Ministry for the Environment
Manatū Mō Te Taiao

Environmental performance indicators

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Land

Proposed indicators for erosion-prone hill country in New Zealand.

Prepared for the Ministry
for the Environment by:
Peter Stephens, Garth Harmsworth
and John Dymond

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Signposts for sustainability

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Executive Summary

Project and Client

The Ministry for the Environment (MfE) confirmed environmental performance indicators for land in October 1998. Landcare Research has undertaken this contract for MfE to assist with the implementation and reporting of indicators for measuring erosion on New Zealand hill country.

Objective

- To detail the indicator design and methodology each regional council and unitary authority (council) is proposing to adopt for reporting on hill country erosion.
- To relate how each of these councils proposes to report and present the information gathered.
- To recommend a methodology for reporting on the state of the environment.

Sources of Information

The 15 councils were written to by MfE, and subsequently contacted by the senior author. This report is based on material received from these councils, as well as from comments on two draft reports, which were summarised at a MfE workshop held on 5 March 1999.

Main Findings

Councils are in the formative stages of designing state of the environment programmes for hill country erosion, so this contract is timely. Nine of the 15 councils contacted have given attention to reporting on hill country erosion. They have considered the following factors concerning which environmental monitoring and reporting system they might use: cost; ownership of the hill country; rating base; existing aerial photographic coverage/s; and proportion of region affected by hill country erosion. Seven councils have operational, or near-operational, environmental indicator programmes, namely, Environment Waikato (EW), Environment Bay of Plenty (EBOP), Taranaki Regional Council (TRC), Gisborne District Council (GDC), Hawkes Bay Regional Council (HBRC), Wellington Regional Council (WRC), and Manawatu-Wanganui Regional Council (MWRC). Two councils, TRC and MWRC have approved land monitoring programmes; TRC=s hill country monitoring was reported in its 1996 State of Environment Report.

The land environmental performance indicator most widely used is an erosion-risk/environmental- risk pressure indicator. Six councils have considered a response indicator. A number of councils have considered using a state indicator for soil erosion in the hill country.

Two approaches to environmental monitoring of hill country are currently being considered. Both approaches use the same method to determine erosion pressure (namely, suitability of land use to land type). However, the approaches differ in the way land use/cover information is acquired. One approach involves sampling, and is preferred by MWRC, GDC, and TRC. The other approach involves use of region-wide databases, and is preferred by EW, EBOP, HBRC,

and WRC. In the future most agencies consider they will be using a combination of both approaches.

At EW and EBOP, they propose to establish a number of environmental baseline sites where further environmental investigation and/or data gathering could be undertaken. All councils undertake erosion control works on hill country.
Staff at EW, EBOP, TRC, HBRC, GDC, and WRC have stored (or intend to store) and analyse monitoring information in a geographic information system. The MWRC would collate results in a database on a sample site basis. The basis for grouping and analysing data varies from council to council. For example, EW and EBOP intend using erosion Aat-risk≅ land classes, while TRC, HBRC, and WRC are using physical sustainability land-use classes for the hill country.

All councils have used the New Zealand Land Resource Inventory (NZLRI) as the key information source to determine land suitability. In a modified and improved form, the Land Cover Database (LCDB) has been used by EBOP, HBRC, and WRC as a basis of region-wide land cover information. Six other councils either have, or will have in the near future, a copy of the LCDB either for their whole region, or for significant parts of their region. All of these councils propose to use a vegetation database for their hill country monitoring.

All councils make use of aerial photographs. A number of these councils are part of local consortiums that purchase region-wide photographic coverages. Aerial photographs would be used for mapping the incidence and location of landslides for farm plan work, and to determine the state indicator for soil erosion. Photography would also be used for mapping land use and vegetation cover of sampling sites and/or improving the land cover information of the vegetation databases.

Proposed method for national monitoring and reporting

An environmental monitoring and reporting method for erosion-prone hill country is proposed, which would enable aggregation of data to a national level. The pressure-state-response indicators associated with this method are:

- area of erosion-prone hill country without established tree cover (denoting pressure)
- soil depth change for erosion-prone hill country (denoting state)
- change in area of erosion-prone hill country without established tree cover (denoting response and pressure).

For the pressure and response indicators, this method involves use of the NZLRI, nation-wide vegetation database(s), and with supplementary vegetation and land-use information from councils. Collection, compilation, and reporting on state indicator measurements is believed to be best undertaken as part of a national effort, utilising benchmark sites.

The following map and explanation indicates the likely content of a national state of the environment report, prepared using the proposed method.

Recommendations

Key recommendations include:

- a nationally consistent vegetation cover database, which could be either the NZLRI or an enhanced LCDB, is maintained and updated (every 5B10 years) so that councils can undertake their monitoring programmes of erosion-prone hill country in such a way that national reporting is possible;
- that council=s are encouraged to reach agreement on an anticipated environmental outcome for erosion-prone hill country. A suggested outcome is Aan increase in the total area of privately owned erosion-prone hill country in a sustainable form of land use≅; and
- methods for determining soil depth changes on benchmark sites in erosion-prone hill country are trialled and evaluated.

From a National State of Environment Report, c. 2005

This map shows where environmental pressure on New Zealand=s erosion-prone hill country have been reduced since 1999. Environmental pressure has been reduced where established tree cover has increased in area by 10%. The localities where this increase in area has occurred are shown by shading in the map. These data have been aggregated from councils Astate of environment≅ monitoring reports and databases. From the national benchmark monitoring sites (not shown on the map), it has also been determined, for a similar time period, there is a 0%<5 mm change in the national average change in soil depth for erosion-prone hill country. (A subset of these sites is also being used for related national environmental

performance monitoring, including measures of soil health, soil carbon and soil biodiversity.)

1. Introduction

Environmental performance indicators for air, freshwater, and land have now been confirmed and a summary of these was published in October 1998 (MfE 1998a). Landcare Research was contacted by MfE in late 1998 to help with the implementation and reporting of indicators for measuring the erosion on hill country. This is the final report for that consultancy.

2. Background

The New Zealand government promotes the sustainable use and management of the nation=s land resources. The Resource Management Act 1991 (RMA 1991) provides the legal framework for environmental management of New Zealand=s natural and physical resources, including land, water, soils, plants, and animals. The purpose of the Act is to Apromote the sustainable management of natural and physical resources≅ (section 5 (1)). Sustainable management can be defined as Athe management of resources to provide for the well-being of people now and in the foreseeable future within environmental limits while avoiding, remedying, or mitigating adverse effects on the environment≅. Under the RMA section 35(2) local authorities are required to monitor the state of the environment as appropriate to their functions.

In mid-1998 the Ministry for the Environment (MfE) prepared and circulated for comment to regional councils and to relevant technical persons a paper that sets out the rationale and process by which indicators for land (and in particular the soil resource) would be developed. The background information and discussion in the mid-1998 report forms the basis of this project brief.

The land indicators have been based on four national land-use risk or susceptibility issues:

- hill country erosion
- high country degradation
- agricultural impacts on water bodies, and
- reduction of soil health in intensively used land.

These issues have been determined by the three priority areas in the Sustainable Land Management Strategy: viz: hill country erosion, high country degradation, and agricultural impacts on water bodies. These issues, in addition to the issue under the general heading of Asoil health≅, are expressed in the policy settings of Environment 2010 Strategy (MfE 1995) and the RMA, and in many cases are incorporated in regional policy statements and plans.

The Stage One land indicators, that is, those which can be implemented over the next 1B2 years, are identified as those that address hill country erosion. Specifically, these performance indicators of soil intactness would measure:

- changes in areas susceptible to hill country erosion
- percent change in area of slip at selected sites.

This project brief sets out a process by which these indicators can be further developed so that regional councils can present relevant information as required for state of the environment reports.

3. Objectives

The objectives of this consultancy were in three parts:

- Part 1 was to report on the indicator design and methodology that each regional council is proposing to adopt in reporting on hill country erosion and how each regional council proposes to report and present the information gathered. (Reported as Stephens *et al.* 1999.)
- Part 2 was to identify the common design elements of each regional council=s approach to collecting and reporting on indicators for hill country erosion, and to propose a model methodology that regional councils may follow in their design and implementation of indicators for measuring soil erosion on hill country land and that provides for comparable data to be collected and reported nationally. (Reported as Harmsworth *et al.* 1999.)
- Part 3 was to present and refine the proposed model methodology in conjunction with stakeholders. (This report, which combines elements of the draft reports for Parts 1 and 2.)

The requirements in undertaking Part 1 of this consultancy were to draw on the information and knowledge available to Landcare Research to:

- report on the status of each regional and unitary council in terms of progress with developing and reporting on hill country erosion and
- describe how those councils that have an operational (or near operational) indicator programme propose to collect, collate, and report on information for soil intactness on erodible hill country. These councils are likely to include:
    - Taranaki Regional Council (TRC)
    - Hawke=s Bay Regional Council (HBRC)
    - Gisborne District Council (GDC)
    - Environment Waikato (EW)
    - Environment Bay of Plenty (EBOP)
    - Manawatu-Wanganui Regional Council (MWRC)
    - Marlborough District Council (MDC).

- In considering the information obtained and presented on each council=s approach to its design and reporting of hill country erosion, comment on the context in which each council propose to use:
    - the Land Cover Database (LCDB) - see Appendix I
    - the New Zealand Land Resource Inventory (NZLRI) - see Appendix II
    - information on slope (digital terrain models) and soil type (soil maps)
    - Aerial photography
    - Geographic Information Systems (GIS)
    - National Soils Database (NSD)
    - AGRIBASE.
- submit to MfE a draft report that records and presents the information gained in the abovementioned activities on the status of and procedure by which councils report or propose to report on soil intactness on erodible hill country.

The requirements in undertaking Part 2 of this consultancy were to:

- identify and describe the common design elements of each regional council=s approach to collecting and reporting on indicators for hill country erosion;
- propose and describe a number of simple and least-cost methodologies that regional councils could employ when collecting, collating, and reporting on hill country erosion, which at the same time provide for comparable data to be collected and reported nationally; and
- submit to MfE a draft report that describes a number of least-cost processes by which a regional council may measure and report on hill country erosion.

