Waikanae Estuary

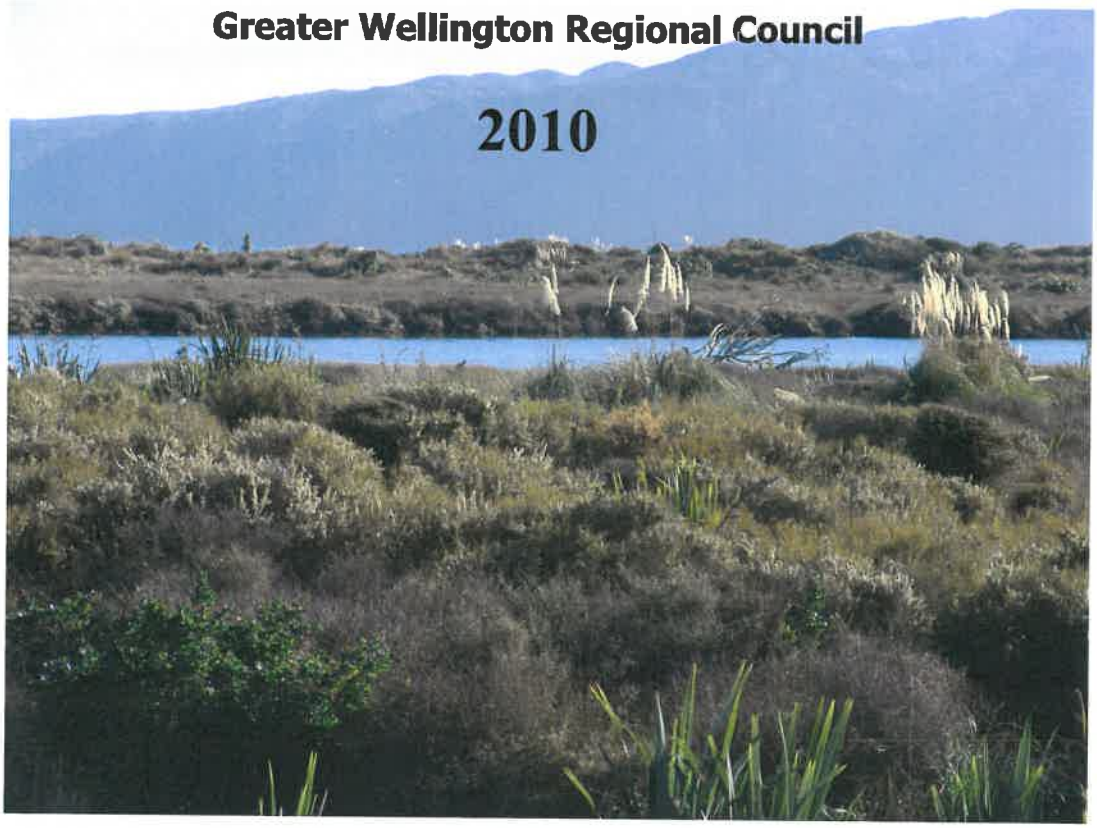
RESTORATION PLAN

Department of Conservation

Kapiti Coast District Council

Greater Wellington Regional Council

2010



naturalTEXTures

• LANDSCAPE ECOLOGY

The Vision 2006

To restore the estuary to as close to its natural state as possible

To encourage indigenous vegetation of the kind that might have developed at the estuary had natural conditions prevailed historically

The Vision 2010

To restore the estuary's natural successional processes

To encourage indigenous associations of the kind that can develop, given the site and given past human interventions

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Report prepared by Isobel Gabites, naturalTEXTures.
115 Kaitawa Road, RD 2, Otaki.

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Appendix I

RPS 2006 review

Part 1 – Review

Where are things at?

In May 2006 Kapiti Coast District Council and the Department of Conservation jointly published a Landscape Plan for Waikanae Estuary, prepared by Geoff Park.

The Plan articulated the vision to restore "the Waikanae Estuary to as close to its natural state as possible". The emphasis was clearly on vegetation, with an undertaking to replace invasive weed species with native species, and to replenish absent seed sources (concentrating them in strategically located 'nodes') so that stabilised duneland could be restored with 'natural' native vegetation cover. Vegetation types were mapped, and photo-points set up for long-term monitoring of progress.

Three government agencies share the administration of the Estuary's public spaces: the Department of Conservation (DOC) administers the Scientific Reserve which incorporates the estuary itself, Puketewhainoa lakelet and Waikanae River; Kapiti Coast District Council (KCDC) administers the Recreation Reserve along the north banks of the river and the associated Waimanu Lagoons, and Greater Wellington Regional Council (GW) maintains interests in the coastal marine area, waterbodies and flood control measures.

Kotuku Developments Ltd and the Webbers (descendents of original Udy owners) are the significant private land holders of other portions of the estuary complex including lakelets and the oxbow.

The entire estuary is frequented by the public – the beach attracts recreational visitors, dog walkers and occasionally vehicles; the paths through the Scientific Reserve are used by walkers, bikers and dog-walkers; the river is accessed from both banks during the whitebaiting season by foot and by vehicle. The Recreation Reserve attracts both walkers along the paths and picnickers adjacent to the lagoon and car parks. The only reserved areas not readily accessible are the north saltmarsh (true left bank) and Puketewhainoa lakelet.

Although the estuary, river and beach continue to attract waterfowl, waders and sea birds, the high level of recreational use and disturbance by dogs, cats, rodents and mustelids, prevents safe breeding along the estuarine fringes, and the only regular breeding ground (for waterfowl, bittern, crakes) is the Puketewhainoa lakelet which is 'protected' by an impenetrable fringe of blackberry and scrub.

While preparing the current Plan it became evident that people living adjacent to the estuary valued the ability to recreate freely through most of the estuarine and coastal habitats, believing the value of the Reserves was that "people and wildlife could coexist", whereas residents further from the estuary (who might only visit occasionally) were generally horrified by the high level of disturbance to what they perceive to be a high value wildlife habitat.

Even though the estuary has been 'peopled' for at least 200 years if not longer, escalating pressures posed by housing encroachment on the estuary have greatly increased the conservation management requirements.

In 2004 the Waikanae Estuary Care Group (WECG) was formed as an operational voluntary support group involving collaboration between agencies and the community. It has been able to assist with the planting programmes proposed in the Landscape Plan which was commissioned by the DOC, and assist with weed control. Prior to 2004 there had been a DOC community group formed, but little planting had been undertaken. Support funding and/or labour for WECG has come from the Greater Wellington's Take Care Programme, Trees for Survival and Take Action programmes, Ministry for the Environment, DOC, KCDC and various corporate bodies.

The WECG has proved a highly successful formula with 100 community members, an active core of 16 to 20, and a committee which meets monthly. Between 2008-2010 over 17,000 plants were raised or bought in, planted and maintained in regular working bees held throughout the year - a fine achievement for a relatively small, but active group. To date it is believed more than 25,000 plants have been planted in the Estuary.

Appendix II compares the actual planting lists of the Restoration Planting Sites (RPS) with the species lists recommended in the 2006 Landscape Plan. The original specifications for each RPS were non-prescriptive and as Appendix II indicates, the original species lists have not always been adhered to closely. Further, with the subsequent losses to frosts, droughts and other adverse factors, the availability or ease of propagation of some species, sites may not be progressing as Park had envisaged. This is not necessarily an issue as Park was probably overambitious in his listings of broadleaf species, for example, but it has resulted in a greater density of certain species (e.g. cabbage tree and ngaio)

than might be naturally expected in some habitats. Unfortunately, RPS 1 on the southern coastal foredune faces was largely removed by coastal erosion in 2010.

Ecosourcing is vital for scientific reserve restoration, however ecosourcing plants has been problematic, with cases of nursery contamination and species misidentification resulting in non-natives and cultivars being accidentally introduced. In addition, there are few sites in Kapiti-Horowhenua offering access to a full range of validated coastal species. This is an issue across many Care Groups but since 2010 the WECG has been benefiting from the newly created KCDC staff role for ecosource database management of plant material District-wide. This has clarified sources, increased availability of seed and increased the range of appropriate coastal species available for propagation. WECG record-keeping of seed sources has also improved. The current Plan also proposes regular scrutiny by taxonomic botanists to ensure planting is true to species.

The 2006 Landscape Plan did not recommend any specific pest or predator control work other than the removal of pest plants from RPSs. Plant loss from rabbit browse has been treated with retrospective control rather than pre-emptive control measures. The current Plan addresses these issues in recognition that successful revegetation relies on the integration of healthy wildlife populations (birds and lizards in particular) and foliage/fruiting vigour.

Weed control is both an opportunity and a liability in duneland. Three agencies undertake weed control, operating under different constraints and with differing priorities. Overall, the control of woody invasive species and pampas has been spectacular in recent years. Unfortunately, in the haste to plant RPSs on cleared land, not enough time was spent on follow-up spraying (or initial spraying was inefficient) for total eradication of entrenched species and reinvasion has resulted in a high labour requirement. Methodologies have subsequently improved.

The control of invasive species has involved a huge amount of toxin application, with unmeasured influences on existing ecosystems or on new plantings. It has also involved the loss of much native vegetation which was mixed with exotic species. Without having Advanced Growsafe certified applicators, the WECG is constrained by law in its ability to participate in herbicide application and can only offer mechanical rather than chemical control. These issues need to be addressed.

As with many restoration planting programmes, the results reflect the ease and availability of propagation material. As a consequence the plantings include a somewhat higher proportion of cabbage tree, ngaio and flax than might be expected to occur naturally. In addition, there have been plants located in unsuitable microenvironments for reasons that include 'educational' or 'beautification' reasons which are questionably appropriate in this setting. There has been a tendency to plant all new species into a RPS without replacing the native species that had been there prior to weed spraying, which in hindsight undermines the vision of restoring natural processes.

Spacing of new plants has deliberately been close to overcome the high losses often experienced within the first two seasons (as much as 30%) and to fast track 'canopy' closure. This is desirable with shrubs and monocotyledons, but in many areas large species, such as ngaio, can be found planted only 1 to 1.5 metres apart. If the larger species are equally successful the result will be overcrowded, weakened plants struggling for resources. A clearer concept of successional stages and the use of planting plans may overcome unintentional losses.

The 2006 Landscape Plan introduced some visionary broad brush concepts and an experimental approach to nodal (RPS) replenishment which have been relatively successful. In some respects, though, it fell short of analysing the natural processes and constraints within which coastal succession occurs, which might have resulted in a higher success rate.

Overall, however, the Plan galvanised volunteers and the combined weed control and plantings have made a positive contribution to the estuary ecosystems which the community is keen to see continued.

Part 2 – Background

What now?

The purpose of RPSs was to replenish lost seed sources from estuary habitats so that successional processes could proceed.

It is time now for broad-scale encouragement of the early stages of succession that will be populated by these previously planted seed sources, so that succession can proceed as 'naturally' as possible.

Just how this might occur depends on the broad picture of proximity to the coast, elevation above the water table, the sand's organic content and moisture holding capability (related mostly to age), and shelter from prevailing winds (either by taller vegetation or micro-siting within the duneland topography).

The objective should be to assist natural successional regeneration to at least reach the stage it would have reached on landforms of various ages, if there had not been grazing, weed invasion, loss of seed sources etc. There is no ecological rationale for fast-tracking succession beyond the current capacity of the land.

Although a general premise of human-assisted revegetation is to shade out threatening weeds with taller native species, this is not always possible or appropriate in young dunelands. Weed management and planting methodologies should be suited to localised circumstances.

Figs. 1, 2, 3, 4, 5 and 6 provide the information required to determine what type of plant association might be expected in different parts of the estuary. It is not intended to be prescriptive, but rather to help inform the process.

The following sections

- Review the expected 'natural' succession on dry dunes and wet areas
- Apply this to 'human induced succession' of the weed infested estuary areas and the recently planted areas, keeping in mind elevation and shelter opportunities
- Provide species lists for (i) future broad-scale plantings and (ii) enhancement of existing plantings as they mature
- Propose a time frame and methodologies for co-ordinating weed control and planting management.
- Review the options for the freshwater Puketewhainoa lakelet
- Schedule new work sites and existing RPS based on the issues discussed above
- Propose pest control priorities which will benefit both the vegetative processes and native wildlife

Factors influencing succession

Frost

The estuary lies towards the southern extent of the frost-prone stretch of coastal duneland and experiences occasional frosts which are a natural limiting factor for juvenile plants. There would naturally be a low occurrence of frost-tender colonising species in the dunelands such as ngaio, akeake, and taupata, and even where soil conditions are suitable, species such as kawakawa, kohekohe and mahoe only establish where overhead shelter is available. Non-local karo and pohutukawa may also invade coastal associations where there is frost shelter, distributed from (garden) sources that had been planted at ages tolerant of frost.

Replicating natural processes, therefore, would involve establishing the frost tender species in the shelter of existing trees and shrubs, such as the dead willows and boxthorn, the scattered taupata or macrocarpa (if retained). The proportion of frost tender species will always be relatively low, and this should be reflected in the associations being planted. Close to the flowing river, and on steep banks, frost is less likely, and a greater range of colonising species may be possible where the substrates and other factors make it suitable.

The plantings to date contain a high proportion of ngaio and taupata, which is not typical of colonising duneland vegetation.

Surface ages and dynamics

Fig. 2 suggests ages of surfaces around the estuary, based on written and photographic records. Further research may refine these ages, but for now they give a general impression of the type and rate of plant succession occurring, and some guidance as to the soil conditions to expect. Very young sands, whether wet or dry, are very infertile (apart from the area at the storm debris zone) whereas the older sands may have begun to weather, increasing their clay content and therefore their moisture retention and organic retention capability. Vegetation associations vary accordingly.

The increase of residential development close to dynamic areas of river and estuary has demanded human intervention on the river course. Reduced tidal flushing is causing the conversion of saline lagoons at the southern end of the estuary to brackish and freshwater waterbodies; the shallowing of the southern end of the estuary with subsequent loss of the saltmarsh habitat so important to coastal birds; and probably the erosion of the bar and foredunes south of the rivermouth at times when the rivermouth is artificially straightened[1].

Any further straightening of the rivermouth will be detrimental for the estuarine habitats. The Department of Conservation has argued for enough flexibility in rivermouth management to ensure periodic flushing and reshaping of the estuary margins to maintain suitable wildlife habitat. Nevertheless, public expectation of greater stability of dunes and predictability of flood events, will inevitably influence management of this estuary in the foreseeable future.

The prospect of changes due to sea-level rise and natural events is discussed later.

Root zones - elevation above water table

Fig. 5 shows 1 metre contours across the site. Highlighted zones are 3-4m (in blue) and >5m (in yellow). Note that MSL (Mean Sea Level) is the 0m contour on 1m-contour plan used in Fig. 5. In the following text it is referred to as 'sea level'. Mean High Water Spring (MHWS) can be as much as 800-900mm higher than this and is one of the key growth-limiting factors.

Although different species have different rooting strategies, it is what happens underground that determines plant associations as much as the external conditions. In general (and as reflected in plant distributions we can see along the coast today) elevation has the following influence on vegetation:

'Wet' estuarine sites:

- <3m above sea level (brackish): expect sedges, saltmarsh herbs, saltmarsh ribbonwood, harakeke (latter requires 500mm periodically well-drained substrate but can cope with brief inundation with brackish water)
- <3m above sea level (freshwater): expect grasses, sedges, herbs, harakeke (latter requires 500mm well-drained soil)
- >3m above sea level (freshwater) e.g. edges of perched lakelet: harakeke, cabbage tree, manuka, koromiko, kahikatea, pukatea, swamp maire (latter three if >300m away from MHWS)

'Dry dune' sites:

- >3m above sea level: native woody shrubs (such as small leaved coprosmas, corokia, tauhinu, coastal shrub daisy, pimelea), vines (e.g. small-leaved pohuehue), grasses and bracken are able to colonise and grow to maturity
- >5m above sea level: native tree species (including kanuka, taupata, kohuhu, mapou, akeake, totara, akiraho) can grow to maturity. Since water tables fluctuate greatly in duneland, only drought tolerant species are likely to mature. Some native tree species, such as taupata or mahoe, may grow within 4m of sea level but are unlikely to be long-lived healthy adults.

This does not mean the listed species will grow (other factors, such as frost or proximity to the shore, may prevent establishment) – but it means they can.

Proximity to sea

Salt-laden wind is a limiting factor. In general terms, where there are strong prevailing on-shore winds, the 'salt zone' (within which vegetation growth is influenced by the presence of salt) extends inland either 1 kilometre or up to 120 metres elevation (whichever occurs first). Within that zone, however, there is a lessening of effect with increasing distance from salt water. There is also a mitigating effect from steep topography, creating sheltered microenvironments.

Observation suggests that the distances from Mean High Water Spring (MHWS) of 100m, 200, and 300m are useful thresholds for plant tolerances, and so are used in Figs 6 and 7 to illustrate broad zones of plant tolerances (and therefore plant associations).

The lines shown in Fig. 4 are based on the assumption that from time to time the southern sand bar may disappear and saline water may dominate the southern portion of the estuary at high tide. The most variable and difficult delineation is shown as dotted lines.

The <100m zone also coincides (in general) with the youngest and least fertile sands. It is immediately clear that even on ground elevated >5m above sea level, within the 100m zone it is highly improbable that any tree species would be expected to survive, and even the hardiest and most adapted of tall shrubs

such as taupata, will be limited in their distribution and vigour.

Successional processes

The 'natural' successional diagrams in Figs 6 and 7 were based on examples drawn from Kapiti/ Horowhenua duneland, Chatham Island and NW Nelson sites (although the latter are less exposed to wind) where there has been the least modification. It was determined how close remnants would have been to the shore as they were maturing, and time frames for successional seres were based on the estimated ages of component species.

A primary source of information has been Dr. Jeremy Gibbs 1978 report on the Kapiti Coast erosion, as well the interpretation of various written and photographic records relating to archaeological sites and land-uses over time.

In broad terms, where there is a strong onshore prevailing wind, we can expect vegetation within 100m of MHWS to advance (on dry dunes) to grassland-shrubland; for vegetation between 100-200m of MHWS to advance to shrubland-treeland; and from 300m or more, coastal forest may become established.

On saturated or damp ground influenced by saline ground water, succession is unlikely to advance beyond a marsh shrubland dominated by saltmarsh ribbonwood. If the influence is fresh water, we can expect vegetation to advance through rushland phases to flaxland-shrubland-cabbage tree around 300m from the shore, and further inland than that, to swamp forest of kahikatea, swamp maire, pukatea and cabbage tree where salt wind exposure is not too severe.

In the absence of ground water mapping around the estuary, assumptions have been made about relative salinities of ground water.

There are several aspects to potential restoration work at the estuary:

(1) enriching existing native successional plant associations with species unnaturally absent, while managing weeds;

(2) utilising exotic grasslands (<100m from MHWS mark) and exotic shrublands (>100m from MHWS mark) as a 'nursery'. (This may involve introducing currently absent species, and may involve strategic removal of exotics);

(3) replanting cleared or bare sites, in order to prevent re-invasion by exotic species, either with appropriate colonising species, or by 'fast-tracking' succession by assisting woody species to become established;

(4) growing a collection of species typical of different seral stages at a strategic location on cleared or bare ground, as a long-term seed source;

(5) maintaining a foredune leading edge vegetation of spinifex and pingao

To date the effort has gone into (3) and (4). This is primarily because weed control must be done on a large scale to be effective, resulting in large areas of cleared or at least grassed, duneland. These are either planted with species that had been present but suppressed by weeds, or (in most cases, to meet the objectives of RPS nodes) planted with a range of species from later successional stages.

A new philosophy of not planting until at least two sweeps of weed control have been undertaken, to lessen the chances of resprouting by entrenched weeds, should ensure a higher success rate with this approach. Over time, as more areas undergo weed control, reinvasion from adjacent areas should also lessen.

Fast-tracking succession (4) is risky, as many species wouldn't normally appear until ground, shade and shelter conditions are suitable and cleared ground doesn't necessarily support their needs. Heavy reliance on human 'gardening' is required for fertility, soil water content and shelter.

Effort is also going into (5) to try to increase resilience of the foredunes to erosion and replace marram. This is complemented by other planting programmes extending to the south and to the north of the estuary.

The review of work to date suggests that the high level of voluntary human input required is reaching a threshold. Any new work would ideally involve less follow-on labour, and more mechanical or institutional approaches. Certainly a similar or greater level of funding will be required to keep momentum going and prevent reinvasion of weeds.

Complete vegetation clearance is warranted where exotics dominate the vegetation but there are some areas where clearance results in the considerable loss of native species (such as knobby club rush, small leaved pohuehue, sand bindweed etc.) which play an important role in covering and stabilising the dry dunes.

The next phase of work, as proposed in this

Restoration Plan, explores opportunities to tackle (i) and (ii) above. This requires greater attention to micro-site assessments, but also requires the widespread planting of early successional native species.

Restoration planting techniques

Enhancing existing successional associations

There are a number of high value locations which should be prioritised for restoration management, both to protect them and to optimise their influence on surrounding vegetation. The key locations are:

- New and ephemeral sand bars where marram readily establishes. Maintain dominance of native species by weeding, not by planting.
- Transition zone between salt meadow and dry dune within the estuary. Maintain dominance of native species by weeding, not by planting. Minimise sand binders here, to slow the dune accretion process.
- Identifying grassland-shrubland areas where hand-pulling or selective herbicide treatment of weeds (rather than broadcast spraying) and seed sowing will result in maintaining native species dominance – likely to be the coastal foredunes.
- Identifying grassland-shrubland areas where high mows followed by spot spraying of weeds will result in maintaining native species dominance with minimal ground clearance.
- Bracken patches. Where these are >200m away from MHWS oversow with seeds of woody shrubs and trees that will overtop bracken in time.
- Dead trees (willows etc.) and existing taller locally-native species which provide shelter. These should be used as nodes for the establishment of suitable shade tolerant species of later successional stages (wetland or dry land).
- Manuka shrubland adjacent to Puketewhainoa lakelet: introduce swamp tree species as seeds or seedlings.

