IN THE MATTER OF	61 consent applications to take, use, divert and dam water and 51 associated discharge and land use consent applications in the Upper Waitaki

STATEMENT OF EVIDENCE OF DAVID ANDREW NORTON

Evidence presented 11 December 2009

Introduction

1. My name is David Andrew Norton. I am an Associate Professor (Reader) at the School of Forestry, University of Canterbury, and hold Bachelor of Science (Honours) and Doctor of Philosophy degrees in botany. I have worked at the University of Canterbury since 1983.

2. I have extensive experience in a wide range of aspects of ecology, conservation biology and sustainable land management, having published over 100 articles in peer-reviewed scientific journals and books, as well as numerous other articles and reports. I am co-author of a book on the threatened plants of New Zealand to be published in January 2010. I have been/am principal supervisor for over 45 postgraduate research students (masterate and doctorate), and teach undergraduate and postgraduate courses in ecology, conservation biology and sustainable land management to both Forestry and Biological Science students.

3. I have considerable research and consultancy experience in the management of native biodiversity in primary production systems. I have published peer-reviewed scientific papers on integrated land management in both agricultural and plantation forest systems (Norton 1998, Norton & Miller 2000), and on the interactions between production management and biodiversity conservation, including the impacts of grazing on forest and grassland ecosystems (Yates et al. 2000, Miller et al. 2004, Ledgard & Norton 2008, Norton et al. 2006a, Norton & Reid 2009, Sage et al. 2009). I currently lead a government and industry funded research programme involving several colleagues and postgraduate students addressing a range of issues relating to sustainable land management in high country pastoral farming systems. A core part of this research has been the development of whole property management plans that aim to integrate economic, biodiversity and social values within high country farms (Norton 2006, 2008).

Scope of Evidence

4. This evidence has been prepared in support of the application by Glenmore Station to renew their existing water rights (applications CRC052501, CRC052502, CRC052503, CRC073109). In this evidence I outline the integrated approach to land management that is being undertaken at Glenmore Station of which this water right renewal application is a part.

Glenmore Station

5. Glenmore Station (19,200 ha) is located on the western side of Lake Tekapo on the edge of the Mackenzie Basin, South Canterbury. It is a long relatively narrow property, extending 30 km northwest from Lake Tekapo to within c. 1.5 km of the boundary of Aoraki/Mount Cook National Park. The property is predominantly pastoral lease (PT001), but includes a small area of freehold title and some land also leased from Mackenzie District Council. These different land tenures are all managed as one farming unit.

6. The land that now forms Glenmore Station was first stocked, probably with cattle initially but then with sheep, some time between 1858 and 1863. Glenmore Station has been farmed by the Murray family since 1918, when on the death of Herbert Nalder the property passed to his daughter Mary, the wife of George Murray. In 1927 the property

was transferred to their son Gerald Murray and his wife Joyce, and has subsequently been farmed by Jim and Anne Murray, and now by Will and Emily Murray.

7. Glenmore Station has a long history of extracting and utilising water from the Cass River. I understand that water was first diverted from the Cass River in 1932 when it was initially used for hydro-electrical power development (some of the infrastructure associated with this is still present). Then in the 1970s a boarder dyke irrigation system was installed and water has been used for irrigation since then.

8. Glenmore Station is a traditional high country property that is farmed in a manner that balances the different environmental attributes of the property. Glenmore Station is an environmentally challenging property, experiencing cold winter temperatures and often dry summers. Summer grazing of high altitude areas is therefore used to spell lower altitude parts of the property which are then used for winter and especially spring/early summer (lambing) grazing. The irrigated flats form a central part of this balanced approach to farm management, enabling the growth of grass for silage production which is essential for winter feed.

9. I have worked closely with Will and Emily Murray over the last few years in assisting them in developing a whole property management plan for Glenmore Station and it is my impression that they are fully committed to farming Glenmore in a sustainable manner that recognizes and promotes the diverse range of values present on the property. Their primary goal is to produce high value merino fibre while also sustaining the significant inherent values (ecological, landscape, historical and recreational) of the property. Maintaining the economic viability of the property is essential for enabling these other values to be successfully managed. The irrigation consents that Glenmore Station are applying for renewal for are an essential part of the economic viability of the property. The whole-property management planning approach being taken by Glenmore Station is new for the high country and is essential to ensure long-term sustainability in this environment. Glenmore Station is thus acting as a role-model for other high country properties.

The Sustainable Farming Fund Project

10. My involvement in whole property management plans arose through a Sustainable Farming Fund project (04/063; "*Can native biodiversity conservation and economic production be compatible activities in the high country?*") with industry funding from the High Country Accord, High Country Section Federated Farmers and Merino Inc. The objectives of the project were:

    a. Determining the optimum way that a whole property farm management plan might be written to facilitate the management of a range of values (economic, native biodiversity, recreation, aesthetic) in an integrated and sustainable manner.

    b. Assessing the role of covenants as a tool for achieving the desired environmental outcomes as part of a farm management plan.

    c. Identifying the most cost-efficient manner for developing and implementing farm management plans.

d. Making a farm management plan template available to the high country farming community.

The final output from this project was a report titled "*Guidelines for Preparing Whole Property Management Plans for High Country Farms*", a copy of which is appended to this evidence.

11. These guidelines were produced to assist high country farmers prepare whole property management plans for their properties. Whole property management plans are management plans that incorporate environmental issues into the economic management of a property. The guidelines were written to enable individual farmers to prepare a management plan to meet their own situation. Most farmers prepare business plans for their properties and many have plans for other parts of their farming operation (e.g., nutrient plans). The management planning process described in the guidelines is designed to complement business and other management planning undertaken by the farmer by providing a broader perspective on the manner in which a property is managed to include a range of environmental considerations.

