Options for managing gorse for water quality purposes

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Prepared for
Bay of Plenty Regional Council

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Although others have provided input and feedback, this report does not represent the Bay of Plenty Regional Council's views or preferences. Any opinions and recommendations contained in the report are our own.

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Executive Summary

This report describes the effect of gorse on water quality, common measures for long term control of gorse and the cost-effectiveness of these gorse control measures based on a quantitative cost-benefit analysis. A tool box of policy options is described to encourage the long term removal of gorse for the purpose of improving water quality in Lake Rotorua and Lake Ōkāreka.

A package of measures that could be applied to remove gorse in the Rotorua and Ōkāreka catchments, included:

- Converting gorse to pine plantation was the most cost-effective option and would be best suited to large blocks of land over 10 to 20ha in size; 40 to 60% of the gorse in the Lake Rotorua and Ōkāreka catchment occur in patches of this size.

- Using Minimal Interference Management to allow gorse to revert to native vegetation has least upfront costs and was the second most cost-effective option if discount rates are assumed to be less than 6%. This option is the most appropriate to use on steep land or gullies in riparian areas because it minimises the risk of erosion that could occur with other options. About 26% of gorse in the catchments is currently steep land (i.e. LUC 7 and 8).

- Converting gorse to dry stock (particularly sheep) was the second most cost-effective option if discount rates are assumed to be greater than 6%. This option would be more appropriate where gorse occurs on flat to rolling land (e.g. 21% occurs on LU Class 4 or better) so as to avoid potential adverse effects of erosion.

A quantitative cost-benefit analysis found that this package of removal measures was very cost-effective (i.e. an annualised cost-effectiveness of $19.5 /kg N) when compared to recent estimates of land-use change. Nevertheless large patches of gorse remain in the catchments of Lake Rotorua and Lake Ōkāreka because of a range of complex tenure and economic reasons. To address this we assessed a toolbox of policy options to encourage the removal of gorse, including:

- A regulatory approach to control current gorse e.g. list gorse as a containment pest requiring, e.g. “land owners and occupiers to control patches of “mature” gorse on all land occupied in the Rotorua lakes catchments unless being controlled by Minimal Interference Management”.

- A regulatory approach to control future expansion or establishment of gorse, e.g. list gorse as a containment pest requiring, i.e. “Land owners and occupiers to prevent the establishment or expansion of gorse patches on land in the Rotorua lakes catchments”.

- A market based approach based on modifying the implementation of Rule 11 so that land in mature, ‘moderate’ to ‘dense’ gorse is ascribed a leaching rate 15 kg N/ha/yr during the benchmarking process. This is higher than currently assumed for land in gorse but less than our most conservative estimate of what gorse actually leaches.

- A gorse control programme to provide property specific advice and funding incentives to encourage voluntary removal.

In our view the most effective combination of policy options would be to implement a gorse control programme (providing advice and incentives) in combination with benchmarking gorse leaching at a higher leaching rate (i.e. 15 kg N/ha/yr) and/or regulatory control of future gorse. Regulatory control of large patches of mature gorse could also be considered to further encourage gorse removal.

Applying this toolbox of policy options to incentivise gorse removal would help reduce the extent of gorse cover. However there will always be small pockets of gorse regenerating when land is disturbed and there will probably still remain landowners who, for their own reasons, prefer the *status quo* despite offers of assistance or incentives.

1 Introduction

1.1 Background

Lake Rotorua is under pressure from development and land-use changes that have contributed to reducing lake quality to its current 'eutrophic' state and recent algae blooms. The Proposed Lakes Rotorua and Rotoiti Action Plan sets a target to reduce nitrogen (N) loads to Lake Rotorua by 320 tonnes/yr, with the majority of these reductions needing to come from agricultural land.

Studies and expert opinion have suggested that gorse stands can leach significant amounts of nitrogen to groundwater (range of 24 to 64 kg/ha/year), that there are substantial stands of gorse in the Lake Rotorua and Lake Ōkāreka catchments (i.e. about 869 ha and 70 ha respectively), and thus gorse could be contributing a substantial nitrogen load to the lakes. Studies have also shown that removing gorse can be a relatively cheap and cost-effective way of reducing the nitrogen load to the lakes (Sullivan and Hutchison 2010).

The Bay of Plenty Regional Council (BOPRC) proposed that the Draft Regional Pest Management Plan for 2011-2016 include new rules to either destroy or control gorse in the Rotorua and Ōkāreka lake catchments. The Board of Inquiry appointed to consider the issues noted that despite submitter support in principle for control of gorse, there were issues related to:

- Inequity in the compliance costs associated with a gorse rule and that the few landowners that would have to eradicate most of the gorse would not benefit.
- Inequity with the implementation of Rule 11 in the Regional Land and Water Plan. When land is being benchmarked using the Overseer model, gorse is currently classified as 'scrub' or 'native' with an assumed leaching rate of about 2.5 kg N/ha/yr to 3.1 kg N/ha/yr. In reality the leaching rate from gorse is about 38 kg/ha/yr. This anomaly in the implementation of benchmarking reduces the incentives to control gorse and reduces the options of landowners with large amounts of gorse to change land use in the future.

After considering the submissions, the Board of Inquiry did not recommend a rule in the Regional Pest Management Plan, but instead recommended further investigation.

Bay of Plenty Regional Council (BOPRC) commissioned Opus International Consultants and AgResearch to develop and assess a suite of options for managing gorse to improve water quality in the Rotorua lakes. While the focus of this report is on gorse, other legumes can also fix nitrogen and where information is available we also discuss broom.

This report does not represent the Bay of Plenty Regional Council's views or preferences. Any opinions and recommendations contained in the report are the consultant's own.

1.2 Report structure

This report is structured to discuss the following issues:

a) Effects of gorse on water quality. We critically review existing literature about the impacts of gorse on water quality. We comment on the certainty of the science and extrapolation of results to all catchments in the Rotorua lakes.

b) Operational measures for long term control of gorse. We describe the key measures available for controlling gorse, where they can be most successfully applied and their strengths and weaknesses.

c) Costs and benefits of operational measures. We assess the costs and benefits of the measures to control gorse using a quantitative cost-benefit analysis. A package of control measures was developed and used to extrapolate the cost-benefit analysis to a catchment scale accounting for gorse cover and density.

d) Policy options. We describe a suite of policy options for managing gorse. We discuss the strength and weaknesses of each option, where the costs and benefits fall, and assess them against criteria of efficiency, effectiveness, fairness and practicality.

2 Effects of gorse on water quality

2.1 General

Gorse (*Ulex europaeus*) is a fast growing perennial, legume shrub, typically growing to a height of 3-4 metres. It was introduced from England prior to 1835 as a quick growing hedge plant. Gorse is regarded as a weed because it is invasive, spreads readily especially on marginal pasture land, and causes a number of negative economic and environmental impacts.

Although gorse is short lived (about 7 – 30 years), it produces a large number of seeds that create a long-lived seed bank. The seeds have a hard, water impermeable and fire-resistant coat that prevents immediate germination and enables seeds to remain viable in the soil for as long as 50 years or more (Sullivan and Hutchison 2010). It rapidly sprouts after cutting and soil disturbance, and fire can stimulate germination from the seed bank. In plantation forests gorse can increase the cost of site preparation and reduce the growth of forest trees (Magesan *et al*. 2012).

Like all legumes, gorse gains a competitive advantage by its ability to fix nitrogen. This is a process by which nitrogen gas is converted to plant-available nitrogen by *Rhizobium* bacteria that form a root nodule on the roots of legumes. Gorse has been found to be particularly good at fixing and accumulating nitrogen compared to indigenous N_2 fixers (Magesan *et al*. 2012).

Broom (*Cytisus scoparius*) has similar characteristics to gorse. It also is an exotic, fast growing, N_2-fixing species that has proliferated as a weed throughout New Zealand. Broom is particularly well adapted to grow in dry conditions. Broom has been shown to release allelochemicals that can prevent establishment of other species in their immediate vicinity – particularly on exposed mineral soils (Horie *et al*. 1989 in McCracken 1993).

The natural spread of gorse and broom is from explosive pods which scatter the seeds over 3 – 5 metres, but seeds can spread large distances attached to the fibres of animals (especially wool on sheep) or mud on machinery (McCracken 1993).

2.2 Effects of gorse on water quality

This section briefly reviews the current science behind gorse as a source of nitrogen to the Rotorua lakes. We draw upon a number of recent studies done for BOPRC including: Magesan *et al*. (2008); Magesan and Wang (2008); Environment Bay of Plenty 2009, Male *et al*. 2010; Sullivan and Hutchison (2010).

Magesan *et al*. (2008) and Magesan *et al*. (2012) provided a useful review of literature concerning nitrate leaching from gorse and broom. We will not repeat the material here except with respect to Dyke *et al*. (1983) who found more nitrate was leached from under gorse than from under other species studied. Nitrate concentrations under gorse were on average 5 g/m^3 compared to 0.06 g/m^3 under radiata pine. Magesan and Wang (2008) estimated that this corresponded to a leaching rate of 35.7 kg/ha/yr assuming 700mm of drainage per year. Dyke *et al*. (1983) also observed a strong nitrate peak after gorse was burnt compared to control sites. The nitrate spike was short lived, and within 17 weeks of the first burning nitrate concentrations were lower than the control site. An analysis of the results shows that on an annual basis the burning induced nitrate spike equated to about 75% more nitrate under the burned gorse than under the control, which would delay the water quality benefits of the gorse removal for about 2 years i.e. approximately the end of the second year after control. No nitrate spike was observed after spraying gorse.

Wardle and Greenfield (1991) studied nitrogen release from root nodules of a range of legumes and non-leguminous plants. It was concluded that in the short term (<56 days) much of the organic N was not mineralised when incorporated into soil systems. For gorse only 8.4% of organic N was mineralised or immobilised by day 56. This suggests that, at least for the underground component, N will release slowly.

Magesan and Wang (2008) studied nitrate leaching from two stands of mature gorse between March 2006 and October 2007. They estimated that the annual nitrogen input from litter fall was 182 to 223 kg N per ha for the two sites. Nitrate leaching was estimated by measuring soil nitrate concentrations below the root zone and multiplying this by the monthly drainage volume calculated by a water balance model (Woodward *et al*. 2001). Soil solution nitrate ranged from 3 to 17 g N/m^3. Nitrate leaching was estimated to be 59 to 64 kg N/ha in the first season and 36 to 40 kg N/ha in the second season. In contrast only 0.8 to 0.7 kg N/ha was leached from nearby radiata pine forest in the entire 20 month period. Annual leaching rates would be similar as most of the leaching occurred in the autumn and winter.

Care should be taken when estimating leaching losses from under gorse because only a portion of the rainfall reaches the soil under a mature gorse canopy. Egunjobi (1967) and Aldridge (1968) found throughfall under gorse over a six month period to be only about 20 to 30% of total rainfall. Throughfall through conifers is typically 60 to 80% although the actual amount depends on climate and vegetation factors[1] (Abrahart 2008). The water balance model used by Magesan and Wang (2008) (i.e. Woodward *et al*. 2001) was designed for pasture and for relatively flat ground, so it may estimate a higher drainage than would occur under a mature gorse canopy and steep slopes often occupied by gorse. For this reason we would recommend taking a conservative approach and using the lower leaching estimate (i.e. 38 kg N/ha) as done by Sullivan and Hutchison (2010). We also recommend that BOPRC commission a job to recalculate the leaching rates under mature gorse on moderate and steep slopes using a water balance model calibrated for canopy cover.

A glasshouse study by Magesan and Wang (2008) found that nitrogen fixation by *rhizobia* in root nodules of gorse were not strongly affected by nitrogen in the soil at normal field concentrations. It also found that broom fixed about half as much nitrogen as gorse but the results were extremely variable.

In a recent study Drake (2011) studied nitrogen fixing and leaching of gorse and broom in the riparian areas of the Selwyn River. A field study of the natural abundance of delta 15 N suggested the gorse and broom fix about three times more N than they take from the soil. There was a positive feedback between N-fixing and N supply; nitrate supply (up to 6.5x field concentration) did not affect the rate of N-fixing per unit biomass, but broom grew more quickly as N availability increased and therefore fixed more N per plant. A 10% increase in

[1] These include: canopy capacity (conifers intercept 20 - 40 percent); vegetation density; intensity, duration and frequency of precipitation; climate conditions (Abrahart 2008).

nitrate supply stimulated an additional 34.5 mg of nitrogen to be fixed per plant per year. A greenhouse study showed that broom contributed considerable N to the soils but there was very little leaching from the soils, suggesting that young plants (less than 1 year old) do not contribute to N leaching, but instead N is efficiently intercepted and strongly conserved in both soils and plants. The same conclusion could be implied for gorse.

Magesan *et al*. (2012) concluded their review of nitrogen cycling in gorse dominated ecosystems by recommending more research to see how soil type, climatic conditions, distribution and age of gorse, land-use change and land-use history contribute to the potential leaching loss of N from soils.

The panel of scientists that provided technical advice to the Lake Taupo Variation 5 Environment Court Hearing in 2008 concluded that the N leaching from the root zone in the Lake Taupo catchment was in the order of 24 kg/ha/yr. This is considerably less than the lower end of the range of leaching rates proposed by Lake Rotorua studies. One possible reason for this is the generally lower natural fertility levels in the pumice soils within the Lake Taupo catchment. Gorse and broom growth would conceivably be slower and so the generation of N from vegetation decomposition less than in the Lake Rotorua catchment. Interestingly, the Court judged that the assigned nitrogen leaching rate for gorse and broom covered land around lake Taupo should be 2 kg N/ha/yr because, in their view, gorse was a transient vegetation cover and would revert to native dominant vegetation or be planted in pines, both of which (at that time) were adjudged to have an N leaching rate (once an equilibrium state was established) of 2kg N/ha/yr.

2.3 Quantifying the nitrogen contribution of gorse

Environment Bay of Plenty (2009) quantified the nitrogen leaching from gorse in the Lake Ōkāreka catchment by applying the nitrate leaching coefficients from Magesan and Wang (2008) (ranging from 36 to 64 kg N/ha/yr) to 71.5 ha of mature gorse mapped in the catchment. They found that 2.57 to 4.57 tonnes per annum of nitrogen derived from gorse was being leached to groundwater in the Lake Ōkāreka catchment – about 23% to 40% of the nitrogen entering the lake from the catchment. The authors considered the higher estimate to be more accurate because below average drainage occurred during the Magesan and Wang (2008) study compared to long term rainfall in the Ōkāreka catchment. They recommended the removal of all medium to old (4-20 year) gorse stands in the catchment and concluded that converting gorse to pines was the most cost-effective option, accepting that there could be some nitrogen inputs from gorse between each pine cropping cycle.

Male *et al*. (2010) quantified the nitrogen leaching from gorse in the Lake Rotorua catchment by applying the average nitrate leaching coefficient from Magesan and Wang (2008) (i.e. 50 kg N/ha/yr) to 864 ha of mature gorse mapped in the catchment. They concluded that about 43 tonnes per annum of nitrogen derived from gorse was being leached to groundwater in the Lake Rotorua catchment - about 7.9% of total N inputs to the lake. Replacing gorse with pine trees was estimated to reduce the nitrogen leaching from former gorse lands by about 40.6 tonnes per year. It was recommended that BOPRC devise strategies to encourage the conversion of all mature gorse areas to forestry as a far lesser amount of nitrogen-loss saving would be achieved if the land was returned to pastoral use.

2.4 Attenuation of leached nitrogen

Attenuation is the temporary storage and /or loss of nutrient (e.g. by denitrification) between where it is generated in the catchment and where it enters the lake. In large catchments about 50% of the nutrient export from below the root zone is attenuated before it leaves the catchment (Alexander *et al*. 2002 in Rutherford *et al*. 2009). However, in some catchments attenuation can be negligible (Wilcock *et al*. 2006 in Rutherford *et al*. 2009). The Lake Taupo Variation 5 Environment Court Hearing accepted the advice of the technical panel of experts that attenuation between root zone and lake was likely to be about 50%; in other words, only 50% of the N leached from the soil in the catchment reaches the lake. Waikato Regional Council use a 50% attenuation figure in their predictive nitrogen modelling.

The Rotan model developed for Lake Rotorua assumed zero attenuation of nitrogen. Rutherford *et al*. (2009) concluded that the satisfactory match obtained indicated that either nitrogen exports have been under-estimated and there is attenuation, or that nitrogen exports have been estimated correctly and attenuation is negligible.

