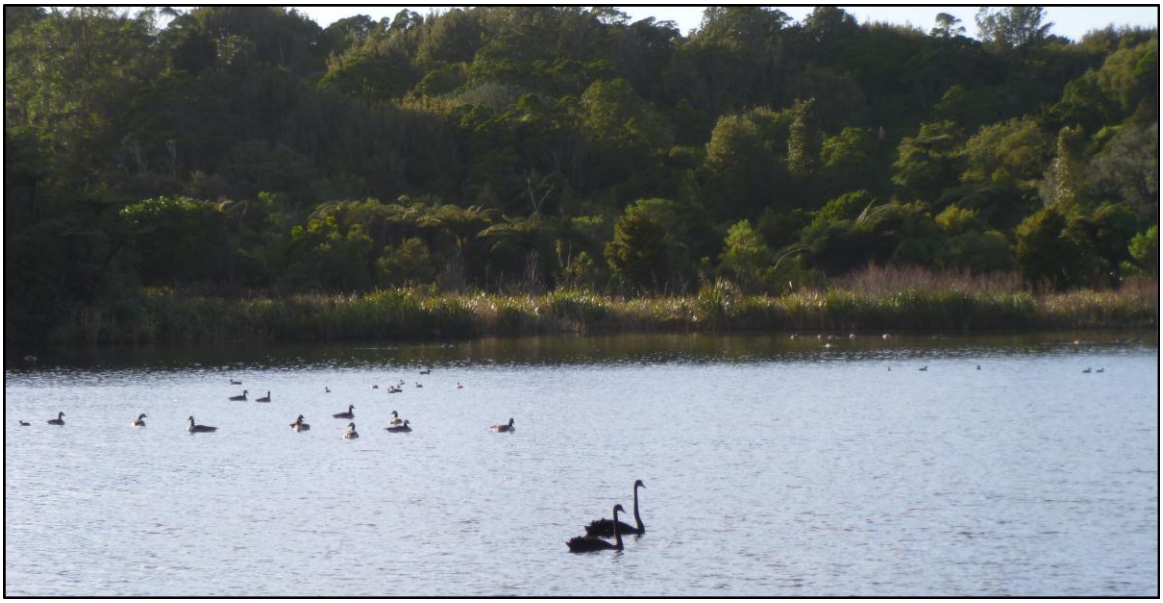
Ecological study of Barrett Domain, New Plymouth



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Te Whare Wānanga o Waikato

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Executive Summary

An ecological survey of Barrett Domain (New Plymouth) was conducted by the Environmental Research Institute, University of Waikato, for the New Plymouth District Council. The main ecological features of the domain were mapped and described, preliminary ecological impact assessments of domain upgrades were conducted, and recommendations made for the future management of the site. Barrett Domain encompasses a regionally significant wetland habitat (Barrett Lake), several hectares of remnant semi-coastal forest and areas of well-established planted native species. Wetland vegetation around Barrett Lake comprised reedland (kuta, raupo) and flaxland, and the lake provides refuge to a number of indigenous water birds. Semi-coastal forest at the site was dominated by tawa, kohekohe and pukatea, with a diverse range of understory and epiphyte species. Planted natives included a significant kauri grove, and patches of pohutukawa and puriri. Swamp forest to the west of the lake comprised mature pukatea and swamp maire, and if acquired in the land transfer, the ecological value of the domain would be greatly enhanced. Four permanent i-Tree vegetation monitoring plots and a National Wetland Monitoring plot were established at the domain and should be re-measured at 5 yearly intervals. Any ecological impacts associated with the construction of a path around the perimeter of Barrett Lake could be offset by restoration planting at the southern lake margin. Management recommendations include:

- Restoration planting with appropriate native species at the southern lake margin and several other key areas within the domain.
- Removing/monitoring exotic species, including the gorse and grey willow on the lake margin, and wandering Jew and climbing asparagus in the forest remnants.
- Fencing (stock proofing) the swamp forest at the west of the lake once it is acquired.
- Continuing with pest control and monitoring.
- Obtaining new interpretive signage.

1 Introduction

Barrett Domain is a scenic and recreation reserve on the south west edge of New Plymouth city. It currently totals 39 ha in 12 separate land parcels, and includes a small lake (Barrett Lake), bush area with walking tracks, a kauri plantation forest, a Riding for the Disabled area (RDA) and farmland managed by a neighbouring farmer for grazing (Figure 1). Barrett Lake is classified as a Regionally Significant Wetland under the Taranaki Council Fresh Water Plan and it is listed as a Key Native Ecosystem with high biodiversity values. The New Plymouth District Council controls and manages the whole Domain; however the underlying title of the three largest (and oldest) parcels is with the Crown. The Council is currently in the process of drafting a new management plan for Barrett Domain, as the existing 1980 management plan no longer provides guidance for day-to-day management or a strategic vision for the future of the reserve.

2 Objectives

In June 2012, the New Plymouth District Council commissioned the Environmental Research Institute, University of Waikato to undertake an ecological survey of Barrett Domain as part of the management plan drafting process. The main objectives of the study were to:

- Identify and map ecological values within the Domain.
- Undertake preliminary ecological impact assessments of potential developments within the Domain, including a path and boardwalk around the perimeter of the lake, upgrading of existing tracks, and construction of new tracks.
- Suggest potential ways to enhance the ecological values within the Domain and provide additional opportunities for the public to appreciate the ecological values within the Domain.

Figure 1: Map of Barrett Domain including main features and current land parcels (NPDC 2012).

3 Methodology

The majority of the data in this report was collected during a rapid qualitative vegetation survey of Barrett Domain conducted between the 25th and 29th of June, 2012. This primarily involved the description and mapping of ecological features at the site. Field sketch maps were later redrawn digitally in CorelDRAW X4 2008. In addition, several historic aerial photographs of the area were obtained, five permanent vegetation monitoring quadrats were established, and several small fyke nets were deployed in the lake for a short period to sample fish.

Permanent quadrats

Four permanent i-Tree vegetation monitoring quadrats (each 168.6 m^2, 7.31 m radius) and one permanent National Wetland Monitoring quadrat (4 m^2) was installed at Barrett Domain. These quadrats provide quantitative baseline data on vegetation structure and composition to allow for future monitoring, and also contribute to the existing network of permanent monitoring quadrats already in New Plymouth. The use of nationally (and in the case of i-Tree, internationally) recognised protocols mean that quick comparison of data with other sites is possible.

Developed by the United States Forest Service and other collaborators, i-Tree is designed to quantify the value of urban forest fragments in terms of ecosystem services. Ultimately, it is intended that this method will provide an internationally recognised standard that enables direct comparison between cities worldwide (for more information see www.ufore.org and www.itreetools.org). Two i-Tree quadrats were installed within the lagoon bush area, one was located within the Rayward bush, and the other was in the Cowling kauri planation. The i-tree Urban Forest Effects (UFORE) protocols were followed to establish the quadrats, as described by Nowak et al. (2003). This method includes collecting data on tree parameters such as stem diameter, crown height and width, dieback and canopy light exposure for each individual tree within the quadrat; species contributions to the shrub and ground tiers are qualitatively recorded and a general site description is also made. To enable the accurate relocation of the quadrats in the future, the centre of each quadrat was marked with a metal peg, GPS coordinates were recorded, and three trees were marked with numbered metal tree tags (a sketch map made showing the trees bearing and distance from the centre of the quadrat enables accurate relocation). In 2010 the i-Tree method also used to survey vegetation within Huatoki (three quadrats) and Ratapihipihi (four quadrats) Scenic Reserves in New Plymouth.

One wetland monitoring quadrat was installed on the western margin of Barrett Lake. Quadrats were established using the National Wetland Monitoring System protocols described by Clarkson et al. (2003). The overall ecological condition of the wetland is compared against an assumed natural state, such as pre settlement. It is scored using five indicators to reflect the extent and impact of the modification. The indicators relate to the major threats known to damage wetlands and are based on changes in hydrology, soil and nutrients, ecosystem intactness, native animal dominance and native plant dominance (Clarkson 2010).

GPS coordinates of quadrats were noted and position in relation to a permanent ground peg sketched. A wetland quadrat had previously been established on the eastern side of the lake in 2007 (Clarkson & Bartlam) so two monitoring points are now available at the site.

4 Results: Ecological Values

The main ecological features of Barrett Domain were mapped (Figure 2) and are described in Sections 4.1-4.11. A native vascular species list for the Domain is provided in Appendix 1. Results of the permanent vegetation monitoring plots are provided in Appendix 2.

Figure 2: Map of main ecological features within Barrett Domain.

4.1 Barrett Lake

Barrett Lake contains around 4 ha of open water with a discontinuous fringe of <1 ha of native wetland vegetation. Barrett Lake is often referred to as Barrett Lagoon; though the wetland form 'lagoon' is usually reserved for water bodies near to the coast which are influenced in some way by saline water processes (Clarkson et al. 2003). Two other names associated with the lake are Rotokare, and Waikare, both translate from Maori to 'rippling waters'. Lakes such as Barrett Lake were a characteristic feature of the landscape around New Plymouth prior to European settlement, though most have since been drained, making the site significant as a representative habitat in the region (Clarkson & Boase 1982; Taranaki Regional Council 2005). The lake is a popular site for many water birds (see full list in Section 4.11.2), with large numbers of native paradise shelducks congregating in December to moult. This issue is discussed further in Section 4.11.3, in relation to a Fish and Game proposal. The main wetland vegetation types on Barrett Lake were mapped (Figure 3) and are described in Sections 4.1.1-4.1.4 .

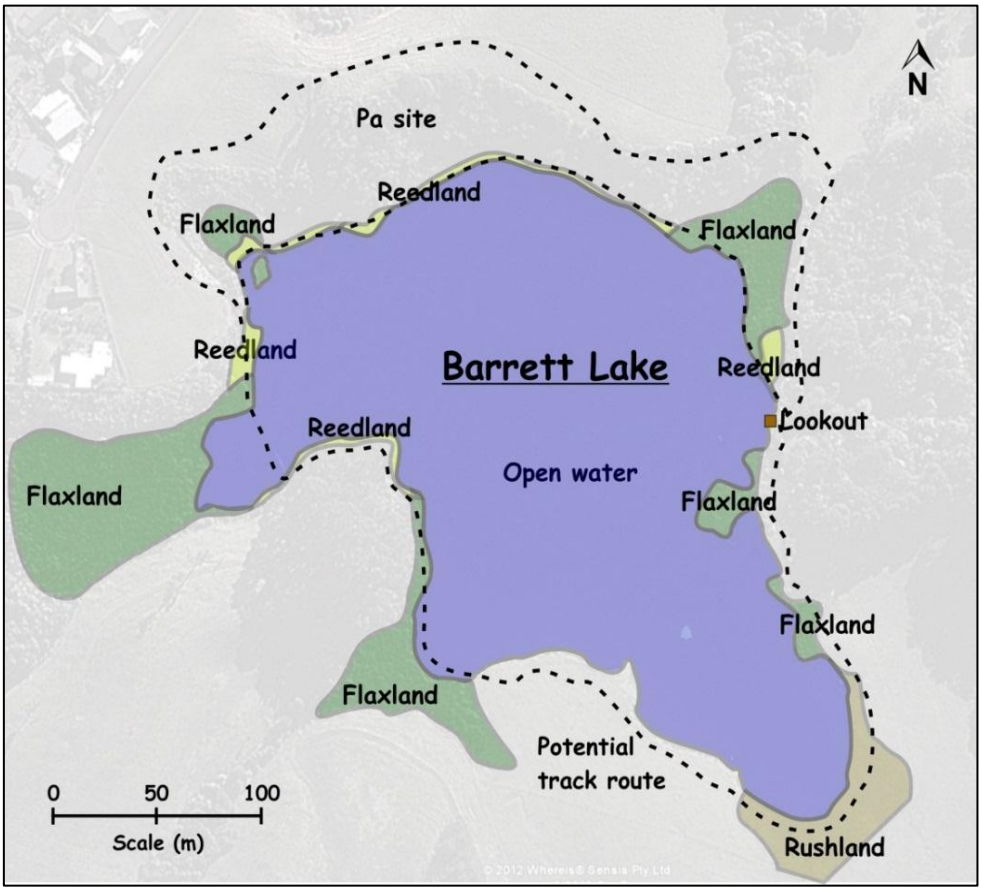

Figure 3: Sketch map of main wetland vegetation types present on Barrett Lake, and potential route/s for the path around the lake.

4.1.1 Open water

The majority of Barrett Lake consists of open water with scattered areas of submerged or partially submerged aquatic plants (Figure 4). Native aquatic species present in these areas included red pondweed (*Potamogeton cheesemanii*), common water milfoil (*Myriophyllum propinquum*) and common duckweed (*Lemna disperma*), along with patches of the exotics water lily (*Nymphaea*) and oxygen weed (*Egeria densa*). The lake water quality appears to be quite high, with good clarity. Fish and invertebrates present in the lake are discussed in Section 4.11.1.

The sketch map of Barrett Lake in the existing Domain management plan suggests that in 1980, over half of the lake area comprised of 'swamp' vegetation as opposed to open water (New Plymouth City Council 1980). The Department of Lands and Survey map (Clarkson & Boase 1982) of the site also illustrates a significant portion of swamp vegetation over the lake. Currently, the majority of the lake consists of open water. To determine whether a large portion of swamp had actually been lost from the lake, historic aerial photographs were obtained. These photographs (see Section 5) suggest that the mapping of swamp area in the management plan had been quite generous, and in reality, the portions of open water and swamp in the lake were probably similar in extent to today.

Figure 4: View of Barrett Lake from the south and the exotic water lily common around the shallow margins

4.1.2 Kuta and raupo reedland

Although not abundant, reedland (Figure 5) is an important vegetation type that occupies some of the margins on Barrett Lake. In the water, several species were common including kuta (*Eleocharis sphacelata*) in the deepest water, raupo (*Typha orientalis*), baumea (*Machaerina rubiginosa*) and kuawa (*Schoenoplactus tabernaemontani* syn. *Scirpus lacustris*). Other species present included *Machaerina arthrophylla*, *Machaerina tenax*, sharp spike sedge (*Eleocharis acuta*) and slender spike sedge (*Eleocharis gracilis*), *Gratiola sexdentata*, *Hydrocotyle pterocarpa*, *Centella uniflora*, swamp millet (*Isachne globosa*), and an uncommon species in the region, burr-reed (*Sparganium subglobosum*).

Figure 5: Small patch of kuta reedland on the lake margin.

4.1.3 Flaxland

Three significant flaxland (Figure 6) areas are present with other smaller patches scattered around the perimeter of the lake. The dominant species was flax (*Phormium tenax*), intermixed with swamp coprosma (*Coprosma tenuicaulis*), kiokio (both *Blechnum novaezelandiae* and *B. minus*), carex (*Carex virgata*, *C. maorica*, *C. secta*), bracken (*Pteridium esculentum*), baumea and swamp millet. In several locations there is minor invasion by gorse (*Ulex europaeus*), blackberry (*Rubus fruticosus*) and grey willow (*Salix cinerea*).

