ECOLOGICAL ENHANCEMENT PLAN

FOR PORT WAIKATO

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ECOLOGICAL ENHANCEMENT PLAN
FOR PORT WAIKATO

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1. INTRODUCTION

Waikato District Council commissioned Wildland Consultants Ltd to prepare an Ecological Enhancement Plan for a defined project area at Port Waikato. The project area covers approximately 414 hectares, encompassing most of the residential dwellings in Port Waikato, the sandspit to the north of the township, and *c.*2 km of the margins of the Waikato River to the east. Recent erosion of the dunes and sandspit area at Port Waikato has triggered discussion between Waikato District Council, Department of Conservation, local iwi (Ngāti Karewa Ngāti Tahinga) and the local Port Waikato Beach Care community group. These discussions have also highlighted some ecological threats relating to the Port Waikato village, particularly in terms of development and pest plant species cultivated in the village which have spread into the dunes.

Waikato District Council requires an assessment of ecological threats at Port Waikato and a long-term Ecological Enhancement Plan to guide restoration over a ten-year timeframe. In collaboration with Ngati Karewa Ngati Tahinga and the community beach care group, a range of goals have been established. The aim of the plan is to provide a guide to improve the local indigenous biodiversity within both terrestrial and aquatic habitats.

This report comprises an Ecological Enhancement Plan, including baseline information derived from field surveys, assessment of any current issues (and potential future issues), and identification of options to restore and enhance the biodiversity of the sandspit, dunes, wetlands and waterways of Port Waikato. The plan provides a works strategy, timeline, and indicative costs that will span over a ten-year period, with a focus on pest plant management and ecological enhancement opportunities, along with suggestions on suitable plant species for the site.

2. GOALS

The over-arching goal of the project is:

To significantly enhance the ecological health of Port Waikato to provide ecological resilience to the effects of climate change.

The goal will be achieved by addressing the following:

- Increasing the cover of indigenous species present throughout the project area.
- Undertaking appropriate dune restoration.
- Reducing the density and diversity of pest animals and plants.
- Improving water quality.
- Improving the ecological values and indigenous biodiversity of terrestrial and aquatic habitats.

3. OBJECTIVES

The objectives of the project are to develop an Ecological Enhancement Plan to restore and enhance the biodiversity of the sandspit, dunes, wetlands and waterways of Port Waikato, by providing:

- Guidelines on planting and maintenance of indigenous species.
- Methods for progressively controlling and/or eradicating invasive exotic plants and fauna.
- Guidance on improving biodiversity and ecological values for all habitats at Port Waikato, with a focus on the dune system and wetlands.
- Methods to improve ecological resilience to climate change and erosion.
- Strategies to reduce sediment and nutrient inputs into the sea and estuary.
- Advice on potential ecological improvements to the surrounding catchments.
- Collection of baseline information on complementary ecological enhancement work being undertaken in the catchment.
- A monitoring network.
- Plans for these activities over the next 10 years.

4. METHODS

A literature review was undertaken to identify relevant ecological information pertaining to the site, including ecological studies for terrestrial, freshwater and marine environments. Digital and hard copy information relating to the ecology of the study site was compiled, together with GIS layers and digital aerial photographs. Hard copy field maps were prepared, showing the project area boundary on aerial photographs.

A site visit was carried out on 7 December 2015, including an on-site meeting with the Port Waikato Beach Care chair, Karen Opie, and Ngāti Karewa Ngāti Tahinga representative, Richard Tiki O Te Rangi Thompson. The history of the site and ecological conservation efforts that have been carried out by the participants was discussed during this meeting. Furthermore, aspirations and goals were discussed in terms of ecological enhancement and restoration works being undertaken at Port Waikato.

A walk-through survey of the site was undertaken. Vegetation types and habitats were identified, described, and mapped (Figure 1), a plant species list was compiled (Appendix 1), and the location and extent of pest plant species were recorded (Appendix 2) and mapped (Figure 2). Incidental observations of indigenous and exotic bird species and pest animals were also made (Appendix 3).

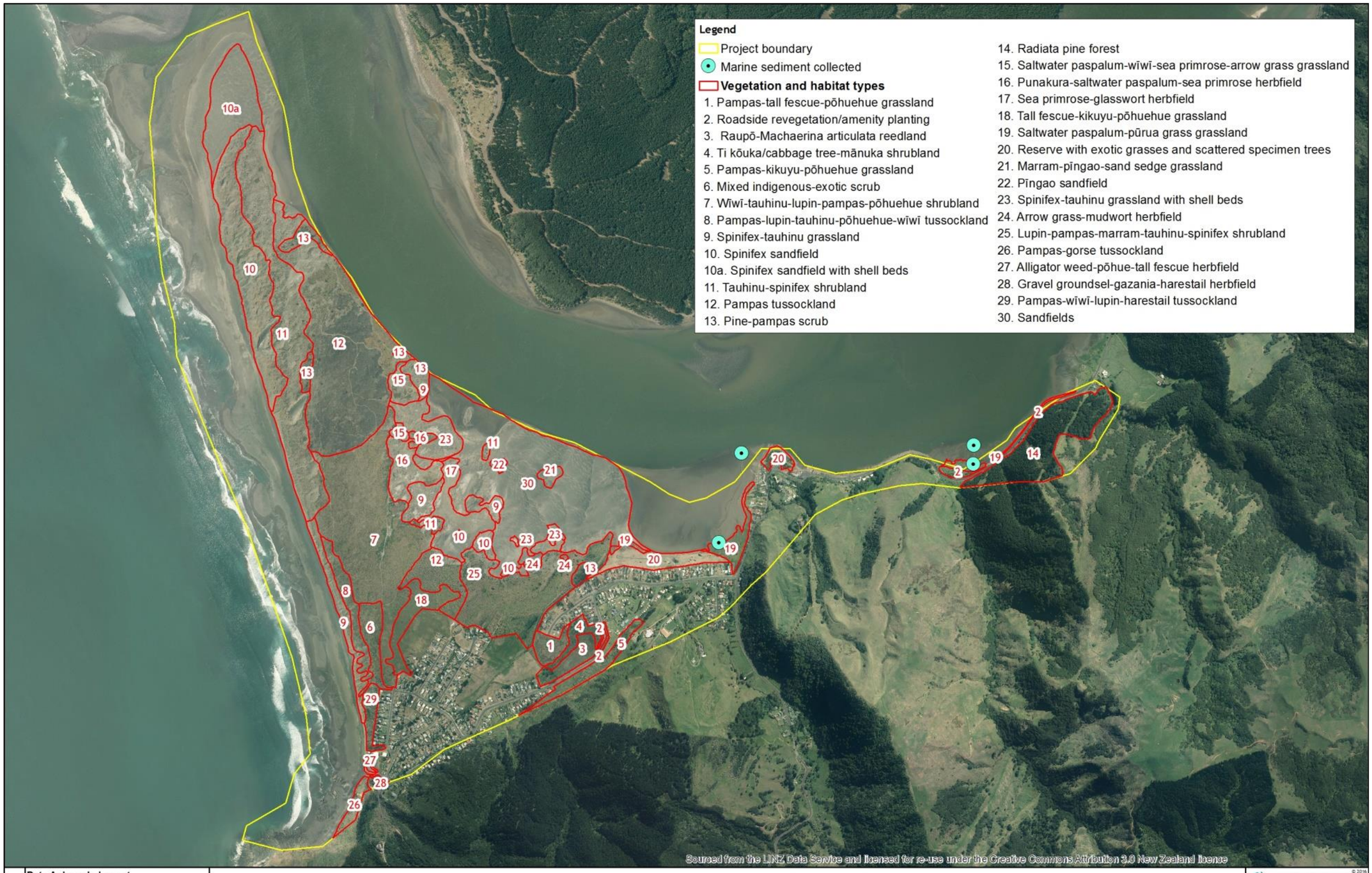


Figure 1. Habitat and vegetation types within project area at Port Waikato Spit

Aquatic surveys, including fish survey (Appendix 4), aquatic freshwater invertebrate collection (Appendix 5) and freshwater nutrient analysis (Appendix 6), were carried out within two watercourses within the project area; marine sediment samples were also collected at the mouth of the watercourses and analysed (Appendix 7). Aquatic freshwater invertebrate samples were preserved in ethanol until they were analysed by the Wildlands in-house invertebrate specialist. Water and sediment samples were kept chilled and sent to Hills Laboratories Ltd, Hamilton for analysis within 12 hours of collection. Representative site photographs were also taken in the field (Appendix 8). High priority management areas were identified (Figure 3).

5. GENERAL SITE DESCRIPTION AND BACKGROUND

Project Area Overview

The project area (*c.*414 ha) extends from the top of the spit to just south of Maunsell Road, and east to west from the just beyond the surf club at Sunset Beach to 2273 Tuakau Bridge-Port Waikato Road in the east. The project area contains a tributary of the Waikato River, Maraetai Stream, which is located east of the main township. There are also several smaller unnamed overland flow paths.

The project area contains most of the private residential land within the Port Waikato township. Private land was not a priority for this project (Council's main priorities lie with the reserves), but recommendations regarding management of private land are included where appropriate.

The focus of this project is the sand dunes, including both the Port Waikato Sand Dunes Recreation Reserve and the Ngati Karewa Ngati Tahina Trust sand dunes; together, these areas cover *c.*325 ha.

The project area is characterised by coastal sand dunes with a mixture of indigenous and exotic vegetation. The southern dunes, especially those that border residential property, are dominated by exotic vegetation, including a range of pest plant species (Plate 1). Parks and reserves are characterised by mown grass and occasional large indigenous and exotic specimen trees. Roadsides are characterised by mixed indigenous-exotic revegetation plantings. Fewer exotic plant species occur to the north, away from the Port Waikato township, although pockets of pest plant infestations are still present (Plate 2). The eastern-most extent of the project area is a pine plantation with a small gully of indigenous bush.

In 2008, a large fire swept through the sand dunes, destroying approximately 17.5 ha of vegetation, including habitat that is known to support the threatened katipō spider (*Latrodectus katipo*) (Plates 2 and 3).

The spit has extended northwards over the past 150 years; dunes on the northern side of the river have eroded and the river mouth has shifted northwards (Tonkin & Taylor 2007).

The ownership of the spit is split from north to south, with the western side owned and operated by Waikato District Council (Port Waikato Sand Dunes Recreation Reserve) and the eastern side owned by Ngati Karewa Ngati Tahinga Trust.

Landforms and Coastal Dynamics

The low-lying Port Waikato sand spit is characterised by sand dunes ranging in altitude from sea level to *c.*20 m asl along the rugged west coast of the North Island. The dynamic environment that characterises the sand spit carries risk of erosion and coastal inundation that compromise the health and integrity of the ecological functioning of the dunes, as well as the health and safety of the township. The significant shoreline advance that the spit has experienced over the past 150 years means that considerable caution is warranted in terms of coastal inundation. The soft shore dynamics of the spit mean that future shoreline changes may occur; such changes include shoreline retreat, which has occurred at Whatipu on the northern side of the Manukau Harbour after over a century of advance, and breaching of the spit, which would result in serious implications for the township at Port Waikato (Tonkin & Taylor 2007).

Parts of the dunes are subject to active erosion and a considerable stretch extending northwards from the small stream at the western end of Maunsell Road has a very steep, and tall, eroding face on the seaward margin. This area has been subject to active back-cutting and inland retreat and has been of particular concern in the vicinity of the surf club and associated carpark.

Vegetation Monitoring

Waikato Regional Council carries out vegetation monitoring at Port Waikato as part of their monitoring programme that surveys the Extent of Coastal Habitat of estuaries and river mouths, along with sixteen other estuaries within the Waikato Region. This programme is used as a monitoring tool highlighting indicators of ecological changes occurring in these estuaries. As part of this programme, a recent survey of exotic pest plants revealed that over 50% of the coastal habitat at Port Waikato is dominated by invasive species (Graeme 2005).

Water Quality and Sediment Monitoring

Water quality and trace elements in sediments are also surveyed at Port Waikato as part of the Waikato West Coast Estuaries sampling programme by Waikato Regional Council. The sediment at the river mouth was comprised of a higher ratio of coarse and medium grain to fine grain sediments compared to the other three estuaries sampled (Aotea Harbour, Kawhia Harbour and Raglan Harbour). Generally, the distribution of trace elements and nutrients at Port Waikato are relative to the grain size of the sediments, i.e. sediments with larger grain size had lower concentrations of trace elements, while finer sediment contained higher concentrations of trace elements (Rumsby 2009). Water quality at the river mouth was generally high (i.e. the concentrations of most trace elements were below the analytical method detection limit with the exception of arsenic and *Escherichia coli*) (Rumsby 2009).

Overall, Port Waikato sediments were concluded to be the most enriched by anthropogenic and natural geothermal activity of the four estuaries surveyed by Rumsby (2009). Anthropogenic activity within the catchment includes a myriad of land uses that have resulted in contamination of the Waikato River's sediments and water by nutrients, trace elements and heavy metals. Rates of sedimentation have also increased substantially, resulting in degraded water quality of the country's longest and most significant river system (Waikato Regional Council 2008). Many of the contaminants and much of the sediment accumulates in the estuary at Port Waikato.

6. ECOLOGICAL CONTEXT

Port Waikato spit is located on the west coast of the North Island, almost equidistant between the Manukau Heads and Raglan and is within the Meremere Ecological District. Meremere Ecological District (*c.*100,000 ha) extends from Port Waikato along the west coast to Lake Waikare to the east, and from Mercer in the north to Taupiri in the south. Meremere Ecological District is within the wider Waikato Ecological Region, which includes the low-lying parts of the Hauraki Plains, the middle and lower Waikato River basin, and the lower Waipa River Valley (Department of Conservation 1996). Waikato Ecological Region is characterised by lowland topography, intensive farming, widespread transformation of the natural landscape, high rural population densities, large urban populations and small remnants of indigenous wetland habitats.

Meremere Ecological District is a well-defined interior basin containing alluvial flats, shallow lakes, and remnant wetlands, including the ecologically significant Whangamarino and Mangatawhiri wetlands. The original forest cover only survives as scattered small remnants, but large areas of secondary kānuka (*Kunzea robusta*) forest are scattered throughout the ecological district, providing important habitats for indigenous fauna. Although over 70% of all dunelands in the Waikato Region are significantly modified (Waikato Regional Council 2011), the sandspit at Port Waikato is considered to be of high natural value. The extensive wetlands in the upper reaches of the estuary are also significant.

Wider Catchment

The Waikato River, which drains into the sea at Port Waikato, is New Zealand's longest and most significant river. It has a catchment of *c.*14,456 km^2 and a mean flow of 400 m^3/s (Waikato Regional Council 2008). This translates to a natural travel time (i.e. without taking into account delay by hydro-electric dams) of four to five days from Taupō to Port Waikato.

The large catchment, it's high rainfall (averaging 1,200 to 3,200 mm per year), and the high flow volumes that characterise the Waikato River result in the transportation of relatively high quantities of contaminants including nutrients, metals and suspended sediments. Many of these contaminants end up being deposited in fine sediments in the estuary at Port Waikato. Therefore, the quality of aquatic habitats within the project area is affected by the ecological health and integrity of the entire upstream catchment.

The wider Waikato River catchment varies in ecological value from highly significant in places such as the Port Waikato Spit, the headwaters at Ruapehu and the source at Lake Taupō to areas with lower ecological values including the *c.*1,420 km of eroding streambanks on pastoral land within the catchment (Waikato Regional Council 2008).

Waikato River Riparian Protection

A survey carried out in 2002 estimated that 45% of the Waikato River's total bank length had some form of riparian vegetation other than pasture (Waikato Regional Council 2008). However, only *c.*30% of the total bank length of waterways that run through pastoral land was fenced. As the survey progressed down the catchment (i.e. from the headwaters to the Tasman Sea), evidence of erosion along the banks of stream tributaries and the Waikato River itself increased, while fencing and intact riparian vegetation decreased.

7. VEGETATION AND HABITATS

Thirty vegetation and habitat types were identified within the project area, ranging from ephemeral wetlands and indigenous-dominated dunelands to forest and roadside amenity plantings. Vegetation types are mapped on Figure 1 and described below.

1. Pampas-tall fescue-pōhuehue grassland

Vegetation Type 1 sits at the end of Ashwell Drive at the southern end of the Ngāti Karewa Ngāti Tahinga owned reserve, which stretches up the spit along the eastern coastline to the top. The grassland is dominated by exotic grasses and herbs including pampas (*Cortaderia selloana*), tall fescue (*Schedonorus arundinaceus*), gravel groundsel (*Senecio skirrhodon*), cocksfoot (*Dactylis glomerata*), fennel (*Foeniculum vulgare*) and occasional boxthorn (*Lycium ferocissimum*). Locally abundant pōhuehue (*Muehlenbeckia complexa*) is present, as well as occasional emergent tī kōuka/cabbage tree (*Cordyline australis*) becoming more frequent moving away from the margins.

Exotic weeds include garden nasturtium (*Tropaeolum majus*), canna lily (*Canna indica*) and agapanthus (*Agapanthus praecox*), which are concentrated along the margins where there is evidence of dumped household garden waste.

2. Roadside revegetation/amenity planting

Vegetation Type 2 is predominantly roadside revegetation/amenity planting situated along Maunsell Drive and Tuakau Bridge-Port Waikato Road. The plantings comprise a range of indigenous species including pōhutukawa (*Metrosideros excelsa*), karo (*Pittosporum crassifolium*), taupata (*Coprosma repens*), māhoe (*Melicytus ramiflorus* subsp. *ramiflorus*), tī kōuka/cabbage tree, harakeke/New Zealand flax (*Phormium tenax*), tītoki (*Alectryon excelsus* subsp. *excelsus*), lemonwood (*Pittosporum eugenioides*), karaka (*Corynocarpus laevigatus*) and *Pseudopanax crassifolius* × *P. lessonii*. Mixed amongst the indigenous plantings are alder (*Alnus glutinosa*), swamp cypress (*Taxodium distichum*), phoenix palm (*Phoenix canariensis*) and bottlebrush

(*Callistemon* sp.) along Tuakau Bridge-Port Waikato Road, and Lombardy poplar (*Populus nigra* 'Italica'), casuarina (*Casuarina cunninghamiana*), cotoneaster (*Cotoneaster glaucophyllus*), crack willow (*Salix fragilis*) and grey willow (*S. cinerea*) along Maunsell Drive.

Along the margins of the river, agapanthus is common (planted), while pampas occurs occasionally along with garden nasturtium and tall fescue, as well as alligator weed (*Alternanthera philoxeroides*), watercress (*Nasturtium officinale*) and arum lily (*Zantedeschia aethiopica*) in the damper areas, particularly along Tuakau Bridge-Port Waikato Road.

3. Raupō-*Machaerina articulata* reedland

Raupō (*Typha orientalis*)-*Machaerina articulata* reedland (*c*.1.8 hectares) is located along Maunsell Drive at the southern extent of the Ngāti Karewa Ngāti Tahinga owned reserve (Plate 4). Within the reedland, *M. articulata* is dominant around the edges, with raupō throughout the centre. Pūrua grass (*Bolboschoenus fluviatilis*) is present along the margins, as well as pampas and pōhue (*Calystegia sepium* subsp. *roseata*). There are a few areas of grey willow shrubland along the margins.

4. Tī kōuka/cabbage tree-mānuka shrubland

The ridgeline between the dune system and the wetland is characterised by abundant tī kōuka/cabbage tree over mānuka (*Leptospermum scoparium*) (Plate 4). Whekī (*Dicksonia squarrosa*), ponga (*Cyathea dealbata*), and *Coprosma macrocarpa* are common in the sub-canopy. Understorey species include kawakawa (*Piper excelsum* subsp. *excelsum*), pōhuehue and *C. macrocarpa*. Indigenous seedlings, including those of ponga, karo, and karaka, are common in the ground cover layer, together with mātātā (*Paesia scaberula*), rautahi (*Carex geminata* agg.), and *Machaerina teretifolia*.

Exotic species are common within this vegetation type, including large infestations of pampas, wild ginger (*Hedychium gardnerianum*), tradescantia (*Tradescantia fluminensis*), and garden nasturtium, and occasional emergent grey willow.