Using exotics as a 'nursery' for native species

The main locations for this approach are within unstable foredunes, where total clearance will result in dune destabilisation and make planting more difficult. Some of this work is already under way. It involves strategic interplanting and later removal (or suppression) of exotic species.

Key locations include:

- Areas of dense marram which can be sprayed with grass-specific herbicide then interplanted with non-grass species. Check for any regrowth of marram (spraying as required) before advancing with the next step, which is to reintroduce native grasses. Typically these marram sites are >3m above sea level within the 0-100m zone (a good location for sand tussock, spinifex, pingao, knobby club rush, groundsel, bidibidi, sand convulvulus etc.) or in the 100-200m zone, i.e. locations where small shrubs, ground creepers, speckled sedge, sand iris and vines might naturally establish.
- Areas of dense lupin and/or gorse (free of blackberry or periwinkle) which would be sprayed, the dead shrubs left to provide shelter, then interplanted with species such as small fine-leaved shrubs, small-leaved pohuehue and toetoe. Sowing of seeds should also be tried. Typically these sites will be in the dry dune areas >4m above sea level. If they are within the 0-100m zone, only the areas that are in the lee of taller dunes will be suitable for woody shrubs (otherwise with more exposure, knobby club rush, sand tussock, small-leaved pohuehue and creeping ground covers are advisable). Areas of gorse >100m from MHWS may have tracks cut through and kanuka interplanted or cut branches of seed-bearing kanuka laid down.
- Locations where pampas has been sprayed, resulting in dead clumps often with little growth between. Plant in the lee of the dead clumps.

Planting into cleared / eroded sites

These will be the areas where blackberry or periwinkle has dominated (commonly damper locations); sand blowouts amongst the steeper, dry dunes: and adjacent to newly formed tracks.

- 'Clean' bare sand in blowouts can be planted as soon as possible with spinifex, pingao, knobby club rush and sand convulvulus. If (as along the Paraparaumu beach front) erosion occurs, replant promptly, concentrating on replenishing the dune crests with spinifex that can trail down the eroded dune faces, offering resilience to further wave action.
- Weed infested sand will require repeat sprays of regrowth before planting after which time this

level of surface exposure makes it imperative to get ground cover (rather than individual woody species) established as fast as possible, using sand bindweed, small-leaved pohuehue, NZ spinach, spinifex, knobby club rush and bracken, i.e. open ground colonising species. In the interim a variety of wind-resistant mulches may be tried: cut bracken fronds, cut kanuka/mānuka branchlets, for example. Hydro-seeding mulch (either with suitable native seeds or without seeds) has been used elsewhere in New Zealand to stabilise sandy surfaces, but would introduce substances and fertiliser into the reserve which may not be appropriate so should be used sparingly if at all. Unassisted grass growth as an interim vegetation cover is acceptable in areas that will have shrubland cover later (with sprayed grass acting as a mulch for newly planted specimens).

Fertiliser and potting mix

To date it appears that most propagation and planting has been based on commercially-driven rather than restoration-driven methodologies. Commercial potting mix is used for all species and fertiliser applied to the plant holes.

While it is clear that to fulfil the mission of planting nodes with seed-source species, some fertility additives are required to help plants overcome the lack of successional soil development, it must be the exception rather than the rule if restoring natural processes is the ultimate goal.

There are several reasons to reassess fertiliser use and potting mixes.

Nitrogen

Studies have shown improved growth of spinifex and pingao when slow-release N fertiliser (eg Magamp which is low in N) is applied at planting, although its application does not seem to alter the survival rates. Once established, however, spinifex and pingao are further boosted by broadcast application of fast-release N-based fertiliser (such as urea).

However, it is important to keep fertiliser levels very low, as a plant that grows too luxuriantly may not cope as well in times of stress. Low levels of fertiliser are thought to replicate the natural accumulation of rotting weed, plankton etc. blown up from the splash zone and, in years past, the accumulation of guano from roosting sea birds.

N-based fertilisers, however, also boost exotic herbaceous growth and marram growth, and for this reason it is recommended that the addition of superficial fast-release fertiliser is applied to spinifex and pingao only on the beach frontages, or blowouts, where marram is not present, and that elsewhere on the foredunes either no fertiliser, or only low doses (10-30mg per plant) of slow release low-N fertiliser are applied at planting.

Phosphorus

Throughout the world there are plants living in very infertile soils (such as sand) which have developed a high sensitivity to phosphorus. They are especially efficient at extracting phosphorus from soils although this efficiency means that too much phosphorus is toxic to them. Some exotic genera which display this adaptation include Protea, Leucodendron, Banksia, Grevillea, Boronia, Acacia. Some known New Zealand examples are mānuka, akeake and Atriplex, but it is likely many foredune species share this adaptation.

It is important not to over-fertilise specialist dune species in case the phosphorus levels become toxic. Even adding a 'normal' slow-release fertiliser pellet to the planting hole of a very small phosphorus-sensitive species could kill it.

There are also species which do their best to increase their uptake of phosphorus: either with abundant growth of fine root hairs (rushes and sedges use this technique); or by increasing the mycorrhizal fungi associated with roots (the fungi break down mineral phosphates into something the plant can absorb – some grasses and coprosmas and totara rely on this and don't need root hairs).

A high proportion of dune plants rely on mycorrhizal fungal associations for nutritional assistance. They have fungal hyphae extending out into the sand where they absorb nutrient that the roots themselves cannot access.

Until these fungal associations develop, the young plant will noticeably respond to phosphorus being applied, unlike the phosphorus-sensitive plants that were already optimising what meagre supplies they had. But such plants, when raised in potting mix, will benefit more from mycorrhizal additives than from fertiliser, especially as they are often being planted into 'barren' sand which may not already contain the fungal-organic associations which may have accumulated during a normal successional development.

It is recommended that propagation medium of all plants utilises a high ratio of 'old' sand (more likely to contain mycorrhizal fungi already), a minimum level

of fertiliser, and for key species (see table below) a tiny addition of soil or duff sourced from sites where these plants grow naturally, again in the hope of introducing the mycorrhizal fungi they require, as this should reduce the need for fertiliser at planting time.

The addition of Trychoderma product (a widespread beneficial soil fungi) is also recommended for optimising the health of plants.

If plants are raised without mycorrhizal additives, very low doses (less than a handful) of slow release Magamp granules at the bottom of the hole may be a good idea as the extra phosphorus may get them through a barren period.

Matching the conditions

Depending on the density of planting out, the addition of large amounts of potting mix to the duneland can, over time, alter the growing environment. Increasing the proportion of sand in the potting mix will dilute this effect.

Any potted coastal plant must be hardened off prior to planting, but traditionally this deals with the plant above ground level and not its roots. The shock to a plant growing roots through its moisture-retentive, fertile potting mix out into dry, infertile sand, should not be underestimated. Many potting mixes contain water retentive material which induce root systems that are less likely to cope with the drought they experience when the roots extend into sand. If this results in root balls staying within the potting mix, plant growth may become constrained.

Local anecdotal accounts of planted nursery plants being found to have roots still only within the potting medium after several years of growth, suggests the traditional approach to potting mix and fertiliser may not be beneficial to stressed, dry dune plants.

One way to counter this stress is to raise the plants in substrates closely resembling the ground they will be planted into. The ratio of sand should be as much as 50%; the proportion of nutrient low; the moisture retentive component (probably peat or bark-based) also low. It is argued that this can slow seedling development and retard planting programmes, but when the project is a non-commercially driven one this should not be a driving factor.

The following table proposes general approaches to experiment with for best results.

Plant group	Potting medium	Plant hole fertiliser
Spinifex Pingao	50:50 sand/bark or pumice 18mth slow release Osmocote (N-rich) fertiliser	Magamp 2 yr slow release (P-rich) fertiliser (small handful) (fast-release surface urea applications after planting only as required)
Manuka Kanuka	50:50 sand/bark or pumice Additive of 'natural' soil/duff from mature stands 18mth slow release Osmocote (N-rich) fertiliser Trichoderma	NIL
Foredune herbs and woody shrubs	50:50 sand/bark or pumice 18mth slow release Osmocote (N-rich) fertiliser Trichoderma	NIL
Coprosma spp, podocarp spp, sedges	Standard potting mix containing 18mth slow release Osmocote (N-rich) fertiliser Trichoderma	NIL
Broadleaf spp	Standard potting mix containing 18mth slow release Osmocote (N-rich) fertiliser Trichoderma	Slow release general fertiliser

Mulch

Three kinds of mulch or weed-suppressant have been utilised to date: jute weed mats, shredded bark and the dead matter from sprayed sites. Jute weed mats have proved unsuitable on dry dune sites as they prevent water penetration, and their use had become limited to moist sites.

It is debateable whether introducing any foreign material (carpet or shredded bark) or material containing residual chemicals is appropriate within a scientific reserve, as it introduces new micro-habitats and potentially introduces spray residues and unknown chemicals to the root zone.

The benefits of artificial weed suppression are clear in areas where bare ground has been planted with woody species and there is a high risk of entrenched weeds resprouting. But there has been little experimentation with growing fast-spreading ground covers as an alternative method to suppress weed seed germination (in sites where entrenched weeds are already well controlled).

As mentioned previously, more use could be made of harvested bracken, mānuka, kānuka or even dead lupin and gorse which has the advantage of creating cool, shady microhabitats for wildlife which rain can readily penetrate, compared to denser mulch materials, some of which are of unknown origin.

It is recommended that future methodologies seek to minimise the use of artificial mulch.

Pest animals

Although the Restoration Plan is not an all-encompassing reserve management plan, the control of pest animals cannot be separated from assisted revegetation as a tool to restore the estuarine ecosystems. Boosting wild populations of birds and lizards in particular will encourage natural dispersal of fruits. Limiting foliar browse by possum, rabbit and hare, reducing seed browse by rodents, and preventing bird and lizard losses to rodents, cats, dogs, hedgehogs, mustelids and possum are critical steps for any restoration programme.

Initial monitoring of rodent and mustelids during 2010 indicated high numbers of mice compared to rats or mustelids. Cats (probably domestic) are known to frequent the reserves and despite well-known regulations, locals still let dogs roam freely through the reserve tracks.

Control methods are limited by the high public usage of the reserves, and made challenging by needing to be reserve-wide rather than site-specific to be effective. The use of toxins requires public notification and advertising and is therefore more expensive than trapping, although the latter requires a higher man-hour effort.

With a high level of community input into the estuary's management it may be possible to create a regular labour force for ongoing monitoring, trapping and baiting that may be uneconomic for agencies to maintain. If volunteer support is forthcoming, 'DOC 200' traps and permanent mouse trap stations are recommended.

Bearing in mind that regular trapping lines create paths for both humans and predators it would be advisable to utilise existing tracks and river banks rather than create a grid or network, or to limit access to any new tracks required.

Recommended site-led pest animal management:

Sites	Key species
Likely bird-breeding locations: Puketewhainoa lakelet, unnamed Weggery Drive lagoon, inner estuary detritus zone	Target mustelids, hedgehogs, cats, dogs and rodents from September-January
New foredune plantings	Target rabbits immediately prior to planting. This may require a seasonal co-ordination for optimal pest control/planting. From time to time estuary-wide rabbit control operations may be required to reduce populations throughout.
Whitebait spawning areas	Target rodents, from February to May

Recommended species-led pest animal management:

Investigate rodent control on a sustained basis throughout the estuary, or at least in planted areas. Any opportunity for community-led trapping rather than toxin application will minimise primary and secondary poisoning risks.

Live cat trapping accompanied by publicity and releasing of 'painted' animals that are thought to be domestic, is worth trialling as a way to alert

neighbours of their pet behaviour. Although dead cat trapping (in conjunction with appropriate notification) would be the ideal method of control, there are challenging issues due to the large number of cat owners in the area.

Cat predation of lizards and birds occurs both night and day so a concerted publicity campaign to keep neighbourhood cats on their property and to avoid keeping cats in close proximity to the estuary at all is recommended.

Given that "exotic flora and fauna shall as far as possible be exterminated" is a statutory requirement of Scientific Reserve management, the allowance of dogs within the Reserve is already a compromise reached in recognition of the modern suburban context. There are a number of areas where a visual barrier between dogs and birds will be beneficial: between Puketewhainoa lakelet and Manly Street; between KCDC Recreation Reserve and the river; and between the small un-named Weggery Drive lagoon and the surrounding reserve. A suitable height of vegetation (at least waist height) should be incorporated into planting plans for these areas.

Floristic integrity & identification

All seed or cuttings should be sourced from equivalent natural duneland habitats within Kapiti and Horowhenua districts. The scarcity of natural remnants makes it important to foster good relations with private landowners.

Accurate record keeping of sources and where propagated material is planted out (in due course providing further seed stock) will address current issues of dubious parentage. This need for record keeping extends to external nurseries supplying material.

At present planting areas are discrete and easy to monitor. This may not be the case in future years, and it will become increasingly important to understand which areas have been modified and which have developed with no or minimal human intervention.

It is recommended that a taxonomic botanist is engaged to

(i) review planted material for species integrity, and

(ii) undertake a survey similar to the Kennedy and Webber survey of 1975 which combined habitat mapping and species lists.

Fauna habitats

The main purpose of the Scientific Reserve status is to protect the ecosystems which result in this being a regionally significant wildlife habitat. The dynamic nature of the estuary creates a mosaic of feeding and breeding opportunities for birds, freshwater, saline and terrestrial vertebrates and invertebrates as well as terrestrial and aquatic flora.

The recent stabilisation of the river course has reduced the area of salt meadow and salt marsh and the entrapment of the south marsh by sand is changing this into a freshwater environment. The old oxbow is also becoming increasingly freshwater in nature.

Once the open mudflats and damp sand flats are no longer flushed by storm surges or spring tides they quickly change into dune ecosystems and the feeding grounds for shore birds are lost, and the relative safety of open nesting grounds for sand nesting birds such as banded dotterel is lost as they become consumed by dry dune vegetation. New habitats emerge – ones better suited to lizards, terrestrial invertebrates and terrestrial bird species (especially exotic species) – but it will be important to resist any future moves to extend the 'hard' river edges further seaward.

The pace of these changes may be mitigated somewhat by eradication of invasive weeds but landscape changes on this scale are affected by external agents and communities, making it very difficult to manage the issues. Another example is the upstream land-use changes causing the Waikanae River to carry more shingle further into the estuary than previously, threatening the food chains of wading birds.

Key ecosystem cycles which can readily be enhanced through restoration planting and pest control programmes include

- Ensuring river, drain and saltmarsh banks are suitable for fish spawning
- Providing adequate perches (trees or built structures) near waterbodies for piscine birds (shags, herons, kingfishers)
- Dominance of pingao and spinifex along foredunes (important for toheroa life cycles by providing preferential spat habitat at spring tide, and as katipo habitat)
- Dense fruiting shrubland cover, important for lizard habitat.

Puketewhainoa lakelet

Although it seems from orientation of the 1845 Gilfillan sketch of Kenakena pa that this water body could be a remnant of the river course at that time, it is more likely to be a relict of a much older river course and lagoon which subsequently caused the Puketewhainoa dune (drawn and labelled by Adkin, 1948 maps) to bank up against it and which created the string of small water bodies running north to the Waikanae River. The hard pan immediately west of the lakelet does suggest either an old river bed or a wind-formed sand flat, causing a perched water table today.

Although maps drawn in the 1940s and earlier do show Puketewhainoa as a discrete lakelet, in 1972 Kotuku Parks built a 1 to 2 metre high causeway across the swampy margins which would have ensured hydrological isolation of the lakelet water body from the rest of south marsh except for a drain cut between the two water bodies (which are at approximately the same elevation). The causeway was constructed to enable sand to be moved from the north-western portion of the Kotuku Park development to raise the southern portion (Manly Street-Olive Terrace) prior to subdivision.

The depth of the lakelet is unknown to the author, but raupo is able to grow throughout, suggesting a maximum possible depth of 2 metres.

There appears to be one stormwater drain into the water body (collecting from portions of Manly, Kotuku and Michael roadways).

Beyond the immediate fringe of carex around the lakelet, blackberry dominates what would probably otherwise be a ring of flaxland or, on higher ground, a shrubland of mānuka, toetoe, cabbage tree etc. There is a small patch of successional bush within 20-30 metres of the carex fringe on land >5m asl to the NE (mānuka, mahoe).

This lakelet is a significant wildlife habitat, known to attract breeding populations of waterfowl and waders, which has benefited from restricted access for dogs, cats and humans. It is essential that any future restoration work maintains this high level of security. This can be achieved not only by maintaining a dense, impenetrable fringing vegetation, but ensuring that the borders adjacent to Manly Street are screened by vegetation tall enough to prevent birds being disturbed by passing pedestrians, dogs or vehicles. This can be achieved with shrub growth as a protective mechanism to preserve the isolation of the lakelet habitat. Tall fringing vegetation is not advisable except on small groves, as it may discourage birds from flying low onto the lakelet.

Is raupo slowly filling up the lakelet? Neither photographs nor neighbour's observations give a clear indication of any trends, but it is certainly expected that the lakelet will slowly infill, at least in part with the organic remains of the raupo itself. While this may, in time, reduce the proportion of open water, creating a different wildlife habitat than at present, it is a natural process that most dune lakelets undergo. In order that the process does not proceed at a faster than 'natural' rate, it will be important to protect it from nutrient-rich inputs such as stormwater discharge.

The neighbouring lakelets which have been modified as stormwater treatment ponds for the Kotuku development (Ngarara and its pre-treatment pond) will be maintained as open water, ensuring an open water feeding option remains for waterfowl in the long term, although they will probably not be suitable for breeding.

It is recommended that

- any stormwater be diverted or treated (see also next section)
- raupo clearance only occur when less than one quarter of the lakelet surface remains as open water (and the waste to be removed).

South marsh water quality

The Kenakena Drain emanates from near the Kenakena shops, is piped under the Kenakena School playing field (in order to prevent ex-tip leachates entering the drain), runs through an open drain to Manly Street where it is joined by stormwater drains from the early Kotuku Park development. Originally Kenakena Drain was fed within embankments directly into the tidal estuary (either entering the river or creating a pond depending on conditions).

Since the mid 1990s the outlet has been blocked by sand accumulation, increasing the water depths in the south marsh (which had been an ephemeral feature for decades). The discharge remains isolated from the tidal estuary except during large rain events, probably hastening the conversion of the south marsh from saline to freshwater.

It is not known whether water from this wetland backfills into Puketewhainoa wetland during floods but they lie within the same contour with only a one to two metre rise separating them and this has a

connecting drain incised through it.

Kenakena drain serves a large suburban stormwater catchment . KCDC undertakes stormwater discharge water quality testing at Donovan Road. In recent years sampling has revealed zinc and copper levels exceed the ANZECC ecological guideline values, the water is acidic and can carry oil slicks.

Flooding of Kenakena Drain prompted KCDC to commission an unofficial report to investigate whether the drain should discharge directly into the estuary once again. The report suggested there was not a strong argument to re-cut a channel through to the estuary on floodwater volume grounds.

While the current situation exists, in order to minimise detrimental effects of contaminated stormwater dischargers, it is recommended that:

- Closing the Puketewhainoa lakelet drain should be considered
- Ensure that Kenakena Drain overflows only into one discrete and hydrologically isolated portion of south marsh, which is planted appropriately (i.e. using Carex, Schoenoplectus, Baumea or Typha species, not Phragmites species). There may also be scope for a floating wetland designed to absorb metals, associated with the Drain itself.

Unnamed Weggery Drive lagoon

This small lagoon is connected to the Waikanae River by a culvert running under the riverside walkway. Smelt are conspicuous and it is expected that the continuum of fringing aquatic rushes provide spawning grounds for whitebait species.

The steep banks on the old dune have been planted with kanuka, but grass still surrounds the lagoon itself. Vegetatively linking the lagoon with this kanuka stand, and with the river, will enhance the ecological merits of this water body. Stormwater from Weggery Drive drains into the lagoon.

Queens Road saltmarsh

So named only because it is located in line between the end of Queens Road and the river, this high value successional oioi-saltmarsh ribbonwood wetland has recently been intersected by the riverside walkway. Not only does this disrupt the natural connectivity of vegetation with the river which formed it, but the raised and consolidated pathway has required tidal drainage to be concentrated through a single culvert beneath the path.

It is possible that this intervention will both raise the ground water within the wetland and slowly convert it from brackish to freshwater. It is unlikely to have an adverse effect on the coastal shrub daisy shrubland where ground level is >1 metre above high ground water level.

Ideally the path should have circumnavigated this wetland rather than intersected it. Suggestions for routing in the next section may have some influence on the future of this section of the walkway.

Planting of flax, sedges and some shrubs has been undertaken around the grassed fringes of this wetland, but is of questionable ecological value other than to extend the area of native vegetation onto drier soils.

Cultural aspects

The Estuary has been peopled for at least 200 years and probably much longer. Vegetation associations and bird populations would have altered according to the resource needs of various settlers, as much as with climate or geomorphic activity, but certainly the greatest recorded changes began to occur in the 1820s when incoming Maori tribes introduced recently learned cultivation practices and, shortly after, domestic cattle, sheep and pigs.

Parts of the estuary still have tangible legacies of previous settlement, such as the historic homestead at Arapawaiti, remnants of estuary bach plantings (macrocarpa, totara etc.), old power lines and fences through the oxbow, but there is no trace of mäori presence remaining. Peripheral to the estuary there were burials uncovered during the Waimanu Lagoon excavations, a burial ground was protected within the Kotuku Park development, and foundations of the Anglican church associated with Kenakena Pa were uncovered during excavations alongside Mazengarb Road.

Written historic accounts suggest that Waikanae mäori actively cultivated a wide range of commercially and handicraft useful varieties of flax, although whether this occurred within the estuary environment is unknown.

The one resource-use tradition which survives is whitebaiting along the Waikanae River, although volumes were recorded as dropping after the Waimea stream swamps were drained to form the Waimanu and Waimea Lagoons.