Figure 6: Flaxland vegetation on the lake edge.

4.1.4 Southern lake margin

At the poorly drained south eastern side of the lake, where stock have periodic access to the littoral zone, a mixture of rushland vegetation and pasture is present (Figure 7). The dominant species was the tall, clump forming fan-flowered rush (*Juncus sarophorus*). Several other rushes were present including *Juncus prismatocarpus*, *Juncus planifolius*, *Juncus australis*, *Isolepis distigmatosa* and *Isolepis inundata*. The native shore lobelia (*Lobelia anceps*) was also present in this area. In the gaps between the rushes, the exotic Mercer grass (*Paspalum distichum*) was probably the most common plant along with a mixture of other pasture grasses and pasture weeds. The area of littoral zone that has been fenced at the southern edge of the lake is frequented by ducks and geese, and as a result, the exotic pasture vegetation has been browsed down to a short turf.

Figure 7: Rushland and pasture fringing the southern lake margin.

4.2 Fred Cowling kauri plantation

In the early 1940s, Fred Cowling, a well-known Taranaki resident concerned about the European decimation of New Zealand bush, planted 2 ha of his land in kauri (*Agathis australis*) trees (Figure 8). The kauri trees thrived despite being well outside of the species natural distribution in the upper North Island. In 1948, Fred donated these trees to the people of New Plymouth (Puke Ariki 2012), and now they form an important feature in the north east corner of Barrett Domain.

Kauri is the most common canopy tree in this area, though mature rimu (*Dacrydium cupressinum*), tawa (*Beilschmiedia tawa*), pukatea (*Laurelia novae-zelandiae*), kahikatea (*Dacrycarpus dacrydioides*) and totara (*Podocarpus totara*) are also present. The kauri appear to have been thinned out some time ago (chainsawed stumps were still present), probably to allow trees to reach their full potential. In several locations some of the kauri has been regenerating naturally by seed. Most of the original kauri trees were now upwards of 25 m in height and around 50 cm in diameter. In the well-developed sub-canopy, native species included mamaku (*Cyathea medullaris*), silver fern (*Cyathea dealbata*), cabbage tree, ribbonwood (*Hoheria populnea*), karaka (*Corynocarpus laevigatus*), pigeon wood (*Hedycarya arborea*), mahoe (*Melicytus ramiflorus*), rewarewa (*Knightia excelsa*), nikau (*Rhopalostylis sapida*) and matai (*Prumnopitys taxifolia*). The shrub layer was both diverse and dense, comprising species such as kanono (*Coprosma grandifolia*), thin-leaved coprosma (*Coprosma areolata*), hangehange (*Geniostoma ligustrifolium*), kawakawa (*Macropiper excelsum*), mapau (*Myrisne australis*), wharangi (*Melicope ternata*) and the king fern para (*Ptisana salicina*). The most common ground covers were ferns, including hen and chicken fern (*Asplenium bulbiferum*), gully fern (*Pneumatopteris pennigera*), kiokio, lance fern (*Blechnum chambersii*), shinning spleenwort (*Asplenium oblongifolium*) and creek fern (*Blechnum fluviatile*). Hook sedge (*Uncinia uncinata*), forest sedge (*Carex dissita*) and bush rice grass (*Microlaena avenacea* and *M. stipoides*) were also common. Climbers present included thread fern (*Blechnum filiforme*), hounds tongue (*Microsorum pustulatum* and *M. scandens*), climbing rata (*Metrosideros fulgens* and *M. perforata*) and NZ jasmine (*Parsonsia heterophylla*).

In some of the well-lit locations (perhaps a result of kauri thinning) along the stream which runs through the site, significant infestations of the exotic wandering Jew (*Tradescantia fluminensis*) were evident. Wandering Jew does respond to some herbicide treatments and mechanical removal, but as the canopy eventually closes over and detritus builds up on the forest floor, the wandering Jew is likely to become less abundant (Standish 2002), allowing a native ground cover of ferns to naturally develop. Climbing asparagus is also a problem exotic in this area, and is perhaps more tolerant of shade than wandering Jew. Control of exotic species is discussed further in Section 6.

Figure 8: Cowling kauri plantation. Dense mats of exotic wandering Jew are common along the stream side.

4.3 Rayward bush

Rayward Bush is a 2 ha fragment of semi-coastal forest located between Barrett Lake and the Fred Cowling kauri plantation (Figure 9). The forest type is predominantly tawa over kohekohe (*Dysoxylum spectabile*), with pukatea also common in the poorly drained basins. Mature totara is also present. Common understory plants included kohekohe, mahoe, karaka, kawakawa, hangehange, thin-leaved coprosma, wheki (*Dicksonia squarrosa*), kanono, pigeon wood, cabbage tree, mamaku, pate (*Schefflera digitata*), hen and chicken fern, and gully fern. Several large tawa and kohekohe in this area displayed significant nest-epiphyte communites including perching lily (*Astelia solandri* and *Collospermum hastatum*) and mature puka (*Griselinia lucida*) with large roots extending down to the ground. Since this area was fenced several years ago to prevent stock grazing, there has been prolific regeneration of native species in the understory, particularly kohekohe. The invasive climbing asparagus was probably the most significant weed in this area. A small tributary of the

Mangaotuku Stream also runs though this site, and at the time of survey appeared to be heavily silted; probably as a result of earthworks from the subdivision currently being developed near the Kororako pa site. The effect of sediment run-off from earthworks should always be considered and managed where possible with precautions such as settling ponds and sediment traps.

Figure 9: Rayward bush semi-coastal forest.

4.4 Lagoon bush

Located between the Mangaotuku Stream and Barrett Lake, the lagoon bush (Figure 10) is the most extensive tract of forest within Barrett Domain, totalling around 9 ha in area. Although some of the larger trees in this semi-coastal fragment were probably removed selectively for timber in the past, it appears largely unmodified with some quite mature trees and a well-developed understory in most areas. Forest composition in the fragment is predominantly tawa over kohekohe. Other native canopy trees present included pukatea (more common in poorly drained areas), rewarewa, karaka, puriri, rimu, matai and titoki (*Alectryon excelsus*). Common understory plants were kawakawa, kanono, mahoe, hangehange, karaka, mamaku, wheki, silver fern, kohekohe, thin-leaved coprosma, pigeonwood, pate, ribbon wood and nikau. Ferns present included gully fern, hen and chicken fern, hairy fern (*Lastreopsis hispida*), filmy fern (*Hymenophyllum demissum*), kiokio, lance fern, shining spleenwort and sickle spleenwort (*Asplenium*

polyodon). The climbers supple-jack (*Ripogonum scandens*) and kiekie (*Freycinetia banksii*) were abundant, along with jointed fern (*Arthopteris tenella*), hounds tongue, climbing rata and NZ Jasmine. Epiphytes including perching lily and large puka were common on tawa and kohekohe. A number of mature planted pohutukawa (*Metrosideros excelsa*) were also present on the margins of this area. Towards the west of this fragment, Barrett Lake flows into a small section of swamp forest dominated by pukatea (this watercourse eventually links ups with a small pond described in Section 4.9). The hydrological regime typical of a natural swamp forest appears to operate here, with pools of open water on the forest floor supporting wetland species such as *Carex secta*, kiokio and swamp coprosma. The exotic oxygen weed *Egeria densa* was present in the pools and wild ginger (*Hedychium*) was growing in a few places along the margins. Problem weeds in the wider lagoon bush fragment include flowering cherry (*Prunus*), wandering Jew, climbing asparagus and African clubmoss (*Selaginella kraussiana*).

A 2 ha band of tall (c. 30 m high) exotic trees dissect the predominantly native lagoon bush fragment. Historic aerial photographs in Section 5 identify this area when it was first cleared of native vegetation. Pine (*Pinus radiata*) is the most common exotic tree, though several large gums (*Eucalyptus*) and redwood (*Sequoia*) trees are also present. Native understory plants were growing at much lower densities below these exotic trees compared with surrounding areas, due to their production of supressing litter. In several locations where large limbs have fallen from these trees however, native regeneration has been prolific in the increased light levels created on the forest floor; with kohekohe and pukatea being very successful. If resources were available, it would be appropriate to remove some of these exotic trees, allowing a canopy of native trees to naturally regenerate.

Figure 10: Lagoon bush showing open pools of water in swamp forest and area of exotic trees (circled).

4.5 Pa site bush

A thin belt (<1 ha) of diverse native vegetation fringes the northern edge of Barrett Lake in the vicinity of the Kororako (Ngati Te Whiti hapu) pa site (Figure 11). Vegetation here was probably supplemented with planted natives at some time in the past. Species included puriri, lemonwood (*Pittosporum eugenioides*), totara, kohekohe, rimu, rewarewa, karaka, kaihikatea, mamaku, mahoe, ribbonwood, karo, kanono, mapau, hangehange, kawakawa and tainui (*Pomaderris apetala*). The exotic coastal banksia (*Banksia integrifolia*) was also present here. A subdivision is currently being developed over much of the pa site, though a small strip of land has been left between the sections and the bush edge. Some of this open area may be suitable for native planting, though any archaeological features of the pa site may be better left in grass.

Figure 11: Pa site bush on lake margin.

4.6 Exotic stand

A tall stand of pine and macrocarpa (*Cupressus*) trees are located at the western edge of Barrett Lake (Figure 12). A dense shrubby native understory dominated by mapau, kawakawa, mahoe, kanono and mamaku is supported below. These exotics were generally in a poor condition with significant wind damage and a number of suspended dead limbs. Because of the risk posed by falling limbs they may need to be removed if a track was constructed below them around the perimeter of the lake. If they were removed, there are significant numbers of native species already growing below that little native supplement planting would be required in this area. An area of mature Norfolk pine (*Araucaria heterophylla*) is also present nearby within pasture, and is currently grazed beneath.

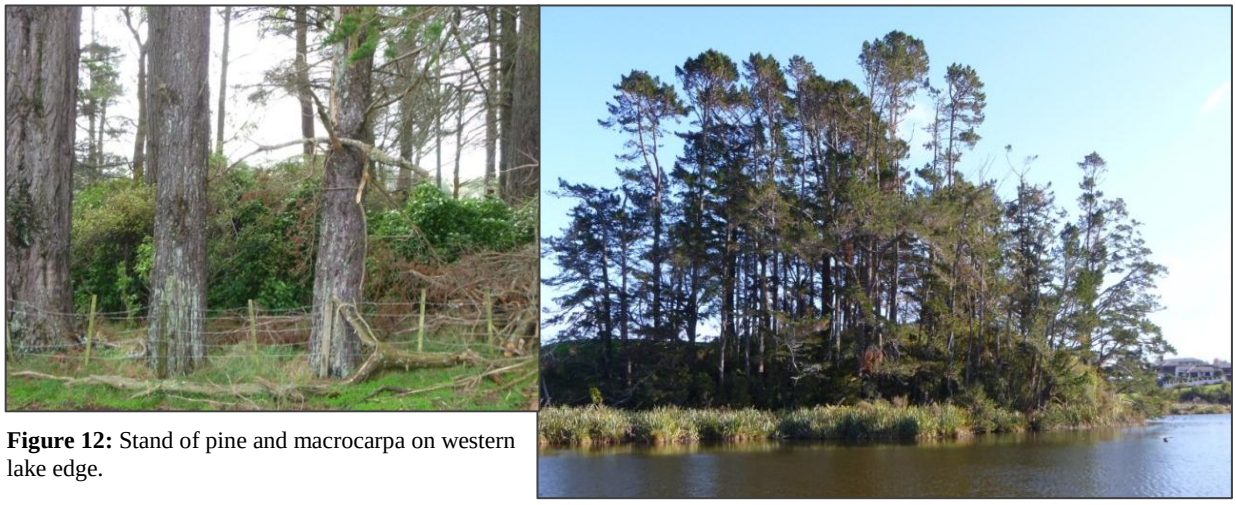

Figure 12: Stand of pine and macrocarpa on western lake edge.

4.7 Proposed land acquisition (swamp forest at west of lake)

A land transfer is currently in process to acquire a section of bush on private land adjoining the west of Barrett Lake. It is the intention that this will be exchanged for a section of Crown owned pasture in the south west of Barrett Domain (Figure 13). This transfer will greatly enhance the ecological value of Barrett Domain and is fully supported. Although only 1 ha in size, the forest is a true swamp forest, having a hydrological regime closely interlinked with Barrett Lake (Figure 14). At this location, flaxland vegetation (see Section 4.1.3) on the margin of the lake grades continuously into a forest dominated by pukatea and swamp maire (*Syzygium maire*). In the understory, nikau was very abundant. Other shrubs included mahoe, hangehange, mapau, karaka, kawakawa, pigeon wood, thin-leaved coprosma, kanono, mamaku and wheki. Kiekie formed a dense cover over many of the tress, especially on the well-lit margins, and supplejack was also present. Ferns included kiokio, gully fern, lance fern, hen and chicken fern, thread fern and jointed fern. Water logged ground and open pools of water were common throughout in this area. Potentially, a track could pass through this forest, though if this was to occur, it would be vital that a boardwalk be constructed to protect the pneumatophores (aerial roots) of pukatea and swamp maire from trampling.

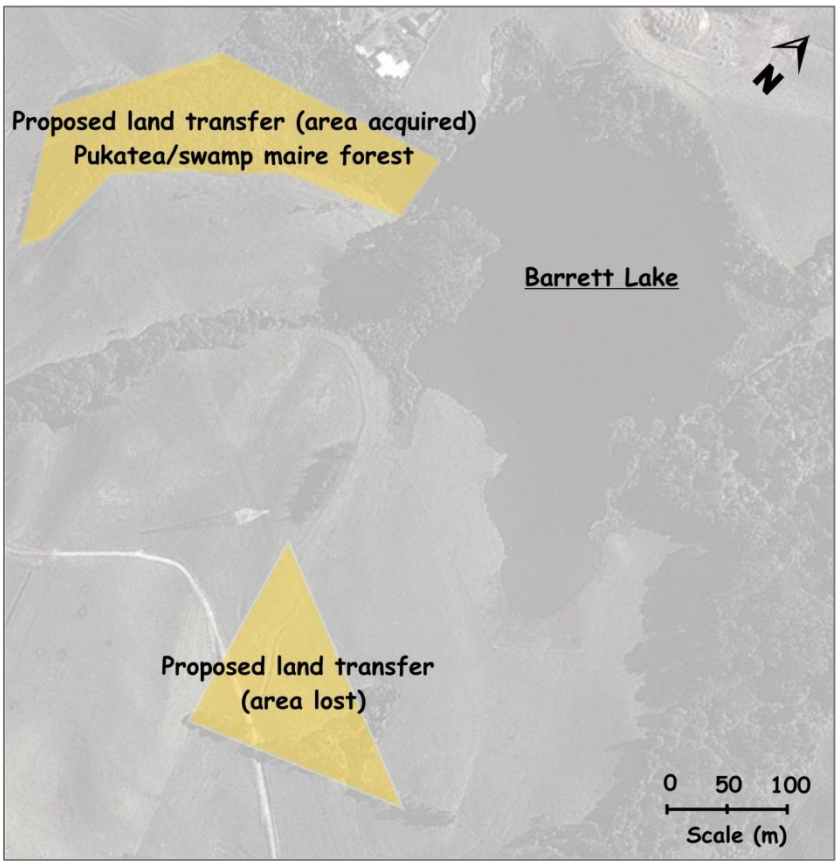

Figure 13: Proposed land transfer at Barrett Domain.