The requirements in undertaking Part 3 of this consultancy were to:

- present and discuss in a workshop for regional council practitioners and relevant scientists the proposed methodology for reporting on hill country erosion. The workshop was held in conjunction with MfE on Friday 5 March 1999;
- incorporate any changes to the draft report on the methodology to report on soil intactness for hill country as a result of comments and discussions by the workshop participants and other selected reviewers; and
- submit the final version of its proposed methodology for reporting on soil intactness, supplied as one disc copy in Microsoft Word 6 or 7 and three paper copies (two bound copies and one unbound copy) to MfE.

4. Regional Council and Unitary Authority Approaches to State of the Environment Reporting on Hill Country

To undertake this work, each regional council and unitary authority was written to by MfE, and were subsequently contacted by the senior author and asked to supply information relevant to the project. This report is based on the information obtained from these agencies and from discussions with their contact staff member. The regional council and unitary authority contacts are given in Appendix III.

4.1 Northland Regional Council

Erosion of land, especially in hill country is recognised as a significant soil conservation and land management issue in Northland. However, Northland Regional Council (NRC) is in the formative stages of developing a programme for state of environment monitoring (SEM) for hill country. This is evident in the issues, objectives, methods, and environmental results associated with Soil Conservation and Land Management activities within the Northland Region (NRC 1998). One of four objectives associated with these activities is AThe protection of soil resources, including soil quality and soil quantity, from degradation or loss as a result of unsustainable land uses and land-use practices≅. To implement such an objective the NRC has a policy Ato encourage the retirement and re-vegetation of land which has a high erosion risk≅. Such encouragement will be implemented by NRC staff assisting land owners to prepare soil conservation plans for areas of high erosion risk and to promote related landcare groups. Anticipated environmental results from the Soil Conservation and Land Management activities include:

- more widespread adoption of soil conservation practices within land use and subdivision proposals; and
- reduction of erosion in high risk areas.

4.2 Auckland Regional Council

Over the last couple of years Auckland Regional Council (ARC) staff have been considering how best to monitor soil intactness in the Auckland Region. Consequently, ARC does not currently have any operational or near-operational environmental-indicator monitoring programmes. However, ARC does have data sets that can be used for such monitoring, with digital copies of the NZLRI (of the whole region) and historical, large-scale aerial photographs of most of the region. They have commissioned colour aerial photographs (stereo pairs) to be flown at 1:10 000 scale over the whole region within this financial year.

In 1997, ARC and Rodney District Council undertook a remote sensing project to assess the accuracy of selected areas of land-cover satellite imagery in the Rodney District. Assessment

was made of the usefulness of this imagery for land use and land-use change mapping, including vegetation loss, to provide information for future monitoring strategies and policies (Thompson 1998). The results of this project showed that the satellite-derived LCDB had a mixed ability to identify vegetation cover, and was only able to provide a general vegetation classification of ground cover. Mainly on account of the inadequate resolution, there were problems identifying young pine trees (up to 4B5 years of age), smaller stands of vegetation, and scattered scrub over pasture.

As a precursor to designing a regional monitoring programme of soil health and soil intactness, ARC ranked Auckland soils' susceptibility to degradation (Hicks 1995). In this ranking three types of degradation were considered, namely, structural breakdown, nutrient loss in the course of primary production, and erosion. Maps of Asoil susceptibility to degradation≅ have been prepared for the Rodney District and for the greater Auckland Region, and it is anticipated these will be used as part of their SEM process.

The principal source of information for the erosion assessment was the NZLRI (1st and 2nd Editions - see Appendix II) where the soils were grouped into one of four categories to aid prioritisation for monitoring. One of these categories was hill country soils. The areas of highest susceptibility to hill country erosion in the Auckland Region have been identified in the Wairoa/Hunua and central Rodney districts.

The usefulness of the NSD was considered to produce data for Auckland (Hicks 1995). It was established that the NSD was not in a condition to supply a consistent body of data. Of some 100 soils mapped in the Auckland region, 47 have profile descriptions in NSD. All 47 have chemical data recorded, but few have data about physical structure or mineralogy. However most of the analytical data has been tabulated in published soil reports and papers. In short, it was concluded that data from the NSD was unlikely to be a useful source of information on soil properties to degradation.

4.3 Environment Waikato

Accelerated erosion[1] is of concern to EW: they have used the NZLRI to determine that over one million hectares in their region are affected by such erosion, with 36 000 ha ranked as having severe to extreme erosion (EW 1996). High-risk erosion areas have been identified in

[1] Erosion is a natural phenomenon. New Zealand does have natural levels of erosion that are high by international standards. Changes to the vegetative cover of the land brought about by activities such as farming, introduction of pests, burning, forestry, road construction ... reduce protection against erosive forces and lead to accelerated erosion (EW 1996).

the following land types: Central Volcanic Area; Western and Central Hill Country; Eastern Ranges; Coastal Margins; and stream banks (EW 1998).

In the Proposed Waikato Regional Plan (EW 1998), four policies are related to soil disturbance and inappropriate land management that may result in accelerated erosion of the soil resource. Three of these policies relate to managing soil disturbance, and the fourth is concerned with promotion of good soil and land management practices. Permitted, controlled and discretionary activity rules are associated with the first three policies. Property Management Plans (farm plans) are being used to assist and encourage farmers to plan how the adverse effects of soil disturbance and vegetation destruction activities, can be avoided, remedied, or mitigated. It is intended to input these plans into their GIS system (Tony Fenton pers. comm.). Some information from EW operations (for example, biodiversity assessments) has already been so (EW 1997).

Environmental performance indicator options for monitoring erosion in EW hill country include land cover (use/type/area/condition), land use relative to land capability, and the extent and frequency of slipping (EW 1998). Proposed techniques to undertake monitoring include the use of satellite imagery and aerial photography at five yearly intervals.

Anticipated environmental results from implementing these policies are grouped into six categories, three of which relate to accelerated erosion. These results are:

- reduction of the areas within the region affected by accelerated erosion;
- improved water quality as a result of reduced severity of accelerated erosion; and
- reduced rates of accelerated infilling of estuaries and lakes.

Environment Waikato has a copy of the LCDB for the region. This database was created in 1998, but has not yet been used to identify the location of hill country erosion pressures (which is the intention). In the absence of significant quantities of directly measured data on the erosion rates in the Waikato region, EW propose to establish a number of environmental baselines/reference points from which a risk-based assessment could be undertaken. Areas that may warrant further investigation or data gathering would be identified on the basis of estimates, rather than actual values, of environmental pressure. Using the NZLRI, topographic and soils data, and average monthly rain/potential evapotranspiration, McLeod and Leathwick (1998) helped EW determine some of the key attributes of the region=s soil resources (leaching and runoff potential) and the specific interpretations (soil versatility) of these characteristics.

4.4 Environment Bay of Plenty

Environment Bay of Plenty=s (EBOP=s) soil-monitoring Sustainable Land Management programmes are supported by its Proposed Regional Policy Statement and Proposed Regional Land Plan, which contain policies that state that they will (amongst others) A... develop monitoring programmes to:

- assess the amount and location of land with accelerated erosion;

- assess land-use changes and their impact on long-term sustainability;
- assess the extent and location of unsustainable land-use practices; and
- acquire and maintain sufficient information on the state of the Bay of Plenty=s land resources to enable state of environment reporting and assessment of progress towards the sustainable management of its natural and physical resources.≅

The intention is that EBOP=s monitoring programmes will form part of the land module for their Natural Environment Regional Monitoring Network (NERMN) programme, as well as being linked to monitoring programmes of other agencies. The programmes will provide information to assist examination of existing policies and to develop new policy.

Two frameworks have been proposed: one for monitoring soil intactness and one for soil health (Hall *et al*. 1998). The next step, following the approval of the frameworks, requires the development of detailed monitoring programmes for inclusion in the Annual Plan budgeting process.

The proposed framework for soil intactness monitoring is based on eight Aat-risk≅ land classes and a four-component hierarchy of monitoring activities. The monitoring framework was developed using the NZLRI and the LCDB (Harmsworth 1998). The NZLRI was used to group Land Use Capability (LUC) classes into suites of land of distinctive characteristics (for example, greywacke steeplands). This process led to the identification of eight the Aat-risk≅ land classes. Those relating to hill country include: steep Tarawera soils, steep Rotomahana soils, Taupo pumice/Waimihia lapilli hill country, and East Coast Tertiary hill country.

Monitoring activities for soil intactness will use four components:

- region-wide monitoring;
- representative-catchment monitoring;
- site-specific monitoring; and
- integration with other monitoring programmes (such as NERMN).

Region-wide monitoring will involve GIS analysis using land cover, land use, land use/land use capability and regional storm databases at a nominal 1:50 000 scale.

Representative catchments will be chosen and more detailed monitoring will be undertaken within these. Such monitoring includes:

- changes in land use in relation to land capability;
- rainstorm data collation;
- erosion severity monitoring (for earth slip, gully, and stream bank); and
- relating erosion to rainstorm data and suspended sediment levels.

Site-specific monitoring for erosion in hill country could include:

- soil loss changes;
- sediment transfer rates;

- loss of topsoil/depth of topsoil; riparian management regimes (especially adjacent to gullies); and
- soil conservation plantings and erosion recovery times.

For their representative-catchment and site-specific monitoring, EBOP envisage using a combination of aerial photography and on-site measurements of erosion.

Soil health monitoring will use the indicators developed at a national level by soil scientists and be based on a framework of key land uses in the BOP region. Soil scientists from Landcare Research have proposed a set of indicators to assess soil health. These included indices that measured chemical biological and physical soil characteristics.

The key land uses identified are: dairying, urban, cropping, forestry, and horticulture. Within each of the land uses specific issues have been identified on which soil health monitoring will focus.

Wherever possible, soil health monitoring will be integrated with soil intactness monitoring in a combined programme.

4.5 Gisborne District Council

The GDC has evaluated an number of methods to undertake land SEM. Two methods considered were the approaches used by TRC (O=Leary *et al*. 1996) and a method trialled in Gisborne in 1995 and subsequently developed by the MWRC (based on Hicks 1998). In their 1998 State of the Environment Report GDC reported on the method trialled. This method appears to be appropriate to meet their SEM requirements (Peter Fantham pers. comm.).

