A COMPARISON OF ENVIRONMENTAL RISK MODELS DEVELOPED FROM NZLRI AND TOPOCLIMATE SOUTH SOIL SURVEY DATA

Tabitha Anthony

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Abstract

Land evaluation models can be prepared with an environmental focus to assist policy makers to determine areas at risk to a particular issue. The Southland Region of New Zealand has seen an increasing number of dairy farm conversions over recent years. The environmental risks due to the intensive nature of dairy farming are well documented, two of the issues are decreased water quality from nutrients and sediment and decreased soil quality from structural breakdown and erosion.

Two models for evaluating the risk of environmental degradation due to dairy farming in Southland were developed. One re-classified the New Zealand Land Resource Inventory within existing Land Use Capability units and the other was based on a recently completed soil survey of the valleys and floodplains of the Southland Region undertaken by Topoclimate South. The models were entitled Land Environmental Risk (LER) and Soil Environmental Risk (SER), respectively.

Using a framework that allowed for differences in the information held in each data source meant different limiting factors were addressed with the two models. The framework listed a number of land characteristics for rural land evaluation that were applicable to environmental issues, but also detailed how other land qualities can be used once a relative ranking is applied to each factor of interest. A limitation method was used for the overall classification. The overall classification is represented numerically one to five, with the environmental risk represented by a letter.

Each model had three limiting factors, the LER model Soil Vulnerability (SVI), Potential Erosion and Slope; the SER, Soil Vulnerability, Leaching risk and flooding risk. One key difference in the results stemmed from the fact that data collected during the Topoclimate Soil survey meant the SVI could be calculated for each soil mapped. Compared with the LER where the SVI was applied from averages of the soil group noted for the LUC.

A range of GIS software packages were used to add attributes to existing data sources, generate maps of the individual models, and to allow comparison of the models by overlaying the attributes. The data generated was examined statistically using a spreadsheet.

Both models reduced the complexity of the data to result in maps that should be understandable by a wide range of users. The LER model resulted in 10 classes, from an original 37 LUC units and complexes. The SER model resulted in 27 classes, from an original 190 soil units and complexes.

The LER model classified 93% of the study area as having a high risk of environmental degradation. The influence of the SVI was the single most dominating factor of the LER classifications. Two classifications, 4 LER S e, and 4 LER sl S e accounted for 88.1% of the study area. Only two SVI rankings were able to be applied which limited the overall rank of classifications generated.

The SER model presented a wider range of ranking, from 1 – 5, the percentage of land under the respective risk rankings were 0.6%, 6.2%, 24%, 52.2% and 17%. Soil vulnerability featured heavily as the most limiting factor, three classes with SVI as the most limiting factor, 4 SER l S, 3 SER LS and 4 SER f l S, accounted for close to 50% of the study site.

The greater detail of data available from the soil survey resulted in what was felt to be a more robust classification. The LER model resulted in an over simplified classification. If the LER model was used to identifying areas to target policy implementation, areas of land would be both under and over-rated in terms of their risk of environmental degradation from dairy farm conversion.

The limitation of working with data that was already classified in the LUC was seen as restrictive for this evaluation. This needs to be understood if evaluation systems based on LRI are to be used for regional planning purposes.

Using the subclass limitation of the LUC units could be a first step in identifying areas for more detailed study if the focus was on soil limitations, if other detailed soil surveys were not available. LUC units with soils as the subclass were all found to have SVI as a limiting factor.

Further research as a result of this study could take the form of a model that addressed a wider number of issues and incorporated information from both data sets.

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CHAPTER ONE

1. INTRODUCTION

1.1 Land evaluation

Land evaluation is fundamentally aimed at supporting strategic planning (Rossiter, 1995). Land evaluation is the interpretative phase, and hence the final operational step, following a land resource inventory or soil survey and the analysis of survey data. It aims to provide users with information that will enable them to make rational land use decisions (Van de Graff, 1992).

The basic feature of land evaluation is the comparison of the requirements of land use with the resources offered by the land. Fundamental to the evaluation procedures is the fact that different kinds of use have differing requirements (Dent & Young, 1981). The product of land evaluation can be a land capability classification or a land suitability classification.

The first step in many land evaluations is often a soil survey, but it is recognised that this is not the only resource that needs to be measured for land evaluation (Dent & Young, 1981). Land refers to all element of the earths terrestrial surface that affect the potential land use and environmental management (Piere et al, 1995). A land resource inventory is not itself a plan for land use, and is only useful when it has been interpreted for some purpose (Hunter 1998).

One of the main criteria constant to all evaluation methods is that the purpose or land use in question must be clear (Dent & Young, 1981, Van de Graff, 1992, Davidson, 1980). This includes knowing the land use requirements and the scale limitations of data that will be used to prepare the evaluation.

In the first instance there must be the clear statement on the objective of the study. For land evaluation to be carried out in a systematic way, the land uses must be specific, either broadly or in detail, and the land use requirements for each kind of use must be identified and subsequently compared with the land qualities and characteristics of land units being considered (Holdgate, 1982).

The basic concept of land use classification is that land has inherent unalterable factors, which dictate the limit of use of that land (Greenall,A.F. 1951). A land classification for planning purposes must be related to the objective of the plan. The foremost essential in a possible list of essential elements in land classification should be a clear and complete definition of why the proposed classification is needed and how it will be used when completed. The first requirement for the successful development and application of any technical system of land classification is a clear understanding of the problems for which the classification is needed (Mclaren & Cameron, 1996).

In a strict sense, to evaluate an area means to ascertain its extent or to express it in numerical form. Thus a soil or geological map are particular kinds of evaluation. Often evaluation is taken to be synonymous with assessment which involves an estimation of value. So the objective of land evaluation or assessment is to judge the value of an area for defined purposes, (Davidson 1981). Soil surveys provide a most important scientific under pinning to LUC classification, and to land use/risk assessment generally (Gibbs, 1963).

For some rating systems the effects of attributes are integrated in various ways or not at all. Integration can be achieved by addition of credit or debit points, by multiplication of coefficients relating to the effects of each single attribute, or intuitively without numbers. For examples, two slight limitations and one moderate limitation may combine to form an overall severe limitation, or one severe limitation may be partly compensated by another extremely favourable attribute to create an overall moderate limitation (Van de Graaff, 1998).

There are several kinds of interpretation that can be made from basic soil surveys. The most obvious is to take a soil property which is known to be linked with a particular problem, and its distribution can then be traced on a single-factor or parametric map. Unfortunately, it is rare that only a single factor is responsible for a particular problem, and so other data, such as climatological information, have to be considered as well. When this occurs, the result is to produce land or soil quality maps. The land use capability systems of the USA (Klingebiel & Montgomery, 1961), Canada (Canada Land Inventory, 1970) and Britain (Bibby & Mackney, 1969) are designed to disseminate information to non-soil scientists such as agricultural advisers, farmers, planners and other people who are concerned with decisions about land use (Bridges & Davidson, 1982).

1.2 Role of land evaluation in NZ, legislative considerations

Land evaluation can form a basis for assessment of the environmental impacts or social consequences of land use practices. A classification based on well-defined land characteristics can be used as a basis to determine sensitivity-vulnerability of land to impacts of land use practices. (Webb & Wilson, 1995)

In New Zealand the main environmental legislation, the Resource Management Act, 1991 (The RMA), is concerned with managing the effects of activities to "promote the sustainable management of natural and physical resources'. Managing the use, development and protection of natural and physical resources in a way, or at a rate, which enable people and communities to provide for their social, economic and cultural well-being and for their health and safety while:

i) sustain the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations;

ii) safeguarding the life-supporting capacity of air, water, soil and ecosystems;

iii) avoiding, remedying and mitigating the adverse effects of activities on the environment.

Under the RMA local authorities are to develop policies 'to achieve integrated management of natural and physical resources' and have statutory responsibility to 'protect land of regional significance'.

To achieve these objectives, authorities need to know the quality of land for which they are responsible and the extent of land of different qualities. It may often be the situation that an initial recognisance evaluation needs to take place to determine priority areas for further investigation. A semi-detailed land resource survey such as the New Zealand Land Resource Inventory (NZLRI) can be used to determine, within and between regions and districts, the general characteristics of land and thereby to develop broad land use strategies (Hunter, 1986).

Land capability classification (LUC), originally devised by Klingbiel and Montgomery (1961), is an interpretative grouping of soils having the same degree but not necessarily the same kind of limitation for cultivation or grazing and requiring similar soil conservation measures.

The USDA LRI/LUC evaluation system was adapted for NZ conditions and for many years has been used by regional authorities for determining soil conservation work. The NZLRI is a spatial land resource database with nationwide coverage at a uniform scale of 1:50 000, appropriate for district and regional planning (NWSCO, 1979). The LRI records five physical factors (rock type, soil unit, slope angle, erosion type and degree, and vegetative cover) these factors along with climate considerations are used to determine land-use capability classification.

Many regional councils' still use the LRI method for a variety of purposes. Predominantly the method is employed to prepare environmental farm plans, to improve sustainable land use in hill country. It is also used for some land monitoring purposes, 11 regional councils use the NZLRI for environmental monitoring activities, of those 8 have recognised hill country erosion issues (Stephens et al 1999).

LUC data has also been used to help determine policy positions, or highlight areas of concern and to assess areas of sustainable land uses for areas of land (Jessen, 2001).

1.3 Southland Region – dairying environmental issue and land evaluation opportunity

From 1992 the conversion of sheep farms to dairy farms has been rapid in the Southland Region of New Zealand. Dairy farms are generally characterised by a high stocking rate and intensive management relative to other pastoral farming systems in NZ. The main environmental impacts of dairying are either on soil quality (e.g. by compaction) or water quality (ground and surface waters), (Ledgard et al, 1991).

In 1993 the Southland Regional Council had an Environmental Impact Assessment (EIA) prepared, as it was concerned at the added stress the intensive agricultural development would have on the region's water quality. The reports authors stated that because of the increasing dairy farming activity in the region and contaminant losses from dairy farms are greater than those from sheep farms, a higher priority is considered justifiable for addressing impacts caused by dairy farm related activities.

The EIA for Southland Dairy Farming Expansion grouped the significant issues regarding the impacts of dairy farming. The issues include groundwater contamination, nutrient enrichment of streams, oxygen depletion, waterborne disease risk, soil loss, ammonia and cadmium toxicity.

The valleys and floodplains of the Southland Region have recently been remapped as a result of a project called Topoclimate South. The main aim of the Topoclimate South project is to obtain accurate information on the region's climate and soils, to stimulate more intensive sustainable use of the region's resources. As a result soils of the area have been remapped at the scale of 1:50 000.

The purpose of the soil map is to enable land users to accurately identify soil types, in order to match soil characteristics with appropriate land uses, to maintain sustainability of land uses, and to provide more accurate information for risk management decisions.

1.4 Aims and objectives

This research project proposed to determine whether reclassifying data from the NZLRI could be confidently used to assess land potentially at risk to environmental degradation from dairy conversion in Southland. The aim of this research topic is to develop and compare land evaluation models to determine environmental risk from two data sets, NZLRI and Soil (as surveyed by Topoclimate South); and determine whether more detailed soils information should be incorporated into classifications based of NZLRI data for planning purposes, such as stratifying areas of land for more intensive study, or determining priority areas for policy implementation.

The objectives of this study are to:

- Review the history of the NZLRI, and how the LRI/LUC data has been used by regional authorities
- Identify a land evaluation procedure that can be applied to LRI and soil data
- Prepare regional scale maps based on a land evaluation that classifies areas at risk to environmental degradation due to dairy conversion in Southland
- Compare and contrast the classification systems developed from the two data sets
- Determine whether more detailed soils information should be incorporated into land evaluation models based on NZLRI data

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Land Evaluation General

It is the risk of land degradation that stands at the root of land evaluation (Beek, 1978). The demand for evaluation arose when it was appreciated that the mapping of natural resources alone did not provide sufficient guidance on how land could be used and what would be the likely consequences. Natural resource surveys express their primary results in terms of the environmental factor mapped: soil maps show soils, vegetation maps are based on plant associations, climatic studies are expressed in terms of averages and variability of rainfall, temperature and other parameters. (Dent & Young, 1981).

As stated by Rossiter (1994) land evaluation involves comparison between the requirements of the land use and the qualities of the land. Evaluation is only meaningful if the nature of the use to which it refers is specified. As the scale and intensity of the evaluation increase, so it becomes necessary to define and describe the land use in more detail. Thus, evaluation must be made in terms relevant to the conditions of the country or region concerned. (Dent & Young, 1981).

The fundamental purpose of land evaluation is to predict the consequences of change. Prediction is needed of the suitability of the land for different forms of production, the inputs and management practices needed, the production or other benefits, and the consequences of such changes upon the environment, (Dent and Young 1981). For land evaluation to be carried out in a systematic way, the land uses must be specific, either broadly or in detail, and the land use requirements for each kind of use must be identified and subsequently compared with the land qualities and characteristics of land units being considered. (Holdgate, 1982).

Most land evaluation is qualitative and based on expert judgement. The experts are mostly soil surveyors and agronomists who interpret their field data to make them understandable to planners, engineers, extension officers and farmers (Beek et al, 1998).

Soil survey and land capability assessment gained impetus is the USA in the 1930s in response to severe soil erosion that threaten food production and the stability of society, (Beek, 1978). This lead to one of the first comprehensive land classification systems, the USDA method which was adopted, often with some modification, by several countries at different levels.

2.2 USDA Framework

The American method of land capability assessment evolved over some 30 years, with a comprehensive handbook being produced in 1961 (Klingbiel & Montgomery, 1961). The aim of this method is to assess the degree of limitation to land use or potential imposed by permanent land characteristics. The land capability assessment (LUC) is determined from soil properties, slope angle, climate, flood and erosion.

There are three levels in the classification structure.

1. **Capability class** – this is the broadest level of classification, with eight classes being defined.

   A brief summary of the classes is as follows (Young, 1973)

Class I	Soils with few limitations that restrict their use
Class II	Soils with some limitations that reduce the choice of plants or require moderate conservation practices.
Class III	Soils with severe limitations that reduce the choice of plants or require special conservation practices, or both.
Class IV	Soils with very severe limitations that restrict the choice of plants, require very careful management, or both.
Class V	Soils with little or no erosion hazard, but with other limitations impractical to remove, that limit their use largely to pasture, range, woodland or wildlife food and cover. (In practice this class is mainly used for level valley-floor lands that are swampy or subject to frequent flooding).

Class VI	Soils with very severe limitations that make them generally unsuited to cultivation and limit their use largely to pasture or range, woodland or wildlife.
Class VII	Soils with very severe limitations that make them unsuited to cultivation and restrict their use largely to grazing, woodland or wildlife.
Class VIII	Soils and landforms with limitations that preclude their use for commercial plant production and restrict it to recreation, wildlife, water supply or aesthetic purpose.

2. **Capability Subclass** – indicates the type of limitations within the classes, displayed as a letter subscript. Limitations include erosion hazard, rooting zone restriction, climate, stoniness, low fertility, salinity or wetness.

3. **Capability Unit** – a subdivision of the subclass. Land in one capability unit may include many different soils but has little variation in the degree and type of limitation to land use, and is suitable for similar crops under similar farm and soil management schemes.

The assignment of any soil mapping unit to a capability class, subclass or unit is only possible is a number of assumptions are made and these are specified fully. The underlying assumption is that soils of different type may well be grouped into the same capability class since they share the same degree of limitation.

Davidson (1980) argues that if the USDA method is considered as a fully defined land classification technique, then it can be severely criticised. If the descriptions of the capability classes are examined, a distinct lack of precise quantitative criteria will quickly be very evident. Phrases such as 'gentle slopes', 'moderate susceptibility to wind or water erosion', less than ideal soil depth', clearly lack precision of definition, thus making them liable to diversity of interpretation. However, it can be argued that the strength of the USDA method lies in its flexibility. Major difficulties arise if any attempt is made to fix rigid limiting values which are relevant to a variety of environments. Consider soil texture: the significance of the textural types will vary according to the climatic regime and to the types of crops or land uses. Thus the lack of precise limiting values give the USDA method distinct flexibility. The method is better described as a framework for land capability assessment since it can be adapted for a wide variety of environmental conditions.

Variations of the USDA system have been developed for several countries. The Canadian Inventory of 1970 was designed to provide a basis for resource and land use planning. As well as being a method of soil capability classification for agriculture, separate land capability assessment for forestry, recreation and wildlife were developed.

The Canadian scheme has seven classes and organic soils are not placed in capability classes. A wider range of subclass limitations are used, though background assumptions are similar to the USDA system (Davidson, 1980).

2.2.1 Soil capability classes for agriculture (Canadian Land Inventory, 1970)

1. **Soils in this class have no significant limitations in use for crops.**

   The soils are deep, are well to imperfectly drained, hold moisture well and in the virgin state were well supplied with plant nutrients. They can be managed and cropped without difficulty. Under good management they are moderately high to high in productivity for a wide range of field crops.

2. **Soils in this class have moderate limitations that restrict the range of crops or require moderate conservation practices.**

   The soils are deep and hold moisture well. The limitations are moderate and the soils can be managed and cropped with little difficulty. Under good management they are moderately high to high in productivity for a fairly wide range of crops.

3. **Soils in this class have moderately severe limitations that restrict the range of crops or require special conservation practices.**

   The limitations are more severe than for class 2 soils. They affect one or more of the following practices: timing and ease of tillage; planting and harvesting; choice of crops; and methods of conservation. Under good management they are fair to moderately high in productivity for a fair range of crops.

4. **Soils in this class have severe limitations that restrict the range of crops or require special conservation practices, or both.**

   The limitations seriously affect one or more of the following practices: timing and ease of tillage; planting and harvesting; choice of crops; and methods of conservation. The soils are low to fair in productivity for a fair range of crops, but may have high productivity for a specially adapted crop.

5. **Soils in this class have very severe limitations that restrict their capability to produce perennial forage crops, and improvement practices are feasible.**

   The limitations are so sever that the soils are not capable of use for sustained production of annual field crops. The soils are capable of producing native or tame species of perennial forage plants, and may be improved by use of farm machinery. The improvement practices may include clearing of bush, cultivation, seeding, fertilising or water control.

6. **Soils in this class are capable only of producing perennial forage crops and improvement practices are not feasible.**

   The soils provide some sustained grazing for farm animals, but the limitations are so sever that improvement by use of farm machinery is impractical. The terrain may be unsuitable for use of farm machinery, or the soils may not respond to improvement, or the grazing season may be very short.

7. **Soils in this class have no capability for arable culture or permanent pasture.**

   This class also includes rockland, other non-soil areas and bodies of water too small to show on the maps.

0. **Organic soils**

In the scheme for classifying land according to recreation capability, the seven classes are differentiated according to the intensity of outdoor recreation use, or the quantity of outdoor recreation which may be generated and sustained per unit of land per annum under perfect market conditions.

A British system of Land Use Capability Classification (Bibby & Mackney, 1969), based on the USDA system, was developed in the 1960s, with the aim of presenting soil survey results in a form suitable for planners, agricultural advisers, farmers and other land users.

Assumptions specified for the British scheme include: the classification is primarily for agricultural purposes; and a moderately high level of management is assumed. Land is graded into seven classes on the basis of limitations which cannot be removed or reduced at acceptable cost.

2.2.2 Land use capability classes of the Soil Survey scheme

Class1	Land with very minor or no physical limitations to use.
Class 2	Land with minor limitations that reduce the choice of crops and interfere with cultivation.
Class 3	Land with moderate limitations that restrict the choice of crops and/or demand careful management.
Class 4	Land with moderately severe limitations that restrict the choice of crops and/or require very careful management practices.
Class 5	Land with severe limitations that restrict its use to pasture, forestry and recreation.
Class 6	Land with very severe limitations that restrict use to rough grazing, forestry and recreation.
Class 7	Land with extremely severe limitations that cannot be rectified.

With the British method classes are more precisely defined, actual limiting values for specific properties are detailed. Three climatic groups are defined, based on the water balance and temperature during the period April to September.

The American subclasses are also used with the addition of a subclass for gradient and soil pattern limitation, with a maximum of two subclass symbols being used in classifications.

2.3 FAO Framework

From a working group established in 1970, the FAO developed a Framework for Land Evaluation (1976). This was done as an aid to agricultural planning, by providing a methodological framework, (Bridges & Davidson, 1981). The FAO framework is concerned with evaluating land, rather than just soil.

Rossiter (1994) summarises the basic principles of the FAO method as follows:

1. Land suitability is assessed and classified with respect to specified kinds of uses.
2. Evaluation requires a comparison of the inputs and outputs needed on different types of land.
3. A multidisciplinary approach is required (in practice, not just soil surveyors)
4. Evaluations should take into account the physical, economic, social and political context of the area concerned.
5. Suitability refers to land use on a sustained basis.
6. 'Evaluation' involves comparison of two or more alternative kinds of use.

A comparison of requirements of land-use types with properties of land units is brought together in a land suitability class, this is central to the Framework. Land suitability is defined as the fitness of a given type of land for a specified use Suitability is indicated separately for each land-use type, showing whether the land is suitable (S) or not suitable (N), includes where appropriate degrees of suitability e.g. S1, S2 and S3 corresponding to highly, moderately and marginally suitable respectively. The major reasons for lowering the classification ie the land limitations, should be indicated (because of erosion hazard in one area or a high water-table in another,. For instance)

A four-tier hierarchical classification is presented and outlined as follows:

1. *Land suitability orders*. These indicate kinds of suitability.

2. *Land suitability classes*. These indicate degrees of suitability within orders.

3. *Land suitability subclasses*. These indicate the kinds of limitation, or main kinds of improvement measures required, within classes.

4. *Land suitability units*. These indicate minor differences in required management within subclasses.

The degree of quantification and detail of the description of land qualities over time, and the description of individual land use types depend of the available data, which in turn depend on the scale of analysis. Scale is an important factor when comparing the value of different land capability/evaluation systems.

Properties of land can be described by either land qualities or characteristics. A land quality is a complex attribute of land, which acts in a manner distinct from the actions of other land qualities in its influence on the suitability of land for a specified kind of use (FAO, 1993). A land quality is the ability of the land to fulfil specific requirements (Davidson, 1992). Land qualities include such things as moisture availability, and resistance to erosion.

Land Characteristics are simple attributes of the land that can be directly measured or estimated, such as soil texture, organic matter, slope angle or effective soil depth.

Effects of land characteristics on suitability are not direct, but through their effect on land qualities. Land characteristics may affect several qualities often in contradictory ways e.g. sandy soils may have low fertility and water holding capacity, by may be easy to till and there are no problems with aeration of the roots. Hence the soil texture is the land characteristic and the others are land quality.

FAO framework does allow the use of land characteristics directly to assess suitability but it is generally clearer to use land quality as an intermediate level of evaluation, both because the total complexity of the problems is broken down into more manageable units, and because land qualities in themselves provide useful information to the land evaluator.

2.4 Evaluation Systems

Generalised steps in any evaluation can be summarised as follows (Dent & Young, 1981):

1. Select the land qualities that are relevant to that land use within the survey area
2. Decide the land characteristics to be used to measure or estimate each of these qualities
3. For each quality, determine the values which will form the boundaries of suitability classes
4. Determine how ratings based on individual qualities are to be combined into overall suitabilities.

For each land quality, as estimated by one or more land characteristics, the values that are to form the boundaries between suitability classes must be determined. The next step is to combine suitability ratings of individual land qualities into an overall suitability for the land use in question.

The requirements of land use can be expressed in terms of land characteristics, land qualities, or a mixture. A land characteristic is an attribute of land that can be measured or estimated. Examples of land characteristics are mean annual rainfall, slope angle, soil drainage class, effective soil depth, topsoil texture, soil available water capacity, pH, and soil nitrogen percentage.

A land quality is an attribute of land which acts in a distinct manner in its influence on the suitability of the land for a specific kind of use Examples of land qualities are temperature regime, moisture availability, drainage, nutrient supply, rooting conditions, erosion hazard and potential for mechanisation.

Land characteristics are simpler to use, and in a local context they can provide a valid basis for estimating suitability classes. The main problem is that no account is taken of interaction between different characteristics.

Advantages of using land characteristics as a basis for evaluation are that they are simpler to use and direct, permitting a direct link between the observed value of the characteristic and the suitability rating. Disadvantages are the very large number of land characteristics, and the fact that it is not always clear which effect on the use is being assessed and most importantly, the failure to take into account interactions.

Advantages of using land qualities are, 1st, fewer in number, 2nd direct attention to the effect upon the land use and 3rd take account of interactions between environmental factors. Main disadvantage is greater complexity, in that they require an intervening stage of converting characteristics into qualities.

As a general rule it is better to start by assessing land use requirements in terms of land qualities. This directs attention to the ways in which the various kinds of use can be favourably or adversely affected. It is in any case necessary to decide which land characteristics are to be used to measure or estimate the qualities. If it is then found that, within the survey area, single characters provide a valid basis for assessing suitabilities, then these characteristics can be employed directly.

There are several ways that land qualities or characteristics can be compiled to form suitability classes. For some rating systems the effects of attributes are integrated in various ways or not at all. Integration can be achieved by addition of credit or debit points, by multiplication of coefficients relating to the effects of each single attribute, or intuitively without numbers. For examples, two slight limitations and one moderate limitation may combine to form an overall severe limitation, or one severe limitation may be partly compensated by another extremely favourable attribute to create an overall moderate limitation.

2.4.1 Parametric/arithmetic methods

According to Riquier (in FAO, 1974) as described by Beek (1978), parametric methods involve the selection of soil properties which are evaluated and awarded numerical scores: then these properties by means of the scores are substituted into mathematical formulae so that overall indices of suitability or performance are produced. The resultant values can be used themselves for assessment purposes, or alternatively they may be used to rank soils or to groups soils into suitability classes

Arithmetic procedures. Where large numbers of land units and uses have to be classified, it is possible to devise additive formulae, on the lines of e.g. s1 + s1 + s2 = overall s1, s1+s2+s2=s2 Weightings for whether a quality is important or only significant can be incorporated. Additive methods of this nature work quite well in the higher suitability range, where several favourable conditions can compensate for one limitation which is less than ideal but not severe. There have also been attempts at productivity ratings based on multiplication of individual ratings, converted to percentages, but these give poor results if applied outside the areas for which they were devised. (Dent & Young, 1981).

The partial effect of each relevant land attribute counts towards a total rating. The arithmetical additive rating systems have a comparatively great advantage in that they allow the effects of all land attributes relevant to a given land use to be summed. Such systems are appropriate for suitability ratings rather than capability classes. For ease of communication the total range of values can be broken up into several classes. These systems require that favourable and unfavourable land attributes be given credit or debit points, and that total scores are determined according to certain working rules.

a) **Additive integration**. Credit and debit points are assigned to individual land attributes. For each land unit these credits and debits are summed and the final score is segmented into the desired number of classes. Credit and debit points can be arbitrary, but should be weighted in accordance with the effect of each land attribute to calibrate the system.

The FAO (1983) provides an example of an additive rating method based on combining suitability classes for individual land attributes to obtain an overall classification:

Each land attribute is rated individually into one of a limited number of suitability classes e.g. in a three class system it is rated s1, s2 or s3. Then a set of working rules to suit local conditions is drawn up, which combines the individual attribute ratings. For example:

		Overall suitability class:
Number of s2 assessments:	0-1	S1
	2-4	S2
	5 or more	S3
Number of s3 assessments:	0-1	S2
	2-3	S3
	4 or more	Not suitable

Overall suitability is indicated by a symbol using a capital S in conjunction with a number, while a lower case s is used for the suitability of individual land attributes. FAO uses a three-class suitability system in which Class 1 represents high suitability, Class 2 moderate and Class 3 marginal suitability, with two classes of unsuitable land, currently not suitable and permanently no suitable.

b) **Multiplicative integration**. Each relevant land attribute is given a rating between 100% (no limitation) to 0% (prohibitive limitation), the actual value depending on observing and assessing the effect of the intensity of such attributes on the land use in question. These attribute ratings are multiplied together, giving a final land class rating between 100% and 0%.

One example of this sort of multiplicative integration is the Storie Index (SIR), which rates soil productivity numerically and was originally developed in California is the 1930s. Relevant land attributes are given coefficients between 0 and 100%, the SIR is calculated by multiplying the coefficients. The final result can be expressed as a percentage. Leamy (1974) adapted and applied the technique in New Zealand. The framework is summarised as follows:

Factor A: Rating based on the physical properties of the soil body

1. Basal form
2. Topsoil texture

Factor B: Rating based on the chemical properties of the soil body

1. Plant nutrient status
2. Soluble salt level

Factor C: Rating based on the nature of the environment

1. Moisture regime
2. Temperature regime
3. Slope
4. Erosion
5. Microrelief
6. Soil drainage

Factor D : Rating based on management

SIR = A x B x C x D

2.4.2 Limiting conditions

Limiting conditions. This is the procedure (as usually employed in land capability classification) of taking the lowest individual rating as limiting to the overall suitability (Dent & Young, 1981).

These schemes are best where a single permanent limitation has an extreme effect on a proposed land use, and where such land use would constitute an extreme degradation hazard, e.g. severe slope. On the other hand, land with a severe but temporary limitation, for example very poor drainage, can often be improved. These systems, should, but often do not, distinguish clearly between permanent and temporary limitations and they cannot take into account the combined effects of two or more limitations.

A continuum of values for any land characteristic or land quality is segmented into a few, say 3 or 5, appropriate ranges, each range being allotted to a capability class. The single most severe permanent limitation for any one attribute for the land use under consideration determines the classification of the land unit, ignoring the effects of all other attributes. Non-experts can use these systems if information on land attributes is provided. For that reason, classification can be done by computer (Van de Graaff, 1998).

2.4.3 Subjective/empirical methods

Subjective combinations. The surveyor, preferably in consultation with the farmer, agronomist, forester, etc., summaries the various combinations of conditions which occur, and judges how they should be assessed for overall suitability (Dent & Young, 1981)

These systems of land evaluation depend largely on experience and intuitive judgement. Although evaluators may consider a range of limitations in the light of their experience of the land degradation hazards of certain uses, the procedures are not explicit, and their standards are not quantifiable and easily transferable to others. For example the definitions of Class I to Class VIII land in Klingebiel and Montgomery (1961) are conceptual. There might well be disagreement between practitioners as to whether a given land unit would be Class II or Class III for example. (Van de Graaff, 1998)

The effect of all or several individual land attributes is not stated explicitly and in a quantitative manner and their combined effect on capability can only be assessed by an expert with local experience. The judgement is less intuitive when more attributes are quantified. (Van de Graaff, 1998).

The method of limiting conditions is the easiest to use, and should always be used for a single severe, i.e. N, limitation. Arithmetic procedures may be necessary when a very large number of land units (or single site observations) are to be evaluated, in order that two surveyors shall achieve the same result. They will in any case be necessary if this step is to be carried out by computer; the constraint that N ratings are limiting is then incorporated. Subjective combination is best wherever the number of units and uses to be considered is small, and where there is experience of the use in the survey area or a similar environment. (Dent & Young, 1981)

The kinds of limitation that cause lowering of suitabilities are the basis for allocating subclasses.