Why whole property management plans?

12. High country farms are unique within the New Zealand agricultural sector not only because of their size and demanding environmental conditions, but also because of the wide range of values present (e.g., native biodiversity, historic, recreation and landscape as well as economic). Most high country farmers chose to farm in these environments because of the presence of these multiple values; they provide both an opportunity and a challenge for farm management, while farmers themselves feel a strong sense of stewardship in terms of sustaining these diverse values for future generations.

13. It is my opinion that three factors are increasingly making management planning a necessary part of farming in these environments;

    a. Resource consent requirements.

    b. The need to be able to demonstrate sustainable land management as part of product marketing.

    c. The desire of some high country farmers to continue managing significant inherent values on their properties after a Tenure Review.

14. The public has become increasingly involved in discussions on high country farm management through the implementation of the Resource Management Act 1991 as well as the tenure review process. Both the tenure review debate and the resource management process have focused on the way farmers manage their land and highlighted the broad range of groups that believe they have a stake in this management (local communities, NGOs, territorial local authorities, Government agencies). As a result, regional and local councils have increasingly been regulating through the planning process to ensure that many farm management activities are open to broader scrutiny through the use of rules in District and Regional Plans that require resource consents for activities as diverse as native vegetation clearance, burning, tree planting, irrigation and tracking. Farm management plans are a tool that can be used by farmers to address these issues.

15. The nature of the farming industry has also been changing, especially with respect to the marketing of farm products overseas. For example, supermarket chains in Europe are increasingly asking questions about the way that animals and the land they are reared on is managed in the production of meat, while the clothing industry has also started to use environmental "clean green" images as a way to distinguish wool products from artificial fibres (e.g., Howies in the UK and Smart Wool in the USA). The New Zealand Merino Company has developed the "Zqüe" initiative to meet the demands of the international market with respect to both animal welfare and environmental management. The Zqüe accreditation programme aims to ensure environmental, social and economic sustainability, animal welfare and traceability. Canterbury Meat Packers have developed their "On-Farm Quality Assurance Programme" to ensure that lamb, sheep and cattle meat products sourced from their producers meet the standards demanded by international supermarket chains such as Waitrose in the UK. It is likely that international schemes such as LEAF (Linking Environment and Farming) will become a requirement for New Zealand producers who wish to sell into particular overseas markets. The focus of LEAF is on viable agriculture which is environmentally and socially responsible. All of these systems require farmers to meet particular standards in the way they manage their animals and land, standards which are readily incorporated into a whole property management plan.

16. Notwithstanding the recent debates over the status and management of Crown pastoral leasehold land and especially the tenure review process, some high country farmers wish to continue farming under a pastoral lease environment, including managing the significant inherent values on their property. Other high country farmers are still keen to freehold their properties including areas that have significant inherent values. In both cases, whole property management plans can provide guidance in integrated land management.

17. Whole property management plans are important for high country farmers as they can assist them in addressing all of the above issues as well as other aspects of farm management. Specifically management plans can:

    a. Assist farmers in the resource consent process through Regional and District Plans by showing how a particular management action (e.g., water extraction, burning or tree planting) fits within the overall goals for the property.

    b. Provide documentation and guidance to assist farmers in meeting environmental and animal welfare certification and auditing requirements (e.g., through the Zqüe programme).

    c. Provide the management planning framework that those farmers who continue to farm SIVs either under leasehold or post-tenure review freehold arrangements.

    d. Enable farmers to set and record their goals and objectives for the property.

    e. Through a formalised monitoring programme, assist farmers to identify developing problems before they become major issues and hence may still be readily manageable.

18. Whole property management plans are likely to be particularly important as part of the process of providing assurances to stakeholders, regulators and markets about the way in which a particular property, including its SIVs, is being managed. When linked to a set

of standards and verifiers, management plans become the central component of the overall environmental and animal welfare certification and auditing process for a property. Management plans also provide an excellent tool to enable farmers to formalize their own best-management-practices, and as such can be an invaluable tool for guiding farm employees and contractors. However, in order to successfully meet the objectives outlined above, management plans needs to be implemented in a cost effective manner; management planning will only work if it adds value to the farming community.

Structure of a whole property management plans

19. I now provide a brief overview of the different parts of a whole property management plan which fall into four sections:

    a. Introduction.

    b. Management Units.

    c. Management Approach.

    d. Implementation.

    However, the different parts that are covered within these sections will vary between properties.

20. The first part of the management plan provides the context for management of the property. It not only reviews the context within which the property is located, but also outlines the likely factors that will constrain the farmer's ability to meet their desired vision and goals for the property. This part of the management plan is divided into five sections.

21. Introduction: The introduction provides a brief background to the property including its location and some comments on the property's history. The introduction outlines the management structure for the property (e.g., family or company) and the approach or philosophy (e.g., holistic farm management) that is taken to property management. In particular, this section needs to clearly articulate the drivers for management plan development; in essence the reasons why the management plan has been developed (e.g., market driven).

22. Management Plan Context: It is not possible to develop a management plan for a high country property without first considering the legislative, market, environmental and socio-economic context within which the property is managed. Each of these issues shapes in some way the vision and goals that are appropriate and possible for the property. Preparation of this section is a useful reminder to the farmer of the diversity of issues that affect the management of the property. The Context section outlines the broad parameters within which property management works (e.g., the provisions of a Regional Plan).