Their preferred technique for land monitoring involves use of 9 km^2 sample Awindows≅ spaced at regular intervals across the district. The intention is to analyse these using currently held aerial photographs to record erosion and vegetation and relate these to LUC. Photography, in colour at a scale of between 1:5000 and 1:8000, could also be specially acquired as needed (proposed at 3- to 5-year intervals). Sixty seven (67) sample windows would give a 7% sample coverage of the district, which would be statistically satisfactory. Over time, an indication of change in land-use sustainability would be compiled. However, this technique generates statistics only, not a map of the district. It is envisaged that the sampling technique would be used in conjunction with manually updated maps of known changes in vegetation, such as scrub clearing or planting of exotic forest.

Measuring and quantifying land-use change is important to ascertain the progress of the Gisborne District toward sustainable land use. However, other councils are spending up to fifty times the cost of their preferred land-monitoring method for SEM and reporting (GDC 1997).

The Council=s notified, proposed, combined Regional Land and District Plan uses land overlays (zones) that are linked to the NZLRI database (at a scale of 1: 63 360). These links will be updated once the 2nd edition 1:50 000 scale NZLRI mapping is completed for the district in mid-1999. At GDC extensive use is made of the NZLRI, being the reference database for land classification and land-use capability within the district. Staff at GDC prefer to derive land cover from the MOF/MAF/GDC vegetation maps based on 1:50000 topomap series and probably from the 2nd edition NZLRI once it becomes available. They have used a GIS system for a number of years.

The Council makes use of aerial photography for resource mapping, for example, they have a district-wide coverage taken at the time of Cyclone Bola (March 1986), and another taken between 1942 and 1953. The GDC cannot afford to commission district-wide aerial photography. However, one company is flying the district on speculation over a 3-year period and GDC is purchasing colour photographs, as and when finances allow, from within a limited budget.

4.6 Taranaki Regional Council

In 1995, the TRC developed a Regional Monitoring Strategy. This strategy involves the TRC in preparing a regional State of the Environment report every 5 years, based on the results of their monitoring programmes. ALand≅ is one of the monitoring programmes that TRC undertakes. One issue addressed in the land monitoring programme is Aaccelerated erosion and sustainable land management in the hill country≅ (TRC 1996).

A key objective of the TRC is the achievement of more sustainable use and development of the hill country (especially the erodible eastern hill country) to reduce erosion potential and associated environmental effects. A project to monitor land-use changes and their sustainability in the eastern hill country has been undertaken (O=Leary *et al*. 1996). This project received funding assistance from MfE.

The method used to monitor the eastern hill country involved analysis of 25 monitoring sites (3 x 3 km). The monitoring sites cover about 8% of the hill country area. An analysis of the location of the monitoring sites (using the NZLRI) indicated that they were highly representative of the physically sustainable land-use classes within the area of rateable Taranaki hill country. The Council=s 1994 colour aerial photographs (which cover the whole region) were used to map each site=s land use, vegetation, and physically sustainable land-use classes to create a 1994 baseline. For 17 of the 25 sites, historical aerial photographs (as early as 1951) were available, and the same mapping procedure was employed for all photographs, regardless of when they were taken. Changes in location and area of each land-use and vegetation class between 1951 and 1994 were also determined. Digital coverages were created and stored in a GIS. The location and area where land-use changes were deemed physically sustainable was determined by comparing the nature of land-use changes with a physically sustainable land-use database (created by Blaschke *et al*. 1992) for the hill country area. This enabled the TRC to determine whether land use in the hill country was becoming

more or less physically sustainable in its potential for production loss as a result of erosion. Results of this monitoring were reported in TRC=s first State of the Environment report (TRC 1996).

The databases of physically sustainable land-use developed by Blaschke *et al*. (1992) was based on the NZLRI LUC classification for the Taranaki Region. The classification was supplemented by research undertaken between 1984 and 1988 by the Ministry of Agriculture and Fisheries, the Ministry of Works and Development, and the Taranaki Catchment Commission. This research generally involved determining the relationship between soil slip erosion, pasture production, slope, and land use. The Council have adopted seven mapping units indicating, broad, physically sustainable land-use classes (namely, Intensive Horticulture, Cash Cropping, Dairying, Drystock Grazing, Pasture and Trees, Forestry, and Protection). As mapping units, these classes do not represent single land uses, but indicate the most intensive physically sustainable land use of a range of land uses. To improve the relationship between land type and soil slip erosion/pasture productivity, a more detailed rule-set was established for the hill country LUC mapping units. The resulting LUC mapping units were divided into more than one physically sustainable land-use class on the basis of their slope angle. Staff at TRC have also used a digital terrain model (DTM) to quantify hill country slope classes to assist in better delineating land types according to slope angle.

The Taranaki Regional Council have adopted a programme of advice and advocacy in the hill country, providing information to farmers on options for achieving more sustainable land management. This is achieved through sustainable land management plans for individual farms that are prepared at no cost to the land owner. There are four types of plans: comprehensive farm plans, agroforestry plans, conservation plans, and riparian management plans. For comprehensive farm plans, recommendations addressing land use (for example, planting erosion-control species or exotic forestry), are made based on discussions with the land owner. Mapping LUC, computer modelling and other techniques to evaluate the property=s physical and financial constraints are employed. By May 1998, 186 of these plans had been prepared, which cover 76 000 ha (TRC 1998).

Anticipated environmental results from the notified TRC Regional Soil Plan, which only relate to erosion-prone hill country, include:

- an increase (from 74% to 79%) in the total area of privately owned land in the hill country that is being sustainably managed;
- an increase of 50% in the area covered by production forestry and soil conservation plantings on LUC Classes VI and VII land in the hill country;
- no net loss in the area of indigenous vegetation on LUC Class VI and VII land in the hill country in private ownership; and
- an increase in the area addressed by the Sustainable Land Management programme with the aim of (a) 50% of that part of the hill country, that is in private ownership, being included in the programme, and (b) 70% of properties in the programme having implemented the farm plan(s) in whole or in part.

Staff at TRC staff are now considering options for the next cycle of hill country monitoring

(Bill Bayfield pers. comm.).

4.7 Hawkes Bay Regional Council

The HBRC=s approach to establishing a regional land SEM has been to identify areas where land is being used outside of its level of sustainability (Eyles *et al*. 1998). The work undertaken to date has been done by HBRC staff, and involves interpretation of the NZLRI, and use of a land cover map (derived from the LCDB) in conjunction with their in-house GIS system.

The NZLRI has been used to prepare a map of physically sustainable land use. The approach used was based on the work of Blaschke *et. al*. (1992), which was subsequently used for land monitoring in the Taranaki hill country (O=Leary *et al*. 1996). Creation of the map involved identifying seven land-use classes representative of the Hawke=s Bay. These are: horticulture, cropping, dairying, pastoral farming, pastoral farming with trees, forestry, and protection. A land-use matrix was developed so that land uses were ordered in terms of increasing versatility. At one end of the scale, land assessed as having its highest level of sustainable use as protection had no other options. At the other end of the scale was horticulture, on land that could be used for all other land uses. This land-use matrix was imposed on the NZLRI LUC classes where each of the 117 LUC classes were assigned to one of the seven land uses.

The land cover types considered essential for the HBRC monitoring needs include: primarily horticulture, primarily pastoral, forestry planted (> 5 years), forestry planted (2-5 years), clear- felled forest, indigenous forest, scrubland, predominantly tussock, riparian trees, soil conservation plantings, dune vegetation, coastal vegetation, bareground, recreational, mine, urban, shelter belts, inland water, inland wetlands, and unclassified. The SPOT satellite data used to create the LCDB had insufficient spatial/spectral resolution to map newly planted forestry, reverting scrublands, small forest blocks and linear plantings (shelter belts), soil conservation plantings, and some of the smaller horticulture and cropping areas. It is fortunate that a number of the land classes not mapped in the LCDB are mapped by others for other purposes using appropriate techniques. Using their in-house GIS system HBRC improved the utility of the LCDB by adding to it these additional land-use classes.

When the two regional databases (land cover and physically sustainable land use) are intersected in a GIS, the areal extent and spatial locality of land being used beyond its physical capability (that is, unsustainably) are established. This spatial information provides a means to target monitoring activities. The HBRC anticipate undertaking such a regional monitoring exercise every 5 years. A State of the Environment report is being prepared using this monitoring system.

Under a Regional Landcare Scheme, the HBRC aims to help land owners develop more sustainable land-use systems through good soil conservation practices to control soil erosion. These farm plans are prepared for hill country properties. Erosion control works are being recorded on a database linked to AGISmo≅, a property enquiry system through which

property information is obtained from AGRIBASE. The next stage of development is likely to be the recording of erosion control works in farm plans on digitally stored NZMS 262 maps. This should enable long-term monitoring of such works to be more quantitatively analysed.

4.8 Manawatu-Wanganui Regional Council

The MWRC has characterised its land resource using the NZLRI. About 61% of the MWRC region is hill country (land generally with slopes greater than 15 degrees, excluding mountain lands). Four types of hill country were recognised, and of these, 50% of the region is vulnerable and can erode easily. Most of this hill country has been cleared of its indigenous cover. Loss of the productive capacity of hill lands (by erosion, including slipping), and accelerated erosion resulting from some land use practices in vulnerable hill soils, have been recognised as significant regional issues (MWRC 1998a).

The Council has developed a regional land SEM strategy (MWRC 1998b). This strategy has been developed using the pressure-state-response model, a similar approach to that of the MfE EPI programme (MfE 1997). They have three indicators (Malcolm Todd pers. comm.) for the hill country erosion, namely:

- A pressure indicator, which indicates the level of protection against hill slope erosion afforded by vegetation;
- A state indicator, which is a measure of how much soil is on the hills, in terms of the percent of hillside in fresh and recent landslide scars on erosion control projects, and how much of the erosion-prone hill country is owned by farmers who have soil conservation plans; and
- A response indicator related to the level of grant funds spent.

Staff at the MWRC propose to use a sampling technique developed by Hicks (1998) to record information for monitoring hill country in the region. This technique uses aerial photography to determine the level of protective vegetation (pressure), the extent of erosion surfaces (state), and changes in the amount and type of protective vegetation cover, for 100 points within each of a number of a randomly located sample sites. The intention is to record information from about 45 sample sites throughout the region, and to remeasure these sites every 3-5 years. This approach does not provide a map of where the environmental monitoring has been undertaken, nor of where environmental results have been achieved.