Recent iterations of the Rotan model have assumed 40% attenuation of nitrogen from the Puarenga Stream catchment, which improved the match between observed and predicted nitrogen concentrations (Rutherford *et al*. 2011).

2.5 Cost-effectiveness of gorse control

Sullivan and Hutchison (2010) did a cost-benefit analysis of controlling gorse to inform the Bay of Plenty Regional Pest Management Strategy. They provided a concise review of the water quality effects of gorse before assessing three scenarios:

1. Do nothing (gorse cover will remain constant over time)
2. Prevent the clearance of gorse and the establishment of new gorse (i.e. allow the natural regeneration of a native tree canopy)
3. Remove all gorse and replace with pines (assuming all gorse is removed over a three year period).

The analysis used adopted a nitrogen leaching value of 38 kg N /ha/yr which was the average of the two sites in the lower leaching year from Magesan and Wang (2008). The costs for gorse control was based on the less expensive of the two herbicide options ($1462 per hectare of gorse), but this did not include the cost of fencing. Pine establishment was priced at $2660/ha but this did not include the cost of roller crushing or follow up spraying. A discount rate of 0.08 was applied to future costs and future benefits where there might be a time delay in controlling N leaching from some of the gorse.

The report found that the water quality benefits of gorse control far outweighed the costs. For Lake Rotorua lake catchment, controlling gorse directly with aerially applied herbicide would cost $10 million (NPV) to convert 864 ha of mature gorse to pines – this equated to $35 per kg N. In the long term, all costs were expected to be recovered by revenue from the pine crop. Allowing gorse to convert to native bush was the most cost-effective option ($1.40 / kg N) but resulted in more nitrogen leaching into the lakes of over the next decade.

In our view the values used in EBOP (2009) (and subsequently Sullivan and Hutchison 2010) are reasonable as a total cost of establishing pines into gorse including the cost of roller crushing. Communications with Rotorua forestry consultants PF Olsen Ltd. suggest that establishment of pines into gorse blocks is likely to range between $2000 and $3000 per hectare including herbicide spraying (pre and post planting), roller-crushing and planting. The higher end of that cost range is more a consequence of planting densities (e.g. 1000 stems per ha compared to 800 stem) and the genetic quality of stock rather than the challenges of clearing the gorse. The higher stem densities are needed to out-compete gorse seedlings.

2.6 Summary of key evidence relating to gorse and its effects on lake water quality

Ecology

- Gorse is a fast growing, invasive legume that is easily spread.
- Gorse is very successful at colonising disturbed ecosystems. Recolonisation is particularly strong if existing areas of gorse are burnt and on steeper land where soil is disturbed by livestock treading.
- Seeds remain viable in the soil for a long time (50 or more years) making long term control a challenge.

Leaching of N

- Mature gorse can leach 38 to 62 kg N/ha/yr (average of two plots in Magesan and Wang 2008). The drainage model used in the study may overestimate drainage for steep land and for soil below a mature canopy. Drainage under a forest canopy is typically two thirds of total rainfall, thus we recommend that a cost-benefit analysis assume a best estimate of 38 kg N/ha/yr and a range of 24 to 62 kg N/ha/yr.
- We would have more certainty in the leaching results of Magesan and Wang (2008) if the analysis was repeated using a different drainage model more suited to soil below a mature canopy and on steep land.
- Young gorse and broom efficiently intercept and conserve nitrogen, resulting in minimal N leaching despite high rates of N fixation (Drake 2011).
- Burning gorse can cause a nitrogen spike effectively delaying the benefits of removal by two years (Dyke 1983).
- Some nitrogen will be attenuated (e.g. lost by denitrification) after leaving the root zone of gorse and before entering the lake. The Rotan model assumes 40% attenuation in the Puarenga Stream catchment and zero attenuation elsewhere. For the sake of consistency we have made the same assumption, but we suspect this under-estimates actual attenuation because the model has not accounted for some N inputs (e.g. current and past gorse cover). The Puarenga catchment contains 18% of the dense gorse in the Rotorua catchment so we have made the assumption that average attenuation over the whole Rotorua catchment is 7% (i.e. 40% of 18%).

- The time taken for nitrate derived from gorse to enter the lakes will vary depending on where the gorse is located in the landscape. Age dating of groundwater fed streams found average residence times ranging from 37 to 127 years (Morgenstern and Gordon 2006), but travel times will be much shorter where the nitrate is leached from close to the lake. Rutherford *et al*. (2011) estimated a mean response time of 35 years for changes occurring on the land to be reflected in nitrogen entering Lake Rotorua. They found that about 47% of nitrogen enters the lake within one year via shallow groundwater and 53% enters the lake via deep groundwater after a lag period of 16 to 127 years.

- Extrapolating the results across the catchment would be improved by a better understanding on how the drainage and leaching rates change with slope, climatic conditions, past land use, soil type and gorse age.

3 Distribution of gorse within the Lake Rotorua and Lake Ōkāreka catchment

3.1 Gorse patch size and ownership

The amount of land covered by gorse was estimated and described in EBOP (2009) and Male (2010). The gorse was categorised by density of cover (i.e. 'dense', 'medium' or 'scattered') and age (i.e. a 'young', 'medium' or 'old'). Analysis of this data by Boffa-Miskell (2011) using 2010 cadastral data is summarised in Table 3.1. It found that Lake Rotorua catchment had 869 ha of gorse in all categories and about 460 ha classified as dense gorse. Nine properties had over 20 ha of gorse equating to about 41% (358 ha) of all gorse in the catchment; 20 properties had over 10 hectares of gorse, equating to about 59% (512 hectares) of the gorse total for the catchment. About 90% of properties with gorse had > 1ha on the property and 70% greater than 5 ha. 61% of gorse was on Māori land and 32% on private land. All properties with over 20ha of gorse were on Māori owned land.

The Lake Ōkāreka catchment had 70.3 ha in gorse which was all classified as dense gorse. Two properties had over 20ha of gorse equating to about 57% (40 ha) of total gorse in the catchment; four properties had over 10 hectares of gorse, equating to about 89% (62.2 ha) of the gorse total for the catchment. 99% of the gorse was on private land.

Table 3.1: Amount of gorse in Rotorua and Ōkāreka catchments according to patch size and density (source Boffa Miskell 2011 raw datasheets).

Size of patch	Lk Rotorua ha	Lk Ōkāreka ha
Scattered gorse		
>0.01 ha	164	0
>10 ha	38	0
>20 ha	17	0
Moderate gorse		
>0.01 ha	345	0
>10 ha	240	0
>20 ha	195	0
Dense gorse		
>0.01 ha	360	70
>10 ha	234	62
>20 ha	180	40
All classes		
>0.01 ha	869	70
>10 ha	512 (59%)	62 (89%)
>20 ha	358 (41%)	40 (57%)

The distribution of gorse in different Lake Rotorua sub-catchments is shown in Table 3.2 and Figure 3.1. Gorse is categorised in the same way as done in Boffa-Miskell (2011).

Table 3.2: Proportion of gorse within Lake Rotorua catchment in each sub-catchment

Sub catchment	% of all gorse	% of dense gorse
Awahou	1.05%	1.45%
Awahou Point area	0.01%	0.02%
Hamurana area	2.63%	2.92%
Hauraki	0.58%	0.55%
Ngongotaha	15.71%	8.29%
Ngongotaha township area	0.05%	
Pohue Bay area	0.97%	1.53%
Puarenga	17.48%	14.65%
Rotokawa area	16.36%	15.65%
Utuhina	12.46%	8.03%
Waimehia area	3.12%	4.46%
Waingaehe	3.47%	4.81%
Waiohewa	7.63%	9.94%
Waiowhiro area	6.09%	6.27%
Waitawa area	0.03%	12.60%
Waiteti	12.35%	8.84%

3.2 Gorse location in relation to land class

In order to assess the potential alternative land uses that gorse covered land could be used for we analysed the proportion of gorse in different Land Use Capability (LUC) Classes. LUC is generally defined as follows:

- LUC 1 Flat land with minimal physical limitations. Suitable for intensive cropping and multiple land uses.
- LUC 2 Very good land with slight physical limitations. Suitable for multiple land uses
- LUC 3 Moderate physical limitations for arable use. Typically undulating to rolling country or flatland with soil or climate limitations. Suitable for multiple land uses
- LUC4 Strongly rolling slopes. Severe physical limitations for arable use. Suitable for pasture, forestry, tree crops, vineyards but only occasional cropping.
- LUC 5 High producing land with physical limitations making it unsuitable for cropping such as moderately steep slopes, stoniness, wetness, flooding. Suitable for pastoral or forestry
- LUC 6 Slight to moderate physical limitations for perennial vegetation cover. Erosion is often a limitation. Suitable for pastoral or forestry

- LUC 7 Severe physical limitations under perennial vegetation. Suitable for forestry or dry stock farming if intensive soil conservation practices are in place.
- LUC 8 Has severe to extreme physical limitations which make it unsuitable for arable, pastoral or commercial forestry. Suitable conservation land.

The results of our analysis for Lake Rotorua and Ōkāreka catchments are shown in Table 3.3 and Table 3.4 respectively.

Table 3.3: Proportion of gorse within Lake Rotorua catchment on different LUC classes

LUC Class	Total gorse (ha)	Total gorse (% of land in gorse)	Dense gorse (ha)	Dense gorse (% of land in dense gorse)
No class	11.06	0.84%	2.75	0.40%
2	0.84	0.06%	0.30	0.04%
3	82.69	6.29%	46.33	6.77%
4	205.55	15.64%	123.63	18.06%
6	712.94	54.25%	344.79	50.37%
7	281.71	21.44%	154.42	22.56%
8	19.39	1.48%	12.36	1.81%

Table 3.4: Proportion of gorse within Ōkāreka catchment on different LUC classes

LUC Class	Total gorse (ha)	Total gorse (% of land in gorse)	Dense gorse (ha)	Dense gorse (% of land in dense gorse)
No class	0.04	0.05%	0.04	0.06%
2	-	-	-	-
3	9.77	11.03%	4.13	6.39%
4	1.10	1.24%	1.10	1.70%
6	9.82	11.10%	1.58	2.44%
7	67.82	76.59%	57.85	89.41%
8	-	-	-	-

The results show that about 22% of gorse in the Lake Rotorua catchment is on good quality pastoral land suitable for dairy or dry stock (Class 3 and 4), about 54% of the gorse is on land most suited to either dry stock or forestry (Class 6) and about 21% is on land better suited to forestry than farming (Class 7). Lake Ōkāreka catchment has a smaller proportion of gorse on good quality land (12% on Class 3 and 4), and more on land suited to forestry (i.e. 77% on Class 7 land).

3.3 Gorse location in relation to slope

The LUC classes incorporates slope into the analysis but the spatial resolution of the LUC data is relatively coarse. In order to get a more fine scale assessment of the potential of gorse covered land we used a Digital Terrain Model (DTM) provided by BOPRC to calculate slopes. The DTM had a 2m grid size and was derived from a combination of LIDAR data and photogrametry. We calculated the proportion of gorse on the following slopes:

- <15° Flat to rolling land
- 15-20° Strongly rolling land
- 20-25° Moderately steep land
- 25 - 35° Steep (should be in a non-pastoral use to avoid P loss via soil erosion)
- >35° Very steep land (should be in a non-pastoral use to avoid P loss).

The results are shown in Table 3.4 and Figure 3.2.

Table 3.4: Proportion of gorse within Lake Rotorua and Ōkāreka catchments on different slopes

Slope (degrees)	Rotorua % of all gorse	Rotorua % of dense gorse	Okāreka % of all gorse	Okāreka % of dense gorse
<15	35%	34%	11%	11%
15.1 - 20	14%	14%	10%	11%
20.1 - 25	15%	15%	18%	18%
25.1 - 35	25%	25%	45%	45%
35.1 - 90	11%	13%	16%	15%

The results show that in Rotorua catchment 49% of gorse was on flat to strongly rolling land (<20°), 40% on steep land and 11% on very steep land (equivalent to LUC class 8).

3.4 Extrapolating results

A number of issues have to be addressed when trying to extrapolate the amount of N leached from a patch of mature dense gorse to the total load from gorse within the landscape. These include:

- The spatial resolution and accuracy of areas of gorse that have been mapped;
- Converting estimates of leaching from 'dense gorse' to estimates of leaching under patches mapped as 'moderate' cover or 'scattered' cover.

3.5 Summary of gorse distribution

- Rotorua catchment has 61% of all gorse on Māori land but gorse in Ōkāreka catchment is primarily on other private land.
- Lake Rotorua and Ōkāreka catchments have about 705 ha and 70 ha of 'dense' to 'moderate density' gorse respectively.
- About 61% of gorse is in patches greater than 10ha and about 42% in patches >20 ha.
- For the Rotorua catchment: 49% of gorse is on flat to strongly rolling land (<20^{o}) which could be suitable for a range of alternative land uses including dry stock. 40% of gorse was on steep land (25-35^{o}) where there would be a risk of loss of sediment and associated phosphorus if used for dry stock farming, and 11% on very steep land (>35^{o}) where there would be a high risk of erosion by removing vegetation cover.

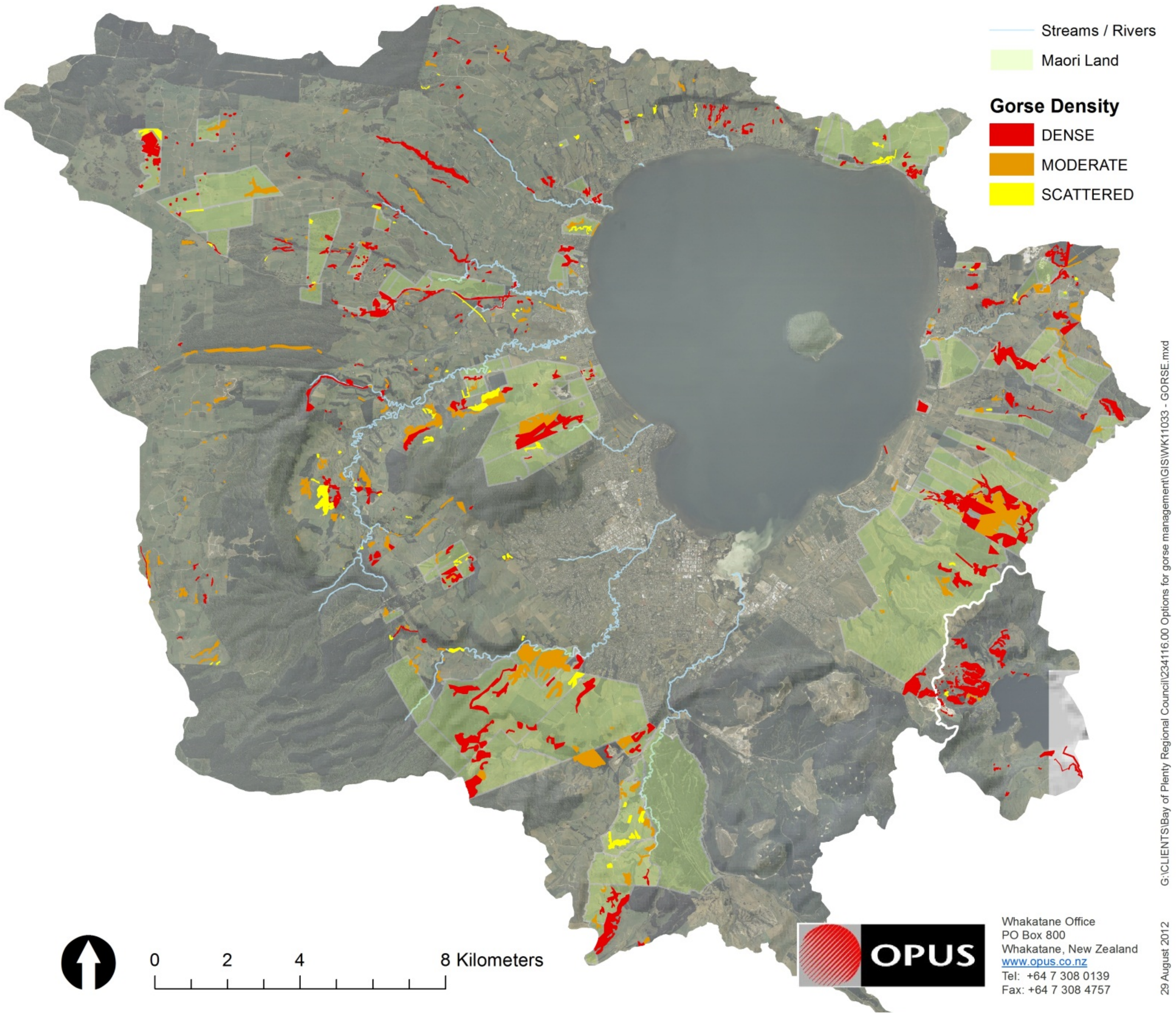

Figure 3.1: Distribution of gorse (dense, moderate and scattered) and Māori land in the Rotorua and Ōkāreka catchments.