Figure 14: Swamp forest to be acquired at western edge of lake.

Within the area of Crown pasture to be exchanged for the swamp forest (see Figure 13), there is also an isolated patch of vegetation and a small pond (Figure 15). A narrow vegetation band around the pond consisted of a canopy with planted pine and macrocarpa, over a native understory of mahoe, hangehange, kawakawa, mapau, kanono, karamu, mamaku, karo, kohukohu and *Carex vigata*. The native climber pohuehue (*Mulenbeckia australis*) was also prevalent over many of the trees. The council may wish to recommend that the new owner keep this area fenced to exclude stock (the existing fence is in a state of disrepair). The exotic trees could also be selectively removed without any concerns, leaving the native understory to regenerate naturally.

Figure 15: Small pond being lost from Barrett Domain in the land transfer.

4.8 Sir Victor Davies memorial planting

Sir Victor Davies (1887-1977) was a respected New Plymouth nurseryman and authority on trees and shrubs. An area of planted natives in Barrett Domain commemorates his years of service and association with the NZ horticultural industry. Trees in this area included kowhai (*Sophora microphylla*), kohukohu (*Pittosporum tenuifolium*), lemonwood, totara, rimu, mahoe, black maire (*Nestegis cunninghamii*), akeake (*Dodonaea viscosa*), cabbage tree, kawakawa and karamu (*Coprosma robusta*). Some large coastal banksia were also present. Most of these trees were currently growing over pasture grasses and bracken fern, though the area is not grazed or accessible to stock. It is not known if the intention for this area of planting is park-land (i.e. with open ground below the trees), but it would be a good location for supplementary planting of native shrubs beneath the existing trees. Adjoining this area between the top paddock and main path through to the lake, a hill slope has been planted with a number of puriri (Figure 16). Currently only grass grows amongst these trees and thus this area would be a good site for further natives to be planted.

Figure 16: Puriri trees now suitable for underplanting near the Sir Victor Davies memorial planting.

4.9 Overflow pond

A pond is located in Barrett Domain near the kauri plantation, as a result of water outflowing from Barrett Lake (Figure 17). Although only small, the pond is sheltered and thus popular with water fowl; it also has some native wetland vegetation including kuta, raupo and kuawa. In the small stream which flows from the lake to the pond, species included *Carex virgata*, *Isolepis* spp., sharp spike sedge and *Cyperus ustulatus*, but exotics Mercer grass, Yorkshire fog (*Holcus lanatus*) and watercress (*Nasturtium officinale*) were also abundant. On the margins of the pond and along the water course from the lake, natives (many planted) included flax, pukatea, kahikatea, mamaku, wheki, akeake, kawakawa, kiokio, karaka, karamu, pohutukawa, kowhai, mapau and black maire.

Figure 17: Small pond near the kauri plantation with native wedland vegetation.

4.10 Mary Rielly Grove

At the northern most edge of Barrett Domain is a stand of native trees planted by Fred Cowling in honour of his wife, Mary Rielly (Figure 18). The dominant canopy species in the Mary Rielly grove was kauri, however a number of totara were also present. Sub canopy species included karaka, mahoe, lacebark, pigeonwood and mamaku and these over topped a shrub layer dominated by kawakawa. A row of exotic cypress trees are present along the southern fence line and stand margins are densely covered with both wandering Jew and climbing asparagus.

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Figure 18: Mary Rielly Grove.

4.11 Fauna

4.11.1 Aquatic fauna

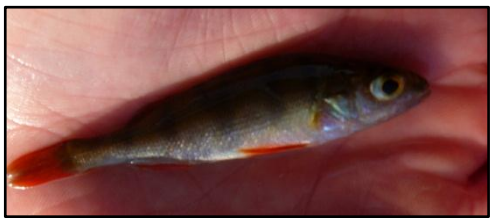

Figure 19: Juvenile perch caught in Barrett Lake.

To investigate what fish species were present in Barrett Lake, several minnow traps and fyke nets were deployed. A fyke net (or hinaki) is a larger version of a minnow trap, and consists of a cone shaped net with one entrance into which fish/eels can swim in, but not out. The only fish captured on this occasion (Figure 19) was a juvenile perch (*Perca fluviatilis*). Whilst conducting this fieldwork, a local resident also mentioned that eels could regularly be seen from the bank of the lake. The Freshwater Biodata Information System (FBIS) administered by the National Institute of Water and Atmospheric research (NIWA) also holds several records for fish and invertebrate surveys conducted in Barrett Lake. In 2002, a combination of nets and traps set in the lake caught wild goldfish (*Carassius auratus*), perch and an unidentified eel (*Anguilla* sp.) (Freshwater Biodata Information System 2012). The Department of Conservation also hold a record for one sighting (unconfirmed) of a koi carp (*Cyprinus carpio*) in Barrett Lake, which was observed during a spotlighting search in 2002 (Chris Rendall, Department of Conservation, pers. com.). Perch are strictly carnivorous fish and eat insect larvae and other fish, including native species such as bullies. They contribute to water quality degradation in lakes and are currently classed as a game fish under the jurisdiction of Fish and Game New Zealand; the Taranaki Regional Council does not currently class the perch as a pest animal. Wild goldfish are also known to out-compete native fish species and other aquatic life such as snails and aquatic plants, leading to the degrading of water bodies and contributing to algal blooms (National Institute of Water and Atmospheric research 2012). A more extensive search to confirm or otherwise the presence of koi in Barrett Lake may be required given their high potential to degrade water bodies. The Taranaki Regional Council currently lists koi as a 'surveillance pest animal' in the region.

The FBIS also reports that sweep-net sampling of the lake margins in 2006 yielded records for a range of invertebrates (Table 1). In addition to this list, there is a possibility that the native freshwater crayfish koura (*Paranephrops planifrons*) is also present in the lake, having recently being found in other lakes in the region such as at Pukekura Park (Puke Ariki 2012). Currently, Barrett Lake may not be continuously linked to the near-by Mangaotuku Stream (due to an elevated culvert obstruction out of the overflow pond), and thus there may be some scope to improve fish passage between the two sites. The FBIS currently holds no records for fish in the Mangaotuku stream (and a survey was beyond the scope of the present study). However, in a survey of the Herekawe Stream in the adjacent catchment, several species have been reported including longfin eel (classified as a 'gradually declining' species), banded kokopu (*Galaxias fasciatus*) and koura (Freshwater Biodata Information System 2012).

Table 1: Invertebrates recorded in sweep-net samples, Barrett Lake, 2006 (Freshwater Biodata Information System 2012).

Invertebrates
Caddisflies
Copepods
Damselflies (*Austrolestes colensonis*)
Diving beetles
Dragonflies
Flatworms
Leeches
Lymnaea snails
Mites
Non-biting midges (*Cornyocera, Cladopelma, Chironomus*)
NZ Backswimmers (*Anisops assimilis*)
Pea mussels
Physella snails
Potamopyrgus snails
Seed shrimps
Springtails
Water fleas

4.11.2 Bird life

Barrett domain provides a range of habitats (open water, wetland, lowland forest, pasture) supporting a number of native and introduced bird species (Figure 20). The site also acts as an important link between the coast and larger tracts of forest and wetland further inland, allowing species to move more freely across the landscape. The numbers of native trees at the domain are a very valuable source of food for native birds. Common trees at the domain of significant importance to native birds include puriri, pohutukawa, tawa, kohekohe, *Coprosma* spp., kowhai, flax, rewarewa, karaka, *Pittosporum* spp., pigeonwood, mapau, pate and kawakawa. Although an exotic, coastal banksia also provides a valuable nectar source in winter when nectar from native species is scarce; for this reason, it is probably not necessary to remove banksia from the Domain as it is not capable of regeneration in the shade and thus poses little threat to the established native vegetation. The lake itself is a valuable food source for water birds, containing fish, invertebrates and suitable wetland vegetation. The Australasian bittern, a nationally endangered wetland bird has been recorded at the lake in the past, and could potentially still reside there. The existing Barrett Domain Management Plan (New Plymouth City Council 1980) lists a total of 40 bird species observations from the site (Table 2). Barry Heartley, Taranaki representative of the

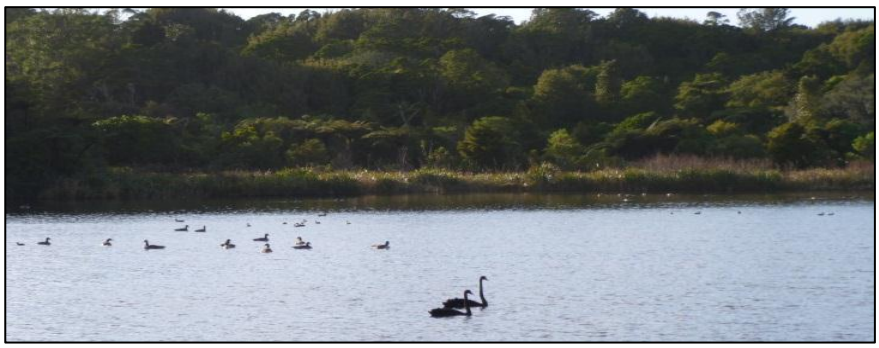

Figure 20: Black swans and Canada geese on Barrett Lake.

Ornithological Society of New Zealand, has been contacted and will possibly be providing a more recent record of bird observations at the site.

Table 2: Bird species recorded at Barrett Lake (New Plymouth City Council 1980), classification status from Heather & Robertson (1996).

Common name	Scientific name	Classification
Australasian bittern	*Botaurus poiciloptilus*	Nationally threatened
Australasian harrier	*Circus approximans*	Abundant native
Australasian shoveler	*Anas rhynchotis*	Common native
Australian magpie	*Gymnorthina tibicen*	Abundant Australian introduction
Bellbird	*Anthornis melanura*	Common endemic
Black shag	*Phalacrocorax carbo*	Common native
Black swan	*Cygnus atratus*	Common Australian introduction
Black-backed gull	*Larus dominicanus*	Abundant native
Blackbird	*Turdus merula*	Abundant European introduction
Californian quail	*Callipepla californica*	Common North American introduction
Canadian goose	*Branta canadensis*	Common North American introduction
Chaffinch	*Fringilla celebs*	Abundant European introduction
Fantail	*Rhipidura fuliginosa*	Abundant native
Goldfinch	*Carduelis carduelis*	Abundant European introduction
Greenfinch	*Carduelis chloris*	Common European introduction
Grey duck	*Anus superciliosa*	Common Native
Grey warbler	*Gerygone igata*	Abundant endemic
Hedge sparrow	*Prunella modularis*	Common European introduction
House sparrow	*Passer domesticus*	Abundant European introduction
Little shag	*Phalacrocorax malanoleucos*	common native
Mallard duck	*Anas platyrhynchos*	Abundant European introduction
Morepork	*Ninox novaeseelandiae*	Common native
Myna	*Acridothered tristis*	Locally abundant Asian introduction
New Zealand dabchick	*Poliocephalus rufopectus*	Uncommon endemic
New Zealand falcon	*Falco novaeseelandiae*	Uncommon endemic
New Zealand Pigeon	*Hemiphaga novaeseelandiae*	Common endemic
Paradise shelduck	*Tadorna variegata*	Common endemic
Pheasant	*Phasianus colchicus*	Common European introduction
Pied shag	*Phalacrocorax varius*	Locally common native
Pied stilt	*Himantopus himantopus*	Common native
Pukeko	*Porphyrio porphyrio*	Abundant native
Red billed gull	*Larus novaehollandiae*	Abundant native
Shining cuckoo	*Chrysococcyx lucidus*	Common native
Silver eye	*Zosterops lateralis*	Abundant native
Song thrush	*Turdos philomelos*	Abundant European introduction
Starling	*Sturnus valgaris*	Abundant European introduction
Tui	*Prosthemandera novaeseelandia*	Common endemic
White heron	*Egretta alba*	Uncommon native
White-faced heron	*Ardea novaehollaniae*	Abundant native
Yellowhammer	*Emberiza citrinella*	Common European introduction

4.11.3 Issues with water birds

Significant numbers of introduced Canada geese (*Branta canadensis*) and native paradise shelducks (*Tadorna variegata*) are known to congregate at Barrett Lake and frequent the adjoining pasture on the southern lake margin. This is considered to be an issue for the farmer who currently grazes the land, primarily because geese and shelducks also graze pasture and defecate in the process. This can then have the potential to pass diseases onto stock (e.g. salmonella), as well as reducing the amount of pasture available to

be grazed by stock. Both Canada geese and paradise shelducks congregate at the lake to breed and undergo their yearly moult of flight feathers. During January, numbers of congregating paradise shelducks at the site are frequently in the order of 500-800 (Fish and Game 2012). Canada geese have recently (March 2011) been re-classified from their former status as a Schedule 1 protected game bird under the Wildlife Act, to a Schedule 5 species, meaning they are no longer a 'protected species' or managed by the New Zealand Fish and Game Council (Department of Conservation 2012). Given the high use of the domain by members of the public, shooting of Canada geese would probably not be a feasible control option at the site.

Fish and Game has recently proposed that two 'sacrifice areas' be created by fencing to allow birds to graze a small section of pasture (Figure 21). Fish and Game recommended that that this area "be maintained in pasture [i.e. not planted], periodically grazed [e.g. in winter] and fertilised to maintain it in good condition" (Fish and Game 2012). There are some serious ecological issues associated with this proposal which must be considered. Fertilisation of pasture should not be permitted within the sacrifice area around the margin of the lake. This has potential to increase fertility levels (nitrogen and phosphorus) in the lake, either through surface runoff of fertiliser or contamination via groundwater leaching, which will reduce water quality considerably and increase the likelihood of exotic weed growth and algal blooms (i.e. eutrophication). Furthermore, periodic grazing within the sacrifice area (which has recently been occurring at the site) allows stock direct access to the littoral zone of the lake, having potential to browse native marginal vegetation, trample the bank, and defecate in the lake (or in very close proximity to the lake). As well as increasing nutrient levels and suspended sediments in the lake (reducing water quality), this will inhibit the development of natural marginal vegetation such as reedland (see Section 4.1.2). One possible solution (assuming that grazing was to be permitted within the sacrifice zone) would be an additional fence which could prevent stock access to the margin of the lake, while at the same time allowing water birds to access the sacrifice zone from the lake (e.g. a fence that birds could walk under). Native planting within the sacrifice area would however increase the water quality of the lake and produce a continuous fringe of vegetation around the lake which would benefit most birds. There is a possibly this could reduce the suitability of the lake for a few select grazing birds including paradise shelducks and pied stilts.