5. Pampas-kikuyu-pōhuehue grassland

On the landward side of Maunsell Drive is a hillside dominated by pampas and kikuyu (*Cenchrus clandestinus*), with locally abundant pōhuehue. Within the grassland are occasional emergent mānuka over agapanthus, with frequent ratstail (*Sporobolus africanus*), ripgut brome (*Bromus diandrus*) and bracken (*Pteridium esculentum*), occasional woody pest plants such as Japanese spindleberry (*Euonymus japonicus*), boxthorn, and herbaceous species such as fennel.

6. Mixed indigenous-exotic scrub

At the southern end of the sand dunes, where Ocean View Road meets Mission Road, mixed indigenous-exotic scrub is characterised by occasional emergent planted pōhutukawa, *Pseudopanax crassifolius* × *P. lessonii* and banksia (*Banksia integrifolia* and *B. intermedia*) over a mix of exotic pest plants including agapanthus, lupin (*Lupinus arboreus*) and pampas with locally abundant exotic garden escapes including red hot poker (*Kniphofia praecox*), Gardners geranium (*Geranium gardneri*) and gazania (*Gazania linearis* and *G. rigens*). Wilding Norfolk pine (*Araucaria heterophylla*) and macrocarpa (*Cupressus macrocarpa*) are also present, with occasional planted tōtara (*Podocarpus totara* var. *totara*), akeake (*Dodonaea viscosa*) and tī kōuka/ cabbage tree (Plate 1).

Other species that are more common on the landward side of the track and dune slopes include quaking grass (*Briza maxima*), harestail (*Lagurus ovatus*), wīwī (*Ficinia nodosa*), vetch (*Vicia sativa*), Yorkshire fog (*Holcus lanatus*), Japanese spindleberry, watsonia (*Watsonia* sp.), houpara (*Pseudopanax lessonii*), native spinach (*Tetragonia implexicoma*), boxthorn, bushy asparagus (*Asparagus sprengeri*), climbing dock (*Rumex sagittatus*), buffalo grass (*Stenotaphrum secundatum*), cocksfoot, gravel groundsel (*Senecio skirrhodon*), and tauhinu (*Ozothamnus leptophyllus*).

7. Tauhinu-wīwī -lupin-pampas-pōhuehue shrubland

This vegetation type covers a large part of the sand dunes, and is characterised by shrubland comprising tauhinu, wīwī, and lupin with locally abundant pampas and scattered pōhuehue. Also present are small pockets of locally common exotic grasses including quaking grass, cocksfoot, and locally abundant populations of *Carex testacea*, taupata, sand wind grass (*Lachnagrostis billardierei* subsp. *billardierei*) and gazania. Around the margins of the shrubland, spinifex is common, along with scattered gravel groundsel and dune oxalis (*Oxalis rubens*).

At the southern end of this vegetation type exotic grass species are dominant; different species are prominent depending on the season. Other species present along the southern end of the shrubland include ripgut broom, hare's tail and occasional gladioli (*Gladiolus undulatus*) and Formosan lily (*Lilium formosanum*).

8. Pampas-lupin-tauhinu-pōhuehue-wīwī tussockland

This vegetation type has a similar species composition to that of Vegetation Type 7, and is situated on the leeward side of the foredune. It is dominated by pampas and lupin, while tauhinu, pōhuehue and wīwī occur slightly less frequently. Isolated populations of marram (*Ammophila arenaria*) occur occasionally throughout this unit. Additional species encountered adjacent to walking tracks include hare's tail, quaking grass, sand wind grass, Yorkshire fog, kānuka, banksia, tī kōuka/cabbage tree and spinifex with occasional dune oxalis.

9. Spinifex-tauhinu grassland

Spinifex is abundant on the windward face and ridge of the foredune together with frequent tauhinu, locally abundant sand wind grass, and occasional pīngao (*Ficinia spiralis*) (Plate 5). There are a few sand blowouts in this type (Plate 3).

Near the inland margins, wīwī and pōhuehue are locally abundant and dune oxalis occurs occasionally. The margins are dominated by exotic species including pampas, lupin, catsear (*Hypochaeris radicans*) and occasional gazania. Other species present include occasional prickly pear (*Opuntia monacantha*) and marram grass.

10. Spinifex sandfield

North of the spinifex-tauhinu grassland, an area of sandfield is characterised by frequently occurring spinifex and occasional pīngao (Plate 6). This unit extends to the top of the spit, where Caspian terns (*Hydroprogne caspia*) and banded dotterel (*Charadrius bicinctus bicinctus*) utilise the habitat for nesting.

a. Spinifex sandfield with shell beds

A sub-unit of this vegetation type includes spinifex sandfield with shell banks (Plate 7). In some parts the shell banks are more widespread and expansive. These areas provide ideal dotterel breeding habitat.

11. Tauhinu-spinifex shrubland

This vegetation type is dominated by tauhinu shrubland with frequent spinifex and scattered hawkbit (*Leontodon taraxacoides*), dune oxalis, hairy birdsfoot trefoil (*Lotus suaveolens*), wīwī, pampas, pōhuehue, *Muehlenbeckia australis* × *M. complexa* hybrid, sand wind grass, broomrape (*Orobanche minor*), sow thistle (*Sonchus oleraceus*), lupin, and exotic grasses (see Plate 1).

This area is in an erosion phase resulting in tauhinu being situated at the top of the dunes, exposed to the seaward side in some places. Maritime pine (*Pinus pinaster*) and occasional radiata pine (*P. radiata*) are scattered along the margins of the shrubland.

12. Pampas tussockland

The vegetation type comprises the *c.*17.5 ha of dunes that were burnt during a fire in 2008 (Plate 8). Following the fire this area was recolonised predominantly by pampas. Wīwī and lupin are locally abundant in this area, while Formosan lily is scattered throughout.

13. Pine-pampas scrub

The pine-pampas scrub (*c.*2-4m tall) covers a small area within the pampas tussockland that is dominated by maritime pine and occasional radiata pine with

frequent pampas, occasional elephant's ear (*Alocasia brisbanensis*), and lupin and walnut (*Juglans regia*) seedlings scattered along the margins. Small infestations of saltwater paspalum (*Paspalum vaginatum*) and marram grass are also present (Plate 9).

14. Radiata pine forest

Along the eastern extent of the project area, an area of radiata pine forest (*c.*15 m tall) is situated on the landward side of Tuakau Bridge-Port Waikato Road on private property. Small patches of remnant indigenous vegetation dominated by kānuka occur in small gullies within the pine forest.

15. Saltwater paspalum-wīwī-sea primrose-arrow grass grassland and turf field

This ephemeral wetland is characterised by abundant saltwater paspalum and isolated patches of indigenous turf field, including wīwī, sea primrose/ māakoako (*Samolus repens* var. *repens*) and arrow grass (*Triglochin striata*). Other species present include purging flax (*Linum catharticum*), *Isolepis cernua*, gravel groundsel, catchfly (*Silene gallica*), bachelor's button (*Cotula coronopifolia*), *Centipeda aotearoana*, *Lilaeopsis novae-zelandiae*, glasswort (*Sarcocornia quinqueflora*), *Gamochaeta simplicicaulis*, punakura (*Lobelia anceps*), sow thistle, sand wind grass, *Pseudognaphalium luteoalbum*, and alder.

16. Punakura-saltwater paspalum-sea primrose herbfield

This ephemeral wetland is dominated by punakura and saltwater paspalum with frequently occurring sea primrose, while *Isolepis cernua*, wīwī, oioi and sand sedge (*Carex pumila*) occur in lower abundance. Along the margins spinifex, lupin, tauhinu and harestail are common, along with occasional pampas.

17. Sea primrose-glasswort herbfield

This vegetation type comprises an ephemeral wetland dominated by sea primrose and glasswort, which has not yet been invaded by saltwater paspalum (Plate 10). Marram is locally abundant along the margins and on dry islands within the ephemeral wetland.

18. Tall fescue-kikuyu-pōhuehue grassland

This unit is an ephemeral wetland dominated by exotic grasses and herbs, including tall fescue (*Schedonorus arundinaceus*), kikuyu (*Cenchrus clandestinus*) and pōhuehue (*Muehlenbeckia complexa*) along with Yorkshire fog, lotus (*Lotus pedunculatus*), gypsy wort (*Lycopus europaeus*), and creeping bent (*Agrostis stolonifera*); climbing dock (*Rumex sagittatus*) and blackberry (*Rubus fruticosus* agg.) are also present. Indigenous species within this unit include occasional emergent tī kōuka (cabbage tree), sea primrose, kiokio (*Blechnum novae-zelandiae*), and spike sedge (*Eleocharis acuta*).

19. Saltwater paspalum-pūrua grass grassland

A damp seepage dominated by saltwater paspalum with frequent patches of pūrua grass and scattered *Schoenoplectus pungens*, along with other exotic grasses and herbs such as orache (*Atriplex prostrata*) and tall fescue. There is a bank around the margins of the seepage which is vegetated with buffalo grass, tall fescue, and pōhuehue. At the western extent of this vegetation type, patches of alligator weed, reed sweetgrass (*Glyceria maxima*), and King Island melilot (*Melilotus indicus*) are present with occasional pampas, gladioli, gravel groundsel, *Isolepis cernua*, sow thistle, and oat grass (*Arrhenatherum elatius* subsp. *elatius*).

20. Mown grass and specimen trees

These areas are reserves. The vegetation cover is mown exotic grasses with scattered specimen trees, including pōhutukawa, karo, tarata (*Pittosporum eugenioides*), tōtara, and banksia.

21. Marram-pīngao-sand sedge grassland

This type comprises isolated patches of sandfield dominated by pīngao and sand sedge being invaded by marram (Plate 11). Elephant's ear is scattered throughout the margins of this vegetation type near the river, indicating it was washed down from gardens or was dumped upriver.

22. Pīngao sandfield

A small area of sandfield with occasional pīngao and locally abundant marram along the margins and in isolated pockets is present throughout the eastern side of the spit.

23. Spinifex-tauhinu grassland with shell beds

This type comprises spinifex dominated grassland with scattered tauhinu and frequent shell beds. Other species present include pampas, sand wind grass and small amounts of pīngao. Dead pīngao roots are visible (Plate 12), indicating this species used to be more widespread.

Shell beds within this unit are generally relatively unvegetated, with occasional tauhinu, wīwī and pampas. On margins, occasional marram and walnut seedlings are present in low abundance.

24. Arrow grass-mudwort herbfield

This herbfield is dominated by arrow grass and mudwort (*Limosella lineata*) together with toad rush (*Juncus bufonius* var. *bufonius*), fleabane (*Conyza sumatrensis*), marram and sand sedge. A mixture of indigenous and exotic grasses, sedges and herbs including saltwater paspalum, sand sedge, marram, penny royal (*Mentha pulegium*), hairy birdsfoot trefoil, punakura, and *Lilaeopsis novae-zelandiae* join these species along the margins.

a. *Lilaeopsis novae-zelandiae* dominated herbfield

A small sub-unit within the arrow grass-mudwort herbfield comprises pockets of locally common *Lilaeopsis novae-zelandiae*, with occasional marram.

b. Seepage dominated by *Isolepis cernua*-punakura sedgeland

Another sub-unit of the above herbfield is characterised by a damp seepage dominated by *Isolepis cernua* and punakura, along with toad rush, hyssop loosestrife (*Lythrum hyssopifolia*), hawkbit, tarweed (*Parentucellia viscosa*), hairy birdsfoot trefoil, and *Gamochaeta simplicicaulis*.

c. Sand sedge sedgeland

Locally common sand sedge occurs with scattered marram, wīwī, scrambling fumitory (*Fumaria muralis*), and beggar's tick (*Bidens frondosa*).

25. Lupin-pampas-marram-tauhinu-spinifex shrubland

This vegetation type consists of a mixture of grassland dominated by pampas, lupin and spinifex, and tauhinu-dominated shrubland. Other species present include occasional emergent banksia, maritime pine, brush wattle, wīwī, and sand wind grass. Exotic grasses and herbs present include hairy birdsfoot trefoil, tarweed, Yorkshire fog, wild carrot (*Daucus carota*), hawkbit, and broad-leaved dock (*Rumex obtusifolius*).

26. Pampas-gorse tussockland

Pampas and gorse are co-dominant on a hillside to the south of the Port Waikato Surf Club, together with occasional emergent pōhutukawa, karo, harakeke and ponga (Plate 13). Agapanthus occurs frequently along with pōhuehue, tall fescue, buffalo grass and a mix of exotic grasses and herbs, including panahi (*Calystegia soldanella*). There is occasional bracken, mingimingi (*Leucopogon fasciculatus*), sow thistle, and lupin.

27. Alligator weed-pōhue-tall fescue herbfield

On the northern side of the pampas-gorse tussockland is a small stream which flows through exotic herbs and grasses including alligator weed and tall fescue, and also pōhue. Other species present along the fringes include gravel groundsel and pampas.

28. Gravel groundsel-gazania-harestail herbfield

In front of the Surf Club car park are stacked tyres filled with gravel and groundsel-gazania-harestail herbfield and occasional pōhutukawa seedlings. Other species present include wīwī and creeping bent.

29. Pampas-wīwī-lupin-harestail tussockland

On the seaward side of the residential houses along Ocean View Road, pampas and wīwī are co-dominant with common lupin and harestail, and frequent emergent pōhutukawa, karo, Norfolk Island pine (*Araucaria heterophylla*) and banksia. Common exotic grasses and herbs include Yorkshire fog, cocksfoot, buffalo grass, agapanthus, ivy (*Hedera helix*), gaillardia (*Gaillardia ×grandiflora*), ice plant (*Carpobrotus chilensis* and *C. edulis*), geranium (*Pelargonium* sp.), gazania, and buffalo grass. Spinifex, pīngao, taupata, harakeke, pōhue, tī kōuka (cabbage tree), and *Pseudopanax lessonii* × *P. crassifolius* are also present, with occasional boxthorn, pig's ear (*Cotyledon orbiculata*), and native spinach.

30. Sandfields

Open sandfields with little to no vegetation occur throughout much of the northern and eastern parts of the spit. These areas are likely inundated by coastal waters during spring tides and freshwaters after high rainfall. As a result, they are prone to significant sand movement, generally preventing vegetation establishment.

8. FLORA

8.1 Overview

Two hundred and seventy vascular plant species were recorded within the project area, comprising 82 indigenous species and 188 exotic and naturalised species. Two At Risk species (as per de Lange *et al.* 2013) - pīngao (At Risk-Declining) and *Centipeda aotearoana* (At Risk-Naturally Uncommon) - were noted within the project area.

Pīngao was scattered throughout the northern half of the spit in low abundance, sometimes mixed with spinifex. Decayed pīngao roots in eroded areas suggest that this species was once more common than it is now. Pīngao is wind-pollinated and therefore isolated individuals are not likely to be fertilised. Pīngao is threatened by competition from marram, dune stabilisation and compaction, browsing, particularly by rabbits, and trampling, particularly by off-road vehicles.

Centipeda aotearoana populations are present within the ephemeral wetlands located in damp seepages along the south-eastern side of the spit. These wetlands, and their associated species, are vulnerable to damage by pedestrians, cycles, animals and vehicles.

The native flora was previously more diverse. Kirk (1870) recorded the following: *Euphorbia glauca* (At Risk-Declining; note this species is now not known to occur naturally in the Meremere Ecological Region likely due to habitat modification) in moist places; *Potentilla anserinoides* previously abundant at the foothills on the landward side of the spit; *Callitriche muellerii* and *Lilaeopsis novae-zelandiae* in swampy areas; *Olearia albida* in sheltered places; *Astelia banksia* along the cliffs; and *Zannichellia palustris* in shallow gravelly sites (Kirk 1870). None of these species were encountered during the current survey.

8.2 Pest plants

Seventeen plant species recorded in the project area are listed as pest plants in the Waikato Regional Council Regional Pest Management Plan (RPMP; WRC 2014); an additional 66 species were identified as environmental pest plants because of their ability to naturalise and compete with indigenous flora for habitat (these are listed in Appendix 2). The control of all these 83 species is recommended within the project area, and the monitoring of all of these species is recommended within private property[1].

The distribution and abundance of RPMP pest plants and other environmental pest plant species present within the dunes are mapped in Figure 2. Pest plants that were identified within private property are not mapped but their presence in adjacent reserve/dune areas should be monitored to ensure they do not spread into the dunes. If any of the pest plant species identified in Appendix 2 (and below) are recorded in the dunes, then they should be controlled.

Pest plants are prioritised according to the five categories in the Waikato Regional Council RPMP (WRC 2014): (i) Exclusion, (ii) Eradication, (iii) Progressive Containment, (iv) Sustained Control and (v) Site-led. A further class of plants are identified in this report: (vi) pest plant species not currently covered by the RPMP (WRC 2014), but for which control is recommended. Brief descriptions of the distribution of all pest plant species are set out below.

Exclusion Pest Plants

Plants classified as 'Exclusion' are present within the Waikato Region, but have not yet become established and therefore the classification is aimed at preventing the establishment of these species. Exclusion plants are considered to be of high potential threat to the region.

No Exclusion Pest Plant species were recorded in the project area.

Eradication Pest Plants

Eradication pest plants are of limited distribution or density in the region or areas of the region. The aim is to eradicate these plants from known sites in the region, as eradication from the entire region may not be practicable (WRC 2014).

[1] It is recognised that control of weeds on private property is outside the mandate of Council. However see Section 15 regarding community involvement.

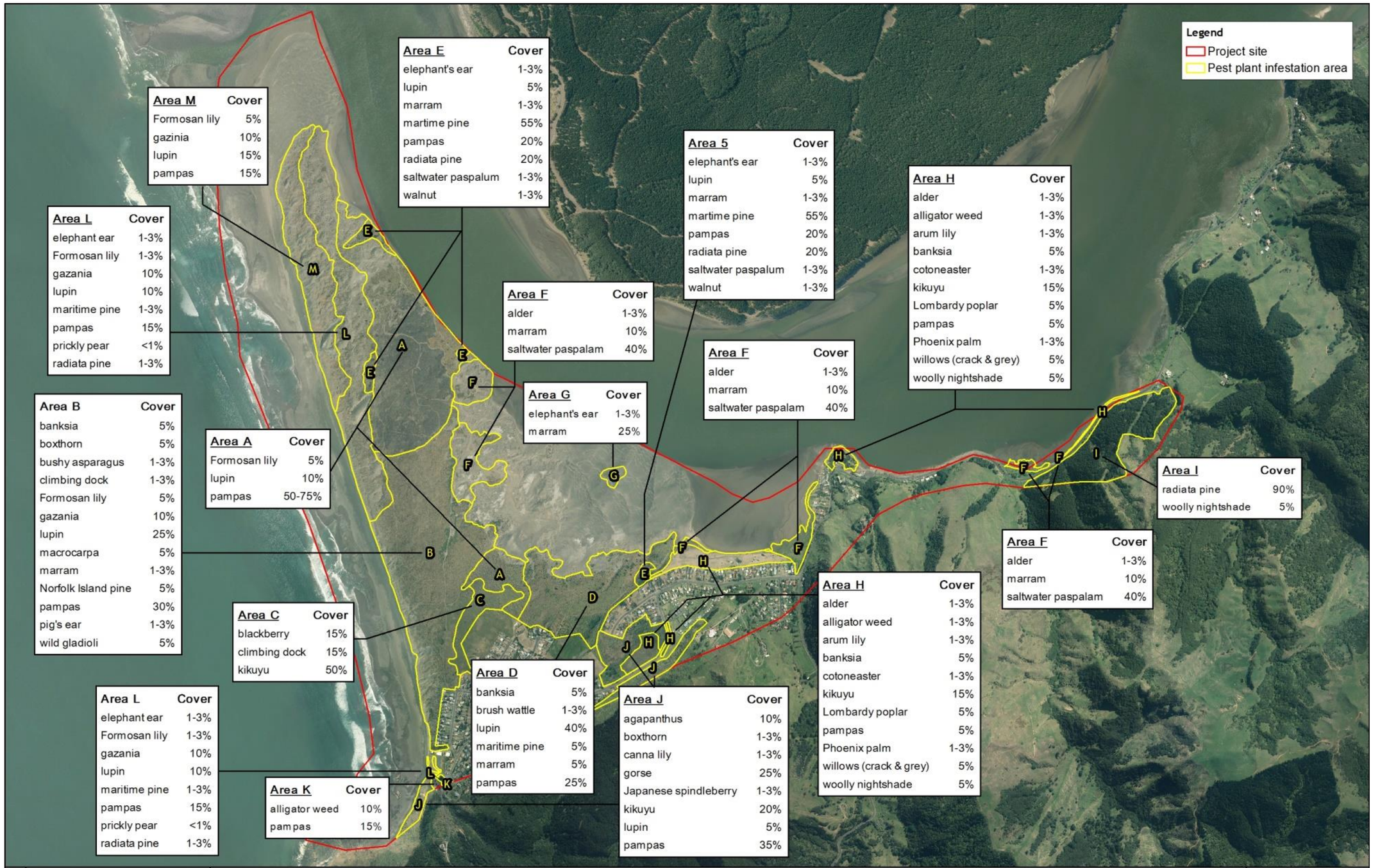


Figure 2. Distribution and abundance of pest plants at Port Waikato

The two Eradication Pest Plants present in the residential area of Port Waikato:

- Lantana (*Lantana camara*)
- Mile-a-minute (*Dipogon lignosus*)

Progressive Containment Pest Plants

Progressive Containment Pest Plants are those that are abundant in certain habitats or areas in the region. The Progressive Containment programme is aimed to contain and reduce the geographic distribution of the plants to an area over time (WRC 2014).