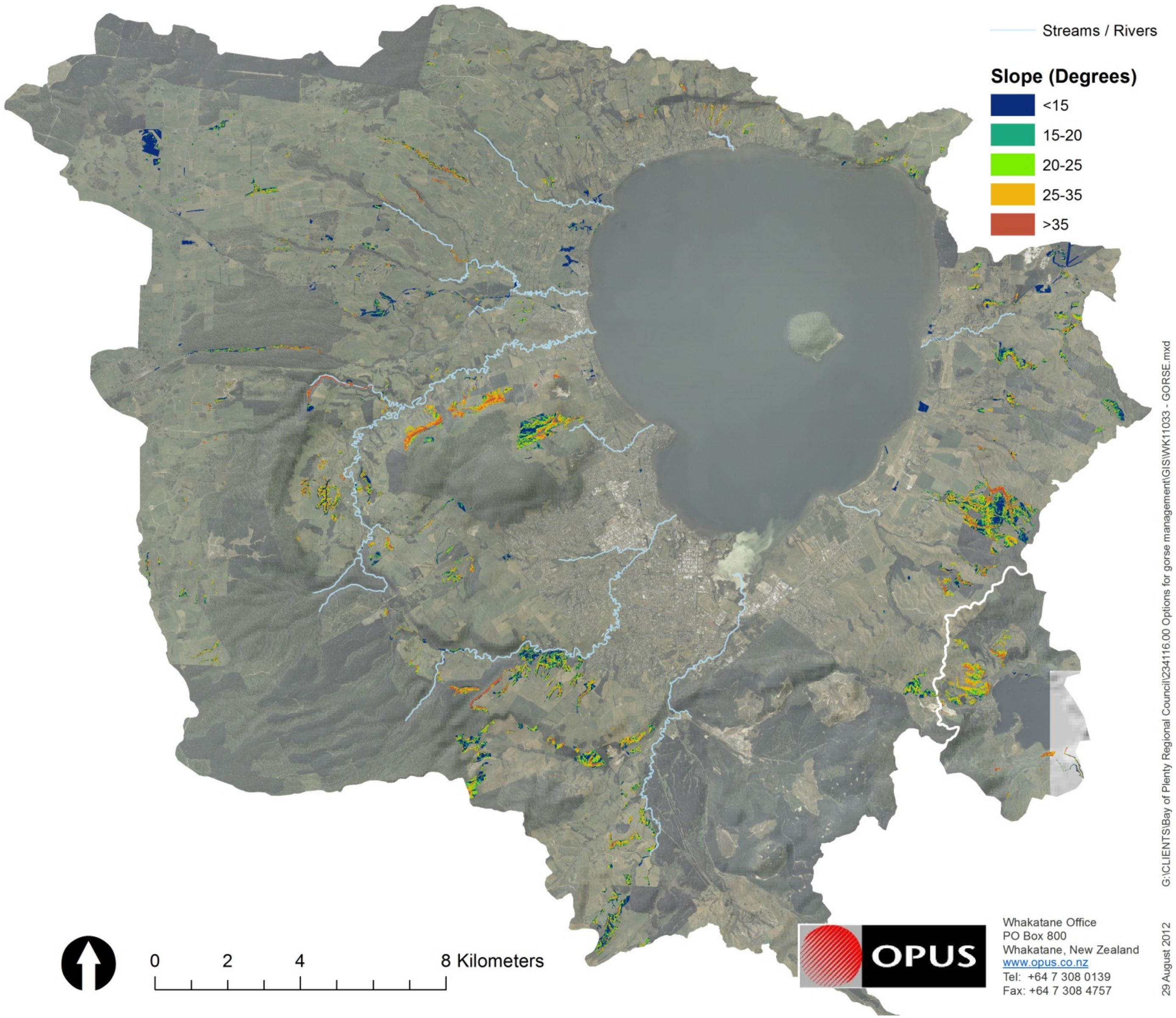

Figure 3.2: The slope of land in gorse in the Rotorua and Ōkāreka catchments.

4 Operational measures for long term control of gorse

4.1 General

This section describes a suite of operational options for managing gorse. These options may be chosen by individual landowners or applied by Council in partnership with landowners using non-regulatory incentives. The options were revised based on feedback from a workshop with Council staff in January 2012.

Gorse is difficult to control on infertile and steep land, and best controlled by a combination of methods. Controlling gorse and broom requires continued intensive management to prevent reinvasion. This is practical on arable land but on marginal land the cost of control can be prohibitive for many landowners. On pastoral land, large stands of gorse can be controlled by aerial application of herbicide and seedling regrowth can be retarded by grazing. In production forestry gorse seedlings growing after initial control will be effectively shaded out by the maturing pine trees within about 10 years. Alternatively, gorse or broom can revert to native bush in 20-30 years so long as there is a nearby source of native seeds and the area is not disturbed by, for example, grazing or fire.

4.2 Gorse control for production forestry

4.2.1 Description

Removing gorse and establishing a forestry plantation is effective at controlling gorse in the long term. A forestry plantation could consist of pines or native species (e.g. totara). Converting to natives (e.g. totara) provides more biodiversity benefits, while converting to a pine plantation is faster with seedlings growing through, and shading out, regenerating gorse within 10 years. This helps make it more cost-effective (see next section).

The general approach to preparing land covered with thick gorse growth for pine establishment is to aerially spray and roller-crush the gorse prior to planting and then spray the gorse once more post-planting (occasionally a second application of herbicide over small sections of a block may be needed. The typical range of cost to establish pines into a gorse stand, including herbicide spraying (pre and post planting), roller-crushing and planting, is $2000 to $3000 per hectare (Ross Larkham, Kit Richards, PF Olsen Ltd, pers comm). The rapid rate of growth of the pine seedlings will generally begin to shade out gorse from year 4 or 5 after planting and complete canopy closure will be achieved by year 10. Stands are typically thinned at year 7 or 8 which can open up the canopy somewhat but gorse regeneration at that stage is usually weak.

Gorse will reappear rapidly following the harvest of pine trees, with dormant seed induced to germinate with the ground disturbance caused by log extraction, but immediate re-planting with pine seedlings will eliminate the need for any crushing to be undertaken between rotations. A spike in N production and leaching could occur between rotations but it would be small (evidence suggests that young gorse leaches little N) and will taper off five years after replanting as the pines begin to overtop the gorse.

The greatest risk, in terms of N leaching, is if there is a delay between harvesting and replanting (possibly as a result of low confidence in the economic future of forestry). Any delay will produce a corresponding increase in gorse growth and N leaching.

Although production forestry controls gorse, it is common to find gorse on the edges of forestry blocks where shading does not occur.

4.2.2 Applying conversion to production forestry

Reach

Conceivably, any block of gorse-covered land within the Lake Rotorua and Lake Ōkāreka catchments that exceeds 20 ha in size is suitable for the commercial establishment of pines for saw logs (Ross Larkham, PF Olsen, pers comm). Distance to mill and port, which can make some remote locations unprofitable for commercial pine production, do not apply in either catchment as mills and the Port of Tauranga are close by.

Gorse blocks of less than 20ha may be suitable for commercial production but this depends on whether there is good road access into the block for log removal. The cost of construction of new roading or upgrading existing tracks or roads to carry logging trucks can be expensive especially if the distance from existing roads is long.

The restriction on economic size limits application of this method to 40% to 60% of the current gorse land.

Incentives and barriers

Financial incentives and funding are available to assist landowners plant and establish a forest on private land. The three main schemes are:

1. New Zealand Emissions Trading Scheme (ETS)
2. The Permanent Forest Sink Initiative (PFSI)
3. Afforestation Grant Scheme (AGS)

Under the Afforestation Grant Scheme (AGS), landowners can receive a government grant for planting new forests on Kyoto-compliant land (that is, land that was not forested as at 31 December 1989). Grant recipients own the new forests and may earn income from the timber after the ten year contract period expires. For the first ten years following establishment of the forest the Crown retains the carbon credits generated under the Kyoto Protocol, and take responsibility for meeting all Kyoto harvesting and deforestation liabilities. The contract will cease after ten years and should the landowner opt to enter the ETS any new carbon credits and the associated harvesting and deforestation liabilities become the responsibility of the landowner. Indigenous or introduced forestry species can be planted under the scheme, and funding can be supplied to assist reversion to natives as well as for the planting of natives. However, species such as pines that produce high sequestration rate forests receive greater funding - $2200 per ha in 2010/11 – than species (including all native tree species) that produce low sequestration forests - $990 per ha in 2010/11.

The minimum block size for AGS is five hectares, however this area may consist of multiple areas of at least 1 hectare. Shelterbelts or riparian strips less than 30 metres average width are not eligible, but afforestation on both sides of a waterway can be assessed as one riparian strip with the width of the waterway excluded from the width measurement.

The view of senior forestry consultants at PF Olsens, Rotorua, is that, despite the availability of funding to assist the establishment of forestry on gorse land in the Rotorua area local landowners with the remaining gorse blocks have not been inclined to establish pines for a variety of reasons. These include:

1. Lack of knowledge of funding schemes and distrust of post-harvest financial obligations;
2. For Māori blocks, the challenge of obtaining multiple block-owner approval before a change in land use can take place;
3. Lack of resources to establish pines (especially amongst Māori block owners);
4. Disinterest in forestry;
5. Annoyance with Rule 11 that prevents conversion of forest land back to pasture in the future.

The view is that some block owners could be encouraged to plant pines if full payment of the pine establishment costs was offered, but for many this would make no difference. Removal of any requirement to retain a planted area in trees may induce some landowners to establish pines but the value of subsidising this may be lost if pasture is re-established after one pine crop and especially if gorse also re-establishes. A two pine crop requirement would help ensure that a gorse seed bank is exhausted and would keep land use options open for future generations, however it will limit alternative land use options for a landowner during his/her working life time.

The creation of rules requiring landowners to convert gorse land to low-N producing land uses will not overcome the financial impediments unless full subsidisation of the cost of pine establishment is also provided.

One mechanism for providing an incentive for converting gorse to forestry would be to form tripartide agreements between the regional council, a forestry manager and landowners. Under this model:

- The regional council would provide advice, coordination and top up funding (in addition to funding already available through, for example, the Afforestation Grant Scheme). If changes were made to implementation of Rule 11 benchmarking then the regional council would receive any nitrogen credits from the gorse removal.
- The landowner would receive a lease on their land and commit to it staying in plantation forestry for two rotations.
- If managed as a plantation forest then a forest manager would manage the forest and own the trees.
- The landowner would continue to own the land, and if managed as a plantation forest they would receive a lease for the use of their land.

If funding is made available for converting gorse to forestry than it would need to be restricted to only apply to land <u>currently</u> covered by moderate to dense gorse. This would help avoid a situation where landowners may let their land revert to gorse in order to receive additional funding.

Strengths and weaknesses

The strengths and weaknesses of converting to plantation forestry are described in Table 4.1.

Table 4.1: Strengths and weaknesses of conversion of land in gorse to plantation forestry

Strengths	Weaknesses
The most cost-effective option in the long term (in terms of $ per kg N).	Considerable initial cost to implement (but in long term this is offset by harvest).
Could be a practical funding mechanism. E.g. a three way partnerships between land owner (leasing land), a forest manager (controlling gorse and managing trees) and regional council (providing a funding incentive for initial gorse control).	Reach limited to 40 to 60% of gorse due to 20ha min block size. Not all land will be suitable or economically viable for production forestry, e.g. ineffective at controlling gorse on areas where trees cannot be planted (e.g. very steep land, rocky outcrops).
Provides a high level of certainty about continued long term control.	Gorse likely to remain around the boundary of the fenced block and short term regeneration between harvest and canopy closure (but N leaching from the young gorse is likely to be limited).
	Could result in a short term increase in erosion if planted on steep riparian land – with resulting sediment and P export.
	Might trigger a resource consent if land clearance and planting requires earthworks on steep slopes, or there is activity near a riparian area (e.g. crossings) or planting in a view shaft.

4.3 Natural succession from gorse to native vegetation using Minimal Interference Management (MIM)

4.3.1 Description

Mature gorse stands will revert naturally to native dominant vegetation over several decades provided there is a diverse and abundant source of native plant seed material within a few kilometres of the site, seed dispersal is possible (e.g. by wind and birds) and the gorse block remains largely undisturbed by fire, grazing and cultivation (see McCracken 1993).

The length of time it takes for MIM to exclude gorse depends on the gorse maturity and density. Lee *et al*. (1986) found that the establishment of native woody species amongst gorse around Dunedin was favoured by low density, taller gorse where litter depth was shallow and areas of bare soil were available. In these stands, native species reached numerical equivalence to gorse after 10-15 years. McQueen (1993) found gorse reverted to natives within 15 to 30 years. Where kanuka or manuka established with the gorse on a newly cleared site, native species could replace the gorse in 25-30 years.

However, it is common for young gorse to exclude establishment of native woody seedlings (initially by a high density of gorse plants and at a later stage by deep litter) (Lee *et al*. 1986). In these situations it may take 25-30 years for native seedlings to establish and 50-60 years for gorse to be excluded.

McCracken (1993) considered that the rate of succession from gorse to natives would be quicker where there are dense stands of gorse or broom and no grazing from feral animals compared to open stands with dense grass on the ground.

The speed of regeneration can be enhanced to some extent by excluding farm livestock, deer, goats, hares and rabbits. All of these animals will consume regenerating native seedlings if given the chance. Conventional 8 or 9 wire post and batten fencing will be sufficient to exclude farm livestock and goats if stays are erected in a goat-proof manner. Deer fencing will be needed if deer are a problem, and 40mm aperture rabbit mesh attached up to 1 metre up the face of a post and batten fence and pegged to the ground as a skirt extending at least 30cm out from the base of the fence will exclude hares and rabbits. Possums do not usually graze regenerating native seedlings and are unlikely to be a problem until the regrowth reaches several metres in height.

Native regeneration within a gorse block may be accelerated by establishing a belt of native coloniser species around the perimeter of the block, especially if the nearest natural stand of indigenous vegetation is some distance away. A belt of natives around a gorse block will also reduce the likelihood of gorse spread to neighbouring pastureland by providing a physical barrier to gorse seed dispersal (Allen 1993). While the planting of a native perimeter buffer is more expensive than initial control of gorse spread using herbicide, once established the native buffer will eliminate the need for on-going herbicide control.

Gorse can function as an effective nurse crop for the establishment of native timber or canopy species such as rimu and totara, and NZ Forest Research (now Scion) have trialled the establishment of these species in gorse over several decades (David Bergin pers comm). The planting of native timber species can produce a sustainable timber resource more rapidly than might be the case if reliance was placed on natural processes only, however this is costly and can have on-going management costs with gorse needing to be pruned regularly to keep it from smothering planted seedlings. Inter-planting native plants amongst gorse is expected to have minimal benefits in mature gorse where native seedlings are already starting to establish, however it may be worth considering in young dense gorse stands where leaf litter is too think for native seedlings to naturally establish.

While gorse can be a useful nursery crop for succession to native vegetation (McQueen *et al*. 2006) its presence can alter the species composition of subsequent forest succession. Sullivan *et al*. (2007) found lower species richness under gorse and fewer small leaved shrubs and orchids. They suggested that it may be necessary to manually establish patches of kanuka and manuka within landscapes dominated by gorse to ensure a native secondary vegetation.

4.3.1 Applying MIM

Using MIM to convert gorse to natives can be applied at a range of scales but is particularly well suited for steep land, where other methods may be less effective. Most sizeable gorse block will have areas that are unsuitable for pine production (such as riparian margins, incised gullies, wetlands and steep outcrops). Even if the majority of the block is to be established in pines these areas should be left undisturbed to enhance natural reversion to indigenous plant cover.