23. Vision and Goals: This is the most important section of the management plan as it describes the vision that the farmer has for their property and the goals that need to be met to achieve this vision. The vision is a generic statement about how the farmer would like to see the property in the future (perhaps when it is handed on to the next generation) and ideally should include a set of more specific outcomes that need to be

met if the vision is to be achieved. The vision and especially management outcomes are likely to have a relatively long time-frame – perhaps 30 years. However, in order to meet this, short-term management goals need to be identified which outline the management steps that will be taken to meet the vision. Five-years is suggested as an appropriate time-frame for these goals because it is short enough to be realistically achievable, but long-enough to see real progress made towards the long-term goals.

24. Summary of Property Management: This section expands on the management structure of the property. It should describe the basic approach towards farming (e.g., the mixture of income streams), the staff employed on the property and contractors used for particular tasks, the way the property is set up in terms of infrastructure, any reliance on external land (e.g., down-country leasehold or freehold land for finishing), and other general matters relating to property management. More specific details on stocking patterns, pasture types, fertilizer regimes are included in latter sections of the plan.

25. Opportunities and Constraints: This section of the management plan outlines both the opportunities that the property offers for sustainable farm management, and the factors that are likely to limit the success in achieving the management goals for the property, and ultimately the long-term vision for the property. Some constraints can also be opportunities (e.g., the location of the property close to a major tourist centre, or the presence of particular environmental conditions).

26. Management Units: Most high country properties are diverse, and this diversity results in a diverse range of intrinsic values across the property and a diverse range of management actions that are required. This section provides both a division of the property into management units and the identification of management objectives for each unit. These management objectives outline the key approaches to the management of each unit and reflect the underlying economic and environmental (including social) values of the property. For example, some parts of the property might have as their primary management objective the production of high quality pasture for lamb finishing and/or silage production while other parts of the property might have as their primary management objective the provision of public access and conservation of particular native biodiversity values (e.g., snow tussock grasslands), with economic use restricted to a limited grazing period.

27. The next section of the whole property management plan is likely to be substantial as it discusses the strategic approach to different aspects of property management in order to meet the goals for the property. While this section is obviously critical to the overall plan, it is not possible to foresee all management approaches that might be used and it is important to allow for regular revision and updating of these. This part of the management plan should be divided up into the main components of management such as stocking, pasture improvement, animal and plant pest control, recreational management, native biodiversity management etc, although the actual components included will vary from property to property. Each of these will then require sufficient detail on the strategic approach to each issue in order to guide day-to-day management but should not be prescriptive in specifying the specific management actions that will be undertaken (e.g., the winter feed species grown or type of herbicide used). The following are likely components for most high country properties:

    a. Finances.

    b. Infrastructure.

c. Pasture and soils.

d. Stock.

e. Plantations and woodlots.

f. Plant and animal pests.

g. Native biodiversity.

h. Recreation and historic resources.

i. Agrichemicals.

j. Energy & water efficiency/quality.

k. Health & safety.

28. The final section of the management plan discusses the implementation of the plan and comprises two parts.

29. Monitoring: This section outlines the methods that the farmer will use to monitor the consequences of management actions. Monitoring is important for several reasons:

a. Providing direct feedback to the farmer on how successful different management actions have been in meeting their goals and vision for the property.

b. Quantifying the outcomes of farm management in order to meet the goals of an environmental and animal welfare certification and auditing programme such as Zqüe or LEAF.

c. Providing assurance to external stakeholders (e.g., territorial local authorities) that management actions are meeting regulatory or legislative requirements.

d. As a more general advocacy tool for showing how high country farming is meeting local, regional and central Government goals in relationship to sustainable land management, native biodiversity conservation and public access.

30. Many of the management actions assessed in the monitoring section relate back to the specific performance targets set with the individual management goals and as such provide the quantification of the success of management at meeting these goals. Monitoring is an integral part of adaptive management, in that management actions should be modified (adapted) in response to the information that monitoring results provide. For example, monitoring may show that a particular stocking level is having unacceptable impacts on tussock cover and hence stocking patterns need to be altered.

31. The monitoring section should identify the different aspects of the property that will be monitored and introduce the methods that will be used for monitoring these. All high country properties already measure a range of indicators of management actions (e.g., weaning percentages and soil fertility levels), but with an increasing focus on environmental and animal welfare certification as well as regulator requirements, additional management actions will need to be monitored. A diverse range of monitoring

indicators are available, not all of which will be applicable on every property. Examples of monitoring indicators include:

a. Economic indicators.
    i. numbers of animals
    ii. average animal body weight (kg/animal)
    iii. weaning percentages (% per ewe, cow or hind)
    iv. wool clip (kg/animal)
    v. soil fertility levels (N, S, P, cations, pH etc)
    vi. agrichemical use (litres/animal/yr or litres/ha/yr)
    vii. fertiliser use (tonnes/ha/yr)
    viii. animal densities (e.g., number animals/ha)
    ix. carbon footprint (balance between emissions and sequestered CO_2)

b. Environmental indicators.
    i. tussock density (numbers/ha)
    ii. bare ground (% cover)
    iii. weed abundance (% cover)
    iv. native animal numbers (e.g., counts of particular species)
    v. pest animal densities (e.g., McLean scale for rabbits)
    vi. stream/lake health (e.g., nutrient levels, invertebrate community composition or water clarity)

c. Recreation indicators.
    i. number of visitors to or through property
    ii. track or hut usage

32. Implementation: This final section of the management plan discusses how the plan will be implemented, the way that farm operations will be reviewed, and the role of external stakeholders if any in this review. Most farmers have an annual business plan and may or may not have an annual work plan. An annual work plan that outlines the specific work programme in relation to the management plan goals is an important component of management planning and should be developed alongside the annual business plan. It does not need to be long, but should outline the key tasks that need to be done in the forthcoming year and should relate directly to the goals in the management plan. Routine farm management activities need not be included in detail, but an outline of seasonal farm tasks should be

Glenmore Station whole property management plan

33. Glenmore Station has developed a whole property management plan which was implemented in February 2008. While I assisted in the preparation of this plan, Will and Emily Murray played the pivotal role in developing the goals and objectives for the property, and in deciding on the management approaches that are required to achieve these. The Glenmore Station Farm Management Plan is based on a number of key assumptions:

a. It is not possible to promote ecological sustainability or protect significant inherent values without having clearly identified management goals.

b. The promotion of ecological sustainability and protection of significant inherent values is not possible without the security of a financially viable farming operation.

c. Management actions need to be undertaken in a planned and staged manner. This is necessary both to ensure that management actions build on a solid base and to spread the resource requirements of management over achievable time frames.

d. The management of significant inherent values is an integral part of farm management, and is of value to Glenmore Station in itself and through its value for marketing the merino fibre produced on Glenmore.