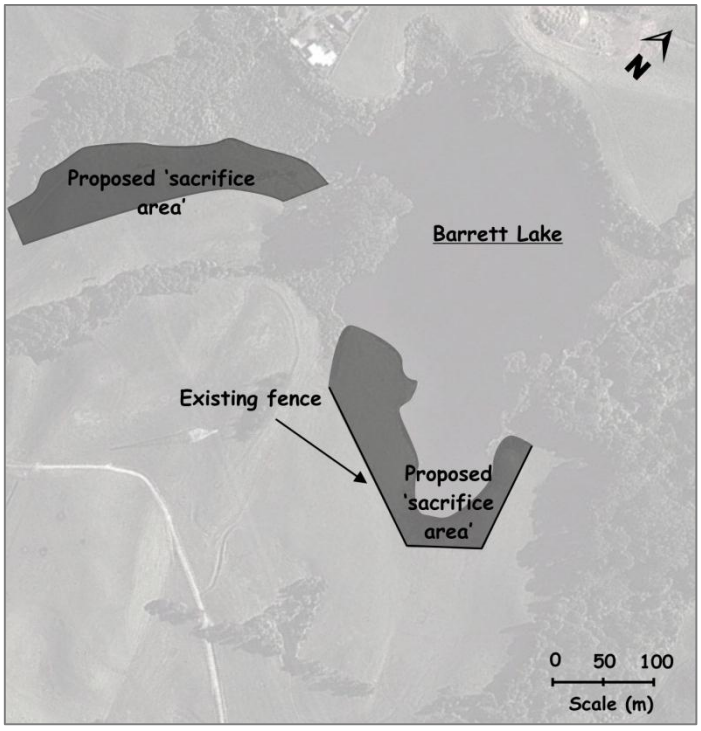

Figure 21: Fish and Games' proposed sacrifice areas for water fowl.

4.11.4 Mammalian pests

According to Taranaki Regional Council (2005) and S. Bartlam (Landcare Research, unpubl. data 2012), pest animals present at Barrett Domain include possums, cats, mustelids, rats, mice and hedgehogs. Hares and rabbits are also probably present in farmland on the site, and could have potential to interfere with new plantings around the lake margin. The New Plymouth District Council currently undertakes some predator control at the site. There are 31 bait stations within Barrett Domain which are serviced quarterly with Pindone cereal pellets targeting possums, and to a lesser extent rats. At the last service (April 2012), the contractor reported a 'medium' take of bait. In April 2012, a pest monitoring exercise was conducted at 11 positions within the domain (Figure 22) by S. Bartlam, Landcare Research. Wax tags were used to determine the density of possums, and rodent and mustelid indices were conducted. A target possum Bite Mark Index (BMI) result for the site was considered to be below 20%, and on this occasion a result of 12% was returned, indicating possums are present at low densities only. A rodent index indicated rats at 18% and mice at 27%, with all rats captured at the site being identified as ship rats. The mustelid index returned no mustelid occurrences on this occasion (S. Bartlam, Landcare Research, unpubl. data 2012). Barrett Domain is also a popular location for dog walking, with dogs having potential to disturb wildlife, particularly water birds (during the moult etc.) and young vulnerable birds. Should a track around the lake be constructed, it is recommended that dogs be kept leashed around the lake for at least part of the year while birds are moulting to minimise any unnecessary disturbances.

Figure 22: 11 positions in Barrett Domain where pest monitoring was conducted in April 2012 (S. Bartlam unpubl. data).

5 Historic photography

A photograph (Figure 23) of Barrett Lake in the early 1900s (referred to then also as Waikere) is presented in the proceedings of the Department of Lands (1906). During that year, the lake was "transferred to the Crown from the native owners". Tall forest extending right to the lake margin is evident in the photo (probably pukatea and swamp maire), along with a seemingly continuous fringe of flaxland vegetation. Today only a few small isolated fragments of each remain.

Historic aerial photographs from 1950 (oldest available image), 1976 and 1993 were obtained from the New Zealand Aerial Mapping archive to give insight into vegetation changes at Barrett Lake (Figure 24). In 1950, vegetation at the site appeared degraded and of less cover than what it is there today. For example, along the northern margin of the lake only a few scattered trees were evident in 1950, although this area now supports forest (pa site bush). Areas of flaxland around the lake were also smaller during this time, and there appeared to be very little reedland vegetation. The Rayward bush area was of a smaller extent than it is today. Within the lagoon bush fragment, a large strip of cleared native bush is quite evident; this area was subsequently planted in exotics which now dominate the area. Photographs from 1976 and 1993 show the significant growth of trees within the domain (including the kauri planation and exotic trees in the lagoon bush), and the widespread native plantings that occurred. The wider catchment also became increasingly urbanised, particularly between 1993 and 2012. The vegetation within the lake displayed minor changes only, which were probably related with water level fluctuations and/or minor sedimentation and nutrient enrichment (e.g. the coalescing of an island and increase in area of flaxland). Overall, the photographs indicate the impressive restoration efforts that have gone into the domain over the last 60+ years, including the fencing off of bush from stock, and extensive plantings of native species.

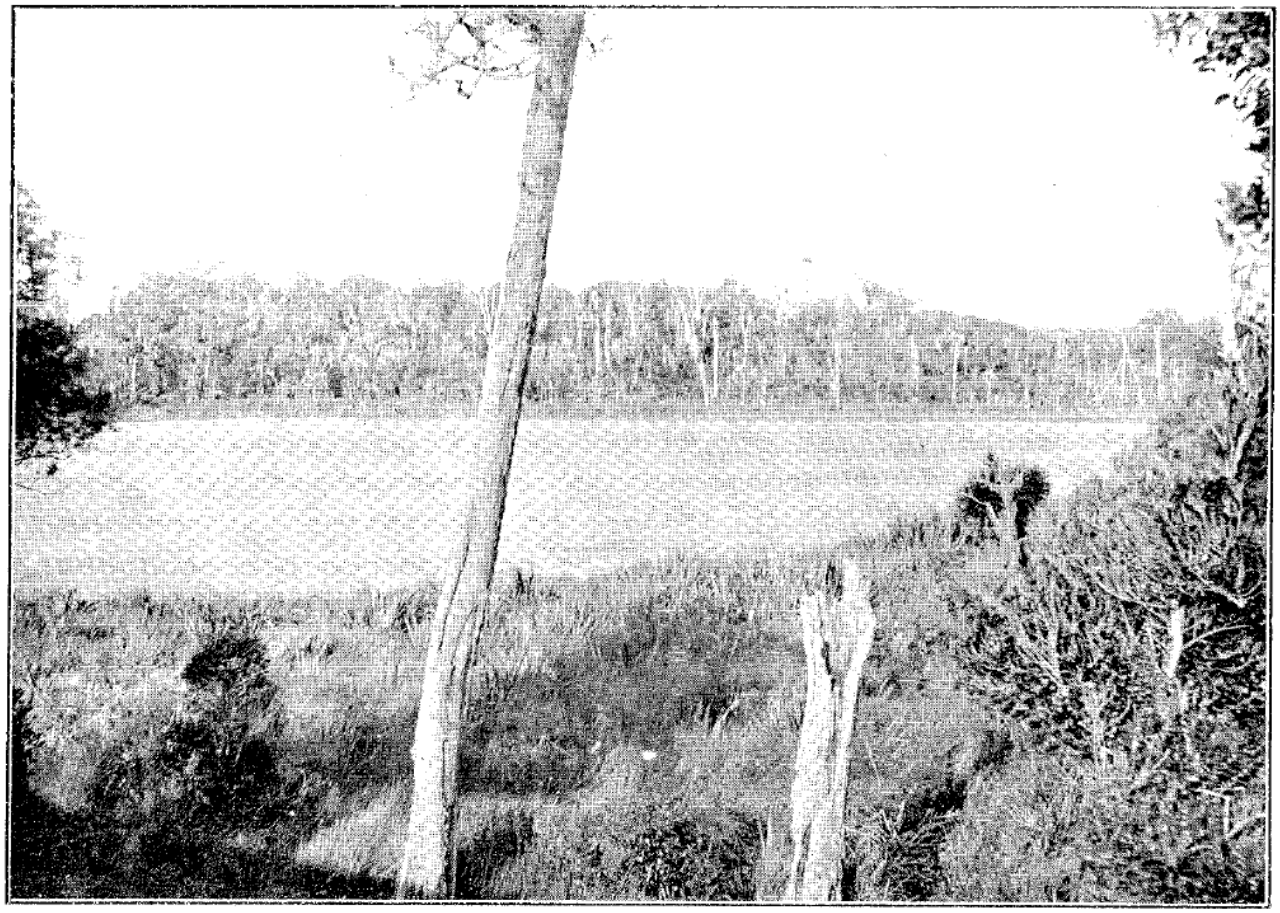

Figure 23: Historic photo of Barrett Lake (Waikare) from Department of Lands 1906. Note the mature forest around the margin of the lake.

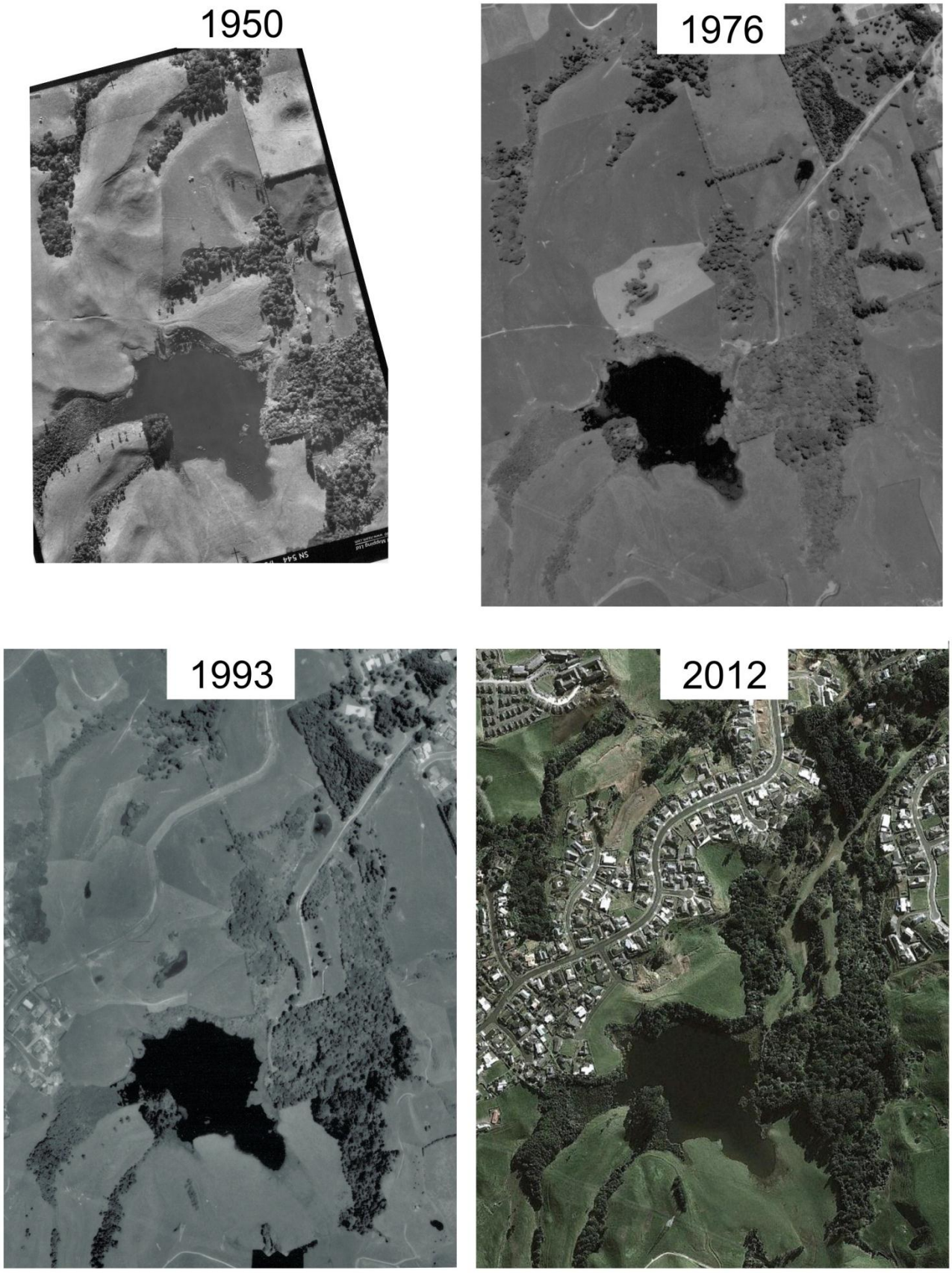

Figure 24: Historic aerial photography of Barrett Domain 1950, 1976, 1993 (NZ Aerial Mapping) and 2012 (Google Earth).

6 Management recommendations

6.1 Vegetation enhancement

6.1.1 Exotic removal

Weeds are not currently a major issue at Barrett Domain, but the control and/or monitoring of several exotic species in particular would be advisable. Firstly, in the areas of flaxland vegetation on the margin of the lake, the localised patches of willow and gorse could be removed before they become a bigger issue as they spread. Given the small size of the gorse and willow, chopping off at a height of 5 cm above ground followed immediately by a coating of Vigilant® gel (systemic herbicide) on the stumps would be appropriate. The cut material should be removed from the site and follow-up treatments may also be necessary if stumps re-sprout or new plants reinvade.

Climbing asparagus is another problematic weed in bush areas at Barrett Domain, especially in Rayward bush, and to a lesser extent, the Lagoon bush. Being quite tolerant of shade, asparagus has formed dense swards over the ground and shrub layer in places, which has the effect of supressing the regenerating native seedlings and saplings. Given the widespread occurrence throughout the domain and resilience of this weed, control options are limited and potentially costly. At this stage, it may be appropriate to only monitor the spread/distribution of this species in the domain. Control may be feasible where, for example, exotic canopy trees have been removed and natives are naturally regenerating to fill the canopy gap, or at newly planted areas where it could comprise the restorations success. Control options include mechanical removal (though tubers readily re-sprout and must be dug-out) or a weed wipe (partial covering OK) with diluted (333 ml/L) glyphosate (Weedbusters 2012). Spraying is not considered appropriate in this instance because of the chance of killing the natives which this species sprawls over. Unfortunately this species is capable of growing from tubers even after being sprayed, and when hand pulled, the tubers break off in the ground; total eradication from the domain is therefore unlikely.

