeckia australis		
X M. complexa		
Parsonsia heterophylla	kaihua	parsonsia
Tetragonia implexicoma	kookihi	NZ climbing spinach

FERNS

Asplenium bulbiferum	manamana	hen & chickens
Asplenium flabellifolium		necklace fern
Asplenium flaccidum	makawe o Raukatauri	hanging spleenwort
Asplenium oblongifolium	huruhuruwhenua	shining spleenwort
Asplenium polyodon	petako	sickle spleenwort
Blechnum chambersii	nini	lance fern
Blechnum novae-zelandiae	kiokio	kiokio

Cyathea medullaris	mamaku	mamaku
Hypolepis ambigua		
Microsorum pustulatum	koowaowao	hound's tongue
Pellaea rotundifolia	tarawera	button fern
Pneumatopteris pennigera	paakau	gully fern
Polystichum richardii	pikopiko	common shield fern
Pteridium esculentum	raarahu	bracken
Pteris macilenta	titipo	brake
Pteris tremula	turawera	shaking brake
Rumohra adiantiformis	karawhiu	leathery shield fern
GRASSES		
Cortaderia toetoe	toetoe	toetoe
Festuca * (C)		"Banks Peninsula Blue"
Microlaena polynoda		
Poa anceps		broad-leaved poa
Spinifex sericeus	koowhangatara	spinifex
SEDGES		
Carex flagellifera	maanaia	Glen Murray tussock
Carex geminata	rautahi	cutty grass
Carex pumila		sand sedge
Cyperus ustulatus	upoko tangata	giant umbrella sedge
Desmoschoenus spiralis (P ?)	piingao	pingao
Isolepis nodosa	wii	leafless sedge
Isolepis prolifer		three square
Uncinia uncinata	matau a Maaui	hooked sedge
RUSHES		
Juncus pallidus	wii	giant rush
MONOCOT HERBS		
Lemna minor	kaarearea	common duckweed
Phormium cookianum	wharariki	coastal flax
Phormium cookianum (P) *		
Phormium tenax	harakeke	swamp flax
Phormium tenax (P) *		
DICOT HERBS		
Acaena pallida (P ?)	piripiri	bidibid
Cardamine sp.	panapana	NZ cress sp.
Crassula sieberiana		crassula sp.
Haloragis erecta	toatoa	shrubby haloragis
Hydrocotyle novae-zeelandiae		pennywort
Tetragonia implexicoma	kookihi	NZ climbing spinach

LIST 4: SOME ADVENTIVE VASCULAR PLANTS IN THE SOUTH BLOCK, QUEEN ELIZABETH PARK, MACKAYS CROSSING, PAEKAKARIKI, BETWEEN WHAREROA STREAM AND PAEKAKARIKI, CENTRED ON NZMS 260 R26 PARAPARAUMU, G.R. 754250, COMPILED ON 30 MAY, 8 AND 15 JUNE 2001, IN 19 HOURS BY BJ MITCALFE AND JC HORNE. Note: Plants marked (C) have been planted in the cemetery.

BOTANICAL NAME	COMMON NAME
GYMNOSPERM TREES	
Auracaria heterophylla	Norfolk Island pine
Chamaecyparis lawsoniana	Lawson's cypress
Cupressus macrocarpa	macrocarpa
Pinus radiata	radiata pine
MONOCOT TREES	
Phoenix canariensis	phoenix palm
DICOT TREES/SHRUBS	
Alnus glutinosa	common alder
Banksia sp.	banksia
Betula alba	silver birch
Buddleja davidii	buddleia
Chamaecytisus palmensis	tree lucerne
Chrysanthemoides monilifera	boneseed
Eucalyptus sp.	eucalypt
Lupinus arboreus	tree lupin
Lycium ferocissimum	boxthorn
Myoporum insulare	boobialla
Nerium sp.	oleander
Paraserianthes lophanta	brush wattle
Phebalium sp.	phebalium
Phytolacca octandra	inkweed
Pomaderris apetala	pomaderris
Prunus campanulata	flowering cherry
Quercus robur	English oak
Racosperma melanoxylon	Tasmanian blackwood
Rhamnus alaternus	evergreen buckthorn
Rosa rubiginosa	sweet brier
Rosa sp.	rose
Rubus fruticosus agg.	blackberry
Salix fragilis	crack willow
Sambucus nigra	elderberry
Ulex europaeus	gorse