Although the MWRC intend using information obtained from aerial photography, they would like to be able to have access to updated NZLRI vegetation information. The Council consider that the LCDB, supplemented with their aerial photography, could be a means of achieving this. Staff at MWRC also see a need to link what is happening on hillsides to off-site effects (such as water quality) (Malcolm Todd pers. comm.). The Council does not have a GIS system, but are currently thinking about purchasing a system.

4.9 Wellington Regional Council

In the Wairarapa hill country, pastoral farming, plantation forestry, indigenous forest, and scrub

reversion are the major land-use/land-cover types. Pasture land occupies some 70% of this hill country. Much of this land is fragile and subject to severe soil erosion. Plantation forestry, indigenous forest, and scrub reversion are all deemed to be long-term sustainable uses for this severely eroded land. Pastoral farming cannot always be classified as sustainable. On the steeper slopes with a high incidence of erosion, soil conservation techniques are required to ensure that the land retains its soil cover. Accordingly, pastorally farmed land with a severe erosion potential has been targeted throughout the region for implementation of soil conservation programmes. In excess of 90% of the properties located on this target land are under an approved soil conservation programme. Programmes are drawn up in consultation with the landowner and address long-term sustainability issues.

The Wairarapa section of the Wellington Regional Council (WRC) have completed the first stage of a regional monitoring programme to monitor extent of sustainable land use with respect to soil erosion on hill country. For WRC, the measure of sustainability is the match of land cover to land erosion potential. Four vegetation cover types were obtained from the LCDB (plantation forests, indigenous forest, scrub, and pasture). The spatial location of erosion-prone land was obtained from the NZLRI where erosion potential was rated as severe or even greater (covering the range of LUC units VIe4 to VIIe11). The first stage was reported in the 1998 Annual Environment Report. Staff used GIS (ArcView) to map vegetation cover and erosion-prone land (Dave Cameron pers. comm.).

The WRC are currently completing the second stage of their regional monitoring programme, where they determine the proportion of pasture land that has been successfully planted with poplars and willows (i.e., sustainable use for this grazing activity). However, some research remains to be undertaken to determine the success, in terms of sustainability, of soil conservation trees in such eroding hill country (Dave Cameron pers. comm.).

In the WRC Proposed Regional Soil Plan, the following environmental results are anticipated:

- the area of land where land use is compatible with LUC and land cover is increased;
- the area of highly erodible land converted to trees is increased; and
- the amount of retired highly eroded land is increased.

To undertake their regional monitoring programme on a regular basis, WRC will require the LCDB be updated frequently.

4.10 Marlborough District Council

Historically the MDC has not undertaken comprehensive land monitoring activities, apart from noting land-use changes (mainly the conversion from pasture to forestry), and its associated pest management strategies. However, the MDC intends to develop its land monitoring programme and associated activities.

In the Integrated Regional Management Plans for the Marlborough Sounds and the Wairau/Awatere catchments a significant hill country issue has been identified. This is erosion on hill slopes and the land use/land management activities that can predispose hill country to erosion and degradation. For soils and land use, the following indicators related to hill country

erosion are likely to be monitored to assess the suitability and effectiveness of the MDC Regional Policy Statement:

- the degree of adoption of land management practices that minimise soil erosion;
- incidents of soil erosion and/or degradation; and
- incidents of unauthorised vegetation clearance on non-arable land.

The MDC have a copy of the LCDB, which they partially funded to determine the spatial location and age class of the exotic forestry in the region. They also have a copy of the recently updated 2nd edition NZLRI (1:50 000) covering the inland Marlborough area and a 1:25 000 scale hard copy inventory covering the Sounds area. Staff see these databases as a useful basis for some better targeted, ongoing environmental monitoring of hill country erosion and land use issues in the future (Nicky Eade pers. comm.).

4.11 Tasman District Council

Tasman District Council=s (TDC=s) approach to SEM is to take issues identified in their Regional Policy Statement, and Regional and District Plan preparation processes, and identify monitoring needs related to the anticipated environmental results developed there (Roper-Lindsay and Fenemor 1995).

Most of the TDC region is hilly or mountainous, with over 60% in the national estate (conservation areas or national parks). The main objective in the TDC draft land stability SEM programme is to identify trends in soil movement, soil loss, and land instability on erodible land in Tasman District. The methods deemed appropriate for their monitoring of hill country erosion include:

- updating maps to show locations susceptible to erosion and deep-seated instability over each 5-year period; and
- map, photograph, and report on erodible areas after any major storm event ... or where soil movement has been reported; correlate extent of soil movement with local land use determined from field inspections, satellite and aerial photography.

Reporting would involve maps of areas of soil movement and soil loss, reports on storm-induced erosion events, and erosion trends and recommended actions TDC could take to address unacceptable trends. Databases needed to undertake such activities would be satellite imagery and land cover categorised on a GIS, and a land-stability layer on a GIS.

4.12 Canterbury Regional Council

The draft Soils and Land Use chapter of the Natural Resources Regional Plan (NRRP) has no specific policies on monitoring hill country erosion prepared at present. However, Canterbury Regional Council (CRC) staff have the following ideas on monitoring hill country erosion, which may be incorporated into the NRRP (Jeromy Cuff pers. comm.):

- Mapping land subject to mass movement and then monitoring land use on these areas. Land-use type will be used to determine the extent of sustainable land with reference to erosion on this land. This is part of ongoing work;

- Monitoring ground cover on hill and high country. Ground cover gives an indication of land at risk to surface erosion processes and is considered a key erosion indicator. Present methods used include stereo photograph, line transects, and classifying satellite imagery for ground cover. This is part of ongoing work;
- Monitoring type of land cover. This can be at various scales, from macro (using LCDB or other vegetation cover classifications (from aerial photographs and satellite imagery)) to micro (from close-up stereo photographs or on land condition monitoring ISPD sites (see Mulcock 1998)). The CRC intend to monitor soil quality at these ISPD sites as well. This is part of ongoing work;
- Monitoring vegetation vigour using indicators such as normalised difference vegetation indices or albedo measurements from remotely-sensed data; and
- Monitoring actual soil loss using the radioisotope ^{137}Cs. Staff at CRC have established some monitoring sites using this approach on arable land and have commissioned studies of historic erosion over the past 40 years in the Mackenzie Basin based on ^{137}Cs. The method could be extended to some hill country and high-country sites in the future.

The NZLRI has been used by CRC staff to provide maps showing areas of land subject to various types of erosion as a result of particular land-use activities. However, the NZLRI vegetation layer is out of date, and this information base is now of little use. The NZLRI is also being used as a basis for stratification of landscapes to design monitoring strategies.

The CRC is part of a consortium that commissioned a regional LCDB, and its delivery is imminent. It is hoped that this coverage would be repeated every 5 years, and that the LCDB (and its associated satellite imagery) will provide useful information on hill- and high-country erosion risk, particularly on vegetation vigour, vegetation type, and ground cover.

The CRC commissioned a new regional aerial photographic coverage 3 years ago, but the hill and high country has not yet been completed. These photographs (and those from previous photographic coverages) may be used to monitor changes in ground cover and erosion scars. Special-purpose in-house aerial photographs are also taken for this task using both natural colour and false colour infrared film.

A GIS is widely used in the CRC. Hill country erosion data, and other SEM data, are incorporated into the GIS. The position of monitoring sites is captured using a Trimble GeoExplorer and differentially rectified to provide better than $\lesssim$2 m positional accuracy.

4.13 West Coast Regional Council

The West Coast Regional Council (WCRC) does not view hill country erosion as a significant issue, as there are few pastoral hill country areas in the region under private ownership. Accordingly, in their proposed Regional Policy Statement environmental performance monitoring includes water quality, river cross-sections, and beach profiles, but not erosion on hill country. However, applying regional rules, principally those in the Soil Conservation and Erosion Control Plan, the WCRC may require management of the effects of activities by way of performance standards on resource consents.

4.14 Otago Regional Council

In the Otago Regional Council=s (ORC=s) Regional Policy Statement (ORC 1998) hill country erosion was not a key issue. However, the following adverse effects on ORC land resource are considered significant management issues of the region: the inappropriate removal of vegetation, and the burning of tussock grassland and post-burn management (where this can lead to a reduction in soil fertility and versatility).

Along with CRC, Landcare Research, and Rural Futures Trust, ORC have embarked on a Land Condition Monitoring programme for both developed and unimproved tussock grassland systems, which includes hill country (Mulcock 1998). This programme has been developed so that land managers can readily measure and monitor changes in land condition on their properties over time. In this programme, a condition assessment model, ISPD, is used. This model describes major vegetation changes that could occur in a particular area under different management practices and climatic conditions. This information is contained in an easy-to-use computer package, which enables individuals to interpret the results on monitoring by showing where a site fits along a gradient of vegetation change (from unmodified, through well-managed, to degraded).

4.15 Southland Regional Council

Hill country erosion is not a significant problem in Southland, as most of the soils are derived from stable indurated rocks that are typically stable and present few erosion problems. However, where Tertiary rocks are present, hill country erosion in more prevalent with localised landslides and slumps usually being associated with high intensity rainfall events (Gary Morgan pers. comm.).

Accordingly, the Southland Regional Council (SRC) does not have any monitoring programme operative for hill country erosion. The SRC does actively promote open-spaced and close-spaced tree planting to control mass movement, and such works are subsidised. These works are undertaken following erosion control farm plans. Aerial photography and the NZLRI are used in preparing these farm plans.

5. Databases, information sources and tools being used for environmental monitoring and reporting of hill country erosion

5.1 Land Cover Database

The LCDB (see Appendix I) has been used for environmental monitoring by EBOP, HBRC, and WRC as a basis of region-wide land cover information. However, supplementary information has needed to be added to the database to make it a useful vegetation database for monitoring purposes. Several agencies (ARC, EW, GDC, WRC, GDC, and MDC) have copies of the LCDB for either their whole region, or significant parts of their region. CRC is expecting a copy of the LCDB for their region very shortly.

5.2 New Zealand Land Resource Inventory

All regional councils and unitary authorities have a copy of the NZLRI (see Appendix II). All agencies with hill country erosion issues and a soil intactness indicator of environmental pressure have used the NZLRI as the key information source to determine land suitability.