Wandering Jew is another problem weed, but is fortunately not as widespread throughout the domain as climbing asparagus. The most severe infestations were probably along the margins of the Mangaotuku Stream within the Cowling kauri plantation. In some places there, no native species at all were visible amongst the dense mats of wandering Jew. If immediate removal was considered necessary, raking and rolling up the mats (removing all material from the site as fragments readily take root) followed by several spray applications of triclopyr 600 EC (6 ml/L + penetrant) on any re-sprouting plants left behind would be appropriate (Weedbusters 2012). Alternatively, the wandering Jew could simply be left as is, and with time, as detritus builds up on the forest floor and the canopy becomes denser, it will most likely die off naturally (Standish 2002).

Although not abundant at the site, other exotic species including buddleia (*Buddleja* sp.), Queensland poplar (*Homalantus populifolius*), Mexican daisy (*Erigeron karvinskianus*), African clubmoss and onion weed (*Allium triquetrum*) could also be removed/monitored if possible.

Whether or not any of the mature exotic trees (pines, gums etc.) at the domain should be removed is a matter for the council to decide. If they were removed, most are in locations where native regeneration of the canopy would occur naturally (i.e., native understory vegetation is already present). Exotic species such as coastal banksia and gum which benefit native birdlife by providing nectar may be better left standing.

6.1.2 Restoration plantings

Although there are already large areas of native vegetation within Barrett Domain, potential still exists to increase the ecological value of the site by planting additional native species in several locations (described below). Only eco-sourced plants of local provenance should be used in restoration plantings and nursery cultivars should be avoided. To increase the chances for success, planting is best conducted in autumn. The council intends to leave the current paddocks within the centre of the domain as they are for grazing by the RDA horses, so these areas are not considered as sites for restoration planting, though several locations would be appropriate for planting.

Lake margin: The southern lake margin (currently in pasture) should be considered the highest priority for planting. At the southernmost tongue of the lake, the New Plymouth District Council (Water & Wastes division) has requested that a 60 m wide strip between the lake edge and adjoining pasture be left free of vegetation to allow for the safe and proper functioning of the spillway (Figure 25). Currently this strip supports short and open rushland vegetation (4.1.4), and it is assumed that this would not affect the operation of the spillway. Outside of this spillway however, within the fenced margin of the lake, native species could be planted on each side of the proposed boardwalk/path (Figure 25). In the littoral zone, water tolerant reedland (see

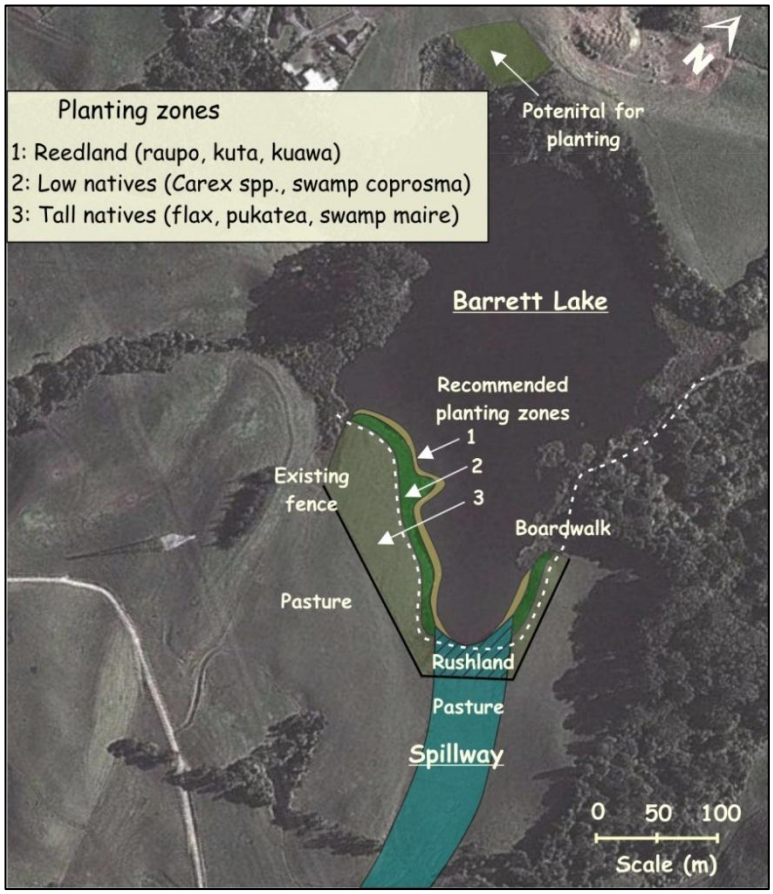

Figure 25: Recommended areas for planting at Barrett Lake.

Section 4.1.2) species such as raupo, kuta, and kuawa could be planted if they were available; though these species would probably establish naturally in the absence of stock disturbance. To preserve the view of the lake from the boardwalk, shorter native species such as *Carex virgata*, *Carex secta*, and swamp coprosma could be planted on the lake side of the boardwalk, while on the landward side larger species such as flax, pukatea, swamp maire and kahikatea would be more appropriate. Given the poor drainage in this area, species typical of the swamp forest described in Section 4.7 would be most suitable for planting here. If these areas were planted, the lake would be fully encircled by a fringe of native vegetation, enhancing lake water quality and wildlife habitat. However, the loss of pasture on the margin could potentially reduce the suitability of the lake for some grazing birds such as paradise shelduck and pied stilt.

At the north side of the lake, an unused grassy hill slope also has potential as a site for native planting (Figure 25), though this may not be considered appropriate if it is historically/archeologically significant to the pa site. Semi-coastal forest species typical of the lagoon bush (see Section 4.4) could be in the final compositional trajectory, though given the exposure at the site, a nurse species (e.g., kanuka) may be required for protection.

Puriri slope adjacent to the Victor Davies memorial planting: Located on the slope between the top paddock and the main path to the lake from Roto St entrance, an area has been fenced some time ago and planted with predominantly puriri trees which are now well established and several meters high (see Section 4.8). No understory vegetation exists between or under these trees other than long grass. This area is thus ideal for enrichment planting with semi-coastal natives such as kanono, mahoe, karaka, hangehange, kawakawa, karamu, thin-leaved coprosma, pigeonwood, pate and ribbon wood. Some grass control may be required prior and after any planting in this area.

Hill near overflow pond: Near the small kahikatea stand just south west of the overflow pond, the steep hill currently in grazed pasture would provide a good planting site. This hill is probably too steep to be grazed by the RDA horses (sheep have been used there in the past), so could be fenced and planted with natives typical of semi-coastal forest.

Recently fenced area between Rayward bush and Lagoon bush: In the paddock between these two sites exotic trees have been removed and an area fenced off. The council probably already intends to plant this area with native species; wetland species (flax, swamp coprosma, *Carex* spp., cabbage tree) would be appropriate closest to the stream and in the poorly drained depression, while semi-coastal forest species would be good on the drier margins.

6.1.3 Fencing improvement

Given the high value of native vegetation within the domain, all fences used to exclude stock should be in good conditions and regularly maintained. Currently, the swamp forest which is being acquired at the west of the lake (see Section 4.7) is only poorly fenced with a single wire, and stock probably have access into the

forest in several places. This should be considered a high priority fragment for new fencing once the land is obtained (e.g. with 8 wire post and batten).

6.2 Pest control

To preserve and enhance the vegetation within the domain (and reduce predation on native birdlife), the pest control operations currently targeting possums should continue. In addition to this, pest control targeting rodents and mustelids would greatly benefit native birds if sufficient resources were available. The best time of year to target predators is just before and during the bird breeding season (when young are most vulnerable), which for most birds is between August and January. The Department of Conservation could provide comment on the most appropriate control techniques at the site.

The introduced perch (and potentially koi) within Barrett Lake are likely to be having some impact on water quality and native species. Once pest fish are established in a water body as big as Barrett Lake, there are currently no eradication options available. Monitoring of fish numbers (e.g., annual surveys) could be appropriate, and if significant increases were detected in the future, control options to reduce densities could be considered. For example, electro-fishing, netting, and rotenone poisoning have been used successfully in the Waikato to reduce pest fish numbers, but total eradication would not be possible.

6.3 New signage

The on-site map of Barrett Domain is dated and in poor condition (Figure 26). A modern sign outlining the main features of the domain could enhance public use and appreciation of the domain. Some of the tracks would also benefit from new signage along the routes and at junctions. Informative signage at key locations could also educate the public on ecological features. For example there could be an interpretive sign at the lake lookout platform explaining the significance of the lake and the unique native wetland plants, birds and fish that live there.

Figure 26: Current signage at Barrett Lake.

7 Environmental impacts of future developments

New Plymouth District Council requested that we briefly consider the environmental impact of several potential developments to occur within Barrett Domain.

7.1.1 Path and boardwalk around perimeter of the lake

No specific proposed route for the path and boardwalk around the lake was provided to us, but it could be assumed the path would follow the margin of the lake closely and where required span over water. The greatest environmental impact would occur during the construction of the path, but once established, impact would probably be negligible. Construction would involve removing some small areas of flaxland vegetation and possibly minor earthworks. Preferably, any machinery used in track construction would not be larger than necessary to complete the job due to the heightened risk of damaging more vegetation than is required for the path. New sediment input into the lake and excessive disturbance of existing lake sediments during construction should also be minimised/avoided where possible in order to preserve the lake water clarity. Sediment traps (e.g. filter socks) may be useful to stop runoff in some areas during construction and machinery should not enter the water unless absolutely vital.

In areas where the boardwalk is required to be established over water, the natural hydrological regime should be preserved where possible by using elevated boardwalks that water can pass freely under. Native reedland vegetation (see Section 4.1.2) including kuta, raupo and kuawa would be likely to naturally colonise around any structures without assistance, and in doing so would reduce the contrast between the boardwalk and natural landscape, helping the path to blend in. Where any vegetation on the lake margin is cleared for the track, this could be offset by replanting species typical of the adjoining areas such as flax, swamp coprosma and pukatea. Although the boardwalk could be perceived as a significant development in the domain, any adverse environmental effects during construction would be offset in the long term by the enhanced opportunity for public to appreciate the lake and its wildlife.

7.1.2 Upgrade of existing tracks

All existing tracks within Barrett Domain were examined to determine the extent of any environmental impacts associated with ‘upgrades’ to either gravel or seal. All tracks in the domain were found to be well established and appeared to be used frequently by the public. The majority of tracks were already 1-2 metres in width, and thus very little vegetation disturbance would occur if these tracks were re-surfaced (e.g. Figure 27). In order to further widen some tracks, the removal of any mature native trees should be avoided (they can be bypassed); but minor shrub clearance on the margins would be acceptable given their abundance and ability to regenerate quickly. Earthworks and re-contouring of the ground during track upgrades should be kept to a minimum, with the machinery used not being excessively large and causing unnecessary damage. Particular care should be taken near the Mangaotuku Stream to ensure no sediment input (runoff etc.) occurs.

Having more formally established tracks at the site has the positive effect of containing/reducing any damage caused by people (vegetation trampling etc.); and makes people less likely to wander off into un-tracked areas causing further damage. Usually in situations where forests tracks are upgraded, compacted gravel as opposed to seal is used, because it provides a more natural look, is more cost-effective, and is low maintenance (does not become slippery with leaf litter etc.). In some locations within the domain, forest tracks were excessively muddy, and thus an upgrade to gravel would probably make them much more accessible to public and thus enhance the appreciation of the forest within the domain. The addition of basic steps on some steeper areas of tracks would also be beneficial. It is not likely that every track will be upgraded and some members of the public would probably appreciate that some tracks are left in their current more natural state.

Figure 27: Bush track suitable for resurfacing in the lagoon bush.

7.1.3 New pedestrian linkages into the domain

Several roads around Barrett Domain either currently provide or have potential to provide pedestrian access into the site, including Roto St (the main pedestrian/vehicular access way to the park), Davies Rd (established link to lagoon bush), Rotokare Cres/Koroako Grove (will be more useful once a track around the lake is established) and Alba St (involves passing through the RDA area). Without further information on the exact path of any potential new routes, the environmental impact cannot be fully determined; the existing access ways described are already well-established so upgrades would probably have little impact.

7.2 Summary of likely impacts of developments

- Minor clearance of some flaxland vegetation around the margin of the lake to allow for path and boardwalk construction.
- Potential for some sediment input into the lake during earthworks associated with path and boardwalk construction (or disturbance of existing lake sediments).
- Alteration to the hydrological regime of the lake if unsuitable boardwalks are constructed.
- Disturbance to wildlife such as birds during the construction and possibly even once the project is complete (e.g., people and dogs using the track, restricted access from lake to shore).
- Minor clearance of shrubs along the margins of some bush tracks to allow tracks to be widened and resurfaced.
- Possibility of minor sediment input into Mangaotuku Stream during bush track upgrades.

7.3 Mitigation of impacts

- Offset the removal of any flaxland vegetation around the lake by planting some of the un-vegetated pasture at the southern margin of the lake with appropriate natives such as flax, swamp coprosma, *Carex* spp., pukatea and swamp maire.
- Where possible, use sediment socks during construction to prevent sediment runoff into the lake and consider doing the construction in summer when heavy rainfalls are less likely. Do not disturb any lake sediments unnecessarily (with diggers etc.).
- If the path around the lake is required to cross a section of open water, the boardwalk should be elevated above water on poles to allow water to flow freely under the path at all times.
- Any larger trees along the path of lake track or bush tracks should be bypassed as opposed to being removed. Smaller shrub removal along bush track margins is inevitable and not considered to be a major issue; natural regeneration would occur rapidly in most areas.
- If any major re-contouring of bush tracks was to occur, sediment socks could be used to prevent runoff into the Mangaotuku Stream.
- Gravel/fill to be used in track resurfacing should come from a local weed-free source if possible.
- No machinery should be permitted to pass through the Mangaotuku Stream during track upgrades (the existing bridges could be used).
- Most birdlife will adapt to increased numbers of people; little can be done to mitigate the impact of the track on birdlife, other than to ensure some areas of wetland are left undeveloped to provide refuge.

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9 Appendices

9.1 Native vascular plants of Barrett Domain

This list was compiled from observations by B.R Clarkson and M.R Boase (1982), A.P Druce (1990), and J.T Efford and R.J Bylsma (Present study).

"P" after a species denotes a planted native.