2.5 Soils maps – as a basis for land evaluation

One of the first and most important steps of land evaluation is often a soil survey, which can be classified in their own right. Soils are classified in order to organize knowledge and thus reduce complexity, as an aid to remembering their properties and to bring out and understand relationships among individual soils and classes of soils. It can group soils in a manner useful for practical applied purposes, such as predicting their behaviour, identifying their best use and estimating their productivity (R.F. Isbell, 1996).

The usefulness of a soil survey depends on 2 things: the accuracy with which soil properties are mapped, and the relevance of those properties to the purpose in hand (Dent & Young, 1981).

The scale of any map determines the smallest area that can be defined within an area. The mapping units shown on district soil maps (usually 1:63 360) are usually a combination of simple and compound units (complexes and associations) at the series taxonomic level. They can provide a base for study of local soil problems, and for making general and sometime specific interpretations for various uses (McLaren & Cameron, 1997).

There are several kinds of interpretation that can be made from basic soil surveys. The most obvious is to take a soil property which is known to be linked with a particular problem, and its distribution can then be traced on a single-factor or parametric map. However, it is rare that only a single factor is responsible for a particular problem, and so other data, such as climatological information, have to be considered as well (Bridges & Davidson, 1982).

CHAPTER THREE

3. THE NEW ZEALAND LAND RESOURCE INVENTORY

3.1 Introduction

Overseas and local experience has proved that classification of land according to its capability for permanent production based on its physical limitations and soil conservation needs, provides the most reliable bases on which to promote soil and water conservation practices (MOW, 1974).

In 1952 the Soil Conservation and Rivers Control Council (SCRCC) adopted the United States Department of Agriculture Land Use Capability/Land Inventory System. The system was modified to suit New Zealand Conditions (MOW, 1974).

In 1970 the SCRCC requested the Ministry of Works to develop a series of national resource surveys at a scale of 1;250,000. In 1973 a 1:63,360 scale field sheet was published as NZLRI initially for the Gisborne-East Coast region. National Coverage was achieved in seven years. The Surveys provide a systematic physical stocktaking of New Zealands' land resource, New Zealand is the only country to have achieved national coverage at the Land Use Capability unit level.

Land use capability (LUC) is an ordered arrangement of the land according to those properties that determine its capacity to sustain production permanently (MOW, 1974). Five factors are recorded in the Land Resource Inventory (LRI), rock type, soil type, slope, erosion and vegetation (figure 1). These are then used alongside other considerations to determine the Land Use Capability (LUC) unit.

$$\text{LRI Code} = \frac{\textbf{rock type - soil type - slope}}{\textbf{erosion - vegetation}}$$

Figure 1: Five factor code used in the NZLRI

Other factors, such as climate and effects of past land use, are also used in determining LUC. Each resource factor was determined to have a role in permanent sustainable production.

3.1.1 Components of the LRI

3.1.1.1 Rock type

Rock types were recorded for each map unit according to the NZLRI Rock Type Classification (Crippen and Eyles, 1985), which was designed specifically for soil conservation purposes.

The primary objectives were:

- To group those rock with similar erosion susceptibilities and characteristics
- To concentrate on those rocks which directly influence surface morphology and land use
- To enable those rock types to be recognised and mapped by earth scientists and by soil conservators with a limited formal geological background.
- To provide information on rock types which could be readily understood and applied by planners and others.

Only those rock types that directly influence surface morphology and land use are recorded. In the case of cover deposits a maximum of 3 rock types are recorded, in stratigraphic order.

The major source of information used in mapping rock types were the NZ Geological Survey 1:250,000 Geological Map of NZ series. These maps didn't show tephra deposits though, and are of a time-stratigraphic basis rather than a lithological basis. A number of NZ soil bureau reports and bulletins provided information on the distribution of tephra within regions.

Rock type is considered to be one of the dominant physical factor affecting slope stability and soil development in a large proportion of hill and mountain lands. Hence the identification of rock types is important in soil conservation planning.

A review of the NZLRI by LINZ (1987) stated the functionality of recording rock type as follows:

- It indicates actual rock type rather than the geological units present
- It is a determinant of the erodibility of land
- In association with environmental factors determines the soil parent material
- It is a basic input to the establishment of land use capability
- It determines the practicality of erosion control measures

3.1.1.2 Soils

Soil information was based on soil bureau, DSIR, soil surveys. In areas that only have soils coverage at scales smaller than that of the worksheets, especially those areas covered by the general survey (NZ soil bureau 1954), more detailed soils information was required. The objective was not to prepare a 1:63,360 soil map but to accurately record, within NZLRI map units, soil sets or soil series which were already recognised by Soil Bureau (Eyles, 1975). As soils are only one of the five inventory factors recorded within a 'homogeneous' map unit, the boundaries need not necessarily correspond exactly to soil boundaries of soil maps covering the same area.

During field work soil profiles were checked to ensure that the correct soil set had been recorded, however it was not supported by the collection of new soil data at recorded and identifiable points in the landscape or by laboratory characterisation of soil samples (Hawley & Leamy, 1980).

A review of the NZLRI by LINZ (1987) stated the functionality of recording soil type as follows:

- It is an important input in the determination of safe land use – i.e. land use capability
- It assists in determining the nature of erosion processes, the ability of the land to recover from erosion events, and the remedial measures which are appropriate to assisting recovery

3.1.1.3 Erosion

Erosion information on worksheets is based on the NZLRI erosion classification (Eyles, 1985). The methods used to record erosion in the NZLRI do not give actual area of erosion; because erosion is assessed within a map unit whose boundaries reflect other physical factors, only areas of map units in which erosion occurs can be obtained. Thirteen erosion types and six erosion severity classes are recorded, (Eyles, 1985)

The classification adopted:

- makes no distinction between accelerated and geologic erosion
- records present erosion

For surficial erosion types (sheet, wind and scree) the erosion ranking is assessed in terms of bare ground. For mass movement and fulvial erosion types the ranking is assessed on a seriousness basis (Eyles, 1985).

For the South Island the erosion ranking was assessed on a collective basis for all erosion types (with the types, as for all inventory parameters, being recorded in order of decreasing importance)

A review of the NZLRI by LINZ (1987) stated the functionality of recording erosion type as follows:

- It is an inventory of present and immediate past erosion events.
- It provides an indication of the current reduction in productivity due to erosion
- It indicates the potential instability of land

3.1.1.4 Vegetation

The approach used is based on: "A classification of plant communities, each characterised for field identification by one or a number of species that were distinctive according to physiognomic, ecological or cultural criteria"

Vegetation influences the processes of soil development and therefore its properties and rates of erosion. Through the process of photosynthesis, plant biomass is the source of all terrestrial production and energy cycles, both natural and cultural. The type of vegetation thus usually indicates something about the pattern of land use. Vegetation is influenced by both natural and cultural factors, sometimes rapidly and dramatically, causing associated changes in hydrology, erosion and regional water balances. It is thus a very useful indication of both natural and cultural characteristics of land that may influence its capacity for sustained productive use.

A review of the NZLRI by LINZ (1987) stated the functionality of recording vegetation type as follows:

- It influences soil erosion processes
- It influences soil development
- It reflects current land use
- It can be an indicator of the lands physical character and its environment.

3.1.1.5 Slope

Slope is expressed in degrees, measured with an Albney level. The MOW handbook defines slope classes within defined degree angles, with a corresponding description:

A – (0 - 3°)	Flat to gently undulating.
B – (4° – 7°)	Undulating
C – (8° - 15°)	Rolling
D – (16°-20°)	Strongly rolling
E – (21° - 25°)	Moderately steep
F – (26° - 35°)	Steep
G – (> 35°)	Very steep

A review of the NZLRI by LINZ (1987) stated the functionality of recording slope type as follows;

- It is a determinant of land stability
- It influences runoff processes
- It influences erosion forms
- It determines the nature and practical aspects of erosion control practices
- It influences land management practices

3.1.2 Other Factors

3.1.2.1 Climate

Although climate is not one of the 5 factors in the inventory code it is nevertheless an important resource factor in assessing LUC. During the preparation of worksheets various climatic information was used including: 1:500,000 isohyet map of NZ (NZ Met service, 1978), records of RF normals (NZMS, 1984), climatological records from individual stations.

Other publications specific to the regions were also used in describing climate regions.

Soil temperature and degree day totals are 2 climatic parameters that are of particular importance in assessing the suitability and versatility of land for plant growth. Data from soil temperature maps at 1:2,000,000 scale and generalised maps of degree day totals in Taranaki and King Country helped confirm the validity of the LUC classification in these areas.

3.1.3 Land use capability

A LUC unit is compiled by grouping inventory units which respond similarly to the same management, are adapted to the same kinds of crop, pasture or forest species, have about the same potential yield, and require the application of the same conservation measures. There are three levels to the LUC classification (figure 2).

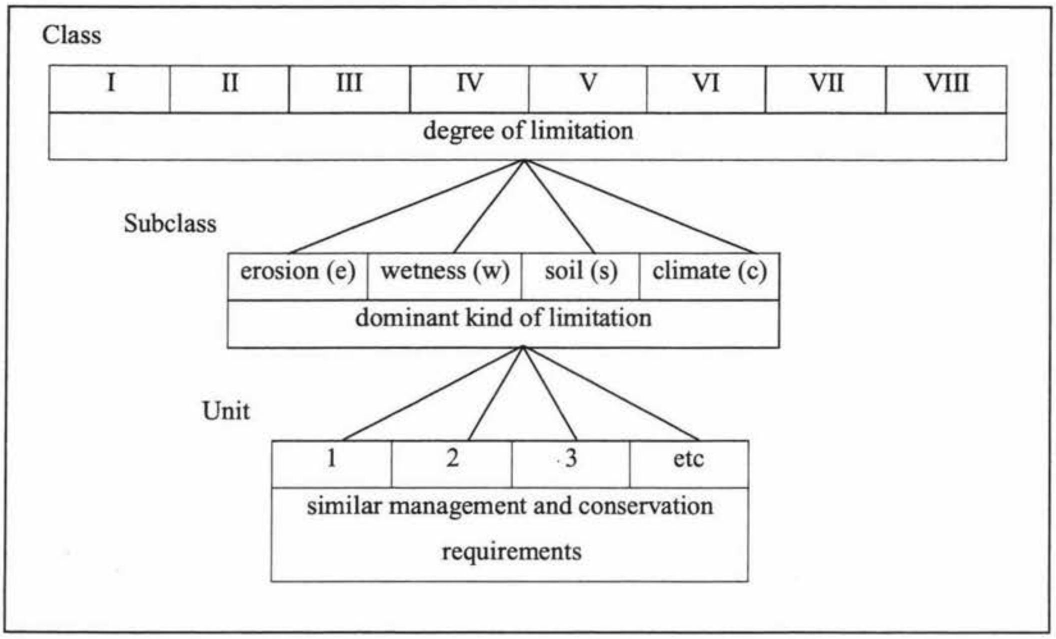


Figure 2: The three levels of the Land Use Capability Classification

3.1.3.1 LUC Class

The major grouping is into eight land use capability classes. The first four classes comprise land suitable for cultivation for cropping, and the limitations to use increase from Class I to Class IV. Classes V to VII comprise land unsuitable for cropping use, but suitable for pastoral or forestry use with the limitations increasing from Class V to Class VIII. The limitations reach a maximum with Class VIII, which is suitable only for protection purposes.

The capability class gives information about the general limitations only of the land – i.e. the total degree of limitation.

3.1.3.2 LUC Subclass

The second category, the capability subclass provides for a grouping of units with the same kind of limitation or hazard. The four general kinds of limitation recognised are:

- e Erodibility – where erosion susceptibility and past erosion damage are the major factors
- w Wetness – where the land units have soils with poor drainage or a high water table, or where there is frequent overflow from streams or coastal waters
- s Soil limitations within the rooting zone – such as shallowness, stoniness, rock outcrops, low moisture-holding capacity, low fertility which is difficult to correct, salinity, or toxicity
- c Climate – where the climate is the only hazard or limitation in the use of the land.

3.1.3.3 LUC Unit

At the most detailed level, the third category, the land use capability unit groups those inventory units which respond similarly to the same management, are adapted to the same kinds of crops, pastures, or forest species, have about the same potential yield, and require the application of the same conservation measures. Descriptions of the units are recorded in the extended legends and regional bulletins.

A review of the NZLRI by LINZ (1987) stated the functionality of the LUC as follows:

- It facilitates the provision of land use guidelines which will ensure land is used within its physical limits (i.e. without exposing the land to any excessive actual or potential degradation).
- It provides a national standard for the LUC classification which is used at a detailed level to plan the implementation of soil conservation programmes, including the allocation of government monies for erosion control practices.

3.1.4 ASSUMPTIONS MADE WHEN ASSESSING LUC

1. The LUC classification is an interpretive classification based on permanent qualities and characteristics of the land. Existing vegetation is not considered a permanent characteristic.

2. A moderately high level of management is assumed.

3. Soil conservation measures have been applied

4. Where it is feasible for an individual farmer to remove or modify physical limitations e.g., high water table, stoniness, salinity, low fertility, the land is assessed according to the limitations remaining after the improvements have been made.

5. LUC assessments of an area can be changed by major schemes that permanently change the nature and extent of the limitations e.g , large drainage schemes, irrigation, or flood control schemes.

3.2 Comparing the LRI/LUC System with soil maps

3.2.1 Benefits of the LRI/LUC System – with particular comparison to soil maps

The NZ LUC assessment system has evolved to be a 'terrain unit classification' in which five physical parameters are always recorded. Other factors are also assessed but not recorded in the inventory, the most important being climate and the effects of past land use.

The ability of the LUC system to take into account a wide variety of physical parameters is its strong point and is a major reason why the LUC classes should not be more precisely defined.

The difference is critical as soil surveys do not provide all the necessary physical information to provide such an assessment.

In a training paper delivered in 1988 G. Eyles gives some examples (pers. comm.)

1. Climate:

The soil survey of Greymouth-Hokitika Region by Mew *et al*, 1980 (at a scale of 1:50,000) ranks the Hokitika soils as 1B for cropping – i.e. soils of flat and easy rolling land with minimal to slight limitations for crop production with the limitation being that of medium nutrient requirements.

While these may be the best soils on the coast – recent, free draining etc, the climate precludes their use for wide variety of crops. The annual rainfall ranges from 2,500 – 3,000 mm pa.

2. Dissection

Example from the King Country Land Used Study Provision Soil map prepared at the 1:63,360 scale.

One soil series – the Benneydale Series, has been subdivided into five LUC classes.

IIIs6, Ive13, Vie26, VIIe19 and VIIIe2

In the LUC classification the LUC class depends on the degree and depth of dissection – a critically important management function.

3. Erosion

Very few soil surveys give more than a cursory look at soil erosion. One of the most detailed approaches would be that of mew el al 1980 in his Soils of the Greymouth-Hokitika Region, as he gives a severity ranking and type for each soil. Usually, however, neither present and potential erosion can be obtained from soil surveys.

These examples illustrate that while soil surveys can analyse the profile accurately, they do not take sufficient account of environment factors to enable them to be the bases of making planning decisions.

MOW, 1979 discusses how information from the NZLRI can be applied to produce table or spatial overlays, and that it is possible to pull out single or multiple factors. These can be used at a range of different levels and objectives, with flexibility due to:

- Inventory presents basic, unclassified information which can be used in a variety of ways for different purposes by a wide range of users.
- The rearrangement of capability units into alternative systems of potential use should be done by drawing up a set of standards for the particular use being considered. The correlation is achieved by giving each unit a rating, based on current knowledge
- The LUC assessment is based on the permanent physical features of the land and therefore does not change when vegetation and land use change.
- The information is produced at a consistent national standard which enables comparisons to be made between regions within the country using a common language of land description
- The worksheets have been produced over a relatively short period of time; periodic revision will keep them up to date and enable the monitoring of major land use changes.
- The scale makes it possible to identify broadly the physical land characteristics before detailed land use planning begins.
- They provide a base on which other factors important in land use planning can be superimposed.
- The technique is well suited to easy computer storage of information and retrieval in computer printout or map form.

Although it is orientated towards agricultural systems, LUC can also be applied to a range of other uses, for example forestry. This is possible because the building block of the land use capability classification the LUC units, are based on physical properties of land, which influence many forms of land use (Hunter, 1998).

It is extremely convenient for land use planners to be able to include or exclude in a scan of a region the broad classes of land with which they are concerned. e.g. exclude "all un-farmable land" i.e. Class VIII. Use of 4 subclasses adds to this convenience (Gibbs, 1965).

Classification by the limitation method is useful in that it outlines the type and magnitude of physical problems that require control measures in any future specified systems of land use. Removal of these, where possible, becomes the key future in realising the full potential of such areas. The concept is direct and easily applied.

3.2.1.1 Advantages in comparison to single factor mapping (LINZ, 1984)

- It demands an integrated thought process throughout compilation – which is appropriate to the assessment of land use capability and hence better integrated policy advice to NWASCA

- Coincides boundaries where appropriate. For example where a change in slope corresponds to a change in rock type, soil unit, and erosion that change is represented by a single polygon boundary. By comparison single theme mapping of those factors may present the change in terms of a number of different lines – all of which may be within an acceptable tolerance given the nature of the land and the scale of mapping. However, the differences will pose a problem in both manual and computerised sieve planning applications as they must be filtered out if they are not to be treated as real differences.

- Takes advantage of the opportunity factor (i.e. when scientists in field or examining photos etc) to compile resource data appropriate to NWASCA objectives. This results in substantial cost saving by avoiding repetition of these processes for each individual theme.

- As a computer database it enables the interactive analysis of all component data elements without the requirement for complex graphics overlay procedures. In effect this overlay process is implemented at the compilation stage where ground truth consequences are most apparent.

- The maps provide for simultaneous access to all factors on the same base.

3.2.2 Limitations of the LRI/LUC system

The LRI/LUC system attempts to provide a single-scale grading of land for all land uses, but has a particular bias towards suitability for arable cropping and soil conservation (Dent & Young, 1981).

LUC suffers from the following limitations:

- The general rating of land capability provided by LUC can be inappropriate for specific land uses. Two examples of inappropriate LUC ratings in relation to the suitability of land for intensive food production are:

  - Sandy soils that possess excellent drainage, aeration and root growth conditions have high value for horticulture under irrigation. However, within the LUC system, sandy soils are downgraded because of the risk of erosion and low soil-water storage under dry land conditions. Neither limitation is significant under intensive irrigation management.

  - On the other hand, land areas with drainage limitations which present a major risk for orchard and berry fruit production are sometimes given high LUC ratings because of their relatively favourable productivity for pasture and for some crops under dry land conditions.

Webb & Wilson (1998), make the following criticism about the LUC system: criteria used in the classification of soils are poorly defined, and classifications are frequently made on subjective assessments of defining criteria.

There are a limited number of attributes used to determine the classification of flat land. Soil attributes are limited to drainage, depth, texture and stoniness. Other attributes of importance to crop growth or management, such as root penetrability within the root zone, aeration and compactability of soil materials under wheeled traffic, are not considered.

Through its association with planning for soil conservation, and a perceived over emphasis in the classification of erosion risk on land, the LUC system has been criticised by some as one which identifies only limitation on land use (Hunter, 1986).

LINZ NZLRI Review 1987 also discusses some limitations of the LRI due to the compilation procedure:

Disadvantages in comparison to single factor mapping

- The necessity to write the codes for all data elements within each polygon restricts the minimum polygon size.
- The large number of codes displayed on the worksheets can create legibility problems and may also be somewhat daunting to new users.
- It is not possible to update any single inventory factor in isolation. Any change to a polygon boundary will necessitate an evaluation of the impact on all other inventory factors.

Commonalities with single factor approach

- The descriptors for each polygon provide a general statement which, consistent with the scale of presentation and objectives of the survey, provides an optimal description of the land encompassed by that polygon. However, due to the non homogeneous nature of the earth's surface there will normally be a level of variation within each polygon. This variation restricts the technical validity of analyses which involve sampling within the polygon in that:
- The description for the polygon as a whole may not be appropriate to any subset of that polygon – with the likelihood of the description being at variance increasing as the size of the subset decreases relative to the original
- Point source analysis is technically invalid in that, in most situations, it is highly unlikely that any point within the polygon will conform to the general description.

Jessen (2001) states there are several considerations that need to be appreciated to avoid inappropriate uses of the NZLRI data:

- LUC information and aspects of inventory data are already 'classified', rather than existing as fundamental data (such as measured soil depth, botanic compositions, actual slopes, etc.) and might not meet particular planning requirements.

- Inventory information and LUC assessments are generalised inside polygons, and information is spatially delimited by the polygon boundaries. As a general guide, mappers accurately reflect the characteristics of 80% of a map polygon.

- While LUC assessments, rock type, soil, and slope factors remain the same over long periods, vegetation and erosion can change quickly.

Hunter (1986), notes that the LUC class which reflects the degree of limitation to sustained use, particularly the limitation determined by soil, slope, climate and erosion is determined by the degree of the single most limiting factor, rather than from interactions of factors.

Hunter goes on to explain that soil properties have an over-riding influence on LUC class on low slope-angle, alluvial terraces, fans and floodplains in situations where other factors are non-limiting. Soil depth and texture criteria, which determine rooting volume, soil water holding capacity and feasibility of cultivation, are applied on well-drained to excessively-drained soils. These standards allow a decreasing land use capability from deep silt loam soils in class I to very shallow, stony or sandy soils in classes VI and VII.

Cutler (1977), states that the characteristics which are considered basic data for land inventory surveys and from them land capability, are essentially the same as those recorded in soil resource surveys. The main difference being that soil resource surveys include quantitative data as well as descriptive material and should therefore be a more reliable source of land resource information.

Basic data required for Land inventory surveys (M.O.W., 1969)		Basic factors of soil formation - data recorded in soil surveys	
Geology	Existing	Parent material	Soil Resource
Soils	Under a	Relief	Surveys
Relief	Given climate	Organisms	
Erosion	↓	including	
Vegetation	Land Inventory	vegetation	↓
Land use	Map	Age of landscape	Soil survey
	↓	Climate	interpretations
	Land Capability	Erosion, etc.	
	Map		

Table 1: Comparison of basic data recorded in Land Resource surveys and soil resource surveys (Cutler, 1977)

3.3 Interpretations of LRI/LUC data

Many regional councils still use the LRI method for a variety of purposes. Predominantly the method is employed to prepare environmental farm plans, to improve sustainable land use in hill country. It is also used for some land monitoring purposes, 11 regional councils use the NZLRI for environmental monitoring activities, of those 8 have recognised hill country erosion issues (Stephens et al 1999).

LUC data has also been used to help determine policy positions, or highlight areas of concern. This has been done both by examining LUC units as they stand and by making additional assessments, or by re-examining LRI data further.

In 1992 Blaschke *et al.* produced a report for the Taranaki Regional Council (TRC) detailing sustainable land use options for the Taranaki region. After developing a classification of sustainable land uses in the region, each LUC unit was assigned a range of sustainable land uses. The allocation of land in the region to sustainable land use classes was made primarily according to the LUC assessment in the NZLRI

To overcome the generalisation of the LUC class assessment developed of the national worksheets, a "purpose-built" classification reflecting the actual and potential sustainable land uses in the Taranaki Region was developed for the project. For example, due to the prominence of dairying in Taranaki, special attention was paid to land suitability for dairying.

This classification considered a number of factors in allocating LUC units to sustainable land use classes, these included:

- The overall degree of limitation, i.e. the LUC class;
- Additional information relevant to specific LUC unit, e.g. pasture production trial results, coastal limitations, etc.
- Range of inventory factors mapped throughout the region, especially slopes for hill country LUC units.
- Existing land uses, where appropriate, e.g. National Park, or specialised horticultural uses.
- Assessment of fertiliser history and present fertility levels.

Variability within LUC units was recognised by the allocation of either one or two minor sustainable land use classes in addition to the principal sustainable land use class. Maps were produced at a scale of 1:250,000 which presented the principal sustainable land use.

The Auckland Regional Authority (1984) produced a framework for preparing a Land Use Suitability Assessment (LUS) with an urban capability focus. As they noted, the NZLRI approach can be modified so that it is applicable to urban situations.

Urban capability was defined as "the physical capability of the land to sustain safe urban development and use". Preparing the Urban Land Use Capability involved assessing the following factors: Lithology, Soils, Terrain, Erosion, Drainage and Vegetation. These were used to compile land units into one of the four LUC classes, A to D (limitations to use increased from A to D, and correspondingly decreased fro A to D). Associated with each urban LUC are several subclasses; "o" for no significant hazards (Class A land only), "f" – flooding, "s" – sediment generation, "n" – foundation problems (e.g. compressibility), "d" – drainage, "e" – erosion and "t" – topographic constraints.

The framework was intended for use as a planning tool both for individual developers as well as local and regional authorities.

Data from the prepared LRI national survey was used to prepare an Erosion Map of New Zealand, it shows the present and potential erosion severity in any given are in the country. The Erosion Map of NZ was designed to provide planners and users of the land with information about erosion which can assist them in making wise land use decisions (NWASCA, 1988).

The map series was printed at a scale of 1:250,000, each map unit has a code which describes the extent and type of erosion and potential for future erosion. The format of the code is as follows:

Potential Erosion Severity	Present Erosion Severity	The Two Dominant Present Erosion Types
	Erosion Association	

An example is: 3 1sS1 Sh / H

FIGURE 3: EROSION MAP CODES

Six rankings of potential erosion are used, from not significant to extreme, and these are indicated for each map unit by a number and a colour. The severity of erosion was a subjective judgement, based on the relative difficulty and cost of repair. The erosion association is a way of identifying areas of land that will develop towards similar conditions of erosion. There are 21 erosion associations described on the map, each with key associated physical factors.

The maps also included features that detailed erosion potential of arable land when under cultivation, shown in terms of slight, moderate or severe risk; where indigenous forest was located, as in general indigenous forest has lower erosion potential compared to similar land under pasture; catchment boundaries, as drainage systems affect erosion.

Jessen (2001) lists several examples of land-use capability and inventory data being used along with other databases and new information in second-level interpretations.

- In the Gisborne-East Coast LUC units are used to define 'target land' under the East Coast Forestry Project, and NZLRI data is used to track progress in allocating afforestation subsidy monies under the scheme.
- Soil spatial information have been linked to soil characteristics from the National Soils Database to develop national soil carbon inventories. A soil map of New Zealand has been produced using IPCC (Inter Government Panel on Climate Change) soil categories, to help monitor soil carbon nationally.
- Soil and rock information have been reinterpreted to form classes relevant to tree growth, and then used to describe soil parent materials in an analysis of environmental factors driving tree distributions.
- Ten soil attributes from the National Soils Database and other unpublished soil datasets were linked to LUC units and soil inventory data to reveal the best and most versatile soils in New Zealand districts, with clear application to the 'protection of high class soils from permanent loss under urban growth' debate.

3.4 A Manual of Land Characteristics for the Evaluation of Rural Land

Webb & Wilson (1995) present a wide range of land characteristics to enable interpretation for a range of land uses including suitability of land for specific uses, assessment of vulnerability of land to degradation or contamination, and land suitability for effluent disposal. The manual discusses the principles of land evaluation, with guidelines on how to apply them to the land characteristics to derive classifications.

Past classifications lack objective definitions of class limits and generally have no clear relationship between the factors used in classification and crop production or management. This has resulted in a lack or precision and poor predictive capability (Wilson, 1984).

The manual adopts some of the central concepts of the FAO "Framework for Land Evaluation" (1976):

- Classification of land suitability is related to well-defined land uses.
- Suitability ratings are based on land qualities (complex attributes of land that have direct effects on crop growth or management)
- High suitability ratings imply that productive capacity can be maintained.

Land characteristics presented are grouped under the following headings: topographic, soil physical, soil chemical, environmental and climatic characteristics. The land qualities associated with each characteristic are presented. A discussion of how a characteristic can affect management is discussed. For each characteristic a numerical rating is given, e.g. Classes for profile available water (PAW):

PAW (mm)	Class	Rating
> 250	Very high	1
150 - 250	high	2
90-150	Moderately high	3
60 - 90	moderate	4
30 – 60	low	5
<30	Very low	6

Table 2: Example of land characteristic rating for Profile Available Water, from Webb & Wilson 1995

The manual proposes methods for estimating land characteristics, recognising that this may differ according to the type of data available from the soil inventory. It is emphasised that the method of determining land characteristics should be clearly stated when preparing a classification. The general procedure for using the manual to develop a classification for land is:

Develop the kind of land evaluation: A land evaluator must identify who will use the classification and what their requirements are for analysis and output. This investigation should result in the selection of a relevant classification.

Determine land use requirements: Different land uses require different inputs for evaluation, the classification must specify what the land use will be.

Derive land qualities: Once the intended land use has been defined, the land qualities effecting land management must be determined from the scientific literature or from field experience. The list of land characteristics and land qualities in the manual (Table 1, pg14, Webb & Wilson, 1995) provides a guide to attributes that need to be checked for significance.

Land qualities are derived from the relevant land characteristics. Sources of data need to be investigated to determine how the selected land characteristics can be measured or estimated. The classification muse be tailored according to the availability of data.

Develop relative ratings for land use: The final step in developing the classification is the creation of a procedure in which that land qualities are rank in relation to one another to determine suitability/versatility ratings.

Webb and Wilson reviewed land use interpretations based on soil surveys. Classifications have included suitability of land for pastoral use (after Gibbs, 1963), cash cropping (after Cutler, 1967), commercial forestry (after Cutler, 1967 and Mew, 1980) horticulture (after Cowie 1974) and assessment of the actual or potential value of land for food production (after Cowie, 1974).

A limitation of these classifications has been their subjectivity, which is due to ill-defined class limits and the lack of any clear relationships between the factors used in the classification and crop production. In addition, the classifications applied to broad land-use grouping (such as cropping, forestry) that contain crops with widely differing requirements.

McIntosh & Hewitt (1992) classified land in Southland and Otago according to suitability for horticulture, forestry and urban use. Their classifications were created to fit the detail available within current regional databases and be easily understood and applied by non-specialists.

They used matching tables to rate land suitability based on the relative ranking of land characteristics. The disadvantages of this approach are the large number of land characteristics used (16 to 20) and the lack of direct correspondence between land characteristics and crop production.

3.5 Tasman District Council

In 1994 Agriculture New Zealand undertook a desk-top study to produce a classification system for productive land in the Tasman District. Using Published information and past experience land units with similar flexibility in terms of activities that could be sustained by that land unit were grouped. The focus of the classification system was on the existing inherent characteristics of the land. The purpose of the project was to provide a land resource classification system that could be used in developing district planning policies on land management.

For the classification four criteria were assessed – climate, topography, soils and existing and past land use.