Four Progressive Containment Pest Plants were recorded within the project area during the survey:

- Alligator weed (*Alternanthera philoxeroides*)
- Kahili ginger, wild ginger (*Hedychium gardnerianum*)
- Pampas (*Cortaderia selloana*)
- Woolly nightshade (*Solanum mauritianum*)

Sustained Control Pest Plants

Sustained Control Pest Plants are those that are abundant in certain habitats or areas in the region and can be maintained at low densities to maintain manageable impacts. The Sustained Control programme is aimed to maintain low densities of pest plants in an area where their externality impacts are manageable (WRC 2014).

Three Sustained Control Pest Plants were recorded within the project area during the survey:

- Chinese privet (*Ligustrum sinense*)
- Gorse (*Ulex europaeus*)
- Tree privet (*Ligustrum lucidum*)

Site-led Pest Plants

Site-led Pest Plants are those that are abundant in certain habitats or areas in the region and are capable of causing damage to a place and its values. The Site-led programme is aimed to exclude, eradicate, contain, reduce or control plants that are capable of causing damage (WRC 2014).

Eight Site-led Pest Plants were recorded within the project area during the survey:

- Busy asparagus (*Asparagus sprengeri*)
- Century plant (*Agave americana*)
- Common walnut (*Juglans regia*)
- Crack willow (*Salix fragilis*)
- Grey willow (*Salix cinerea*)
- Reed sweetgrass (*Glyceria maxima*)
- Royal fern (*Osmunda regalis*)

- Saltwater paspalum (*Paspalum vaginatum*)

Environmental Pest Plants not in the RPMP 2014-2024

Environmental pest plant species are not identified as pest plants in the RPMP (WRC 2014), but are having adverse ecological effects and therefore their control is recommended. They are present in small to moderate and sometimes severe infestations within the project area.

Sixty-five species in this category were recorded in the project area and in residential areas and/or private property around Port Waikato township:

- Arum lily (*Zantedeschia aethiopica*)
- Banana palm (*Musa ×paradisiacal*)[1]
- Banksia (*Banksia intermedia* and *B. integrifolia*)
- Bear's breeches (*Acanthus mollis*)[1]
- Blackberry (*Rubus fruticosus* agg.)
- Bottlebrush (*Callistemon* sp.)[1]
- Boxthorn (*Lycium ferocissimum*)
- Brush wattle (*Paraserianthes lophantha*)
- Canna lily, Indian shoot (*Canna indica*)[1]
- Cape honeysuckle (*Tecomaria capensis*)[1]
- Castor oil plant (*Ricinus communis*)[2]
- Chinese windmill palm (*Trachycarpus fortunei*)[1]
- Climbing dock (*Rumex sagittatus*)[1]
- Common alder (*Alnus glutinosa*)
- Coral tree (*Erythrina ×sykesii*)[1]
- Cotoneaster (*Cotoneaster glaucophyllus*)
- Dally pine (*Psoralea pinnata*)
- Elephants ears (*Alocasia brisbanensis*)
- False acacia, black locust, robinia (*Robinia pseudoacacia*)[1]
- Feijoa (*Feijoa sellowiana*)[1]
- Fig (*Ficus carica*)[1]
- Formosan lily (*Lilium formosanum*)
- Gaillardia (*Gaillardia ×grandiflora*)[1]
- Garden nasturtium (*Tropaeolum majus*)[1]
- Gazania (*Gazania linearis* and *G. rigens*)
- Geranium (*Pelargonium* sp.)
- German ivy (*Delairea odorata*)
- Gladioli (*Gladiolus undulatus*)
- Grape (*Vitis vinifera*)[1]
- Ice plant (*Carpobrotus chilensis* and *C. edulis*)
- Indian hawthorn (*Rhaphiolepis umbellata*)
- Iris (*Iris* sp.)
- Italian arum (*Arum italicum*)[1]

[1] Only present on private property within the study area, i.e. not found within the dunes.
[2] Present only on private property within the study area, i.e. not found within the dunes.

- Ivy (*Hedera helix*)
- Japanese honeysuckle (*Lonicera japonica*)
- Japanese spindleberry (*Euonymus japonicus*)
- Jasmine (*Jasminum polyanthum*)[1]
- King Island melilot (*Melilotus indica*)
- Lombardy poplar (*Populus nigra* 'Italica')
- Loquat (*Eriobotrya japonica*)[1]
- Lupin (*Lupinus arboreus*)
- Macrocarpa (*Cupressus macrocarpa*)
- Maritime pine (*Pinus pinaster*)
- Marram (*Ammophila arenaria*)
- Montbretia (*Crocosmia ×crocosmiiflora*)
- Moreton Bay fig (*Ficus macrophylla*)[1]
- Norfolk Island pine (*Araucaria heterophylla*)
- Phoenix palm (*Phoenix canariensis*)
- Pig's ear (*Cotyledon orbiculata*)
- Prickly pear (*Opuntia vulgaris*)
- Radiata pine (*Pinus radiata*)
- Rain daisy, dimorphotheca (*Osteospermum fruticosum*)[1]
- Red hot poker (*Kniphofia praecox*)
- Sheoak (*Casuarina cunninghamiana*)
- Silky oak (*Grevillea robusta*)[1]
- Silver poplar (*Populus alba* 'Nivea')[1]
- Swan plant (*Gomphocarpus fruticosus*) [1]
- Sydney golden wattle (*Acacia longifolia*)
- Tasmanian ngaio (*Myoporum insulare*)
- Tortured willow (*Salix matsudana* 'Tortuosa')
- Tradescantia (*Tradescantia fluminensis*)
- Tuber ladder fern (*Nephrolepis cordifolia*)
- Velvet groundsel (*Roldana petasitis*)
- Watsonia (*Watsonia* sp.)
- Yucca (*Yucca elephantipes*)

Pest Plants by Habitat Type

Pest plants are common throughout the southern dunes and along the margins, particularly along the eastern coast of the spit. A survey carried out by the Waikato Regional Council in 2008 found that invasive exotic species comprised 30-50% cover within the coastal vegetation surrounding Port Waikato (Waikato Regional Council 2011). This survey supports this finding, as approximately half of the dunelands are dominated by exotic species, and much of the remaining duneland is not vegetated (i.e. it comprises sandfields). Many of the pest plants encountered along the margins and throughout the southern dunes are garden escapes or have established as a result of garden waste being dumped in the dunes or upriver. Such species found within the project area include alder, prickly pear, geranium, German ivy (*Delairea odorata*), ivy, jasmine (*Jasminum polyanthum*), Japanese honeysuckle (*Lonicera japonica*),

[1] Present only on private property within the study area, i.e. not found within the dunes.

agapanthus, aloe (*Aloe arborescens*), kangaroo paws (*Anigozanthos* sp.), arum lily (*Zantedeschia aethiopica*), canna lily (*Canna indica*), gladioli, red hot poker, Formosan lily, gaillardia (*Gaillardia ×grandiflora*), gazania, bear's breeches (*Acanthus mollis*), ice plant, century (*Agave americana*), pig's ear, elephant's ear, everlasting pea (*Lathyrus latifolius*), and garden nasturtium. All of these species compromise the ecological integrity of the sensitive dune system of the Port Waikato spit. A map showing the distribution and density of pest plants within the project area is provided in Figure 2; only pest plant species of high priority for control that are not on private property are listed on the map. A full list of exotic species within the project area is provided in Appendix 2.

Pest plants present that are priorities for control within the duneland system are listed below according to their presence in respective vegetation types (described in the previous section):

No.	Vegetation Type	Pest Plant Species	Notes
3	**Raupō-*Machaerina articulata* reedland**	Grey willow	Grey willow occurs occasionally along the margins; this is priority for control
6	**Mixed indigenous-exotic scrub**	Macrocarpa, Norfolk Island pine, bushy asparagus, climbing dock, agapanthus, gazania, boxthorn	Occur in varying abundance; priorities for control
11	**Tauhinu-spinifex shrubland**	Wilding maritime pine	Scattered in abundance; high priority for control
13	**Pine-pampas scrub**	Maritime pine, elephant's ear, walnut seedlings, saltwater paspalum, marram	Saltwater paspalum and marram occur in low abundance throughout this unit and should be controlled to minimise their spread into the northern dunes where they are currently not present or are present in low abundance
20	**Mown grass and specimen trees**	Banksia	Consideration should be given to controlling all banksia within the project area as they have the potential to naturalise into the dunes
22	**Pīngao sandfield**	Marram	High priority for control as it is abundant along the margins and isolated pockets
23	**Spinifex-tauhinu grassland with shell beds**	Marram, walnut seedlings, pampas	All of these occur occasionally and are therefore priority for control
24	**Arrow grass-mudwort herbfield**	Marram, saltwater paspalum	Saltwater paspalum is dominant in some places and should be removed in a staged manner; where marram and saltwater paspalum are less abundant, control should be undertaken as a priority

9. FAUNA

9.1 Avifauna

Twenty-two indigenous and fourteen exotic bird species were recorded within the project area (Appendix 3). Nine of these indigenous bird species are considered 'Threatened' or 'At Risk' by Robertson *et al*. (2013); these are listed in Table 1.

Table 1: Avifauna recorded within project area during site visit on 7 December 2016.

Species	Common Name	Threat Ranking
Botaurus poiciloptilus	Matuku; Australasian bittern	Threatened-Nationally Endangered
Charadrius bicinctus bicinctus	Tūturiwhatu; banded dotterel	Threatened-Nationally Vulnerable
Haematopus unicolor	Tōrea, tōrea pango, variable oystercatcher	At Risk-Recovering
Himantopus himantopus leucocephalus	Poaka; pied stilt	At Risk-Declining
Hydroprogne caspia (*Sterna caspia*)	Taranui; Caspian tern	Threatened-Nationally Vulnerable
Larus bulleri	Black-billed gull	Threatened-Nationally Vulnerable
Larus novaehollandiae scopulinus	Tarāpunga; red-billed gull	Threatened-Nationally Vulnerable
Phalacrocorax carbo novaehollandiae	Kawau; black shag	At Risk-Nationally Uncommon
Phalacrocorax varius varius	Kāruhiruhi; pied shag	Threatened-Nationally Vulnerable

In addition to the species observed, the northern New Zealand dotterel (*Charadrius obscurus aquilonius*), classified as 'Threatened-National Vulnerable', is known to nest at the northern end of the spit.

9.2 Terrestrial invertebrates

Dunes at the Port Waikato Spit are known to provide habitat for katipō (*Latrodectus katipo*). Katipō are classified as At Risk-Declining (Sirvid *et al*. 2012), protected under the Wildlife Act, and are iconic fauna of New Zealand's coastal sand dune systems.

9.3 Aquatic fauna

9.3.1 Fish

The New Zealand Freshwater Fish Database (NIWA 2016; accessed 11 January 2016) contains records of 17 indigenous and nine exotic fish species in the lower Waikato River catchment (Appendix 4). These records cover a large geographic area with a wide variety of habitats and it is likely that many of the species recorded are not likely to be present within streams within the project area. Dead koi carp (*Cyprinus carpio*) washed downstream from further up the catchment were observed on the beach close to the Cobourne Reserve.

Fish communities in two streams within the project area were sampled using electric-fishing. The first stream reach (hereafter 'Watercourse 1') ran in a southerly direction adjacent to Port Waikato Road from the intersection of Port Waikato Road and Maunsell Road (Figure 1). Īnanga (*Galaxias maculatus*) and longfin eel (*Anguilla dieffenbachii*) were seen in this stream. The second stream (hereafter 'Watercourse 2') was located in an area of radiata pine forest close to the eastern extent of the project area (Figure 1). Cran's bully (*Gobiomorphus basalis*) and banded kōkopu (*Galaxias fasciatus*) were recorded within this stream reach. Īnanga and longfin eel are classified as 'At Risk-Declining' (Goodman *et al*. 2014).

9.3.2 Aquatic macroinvertebrates

Kick-nets and dip-nets were used to collect samples of freshwater invertebrates from the water column in Watercourses 1 and 2, in the stream bed sediments, and on submerged vegetation and woody debris (c.f. Stark and Maxted 2004). Samples were preserved in ethanol for later analysis in a laboratory. Invertebrates collected were identified and counted (Appendix 5).

Watercourse 1

Eight taxa were recorded in the sample from Watercourse 1 and, with the exception of twenty-five introduced snails from the Family Lymnaeidae and four freshwater shrimp (*Paratya curvirostrum*), all were pollution-sensitive EPT[1] taxa. A high diversity of EPT taxa indicates that a stream has very good water quality. The most abundant taxon in the sample from Watercourse 1 was *Deleatidium* mayfly larvae (27 individuals). *Deleatidium* larvae have been assigned as tolerance score of 8[2] (Landcare Research 2015) and are often found in stony-bottomed streams with good water quality. One taxon (*Zelandoperla* stonefly larvae) has been assigned a tolerance score of 10, the highest score possible.

The MCI (Macroinvertebrate Community Index) score was 130. This score is within the "excellent" biological quality class (Stark and Maxted 2007).

Watercourse 2

Five taxa were recorded in the sample form Watercourse 2. Three of these taxa (*Deleatidium* mayfly larvae, and *Costachorema* and *Helicopsyche* caddisfly larvae) are in the pollution sensitive EPT group and are again indicative of good water quality within the sample reach. None of the taxa recorded in this sample had a tolerance score of less than 5 and this is another indication of an unpolluted stream.

The MCI (Macroinvertebrate Community Index) score was 144. This score is within the "excellent" biological quality class (Stark and Maxted 2007).

[1] Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies).

[2] The lower the score the greater the tolerance of poor water quality. Scores range from 1 to 10, with 1 being species very tolerant of pollution and 10 being species only present in clean, unpolluted freshwater.

9.3.3 Maui's Dolphin

The west coast from Taranaki to Muriwai is habitat for Maui's dolphin (*Cephalorhynchus hectori maui*), which is classified as critically endangered according to the IUCN Red List of Threatened Species (Reeves *et al.* 2013). Maui's dolphins are known to utilise the west cost of the Port Waikato spit, as well as the Waikato River mouth as feeding grounds. No Maui's dolphins were observed during the site visit.

9.4 Introduced mammals

A Norway rat (*Rattus norvegicus*) was observed in the canal at the end of the Maraetai Bay walkway. European rabbit (*Oryctolagus cuniculus*) sign was plentiful in the dunes and brushtail possum (*Trichosurus vulpecula*) droppings were observed in radiata pine forest. It is probable that the full suite of introduced mammalian predators is present within the project area: mustelids (stoat, *Mustela erminea*; ferret, *M. furo*; weasel, *M. nivalis vulgaris*), feral and domestic cat (*Felis catus*), house mice (*Mus musculus*), European hedgehog (*Erinaceus europaeus*), and ship rats (*Rattus rattus*).

Horse (*Equus caballus*) sign was plentiful throughout the dunes, particularly throughout the damp turfs and herbfields. These areas are likely used for exercise and recreation by local residents.

A list of introduced animals encountered during the survey is provided in Appendix 3.

10. SEDIMENT AND WATER SAMPLES

Assessment of the catchment within the project area included two stream tributaries to the Waikato River, and subsequently the estuary around the Port Waikato area. Sediment and water samples were collected at each of these two tributaries in order to detect issues affecting water quality and ecological health of the aquatic environments. Results from the sediment and water samples re provided in more detail below.

10.1 Sediment

Sediments within aquatic ecosystems accumulate chemical contaminants from both natural weathering processes and human-driven changes of the surrounding terrestrial environment. As a result of these processes, large quantities of nutrients, metals, and sediment can be transported into freshwater, estuarine, and marine environments by storms and floods. The result is a series of potential adverse impacts on the ecological health and integrity of the aquatic environment including halting of biological processes and ecosystems services. Some of the most influential human-driven land-use changes that affect aquatic environments include land conversion and development, agriculture and farming, as well as industrial activities. Therefore, analysis of sediments from aquatic systems can provide useful information on land use practices within the catchment.

Marine sediment analysis carried out within the project area included two small catchments within the lower reach of the Waikato River. Upper and lower intertidal sediments were collected at each of these locations to compare the potential distribution of contaminants along a longitudinal gradient from the tributary to the estuarine environment. Both samples were analysed for (1) inorganic nutrients including total recoverable phosphorus, ammonium, nitrite, nitrate and total nitrogen, (2) heavy metals including arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc, and (3) grain size from 2 mm to 63 μm.

Marine sediments have not been historically or widely studied in New Zealand, so there is little background information with which to compare results presented here. Some local authorities, including Auckland Council and Waikato Regional Council, have a marine sediment monitoring programme, the latter which includes sites at Port Waikato. Two of the 19 sites that WRC sampled in 2008[1] coincide closely with the two sites selected for this project. This allows a small, but not statistically significant, comparison between the 2008 sample and our 2015 sample. The referenced site locations sampled in 2015 are shown in Figure 1, and the results are summarised below, with more detail in Appendix 7.

Inorganic Nutrients

Inorganic nutrients showed high levels of phosphorus (over 500 mg/kg dry weight) in the western lower intertidal sample (W1), and both of the eastern samples (E1 and E2). However, these results are lower than the two WRC sites that correlate: PW9 (near W1 and W2) was 690 mg/kg and PW10 (near E1 and E2) was 780 mg/kg in 2008. High phosphorus is likely sourced from phosphate-fertiliser used within the catchment, usually for improving growth of pasture for grazing livestock.

Nitrogen and derivatives were not elevated; these were not tested for in 2008.

Metals

Metals, including trace elements and heavy metals, were lower in 2015 samples compared to samples collected in 2008. In 2008 the concentration of arsenic exceeded the Australian and New Zealand Guidelines for Fresh and Marine Water Quality document (ANZECC 2000 Guidelines) ISQG-high guideline values at both sites, while in 2015 arsenic concentrations were under the guidelines levels at both the western sites but exceeded the maximum in both the eastern samples. The elevated level of arsenic is thought to be related to the geothermal inputs into the Waikato River, which is unique to this estuarine environment (Robinson *et al.* 1995).

Some trace element concentrations were slightly elevated, including cadmium at the upper intertidal western site, copper at the lower intertidal eastern site, and zinc at the same site. These correlate with the 2008 results and are likely related to the high proportion of fine grain size. All other trace elements and heavy metals were within the range of natural background concentration within Waikato soils (Taylor 2015).

[1] This was the first sampling of the monitoring programme. The Council intends to resample these points in the future.

Grain Size

Due to ongoing land use changes the most important land-based stressor in the New Zealand context is sedimentation, which impacts both water clarity via increase of suspended sediments and deposition effects resulting in adverse impacts on benthic flora and fauna (Morrison *et al.* 2008).

The results of grain size analysis were similar between 2008 and 2015 samples, with fine grain (<63µm) being the least abundant from 13% to 25% across all samples. Due to the majority composition of particles being of medium and/or coarse grain size, the Port Waikato system is more typical of a sandy river environment than a low-energy estuarine system (WRC TR0908).

