AOTEA WETLAND
An assessment

Keith Thompson
Wetland ecologist
7 May 2009

On Wednesday 5 May 2009 I visited Aotea Wetland (NZMS Sheet 260 R14 698531), in the company of David Morrison and John Dodgson, with the purpose of assessing its hydrological status, plant diversity, substrate type and overall significance as a wetland representative of its type. I am grateful to David Morrison for permission to access the land to carry out this survey.

Vegetation
The overall wetland type is a **dune flush** or **dune fen**.

There are three main community types. The *Typha* (raupo) -dominated communities (**reed swamp**) – Community 1 - are located in the permanently flooded swamp and also where springwater seeps from the ground around the wetland edges. Main associated plants in this community are *Eleocharis sphacelata* (bamboo spike-sedge), *Phormium tenax* (flax) and *Salix cinerea* (grey willow).

Marginal to the raupo swards are two **herbaceous fen** communities. Both are stable, species-rich communities, with a good mix of native and exotic species and no aggressive weeds, a condition only possible in water which is relatively low in nutrients. The wetter of the two communities, closest to the raupo – Community 2 - is dominated by *Isachne globosa* (swamp millet), *Eleocharis gracilis* (slender spike-sedge), *Carex gaudichaudiana, Sparganium subglobosum* (burr-reed), and *Blechnum novae-zelandiae* (swamp piopio), *Cyperus congestus.*

The second fen community – Community 3 - is a low-growing hummock and hollow complex accessed by stock, but still very diverse in species: *Isachne, Agrostis stolonifera* (creeping bent), *Ranunculus flammula* (spearwort), *Epilobium ciliatum* (willow herb), *Myriophyllum propinquum, Centella uniflora, Carex flacca, Cyperus brevifolius.*

The presence of a few oak trees indicates that the area has been used for duck hunting at some stage, and the stopbank across the top of the wetland may have been constructed partly to establish ponds above it and partly to try to reduce water flow across Community 3 so that it could be accessed by stock.

Substrate
A wetland can be delimited in two ways: firstly, it is "characterised by plants which are adapted to (as opposed to 'tolerant of') waterlogging" and, secondly, "peat substrates will only form and persist if the surface layers are waterlogged for most of the year". So, by mapping the extent of the peat it is possible to set a minimum area for the extent of the wetland.

Using a peat borer I established that most of Community 3 is established on a peat soil, 40-50cm in depth, underlain by compacted dune sand. The functional wetland therefore covers much of the flat area to the west of the raupo, although there is some evidence from channelisation that there could be some peat degradation taking place now.

Most of Community 1 is established on about 1.5m of herbaceous swamp peat, underlain by 40cm of blue clay (either downwash or marine – this could be established with further tests), then dune sands. Interestingly, there is no obvious evidence in the lower peats of the presence of raupo, so this plant may be of more recent introduction to the wetland. I can't attach an age to wetland establishment, but it is of the order of hundreds, rather than tens, of years.

So the 'spine' of raupo (Community 1) is located over a shallow, 2 metre deep channel, with a gradually upward-sloping sand basement to the west and a steeply-sloping one to the east.

Hydrology

By far the most important factor in wetland formation and their on-going management is water supply/hydrology. The nature and condition of a wetland is, primarily, a function of its water supply.

The supply for the present wetland is a number of seeps from the toes of adjacent sand dunes. Two of these water sources can be quantified: the spring, on the other side of the road, which is currently tapped as a water supply for Aotea residents, used to be one of the sources for wetland water, and the overflow from abstraction still is. From the south, a substantial input passes through a culvert under a stopbank from the upper wetland to the lower. There is also a spring inflow above the stopbank along the southwest boundary of the wetland and the extreme clarity of the water and the abundance of submerged plants in two ponds there testify to the water's underground origins and low nutrient status.

Spring inflows are indicated by tall, vigorous stands of raupo. Where raupo is small in stature, flow rates are low and water levels usually below the surface.

There is a considerable S – N slope in the wetland, particularly the upper section beyond the stopbank, and this suggests a fairly substantial water supply is available. This brings me to the other aspect of wetland hydrology – water losses.

Water can be lost through evaporation (including transpiration from vegetation), artificial abstraction, seepage and surface outflow. At the time of inspection there is no visible surface outflow, so that either the inflow is balanced against evaporation or else there is significant seepage into underlying sands. Since I am told that the existing outflow channel probably discharges only some 20 days in the year, most of the excess water above evaporative losses must be seepage. As inputs will be low in iron and peats are relatively low in tannins, hardpan deposits (which would hinder seepage) have probably not formed.

Artificial abstraction occurs at one spring location and the pine forest will be diminishing dune aquifer recharge, as the previous dune vegetation would not have

been as substantial a water user as pines are. So this means that, either the wetland has already shrunk in area, or else the outflow channel used to be functioning much more frequently in the past. However, firstly, there is not much additional flat land available for wetland to the west and, secondly, the existing outlet channel is artificial: it was constructed relatively recently when a landowner to the north of the road in Aotea settlement complained about high water levels on their property. Historically, a proportion of Aotea settlement would have been an extension of the wetland and the briefness of my field visit does not permit me to further speculate about historical outflows or seepage at this stage. However, I would say that currently the water supply to the wetland is borderline between barely adequate and inadequate for sustainability of the wetland area as defined by the peat deposit. Any further abstraction for human consumption or deepening or relocation of the exit channel could well accelerate degradation. The considerable slope of the wetland, and the relatively high rate of water movement down it, makes it quite vulnerable to damage through additional water losses.