Taxonomic Group	Formal Name	Common Name
Gymnosperm trees		
	Agathis australis [P]	Kauri
	Dacrydium cupressinum	Rimu
	Dacrycarpus dacrydioides	Kahikatea
	Phyllocladus trichomanoides [P]	Tanekaha
	Prumnopitys taxifolia	Matai
	Prumnopitys ferruginea	Miro
	Podocarpus totara [P]	Totara
Monocot trees		
	Cordyline australis	Cabbage tree
	Rhopalostylis sapida	Nikau
Dicot trees & shrubs		
	Ackama rosaefolia [P]	Makamaka
	Alectryon excelsus	Titoki
	Aristotelia serrate	Wineberry
	Beilschmiedia tawa	Tawa
	Brachyglottis repanda	Rangiora
	Coprosma areolata	Thin-leaved coprosma
	Coprosma grandifolia	Kanono
	Coprosma repens [P]	Taupata
	Coprosma robusta	Karamu
	Coprosma tenuicaulis	Swamp coprosma
	Corokia chathamica [P]	Korokio
	Corokia cotoneaster [P]	Korokio
	Corynocarpus laevigatus	Karaka
	Dodonaea viscosa var. [P]	Akeake
	Dysoxylum spectabile	Kohekohe
	Eleocarpus dentatus	Hinau
	Entelea arborescens [P]	Whau
	Fuchsia excorticata	Kotukutuku
	Geniostoma rupestre var. ligustrifolium	Hangehange
	Griselinia lucida	Puka

Hebe ligustrifolia [P]	
Hebe stricta var. stricta	Koromiko
Hedycarya arborea	Pigeonwood
Hoheria populnea var. lanceolata [P]	Lacebark
Knightia excelsa	Rewarewa
Kunzea ericoides [P]	Kanuka
Laurelia novae-zelandiae	Pukatea
Leptospermum scoparium	Manuka
Litsea calicaris [P]	Mangeao
Lophomyrtus X *ralphii* [P]	Ramarama hybrid
Macropiper excelsum	Kawakawa
Melicope ternata [P]	Wharangi
Melicytus ramiflorus	Mahoe
Meryta sinclairii [P]	Pukanui
Metrosideros excelsa [P]	Pohutukawa
Myrsine australis	Mapau
Nestegis cunninghamii	Black maire
Nothofagus fusca [P]	Red beech
Nothofagus menziesii [P]	Silver beech
Olearia albida [P]	
Olearia furfuracea [P]	Akipiro
Olearia paniculata [P]	Akiraho
Pittosporum crassifolium	Karo
Pittosporum eugenioides [P]	Lemonwood
Pittosporum ralphii [P]	
Pittosporum tenuifolium [P]	Kohukohu
Pomaderris apetala [P]	Tainui
Pseudopanax arboreus	Fivefinger
Pseudopanax crassifolius	Lancewood
Pseudopanax laetus [P]	
Schefflera digitata	Pate
Sophora microphylla [P]	Kowhai
Syzygium maire	Swamp maire
Vitex lucens [P]	Puriri
Weinmannia racemosa	Kamahi

Monocot lianes

Freycinetia banksii	Kiekie
Ripogonum scandens	Supplejack

Dicot lianes and related trailing plants

Clematis paniculata	White clematis
Metrosideros fulgens	Rata
Metrosideros perforata	White rata
Muehlenbeckia australis	Pohuehue
Parsonsia heterophylla	NZ jasmine

Ferns

Adiantum cunninghamii	Common maidenhair
Arthropteris tenella	Jointed fern
Asplenium bulbiferum	Hen and chicken fern
Asplenium flaccidum	Hanging spleenwort
Asplenium lyallii	Lyalls spleenwort
Asplenium oblongifolium	Shining spleenwort
Asplenium polyodon	Sickle spleenwort
Azolla filiculoides	Water fern
Blechnum chambersii	Lance fern
Blechnum colensoi	Colensos hard fern
Blechnum filiforme	Thread fern
Blechnum fluviatile	Creek fern
Blechnum membranaceum	
Blechnum minus	Swamp kiokio
Blechnum novae-zelandiae	Kiokio
Cyathea dealbata	Silver fern
Cyathea medullaris	Mamaku
Deparia petersenii subsp. Conrua	
Dicksonia squarrosa	Wheki
Diplazium australe	
Huperzia varia	Clubmoss
Hymenophyllum demissum	Drooping filmy fern
Hymenophyllum venosum	Veined filmy fern
Lastreopsis glabella	Smooth sheild fern
Lastreopsis hispida	Hairy fern
Lastreopsis microsora subsp. Pentangularis	
Loxogramme dictyopteris	Lance fern
Microsorum pustulatum	Hounds tounge
Microsorum scandens	Fragent fern
Paesia scaberula	Lace fern
Pneumatopteris pennigera	Gully fern
Pteridium esculentum	Bracken fern
Pteris macilenta	Sweet fern
Pteris tremula	
Ptisana salicina	King fern
Pyrrosia eleagnifolia	Leather leaf fern
Rumohra adiantiformis	Leathery shield fern
Tmesipteris elongata	Fork fern

Orchids

Earina mucronata agg.	Bamboo orchid
Drymoanthus adversus	
Nematoceras trilobum	Spider orchid

Winika cunninghamii	Bamboo orchid

Grasses

Austroderia toetoe	Toetoe
Isachne globosa	Swamp millet
Microlaena avenacea	Bush rice grass
Microlaena stipoides	Slender rice grass

Sedges

Machaerina rubiginosa	Baumea
Machaerina tenax	Baumea
Machaerina arthrophylla	Baumea
Carex dipsacea var. dipsacea	
Carex dissita	Forest sedge
Carex geminata	Rautahi
Carex lessoniana	Rautahi
Carex maorica	Maori sedge
Carex secta	Pukio
Carex solandri	Forest sedge
Carex virgata	Swamp sedge
Cyperus ustulatus	Coastal cutty grass
Eleocharis acuta	Sharp spike sedge
Eleocharis gracilis	Slender spike sedge
Eleocharis sphacelata	Kuta
Isolepis distigmatosa	
Isolepis inundata	
Schoenus maschalinus	Dwarf bog rush
Schoenoplectus tabernaemontani	Kuawa
Uncinia uncinata	Hook sedge

Rushes

Juncus australis	Wiwi
Juncus planifolius	Grass-leaved rush
Juncus prismatocarpus	
Juncus sarophorus	Fan-flowered rush

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

Astelia solandri	Perching lily
Collospermum hastatum	
Lemna sp. (L. minor of NZ authors)	Common duckweed
Phormium tenax	Flax
Potamogeton cheesemanii	Red pondweed
Sparganium subglobosum	Bur-reed
Typha orientalis	Raupo

Composite herbs (F. Asteraceae)

Euchiton involucratus	
Euchiton limosa	

Dicot herbs other than Composites

Centella uniflora	Centella
Epilobium pallidiflorum	Swamp willow herb
Epilobium rotundifolium	Round-leaved willow herb
Geranium sp.	
Gratiola sexdentata	
Hydrocotyle pterocarpa	
Lilaeopsis novae-zelandiae	
Lobelia anceps	Shore lobelia
Myriophyllum propinquum	Common water milfoil
Persicaria decipiens	
Potentilla anserinoides	Silverweed
Solanum nodiflorum	Small-flowered nightshade
Stellaria parviflora var.	NZ chickweed
Wahlenbergia albomarginata	Harebel

9.2 i-Tree quadrat data (Quadrat 1)

Location	Barrett Domain, Lagoon bush Q1
Date	29.6.2012
Crew	Jackson Efford & Rebecca Bylsma
GPS	NZTM E1690319 N5672722

Q1 Ground Covers (Percentage)	
Duff/Mulch	60
Bare soil	2
Seedlings	37
Herb/ivy	1

Q1 Shrub data

Species	% Shrub area	Height	% Mass missing
Dysoxylum spectabile	5	<0.5 m	-
Dysoxylum spectabile	3	0.5-1 m	-
Dysoxylum spectabile	3	>1 m	-
Geniostoma rupestre	1	<0.5 m	-
Geniostoma rupestre	2	0.5-1 m	-
Geniostoma rupestre	2	1 m	-
Cyathea dealbata	1	<0.5 m	-
Cyathea dealbata	1	0.5-1 m	-
Laurelia novae-zelandiae	1	<0.5 m	-
Laurelia novae-zelandiae	1	0.5-1 m	-
Laurelia novae-zelandiae	1	>1 m	-
Coprosma grandifolia	3	<0.5 m	-
Coprosma grandifolia	1	0.5-1 m	-
Coprosma grandifolia	1	>1 m	-
Asplenium oblongifolium	2	<0.5 m	-
Lastreopsis hispida	6	<0.5 m	-
Macropiper excelsum	1	<0.5 m	-
Hedycarya arborea	1	<0.5 m	-
Hedycarya arborea	1	0.5-1 m	-
Melicytus ramiflorus	2	<0.5 m	-
Melicytus ramiflorus	1	0.5-1 m	-
Melicytus ramiflorus	1	>1 m	-

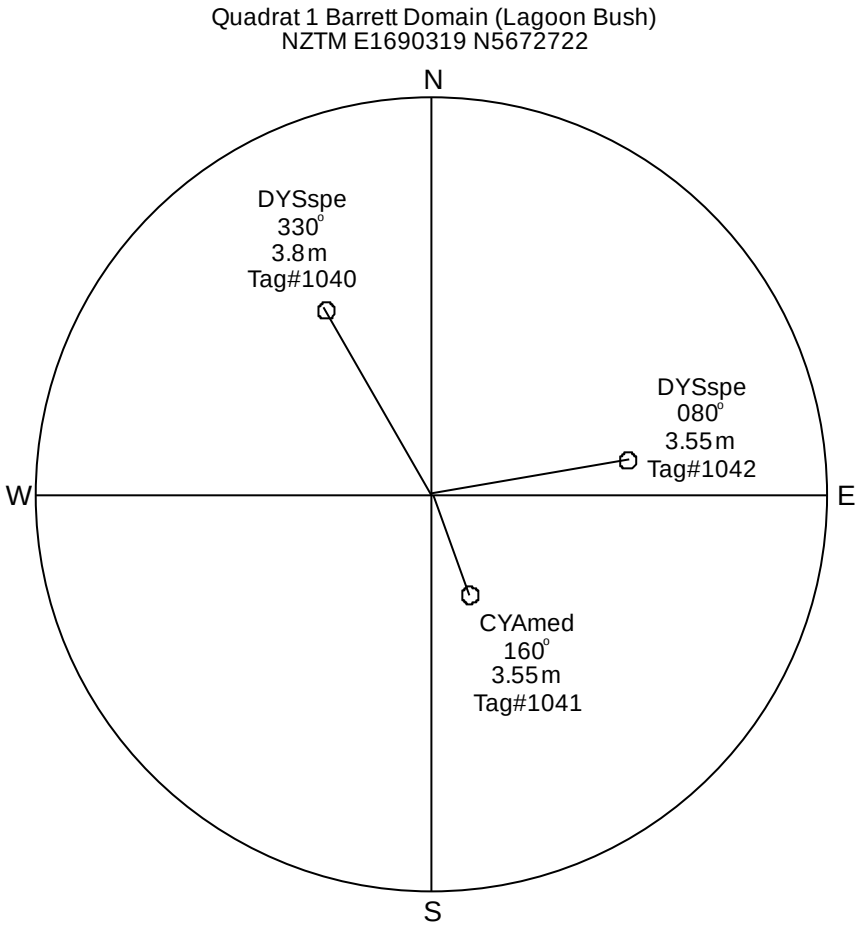
Q1 Epiphytes/Lianes	Rank
Griselinia lucida	1
Ripogonum scandens	2
Microsorum scandens	3
Arthropteris tenella	4
Astelia solandri	5
Asplenium polyodon	6
Tmesipteris elongata	-
Metrosideros fulgens	-
Blechnum filiforme	-
Freycinetia banksii	-

Q1 Seedling data (1/4 plot tally)

Species	Height (cm)				
	<15	16-45	46-75	76-105	106-135
Knightia excelsa	8	1			
Dysoxylum spectabile	>100	>100	3		
Beilschmiedia tawa	1				
Lastreopsis hispida	>100	23			
Geniostoma rupestre	1	2			
Hoheria populnea	2	1			
Myrsine australis		1			
Corynocarpus laevigatus	1	1	1	1	
Macropiper excelsum	1	1	1		
Hedycarya arborea	3	2		1	
Pseudopanax lessonii	1				
Laurelia novae-zelandiae	1				1
Coprosma grandifolia	3				

Q1 Tree data

Dist. (m)	Dir. (°)	Spp.	Stem diameters (cm dbh) d1	d2	d3	Crown base (m)	Height (m)	Width (m)	Width (m)	CLE	% Canopy missing	% Die back
6.6	20	*Dysoxylum spectabile*	26.5			8	18	8	7.2	1	10	-
3.8	41	*Macropiper excelsum*	4.5			3	3.5	1	1	0	-	-
3.7	58	*Dysoxylum spectabile*	41.7			13	18	10	10	1	-	-
4.2	95	*Dysoxylum spectabile*	21.8			10	18	6	6	1	15	-
3.8	135	*Dysoxylum spectabile*	9.1	11.8		4	10	6	5	1	-	-
3.4	150	*Dysoxylum spectabile*	22.9			12	18	8	8	1	-	-
1.9	160	*Cyathea medullaris*	63			18	20	5	7	1	-	-
5.6	190	*Dysoxylum spectabile*	3.4			3	5	2	2	0	-	-
4.3	225	*Melicytus ramiflorus*	30.2			15	18	8	7	1	20	-
3.9	260	*Dysoxylum spectabile*	37.5			13	18	8	8	1	-	-
3.8	330	*Dysoxylum spectabile*	33.3			10	20	9	6	1	-	-
4	345	*Dysoxylum spectabile*	70			15	23	10	10	1	-	-



9.3 i-Tree quadrat data (Quadrat 2)

Location	Barrett Domain, Lagoon bush Q2
Date	29.6.2012
Crew	Jackson Efford & Rebecca Bylsma
GPS	NZTM E 1690289 N 5672549

Q2 Ground Covers (Percentage)	
Duff/Mulch	68
Bare ground	2
Seedlings	30
Herb/ivy	2

Q2 Shrub data

Species	% Shrub area	Height	% Mass missing
Dysoxylum spectabile	10	<0.5 m	-
Dysoxylum spectabile	10	0.5-1 m	-
Dysoxylum spectabile	15	>1 m	-
Geniostoma rupestre	3	<0.5 m	-
Geniostoma rupestre	2	0.5-1 m	-
Geniostoma rupestre	1	> 1 m	-
Corynocarpus laevigatus	10	<0.5 m	-
Corynocarpus laevigatus	5	0.5-1 m	-
Corynocarpus laevigatus	5	>1 m	-
Vitex lucens	1	<0.5 m	-
Vitex lucens	2	0.5-1 m	-
Vitex lucens	3	>1 m	-
Macropiper excelsum	2	<0.5 m	-
Macropiper excelsum	2	0.5-1 m	-
Macropiper excelsum	2	>1 m	-
Asplenium bulbiferum	3	<0.5 m	-
Asplenium bulbiferum	3	0.5-1 m	-
Hedycarya arborea	2	<0.5 m	-
Hedycarya arborea	1	0.5-1 m	-
Hedycarya arborea	1	>1 m	-
Coprosma grandifolia	2	<0.5 m	-
Coprosma grandifolia	1	0.5-1 m	-
Coprosma grandifolia	1	>1 m	-
Melicytus ramiflorus	2	<0.5 m	2
Melicytus ramiflorus	1	0.5-1 m	2
Melicytus ramiflorus	1	> 1 m	2
Pneumatopteris pennigera	1	<0.5 m	-
Pneumatopteris pennigera	1	0.5-1 m	-
Hedychium sp.*	+	<0.5 m	-
Hedychium sp.*	+	0.5-1 m	-
Schefflera digitata	+	<0.5 m	-