Land Class	Criteria												
	Climate					Topography		Soil					
	Altitude	Length of Growing season	Heat over summer	Rainfall	Wind	Slope (Degs)	Orient-ation (North/ South)	Fertility	Water Holding Capacity	Rooting Depth (m)	Erosion	Structure/ Texture	Drainage & Permeability
A	<50 m	1-4	1-5	4-6	1-5	<=3	N/a	1-5	1-5	>=1.0	0	3-6	1-3
B	<50	1-9	1-7	3-6	1-5	<=15	N	1-5	1-5	>=0.8	0-1	2-6	1-3
C	<300	1-9	1-8	2-6	1-5	<=15	N/S	1-5	1-4	>=0.6	0-1	2-6	1-3
D	<300	1-11	1-8	2-5	1-5	<=18	N/S	1-4	1-3	>=0.6	0-1	2-6	1-3
E	<300	1-11	1-8	2-5	1-5	<=28	N	1-4	1-3	>=0.6	0-2	2-5	1-4
F	<1200	1-12	1-10	1-6	1-6	<=35	N/S	1-4	1-3	>=0.2	0-3	2-4	1-4
G	<600	1-12	1-10	1-5	1-6	<=35	N/S	1-5	1-3	>=0.8	0-4	2-4	1-4
H		1-12	1-10	1-6	1-6		N/S	1-5	1-5		0-6	1-6	1-5

Table 3:Summary of Land Classification Criteria – Productive Land in the Tasman District

As part of their report, Ag NZ compared the results of their system with LUC maps, they found that the LUC system consistently undervalued some types of soils and climate area. The comparison in table xyz shows that the two systems are comparable in the less flexible classes but markedly different in the flexible classes.

Agriculture NZ classes	LUC Classes	
	Range	*Most Common*
A	I-IV	Variable
B	II-VI	Variable
C	III-V	Variable
D	III-IV	Variable
E	III-VII	VI
F	IV-VIII	VI
G	VI-VIII	VII
H	VII-VIII	VIII

Table 4: Comparison of Agriculture NZ and LUC classes based on soil types

The report stated a number of reasons why the LUC system was not ideal for some planning uses. Firstly that as the emphasis of the LUC was conservation, with particular emphasis on soil erosion, production was a secondary consideration. The national system of classes limits the value for use within a region. Significant changes in technology mean that some areas classed as being difficult to crop, are now highly productive due to the use of trickle irrigation.

CHAPTER FOUR

4. METHODOLOGY

4.1 Introduction

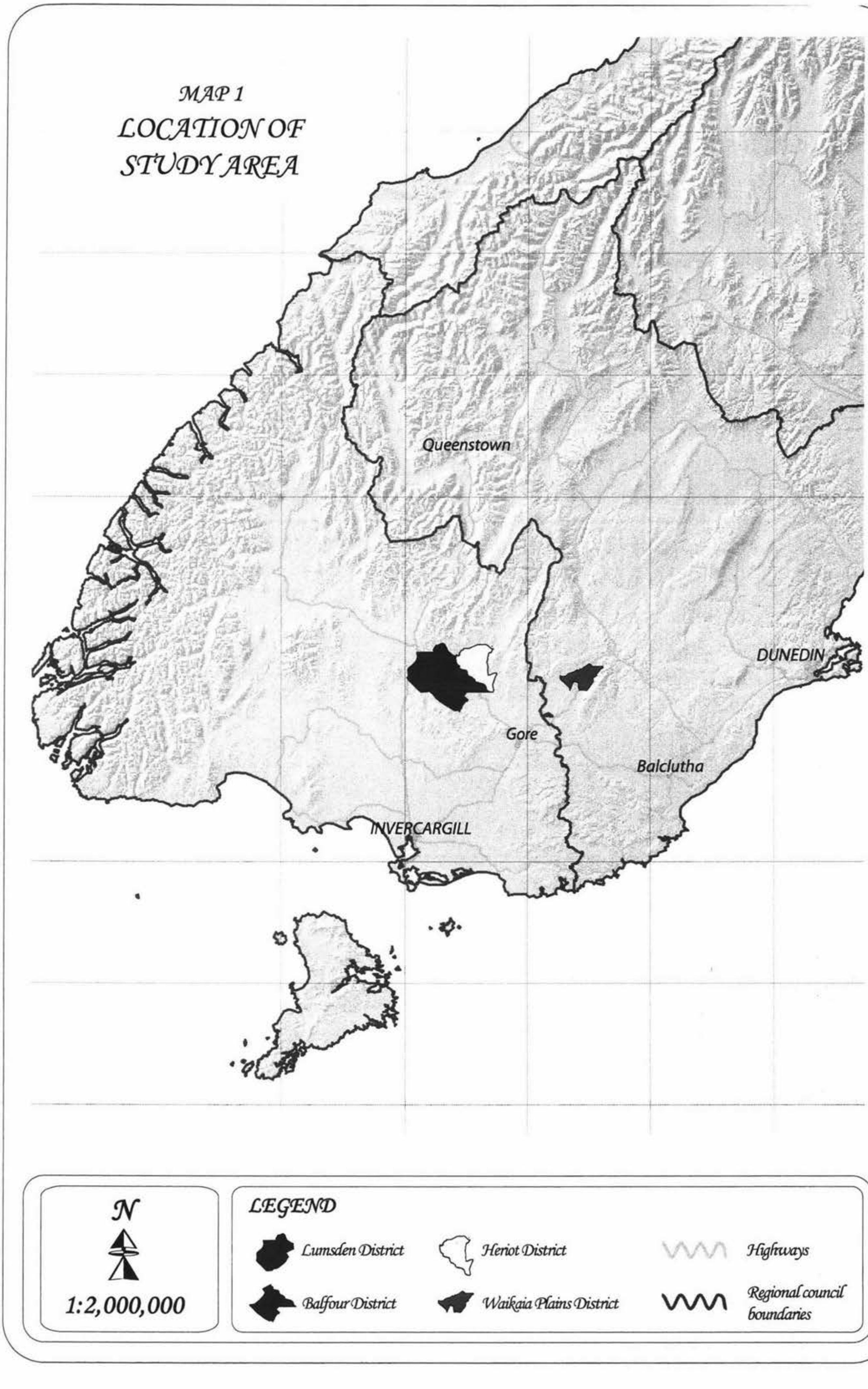
A three-step method was used to determine whether reclassifying data within the NZLRI could be confidently used to assess land potentially at risk to environmental degradation from dairying. Firstly, a framework focussing on environmental threats from dairy land use was developed using principles taken from a number of existing land evaluation frameworks. Secondly, the new framework was used within a Geographic Information System (GIS) to generate two similar classifications from two different data sources. The two data sets were sourced from the NZLRI database and the more recent Topoclimate South soil survey. Thirdly, the results were used to compare the compatibility of the two classifications.

4.1.1 Study Sites

Four districts within the Southland Region were selected for the study. These districts were mapped by Topclimate South as Heriot, Lumsden, Balfour-Riversdale and Waikaia blocks (See map 1).

The soils are primarily southern-yellow-brown and yellow earths, with areas of recent and gley soils.

These four districts have been noted as having significant areas of land recently converted to dairy farming (Nick Round-Turner, pers. comm.). Further, initial appraisal indicated that they have a range of contrasting soil types and LUC classes.


MAP 1
LOCATION OF
STUDY AREA
Queenstown
DUNEDIN
Gore
Balclutha
INVERCARGILL
N
1:2,000,000
LEGEND
Lumsden District
Heriot District
Highways
Balfour District
Waikaia Plains District
Regional council boundaries

4.1.2 Data sources

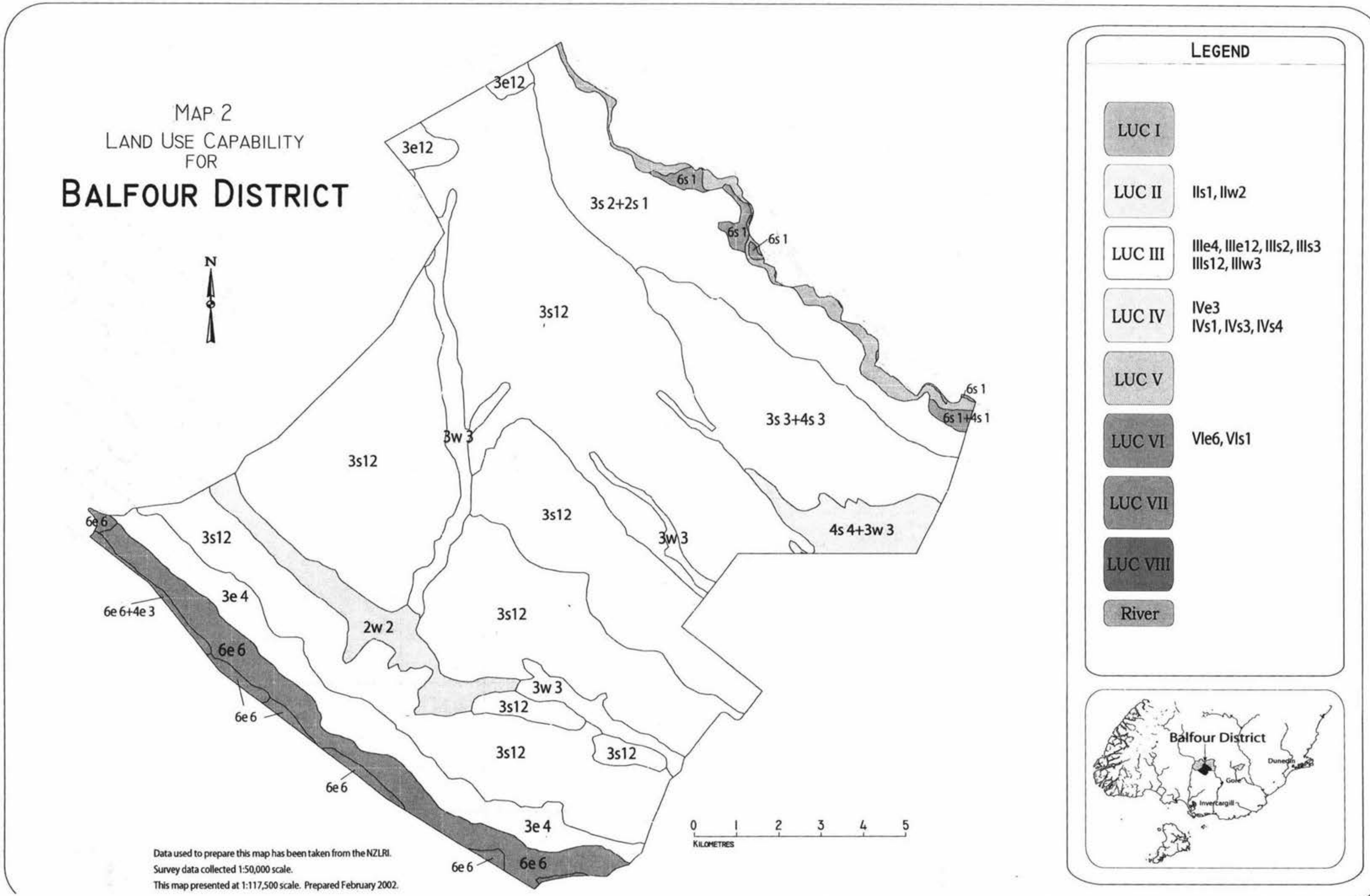
4.1.2.1 New Zealand Land Resource Inventory

The purpose and information detailed within the NZLRI system are described in Chapter 3. Table 5 shows the areas of LUC classes within the study area. There are 25 discrete LUC units (e.g. IIw2, IIIs12, etc), and a total of 37 LUC classes when complexes are included (e.g. 3s 3+4s 3) within the study site, see maps 2-5. There are a total of 250 polygons, ranging in size from 0.1ha to 7486.3ha. The average size of the units was 288.9 ha.

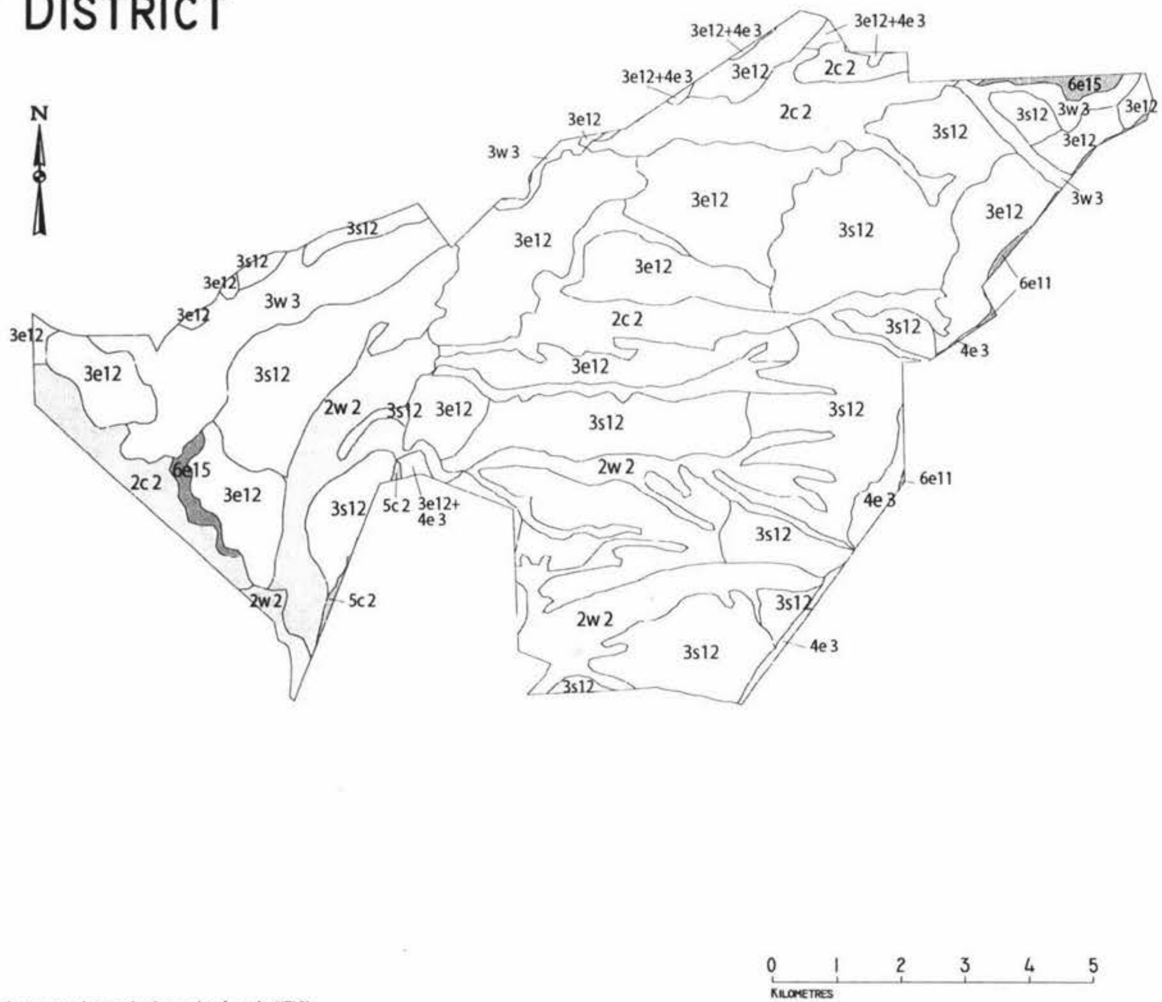
LUC areas (ha)						
II	III	IV	V	VI	RIV	TOTAL
4845.29	52850.23	7218.47	12.04	5951.49	1368.83	72246.35
c	c	c	c	c		
1313.65			12.04			
s	s	s	s	s		
726.89	42231.62	4513.18		940.92		
w	w	w	w	w		
2804.75	2910.50	312.57				
e	e	e	e	e		
	7708.11	2392.72		5010.57		

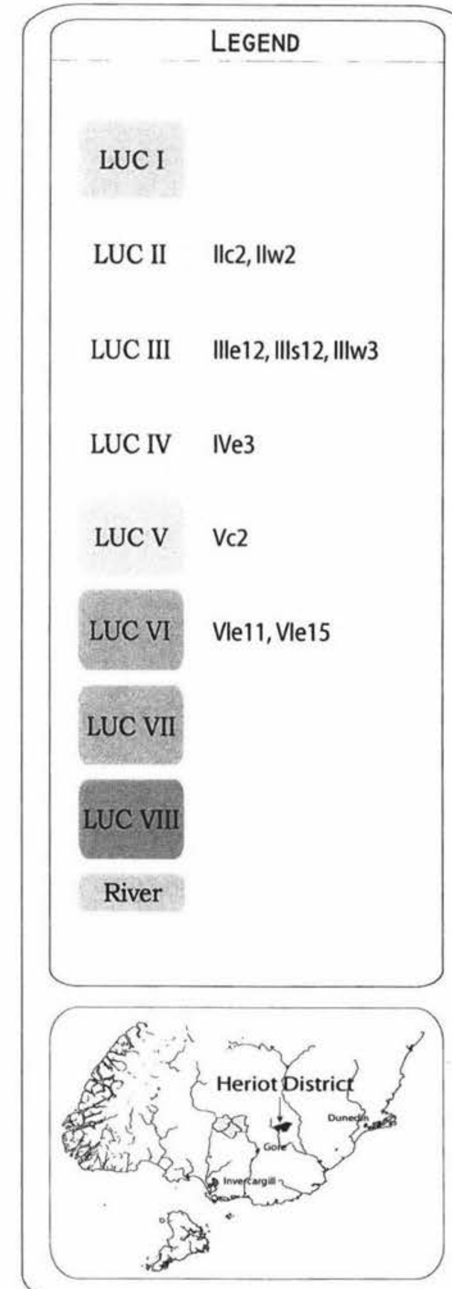
Table 5: LUC class areas within the study area

The format in which the LRI data was obtained was as an ArcView shape file. The accompanying attributes database detailed the five LRI factors, along with LUC data. For interpretation of some of the data, such as soils units, it was necessary to refer to the extended legend (South Island : Land Use Capability Extended Legend, hard copy only).


MAP 2
LAND USE CAPABILITY
FOR
BALFOUR DISTRICT
N
3e12
3e12
3s 2+2s 1
6s 1
6s 1
6s 1
3s12
6s 1
6s 1+4s 1
3s 3+4s 3
3w 3
3s12
3s12
3w 3
4s 4+3w 3
6e 6
3s12
3e 4
6e 6+4e 3
2w 2
3s12
6e 6
3w 3
3s12
6e 6
3s12
3s12
6e 6
3e 4
6e 6
6e 6
0 1 2 3 4 5
KILOMETRES
Data used to prepare this map has been taken from the NZLRI.
Survey data collected 1:50,000 scale.
This map presented at 1:117,500 scale. Prepared February 2002.
LEGEND
LUC I
LUC II
IIs1, IIw2
LUC III
IIIe4, IIIe12, IIIs2, IIIs3
IIIs12, IIIw3
LUC IV
IVe3
IVs1, IVs3, IVs4
LUC V
LUC VI
VIe6, VIs1
LUC VII
LUC VIII
River
Balfour District
Dunedin
Gore
Invercargill

Map 3
Land Use Capability for
Heriot District

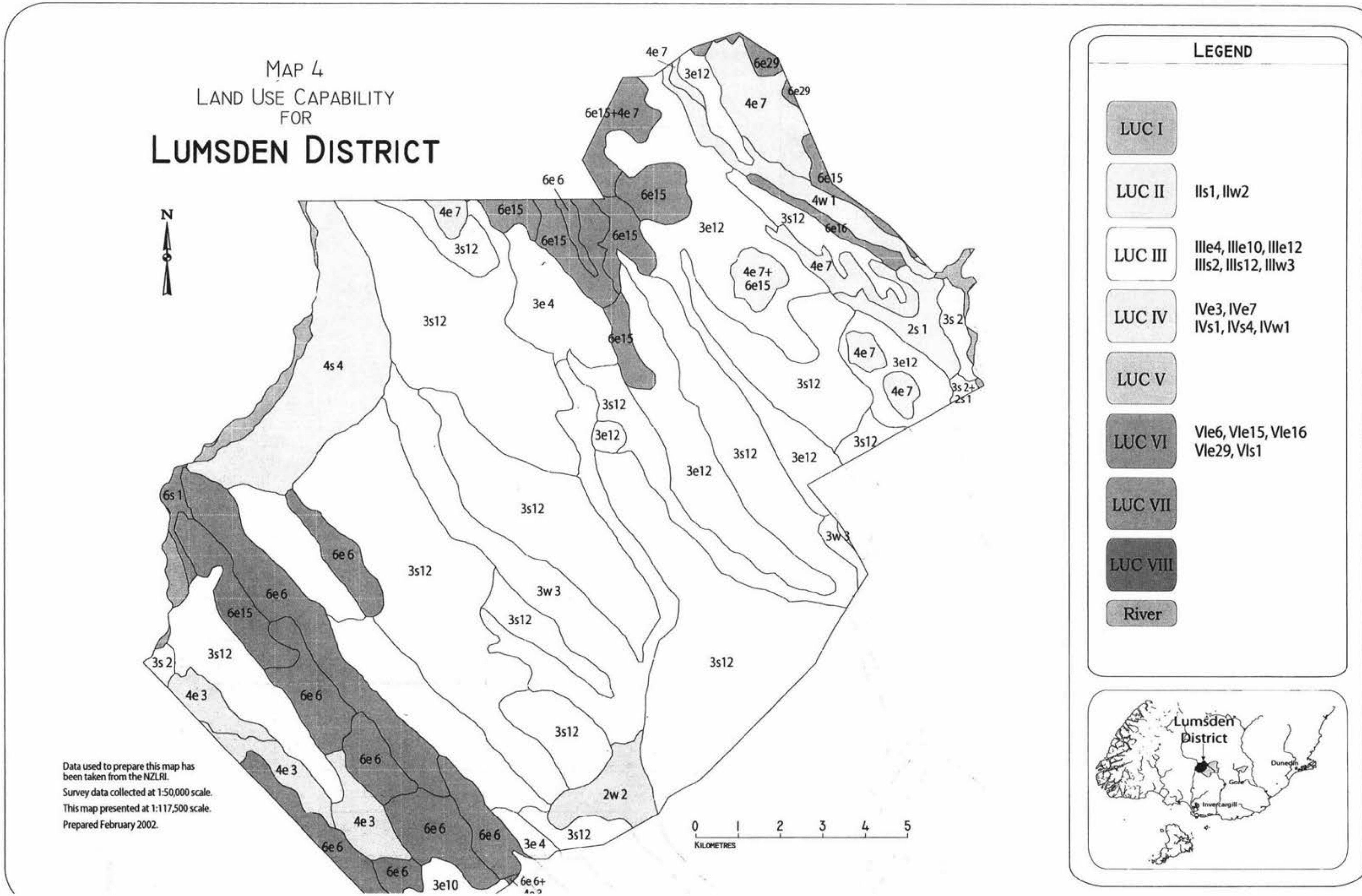


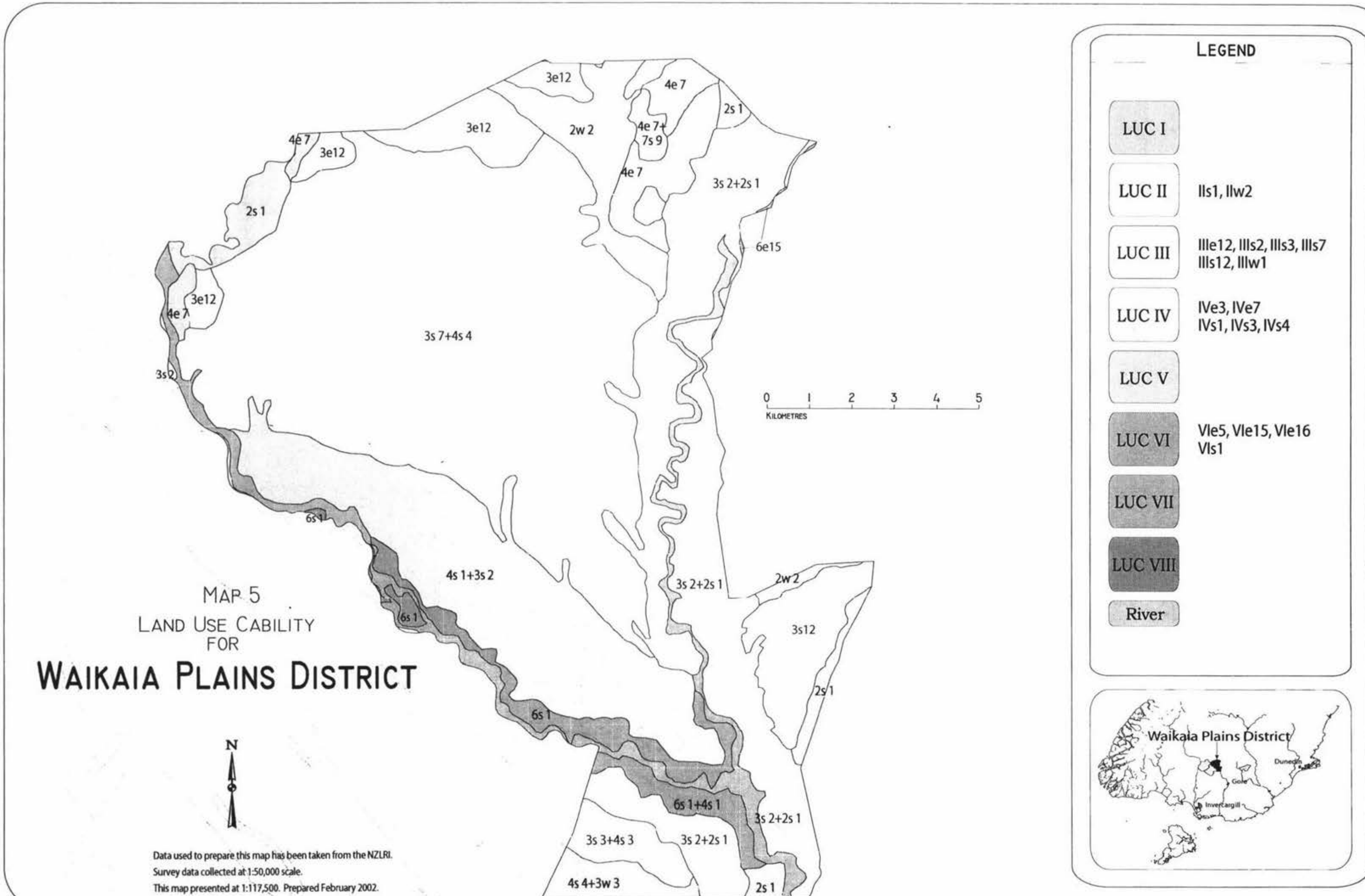


Data used to prepare this map has been taken from the NZLRI

Survey data collected at 1:50,000 scale.

This map presented at 1:117,500 scale.


Map 4
Land Use Capability
for
Lumsden District
N
Legend
LUC I
LUC II
IIs1, IIw2
LUC III
IIIe4, IIIe10, IIIe12
IIIs2, IIIs12, IIIw3
LUC IV
IVe3, IVe7
IVs1, IVs4, IVw1
LUC V
LUC VI
VIe6, VIe15, VIe16
VIe29, VIs1
LUC VII
LUC VIII
River
Lumsden District
Dunedin
Gore
Invercargill
Data used to prepare this map has been taken from the NZLRI.
Survey data collected at 1:50,000 scale.
This map presented at 1:117,500 scale.
Prepared February 2002.
0 1 2 3 4 5
Kilometres
4e 7
3e12
6e29
4e 7
6e15+4e 7
6e 6
6e15
4w 1
3s12
6e16
4e 7
4e 7+
6e15
3s 2
2s 1
3e12
3s 2+
2s 1
3s12
3e4
3s12
4s 4
6s 1
6e 6
6e15
3w 3
3s 2
4e 3
2w 2
3e 4
3e10
6e 6+



MAP 5
LAND USE CABILITY FOR
WAIKAIA PLAINS DISTRICT
LEGEND
LUC I
LUC II
IIs1, IIw2
LUC III
IIIe12, IIIs2, IIIs3, IIIs7
IIIs12, IIIw1
LUC IV
IVe3, IVe7
IVs1, IVs3, IVs4
LUC V
LUC VI
VIe5, VIe15, VIe16
VIs1
LUC VII
LUC VIII
River
0 1 2 3 4 5
KILOMETRES
N
Waikaia Plains District
Dunedin
Gore
Invercargill
3e12
4e 7
2s 1
3e12
2w 2
4e 7+
7s 9
4e 7
3s 2+2s 1
6e15
2s 1
3e12
4e 7
3s 7+4s 4
3s 2
6s 1
4s 1+3s 2
6s 1
3s 2+2s 1
2w 2
3s12
2s 1
6s 1
6s 1+4s 1
3s 2+2s 1
3s 3+4s 3
3s 2+2s 1
4s 4+3w 3
2s 1
Data used to prepare this map has been taken from the NZLRI.
Survey data collected at 1:50,000 scale.
This map presented at 1:117,500. Prepared February 2002.

4.1.2.2 Topoclimate South

The purpose of the Topoclimate soil maps is to enable land users to accurately identify soil types, in order to match soil characteristics with appropriate land uses, to maintain sustainability of land uses, and to provide more accurate information for risk management decisions.

Soils have been previously mapped at the scale of 1:253 440 (N.Z. Soil Bureau, 1968). Topoclimate South has remapped the soils of the Heriot, Lumsden, Balfour-Riversdale and Waikaia Districts at the scale of 1:50 000. The field surveys for these areas were completed in June 1999.