34. Will and Emily Murray see the production of this management plan as being undertaken for four main reasons:

a. As a "stock-take" of their farm management, past, present and future.

b. To provide documentation and guidance to assist them in meeting environmental and animal welfare certification and auditing requirements associated with the marketing of their farm products (e.g., through the Zqüe programme).

c. To assist in obtaining discretionary consents from LINZ for a variety of farm management activities that they might wish to undertaken under their pastoral lease.

d. To assist in the resource consent process through Regional and District Plans by showing how a particular management action (e.g., water extraction, burning or tree planting) fits within the overall goals for the property.

35. The vision and long-term goals outline how Will and Emily Murray would like to see Glenmore Station at the end of their period of stewardship (in approximately 30 years time). Their vision is:

"*The economic potential of Glenmore Station is being fully utilized while maintaining and, where appropriate, enhancing other values present (especially native biodiversity and recreation), in a manner that is resilient, dynamic and flexible.*"

This vision is founded on the assumption that to successfully manage Glenmore Station the property must remain balanced (especially bottom blocks including irrigated land versus tussock tops) to ensure that the underlying ecosystem values (which support economic, biodiversity and recreational opportunities) are sustained. Without this balance, it is not possible to manage the whole property in an ecologically sustainable manner, which will result in a loss of the full range of values present.

36. In order to achieve this vision, Will and Emily Murray have identified seven outcomes they believe that it is important to achieve over the 30-odd years of their stewardship of Glenmore Station:

a. Glenmore Station is an economically viable farming unit.

b. Glenmore Station provides for the family needs.

c. Farm management is a multifaceted and sustainable operation.

d. Animal welfare issues are a central consideration in farm management.

e. Significant inherent values on Glenmore Station are being sustainably managed.

f. Appropriate public use of Glenmore Station is facilitated.

g. Management activities are monitored.

37. In order to meet the vision and 30-year outcomes, a series of five-year management goals have been developed. These goals have been split into two groups. The first set relates to management outcomes that are essential for the core viability of Glenmore Station – unless these goals are meet it will not be possible to meet the other goals and the overall vision. These are:

a. Maximising the economic potential of Glenmore.

b. Ensuring Glenmore continues to irrigate.

c. Sustainably managing significant inherent values.

38. The remaining goals, which are grouped within broad management activity areas (see Paragraph 27 above), provide the targets that current management is working towards and can be regarded as "stepping-stones" towards achieving the 30-year outcomes. Each five-year management goal has a performance indicator that can be used to measure the success of farm management in achieving the goal against. Five-years has been chosen as the time-period for these goals because it is short enough to be realistically achievable, but long-enough to see real progress made towards the long-term goals.

39. A key part of the Glenmore management plan is the focus on environmental monitoring. Monitoring is seen as fundamentally important to management as it provides direct feedback to Will and Emily on the success of different management actions and provides the basis for modifying management if the goals for the property are not being achieved. The monitoring being undertaken on Glenmore Station is described in more detail below.

Environmental work at Glenmore Station

40. Will and Emily Murray have been very proactive in facilitating the implementation of a range of environment research projects on Glenmore Station as part of our high country research programme. The Murray Family also has a long history of association with other research groups, especially through facilitating long-term research on wading birds in the Mackenzie Basin. The following paragraphs provide a brief summary of the environmental research we have been undertaking on Glenmore Station over the last few years. All of this research is focused on sustaining native biodiversity within the context of Glenmore Station as a sustainable farming operation and has been developed with strong input and support from the Murray family.

41. Influence of management inputs of plant biodiversity: This study investigated the effects of different grazing patterns (0.02-2.07 su ha^{-1} yr^{-1}), and fertiliser and seed inputs on plant biodiversity in a short tussock grassland with a strong *Hieracium pilosella* component. Ordination of floristic data separated the block with the highest stocking rate from other blocks. Several exotic species were significantly more abundant in this block, while several indigenous species were either absent or uncommon, but were significantly

more abundant in other study blocks. *H. pilosella* was significantly more abundant in blocks with lower stocking rates. Diversity was significantly higher and evenness significantly lower in the highest stocking rate block than in other blocks. Plants of the native tussock *Festuca novae-zelandiae* were also significantly taller in the highest stocking rate block. These floristic differences were most likely caused by differences in management inputs. Fertiliser and over-sowing reduce the abundance of *H. pilosella* and diversity of native species, but increase the abundance of other exotic species and native tussocks (Norton et al 2006a).

42. Small-scale vegetation patterns in short-tussock grassland: Spatial studies of ecology rarely look at small scale spatial community organisation within multiple plots on multiple sites, therefore it is difficult to draw conclusions which can be generalised. We hypothesised that spatial patterns of *Festuca novae-zealandiae* should be consistent within a site and between a variety of sites because species autoecology is consistent. Tussocks were mapped in 15 plots ranging in size from 100 to 400m^2 spread over four sites. At very small scales regularity was detected in ten of the plots with randomness in the other five plots. At larger scales, all but one plot indicated that there was only either randomness or aggregation. Although the results indicate that small scale spatial patterns of *Festuca novae-zealandiae* were broadly consistent, within site, variation is important and cannot be ignored (Dickinson 2008).

