

**BEFORE THE HEARINGS PANEL**

**IN THE MATTER** of hearings on  
submissions concerning  
the Proposed One Plan  
notified by the  
Manawatu-Wanganui  
Regional Council

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**SECTION 42A REPORT OF DR GRANT BRODIE DOUGLAS  
ON BEHALF OF HORIZONS REGIONAL COUNCIL**

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## 1. INTRODUCTION

### **My qualifications/experience**

1. My full name is Grant Brodie Douglas. I have a Doctor of Philosophy degree (PhD) in Plant Science from Massey University, Palmerston North, New Zealand. I hold a Bachelor of Agricultural Science Honours Degree from Massey University, and a Master of Agricultural Science Honours Degree (Plant Science) from Massey University.
2. I have worked as a Research Scientist, Plant Materials Centre, Water and Soil Division, Ministry of Works and Development, Palmerston North (1982-1988); Research Scientist, DSIR Grasslands, Palmerston North (1988-1992); Research Scientist, AgResearch, Palmerston North (1992-present). The predominant responsibility of the positions was selection and management of vegetation for multiple purposes, but particularly soil conservation / revegetation in hill country.
3. My current position is Senior Scientist in AgResearch in the Climate, Land and Environment Group based at the Grasslands campus, Palmerston North. Research focuses on the ways to mitigate erosion and maintain soil intactness in hill country, and the effects of establishing and managing vegetation for multiple purposes in these landscapes.
4. During the last few years, I led the production of a scoping report on revising and updating the second edition of the Land Use Capability Survey handbook, and managed the two-year project to produce the third edition handbook, released in March 2009. I was involved in seven Land Use Capability Awareness workshops around New Zealand in March/April 2009, presenting on applications of the Land Use Capability (LUC) classification. These workshops aimed to raise the profile of LUC to the wider agribusiness community.
5. I have read the Environment Court's practice note, Expert Witnesses – Code of Conduct, and agree to comply with it.

### **My role in the Proposed One Plan**

6. I have not had direct involvement in the development of the Proposed One Plan. I understand that production of the third edition of the Land Use Capability Survey Handbook has been an important component in Horizons' Sustainable Land Use Initiative (SLUI).

## Scope of evidence

7. This report is to inform the Hearing Panel of the following:
  - a. An overview of the LUC classification and the underlying principles;
  - b. Examples of where LUC is being used;
  - c. Recent projects in relation to LUC.
  
8. My evidence is restricted to that based on knowledge and experience gained from involvement in a scoping report to appraise the value of producing a third edition of the Land Use Capability Survey Handbook (and elements required), and participating in and leading the project to produce the third edition handbook. I have not been involved in Land Resource Inventory (LRI) surveys or conducting a subsequent assessment of Land Use Capability, at any scale, eg. farm, district.

### **SUMMARY**

- i. The capability of land in New Zealand for long-term, sustained production is assessed using the Land Use Capability (LUC) classification, which considers the land's physical limitations.
- ii. The LUC classification has been used in New Zealand since the 1950s at scales ranging from farm to national.
- iii. The third edition of the Land Use Capability Survey Handbook was released early in 2009 in response to demand from Regional Councils. The handbook will be an important reference for ongoing sustainable land management.

### **RECOMMENDATION**

I recommend that the Land Use Capability classification be recognised by the Hearing Panel as a robust, standardised, scientifically-based classification that can be used at any scale.

## 2. EXECUTIVE SUMMARY OF EVIDENCE

9. Land Use Capability (LUC) is one of many ways of assessing and classifying land. 'Capability' in this context refers to land's suitability for one or more productive uses, after considering its physical limitations. The LUC classification is defined as a systematic arrangement of different types of land according to those attributes that determine its capacity for long-term sustained production. The classification has been used in New Zealand since the 1950s at scales ranging from farm, through regional to national. Interest in using the classification at the farm scale has increased recently.