1 x adventive unidentified shrub (to be identified)

DICOT LIANES

Calystegia silvatica	greater bindweed
Mesembryanthemum sp.	ice plant
Senecio angulatus	Cape ivy
Senecio mikanioides	German ivy
Tecoma capensis	Cape honeysuckle

GRASSES

Anthoxanthum odoratum	sweet vernal
Arenaria ammophila	marram grass
Bromus diandrus	ripgut brome
Bromus willdenowii	prairie grass
Cortaderia selloana	pampas grass
Cynodon dactylon	Indian doab
Dactylis glomerata	cocksfoot
Ehrharta erecta	veld grass
Festuca arundinacea	tall fescue
Festuca (C)	"Banks Peninsula Blue"
Glyceria fluitans	floating sweet grass
Lagurus ovatus	hare's-tail
Paspalum dilitatum	paspalum
Sporobolus africanus	rat's-tail
Stenotaphrum secundatum	buffalo grass

SEDGES

Carex lurida	sallow sedge

RUSHES

Juncus effusus	soft rush

MONOCOT HERBS

Agapanthus praecox	African lily
Canna indica	canna lily
Lilium longiflorum (C)	Xmas lily
Orobanche minor	broom rape
Watsonia bulbillifera	watsonia
Zantedeschia aethiopica	arum lily

DICOT HERBS

Achillea millefolium	common yarrow
Aloe vera	aloe
Anagallis arvensis	scarlet pimpernel
Apium nodiflorum	water celery

Arctotheca calendula	Capeweed
Capsella bursa-pastoris	shepherd's purse
Carpobrotus edulis	ice plant
Cerastium glomeratum	annual mouse-ear chickweed
Chenopodium album	fathen
Cirsium vulgare	Scotch thistle
Conium maculatum	hemlock
Conyza bilboana	Canadian fleabane
Cotula coronopifolia	bachelor's buttons
Crepis capillaris	smooth hawksbeard
Crososmia X crocosmiiflora	montbretia
Digitalis purpurea	foxglove
Dimorphotheca pluvialis	rain daisy
Foeniculum vulgare	fennel
Fumaria muralis	scrambling fumitory
Galium aparine	cleavers
Gazania sp.	gazania
Geranium molle	dove's-foot
Geranium *	climbing geranium
Geranium (C) *	pelargonium
Hypochoeris radicata	catsear
Lactuca sp.	wild lettuce
Lavatera arborea	tree mallow
Myosotis sylvatica	garden forget-me-not
Physalis peruviana	Cape gooseberry
Plantago coronopus	buck's-horn plantain
Plantago lanceolata	narrow-leaved plantain
Polycarpon tetraphyllum	allseed
Polygonum aviculare	wireweed
Polygonum hydropiper	water pepper
Ranunculus repens	creeping buttercup
Raphanus raphanistrum	wild radish
Rumex acetosella	sheep's sorrel
Rumex conglomeratus	clustered dock
Rumex obtusifolius	broad-leaved dock
Rumex sagittatus	climbing dock
Senecio elegans	purple groundsel
Senecio jacobaea	ragwort
Silene gallica	catchfly
Silybum marianum	variegated thistle
Sisymbrium officinale	hedge mustard
Solanum chenopodioides	velvety nightshade
Solvia sessilis	Onehunga weed
Sonchus asper	rough sow thistle
Sonchus oleraceus	sow thistle
Spergula arvensis	corn spurrey