So although there may well be another springflow from the hill behind the Aotea settlement, it would probably not be a significant source of water for the existing wetland, because the general flow of water is from south to north. Consequently the establishment of a subdivision and some backfilling at the northern end of the wetland, adjacent to the road, would probably not, in itself, have any deleterious hydrological influence on the wetland. On the other hand, any injudicious re-routing of the outlet channel could well have a direct influence on the wetland, as could setting the invert level of the channel at too low an elevation.

Status/significance

Environment Waikato will have a better record of coastal wetlands in the region, but I believe that Aotea Wetland is a significant dune wetland and well worthy of both preservation and enhancement. Very few dune wetlands have survived agricultural and roading development and human settlement in the Waikato region and of those that have, most are greatly reduced in area, or are now in poor or degraded condition. Aotea Wetland, on the other hand, is still very healthy, with a good, high-quality water supply, a diverse flora with at least three wetland community types which are now rare or endangered and a level of agricultural damage which could be easily reduced or eliminated.

Recommendations

- I consider that Aotea Wetland is worthy of regional designation as a ‘significant wetland’.
- Whilst I always start to get concerned when residential land enters the catchment of wetlands, the Lot 4 subdivision will not present any significant threat to the integrity of the wetland, or to possible restoration work on it. However, I would prefer to see some documentation of mean winter high water levels in a way which makes retaining the normal water regime of the wetland sacrosanct. I would also like the residents to understand that there are such things as 100-year flooding events and no guarantee can be given that Lot 4 is, or could be, proofed against that if it were to involve any alteration of the normal functioning of the wetland.
- I would not support further residential sections extending into the catchment of the wetland in the future. That catchment edge is well set back into the pine

forest at the northwestern end, although it is almost contiguous with the forest edge at the south-western edge.

- The location of Lot 4 requires blocking of the exit channel from the wetland. This channel will have to be re-located and I strongly recommend that its location and invert level is subject to the advice of an appropriate wetland ecologist. The channel should, for instance, be re-located as far as possible to the north, so as to allow excess water to flow through the wetland before it exits. The elevation of the invert is critical as it should not compromise the normal functioning of the wetland.
- I would strongly support any initiative to fence off the wetland from stock access, with a good buffer zone to permit the wetland vegetation to establish a natural transition zone. Along the western margin, it would be good to locate the fence so as to include most of the peat substrate, since this seems to be retaining its moisture and continuing to support a wetland flora. Again, a wetland ecologist, or suitable soils specialist, could advise on fence locations. Environment Waikato or the QE2 Trust would probably help with fencing costs.
- Continued surveillance for, and treatment of, weed infestations is important, **particularly** the Mexican devil at the moment. There are no other obvious threats, although a programme to gradually remove willows would be a good restoration development. There are various grants options available to private landowners wishing to enhance local biodiversity.

Keith Thompson
PO Box 13062
Hamilton
Em: bogman@ihug.co.nz
Ph: 021945252

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[It is my intention that this document should be publicly available, of course]

Supplement to
5 May 2009 Assessment of Aotea Wetland

Keith Thompson
28 Sept 2009

Preamble

My initial assessment of Aotea Wetland was for personal interest as a wetland ecologist and trustee of the National Wetland Trust and I did not have the resources to complete a full investigation, with detailed recommendations for sustainable management. I expected that my preliminary study would provide the basis for further investigation by the either District or the Regional Council.

However, the Landowner, David Morrison, asked me to provide advice on appropriate measures to conserve the wetland and this has given me the opportunity to be more thorough in my assessment. I have not had time to integrate new material with the preliminary report, so I am presenting it for the time being as a supplement. This consists of three new sections: "Survey", "Management recommendations" and "Wetland history".

Survey

During July, the wetland and its main features were delimited with a GPS unit and an engineer's level was used to determine ground level elevations. I am grateful to CKL Surveying for using the GPS data to prepare a base map and eventually this map will show vegetation types in relation to surface elevation, fences and proposed fences and other features. Until it can be digitised, features and structures have been added manually to the map (28 Sept 2009 version).

The wetland is over 800m in length and shaped like a tennis racquet, with a steeply sloping (over 20 vertical metres) handle and an almost level head. The main water supply, two substantial springs, derives from Puketaha Hill, a large titanomagnetite-rich sand dune (the Mitawai 'black sands') established during the last few thousand years of the Quaternary. The rainwater-derived aquifer within this dune discharges year-round at an almost constant rate, so that the 'floodplain' (the 'racquet head'), at the bottom of the wetland, is almost permanently waterlogged.