10.2 Water samples

Water samples were collected from Watercourses 1 and 2 (as described above) and tested for:

- Turbidity
- pH
- Electrical conductivity
- Total Nitrogen
- Nitrate-N + Nitrite N
- Total Kjedahl Nitrogen
- Total Phosphorous
- *Escherichia coli*
- Heavy metals

Nitrogen and phosphorous levels were low at both sampling sites, indicating a low level of nutrient input further upstream. Arsenic, cadmium, chromium, nickel, and zinc levels were at or below the lower threshold for detection. Copper and lead were detected in trace amounts at both sampling sites, but levels were well below those required for safe drinking water.

Escherichia coli levels were high in both watercourses (600 cfu/100 ml in Watercourse 1 and 1,100 cfu/100 ml in Watercourse 2). These values would trigger a Red Mode alert level under Ministry for the Environment guidelines (MfE 2013); however, this value should be treated with caution as a courier delay meant the sample was late in arriving at the laboratory and was above the 8°C threshold required for accurate analysis. In addition, as these data are based on one-off sampling it is important to acknowledge that water quality can vary on a daily, seasonal, and annual basis, and with rainfall and flood events. Despite this, it is recommended that further testing take place at both sampling sites to investigate the possibility of faecal contamination entering the watercourses.

Full water quality results are provided in Appendix 6.

11. ECOLOGICAL VALUES

Ecological values at Port Waikato are associated with the following habitats:

- Dunes on the spit.
- Intertidal flats in the estuary.
- Aquatic habitats in the estuary.
- Freshwater wetland in the village.
- Riparian habitat along the estuary and lower river.
- Tributary streams.

These are discussed further below.

Overview

The diversity of the project area is high, as are the ecological values. Overall, less than 20% of endangered habitats present within the dunes, including dune hallows and damp seepages, as well as coastal turfs and shall beds (Holdaway *et al* 2012), are formally protected (Leathwick *et al.* 2003). Ecosystems on the Spit warrant additional recognition of high natural significance due to the presence of 'Threatened' and 'At Risk' indigenous species, the presence of dunelands and wetlands (under-represented habitat types), and its important shorebird habitat, particularly as a nesting site.

Some ecological values of the Spit are being compromised by pest plant infestations and trampling. For example, the southern part of the project area, including the southern dunes, residential area, roadside margins and vegetation surrounding the Surf Club at Sunset Beach, is dominated by exotic pest plants. However, small patches of indigenous-dominated vegetation are present at the southern extent of the Ngāti Karewa Ngāti Tahinga owned land, which includes a raupō reedland and cabbage tree forest.

The northern dunes are also dominated by indigenous species including spinifex and tauhinu with locally abundant populations of pīngao. As a result of the fire in 2008, much of the vegetation in the middle of the dunes, however, is dominated by pampas. A series of low-lying ephemeral wetlands are present in the south-eastern area of the dunes (Plate 14) comprising a mix of wetland indigenous species, including an At Risk species, but are generally dominated by exotic pest plants such as saltwater paspalum.

Dunes and Dune Hollows

Protection of indigenous vegetation associated with sand dunes and wetlands is identified as two of the four National Priorities for protection of indigenous biodiversity on private land by the Ministry for the Environment (2007) due to their rarity (2007). Dune deflation hallows, or damp seepages, are considered 'Endangered' according to Holdaway *et al.*(2012). These ecosystems have become naturally uncommon due to human activity and are therefore a priority for protection (Wiser *et al.* 2013).

Although vegetation and habitats present at the Port Waikato Spit are generally of high ecological value, much of the southern dunes are becoming increasingly compromised by intrusion of pest plants and damage to sensitive ecosystems by recreational vehicles. Such ecosystems include under-represented habitat types once characteristic of dunelands including low-lying seepages and ephemeral wetlands. Populations of *Centipeda aotearoana*, an At Risk-Naturally uncommon species, are found within the ephemeral wetlands located in damp seepages along the south-eastern side of the spit. Other notable species that were historically present in these areas include *Euphorbia glauca* (At Risk-Declining), *Callitriche muellerii*, and *Lilaeopsis novae-zelandiae* (Kirk 1870). These wetlands are of high ecological value due not only to their rarity, but also due to the threatened indigenous biodiversity they often host.

Extensive areas of spinifex grassland and tauhinu shrubland, and locally abundant populations of pīngao are present within the duneland. The dunes provide important habitat for two 'At Risk' plant species (pīngao and *Centipeda aotearoana*) and provide important breeding and nesting ground for three 'Threatened' bird species (banded dotterel, northern New Zealand dotterel and Caspian tern). Furthermore, the surrounding river mouth of the Waikato River is an important feeding ground for Maui's Dolphin, a Critically Endangered species according to the IUCN Red List.

Intertidal Flats in the Estuary

The intertidal flats of the Spit contain coastal turf and shell barriers (adjacent to the turf fields and ephemeral wetlands that form in the dune hallows) are considered to be 'Critically Endangered' (Holdaway *et al.* 2012). These areas provide habitat for indigenous flora and fauna, including birds and benthic macroinvertebrates.

Bird species

The intertidal flats and estuary habitats near Port Waikato are used by a wide variety of bird species, including migratory shorebirds and indigenous wading birds. Noteworthy fauna, as mentioned above, include banded dotterel, northern New Zealand dotterel and Caspian tern, as well as wrybill (*Anarhynchus frontalis*) and bar-tailed godwit (*Limosa lapponica*; New Zealand Wildlife Service 1981). The sand islands that form at high tide are utilised as roosts, while the northern end of the spit is occupied as a breeding and nesting ground.

The estuarine areas near the river host some 31 species of birds recorded over the years including white-faced heron (*Egretta novaehollandiae*), variable oyster catcher (*Haematopus unicolor*), Pacific reef egret (*E. sacra*), black swan (*Cygnus atratus*), mallard (*Anas platyrhynchos*), grey duck (*A. superciliosa*), New Zealand shoveler (*A. rhynchotis variegata*), spotless crake (*Porzana tabuensis plumbea*), pied stilt (*Himantopus leucocephalus*) and white-fronted tern (*Sterna striata*), as well as shags (*Phalacrocorax* spp.) and some gulls (*Larus* spp.; Cromarty & Scott1995). Low numbers of the Australasian bittern (*Botaurus poiciloptilus*), New Zealand dabchick (*Poliocephalus rufopectus*), New Zealand scaup (*Aythya novaeseelandiae*) and brown teal (*Anas aucklandica chlorotis*) have also been recorded occasionally.

Benthic fauna

The intertidal sand flats and estuarine areas of Port Waikato also provide habitat for a range of benthic macroinvertebrate species, including polychaetes, bivalves, gastropods and crustaceans. Data on macroinvertebrate diversity and abundance is limited for this area, but common species likely present include *Aonides oxycephala* and capitellids (polychaete worms), *Austrovenus stutchburyi* and mud crabs (*Helice crassa*). Increased sedimentation and associated pollutants including nitrogen, phosphates and heavy metals can have adverse impacts on benthic fauna, causing shifts of community assemblages. This results in a shift of available food resources for migrating and wading bird species and has unknown cascading impacts on the ecosystem. Macroinvertebrate communities within the Port Waikato intertidal flats and estuarine areas should be monitored on a regular basis to fill this information gap.

Aquatic Habitat in the Estuary

Aquatic environments in the Port Waikato estuary are generally in good condition. Pest plants occur within tributaries, and should be addressed, but reduce in abundance with distance from the main Waikato River. The results of samples collected during this survey indicate that metals and nutrients are all below threshold levels, which is indicative of high water quality. The exception is *Escherichia coli* levels, which were elevated in both samples; however, these results should be interpreted with care as outlined in section 10.2 and further testing should be carried out before it is concluded that faecal contamination of the aquatic environments is present in the Port Waikato area. Sediment results of samples collected in 2015 translate to generally good aquatic benthic health, with medium to coarse grain particles dominating the composition. Generally, metal concentrations were below threshold limits with the exception of arsenic, cadmium, copper and zinc levels at some sites. The slightly elevated concentration of these metals is indicative of land use change within the catchment, including artificial fertilisation, fungicide and pesticide use to improve agricultural output as well as geothermal inputs into the Waikato River that occur naturally.

Freshwater Wetland in the Village

The raupō-*Machaerina articulata* reedland present within the village is a high value site due to the habitat values it provides for threatened avifauna associated with freshwater wetlands, such as the North Island fernbird (*Bowdleria punctate,* At Risk-Declining) and spotless crake. The wetland has relatively low abundance of pest plants, and a complimentary diversity of indigenous species within the wetland including pūrua grass and associated species assemblages along the margins, including a tī kōuka-mānuka shrubland with whekī, ponga, and *Coprosma macrocarpa* all common in the sub-canopy and a diverse indigenous understorey including kawakawa and pōhuehue together with mātātā, rautahi, and *Machaerina teretifolia*.

Riparian Habitat Along the Estuary and Lower River

Much of the riparian buffer throughout the Waikato River catchment has been degraded by farming and agriculture. However, some of the riparian habitat along the estuary and lower river are still in-tact. The riparian habitat along the estuary and lower river provides refugia and food resources for a variety of indigenous and

migrating birds, benthic fauna as well as pelagic fishes and invertebrates during mid and high tides.

Tributary Streams

The two tributary streams within the project area provide habitat for indigenous freshwater fish and pollution-sensitive macroinvertebrates. Two 'At Risk-Declining' fish species were caught during the stream surveys: īnanga and longfin eel (Goodman *et al*. 2014); additionally, Cran's bully and banded kōkopu were also identified.

Both tributaries had MCI scores reflecting streams of "excellent" biological quality (Stark and Maxted 2007), as the samples were dominated by pollution-sensitive EPT taxa. These results indicate high quality aquatic environments within the tributaries that lead to the Waikato River within the project area.

12. THREATS

Overview

Despite the wide range of ecological restoration efforts being undertaken within the sand dunes of the Waikato Region including reducing off-road vehicle numbers, the ecological integrity of the majority of dune ecosystems is still compromised. Beach Care groups supported by Waikato Regional Council, restoration advice provided by the Department of Conservation, the Dune Restoration Trust and many more grass-roots, community groups are working toward restoring dunes in the Waikato Region through enhancement planting of indigenous species, control of pest animals and plants, and postage of signs aiming to educate people on the adverse impacts of vehicles, pedestrians, and dogs in these vulnerable environments.

Human Use and Behaviour

Ecological threats that should be addressed within the project area include the presence of pest plant and animal species and the use of off-road vehicles, bicycles and horses within the sensitive dune ecosystem. Successful protection and restoration of the Port Waikato spit will require a change in attitudes and behaviour, in addition to the implementation of ecological management techniques. Currently, signage is posted at entrances to the Spit - at Ocean View Road and Mission Road - discouraging use of motorbikes and quadbikes on the dunes (Plate 15). Anecdotal evidence of local dune users suggest these signs have resulted in a decreased presence of motorised vehicles on the Spit (Karen Opie, pers. comm., 2015).

Ongoing use of the eroding foredune face may be a factor contributing to instability, although other factors are likely to be playing a dominant role in these processes.

Pest Plants

Exotic species and pest plants are common throughout the southern dune system at Port Waikato, and are dominant throughout the residential areas and surrounding reserves. Pest plant incursions prevent establishment of indigenous species, and have

the ability to displace indigenous vegetation especially within the fragile dune system. Furthermore, infestations and spread of exotic species result in loss of natural character and adversely affect natural dune movement and repair, ultimately resulting in higher risk of erosion and coastal inundation. Species such as gorse and pampas can also make the dunes significantly more vulnerable to fire. As such, priorities as to which pest plants to target, and priority areas for management are identified in the next section.

Pest Animals

Pest animals are also a concern within the dune system, particularly rabbits. Rabbit sign was seen within the fragile dune wetland environments, and will be browsing on a range of rabbit-palatable species. Large numbers of rabbits can be a contributing cause to the decline of pīngao throughout the dune system, which is preferred by rabbits to spinifex in terms of browsing (Bergin 2011). The browsing pressure of rabbits/hares combined with the spread of pest plants creates a difficult environment for indigenous vegetation to establish and thrive.

Direct impacts of human disturbance within the dune environment are readily evident, as shown by the presence of tyre tracks of off-road vehicles and bicycles. Significant damage to critical coastal environments, particularly coastal dunes, is caused when processes of dune recovery and sand migration are interrupted and/or disturbed. The interruption of dune recovery processes leads to sand instability and large scale sand migration along the coast (Auckland Council District Plan 2011). Evidence of coastal erosion is visible on the western dunes of the Port Waikato spit via the 5-6 m drop from top of dunes to beach. The Surf Club at Sunset Beach (south end of the dunes) has also suffered coastal erosion after a large storm in 2008 (Waikato Regional Council 2011).

13. STRATEGIC MANAGEMENT

13.1 Overview

A range of ecological enhancement activities are currently being carried out within the project area and wider catchment. The Port Waikato Beach Care group carries out regular monitoring of shore birds that frequent the dunes at Port Waikato, and erect fencing to protect them and their nesting grounds. Additionally, the Beach Care group hosts planting and weeding bees to improve the ecological integrity of the Spit. Other groups that have carried out ecological restoration projects include the Waikato River Cleanup Trust, Waikato University, Waikato Regional Council, NIWA, Landcare Research, Waikato Biodiversity Forum, Waikato River Authority, the Waikato Raupatu River Trust, and many more.

Freshwater restoration in New Zealand has been internationally recognised as successfully working toward targets for improving water quality in associated rivers (Rutherford 2010). These efforts are important in improving ecological integrity and resilience of the Waikato River and associated ecosystems, including the estuary and sandspit at Port Waikato. However, more work is needed to complement the

ecological restoration efforts of these groups in order to prevent the loss of vulnerable species and habitat types.

Some vegetation and habitat types within the project area retain a high degree of naturalness and will respond well to selective management of key pest plant and animal species, along with appropriate planting to improve the ecological integrity of existing indigenous plant populations. Furthermore, riparian restoration within the wider catchment, both within the project area and beyond, will improve water quality, water clarity and sediment health within aquatic ecosystems. This section outlines the management opportunities within the project area and guidelines for their implementation, as well as recommendations and advice on how to improve the ecological values of the wider catchment, particularly in terms of aquatic health.

The over-riding aim of this Ecological Enhancement Plan is to manage the dunes in a way that retains and enhances their ecological values and resilience, and provides a safe environment for recreational users of the Spit:

- Managing the southern part of Port Waikato Spit back to indigenous-dominated vegetation by controlling and removing pest plant species and pest animal browsers, and planting with indigenous species where appropriate.
- Retaining the indigenous-dominated nature of the northern dunes.
- Retaining and enhancing breeding habitat for indigenous fauna, including birds and invertebrates, by reducing predator numbers is also a priority.

Currently, off-road vehicle and walking tracks traverse ephemeral wetlands and vulnerable dune ecosystems that were first documented in 1870 (Kirk 1870). Browsing by rabbits or hares are also impacting these areas which would otherwise be dominated by turf fields. These wetlands are priority areas for management as they will likely regenerate naturally if trampling and vehicle damage is eliminated and pest plants and animals are controlled to maintain current levels or achieve a reduction in extent. Otherwise, these wetlands contain moderate to high ecological values, depending on the presence of pest plants, particularly salt water paspalum. Additionally, along the foredune exotic vegetation dominates the southern extent of the dunes and is encroaching northwards; this is resulting in increased risk of erosion and loss of ecological functioning including habitat for indigenous flora and fauna. Pest plant control and removal of larger exotic trees, including banksia and Norfolk Island pine, is required to ensure natural dune processes can function.

Other matters are also addressed in the Plan:

- Pest animal control, including rabbits, hares, possums and hedgehogs.
- Fencing and designated accessways.
- Signage.
- Ecological resilience to climate change.
- Reducing sediment and nutrient input into aquatic environments.
- Improvement of ecological integrity of the surrounding catchment.

13.2 High priority areas for management

Four areas have been identified as a high priority for management:

Management Zone 1 - Ephemeral dune wetlands, turf fields, and seepages.
Management Zone 2 - Nesting grounds at the top of the spit.
Management Zone 3 - Foredunes.
Management Zone 4 - Raupō-*Machaerina articulata* reedland.

These are described below and illustrated in Figure 3.

13.3 Management Zone 1 - Ephemeral dune wetlands, turf fields, and seepages

A series of shallow ephemeral wetland remnants, turfs, and seepages are present along the south-eastern side of the spit. Evidence of browsing by rabbits or hares is present throughout much of Management Zone 1 which requires control. The first priority for pest animal control is to determine whether rabbits or hares are in higher abundance as the two species require different control approaches. A night of spotlighting by two trained professionals to determine what species is present in the area is proposed. Following that, two approaches are recommended: (1) if hares are present, annual control by spotlight shooting, and/or (2) if rabbits are present, annual control by Pindone deployment and fumigation of warrens.

For pest plant control, Management Zone 1 has been divided into sub-units based on their vegetation types (described in Section 7); as such, management action is taken according to these units:

***Saltwater paspalum-wīwī-sea primrose-arrow grass grassland* (*Vegetation Type 15*)**

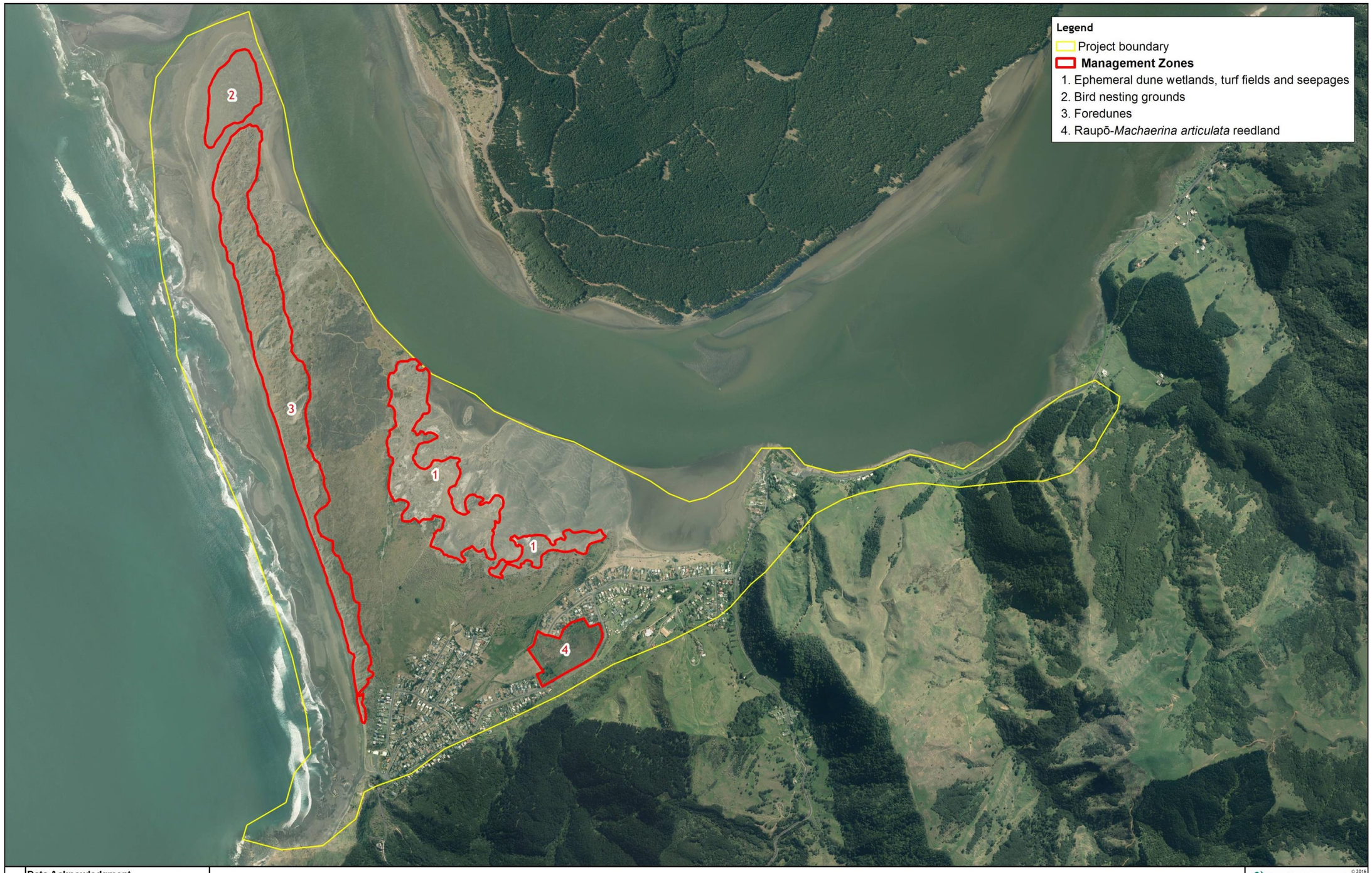
One of the most serious threats to this area is vehicle and human traffic including push-bikes, dogs, horses and to a lesser extent, foot traffic. Many tyre tracks were seen through the turf fields, which are highly vulnerable to vehicle damage and trampling. These ecosystems are rare and should be protected.