McCracken (1993) developed a scoring system for identifying the potential for successful succession from gorse or broom to native vegetation, based on rainfall, aspect and distance from a suitable seed source. Based on this scoring system all gorse areas in the Lake Rotorua and Ōkāreka catchments would have moderate to high potential for succession to occur quickly with MIM. This is because of the high annual rainfall (1927mm and 1529mm in Rotorua and Ōkāreka catchments respectively (EBOP 2007)), and close proximity to native seed sources (most gorse patches are within 2km of a seed source).

A mechanism for assisting the conversion of gorse to native vegetation would be to develop a property management plan and provide funding for Minimal Interference Management. Conditions of funding would need to include success principles identified by McCracken (1993), including:

- Land is committed to a natural vegetation land use for at least 50 years (e.g. through a land management agreement);
- The area is fenced to exclude browsing animals;
- There is control of gorse for a minimum of 10m width around the area or there is a 10m buffer planted in native vegetation.
- There is a fire management plan and a pest management plan.

Any funding mechanism for MIM should maintain flexibility particularly as this option could be used in association with converting the land to lifestyle blocks.

Strengths and weaknesses

The strengths and weaknesses of MIM are described in Table 4.2.

Table 4.2: Strengths and weaknesses of Minimal Interference Management to allow natural succession of gorse

Strengths	**Weaknesses**
Cheap to implement and cost-effective (in terms of $ per kg N) but not as cost-effective as converting to pines.	Native regeneration takes a long time for complete exclusion of gorse. Native trees can shade out mature gorse in 25 – 30 years but dense patches of young gorse may take up to 60 years to be shaded out.
Retirement of steep land reduces risk of erosion that can carry sediment and phosphorus to	Requires planting a buffer of native plants or on-

streams.	going boundary control of gorse.
Provides additional biodiversity benefits of having more native bush in the catchment.	Continued potential for gorse to re-establish if area is disturbed by fire, animals or landslips.
Well suited to steep, riparian areas which are and not suitable for forestry.	The land needs to be protected with a long term covenant or land management agreement because N benefits take many years to be realised.
Provides a high level of certainty about continued long term control.	

4.4 Control of gorse for the re-establishment of pasture

4.4.1 Description

Gorse covered land has traditionally been cleared for re-establishment in pasture in a variety of ways including burning, rotary slashing, roller-crushing, ground-based application of herbicide, aerial application of herbicide and cultivation, or any combination of the above.

Large blocks of dense mature gorse need to be physically cleared of the gorse plants before pasture can be successfully established. On very steep land gorse is generally aerially sprayed with herbicide and once the gorse is dead the vegetation is crushed by roller crushers operated from bulldozers on ridge lines. Grass seed is then over-sown by helicopter. Repeated regeneration is to be expected and this is controlled by periodic aerial application of herbicide. Because steep land is more at risk of surface erosion and soil disturbance regeneration typically continues for decades and may require some control effort as frequently as every 5 years (MacGibbon, personal experience).

On hill country that can be cultivated, burning of gorse has been favoured because it is the most effective and low-cost method of removing the large biomass of mature gorse stands so that good cultivation can occur. The negative element of this approach is that large scale regeneration occurs because the heat of the fire induces gorse seed germination and there is a risk of soil erosion.

Herbicide application can achieve good gorse kill but with mature gorse stands the vegetation needs to be removed before cultivation and grass seed application can occur. Recent efforts to clear gorse covered pine forest land for conversion to dairying in the central North Island have seen excavators, scrapers and bulldozers used to strip the dead gorse vegetation from land surface and stockpile it in gullies or windrows. This has left the land surface suitable for cultivation (but has also resulted in much of the valuable fertile topsoil being stripped from the land as well. It is interesting to observe that 5 years after this land was cleared and converted to dairying gorse regeneration is occurring in a substantial way on the steeper slopes.

Repeated regeneration of gorse is to be expected wherever there is a significant gorse seed bank in the soil and where soil disturbance (caused by livestock treading and surface erosion) on hill slopes occurs. Sheep grazing will slow down the growth rate of regenerating gorse but grazing does not generally result in the death of gorse seedlings. Cattle are less inclined to graze gorse than sheep.

Evaluation of the real cost of conversion of mature gorse stands to pasture should include the on-going cost of control of gorse regeneration; it can take decades of concerted effort to eliminate regeneration.

4.4.2 Applying conversion to pasture

Conversion of land in gorse to dry stock farming is more appropriate where the gorse occurs on relatively flat land. It is not a good option for steep land because of the risk of increasing erosion which would pollute streams and favour rapid regeneration of the gorse. Land converted from gorse requires on-going management (e.g. spot spraying) to prevent regeneration of the gorse including minimising soil disturbance (e.g. caused by erosion or livestock tracks). Sheep grazing will slow down the regeneration of gorse more effectively than cattle grazing but it does not generally kill gorse seedlings on its own.

Currently any benchmarked property that wanted to convert land in gorse to dry stock would have to obtain resource consent; this is a potential barrier and consideration should still be given to streamlining the consent process to encourage changes in land use that replace gorse with land uses that leach less nitrogen. An alternative approach would be to modify implementation of Rule 11 benchmarking process as discussed previously.

Strength and weaknesses

The strengths and weaknesses of converting gorse to dry stock pasture are described in Table 4.3.

Table 4.3: Strengths and weaknesses of converting land in gorse to dry stock farming.

Strengths	**Weaknesses**
A cost-effective option in terms of $ per kg N (but not as cost-effective as converting to pines).	Is appropriate for relatively flat land but not for steep land or riparian gullies that are prone to erosion.
Provides an option for landowners who are not comfortable with forestry as a land use.	Need for on-going management to prevent gorse from re-establishing. This requirement poses a long term risk to exclusion of gorse if land ownership or economic conditions change.
	Would require a consent or modifications to how Rule 11 is currently implemented.

4.5 Bio-control agents to encourage natural succession to native vegetation

Six biological control agents have been released in New Zealand to attack gorse (Landcare Research 2007). These include the gorse seed weevil and gorse pod moth that feed on gorse seeds, and the gorse spider mite, gorse thrips, gorse soft shoot moth and gorse colonial hard shoot moth that all feed on foliage.

Bio control agents have the potential to reduce the vigour of gorse or broom stands and so encourage the secondary succession of native flora, and to reduce the volume of viable seed production thus reducing regeneration. However, to date the combined impact of these bio control agents has been less than hoped for.

4.6 Summary

- Gorse is difficult to control on infertile and steep land, and best controlled by combination of methods.
- It is likely to be impractical to completely eliminate gorse due to its long lived seed bank and its strong competitive ability on disturbed sites.
- Replacing gorse with pasture requires on-going control about every five years.
- Pines will begin to shade out gorse after 4 to 5 years with complete canopy closure by year 10.
- Gorse will germinate and re-establish after harvest of plantation forestry which could cause a temporary nitrogen spike. This is expected to be mild unless there is a delay between harvest and replanting.
- Replacing gorse with pine plantation typically costs $2000 to $3000/ha.
- Mature gorse will be shaded out by natural succession within 25 to 30 years so long as the site is not disturbed and there is a seed source nearby. However, at some sites (with dense young gorse) it may take around 25 years for natives to initially establish and closer to 50-60 years for gorse to be shaded out.

5 Cost-benefit analysis of gorse control measures

5.1 Method used for cost-benefit analysis

A quantitative cost-benefit analysis was undertaken for alternative operational measures for managing gorse. To estimate the expected cost-effectiveness of the different options a discounted cash flow analysis (Boardman *et al*. 2006) was undertaken using estimates of N reduced by removing gorse, together with assumed whole of life costs. The economic cash flow analysis considered costs and benefits at a regional level i.e. ignoring any costs of leasing land and ignoring any subsidy payments that might come from within the region. We included carbon credits that could be gained through the Afforestation Grant Scheme as a benefit.

The analysis only considered costs and benefits of converting land out of gorse. It did not account for the net benefits of the land changing to a more productive land use (e.g. the costs of managing a production forest or the revenue from harvest).

Our benefits are expressed as kg N/yr rather than dollars, nevertheless we applied the same discount rate to these benefits (in kg) as we did to the costs (in dollars). We did this on the basis that a kg of N entering the lake in 10 years' time is considered less valuable than a kg of N entering the lake this year.

The analysis accounted for the time-lag between N leaving the root zone and entering the lake. It was assumed that 50% of leached N would reach the lake within one year via rapid flow and that 50% of the N would reach the lake via deep ground water between 16 and 127 years. We also assumed 7% average attenuation over the whole catchment (see discussion in previous chapters).

The expected costs over a 28-year period for each scenario (60 yr for gorse to native plantation) were discounted (assuming discount rates of 0, 4 and 8% yr^{-1} real) back to the present and summed to give the net present value (NPV_R, \$ ha^{-1}) of the costs:

$$NPV_{\mathrm{R}} = \sum_{\mathrm{t}=1}^{\mathrm{T}} \left(\frac{\mathrm{C_t}}{(1+\mathrm{r})^{\mathrm{t}}} \right) - \mathrm{C_0}$$

Where: t is the time of the cash flow

T is the period of analysis; 28 years

r is the discount rate (assumed to be 1, 4 and 8% yr^{-1} real)

C_t is the cost at time t.

C_0 is the initial investment in removing gorse and planting.

To then express project costs in annualised terms (\$ ha^{-1} yr^{-1}) the annuity for each scenario was estimated using the PMT() function in MS Excel. An annuity spreads the net present value equally across the period of analysis.

The software package @RISK was used to provide a robust and integrated estimate of the uncertainty around removal rates, costs and cost-effectiveness. A range of estimates were made for each variable in the analysis (i.e. realistic minimum, maximum and median values) and a pert distribution was fitted to these estimates to represent the variable. The software @RISK combined all distributions to produce distributions for analysis results; from these we identified the median, 5th percentile, 95th percentile values for the outputs i.e. cost-effectiveness of each management option and of the overall intervention package.

In addition a sensitivity analysis was undertaken to show how the cost-effectiveness of each option changed with different discount rates and how it changed if the average nitrogen leached from dense gorse was 24 kg N/ha/yr instead of 38 kg N/ha/yr.

Package of operational gorse management options

We also assessed the potential total N removal, total cost and cost-effectiveness of removing all patches of 'dense' to 'moderately dense' gorse from the catchment using three interventions – 'gorse to pine', 'gorse reverting to natives by MIM', and 'gorse to dry stock'.

To apply the analysis to a catchment scale we had to account for both the area of gorse in the catchment and the density of gorse in the catchment. Nitrogen removal was assessed by multiplying N removal rates (kg/ha/yr) by the weighted area of gorse likely to be applicable for that option. This area of gorse was weighted so that areas used were equivalent to a patch of 100% dense gorse. Weighting required us making broad assumptions about average gorse density in each category; the category of 'dense gorse' was weighted by 0.9 and the category 'moderate gorse' was weighted by 0.45. After weighting, the area equivalent to 100% dense gorse was estimated to be 542ha in Lake Rotorua and Lake Ōkāreka catchments.

Costs were assessed by multiplying the total costs (NPV $/ha) by the total area of 'dense' to 'moderately dense' gorse applicable to that option. The total (unweighted) area of gorse in the Lake Rotorua and Lake Ōkāreka catchments was estimated to be 775ha (see Boffa Miskell 2010). Annualised costs were used to calculate cost-effectiveness in terms of $/kg N and corresponding total costs were used to calculate cost-effectiveness in terms of tonnes N / year per $1 million as Present Value (PV).

The net result of this process was that cost-effectiveness of the hypothetical package of options was 1.43 times higher (i.e. less cost-effective) than it would have been if we did not account for the density of gorse. To put it another way, the cost-effectiveness of different gorse management options assume 100% cover of mature gorse and should be multiplied by about 1.43 to account for the fact that most patches of gorse in the catchment do not have 100% cover.

5.2 Assumptions for cost-benefit analysis

5.2.1 Comparison of gorse management operational options

In order to undertake a cost-benefit analysis we made a number of assumptions with the median intended to represent a typical gorse block. Actual costs and benefits will be different for each block being considered, for example to cost fencing we assumed a 10ha block size, smaller block sizes will be cost more per hectare and larger blocks a little less.

A summary of the costs included in the analysis (using an 8% discount rate) are provided in Appendix 2. All options included surveillance costs of $10,000 for the first 2 years and

$4,000 per year thereafter. These costs were applied to 450 ha on a pro rata basis (about one third of gorse in Rotorua and Ōkāreka catchments (see Sullivan and Hutchison 2010).

Because this is a regional analysis we have assumed carbon credits would be gained, but we have not included any cost for leasing land, or any benefits that could come from regional subsidies. Nor have we included any benefits from improved land productivity.

The option of Minimal Interference Management for reversion of gorse to native assumed native seedlings were already present and the gorse exclusion occurred according to a logistic function sigmoid curve between years 5 and 28. This option would be considerably less cost-effective if the gorse stand consisted of dense young gorse as it would delay benefits by another 25 years.

The key assumptions used in the cost-benefit analysis are summarised below. The costs for conversion of gorse to pine are conservative because we have assumed a second aerial spray release which is often not required.

Table 5.1: Key assumptions used in cost-benefit analysis

Variable	**Assumption**
N loss from gorse	38 kg/ha/yr (range of 24 to 60)
N loss from pine	4 kg/ha/yr (range 2.4 - 5.2) (Rutherford *et al*. 2011).
N loss from native	2.5 kg/ha/yr (range 1.5-3.5) applied to a gradual reversion to natives (based on Rutherford *et al*. 2011).
N loss for native plantation	As for pine
N loss from dry stock	16 kg/ha/yr (Rutherford *et al*. 2011) +/- 30%.
Implementation period	Expenditure assumed to start at year 0, with gorse excluded by year 1 and 28 depending on the option.
Time for gorse exclusion: pine and plantation	Year 1. We assumed some N loss as gorse regrowth matured in years 4-6 by modifying the leaching rate under the pine plantation regime. We assumed a 28 year rotation for pine.
Time for gorse exclusion: MIM	Gradual exclusion according to a logistic sigmoid function between year 5 and 28.
Time for gorse exclusion: native plantation	Year 1. N loss from gorse regrowth accounted for in leaching rate. Natives take longer to grow and exclude gorse compared to pine, this was accounted for by assuming additional expenditure for gorse control for the first 5 years. We assumed 60 years for the purpose of our cost-benefit analysis.
Attenuation between root zone and lake	7% (range 0 to 40%) Rotan model assumes 40% attenuation in Puarenga catchment and this catchment contains 18% of Rotorua catchment's dense gorse.
Time to reach lake	50% takes one year via rapid flow and 50% takes 16-127 years via deep groundwater (see Rutherford *et al*. 2011).
Discount rate	8% but also a sensitivity analysis using 0% and 4%. The same discount rate was applied to both N removal and costs. An 8% yr^{-1} real discount rate corresponds to the typical rate used to assess long-

	term projects, such as forestry (Manley 2005).
Costs	**See appendix 2 for the range of assumed costs.**
Gorse removal 'gorse to pine'.	Initial aerial spray plus roller crusher = $1880/ha +/- 33% (Including one aerial spray release). A second aerial spray release in year 2 costing $865/ha.
Gorse removal 'gorse to native planation'	Aerial spray plus roller crusher = $1880/ha +/- 33%. Manual spray releasing of natives = $0.50/plant x 2 times per year in years 2, 3 and 5 ($2500/ha each year).
Gorse removal 'gorse to dry stock	Aerial spray plus roller crusher = $1880 +/- 33%. Cultivation, pasture drilling and fertiliser after burning and spray regrowth = $475/ha +/- 30%. Gorse control in year 3 and every 5 years thereafter at $100/ha.
Planting 'gorse to pine'	$1000/ha (+/-30%) (Male *et al.* 2010).
Planting 'gorse to native plantation'	$12,500/ha (-35%, + 20%). Planting at 2m spacing (2500 plants per ha) at $5/plant.
Buffer planting: 'MIM gorse to native'	For the MIM option we assumed planting a 4m wide strip and 10ha blocks, i.e. 0.5ha. This would be planted at 2m spacings (1250 plants) at $5/plant, i.e. $6250/10ha block (620/ha).
Fencing: 'gorse to pine', 'gorse to native plantation'	Assumed a square 10ha block (1265m) at $15/m ($18975/10ha or $1897/ha block) and half of length already fenced i.e. $949/ha.
Fencing: 'MIM gorse to native'	Assumed a square 10ha block (1265m) at $15/m ($18975/10ha or $1897/ha block) and a quarter of the length already fenced i.e. $1423/ha.
Fencing: gorse to dry stock'	Assumed no additional fencing was required.
Carbon credits	Via Afforestation Grant Scheme: Pine = $2200/ha, natives (and MIM) = $990/ha. Paid in the first year.
Boundary control	Boundary control of gorse will still be required by many options and has not been costed.
Plantation management and revenue from harvest	Our analysis has not accounted for any cost or revenue related to managing and harvesting a plantation forest. Accounting for this would considerably improve cost-effectiveness of some of the options.