43. Barriers to restoration success: High country ecosystems have crossed ecological thresholds as a result of the impacts of 700 years of human settlement that are now preventing the re-establishment of native woody species. One of these thresholds involves change in establishment conditions for native woody seedlings as soil moisture conditions are significantly drier in an open-grassland environment today than they would have been in a woody environment in the past. A randomised shade experiment has been established with measurements being made of plant (mouse-ear hawkweed) and soil moisture levels under the different treatments. This research showed that shade significantly increased soil and plant moisture levels over those occurring in unshaded sites, suggesting that loss of shade represents a significant limitation to the natural regeneration of native woody vegetation in this environment (Payne 2009).

44. Grazing limiting mouse-ear hawkweed flowering: A statistically significant difference in *Hieracium pilosella* inflorescence density and sheep grazing density is documented supporting the suggestion that grazing during flowering may reduce fecundity and seedling establishment of *Hieracium* species (Norton & Reid 2009).

45. Hawkweed invasion in summer grazing country: Several *Hieracium* species are present through the South Island high country and some of these species still appear to be expanding their range into high-altitude tussock grassland communities. This project is investigating the distribution of mouse-ear and king-devil hawkweeds in high altitude (1100-2000 m) tussock grassland communities in a summer grazing block on Glenmore Station. The research will establish both the type of community that hawkweed species are invading and provide a benchmark for comparing future assessments of hawkweed abundance in this area against.

46. Rabbit and hare diet: This research is looking at seasonal differences in the diet of rabbits and hares in degraded short tussock grassland and river flat sites on Glenmore Station. The research is still ongoing and aims to collect data over two years on animal diet.

47. Relative impacts of hares and merino sheep in summer grazing country: We established five 20 x 20 m exclosure plots in tall-tussock grassland in January 2009, with sufficient fencing material available to build a further five in short-tussock grasslands over the 2009/10 summer. The exclosure plots are fully sheep proof, and half of each plot (20 x 10 m) is also rabbit and hare proof. These plots have been established in order to undertake a long-term study of the relative impacts of sheep and hares on biodiversity values in summer grazing country.

48. Spatial habitat use of merinos: We have been undertaking a number of studies investigating spatial habitat use by merino ewes in both lambing and summer grazing blocks on Glenmore Station. We have recently secured additional funding to continue this research over the next three years. The focus of this research is on better understanding the way that ewes utilise habitat, how they respond to adverse weather events, and how the grazing patterns impact on native biodiversity.

Monitoring on Glenmore Station

49. Monitoring at Glenmore Station focuses on a range of economic, environmental and social attributes. Within the Glenmore Station Management Plan the following areas of monitoring are identified:

    a. Stock number and condition

    b. Pasture and soil condition

    c. Chemical-use (including fertilizer use)

    d. Plant and animal pests

    e. Landscape photo monitoring

    f. Land-cover

    g. Aquatic health

    h. Other biodiversity monitoring

    i. Recreational use

    j. Energy use

    The following paragraphs discuss the land-cover, aquatic and soil monitoring programme being undertaken, and some of the initial results from this.

50. Environmental monitoring at Glenmore involving land-cover, aquatic and soil attributes was developed as part of the ARGOS (Agricultural Research Group on Sustainability) programme. Full details on the methods used are provided in Norton et al. (2006b). The primary goal of the ARGOS high country monitoring programme is to assess the response of high country ecosystems to:

    a. Management inputs.

    b. External perturbations such as climate change or species invasion.

51. Land-cover monitoring is based on 25 m long sampling transects. These were located in a stratified random manner across Glenmore using the broad landform patterns present and farm management units (e.g., over-sown versus undeveloped) as a basis for stratification. An attempt was made to keep the density of monitoring sites proportional to the area of each landform/management unit, although high mountainous areas were usually under-sampled relative to the more accessible and usually more developed lower parts of properties. No permanent vegetation monitoring sites were located within regularly cultivated blocks, as the monitoring layout with permanently fixed metal standards is not compatible with cultivation.

52. Monitoring points were located randomly and marked by labelled metal standards set 25 m apart. Land-cover measurements were then made within a transect located between the two metal standards and photos taken from each end looking down the transect. The transect involved ten 2x2 m contiguous plots that were centred along the centre-line between the two standards starting at 2.5 m from the first standard and finishing 2.5 m before the second standard. Vegetation cover abundance measurements were made in the first two 2x2 m plots at each end of the transect, while photographs were taken looking down the transect from either end, and across each transect (Appendix 1).

53. Forty eight monitoring sites were established across Glenmore over the 2005/06 summer spread across seven landform/management units as follows (Appendix 2):

    a. Improved downlands – 12 monitoring sites

    b. Unimproved downlands – 10 monitoring sites

    c. Improved river flats – 2 monitoring sites

    d. Unimproved river flats – 3 monitoring sites

    e. Improved lower mountain slopes – 8 monitoring sites

    f. Unimproved lower mountain slopes – 7 monitoring sites

    g. Higher mountains (unimproved) – 6 monitoring sites

    These sites were re-photographed during the 2008/09 summer and a full re-measurement is being undertaken over the 2009/10 summer.

54. Two examples of photopoints spanning the three periods sampled are included as Appendix 3, to illustrate the type of information that can be gained from the photo-monitoring. However, a full assessment of the land-cover monitoring will not be undertaken until after the 2009/2010 reassessment has been completed.