***Sea primrose-glasswort turf field* (*Vegetation Type 17*)**

Marram is locally abundant along the margins and on dry islands within this ephemeral wetland. This species should be controlled before is spreads into surrounding areas. The top restoration priority for this unit, however, is to prevent vehicles from driving on it. Tyre tracks were widespread throughout the ephemeral wetland, resulting in fragmentation of habitat and damage to vegetation.

***Tall fescue-kikuyu-pōhuehue grassland* (*Vegetation Type 18*)**

This unit borders the new subdivision and is not likely to improve in terms of ecological values unless significant pest plant control is carried out (followed by planting accompanied by pest animal control). However, sign of rabbit browsing and presence (scat) were observed. As such, rabbit control is recommended.



Data Acknowledgment
Map contains data sourced from LINZ
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Figure 3. Priority Management Zones for restoration at Port Waikato

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Scale: 1:15,000
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***Arrow grass-mudwort turf field* (*Vegetation Type 24*)**

Although in very good condition, saltwater paspalum poses a threat to the integrity of this turf field and should be monitored to ensure it is not adversely affecting indigenous species.

***Lilaeopsis novae-zelandiae dominated turf field* (*Vegetation Type 24a*)**

A small sub-unit within the arrow grass-mudwort turf field consists of pockets of *Lilaeopsis novae-zelandiae* dominated turf field, with occasional marram infestations.

As the marram infestations are currently relatively small, it is a high priority for control in order to prevent further spread. Horse tracks observed throughout this unit have created deep depressions that take months (if not years) to return to their natural height, as well as trampling vegetation. To a lesser degree, push-bikes are also causing damage in this area. Both horses and push-bikes, along with vehicles and dogs, should be excluded from these vulnerable ecosystems.

13.4 Management Zone 2 - Nesting grounds at the top of the spit

Nesting grounds for Caspian tern, banded dotterel and northern New Zealand dotterel are concentrated at the north end of the spit. Simple fencing is already constructed around the majority of these fences, along with signage. This is a sound management practice and appears to be effective. If successful, it is possible the nesting grounds will expand and therefore fencing should be installed at all other known nesting grounds. Pest animal control is also recommended to reduce the number of possums and hedgehogs that are likely present within the project area and can have adverse impacts on nesting birds. A series of DOC200s or DOC250s should be set up in a 100m grid throughout known breeding areas (which include both Management Zone 2 and the eastern side of Management Zone 1). Traps should be checked regularly (every two weeks) throughout the breeding season, starting one month prior and continuing one month after to ensure eggs and fledglings are protected (July through March). Animal carcases should be buried in the dunes.

Signage posted at Ocean View Road and Mission Road discouraging use of motorbikes and quadbikes on the dunes will continue to ensure protection from off-road vehicles and foot traffic, which pose a significant threat to nesting grounds. More signage to encourage beachgoers to keep their dogs leashed or off the northern dunes entirely should be erected, as dogs can easily bypass the fencing.
Revegetation activities in this area are also an option, particularly along the southern extent. Spinifex and pīngao are important sand binders that will help to trap sand and re-establish dunes after large storm events. Pest plants should be monitored and controlled when necessary in this zone, particularly marram, and any other exotic species that may wash down river, including alder, walnut and prickly pear, all of which were observed nearby.

13.5 Management Zone 3 - Foredunes

The foredunes are particularly vulnerable to erosion, especially when exotic vegetation and pest plants are dominant. Erosion is evident along the foredunes at the

spit where sections of sand and vegetation up to 15 m^2 tall have collapsed on to the beach. Large blowouts - one which is over 3,000 m^2 - occur along the foredunes, which are continuing to erode due to the lack of appropriate vegetation cover. As mentioned above, indigenous grasses and sedges act as sand binders to entrap sand and build the dune system.

A diverse mixture of indigenous species are present within the dune system, which need to be protected and encouraged to expand by controlling exotic vegetation and pest plants that are otherwise outcompeting indigenous species. Pest plant control should also be carried out, working from the north to the south, targeting pest plants including pampas, agapanthus, marram and gazania.

Within areas cleared of pest plants, revegetation should be carried out. Revegetation of foredune areas, predominantly with spinifex, would benefit the foredune. Plant schedules for foredunes and blowouts are provided in Appendix 9. It should be noted, however, that this approach is unlikely to address all of the erosion issues along the foredune. The scale of erosion in the vicinity of the surf club, for example, will require a carefully planned and implemented approach to address this area and adjacent sections of dune to the north.

13.6 Management Zone 4 - Raupō-*Machaerina articulata* reedland

The raupō-*Machaerina articulata* reedland (*c.*1.8 hectares) located along Maunsell Drive at the southern extent of the Ngāti Karewa Ngāti Tahinga owned reserve (Plate 4) has high ecological values due to the rare occurrence of this vegetation type and the habitat it provides for Australasian bittern (*Botaurus poiciloptilus*) and spotless crake (*Porzana tabuensis tabuensis*), which are classified as Threatened-Nationally Endangered and At Risk-Relict, respectively (Robertson *et al*. 2013).

Grey willows are present in this zone and are priority for control to prevent further spreading. Control of pest plants within wetland environments must be carried out carefully as to reduce adverse impacts on the aquatic environments. All willows and exotic trees within the wetland should be controlled using a concentrate herbicide such as Metsulfuron or Triclopyr in late spring or early summer using either drill and fill[1] or basal spray[2] methodology. Spraying must be carried out in late spring or early summer to ensure the treatment will be effectively transmitted to the cambium layer during this period of peak growth.

All other pest plant species should be controlled in the wetland area, working toward the margins which comprise mānuka and cabbage tree forest. Pest plant species prevalent along the margins include pampas, ginger, tradescantia, garden nasturtium and royal fern.

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1 'Drill and fill' is a herbicide application technique in which a series of holes (*c.*10 mm diameter) are drilled around the circumference of the tree at drill height (i.e. *c.*1 m) or as low as practical; these holes are then filled with herbicide concentrate so it is able to enter the cambium layer.

2 'Basal spray' is a herbicide application technique in which a herbicide concentrate is added to a carrier oil and applied around the circumference of the trunk of the target species, to approximately the height of the diameter measurement of the tree.

13.7 Other management on the Spit

In addition to the above management, the following management is required to improve ecological resilience at the Port Waikato Spit.

Pest Plant Control

Due to the high concentration and diversity of exotic vegetation and pest plants within the southern dunes, control of most pest plant species is not a practical option in the short term for this area. Instead, the immediate focus should be on limiting the spread of those infestations northward in order to retain the high value dunes with a diversity of indigenous dune species. Some species that occur in low abundance and/or cause serious damage should be priority for control throughout the dunes, including the southern area. Such species include wilding radiata and maritime pine, Norfolk Island pine, banksia, and prickly pear.

Species that are within the dune system that should be controlled from north to south include marram, Formosan lily, pampas, gazania, saltwater paspalum, walnut and alder seedlings, and elephant's ear.

Other pest plants located within the margins of the dunes and riparian areas of tributaries within the catchment and/or reserves are a high priority for control due to their ability to spread quickly and effectively; these include alligator weed, woolly nightshade, arum lily, and Kahili ginger.

Enrichment Planting

The dune flora present at the site is relatively diverse. Regeneration of indigenous species will naturally occur over time to fill the spaces left following pest plant control. Therefore the focus of restoration effort at Port Waikato Spit should be on restoring the dunes to indigenous vegetation cover and habitats. This will involve the control of key pest plant species in order to allow indigenous species to regenerate. In most cases it will not be necessary to carry out extensive plantings as there is plenty of evidence to suggest that indigenous species will rapidly regenerate following the removal of pest plants. Planting recommendations in this report therefore tend to favour planting clusters of indigenous species in areas that are currently dominated by adventive plants, particularly with regards to the foredune and mid-dune areas or in areas that are otherwise devoid of vegetation including blowouts.

Enrichment planting should be undertaken to accelerate revegetation of indigenous species in areas where large dense pest plant infestations are removed exposing bare sand, or to enhance species diversity within the site, particularly in areas where indigenous species have been outcompeted by exotics. Planting schedules for blowouts, foredunes, mid-dunes, and back-dunes are provided in Appendix 9.

If enrichment planting is undertaken at the site, care should be taken to ensure that only eco-sourced plants are used. All plant stock should be sourced from seed collected from natural populations occurring in the west coastal sand dunes of the Meremere, Awhitu, or Raglan Ecological Districts.

Planting should be carried out in consultation with local residents, and local community dune restoration organisations such as Port Waikato Beach Care who have been undertaking restoration for many years.

Sand-binders: spinifex and pīngao

Spinifex, and to a lesser degree pingao, are flourishing in foredune areas that are not affected by human disturbance. Given the abundance of spinifex, it is recommended that this species is be planted where foredunes have eroded or to replace plants that have been damaged by trampling or rabbit browse. Pīngao should be planted at a rate of 1:20 in relation to that of spinifex due to it being naturally less common within the dune environment.

Planting technique, planting depth and the use of fertiliser are important factors to consider when planting sand-binding plants. Below are the planting guidelines for spinifex and pīngao taken from an article produced by the Dune Restoration Trust of New Zealand (2011):

Spinifex

Large numbers of container-grown seedlings can be quickly planted on foredunes and in blow outs using spades. Spinifex grown in root trainers can be planted quickly in spade holes. Deep planting (sand level at least 10 cm above surface of potting mix) will maximise root contact with moist sand horizons and result in greater survival and better growth, especially under conditions of moderate sand scouring by wind. The use of plants at least 60 cm high will allow deep burial.

Results from planting trials have consistently shown that applying slow-release fertiliser at planting significantly improves early establishment and growth of spinifex (Bergin *et al.* 1998). Spinifex seedlings planted with fertiliser have produced several stolons within a year of planting. The technique involves incorporating 30 g of slow-release NPK fertiliser to the sand around the root system as the seedling is planted.

Pīngao

As with spinifex, deep planting of pīngao will increase survival especially on highly dynamic beaches where there is substantial sand movement.

Planting pits need to be sufficiently deep to allow root collars of seedlings to be planted at least 10 cm below the sand surface. Trials have demonstrated that planting pīngao seedlings in groups of 10 to 20, with approximately 50 cm spacing between plants, has been effective in starting the dune building process within six months. Close spacing provides mutual shelter on exposed sites and application of fertiliser promotes growth, and thus the trapping of sand.

Application of a slow-release NPK fertiliser (e.g. Magamp, 30 g per plant, incorporated with the sand around each seedling) does not always increase survival but it is known to significantly increase early growth and health. Occasionally, if there are high rates of sand accumulation at a planting site, or the sand is enriched, there may be no immediate benefit from fertiliser. As a general rule however, it is advisable to apply slow-release fertiliser to all plantings.

Coastal trees and other dune species

Pōhutukawa, karo, taupata, houpara, harakeke and ngaio could be planted at 5-10 metre spacings in areas left open by removal of the pine, Norfolk Island pine, banksia and other exotic trees. Tauhinu, wīwī, sand pimelea (*Pimelea villosa*), sand wind grass, and New Zealand shore spurge could be planted on the dunes, along with kōkihi in shaded areas. Tauhinu can also be planted on the leeward side of the dunes, but is not a priority due to the abundance of potential seed already present within the site. However, the focus for revegetation species should be on spinifex, pīngao, and tauhinu as these are the indigenous species which are most abundant naturally on site.

Pest Animal Control

Rabbit populations within the sand dunes are damaging palatable indigenous plants, and also potentially destabilising dunes through burrowing. Rabbits should be controlled within the dunes to reduce the population size via shooting, warren disturbance, and poisoning with pindone-based baits. Horses should be excluded entirely from the dune environment or horse riders should be encouraged to stay on designated paths. All other livestock should continue to be excluded from dunes and wetlands.

Feral and domestic cats (*Felis catus*) and dogs (*Canis familiaris*), mustelids, and hedgehogs (*Erinaceus europaeus*) all pose a significant threat to ground nesting shore birds such as oystercatchers and dotterels. Domestic dogs should be banned from any areas where ground nesting shorebirds may be present and traps should be deployed close to nests to protect nests from cats, mustelids and hedgehogs. Live traps for cats should be deployed as outlined in the works programme (Appendix 9). These traps should only be set when they can be checked on a daily basis (i.e., when pest plant control is being carried out) to ensure any domestic cats caught in the traps can be set free. An electric wand can be used to detect chipping that most domestic cats have fitted.

Aquatic pest fauna are likely present within the wider catchment, but were not detected within the project area. Aquatic pest fauna including koi carp (*Cyprinus carpio*), catfish (*Amieurus nebulous*) and gambusia/mosquito fish (*Gambusia affinis*) are known to cause problems within the Waikato River catchment and should be managed upstream to reduce their spread to tributaries that have not yet been impacted.

Fences and Designated Accessways

Significant damage to dune vegetation can occur from human-induced disturbance, including off-road vehicles, push-bikes, horses, dogs, and pedestrian traffic during

times of peak beach use. Due to the hyper-sensitivity of dune systems to disturbance, fencing is an effective option to protect damaged or vulnerable parts of the dune system, particularly the ephemeral wetlands, seepages and turf fields together with the nesting grounds for indigenous birds.

In conjunction with fencing, accessways should be clearly marked and identified. These includes pedestrian accessways and walking paths to the dunes and beach, as well as formalised vehicle accessways for off-road vehicles to utilise. It is important that barriers of some form be constructed to reduce the likelihood of vehicles accessing the foredunes, which are vulnerable to erosion.

The location of designated accessways should be outside places of high ecological significance, including the ephemeral wetlands, seepages and turf fields despite these areas being favoured for off-road vehicle use. Outside of such areas of ecological significant, existing informal tracks indicate preferred location of accessways, and these can be formalised through low profile fences and signage.

Signage

Use of formalised accessways is dependent on appropriate signage, in addition to fencing and barriers discussed above. Simple signs posted at both the beach and the landward ends of a formal accessway will encourage its use; one effective example is already in place at the corner of Ocean View Road and Mission Road emphasising a widely supported 'Neighbourhood Watch' style approach to keeping motorised bikes and quadbikes off the dunes (Plate 15).

Signs are best if simple in design (i.e. a treated wooden post), and are effective if clearly identifiable by using colours, large text and height. Keeping signage basic and low cost reduces loss to vandalism and, if necessary, can be replaced, repaired or lifted in the changing dune environment. Beach access signs should also be positioned on roads so people can easily identify where to enter the beach and dune reserve.

Signage should be designed and written by the community (or appear to be) rather than by local governing authority to increase effectiveness. This will likely gain respect of the public whom will be more willing to abide by community-based projects and efforts to protect the dunes than those promoted solely by Council or other government departments.

Ecological Resilience to Climate Change

Ecological resilience to climate change at Port Waikato can be improved by ensuring that habitats are in good condition, with high species diversity. High species diversity is required to support high functional diversity, which enables an efficient ecological balance to be established in which resource consumption and temporal stability are in balance through population expansion and collapse (c.f. Thrush *et al*. 2013).

At Port Waikato, the importance of maintaining species diversity is relevant to both terrestrial and aquatic ecosystems. An increase in annual mean westerly winds, and associated storms and storm surges is predicted as a result of climate change (Ministry for the Environment 2008) and these weather conditions will increase the

vulnerability of dunes to erosion. Erosion on sand dunes is significantly reduced when sandbinders (e.g. spinifex and pīngao) are the dominant vegetation cover of the foredunes. Therefore, restoration planting of the foredunes could help improve ecological resilience to climate change of that area.

As described above, the aquatic environments of Port Waikato are influenced by a large catchment characterised by high flow volumes over hundreds of kilometres; as such, management of water quality at Port Waikato requires a catchment wide approach. Maintaining high water quality is necessary to retain high species diversity, especially of indigenous flora and fauna, which improves ecological resilience to climate change. Recommendations on how to improve water quality are provided below, in Section 13.3.3.

Reducing Sediment and Nutrient Input into the Aquatic Environment

Reducing sediment and nutrient input into the sea and estuary can only be effective if catchment-wide management techniques are carried out including riparian restoration (extending out at least 20 m on either side of waterways on rural properties), minimising contaminants in point source pollution and identifying and reducing non-point source pollution.

Promoting fencing and assisting landowners with costs associated with restoration of riparian margins throughout the catchment will benefit the water quality of the Waikato River substantially. In 2002, over 60% of the total bank length of waterways present in pastoral land in the Waikato River Catchment was not fenced, resulting in hundreds of kilometres of eroding stream banks, and impacting on the levels of sediment entering the waterway (Waikato Regional Council 2008). One case study carried out in a catchment in the lower Waikato River approximated a 40% increase in bank stability improvement within a few years of fencing off stock access to the riparian margin (Waikato Regional Council 2008).

In addition to improving bank stabilisation, riparian vegetation slows water as it enters the waterway which allows nutrients, sediment and other contaminants to be taken up by riparian vegetation and associated habitats; this results in water of higher quality entering the waterway. Fencing also prevents stock from entering the waterway, significantly reducing trampling of vulnerable riparian areas. Riparian vegetation also slows down water during heavy rainfall events, resulting in less erosion of the stream banks and therefore less incised channelling; this improves habitat availability for indigenous fish species in terms of refuge and spawning.

Build on existing initiatives and focus on the status of the Waikato River and how it is affected by eutrophication (i.e. nutrient enrichment) and sedimentation may help encourage people to implement individual actions which improve water quality in the Waikato River. If key information such as the primary source of contaminants entering the river are agriculture, dairy and farming is clearly and concisely conveyed in the campaign, people may be motivated to investigate alternatives or mitigation. For example, farmers may choose to reduce the rate at which they apply nitrogen and phosphorus-based fertilisers to their pastures, or use effluent collected from milking sheds to spray back onto pasture, completing the nutrient cycle, or increase riparian buffers.

Improving Ecological Integrity of the Surrounding Catchments

The ecological integrity of the wider Waikato River catchment is contingent on the intactness of the riparian margin of the higher and lower order tributaries. Therefore, stock exclusion, pest plant control and restoration of appropriate indigenous vegetation are recommended to improve the ecological integrity of the surrounding catchment.

Riparian vegetation provides a range of ecological benefits, both to terrestrial and aquatic environments by providing habitat for feeding, breeding/spawning, food source and refuge for indigenous flora and fauna. Riparian vegetation also decreases suspended sediment in the water column of associated rivers and streams, as well as other contaminants including nutrients, metals and chemicals.

14. MONITORING

14.1 Overview and current works

Monitoring is an important tool to ensure the success of pest plant control and other management activities. It is recommended that a series of strategically placed permanent photopoints be established to help gauge the success of pest plant control operations. It is also recommended that comprehensive records are kept of all planting and pest plant control operations, track works and pest animal control, and any other management action undertaken within the project area.

14.2 Photopoints

Permanent photopoints are used to capture images of the vegetation or landscape over time. This is particularly useful for observing changes in growth patterns, vegetation density, and/or, sand deposition.

Permanent photopoints could be established to monitor planting areas, significant weed infestations, seepages/ herbfields, and at high points (to record representative part of the project area). Photopoint locations may be marked with a stake and/or plastic trail blazer, or simply by recording a GPS point. The direction and focus of the photograph is determined for each photopoint prior to the initial observation, and recorded so that it can be repeated as closely as possible for successive photographs. Each time a new photograph is taken, notes are made on the size, density, and extent of the dominant vegetation type(s), along with other species and other relevant observations, including nesting birds or disturbances.