Q2 Epiphytes/Lianes	Rank
Astelia solandri	1
Collospermum hastatum	2
Freycinetia banksii	3
Asplenium oblongifolium	4
Arthropteris tenella	5
Microsorum scandens	-
Blechnum filiforme	-
Metrosideros fulgens	-
Parsonsia heterophylla	-
Asplenium flaccidum	-
Microsorum scandens	-

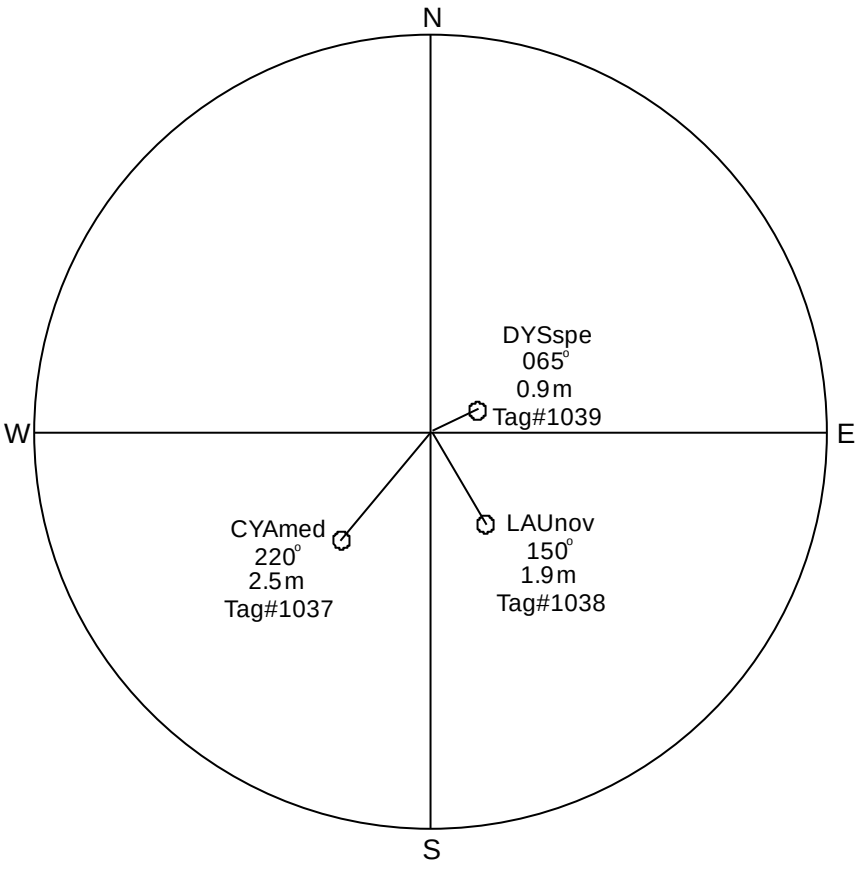
Q2 Seedling data (1/4 plot tally)

Species	Height (cm)				
	<15	16-45	46-75	76-105	106-135
Pneumatopteris pennigera		2	1		
Hedycarya arborea	20	2	1	1	
Asplenium bulbiferum		1	5	1	
Dysoxylum spectabile	>100	>100	10	7	6
Vitex lucens	1	3	2	1	
Schefflera digitata		1		2	1
Knigtia excelsum	15	6	3	1	1
Geniostoma rupestre		1	2	1	1
Corynocarpus laevigatus	6	1	1	5	6
Coprosma grandifolia	2	2	3	2	1
Myrsine australis		1			
Alectryon excelsus	5	3	1		
Macropiper excelsum	2	1	1	2	1
Hedychium sp.*			1	1	
Beilschmiedia tawa	4	1			
Melicytus ramiflorus		1	1		
Parsonsia heterophylla	6		1	2	1
Laurelia novae-zelandiae	1	1			
Macropiper excelsum		1	1		

Q2 Tree data

Dist. (m)	Dir. (°)	Spp.	Stem diameters (cm dbh)			Crown base (m)	Height (m)	Width (m)	Width (m)	CLE	% Canopy missing	% Die back
			d1	d2	d3							
5.5	18	*Laurelia novae-zelandiae*	90.2			18	30	12	12	1	20	5
6.1	20	*Dysoxylum spectabile*	6.5			5	7	3	2.5	1	-	-
4.7	22	*Dysoxylum spectabile*	3.9			4	5	3	3	0	-	-
4.3	25	*Dysoxylum spectabile*	11.4			4	11	4	4	1	-	-
6.2	38	*Dysoxylum spectabile*	3.4			2	4	1	1.5	0	-	-
5.2	40	*Dysoxylum spectabile*	5.9			3	6	3	3	0	-	-
4	43	*Dysoxylum spectabile*	4.1			3	5	2	1.5	0	-	-
4.1	51	*Dysoxylum spectabile*	8.2			4	7	2	2	1	-	-
0.9	52	*Dysoxylum spectabile*	9.2			4	10	4	3.7	1	-	-
2.9	75	*Dysoxylum spectabile*	3.2			1.5	3	1	1	0	-	-
0.8	90	*Dysoxylum spectabile*	3.6			2	4	4	2	1	-	-
2	143	*Laurelia novae-zelandiae*	19.3			8	12	6	5	1	-	-
3.5	145	*Dysoxylum spectabile*	3.3			2.2	4	2	2	1	-	-
5.3	145	*Schefflera digitata*	4			1.5	4	2	1.5	1	-	-
3.8	147	*Dysoxylum spectabile*	3.4			2	5	2	1.8	1	-	-
5.4	147	*Dysoxylum spectabile*	28.6			5	17	6	7	1	-	-
6.9	149	*Laurelia novae-zelandiae*	57.9			14	23	12	12	1	-	-
3.8	162	*Dysoxylum spectabile*	3.4			1	4	2	2	1	-	-
7.2	190	*Dysoxylum spectabile*	17.6			6	12	5	5	1	-	-
2.7	235	*Cyathea medullaris*	17.3			10	12	3	3	1	-	-
6.3	265	*Cyathea medullaris*	12.2			10	12	3	3	1	-	-
6.7	270	*Dysoxylum spectabile*	21.4			6	15	5.8	5	1	-	-
5	310	*Dysoxylum spectabile*	102	est.		10	24	10	10	1	20	30
5.6	320	*Dysoxylum spectabile*	5.2			3	5	3	3	1	-	-
5.3	330	*Dysoxylum spectabile*	19.7			7	15	3	5	1	-	-
5.4	340	*Dysoxylum spectabile*	6.9			4	9	4.5	4	1	-	-
2	342	*Cyathea medullaris*	32.7			12	15	6	4	1	-	-

Quadrat 2 Barrett Domain (Lagoon Bush)
NZTM E1690289 N5672549



9.4 i-Tree quadrat data (Quadrat 3)

Location	Barrett Domain, Rayward Bush Q3
Date	29.6.2012
Crew	Jackson Efford & Rebecca Bylsma
GPS	E 1690163 N 5672908

Q3 Ground Covers (Percentage)	
Duff/Mulch	78
Bare soil	2
Seedlings	20
Herb/ivy	10

Q3 Shrub data

Species	% shrub area	Height	% Mass missing
Macropiper excelsum	10	<0.5 m	-
Macropiper excelsum	7	0.5-1 m	-
Macropiper excelsum	7	>1 m	-
Hedycarya arborea	3	<0.5 m	-
Hedycarya arborea	3	0.5-1 m	-
Hedycarya arborea	2	>1 m	-
Geniostoma rupestre	5	<0.5 m	-
Geniostoma rupestre	1	0.5-1 m	-
Geniostoma rupestre	1	>1 m	-
Dysoxylum spectabile	3	<0.5 m	-
Dysoxylum spectabile	2	0.5-1 m	-
Dysoxylum spectabile	3	>1 m	-
Dicksonia squarrosa	1	<0.5 m	-
Dicksonia squarrosa	2	0.5-1 m	-
Asplenium polyodon	1	<0.5 m	-
Asplenium polyodon	1	0.5-1 m	-
Ripogonum scandens	2	<0.5 m	-
Ripogonum scandens	2	0.5-1 m	-
Ripogonum scandens	2	>1 m	-
Myrsine australis	1	<0.5 m	-
Knightia excelsa	0.5	<0.5 m	-
Asparagus scandens	2	<0.5 m	-
Asparagus scandens	3	0.5-1 m	-
Asparagus scandens	3	>1 m	-
Laurelia novae-zelandiae	0.5	<0.5 m	-
Prunus sp.*	0.5	<0.5 m	-
Prunus sp.*	0.5	0.5-1 m	-

Q3 Epiphytes/Lianes	Rank
Ripogonum scandens	1
Arthropteris tenella	2
Asplenium polyodon	3
Astelia solandri	4
Microsorum scandens	5
Tmesipteris elongata	6

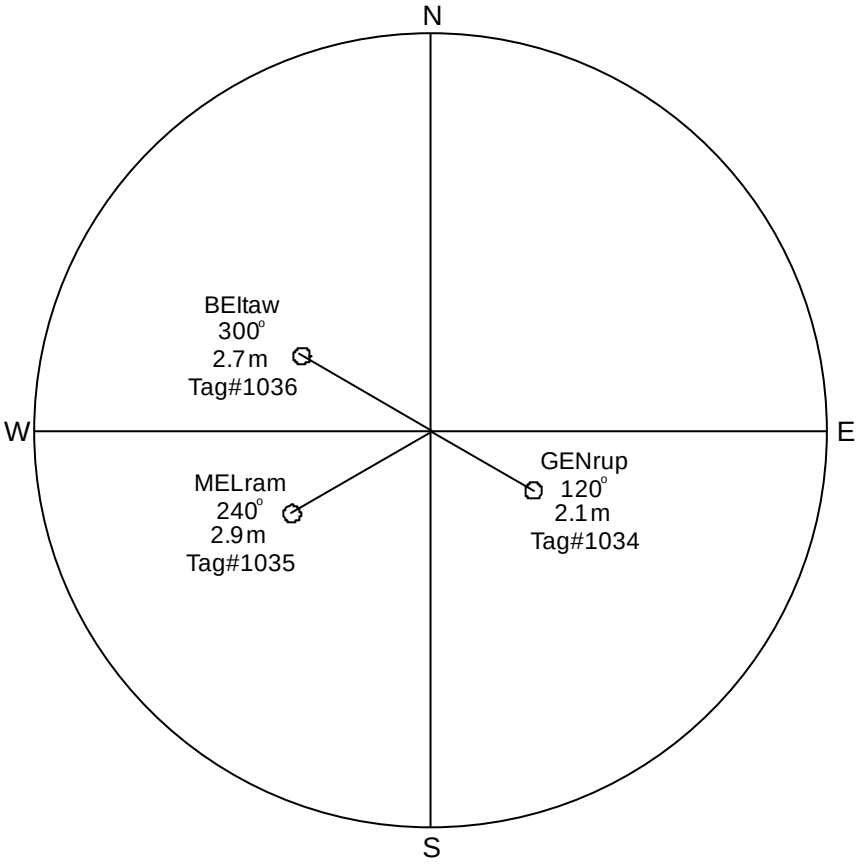
Q3 Seedling data (1/4 plot tally)

Species	Height				
	<15	16-45	46-75	76-105	106-135
Rhopalostylis sapida	8	4	1		
Dysoxylum spectabile	>100	15	8	4	5
Macropiper excelsum	2	1	1	3	1
Hedycarya arborea	7	5	2	1	1
Geniostoma rupestre	7	4	5	3	3
Myrsine autralis	3	3	2	2	
Asparagus scandens	>100	5	6		
Adiantum cunninghamii	5	1			
Melicytus ramiflorus	1	3	1	2	2
Hoheria populnea			1	2	1
Corynocarpus laevigatus	1	1			
Knightia excelsum	1	1	3		
Prunus sp.*	2	3			
Laurelia novae-zelandiae	1	2	3	3	3
Dicksonia squarrosa	1				
Pseuodopanax hybrid	1				
Coprosma robusta		1			
Coprosma areolata	1	1			

Q3 Tree data

			Stem diameters (cm dbh)										
Dist. (m)	Dir. (°)	Spp.	d1	d2	d3	d4	Crown base (m)	Height (m)	Width (m)	Width (m)	CLE	% Canopy missing	% Die back
5.4	6	*Myrsine australis*	6.3				5.5	7.5	2.5	2	2	-	-
5.3	7	*Myrsine australis*	3.4				6	7	2	2	1	-	-
6.7	100	*Beilschmiedia tawa*	7.3	10.4	14.5		4.5	18	10	8	1	-	-
1.9	100	*Coprosma areolata*	4.7				2.8	4	2	1.5	0	-	20
4.2	110	*Geniostoma rupestre*	3.9	3.8			4.1	5.5	2	3.2	0	-	-
5.2	110	*Macropiper excelsum*	4.3	3.7			2.5	4.5	2	1.5	0	-	-
2.3	120	*Geniostoma rupestre*	5				4	6	3	3	0	-	-
6.3	140	*Geniostoma rupestre*	5.3				2	5.2	3	2	0	-	-
4.5	142	*Macropiper excelsum*	4.9				1.5	4	2	1.8	0	-	-
4.8	155	*Macropiper excelsum*	3.9	6.5	6.9		3.5	6.5	4.5	4	1	-	-
2.8	155	*Macropiper excelsum*	4.8				4	6	2	1.5	1	-	-
1.7	160	*Cordyline australis*	15.5				7	9	4	2	1	-	-
6.5	172	*Melicytus ramiflorus*	34.4				12	14	2	2	1	-	-
7.1	200	*Myrsine australis*	9.5				6	10	4	3.5	1	-	10
3.9	215	*Melicytus ramiflorus*	16.1				7	13	5	3	1	-	-
7.3	220	*Macropiper excelsum*	4.8	7.4	2.9	4.8	3	5	4	3	0	-	10
6.2	222	*Melicytus ramiflorus*	6.9				6	10	3	2.5	1	-	-
5.5	225	*Macropiper excelsum*	7.8	4.6	5.9		3	5	4	3.5	1	-	-
4	236	*Macropiper excelsum*	4.5	7.2			3	6	4	3	1	-	-
2.6	240	*Melicytus ramiflorus*	6.7				2.5	7	2	2	1	-	-
6.4	255	*Cyathea medullaris*	24.1				6	8	6	7	1	-	-
1.8	280	*Coprosma areolata*	2.9				2.7	4	1	1	0	-	-
5.3	280	*Geniostoma rupestre*	5.2	5			3.5	6	3.5	3	0	-	-
3	300	*Beilschmiedia tawa*	61				15	23	15	10	1	-	20
2.5	330	*Macropiper excelsum*	4.8				2.5	5	3	3	0	-	-
2.8	333	*Macropiper excelsum*	8.3				2.5	5	3.5	2	0	-	-
2.2	340	*Prunus* sp.*	3.3				5	6	1	1	0	-	-
3.6	350	*Melicytus ramiflorus*	11.9				6	11	3	3.5	1	-	-
2.6	350	*Melicytus ramiflorus*	5.3				5	10	3	2.5	1	-	-
2	340	*Prunus* sp.*	6.2				8	10	3	3.5	1	-	100