55. Aquatic monitoring followed standard protocols (Stark et al. 2001). Lakes and tarns were not sampled during this monitoring. Aquatic systems were divided based on their size and source, with three main types recognised:

    a. Large (>5 m) streams/rivers with unstable beds.

    b. Smaller (<5 m) non-spring fed streams with more stable beds.

    c. Smaller (<5 m) spring fed streams with stable beds.

In addition, consideration was given to the type of land management occurring within the catchment of individual streams.

56. Final monitoring sites were chosen randomly, the monitoring being established on the first section of stream immediately upstream from the random point that was relatively uniform for at least 10 m (the sampling reach). The upstream end of this reach was marked by a metal standard, with a second standard located 25 m downstream from this on the opposite bank. Within each sampling reach the following were recorded:

    a. Physio-chemical variables (width, depth, velocity, substrate size, stream channel stability (Pfankuch Channel Stability evaluation system), water temperature, pH, conductivity and turbidity)

    b. Phosphorous and nitrogen levels (samples sent to Hill Laboratories for analysis).

    c. Quantitative benthic invertebrate fauna using a Surber sampler (Protocol C3, Stark et al. 2001)

    d. Semi-quantitative benthic invertebrate fauna using a "kick net" (Protocol C1, Stark et al. 2001).

57. We are also monitoring water level at three points on the property (two tarns and Joseph Creek). Some initial results are included as Appendix 4.

58. During the 2005/06 summer, 10 aquatic monitoring sites were located on Glenmore Station. These monitoring sites were spread between the three main stream types present (Table 1), with one stream (Joseph Stream) sampled three times to assess the influence of management actions, upstream and downstream of a recently cultivated area, and downstream of a fenced off riparian planting. Monitoring site locations are illustrated in Appendix 2. These sites will be re-measured during the 2009/10 summer, with a full assessment of the aquatic monitoring results then undertaken.

59. Soil monitoring sites (SMSs) are based on management units (MUs), with three individual soil assessments made in each MU. Selection of MUs for soil monitoring at Glenmore were based on the established land-cover monitoring system, with MUs spread between three broad management zones:

    a. Cultivated and often irrigated flats (3 MUs)

    b. AOSTD (Aerial, Oversown, Top Dressed) lower hill country. (7 MUs)

    c. Undeveloped (native) higher hill country (2 MUs)

    Within each of the three management zones, MUs were selected randomly based on the land-cover monitoring sites. The selected land-cover monitoring sites were then used as the location for the first SMS (Appendix 2).

60. Within each SMS the following were measured:

    a. Nutrient analysis and microbial activity – based on a sample of ten soil cores (0-7.5 cm depth) collected from each SMS, with the 10x3 samples collected from each MU combined into a single prior to lab analysis. Individual soil cores were collected randomly from the area around the SMS. Soil nutrient analyses

included pH, Olsen-P, Resin - P, calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), P retention (ASC), anaerobic mineralisable-N (AMN), sulphate-S (SS), cation exchange capacity (CEC), % base saturation (%BS), weight/volume (w/v), and soil C and N. In addition soil respiration and soil microbial biomass were determed, and bulk density measured.

b. Soil texture, ground cover, thatch build-up, soil porosity, the presence of mottles and gleying and soil aggregation (all assessed in the field) from a single representative soil pit.

c. Earthworms and other macroinvertebrates present were collected from this pit for subsequent analysis.

61. Soil monitoring was undertaken in 2006 and 2008, and is scheduled to be repeated in 2010 when a full analysis of changes will be undertaken.

Conclusions

62. It is my opinion that Will and Emily Murray are fully committed to farming Glenmore Station in a sustainable manner that focuses on the full range of values that are present on the property including environmental, social and economic values. To be able to do this, the Murrays need to have an economically viable farming operation, with irrigated land an essential component of this. Without the irrigated flats, the Murray's are unable to maintain the balance of the property which in turn means that they are unable to manage the other values that are present.

63. I am therefore requesting that Environment Canterbury grant these consents for water extraction and to enable Glenmore Station Ltd. to continue to farm in a sustainable manner.

Literature cited

Dickinson Y 2008. The spatial patterning of *Hieracium pilosella* invaded short tussock grasslands. Unpublished M.For.Sc thesis, University of Canterbury, Christchurch.

Ledgard NJ, Norton DA 2008. The impact of browsing on wilding conifers in the South Island high country. *New Zealand Journal of Forestry 52(4):* 29-34.

Miller CJ, Norton DA, Miller TK 2004. Kahikatea *Dacrycarpus dacrydioides* and Totara-Matai *Podocarpus totara-Prumnopitys taxifolia* forest patches in the agricultural landscape, Westland, New Zealand: representatives of a past and future condition. *Pacific Conservation Biology 9*: 278-293.

Norton DA 1998. Native biodiversity conservation and plantation forestry: options for the future. *New Zealand Forestry 43(2)*: 34-39.

Norton DA 2006. Managing high country landscapes into the future. In, R.S. Lough, editor. High Country landscape Management Forum 2005 Proceedings. Otago Regional Council, Dunedin. Pp 97-103.

Norton DA 2008. *Guidelines for Preparing Whole Property Management Plans for High Country Farms.* School of Forestry, University of Canterbury, Christchurch.

Norton DA, Espie PR, Murray W, Murray J. 2006a. Influence of pastoral management on plant biodiversity in a depleted short tussock grassland, Mackenzie Basin. *New Zealand Journal of Ecology 30*: 335-344.

Norton DA, Lucock D, Sage DE, Stevenson M 2006b. High country environmental monitoirng report 2005-06. Unpublished ARGOS High Country Environmental Report 1.