The recent Mitawai black sand dunes comprise the western slopes of the wetland and the much older, Nihinihi consolidated yellow-brown sands (mixed with some clay and silts) make up the eastern slopes. The Mitawai at least partly overlap the older Nihinihi and the Puketaha aquifer may well lie at the interface between the two deposits and discharge along this interface.

There are two other spring inflows to the wetland: a small one from the black sands above the ponds along the eastern extension of the wetland, and a larger one (the 'Waimari' spring), partly tapped for potable water supply, discharging from the Nihinihi escarpment into the ''floodplain' of the wetland. It is the Waimari spring that

has contributed the clay material underlying the peat in the central channel of the lower wetland (Point X on the map).

A major feature of the wetland is that it is very dynamic. The upper springs also carry large quantities of sand and this has spread out, delta-like, across the wetland. As the streams fan out and deposit the sand, they move, over the years, from east to west and back again. Over the past 50 years, as much as five metres depth of sand may have built up in the middle of the upper wetland (the 'handle').This has resulted in large expanses of inter-bedded layers of peat and sand. The 'floodplain' of the lower wetland has also been formed this way, with water-transported sand spreading out as the water flow lost energy. Over the hill to the east of Aotea Wetland, the Taro Spring has also discharged large quantities of sand into the Te Kowiwi Wetland, where the build-up has pushed the brackish water zone well down towards the estuary.

Wetland history

Even though the wetland is very dynamic, with its sand flows and sand/peat inter-bedding, it also very likely to be old – as old as the dunes. As soon as a dune reached a certain size, its aquifer would have been big enough to supply enough water to start a wetland.

. The deepest peat found to date is no more than 2 metres, although there could well be some that is deeper, closer to the southern end of the 'raquet head'. As a rule of thumb, consolidated peat accumulates at about 1mm/yr, but recent peat deposits may accumulate at up to 5mm per year. So Point X surface peat may be of the order of 500 years old; it could be carbon dated of course, but that would cost several hundred dollars and still not give a reliable age for the wetland.

It is likely that there are buried peat layers below the sand 'fan' of the wetland floodplain, since its formation would have been similar to that on the wetland 'handle' further up. Indeed, a survey carried out by HMS Pandora in 1854 shows the wetland stream extending straight down (to the NE) towards the harbour – through what is now Aotea township. This strongly suggests that, as water-borne sand was built up at the base of the wetland (under what is now Aotea township), it eventually caused the outlet to flip to the west, where it still is (although the present outlet is artificial and the flow-rate is now less than it was).

Although the Mitiwai sands are unconsolidated and may have been mobile to some extent during early Maori burning, the Nihinihi sandstones clearly retain good aquifers and the clay deposit under the peat in the lower wetland shows that there has been long-term flow from the Waimari spring at least, but almost certainly also Puketaha by the time it approached its present size.

Management recommendations

Currently most of Aotea Wetland is exposed to cattle grazing. Although this has caused a great deal of pugging, stock have made little change to the nutrient status, because the high-quality water supply to the wetland flushes nutrients away. Consequently there is still high plant diversity and considerable restoration potential.

Exit channel
The exit channel would have to be re-located and the most suitable line is indicated on the map. It should be at the bottom of the wetland, so as to avoid the possibility that stagnation could occur if the exit were placed higher up. Winter and summer wetland water levels have been noted and the exit channel invert would be placed at a similar elevation to that in the present channel. During significant rainfall events (particularly winter), there is shallow open-water ponding at the bottom of the wetland, before drainage down the channel occurs. This situation would be retained, as any lowering of the invert would reduce the storage capacity of the lower wetland.

Stock exclusion
Existing fences have been plotted on the map and the highest priority for stock exclusion is along the western margin of the lower wetland (labelled numeral 1 on the map). This would exclude stock from accessing both sides of the lower wetland. The exact location of the fence still requires some thought (stock exclusion can sometimes result in certain aggressive plant species dominating a previously grazed sward), but it is more than likely that it will be placed to include all the shallow peat area (Vegetation Type 3).

There is also a small amount of grazing around the ponds at the east of the lower wetland. These ponds are artificial (originally for hunting), but are now quite mature. Since there is a spring inflow at this point there could be some value in fencing here. This still needs some thought, as realignment of the existing fence to leave some of the grazing area is another possibility. The ponds are actually retained by a low artificial bund, but this should stay; it does not interfere with the water supply to the 'floodplain' peat area.

Stock exclusion from the lower wetland would be completed by the fenceline labelled numeral 2. This has been labelled Priority 2, because there is some value in stock controlling weeds here, but there are steep erosion-prone slopes here and fencing would be adviseable eventually.

The western margin of the upper wetland is currently fenced, but the eastern boundary is not. Most of the top half of the upper wetland is currently available for summer grazing. I don't think fencing this off should be a condition of subdivision consent, as it is a 500 metre boundary, but at some stage it would be good to see most of this area retired. It is not good grazing country.

Culvert
The upper and lower wetlands are separated by an earth dam, penetrated by a culvert which maintains the hydrological continuity between the two halves. It also ponds a substantial water body on the south side, elevated almost 2 metres above the lower side, and this has matured into a very attractive wetland. The dam was originally constructed as an access link across the swamp, but is it now badly eroded and a decision needs to be taken whether to repair it or allow it to burst.