Auger observations, to a depth of one metre were used to describe and map the soil pattern, of the study areas. Soil descriptions for each significant profile form were then described from a typical profile pit. This is the site from which samples have been taken for laboratory analyses. (From Topoclimate Soil Reports, 1999)

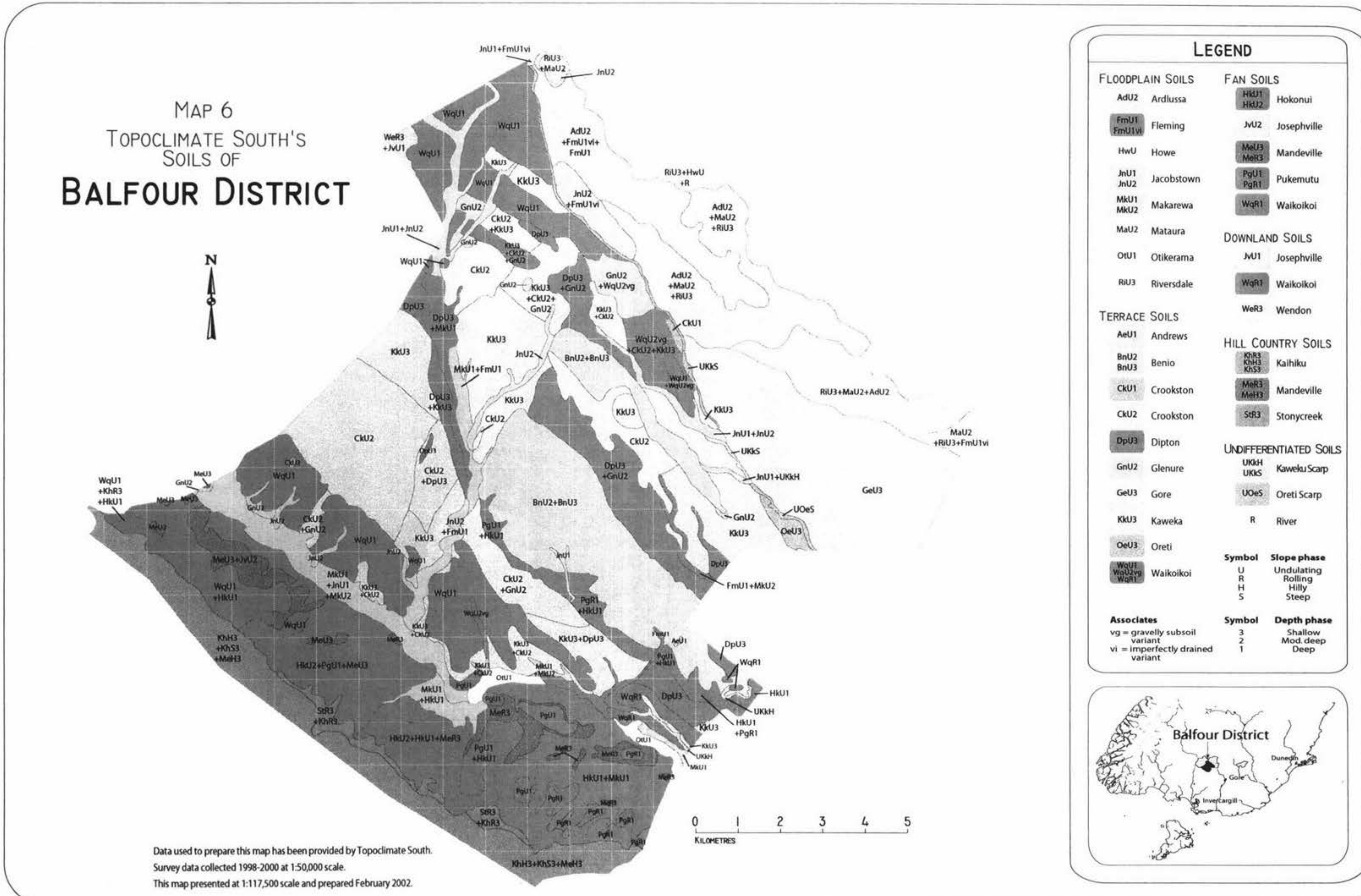
There were 98 soil associates mapped within the chosen study site, with a total 190 soil composites (more than one soil associate within a polygon) recorded, see maps 6-9. Overall there were 455 separate polygons, ranging in size from 0.7ha to 3591ha, the average mapping unit was 157.8ha.

Data for the Topoclimate South was supplied as Map Info files, and soil reports in word documents. The Map Info files contained soil names. For each soil associate mapped a descriptive report containing soil profile and chemical analysis was provided, this was used to supplement the GIS information. An example is shown in Appendix II.

Table 6: Areas of Soils Grouped by Landform

Landform	*Total Area* (ha)	%
Floodplain	197.03.5	27.2
Fan	14358.6	19.9
Terrace	22527.3	31.2
Downland	6791.2	9.4
Hill Country	7222.5	10
Undifferentiated	1650.6	2.3
Total	72253.7	

Map 6
Topoclimate South's Soils of
Balfour District

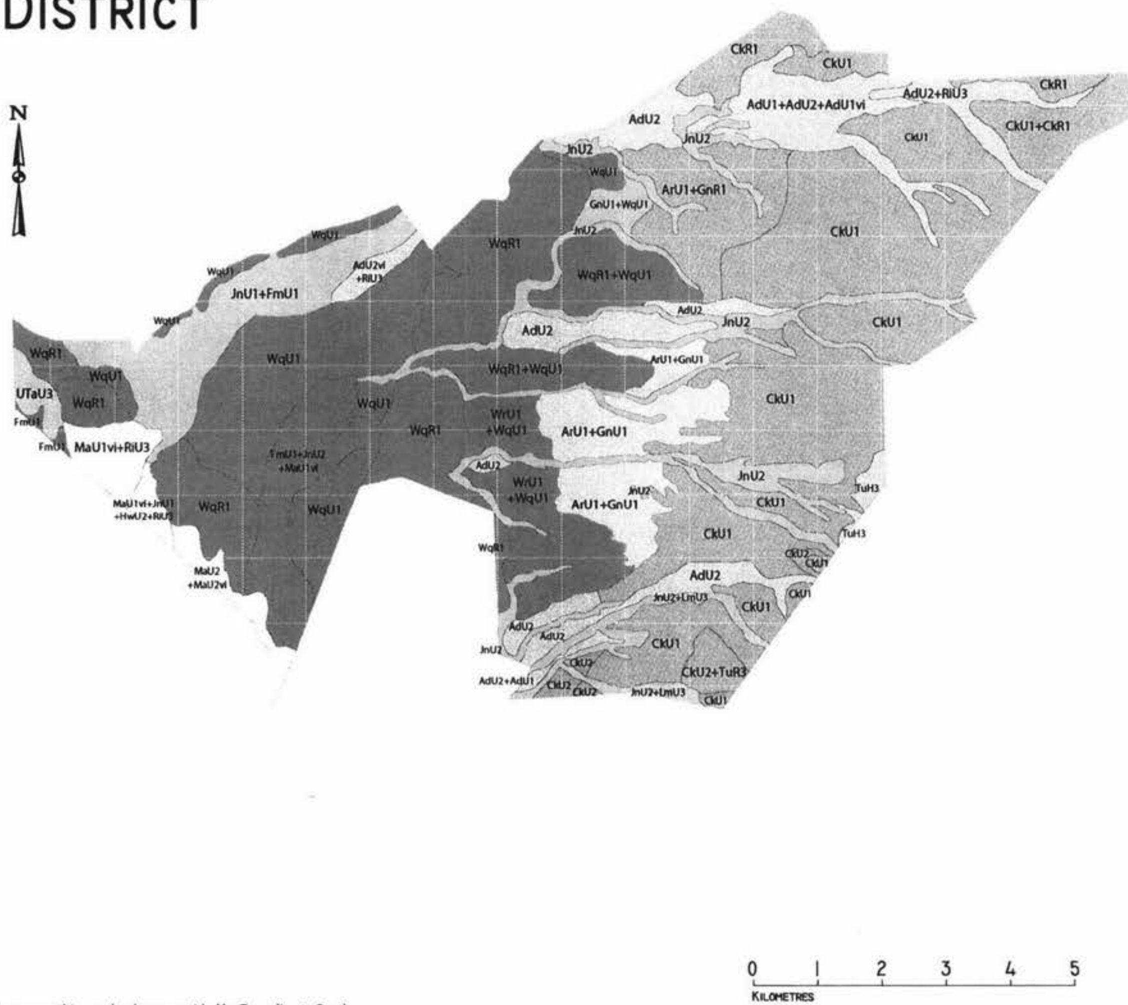


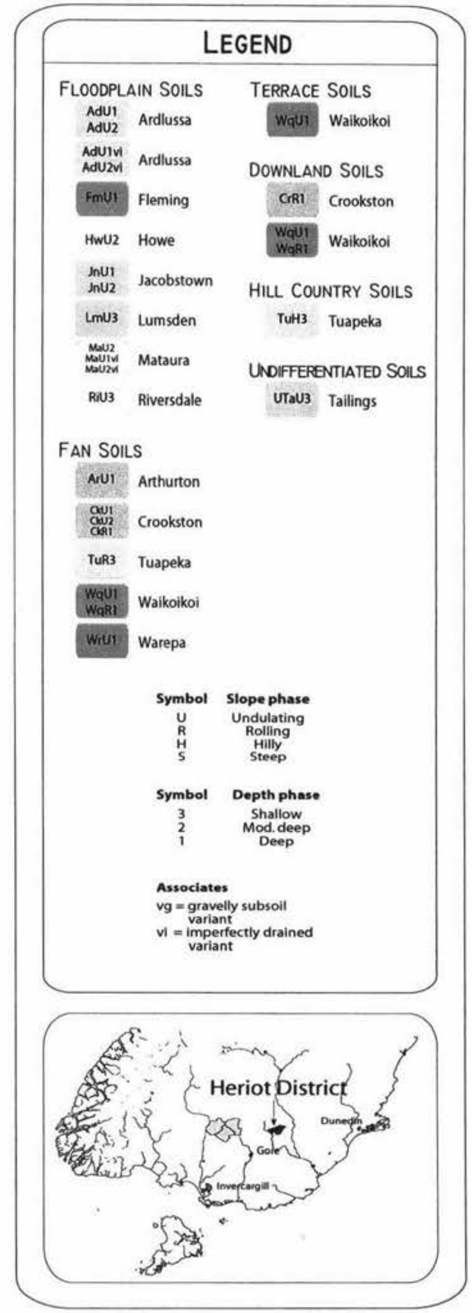
Data used to prepare this map has been provided by Topoclimate South.
Survey data collected 1998-2000 at 1:50,000 scale.
This map presented at 1:117,500 scale and prepared February 2002.

Map 7

Topoclimate South's Soils of

Heriot District

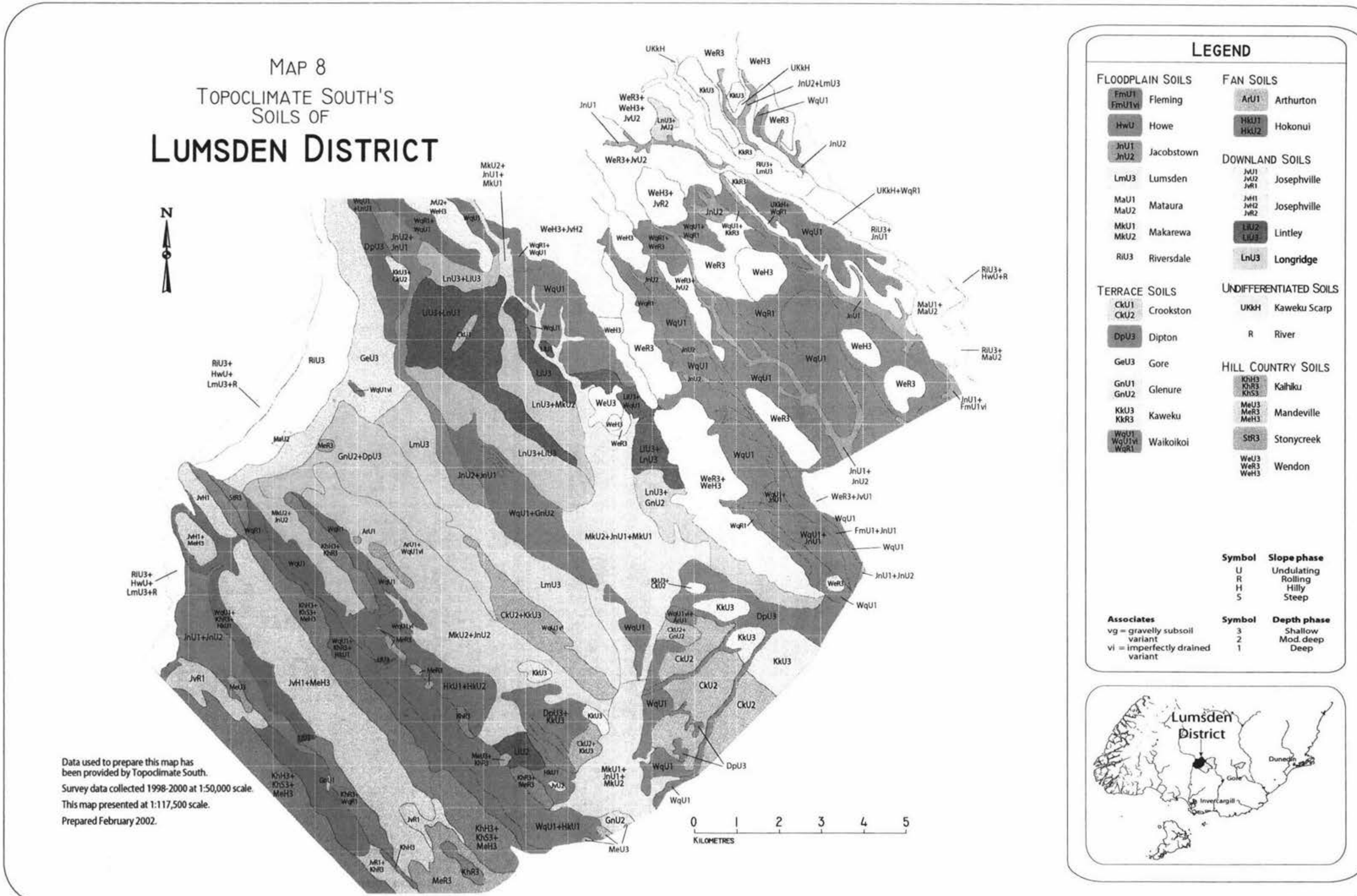




Data used to prepare this map has been provided by Topoclimate South.

Survey data collected 1998-2000 at 1:50,000 scale.

This map presented at 1:117,500 scale and prepared February 2002.

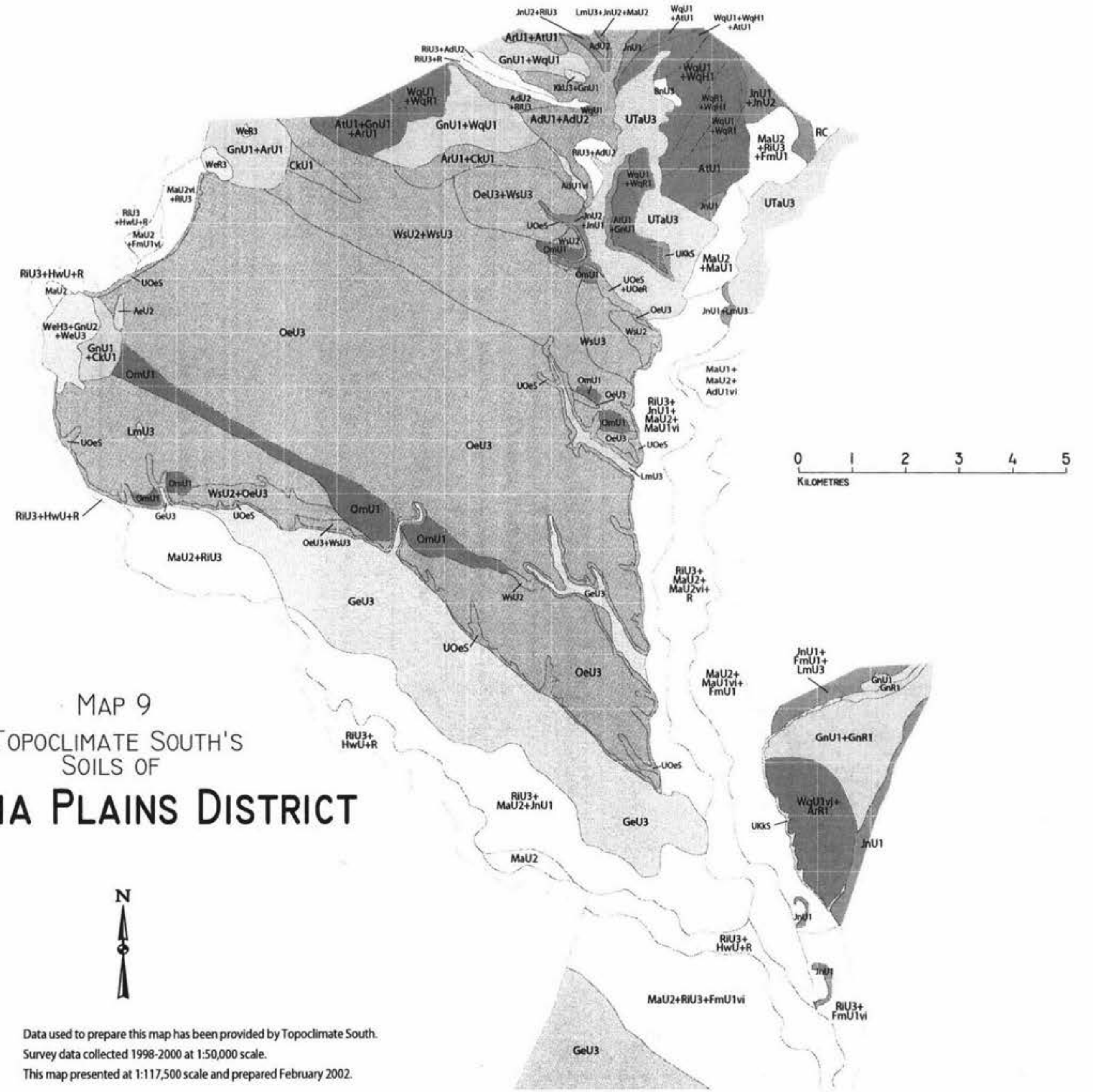


Map 8
Topoclimate South's Soils of
Lumsden District
N
Legend
Floodplain Soils
FmU1 FmU1vi Fleming
HwU Howe
JnU1 JnU2 Jacobstown
LmU3 Lumsden
MaU1 MaU2 Mataura
MkU1 MkU2 Makarewa
RiU3 Riversdale
Fan Soils
ArU1 Arthurton
HkU1 HkU2 Hokonui
Downland Soils
JvU1 JvU2 JvR1 Josephville
JvH1 JvH2 JvR2 Josephville
LiU2 LiU3 Lintley
LnU3 Longridge
Terrace Soils
CkU1 CkU2 Crookston
DpU3 Dipton
GeU3 Gore
GnU1 GnU2 Glenure
KkU3 KkR3 Kaweku
WqU1 WqU1vi WqR1 Waikoikoi
Undifferentiated Soils
UKkH Kaweku Scarp
R River
Hill Country Soils
KhH3 KhR3 KhS3 Kaihiku
MeU3 MeR3 MeH3 Mandeville
StR3 Stonycreek
WeU3 WeR3 WeH3 Wendon
Symbol Slope phase
U Undulating
R Rolling
H Hilly
S Steep
Associates
vg = gravelly subsoil variant
vi = imperfectly drained variant
Symbol Depth phase
3 Shallow
2 Mod. deep
1 Deep
Lumsden District
Dunedin
Gore
Invercargill
0 1 2 3 4 5
Kilometres
Data used to prepare this map has been provided by Topoclimate South.
Survey data collected 1998-2000 at 1:50,000 scale.
This map presented at 1:117,500 scale.
Prepared February 2002.

MAP 9

TOPOCLIMATE SOUTH'S SOILS OF

WAIKAIA PLAINS DISTRICT



Data used to prepare this map has been provided by Topoclimate South.
Survey data collected 1998-2000 at 1:50,000 scale.
This map presented at 1:117,500 scale and prepared February 2002.

LEGEND

FLOODPLAIN SOILS

AdU1, AdU2	Ardlussa
AdU1v1	Ardlussa
FmU1, FmU1vi	Fleming
HwU	Howe
JnU1, JnU2	Jacobstown
LmU3	Lumsden
MaU1, MaU2, MaU1vi, MaU2vi	Mataura
RiU3	Riversdale

TERRACE SOILS

AeU2	Andrews
ArU1, ArR1	Arthurton
AtU1	Athol
BnU3	Benio
CkU1	Crookston
GnU1, GnR1	Glenure
GeU3	Gore
KkU3	Kaweku
OeU3	Oreti
OmU1	Otama

TERRACE SOILS (CON.)

WqU1, WqR1, WqH1, WqU1vj	Waikoikoi
WsU2, WsU3	Wendonside

HILL COUNTRY SOILS

GnU2	Glenure
WeU3, WeR3, WeH3	Wendon

UNDIFFERENTIATED SOILS

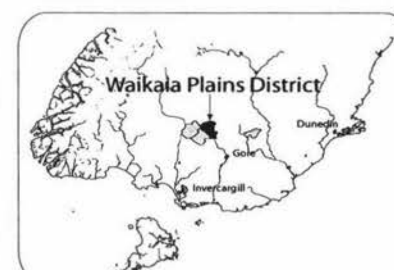
UKkS	Kaweku Scarp
UOeR, UOeH, UOeS	Oreti Scarp
UTaU3	Tailings
R	River
RC	River Complex

Symbol	Slope phase
U	Undulating
R	Rolling
H	Hilly
S	Steep

Associates

vj = argillic taxadjunct
vi = imperfectly drained variant

Symbol	Depth phase
3	Shallow
2	Mod. deep
1	Deep



4.2 Land evaluation framework

A four-step land evaluation framework for deriving environmental risk classifications was developed, based upon principles taken from a number of different frameworks discussed in Chapter 1. However, the majority of the framework has been built around Webb and Wilson's (1998) procedure adapted from the FAO Framework for Land Evaluation .

The four steps of the framework include: defining the land evaluation purpose; identifying specific and measurable environmental impacts of dairy farming; derive appropriate land qualities; and finally, develop a relative rating for environmental risk (Figure 4).

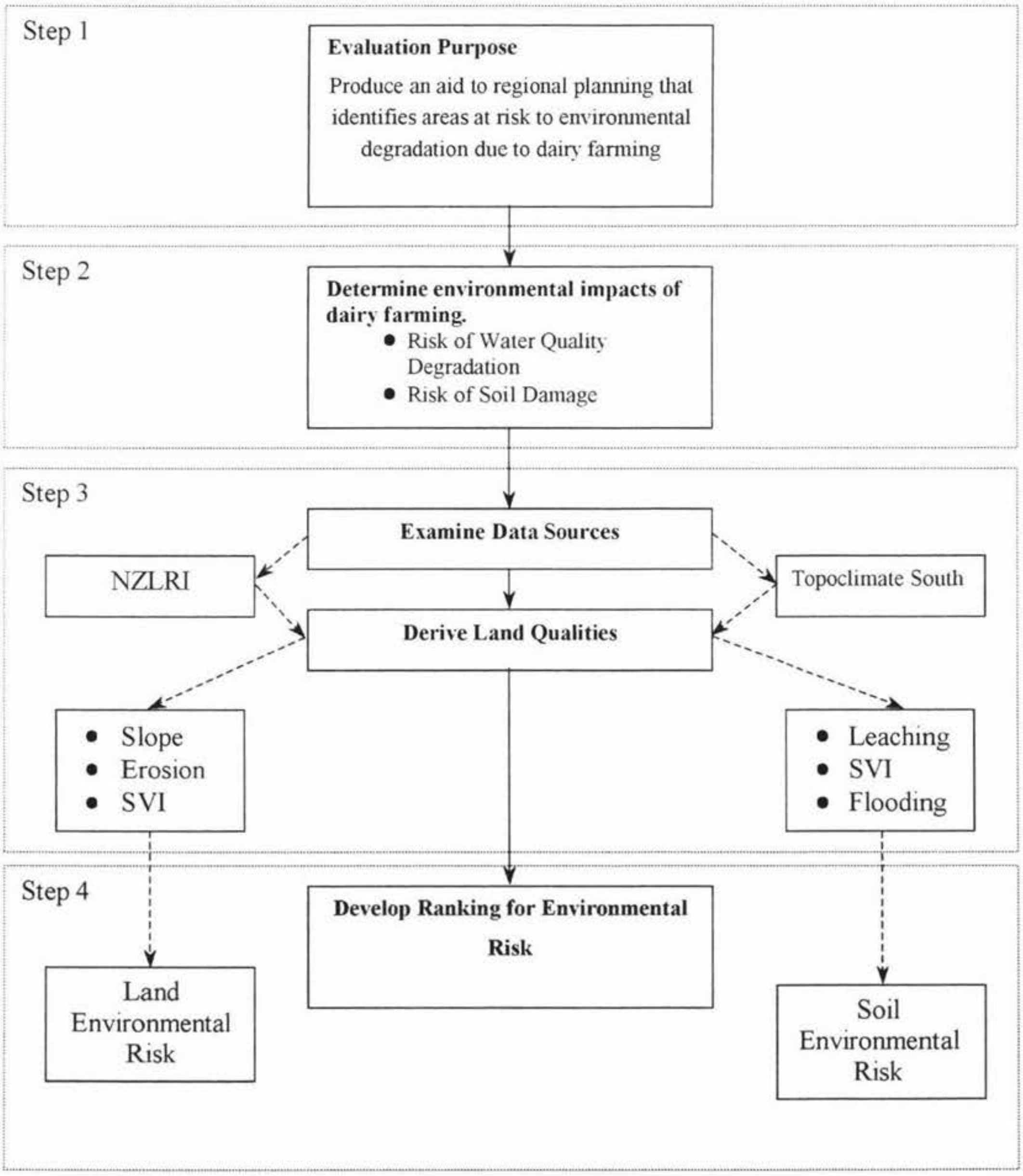


Figure 4: Four steps of the land evaluation framework

4.2.1.1 Description of steps

1. Identify the purpose of undertaking the land evaluation.

   "*A land evaluator must identify who will use the classification and what their requirements are for analysis and out*put" (Webb & Wilson, 1998, page 29). As stated in the objectives, the classification is aimed at a regional council planning level, to broadly identify areas at risk of environmental degradation due to increased dairying pressure.

2. Determine the main environmental impacts of dairy farming.

   The environmental impacts to be considered are:

   - Decreased water quality – leaching and surface contamination (from nutrients and sediment)
   - Decreased soil quality – structural breakdown and erosion.

   These impacts were identified in the Environmental Impact Assessment for Southland Dairy Farming Expansion as significant (see page 5).

3. Derive land qualities

   "*Land qualities are determined from scientific literature or from field experience. Land qualities are derived from the relevant land characteristics. Sources of data need to be investigated to determine how the selected land characteristics can be measured or estimated. The classification must be tailored according to the availability of the data*" (Webb & Wilson, 1998, page 29).

   Land qualities derived are detailed below.

4. Develop a relative rating for environmental risk

For each land quality determined, the range of rankings fell into five classes. Each of these is set out in the land qualities detailed below. A limitation method was used for the overall classification. The overall classification is represented numerically one to five, with the environmental risks indicated by a letter. The dominant risk is indicated by a capital letter. When another factor is also a risk, but to a lesser degree, it is represented by a lower case letter. When two factors were limiting to the same degree there is no distinction between the case of the letter. However, if the third factor was also limiting but to a lesser degree it was represented as a lower case.

When dealing with composite polygons the overall ranking was determined by looking at the most limiting feature, if the ranking was two classes higher then the middle rank was used

As noted by Dent & Young (1981), it is not always possible to acquire data that is tailored to specific land evaluation purposes, often only general soil or land surveys are available, and the interpretation of these is part of a land evaluation. This is also reflected by Webb & Wilson (1998) who state in their framework that sources of data need to be investigated to determine how selected land characteristics can be measured or estimated. Because of this reasoning, the framework has been adapted slightly to accommodate differences in the two data sources used in this study.

4.2.2 Accommodating LRI data

Data within the LRI has been reclassified to address as many of the specific environmental concerns raised above.

4.2.2.1 Erosion Potential

Erosion leads to decreased soil quality, and can also lead to increased sediment loads in receiving water bodies, reducing water quality.

Erosion potential and ranking was taken from the extended legend, the potential rather than recorded value was used to take into account the age of the information presented on the LRI maps and because the classification is assessing risk.

Erosion was ranked as follows:

Table 7: Potential Erosion Rank

LRI Rank	*LRI Description*	*Overall Rank*
0	Negligible	1
1	Slight	2
2	Moderate	3
3	Severe	4
4	Very severe	5

4.2.2.2 General SVI

Soil types as according to the extended legend where compared with the general classes given by Shepherd (1998), and were assigned the following environmental risk ranking.

Table 8: Soil Vulnerability Index Rank

SVI Class	*SVI Figure*	*Rank*
Very low	SVI < 0.4	1
Low	SVI 0.4 – 0.5	2
Moderate	SVI 0.5 – 0.6	3
High	SVI 0.6 – 0.7	4
Very high	SVI > 0.7	5

Adapted from Shepherd 1998

4.2.2.3 Slope

Slope is a determinant of land stability, influences runoff processes and influences erosion forms. Increased runoff (including nutrients carried in surface water and sediment from erosion) can lead to decreased water quality. Land stability and erosion directly influence soil quality.

Slope classes were assigned the following rankings.

Table 9: Slope classes

LRI Class	*Angle*	*Rank*
A	$(0\text{-}3^0)$	1
B	$(4^{0\text{-}}7^0)$	1
C	$(8^{0\text{-}}15^0)$	2
D	$(16^0\text{-}20^0)$	3
E	$(21^0\text{-}25^0)$	4
F	$(26^0 - 35^0)$	5

4.2.2.4 Evaluation Classification

1 – Slight risk of environmental degradation

2 – Low risk of environmental degradation

3 – Moderate risk of environmental degradation

4 – High risk of environmental degradation

5 – Very high risk of environmental degradation

E – indicates risk due to erosion potential

S – indicates risk due to soil vulnerability

Sl – indicates risk due to slope

4.2.3 Accommodating Topoclimate South soils data

After examining the available data, it was determined that three land qualities would be used in the framework: Flooding risk, leaching and SVI.

4.2.3.1 Structural Vulnerability Index

The structural vulnerability index (SVI) devised by Hewitt and Shepherd (1997) was used to integrate the compaction/pugging dimension into the impact assessment. This index estimates the inherent susceptibility of NZ soils to physical degradation by focusing on structural vulnerability. The index may be used as a first approximation rating of the structural vulnerability of NZ soil to aid resource management. Soils that are identified as highly vulnerable could be targeted for more intensive monitoring and appropriate management practices implemented. Soils that are less vulnerable may also become degraded but it is likely that their inherent resistance or resilience will suit them to more intensive use and higher levels of sustainable production.

SV for mineral soils is calculated as follows:

$$SV = 1 - [(DR/10 + PR/100 + \sqrt{OC/5} + \sqrt{CL/8.5} - 0.7)/2.3]$$

DR = drainage class code, defined as 1=very poorly drained, 2=poorly drained, 3=imperfectly drained, 4=moderately well drained, 5=well drained or excessively drained.

PR = phosphate retention (%)

OC = organic carbon (%)

CL = clay (%)

Chemical analysis from the Topoclimate reports was used to calculate the SVI. The Topoclimate Soils data was originally analysed in order to acquire the necessary data to calculate SVI.

For ranking classification refer to Table 8.

4.2.3.2 Leaching

Leaching of nutrients and biocides can lead to decreased water quality in surface and groundwater. A Leaching class risk was determined using the Web and Wilson methodology

The calculation of potential leaching loss is determined from the potential of the soil to retain and assimilate biocides (based on the weighted average cation-exchange capacity in the upper 0.6m) and the amount of water leaching through the profile (based on soil water surplus).