5.3 Slope/topography

While TRC used a critical slope angle to help separate hill country NZLRI LUC units into physically sustainable land-use classes, specific land slope information (in the form of a DTM) has not been used by any agency as part of their monitoring system (general slope information is contained within the NZLRI).

5.4 Aerial photography

All agencies that have hill country erosion issues make use of aerial photographs. A number of these agencies (ARC, EW, TRC, MWRC, and CRC) are part of local consortiums to purchase region-wide photographic coverages. Aerial photographs could be used for mapping landslide incidence and location for farm plan work and to determine the state indicator for soil intactness, and mapping land use and vegetation cover, for either sampling sites or to improve the land cover information of the NZLRI and/or the LCDB.

5.5 Geographic Information Systems

Six agencies (EW, EBOP, TRC, HBRC, WRC, and CRC) either use or intend to use spatial information manipulation and management systems for their monitoring programmes in the short term. One has out-sourced their work to date. Such GIS systems are essential for the generation and analysis of region-wide databases such as the NZLRI, and the LCDB.

5.6 National Soils Database

Only ARC have considered using the NSD as an input to their monitoring efforts, but concluded that data from the NSD was unlikely to be a useful source of information.

5.7 AGRIBASE

The HBRC is the only agency using AGRIBASE, as part of its corporate property management database. The TRC has considered use of AGRIBASE, but have found it was too inaccurate and expensive.

Table 1. Summary of Regional Council and Unitary Authority Environmental Monitoring Activities (shaded rows indicate those agencies with recognised hill country erosion issues)

Council/Authority	Plan[1]	Monitoring Programme[2]	Farm Plans[3]	Indicators[4]	Performance[5]	Use of GIS[6]	Use of NZLRI	Use of LCDB	Use of AGRIBASE	Use of Aerial Photos
Northland	❄	✠	✠	✠	❄	✠	✠	✠	✠	❄
Auckland	❄	❄	(❄)	(❄)[P]	✠	✠	❄	(❄)	✠	❄
Env. Waikato	❄	❄	❄	❄[P,S,R]	❄	❄(M)	❄	❄	✠	❄
Env. Bay of Plenty	❄	❄	❄	❄[P,S,R]	❄	❄ (M,F)	❄	❄	✠	❄
Gisborne	❄	(❄)	✠	❄ [P]	(❄)	(❄) (F)	❄	✠	✠	❄
Taranaki	❄	❄	❄	❄ [P,R]	❄	❄(M)	❄	✠	✠	❄
Hawkes Bay	✠	❄	❄	❄ [P,R]	(❄)	❄ (M)	❄	❄	❄	❄
Manawatu-Wanganui	❄	❄	❄	❄ [P,S,R]	✠	✠	❄	✠	✠	❄
Wellington	❄	❄	❄	❄ [P,R]	❄	❄	❄	❄	✠	❄
Marlborough	❄	✠	✠	✠	✠	✠	❄	(❄)	✠	(❄)
Tasman	✠	❄	✠	✠	✠	✠	✠	✠	✠	❄
West Coast	✠	✠	✠	✠	✠	✠	✠	✠	✠	❄
Canterbury	❄	❄	❄	❄[P,R]	✠	❄	❄	✠	✠	❄
Otago	✠	(❄)	✠	✠	✠	✠	✠	✠	✠	✠
Southland	✠	✠	❄	✠	✠	✠	❄	✠	✠	❄

Where:

❄ indicates yes

(❄) indicates probably yes or pending

✠ indicates no

[1] Whether Regional (Land, Soil, ...) Plans are proposed or approved to include erosion in hill country

[2] Proposed or Approved Land Monitoring Programme

[3] Sustainable and/or Soil Conservation Farm Plans to improve sustainable land use in hill country

[4] Developed environmental indicators [where P=Pressure; S=State; R=Response]

[5] Developed environmental performance expectations

[6] Whether GIS is used for monitoring (M) and/or farm plan (F) work (either in-house or out sourced)

6. Summary of Regional Council and Unitary Authority Approaches

Nine of the 15 resource management agencies reviewed by Stephens *et al.* (1999) recognised hill country issues and of these nine, eight regarded hill country erosion as a major issue (Stephens *et al.* 1999). Of these agencies, seven have operational, or near-operational, environmental indicator programmes: EW, EBOP, GDC, TRC, HBRC, WRC, and MWRC. Table 1 summarises the information obtained from the 15 resource management agencies. From information obtained, the following results are drawn:

- Resource management agencies who have identified erosion on hill country as a key issue have considered the following factors in the decision-making process related to which environmental monitoring and reporting system they might use: cost, ownership and land tenure of the hill country, rating base, existing aerial photographic coverage/s, and proportion of region affected by hill country erosion;
- Nine of the 15 agencies propose to have a regional land/soil plan, which will include policies concerned with erosion in hill country;
- Seven agencies are proposing to have land monitoring programmes for erosion in hill country. Two agencies, TRC and MWRC, have approved land-monitoring programmes. One, TRC, reported its SEM activities in their 1996 State of Environment Report (TRC 1996). The Wairarapa branch of WRC reported SEM activities in their 1998 Annual Environment Report, whilst GDC reported on methods trialled for monitoring in their 1998 Environment Report;
- The environmental performance indicator most widely used by the resource management agencies is an erosion/environmental risk pressure indicator (determined by considering suitability of land cover/land use to land capability). Seven agencies have considered a response indicator (a change of land use from pasture to trees where erosion is an issue). Most agencies have considered using state indicators for hill country erosion. Only EW, EBOP, GDC, and MWRC have progressed to the point of establishing their state indicator(s). At EW, options for erosion state indicators for hill country include land condition and the extent and frequency of slipping. The following are favoured by EBOP as state indicators for erosion in hill country: soil loss changes, sediment transfer rates, loss of topsoil/depth of topsoil, riparian management regimes (especially adjacent to gullies, soil conservation plantings), and erosion recovery times. For MWRC and GDC, the state indicator is a measure of how much soil is on the hills, in terms of the percent of hillside in fresh and recent landside scars. Both MWRC and GDC would measure state for each of their monitoring sites, whereas EBOP would only measure state in representative catchments and specific sites; and
- Erosion control works are undertaken in hill country by all agencies. Most of this work is undertaken as part of farm/soil conservation plans, the remainder as localised and site-specific activities.

6.1 Common design elements

As mentioned in Stephens *et al.* (1999), most regional councils recognise the need to identify erosion risk areas within hill country, and most have prepared either formal or informal goals and anticipated environmental outcomes to reduce erosion in high- and moderate-erosion-risk hill country. An erosion-/environmental-risk pressure indicator for land is therefore the most likely indicator to be used by the resource management agencies in their SEM Programmes. Six agencies have also considered a response indicator, and only four regional councils were intending to use state indicators to measure changes in soil intactness.

The common design method for identifying areas of erosion risk is through some form of categorisation of land using the NZLRI, either to identify hill country simply (MWRC and GDC) or to subdivide hill country further into categories of risk (HBRC, EW, WRC, TRC, and EBOP). All resource management agencies have a copy of the NZLRI. All agencies that have hill country erosion issues and have a soil intactness indicator of environmental pressure have used the NZLRI as the key information source to determine land suitability. For environmental monitoring, HBRC and EBOP are further defining risk areas by intersecting hill country categories with regional land-cover databases.

Resource management agencies are considering land-use-change mapping either regionally (EW, EBOP, HBRC, and WRC) or by sampling within window areas (MWRC, TRC, and GDC). Land use/cover is usually derived from the LCDB in an improved form (Stephens *et al.* 1999) or from more detailed aerial photography. The improved LCDB has been used for environmental monitoring by EBOP, HBRC and WRC as a basis of region-wide land cover information. Several (ARC, EW, GDC, WRC, and MDC) have copies of the LCDB for either their whole region, or significant parts of it. A copy of the LCDB for the Canterbury Region is expected very shortly. All of these agencies propose to use the LCDB information as part of their hill country monitoring system. All agencies that have hill country erosion issues make use of aerial photographs. A number of these agencies (ARC, EW, TRC, MWRC, and CRC) are part of local consortiums to purchase region-wide photographic coverages. Aerial photographs would be used to map landslide-incidence and location for farm-plan work and to determine the state indicator for soil intactness, and to map land use and vegetation cover, for either sampling sites or to improve the land cover information of the NZLRI and/or the LCDB. The most common re-map period for detecting land use change is considered by local authority staff to be 5–10 years.

In terms of environmental monitoring, only TRC, WRC, EBOP, and HBRC use farm plans. Of these, TRC refers to a broader range of plans to reduce erosion risk in hill country, and uses the term "sustainable land management plans" (Stephens *et al.* 1999) to cover: farm plans, agro-forestry plans, conservation plans, and riparian management plans. Farm-based sustainable land management plans may therefore be a more appropriate term for plans used to mitigate erosion risk in hill country.

Specific slope/topographic information (in the form of a DTM) has not been used by any agency as part of their monitoring system (general slope information is contained within the NZLRI), although TRC did use a critical slope angle to help separate hill country NZLRI LUC

units into physically sustainable land-use classes.

Table 1 indicates that 6 of the 15 regional councils reviewed have in-house GIS while TRC has contracted outside agencies for GIS work. It is difficult to gauge how many councils may have access to GIS through external agencies, and would use other agencies to generate maps once their environmental monitoring programmes became operative. Six agencies (EW, EBOP, TRC, HBRC, GDC, WRC, and CRC) either use, or intend to use in the short term, spatial information manipulation and management systems for their monitoring programmes. Such GIS systems are essential for the generation and analysis of region-wide vegetation databases such as the NZLRI and the LCDB.

6.2 Collection of information

Most councils are considering two basic approaches to environmental monitoring of hill country, with both methods comparing land suitability to land type to determine soil intactness pressure. To undertake this, the NZLRI LUC classification provides the key source of land type information. In some cases these data have been supplemented by soil characteristic and hill slope erosion research and/or further interpretation. The two approaches differ in the way land use/cover information is acquired. One approach involves sampling, the other region-wide mapping.

Sampling approach. This approach is preferred by MWRC, GDC, and TRC to determine Afarm scale≅ detail. It involves selecting a number of monitoring sites and using aerial photography as the prime source of up-to-date land use/cover and bare ground information. In using this approach TRC ensured that the sample sites represented the range of land types in the hill country. They used a region-wide database depicting physically sustainable land uses for this purpose. The MWRC and GDC approach does not ensure that the monitoring sites represent the range of land types in the hill country.