Although the original wetland was continuous, and without the open-water wetland, to try to restore the original configuration now would create a great deal of damage downstream and repair through natural processes would take a long time. Indeed the 'purist' option may even result in permanent hydrological (and therefore vegetation)

changes in the lower wetland. More thought is required, after gauging water flow rates, but my feeling at this stage is that there is an attractive and mature wetland now and we should maintain that, even though it is not entirely 'original'. Also on the positive side is the fact that the bund does provide the only means of crossing the wetland in the entire 800m length.

On the negative side of retaining the culvert structure is the fact that further sand movement in the upper wetland over the next few decades may require on-going maintenance of the bund with an ever-increasing differential between water levels above and below the bund. As I said, more study and more thought required, but I almost certainly favour retaining (ie repairing) the bund at this stage, with on-going monitoring of the wetland dynamics to plan a future course of action.

A decision regarding the bund needs to be taken quickly, because nature is not far from taking that decision itself!

Weed removal

Only two aggressive weed species have been recorded for Aotea Wetland: the Mexican devil (*Ageratina adenophora*) and the grey willow (*Salix cinerea*) and a control operation (herbicide spraying) for the former has already commenced. Other aggressive weeds of lowland wetlands in agricultural areas, such as the highly invasive exotic grasses *Glyceria aquatica* and *Phalaris arundinacea*, are mercifully absent and, although there are many other exotic species present, the low nutrient status of the spring water reduces their growth rates so that native wetland plants are not out-competed. The resulting mixed native/exotic plant communities are therefore stable and this unusual (for a lowland fen) feature is an important component in the uniqueness of Aotea Wetland.

It is therefore well worth removing the willows and, because the number of trees is not great, this should be done by individual poisoning (drilling trunk and injecting herbicide in late Spring). In some locations, such as the northern end of the wetland, willow removal should be accompanied by a planting programme with appropriate native species. In places where the willows are sparse, there is already a healthy understorey of native species which will develop as their shading is removed. Eco-sourced swamp manuka, koromiko and putaputaweta can also be planted as these would have been the dominant woody species before willow invasion.

Gorse is an invasive species on seasonally-flooded and adjacent high ground, but this is easily controlled by spot-spraying which, in fact, is already being done in some places.

A weed-control programme should be prepared and integrated with a planting programme.

Planting and restoration

Although the wetland is largely intact, there is scope in some areas for restoration plantings of native species. In fact, it is quite exciting to be able to plan an enhancement programme starting with an already high quality wetland. As suggested above, certain woody native species can be introduced to replace the willows, but the marginal seasonally flooded or waterlogged areas can be given the biggest makeover.

Once stock have been fenced out, the northern edge of the setlan can be planted out with appropriate wetland species such as koromiko, manuka, lancewood, cabbage tree, fuchsia and flax, native sedges, such as *Carex secta, C. geminata, C. dissita,* and the spectacular *Gahnia xanthocarpa,*, rushes such as *Juncus sarophorus* and *Bolboschoenus* spp and, on the higher ground, kowhai, kanuka, etc. Around the eastern ponds can also be revegatated with these species and perhaps the fringe of natives could be expanded by, say, 20-30m at least when the pines come down. The planting programme will also make the area more attractive to several species of birds.

Some enhancement planting could also be planned, perhaps at a later date, for the upper (southern) wetland sector, although the task is a more difficult one here due to the mobility of the sloping sand/peat substrate and the closer proximity of the surrounding pine forest. It would at least be good to fence off, and plant appropriately, the two major spring input areas at the southern extremity of the wetland.

It goes without saying that this restoration programme, or something like it – and even just parts of it – will greatly enhance the conservation value and the visual amenity of the wetland. It is also expected to have cultural value as it will protect the springs and enhance natural landscape character in the vicinity of the historic pa. Indeed, I believe that there is a good case to be made for covenanting the wetland, perhaps with the QEII Trust or Environment Waikato. This would, of course, also have the benefit of being able to tap into external funds for things such as fencing and culverts necessary to preserve the wetland's character and hydrological integrity.

Monitoring

Any significant changes to the status of a wetland need to be monitored in case there are negative impacts that need to be corrected. Also, all wetlands, particularly this one, are dynamic and spontaneous changes do occur, such as volume or direction of water flow, which may require management input. Then there is of course the question of who is willing to carry out the on-going monitoring.

Funding

Obviously, full restoration, considering all of the above enhancements, would be an expensive undertaking, demanding significant manpower inputs. Of course, tasks can be prioritised and addressed sequentially, such as starting with fencing stock out of the northern sector, first, then progressively eliminating the willows. Planting can be done at any stage, but it will need to be done soon after fencing so that weedy species do not start to dominate retired areas. In fact, one of the highest priorities has to be reconstructing the culvert between the N and S sectors of the wetland, before the bund collapses.