The influence of modern parks and reserves horticultural practices is evident in the choice of trees

in the Recreation Reserve: pohutukawa, Norfolk pine, Tasmanian ngaio, whau and karo – coastal species typical of rocky coastlines, none locally native and all bar the pine potentially invasive in the estuarine/ duneland habitats.

To achieve community endorsement of restoration and protection efforts within the estuary environment it would be useful to introduce some simple elements which subtly underscore the vision.

The obvious step is to literally offer a vision – by creating several lookout points whereby visitors get an impression of the scale and beauty of the estuary. At present the only seating offered in the Recreation Reserve is orientated towards the man-made lagoon. Several ideal locations exist within the Recreation Reserve to shift the focus to the estuary.

One, the small knoll created alongside the pathway between the Waimanu Lagoon car park and the wetland, could have a formal path leading to a simple bench seat on its apex. Once the Tasmanian ngaio along the river edge is removed (planned for 2010) the views will be outstanding and (apart from two Norfolk pines) relatively natural.

The second, which requires more path-forming, is on a natural terrace on the western end of the large old dune (Weggery Drive). As this is also a primary planting site it would be advantageous to have a formed path, and again a simple bench seat which is not visually intrusive, would provide a spectacular vantage point. A walkway route around the back of the Queens Road saltmarsh (rather than through it as at present) would make this proposed lookout only a short detour off the main route.

Needless to say, the inclusion of mäori design elements in any furniture or concreting etc. would be totally appropriate and allow visitors to reflect on those who have shared the same views over hundreds of years.

Future change

Sea level rise is currently anticipated to involve a 0.8 – 2.0 metre rise over the next 90 years (pers. comm Prof. P. Barrett, Antarctic Research Centre). Added to an increase in storm surges, this amount of rise would not only completely reshape the estuary, but the huge amount of sand likely to be displaced along the Kapiti Coast could generate a new dune building phase of unstable foredunes.

It is likely that seawalls will be required along the Manly Street and Kotuku Drive boundaries as rises in the wetland water table levels threaten properties. The old oxbows each side of the Waikanae River are likely to become more important floodwater ponding areas.

Other hazards loom large for the Kapiti Coast. This is an area caught between two major tectonic processes – moho versus mountains. Faults related to both the sinking moho of the Wanganui Basin and the uplift of the Tararua Ranges run parallel to the coast onshore and offshore. At least some of the major dune building phases are now attributed to activity of these faults, but the vertical offsets of future movements on these faults relative to sea level could be up or down.

Tsunami risk along the Kapiti Coast is considered to be low, with the majority of tsunami likely to be generated to the east of New Zealand, and only affecting the west coast when extremely large ones are able to wrap around the islands. Nevertheless a number of past events are recorded at the north end of Kapiti Island. It is assumed that any tsunami event here will destabilise dunes, possibly triggering another dune building phase.

So the key change that can be predicted is that of sea level rise accompanied by increased storminess. Increasing resilience of foredune vegetation is important, as is having a diverse range of habitats providing seed source for a natural shift plant associations to keep pace with changes in ground water and salinity profiles.

Weeds

Three agencies undertake weed control across the estuary, operating under different constraints and with differing priorities. Overall, the control of woody invasive species and pampas has been spectacular in recent years. The DOC is beginning to spray marram along foredunes. The old oxbow is a major repository of exotic weeds still in private hands, but this Plan can anticipate its pending conversion to public open space. In mid-2010 a large area of gorse owned by Kotuku Park adjacent to the north marsh was cleared which removes the other major repository of weeds within the estuary.

The control of invasive species has involved a great amount of toxin application, with unknown influences on existing ecosystems or on new plantings. It has also involved the loss of much native vegetation which was mixed with exotic species.

Some of the constraints on herbicide choice include

residual effects on wetland habitats; selective herbicides with lesser impact versus non-selective herbicides with guaranteed success rates; cost-effectiveness of applications versus likely kill success rate.

The WECG is constrained in its ability to participate in herbicide application and can only offer mechanical rather than chemical support. However there are many opportunities to encourage volunteer labour to tackle weeds that are not cost-effective for agencies to tackle and this labour force can also be extremely useful for regular surveying of the weed situation.

Reinfestation through resprouting of entrenched weeds is reducing as the methodology of spraying prior to planting is refined (ensuring enough time to allow follow-up spraying prior to planting).

Germination of weed seeds will continue to be a problem as long as (i) there is an upwind seed source of wind-blown seed species and (ii) there are birds transporting fruiting seed species (iii) seeds in accumulated duff continue to germinate (iv) there are garden escapees from adjacent properties (expected to increase). All but the activities of birds can be counteracted. It is not going to be possible to entirely shade out light-demanding seeds, as the natural foredune cover, in particular, is naturally sparse and often not tall enough to shade effectively.

As can be seen now, karo and boneseed in particular germinate in the shade of taller shrubs such as taupata and ngaio. With a large area of tall shrubs expected to develop over the next few years is it more critical than ever that the parent trees are destroyed and seedlings sought out.

Recommended approaches:

General

- Prepare a comparative plant ID kit to assist with distinguishing between similar native/exotic species
- Seek to lessen the need for widespread spraying and concentrate on strategic/specific spraying or hand/mechanical weeding or Vigilant application where feasible
- Experiment with high mows (rather than low mows) followed by spot spraying to eradicate blackberry and gorse from a matrix of natives rather than total removal of all species
- Establish a regular a 'border check' to eradicate garden escapees as soon as they appear
- Utilise an inter-agency grid reference system for surveying and reporting, and to support future control measures

Site-led weed control

- Ensure complete clearance of environmental weeds within 5 metres of any planting areas, and ensure adequate time for follow-up spraying of entrenched weeds prior to planting (e.g. 3 sprays for periwinkle and ivy)
- Incorporate coastal ground cover species into all plantings to encourage suppression of seed germination in disturbed ground as fast as is practicable
- Prioritise complete environmental weed clearance from high value natural areas: sand bar, south marsh and borders, north marsh and borders, Puketewhainoa lakelet borders, salt meadows and detrital zones, Queens Road swamp, oxbow channels, unnamed Weggery Street lagoon

Species-led weed control

- Prioritise upwind areas and a roll-back approach for eradication of exotic grasses and sedges and other wind-distributed seed species. Remove pampas flowerheads if flowering occurs before spraying, noting location on grid reference.
- Identify sites of dense blackberry requiring spraying and co-ordinate replanting of these locations.
- Drill and poison trees and concentrate planting efforts in their shelter

Encourage the WECG to target

- Herbaceous weeds (such as purple groundsel, pink ragwort, fleabane, tree mallow, agapanthus, Lilium, arum lily)
- Foredune species able to be hand-weeded such as young marram along the sand bar and estuary foredunes/salt meadows, Juncus acutis in the salt meadows, South African ice plant
- Water celery and exotic umbrella sedge in wetlands
- Weed seedlings growing in the shelter of taller trees such as taupata

Refer to Table I for weed species currently recorded in the estuary, the priority relationships between agencies, and the scope for WECG involvement.

Table I

Weeds recorded 2010

DOC ranking for species-led control: A: Very serious - treat as soon as practical B: Moderately serious - include in treatment schedule C: Potentially troublesome - treat when convenient and resources allow		GW RPMS Pest Plants	Could be the primary concern of Care group throughout, or follow-up site hand weeding by Care Group
Arum lily *Zantedeschia aethiopica.*	A	Site-led/KNE	Yes
Bindweed *Calystegia* spp.	A	Site-led/KNE	
Blackberry *Rubus fruticosus*	A	Site-led/ health/KNE	
Boneseed *Chrysanthemoides monilifera*	A	Containment/KNE	Yes
Boxthorn *Lycium ferocissimum*	A	Site-led/KNE	
Evergreen Buckthorn *Rhamnus alaternus*	A	Containment/KNE	Yes
Everlasting Pea *Lathyrus latifolius*	A		
Gorse *Ulex europaeus*	A	Site-led/boundary	
Grey Willow *Salix cinerea*	A		
Japanese Honeysuckle *Lonecera japonica*	A	Site-led/KNE	
Karo *Pittosporum crassifolium*	A		Yes (juveniles)
Pampas - Common *Cortaderia selloana* - Purple *Cortaderia jubata*	A	Site-led/KNE	
Periwinkle *Vinca major*	A	Site-led/KNE	
Phragmites *Phragmites australis*	A	Reg Surveill. /Site-led/KNE	
Pseudopanax hybrids	A		Yes
Spartina *Spartina* spp.	A	Reg Surveill. /Site-led/KNE	
Tree Lucerne *Chamaecytisus palmensis*	A		Yes
Wandering Jew *Tradescantia fluminensis*	A	Site-led/KNE	
Agapanthus *Agapanthus campanulatus*	B		Yes
Broom *Cytisus scoparius*	B	Site-led/KNE	
Climbing Dock *Rumex sagittatus*	B	Site-led/KNE	
Flowering Cherry *Prunus* spp.	B		Yes (juveniles)
Ivy - English *Hedera helix*	B		
Ivy - German *Senecio mikanioides*	B	Site-led/KNE	
Marram grass *Ammophila arenaria*	B	Site-led/KNE	
Silver poplar *Populus alba*	B	Site-led/KNE	Yes (juveniles)
spiky rush *Juncus acutus*	B		Yes
Sweet Pea vine/Mile-a-minute *Dipogon lignosus*	B	Site-led/KNE	
Tall Fescue *Festuca arundinacea*	B		
Tasmanian Ngaio and hybrids	B		
Acacia *Acacia* spp.	C		Yes (juveniles)
Flax cultivars	C		
Fleabane *Conyza* spp.	C		Yes
Iceplant *Carpobrotus edulis*	C		Yes
Kikuyu Grass *Pennisetum clandestinum*	C		
Lilium *Lilium* spp.	C		Yes
Lupin *Lupinus arboreus*	C		
Macrocarpa *Cupressus macrocarpa*	C		Yes (juveniles)
Mallow *Malva Sylvestris*	C		Yes
Pine species *Pinus spp.*	C	Site-led/KNE	Yes (juveniles)
Pink Ragwort *Senecio glastifolus*	C	Site-led/KNE	Yes
Purple groundsel *Senecio elegans*	C		Yes
Sweet Briar *Rosa rubiginosa*	C		
Umbrella sedge *Cyperus eragrostis*	C		Yes
Water celery *Aplum nodiflorum*	C		Yes

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Fig. 1

History

Overlay from Adkin, 1948 (although the maps are not dated and refer to historical locations)

Site of Hadfield's church, Mazengarb Road

Hocken Library

(above) Gilfillan, John Alexander, 1793-1864 :Wai-Kanae and Kapiti **1845.** This is the original sketch (printed in The Kapiti Coast, W. C. Carkeek) for a watercolour held by Alexander Turnbull Library PUBL-0066-141 which is described: "*The mouth of the Waikanae River showing a fenced pa (Kenakena) with a large number of buildings. The large building with peaked roof is believed to be the first Maori Missionary church built by Bishop Octavius Hadfield. Kapiti Island is visible in the background.*" The painting of the 'church' gives the building a finial, absent in this sketch.
(left) Orientation of the church and the offshore islands suggests Gilfillan may have been sitting on Puketewhainoa dune for his sketch.

(right) The 1849 sketch by W. Swainson from the opposite viewpoint seems to confirm the location of the church in relation to high dunes in Gilfillan's sketch.

1849 W. Swainson, Te Papa

1849 W. Swainson. Possibly a kumara pit', Waikanae. ATL.

1840 *"Passing through the large village [Kenakena?], and crossing the high sand hill at the back, we came to the banks of the Waikanae River - here narrow and deep. We followed the stream for about 200 yards and then diverged across some fertile potato grounds on a sandy flat in the midst of which an oblong stockade surrounds the dozen houses of which the village [Arapawaiti] is composed."*

[E.J. Wakefield 1840, Adventure in New Zealand, as quoted in The Kapiti Coast, W.C. Carkeek.]

"I have been repeatedly assured by old Maoris that they had eaten the flesh of the moa in their youth and they seemed well aquainted with the habits of the birds."

On the Shifting of Sand-dunes, H.C.Field, Transactions and Proceedings of the RSNZ, Vol 24, 1891.

There is widely held scepticism over Field's claims, but it is likely that there were Muaupoko inhabitants in the vicinity prior to Ngati Toa (pre- 1824) who would have tasted moa.

Northern tribes raid in 1819-20, fighting with Muaupoko residents throughout Kapiti. Ngati Toa returns in 1822, with Ati Awa allies. Part of Ngati Toa settles at the mouth of the Waikanae River, but relocates to Kapiti Island.
[Hoani te Okoro evidence in Ngakaroro Hearing 1874, quoted in Carkeek]

Ngati Toa's successful suppression of resident iwi encourages further migration of Taranaki sub-tribes of Ati Awa, Ngati Tama and Ngati Raukawa. Towards the late 1820s Ati Awa are granted land at Waikanae.

Ati Awa reside in Kenakena Pa. Arapawaiti Pa is settled by a sub-tribe, Ngati Rukao. Waimea Pa is settled by Ngati Kura and Ngati Mutunga. After the Kuititanga battle of 1839 Waimea Pa is abandoned.

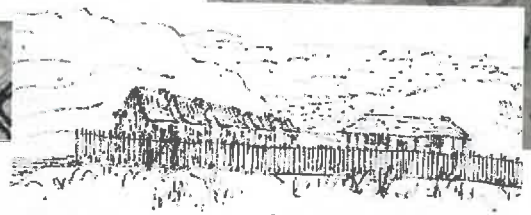
Records from 1840 indicate the sand flats are being cultivated by the Maori.
Bishop Hadfield builds a church and school at Kenakena.

1820 **1830** **1840**

Major Durie's Waikanae, W. Swainson. Te Papa 1916-0001-36

1847 Major Durie establishes police station "The spot I have chosen consists of between two and three acres of level land about one eight of a mile from the pa. It is bounded on the south by Mr Hadfield's line, on the north by the Waikanae River, on the west by the beach and the east by a ridge of sandhills." Some of the property was carried away by the river. Wi Parata recalled in 1881 that Durie's house was close to the 'Hadfield house'.
[The Kapiti Coast, W.C. Carkeek].

Note the grazing cow, the toetoe and blowout in the high dune behind. Barracks and a parade ground were added a few years later.



Part: Waikanae 1852. R.H. Wynyard. ATL A-081-028

1851 "At Waikanae . . . there was a constabulary station a short distance from the river's mouth, on the south side. A nice grassy flat served as a parade-ground, and the men lived in whares on both sides of it, while the commanding officer's house faced the upper end."
On the Shifting of Sand-dunes, H.C.Field. Transactions and Proceedings of the RSNZ, Vol 24, 1891.

1868 "The place seemed entirely changed.. . . The river by this time had entirely changed its course for a considerable distance inland; the new channel had cut right through the old parade-ground".
On the Shifting of Sand-dunes, H.C.Field. Transactions and Proceedings of the RSNZ, Vol 24, 1891.

1847 Police station is established near the river on the sand flats.

1848 earthquake damages buildings and opens cracks in the ground not far inland.

1848 Ex-whaler Thomas Wilson and his Maori wife Hanake open "Ferry Inn" beside the river.

From ~1846 - 1851 there is a major destabilisation of duneland through Kapiti. Coastal pa are relocated inland as encroaching sands bury settlements and rivermouths change course. Kenakena Pa, largely abandoned by Ati Awa returning to Taranaki in 1848, is disappearing. By 1854 Hadfield's church is in ruins.

1855 earthquake proves less damaging than the one in 1848.

1860 - 1898 dunes north of the river accrete 26 metres.
[J.Gibb, 1978. The problem of coastal erosion along the 'Golden Coast', MOW.]

Reported in the Evening Post: Ati Awa women able to source several varieties of flax at Waikanae: Oue, Raumoa, Huhiroa, Ngutunui, Atiraukawa, Rataroa, Ateweke and Taririki. [Evg Post 20-12-1879]

1850

1860

1870

1880s "Since 1880 the hotel, as such, has ceased to exist, and has been occupied as a residence by my eldest son . . . A sandhill 30ft to 40ft [9-12m] high, which formerly stood almost behind the hotel [(a)?], and which, from the immense amount of pipi shells which it contained, formed a very conspicuous landmark for entering the river, has been entirely blown away, and its contents are now scattered over nearly flat ground.

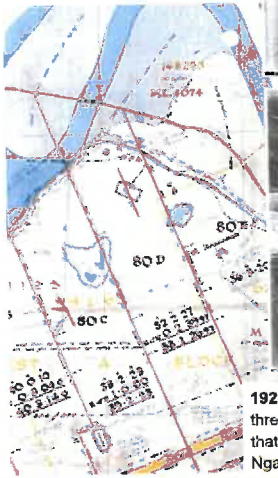
"An isolated hill nearly as high, which stood close to the beach on the south side of the river [(b)?] . . has also almost been blown away: and where the track passed there is now a damp sand-flat eight or ten chains wide [160-200m], arising from the other sandhills behind it being blown further inland. A very appreciable portion of this flat occupies the site of a shallow lagoon, [(c)?] the size of which has been proportionately reduced."

On the Shifting of Sand-dunes, H.C.Field. Transactions and Proceedings of the RSNZ, Vol 24, 1891.

H. Stevens Hislop 1907. ATL PA1-o-229-43-4 and -6.

1907 The orientation of the houses in the background (indicated on the Ngarara West A Block Sec 80 Plan, reorientated to suit) would suggest the southern side of the river was very shallow (possibly later becoming the "sandy formation covered with rushes" shown in yellow on the plan,and that the lagoon nearest the present rivercourse may be a relict of the 1907 rivercourse. The bottom photo appears to be in the same location but looking seawards.

Note the shoreline plants - they look like *Austrofestuca*. Note also the fencing which implies grazing continued until at least 1907. The high dunes behind the hotel may be similar in age to the ones lost in the 1880s.



Te Papa A.005793

Te Papa A.005832

1921 Photographer Leslie Adkin visited the estuary with three friends, and dined in one of the fishermen's huts that perched along the edges of the estuary (shown on the Ngarara Plan).

Dunes are destabilised during the 1880s

The 1887 Ngarara West settlement awards titles to Maori owners for land previously held communally. A re-hearing in 1891 finalises the titles: Ngarara West A Block 80 encompasses the Estuary.

During this decade the river is probably following its most southerly course past Arapawaiti in 100 years.

In 1902 lupin is introduced to the Kapiti Coast. Photos taken in 1908 show marram plantings within very high dunes in Waikanae, presumably to counter the blowouts and drifts occurring.

1898 - 1923 dunes north of the river erode back 40 metres.

[J.Gibb, 1978. The problem of coastal erosion along the 'Golden Coast'. MOW.]

The shallow waters of the 1907 photos appear to now be exposed bare sand banks. The river is shifting back to the north.

In 1928 a large flood cuts off the oxbow at Arapawaiti. [C.& J. Maclean. Waikanae: Past & Present]

1880

1900

1920

July, 1932. Leslie Adkin. ATL PA1-f-009-44-274

1932 (above) This view, taken from the high dune now developed with Weggery Drive housing, shows that this dune had been stabilised with shrubland (which appears to be either tauhinu or coastal shrub daisy) but that grazing may have subsequently destabilised the sand. In contrast, the foredunes appear well vegetated. Waimea Stream flows into the river, which is closer to the high dune than at present. The shallow flats on the southern side, which were developing in 1920s, are becoming vegetated.

July, 1932. Leslie Adkin. ATL PA1-f-009-44-274

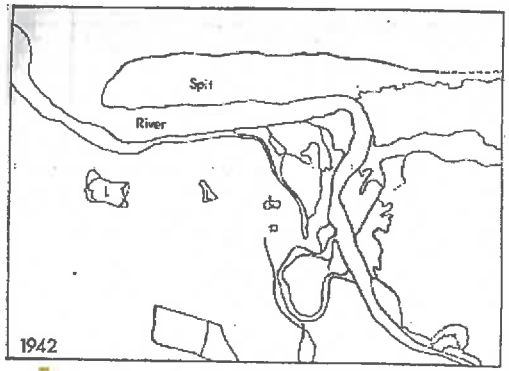
1932 (right) Taken form the same high dune on the northern banks, this photo shows the river taking its most northerly course past Arapawaiti, giving us a maximum possible age of the now exposed low-lying land below the dune of 78 years.

July, 1932. Leslie Adkin. ATL PA1-f-009-44-274

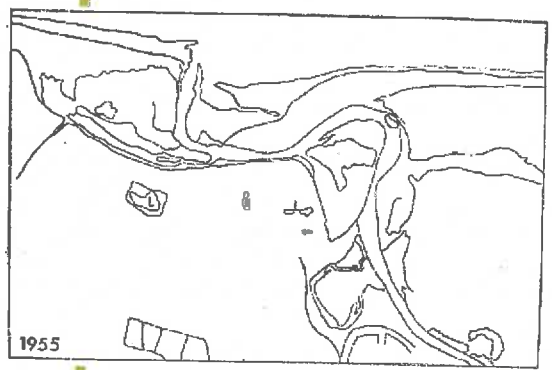
1932 (right) The old Hotel (Field homestead) is visible in this view of the Arapawaiti area. In the twenty five years since the Hislop photos were taken, wet and bare sand areas have become dense shrubland.

Te Papa

1949 Stewart Maclennan's watercolour tells us the northern foredunes were well vegetated, but possibly being eroded by the river, which itself was able to take a convuluted course seawards. Marram was well established on the southern dunes, but there appears to be a broad swathe of unvegetated dry sand in front of the artist where today there are stable foredunes.



Kennedy and Weeber, 1975



Kennedy and Weeber, 1975

During the 1930s the river takes a northerly course through to the Estuary.

1923 - 1968 dunes north of the river accrete 71 metres.
[J.Gibb, 1978. The problem of coastal erosion along the 'Golden Coast', MOW.]