Spergularia rubra	sand spurrey
Stellaria media	chickweed
Tradescantia fluminensis	wandering willie
Trifolium repens	white clover
Tropaeolum majus	nasturtium
Vicia hirsuta	hairy vetch

LIST 5: SOME INDIGENOUS VASCULAR PLANTS IN PAEKAKARIKI HOLIDAY PARK, (INCLUDING HOUSE GARDENS), SOUTH BLOCK, QUEEN ELIZABETH PARK, MACKAYS CROSSING, PAEKAKARIKI, LIST CENTRED ON NZMS 260 R26 PARAPARAUMU, G.R. 753237, COMPILED ON 15 JUNE 2001, IN 1 HOUR BY BJ MITCALFE AND JC HORNE. Note: (1) This list does NOT include indigenous species already listed elsewhere in the south block; (2) All plants in this list except *Hebe stricta* have been planted.

BOTANICAL NAME	COMMON NAME
TREES/SHRUBS	
Brachyglottis repanda x B. monroi *	
Clianthus puniceus *	kaka beak
Coprosma repens *	
Hebe diosmiifolia *	
Hebe macrocarpa var. latisepala *	
Hebe stricta var. atkinsonii	koromiko
Hebe *	
Knightia excelsa	rewarewa
Pseudopanax "nigra" *	

LIST 6: SOME ADVENTIVE VASCULAR PLANTS IN PAEKAKARIKI HOLIDAY PARK, (INCLUDING HOUSE GARDENS), SOUTH BLOCK, QUEEN ELIZABETH PARK, MACKAYS CROSSING, PAEKAKARIKI, LIST CENTRED ON NZMS 260 R26 PARAPARAUMU, G.R. 753237, COMPILED ON 15 JUNE 2001, IN 1 HOUR BY BJ MITCALFE AND JC HORNE. Note: (1) This list does NOT include species already listed elsewhere in the south block, or in the north block. (2) Almost all plants in this list have been planted.

TREES/SHRUBS

Abelia sp.	abelia
Artemisia stellariana	beach wormwood
Buddleja sp.	buddleia
Camellia sp.	camellia
Coleonema pulchrum	breath of heaven
Correa sp.	Australian fuchsia
Cotoneaster sp. 1	cotoneaster
Cotoneaster sp. 2	"
Escallonia sp.	escallonia
Euonymus	spindle bush
Euryops, OR	Paris daisy
Argyranthemum frutescens OR	" "
Gamolepis chrysanthemoides	" "
Fuchsia sp.	fuchsia
Geranium	geranium
Geranium	pelargonium
Grevillea sp. 1	grevillea
Grevillea sp. 2	"
Hydrangea macrophylla	hydrangea
Lavandula	lavendar
Nerium sp.	oleander
Polygala myrtifolia	sweet pea shrub
Protea sp. 1	protea
Protea sp. 2	"
Rhaphiolepis umbellata	sexton's bride
Tamarix parviflora	tamarisk sp.

DICOT LIANES

Hedera helix	English ivy
Ipomoea indica	blue morning glory
Pandorea ?	(to be confirmed)

FERNS

Nephrolepis sp.	ladder fern

SEDGES	
Cyperus papyrus	papyrus
MONOCOT HERBS	
Alocasia macrorrhiza	elephant's ear
Iris	flag
Kniphofia	red hot poker
Narcissus	narcissus
DICOT HERBS	
Arctotis	arctotis
Bellis perennis	English daisy
Lamium amplexicaule	henbit
Opuntia sp.	prickly pear
Oxalis corniculata	horned oxalis
Oxalis pes-caprae	Bermuda buttercup
Urtica urens	small nettle
Veronica persica	scrambling speedwell
Vinca major	periwinkle

Appendix 3 Weed Survey List and comments on distribution (northern section)

(from weed survey undertaken for Parks and Forests Group, WRC, June 2001).