However, there are funding sources for conservation enhancement of private land. For instance, the Department of Conservation has the annual Community Conservation Fund, the Ministry for the Environment has the Biodiversity Condition Fund, and there are others. If the QEII Trust agree to convenanting, then they will contribute to the cost of fencing. EW will also contribute to fencing costs, and maybe also to some hydrological management, if an area is retired from stock and there are biodiversity gains.

I could look into options, but I think both avenues should be explored for funding and assistance, because there is both a materials cost and a manpower cost in rehabilitation. The next funding round for the Waikato CCF may e several months away, but the 2010 MfE/BCF may be closer.

Ecological survey & restoration proposal: the report

My ecological survey will naturally be important for 'selling' the wetland to grant donors, so I'd better get it finished! Actually, it's pretty close to completion now. Most of the fieldwork is done, although I need to put another day into 'plant hunting' to add to the species list – my initial survey early in the year was pretty superficial. Completing the final version of the map is a priority for me, but I won't be able to plug into CKL for computer graphics assistance now until about mid-January. I need to re-write those parts of the report which were targeted specifically at the hearing, so it is in a form which can be used for any purpose. That can be done quite quickly – and I also need to incorporate some photographs.

[**Keith Thompson** 22.12.09]
[bogman@ihug.co.nz]

INSPECTION OF SAND DUNES, CARTER HOLT HARVEY FORESTS JOINT VENTURE FOREST, AOTEA HARBOUR

David Bergin
2006

ABSTRACT

A 40 ha elevated coastal sand dune site that is part of a joint venture forest was inspected for dune stability and vegetation cover. The exposed site, previously planted with marram grass, is largely stable where established marram grass clumps have formed thatch-like hummocks and where a range of exotic and native species are now colonising the stabilised sand. Pohutukawa is regenerating in the vicinity of a small degraded forest remnant in the centre of the site. The site is under major threat from cattle grazing and trampling and from browsing by hares and possibly rabbits. The removal of cattle grazing and animal pests is essential to ensure ongoing stability of the sand dune and to encourage recovery of existing vegetation and continuing plant succession. With the control of animals, there is good potential for continued natural regeneration and eventually development of a coastal native forest community.

KEYWORDS: sand dunes, stability, native plants, radiata pine, pohutukawa

INTRODUCTION

A 40 ha sand dune site that is part of a joint venture forest at Aotea Harbour, west coast North Island, was inspected on 28th November 2006 at the request of Carter Holt Harvey Forests Ltd (CHH). In 1994 a joint forest venture was established over several hundred hectares overlooking Aotea Harbour between CHH and local landowners. This involved the standard practice of stabilising bare sand by first planting with marram grass (*Ammophila arenaria*), then oversowing with yellow tree lupin (*Lupinus arboreus*), and finally planting in radiata pine (*Pinus radiata*) (Gadgil 2006).

The pine forest is now 12 years old. However, several elevated exposed areas were not planted in pines including a 40 ha area. These had been planted with marram grass some 8 years ago but with the demise of yellow tree lupin throughout the country due to the 'lupin blight' caused by the fungus *Colletotichum gloeosporioides* (Dick 1994), it can no longer be relied upon for providing nitrogen for maintaining marram grass planting and eventually establishment of radiata pine. These areas did receive some topdressing with nitrogen fertiliser after planting of marram grass.

This report briefly describes the site including the status of sand stability and present vegetation cover. Factors influencing sand dune stability and vegetation cover are discussed and management options are suggested.

DESCRIPTION OF SITE AND VEGETATION COVER

The 40 ha site is an elevated sand dune and includes the highest point of the property at 145 m above sea level. The site is approximately 1 km from the Tasman Sea to the west and a similar distance from the Aotean Harbour to the north (NZMG 2669040E, 6351720N). Consequently, the site is very exposed and subject to strong prevailing westerly winds. Lines of marram grass planted 8 years ago are clearly visible where most of what were well-established clumps have for the most part died and lie as low rounded thatch-like mounds. The marram grass has successfully stabilised the area. Some marram grass clumps have a few live shoots. As marram grass only thrives in mobile sand, the fact that most of the 40 ha site is covered in dead marram grass clearly indicates that sand movement since planting has decreased significantly.

Exotic herbaceous weeds and grasses now cover a significant proportion of areas between marram grass clumps and this cover is likely to be slowly increasing. Yellow serradela (*Ornithopus pinnatus*) and dandelion (*Taraxacum officinale*) are the dominant exotic herbs with hares tail (*Lagarus ovatus*), hairy birdsfoot trefoil (*Lotus suaveolens*), catchfly (*Silene gallica*), sheep's sorrel (*Rumex acetosella*) and fleabane (*Conyza sumatrensis*). Native shrubs and ground cover are scattered throughout the open dune area including tauhinu (*Ozothamnus leptophyllus*) and knobby club rush (*Isolepis nodosa*) with pohuehue (*Muehlenbeckia complexa*) invading from lower slopes.

Several small pockets of mobile sand do occur usually near the crest of small undulating dunes and the largest near the highest most exposed site. These are characterised by a deflation zone where sand has been blown by the prevailing westerly wind resulting in an active small dune landward. The largest blowout near the highest elevation has trailing arms dominated by vigorous marram grass that has rejuvenated from the originally transplanted culms.