The south marsh begins forming after 1942 and in 1950-52 the river breaks through the north spit leaving the old river course exposed and south marsh isolated.
[Kennedy & Weeber, 1975]

Eastern end of the oxbow closes off between 1952-5 although brackish water still enters the western end.
[Kennedy & Weeber, 1975]

1930

1940

1950

Section of Whites Aviation aerial August 1958, ATL WA-47310-F

1958

(a) Sandflats created since the river eroded the old Parade Ground in the 1860s (and sparsely vegetated with grasses/sedges in the 1920s) now appear to be dense rushland
(b) The watercourse shown in 1907 photos is now cut off, forming a lakelet
(c) Open water sits on sand flats
(d) The shallow Puketewhaino lakelet appears full of raupo
(e) Approx. location of Manly Street
(f) Wetland areas (relicts of old rivercourse in 1820s and 1940s) remain, but have been blocked by sand build-up against the Kenakena drain. Visible as rushland in 1958. A large portion of this duneland has subsequently eroded away.
(g) The dry dune flats (also illustrated in the 1949 painting) are not yet vegetated, indicating a maximum possible age for present vegetated dunes of fifty years. The current path is probably where the macrocarpas once stood.
(h) Land accreted since the 1930s appears to be rushland (giving us a maximum possible age for the present wetland woody vegetation of 52 years)
(i) Northern foredunes appear marram-dominated with heavy recreational use
(j) Land inland of the Waimea Stream is being grazed. The stream now appears confined within what appeared in the 1930s to be a broader wetland.

Kapiti Observer Coll. Hp251, KCDC Library

1970 The area of saltmarsh at the mouth of the Waimeha Stream is destroyed.

1968-71 The swampy Waimeha streambed is excavated. The peat and sand is used to create groynes both sides of the river. Maori burials are exposed, plus the pakeha graves of Major Durie's daughter and whaler William Browne

Whitebaiters claim drops in harvest in subsequent years once the lagoon entrance is restricted.

1970 The foredunes, although more eroded and steepened than in 1958 photos, have shrubby vegetation developing within the hollows.

Kapiti Observer Coll. Hp277, KCDC Library

Note the oxbow is well watered, and turned into a small boat harbour.

Artificial groyne to direct river to the sea

During the 1950s the river returns to a more southerly course through to the Estuary allowing sand flats each side to develop into rushland. Fishing huts proliferate along the edge of stable dunes - cherry, plum and apple trees are naturalised or planted.

Settlement of Waikanae Beach escalates between 1966-1978. The greatest increase in population occurs during the 1986-1996 decade. [NZ Statistics]

Approx. 1966 a mole is built extending from north marsh across the sand flats to straighten the course of the river (rebuilt with rubble in 1970s).

In 1968 the Waikanae Land Co. purchases 48.5ha for subdivision, lagoons and a marina on the northern side. By 1971 the lagoon is dredged and 5.6ha of lagoon and fringing land is put aside as public reserve. The Company goes into liquidation during 1979 although subdivision continues.

1960

1970

Kotuku development along estuary boundary 1995/6. Note the extensive, vegetated southern sand bar which was lost during erosion occurring after 1995. [Lumsden, 1998 Report]. The Manly St lagoons are open to the sea.

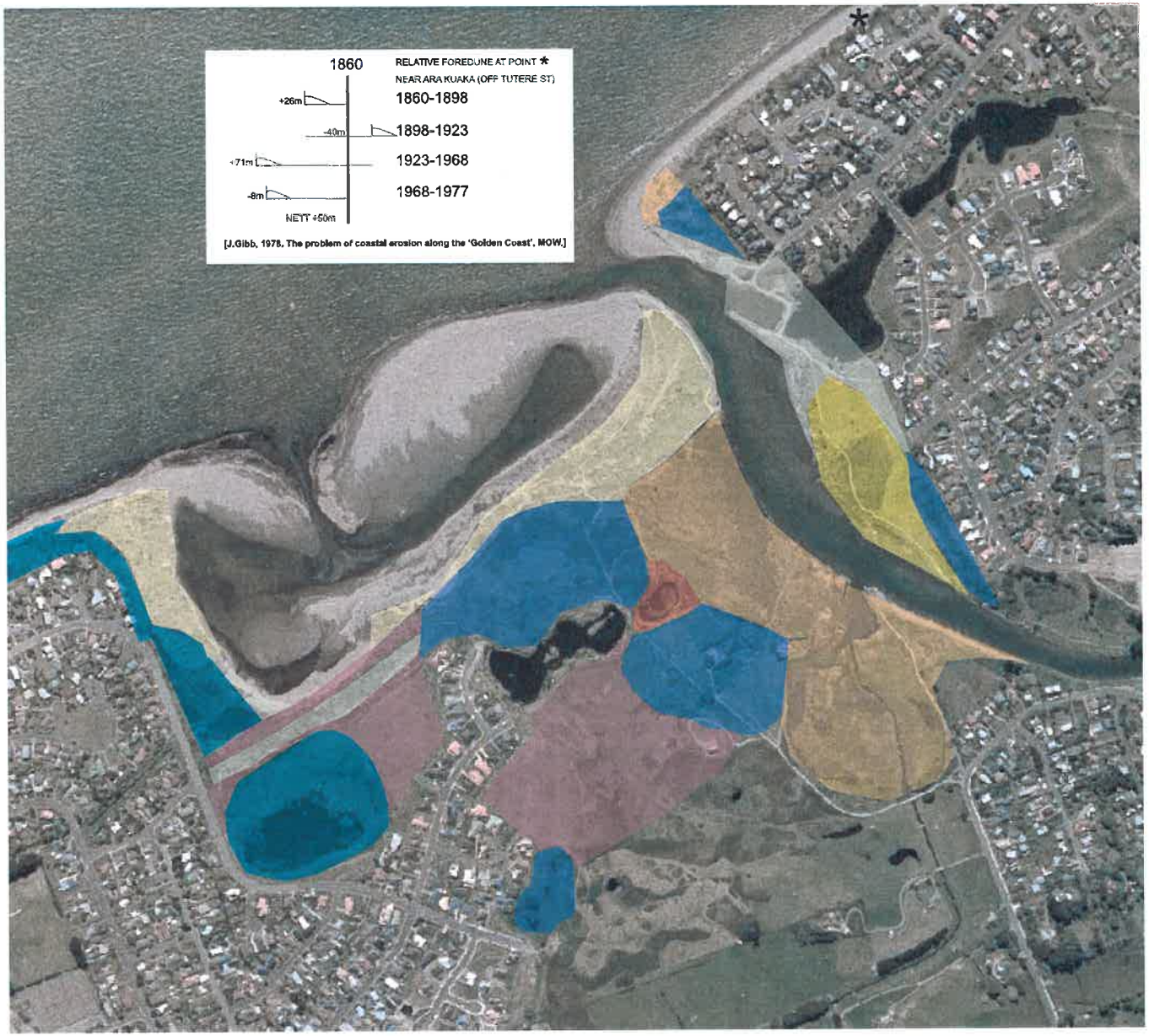
The rushland -saltmarsh that was filling in during the 1950s is now dense rushland-shrubland fringed with harakeke and coastal shrub daisy. Exotic trees planted alongside huts have been removed or killed .The mobile sand drifts west of the wetland have barely stabilised as dunes behind sand flats, with a light cover of marram, knobby clubrush and pampas (recently killed).

Kotuku Parks Ltd, formed in 1972, acquires a substantial block of land in 1973 on the southern side. Initially a sewage treatment plant is mooted but objections prevent this proposal developing. In 1975 Kennedy and Weeber survey and report on the biota of the estuary. The Dept of Lands & Survey acquires 28.29ha of Kotuku Park land in 1978, creating Waikanae Estuary Scenic Reserve.

In 1985 Kotuku enters into a joint venture with adjacent landowners that involves 40ha of land adjoining the Waikanae Estuary. In 1989 a subdivision concept plan is approved by the Kapiti Borough Council. The Scenic Reserve is upgraded in status to Scientific Reserve in 1987.

The Kotuku concept plan is the governing document for 18 years of specific applications and developments. In 1999 a further 2.29ha is obtained by DOC for the Waikanae Estuary Scientific Reserve.

1970 **1980** **1990** **2000**



Surface more than 180 years old (pre-1830s)

Surface less than 160 years old (1850s)

Surface less than 130 years old (1880s)

Surface less than 110 years old (1900s)

Surface less than 90 years old (1920s)

Surface less than 80 years old (1930s)

Surface less than 60 years old (1950s)

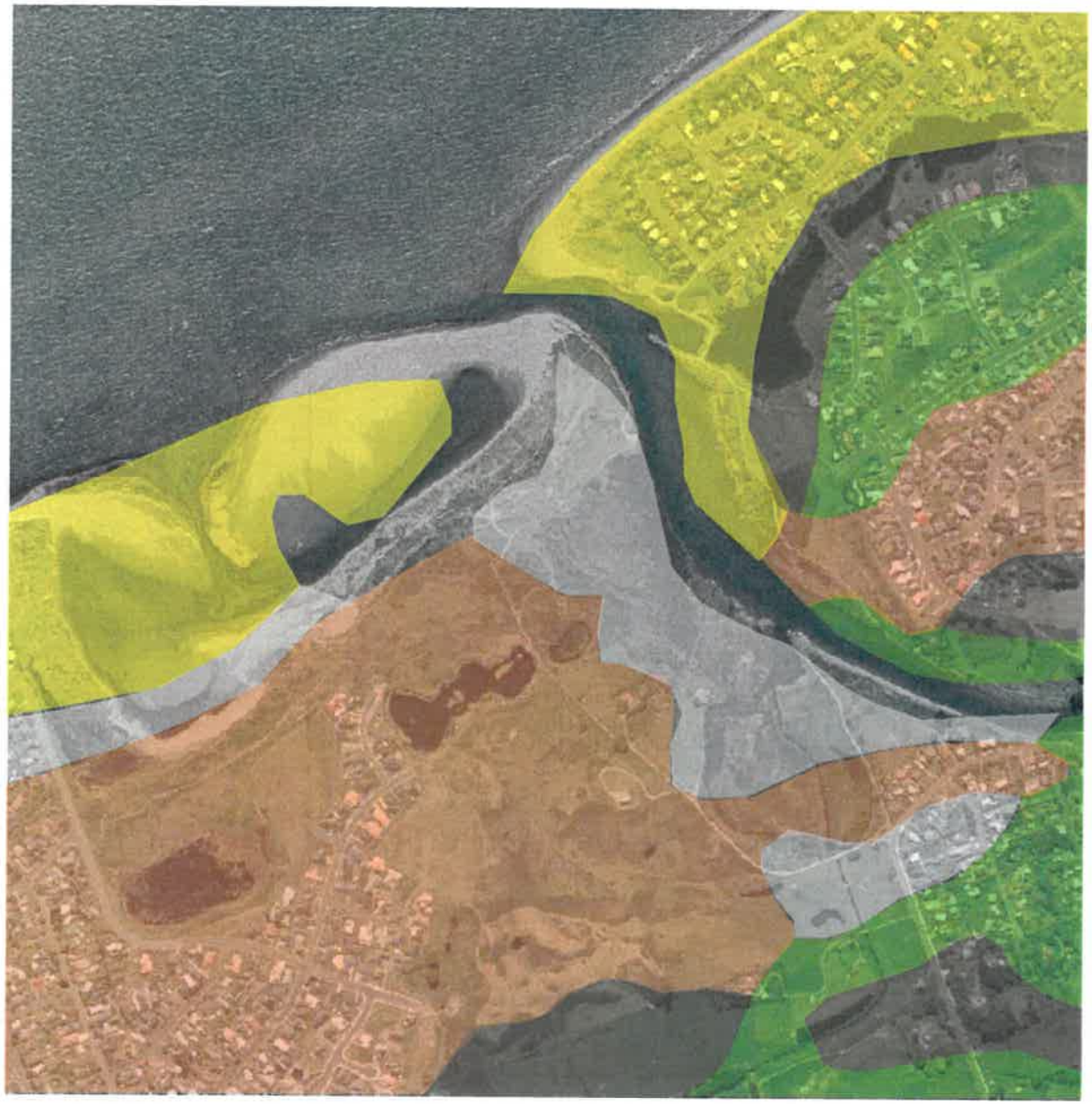
Surface less than 40 years old (1970s)

This plan attempts to provide a snapshot in time of present surfaces, even though some areas represent the return of land following erosion of a previous landform, or perhaps are a 'work in progress' as dune formation is currently active.

Areas are approximate, and are generated from an assessment of photographs, survey plans, paintings and the written history of the area.

SURFACE AGES

Fig. 2



Waitarere-Motuiti (not separately distinguished)
Forming from 900 years ago (Motuiti) and again during Maori then European occupation (Waitarere)

Taupo
Forming 1800 years ago
(Taupo eruption 230AD)

Foxton
Forming from 6500 years ago
(end of glacial period)

Peat

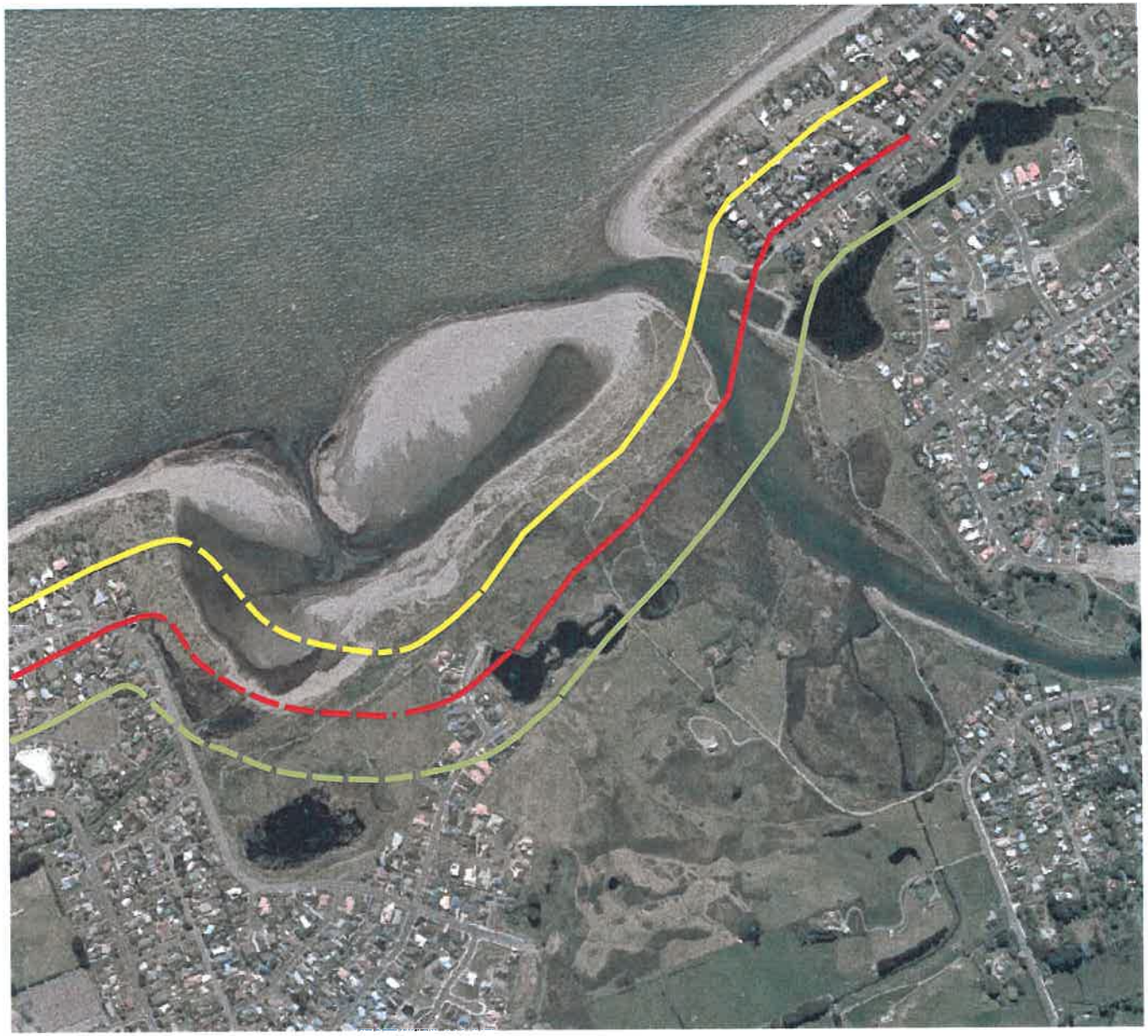
Unidentified / recent

Overlay is not accurate at this scale.

Source: McFadgen,B.G. Archaeology of the Wellington Conservancy: Kapiti-Horowhenua. Dept of Conservation, 1997.

DUNES - building phases

Fig. 3



100m

200m

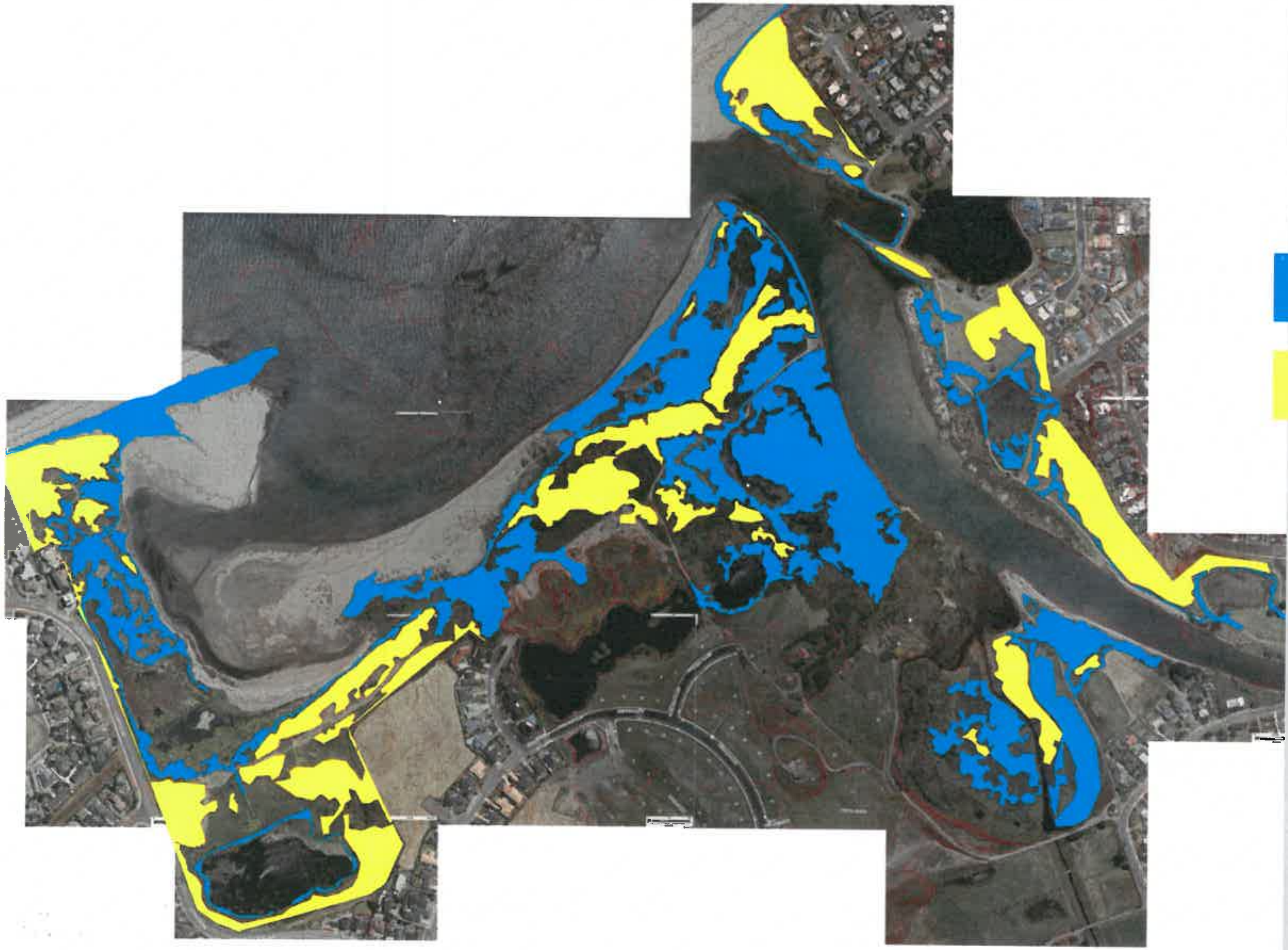
300m

Distance from effects of prevailing salt wind blowing off the sea (at high tide).

Dashed lines suggests area of greater variability due to changing sand bars.