Norton DA, Reid N 2009. Sheep grazing reduced *Hieracium pilosella* flowering. *New Zealand Journal of Agricultural Research 52*: 129-131.

Payne T 2009. Influence of shade on foliage and soil moisture levels in degraded tussock grasslands: Identifying ecological thresholds for restoration. Unpublished B.Sc. Honours dissertation, University of Canterbury, Christchurch.

Sage DJM, Norton DA, Espie, PR 2009. Effect of grazing exclusion on the woody weed *Rosa rubiginosa* in high country short tussock grasslands. *New Zealand Journal of Agricultural Research 52*: 123-128.

Stark JD, Boothroyd IKG, Harding J, Maxted J., Scarsbrook MR 2001. Protocols for sampling macroinvertebrates in wadeable streams. New Zealand Macroinvertebrate Working Group Report No.1, Sustainable Management Fund Project 5103 report prepared for Ministry for the Environment.

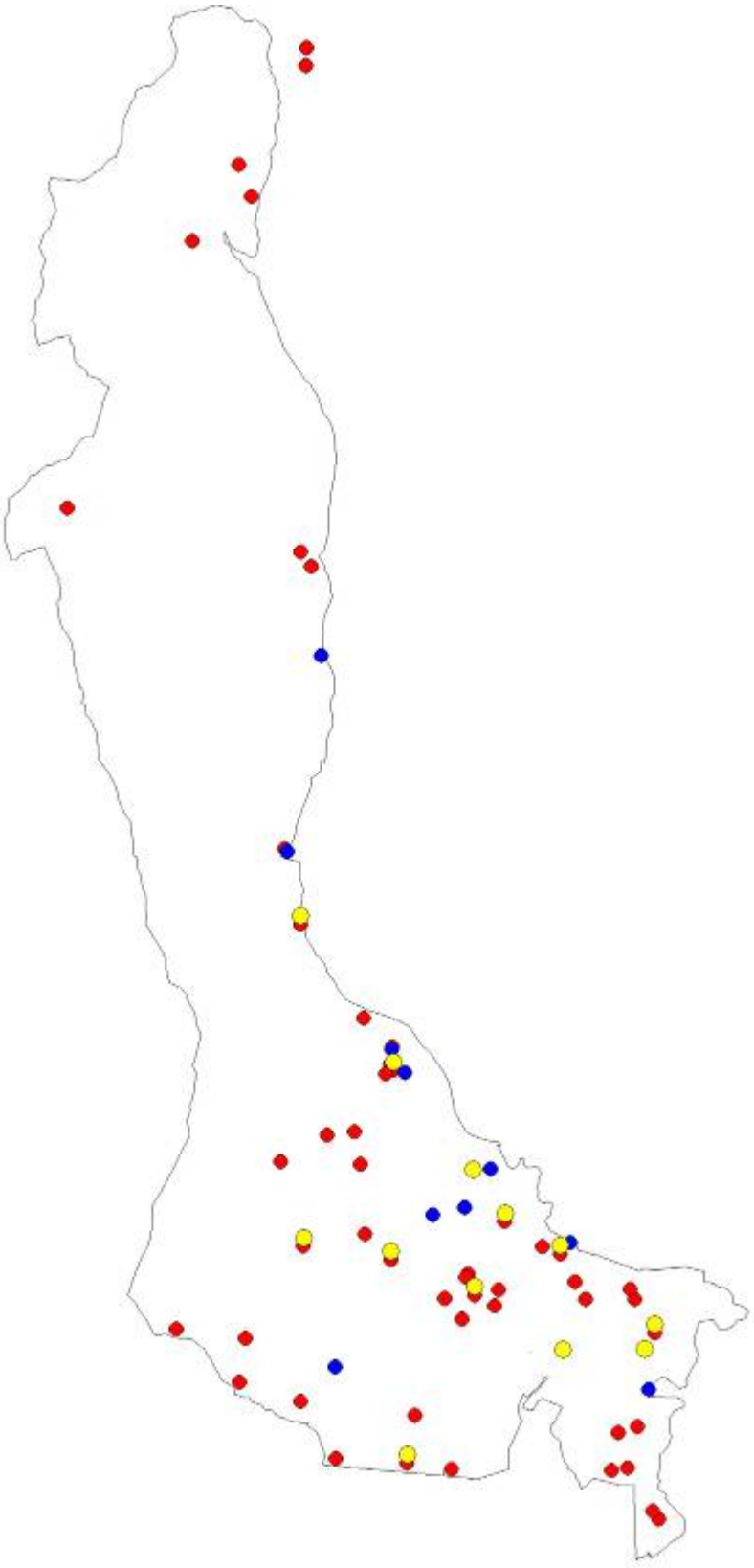
Yates CJ, Norton DA, Hobbs RJ 2000. Grazing effects on soil and microclimate in fragmented woodlands in south western Australia: implications for restoration. *Austral Ecology 25*: 36-47.

Appendix 1

Landscape view along one monitoring transect, with two close up photographs taken from both ends of the transect.

Appendix 2

Location of land-cover (red and yellow), soil (yellow) and aquatic (blue) monitoring sites.