A remnant of pohutukawa (*Metrosideros excelsa*) forest exists near the highest point comprising approximately 20 trees up to 15 m high. Edge trees have died or are partially defoliated due to extreme exposure particularly along the westerly edges. The stand is relatively open with no other species present in the forest including no regeneration. Ground cover is dominated by leaf litter where it has accumulated in a thin layer but winds have reduced most of the ground to bare sand and where light levels are higher, short sparse exotic weed cover. A majority of tree limbs have epicormic shoots indicating trees are under severe stress from exposure to high winds and decreasing shade as light levels increase as the forest loses condition.

Despite the exposed conditions of the pohutukawa remnant, trees are about to flower and appears to be the only seed source in the immediate vicinity. Regeneration of pohutukawa is common around the remnant indicating that the stand is proving to be an effective seed source. Numerous small pohutukawa plants are established over a wide area up to 100 m away from the stand.

SAND STABILITY AND THREATS

Overall, this site is relatively stable. While about 50% of the ground cover is still bare sand, the 40 ha site has a cover of a small hummocks of marram grass thatch and a low cover of mainly exotic weeds and grasses. Only a few small blowouts where there is actively mobile sand occur over the site and in terms of extent and area affected, appear to be no worse than blowouts in adjacent the adjacent farmland to the south where sand dunes are dominated by pasture and grazed.

Over the 40 ha site, the marram grass established at a spacing of 1-1.5 m apart has effectively initiated the process of sand stabilisation where they appear to have grown into dense clumps within 3-5 years of planting. Most of these have now died back and formed slightly raised hummocks of thatch. This is a natural process whereby marram grass will only continue to survive where there is a constant supply of sand. Once a cover of marram grass has become established, it starves itself of sand and begins to die back. However, the senescent marram grass clumps do allow the establishment of a wide range of other plant species on more sheltered semi-stabilised site, particularly exotic weeds and grasses. In addition, hardy pioneer native species are establishing between and amongst the mounds of dying marram grass including on this site tauhinu and knobby club rush. Of most interest is the establishment of numerous pohutukawa seedlings in the shelter of marram grass thatch.

The major threat to this largely stable dune system is the continuing grazing by cattle. Cattle are grazing surviving parts of marram grass, native species such as knobby club rush and pohutukawa regeneration, as well as the dominating exotic grasses and herbs. Trampling is seriously damaging existing cover where footfalls are disturbing the soft sand substrate and light plant cover including non-palatable well established native species such as tauhinu which have broken stems and branches. Small plants are being pulled out of the sand while browsing and the sand surface disturbed by both grazing and trampling is left vulnerable to wind and blowouts. The presence of hares and probably rabbits is also reducing regeneration and growth of vegetation. Exotic herbs and grasses are low in stature due to constant grazing. Regenerating pohutukawa is mostly small plants at the edges of clumps of marram grass thatch producing short coppicing shoots in response to constant browsing. The occasional larger plant of pohutukawa up to 40 cm high had been severely browsed by cattle.

Without the presence of cattle, it is expected that the sand dune site will continue to develop into a complete cover of a mixture of native low ground cover, shrub, and tree species and exotic grasses and herbaceous species. There appears to be no immediate threat from vigorous woody exotic weeds and in the long term the site has the potential to become dominated by native shrubs and trees. The existence of the remnant pohutukawa stand in the central elevated part of the open site provides a local seed source and an excellent opportunity to encourage natural regeneration of a pohutukawa-dominated coastal forest. Coastal pohutukawa forest is a threatened ecosystem throughout its natural range in northern New Zealand.

MANAGEMENT OPTIONS

Removing cattle and control of hares and rabbits is the most important management option for ensuring stability of the 40 ha open sand dune site. The site is already relatively stable but threatened by the existence of cattle. Without grazing animals, the recovery of existing native and exotic vegetation and further regeneration can be expected.

With the existing native species on the site including numerous regenerating pohutukawa, there is a good prospect of a native plant succession occurring and eventually the development of a coastal forest dominated by native trees and shrubs. Areas that do remain open in the short term are likely to become dominated by exotic grasses and herbs, but as is occurring on lower slopes at present, natives such as knobby club rush, pohuehue and tauhinu are likely to increase. The eventual development of shrubs and trees will provide shelter and subsequently help enhance the degraded pohutukawa forest remnant.