Region-wide approach. This approach. which involves the use of region-wide land cover information, is preferred by EW, EBOP, HBRC, and WRC. Regional land cover information is being acquired from the LCDB, and aerial photography (and other data sources) are used in a supplementary role to ensure that the LCDB=s very general land cover classification is made more appropriate for environmental monitoring. The NZLRI is used to provide region-wide assessments of land types and erosion risk. The approach of EW will also involve the use of region-wide soil and climate data to characterise the hill country for accelerated erosion risk.

Although particular approaches are currently being used, many agencies consider that in the future they may well use a mix of approaches, to best suit their future needs and issues. For example, GDC will use both approaches once the NZLRI update is available (in mid-1999) in digital format. They intend to use the region-wide approach to provide a source of major land-use changes as other vegetation databases are updated.

6.3 Reporting

For comparable data to be collected and reported nationally, methods for monitoring hill country erosion need to be consistent within, and between, regions to allow aggregation up to the national level. There also needs to be consistency in defining hill country and categories of risk within hill country. The determining of land type areas of different risk and the collection of land cover data, either from the LCDB or aerial photographs, provide pressure indicators, while any change in land use in time on different areas of risk provides a response. A state or condition indicator would be an independent check on the effectiveness of the response, and on the relationship between pressure and response.

Only one council (TRC) appears to have reported on the state of environment of hill country erosion (TRC 1996), but WRC have reported (in 1998) on the first stage of their monitoring programme. At TRC, staff were able to identify areal extent and spatial location of physically sustainable land-use changes enabling them to determine whether land use was becoming more or less physically sustainable in the hill country. It is expected that EW, EBOP, HBRC, and WRC will be able to report in a similar manner, using regional database coverages, rather than collation of data from representative sample sites. Both MWRC and GDC will be able report statistics for a large number of sample sites in their region X on the basis of changes in erosion (extent of bare ground), vegetation (type, and condition) and hillslope-soil erosion-vegetation interactions X but may have difficulty collating data to represent hill country risk areas at the regional level.

The review by Stephens *et al.* (1999) indicates that while there is some variation between regional council approaches, there are also a number of commonalities. Most councils have, to varying degrees, defined risk areas and intend to carry out land-use change mapping. Most councils see the need to collate and report information at the regional level, using either a sampling or regional approach. Most councils are using the NZLRI, are presently using GIS for data analysis and manipulation, and intend to report on land use change over time either in window areas or at the regional level. The appropriate frequency for state of environment reporting in the hill country seems to be about every 5B10 years.

Stephens *et al.(*1999) identified the importance of developing environmental goals and, more specifically, anticipated environmental outcomes for SEM programmes in the hill country. This is an essential first step for most councils before developing their performance indicator programme, and allows indicators to be finalised to monitor achievement of goals and anticipated outcomes. It also provides some specific targets for the hill country. Six councils (NRC, EW, EBOP, TRC, HBRC, and WRC) have developed a set of environmental outcomes they anticipated from implementing sustainable land-use policies for their hill country. These outcomes are quite variable, for example:

Anticipated environmental outcomes for EW include:

- reduction of the areas affected by accelerated erosion; and
- reduced rates of accelerated infilling of estuaries, lakes, ... systems.

Outcomes for EBOP could include (though methods to determine these have not been established):

- soil loss changes;
- sediment transfer rates;
- loss of topsoil/depth of topsoil; and
- riparian management regimes (especially adjacent to gullies).

Anticipated environmental results from the notified TRC Regional Soil Plan, which only relate to erosion-prone hill country, include:

- an increase (from 74% to 79%) in the total area of privately owned land in the hill country that is being sustainably managed;
- an increase of 50% in the area covered by production forestry and soil conservation plantings on LUC Classes VI and VII land in the hill country;
- no net loss in the area of indigenous vegetation on LUC Class VI and VII land in the hill country in private ownership; and
- an increase in the area addressed by the Sustainable Land Management programme with the aim of (a) 50% of that part of the hill country, that is in private ownership, being included in the programme, and (b) 70% of properties in the programme having implemented the farm plan(s) in whole or in part.

To contribute to national reporting, each regional council and unitary authority will need to define within its SEM programme indicators that can be aggregated up for national reporting and regionally specific indicators that are not intended for aggregation. Many SEM programmes will probably include regionally specific indicators. Three councils only, EW, EBOP, and HBRC, (Stephens *et al.* 1999) identified a clear need to link their environmental monitoring efforts in hill country to other regional council monitoring programmes, so that links are established between erosion and off-site impacts (sediment supply, water quality, and impact on riparian vegetation). Other SEM programmes will link external environmental monitoring initiatives (e.g., community, sector-based, iwi) to those developed by the regional council for local, regional, and national reporting.

7. Proposed Methods to Report on Hill Country Erosion

This section proposes methods to report on hill country erosion so that national SEM reports can be produced. In preparing a method that regional councils and unitary authorities could employ, we have considered what is currently being used (or proposed to be used), the common elements of these approaches, and the requirements for aggregation of regional reports to a national report. This requirement to aggregate regional data includes: a nationally consistent framework, development of nationally consistent regional databases, and anticipated environmental results. The methods proposed in this report are similar to those to which most local authorities are already committed, and many local authorities have been assembling the necessary databases to underpin these for some time.

7.1 Environmental goals

The New Zealand Government=s Environment 2010 (E2010) goal (MfE 1995, 1997, 1998a) for land is: Ais the maintenance and enhancement of the quality, productivity and life supporting capacity of soils and soil ecosystems≅. E2010 goals are consistent with the RMA 1991 and local authority goals, as local authorities were involved with the development of E2010, and key aspects of the RMA were considered. As erosion is a major issue for hill country ecosystems, this goal essentially amounts to Aretaining hill country soils≅.

Inappropriate land use and inadequate soil conservation management often leads to soil loss from accelerated erosion. A strategy for retaining hill country soils should therefore have a key goal, namely, A To have appropriate land use (i.e., have established tree cover[2] (forestry, scrub, indigenous forest, and/or soil conservation plantings)) on most of the erosion-prone[3] hill country≅.

For indicators to measure environmental performance there is a need to measure them (the indicators) in relation to the key environmental goal for erodible hill country. Accordingly, the environmental outcomes anticipated by resource management agencies are derived from implementing hill country objectives. Policies should reflect the environmental goal above. The time frame for achieving these results needs to be determined by each regional council and unitary authority depending on their resources and community support. These agencies would also need to determine what Amost≅ meant in per cent terms (e.g., 80%, 90%, 95%, ...) based on what is achievable within a specified time frame.

[2]Where tree cover (including scrub) has reached 6-8 years of age. At this age their root systems are developed well enough to give slopes protection against landslides caused during rainstorms (Marden and Rowan 1993, Bergin *et al.* 1995). Tree cover at this age is discernable using satellite data types (SPOT XS, and Landsat TM) to map vegetation cover.

[3]Where erosion types include mass movement erosion (landslip, slump, earthflow and debris avalanche) and gully erosion.

Erosion-prone hill country is defined as all NZLRI LUC Class VIe , VIIe, and VIIIe land with slope angles greater than 15 degrees, below an altitude of ~1000 metres a.s.l.

7.2 Environmental performance indicators for hill country erosion

The following proposed indicators for the hill country soil ecosystem have been developed to check the progress towards attainment of the environmental performance goal. Pressure and response environmental performance indicators will be needed to check the progress of the goal and the overall effectiveness (i.e., using an independent state indicator) of the environmental strategy in retaining soil in the hill country. The following three indicators (summarised in Table 2) are proposed for national monitoring of erosion-prone hill country:

- area of erosion-prone hill country without established tree cover (existing Stage 1 X pressure);
- soil depth change for erosion-prone hill country (proposed Stage 2 X state); and
- change in area without established tree cover on erosion-prone hill country (existing Stage 1 X response (and pressure)).

A state (or condition) indicator should be used independently to check the effectiveness of the strategy and the relationship between pressure and response. It should also measure the actual soil loss/soil gain within error limits. We would expect all resource management agencies to map, record, and report on the pressure and response indicators. However, our proposed state indicator should be part of a national monitoring programme, which would include a suitable number of national benchmark sites.

Table 2: Proposed pressure, state, and response indicators for erosion-prone hill country

Environmental Performance Indicators for Erosion-Prone Hill Country		
Pressure	**State**	**Response**
Area of erosion-prone hill country without established tree cover	Soil depth change (used to check whether response is effective, and determining actual soil loss or gain)	Change in area of erosion-prone hill country without established tree cover
To check progress of environmental goal	Provide trends	To check progress of environmental goal

7.3 Implementation of the Proposed Method

Step 1

Produce a spatial database of all erosion-prone hill country in region of interest using the

NZLRI and determine the spatial location and areal extent at a scale of 1:50 000. (Erosion-prone hill country is defined as all LUC Class VIe , VIIe, and VIIIe land slope angles above 15 degrees, below an altitude of ~1000 metres a.s.l.) Maps could be printed at a scale of 1:250 000. Such a database should cover all hill country regardless of land tenure. However, we expect that local authorities would generally only monitor those hill country areas in private ownership (for example, excluding non-rateable areas such as permanent Forest Estates, National Parks, and Forest Parks). Erosion-prone hill country can be consistently defined nationally using the NZLRI North Island correlation of regional LUC units (Page 1985).

Step 2

From the LCDB or similar vegetation spatial database (at a scale of 1:50 000), produce a national database of established pasture, exotic forest, indigenous forest, scrub, and soil conservation plantings for all erosion-prone hill country. Calculate the area of erosion-prone hill country without established tree cover at a scale of 1:50 000. This is the **pressure indicator**. It should be calculated about every 5 years (it is probably too costly to be calculated more often, and it would not provide enough feedback to policy if carried out less often) to obtain change in environmental pressure. The change in the area (after ~ 5 years) of established tree cover will give the **response indicator**.

In many instances established soil conservation plantings will not be detectable using satellite imagery, the prime source of information to generate the 1:50 000 scale vegetation databases. Accordingly, information of the spatial locality and areal extent of these established plantings will need to be sourced by other means, in particular from aerial photographs.

All vegetation information needs to be standardised across all resource management agencies.