Ice Plant *Carpobrotis edulis*
Patches throughout: predominantly coastal and trackside

German Ivy *Senecio mikaniodes*
Local patches:

1. Hillside above Raumati South car park, ground cover under grasses and scrub.
2. Under bush canopy
3. Under fence line 3m above track
4. Fence line invasive from adjacent gardens.

Cape Ivy *Senico argulatus*
Local patches: found on northern boundary of the Park. Covering fenceline, and invasive into Park – approximately $200m^2$ from adjacent gardens

Variegated Thistle *Silybum marianum*
Locally scattered: four plants observed along track near eastern slopes of Park. One large patch and individuals (total 10….) observed outside of fence in southeastern corner.

Brush Wattle *Paraserianthes lophanta*
One small patch: one site associated with previously removed adult tree. Seedlings up to 1m in height – some with flowers

Tasmanian Blackwood *Racosperma melanoxylon*
One small patch: planted with pines as a probable windbreak, one small plant found apart from plantation.

Boneseed *Chrysanthemumoides monilifera*
Patches throughout: in patches and scattered throughout, more common along coastal dunes than inland. Forming up to 40% of ground cover in some areas (estimated).

Italian Buckthorn *Rhamnus alaternus*
Local patches: mostly found in one area at northern end of dunes, but scattered individuals found throughout – almost rare. Forming approximately 10% 0f canopy in northern patches.

Blackberry *Rubus fruticosus*
Scattered throughout, patches throughout

Jerusalem Cherry *Solarium pseudocapsicum*

Patches throughout: common along trackside in North and East of Park. Sparse throughout most of the area.

Ragwort *Senecio jacobea*
Locally scattered: central-Eastern area of Northern dunes. Likely to be more common that observed due to inconspicuous nature of non-flower individuals.

Pampas *Cortaderia selloana*
Locally scattered: associated with pine plantation at Southern end of area also one plant observed at Northern end of park, adjacent to fence line.

Gorse *Ulex europaeus*
Patches throughout: most common at Southern end of Northern dunes. Isolated patches also to north.

Willow *Salix sp*
Local patches: found along Whareroa stream. Forming dense stands.

Boobialla (Tasmanian Ngaio) *Myoporum insulare*
Scattered throughout: intential planting along track sides, and roaded carparks. Easily mistaken for native ngaio (*Myoporum laetum)*

Pohutukawa *Metrosidesos excelsa*
Scattered throughout: intential planting along side tracks and picnic areas. Common around carpark on southside of Whareroa stream.

Pine *Pinus radiata*
Plantation in north-eastern corner, with wilding seedlings below one individual in North-west corner. Plantation at Southern end, adjacent to carpark.

Agapanthus *Agapanthus praecox*
Local patches: planted on hill above Raumati South carpark and along side of track also as a garden escape along northern boundary. One small patch found at Southern picnic area.

Montbretia *Crocosmia x crocosmiiflora*
One small patch: Whareroa streamside, across stream from track.

Boxthorn *Lycium ferocissimim*
Scattered throughout: more common in central-coastal area, often found as individuals or small patches 2-3 plants several larger patches– 10 plants.

Karo *Pittosporum crassifolium*
Local patches: intential planting around picnic area at South end of the Northern dunes. More common at northern end near coast.

Inkweed *Phytolacca octandra*
Patches throughout: common along trackside in the north. Less common but still mostly trackside in the south.

Elderberry *Sambucus nigra*
Locally scattered: juveniles observed at five sites all associated with previously poisoned adult plants.

Macrocarpa *Cupressus macrocarpa*
Locally scattered: side of track just north of picnic areas.

Tree Lucerne *Chamaecytisus palmensis*
Locally scattered: intentional planting along Eastern boundary, also found to the west of the main track.

Lupin *Lupinus arboreus*
Scattered throughout.