Distance MHWS

Fig. 4



3-4m asl

>5m asl

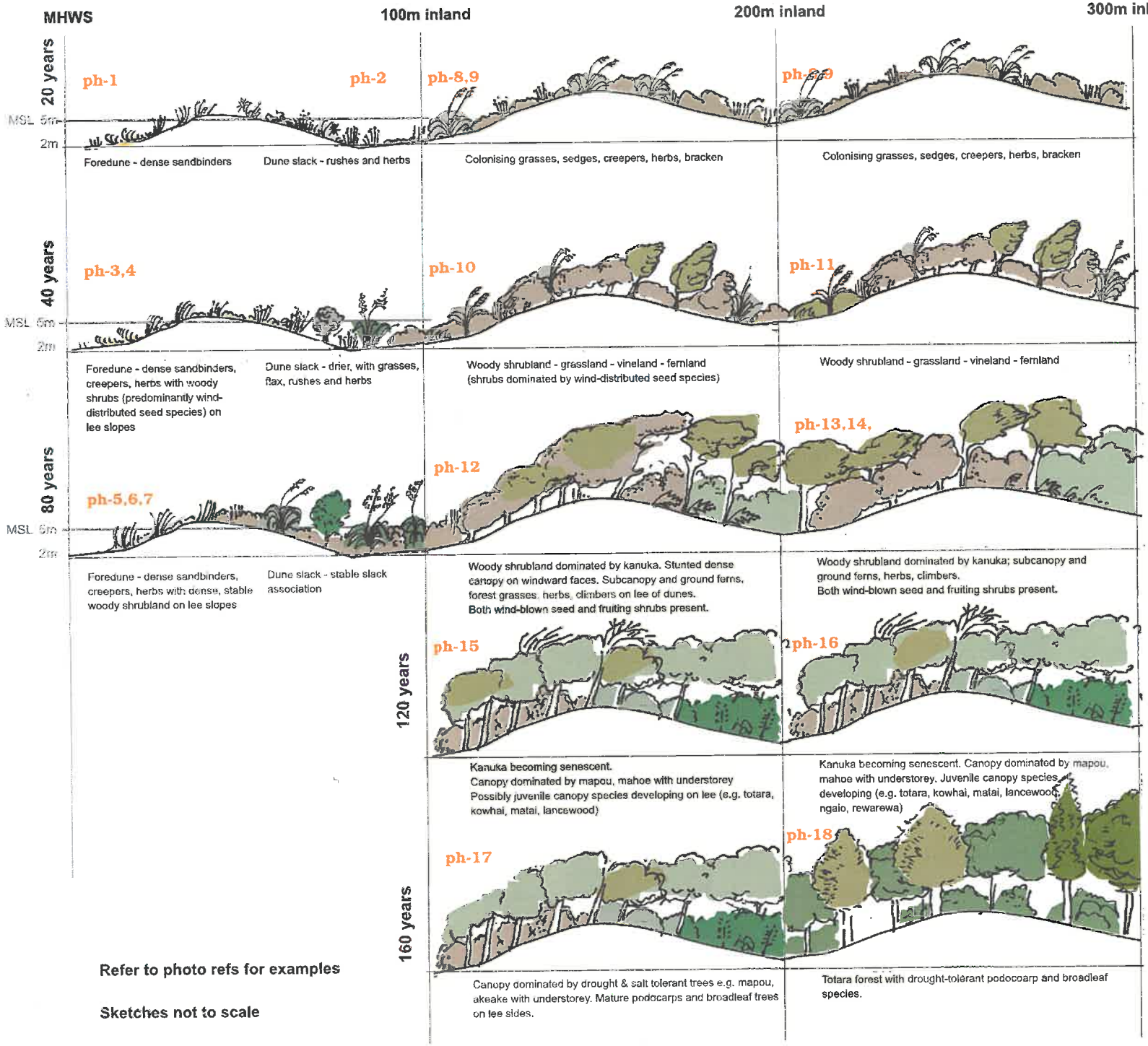
Over time, without constraints such as saltburn, dunes >5m asl might be expected to support trees; tall shrubland such as kanuka between 4-5m asl; low shrubland-grassland between 3-4m asl.

Species will be determined by drainage, ground water salinity and proximity to wind-borne salts.

ELEVATION

Fig. 5

SPATIAL SUCCESSION - Dry Dunes



Refer to photo refs for examples

Sketches not to scale

Fig. 6

to twenty years

ph-1

Likely species

Foredune:
sand sedge *Carex pumila*
pingao *Ficinia spiralis*
spinifex *Spinifex sericeus*
sand tussock *Poa billardierei*

Lee dune:
spinifex *Spinifex sericeus*
sand tussock *Poa billardierei*
shore groundsel *Senecio lautus*
sand daphne *Pimelea arenaria*

Dune slack:
knobby clubrush *Ficinia nodosus*
sand sedge *Carex pumila*
mudwort *Limosella lineata*
ice plant *Disphyma australe*
sand iris *Libertia peregrinans*

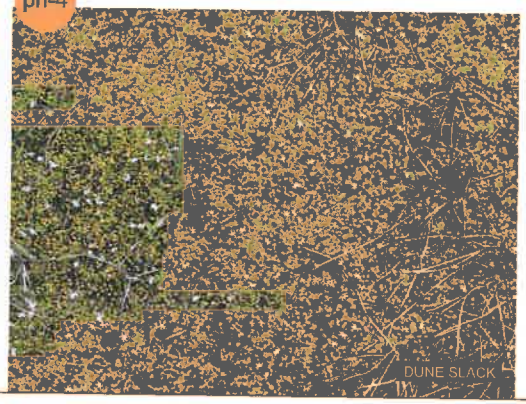
Less than 100m from MHWS

to forty years

ph-2

ph-3

ph-4



Likely species

Foredune:
as above plus . . .
knobby clubrush *Ficinia nodosus*
sand bindweed *Calystegia soldanella*
shore groundsel *Senecio lautus*
sand daphne *Pimelea arenaria*
NZ spinach *Tetragonia implexicoma*

Lee dune:
tauhinu *Ozothamnus leptophyllus*
coastal shrub daisy *Olearia solandri*
sand coprosma *Coprosma acerosa*
small-leaved pohuehue *Muehlenbeckia complexa*

Dune slack:
Selliera rotundifolia
knobby clubrush *Ficinia nodosus*
sand sedge *Carex pumila*
mudwort *Limosella lineata*
ice plant *Disphyma australe*

to eighty years

ph-5

ph-6

ph-7

Likely species

Foredune:
as above

Lee dune:
as above plus . . .
coastal bidibid *Acaena pallida*
bidibid *Acaena anserinifolia*
Coprosma propinqua
corokia *Corokia cotoneaster*
occ. taupata *Coprosma repens*

Dune slack:
as above plus . . .
toetoe *Cortaderia toetoe*
occ. harakeke *Phormium tenax*

to twenty years

Likely species
bracken *Pteridium esculentum*
knobby clubrush *Ficinia nodosus*
pohuehue *Muehlenbeckia australis*
sand bindweed *Calystegia soldanella*
sand coprosma *Coprosma acerosa*
sand daphne *Pimelea arenaria*
sand tussock *Poa billardierei*
shore groundsel *Senecio lautus*
small-leaved pohuehue *Muehlenbeckia complexa*
spinifex *Spinifex sericeus*

to forty years

Likely species
bracken *Pteridium esculentum*
coastal shrub daisy *Olearia solandri*
kanuka *Kunzia ericoides*
knobby clubrush *Ficinia nodosus*
pohuehue *Muehlenbeckia australis*
sand bindweed *Calystegia soldanella*
sand coprosma *Coprosma acerosa*
small-leaved pohuehue *Muehlenbeckia complexa*
tauhinu *Ozmothamnus leptophyllus*
toetoe *Cortaderia toetoe, C. fulvida*

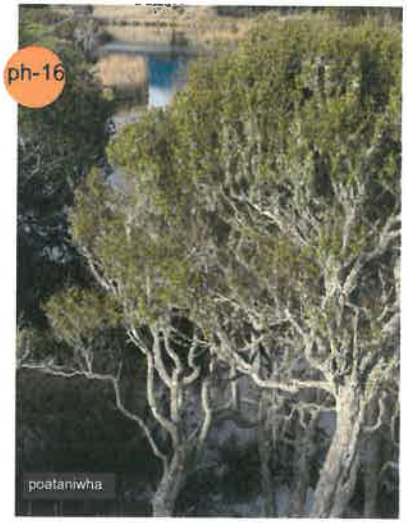
occ. taupata *Coprosma repens*
occ. harakeke *Phormium tenax*

to eighty years

Likely species
akeake *Dodonaea viscosa*
bracken *Pteridium esculentum*
broom *Carmichaelia australis*
Carex testacea
coprosmas: C. crassifolia, C. propinqua, C.robusta, C. propinqua x robusta, C. rhamnoides, C.repens
corokia *Corokia cotoneaster*
hounds tongue *Microsorum pustulatum*
kanuka *Kunzia ericoides*
kowhai *Sophora microphylla*
knobby clubrush *Ficinia nodosus*
mahoe *Melicytus ramiflorus*
mapou *Myrsine australis*
Microlaena stipoides
mingimingi *Leucopogon fasciculatus*
native jasmine *Parsonsia heterophylla*
NZ spinach *Tetragonia implexicoma*
poataniwha *Melicope simplex*
pohuehue *Muehlenbeckia australis*
spleenworts *Asplenium oblongifolium, A. falcatum, A. hookerianum*
weeping matipo *Myrsine divaricata*

Between 200-300m from MHWS

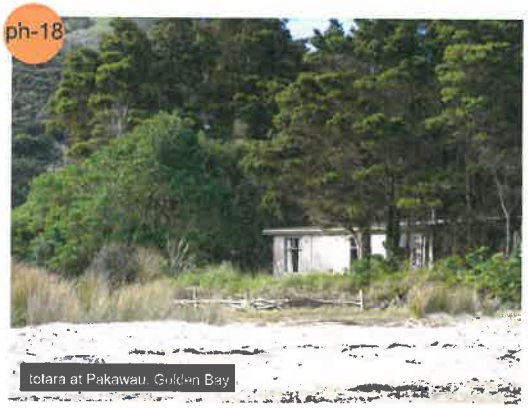
to 120 years



Likely species
as previous (although losing kanuka, and corokia being shaded out) plus . .

thin-leaved coprosma *Coprosma areolata*
kawakawa *Macropiper excelsum*
lancewood (juv) *Pseudopanax crassifolius*
matai (juv) *Prumnopitys taxifolia*
ngaio *Myoporum laetum*
NZ passionvine *Tetrapathea tetrandra*
totara (juv) *Podocarpus totara*

to 160-180 years

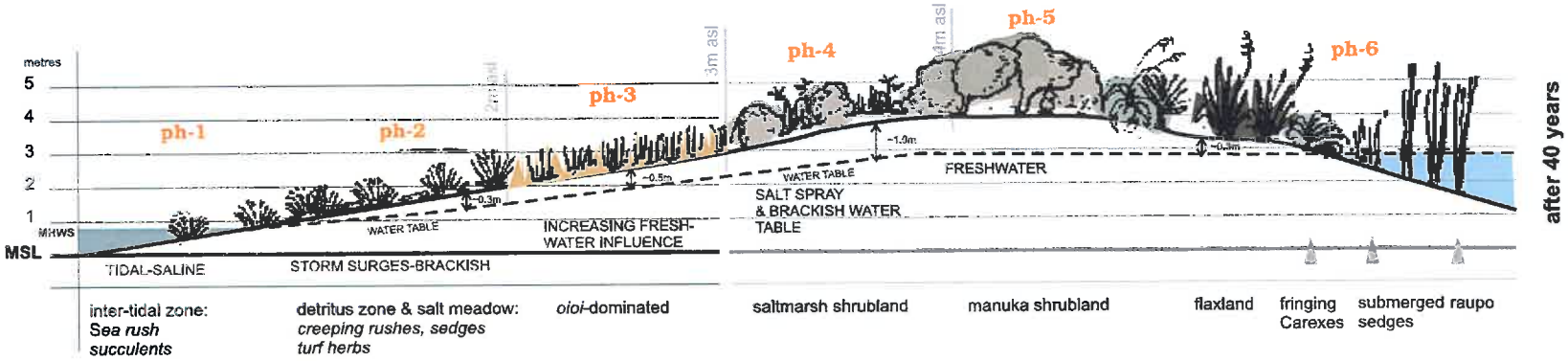


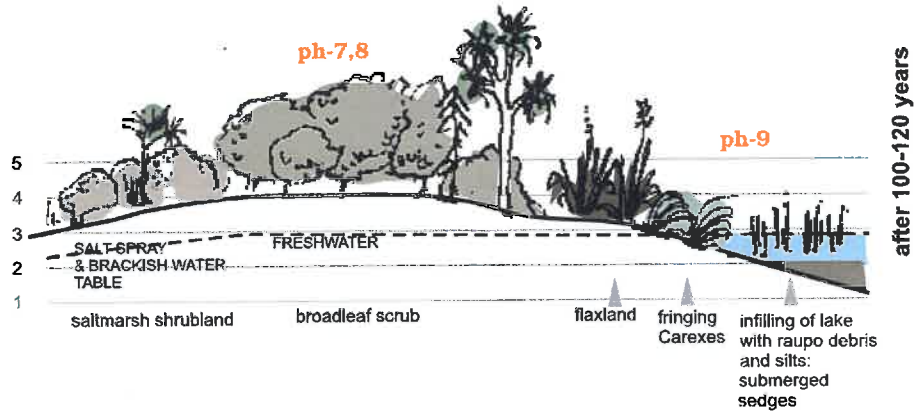
Likely species
as previous plus . .

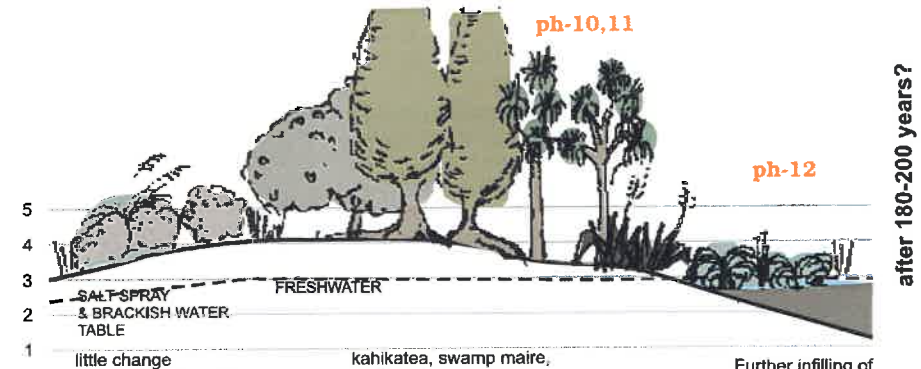
Asplenium spp
Blechnum spp.
turutu *Dianella nigra*
hinau *Elaeocarpus dentatus*
hangehange *Geniostoma ligustrifolium*
leather-leaf fern *Pyrrosia eleagnifolia*
round-leaved fern *Pellaea rotundifolia*
rewarewa *Knightia excelsa*
rohutu *Lophomyrtus obcordata*

Between 200-300m from MHWS

SPATIAL SUCCESSION - wetlands







Drawings not to scale

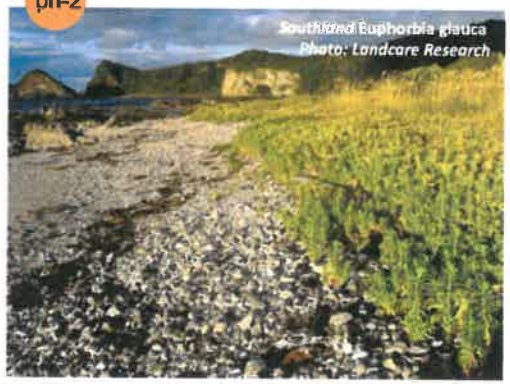
Fig. 7

To 20 years

ph-1

Likely species
glasswort *Sarcocornia quinquefolia*
sea rush *Juncus krausii* var *australiensis*

ph-2



Likely species
sea rush *Juncus krausii* var *australiensis*
Euphorbia glauca
Isolepis cernua
Carex pumila
batchelor's button *Cotula coronopifolia*
Leptinella dioica
Samolus repens
Lilaeopsis novae-zelandiae
Triglochin striata

ph-3

Likely species
oioi *Apodasmia similis*
occ. *Carex litorosa*
occ. saltmarsh ribbonwood *Plagianthus divaricatus*

ph-4

Likely species
coastal shrub daisy *Olearia solandri*
giant umbrella sedge *Cyperus ustulatus*
saltmarsh ribbonwood *Plagianthus divaricatus*

SALINE INFLUENCE

FRESHWATER INFLUENCE

ph-5

Likely species
broom *Carmichaelia australis*
coastal shrub daisy *Olearia solandri*
Coprosma propinqua
manuka *Leptospermum scoparium*
swamp coprosma *Coprosma tenuicaulis*
occ, harakeke *Phormium tenax*
occ. toetoe *Cortaderia toetoe*

Likely species
Carex maorica
purei *Carex secta*
Carex virgata
giant umbrella sedge *Cyperus ustulatus*
swamp kioklo *Blechnum novae-zealandiae*

ph-6

To 60 - 100 years

ph-7

Likely species
broom *Carmichaelia australis*
coastal shrub daisy *Olearia solandri*
Coprosma propinqua
Coprosma tenuicaulis
Coprosma crassifolia
mahoe *Melicytus ramiflorus*
manuka *Leptospermum scoparium*
swamp tangle fern *Gleichenia dicarpa*
occ, harakeke *Phormium tenax*
occ. toetoe *Cortaderia toetoe*

ph-8

Likely species
broom *Carmichaelia australis*
Coprosma propinqua x robusta
five finger *Pseudopanax australis*
karamu *Coprosma robusta*
mahoe *Melicytus ramiflorus*
manuka *Leptospermum scoparium*
occ, cabbage tree *Cordyline australis*

ph-9

Likely species
Blechnum minus
Carex maorica
Carex secta
Carex virgata
Cyperus umbellata
Hypolepis distans
Paesia scaberula

To 120-150+ years

ph-10

ph-11

Likely species

cabbage tree *(fringing)*

kahikatea *Dacrycarpus dacridioides*
pukatea *Laurelia novae-zealandiae*
swamp maire *Syzygium maire*
mamaku *Cyathea medullaris*
Astelia grandis

Likely species

purei *Carex secta*
swamp fern *Blechnum minus*
Hypolepis distans

ph-12

Part 3 - Site works

What to plant, where?

The information on growth constraints illustrated by Figs 2 to 7 in Part 2 is synthesized into a restoration map in Fig 8 (A, B, and C). In essence Fig. 8 identifies plant associations likely to succeed in the given conditions, and a sense of how far succession would have naturally proceeded in different parts of the estuary.

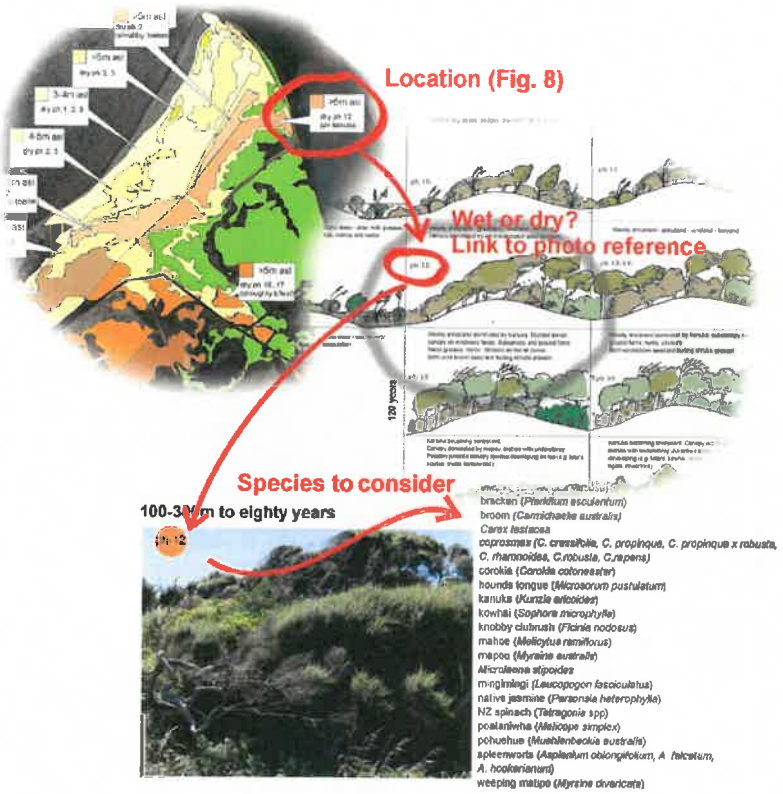
Given that the RPS to date provide a range of species for 'natural' dissemination, it is time to provide appropriate colonising vegetation throughout, however this is such a enormous task that there needs to be prioritising. Fig. 9 (A, B and C) identify priority areas, and the following 'Priority sites' section itemises work required.