5.2.1 Package of gorse management operational options

We made a number of assumptions in order to extrapolate the results of gorse management from a 'patch scale' to a 'catchment scale' and to assess a package of gorse management options. These relate to 1. the converting estimates of 'dense' and 'moderate' gorse cover into an equivalent cover of 'dense gorse'; and 2. Estimating the extent to which different management options could be applied based on current gorse patch size and location with respect to topography. Plantation forests require conversion of large areas to be economic, using MIM is likely to be a good option on steep land as it avoids creating issues of sediment and phosphorus loss due to erosion, and converting to dry stock farming could be a realistic option on flat to rolling land.

Our key assumptions were:

- Lake Rotorua and Ōkāreka catchments have 775 ha of 'dense' and 'moderately dense' gorse.
- This area of existing gorse was estimated to correspond to 542 ha of gorse estimated to leach at 38 kg/ha/hr based on weighting 430ha of 'dense' gorse at 90% cover, and 335 ha 'moderate' gorse at 45% cover.
- 60% of gorse would be converted to pine. This is thought realistic because about 60% of gorse is currently in blocks sizes of >10ha.
- 26% of gorse would revert to natives by MIM. This is thought realistic because 26% of current gorse is on steep land (i.e. LUC 7 and 8).
- 14% of gorse converted to dry stock farming. This is thought realistic because it represents a proportion of the gorse currently on flat land (35% of gorse in Rotorua catchment was on flat land (<15^{o}) and 21% on LUC 4 or better).

It is unlikely that our assumption of removing all 'dense' and 'moderately dense' gorse would be realised in practice. Nevertheless we believe that the proportion to which the different management options could be applied is realistic.

The cost-effectiveness of the package of options is compared with land use change Scenario 3 from Nimmo-Bell (2011). Nimmo-Bell (2011) did a marginal cash flow analysis for three land-use and land management change scenarios to reduce N loads compared to the status quo in the Rotorua catchment. Scenario 3 assumed a 75% reduction in dairy land use with about 400 ha of dairy land converted to new lifestyle lots while 900 ha is converted to dry stock and 2700 ha to forestry. It also assumed that 1153 ha of dry stock would be converted to new lifestyle blocks and 5803 ha of dry stock to forestry (Beca 2011).

5.3 Results of cost-benefit analysis

5.3.1 Comparison of gorse management operational options

The cost-effectiveness of different operational options for gorse management is shown in Table 5.2 and Figure 5.1. This comparison shows that at a discount rate of 8% the most cost-effective gorse management option is conversion of 'gorse to pine', followed by 'gorse to dry stock', 'MIM gorse to natives', and 'gorse to native plantation'. At lower discount rates 'MIM gorse to natives' becomes more cost-effective than 'gorse to dry stock'.

Converting 'gorse to native plantation' was considerably less cost-effective than the other options because of the high cost of planting natives and the high cost of controlling gorse while the native become established. Recent trials by Tane's Tree Trust have shown that the cost of planting natives could be halved by using bare rooted material and it is likely that further technological advances could reduce these costs further. Table 5.2 and Figure 5.1

indicate cheaper planting costs affect the overall cost-effectiveness of converting 'gorse to native planation'. Although still more expensive than other gorse management options it has a similar cost-effectiveness to land-use change Scenario 3 (Nimmo-Bell 2011).

MIM is sensitive to the assumed discount rate because of the long period of time (28 years) before full exclusion of gorse. The MIM option assumes that the gorse is mature so that native seedlings are able to establish; this would allow natives to shade out the gorse after about 28 years from eliminating disturbance by fencing. However, if the stand of gorse under consideration is young gorse then it could take an additional 25 years for the first native seedlings to become established (i.e. about 52 years for gorse exclusion). In this situation the cost-effectiveness of the MIM option is extremely sensitive to the assumed discount rate and would be $2.7/kg, $13.2/kg, $22.1/kg and $153/kg for discount rates of 0%, 3%, 4%, and 8% respectively (not graphed).

A large proportion of the costs associated with options for gorse control are upfront costs, so deciding on an appropriate discount rate depends to some extent on how society values current reductions in nitrogen over future reductions in nitrogen. A higher discount rate implies that society values the benefits of N reductions this year more highly than N reductions in future years. A 0% discount rate implies that society doesn't care how long it takes to reduce N loads to the lake.

Comparison with estimates from Sullivan and Hutchison (2010)

Sullivan and Hutchison (2010) estimated that cost effectiveness of converting gorse to pine as $35/ kg N to $37/kg N, this is considerably more than our estimate of $11.7/kg N. The discrepancy can be mostly explained by our analysis including $2200/ha of carbon credits from the Afforestation Grant Scheme, annualising costs over 28 years rather than 20 years, and differences in how costs were applied.

Sullivan and Hutchison (2010) estimated the cost of preventing nitrogen entering lake Rotorua through bush succession to be only $1.4/kg N, this is considerably less than our estimate of $24/kg N. This discrepancy can be explained by our analysis assuming additional costs for fencing and planting, accounting for the delay in half the nitrogen reaching the lake and assuming gorse will be eliminated by MIM within 28 years rather than within 20 years assumed by Sullivan and Hutchison (2010).

Table 5.2: Cost-effectiveness ($/kg N) for different gorse management options. Assuming an average leaching rate of 38 kg N/ha/yr. Values are negative because they are costs.

Management options	Discount rate		
	8%	4%	0%
Gorse to pine	-$11.7	-$6.6	-$3.4
MIM gorse to natives	-$24.0	-$6.2	-$2.3
Gorse to native plantation	-$78.7	-$36.8	-$11.8
Gorse to native plantation (planting costs halved)	-$53.1	-$25.3	-$8.4
Gorse to drystock	-$19.6	-$11.2	-$5.9

Multiply by 1.43 to account for 'dense' and 'moderate' gorse not having 100% cover.

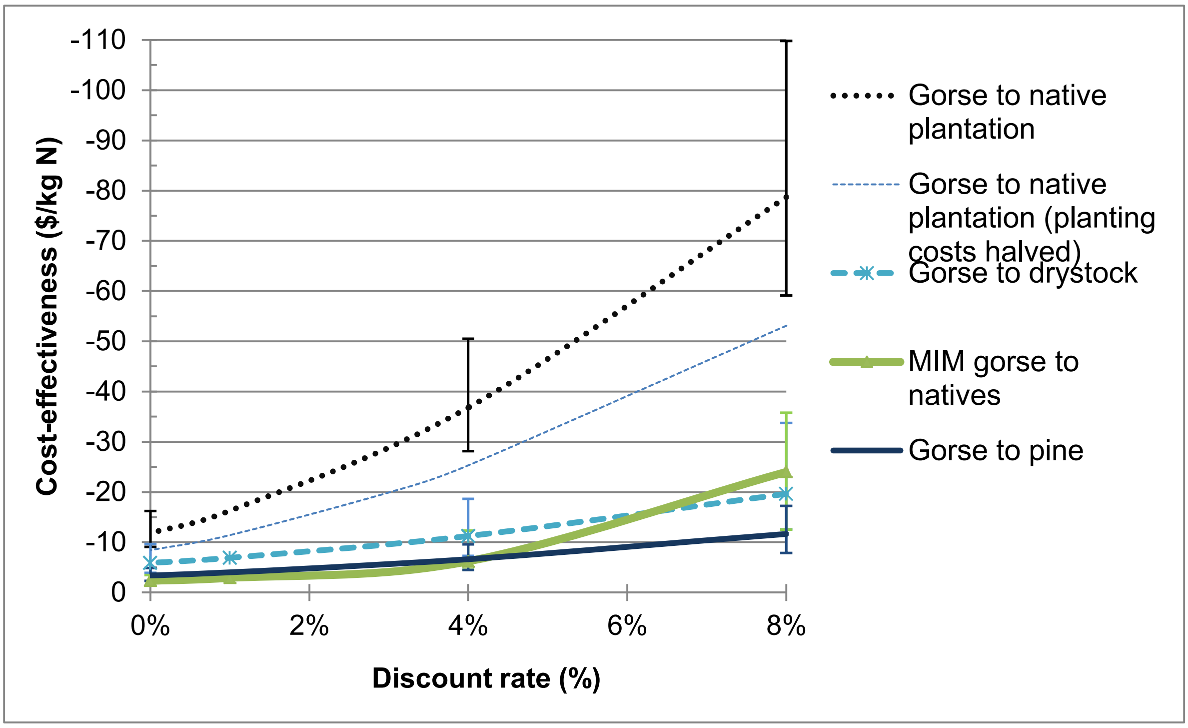

Figure 5.1: Cost-effectiveness of gorse management options. Assumes 100% cover of dense gorse and leaching at 38 kg N/ha/yr. Error bars represent the 5% to 95% range.

5.3.2 Package of operational options for gorse management address current gorse

The different operational options for removing gorse were combined into a package reflecting how they might be realistically applied based on current gorse patch size and its location with respect to topography. This combined package consisted of 60% of gorse converted to pine, 26% allowed to revert to native using MIM, and 14% converted to dry stock farming.

Our analysis indicated that, at a 4% discount rate, using the package of options to remove 775ha of ‘dense’ and ‘moderately dense’ gorse, could remove 10.3 tonnes N/yr (4.5% of the catchment target) for a total cost of $1.768 million [2]. This equates to an annualised cost-effectiveness of $10.5/kg N. All costs and benefits are expressed in terms of present value (see Table 5.3).

If an 8% discount rate was used then the package of options could remove 8.02 tonnes N/yr (3.5% of the catchment target) for a total cost of $1.69 million. This equates to an annualised cost-effectiveness of $19.5/kg N (see Table 5.3)

To put these figures in context of alternative options for removing nitrogen we have compared the cost-effectiveness of the package with land use change Scenario 3 from Nimmo-Bell (2011) (see Figure 5.2). Applying the package of gorse management options was considerably more cost-effective (e.g. half the cost) than the estimates for land-use change.

[2] Total cost of $1.9 million at a discount rate of 0%.

A sensitivity analysis was undertaken to test how cost-effectiveness would change if we used a much more conservative estimate of nitrate leaching from gorse (i.e. 24 kg N/ha/yr rather than 38 kg N/ha/yr) (see Table 5.4). Even with this conservative assumption the package of gorse management options is still much more cost-effective than land use change Scenario 3 (about half).

Table 5.3: Cost-effectiveness of hypothetical package of options to manage current 'dense' and 'moderate' gorse. Assuming leaching rate of 38 kg N/ha/yr.

	Discount rate		
	8%	**4%**	**0%**
Nitrogen removed as Tonnes/year per $1M (PV) (median)	4.6	5.7	7.4
Nitrogen removed as $/kg N (median PV)	-$19.5	-$10.5	-$4.9
Nitrogen removed as $/kg N (range)	-14.2 to -26.5	-7.8 to -14.0	-3.7 to -6.3
TN reduction (kg/yr) PV	8,022	10,309	14,275
TN reduction as % catchment target	3.5%	4.5%	6.2%

PV = present value

Table 5.4: Cost-effectiveness of hypothetical package of options to manage current 'dense' and 'moderate' gorse. Sensitivity analysis assuming a low leaching rate of 24 kg N/ha/yr.

	Discount rate		
	8%	**4%**	**0%**
Nitrogen removed as Tonnes/year per $1M (PV)	2.6	3.2	4.2
Nitrogen removed as $/kg N (PV)	-$34.7	-$18.7	-$8.6
TN reduction (kg/yr) (PV)	4,513	5,816	8,089
TN reduction as % catchment target	2.0%	2.5%	3.5%

PV= present value

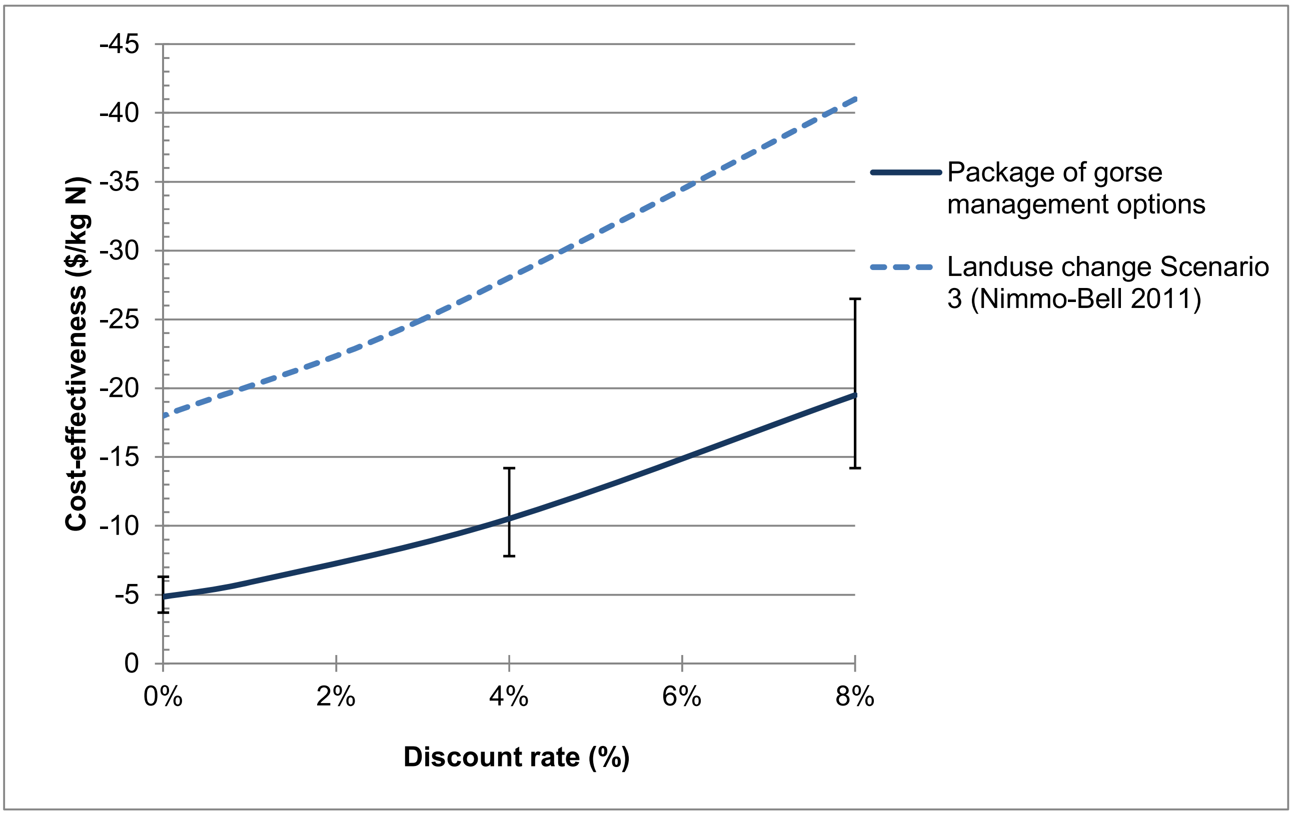

Figure 5.2: Cost-effectiveness of hypothetical gorse management package compared to land use change Scenario 3 from Nimmo-Bell (2011). Error bars represent the 5% to 95% range.

5.3.3 Potential to subsidise options for gorse removal

Because removing gorse is so much cheaper than the estimate for land-use change, Council could give consideration to not only paying for gorse removal but also to providing an additional one-off cash incentive under some circumstances. Table 5.5 shows that potential expenditure and incentives in excess of estimated costs that would still ensure gorse management options were more cost-effective than estimates for land-use change. Using land-use change as a point of *comparison*, and assuming an 8% discount rate, it would be cheaper for Council to spend $5480/ha to convert dense gorse to pine, $2,420/ha to convert dense gorse to dry stock, and $685/ha to for MIM to revert dense gorse to natives. In the case of converting dense gorse to pine the Council could offer an additional $4075/ha (including the carbon credit) and still be more cost-effective than the estimates for land-use change.

The cost-effectiveness (and hence potential incentives) reduces for areas of gorse that are less dense (i.e. less cash incentives would apply to moderate gorse compared to dense gorse), and the benefits are more if we apply a lower discount rate.