The regional databases produced from steps 1 and 2 will have direct application to national SEM programmes for hill country erosion, and could provide underpinning information for other national environmental issues, such as soil health, biodiversity, and ecological integrity.

7.4 Anticipated environmental outcome

The proposed anticipated environmental outcome for use by all resource management agencies is: Aan increase in the total area of privately owned erosion-prone hill country in a sustainable form of land use≅. This result can be determined by utilising regional databases in steps 1B 2.

8. A Stage 2 State Indicator for Hill Country Erosion

8.1 A state indicator

A state indicator is needed to:

- validate the pressure/state model;
- check the effectiveness of the response; and
- provide information on trends and cumulative effects.

A state indicator for erosion-prone hill country needs to:

- be measurable and repeatable;
- be statistically robust, with known error limits to determine trends;
- use a regional approach, because of spatial variability of erosion-producing rainstorms;
- show cumulative effects either positive or negative (showing soil regeneration as well as soil erosion/soil loss); and
- be affordable.

The state indicator should tell us something about the net soil resource, in erosion-prone hill country, over time. Is the net soil resource changing? In what direction? Is the soil being maintained, enhanced, or lost? Are sustainable land management policies for the hill country effective?

As a result of examination of the above criteria, we have refined the Stage 1 indicator Apercent change in area of slip at selected sites≅ (MfE 1998a), and propose a new Stage 2 indicator Asoil depth change≅ to replace Apercent change in area of soil slip...≅. Soil depth change would allow a more regionally consistent statistical approach (i.e., with error limits) to be adopted when checking the response, and the pressure/response relationship, for erosion-prone hill country. Soil depth change is also an effective surrogate for indicating soil erosion from slipping. Although soil slip is a dominant erosion process in hill country, it is very dependent on the timing of erosion-producing high-intensity rainstorms in any part of the region. Following intense rainstorms, landform-related soil recovery rates and the temporal nature of slipping may obscure soil loss trends. Also Asoil depth change≅ would represent a greater range of hill country erosion processes. Other hill country erosion processes that cause soil loss include mass movement (slump, earthflow and debris avalanche), gully, and tunnel gully erosion.

An effective state indicator in the hill country needs to measure soil loss from all forms of erosion and also indicate soil recovery and addition. We believe that Asoil depth change≅ will provide a more complete understanding on how the total soil resource in hill country is changing through time. Such an indicator (or any state indicator for that matter) is somewhat problematic for earthflow erosion. In earthflows the soil can remain relatively intact, even though the erosion can be active. Our proposed state indicator is considered appropriate only if the measurements are taken from valley floor to the top of hillsides, and traversing earthflow

movements. This proposed Stage 2 state indicator will be used to calibrate or check independently the pressure/state/response model.

8.2 Proposed method for measuring the state indicator

A proposed method for measuring the state indicator in the hill country is given. It is considered that the proposed Stage 2 indicator Asoil depth change≅ be part of a framework of national benchmark sites, and be measured as part of a nation-wide monitoring effort.

The sampling method for determining soil depth change still needs to be trialled and the most acceptable statistical approach established. The pressure-state-response model where this indicator would be required is shown in Table 2. In terms of providing information which can be used to validate the pressure-state-response model, independently check the effectiveness of attaining strategic goals, and provide actual data on soil loss or soil gain, it is recommended that the sampling areas should be located across all erosion-prone hill country. Measurement of average soil depth could use the following, or a combination of the following, sampling approaches:

- a regular grid network across erosion-prone hill country;
- cluster sampling in defined areas (e.g., along eco-gradients, or erosion risk categories); or
- either one, or a combination of, the above two statistical approaches within representative basins under specific land uses.

It is proposed that the first approach from the above list be trialled for use in erosion-prone hill country. It is proposed that a cluster sampling on a regular grid be adopted. Within each resource management agency region, at least 40 clusters or sample points should be used for each hill country category. Each cluster would be independent of land cover or land use. At each of the 40 clusters, a transect from valley bottom to ridge top should be drawn to sample across landform types. Each transect should comprise at least 10 points. The grid reference of the ends of each transect would be established. At each sample point a corrosion-resistant plate would be permanently inserted into the soil, and the distance from this plate to the soil surface measured. Repeated measurements at these sample points would provide soil depth changes.

In areas with no soil, the value recorded at sample points would be zero. In areas with soil accumulation or regeneration, recorded depth values would indicate some addition since the last measurement. Soil depths should be measured once at each transect every 5 years. These measurements would pick up any variable soil loss pattern in the intervening 5-year period (e.g., from storm events) from the hill country erosion processes.

The regular grid network needs enough sample points to measure changes in soil depth to give an $s_m = s / \sqrt{n}$ acceptable margin of error of less than ✂ 5% so that long-term trends can be detected early. The following statistical equation shows that the larger the number of clusters (n), the smaller the standard error of the mean (s_m), where s is the standard deviation of the transect depths (i.e., one value for each transect).

The above equation shows that the proposed method needs to maximise the number of

clusters while reducing the time for recording soil depth in the field to remain cost-effective. Clusters should therefore be positioned in areas accessible for fieldwork.

This state indicator we have proposed is the only way we know of being able to actually measure the quantity of soil resource in erosion-prone hill country. However, the cost of establishing and then re-measuring every five years soil depth changes for a national set of benchmark sites may not be affordable. Because of this we believe it prudent to trial this approach, while at the same time trialling and evaluating other methods for establishing the most appropriate surrogate of measuring soil depth. Such surrogates could include: percent of erosion-prone hill slopes devoid of vegetation or the accumulated proportion of hillsides that have eroded.

9. National Monitoring

The following three environmental performance indicators for national monitoring of erosion-prone hill country erosion are proposed. Two of the indicators already exist as Stage 1 indicators (MfE 1998a) and one is new X as proposed in this report. The proposed indicators are:

- area of erosion-prone hill country without established tree cover (existing Stage 1 X pressure);
- soil depth change for erosion-prone hill country (proposed Stage 2 X state); and
- change in area without established tree cover on erosion-prone hill country (existing Stage 1 X response (and pressure)).

All three indicators can be aggregated up to the national level but rely on regionally consistent databases. The pressure and response indicators (areal measures) can be added to provide regional and national totals of erosion-prone hill country. The state indicator can be used to calculate the change in soil depth in New Zealand erosion-prone hill country. Soil depth accuracies need to be within a 5% margin of error, to enable trends to be accurately shown at both the regional and national level. The average soil depth change can be calculated for national reporting using the following equation:

$$x_m = \sum_{i=1}^{n} x_i A_i \,/\, \sum_{i=1}^{n} A_i$$

where x_m is the national average change in soil depth, x_i is the average soil depth change of the ith region, A_i is the area of erosion-prone hill country in the ith region, and n is the number of regions.

A likely result of preparing a national State of the Environment Report in 2005, using the method proposed here, is given in Appendix IV.

10. Recommendations

The following recommendations are given:

- the proposed pressure and response environmental performance indicators for erosion-prone hill country (namely area, and change in area, with established tree cover) be adopted for national state of environment reporting;

- the method of measuring change in soil depth for erosion-prone hill country (state indicator) be trialled and evaluated before any national application. Further, this indicator should be compared with other potential state indicators (although they would not be measuring the soil resource, rather using surrogates);

- to enable national state of environment reporting, it is desirable that the environmental outcome (an increase in the total area of privately owned erosion-prone hill country in a sustainable form of land use) be agreed for regional and national levels of reporting; and

- that MfE ensures that a nationally consistent vegetation-cover database is maintained and updated every 5-10 years so that regional councils and unitary authorities can undertake environmental monitoring programmes using agreed methods.

We note that the method proposed in this report could be used to link erosion-prone hill country state of environment monitoring and reporting programmes to other related programmes, such as:

- linking on-site and off-site effects of erosion (e.g., water quality indicators such as sediment yield could be related to land type and changes in land use/vegetation cover); and
- using land type and land-use/vegetation-cover information to underpin biodiversity characterisation.

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APPENDIX I

The Land Cover Database

The Land Cover Database (LCDB) is a database containing land cover (vegetation) information initiated in 1996 by the Ministry of Forestry (MOF) (now MAF) to update information of New Zealand=s forest cover. Initial funding for this project came from MOF and MfE (Green Package Greenhouse Gases). The LCDB mapping has been undertaken on a regional basis, and MOF have secured funding from a number of interested local authorities to ensure that the mapping has been undertaken. Seventy five percent (75%) of New Zealand has been covered by this mapping at the time of preparing this report (see Fig. 1). The current LCDB vectors are public domain.

SPOT 20 m ground resolution multispectral satellite data has been the prime source of up-to-date information used to create the 1:50 000 database. Most of the mapping has been undertaken by TerraLink. The LCDB land cover classification includes: urban, quarries/dumps, urban open space, primarily pasture, primarily horticulture, plantation forest, shelter belts, tussock grassland, indigenous forest, shrubland, bare ground, inland wetlands, coastal wetland, and coastal sand. This classification (especially in the non-forested areas) has not been adhered to for all mapping completed to date.

It is expected that the remainder of New Zealand will be covered by the LCDB by late 1999, and that the regional data sets will be merged to create a database for each of the main islands. The future of the LCDB is uncertain. The real benefits from such a database will accrue when the second and subsequent national coverages are created and made available for widespread use. It is expected that coverages would be created about every five years. Although MAF is still very interested in subsequent national coverages of the LCDB, it does consider itself as having the future key co-ordinating role for the database (Steve Thompson pers. comm.).

Both HBRC and ARC have found that the land cover classification needs improvement for environmental performance monitoring of the land. For terrestrial biodiversity monitoring the native and non-native LCDB land cover information would provide a coarse-scale measure of biodiversity state and pressure. It has been suggested that further subdivision of existing land cover classes should be considered (MfE 1998b).