The soil water surplus was assessed from the climatic water balance, and profile-available water (PAW) storage capacity. Soil water surplus for all soils in the area was found to be > 300

Table 10: Leaching classes

PAW[1] $PAW = \frac{AWC(\%)}{100} *$ depth soil layer mm	Soil Water Surplus (based on PAW of 160mm) 300-500mm		
(mm)	Minimum weighted CEC within upper 0.6m (meq/100g): >12	6-12	<6
>250	minimal (1)	minimal (1)	moderate (3)
150-250	minimal (1)	slight (2)	moderate (3)
90-150	slight(2)	moderate(3)	severe (4)
60-90	moderate(3)	severe(4)	v severe(5)
30-60	severe (4)	v severe(5)	v severe(5)
<30	v severe(5)	v severe(5)	v severe(5)

(Modified From Webb & Wilson, 1999)
(Numbers is parentheses represent overall risk rank)

4.2.3.3 Flooding

Flooded areas more likely to exacerbate other problems, such as reduction of water quality due to nutrient and sediment contamination, wet soils are more vulnerable to pugging damage. Flooding risk was determined during soil mapping, and assigned the following classes:

Table 11: Flooding classes

Description	*Numerical Rank*
No Flooding	1
Infrequent Flooding	3
Frequent Flooding	5

4.2.3.4 Evaluation Classification

1 – Slight risk of environmental degradation

2 – Low risk of environmental degradation

3 – Moderate risk of environmental degratation

4 – High risk of environmental degradation

5 – Very high risk of environmental degradation

F – indicates risk due to flooding potential

S – indicates risk due to soil vulnerability

L – indicates risk due to leaching index

4.3 Data processing and map preparation

A range of GIS software was used to process the two data sources through the newly developed evaluation framework. Additionally, these programs were also used to prepare and present a number of maps.

4.3.1 Geographical Information Systems

A GIS can be considered as a tool for dynamically managing, manipulating, and presenting spatially related data through a computer. Principle components include the computer hardware, software and digital geographic data, although in recent years the term 'Geographic Information System' has become synonymous with the software component.

Information used within a GIS can be divided into two categories. Firstly, coordinate information provide a spatial reference for the data as either points (or pixels), lines, or polygons. This information is stored within a 'spatial feature database' as either raster (image or bitmap) formats, or vector (drawing) formats. Individual GIS software tends to exhibit a design tendency where one format is favoured over the other (e.g. Arcview is said to be vector based).

The second category of information is attribute data that describe the characteristics of a given spatial feature. Modern GIS tend to store attribute data in relational databases, or at least in relational database formats (e.g. Microsoft Access, dBase). A defining feature of any GIS is the ability to link the attribute database to the spatial database for analysis and display.

4.3.1.1 Software used

A number of GIS software programs were used, including ArcView, ArcExplorer, and MAPublisher. ArcView is the most suitable of the three for spatial processing, but access and use was limited because this study has been undertaken extramurally. This limitation was overcome by making use of freely available GIS orientated software, and software the author already had off-campus access to. This included the free ArcExplorer to view data, and Microsoft Excel as an attribute database editor. MAPublisher was used exclusively to produce maps.

Arcview 3.1: This is a powerful vector based GIS suitable for use on desktop computers. As well as being relatively easy to use, it is capable of a wide range of geoprocessing functions (e.g. merging data, clipping data, union of data, overlaying and intersecting data), and database functions (e.g. querying, calculations). While also being suitable for producing accurate maps, it is not as versatile as more cartographic orientated software.

ArcExplorer 3: This software is freely available from www.esri.com. As freeware, it has limited data processing functions (e.g. buffering, querying, labelling) with it's main value being a 'light-weight' means of viewing and querying spatial data. While map production is quick and easy, versatility and quality are very limited.

Excel: This is Microsoft's leading spreadsheet software. While it is not a database program, it can be used as a database editor provided certain elementary database principles are observed.

MAPublisher: In contrast to Arcview, MAPublisher has limited geoprocessing and database management functions, but is highly versatile for producing cartographic quality vector-based maps. This is not standalone software, but rather a set of filters used within either the Adobe Illustrator or Freehand graphics drawing software packages.

4.3.1.2 Processing functions

Data processing was achieved mainly through ArcView and excel. Some of the more important functions included clipping extents, updating attribute data, calculating areas, and querying/filtering data.

Clipping extents: To obtain a spatially matching data set from the NZLRI, district extents supplied with the Topoclimate South data were used within ArcView's Geoprocessing Wizard to 'clip' the desired areas.

Updating attribute data: The attribute database supplied with the Topoclimate South data was limited to two fields – the identifier key and the soil names. Attributes relevant to the evaluation framework were obtained from a range of Topoclimate South reports (word documents), and manually inputted using excel. However, as a database, the spreadsheet needed to be treated as a table (e.g. new fields, or renaming fields, could only be inserted using ArcView or Microsoft Access). Overall classifications were added manually according to the rules set out in the classification criteria, as a new field for both data sources. These were then saved as dbase file and used for the new map production.

Calculations: A script/extension was run to re-measure polygon areas within the clipped boundary for the NZLRI data. For the Topoclimate South data a script was run to generate area measurements. Appropriate formulas were set up in excel to calculate the SVI and PAW for the Topoclimate south data.

Querying data: Microsoft excel was used to query and filter data. Essentially this involved using a variation on the conventional SQL statements fundamental to database manipulation, whereby individual attributes of interest were identified from within one or two fields, and a new corresponding value placed in another field. SQL equations were not used.

4.3.1.3 Map production

MAPublisher was used to produce a series of maps based upon a generic template. The template had five layers:

- Layer 1 included borders, titles, legend and label text.
- Layer 2 was the map grid.
- Layer 3 was a mask.
- Layer 4 included map polygons and legend objects.
- Layer 5 represented the base outline, including the template extent and location map.

To begin with, the appropriate ArcView shapefile was imported to Layer 4 at a scale that allowed it to fit onto an A4 landscape page (1:117,500). Secondly, thematic classifications were applied according to the attribute of interest (e.g. LUC, LER, soils). This involved manually designing the legend structure and appropriate thematic colours; making legend objects active (linking them to the shapefile); and then running a classification function to attribute legend colours to the polygons. In turn, each polygon was then labelled with an automatic placement function, and then manually adjusted or resized where necessary.

Thirdly, a mask was merged with Layer 4 to hide unnecessary detail. Grid and scale bars were calculated, and inserted within Layer 2. Co-ordinates were placed manually. Finally, titles and legend text were edited where appropriate.

Resulting maps have had text and outlines colour coded for ease of reference. For the Topoclimate South soil maps the text and outlines are black; reddish brown for the LUC maps; dark blue for the SER maps; and green for the LER maps.

4.4 Comparing classification results

The Geoprocessing tool in ArcView was used to join the two databases (e.g. LER and SER). Once this 'overlaying' had been done the dbase file was saved into an Excel spreadsheet for examination.

Within the Excel programme the dbase file was saved as a spreadsheet and the Pivot Table function used to examine the data field values. Various table were generated to summarise the data, for example sum, count and average values. Fields within the pivot tables corresponded to the different data fields within the classifications e.g. LER rank, SVI and overall area. Using the pivot table it was possible to display several facts about each class.

ArcExplorer was used to select areas of single classification units (across the entire study site) and overlay information from the second evaluation model.

CHAPTER FIVE

5. RESULTS AND DISCUSSION

5.1 Land Environmental Risk

The application of the evaluation model resulted in 10 classes of Land Environmental Risk(LER) classification (see table 12), this was from the original 37 LUC units and complexes. Overall 3342 ha were LER class 3 (4.6%), 67375 ha were LER class 4 (93.3%) and 1530 ha LER class 5 (2.1%).

Maps 10-13 show the distribution of classes across the study site, the areas of class 3 and 5 LER are generally narrow tracks of land compared with class 4. The spread of classes across the district maps is even, though the Heriot district has the smallest area of class 5 land.

The biggest individual class was 4LER S e (52100 ha), having a high risk due to soil vulnerability and moderate erosion potential risk. The second biggest class was 4LER sl S e (11544 ha), together these classes accounted for 88.1% of the total area of the study site.

Table 12: Land Environmental Risk Classification – Description & Total Areas

Environmental Risk Class	*Classification Description*	*Total Area* (ha)	*%*
3LER S	Moderate risk of environmental degradation due to soil vulnerability.	313	0.4
3LER s e	Moderate risk of environmental degradation due to soil vulnerability and potential erosion.	2910	4.0
3LER sl s e	Moderate risk of environmental degradation due to soil vulnerability, potential erosion and slope class.	119	0.2
4LER S	High risk of environmental degradation due to soil vulnerability	2040	2.8
4LER S e	High risk of environmental degradation due to high soil vulnerability, and moderate erosion potential	52100	72.1
4LER SL s e	High risk of environmental degradation due to slope class, and moderate soil vulnerability and erosion potential.	84	0.1
4LER sl S e	High risk of environmental degradation due to high soil vulnerability and moderate slope class and erosion potential	11544	16
4LER sl S E	High risk of environmental degradation due to high soil vulnerability and erosion potential, and moderate slope class	1605	2.2
5LER	Very high risk of environmental degradation (areas mapped as rivers)	1369	1.9
5LER SL s e	Very high risk of environmental degradation due to slope class, and high soil vulnerability and erosion potential	161	.2

The most common LER class, 4LER S e, is also reflected by the number of LUC units which were re-classified by the ER model. There are 13 LUC units and complexes in the 4LER S e class, of these 11 have soil as the subclass.

The 2nd largest LER class, 4LER sl S e, is made up of 11 LUC units and complexes. The subclass of all these LUC units is erosion.

Table 13: :Land Environmental Risk Classification – Land Use Capability Unit

Environmental Risk Class	*Land Use Capability Unit*
3LER S	IVw1
3LER s e	IIIw2
3LER sl s e	IIIe10
4LER S	IIc2, IIs2
4LER S e	IIw2, IIIe4, IIIs2, IIIs2+IIs2, IIIs2+IVs1, IIIs3+IVs3, IIIs7+IVs4, IIIs12, IVs1+IIIs2, IVs4, IVs4+IIIw3, VIs1, VIs1+IVs1
4LER SL s e	Vc2, VIe5, VIe29
4LER sl S e	IIIe12, IIIe12+IVe3, IVe3, IVe3+IIIe12, IVe3+VIe16, VIe6, VIe6+IVe3, VIe15, VIe15+IVe3, VIe15+IVe7, VIe16
4LER sl S E	IVe7, IVe7+VIe15
5LER	rivers
5LER SL s e	IVe7+VIIs9, VIe11

Soil vulnerability had the biggest influence on the risk classes, appearing as a factor in all but one of the resultant classifications. This is not unexpected due to the broad nature with which this factor had to be applied. With only general soils data being available within the LRI database only two SVI rankings were applied. Of the two SVI rankings 4.8% of the total area of the study site had a moderate SVI, and 93.3% had a high soil vulnerability (the remainder of the land was river and hence did not have SVI applied). The narrow range of SVI able to be applied also restricted the number of overall ranking classes, so that a moderate risk class was the lowest that was generated.

Table 14: Area of SVI rankings within LER classification

RANK	M	H	R	Area ha
3LER S	313			313
3LER s e	2911			2910
3LER sl s e	119			119
4LER S		2040		2040
4LER S e		52101		52100
4LER sl S e		11544		11544
4LER sl S E		1605		1605
4LER SP s e	72	12		84
5LER			1369	1369
5LER SL s e	19	142		161
Total ha	3434	67444	1369	72246

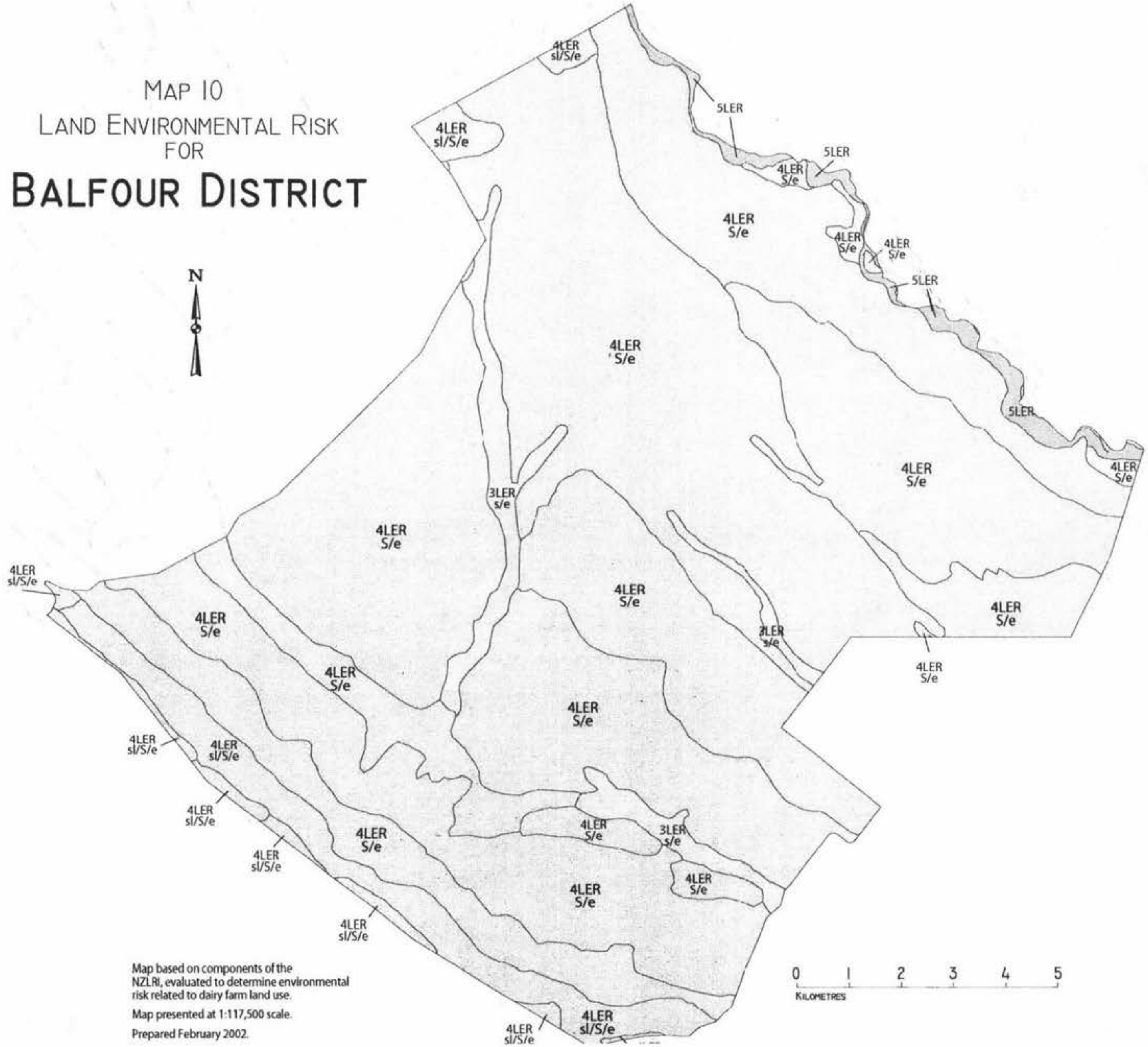
Erosion was only the most limiting factor in one LER class, 4 LER sl S E which accounted for 2.2% of the total land area. The majority of the land area, 80.9%, had a low environmental risk rank due to erosion potential, 11.5% of the total area had a moderate environmental risk due to erosion potential. The remainder of the land area had either slight erosion potential, or was mapped as river.

Slope was the least applied factor of the LER classification, reflecting the nature of the study site i.e. valley floors and flood plains. With one exception, LER rankings with slope as a factor were from LUC units of class IV and above. Slope was the most limiting factor is the highest LER class generated, 5 LER SL s e.

LUC units with erosion as the subclass appear in all the LER classes that have slope, soil vulnerability and erosion potential as risk factors. LUC units that have soil as the subclass, appear in the LER classes that have soil vulnerability as the highest risk factor, with erosion to a lesser degree.

The highest land use capability classes for the study site, i.e. class II, were not in the lower environmental risk classes. It was noted that all the LUC class II units had a high soil vulnerability index applied.

Map 10
Land Environmental Risk for
Balfour District



Legend

LER 1	
LER 2	
LER 3	3s/e
LER 4	4sl/S/e, 4S/e
LER 5	5 LER

LER = Land Environmental Risk

LER 1 = Negligible risk
LER 2 = Slight risk
LER 3 = Moderate risk
LER 4 = Severe risk
LER 5 = Very severe risk

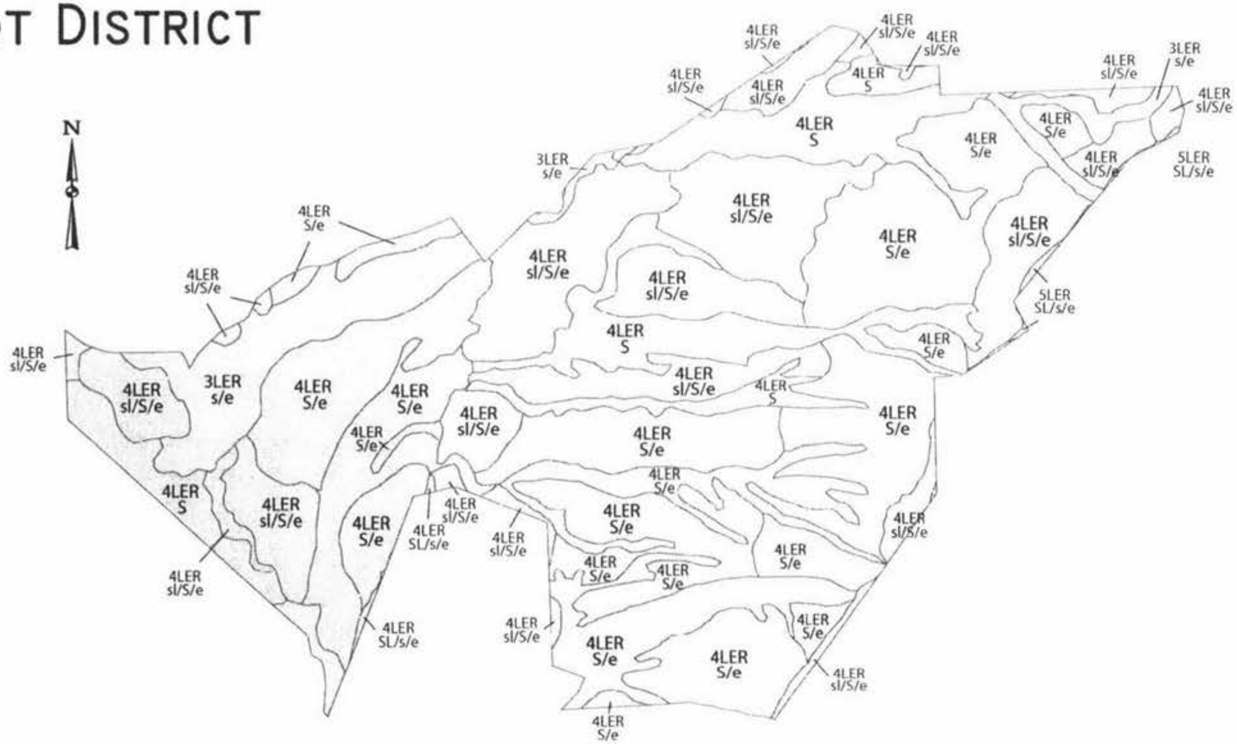
Limiting factors

S = soil vulnerability
SL = slope
E = erosion

The single-most limiting factor is represented as capital letters; lower case letters indicate that the factor is also limiting, but to a lesser degree.

Limiting factors are not presented in an order of severity.

Map II
Land Environmental Risk for
Heriot District



LER 1	
LER 2	
LER 3	3s/e
LER 4	4S, 4S/e, 4sl/S/e 4SL/s/e
LER 5	5Sl/s/e

LER = Land Environmental Risk

LER 1 = Negligible risk
LER 2 = Slight risk
LER 3 = Moderate risk
LER 4 = Severe risk
LER 5 = Very severe risk

Limiting factors

S = soil vulnerability
SL = slope
E = erosion

The single-most limiting factor is represented as capital letters; lower case letters indicate that the factor is also limiting, but to a lesser degree.

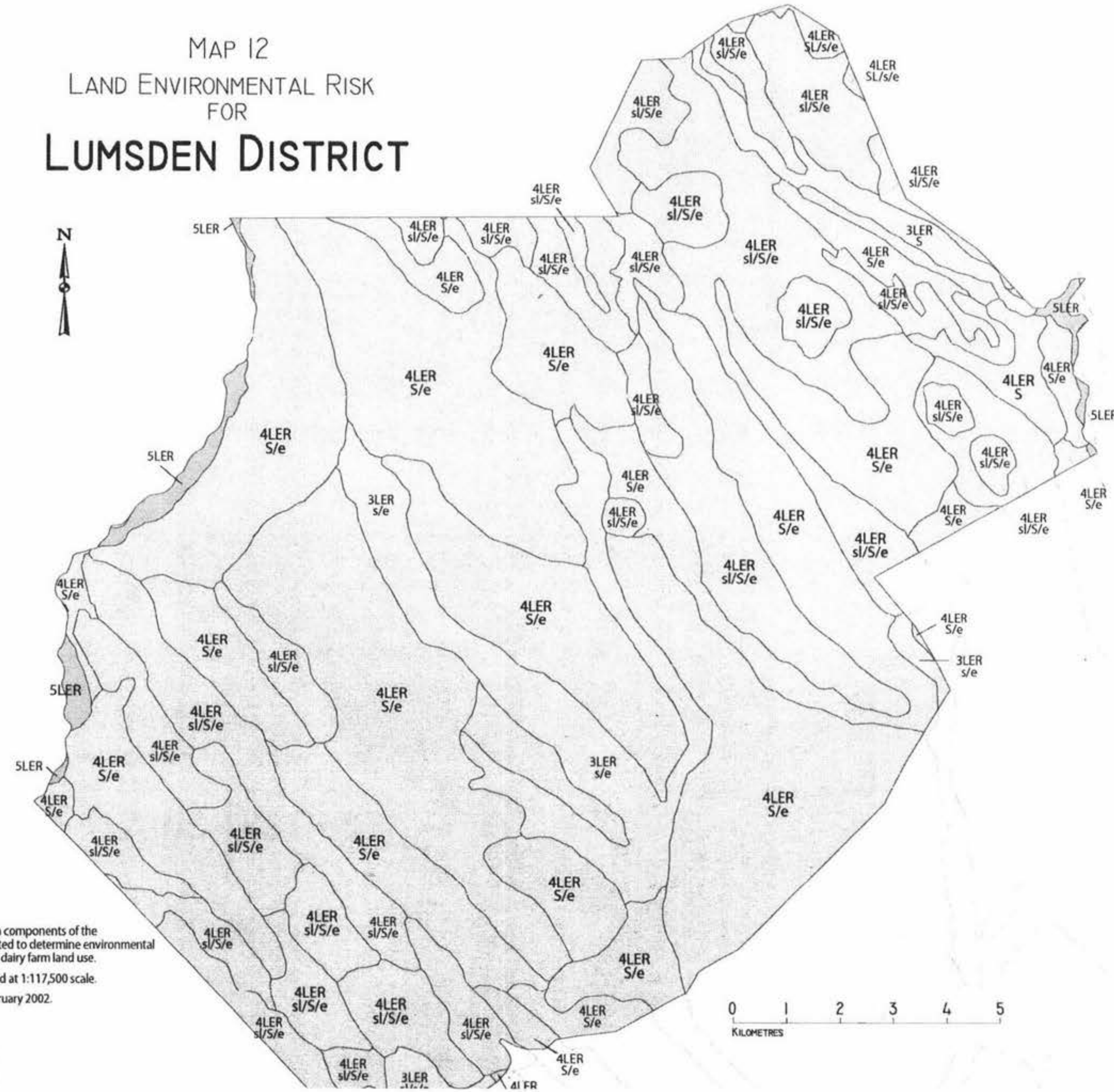
Limiting factors are not presented in an order of severity.

0 1 2 3 4 5
Kilometres

Map based on components of the NZLRI, evaluated to determine environmental risk related to dairy farm land use.

Map presented at 1:117,500 scale.

Map 12
Land Environmental Risk for
Lumsden District



Map based on components of the NZLRI, evaluated to determine environmental risk related to dairy farm land use.

Map presented at 1:117,500 scale.

Prepared February 2002.

Legend

LER 1	
LER 2	
LER 3	3S, 3s/e, 3sl/s/e
LER 4	4S, 4S/e, 4sl/S/e 4sl/S/E, 4SL/s/e,
LER 5	5 LER

LER = Land Environmental Risk

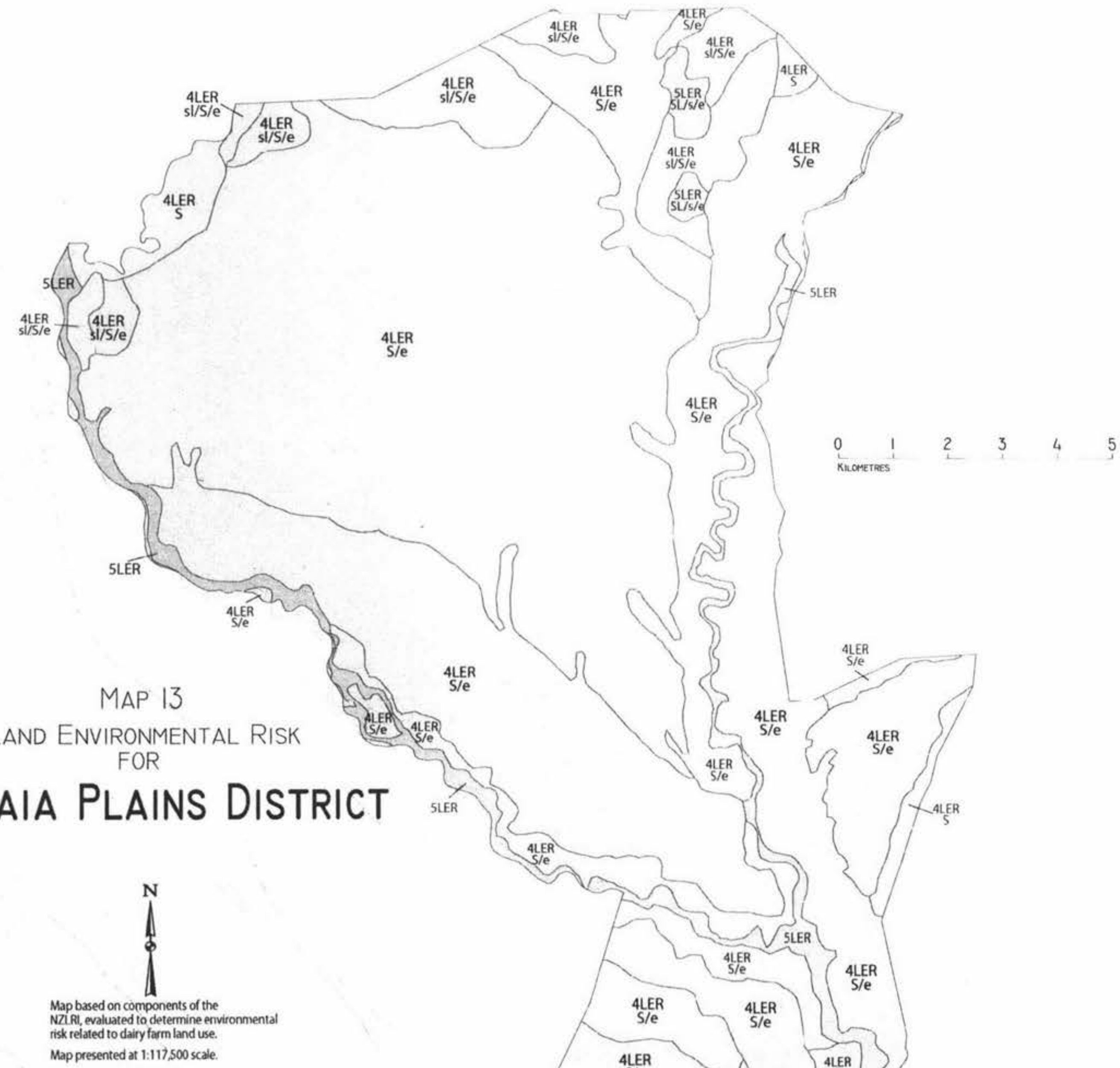
LER 1 = Negligible risk
LER 2 = Slight risk
LER 3 = Moderate risk
LER 4 = Severe risk
LER 5 = Very severe risk

Limiting factors

S = soil vulnerability
SL = slope
E = erosion

The single-most limiting factor is represented as capital letters; lower case letters indicate that the factor is also limiting, but to a lesser degree.

Limiting factors are not presented in an order of severity.



MAP 13

LAND ENVIRONMENTAL RISK FOR

WAIKAIA PLAINS DISTRICT

Map based on components of the NZLRI, evaluated to determine environmental risk related to dairy farm land use.

Map presented at 1:117,500 scale.

Prepared February 2002

LEGEND

LER 1	
LER 2	
LER 3	
LER 4	4S, 4S/e, 4sl/S/e
LER 5	5LER, 5SL/s/e

LER = Land Environmental Risk

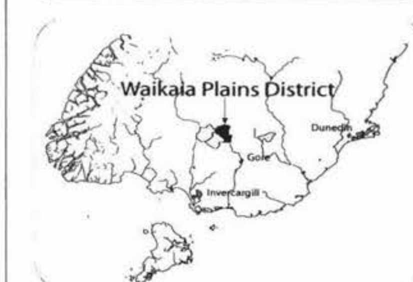
LER 1 = Negligible risk
LER 2 = Slight risk
LER 3 = Moderate risk
LER 4 = Severe risk
LER 5 = Very severe risk

Limiting factors

S = soil vulnerability
SL = slope
E = erosion

The single-most limiting factor is represented as capital letters; lower case letters indicate that the factor is also limiting, but to a lesser degree.

Limiting factors are not presented in an order of severity.



5.2 Soil Environmental Risk Model

Application of the ER model to the Topoclimate soils data resulted in 27 classes of Soil Environmental Risk (SER) (see table 15), from the original 190 soil units and composites. Overall 411 ha were SER class 1 (0.6%), 4523 ha were SER class 2 (6.2%), 17342 ha were SER class 3 (24%), 37710 ha were SER class 4 (52.2 %) and 12268 ha were SER class 5 (17%).

Maps 14-17 display the SER rankings for the four districts within the study area. Overall rankings were spread fairly evenly across the districts, though the Heriot district has the largest area of SER class 2 land, and the Waikaia Plains district the largest single area of class 3.

The largest individual SER class was 4 SER l S, totalling 20458 ha, 28.3% of the total area. The next largest classes were 3 SER LS and 4 SER flS totalling 8897 ha (12.3%) and 6368 ha (8.8 %) respectively. These three classes account for nearly half of the total area (49.4%).