These potential cash incentives assumes that the carbon credits are used to off-set the costs i.e. any cash incentive would be less the carbon credits received by the landowner (assumed to be $2200/ha for pine and $990 for natives). It also assumes that if there was a nitrogen credit from any land use change (e.g. if there was a change to the current implementation of Rule 11), then this would be taken by the Council and not be used to offset land use intensification in other parts of the catchment.

A sensitivity analysis was undertaken to test how the potential incentives would change if we used a more conservative estimate of nitrate leaching from gorse (i.e. 24 kg N/ha/yr rather than 38 kgN/ha/yr). The results are shown in Table 5.6. If gorse was to leach at this much lower rate than the cost-effectiveness of all the options reduces but it would still be efficient to provide an incentive of about $775/ha to convert dense gorse to pine (over and above the conversion costs).

It should be noted that these are conservative estimates because the analysis only considered costs and benefits of converting land out of gorse. It did not account for the net benefits of the land changing to a more productive land use (e.g. the costs of managing a production forest or the revenue from harvest).

It is possible that providing a cash subsidy would have a perverse effect of incentivising some landowners to make their gorse grow denser. This could be avoided by only offering incentives for a short period of time, bench making the gorse it applies to, or applying it in combination with other policies to control future gorse expansion.

Table 5.5: Potential expenditure and incentives in excess of estimated costs that would still ensure gorse management options were more cost-effective than estimates for land-use change Scenario 3 (Nimmo-Bell 2011). Values assume that any cash incentive would be less the carbon credits received by the landowner (assumed to be $2200/ha for pine and $990 for natives) and any N credits are taken for the lake.

	Dense gorse			**Moderate gorse**		
	Discount rate			**Discount rate**		
Assumed discount rate	**8%**	**3%**	**0%**	**8%**	**3%**	**0%**
Scenario 3 comparison ($/kg N)	41	25	18	41	25	18
Gorse to pine plantation ($/ha)	5,480	8,050	10,700	1,480	2,700	3,950
MIM gorse revert to native ($/ha)	685	3,550	8,650	0	1,100	3,600
Gorse to native plantation ($/ha)	0	0	0	0	0	8,100
Gorse to drystock ($/ha)	2,420	3,950	5,580	0	520	1,200
Potential incentive over and above costs (PV $/ha)						
Gorse to pine plantation	4,075	6,575	9,142	75	1,225	2,392
MIM gorse revert to native	0	2,341	7,367	0	0	2,317
Gorse to native plantation	0	0	0	0	0	0
Gorse to drystock	0	1,002	2,420	0	0	0

PV = present value

Table 5.6: Potential expenditure and incentive in excess of estimated costs beyond which gorse management options become less cost-effective than estimates for land use change Scenario 3 (Nimmo-Bell 2011). Sensitivity analysis assuming a low leaching rate of 24 kg N/ha/yr. Values assume that any cash incentive would be less the carbon credits received by the landowner (assumed to be $2200/ha for pine and $990 for natives) and any N credits are taken for the lake.

	Dense gorse			**Moderate gorse**		
	Discount rate			**Discount rate**		
Assumed discount rate	**8%**	**3%**	**0%**	**8%**	**3%**	**0%**
Scenario 3 comparison ($/kg N)	41	25	18	41	25	18
Gorse to pine plantation ($/ha)	2,180	3,380	5,150	0	350	1,180
MIM gorse revert to native ($/ha)	0	350	1,180	0	120	1,560
Gorse to native plantation ($/ha)	0	0	0	0	0	0
Gorse to drystock ($/ha)	0	0	20	0	0	0
Potential incentive over and above costs (PV $/ha)						
Gorse to pine plantation	775	1,905	3,592	0	-1,125	-379
MIM gorse revert to native	0	-859	-103	0	0	277
Gorse to native plantation	0	0	0	0	0	0
Gorse to drystock	0	0	0	0	0	0

PV = present value

5.4 Summary of cost-effectiveness analysis

- A quantitative cost-benefit analysis was undertaken for alternative gorse management options. All approaches were considered effective at removing gorse cover.
- The gorse management options of ‘gorse to pine’, ‘reverting gorse to natives using MIM’, and ‘gorse to dry stock’ were a very cost-effective way of reducing the nitrogen load to the lakes.
- At a discount rate of 8% the most cost-effective gorse management option was: conversion of ‘gorse to pine’ ($11.6/kg), followed by ‘gorse to dry stock’ ($19.6/kg), ‘MIM gorse to natives’ ($24/kg), and ‘gorse to native plantation’ ($79/kg). At lower discount rates ‘MIM gorse to natives’ becomes more cost-effective than ‘gorse to dry stock’.
- Allowing gorse to revert to natives by MIM takes a long time so the benefits of the approach are delayed. Applying this approach to dense stands of young gorse could take 25 years longer to remove gorse compare to mature gorse and this limits its cost-effective application across the landscape.
- The option of converting ‘gorse to native planation’ was less cost-effective than estimates of land-use change. The cost of planting natives would need to reduce by half for it to be more cost-effective, but developing propagation / planting methods may achieve this amount of saving.

- Converting gorse to dry stock was cost-effective but would require on-going management and there is a much higher risk of gorse regrowth compared to options that involve planting or reversion to tree cover. Grazing sheep are likely to be a better option for preventing reestablishment of gorse rather than cattle but the economics of livestock may dictate how the land is managed.

- A package of operational measures for managing gorse was developed based on the extent to which different management options could be applied across the Rotorua catchment. This assumed 60% of the gorse converted to pine, 26% allowed to revert to native using MIM, and 14% converted to dry stock farming.

- At an 8% discount rate to calculate present value, the package of options applied to 775 ha of ‘dense’ and ‘moderately dense’ gorse could remove 8.02 tonnes N/year (3.5% of the catchment target) for a total cost of $1.69 million. This equated to an annualised cost-effectiveness of $19.5 /kg N.

- The package of gorse management measures was very cost-effective compared to recent estimates of land use change (Scenario 3 in Nimmo-Bell 2011) – equivalent to half the costs.

- Removing gorse was sufficiently cheap that Council could consider paying for both gorse removal as well as providing an additional one-off cash incentive under some circumstances. Our estimates of potential cash incentives assumed that Council would take any nitrogen credit resulting from a change in land use (only relevant if there is a change to implementation of Rule 11).

- The options considered would have additional benefits not considered in this analysis including regional economic benefits of changing land in gorse to a more productive land use (in the case of production forestry and dry stock options) or biodiversity benefits in the case of native production forests and MIM options.

6 Policy options to encourage gorse removal

6.1 Introduction

The previous chapters of this report have identified a number of operational measures for long term removal of gorse. A package of options was developed that reflected the proportion to which different measures might realistically be used in the Lake Rotorua catchment, this assumed 60% of the gorse converted to pine, 26% allowed to revert to native using MIM, and 14% converted to dry stock farming. Applying these measures to remove gorse was shown to be a very cost-effective way to reduce nitrogen loads to the lake.

Large areas of gorse remain in the Rotorua catchment despite methods being available to remove gorse and it being a very cost-effective way to reduce nitrogen loads to the lake. Some reasons for this were discussed in Section 4.2.2, but one reason is a mismatch between who pays and who receives the benefits of gorse removal. This section describes a toolbox of four different policy options to encourage the removal of gorse, including:

a) A regulatory approach to control current gorse e.g. list gorse as a containment pest requiring "land owners and occupiers to control patches of "mature" gorse on all land occupied in the Rotorua lakes catchments unless being controlled by Minimal Interference Management".

b) A regulatory approach to control future expansion or establishment of gorse, e.g. list gorse as a containment pest requiring: "Land owners and occupiers to prevent the establishment or expansion of new gorse patches on land in the Rotorua lakes catchments".

c) A market based approach based on modifying the implementation of Rule 11 so that land in mature, moderate-dense gorse is ascribed a leaching rate 15 kg N/ha/yr during the benchmarking process. This is higher than currently assumed for land in gorse but less than our most conservative estimate of what gorse actually leaches.

d) A gorse control programme to provide assistance and funding incentives to encourage voluntary removal.

For each option we discuss the strengths and weaknesses, how it might be implemented, where the costs fall and the certainty of it working i.e. encouraging the removal of gorse on a wide scale.

The different policy options and removal approaches are compared against criteria in the code of good regulatory practice. In particular each option is compared against criteria of:

i. Efficiency, i.e. are the costs justified by the benefits?

ii. Effectiveness, i.e. does it achieve the desired outcome of removing gorse? What is the extent of gorse removed by the option, and how long term is the removal?

iii. Fairness, i.e. Does it treat all those affected equitably? Are those who pay also receiving some benefit?

iv. Practicability, i.e. can the policy be effectively implemented?

6.2 Current regulatory framework

The Regional Pest Management Plan 2011-2016 (RPMP) became operative in July 2011. It identifies the primary pest management roles and responsibilities for Council as well as landowners and occupiers across the region.

The RPMP is a statutory document created in accordance with the Biosecurity Act 1993. For any species or rule to be included in a regional pest management plan, it must meet specific requirements set out in the Biosecurity Act 1993, namely that the benefit of action must outweigh its cost, taking into account what might happen if no action is taken at all. A cost benefit analysis was undertaken to support the Regional Pest Management Strategy (Sullivan and Hutchinson 2010b), and it has been demonstrated that gorse meets this requirement, i.e. it is cost-effective to take action.

Additionally, BOPRC has ensured that all species and rules included in the Plan are consistent with their Pest Management Policy. The Pest Management Policy seeks to:

- Prevent new pests entering and establishing in the Bay of Plenty.
- Manage established pests where it is practical and cost-effective to do so, using Council's regulatory and/ or operational roles.
- Support the voluntary efforts of landowners/occupiers and communities to manage established pests.

Within the plan, gorse is classified as a "Containment" pest plant, which is a plant that BOPRC want to minimise the effects and prevent the further spread. The rule and statutory obligations in the RPMP for gorse require that landowners and occupiers shall destroy gorse within 10 metres of any property boundary, and no person shall knowingly communicate, cause to be communicated, release, or cause to be released, or otherwise spread gorse.

Currently enforcement occurs on properties where the adjacent property has no gorse on the boundary, or where the gorse has been treated to control it (pers comms John Mather, BOPRC).

The RPMP is a high-level strategic document that outlines the overall outcomes BOPRC wants to achieve from pest management over a five year period. BOPRC must also prepare an annual operational plan in accordance with requirements of the Biosecurity Act. The operational plan outlines the nature and scope of activities that BOPRC intends to undertake in the implementation of the Plan.

6.3 Regulation to control current gorse

The Draft Regional Pest Management Plan for 2011-2016 proposed additional new rules to either destroy or control gorse in the Rotorua and Ōkāreka lake catchments. Despite submitter support in principle for control of gorse there were a number of issues relating to the proposed regulatory approach to controlling gorse (BOPRC 2011b). Issues identified by submissions included:

- Feasibility of eradication – gorse seeds are very long lived and can quickly regenerate on disturbed soils. Even with regulation and good intentions small patches of gorse are likely to remain in the landscape (e.g. on the edge of forestry blocks).
- Enforcement - some landowners cannot afford to remove gorse.
- Inequity issues – compulsory control of gorse may cause a mismatch between those who pay for removal and those who benefit.
- Māori land issues – 61% of gorse in Rotorua catchment is on Māori land, which is mostly in multiple ownership (including all properties with over 20 ha of gorse).
- Removing gorse from some areas can create additional issues. In some situations removing gorse may cause more harm than good, e.g. where the gorse is helping prevent erosion on very steep land or where the patch of gorse is slowly reverting to native trees through Minimal Interference Management.
- Gorse acts as a very good crop for producing honey while pine plantation (a common alternate land use) is very poor for honey production.

One of these issues with a regulatory approach - the feasibility of eradication - could be addressed by limiting the definition of gorse to only refer to patches of moderate to dense patches of mature gorse (e.g. over 1.5 m high), covering more than a set area (e.g. five to ten hectares[3]. This would target the main areas of gorse in the catchment and create more flexibility regarding gorse control. However this does not address the other issues associated with a regulatory approach. We have summarised the strengths and weaknesses of a regulatory to managing patches of mature gorse in Table 6.1.

6.3.1 Efficiency, effectiveness, fairness, practicality

If regulation to control gorse had good compliance than it could be effective at removing up to 70% of the gorse in the catchment (assuming a patch size cut off of 5 ha). The approach gives Council little influence over how the gorse is removed so there would be no certainty that the best removal options would be used in each case (e.g. MIM on steep land).

It is expected that gorse removed as a result of a regulatory approach would be cost-effective (in terms of $ /kg N removed) because most of our measures assessed were cost-effective, but it is unlikely that the options chosen would be the most cost-effective combination from a regional perspective. Instead, there is a strong likelihood that landowners would adopt the cheapest option in the short term, which from our analysis was MIM. Furthermore, MIM is only effective at removing gorse if land remains undisturbed for the long term (30-50 years), thus landowners should only be encouraged to use this approach if there was some form of covenant or land use agreement.

A regulatory approach is fair in the sense that the same obligation to remove gorse is placed on all landowners. At the same time it is not fair in the sense that it takes no account

[3] 59 % (512 ha) of gorse in Rotorua catchment are in patches over 10 ha, while 70% are in patches over 5 ha.

of the historical reasons why gorse dominates in some areas. It is also unfair because the costs will fall on individual landowners (and to a large extent, owners of Māori blocks), while the benefits are provided to the whole community (i.e. less nitrogen leaching and a cleaner lake). In some cases it could be argued that individual landowners derive benefits from removing gorse by opening the land for more productive land use, however this is clearly not perceived as a sufficient benefit in many cases otherwise it would be removed voluntarily.

Another significant disadvantage of a regulatory approach is the practicality of applying and effectively enforcing it. Council land management staff expressed a view that a separate rule requiring control of gorse would be difficult to apply and not practical to enforce. Issues related to the cost of removal and difficulties to make decisions for land in multiple-ownership are not helped by regulation. Instead there was a view that there should be advice and incentives for landowners to appropriately manage gorse.

Table 6.1: Strengths and weaknesses of an additional rule for gorse as a containment pest plant requiring 'Land owners and occupiers to control patches of "mature" gorse on all land occupied in the Rotorua lakes catchments unless being controlled by Minimal Interference Management. For the purpose of this rule there will need to be a specific definition regarding the area and density of gorse patches.

Strengths	**Weaknesses**
Is fair on landowners who are currently controlling gorse.	It is not feasible to completely control gorse on steep and marginal land, and sometimes gorse on steep land is beneficial (e.g. to control erosion).
Obliges landowners to take some action to control gorse (but this is not guaranteed).	High risk of non-compliance and inability to pay due to prohibitive costs on marginal land.
Can incorporate flexibility to allow gorse to remain in catchment if in process of conversion to forestry or native succession.	Equity issue in that the cost of control is placed on individual land owners but improvements in water quality benefit the whole region.
	Equity issue in that most of the land in gorse is undeveloped Māori land. A rule requiring control of gorse creates a financial burden on owners with little ability to meet costs and could limit future land use options.
	Difficult to define what control would be required on the margins of areas in forestry or regenerating to native trees.

6.4 Regulation to prevent further expansion of gorse

An alternative regulatory approach would be to prohibit the establishment or expansion of new areas of gorse. In addition to the current rule requiring control of gorse along property boundaries, landowners would be obliged to prevent gorse further expanding or encroaching onto land not currently in gorse, but it would not require removal of current areas in gorse. To apply such a rule properties would need to be benchmarked, this has already occurred to some extent with the work done by BOPRC (2009).

One difficulty with such a rule is that where there is a gorse seed bank it regenerates very quickly when land is disturbed or if plant cover is removed. In many cases this is a temporary phenomenon until forest grows. Thus to make implementation of such a rule more practical some caveats may be needed around gorse maturity, extent and whether the land is being replanted with pines.

6.4.1 Efficiency, effectiveness, fairness, practicality

A rule of this nature would do nothing to remove current areas of gorse so it is ineffective on its own. However, it could provide real benefits if applied in combination with a non-regulatory approach to removing gorse. The two main benefits are: firstly, it fills a gap in the non-regulatory approach which doesn't easily address future gorse expansion. Secondly, because currently implementation of Rule 11 credits treats gorse as 'scrub' it creates a potential perverse incentive to allow marginal land currently being farmed to revert to gorse to provide a nitrogen credit elsewhere on the property – with adverse implications for the lake.