Photopoints should be established prior to any restoration activities commencing. Typically, photopoints are re-measured annually for the first three years after works have taken place, after which biennial photographs are generally sufficient. Additional photopoints to monitor particular features/management activities can be established as required.

Photopoint monitoring of dune erosion will also be useful but will also need to be combined with other methods, such as aerial photography and GPS/topographical surveys, especially in the vicinity of the surf club.

14.3 Pest plants

Regular pest plant surveys are an important management tool for assessing the success of control operations, identifying when follow-up control is required, reviewing priorities, and identifying any new pest plant species and infestations that may have established.

The areas most vulnerable to reinvasion by weeds are the reserve boundaries, public access points and tracks, estuary margins, and bare areas exposed by erosion, track works, or previous weed control. It is recommended that a survey of these areas is undertaken at least annually for the first five years, and a comprehensive survey of the entire reserve is undertaken at 3-5 year intervals.

14.4 Birds

Birds could be monitored to document changes in species diversity and relative abundance in response to the enhancement of habitats, and to provide information which could be used to promote the project and to provide interpretive material for the benefit of visitors. Periodic walk-through surveys and records of incidental observations would be appropriate techniques.

15. OTHER PARTIES

To maximise resources and foster good will, it is recommended that work is undertaken in concert with the Port Waikato Beach Care community group and other interested parties (see Section 13.1). Further engagement of the local community is required due to the presence of pest plants on private land. It is therefore recommended that public meetings are held to outline the project and ways that landowners can help e.g. by allowing access for weed control.

16. IMPLEMENTATION PROGRAMME

The following recommended implementation programme is provided to guide management activities such as pest plant control, enrichment planting, pest animal control, fencing, accessways, and appropriate signage. A detailed schedule for the proposed works programme is presented in Appendix 10. An indicative outline of costs associated with the proposed works is presented in Appendix 11.

<u>Year 1</u>

- Establish monitoring within the entire project area, to include sites where active management is planned for, prior to works being undertaken. A minimum of one photopoint should be established in each of the management zones and 10-15 photopoints should be established throughout the project area. Each photopoint

does not require re-measuring every year, but their early establishment provides good reference points for monitoring of future works.

- Determine where fences are required (particularly around Management Zones 1 and 3) and where designated accessways could be established, particularly for vehicle traffic and design signs that will be utilised to interact with public regarding fencing and accessways.
- Fell all exotic tree species within the project area including wilding radiata pine, maritime pine, Norfolk Island pine, and banksia. The felled material should be left *in situ* in order to reduce adverse impacts on the dune system and provide habitat for katipō and other indigenous invertebrates. The trees should be delimbed to reduce health and safety risk.
- Control marram in Management Zones 1 and 2, and where possible saltwater paspalum in Management Zone 1. Exotic seedlings, particularly of woody species, should also be controlled along the eastern coast of the spit, through to Management Zone 2. Priority species including marram and pampas should be controlled in Management Zone 3, as well as agapanthus and gazania where possible.
- Control alligator weed, woolly nightshade, arum lily and Kahili ginger throughout the project area.
- Control dally pine (*Psoralea pinnata*), coral tree (*Erythrina ×sykesii*), prickly pear and Japanese spindleberry when encountered to prevent further spread.
- Plant sand binders in open areas and blowouts within Management Zone 3 to reduce erosion, with a focus on spinifex which is currently the dominant sand-binding species in the project area.
- Monitor dune vegetation (for rabbit damage and vehicle damage) particularly in Management Zone 1, and implement control as required.

<u>Year 2</u>

- Erect signs and fencing to designate vehicle and pedestrian accessways, sensitive habitats (including seepages and turf fields in Management Zone 1) and bird nesting grounds (Management Zone 2, and any other known areas).
- Undertake follow-up control on any exotic tree species within the project that may have been missed in Year 1, or that are re-sprouting.
- Undertake follow-up control of marram in Management Zones 1 and 2, and where possible saltwater paspalum in Management Zone 1; continue control of marram and pampas in Management Zone 3, and agapanthus and gazania where possible.
- Undertake follow-up control of any exotic woody seedlings that have since established along the eastern coast of the spit.
- Undertake six-monthly surveillance and control of pest plants working from the top of the spit (Management Zone 2) southward in a manner that will eventually cover the entire project area. It is important to work from north to south when controlling pest plants in the dunes because few pest plants have established in the northern dunes, while the southern dunes have been colonised by a variety of pest plants. Focus on isolated populations over large infestations.

- Plant sand binders in open areas and blowouts within Management Zone 3 and in any other areas where pest plant control has left open sand; focus on spinifex which is the dominant species.
- Remeasure photopoints established in Year 1 and reassess management priorities.
- Monitor dune vegetation (for rabbit damage and vehicle damage) particularly in Management Zone 1, and implement control as required

Year 3

- Maintain fencing and update signs based on management priorities, if required.
- Continue follow-up control of marram in Management Zones 1 and 2, and where possible saltwater paspalum in Management Zone 1; continue control of marram and pampas in Management Zone 3, and agapanthus and gazania where possible.
- Undertake follow-up control of any exotic woody seedlings that have since established along the eastern coast of the spit.
- Undertake six-monthly surveillance and control of pest plants working from the top of the spit (Management Zone 2) southward. Focus on isolated populations over large infestations.
- Plant sand binders in open areas and blowouts within Management Zone 3 and in any other areas where pest plant control has left open sand; focus on spinifex which is the dominant species.
- Remeasure photopoints established in Year 1 and reassess management priorities.
- Monitor dune vegetation (for rabbit damage and vehicle damage) particularly in Management Zone 1, and implement control as required; do this six monthly or annually.

Year 4 Onwards

- Continue to maintain fencing, particularly for vehicle accessways; replace or update signage if required.
- Undertake surveillance and control of weeds annually within all management zones.
- Continue to undertake six-monthly surveillance and control of pest plants working from the top of the spit (Management Zone 2) southward. Focus on isolated populations over large infestations until the entire project area has been covered.
- Remeasure photopoints established in Year 1 biennially and reassess management priorities as required.
- Monitor dune vegetation (for rabbit damage and vehicle damage) particularly in Management Zone 1, and implement control as required; do this six monthly or annually.

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VASCULAR PLANT SPECIES RECORDED AT PORT WAIKATO

Key P = planted
N = natural at site

INDIGENOUS SPECIES

Gymnosperms

Agathis australis (P)	kauri
Podocarpus totara var. *tōtara* (P)	tōtara

Monocot. trees and shrubs

Cordyline australis (P&N)	tī kōuka, cabbage tree

Dicot. trees and shrubs

Alectryon excelsus subsp. *excelsus* (P&N)	tītoki
Beilschmiedia tawa (N)	tawa
Coprosma macrocarpa subsp. *minor* (N)	karamū, kāramuramu
Coprosma repens (P&N)	taupata
Coprosma robusta (N)	karamū, kāramuramu
Coprosma macrocarpa subsp. *minor* × *C. propinqua* (N)	
Corynocarpus laevigatus (N)	karaka
Dodonaea viscosa (P)	akeake
Dysoxylum spectabile (N)	kohekohe
Kunzea robusta (N)	kānuka
Leptospermum scoparium agg. (N)	mānuka
Leucopogon fasciculatus (N)	mingimingi
Litsea calicaris (N)	mangeao
Melicytus ramiflorus subsp. *ramiflorus* (N)	māhoe
Metrosideros excelsa (P&N)	pōhutukawa
Myoporum laetum (P&N)	ngaio
Myrsine australis (N)	māpou, matipou, māpau
Ozothamnus leptophyllus (N)	tauhinu
Piper excelsum subsp. *excelsum* (N)	kawakawa
Pittosporum crassifolium (N)	karo
Pittosporum eugenioides (P)	tarata; lemonwood
Pseudopanax lessonii× *P. crassifolius* (P&N)	
Pseudopanax lessonii (N)	houpara
Vitex lucens (N)	pūriri

Dicot. lianes

Calystegia soldanella (N)	panahi, shore bindweed
Calystegia sepium subsp. *roseata* (N)	pōhue
Calystegia sepium × *C. tuguriorum* (N)	pōhue
Muehlenbeckia complexa (N)	pōhuehue
Muehlenbeckia australis × *M. complexa* (N)	

Ferns

Blechnum novae-zelandiae (N)	kiokio
Blechnum parrisiae (N)	pukupuku
Cyathea dealbata (N)	ponga, silver fern
Cyathea medullaris (N)	mamaku
Dicksonia squarrosa (N)	whekī
Paesia scaberula (N)	mātātā
Pteridium esculentum (N)	rārahu, bracken
Pteris macilenta (N)	titipo, sweet fern
Pyrrosia eleagnifolia (N)	leather-leaf fern

Grasses

Lachnagrostis billardierei (N)	sand wind grass
Lachnagrostis filiformis (N)	
Microlaena stipoides (N)	pātītī, meadow rice grass
Oplismenus hirtellus subsp. *imbecillis* (N)	
Spinifex sericeus (N)	kōwhangatara, spinifex

Sedges

Bolboschoenus fluviatilis (N)	pūrua grass, kukuraho
Carex dissita (N)	
Carex geminata agg. (N)	rautahi
Carex pumila (N)	sand sedge
Carex testacea (N)	
Cyperus ustulatus f. *ustulatus* (N)	toetoe upoko-tangata
Eleocharis acuta (N)	spike sedge
Ficinia nodosa (N)	wīwī
Ficinia spiralis (N)	pīngao
Isolepis cernua (N)	
Machaerina articulata (N)	
Machaerina juncea (N)	
Machaerina tenax (N)	
Machaerina teretifolia (N)	
Schoenoplectus pungens (N)	

Rushes

Apodasmia similis (N)	oioi
Juncus kraussii var. *australiensis* (N)	wi, wīwī sea rush

Monocot. herbs (other than orchids, grasses, sedges, and rushes)

Arthropodium cirratum (P)	rengarenga
Collospermum hastatum (N)	kahakaha
Phormium tenax (P&N)	harakeke, flax
Triglochin striata (N)	arrow grass
Typha orientalis (N)	raupō

Composite herbs

Centipeda aotearoana (N)	
Cotula coronopifolia (N)	bachelor's button
Pseudognaphalium luteoalbum agg. (N)	pukatea
Senecio lautus var. *lautus* (N)	

Dicot. herbs (other than composites)

Apium prostratum subsp. *prostratum* var. *filiforme* (N)	tūtae-kōau, New Zealand celery
Haloragis erecta subsp. *erecta* (N)	toatoa
Lilaeopsis novae-zelandiae (N)	
Limosella lineata (N)	mudwort
Lobelia anceps (N)	punakura
Oxalis rubens (N)	sand oxalis
Samolus repens var. *repens* (N)	māakoako
Sarcocornia quinqueflora (N)	ureure, glasswort
Tetragonia implexicoma (N)	kōkihi, rengamutu, rengarenga, tūtae-ikamoana

NATURALISED AND EXOTIC SPECIES

Gymnosperms

Araucaria heterophylla	Norfolk Island pine
Cupressus macrocarpa	macrocarpa
Pinus pinaster	maritime pine
Pinus radiata	radiata pine
Taxodium distichum	swamp cypress

Monocot. trees and shrubs

Agave americana	century plant
Alocasia brisbanensis	elephants ears
Asparagus aethiopicus	bushy asparagus
Musa ×paradisiacal	banana palm
Phoenix canariensis	Phoenix palm
Trachycarpus fortunei	Chinese windmill palm
Yucca elephantipes	yucca

Dicot. trees and shrubs

Acacia longifolia	Sydney golden wattle
Alnus glutinosa	common alder
Banksia intermedia	
Banksia integrifolia	banksia
Callistemon sp.	bottlebrush
Casuarina cunninghamiana .	sheoak
Cotoneaster glaucophyllus	cotoneaster
Eriobotrya japonica	loquat
Erythrina ×sykesii	coral tree
Euonymus japonicus	Japanese spindleberry
Feijoa sellowiana	feijoa
Ficus carica	fig
Ficus macrophylla	Moreton Bay fig
Gomphocarpus fruticosus	swan plant
Grevillea robusta	silky oak
Juglans regia	common walnut
Lantana camara	lantana
Ligustrum lucidum	tree privet
Ligustrum sinense	Chinese privet
Lupinus arboreus	lupin
Lycium ferocissimum	boxthorn
Melilotus indica	King Island melilot
Myoporum insulare	Tasmanian ngaio
Nerium oleander	oleander
Opuntia vulgaris	prickly pear
Paraserianthes lophantha	brush wattle
Pelargonium sp.	geranium
Populus alba 'Nivea'	silver poplar
Populus nigra 'Italica'	Lombardy poplar
Psoralea pinnata	Dally pine
Rhaphiolepis umbellata	Indian Hawthorn
Ricinus communis	castor oil plant
Robinia pseudoacacia	false acacia, black locust, robinia
Roldana petasitis	velvet groundsel
Rubus sp. (*R. fruticosus* agg.)	blackberry
Salix cinerea	grey willow
Salix fragilis	crack willow
Salix matsudana 'Tortuosa'	tortured willow
Solanum mauritianum	woolly nightshade
Tecomaria capensis	Cape honeysuckle
Ulex europaeus	gorse

Dicot. lianes

Delairea odorata	German ivy
Dipogon lignosus	mile-a-minute
Hedera helix	ivy

Jasminum polyanthum	jasmine
Lonicera japonica	Japanese honeysuckle
Rumex sagittatus	climbing dock
Vitis vinifera	grape

Ferns

Nephrolepis cordifolia	tuber ladder fern
Osmunda regalis	royal fern

Grasses

Agrostis stolonifera	creeping bent
Aira caryophyllea subsp. *caryophyllea*	silver hairy grass
Ammophila arenaria	marram
Anthoxanthum odoratum	sweet vernal
Arrhenatherum elatius subsp. *elatius*	tall oat grass
Avena fatua	wild oat
Briza maxima	large quaking grass
Briza minor	shivery grass
Bromus diandrus	ripgut brome
Bromus uniloides	brome
Bromus willdenowii	prairie grass
Catapodium rigidum	hard grass
Cenchrus clandestinus	kikuyu grass
Cortaderia selloana	pampas
Dactylis glomerata	cocksfoot
Ehrharta erecta	veldt grass
Glyceria maxima	reed sweetgrass
Holcus lanatus	Yorkshire fog
Lagurus ovatus	harestail
Lolium perenne	rye grass
Paspalum dilatatum	paspalum
Paspalum vaginatum	saltwater paspalum
Poa annua	annual poa
Schedonorus arundinaceus	tall fescue
Sporobolus africanus	ratstail
Stenotaphrum secundatum	buffalo grass
Vulpia sp.	

Sedges

Cyperus eragrostis	umbrella sedge
Cyperus esculentus	yellow nut grass

Rushes

Juncus articulatus	jointed rush
Juncus bufonius var. *bufonius*	toad rush

Monocot. herbs (other than orchids, grasses, sedges, and rushes)

Agapanthus praecox	agapanthus
Alisma plantago-aquatica	water plantain
Aloe arborescens	aloe
Aloe sp.	aloe
Anigozanthos sp.	kangaroo paws
Arum italicum	Italian arum
Canna indica	canna lily, Indian shoot
Crocosmia ×crocosmiiflora	montbretia
Gladiolus undulatus	gladiolus
Hedychium gardnerianum	kahili ginger, wild ginger
Iris sp.	
Kniphofia praecox	red hot poker
Lilium formosanum	Formosan lily
Tradescantia fluminensis	tradescantia
Watsonia sp.	watsonia
Zantedeschia aethiopica	arum lily

Composite herbs

Arctotheca calendula	cape weed
Aster subulatus	sea aster
Bellis perennis	lawn daisy
Bidens frondosa	beggars' ticks
Cirsium arvense	California thistle
Cirsium vulgare	Scotch thistle
Conyza sumatrensis	broad-leaved fleabane
Crepis capillaris	hawksbeard
Gaillardia ×grandiflora	gaillardia
Gamochaeta calviceps	silky cudweed
Gamochaeta coarctata	purple cudweed
Gamochaeta purpurea	spoonleaf purple everlasting
Gamochaeta simplicicaulis	simple-stem everlasting
Gazania linearis	gazania
Gazania rigens	gazania
Hypochaeris radicata	catsear
Leontodon taraxacoides	hawkbit
Osteospermum fruticosum	rain daisy, dimorphotheca
Senecio skirrhodon	gravel groundsel
Sonchus oleraceus	puha, sow thistle

Dicot. herbs (other than composites)

Acanthus mollis	bear's breeches
Alternanthera philoxeroides	alligator weed
Anagallis arvensis	scarlet pimpernel
Aphanes arvenis	parsley piert
Apium nodiflorum	water celery
Atriplex prostrata	orache

Carpobrotus chilensis	ice plant
Carpobrotus edulis	ice plant
Centaurium erythraea	centaury
Centranthus ruber	spur valerian
Cerastium fontanum subsp. *vulgare*	mouse-ear chickweed
Cotyledon orbiculata	pig's ear
Daucus carota	wild carrot
Dysphania ambrosioides	Mexican tea
Foeniculum vulgare	fennel
Fumaria muralis	scrambling fumitory
Galium aparine	cleavers
Geranium gardneri	gardners geranium
Lathyrus latifolius	everlasting pea
Lavatera arborea	tree mallow
Linaria purpurea	purple linaria
Linum catharticum	purging flax
Lotus pedunculatus	lotus
Lotus suaveolens	hairy birdsfoot trefoil
Lycopus europaeus	gypsy wort
Lythrum hyssopifolia	hyssop loosestrife
Medicago nigra	bur medick
Mentha pulegium	penny royal
Myosotis discolor	grassland forget-me-not
Nasturtium officinale	watercress
Ornithopus pinnatus	yellow serradella
Orobanche minor	broomrape
Oxalis incarnata	lilac oxalis
Parentucellia viscosa	tarweed
Persicaria maculosa	willow weed
Plantago lanceolata	narrow-leaved plantain
Plectranthus ecklonii	blue spur flower
Polycarpon tetraphyllum	allseed
Polygonum aviculare	wireweed
Prunella vulgaris	selfheal
Ranunculus repens	creeping buttercup
Rumex obtusifolius	broad-leaved dock
Silene coronaria	rose campion
Silene gallica	catchfly
Solanum nigrum	black nightshade
Trifolium repens	white clover
Tropaeolum majus	garden nasturtium
Verbascum virgatum	moth mullein
Verbena bonariensis	purple-top
Veronica anagallis-aquatica	water speedwell
Vicia disperma	small French tare
Vicia sativa	vetch

PEST PLANT SPECIES RECORDED AT PORT WAIKATO

Classification according to Waikato Regional Pest Management Plan 2014-2024.