In addition to providing 'nursery' vegetation, the principles applied are:

- Weed control (rather than planting) within high value natural habitats but with infill planting to cover bared ground if required. This applies to Puketewhainoa lakelet, the un-named Weggery Drive lagoon, the inner estuary salt meadows and detrital zones, and the coastal sand bar
- Thinning as required to reduce density of sand binding species adjacent to the salt meadows, so that encroachment is slowed
- Specific bird habitat screening vegetation adjacent to Puketewhainoa lakelet, Waikanae river (north bank), and the small un-named Weggery Drive lagoon, but not so high that it prevents birds circling and landing
- Enrichment planting of nodes with a wider range of species, especially as shade cover increases
- Upwind roll-back of exotic weeds and replacement with native colonising species suited to microenvironments as indicated in planting plan
- Track-side plantings
- Restriction of tall tree species to areas >300m from MHWS and >5m above sea level, and on dune lees only

Using the guides

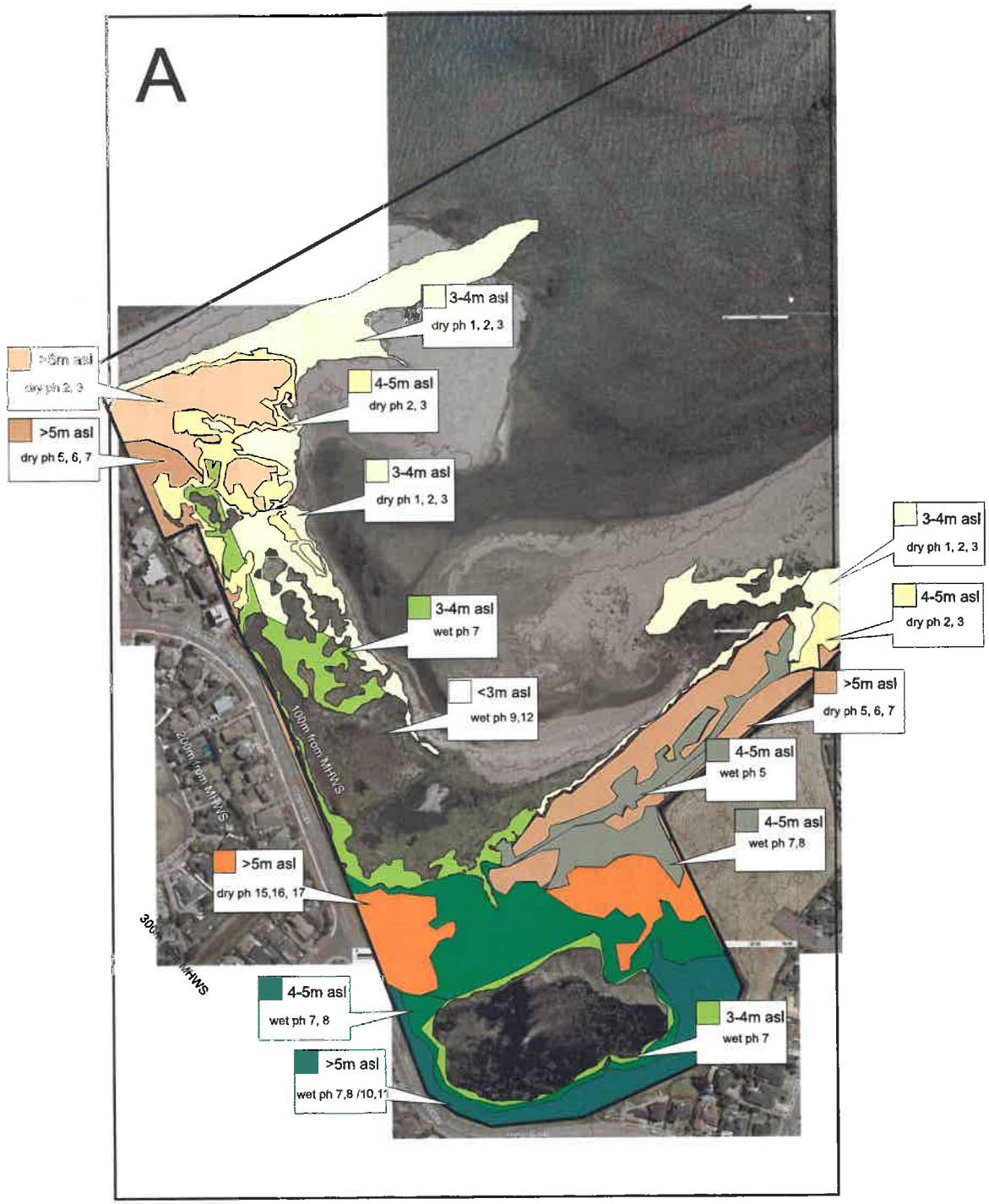
While Figures 1 to 5 provide a background understanding of site conditions, this information is synthesized in Figs 6 and 7 to create a map (Fig. 8) of the types of vegetation associations we can expect to achieve.



Find the area of interest on Fig 8. It will be described by its elevation and dry/wet character. There is a photo reference which you will find in Fig 6 or 7 and when you look at the actual photo you'll find a suggested species list.

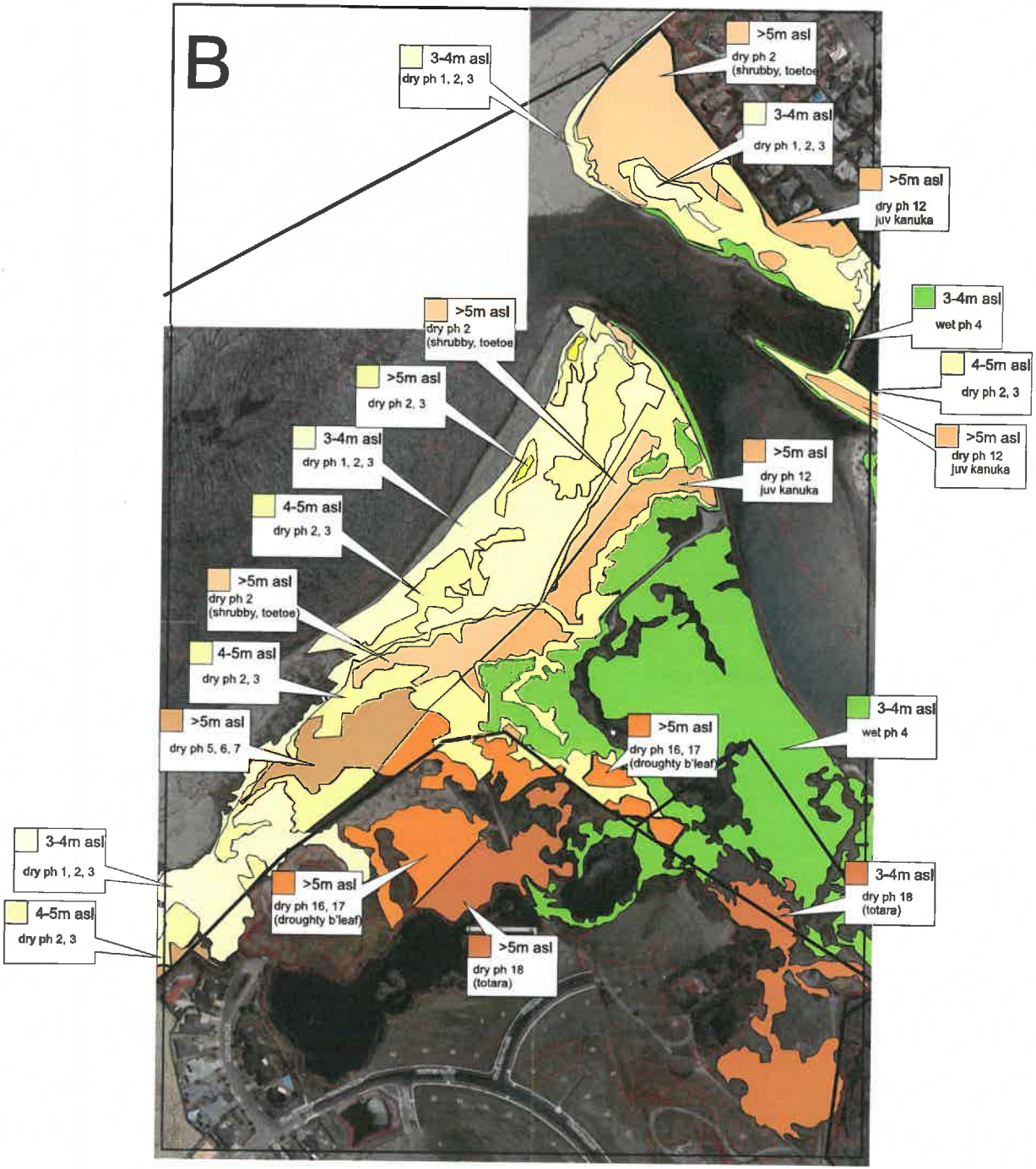
Fig 9 (split into areas A, B, and C) prioritises areas to tackle first and suggests approaches to take and species to use. These are not intended to be too prescriptive, and final plant choices or substitutions can be made from the lists found in Figs 6 and 7.

Fig. 10 offers examples of typical planting guidelines and advice on staging to achieve the desired outcomes. For example, undergrowth ferns and shrubs may need to be planted 3 to 5 years after their sheltering companions are planted.



VEGETATION OBJECTIVES - A

Fig. 8



VEGETATION OBJECTIVES - B

Fig. 8

VEGETATION OBJECTIVES - C

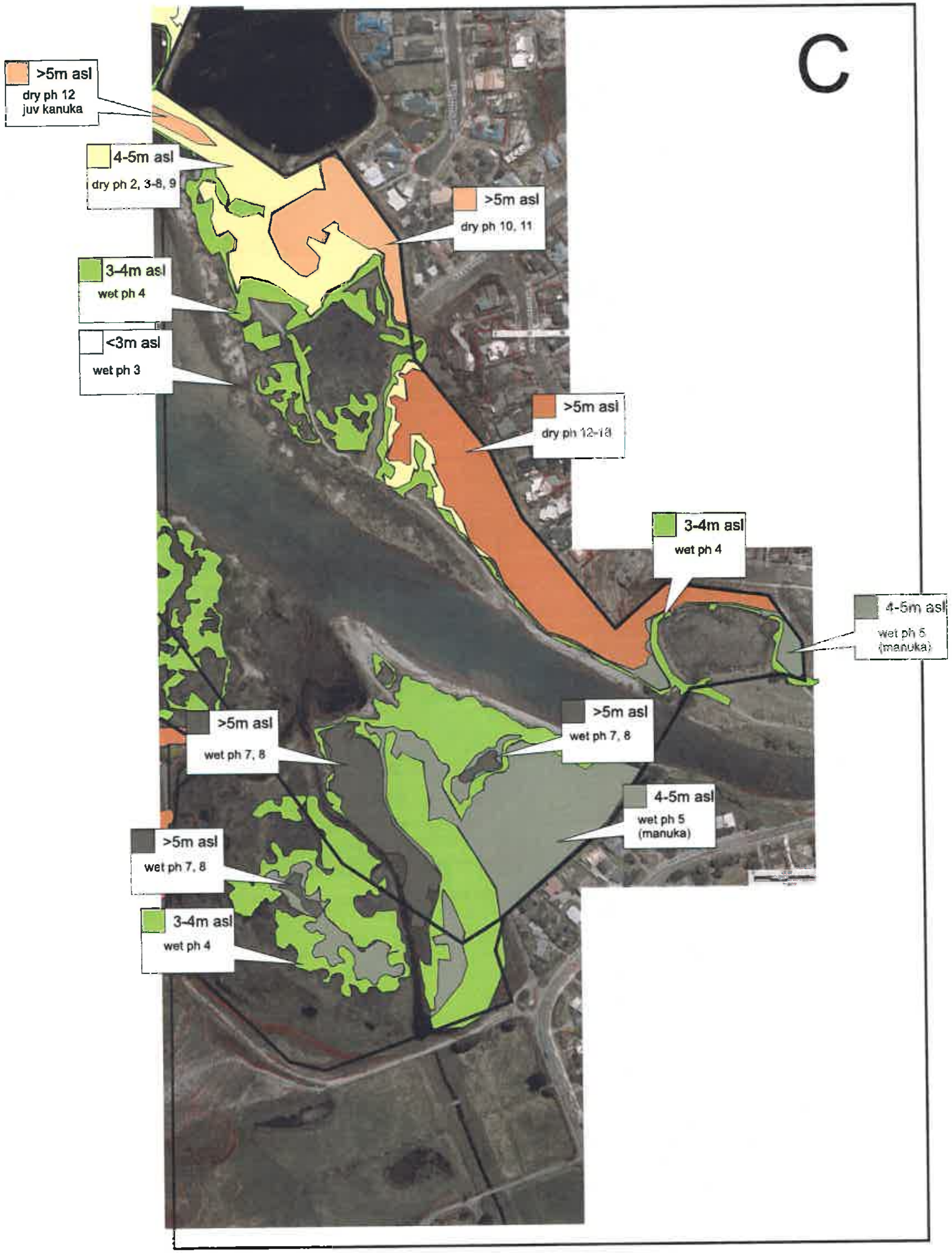
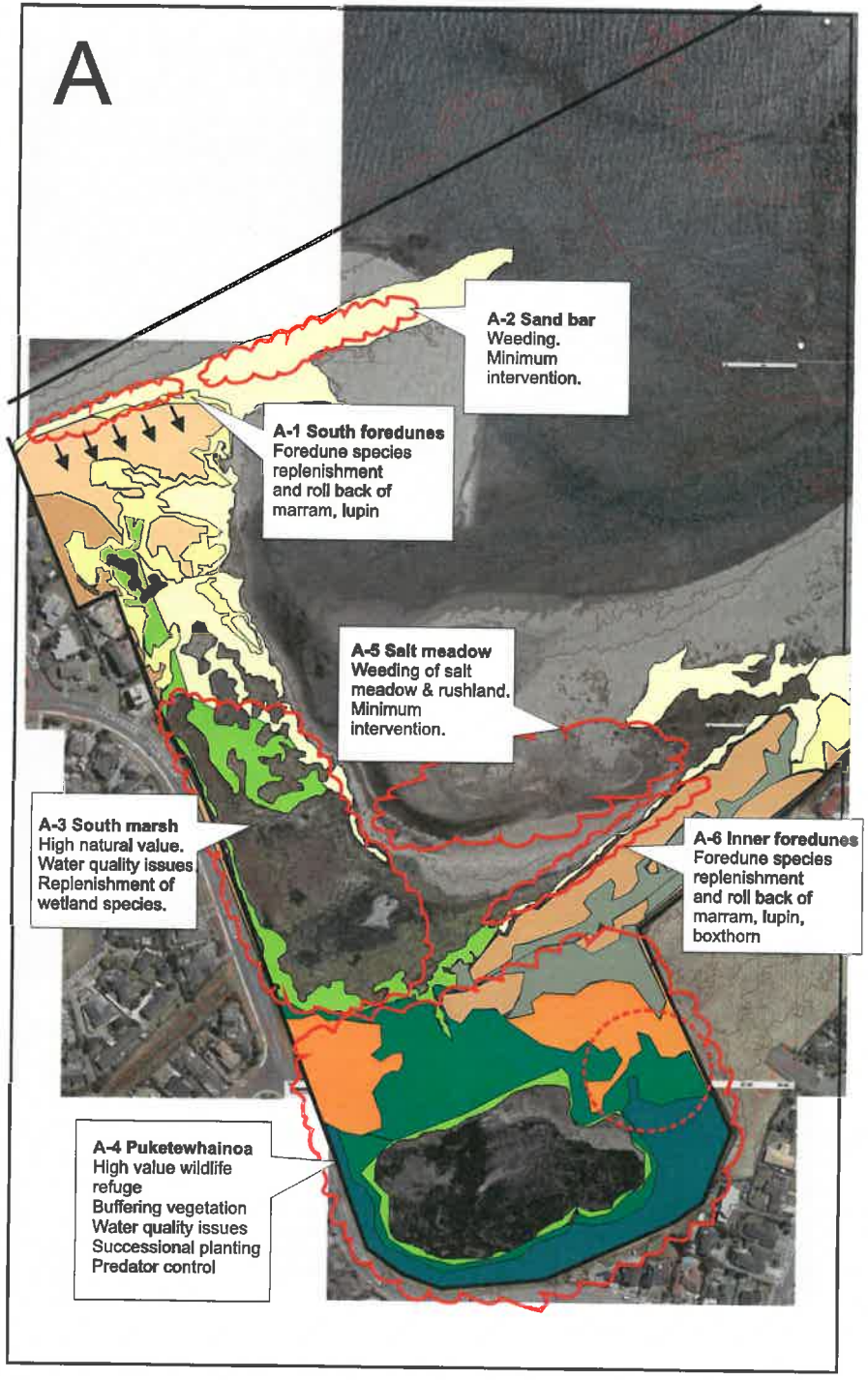
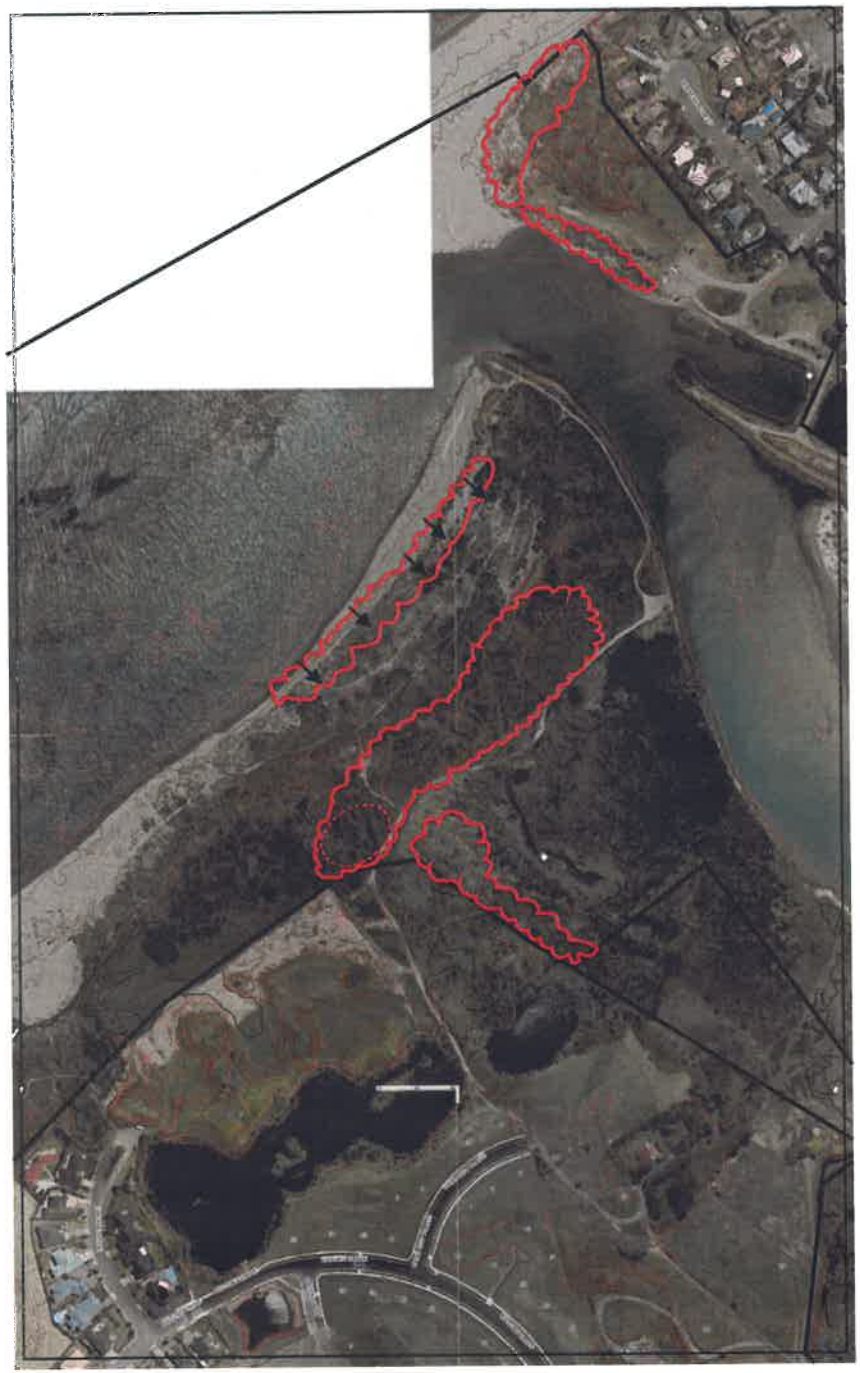


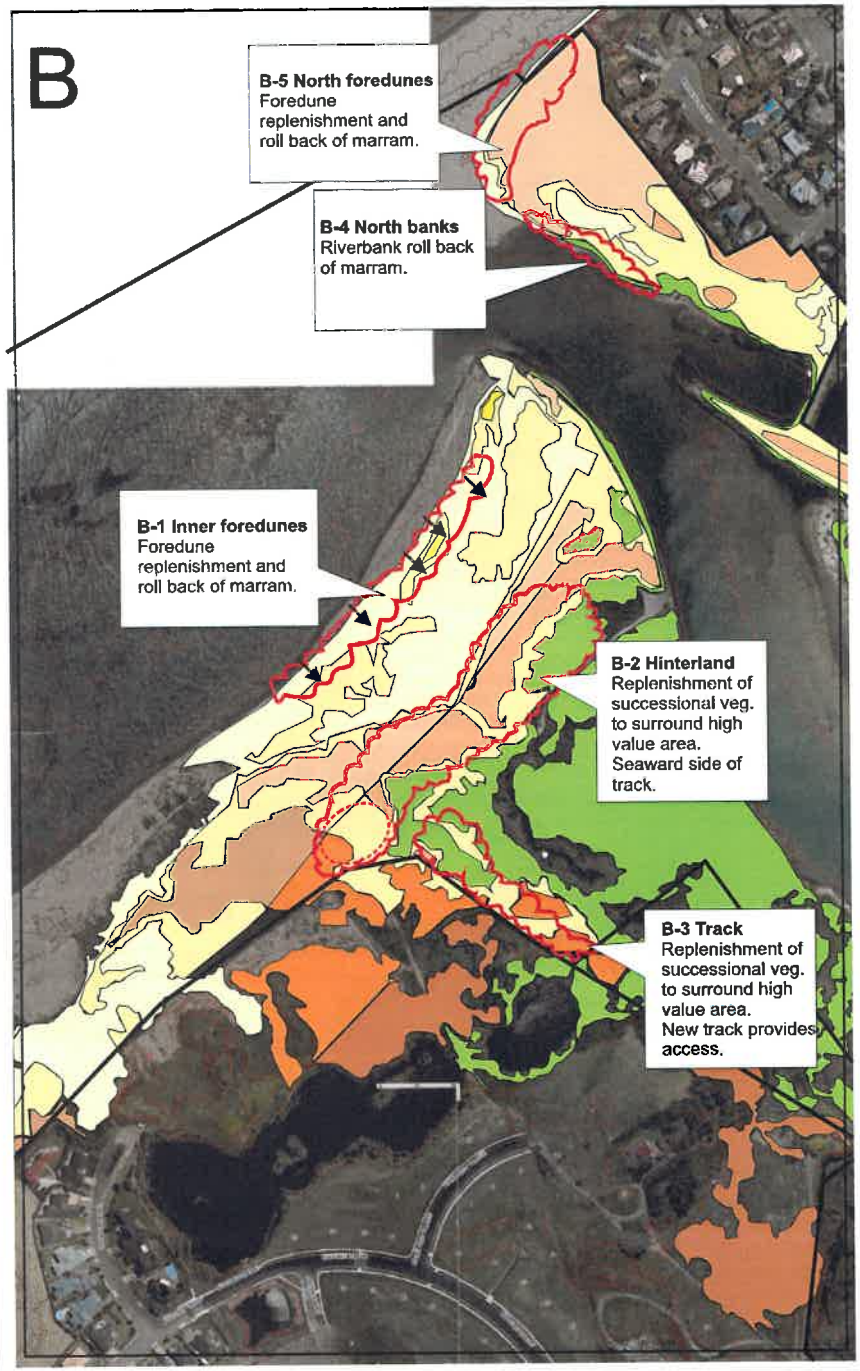
Fig. 8


A
A-2 Sand bar
Weeding.
Minimum
intervention.
A-1 South foredunes
Foredune species
replenishment
and roll back of
marram, lupin
A-5 Salt meadow
Weeding of salt
meadow & rushland.
Minimum
intervention.
A-3 South marsh
High natural value.
Water quality issues
Replenishment of
wetland species.
A-6 Inner foredunes
Foredune species
replenishment
and roll back of
marram, lupin,
boxthorn
A-4 Puketewhainoa
High value wildlife
refuge
Buffering vegetation
Water quality issues
Successional planting
Predator control