The cost of implementing a rule of this nature would be more than other alternatives because it is likely that additional work would be needed to benchmark gorse on properties.

We consider this approach to be fairer than a regulatory approach to control all gorse because it does not target landowners who, for whatever reason, currently have gorse on their land. Instead it is an extension of the current policy of containment to prevent further expansion.

The practicality of enforcing this approach depends to a large extent on the ability to accurately benchmark the current extent and density of gorse. While it would be easier for landowner to comply with this rule (compared to controlling all gorse), it would be more difficult to identify landowners where enforcement action is required because it would require a comparison with previous land maps.

The strengths and weaknesses of the approach are summarised in Table 6.2.

Table 6.2: Strengths and weaknesses of an additional rule for gorse as a containment pest plant requiring 'Land owners and occupiers to prevent the establishment or expansion of new gorse patches on land in the Rotorua lakes catchments.' For the purpose of this rule there will need to be a specific definition regarding the extent and density of new gorse patches.

Strengths	**Weaknesses**
Prevents the establishment of new areas of gorse (thus fills a gap with a non-regulatory approach).	Does nothing to remove current patches of gorse if applied on its own.
Can incorporate flexibility to allow gorse to remain in catchment if in process of conversion to forestry or native succession.	Practical difficulties to ensure an accurate benchmark and defining the extent of new gorse that is acceptable / unacceptable.
Is fair in that it doesn't required investment in currently undeveloped land.	If a land use on marginal land becomes uneconomic then there remains a risk of inability to pay for compliance.
Removes a possible incentive to allow some land currently being farmed to revert to gorse (e.g. to provide N credit for intensification elsewhere on the property). This could also be addressed by changing the way Rule 11 is implemented.	

6.5 Market incentive by modifying implementation of Rule 11 of Water and Land Plan

Rule 11 of the BOPRC Water and Land Plan seeks to protect lake water quality. It requires that nutrient benchmarks are set for all properties larger than 4,000 square metres in five Rotorua lake catchments. After benchmarking, landowners are not able to change or intensify land use without offsetting any increased export of nitrogen or phosphorus.

Benchmarking under Rule 11 is implemented using the Overseer model to identify nutrient loss from different properties. Overseer has no specific category for gorse, and gorse is usually classed as either 'native' or 'scrub' and given a leaching rate of 2.5 to 3.1 kg N/ha/year. The literature suggests that the actual N leaching rate by gorse is closer to 24-38 kg N/ha i.e. 12 times higher. This creates a situation where the cost of gorse control cannot be offset by increasing stocking rates on other parts of the property. Converting land in gorse (with a high N leaching rate) to dry stock farming (with a lower N leaching rate) would require a consent (a discretionary activity) and obtaining resource consent can be expensive and may be cost prohibitive if only small areas of land are involved.

Modifying the way benchmarking is implemented to credit gorse with a higher leaching rate would create a non-regulatory incentive to control gorse by allowing higher stocking rates elsewhere on the property or catchment to balance the N benefits of gorse control. It would also remove the need to obtain a resource consent to convert land in gorse to dry stock farming (because the regulation would recognise this as reducing N leaching), which is one less barrier to this occurring.

In our view there are no water quality benefits from increasing the nitrogen attributed to gorse up to 38 kg N/ha/yr because gains from removing gorse will be offset by equivalent N leaching land use elsewhere in the catchment, consequently this approach would not meet the requirements of the Biosecurity Act. However, there could be water quality benefits by increasing the nitrogen credit for gorse to about 15 kg N/ha/yr. This lower value splits the difference between the current situation (3.1 kg N/ha/yr) and our most conservative estimate of what gorse actually leaches. It is also similar to the N leaching rate from dry stock farming. Doing this provides a non-regulatory incentive to remove gorse but also ensures that some benefits (in terms of less N leaching) are accrued for the lake.

If this approach is not taken then consideration should still be given to streamlining the consent process to encourage changes in land use that replace gorse with land uses that leach less nitrogen.

6.5.1 Efficiency, effectiveness, fairness, practicality

Implementing this policy option would have most influence on areas suitable for conversion from gorse to dry-stock farming. We estimated this to be about 14% of the gorse in the Rotorua catchment and the cost-effectiveness of this conversion was $20 /kg N removed. There are also regional economic benefits of converting unproductive gorse land to dry stock farming which were not included in our cost-benefit analysis.

This policy change would also provide a market incentive to convert to other land uses other than gorse. However it would be more effective if applied in combination with a non-regulatory approach of providing advice and incentives for gorse removal. In this case it is recommended that any subsidisation or incentives provided by Council for gorse removal are either contingent on the Council (aka the lake) getting any resulting N credit from a land use change, or the subsidisation adjusted accordingly.

One argument against allowing a higher N credit to land with gorse is that it would provide a perverse incentive for landowners who have not already controlled gorse on their property. The counter argument is that many land owners with large patches of gorse on their land (and the majority of gorse in the catchment) have historical reasons for not having previously developed that land and providing a higher N credit for gorse is more equitable for these landowners.

Implementing the policy itself would be cheap. However any changes to the gorse N credit are likely to be controversial and would require careful definition as to what maturity, density and area of gorse it would apply to (e.g. 15 kg N/ha/yr would not be appropriate to apply to young gorse or scattered fragments of gorse). While there remains some uncertainty about precise leaching rates from dense mature gorse, we think it is highly likely to be in the range of 24 to 62 kg N/ha/yr (best estimate is 38 kg/ha/yr), and very unlikely to be less than 15 kg N/ha/yr.

The strengths and weaknesses of changing the way Rule 11 is implemented to account for gorse are summarised in the Table 6.3.

Table 6.3: Strengths and weaknesses of the benchmarking process crediting land in mature, moderate to dense gorse with a leaching rate 15 kg N/ha/yr. This is higher than currently assumed for land in gorse but less than what gorse actually leaches.

Strengths	Weaknesses
Non-regulatory incentive to control gorse (by ability to increase intensity of land use elsewhere on property), while at the same time reducing N leaching to the lake.	15 kg N/ha/yr is still less than the actual leaching rate of gorse so the rationale would need to be explained to landowners.
Removes the current barrier of needing consent to convert land in gorse to dry stock farming (which would have both a lower N leaching rate and economic benefits).	Gorse tends to be transient which creates difficulties for benchmarking (see Environment Court 2008), however this is not so relevant if considering large areas.
Removes a possible incentive to allow some land currently being farmed to revert to gorse (e.g. to provide N credit for intensification elsewhere on the property). This could also be addressed using a regulatory approach.	MIM (reverting to native) is a good approach for removing gorse from some areas (e.g. steep land where direct removal of gorse may increase erosion and P loss). Benchmarking would need to consider land in MIM as bush.
Fairer to landowners who have undeveloped (gorse covered) land, because it maintains land use options (e.g. for dry stock farming or life style blocks) without consent costs. Although it could be also argued that these landowners are receiving a small (unfair) benefit for leaving their land in gorse.	If a non-regulatory approach is taken, then Council funding should be contingent upon any N credit from the land use change going to the Council and not being used to off-set intensification elsewhere. Should not be applied in combination with a rule to remove current gorse because this could halve the N benefit to the lake for land converted out of gorse.

6.6 Non-regulatory incentives

6.6.1 Description

BOPRC land management staff regularly work in partnership with landowners developing property plans to, for example, control pests (Property Pest Control Plans) or improve biodiversity outcomes (Biodiversity Management Plans). This same approach of developing property management plans in partnership with landowners could be used to help control gorse using a combination of operational measures described earlier in the report (e.g. converting to plantation forestry, or pasture or allow reverting to natives using MIM).

To ensure more effective outcomes than the current non-regulatory approaches, we recommend that there is a dedicated gorse control programme, and easy access to funding to both subsidise removal and provide direct incentives. As described earlier in this report many of the control measures are sufficiently cost-effective that they are cheap ways to remove nitrogen even if Council covered the full cost of removal.

Agreements made with landowners can have bespoke conditions such as allowing landowners to remove trees early if the land is subdivided, but the implication of specific conditions would need careful consideration. To encourage conversion of gorse to forestry Council could help co-ordinate tripartide agreements between the regional council, a forestry manager and landowners. As discussed in Chapter 4 this could involve the regional council providing advice, coordination and top up funding, the landowner committing to land staying in plantation forestry and receiving a lease, and a forest manager managing the forest and owning the trees.

6.6.2 BOPRC programmes and funding for gorse control

There are currently a number of programmes which can assist landowners remove gorse. Funding for gorse control is currently the responsibility of individual landowners and occupiers, *“unless the control is part of an approved Council programme (an Environmental Programme, Care Group, Community Control Programme) in which case funding support may be given by Council”* (Regional Pest Management Plan).

The Operations, Monitoring and Regulation Committee, in October 2011, approved the use of Council funding and resources to support landowners and the community to manage pests within the region through “approved programmes”. These include:

- Biodiversity Management Plans (BMP) - funded through the Biodiversity Programme
- Care Groups - funded through the Biodiversity, Biosecurity and Sustainable Land Use Implementation Programmes (SLUI)
- Riparian Management Plans (RMP) - funded through the Sustainable Land Use Programme
- Council / Industry partnerships - jointly funded and / or jointly managed with the industry group
- Joint Agency partnerships - jointly funded and / or jointly managed with the agency
- Property Pest Control Plans
- Other programmes specifically approved by Council

The approved programmes with potential relevance to encouraging gorse control are Biodiversity Management Plans, Care Groups, Property Pest Control Plans, and the other programmes not defined (see Appendix 1 for more detail). Other possible sources of assistance for controlling gorse are listed in Table 6.4.

Table 6.4: Other possible sources of assistance for controlling gorse.

Agency	Offers legal protection	Possible funding assistance	Offers management advice
Department of Conservation	Yes	Yes	Yes
Bay of Plenty Regional Council	Yes	Yes	Yes
District councils	Yes	Yes	Not generally
Nga Whenua Rahui	Yes	Yes	Yes
QEII National Trust	Yes	Yes	Yes
Natural Heritage Fund	No	Yes	No
Lottery Grants Board	No	Yes	No
NZ Landcare Trust	No	No	Yes

6.6.3 Efficiency, effectiveness, fairness, practicality

Establishing a programme of advice and incentives to remove gorse puts some or all of the cost of removing gorse on Council, so is more expensive for Council than other measures discussed. However it would still be a cost-effective and cheap way to reduce the nitrogen load to the lake, and possibly more efficient than other policy options because Council would have some influence to ensure the most appropriate removal method occurs on particular properties.

The Council would need to commit about $1.7 million to implement the package of measures to remove 775 ha of ‘dense’ and ‘moderately dense’ gorse in the Rotorua and Ōkāreka catchments (as discussed in previous chapter). This cost includes a component for staff time to set up farm plans and assumes some of the costs are offset by carbon credits from the Afforestation Grant Scheme. The cost does not include any additional incentives that Council might choose to encourage gorse removal.

A funded gorse removal programme is likely to be more effective at ensuring removal of more gorse than the other policy options discussed because funding can be used to address landowner’s inability to pay and removal measures can be targeted towards gorse on most types of land. Nevertheless there is no guarantee landowners will take up any of the assistance offered and some landowners may not want to be associated with the Council through long term agreements. Also, small patches of gorse are likely to remain in the catchment and the responsibility for these patches should ultimately remain with the landowners.

While effective at reducing current areas of gorse, this approach is unlikely to be effective at controlling the expansion of gorse. There would need to be a limited time frame for the programme to prevent any offer of Council funding creating a perverse incentive for landowners to allow the area and density of gorse to increase.

This option is considered fair in that the regional community reap the benefits of gorse removal and the regional community (i.e. Council) covers the costs of gorse removal. It is also fair in that it recognises that there are complex and historical issues for why large areas of gorse remain on many properties (e.g. Māori land in multiple ownership). However it could be argued that providing financial incentives for gorse removal is unfair on those landowners who have already removed gorse from their land – the concept of fairness is complex.

A funded gorse removal programme would be practical and easy to implement, there are established funding programmes with which it could be incorporated. In our view this type of programme would be most effectively implemented in association with other policy approaches such as changing the implementation of Rule 11.

The strengths and weaknesses of a establishing a funded gorse removal programme are listed in Table 6.5.

Table 6.5: Strengths and weaknesses of a funded gorse control programme (e.g. providing incentives for gorse removal through Property Pest Control Plans).

Strengths	**Weaknesses**
Removing gorse is a very cost-effective way to reduce N entering the lake.	Will not remove all gorse in the catchment.
Will reduce current coverage of gorse but not necessarily the future expansion of gorse.	Will cost the Council more than a regulatory approach because of need for assistance and funding.
Is fair because both costs and benefits stay with the community, and it recognises that current gorse cover reflects complex and historical issues.	Incentive may still not be enough to ensure land use change.
Allows landowners to remove gorse voluntarily and in partnership with the Council.	Does not address future gorse expansion unless applied in combination with other approaches.
Can provide a good level of certainty about long term control.	

6.7 Comparison of policy options

We summarised in Table 6.6 how each of the policy options compare against criteria of efficiency, effectiveness, fairness and practicality. All policy options for managing gorse were considered to be efficient because they are relatively low cost to implement compared to considerable water quality benefit of removing gorse from the catchment. A funded programme of gorse removal would cost Council more but from the perspective of region wide benefits would probably be the most cost-effective approach.

All policy options were considered to be effective. Regulatory control of current gorse was considered less effective on its own because we believe that there is a high risk of non-compliance. Regulatory control of future gorse expansion would not, on its own, reduce current gorse, but is likely to have better compliance because it is more manageable but there remain practical implementation issues. Crediting areas of gorse with a higher leaching rate would provide an incentive to control gorse, but it is less certain of addressing the real issues for not removing gorse compared to a programme of gorse removal using property management plans.

Determining fairness is complex, so we primarily assessed it in terms of whether those who pay also receive some benefit. On this basis a Council funded gorse removal programme would be most fair because the regional community would both pay and receive the benefits of cost-effective reduction in nitrogen load. In our view benchmarking gorse leaching as 15 kg/ha/yr is also fair because it increases options for landowners with gorse, but it is a compromise and is still less than the actual rate of N leaching from gorse.

Regulatory control of future gorse is fair in that it prevents future nutrient loads from gorse expansion but could create a perceived inequity based on past land use.

Regulatory options were considered less practical to implement because they require defining the extent, density and maturity of gorse cover – however this is not insurmountable.

Table 6.6: Comparison of policy options against criteria in the code of good regulatory practice.

Code of good regulatory practice guidelines	**Option 1** Regulatory control of current gorse	**Option 2** Regulatory control of future gorse	**Option 3** Benchmark gorse leaching as 15 kg/ha/yr	**Option 4** Funded gorse control programme	**Option 4 + (option 2 or 3)**
Efficiency *Are the costs justified by the benefits?*	√√	√√	√√	√√	√√
Effectiveness at removing current gorse *Will it remove large areas of gorse?*	√	X	√	√√	√√
Effectiveness at preventing future expansion of gorse	√√	√√	√√	X	√√
Fairness *Are those who pay also receiving some benefit?*	X	√	√	√√	√√
Practicality *Can it be reasonably implemented?*	√	√	√√	√√	√√
Cost to Council	low	low	very low	high	high

Key: 'x' = does not meet criteria, '√' =meets criteria, '√√' =meets criteria very well.

6.8 A toolbox of options

Each of the policy options offer different strengths and weaknesses for managing gorse. They should be considered as a toolbox of options, with the greatest benefits achieved when used in combination. In our view the most effective combination would be a funded gorse control programme used in combination with benchmarking gorse leaching at 15 kg N/ha/yr and/or regulatory control of future gorse. Regulatory control of large patches of mature gorse should also be considered to further encourage gorse removal.

Regulatory control of current gorse and benchmarking gorse N leaching as 15 kg N/ha/yr should not be applied together (unless in combination with a funded gorse removal programme), because under this combination removing gorse would have half the N reduction benefit. In contrast, benchmarking gorse N leaching as 15 kg N/ha/yr in the absence of regulatory control provides a market incentive to remove gorse and keeps open the option that if Council pays for gorse removal than any nitrogen credit goes to benefit the lake and is not used to offset land use intensification in other parts of the catchment.

Currently any benchmarked property that wanted to convert land in gorse to dry stock has to obtain resource consent, which acts as a potential barrier. The option of benchmarking areas of gorse with a higher leaching rate (e.g. 15 kg N/ha/yr) would address this, but it could also be addressed by streamlining the consent process to encourage changes in land use that replace gorse with land uses that leach less nitrogen. If it is decided to not make any changes to the way Rule 11 is implemented that it is recommended that the consent process is streamlined to make it easier to convert land in gorse to dry stock farming (or other land uses) which leach less nitrogen.