Quadrat 3 Barrett Domain (Rayward Bush)
NZTM E1690163 N5672908



9.5 i-Tree quadrat data (Quadrat 4)

Location	Barrett Domain, Kauri Plantation Q4
Date	29.6.2012
Crew	Jackson Efford & Rebecca Bylsma
GPS	E 1690299 N 5673214

Q4 Ground Covers (Percentages)	
Duff/Mulch	60
Bare soil	5
Seedlings	20
Herb/ivy	15

Q4 Shrub data

Species	% Shrub area	Height	% Mass missing
Macropiper excelsum	4	<0.5 m	2
Macropiper excelsum	3	0.5-1 m	2
Macropiper excelsum	2	>1 m	2
Melicytus ramiflorus	3	<0.5 m	-
Melicytus ramiflorus	2	0.5-1 m	-
Melicytus ramiflorus	1	>1 m	-
Hoheria populnea	1.5	<0.5 m	-
Hoheria populnea	0.5	0.5-1 m	-
Hoheria populnea	0.5	<0.5 m	-
Coprosma grandifolia	0.5	0.5-1 m	-
Coprosma grandifolia	1.5	0.5-1 m	-
Coprosma grandifolia	1	<0.5 m	-
Corynocarus laevigatus	0.1	0.5-1 m	-
Corynocarus laevigatus	0.1	<0.5 m	-
Corynocarus laevigatus	0.1	0.5-1 m	-
Dicksonia squarrosa	0.1	<0.5 m	-
Dicksonia squarrosa	0.01	0.5-1 m	-
Dicksonia squarrosa	0.5	>1 m	-
Pneumatopteris pennigera	0.5	<0.5 m	-
Pneumatopteris pennigera	0.1	0.5-1 m	-
Pneumatopteris pennigera	0.5	>1 m	-
Asplenium bulbiferum	1	<0.5 m	-
Asplenium bulbiferum	0.5	0.5-1 m	-
Asparagus scandens	1.5	<0.5 m	-
Asparagus scandens	0.5	0.5-1 m	-
Asparagus scandens	0.5	>1 m	-

Epiphytes/Lianes	Rank
Microsorum scandens	1
Blechnum filiforme	2
Asplenium flaccidum	3
Metrosideros perforata	4
Metrosideros fulgens	5
Tmesipteris elongata	6
Asplenium polyodon	7

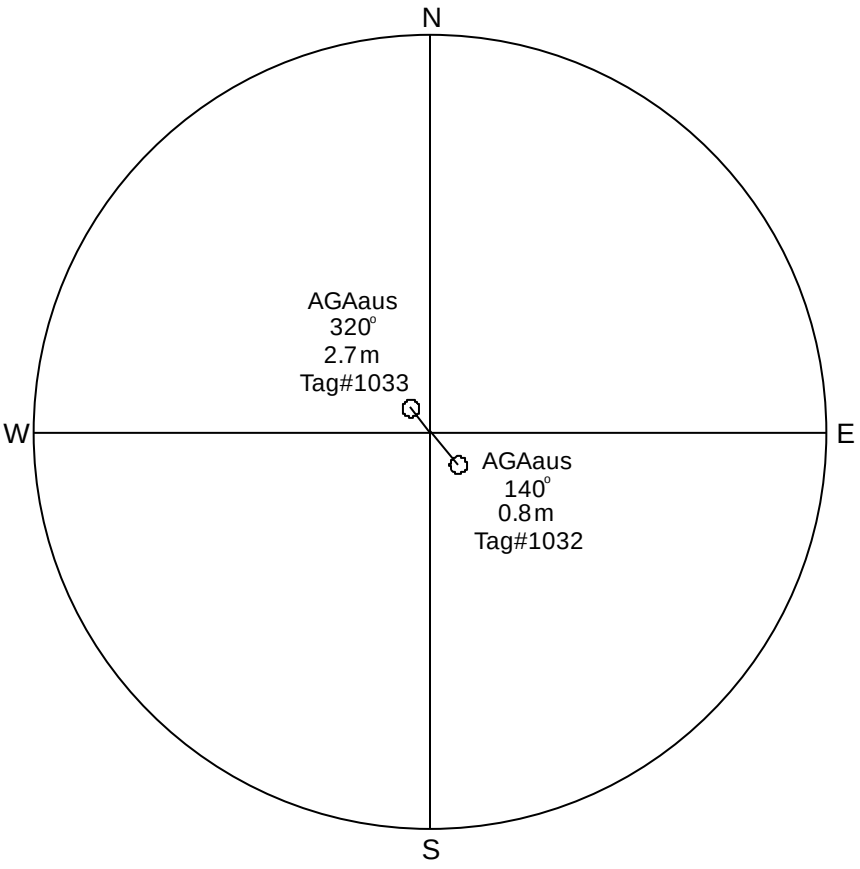
Q4 Seedling data (1/4 plot tally)

Species	Height				
	<15	16-45	46-75	76-105	106-135
Corynocarpus laevigatus	3	4	5	3	
Hoheria populnea	4	1	2	1	2
Dicksonia squarrosa		1	1		
Geniostoma rupestre	2	3	2		1
Tradescantia fluminensis	>100				
Melicytus ramiflorus	3	1	1	1	1
Pneumatopteris pennigera		1	1	1	
Macropiper excelsum	1	1	1	1	
Ptisana salicina					1
Laurelia novae-zelandiae	1		1		1
Asparagus scandens	>100				

Q4 Tree data

Dist. (m)	Dir. (°)	Spp.	Stem diameters (cm dbh)				Crown base (m)	Height (m)	Width (m)	Width (m)	CLE	% Canopy missing	% Die back
			d1	d2	d3	d4							
3.9	25	*Dicksonia squarrosa*	17.2				6.5	8	3	3.5	1	-	-
4.6	27	*Dicksonia squarrosa*	10.8				3	4	3	3	1	-	-
5.7	30	*Agathis australis*	32.1				15	27.5	7.6	8	1	-	-
5.1	31	*Dicksonia squarrosa*	15.4				3	4	3	3.5	1	-	-
6.7	35	*Cyathea medullaris*	17.9	18.7			11.5	13	6	4	1	-	-
2.6	52	*Agathis australis*	42.1				15	27.5	8.5	8.5	1	-	-
5.5	58	*Dicksonia squarrosa*	13.7				2.5	4	4	4.5	0	-	-
4.6	72	*Macropiper excelsum*	5.4				2	4	2	2.7	0	-	-
1.1	73	*Dysoxylum spectabile*	3.6				3	5	2	2.2	0	-	-
1.7	73	*Hoheria populnea*	3.8				3	5	2	2.5	0	-	-
3.5	73	*Agathis australis*	45.8				15	27.5	8	7	1	-	-
1.3	90	*Dysoxylum spectabile*	4.6				3	5	2	2.5	1	-	-
1.2	90	*Macropiper excelsum*	2.5				1.7	4	2	2	0	-	-
6.9	120	*Agathis australis*	52.5				9	27.5	7	8	1	-	-
4.9	120	*Agathis australis*	38.7				9	27.5	7	8	1	-	-
4.5	120	*Macropiper excelsum*	2.5				1.7	3	2	2	0	-	-
0.8	120	*Agathis australis*	52.7				14	27.5	7	10	1	-	-
4.3	160	*Macropiper excelsum*	3.5				2	6.7	4.2	3.2	0	-	-
5.2	167	*Macropiper excelsum*	5.4	3			2	3	2	1.8	0	-	-
5	170	*Agathis australis*	29.4				15	27.5	6	7	1	20	20
6.8	187	*Cyathea medullaris*	13.2				4	5	4	4	1	-	-
4	187	*Macropiper excelsum*	3.7				2	3	2	1.8	0	-	-
5.5	200	*Macropiper excelsum*	4.2				5	5	2	1.9	0	-	-
6.4	210	*Macropiper excelsum*	5.3				2.5	6.2	2	2.3	0	-	-
6.4	220	*Macropiper excelsum*	6				3	6.5	2	2.1	0	-	-
7.1	225	*Agathis australis*	4.6				15	27.5	9	10	1	-	-
5.6	238	*Macropiper excelsum*	3.9				2.7	5	2	2.5	0	-	-
4.6	238	*Macropiper excelsum*	5.9	5.5			2.7	5	2	2	0	-	-
6.5	240	*Dicksonia squarrosa*	19.2				4.5	6	3	3.5	0	-	-
6	245	*Macropiper excelsum*	4.3	3.9	3.7		3	5	3	3		-	-
6.8	270	*Macropiper excelsum*	5.5	3.2	6.4		3	5.5	3.7	3	0	-	-
3.6	285	*Macropiper excelsum*	5.2	3.7			4	6	2	2	0	-	-
5.8	285	*Agathis australis*	28.9				14	27.5	10	10	1	-	-
4.5	287	*Macropiper excelsum*	4	3.1			4	6	2	3	0	-	-
5.9	300	*Macropiper excelsum*	4.4	2.8	3.9	3	3	4	4	3.7	0	-	-
			2.8	2.7								-	-
5.5	320	*Agathis australis*	46.8				15	27.5	8	9	1	-	-
6.8	320	*Agathis australis*	36.2				15	27.5	8	7	1	-	-
2	350	*Cyathea medullaris*	24				2	3	2	1.8	0	-	-

Quadrat 4 Barrett Domain (Kauri Grove)
NZTM E1690299 N5673214



9.6 National Wetland Monitoring Data

WETLAND RECORD SHEET

Wetland name: Barrett Lagoon (Barrett Lake)
Region: Taranaki
Altitude: 63 m
Date: 25/06/2012
GPS/Grid Ref.: NZMG E2599973 N6234442
No. of plots sampled: 1

Classification: I System	IA Subsystem	II Wetland Class	IIA Wetland Form
Palustrine (+lacustrine)	Permanent	Swamp	Basin

Field team: J. Efford, R. Bylsma

Indicator	Indicator components	Specify and Comment	Score 0– 5[1]	Mean score
Change in hydrological integrity	Impact of manmade structures	Path and viewing platform	3.5	3.83
	Water table depth	Little change, quite high	4	
	Dryland plant invasion	Some blackberry, gorse, grey willow	4	
Change in physico-chemical parameters	Fire damage	No evidence of fire damage	5	4.16
	Degree of sedimentation/erosion	Some impact from urban/farmland. Southern margin only fenced recently	4	
	Nutrient levels	Input from pasture runoff/urban stormwater	3.5	
	Von Post index	N/A		
Change in ecosystem intactness	Loss in area of original wetland	Probably little change	4	4
	Connectivity barriers	Possible culvert obstruction (for fish etc) between lake overflow pond and Mangaotuku Stream.	4	
Change in browsing, predation & harvesting regimes	Damage by domestic or feral animals	Southern margin only recently fenced to stock	4	4.16
	Introduced predator impacts on wildlife	Urban dwelling predators and possums present	3.5	
	Harvesting levels	None known	5	
Change in dominance of native plants	Introduced plant canopy cover	Mercer grass, gorse, blackberry, grey willow	3.5	3.5
	Introduced plant understorey cover	Mercer grass on margins	3.5	
Total wetland condition index /25				19.65

[1] Assign degree of modification as follows: 5=v. low/ none, 4=low, 3=medium, 2=high, 1=v. high, 0=extreme

Main vegetation types:

Raupo and kuta reedland, flaxland

Native fauna:

pukeko, shelduck, tui, fantail

Pressure	**Score**[2]	**Specify and Comment**
Modifications to catchment hydrology	2.5	Some drains, farmland and urban
Water quality within the catchment	2	Farmland
Animal access	2	Houses and farms nearby
Key undesirable species	2	Gorse, blackberry, grey willow
% catchment in introduced vegetation	3	
Other landuse threats	3	Urban development
Total wetland pressure index /30	14.5	

[2]Assign pressure scores as follows: 5=very high, 4=high, 3=medium, 2=low, 1=very low, 0=none

WETLAND PLOT SHEET

Wetland name: Barrett Lake Date: 25/06/2012 Plot no: 1

Plot size (2m x 2m default): Altitude: 63 m GPS/GR: NZMG E2599973 N6234442

Field leader: J. Efford Structure: Reedland/flaxland Composition: *Baumea rubiginosa*

Canopy (bird's eye view)			Subcanopy			Groundcover		
Species[1] (or Substrate)	%	H	Species	%	H	Species	%	H
Baumea rubiginosa	30	1.3 m				*Centella uniflora*	+	
Phormium tenax	25	1.3				*Hydrocotyle pterocarpa*	+	
Isachne globosa	20	0.8						
Litter	20	0.5						
Blechnum minus	5	0.5						
*Lotus pedunculatus**	+	0.2						

[1] % = % cover: total Canopy % cover = 100%; H = maximum height in m; indicate introduced species by *

Additional species in vicinity in same vegetation type:

Gratiola sexdentata, *Coprosma tenuicaulis*, *Coprosma robusta*, *Potamogeton cheesemanii*, gorse, water lily

Comments:

Accessed from Kororako Grove subdivision. Plot marked with bamboo pegs.

Indicator (use plot data only)	%	Score 0–5[2]	Specify & Comment
Canopy: % cover introduced species	1	4	
Understorey: % cover introduced spp[3]	0	5	
Total species: % number introduced spp	1	4	
Total species: overall stress/dieback	NA	5	
Total /20	NA	18	

[2]5=0%: none, 4=1– 24%: very low, 3=25–49%; low, 2=50–75%: medium, 1=76–99%: high, 0=100%; v. high

[3]Add subcanopy and groundcover % cover for introduced species

Field measurements:

Water table cm	0 cm	Water conductivity uS (if present)	
Water pH (if present)		Von Post peat decomposition index	N/A

9.7 Permanent quadrat positions within Barrett Domain