SITES - A

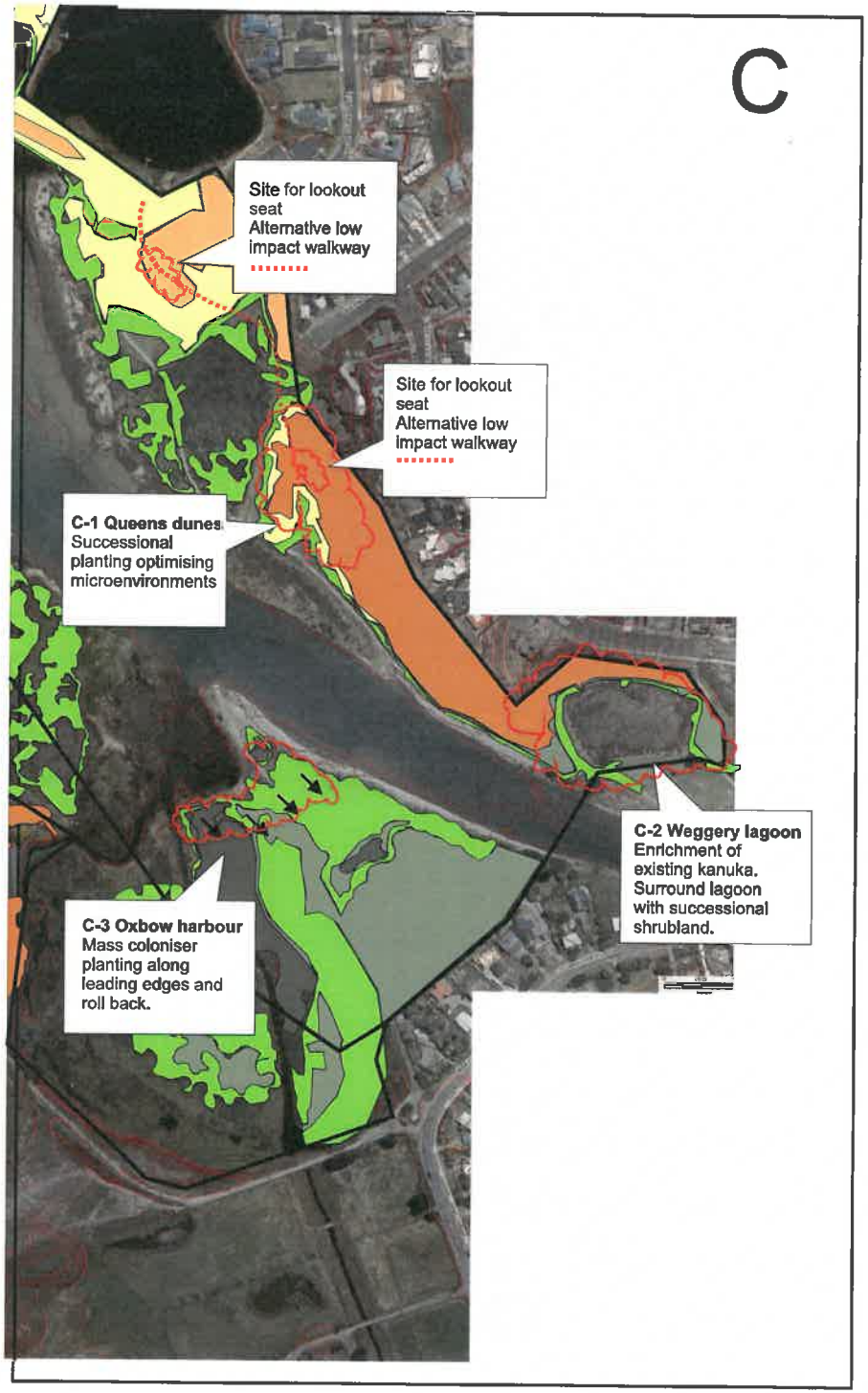
Fig. 9




B
B-5 North foredunes
Foredune replenishment and roll back of marram.
B-4 North banks
Riverbank roll back of marram.
B-1 Inner foredunes
Foredune replenishment and roll back of marram.
B-2 Hinterland
Replenishment of successional veg. to surround high value area. Seaward side of track.
B-3 Track
Replenishment of successional veg. to surround high value area. New track provides access.

SITES - B

Fig. 9


C
Site for lookout seat
Alternative low impact walkway
Site for lookout seat
Alternative low impact walkway
C-1 Queens dunes
Successional planting optimising microenvironments
C-2 Weggery lagoon
Enrichment of existing kanuka. Surround lagoon with successional shrubland.
C-3 Oxbow harbour
Mass coloniser planting along leading edges and roll back.

SITES - C

Fig. 9

Priority sites

A-1 South foredunes

Dry dune:

partly 3-4m asl (refer dry ph 1, 2, 3); 4-5m asl (refer dry phs 2, 3); >5m asl (refer dry phs 2, 3)

Current site:

Incorporates RPS-1. Currently dominated by marram on front dunes with lupin, exotic grasses, purple groundsel, climbing dock and occasional boxthorn on back dunes. The front faces have experienced storm surge erosion, removing much of the spinifex and pingao previously planted. Other native species present include groundsel (Senecio lautus), shore bindweed (Calystegia soldanella) , small-leaved pohuehue (Muehlenbeckia complexa), occasional taupata (Coprosma repens).

Objectives
1. Continue front dunes marram replacement with sand binders (spinifex (Spinifex sericeus), pingao (Ficinia spiralis), knobby club rush (Ficinia nodosus), sand tussock (Poa billardierei), shore bindweed (Calystegia soldanella), rolling back downwind with time. Ensure spinifex grows along crests of dunes.
2. Beyond the foredune faces, hollows (especially where dead boxthorn or lupin provides shelter) can be planted with sand coprosma (Coprosma acerosa), shore daphne (Pimelea arenaria), sand piripiri (Acaena pallida), toetoe (Cortaderia fulvida), tauhinu (Ozothamnus leptophyllus) and the drier slopes with sand tussock (Poa billardierei), knobby club rush (Ficinia nodosus), shore groundsel (Senecio lautus), spinifex and small-leaved pohuehue (Muehlenbeckia complexa).
3. Stable rear dunes/hollows: inclusion of woody shrubs (tauhinu, coastal shrub daisy (Olearia solandri), Coprosma propinqua and manuka (Leptospermum scoparium)) in the hollows amongst knobby club rush, sand tussock and toetoe (C. fulvida). It does not matter if there are bare patches as long as there are ground covers in the mix, such as sand bindweed and small leaved pohuehue.

Work	Timing
Spot spray lupin, boxthorn, exotic creepers. Leave woody skeletons (other than blackberry) in situ. Manually remove purple groundsel.	
Grass spray, leaving dead marram in situ.	prior to planting of herbs, shrubs
Respray marram and other grasses (avoiding spinifex if possible) as required.	prior to planting of grasses/sedges
Manually weed new seedlings of exotic weeds as they appear.	
Plant spinifex, pingao along beach to encourage incipient dune formation.	
Interplant dead grasses as per zones described above; concentrate woody species in shelter of dead shrubs and in hollows. Cluster woody shrubs. Concentrate ground creepers and sand binders in any bare sand patches. Do not add fertiliser to holes.	planting grasses/sedges only when marram is completely dead
Lightly fertilise front face spinifex	Spring
Continue this regime downwind with time.	

A-2 Sand bar

Dry dune:

3-4m asl (refer dry ph 1)

Current site:

Fluctuating sand bar with woody detritus. As of 2010 is being populated with marram, spinifex, shore groundsel.

Objectives
1. Maintain as natural a process as possible with minimal intervention.

Work
Hand weed or spot spray marram (and other exotic weeds) as they appear.

A-3 South Marsh

Wet dune:

mostly <3m asl (refer wet phs 9, 12); partly 3-4m asl (refer wet ph 7)

Dry dune:

fringing estuary 3-4m asl (refer dry phs 1, 2 & 3)

Current site:

The South Marsh is increasingly a perched freshwater body with seasonally fluctuating water level and with input from the Kenakena Drain. This is likely to be introducing contaminants into the South Marsh and possibly to the Puketewhainoa lakelet. Ideally water discharge should be controlled, and vegetation used to help mitigate contaminant input into the estuary. With greater constraints on rivermouth flooding allowing for dune building, it is likely that the south marsh will slowly deepen in the first instance (the yellowing of flaxes may be a symptom of this process) and in time, infill with plant debris. Options for creating a functional water polishing pond should be investigated.

The majority of the area is suited to wetland species. Although the southeastern extent is probably old enough and distant enough from the coast to support wetland trees, it has been agreed that residential view shafts of the estuary will be maintained. The seaward dry dunes are predominantly native - removal of exotic species such as marram and karo is recommended.

Objectives
1. Investigate hydrological situation with intention to develop one of the south marsh ponds into a water quality treatment pond. Assess need to maintenance access (e.g. intermittent rushland and silt removal). If it appears that the Kenakena drain needs to discharge into the easternmost portion of the South Marsh, block the drain linking this water body with Puketewhainoa lakelet.
2. Continue current planting of wetland flaxland/shrubland as begun with RPS 2, 3 and part 4, and extend only dry dune areas

Work	**Timing**
1. Maintain northern plantings and infill where required with swamp coprosma (C. tenuicaulis), manuka (Leptospermum scoparium), Coprosma propinqua, swamp kiokio (Blechnum novae-zealandiae), swamp fern (Blechnum minus), Hypolepis distans, Paesia scaberula. Replace exotic umbrella sedge with native umbrella sedge (Cyperus ustulatus).	Ongoing
2. Maintain roadside plantings and extend with coastal shrub daisy, tauhinu and manuka. Remove ngaio.	
3. Introduce mahoe (Melicytus ramiflorus) and manuka as infill along the southern fringes (3-4m asl) of the wetland,	
4. Depending on outcome of water quality investigations, introduce suitable rushes (such as raupo, kuta) to optimise water treatment.	Pending investigations
5. Replace exotic weeds on the dune frontage with foredune ground covers and herbs. Minimal planting of sand binders here.	Lower priority

A-4 Puketewhainoa lakelet

Dry dune:

>5m asl (refer dry phs 15, 16, 17); small area of younger dune >5m asl (refer dry phs 5, 6, 7)

Wet dune:

4-5m asl (refer wet phs 7, 8); >5m asl (refer phs 7, 8, 10, 11)

Current site:

A complex area with respect to elevation and drainage, encompassing a lakelet with high conservation value for birdlife. The riparian rushland, brackenland and a patch of manuka dominated shrubland, remain highly natural. Blackberry dominates the southern boundary and the old hard pan north of the water body. The lakelet is linked to the South Marsh by a cut channel through a man-made causeway. The water body appears to have been larger (presumably partially drained by cut channel) and appears to be perched on hard pans created by old river courses.

Dry dunes (>5m asl) near road have been planted, and with a high proportion of ngaio and saltmarsh ribbonwood. To redress the balance of more likely dune species, some replacement is recommended. Undisturbed soils have relatively high humic content due to their age, so the least disturbance or exposure the better.

Objectives
1. Treat holistically with predator control, water quality control, weed replacement with native vegetation.
2. Investigate water depths within lakelet, to inform consequences of drain blockage, and of anticipated spread of raupo. Investigate stormwater discharges into lakelet and redirect discharges if required, to maintain high water quality.
2. Block South Marsh drain, if required, to maintain water quality

Objectives
3. Enrichment of existing manuka-mahoe stand with ferns, climbers, understorey species (i.e. treat as node).
4. Plan lakelet fringing vegetation to visually protect wildlife from roadside disturbances.
5. Maintain the lakelet's isolation from the public, dogs and cats.
6. To maintain high values as wildlife habitat, maintain at least one quarter of the lakelet as open water (i.e. clear raupo as required).

Work	Timing
1. Spray and mulch blackberry along south boundary. Avoid spraying bracken.	Over two-three seasons
2. Replant south boundary according to elevation, with (3-4m asl) dense harakeke and toetoe (C. toetoe), or maintain bracken; (4-5m asl) manuka (predominantly), coastal shrub daisy, Coprosma propinqua, C. propinqua x robusta, C. robusta, C. tenuicaulis, C. crassifolia, NZ broom (Carmichaelia australis), five finger, mahoe, cabbage tree; and (>5m asl) as above but also kahikatea, swamp maire. Bark mulch and fertiliser may be used in this area.	Once blackberry removed. Fringing vegetation high priority.
3. Enrich existing manuka - mahoe stand with NZ jasmine (Parsonsia heterophylla), Clematis forsteri, hounds tongue (Microsorum pustulatum), shining spleenwort (Asplenium oblongifolium)	As stock becomes available
4. Continue clearance of blackberry, briar and climbing dock from old hard pan area north of the lakelet.	Over two seasons
5. Continue to plant this area (4) with suitable shallow-rooting species such as harakeke but also introduce bracken (Pteridium esculentum) and hard fern (Paesia scaberula) by laying down fertile fronds or transplanting. Ensure a dense fringing vegetation of harakeke and toetoe protecting the lakelet margins	Fern introductions during fertile season. Fringing vegetation high priority.
6. Dry dunes adjacent to road: continue planting (RPS 3) maintenance. To maintain a more naturalistic dune vegetation, remove some of the ngaio and any harakeke on the dunes, replacing with kanuka, predominantly, with some poataniwha (Melicope simplex), corokia (Corokia cotoneaster).	
7. Dunes south of track (4-5m asl, wet dune, close to RPS 5): small leaved coprosmas (C. crassifolia, C. tenuicaulis, C. propinqua), manuka with occasional harakeke and toetoe (C. toetoe).	
8. Younger dunes south of track (>5m asl): plant densely with ground covers, small shrubs, knobby club rush	

A-5 Salt meadow

Wet dune:

<3m asl (refer phs 1, 2)

Current site:

low lying area, transitional between tidal zone and dry dune affected by storm surges and occasional inundation. Accumulation of woody detritus. Tending towards dune building, and being invaded by exotic species such as Juncus acutis, marram, Atriplex etc. Cars occasionally damage the turf.

Objectives
1. With minimum intervention, keep area clear of exotic weeds

Work	Timing
1. Confirm with botanist range of species present in rushland and salt meadow.	
2. Spot spray exotic Juncus, marram and other grass spp.	
3. Hand weed exotics as they appear. No planting required.	Ongoing

A-6 Inner foredunes

Dry dunes:

young foredunes 3-4m asl (refer dry phs 1, 2, 3); 4-5m asl (refer dry phs ; older high dunes >5m asl (refer dry phs 5, 6, 7)

Current site:

Above the flax fringe of the wet dune area, including accumulated woody detritus, these dunes support exotic grasses, boxthorn, occasional taupata and a range of exotic and native ground covers intertwined through the mixed grassland-shrubland. The eastern end of this area is prone to dune accretion, but this in turn makes the salt meadows vulnerable.

Objectives
1. Replace exotic species without encouraging further dune accretion.
2. Roll back marram and other grasses from upwind leading edges.

Work	**Timing**
1. Spray exotic shrubs and grasses, in strips from leading edge. Leave dead plants in situ.	one season (unless periwinkle, convulvulus or blackberry is present, which may take longer to eradicate)
2. On foredunes plant tauhinu (Ozothamnus leptophyllus), shore bindweed (Calystegia soldanella), knobby club rush (Ficinia nodosus), sand daphne (Pimelea arenaria), speckled sedge (Carex testacea) and sand wind grass Lachnogrostis billardierei amidst the dead plants. Fertiliser is not required.	primary planting
3. On higher dunes concentrate toetoe (C. toetoe) on crests and in lee hollows concentrate woody shrubs including coastal shrub daisy, tauhinu, sand coprosma, corokia and small-leaved pohuehue (Muehlenbeckia complexa) all interspersed with coastal bidibidi (Acaena pallida) and NZ spinach (Tetragonia implexicoma). Fertiliser is not required.	secondary planting

B-1 Inner foredunes

Dry dunes:

young dunes 3-4m asl (refer dry phs 1, 2, 3); minor areas of 4-5m asl (refer dry phs 2, 3) and >5m asl (refer dry phs 2, 3)

Current site:

Fairly sparse vegetation cover dominated by exotic grasses and herbs, with scattered lupin. Native species present include knobby club rush, occ. harakeke, shore bindweed. Planting of spinifex and pingao has been progressing to the southwest of this area.

Objective
1. Replacement of exotic species with similarly suited native species
2. Acceptance of mobile sands, and tolerance of selected exotic species. Note that dune accretion is not threatening other habitats along this stretch of shoreline, unlike further to the southwest.

Work	Timing
1. In strips parallel to leading edge, spot spray or manually kill woody exotic shrubs. Target spray marram, trying to avoid damage to knobby club rush or spinifex.	
2. Interplant dead marram with spinifex, pingao, knobby club rush, NZ ice plant, shore bindweed, shore groundsel (Senecio lautus), sand coprosma (C. acerosa) and shore daphne (Pimelea arenaria). Planting does not need to be dense. Fertiliser is not required.	Wait for marram to be killed
3. Hand weed fleabane (low priority) and purple groundsel.	Ongoing
4. Fertilise spinifex lightly to encourage spread	Spring
5. Continue this regime, rolling back downwind from leading edge over time	

B-2 Hinterland

Dry dunes:

4-5m asl (refer dry phs 2, 3); exposed young dunes >5m asl (refer dry phs 2); less exposed dunes >5m asl (refer dry ph 12)

Wet dune:

3-4m asl (refer wet ph 4)

Current site:

This site encompasses the lineal dune ridge, sheltered hollows in the lee of high dunes, and grassed fringes of the North Marsh wetland on the seaward side of the vehicular track to the river. The southern extent of this area is on 'old' ground. A low, damp area (circled on Fig 9 (B)) has native shrubs and ferns naturalising under willows. The lee of the dune ridge has dense cover of knobby club rush, small-leaved pohuehue, lupin, marram and blackberry. In places there are flat sites and vegetation indicating previous fishing bach sites. On the seaward side of the dune ridge pampas has recently been sprayed and vegetation cover is sparse (dominated by marram and knobby club rush). There are some minor blowouts.

Objectives
1. Stabilise the dune ridge, using native colonising species.
2. Use the willows site as a node that will support a diversity of species.
3. Return wetland species to the low-lying damp areas.

Work	**Timing**
1. Continue to spot spray pampas and woody exotic weeds.	
2. Spray marram on windward side of dune ridge, taking care to avoid killing knobby club rush.	
3. Kill willows and leave standing. Underplant with broadleaf species including mapou (Myrsine australis), mahoe (Melicytus ramiflorus), kohuhu (Pittosporum tenuifolium), karamu (Coprosma robusta) in the moister hollow and with kanuka, Coprosma propinqua and corokia (Corokia cotoneaster) on the drier slopes. Mulch and fertiliser may be used.	
4. Spray blackberry and boxthorn along the lee side of dune ridge, trying to avoid killing too much native vegetation.	
5. Plant into hollows along lee side of dune using predominantly kanuka (80%) and small-leaved pohuehue with some knobby club rush. Do not mulch. Spread branches of kanuka across areas of exposed sand. Marram that is interspersed with native species can be left (it is unlikely to spread into the wetland downwind) but monospecific clusters of marram may be sprayed and replaced.	
6. On seaward side of dune ridge, plant toetoe (C. fulvida) immediately in the lee of dead pampas. Interplant spaces with tauhinu, coastal tree daisy, sand coprosma, shore bindweed, NZ spinach and knobby club rush.	
7. Plant wet dune areas (adjacent to the roadway) with manuka (80%) and toetoe (C. toetoe).	

B-3 Track

Dry dunes:

4-5m asl (refer dry phs 2, 3); >5m asl (refer dry phs 16, 17)

Wet dunes:

3-4m asl (refer wet ph 4)

Current site:

Although on relatively 'young' land, this site is also relatively sheltered. A portion has recently been cleared of gorse, and most of it remains in gorse growing on the fringes of the North Marsh. The new track (proposed in 2010) will run directly through this site, providing access for planting.

Objectives
1. Replant cleared ground (track-sides and cleared weed areas) with woody colonising species
2. Shade out sprayed gorse with woody colonising species, taking advantage of the dead gorse shelter to establish plantings and minimising exposure of gorse seed bank.

Work	**Timing**
1. Respray weed regrowth on cleared sites	
2. Plant cleared sites with kanuka where dry dunes 4-5m asl, with manuka and occ. toetoe where wet dunes 3-4m asl, or with mapou (Myrsine australis), kanuka and corokia where dunes are >5m asl. Combine with kanuka slash if available, otherwise mulch areas. Fertiliser is not required.	
3. Spray dense gorse. Leave standing. Clear 'squeeze' tracks through gorse where kanuka/manuka can be planted (according to elevation) and kanuka slash laid. Aim for 1m spacings if possible.	
4. When track work is completed, plant track sides with coastal shrub daisy, tauhinu, corokia and manuka, keeping at least 0.5m from edge of path.	

B-4 North banks

Dry dunes:

4-5m asl (refer dry ph 2, 3), minor >5m asl (refer dry ph 2)

Wet dunes:

minor 3-4m asl (refer wet ph 4)

Current site:

The site is a 100m strip of rank exotic grasses with minor knobby club rush approximately 15 metres wide established on earth works dating back to late 1960s. It has been subject to woody weed removal for some years. The river edge occasionally erodes but has no capacity for recovery.