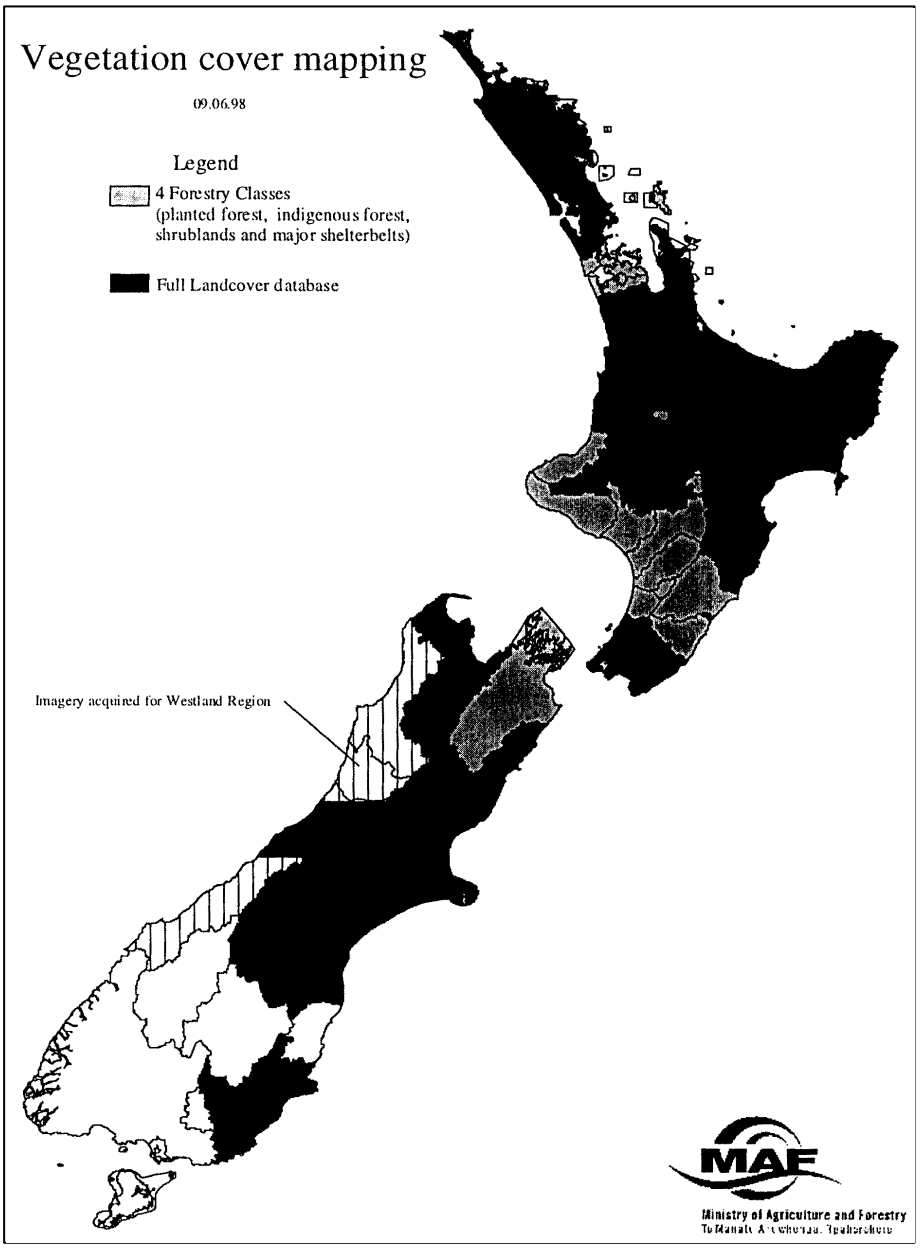

Figure 1. Extent of LCDB vegetation cover mapping

APPENDIX II

The New Zealand Land Resource Inventory (from Stephens *et al.* 1997)

The New Zealand Land Resource Inventory (NZLRI) is a nationally significant database of physical land resource information. While originally published in the form of printed maps, the data is now primarily managed in a GIS. Landcare Research is the custodian of the NZLRI, which covers New Zealand in 12 regions. Each region has a separate LUC classification. The 1st edition NZLRI was mapped at a scale of 1:63 360. Second edition, 1:50 000 scale NZLRI mapping has been completed for Northland, Wellington, part of Marlborough, part of Waikato, and the Gisborne East Coast region.

The NZLRI comprises two sets of information: an inventory of five physical factors, and a LUC assessment. The NZLRI contains mapped areas (or polygons) called >inventory map units=. The five physical factors (rock, soil, slope, erosion, and vegetative cover) are used to define each multifactor inventory map unit. The inventory (of five physical factors) records land attributes that are important for sustainable-land-use planning. The inventory is established by reference to pre-existing information, field verification, and aerial photograph interpretation. There are approximately 100 000 inventory map units delineated in the NZLRI.

Each inventory map unit also has a LUC assessment, established on the basis of the five physical factors, climate, and the effects of past land use. Assessments appear in a three-part hierarchy. Each level increases in detail, from LUC class, to LUC subclass, and finally to LUC unit.

The LUC class is the broadest category of the LUC classification system. It expresses the **total degree of limitation** to sustainable use. Eight LUC classes are used in New Zealand, class I representing negligible and class VIII extreme limitation.

The LUC subclass is the second category and expresses the **major kind of limitation**. The NZLRI uses four ALUC subclass≅ limitations: erosion (e), wetness (w), soil (s), and climate (c). The ALUC subclass≅ comprises the LUC class and subclass limitation, and is expressed, for example, as VIe.

The LUC unit is the most detailed category. Each LUC unit is defined by its assemblage of physical attributes: rock, soil, landform, slope, erosion, and climate (although other factors such as vegetative cover, land use, and productivity indices are also taken into account). A LUC unit groups together inventory map units that respond similarly to the same management; which are adapted to the same kinds of crops, pasture or forest species; which have about the same potential yield; and that require the same soil conservation and other land management measures. There are over 700 different LUC units in the NZLRI. Each unit is indicated by an Arabic number which follows the subclass limitation symbol (for example, VIe1). Each of the 12 NZLRI regions has a unique set of LUC units. Units from the 1st edition mapping of the

North Island have been correlated. In this correlation, LUC units which are essentially the same, but belong to different regions, are grouped together to help users working across regional boundaries.

The key to the NZLRI=s usefulness is that it is a spatial database covering the whole of New Zealand . The NZLRI can be used for primary or secondary interpretations of data. Primary interpretations seek information on one, or a combination of, existing factor(s) recorded in the NZLRI. Users making primary interpretations need only understand the principles of the mapping and LUC classification system, limitations of scale, and the significance of the time of data collection for the changeable factors such as vegetation cover and erosion. If these requirements are not recognised, the use of the NZLRI database can be inappropriate.

Secondary interpretations are those where the NZLRI intersects with other databases or where new knowledge is added from other sources to establish useful new interpretations. Although the primary uses of the NZLRI database are limited by the factors recorded, the secondary uses appear boundless.

The NZLRI programme for the 1st edition mapping was completed between 1973 and 1979. Second-edition mapping has been undertaken episodically since that time. Information such as rock, soil, slope, and characteristic erosion associations have not changed significantly and have therefore not become outdated. However, erosion type and extent as well as vegetation cover are regarded as temporal and can change, and here the NZLRI does become out of date.

In terms of sustainable land-use monitoring, the date of vegetation-cover information in the NZLRI is vital. It is important to have up-to-date vegetation-cover information which indicates land changes and from which land use can be inferred. Cost-effective methods of updating the NZLRI vegetation factor using satellite data have been developed. Similar mapping techniques are being employed to map the Land Cover Database (LCDB). However, the vegetation classes mapped for the LCDB are less specific compared with the NZLRI vegetation cover classification.

The NZLRI is applicable to national environmental monitoring by being able to:

- contribute to the classification of land type;
- extrapolate soil properties from the NSD to GIS-produced maps of soil type and specific soil characteristics;
- help develop a rating for all land types that indicates their propensity to erode;
- provide a consistent LUC assessment for all land types; and
- show past vegetation types.

APPENDIX III

Contacts in the Regional Councils and Unitary Authorities

Council	Contact	Phone	E-mail	Address
Northland RC	Tony Phipps	09 438-4639	**Error! Bookmark not defined.**	P Bag 9021, Whangarei
Auckland RC	Tony Thompson	09 379-4420	Tthompson@ arc.govt.nz	P Bag 92012, Auckland
Environment Waikato	Tony Fenton	07 856-7184	Tony.Fenton @wairc.govt.nz	PO Box 4010, Hamilton East
Environment Bay of Plenty	Wayne Smith	07 307-2545	wayne @boprc.govt.nz	PO Box 364, Whakatane
Gisborne DC	Peter Fantham Trevor Freeman	06 867-2049	**Error! Bookmark not defined.**	PO Box 747, Gisborne
Taranaki RC	Bill Bayfield Chris Spurdle	06 765-7127	Bill.Bayfield@ trc.govt.nz	P Bag 713, Stratford
Hawkes Bay RC	Garth Eyles	06 844-2495	**Error! Bookmark not defined.**	P Bag 6006, Napier
Manawatu-Wanganui RC	Malcolm Todd	06 357-9009	Malcolm.Todd@ mwrc.govt.nz	P Bag 11025, Palmerston North
Wellington RC	Dave Cameron	06 378-2484	Dave.Cameron@ wrc.govt.nz	PO Box 41, Masterton
Marlborough DC	Nicky Eade	03 578-5249	nea@ marlborough.govt.nz	PO Box 443, Blenheim
Tasman DC	Andrew Fenemor	03 544-8176	**Error! Bookmark not defined.**	P Bag 4, Richmond
Canterbury RC	Jeromy Cuff	03 688-9069	**Error! Bookmark not defined.**	PO Box 550, Timaru
West Coast RC	Henk Stengs	03 768-0466	**Error! Bookmark not defined.**	PO Box 66, Greymouth
Otago RC	Ian Brown	03 474-0827	Ian.Brown@ orc.govt.nz	PO Box 1954, Dunedin
Southland RC	Gary Morgan	03 215-6197	Gary.Morgan@ SRC.govt.nz	P Bag 90116, Invercargill

APPENDIX IV

From a National State of Environment Report, c. 2005

This map shows where environmental pressure on New Zealand=s erosion-prone hill country have been reduced since 1999. Environmental pressure has been reduced where established tree cover has increased in area by 10%. The localities where this increase in area has occurred are shown by shading in the map. These data have been aggregated from councils Astate of environment≅ monitoring reports and databases. From the national benchmark monitoring sites (not shown on the map), it has also been determined, for a similar time period, there is a 0≪5 mm change in the national average change in soil depth for erosion-prone hill country. (A subset of these sites is also being used for related national environmental performance monitoring, including measures of soil health, soil carbon and soil biodiversity.)