Common Name	Species Name	Species Name Classification
Alligator weed	*Alternanthera philoxeroides*	Progressive containment
Arum lily	*Zantedeschia aethiopica*	Not in RPMP
Banana palm	*Musa ×paradisiacal*	Not in RPMP - control on public/ reserve land
Banksia	*Banksia intermedia*	Not in RPMP
Banksia	*Banksia integrifolia*	Not in RPMP
Bear's breeches	*Acanthus mollis*	Not in RPMP
Blackberry	*Rubus* sp. (*R. fruticosus* agg.)	Not in RPMP
Bottlebrush	*Callistemon* sp.	Not in RPMP
Boxthorn	*Lycium ferocissimum*	Not in RPMP
Brush wattle	*Paraserianthes lophantha*	Not in RPMP
Bushy asparagus	*Asparagus sprengeri*	Site lead control
Canna lily, Indian shoot	*Canna indica*	Not in RPMP
Cape honeysuckle	*Tecomaria capensis*	Not in RPMP
Castor oil plant	*Ricinus communis*	Not in RPMP
Century plant	*Agave americana*	Site lead control
Chinese privet	*Ligustrum sinense*	Sustained control
Chinese windmill palm	*Trachycarpus fortunei*	Not in RPMP
Climbing dock	*Rumex sagittatus*	Not in RPMP
Common alder	*Alnus glutinosa*	Not in RPMP
Common walnut	*Juglans regia*	Site lead control
Coral tree	*Erythrina ×sykesii*	Not in RPMP
Cotoneaster	*Cotoneaster glaucophyllus*	Not in RPMP
Crack willow	*Salix fragilis*	Site lead control
Dally pine	*Psoralea pinnata*	Not in RPMP
Elephants ears	*Alocasia brisbanensis*	Not in RPMP
False acacia, black locust, robinia	*Robinia pseudoacacia*	Not in RPMP
Feijoa	*Feijoa sellowiana*	Not in RPMP - control on public/ reserve land
Fig	*Ficus carica*	Not in RPMP - control on public/ reserve land
Formosan lily	*Lilium formosanum*	Not in RPMP
Gaillardia	*Gaillardia ×grandiflora*	Not in RPMP - control on public/ reserve land
Garden nasturtium	*Tropaeolum majus*	Not in RPMP - control on public/ reserve land
Gazania	*Gazania linearis* and *G. rigens*	Not in RPMP
Geranium	*Pelargonium* sp.	Not in RPMP
German ivy	*Delairea odorata*	Not in RPMP
Gladiolus; gladioli	*Gladiolus undulatus*	Not in RPMP
Gorse	*Ulex europaeus*	Sustained control
Grape	*Vitis vinifera*	Not in RPMP - control on public/ reserve land
Grey willow	*Salix cinerea*	Site lead control
Ice plant	*Carpobrotus chilensis* and *C. edulis*	Not in RPMP
Indian Hawthorn	*Rhaphiolepis umbellata*	Not in RPMP - control on public/

Common Name	Species Name	Species Name Classification
		reserve land
Iris	*Iris* sp.	Not in RPMP
Italian arum	*Arum italicum*	Not in RPMP
Ivy	*Hedera helix*	Not in RPMP
Japanese honeysuckle	*Lonicera japonica*	Not in RPMP
Japanese spindleberry	*Euonymus japonicus*	Not in RPMP
Jasmine	*Jasminum polyanthum*	Not in RPMP
Kahili ginger, wild ginger	*Hedychium gardnerianum*	Progressive containment
King Island melilot	*Melilotus indica*	Not in RPMP
Lantana	*Lantana camara*	Eradication
Lombardy poplar	*Populus nigra* 'Italica'	Not in RPMP
Loquat	*Eriobotrya japonica*	Not in RPMP
Lupin	*Lupinus arboreus*	Not in RPMP
Macrocarpa	*Cupressus macrocarpa*	Not in RPMP
Maritime pine	*Pinus pinaster*	Not in RPMP
Marram	*Ammophila arenaria*	Not in RPMP
Mile-a-minute	*Dipogon lignosus*	Eradication
Montbretia	*Crocosmia ×crocosmiiflora*	Not in RPMP
Moreton Bay fig	*Ficus macrophylla*	Not in RPMP - control on public/ reserve land
Norfolk Island pine	*Araucaria heterophylla*	Not in RPMS
Pampas	*Cortaderia selloana*	Progressive containment
Phoenix palm	*Phoenix canariensis*	Not in RPMP
Pig's ear	*Cotyledon orbiculata*	Not in RPMP
Prickly pear	*Opuntia vulgaris*	Not in RPMP
Radiata pine	*Pinus radiata*	Not in RPMP
Rain daisy, dimorphotheca	*Osteospermum fruticosum*	Not in RPMP - control on public/ reserve land
Red hot poker	*Kniphofia praecox*	Not in RPMP
Reed sweetgrass	*Glyceria maxima*	Site lead control
Royal fern	*Osmunda regalis*	Site lead control
Saltwater paspalum	*Paspalum vaginatum*	Site lead control
Sheoak	*Casuarina cunninghamiana.*	Not in RPMP
Silky oak	*Grevillea robusta*	Not in RPMP
Silver poplar	*Populus alba* 'Nivea'	Not in RPMP
Swan plant	*Gomphocarpus fruticosus*	Not in RPMP - control on public/ reserve land
Sydney golden wattle	*Acacia longifolia*	Not in RPMP
Tasmanian ngaio	*Myoporum insulare*	Not in RPMP
Tortured willow	*Salix matsudana* 'Tortuosa'	Not in RPMP
Tradescantia	*Tradescantia fluminensis*	Not in RPMP
Tree privet	*Ligustrum lucidum*	Sustained control
Tuber ladder fern	*Nephrolepis cordifolia*	Not in RPMP
Velvet groundsel	*Roldana petasitis*	Not in RPMP
Watsonia	*Watsonia* sp.	Not in RPMP
Woolly nightshade	*Solanum mauritianum*	Progressive containment
Yucca	*Yucca elephantipes*	Not in RPMP - control on public/ reserve land

FAUNA WITHIN THE PORT WAIKATO PROJECT AREA

MAMMALS

Introduced (feral)

Erinaceus europaeus	European hedgehog*
Felis catus	cat*
Mustela erminea	stoat*
Mustela furo	ferret*
Mustela nivalis vulgaris	weasel*
Oryctolagus cuniculus	European rabbit
Rattus exulans	kiore; Pacific rat*
Rattus norvegicus	pouhawaiki; Norway rat
Rattus rattus	ship rat*
Trichosurus vulpecula	brushtail possum

BIRDS

Indigenous

Ardea novaehollandiae	white-faced heron, blue heron
Charadrius bicinctus bicinctus	tūturiwhatu; banded dotterel
Charadrius obscurus	tūturiwhatu; New Zealand dotterel
Chrysococcyx lucidus lucidus	pīpīwharauroa; shining cuckoo
Circus approximans	kāhu; swamp harrier
Gerygone igata	riroriro; grey warbler
Haematopus finschi	tōrea, pied oystercatcher
Haematopus unicolor	tōrea, tōrea pango, variable oystercatcher
Himantopus himantopus leucocephalus	poaka; pied stilt
Hirundo neoxena neoxena	welcome swallow
Hydroprogne caspia	taranui; Caspian tern
Larus bulleri	black-billed gull
Larus novaehollandiae scopulinus	tarāpunga; red-billed gull
Limosa lapponica	bar-tailed godwit
Morus serrator	tākapu, Australasian gannet
Phalacrocorax carbo novaehollandiae	kawau; black shag
Phalacrocorax varius varius	kāruhiruhi; pied shag
Prosthemadera novaeseelandiae	tūī
Rhipidura fuliginosa	pīwakawaka, fantail

* Animal pest not seen during the site visit in December 2015, but are likely present within the project area.

Tadorna variegata	pūtangitangi; pari; paradise shelduck
Todiramphus sanctus vagans	kōtare sacred kingfisher; New Zealand kingfisher

Introduced

Acridotheres tristis	common myna
Alauda arvensis	Eurasian skylark
Anas platyrhynchos platyrhynchos	mallard
Carduelis carduelis britannica	European goldfinch
Carduelis chloris	European greenfinch
Emberiza citrinella	yellowhammer
Fringilla coelebs	chaffinch
Gymnorhina tibicen	Australian magpie
Passer domesticus domesticus	house sparrow
Phasianus colchicus	common pheasant
Prunella modularis	dunnock
Sturnus vulgaris vulgaris	common starling
Turdus merula merula	Eurasian blackbird
Turdus philomelos	song thrush

FISH[1]

Indigenous

Anguilla dieffenbachii	longfin eel
Galaxias fasciatus	banded kōkopu
Galaxias maculatus	inanga
Gobiomorphus basalis	Crans bully

Introduced

Cyprinus carpio	European (koi) carp

FROGS

Introduced

Litoria raniformis	southern bell frog

CRUSTACEAN

Paratya curvirostris	freshwater shrimp

[1] Note: For list of all fish records for the area, refer to Appendix 4.

APPENDIX 4

FISH SPECIES WITHIN THE WAIKATO RIVER CATCHMENT

Source: New Zealand Freshwater Fish Database, accessed 19 January 2016

Species	Common Name	Threat Ranking
Galaxias fasciatus	Banded kōkopu	Not threatened
Gambusia affinis	Gambusia	Introduced and naturalised
Cheimarrichthys fosteri	Torrentfish	At Risk-Declining
Galaxias brevipinnis	Kōaro	At Risk-Declining
Anguilla australis	Shortfin eel	Not threatened
Ameiurus nebulosus	Catfish	Introduced and naturalised
Carassius auratus	Goldfish	Introduced and naturalised
Galaxias maculatus	Inanga	At Risk-Declining
Gobiomorphus cotidianus	Common bully	At Risk-Declining
Mugil cephalus	Grey mullet	Not threatened
Retropinna retropinna	Common smelt	Not threatened
Anguilla dieffenbachii	Longfin eel	At Risk-Declining
Gobiomorphus huttoni	Redfin bully	At Risk-Declining
Gobiomorphus gobioides	Giant bully	Not threatened
Galaxias argenteus	Giant kōkopu	At Risk-Declining
Aldrichetta forsteri	Yelloweyed mullet	Not threatened
Geotria australis	Lamprey	Threatened-Nationally vulnerable
Cyprinus carpio	Koi carp	Introduced and naturalised
Neochanna diversus	Black mudfish	At Risk-Declining
Oncorhynchus mykiss	Rainbow trout	Introduced and naturalised
Salmo trutta	Brown trout	Introduced and naturalised
Scardinius erythrophthalmus	Rudd	Introduced and naturalised
Ctenopharyngodon idella	Grass carp	Introduced and naturalised
Rhombosolea retiaria	Black flounder	Not threatened
Galaxias postvectis	Shortjaw kōkopu	Threatened-Nationally Vulnerable
Gobiomorphus basalis	Crans bully	Not threatened
Perca fluviatilis	Perch	Introduced and naturalised

FRESHWATER MACROINVERTEBRATES WITHIN THE TRIBUTARIES SAMPLED

Order/Phyllum	Family	Species	Status	MCI Score
DECAPODA (shrimp)	**Atyidae**	*Paratya curvirostris*	Indigenous	5
MOLLUSCA (snails)	**Lymnaeidae**	*Pseudosuccinea* species	Introduced	3
		Lymnaea species	Introduced	3
DIPTERA (flies)	**Chironomidae: Tanypodinae**	Unidentified species	Not known	5
COLEOPTERA (beetles)		Undescribed genus and species	Not known	6
	Conoesucidae	*Pycnocentrodes aeris*	Indigenous	5
		Pycnocentria evecta	Indigenous	7
EPHEMEROPTERA (mayflies)	**Leptophlebiidae**	*Deleatidium myzobranchia*	Indigenous	8
	Gripopterygidae	*Zelandoperla fenestrata*	Indigenous	10
	Heliocopsychidae	*Heliopsyche albescens*	Indigenous	10
	Hydrobiosidae	*Costachorema* species	Indigenous	6
		Psilochorema leptoharpax	Indigenous	8
	Leptoceridae	*Hudsonema amabile*	Indigenous	6

FRESHWATER NUTRIENT ANALYSES

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Web www.hill-labs.co.nz

ANALYSIS REPORT

Client:	Wildland Consultants Limited	**Lab No:**	1512328	SPv1
Contact:	Nick Goldwater	**Date Registered:**	08-Dec-2015	
	C/- Wildland Consultants Limited	**Date Reported:**	15-Dec-2015	
	PO Box 46299	**Quote No:**	68059	
	Herne Bay	**Order No:**		
	AUCKLAND 1011	**Client Reference:**	Freshwater/Sediment	
		Submitted By:	Sarah Sue Roth	

Sample Type: Aqueous

Sample Name:		Pam's Culvert 07-Dec-2015 2:00 pm	Ansell Rd 07-Dec-2015 3:00 pm			
Lab Number:		1512328.1	1512328.2			
Individual Tests						
Turbidity	NTU	9.6	10.5	-	-	-
pH	pH Units	7.9	7.6	-	-	-
Electrical Conductivity (EC)	mS/m	26.8	21.5	-	-	-
Total Nitrogen	g/m³	0.36	0.31	-	-	-
Nitrate-N + Nitrite-N	g/m³	0.054	0.029	-	-	-
Total Kjeldahl Nitrogen (TKN)	g/m³	0.31	0.28	-	-	-
Total Phosphorus	g/m³	0.090	0.044	-	-	-
Escherichia coli	cfu / 100mL	1,100 #1	600 #1	-	-	-
Heavy metals, totals, trace As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Arsenic	g/m³	< 0.0011	< 0.0011	-	-	-
Total Cadmium	g/m³	< 0.000053	< 0.000053	-	-	-
Total Chromium	g/m³	< 0.00053	< 0.00053	-	-	-
Total Copper	g/m³	0.00173	0.00128	-	-	-
Total Lead	g/m³	0.00019	0.00028	-	-	-
Total Nickel	g/m³	< 0.00053	< 0.00053	-	-	-
Total Zinc	g/m³	< 0.0011	0.0016	-	-	-

Analyst's Comments

Please interpret this result with caution as the sample was > 8 °C on receipt at the lab. The sample temperature is recommended by APHA to be less than 8 °C on receipt at the laboratory (but not frozen).

#1 Statistically estimated count based on the theoretical countable range for the stated method.

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Heavy metals, totals, trace As,Cd,Cr,Cu,Ni,Pb,Zn	Nitric acid digestion, ICP-MS, trace level	0.000053 - 0.0011 g/m³	1-2
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-2
Total Digestion	Boiling nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	1-2
Total Kjeldahl Digestion	Sulphuric acid digestion with copper sulphate catalyst.	-	1-2
Total Phosphorus Digestion	Acid persulphate digestion.	-	1-2
Turbidity	**Analysis using a Hach 2100N, Turbidity meter. APHA 2130 B 22nd ed. 2012.**	0.05 NTU	1-2

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The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked *, which are not accredited.

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
pH	pH meter. APHA 4500-H^+ B 22nd ed. 2012. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field.	0.1 pH Units	1-2
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.1 mS/m	1-2
Total Nitrogen	Calculation: TKN + Nitrate-N + Nitrite-N. Please note: The Default Detection Limit of 0.05 g/m^3 is only attainable when the TKN has been determined using a trace method utilising duplicate analyses. In cases where the Detection Limit for TKN is 0.10 g/m^3, the Default Detection Limit for Total Nitrogen will be 0.11 g/m^3.	0.05 g/m^3	1-2
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m^3	1-2
Total Kjeldahl Nitrogen (TKN)	Total Kjeldahl digestion, phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-N_{org} D. (modified) 4500 NH_3 F (modified) 22nd ed. 2012.	0.10 g/m^3	1-2
Total Phosphorus	Total phosphorus digestion, ascorbic acid colorimetry. Discrete Analyser. APHA 4500-P B & E (modified from manual analysis) 22nd ed. 2012. Also modified to include the use of a reductant to eliminate interference from arsenic present in the sample. NWASCA, Water & soil Miscellaneous Publication No. 38, 1982.	0.004 g/m^3	1-2
Escherichia coli	Membrane filtration, Count on mFC agar, Incubated at 44.5°C for 22 hours, MUG Confirmation. Analysed at Hill Laboratories - Microbiology; 1 Clow Place, Hamilton. APHA 9222 G, 22nd ed. 2012.	1 cfu / 100mL	1-2

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

Martin Cowell - BSc
Client Services Manager - Environmental Division

MARINE SEDIMENT RESULTS

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Web www.hill-labs.co.nz

ANALYSIS REPORT

Client:	Wildland Consultants Limited	**Lab No:**	1512316	SPv1
Contact:	Sarah Sue Roth	**Date Registered:**	08-Dec-2015	
	C/- Wildland Consultants Limited	**Date Reported:**	05-Jan-2016	
	PO Box 46299	**Quote No:**	72780	
	Herne Bay	**Order No:**		
	AUCKLAND 1011	**Client Reference:**	Marine Sediment	
		Submitted By:	Sarah Sue Roth	

Sample Type: Sediment

		Sample Name:	W1 07-Dec-2015 3:00 pm	W2 07-Dec-2015 3:00 pm	E1 07-Dec-2015 3:00 pm	E2 07-Dec-2015 3:00 pm	
		Lab Number:	1512316.1	1512316.2	1512316.3	1512316.4	
Individual Tests							
Dry Matter	g/100g as rcvd		78	81 #1	78	64 #2	-
Total Recoverable Phosphorus	mg/kg dry wt		520	510	820	520	-
Ammonium-N*	mg/kg dry wt		< 5	5	< 5	< 5	-
Nitrite-N*	mg/kg dry wt		< 1.0	< 1.0	< 1.0	< 1.0	-
Nitrate-N*	mg/kg dry wt		< 1.5	< 1.5	1.6	< 1.5	-
Nitrate-N + Nitrite-N*	mg/kg dry wt		< 1.0	< 1.0	1.6	< 1.0	-
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg							
Total Recoverable Arsenic	mg/kg dry wt		9.3	10.9	32	28	-
Total Recoverable Cadmium	mg/kg dry wt		0.024	0.030	0.061	0.076	-
Total Recoverable Chromium	mg/kg dry wt		13.4	11.6	10.2	12.1	-
Total Recoverable Copper	mg/kg dry wt		7.4	11.3	26	18.7	-
Total Recoverable Lead	mg/kg dry wt		6.2	8.7	18.4	15.9	-
Total Recoverable Mercury	mg/kg dry wt		< 0.010	0.016	0.052	0.051	-
Total Recoverable Nickel	mg/kg dry wt		7.4	10.1	13.0	11.6	-
Total Recoverable Zinc	mg/kg dry wt		54	58	80	71	-
3 Grain Sizes Profile							
Fraction >/= 2 mm*	g/100g dry wt		14.7	37.1 #1	38.3	7.8 #2	-
Fraction < 2 mm, >/= 63 µm*	g/100g dry wt		77.1	43.8	52.8	50.9	-
Fraction < 63 µm*	g/100g dry wt		8.2	19.1	9.0	41.3	-

Analyst's Comments

#1 Two large stones were not included when subsampling for sieve because they are not representative of the sample.

#2 It should be noted that a significant portion of the sample was comprised of worms, which broke up during the drying and sieving process, thereby significantly altering the portion of >2mm and <2mm fractions. should be kept in mind when interpreting these results.

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Sediment

Test	Method Description	Default Detection Limit	Sample No
Individual Tests			
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-4
Dry Matter	Drying for 16 hours at 103°C, gravimetry (Free water removed before analysis).	0.10 g/100g as rcvd	1-4
2M KCl Extraction*	2M potassium chloride extraction of as received fraction for analysis of NH4N, NO2N and NO3N. Analyst, 109, 549, (1984).	-	1-4

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The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked *, which are not accredited.

Sample Type: Sediment			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	1-4
Total Recoverable Phosphorus	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2.	40 mg/kg dry wt	1-4
Ammonium-N*	2M potassium chloride extraction on as received fraction. Phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-NH_3 F (modified) 22nd ed. 2012.	5 mg/kg dry wt	1-4
Nitrite-N*	**FIA determination of 2M potassium chloride extraction on as received fraction. APHA 4500-NO_3^- I (modified) 22nd ed. 2012.**	1.0 mg/kg dry wt	1-4
Nitrate-N*	Calculation: (Nitrate-N + Nitrite-N) - Nitrite-N.	1.5 mg/kg dry wt	1-4
Nitrate-N + Nitrite-N*	Automated cadmium reduction, FIA determination of 2M potassium chloride extraction on as received fraction. APHA 4500-NO_3^- I (modified) 22nd ed. 2012.	1.0 mg/kg dry wt	1-4
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, trace level.	0.010 - 0.4 mg/kg dry wt	1-4
3 Grain Sizes Profile*		0.1 g/100g dry wt	1-4
3 Grain Sizes Profile			
Fraction < 2 mm, >/= 63 µm*	Wet sieving using dispersant, 2.00 mm and 63 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-4
Fraction < 63 µm*	Wet sieving with dispersant, 63 µm sieve, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-4

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

Ara Heron BSc (Tech)
Client Services Manager - Environmental Division

APPENDIX 8

SITE PHOTOGRAPHS

Plate 1: Southern end of the foredunes; characterised by spinifex-tauhinu scrub and mixed indigenous-exotic scrub on the leeward side of the dunes. 8 February 2013.

Plate 2: Southward view with tauhinu-spinifex shrubland in the foreground and evidence of a large fire that swept through the dunes in the midground, now dominated by pampas. 8 February 2013.

Plate 3: Tauhinu-spinifex shrubland in foreground with large blow out visible; pampas tussockland to left of burned area. 8 February 2013.