10. The LUC classification comprises three key stages: 1) preparation of a Land Resource Inventory (LRI) comprising at least five physical factors; 2) using this as a basis for assessing Land Use Capability for one or more productive uses long-term; and 3) interpretation of the information.
11. The LUC classification comprises three hierarchical levels – LUC class, LUC subclass, and LUC unit. The highest level, LUC class (eight classes), indicates the land's general capability for sustained production. LUC subclass (four options) refers to the main physical limitation or hazard to sustained productive use. An LUC unit groups areas of land that require similar management and conservation treatment, and which are suitable for the same kind of crops, pasture or forestry species.
12. Recent/current examples of the use of Land Use Capability are:
  - a. Integral part of preparing Whole Farm Plans in Horizons' Sustainable Land Use Initiative (SLUI);
  - b. Identifying the worst eroding land in the Gisborne District Council area as part of the East Coast Forestry Project; and
  - c. A component in the most advanced level of Meat & Wool New Zealand's Land and Environmental Plan Tool Kit.
13. Recent projects involving Land Use Capability and Horizons are:
  - a. A scoping report on updating the Land Use Capability Survey Handbook (1971-74);
  - b. Production of the third edition of the Land Use Capability Survey Handbook (2009);
  - c. Single classification of all LUC units within Horizons' Region;
  - d. Use of the pasture productivity indices in the extended legends associated with the LUC worksheets used as a basis for defining the soil's natural capital and for calculating the N loss limit.

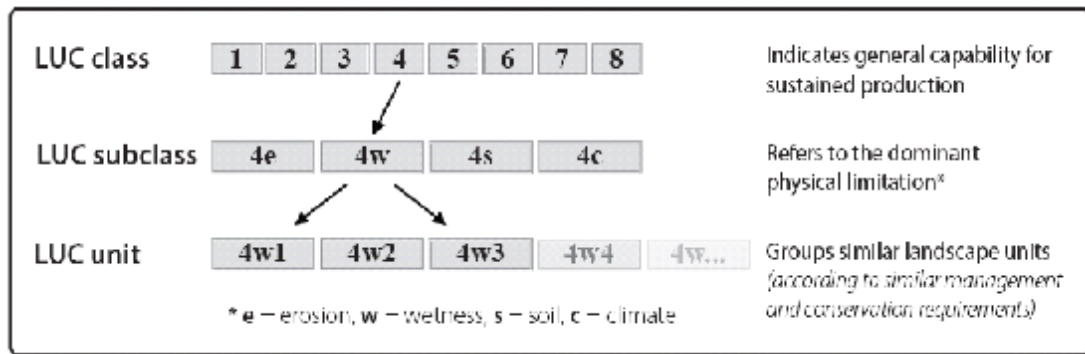
### **3. EVIDENCE**

#### **What is the Land Use Capability and what are the underlying principles?**

14. The capability of land in New Zealand refers to its suitability for one or more productive uses after considering its physical limitations, and it has been assessed since the 1950s using a Land Use Capability (LUC) classification. The LUC classification is defined as a systematic arrangement of different types of land according to those attributes that determine its capacity for long-term sustained production (SCRCC, 1971; NWASCO, 1979; Lynn *et al.*, 2009), and it is the basis for land evaluation and planning by Regional

Councils throughout New Zealand. The classification is transparent, robust, applicable nationally, and based on good science. It has been used to help achieve sustainable land development and management at scales ranging from farm, through regional, to national.

15. The LUC and associated multifactor mapping system is an adaptation of the United States Department of Agriculture system of LUC mapping and defined LUC classes, described in a handbook published in 1961. From 1970 to the early 1980s, the entire rural landscape of New Zealand was classified at a scale of 1:63,360 (1 inch to 1 mile), which was later converted to 1:50,000 on the New Zealand Map Grid. This near-national coverage (Stewart Island excluded) comprised independent classifications for 10 regions of the North Island, one first edition South Island-wide classification, and a second edition Marlborough regional classification. Second edition coverages were compiled at 1:50,000 and are at considerably more detail. The LUC classification system used in New Zealand is unique.
16. The LUC classification system has three key stages: 1) A physical resource inventory of five factors considered critical for long-term land use and management is prepared. These are rock type, soil type, slope, erosion type and severity, and vegetation cover. Climate and the effects of previous land use are also identified (Lynn *et al.*, 2009). 2) The resource inventory is used as a basis for assessing LUC for one or more productive uses long-term, using an eight class system (Lynn *et al.*, 2009). 3) The assessment is used for interpretation such as for determining land use options. A programme of recommended works to address soil and water issues and efficiency of resource use is an inherent component.
17. The LUC classification comprises three hierarchical levels – LUC class, LUC subclass, and LUC unit – which collectively describe the land's overall capability for use. It notes the main physical limitation or hazard to sustained productive use, and groups areas of land that require similar management and conservation treatment, and which are suitable for the same kind of crops, pasture or forestry species. The relationship between the three components is shown in Figure 1 (Lynn *et al.*, 2009).