Table 15: Soil Environmental Risk Classification : Description and total Areas

Soil Environmental Risk Class	*Classification Description*	*Total Area*	*%*
1 SER	Minimal risk of environmental degradation from increased dairying.	411	0.6
2 SER S	Slight risk of environmental degradation from increased dairying due to a low Soil Vulnerability	4054	5.6
2 SER L	Slight risk of environmental degradation from increased dairying due to a slight leaching potential risk.	7	<0.1
2 SER LS	Slight risk of environmental degradation from increased dairying due to a moderate leaching loss potential and low Soil Vulnerability.	462	0.6
3 SER S	Moderate risk of environmental degradation due to soil vulnerability.	2152	3.0
3 SER L	Moderate risk of environmental degradation due to potential leaching loss.	128	0.2
3 SER l S	Moderate risk of environmental degradation due to soil vulnerability and low potential leaching loss.	272	0.4
3 SER F S	Moderate risk of environmental degradation due to infrequent flooding and moderate soil vulnerability.	4732	6.5
3 SER L S	Moderate risk of environmental degradation due to potential leaching loss and soil vulnerability.	8897	12.3
3 SER FlS	Moderate risk of environmental degradation due to infrequent flooding, low potential leaching, and moderate soil vulnerability.	124	0.2
3 SER FLS	Moderate risk of environmental degradation due to infrequent flooding, and moderate potential leaching and soil vulnerability.	1038	1.4
4 SER L	High risk of environmental degradation due to severe leaching potential.	2323	3.2
4 SER S	High risk of environmental degradation due to high soil vulnerability.	812	1.1
4 SER l S	High risk of environmental degradation due to high soil vulnerability and moderate potential leaching.	20458	28.3
4 SER L s	High risk of environmental degradation due to severe leaching potential and moderate soil vulnerability.	359	0.5
4 SER F s	High risk of environmental degradation due to frequent flooding and moderate soil vulnerability.	336	0.5
4 SER f S	High risk of environmental degradation due to high soil vulnerability and infrequent flooding.	1571	2.2
4 SER f l S	High risk of environmental degradation due to high soil vulnerability, infrequent flooding and moderate leaching potential.	6368	8.8
4 SER L S	High risk of environmental degradation due to severe leaching potential and high soil vulnerability.	3321	4.6
4 SER f L S	High risk of environmental degradation due to severe leaching potential, high soil vulnerability and infrequent flooding.	2161	3.0
5 SER l S	Very high risk of environmental degradation due to very high soil vulnerability and a moderate or severe leaching potential.	1501	2.1
5 SER F s	Very high risk of environmental degradation due to frequent flooding and high soil vulnerability.	344	0.5
5 ER F l s	Very high risk of environmental degradation due to frequent flooding, severe or moderate leaching potential and high soil vulnerability.	1667	2.3
5 SER f l S	Very high risk of environmental degradation due to very high soil vulnerability, moderate or severe leaching potential and infrequent flooding.	2810	3.9
5 SER F l S	Very high risk of environmental degradation due to very high soil vulnerability, frequent flooding and severe or moderate leaching potential.	4577	6.3
5 SER FLS	Very high risk of environmental degradation due to frequent flooding, very severe leaching potential and very high soil vulnerability.	604	0.8
5 SER	Very high risk of environmental degradation due to either disturbed site (such as mine tailings) or river complex. Very high risk of environmental degradation due to	764	1.0

Soil vulnerability for the area was predominantly moderate to high, 50.5% of the total area had a ranking of high soil vulnerability and 25.1% moderate SVI. Unlike the LER data however, the SVI applied to the SER model had a wide range, with very low and very high rankings calculated, see table 16.

Table 16: Soil Environmental Risk Classification : Soil Vulnerability Index

SER	*Soil Vulnerability Class*						*Area ha*
Rank	*VL*	*L*	*M*	*H*	*VH*	*O **	
1ER	411						411
2ER S		4054					4054
2ER L	7						7
2 ER LS		462					462
3 ER S			2152				2152
3 ER L		128					128
3 ER l S			272				272
3 ER F S			4732				4732
3 ER L S			8897				8897
3 ER FlS			124				124
3 ER FLS			1038				1038
4 ER L		2323					2323
4 ER S				812			812
4 ER l S				20458			20458
4 ER L s		359					359
4 ER F s			336				336
4 ER f S				1571			1571
4 ER f l S				6368			6368
4 ER L S				3321			3321
4 ER f LS				2161			2161
5 ER l S					1501		1501
5 ER F s			242	102			344
5 ER F l s				1667			1667
5 ER f l S					2810		2810
5 ER F l S					4577		4577
5 ER FLS					604		604
5 ER						764	764
Total	418	7326	17793	36460	9492	764	72253

The SVI played a dominant role in determining the overall SER risk as reflected in the moderately high correlation between the two of 0.73 . See figure 5.

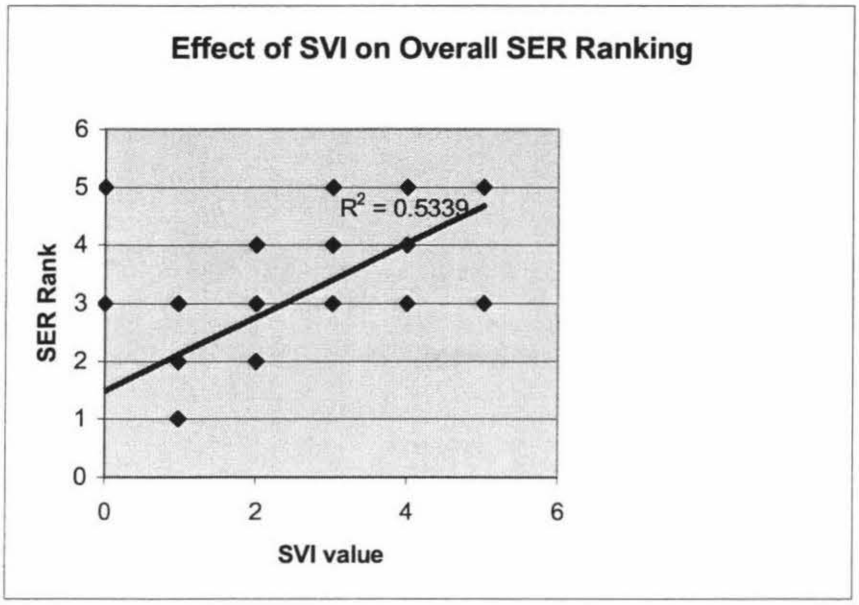


Figure 5: Effect of SVI on overall ranking.

The effect of a leaching risk on the area was varied, 20% of the area was found to have a slight environmental risk due to leaching, with a 58% and moderate risk and 19% a severe risk. Examining the effect of leaching on the individual risk classes, leaching was found to be the single most limiting factor (e.g. 2 ER L, 4 ER Ls) over 6% of the area, and as an equal limiting factor (e.g. 3 ER FLS, 4 ER LS) over 45.7% of the area. A leaching risk was often found with a soil vulnerability risk, table 17, a moderate positive correlation between the two (0.54) was calculated, figure 6.

Table 17: Overlay leaching and SVI

Leaching Rank Area (ha)	Soil Vulnerability Index				
	SL	L	M	H	VH
VL	410	4053	7462	2485	
L	6.6	462	396		
M		128	9934	28406	3386
H		2323	359	5569	5502
VH					604

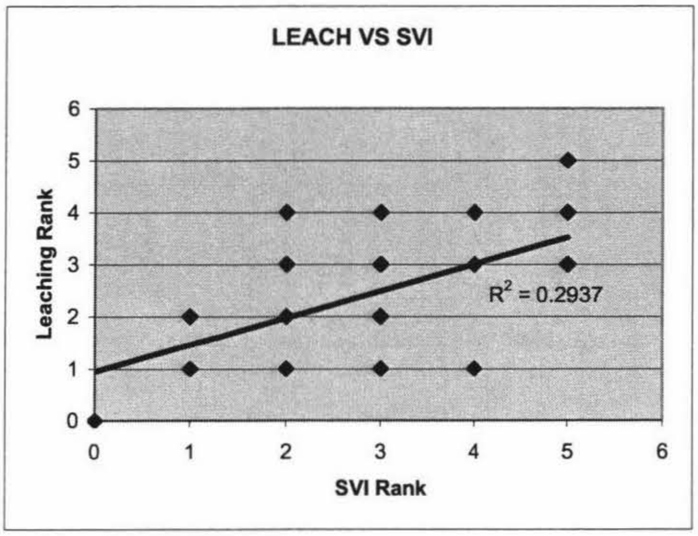
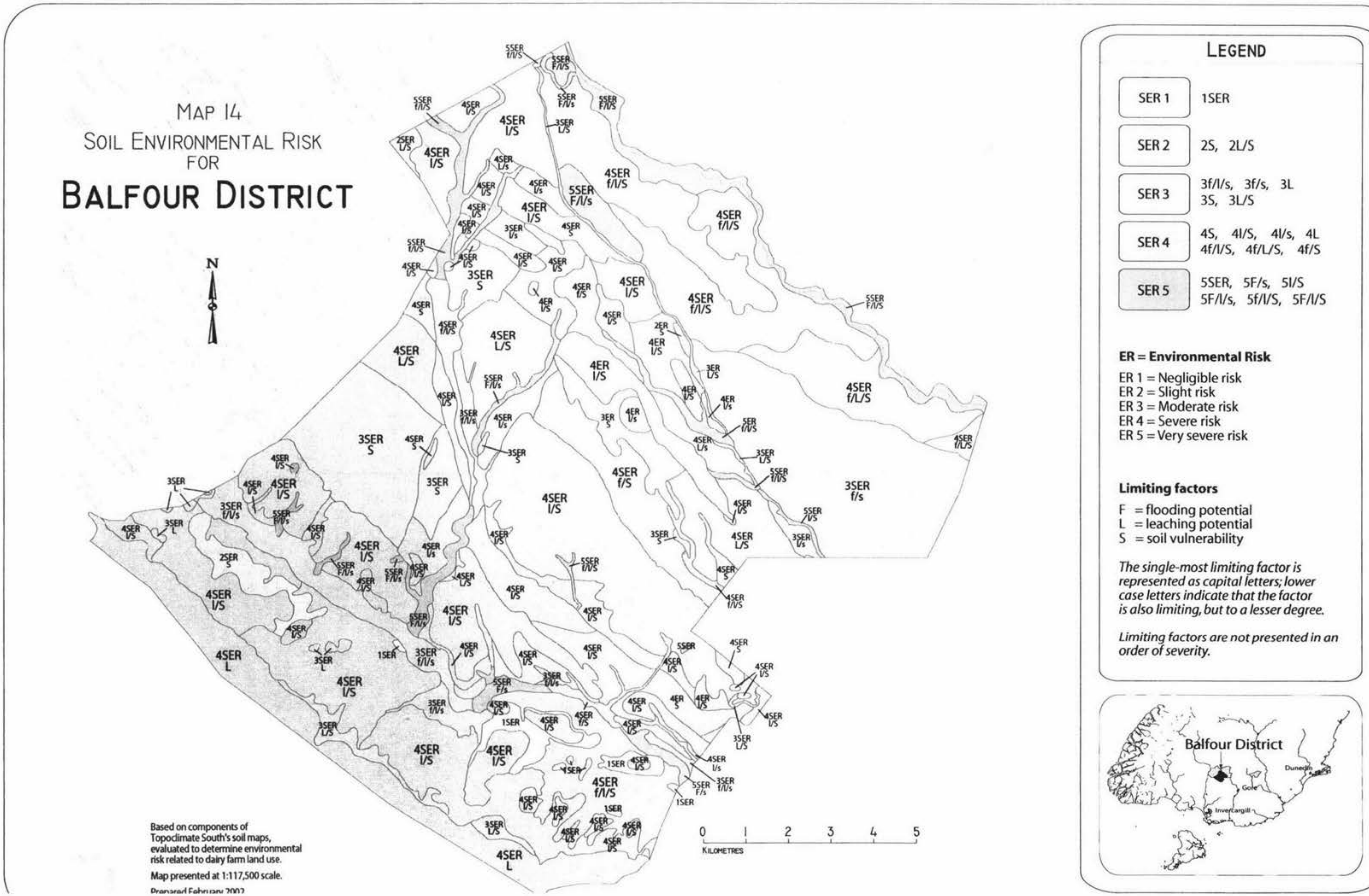


Figure 6: Leaching vs. SVI.

The risk of flooding was moderate for 18783 ha of the total land area, and very high for 7549 ha of the study site respectively. Flooding was the most limiting factor for 10% of the area, predominantly as a class 5. Areas prone to flooding were commonly associated with high to very high SVI rankings.

Table 18: Flooding risk rank and associated SVI rank

Flooding Rank *Area (ha)*	*SVI Rank*		
	3	*4*	*5*
3	5893	10100	2789
5	578	1768	5202



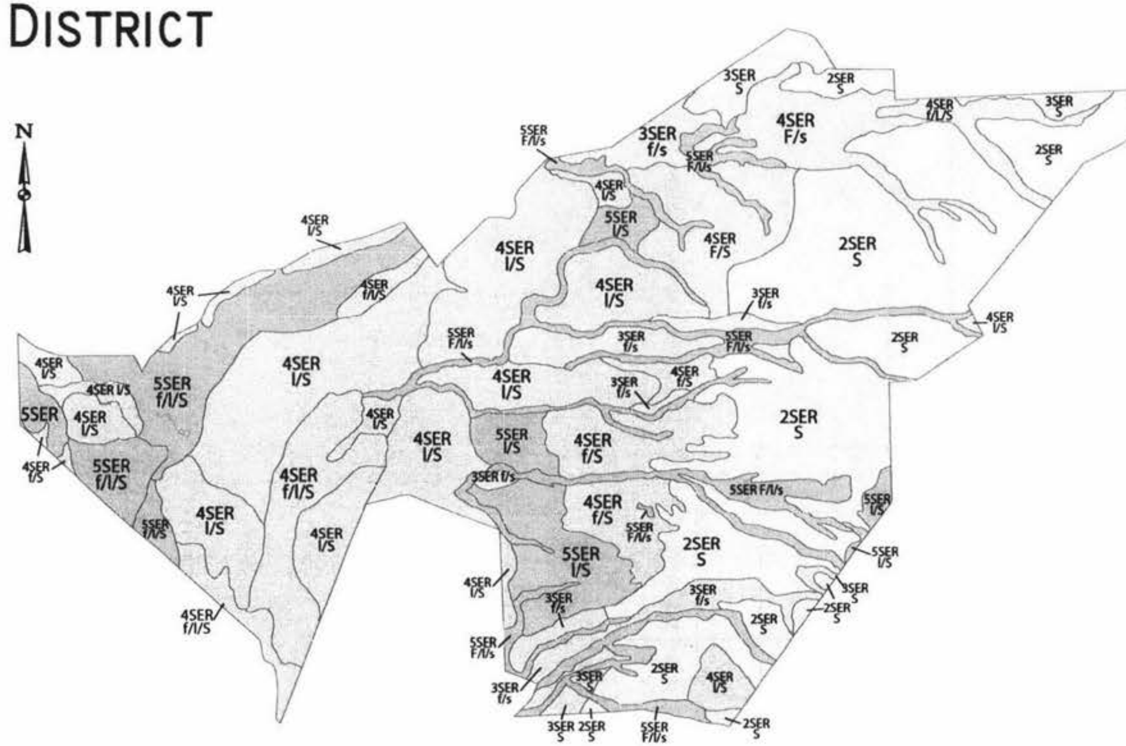
MAP 14
SOIL ENVIRONMENTAL RISK
FOR
BALFOUR DISTRICT
N
LEGEND
SER 1 1SER
SER 2 2S, 2L/S
SER 3 3f/l/s, 3f/s, 3L 3S, 3L/S
SER 4 4S, 4l/S, 4l/s, 4L 4f/l/S, 4f/L/S, 4f/S
SER 5 5SER, 5F/s, 5l/S 5F/l/s, 5f/l/S, 5F/l/S
ER = Environmental Risk
ER 1 = Negligible risk
ER 2 = Slight risk
ER 3 = Moderate risk
ER 4 = Severe risk
ER 5 = Very severe risk
Limiting factors
F = flooding potential
L = leaching potential
S = soil vulnerability
The single-most limiting factor is represented as capital letters; lower case letters indicate that the factor is also limiting, but to a lesser degree.
Limiting factors are not presented in an order of severity.
Balfour District
Dunedin
Gore
Invercargill
0 1 2 3 4 5
KILOMETRES
Based on components of Topoclimate South's soil maps, evaluated to determine environmental risk related to dairy farm land use.
Map presented at 1:117,500 scale.
Prepared February 2002

Map 15

Soil Environmental Risk

for

Heriot District



Based on components of Topoclimate South's soil maps, evaluated to determine environmental risk related to dairy farm land use.

Map presented at 1:117,500 scale.

Prepared February 2002.

0 1 2 3 4 5

Kilometres

Legend

SER 1	
SER 2	2S
SER 3	3S, 3f/s
SER 4	4l/S, 4f/S, 4f/l/S 4f/L/S, 4F/s
SER 5	5SER, 5l/S, 5f/l/S 5F/l/s,

ER = Environmental Risk

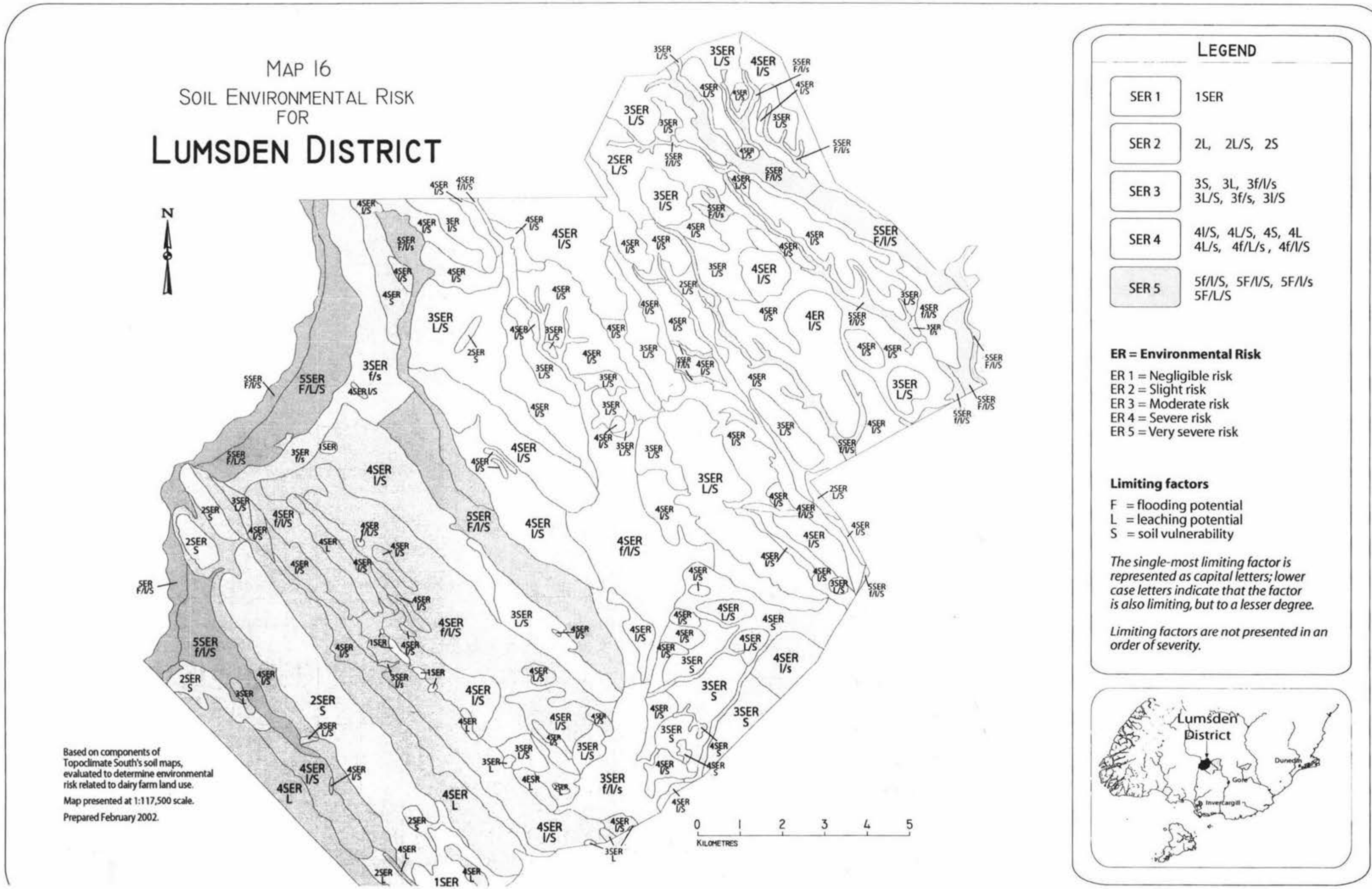
ER 1 = Negligible risk
ER 2 = Slight risk
ER 3 = Moderate risk
ER 4 = Severe risk
ER 5 = Very severe risk

Limiting factors

F = flooding potential
L = leaching potential
S = soil vulnerability

The single-most limiting factor is represented as capital letters; lower case letters indicate that the factor is also limiting, but to a lesser degree.

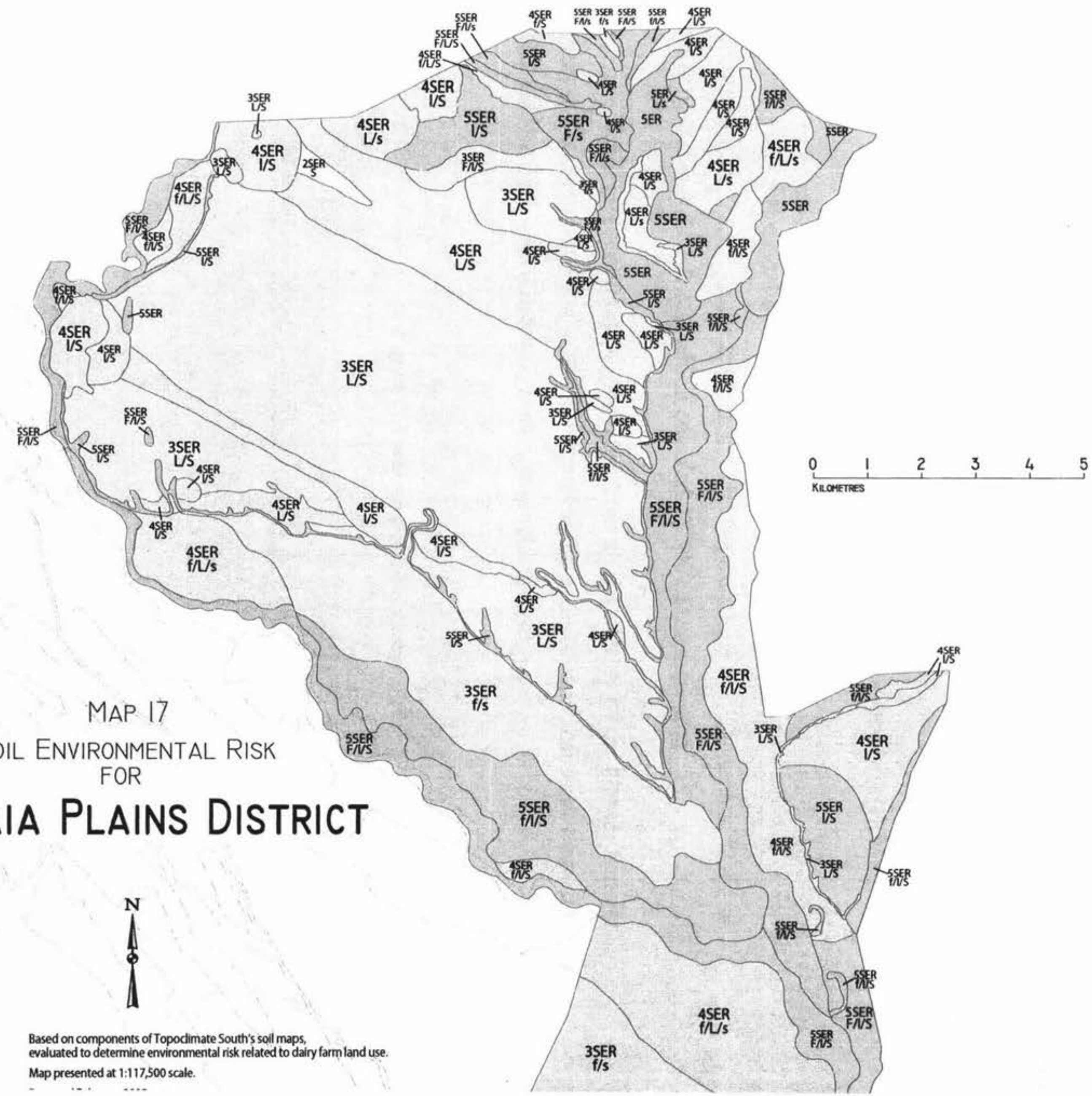
Limiting factors are not presented in an order of severity.


MAP 16
SOIL ENVIRONMENTAL RISK
FOR
LUMSDEN DISTRICT
N
LEGEND
SER 1 1SER
SER 2 2L, 2L/S, 2S
SER 3 3S, 3L, 3f/l/s 3L/S, 3f/s, 3l/S
SER 4 4l/S, 4L/S, 4S, 4L 4L/s, 4f/L/s, 4f/l/S
SER 5 5f/l/S, 5F/l/S, 5F/l/s 5F/L/S
ER = Environmental Risk
ER 1 = Negligible risk
ER 2 = Slight risk
ER 3 = Moderate risk
ER 4 = Severe risk
ER 5 = Very severe risk
Limiting factors
F = flooding potential
L = leaching potential
S = soil vulnerability
The single-most limiting factor is represented as capital letters; lower case letters indicate that the factor is also limiting, but to a lesser degree.
Limiting factors are not presented in an order of severity.
Lumsden District
Dunedin
Gore
Invercargill
0 1 2 3 4 5
KILOMETRES
Based on components of Topoclimate South's soil maps, evaluated to determine environmental risk related to dairy farm land use.
Map presented at 1:117,500 scale.
Prepared February 2002.

MAP 17

SOIL ENVIRONMENTAL RISK FOR

WAIKAIA PLAINS DISTRICT



Based on components of Topoclimate South's soil maps, evaluated to determine environmental risk related to dairy farm land use.

Map presented at 1:117,500 scale.

LEGEND

SER 1	
SER 2	2S
SER 3	3L/S, 3f/s, 3F/I/S
SER 4	4I/S, 4f/L/S, 4L/S, 4f/I/S, 4L/s, 4f/S,
SER 5	5ER, 5I/S, 5F/I/S, 5F/I/s 5F/s, 5F/L/S, 5L/s

ER = Environmental Risk

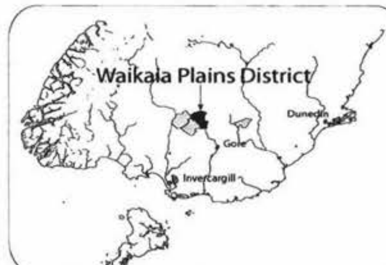
ER 1 = Negligible risk
ER 2 = Slight risk
ER 3 = Moderate risk
ER 4 = Severe risk
ER 5 = Very severe risk

Limiting factors

F = flooding potential
L = leaching potential
S = soil vulnerability

The single-most limiting factor is represented as capital letters; lower case letters indicate that the factor is also limiting, but to a lesser degree.

Limiting factors are not presented in an order of severity.



5.3 Comparison of models

The need to adjust the risk models to take into account the original data meant the generation of environmental risk rankings with differing limitations. However, the overall ranking was derived in the same way for each model and the limitation rankings were determined following the same criteria. For this reason it is possible to examine the broad classes generated between the two models.

As noted previously the LER model only generated 3 overall risk rankings and 10 individual classes. Compared with the SER model which classified land into the possible five risk rankings and resulted in 27 individual classes.

The largest overall risk rank from the LER model was class four, at 93.3% of the area, a risk ranking of 4 was also the largest for the SER model, but this accounted for 52% of the area. Classes were more evenly distributed on either side of the class four in the SER model, see figures 7 & 8.

The LER model was dominated by one individual class, 4 LER S e, accounting for 72.1% of the total area. The largest single class generated from the SER model was 4 SER 1 S, which covered 28.3% of the total area.

Table 19 presents data generated from a GIS overlay of the classes generated from the two models. Using this information the areas of land that were classified into similar class and individual rankings are discussed.

Figure 7: Total Area of LER classes

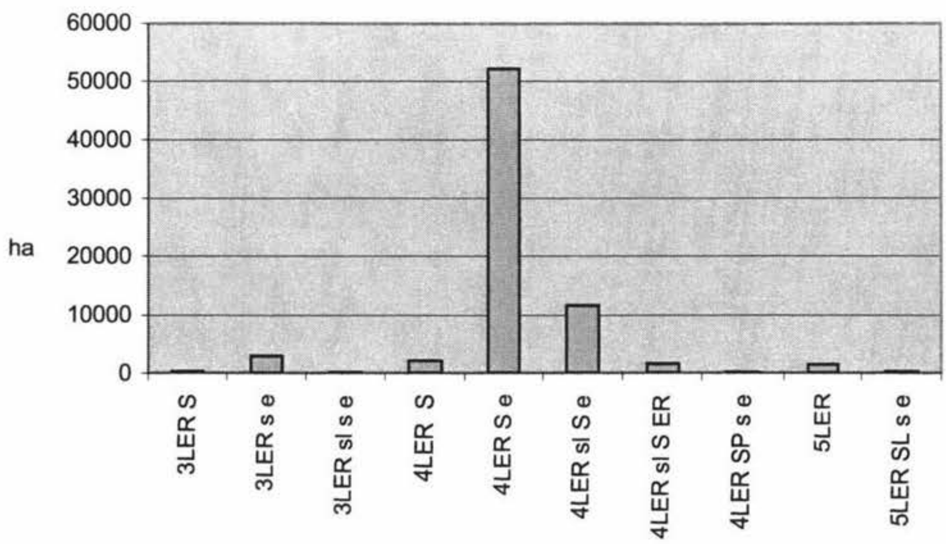


Figure 8: Total Area of SER Classes

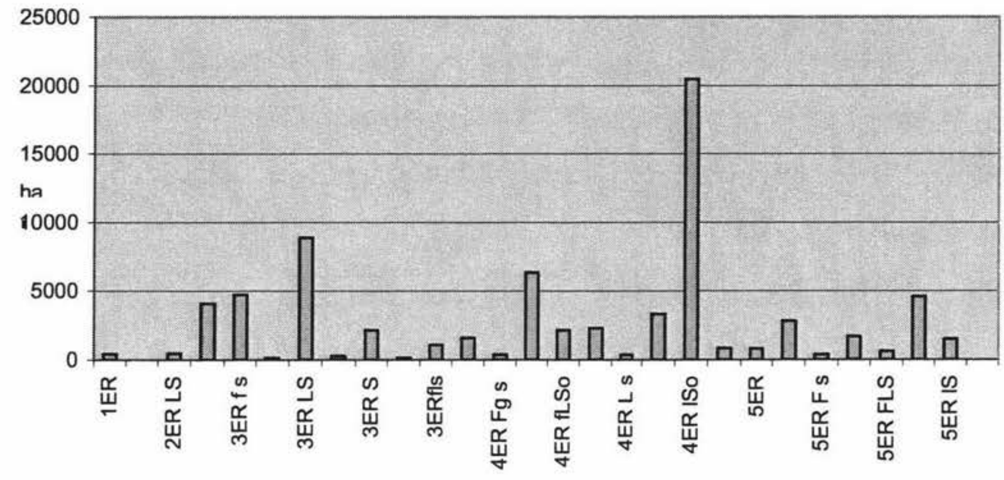


Table 19: GIS Overlay - Comparison of environmental risk models

SER	LER									
ha	3LER S	3LER se	3LER sl s e	4 LER S	4LER S e	4LER sl S e	4LER sl S E	4LER SL s e	5LER SL s e	5 LER
1ER			101		232	77				
2ER S		44	8	171	2129	1686			16	
2ER L					7					
2 ER LS		4			28	431				
3 ER S		19		9	1971	153				
3 ER L			8		65	55				
3 ER l S					65	158	49			
3 ER F S		41		231	4404	56				
3 ER L S	17	90		19	6886	1404	462	16		5
3 ER FlS					94	30				
3 ER FLS		172			866					
4 ER L			2		131	2190				
4 ER S		4			808					
4 ER l S		300	133		15313	3869	755	63	14	2
4 ER L s			0		128	106	121		4	
4 ER F s			264		53	19				
4 ER f S		87	60		1025	398	0			
4 ER fl S	0	697	209		5334	94	7	6		22
4 ER L S	6	90			3091	112	23			
4 ER fLS		68	155		1852	15	7			64
5 ER l S			44		1113	314	12		2	17
5 ER F s		48			290	6				
5ER F l s	3	124	251		1062	164	62		1	
5ER fl S		511	294		1835	124	31			16
5ER Fl S	286	612	153		2299	68	24	0.04		1563
5ER FLS					600	0				4
5 ER			49		499	16	53		125	23

Shaded boxes show the areas of corresponding risk

5.3.1.1 LER Class 3

The areas ranked as a moderate risk of environmental degradation from the LER model did not correspond well with areas of slight to moderate risk under the SER model. The area of land ranked as class 3 was much higher under the SER model, 17341 ha compared with 4952 ha under the LER model. Land ranked as LER 3 had significant areas of high or very risk under the SER model.