Removing 775 ha of 'dense' and 'moderately dense' gorse from the catchments was estimated to cost about $1.7 million (including carbon credits but excluding any productivity benefits). This cost has to be covered by someone and we recommend that the cost is covered by Council through a gorse control programme because:

- It provides much more certainty that gorse will actually be removed;
- It is a very cost-effective way to remove nitrogen from the lakes;
- It is fair because the community receives a considerable benefit from less N leaching to the lake.

As discussed a funded programme of gorse removal would be more effective if implemented in combination with other policy measures. A combined approach would also help send a message that, even with Council assistance, gorse removal is ultimately the responsibility of the landowner.

None of these policies (individually or in combination) will completely eliminate gorse from the catchment, but in our view policy changes to incentivise gorse removal would help remove large areas of gorse.

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Appendix 1: Council programmes and plans that are potential funding sources for gorse management.

Biodiversity Management Plans

Council's Biodiversity Programme is a voluntary programme to empower landowners and community groups to protect valuable sites of native biodiversity across the Bay of Plenty. BOPRC work in partnership with landowners/community groups who would like to protect these sites.

Assistance to private landowners through this programme can be for sites with particularly high biodiversity values on private land across the region that have been specifically identified by BOPRC, or for other places that have not been identified as being of outstanding value but which are still of great significance to those who own them.

Assistance to support community care groups can be for sites on publicly owned land in their local area which has significance for them and their community. Both Environment Bay of Plenty and the group work collaboratively with the landowner (the Department of Conservation or a district council for example).

In each case a Biodiversity Management Plan based on clear objectives is drawn up collaboratively by the landowner(s) and a Bay of Plenty Regional Council Land Resources staff member. We can provide financial and technical assistance with the implementation of this plan.

Care Groups

Care Groups are organised community groups which work to protect and enhance a local area of environmental importance. The focus can be coastal, estuary, steam/lake, and/or pest control.

Where the focus of the activity is biodiversity, biosecurity and/or pest control, funding may be available to for gorse control through the Biodiversity Programme (described above), or the Biosecurity Programmes.

Property Pest Control Plans

Council will also consider assisting landowners to meet their obligations under the RPMP by developing Property Pest Control Plans.

Such plans act as agreements between Council and landowners on how they will manage a specified pest on their property. Council may support the plans by providing advice, funding, resources and materials. Property Pest Control Plans will be developed, in agreement with the landowners where there is clear evidence that the following criteria exist:

- It would be unlikely that landowners could meet their obligations (Rules D (1), D (2), D (3), D (4), E (1)) under the RPMP due to the extent and / or density of a pest infestation.
- Specialist skills, materials and / or equipment are needed to control a specific pest in an effective manner.

Prior to deciding whether to develop a Property Pest Control Plan with a landowner(s) Council will assess:

- The nature of the pest problem (this will include determining the scale of the problem and reasons for it).
- The resources and costs necessary to control the pest
- Future management of the site needed to prevent further pest problems
- Risks of no action

A Property Pest Control Plan will be developed if the above criteria are met. Such Plans will specify:

- The property or properties to which it applies
- Term of the Plan
- The pest control objective for the Plan
- Annual milestones
- Control methods and timeframes
- Resources and costs
- S80D exemption (if required)
- Council and landowner obligations

Property Pest Control Plans may also include the implementation of alternative land uses that will assist with minimising the risks of the pest re-infesting the property.

Other unspecified programmes

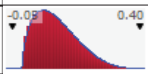
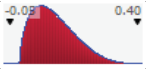
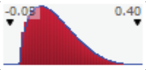
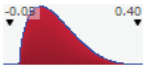
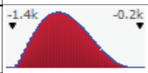
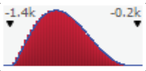
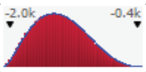
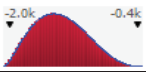
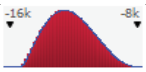
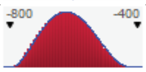
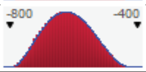
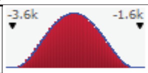
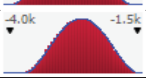
Council may approve other programmes to support pest management on a case-by-case basis.

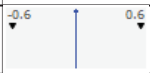
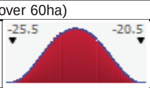
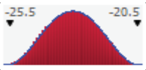
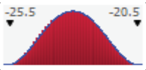
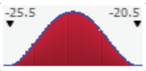
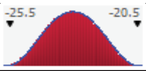
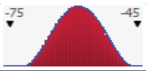
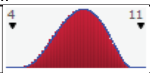
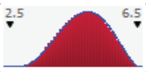
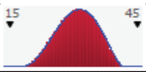
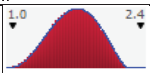
Appendix 2: Inputs to @RISK cost-benefit analysis (8% discount rate)

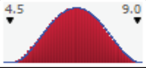
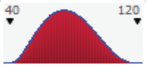
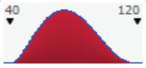
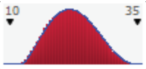
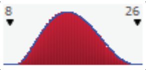
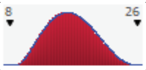
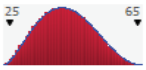
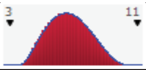
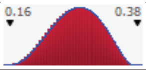
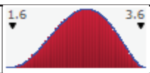
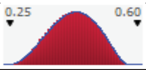
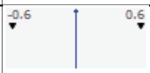
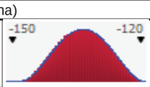
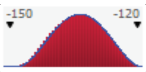
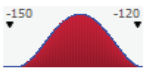
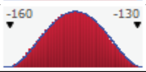
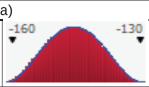
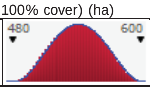
Appendix 2

@RISK Input Results, 8 % discount rate

Performed By: Keith Hamill
Date: Friday, 6 July 2012 10:11:24 p.m.

Name	Worksheet	Cell	Graph	Min	Mean	Max	5%	95%
Category: Attenuation %								
Attenuation % / distribution	1 gorse to pine	B6		0.00	0.11	0.37	0.02	0.24
Attenuation % / distribution	3 gorse to native plantation	B6		0.00	0.11	0.38	0.02	0.24
Attenuation % / distribution	4 gorse to drystock	B6		0.00	0.11	0.37	0.02	0.24
Attenuation % / distribution	2 MIM gorse to native	B6		0.00	0.11	0.38	0.02	0.24
Attenuation % / distribution	5 MIM gorse to native 25yr lag	B6		0.00	0.11	0.38	0.02	0.24
Category: Carbon credit ($/ha)								
Carbon credit ($/ha) / distribution	1 gorse to pine	B26		2,200	2,200	2,200	2,200	2,200
Carbon credit ($/ha) / distribution	3 gorse to native plantation	B26		990	990	990	990	990
Carbon credit ($/ha) / distribution	4 gorse to drystock	B26		0	0	0	0	0
Carbon credit ($/ha) / distribution	2 MIM gorse to native	B26		990	990	990	990	990
Carbon credit ($/ha) / distribution	5 MIM gorse to native 25yr lag	B26		990	990	990	990	990
Category: Establishment cost - fencing								
Establishment cost - fencing / distribution	1 gorse to pine	B20		-1,322	-901	-329	-1,200	-564
Establishment cost - fencing / distribution	3 gorse to native plantation	B20		-1,319	-901	-303	-1,200	-564
Establishment cost - fencing / distribution	4 gorse to drystock	B20		0	0	0	0	0
Establishment cost - fencing / distribution	2 MIM gorse to native	B20		-1,980	-1,352	-490	-1,800	-846
Establishment cost - fencing / distribution	5 MIM gorse to native 25yr lag	B20		-1,979	-1,352	-472	-1,800	-846
Category: Establishment cost - planting etc								
Establishment cost - planting etc / distribution	1 gorse to pine	B19		-1,289	-1,000	-710	-1,186	-814
Establishment cost - planting etc / distribution	3 gorse to native plantation	B19		-14,952	-12,188	-8,380	-14,157	-9,965
Establishment cost - planting etc / distribution	4 gorse to drystock	B19		0	0	0	0	0
Establishment cost - planting etc / distribution	2 MIM gorse to native	B19		-771	-615	-443	-718	-507
Establishment cost - planting etc / distribution	5 MIM gorse to native 25yr lag	B19		-770	-615	-442	-719	-507
Category: Establishment cost - prepare site ($/ha)								
Establishment cost - prepare site ($/ha) / distribution	1 gorse to pine	B18		-3,439	-2,617	-1,775	-3,145	-2,086
Establishment cost - prepare site ($/ha) / distribution	3 gorse to native plantation	B18		-9,604	-7,317	-4,970	-8,793	-5,832
Establishment cost - prepare site ($/ha) / distribution	4 gorse to drystock	B18		-3,592	-2,597	-1,596	-3,242	-1,951
Category: Harvesting cost								
Harvesting cost / distribution	1 gorse to pine	B22		0	0	0	0	0

Name	Worksheet	Cell	Graph	Min	Mean	Max	5%	95%
Harvesting cost / distribution	3 gorse to native plantation	B22		0	0	0	0	0
Harvesting cost / distribution	4 gorse to drystock	B22		0	0	0	0	0
Harvesting cost / distribution	2 MIM gorse to native	B22		0	0	0	0	0
Harvesting cost / distribution	5 MIM gorse to native 25yr lag	B22		0	0	0	0	0
Category: Harvesting return								
Harvesting return / distribution	1 gorse to pine	B23		0	0	0	0	0
Harvesting return / distribution	3 gorse to native plantation	B23		0	0	0	0	0
Harvesting return / distribution	4 gorse to drystock	B23		0	0	0	0	0
Harvesting return / distribution	2 MIM gorse to native	B23		0	0	0	0	0
Harvesting return / distribution	5 MIM gorse to native 25yr lag	B23		0	0	0	0	0
Category: Land lease ($/ha)								
Land lease ($/ha) / distribution	1 gorse to pine	B27		0	0	0	0	0
Land lease ($/ha) / distribution	3 gorse to native plantation	B27		0	0	0	0	0
Land lease ($/ha) / distribution	4 gorse to drystock	B27		0	0	0	0	0
Land lease ($/ha) / distribution	2 MIM gorse to native	B27		0	0	0	0	0
Land lease ($/ha) / distribution	5 MIM gorse to native 25yr lag	B27		0	0	0	0	0
Category: Land mgt agreements ($/ha) (pro rata over 60ha)								
Land mgt agreements ($/ha) (pro rata over 60ha) / distribution	1 gorse to pine	B24		-25	-23	-21	-24	-22
Land mgt agreements ($/ha) (pro rata over 60ha) / distribution	3 gorse to native plantation	B24		-25	-23	-21	-24	-22
Land mgt agreements ($/ha) (pro rata over 60ha) / distribution	4 gorse to drystock	B24		-25	-23	-21	-24	-22
Land mgt agreements ($/ha) (pro rata over 60ha) / distribution	2 MIM gorse to native	B24		-25	-23	-21	-24	-22
Land mgt agreements ($/ha) (pro rata over 60ha) / distribution	5 MIM gorse to native 25yr lag	B24		-25	-23	-21	-24	-22
Category: maintenance cost - prepare site ($/ha)								
maintenance cost - prepare site ($/ha) / distribution	2 MIM gorse to native	B18		-70	-59	-47	-66	-51
maintenance cost - prepare site ($/ha) / distribution	5 MIM gorse to native 25yr lag	B18		-70	-59	-47	-66	-51
Category: N loss from forestry (kg/ha/hr) deep flow								
N loss from forestry (kg/ha/hr) deep flow / distribution	1 gorse to pine	B10		4.87	7.75	10.17	5.99	9.40
N loss from forestry (kg/ha/hr) deep flow / distribution	3 gorse to native plantation	B10		3.05	4.84	6.37	3.74	5.87
N loss from forestry (kg/ha/hr) deep flow / distribution	4 gorse to drystock	B10		19.57	30.99	40.74	23.96	37.60
Category: N loss from forestry (kg/ha/hr) rapid flow								
N loss from forestry (kg/ha/hr) rapid flow / distribution	1 gorse to pine	B5		1.07	1.69	2.21	1.30	2.05
N loss from forestry (kg/ha/hr) rapid flow / distribution	3 gorse to native plantation	B5		0.66	1.05	1.38	0.81	1.28

Name	Worksheet	Cell	Graph	Min	Mean	Max	5%	95%
N loss from forestry (kg/ha/yr) rapid flow / distribution	4 gorse to drystock	B5		4.89	6.86	8.85	5.58	8.14
Category: N loss from gorse (kg/ha/yr) deep flow								
N loss from gorse (kg/ha/yr) deep flow / distribution	1 gorse to pine	B9		45.71	76.73	114.27	55.52	99.44
N loss from gorse (kg/ha/yr) deep flow / distribution	3 gorse to native plantation	B9		45.51	76.73	114.38	55.53	99.44
N loss from gorse (kg/ha/yr) deep flow / distribution	4 gorse to drystock	B9		45.78	76.73	113.86	55.53	99.44
N loss from gorse (kg/ha/yr) deep flow / distribution	2 MIM gorse to native	B9		13.30	22.41	33.26	16.22	29.04
N loss from gorse (kg/ha/yr) deep flow / distribution	5 MIM gorse to native 25yr lag	B9		2.10	3.53	5.24	2.56	4.58
Category: N loss from gorse (kg/ha/yr) rapid flow								
N loss from gorse (kg/ha/yr) rapid flow / distribution	1 gorse to pine	B4		9.93	16.70	24.92	12.08	21.64
N loss from gorse (kg/ha/yr) rapid flow / distribution	3 gorse to native plantation	B4		9.91	16.70	24.85	12.08	21.64
N loss from gorse (kg/ha/yr) rapid flow / distribution	4 gorse to drystock	B4		9.95	16.70	24.77	12.08	21.64
N loss from gorse (kg/ha/yr) rapid flow / distribution	2 MIM gorse to native	B4		25.63	42.87	63.95	31.03	55.56
N loss from gorse (kg/ha/yr) rapid flow / distribution	5 MIM gorse to native 25yr lag	B4		4.04	6.76	10.10	4.89	8.76
Category: N loss from native (kg/ha/hr) deep flow								
N loss from native (kg/ha/hr) deep flow / distribution	2 MIM gorse to native	B10		1.11	1.75	2.30	1.35	2.12
N loss from native (kg/ha/hr) deep flow / distribution	5 MIM gorse to native 25yr lag	B10		0.17	0.28	0.36	0.21	0.34
Category: N loss from native (kg/ha/hr) rapid flow								
N loss from native (kg/ha/hr) rapid flow / distribution	2 MIM gorse to native	B5		1.69	2.71	3.56	2.09	3.28
N loss from native (kg/ha/hr) rapid flow / distribution	5 MIM gorse to native 25yr lag	B5		0.27	0.43	0.56	0.33	0.52
Category: Plantation Mgt								
Plantation Mgt / distribution	1 gorse to pine	B21		0	0	0	0	0
Plantation Mgt / distribution	3 gorse to native plantation	B21		0	0	0	0	0
Plantation Mgt / distribution	4 gorse to drystock	B21		0	0	0	0	0
Plantation Mgt / distribution	2 MIM gorse to native	B21		0	0	0	0	0
Plantation Mgt / distribution	5 MIM gorse to native 25yr lag	B21		0	0	0	0	0
Category: Survellance & advice (prorata over 450ha)								
Survellance & advice (prorata over 450ha) / distribution	1 gorse to pine	B25		-146	-133	-121	-142	-125
Survellance & advice (prorata over 450ha) / distribution	4 gorse to drystock	B25		-146	-133	-121	-142	-125
Survellance & advice (prorata over 450ha) / distribution	2 MIM gorse to native	B25		-146	-133	-121	-142	-125
Survellance & advice (prorata over 450ha) / distribution	5 MIM gorse to native 25yr lag	B25		-159	-144	-131	-153	-136
Category: Survellance & advice (prorata over450ha)								
Survellance & advice (prorata over450ha) / distribution	3 gorse to native plantation	B25		-159	-145	-131	-154	-136
Category: Total gorse in catchment (weighted for 100% cover) (ha)								
Total gorse in catchment (weighted for 100% cover) (ha) / All	package of options	F8		490	542	594	509	576