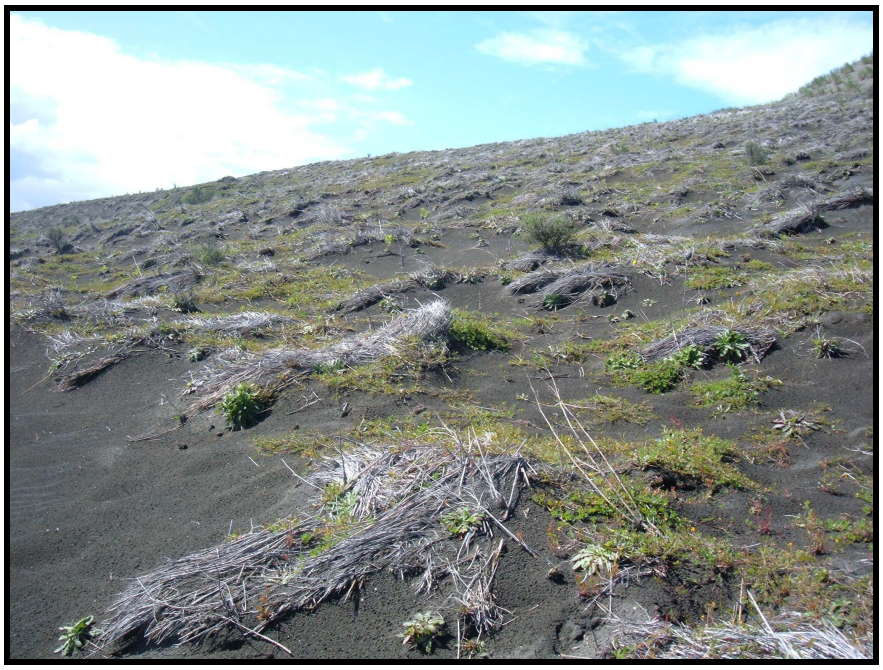
It is likely that the few small blowouts that do occur on the site will not require further intervention once cattle and animal pests are removed. Removing trampling disturbance will lead to increased plant cover that is highly likely to prevent spread of these blowouts.

Brief annual inspections of this open site will allow monitoring of vegetation cover development including around the small blowouts, ensuring cattle remain excluded and animal pests are controlled, and early identification of any vigorous problem weed species where control may be desirable.

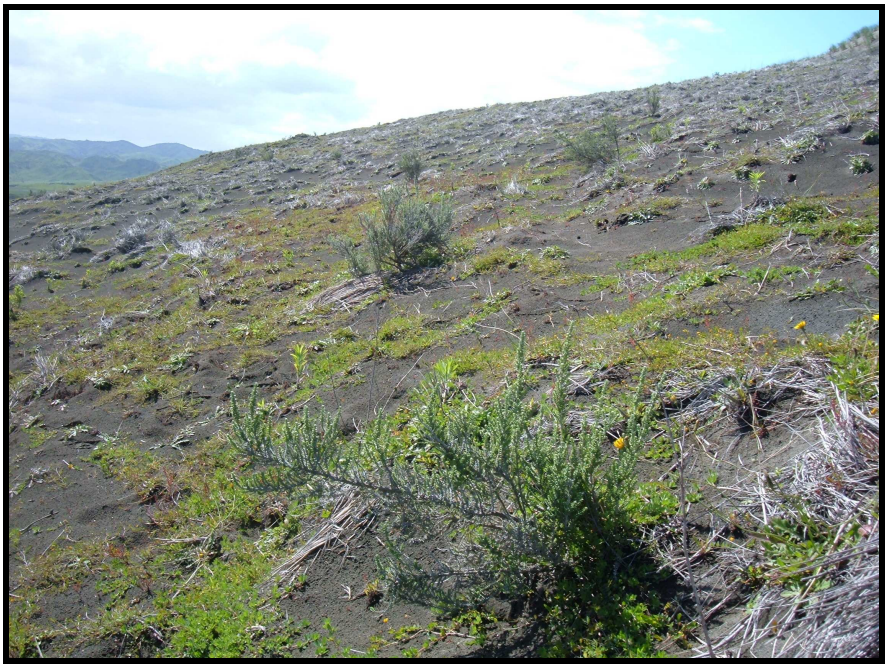
REFERENCES

Dick, M.A. 1994: Blight of *Lupinus arboreus* in New Zealand. *New Journal of Forestry Science, 24*: 51-68.

Gadgil, R.L. 2006: Marram grass friend or foe? A review of the use of *Ammophila arenaria* on New Zealand sand dunes. *Coastal Dune Vegetation Network Bulletin No. 5*. New Zealand Forest Research Institute. 32p.