Of the total area ranked as LER 3, 2% corresponded with 1 SER, 1 % with 2 SER, 7% with 3 SER, 42% with 4 SER and 48% 5 SER. Of the limiting factors within the SER Class on this area the dominant factor is flooding. The LER model did not have a component that incorporated flooding in to the final rank.

5.3.1.2 LER Class 4

Corresponding areas ranked Class 4 land under both models was higher, with the overlap representing 54% of the total Class 4 LER and 94% of the Class 4 SER. Of the remaining 4LER area, less than 1% corresponded with 1 SER, 7% corresponded with 2 SER, 26% with 3 SER and 13% with 5 SER.

The single largest overlap of classes was 4 SER l S with 4 LER S e, which accounted for 23% of the total area of 4 LER. Similarly ranked 4 SER LS corresponded with 4 LER S e to make up 5% of the total area of 4 LER. The area of class 4 from the LER model was nearly double that of the class 4 from the SER model, with 65843 ha and 37701 ha respectively.

Using 4 LER S e as an example, figure 9 shows how SER classes were distributed over the same area.

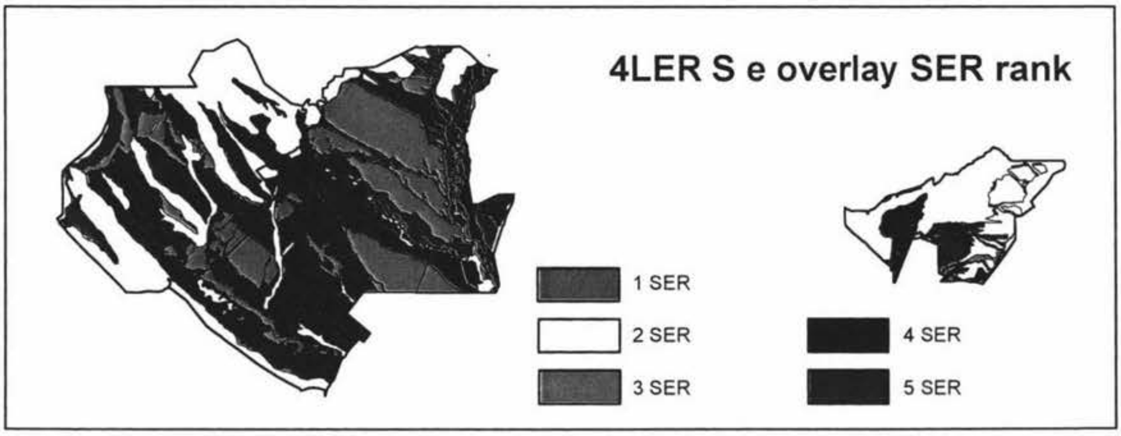


Figure 9: Relation between 4LER S e SER rank

5.3.1.3 LER Class 5

Compared with the SER model, only a small percentage of the total area was ranked as class 5 with the LER model. 93% of class 5 LER corresponded with class 5 SER, this represents only 14% of the total area mapped as 5 SER. Less than 1% of 5 LER corresponded with SER classes 1-3, and 6% corresponded with 4 SER.

The biggest proportion (67%) of land classified as 5 SER was classified as class 4 LER. Flooding was a significant factor in allocating land to SER class 5, as noted previously flooding risk was not incorporated into the LER model.

5.3.2 Comparing LUC with Indexes Generated from Soils data

As discussed in section 5.1 the lack of detail available to apply to LRI soils data limited the overall LER classes that resulted. For this reason, it is worthwhile to compare the LUC units with the risk rankings as determined by the topoclimate soils data.

To examine this, several LUC units were over-layed with the SVI and leaching rankings from the SER model. The first example, as illustrated by figure 10, shows the area mapped as 3s12 from the LRI maps, with the SVI rankings as generated by applying the SVI formula to soil characteristics data collected from the Topoclimate soils survey. The unit 3s12 covers 27300 ha of the study area.

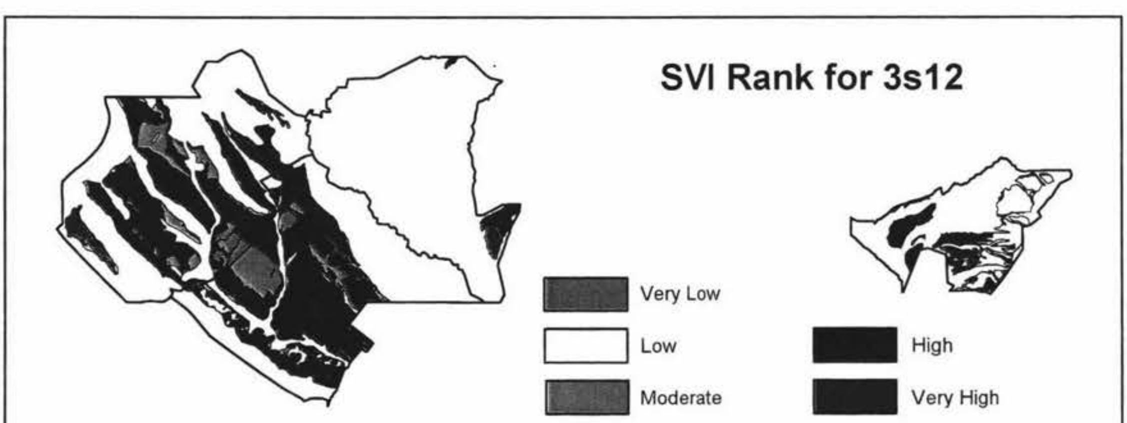


Figure 10: LUC unit 3s12 with SVI from Topoclimate Soils data

Under the LER model the same area showed only a high SVI ranking. While the SVI for the area is predominantly high, 72% of the total area of 3s12 under the SER model has a high SVI rank, there is variation. 14% of the area has a moderate ranking, and 8% of the area has a low SVI rank.

A weighted average for SVI for LUC unit 3s12 (with very low =1, low =2, etc), was found to be 3.7. However, it is worthwhile noting that the Heriot district had the highest proportion of low SVI rank.

Figure 11, also shows LUC unit 3s12, this time with the leaching classes generated from the soils data. The map shows much of the unit is dominated by a moderate leaching class, but in the Heriot district the leaching class was predominantly very low. The weighted average for all of unit 3s12 was calculated as 2.7.

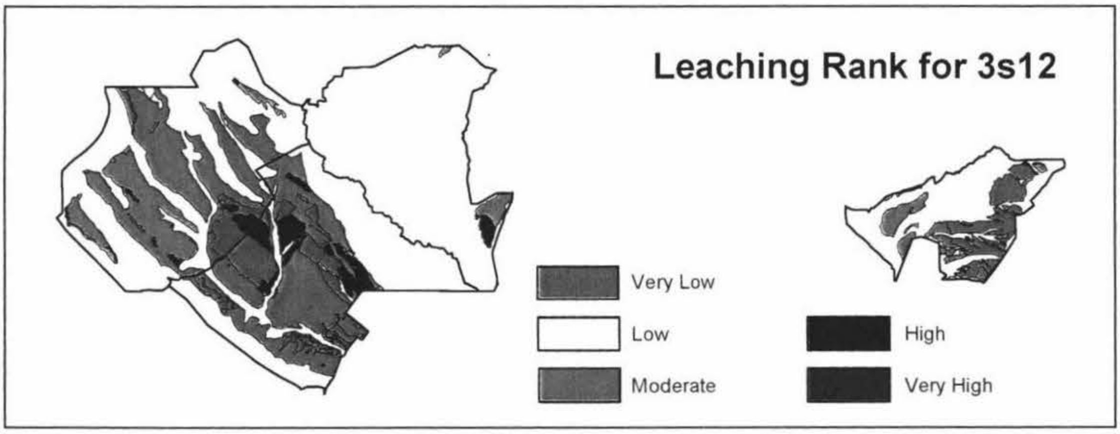


Figure 11: LUC unit 3s12 with leaching rank from Topoclimate Soils data

Figure 12 also displays an overlay of Topoclimate SVI on an LUC unit, in this case 3w3. Under the LER model that area of land had a moderate SVI applied, and was one of the few units ranked as having a moderate risk of environmental degradation.

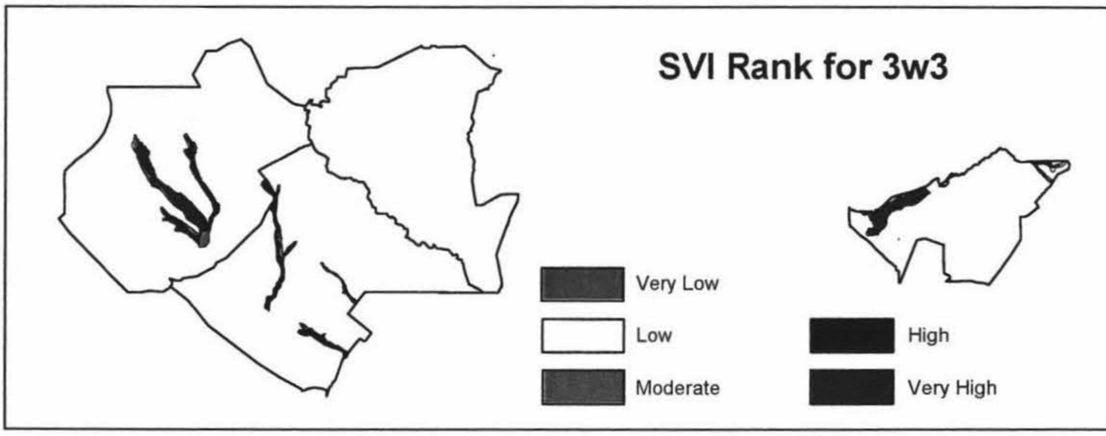


Figure 12: LUC unit 3w1 with SVI rank from Topoclimate Soils data

From the SVI data alone it can be seen that under the SER model the same area would have had a severe environmental risk due to very high soil vulnerability.

CHAPTER SIX

6. CONCLUSIONS

The Land Environmental Risk (LER) model, based on data from the New Zealand Land Resource Inventory, did not generate a satisfactory map that would be useful for planning purposes. If a policy that required identifying areas to target policy implementation were to be developed with a model similar to the LER and based on the LRI it would be likely that areas of land would be both under and over-rated in terms of their risk of environmental degradation from dairy farm conversion.

The LER model did not stratify the study site into the entire range of classes applicable under the model framework. The Soil Environmental Risk (SER) model, based on the Topoclimate South soil survey, classified the study area into the full range of potential risk classes. The LER model did not stratify the land to the same degree as the SER. This is attributed to the greater detail of soils information interpreted from the Topoclimate South soil survey. Both models showed significant areas of land at risk to environmental degradation to dairy farming.

Both models reduced the number of classes relative to the original data, this simplification would assist a wider range of users to be able to interpret the resultant maps.

The evaluation framework applied required the models to apply land characteristics based on available data. Though the soil component recorded in the LRI was never claimed to compare with a detailed soils map, the soil component did have the greatest influence on the LER classes recorded for the area.

Soil Vulnerability was a limiting factor under both models, the SER model produced maps that showed a great deal more stratification than the LER model. With one exception all classes of LER that had soil vulnerability as the single most limiting feature were derived from LUC classes that had soil as the subunit. This suggests that the LUC system could still be used as an initial survey to determine an area of interest for more detailed collection of data to asses soil vulnerability.

It can be concluded that it was the lack of detail available to be appropriately applied to the soils component of the LRI for generation of the LER classes that resulted in the over simplification of the classification.

A moderate correlation between soil vulnerability and leaching index calculated from the Topoclimate Soil survey data was found. However the correlation was not strong enough to suggest that it could be applied to areas where one factor was calculated to assign the other factor. For example further investigation would be needed to determine if there are other factors that could be modelled to assign a leaching index to updated LER units where more detailed SVI rankings were applied.

Flooding was an issue not addressed with the LER model. Using GIS to incorporate a buffering layer from a rivers overlay would likely improve a model based on LRI data.

The LUC classes did not correspond with the LER model, some of the versatile LUC classes were found to have a high environmental degradation risk. This would also have policy implications as degradation of high class land can be considered a sustainability issue.

For three of the four districts included in the study site the distribution of the more detailed SER index rankings, e.g. SVI, was relatively even. This suggests that this could be used to generate more accurate index ranking for LUC units which could then be applied to LUC units outside a study area, where for a hypothetical situation there had not been more detailed soils mapping undertaken.

However, the Heriot district commonly showed detailed index ranking for the same LUC unit as being different from the other study sites. This suggests change in landscape unit that is not represented well by the LUC classification applied.

6.1 Further research

Not all the environmental risk issues associated with dairy farming were addressed with these models. A new environmental risk model that used information from both data sets to address a wider range of issues could be generated, moving on from the issues addressed in this study.

A study to determine whether a modification could be made to the current LUC system to take into account district differences would contribute to a more robust use of the LRI/LUC information. Also what proportion of LUC units would need to have more detailed soil surveys undertaken to be able to confidently apply data surveyed in one district for a particular unit, to a unit in another district.

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8. APPENDICES

8.1 Appendix I: LUC data

LUC	Soil Code	Soil	SVI[2]	Slope	Erosion[3]	LER
2c 2	98f	Recent	H	B	0	4LER S
2s 1	98f	Recent	H	A	0	4LER S
2w 2	98f	Recent	H	A	1Sb	4LER S e
3e 4	21b	Yellow-grey earth	H	B +C	2W R	4LER S e
3e10	36c	Lowland yellow-brown earth	M	B +C	1 Sh R	3LER sl s e
3e12	29a	Yellow-grey earth	H	B +C	2 Sh W R	4LER sl S e
3e12+4e 3	29a	Yellow-grey earth	H	C +D	2 Sh R W	4LER sl S e
3s 2	98f	Recent	H	A	1Sb D	4LER S e
3s 2+2s 1	98f	Recent	H	A	1Sb D	4LER S e
3s 2+4s 1	98f	Recent	H	A	1Sb D	4LER S e
3s 3+4s 3	27e	Yellow-grey/ Yellow-brown earth	H	A	1-2 W	4LER S e
3s 7+4s 4	27b	Yellow-grey/ Yellow-brown earth	H	A	1W	4LER S e
3s12	29d	Yellow-grey/ Yellow-brown earth	H	A +B	1W	4LER S e
3w 3	90f	Gley recent	M	A	1Sb	3LER s e
4e 3	36c	Lowland yellow-grey earth	H	C +D	2Sh R	4LER sl S e
4e 3+3e12	29aH	Yellow-grey earth/hill	H	D +C	2Sh R	4LER sl S e
4e 3+6e16	29a	Yellow-grey earth	H	C +D	2Sh R	4LER sl S e
4e 7	29a	Yellow-grey earth	H	C	3-4Sh R	4LER sl S ER
4e 7+6e15	29d	Yellow-grey/ Yellow-brown earth	H	C +D	3-4Sh R	4LER sl S ER
4e 7+7s 9	29d	Yellow-grey/ Yellow-brown earth	H	C +G	3-4Sh R	5LER SL s e
4s 1+3s 2	98f	Recent	H	A	1Sb	4LER S e
4s 4	27b	Yellow-grey/ Yellow-brown earth	H	A	1W	4LER S e
4w 1	90f	Gley recent	M	A	0	3LER S
5c 2	36 H	Yellow-brown earth/Hill	H	E	1Sh	4LER SP S e
6e 5	76dH	Brown-glanular/hill	M	E +F	1-2Sl Sh	4LER SP s e
6e 6	35aH	Yellow-brown earth/Hill	H	D	1-2 Sh Sl	4LER sl S e
6e 6+4e 3	36cH	Yellow-brown earth/Hill	H	D +C	1-2 Sh Sl	4LER sl S e
6e11	41c	yellow-brown earth/hill	M	F +E	2Sh Sl Sc	5LER SL s e
6e15	29aH	Yellow-grey earth/Hill	H	E	2Sh Ss SL	4LER sl S e
6e15+4e 3	29aH	Yellow-grey earth/Hill	H	E +D	2Sh Ss SL	4LER sl S e
6e15+4e 7	29dH	Yellow-grey/ Yellow-brown earth/Hill	H	D +C	2Sh Ss SL	4LER sl S e
6e16	29dH	Yellow-grey/ Yellow-brown earth/Hill	H	D	2Sh G Sl	4LER sl S e
6e29	57c	yellow-brown earth	M	E +D	2Sh W G	4LER SP s e
6s 1	98f	Recent	H	A	1Sb	4LER S e
6s 1+4s 1	98f	Recent	H	A	1Sb	4LER S e
rive	rive			rive		5LER

[2] SVI figures relate to average figures, given by Shepard (ref)

[3] Erosion figures represent potential erosion, according to *South Island: Land Use Capability Extended Legend*

8.2 Appendix II: Topoclimate South soil survey report

FLEMING SERIES

Soil associates: Fleming, undulating, deep (FmU1).
Fleming, undulating, deep, imperfectly drained (FmU1vi).

Typifying profiles: Fleming, undulating, deep (FmU1). Profile RT5.
Fleming, undulating, deep, imperfectly drained (FmU1vi). Profile M3156

PROFILE INFORMATION

Profile: RT5

Map reference: NZMS 260 F44 2171610 5479922

[redacted]

New Zealand Soil Classification: Fragic Perch-gley Pallic; stoneless; silty

Landform/landscape: Floodplain

Parent material: Fine hard sandstone and subschist alluvium.

Drainage: Poorly drained

Flooding: Yes – infrequently

Vegetation and landuse: Improved pasture; sheep and mixed cropping

Slope and aspect: < 2°

Site notes: Description and samples were taken from a cutting in a silage pit

Photographic reference: Digital: Yes
35 mm: No

Profile description: RT5

Horizon	*Depth (cm)*	*Description*
Apg	0-28	Dark greyish yellow (2.5Y5/2) silt loam; 10% bright brown (7.5YR5/8) 1-5 mm mottles; yellowish grey (2.5Y6/1) on ped surfaces; weak soil strength; moderately developed 10-40 mm polyhedral peds; abundant roots (228 est.).
Apg/Bg	28-38	Olive yellow (5Y6/3) silt loam (est.); 50% dark greyish yellow (2.5Y5/2) 10 mm earthworm casts; weak soil strength; moderately developed 5-50 mm polyhedral and blocky peds; few Mn/Fe concretions; many roots.
Bg	38-53	Olive yellow (5Y6/3) silt loam; 25% bright yellowish brown (10YR6/6) 2 mm mottles, 10% dull yellow (2.5Y6/3) 5-10 mm mottles; 10% dark greyish yellow (2.5Y5/2) 10 mm earthworm casts; slightly firm soil strength; moderately developed 5-60 mm blocky peds; common roots.
BCx(g)	53-94	Dull yellowish brown (10YR5/4) silt loam (est.); 20% grey (7.5Y6/1) 5 mm mottles, 20% bright brown (7.5YR5/8) 5 mm mottles; firm soil strength; weakly developed 150 mm prismatic peds; grey (7.5Y6/1) 5 mm gammations; bright brown (7.5YR5/8) 2 mm selvedge; few roots between peds.
		On gravels

Profile notes:

Laboratory analysis: RT5

Horizon	Depth (cm)	pH (H_2O)	Exchangeable cations (cmol(+)/kg)				CEC (cmol(+)/kg)	BS %
			Ca	Mg	K	Na		
Apg	0-28	4.9	5.03	1.24	1.60	0.12	22.7	35
Apg/Bg	28-38	5.6	4.46	1.04	1.01	0.12	14.5	46
Bg	38-53	5.6	3.39	1.00	0.59	0.16	11.6	44
BCx(g)	53-94	5.8	4.30	1.74	0.20	0.15	11.0	58
Horizon	Depth (cm)	P retention (%)	C (%)	N (%)	C/N Ratio	Sand (%)	Silt (%)	Clay (%)
Apg	0-28	25	4.92	0.41	12	6	68	26
Apg/Bg	28-38	31	1.53	0.13	12	-	-	-
Bg	38-53	28	0.66	0.06	11	4	70	26
BCx(g)	53-94	20	0.26	0.02	13	-	-	-

Summarised Topoclimate South soil survey data for Balfour-Riversdale area

SOIL		FLOODING RANK	PAW	CEC-WGHT AV. 60CM	LEACHING CLASS	SVI RANK	FINAL RANK
Andrews, undulating, deep	AeU1	0	321				5ER
Ardlussa, undulating, moderately deep	AdU2	5	93	12.5	SL	M	5ERf s
Benio, undulating, moderately deep	BnU2	0	82	15.5	MOD	M	3ERls
Benio, undulating, shallow	BnU3	0	55	15.5	SEV	VH	5ERls
Crookston, undulating, deep	CkU1	0	98	8.8	MOD	M	3ERls
Crookston, undulating, mod. deep	CkU2	0	98	12.3	SL	M	3ER s
Dipton, undulating, shallow	DpU3	0	95	19.6	SL	H	4ER s
Fleming, undulating, deep	FmU1	3	95	17.2	SL	H	4ERf s
Fleming, undulating, deep, imperfectly drained variant	FmU1vi	3	95	10.1	MOD	VH	5ERfls
Glenure, undulating, moderately deep	GnU2	0		10.8	MOD	H	4ER ls
Gore, undulating, shallow	GeU3	3	127	13.1	SL	M	3ERf s
Hokonui, undulating, deep	HkU1	0	84	19.6	MOD	H	4ER ls
Hokonui, undulating, moderately deep	HkU2	0	84	19.6	MOD	H	4ER ls
Howe, undulating	HwU	5	89	6.7	SEV	VH	5ERfls
Jacobstown, undulating, deep	JnU1	3		17.8	MOD	VH	5ERfls
Jacobstown, undulating, mod.deep	JnU2	5		12.3	MOD	H	5ERfls
Josephville, undulating, deep	JvU1	0	95	27.5	SL	VL	1ER
Josephville, undulating, moderately deep	JvU2		95	27.5	SL	M	3ER s
Kaihiku, hilly, shallow	KhH3	0	58	23.9	SEV	L	4ER l
Kaihiku, rolling, shallow	KhR3	0	58	23.9	SEV	L	4ER l
Kaihiku, steep, shallow	KhS3		58	23.9	SEV	M	4ER ls
Kaweku Scarp, hilly, undifferentiated	UKkH	0			MOD	M	3ER ls
Kaweku Scarp, steep, undifferentiated	UKkS				MOD	M	3ER ls
Kaweku, undulating, shallow	KkU3	0	53	16.1	SEV	L	4ER l
Makarewa, undulating, deep	MkU1	5		22.8	MOD	H	5ERfls
Makarewa, undulating, mod. deep	MkU2	0		22.8	MOD	H	4ER ls
Mandeville, hilly, shallow	MeH3	0	85		MOD	M	3ER ls
Mandeville, rolling, shallow	MeR3	0	84	29.59	MOD	M	3ER ls
Mandeville, undulating, shallow	MeU3	0	85	23.7	MOD	L	3ER l
Mataura, undulating, moderately deep	MaU2	3	146	11.6	MOD	H	4ERfls
Oreti Scarp, steep, undifferentiated	UOeS	0		12.3	MOD	VH	5ER ls
Oreti, undulating, shallow	OeU3		78	12.3	MOD	M	3ER ls
Otikerama, undulating, deep	OtU1	5	100	16.4	SL	H	5ERf s
Pukemutu, rolling, deep	PgR1	0		17.2	MOD	H	4ER ls
Pukemutu, undulating, deep	PgU1	0		17.2	MOD	H	4ER ls
River, undifferentiated	R						5ER
Riversdale, undulating, shallow	RiU3	5	89	5.9	VSEV	VH	5ERfls
Stonycreek, rolling, shallow	StR3	0	81			M	
Waikoikoi, rolling, deep	WqR1	0	88	8.9	SEV	VH	5ER ls
Waikoikoi, undulating, deep	WqU1	0	84	8.9	SEV	H	4ER ls
Waikoikoi, undulating, mod. deep, gravelly subsoil variant	WqU2vg	0	92	10.9	MOD	H	4ER ls
Wendon, rolling, shallow	WeH3		83	18.5	MOD	M	3ER ls

Summarised Topoclimate South soil survey data for Heriot area

SOIL		FLOODING RANK	PAW mm	CEC-wght av 60cm	POT LEACHING LOSS	SVI RANK	FINAL RANK
Ardlussa, undulating, deep	AdU1	5	93	12.5	SL	M	5ERf s
Ardlussa, undulating, deep, imperfectly drained variant	AdU1vi	3	93	17.6	SL	M	3ERf s
Ardlussa, undulating, moderately deep	AdU2	3	94	15.1	SL	M	3ERf s
Ardlussa, undulating, moderately deep, imperfectly drained variant	AdU2vi	3	93	17.6	SL	M	3ERf s
Arthurton, undulating, deep	ArU1	0	78	13.6	MOD	H	4ER ls
Crookston, rolling, deep	CkR1	0	98	15.8	SL	M	3ER s
Crookston, undulating, deep	CkU1	0	98	19.8	SL	L	2ER s
Crookston, undulating, moderately deep	CkU2	0	98	19.8	SL	M	3ER s
Fleming, undulating, deep	FmU1	3	95	13.4	SL	VH	3ERf
Glenure, rolling, deep	GnR1	0		10.9	MOD	H	4ER ls
Glenure, undulating, deep	GnU1	0		10.9	MOD	H	4ER ls
Howe, undulating, moderately deep	HwU2	5	89	6.7	SEV	H	4ERfls
Jacobstown, undulating, deep	JnU1	3		11.2	MOD	VH	5ERfls
Jacobstown, undulating, moderately deep	JnU2	3		11.3		VH	5ERfls
Lumsden, undulating, shallow	LmU3	5		14.8		VH	5ERfls
Mataura, undulating, deep, imperfectly drained variant	MaU1vi	3	144	14	SL	VH	5ERf S
Mataura, undulating, moderately deep	MaU2	3	144	10.1	MOD	H	4ERflS
Mataura, undulating, moderately deep, imperfectly drained variant	MaU2vi	3	144	14	SL	VH	5ERf S
Riversdale, undulating, shallow	RiU3	5	89	5.9	VSEV	VH	5ERfls
Tailings, undulating, shallow, undifferentiated	UTaU3	0					5ER
Tuapeka, hilly, shallow	TuH3	0	68	14.1	MOD	VH	5ER IS
Tuapeka, rolling, shallow	TuR3	0	68	14.1	MOD	VH	5ER IS
Waikoikoi, rolling, deep	WqR1	0	88	13.6	MOD	VH	5ER IS
Waikoikoi, undulating, deep	WqU1	0	84	11.3	SEV	VH	5ER IS
Warepa, undulating, deep	WrU1	0		12.6	MOD	VH	5ER IS

Summarised Topoclimate South soil survey data for Lumsden-Balfour area

SOIL		FLOODING RANK	PAW MM	CEC WHGT AV 60CM	POT LEACHING LOSS	SVI RANK	FINAL RANK
Arthurton, undulating, deep	ArU1	0	78	8.6	SEV	H	4ER ls
Crookston, undulating, deep	CkU1	0	98	8.8	MOD	M	3ER ls
Crookston, undulating, moderately deep	CkU2	0	98	12	MOD	H	4ER lS
Dipton, undulating, shallow	DpU3	0	95	19.6	SL	H	4ER S
Fleming, undulating, deep	FmU1	3	95	17.2	SL	H	4ERf s
Fleming, undulating, deep, imperfectly drained variant	FmU1vi	3	95	10.1	MOD	VH	5ERflS
Gore, undulating, shallow	GeU3	0	127	11.7	MOD	H	4ER lS
Glenure, undulating, deep	GnU1	0		12.8	MOD	VH	5ER ls
Glenure, undulating, moderately deep	GnU2	0		12.8		VH	5ER lS
Hokonui, undulating, deep	HkU1	0	84			H	
Hokonui, undulating, moderately deep	HkU2	0	84			H	
Howe, undulating	HwU	5	89	6.7	SEV	VH	5ERfls
Jacobstown, undulating, deep	JnU1	3		17.8	MOD	VH	5ERfls
Jacobstown, undulating, moderately deep	JnU2	5		12.3	MOD	H	5ERfls
Josephville, hilly, deep	JvH1	0	95	27.6	SL	VL	1ER
Josephville, hilly, moderately deep	JvH2	0	95	27.6	SL	VL	1ER
Josephville, rolling, moderately deep	JvR2	0	95	27.6	SL	VL	1ER
Josephville, undulating, deep	JvU1	0	95	27.6	SL	VL	1ER
Josephville, undulating, moderately deep	JvU2	0	95	27.6	SL	VL	1ER
Kaihiku, hilly, shallow	KhH3	0	58	23.9	SEV	L	4ER l
Kaihiku, rolling, shallow	KhR3	0	58	23.9	SEV	L	4ER l
Kaihiku, steep, shallow	KhS3	0	58	23.9	SEV	L	4ER l
Kaweku, rolling, shallow	KkR3	0	53	16.2	SEV	H	4ER ls
Kaweku, undulating, shallow	KkU3	0	53	16.2	SEV	H	4ER ls
Lintley, undulating, moderately deep	LiU2	0		18.2	MOD	M	3ER ls
Lintley, undulating, shallow	LiU3	0		16	MOD	M	3ER ls
Lumsden, undulating, shallow	LmU3	5		14.8	MOD	VH	5ERfls
Longridge, undulating, shallow	LnU3	0		12.7	MOD	H	4ER ls
Mataura, undulating, deep	MaU1	3	146	10.1	MOD	H	4ERfls
Mataura, undulating, moderately deep	MaU2	3	146	10.1	MOD	H	4ERfls
Mandeville, hilly, shallow	MeH3	0	85			VL	
Mandeville, rolling, shallow	MeR3	0	84			VL	
Mandeville, undulating, shallow	MeU3	0	85	23.7	MOD	L	3ER l
Makarewa, undulating, deep	MkU1	3		24.2	MOD	M	3ERfls
Makarewa, undulating, moderately deep	MkU2	0			MOD	M	3ER ls
River, undifferentiated	R						5ER
Riversdale, undulating, shallow	RiU3	5	89	5.9	VSEV	VH	5ERfls
Stonycreek, rolling, shallow	StR3	0	81	19.2	MOD	M	3ER ls
Kaweku Scarp, hilly, undifferentiated	UKkH	0	53	18.2	SEV	H	4ER ls
Wendon, hilly, shallow	WeH3	0	83	15.1	MOD	H	4ER ls
Wendon, rolling, shallow	WeR3	0	85	19.4	MOD	M	3ER ls
Waikoikoi, rolling, deep	WqR1	0	88	13.8	MOD	VH	5ER ls
Waikoikoi, undulating, deep	WqU1	0	84	13.8	MOD	VH	5ER ls
Waikoikoi, undulating, deep, imperfectly drained variant	WqU1vi	0	82	16.1	MOD	H	4ER ls