Plate 4: Raupō reedland with mānuka and cabbage trees in background. Exotic trees in rear of background. 7 December 2015.

Plate 5: Spinifex grassland with occasional pīngao. 7 December 2015.

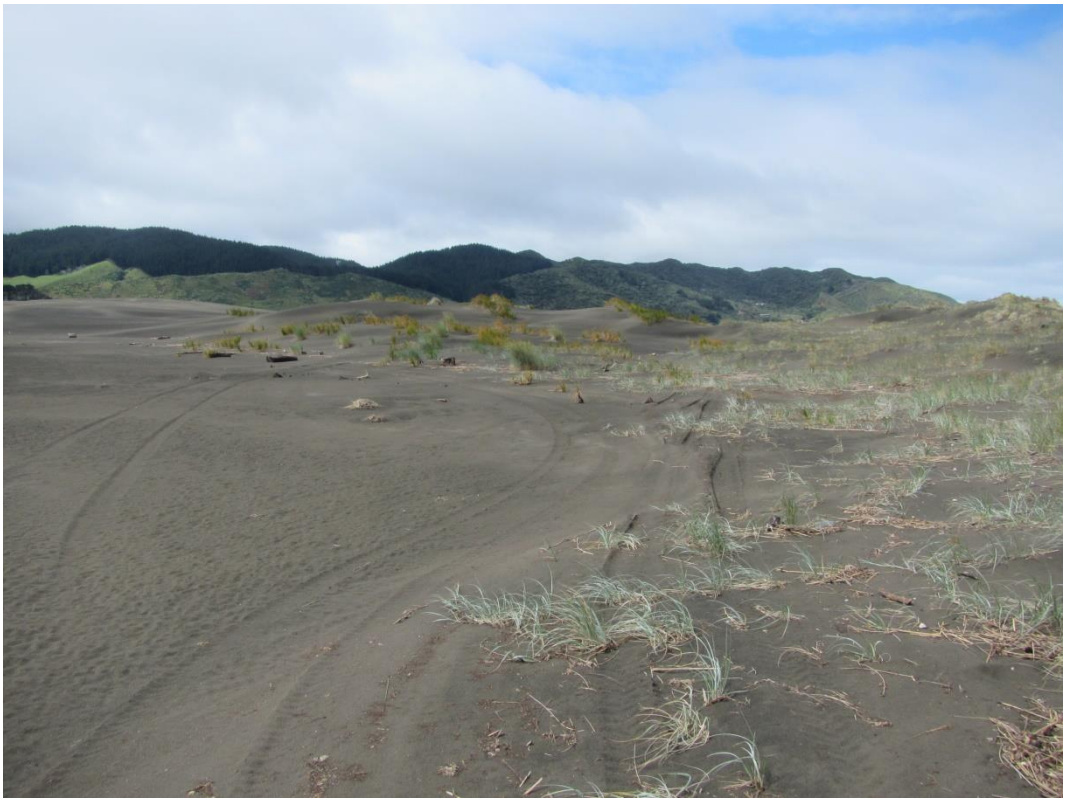

Plate 6: Tyre tracks through spinifex and pīngao grasslands, resulting in damage to the vegetation. 7 December 2015.

Plate 7: Shell beds within a spinifex sandfield with marram infestations and tyre tracks. 7 December 2015.

Plate 8: Pampas tussockland on left and burned area on right with emergent maritime pine. 8 February 2013.

Plate 9: Burn area with maritime pine establishing
on both sides of the walking track. 8 February 2013.

Plate 10: Herbfield in damp seepage undisturbed by vehicle
or pedestrian traffic. 7 December 2015.

Plate 11: Marram infestation within pīngao-spinifex sandfield vegetation type. 7 December 2015.

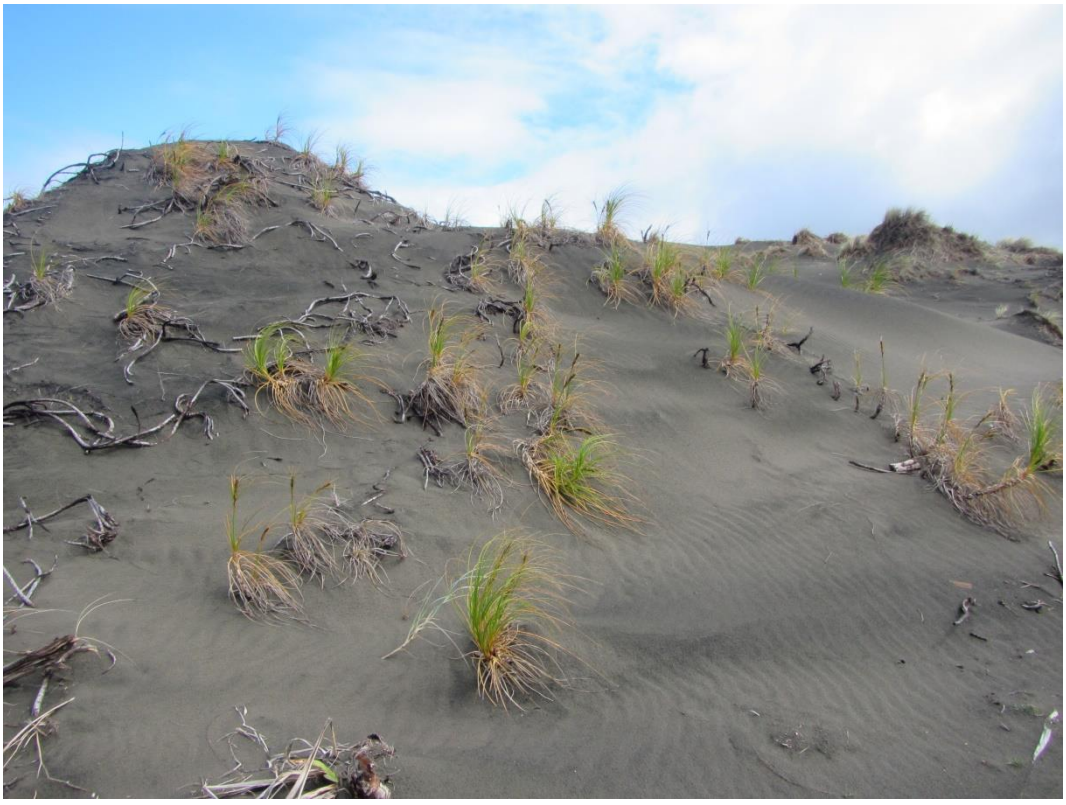

Plate 12: Dead roots of pīngao, indicating that pīngao was probably more common in the recent past. 7 December 2015.

Plate 13: Southern end of the project area at Sunset Beach with the Port Waikato Surf Club visible on the left of the photograph. 8 February 2013.

Plate 14: Small damp seepage on the eastern side of the dune with tyre tracks evident, resulting in crushing of vulnerable turf vegetation. 8 February 2013.

Plate 15: Signs at an entrance to the sand dunes. 7 December 2015

PLANTING SCHEDULES

Table 1: Plant schedule for blowouts.

Species	Common Name	Grade	Spacing (m)	Composition (%)
Ficinia spiralis	Pingao	RT/bare rooted	1	10
Spinifex sericeus	Spinifex	RT/bare rooted	1	90
Total				**100**

Table 2: Plant schedule for foredunes.

Species	Common Name	Grade	Spacing (m)	Composition (%)
Ficinia spiralis	Pingao	RT/bare rooted	1	10
Ozothamnus leptophyllus[1]	Tauhinu	PB3	3	2.5
Spinifex sericeus	Spinifex	RT/bare rooted	1	87.5
Total				**100**

Table 3: Plant schedule for mid-dunes and back-dunes.

Species	Common Name	Grade	Spacing (m)	Composition (%)
Coprosma acerosa	Sand coprosma	PB3	3	5
Coprosma repens	Taupata	PB3	1	5
Euphorbia glauca	NZ shore spurge	PB3	1	2.5
Ficinia nodosa	Knobby clubrush, wīwī	RT	1	20
Ficinia spiralis	Pingao	RT/bare rooted	1	10
Lachnagrostis billardierei subsp. *billardierei*	Sand wind grass	RT	1	20
Metrosideros excelsa	Pohutukawa	PB8	5	7.5
Myoporum laetum	Ngaio	PB3	5	7.5
Phormium tenax	Harakeke, flax	PB3	1	7.5
Pimelea villosa	Pimelea	RT		2.5
Pittosporum crassifolium	Karo	PB3	3	5
Pseudopanax lessonii	Houpara	PB3	3	5
Tetragonia tetragonoides[1]	Kōkihi	RT		2.5
Total				**100**

1. Plant in shaded areas, i.e. under pohutukawa.

PRELIMINARY 10 YEAR PROGRAME OF RESTORATION WORKS

PORT WAIKATO ECOLOGICAL ENHANCEMENT - PRELIMINARY 10 YEAR PROGRAMME OF WORKS

Key

- Initial Pest Plant Control
- Follow Up/Maintenance Pest Plant Control
- Monitoring/Identifying requirements/Consents
- Planting
- Pest Animal control
- Other

Year	1			2				3				4				5			
Month	**Winter**	**Spring**	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**
Task																			
PEST PLANT CONTROL (Refer Sections 13 and 16)																			
Exotic tree removal																			
Exotic tree removal in Year 1, and follow-up Year 2-4 ONLY																			
Pest plant control in priority zones (Figure 3)																			
Zone 1 - apply for consent to use Haloxyfop within MHWS (for saltwater paspalum), annually																			
Zone 1 - control of marram and salt water paspalum, including follow-up control																			
Zone 2 - control of marram, including follow-up control																			
Zone 3 - control of marram, pampas, agapanthus and gazania, including follow-up control																			
Zone 4 - control of all other pest plants, including follow-up control																			
Pest plant control outside priority zones																			
Control of exotic seedlings between Zones 1 and 2, including follow-up control																			
Control of low abundance pest plants throughout project area, including follow-up control																			
PEST ANIMAL CONTROL (Refer Sections 13 and 16)																			
Rabbits/Hares																			
Identifying populations/densities of rabbits, hares, or both by spotlighting																			
If hares present - Initial spotlight shooting of hares and follow-up control																			
If rabbits present - apply for consent to use Pindone to control rabbit populations, annually																			
If rabbits present - Pindone/warren fumigation for control and follow-up control																			
Mustelids, hedgehogs, cats and rats																			
Establishment of 100m grid of DOC200s/DOC250s/live capture cat cages around known dotterel and Caspian tern breeding areas.																			
Check/refill/reset traps (every two weeks over breeding season, July - March = 20 visits per annum)																			
PLANTING (Refer Sections 13 and 16)																			
Identify planting requirements in blowouts, foredunes and mid-back dunes																			
Order plants																			
Planting - blowouts (0.5 ha per annum)																			
Planting - foredunes (0.5 ha per annum)																			
Planting - mid-back dunes (0.5 ha per annum)																			
MONITORING (Refer Section 14)																			
Establish photopoints and remeasure annually for Year 1-3 and biennially for Year 4-10																			
Monitor for rabbit/hare damage and vehicle damage in Zone 1, annually																			
Monitor for upcoming pest control requirements, annually																			
ACCESSWAYS & SIGNAGE (Refer Sections 13 and 16)																			
Identify accessway, fencing and signage locations including community engagement, mapping and planning																			
Fencing implementation (post & 3wire at $10/m)																			
Signage implementation																			
MANAGEMENT																			
Project Management																			
Quarterly Reporting for 10 years (total = 40 reports)																			

Year	6				7				8				9				10			
Month	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer
Task																				
PEST PLANT CONTROL (Refer Sections 13 and 16)																				
Exotic tree removal																				
Exotic tree removal in Year 1, and follow-up Year 2-4 ONLY																				
Pest plant control in priority zones (Figure 3)																				
Zone 1 - apply for consent to use Haloxyfop within MHWS (for saltwater paspalum), annually																				
Zone 1 - control of marram and salt water paspalum, including follow-up control																				
Zone 2 - control of marram, including follow-up control																				
Zone 3 - control of marram, pampas, agapanthus and gazania, including follow-up control																				
Zone 4 - control of all other pest plants, including follow-up control																				
Pest plant control outside priority zones																				
Control of exotic seedlings between Zones 1 and 2, including follow-up control																				
Control of low abundance pest plants throughout project area, including follow-up control																				
PEST ANIMAL CONTROL (Refer Sections 13 and 16)																				
Rabbits/Hares																				
Identifying populations/densities of rabbits, hares, or both by spotlighting																				
If hares present - Initial spotlight shooting of hares and follow-up control																				
If rabbits present - apply for consent to use Pindone to control rabbit populations, annually																				
If rabbits present - Pindone/warren fumigation for control and follow-up control																				
Mustelids, hedgehogs, cats and rats																				
Establishment of 100m grid of DOC200s/DOC250s/live capture cat cages around known dotterel and Caspian tern breeding areas.																				
Check/refill/reset traps (every two weeks over breeding season, July - March = 20 visits per annum)																				
PLANTING (Refer Sections 13 and 16)																				
Identify planting requirements in blowouts, foredunes and mid-back dunes																				
Order plants																				
Planting - blowouts (0.5 ha per annum)																				
Planting - foredunes (0.5 ha per annum)																				
Planting - mid-back dunes (0.5 ha per annum)																				
MONITORING (Refer Section 14)																				
Establish photopoints and remeasure annually for Year 1-3 and biennially for Year 4-10																				
Monitor for rabbit/hare damage and vehicle damage in Zone 1, annually																				
Monitor for upcoming pest control requirements, annually																				
ACCESSWAYS & SIGNAGE (Refer Sections 13 and 16)																				
Identify accessway, fencing and signage locations including community engagement, mapping and planning																				
Fencing implementation (post and 3wire at $10/m)																				
Signage implementation																				
MANAGEMENT																				
Project Management																				
Quarterly Reporting for 10 years (total = 40 reports)																				

INDICATIVE 10 YEAR IMPLEMENTATION COSTINGS

PORT WAIKATO ECOLOGICAL ENHANCEMENT
PROVISIONAL 10 YEAR IMPLEMENTATION COSTINGS

	YEAR 1		YEARS 2-10 (COSTS GIVEN ARE PER ANNUM)		TOTAL - 10 YEARS	
	LOW	HIGH	LOW	HIGH	LOW	HIGH
PEST PLANT CONTROL (Refer Sections 13 and 16)						
Exotic tree removal						
Exotic tree removal in Year 1, and follow-up Year 2-4 ONLY	10,500.00	18,400.00	1,333.33	2,633.33	14,500.00	26,300.00
Pest plant control in priority zones (Figure 3)						
Zone 1 - apply for consent to use Haloxyfop within MHWS (for saltwater paspalum), annually	1,200.00	2,390.00	1,200.00	2,390.00	12,000.00	23,900.00
Zone 1 - control of marram and salt water paspalum, including follow-up control	10,700.00	17,800.00	3,566.67	5,344.44	42,800.00	65,900.00
Zone 2 - control of marram, including follow-up control	1,800.00	3,600.00	900.00	1,788.89	9,900.00	19,700.00
Zone 3 - control of marram, pampas, agapanthus and gazania, including follow-up control	35,600.00	53,400.00	14,233.33	17,800.00	163,700.00	213,600.00
Zone 4 - control of all other pest plants, including follow-up control	8,900.00	12,500.00	2,677.78	4,455.56	33,000.00	52,600.00
Pest plant control outside priority zones						
Control of exotic seedlings between Zones 1 and 2, including follow-up control	3,600.00	5,400.00	900.00	1,788.89	11,700.00	21,500.00
Control of low abundance pest plants throughout project area, including follow-up control	71,200.00	89,000.00	17,800.00	21,355.56	231,400.00	281,200.00
PEST ANIMAL CONTROL (Refer Sections 13 and 16)						
Rabbits/Hares						
Identifying populations/densities of rabbits, hares, or both by spotlighting	1,500.00	4,500.00	n/a	n/a	1,500.00	4,500.00
If hares present - Initial spotlight shooting of hares and follow-up control	6,000.00	8,900.00	1,488.89	8,877.78	19,400.00	88,800.00
If rabbits present - apply for consent to use Pindone to control rabbit populations, annually	120.00	240.00	120.00	240.00	1,200.00	2,400.00
If rabbits present - Pindone/warren fumigation for control and follow-up control	6,400.00	12,700.00	3,166.67	12,633.33	34,900.00	126,400.00
Mustelids, hedgehogs, cats and rats						
Establishment of 100m grid of DOC200s/250s around known dotterel and Caspian tern breeding areas - Approx. 50 traps over 50 ha. Establish grid, distribute and set out traps, GPS locations, and do first set	2,200.00	3,300.00	n/a	n/a	2,200.00	3,300.00
Check traps (every two weeks over breeding season, July - March = 20 visits per annum)	21,780.00	43,560.00	21,780.00	43,560.00	217,800.00	435,600.00
DOC200s (double set) - ×50 + allowance for 20% replacement per annum, due to harsh environment and public interference	6,500.00	6,500.00	1,300.00	1,300.00	18,200.00	18,200.00
DOC250s - ×12 + allowance for 20% replacement per annum, due to harsh environment and public interference	1,700.00	1,700.00	344.44	344.44	4,800.00	4,800.00
Live cage traps (or kill traps) for cats ×6 + allowance for 20% replacement per annum, due to harsh environment and public interference	1,100.00	1,100.00	211.11	211.11	3,000.00	3,000.00
PLANTING (Refer Sections 13 and 16)						
Identify planting requirements - estimated at 0.5 ha in each vegetation type per annum (prioritised)	1,200.00	2,390.00	1,200.00	2,390.00	12,000.00	23,900.00
Source & Order plants (all sites)	300.00	600.00	300.00	600.00	3,000.00	6,000.00
Blowouts - Annual Plant Supply and Planting (5,000 plants p.a.)	18,900.00	25,680.00	18,900.00	25,680.00	189,000.00	256,800.00
Foredunes - Annual Plant Supply and Planting (5,000 plants p.a.)	18,900.00	25,680.00	18,900.00	10,680.00	189,000.00	256,800.00
Mid and Back Dunes - Annual Plant Supply and Planting (5,000 plants p.a.)	18,900.00	25,680.00	18,900.00	25,680.00	189,000.00	256,800.00
MONITORING (Refer Section 14)						
Establish photopoints and remeasure annually for Year 1-3 & biennially for Year 4-10 (total of six visits after year 1)	1,600.00	3,200.00	1,600.00	1,600.00	11,200.00	12,800.00
Equipment (20 waratahs stakes) + allowance for 20% replacement per annum, due to harsh environment and public interference	300.00	300.00	66.67	66.67	900.00	900.00
Annual monitoring for rabbit/hare & vehicle damage in Zone 1	1,200.00	1,200.00	1,200.00	1,200.00	12,000.00	12,000.00
Annual monitoring for/identifying of pest plant and pest animal control requirements for coming year	1,200.00	1,200.00	1,200.00	1,200.00	12,000.00	12,000.00
ACCESSWAYS & SIGNAGE (Refer Sections 13 and 16)						
Identify accessway, fencing and signage locations including engagement, mapping and planning + 10% allowance for annual inspections	1,200.00	1,200.00	122.22	122.22	2,300.00	1,200.00
Fencing implementation (post & 3 wire at $10-15/m) + allowance for 10% replacement per annum, due to harsh environment and public interference	10,000.00	20,000.00	1,000.00	2,000.00	19,000.00	20,000.00
Signage implementation + allowance for 10% replacement per annum, due to harsh environment and public interference	5,000.00	10,000.00	500.00	1,000.00	5,000.00	10,000.00
MANAGEMENT						
Management	14,340.00	28,680.00	14,340.00	28,680.00	143,400.00	286,800.00
Quarterly reporting (for 10 years = 40 reports)	2,390.00	4,780.00	2,390.00	4,780.00	23,900.00	47,800.00
TOTAL	**286,230.00**	**435,580.00**	**151,641.11**	**230,402.22**	**1,633,700.00**	**2,595,500.00**
Contingency 10%	28,623.00	43,558.00	15,164.11	23,040.22	163,370.00	259,550.00
TOTAL (INCLUDING CONTINGENCY)	**$314,853.00**	**$ 479,138.00**	**$166,805.22**	**$253,442.44**	**$1,797,070.00**	**$2,855,050.00**

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