Any vegetation along this edge will be vulnerable to river-straightening earth works in the future, but establishing resilience in the short term is important.

Objective
1. Stabilise banks using native species, with capacity for regrowth after erosion events
2. Replace exotic species with native species
3. Create vegetation dense enough to reduce short-cut tracks being made through to the river.
4. Roll back from the upwind end, establishing small areas of planting at a time, to minimise destabilisation of the edges and the dunes

Work	**Timing**
For each unit of work (approximately 20m lengths starting at the seaward end of the site):	Approx. 5-6 years overall
1. Spray the exotic grasses. Do not clear.	Two sweeps to ensure results
2. Interplant a cross section (inner edge to river edge) of (i) woody shrubs tauhinu, coastal shrub daisy, knobby club rush along interior edge (ii) knobby club rush (in clusters), sand coprosma, shore groundsel, small leaved pohuehue along central sections (iii) oioi, sea rush, sand sedge (Carex pumila), in spring tide zone. At the seaward end, add spinifex to the riparian margin. Only mulch the shrubby internal edge, so that ground covers and binders on the river edge are able to spread freely.	Proceed once it is clear that this approach is working. Adjust methods as required.

B-5 North foredunes

Dry dunes:

Mostly >5m asl (refer dry ph 2); minor 4-5m asl (refer dry phs 2, 3) and 3-4m asl (refer dry phs 1, 2 and 3)

Current site:

At least 90 years of established dunes have resulted in a varied topography with woody shrubs (mostly exotic) establishing in hollows and dense cover (dominated by marram) on the crests. Planting began in 2010 (RPS 9, 10). Naturalised native species include shore groundsel and spinifex with occasional taupata in dune hollows. The intention with this site is to increase species diversity and improve micro-siting of plants.

Objectives
1. Stabilisation/accretion of foredune with native sand binders
2. Replacement of exotic dune vegetation with native species

Work	**Timing**
1. Plant Carex pumila and spinifex along leading edge	first season
2. Roll back strips of marram spraying from leading coastal edge. Avoid loss of shore groundsel	subsequent seasons
3. Interplant dead marram on front faces with spinifex, ensuring the crests of dunes are well planted	
4. Beyond front faces, interplant with sand coprosma (C. acerosa), shore daphne (Pimelea arenaria), sand bidibidi (Acaena pallida), shore groundsel (Senecio lautus), knobby club rush (Ficinia nodosus) and spinifex. In hollows plant Muehlenbeckia complexa and tauhinu (Ozothamnus leptophyllus). Plant spinifex along river leading edge.	

C-1 Queens dunes

Dry dunes:

Mostly >5m asl (refer dry phs 12-14); minor 4-5m asl (refer dry phs 2, 3-8, 9)

Wet dunes:

3-4m asl (refer wet ph 4)

Current site:

Northern end of high, old dune which had its surface disturbed during 1930s and has been grassed since. The crest of the dune has been developed for residential housing and roading, and gardens supply the reserve with weeds. Ngaio, kanuka, mapou and coastal shrub daisy have been planted at intervals along the high face (RPS 15); in 2010 the low outlying dune landforms (noted here as a potential seating site) were planted with a diversity of trees, shrubs and harakeke.

Although an older dune, the steep slopes on this site may still be susceptible to blowouts if the surface is disturbed. Most woody weeds have been removed but exotic creepers and garden escapees create an ongoing challenge.

Objectives
1. Establish a drought-tolerant coastal forest that succedes through a nursery stand of kanuka
2. Optimise microtopography for establishing a variety of species upwind of the main slopes (the unnamed 2010 planting has made a start)

Work	**Timing**
1. Spot spray exotic creepers, blackberry and garden escapees	
2. Spot spray grass ready for bulk planting of kanuka across entire site at approx. 1.5m spacings	
3. Bulk planting of kanuka across entire site	
4. Remove flax from 2010 plantings	
5. Interplant 2010 plantings and remaining taupata on the higher dune with poataniwha (Melicope simplex), corokia (Corokia cotoneaster) and NZ broom (Carmichaelia australis)	
6. As plantings mature, introduce climbers - NZ jasmine (Parsonsia heterophylla), Clematis forsteri, NZ passionvine (Tetrapathaea tetrandra)	years 5-7?
7. Trial establishing bracken downwind of the kanuka plantings.	

C-2 Weggery lagoon

Dry dunes:

>5m asl (refer dry phs 12-18)

Wet dunes:

3-4m asl (refer wet ph 4); 4-5m asl (refer wet ph 5)

Current site:

This waterbody has a small culvert linking it with the Waikanae river and although boulders appear to limit the flow of water there are smelt in the lagoon indicating at least some fish passage is possible. It is a popular feeding place for waterfowl and waders. It is fringed with rushland and the dry edges have been planted previously with flax and shrubs. The steep dune slopes surrounding the lagoon have been planted with kanuka and the crest of the dune ridge with ngaio. The latter is proving unsuitable, as wind turbulence is exacerbating erosion around their roots, and the density is unnatural. In 2010 further planting of kanuka was undertaken, narrowing the grassed area between the dune slopes and the lagoon.

Objectives
1. Enhance the lagoon as a wildlife habitat by ensuring water quality through shading by tall trees on north side and management of stormwater discharges
2. Enrich existing plantings and encourage successional processes
3. Protect wildlife from disturbance by dogs and predators
4. Recreate a zonal vegetation sequence from water to dune crest

Work	**Timing**
1. Enrich current kanuka plantings with ground ferns (hounds tongue Microsorum pustulatum, shining spleenwort Asplenium oblongifolium) climbers (Clematis forsteri, Parsonsia heterophylla), Coprosma rhamnoides and Coprosma propinqua.	
2. As kanuka canopy matures further, introduce mahoe, poataniwha (Melicope simplex) and kawakawa (Macropiper excelsum)	
3. Enrich fringing lagoon vegetation with coastal tree daisy, manuka, saltmarsh ribbonwood, toetoe (C. toetoe). Concentrate cabbage tree and swamp maire in clusters along north fringe of lagoon (to encourage some future shading of the waterbody).	

C-3 Oxbow harbour

Wet dunes:

3-4m asl (refer wet ph 4); 4-5m asl (refer wet ph 5); >5m asl (refer wet ph 7, 8)

Current site:

Site encompasses the northern leading edge of the land between the oxbow and the river. It straddles the roadway to the boat launching area and extends back into the area of planting RPS08. Vegetation is dominated by exotic species.

Objectives
1. Revegetate barren consolidated land
2. Establish colonising species for successional enhancement, rolling back from leading edge.

Work	**Timing**
1. Define allowable parking areas	
2. Rip planting areas where ground is highly consolidated	
3. Broadcast spray to remove exotic species, in manageable strips, rolling back from leading edges	
4. Plant in bulk according to elevation with coastal shrub daisy (3-4m)/ manuka (4-5m) / manuka, mahoe, karamu (>5m). Mulch and fertiliser are acceptable. Riparian edges planted with sea rush, oioi, umbrella sedge, Carex litorosa with saltmarsh ribbonwood along fringing dry land.	

Minimum spacings

4-5m apart	large trees	e.g. totara, kahikatea, swamp maire, ngaio
2m apart	small trees, flax, toetoe, cabbage trees, tree ferns	e.g. mapou, kanuka, akeake
1.5m apart	shrubs	e.g. manuka, corokia, mingimingi, coastal shrub daisy
750mm apart	ground ferns, small woody ground covers, spinifex	e.g. sand coprosma, sand daphne, hounds tongue, spinifex
300mm apart	rushes, grasses, sedges, herbaceous ground covers	e.g. shore bindweed, sand daphne, knobby clubrush, oioi, pingao

Combinations

shrubland - same mature heights together	e.g. group together flax, toetoe and manuka; or coastal shrub daisy, mingimingi, tauhinu; or sand coprosma, small leaved pohuehue, pimelea, knobby clubrush, spinifex
trees over semi-shade tolerant shrubs	maintain recommended tree spacings; infill with small- leaved coprosmas, corokia (not sun-demanding species such as flax or toetoe or coastal shrub daisy) which will become understorey
nursery plantings	e.g. toetoe, manuka, kanuka. Interplant with occasional seed source semi-shade-tolerant tree species and ground ferns and climbers after 4-5 years growth
bare sand	First priority is to establish ground covers - shore bindweed, NZ climbing spinach, NZ iceplant, spinifex, sand sedge (if damp), small-leaved pohuehue, pimelea, bidibidi, sand iris (if damp) etc

Planting

Spinifex, pingao	Bury plants 50-100mm below ground level. Aim to get roots into damp sand.
Soak plants	The day before planting, ensure plant roots are well soaked
Rain capture	Create a depression around the plant to help direct rainwater
Root care	Don't tease out roots when planting. If plants are root-bound, discard.
Stem care	Do not mulch around grasses, sedges, rushes as stem bases can rot if buried.

Record keeping

Seed sources	Identify bona fide seed sources for locally native coastal plants (Kapiti, Horowhenua). Keep nursery records of sources. Collect from a range of individuals of each species if possible.
Planted areas - photo points, maps	Record areas planted, dates, dates of infill planting. Record photos from photo points every 2 years.
Species lists & volumes & losses	Maintain records of species planted and the quantities used. If possible keep track of losses.
Experimental areas	Maintain records (as above) for particular experiments with potting mixes and fertiliser uses.

Planting tips

Fig.10

Appendix I

RPS 2006 review

The following lists record the 2006 proposed versus actual plantings to 2010 and do not reflect the plantings proposed in this current Restoration Plan.

The lists reflect firstly what has been (or was planned to be) planted. Secondly, in **bold** are the species recommended by G. Park in 2006. **Underlined** are species he proposed should be dominant.

RPS1		2008	2009	2010	2011
Coprosma acerosa	**sand coprosma**				*
Coprosma repens	taupata				*
Coprosma robusta	karamu			*	
Cordyline australis	**ti kouka**			*	
Cortaderia toetoe	**toetoe (fulvida/toetoe)**				*
Spinifex sericeus/Ficinia spiralis spinifex/pingao		748	1000		
Ficinia nodosa	knobby club rush			*	*
Leptospermum scoparium	**manuka**			*	
Melicytus ramiflorus	mahoe			*	
Muehlenbeckia complexa	mingimingi				*
Myoporum laetum	**ngaio**				*
Myrsine australis	mapou				*
Olearia solandri	coastal shrub daisy			*	*
Phormium tenax	harakeke			*	*
Pittosporum tenuifolium	kohuhu			*	
Plagianthus divaricatus	saltmarsh ribbonwood			*	
Poa billardierei	sand tussock				*
Podocarpus totara	totara			*	
Sophora microphylla	kowhai			*	

Plus . . .
Ozothamnus leptophyllus **tauhinu**
Pimelea prostrata (why not P. arenaria?) **sand daphne**

Comment: RPS1 species list is not well suited to foredune environments and is overambitious in its broadleaf species selection. Most of the foredune species planted were removed by erosion.

RPS 2		2008	2009 RPS 2-4	2010 Horseshoe extension 800 plants incl grasses
Carex litorosa			150	*
Carex secta			120	*
Coprosma propinqua			20	*
Coprosma repens	**taupata**	75	25	
Coprosma robusta	karamu		20	*
Cordyline australis	**ti kouka**	70	50	*
Cortaderia toetoe	**toetoe**	330	40	
Cyperus ustulatus	umbrella sedge		200	
Dodonaea viscosa	**akeake**			*
Ficinia nodosa	knobby club rush		300	
Leptospermum scoparium	**manuka**			*
Melicytus ramiflorus	**mahoe**			*
Myoporum laetum	**ngaio**	122	20	
Olearia solandri	**coastal shrub daisy**	10	70	*
Phormium tenax	**harakeke**	135	40	*
Pittosporum tenuifolium	kohuhu		20	*
Plagianthus divaricatus	**s/m ribbonwood**		20	*
Sophora microphylla	**kowhai**		10	*

Plus . . .

Ozothamnus leptophyllus **tauhinu**

Myrsine australis **mapou**

Comment: The South Marsh area is not well suited to trees other than cabbage tree but as expected the wetland species are thriving in this environment. Tall trees are problematic along the roadside as they will impede views and shrubland would be advisable.

RPS 3		2008	2008 RPS 3-5	2009 Hadfield/3-5 infilling	2010 Bridge	RPS 3-5
Carex litorosa					*	
Carex secta					*	
Coprosma propinqua	mingimingi			80		
Coprosma repens	**taupata**	25		20		*
Cordyline australis	**ti kouka**	50	50	29	*	*
Cortaderia toetoe	**toetoe**		30	20	*	*
Ficinia nodosa	knobby club rush				*	
Kunzia ericioides	**kanuka**	25			*	*
Melicytus ramiflorus	**Mahoe**			40		
Muehlenbeckia complexa	small leaved pohuehue				*	
Myoporum laetum	ngaio	30	30	30		*
Myrsine australis	mapou	20				
Olearia solandri	**coastal shrub daisy**		10	20	*	*
Phormium tenax	**harakeke**	50	22	26	*	*
Pittosporum tenuifolium	kohuhu		10	100		*
Plagianthus divaricatus	saltmarsh ribbonwood			20		
Podocarpus totara	totara					*
Sophora microphylla	**kowhai**					*

plus . . .

Coprosma robusta **karamu**

Dodonaea viscosa **akeake**

Comment: Carex litorosa is not suitable in this environment, and more than enough cabbage trees and ngaio have been planted. Otherwise this list is suitable.

RPS 4		2008	2009 see RPS 2-4	2010 _
Cyperus ustulatus	umbrella sedge	15		
Hebe stricta	koromiko	5		
Kunzia ericoides	kanuka	25		
Olearia solandri coastal	shrub daisy	20		
Plus . . .				
Phormium tenax	**harakeke**			
Cordyline australis	**ti kouka**			
Cortaderia toetoe	**toetoe**			
Sophora microphylla	**kowhai**			
Melicytus ramiflorus	**mahoe**			
sedges				

Comment: Suitable list but dominants not yet planted

RPS 5		2008		2009	2010 see RPS 3-5	2011
Coprosma repens	taupata			55		*
Coprosma robusta	**karamu**	37	25	80		
Cordyline australis	**ti kouka**	100	50	283		*
Cortaderia toetoe	toetoe	100	150	170		*
Kunzia ericoides	**kanuka**		13			
Leptospermum scoparium	manuka			80		
Melicytus ramiflorus	mahoe			50		
Myoporum laetum	**ngaio**			150		
Olearia solandri coastal	shrub daisy					*
Phormium tenax	harakeke	100	150	230		*
Pittosporum tenuifolium	**kohuhu**		25	160		
Poa cita	silver tussock			100		
Podocarpus totara	**totara**			60		

Plus . . .

Myrsine australis	**mapou**
Sophora microphylla	**kowhai**
Dodonaea viscosa	**akeake**

Comment: Overly ambitious to introduce broadleaf species on dry foredunes where dune sedge and shrub species would be more appropriate. Toetoe will provide excellent 'nursery' for next seral stage and is well suited to lower elevation. Totara would be better suited along inland extent of node.

RPS 6		2008	2009	2010	2011 (RPS6-8)
Coprosma propinqua	mingimingi		130	100	*
Coprosma repens	taupata				*
Coprosma robusta	**karamu**	30			
Cordyline australis	**ti kouka**	70	50	100	*
Cortaderia toetoe	**toetoe**		120	150	*
Cyperus ustulatus	umbrella sedge	60			
Dacrydium dacrydioides	**kahikatea**	20			
Myoporum laetum	ngaio				*
Myrsine australis	mapou	25			
Olearia solandri coastal	shrub daisy	80	50	100	*
Phormium tenax	**harakeke**	70	150	150	*
Pittosporum tenuifolium	**kohuhu**	50			
Plagianthus divaricatus	s-m ribbonwood	30		150	
Poa cita	silver tussock				
Podocarpus totara	totara		103	50	

Plus . . .
Melicytus ramiflorus **mahoe**
Sophora microphylla **kowhai**

Comment: These plantings provide a fast-track successional stage beyond what might be expected naturally so will provide the ongoing seed-source. The area will now benefit from a diversity of shrubland species.

RPS 7		2008	2009	2010
Cordyline australis	ti kouka		50	
Cortaderia toetoe	toetoe		50	
Spinifex sericeus/Ficinia spiralis	**spinifex/pingao**	1600	400	*
Muehlenbeckia complexa	mingimingi		100	

Plus . . .
Carex pumila

Comment: cabbage tree is not particularly appropriate here – but concentration on foredune species is.

RPS 8		2008	2009	2010	2011
Carex litorosa					*
Coprosma propinqua	mingimingi				*
Coprosma repens	taupata	50			*
Coprosma robusta	karamu	13			*
Cordyline australis	**ti kouka**	150			*
Cortaderia toetoe	**toetoe**	240			*
Cyperus ustulatus	umbrella sedge	807			
Dacrydium dacrydioides	kahikatea	100			
Ficinia nodosa	knobby club rush				*
Kunzia ericoides	kanuka	50			
Leptospermum scoparium	manuka				*
Melicytus ramiflorus	mahoe				*
Myrsine australis	mapou	38			
Olearia solandri	coastal shrub daisy	60			*
Phormium tenax	**harakeke**	275			*
Pittosporum tenuifolium	kohuhu	17			
Plagianthus divaricatus	s-m ribbonwood	55			
Podocarpus totara	totara	35			*
Sophora microphylla	**kowhai**				*

Plus . . .
Laurelia novae-zealandiae pukatea

Comment: Kowhai is not appropriate in damp ground, otherwise this list is suitable although care should be taken to suit elevation above water table, and to avoid harakeke damaging vulnerable tree juveniles.

RPS 9		2008	2009	2010
–				
plus . . .				
Spinifex sericeus	**spinifex**			
Euphorbia glauca	sea spurge			
Coprosma acerosa	sand coprosma			
Pimelea arenaria	sand daphne			

Comment: All suitable but diversity of foredune species can be increased.

RPS 10		2008	2009	2010	2011
Coprosma acerosa	sand coprosma			*	*
Coprosma repens	**taupata**			*	*
Coprosma robusta	karamu			*	
Cordyline australis	**ti kouka**			*	*
Cortaderia toetoe	**toetoe**			*	*
Dodonaea viscosa	akeake			*	
Ficinia nodosa	knobby club rush			*	
Kunzia ericoides	kanuka			*	*
Leptospermum scoparium	manuka			*	
Melicytus ramiflorus	mahoe			*	*
Muehlenbeckia complexa	small leaved pohuehue			*	
Myoporum laetum	**ngaio**			*	*
Myrsine australis	mapou			*	
Olearia solandri	coastal shrub daisy			*	*
Phormium tenax	**harakeke**			*	*
Pittosporum tenuifolium	kohuhu			*	
Sophora microphylla	kowhai			*	

Comment: Not yet planted. Inadvisable to introduce broadleaf species or trees; rather, concentrate on dune shrubland –grassland-fernland.

RPS 11		2008	2009	2010
Cordyline australis	ti kouka			*
Ficinia nodosa	knobby club rush			*
Olearia solandri	coastal shrub daisy			*
Phormium tenax	harakeke			*

Plus . . .

Coprosma repens	**taupata**
Myoporum laetum	**ngaio**
Plagianthus divaricatus	**saltmarsh ribbonwood**
Sophora microphylla	**kowhai**

Comment: Park list overambitious in this windy, low elevation site. Better suited to saltmarsh shrubland.

RPS 12		2008	2009	2010

Plus . . .

Coprosma repens	**taupata**
Myoporum laetum	**ngaio**
Phormium tenax	**harakeke**
Plagianthus divaricatus	**saltmarsh ribbonwood**
Sophora microphylla	**kowhai**

Comment: Kowhai inappropriate but others should withstand the exposure of this site.

RPS 13		2008	2009	2010
Plus . . .				
Coprosma repens	**taupata**			
Cordyline australis	**ti kouka**			
Kunzia ericoides	**kanuka**			
Myoporum laetum	**ngaio**			
Olearia solandri	**coastal shrub daisy**			
Phormium tenax	**harakeke**			
Plagianthus divaricatus	**saltmarsh ribbonwood**			
Sophora microphylla	**kowhai**			

Comment: Maintain views by using shrubland rather than trees. Kowhai and ngaio inappropriate.

RPS 14		2008	2009	2010	2011
Carex secta	purei		50		
Coprosma propinqua	mingimingi		170	*	*
Coprosma robusta	karamu				
Cordyline australis	ti kouka	90	110	*	*
Cortaderia toetoe	toetoe	100			
Cyperus ustulatus	umbrella sedge		50		
Dodonaea viscosa	akeake				*
Ficinia nodosa	knobby club rush		100		
Kunzia ericoides	kanuka	40			*
Leptospermum scoparium	manuka		91		
Myoporum laetum	ngaio	20			*
Olearia solandri coastal	shrub daisy	140	40	*	
Phormium tenax	**harakeke**	170	50	*	
Plagianthus divaricatus	s/m ribbonwood	140	65	*	
Poa cita	silver tussock		123		
Podocarpus totara	totara				*

Comment: Ngaio, totara and silver tussock not appropriate but all others suitable.

RPS 15		2008	2009	2010
Coprosma robusta	**karamu**	32		
Myoporum laetum	**ngaio**	218		
Myrsine australis	**mapou**	92		
Pittosporum tenuifolium	**kohuhu**	158		
Plus . . .				
Cordyline australis	**ti kouka**			
Dodonaea viscosa	**akeake**			
Kunzia ericoides	**kanuka**			
Melicytus ramiflorus	**mahoe**			
Podocarpus totara	**totara**			

Comment: Bulk kanuka should have used to assist with establishment. Too many ngaio compared to species likely to dominate naturally.

RPS 16		2008	2009	2010

Plus . . .

Carex litorosa	
Coprosma propinqua	**mingimingi**
Cordyline australis	**ti kouka**
Kunzia ericoides	**kanuka**
Myoporum laetum	**ngaio**
Phormium tenax	**harakeke**

Comment: Not yet planted. Carex and ngaio not well suited to this environment.