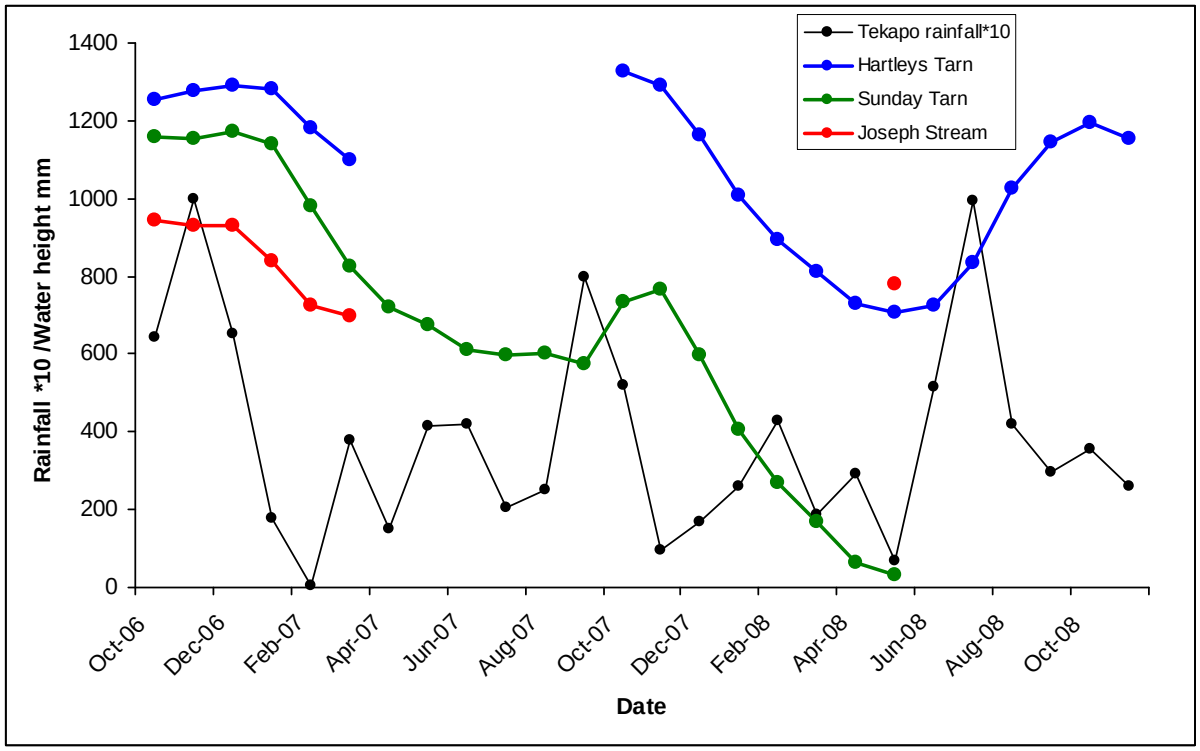
Appendix 3

A – Repeat monitoring land-cover transect 1, Old Glenmore.

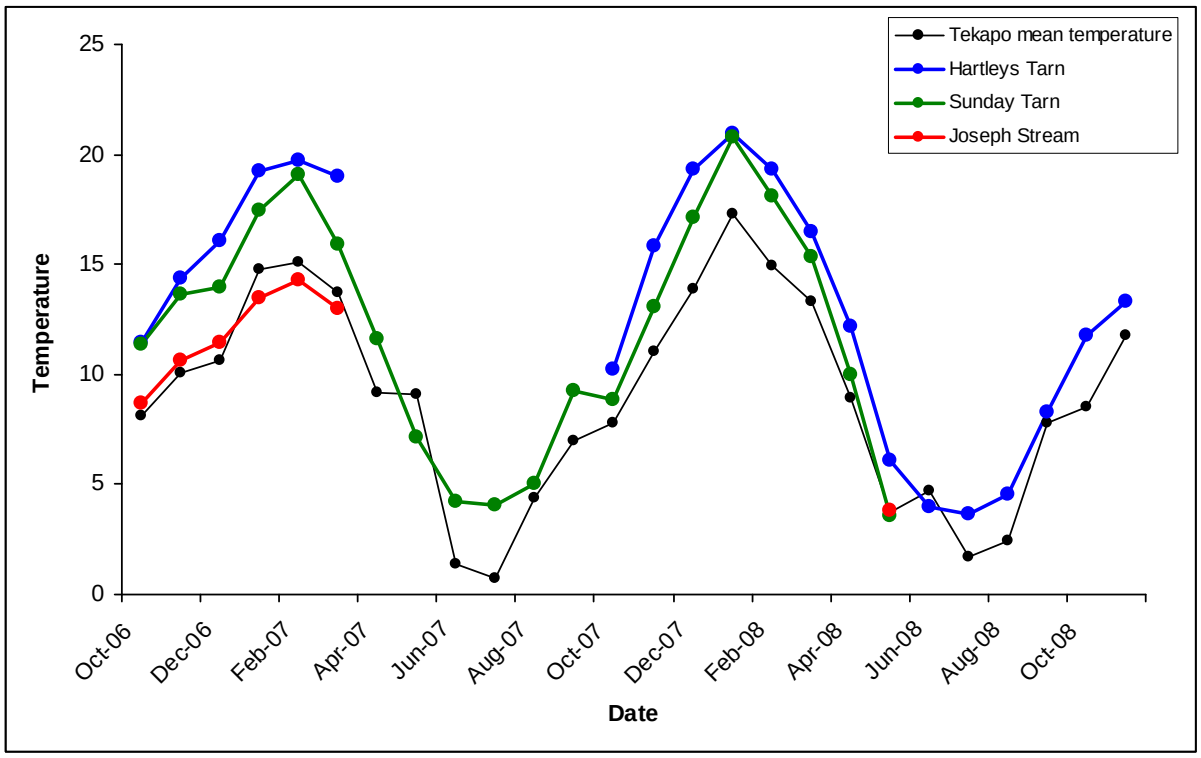
B – Repeat monitoring land-cover transect 32, Sardine.

Appendix 4

Preliminary results from tarn and stream water level and temperature monitoring.



Water level (mm) and Tekapo EWS rainfall (mm)



Water temperature (°C) and Tekapo EWS temperature (°C)