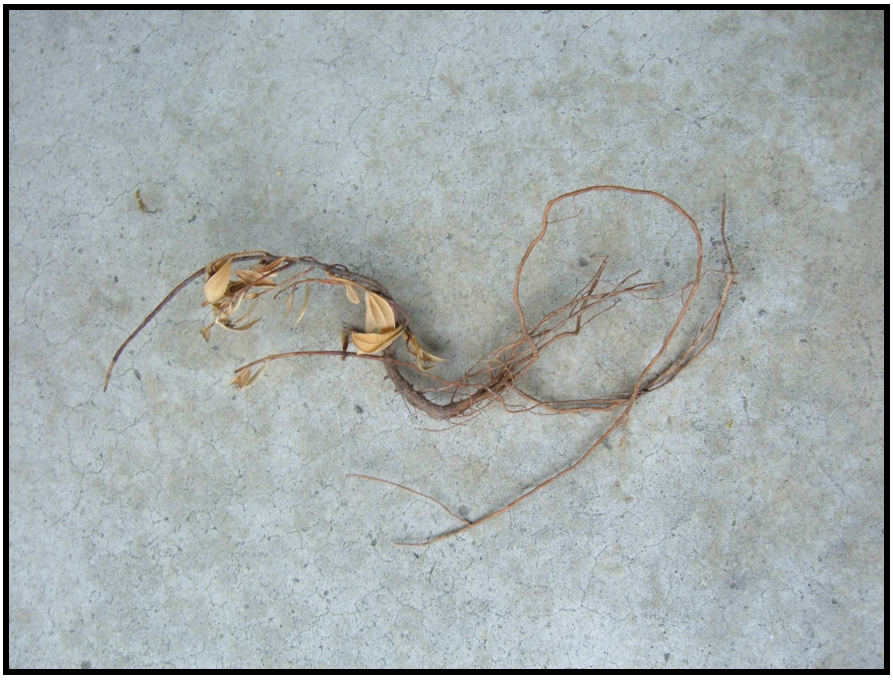
The 40 ha exposed dune site where marram grass was planted 8 years ago has largely stabilised the sand. Lower slopes are being invaded by exotic grasses and native rushes and ground cover species (upper). The planted marrram grass has died over most of the site due to the increasing stability and lack of mobile sand which normally encourages marram grass to grow vigorously. In between the thatch-like mounds of dead marram grass, a wide range of exotic herbs and grasses are colonising bare semi-stabilised sand along with selected native species (lower).



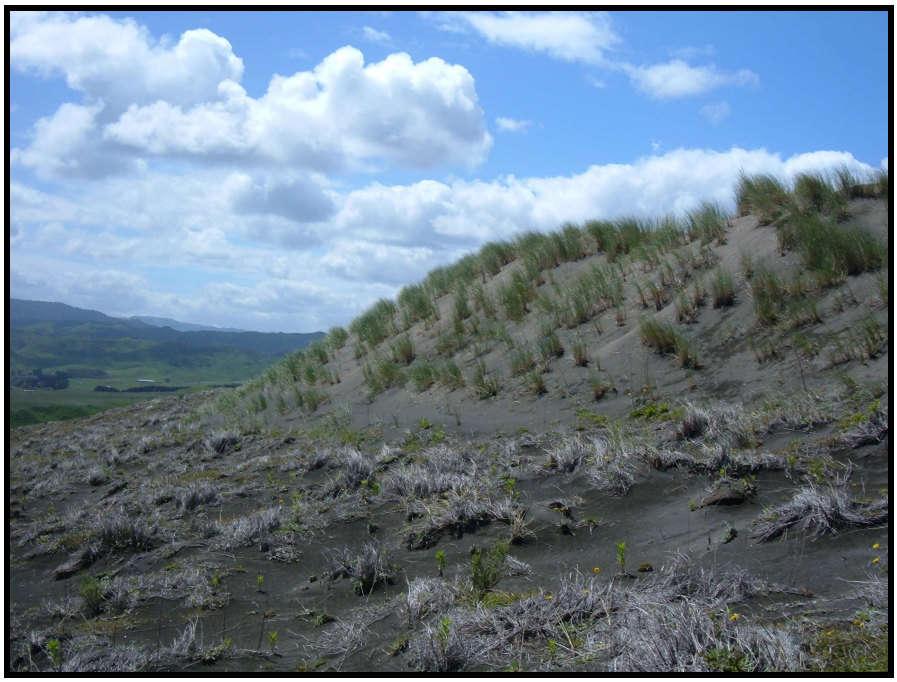
Tauhinu is a hardy coastal native shrub found scattered over the 40 ha site (upper). It produces large quantities of seed and can be expected to continue to colonise this site. While it is not palatable, established plants are however subject to major disturbance including uprooting and breakage of stems and branches from cattle trampling especially on steeper slopes (lower).

A small remnant of pohutukawa exists near the highest point. Trees along the most exposed edge are dead or partially defoliated due to severe exposure (upper). Cattle grazing is contributing to an open windswept understorey (lower).

Seedlings of pohutukawa are common within 100 m of the remnant pohutukawa stand. Most are growing within the protection of dead marram grass clumps but are being constantly browsed by cattle and animal pests. Coppice shoots are forming on most in response to continual browsing (upper). The occasional taller plants are also severely damaged by browsing (lower).



The stability of the dune is threatened by grazing cattle in particular but also animal pests such as hares and rabbits. The exotic grass and herb species including live marram grass are being continually grazed and native plants such as knobby club rush (upper) are also browsed. Small plants are being uprooted including pohutukawa regeneration (lower). Removal of cattle and control of animal pests is required to encourage further development of the vegetation cover and reduce risk of dune instability.



The few small areas of mobile dune are associated with localised blowouts characterised by marram grass growing vigorously along the deposition zones and bare sand in the deflation areas. Removal of cattle and animal pests will likely see these small pockets of bare sand revegetated by a mixture of exotic and native species. Occasional monitoring is suggested to ensure that these blowouts do become stabilised including the largest blowout near the highest part of the site landward of the pohutukawa remnant.