Summarised Topoclimate South soil survey data for Waikaia area

SOIL		FLOODING RANK	PAW MM	CEC WHGT AV 60CM	POT LEACHING LOSS	SVI RANK	FINAL RANK
Andrews, undulating, moderately deep	AeU2	6	321				
Ardlussa, undulating, deep	AdU1	0	93	12.9	SL	M	3ER s
Ardlussa, undulating, deep, imperfectly drained variant	AdU1vi	3	93	17.6	SL	M	3ERf s
Ardlussa, undulating, moderately deep	AdU2	3	94	14.4	SL	M	3ERf s
Arthurton, rolling, deep	ArR1	0	78	8.6	SEV	H	4ER ls
Arthurton, undulating, deep	ArU1	0	78	8.6	SEV	H	4ER ls
Athol, undulating, deep	AtU1	0	85	12.4	MOD	H	4ER ls
Benio, undulating, shallow	BnU3	0	55			L	
Crookston, undulating, deep	CkU1	0	98	8.8	MOD	M	3ER ls
Glenure, rolling, deep	GnR1	0		10.7	MOD	H	4ER ls
Glenure, undulating, deep	GnU1	0		10.7	MOD	H	4ER ls
Glenure, undulating, moderately deep	GnU2	0		10.7	MOD	H	4ER ls
Gore, undulating, shallow	GeU3	3	127	13.1	SL	M	3ERf s
Howe, undulating	HwU	5	89	6.7	SEV	VH	5ERfls
Jacobstown, undulating, deep	JnU1	5		11.2	MOD	VH	5ER ls
Jacobstown, undulating, moderately deep	JnU2	0		11.3	MOD	VH	5ER ls
Kaweku Scarp, steep, undifferentiated	UKkS	0	53	10.3	VSEV	VH	5ER ls
Kaweku, undulating, shallow	KkU3	0	53	16.2	SEV	VH	5ER ls
Lumsden, undulating, shallow	LmU3	5		14.8	MOD	VH	5ERfls
Mataura, undulating, deep	MaU1	3	144	10.1	MOD	H	4ERfls
Mataura, undulating, deep, imperfectly drained variant	MaU1vi	3	144	14	SL	VH	5ERf s
Mataura, undulating, moderately deep	MaU2	3	144	10.1	MOD	H	4ERfls
Mataura, undulating, moderately deep, imperfectly drained variant	MaU2vi	3	144	14	SL	VH	5ERf s
Oreti Scarp, hilly, undifferentiated	UOeH	0		12.3	MOD	VH	5ER ls
Oreti Scarp, rolling, undifferentiated	UOeR	0		12.3	MOD	VH	5ER ls
Oreti Scarp, steep, undifferentiated	UOeS	0		12.3	MOD	VH	5ER ls
Oreti, undulating, shallow	OeU3				MOD	M	3ER ls
Otama, undulating, deep	OmU1	0	115	7.1	MOD	H	4ER ls
River Complex, undifferentiated	RC						5ER
River, undifferentiated	R						5ER
Riversdale, undulating, shallow	RiU3	5	89	5.9	VSEV	VH	5ERfls
Tailings, undulating, shallow, undifferentiated	UTaU3	0					5ER
Waikoikoi, hilly, deep	WqH1	0	88	12.1	MOD	H	4ER ls
Waikoikoi, rolling, deep	WqR1	0	88	12.1	MOD	H	4ER ls
Waikoikoi, undulating, deep	WqU1	0	84	12.1	MOD	H	4ER ls
Waikoikoi, undulating, deep, argillic taxadjunct	WqU1vj	0	82	6.6	SEV	VH	5ER ls
Wendon, hilly, shallow	WeH3	0	83	15.1	MOD	H	4ER ls
Wendon, rolling, shallow	WeR3	0	85	19.4	MOD	M	3ER ls
Wendon, undulating, shallow	WeU3	0	85	19.4	MOD	M	3ER ls
Wendonside, undulating, moderately deep	WsU2	0	77	9.4	SEV	H	4ER ls
Wendonside, undulating, shallow	WsU3	0	77	9.4	SEV	H	4ER ls

Profile Available Water (PAW) calculations

				PAW (GeU3)		
Month	Rain mm	Evap	R-E		excess	
Jan	100.8	123	*22.2*	-63	0	
Feb	81.6	92	*10.4*	-73.4	0	
Mar	94.7	68	26.7	-46.7	0	
April	101.3	39	62.3	15.6	5.6	
May	108.2	23	85.2	10	85.2	
June	97.4	15	82.4	**10**	82.4	
July	76.7	16	60.7	10	60.7	
Aug	76.3	29	47.3	10	47.3	
Sept	78.3	53	25.3	10	25.3	
Oct	90.2	86	4.2	10	4.2	
Nov	92	109	*17*	-7	0	
Dec	92.2	126	*33.8*	-40.8	0	
	1089.7	779			310.7	
			paw			

Month	R-E	beg month	*end month*	
Jan	-22.2	31.2	9	
Feb	-10.4	9	0	
Mar	26.7	0	26.7	
April	62.3	26.7	89	7
May	85.2	82	82	85.2
June	82.4	82	82	82.4
July	60.7	82	82	60.7
Aug	47.3	82	82	47.3
Sept	25.3	82	82	25.3
Oct	4.2	82	82	4.2
Nov	-17	82	65	0
Dec	-33.8	65	31.2	
				312.1

8.3 Appendix III: Comparison of LUC data with Topoclimate results

LUC With TOPO SVI

Sum of HA_ALL			%
LUC	SVI_	Total	
2c 2	0	48.8	3.714925169
	H	456.45	34.74749166
	L	171.27	13.03801708
	M	496.04	37.76130083
	VH	141.06	10.73826525
2c 2 Total		1313.62	
2s 1	H	352	48.32974064
	M	26.3	3.611000508
	VH	350.03	48.05925885
2s 1 Total		728.33	
2w 2	0	187.15	6.672561386
	H	1176.4	41.9428331
	L	153.85	5.48529826
	M	1068.65	38.10116338
	VH	212.89	7.590283695
	VL	5.83	0.207860181
2w 2 Total		2804.77	
3e 4	H	1429.75	88.78835489
	L	47.38	2.942327158
	M	133.16	8.269317949
3e 4 Total		1610.29	
3e10	L	17.21	14.5170814
	VL	101.34	85.4829186
3e10 Total		118.55	
3e12	0	7.68	0.130182289
	H	3336.77	56.56098396
	L	679.88	11.52452275
	M	1458.4	24.72107428
	VH	416.69	7.063236725
3e12 Total		5899.42	
3e12+4e 3	H	48.26	60.40806108
	L	6.03	7.547878333
	M	25.6	32.04406058
3e12+4e 3 Total		79.89	
3s 2	0	10.27	5.729108557
	H	31.35	17.4885641
	L	0.39	0.217561084
	VH	137.25	76.56476626
3s 2 Total		179.26	
3s 2+2s 1	0	287.91	5.506919274
	H	3069.77	58.71618068
	M	167.25	3.199028337
	VH	1703.22	32.57787171
3s 2+2s 1 Total		5228.15	
3s 2+4s 1	VH	1.57	
3s 2+4s 1 Total		1.57	
3s 3+4s 3	H	655.3	31.60189235
	L	0.09	0.004340257
	M	1389.88	67.02706874
	VH	28.34	1.366698656
3s 3+4s 3 Total		2073.61	
3s 7+4s 4	0	10.27	0.137183373
	H	1772.42	23.67541906
	L	47.02	0.62807811
	M	5322.95	71.10226239
	VH	333.67	4.457057063
3s 7+4s 4 Total		7486.33	
3s12	0	3	0.010989164
	H	19636.59	71.92990232
	L	2098.09	7.685418332
	M	3970.21	14.5430962
	VH	1359.58	4.980215842
	VL	232.15	0.850378137
3s12 Total		27299.62	
3w 3	H	1418.19	48.72400074
	L	48.48	1.665601616
	M	321.39	11.04182557
	VH	1122.6	38.56857208
3w 3 Total		2910.66	
4e 3	H	148.49	23.044929
	L	461.08	71.55738341
	M	2.93	0.454721813
	VH	31.85	4.942965779
4e 3 Total		644.35	
4e 3+3e12	H	0.12	

4e 3+3e12 Total		0.12	
4e 3+6e16	H	0.77	
4e 3+6e16 Total		0.77	
4e 7	0	53.16	3.617064707
	H	737.94	50.21024699
	M	611.05	41.57651221
	VH	67.55	4.59617609
4e 7 Total		1469.7	
4e 7+6e15	H	116.35	85.26932942
	M	20.1	14.73067058
4e 7+6e15 Total		136.45	
4e 7+7s 9	0	124.79	87.8246182
	H	12.85	9.043563938
	M	4.06	2.857343937
	VH	0.39	0.274473925
4e 7+7s 9 Total		142.09	
4s 1+3s 2	H	330.21	12.57013864
	M	1496.54	56.96894486
	VH	800.19	30.4609165
4s 1+3s 2 Total		2626.94	
4s 4	H	80.56	6.686919999
	L	3.43	0.284708734
	M	490.3	40.6975779
	VH	629.49	52.25110812
	VL	0.96	0.079685243
4s 4 Total		1204.74	
4s 4+3w 3	H	10.55	1.547919479
	M	663.75	97.38687716
	VH	7.26	1.065203357
4s 4+3w 3 Total		681.56	
4w 1	H	10.46	3.346557461
	M	16.6	5.310980292
	VH	285.5	91.34246225
4w 1 Total		312.56	
5c 2	H	12.04	
5c 2 Total		12.04	
6e 5	VH	0.04	
6e 5 Total		0.04	
6e 6	H	370.68	11.22973268
	L	2779.88	84.21633019
	M	71.83	2.176086377
	VH	4.29	0.129965343
	VL	74.2	2.247885412
6e 6 Total		3300.88	
6e 6+4e 3	L	48.22	94.92125984
	VL	2.58	5.078740157
6e 6+4e 3 Total		50.8	
6e11	H	1.57	8.211297071
	L	16.33	85.40794979
	VH	1.22	6.380753138
6e11 Total		19.12	
6e15	0	8.15	0.643592113
	H	718.96	56.77509022
	L	322.84	25.4941445
	M	198.76	15.69575071
	VH	17.62	1.391422457
6e15 Total		1266.33	
6e15+4e 3	H	0.38	
6e15+4e 3 Total		0.38	
6e15+4e 7	H	23.26	11.2503023
	L	62.94	30.44256348
	M	119.3	57.7025393
	VH	1.25	0.604594921
6e15+4e 7 Total		206.75	
6e16	H	4.91	5.202924658
	M	55.07	58.35540956
	VH	34.39	36.44166578
6e16 Total		94.37	
6e29	H	56.17	78.12239221
	M	15.73	21.87760779
6e29 Total		71.9	
6s 1	H	102.42	14.41601216
	L	2.4	0.337809307
	M	1.26	0.177349886
	VH	604.38	85.06882865
6s 1 Total		710.46	
6s 1+4s 1	H	243.89	89.55678772
	VH	28.44	10.44321228
6s 1+4s 1 Total		272.33	
rive	0	23.33	
	H	87.55	
	M	4.63	
	VH	1599.46	
rive Total		1714.97	
Grand Total		72673.72	

Sum of HA_ALL			
OVERALL	LUC	Total	
1ER	2w 2	4.48	1.091405184
	3e10	101.34	24.68816995
	3s12	226.92	55.28162152
	4s 4	0.96	0.233872539
	6e 6	74.2	18.07639836
	6e 6+4e 3	2.58	0.62853245
1ER Total		410.48	
2ER L	2w 2	1.35	20.51671733
	3s12	5.23	79.48328267
2ER L Total		6.58	
2ER LS	3e12	274.7	59.4395759
	3s12	27.58	5.967888519
	3w 3	4.03	0.872030121
	6e15	92.89	20.09996971
	6e15+4e 7	62.94	13.61924958
2ER LS Total		462.14	
2ER S	2c 2	171.27	4.224758014
	2w 2	151.11	3.727466477
	3e 4	6.13	0.151210175
	3e10	7.54	0.185990982
	3e12	405.18	9.994671876
	3e12+4e 3	6.03	0.148743451
	3s 2	0.39	0.009620223
	3s 3+4s 3	0.09	0.002220052
	3s 7+4s 4	47.02	1.159853575
	3s12	1920.93	47.38403931
	3w 3	44.45	1.096458771
	4e 3	201.34	4.96650189
	4s 4	0.69	0.017020395
	6e 6	843.11	20.79719583
	6e11	16.33	0.402816012
	6e15	229.95	5.672231596
	6s 1	2.4	0.059201373
2ER S Total		4053.96	
3ER f s	2c 2	223.58	4.724832101
	2s 1	7.42	0.156804071
	2w 2	178.68	3.775977278
	3e12	45.47	0.960900419
	3e12+4e 3	8.09	0.170962929
	3s 2+2s 1	35.1	0.741755107
	3s 3+4s 3	1369.27	28.93626823
	3s 7+4s 4	126.74	2.678348781
	3s12	97.97	2.070363185
	3w 3	41.26	0.871932071
	4e 3	2.1	0.044378511
	4e 7	0	0
	4s 1+3s 2	1454.57	30.73888107
	4s 4	489.54	10.34526481
	4s 4+3w 3	650.97	13.75670433
	6s 1	1.26	0.026627106
3ER f s Total		4732.02	
3ER L	2w 2	0.19	0.148518721
	3e 4	6.1	4.768232627
	3e10	7.77	6.073634019
	3s12	59.18	46.25967326
	4e 3	5.58	4.361760338
	6e 6	49.11	38.38818104
3ER L Total		127.93	
3ER LS	2s 1	18.59	0.208950359
	2w 2	5.75	0.064629616
	3e 4	133.16	1.49670951
	3e12	1103	12.39764636
	3s 2+2s 1	47.48	0.53367203
	3s 3+4s 3	20.61	0.231655024
	3s 7+4s 4	5087.4	57.18203634
	3s12	1536.22	17.26701023
	3w 3	89.55	1.006536021
	4e 7	441.43	4.961643728
	4e 7+6e15	20.1	0.225922658
	4s 1+3s 2	41.97	0.471739998
	4s 4	0.76	0.008542349
	4s 4+3w 3	12.78	0.143646347
	4w 1	16.6	0.186582892
	6e 6	71.83	0.807364404
	6e15	56.55	0.635618224
	6e15+4e 7	117.64	1.322265746
	6e16	55.07	0.618983123
	6e29	15.73	0.17680415
	rive	4.63	0.052040891
3ER LS Total		8896.85	
3ER ISo	3e12	47.95	17.65009018
	3s12	65.42	24.08068613
	4e 7	48.7	17.92616042
	6e15	107.94	39.73202783

	6e15+4e 7	1.66	0.611035447
3ER lSo Total		271.67	
3ER S	2c 2	8.56	0.397810185
	2w 2	10.46	0.486109175
	3e12	101.32	4.708659807
	3e12+4e 3	17.07	0.793296712
	3s12	1960.72	91.12083949
	3w 3	18.55	0.862076978
	4e 3	0.83	0.038572717
	6e15	34.27	1.592634935
3ER S Total		2151.78	
3ERFl S	3e12	30.13	24.28859331
	3s 7+4s 4	93.92	75.71140669
3ERFl S Total		124.05	
3ERfls	2w 2	621.29	59.88106483
	3s12	244.22	23.53836961
	3w 3	172.03	16.58056557
3ERfls Total		1037.54	
4ER f S	2c 2	60.38	3.8435831
	2w 2	69.38	4.416492142
	3e12	398.12	25.34294972
	3s12	955.64	60.83275512
	3w 3	87.1	5.544486387
	4e 7	0.31	0.019733534
4ER f S Total		1570.93	
4ER Fg s	2c 2	263.9	78.4319553
	2w 2	16.84	5.004903855
	3e12	18.94	5.62903082
	3e12+4e 3	0.44	0.130769459
	3s12	36.35	10.80334057
4ER Fg s Total		336.47	
4ER flS	2c 2	38.88	0.610547011
	2s 1	170.06	2.670515039
	2w 2	347.69	5.459904586
	3e 4	71.59	1.124204232
	3e12	63.12	0.991196691
	3s 2	31.35	0.492300638
	3s 2+2s 1	2034.9	31.95478686
	3s 3+4s 3	290.16	4.556489732
	3s12	2458.2	38.60202322
	3w 3	697.02	10.9455627
	4e 3+6e16	0.77	0.012091595
	4e 7	6.78	0.106468846
	4s 1+3s 2	6.02	0.094534285
	4s 4	8.86	0.139131855
	4w 1	0.01	0.000157034
	5c 2	5.62	0.088252937
	6e 6	26.55	0.416924464
	6e15	3.33	0.052292221
	6e16	0.66	0.010364224
	6s 1	84.73	1.330546509
	rive	21.76	0.341705323
4ER flS Total		6368.06	
4ER fLSo	2c 2	16.11	0.745253692
	2s 1	139.11	6.435272566
	2w 2	38.45	1.778709152
	3e12	11.38	0.526442397
	3e12+4e 3	0.02	0.000925206
	3s 2+2s 1	852.12	39.41934051
	3s 3+4s 3	358.62	16.58987454
	3s 7+4s 4	7.64	0.353428815
	3s12	32.89	1.521501795
	3w 3	67.62	3.128122571
	4e 7	7.39	0.341863736
	4s 1+3s 2	308.11	14.25326598
	4s 4+3w 3	10.53	0.487121128
	6e 6	0.49	0.022667555
	6e15	3.21	0.148495615
	6s 1+4s 1	243.89	11.28242848
	rive	64.1	2.965286259
4ER fLSo Total		2161.68	
4ER L	2w 2	2.55	0.109782244
	3e 4	35.15	1.513272889
	3e10	1.9	0.081798535
	3s12	90.4	3.891888168
	4e 3	254.16	10.94206081
	4s 4	2.74	0.117962097
	6e 6	1887.66	81.26727456
	6e 6+4e 3	48.22	2.075960702
4ER L Total		2322.78	
4ER L s	2s 1	0.29	0.080757449
	3e12	106.02	29.52380952
	3s 2+2s 1	84.67	23.57839042
	3s 7+4s 4	13.92	3.876357561
	3s12	29.22	8.13700919
	4e 7	120.92	33.67307157
	4e 7+7s 9	4.06	1.130604288

4ER L s Total		359.1	
4ER LeS	2w 2	1.99	0.059918463
	3e12	111.61	3.360552575
	3s 2+2s 1	13.38	0.40286886
	3s 3+4s 3	4.25	0.127966566
	3s 7+4s 4	1289.12	38.81511993
	3s12	1779.02	53.56590128
	3w 3	89.64	2.699040702
	4e 7	23.29	0.701256782
	4s 1+3s 2	3.2	0.096351297
	4s 4+3w 3	0.02	0.000602196
	4w 1	5.66	0.170421356
4ER LeS Total		3321.18	
4ER ISo	2c 2	90.56	0.442830123
	2s 1	42.83	0.209434785
	2w 2	344.47	1.684426815
	3e 4	1358.16	6.641278261
	3e12	2599.22	12.70994823
	3e12+4e 3	42.37	0.207185427
	3s 2+2s 1	7.74	0.037847893
	3s 3+4s 3	2.27	0.011100093
	3s 7+4s 4	464.74	2.272536122
	3s12	13039.39	63.76142527
	3w 3	300.3	1.468439552
	4e 3	144.13	0.704782526
	4e 3+3e12	0.12	0.000586789
	4e 7	638.45	3.121962144
	4e 7+6e15	116.35	0.568940865
	4e 7+7s 9	12.85	0.062835325
	4s 1+3s 2	12.88	0.062982023
	4s 4	65.93	0.322391674
	4w 1	1.66	0.008117248
	5c 2	6.42	0.031393213
	6e 6	343.64	1.680368191
	6e11	0.72	0.003520734
	6e15	711.64	3.479854555
	6e15+4e 3	0.38	0.001858165
	6e15+4e 7	23.26	0.113739274
	6e16	4.25	0.020782112
	6e29	56.17	0.274666166
	6s 1	17.69	0.086502483
	rive	1.69	0.008263946
4ER ISo Total		20450.28	
4ER S	3s12	802.63	98.79495827
	3w 3	4.02	0.494817951
	4s 4	5.77	0.710223776
4ER S Total		812.42	
5ER	2c 2	48.8	6.383173536
	2w 2	187.15	24.47973212
	3e12	7.68	1.004565016
	3s 2	10.27	1.343344103
	3s 2+2s 1	287.91	37.65941583
	3s 7+4s 4	10.27	1.343344103
	3s12	3	0.392408209
	4e 7	53.16	6.953473467
	4e 7+7s 9	124.79	16.32287347
	6e15	8.15	1.066042302
	rive	23.33	3.05162784
5ER Total		764.51	
5ER f I So	2c 2	115.28	4.101878011
	2s 1	178.77	6.360970958
	2w 2	59.34	2.111428185
	3e12	121.19	4.312166865
	3s 2	6.91	0.245870724
	3s 2+2s 1	114.5	4.074124152
	3s 3+4s 3	28.34	1.008390205
	3s 7+4s 4	21	0.747219277
	3s12	689.61	24.5376136
	3w 3	510.53	18.16561226
	4e 3	0.38	0.013521111
	4e 7	31.43	1.118338184
	4s 1+3s 2	718.71	25.57304602
	6e15	2.28	0.081126664
	6e15+4e 7	0.17	0.006048918
	6s 1	196.34	6.98614442
	rive	15.64	0.556500452
5ER f I So Total		2810.42	
5ER F s	2w 2	267.96	77.85008716
	3e12	5.57	1.618245206
	3s 7+4s 4	0.97	0.281812899
	3s12	21.4	6.217315514
	3w 3	48.3	14.03253922
5ER F s Total		344.2	
5ER Fgls	2c 2	250.52	15.02918609
	2w 2	342.09	20.52264996
	3e12	153.32	9.197967472
	3e12+4e 3	5.87	0.352152812

	3s 2+2s 1	161.63	9.696500669
	3s 7+4s 4	10.92	0.655112215
	3s12	547.51	32.84619861
	3w 3	124.19	7.450401646
	4e 3	4.36	0.26156495
	4e 7	61.72	3.702703838
	4w 1	3.13	0.187774838
	6e11	0.85	0.050993167
	6e15	0.78	0.04679373
5ER Fgls Total		1666.89	
5ER FLS	2w 2	32.87	5.439261306
	4s 4	567.27	93.8706955
	6e 6	0.08	0.013238239
	rive	4.09	0.676804951
5ER FLS Total		604.31	
5ER FISo	2s 1	153.21	3.061744481
	2w 2	13.27	0.26518732
	3e12	13	0.259791647
	3s 2	130.34	2.604711022
	3s 2+2s 1	1505.18	30.07947626
	3s 2+4s 1	1.57	0.031374837
	3s 7+4s 4	10.02	0.200239408
	3s12	113.04	2.258988291
	3w 3	612.07	12.23159026
	4e 7	23.85	0.476617753
	4s 1+3s 2	26.41	0.527776723
	4s 4	62.22	1.243402791
	4w 1	285.5	5.70542425
	6e 5	0.04	0.000799359
	6e 6	4.21	0.084132526
	6e15	15.34	0.306554144
	6e15+4e 7	1.08	0.021582691
	6e16	34.39	0.687248826
	6s 1	408.04	8.154260283
	6s 1+4s 1	28.44	0.568344188
	rive	1562.79	31.23075294
5ER FISo Total		5004.01	
5ER IS	2c 2	25.78	1.716972587
	2s 1	18.05	1.202147215
	2w 2	107.41	7.15360844
	3e12	282.5	18.81476943
	3s 2+2s 1	83.54	5.563843674
	3s 7+4s 4	302.65	20.15677865
	3s12	556.93	37.09206916
	4e 3	31.47	2.095932014
	4e 7	12.27	0.817193702
	4e 7+7s 9	0.39	0.025974372
	4s 1+3s 2	55.07	3.667714522
	4s 4+3w 3	7.26	0.483522924
	6e11	1.22	0.081253164
	rive	16.94	1.128220156
5ER IS Total		1501.48	
Grand Total		72673.72	

Sum of HA_ALL			
RANK	OVERALL	Total	% of Class
3LER S	3ER LS	16.6	5.310980292
	4ER flS	0.01	0.003199386
	4ER LeS	5.66	1.810852316
	4ER lSo	1.66	0.531098029
	5ER Fgls	3.13	1.00140773
	5ER FlSo	285.5	91.34246225
3LER S Total		312.56	
3LER s e	2ER LS	4.03	0.13845657
	2ER S	44.45	1.527145046
	3ER f s	41.26	1.41754791
	3ER LS	89.55	3.076621797
	3ER S	18.55	0.6373125
	3ERfls	172.03	5.910343359
	4ER f S	87.1	2.992448448
	4ER flS	697.02	23.94714601
	4ER fLSo	67.62	2.323184432
	4ER LeS	89.64	3.079713879
	4ER lSo	300.3	10.31724763
	4ER S	4.02	0.138113005
	5ER f l So	510.53	17.54000811
	5ER F s	48.3	1.659417452
	5ER Fgls	124.19	4.266729883
	5ER FlSo	612.07	21.02856397
3LER s e Total		2910.66	
3LER sl s e	1ER	101.34	85.4829186
	2ER S	7.54	6.360185576
	3ER L	7.77	6.554196542
	4ER L	1.9	1.602699283
3LER sl s e Total		118.55	
4LER S	2ER S	171.27	8.387570704
	3ER f s	231	11.31271579
	3ER LS	18.59	0.91040427
	3ER S	8.56	0.41920713
	4ER f S	60.38	2.956977399
	4ER Fg s	263.9	12.92392076
	4ER flS	208.94	10.23237592
	4ER fLSo	155.22	7.601557335
	4ER L s	0.29	0.014202111
	4ER lSo	133.39	6.532481207
	5ER	48.8	2.389872426
	5ER f l So	294.05	14.40045055
	5ER Fgls	250.52	12.26866476
	5ER FlSo	153.21	7.503122016
	5ER lS	43.83	2.146477632
4LER S Total		2041.95	
4LER S e	1ER	232.36	0.445307872
	2ER L	6.58	0.012610285
	2ER LS	27.58	0.052855875
	2ER S	2128.76	4.079676303
	3ER f s	4404.1	8.440266824
	3ER L	65.47	0.125470418
	3ER LS	6886.13	13.19696978
	3ER lSo	65.42	0.125374595
	3ER S	1971.18	3.777681061
	3ERFl S	93.92	0.179993611
	3ERfls	865.51	1.658712413
	4ER f S	1025.02	1.964406417
	4ER Fg s	53.19	0.10193633
	4ER flS	5333.5	10.22142165
	4ER fLSo	1852.25	3.549756869
	4ER L	130.84	0.250749191
	4ER L s	127.81	0.244942327
	4ER LeS	3090.98	5.923729241
	4ER lSo	15313.27	29.34721845
	4ER S	808.4	1.549263573
	5ER	498.6	0.955545296
	5ER f l So	1834.75	3.516218877
	5ER F s	290.33	0.556404865
	5ER Fgls	1062.15	2.035564453
	5ER FLS	600.14	1.150142306
	5ER FlSo	2298.53	4.405033152
	5ER lS	1112.86	2.132747971
4LER S e Total		52179.63	
4LER sl S e	1ER	76.78	0.665103958
	2ER LS	430.53	3.729450471
	2ER S	1685.61	14.60153534
	3ER f s	55.66	0.482152726
	3ER L	54.69	0.473750136
	3ER LS	1404.09	12.16287857
	3ER lSo	157.55	1.364771146
	3ER S	153.49	1.329601544
	3ERFl S	30.13	0.261000029

	4ER f S	398.12	3.448700024
	4ER Fg s	19.38	0.167878545
	4ER flS	94.43	0.817996441
	4ER fLSo	15.1	0.130803201
	4ER L	2190.04	18.97114187
	4ER L s	106.02	0.918394395
	4ER LeS	111.61	0.966817567
	4ER lSo	3869.01	33.51515845
	5ER	15.83	0.137126799
	5ER f l So	124.02	1.074318741
	5ER F s	5.57	0.048249922
	5ER Fgls	164.33	1.42350265
	5ER FLS	0.08	0.000692997
	5ER FlSo	68.02	0.589220777
	5ER lS	313.97	2.719753709
4LER sl S e Total		11544.06	
4LER sl S ER	3ER f s	0	
	3ER LS	461.53	28.73517417
	3ER lSo	48.7	3.032095383
	4ER f S	0.31	0.019300813
	4ER flS	6.78	0.422127448
	4ER fLSo	7.39	0.460106466
	4ER L s	120.92	7.528562089
	4ER LeS	23.29	1.450051365
	4ER lSo	754.8	46.99436541
	5ER	53.16	3.309778041
	5ER f l So	31.43	1.956853345
	5ER Fgls	61.72	3.842729508
	5ER FlSo	23.85	1.484917349
	5ER lS	12.27	0.763938611
4LER sl S ER Total		1606.15	
4LER SP s e	3ER LS	15.73	18.73065015
	4ER flS	5.62	6.69206954
	4ER lSo	62.59	74.52964992
	5ER FlSo	0.04	0.047630388
4LER SP s e Total		83.98	
5LER	3ER LS	4.63	0.269975568
	4ER flS	21.76	1.26882686
	4ER fLSo	64.1	3.737674712
	4ER lSo	1.69	0.098543998
	5ER	23.33	1.360373651
	5ER f l So	15.64	0.911969306
	5ER FLS	4.09	0.238488137
	5ER FlSo	1562.79	91.12637539
	5ER lS	16.94	0.987772381
5LER Total		1714.97	
5LER SL s e	2ER S	16.33	10.09769973
	4ER L s	4.06	2.510511996
	4ER lSo	13.57	8.391046253
	5ER	124.79	77.16423448
	5ER Fgls	0.85	0.525599802
	5ER lS	1.61	0.99554786
5LER SL s e Total		161.21	
Grand Total		72673.72	