**Figure 1.** Components of the Land Use Capability Classification (Lynn et al., 2009)

18. The LUC class is the broadest grouping in the classification and indicates general capability for sustained production, after considering the land’s physical limitations and versatility of use. There are eight classes (Figure 2; Lynn *et al.*, 2009), with LUC Class 1 being the most versatile multiple-use land with negligible physical limitations to arable use. LUC Class number increases with increasing limitations to use, and decreasing versatility of use. LUC Classes 1-4 are suitable for multiple uses whereas LUC Classes 5-7 are suitable for pastoralism or forestry. Class 8 is unsuitable for sustainable productive use, and is referred to as conservation land, retirement land or protection land.

LUC Class	Arable cropping suitability†	Pastoral grazing suitability	Production forestry suitability	General suitability
	1	High	High	High
2	↓ Low	↓ ↓ Low	↓ ↓ Low	
3				
4				
5	Unsuitable			Low
6				
7				
8		Unsuitable	Unsuitable	Conservation land

**Figure 2.** Increasing limitations to use and decreasing versatility of use from LUC Class 1 to LUC Class 8 (Lynn *et al.*, 2009)

19. The LUC subclass identifies the dominant physical limitation or hazard to sustained productive use (Lynn *et al.*, 2009). Four limitations are recognised:

‘e’ erodibility – where susceptibility to erosion is the dominant limitation.

‘w’ wetness – where a high water table, slow internal drainage, and/or flooding constitutes the dominant limitation.

‘s’ soil – where the dominant limitation is within the rooting zone. This can be due to shallow soil profiles, subsurface pans, stoniness, rock outcrops, low soil water holding capacity, low fertility (where this is difficult to correct), salinity, or toxicity.

‘c’ climate – where the climate is the dominant limitation. This can be summer drought, excessive rainfall, unseasonal or frequent frost and/or snow, and exposure to strong winds or salt spray.

Only the dominant limitation is recorded for each map unit. The four limitations are applicable to each of the eight LUC classes, except for erodibility (‘e’), which is excluded from LUC Class 1.

20. The LUC Unit is the most detailed level of the LUC classification. Each LUC unit comprises land which is essentially homogeneous with respect to management requirements, kind and intensity of conservation treatment, and suitability for the same type of crops, pasture or forestry species with similar potential yields. The level of detail specified for an LUC unit depends on the scale of mapping and the objectives of the survey. Each LUC unit is described in an ‘extended legend’ associated with the worksheets for the relevant survey area. It includes information on the inventory factors, climate, strengths and limitations, land use, soil conservation and water management measures, and suitability for productive uses. Productivity indices for pastoral use (based on stock-carrying capacity) and forestry (site index for *Pinus radiata*) are included.

#### **Where is land use capability also being used?**

21. LUC classification is an integral part of current activities and initiatives in New Zealand, and four examples are presented, involving application at different scales.



## **Horizons Regional Council's Sustainable Land Use Initiative (SLUI)**

22. Horizons is the lead agency for SLUI, which is a regional initiative born out of the February 2004 storm event. SLUI aims to reduce the Region's reliance on government relief/recovery assistance in the future, protect hill country and lowland communities and assets from future storm events and the ongoing impacts of the 2004 storm event, and protect the soil asset upon which our rural economy is based (Douglas *et al.*, 2008).
23. Two significant components of SLUI are an update of land resource information and development and delivery of Whole Farm Plans (WFPs). The development of individual WFPs, incorporating physical, farm management and business plans to achieve environmental and economic sustainable land use, is a key mechanism for delivering future-proofing assistance to the Region's landowners. The target is 100 plans per year with the majority of plans on the most 'at risk' landscapes to erosion. Key elements of each WFP, conducted at the farm scale, are a Land Resource Inventory (LRI), a subsequent assessment of LUC, and a recommended works plan to address the soil and water issues on the farm (Lynn *et al.*, 2009).

### **Soil conservation plans**

24. Soil Conservation Plans are prepared by a number of Regional Councils, including Taranaki, Hawke's Bay, Bay of Plenty, Horizons, and Greater Wellington Regional Councils. They comprise a works programme to address the soil (and water) issues on individual farms over a specified timeframe, eg. 5-10 years (Manderson *et al.*, 2007; Douglas *et al.*, 2008). LUC (physical inventory and classification) is an integral part of Soil Conservation Plans and the basis upon which recommendations are made.

### **East coast forestry project**

25. This project was established in 1992 to address the severe and widespread erosion in Gisborne District. It aims to achieve sustainable management of 60,000 ha of severely eroded land in the area by 2020 (Lynn *et al.*, 2009). LUC is being used to identify the worst eroding land that requires land use change or special management to minimise erosion, and for assisting with allocation of grant monies. Land targeted for treatment is defined to include selected LUC units within regional LUC 8e and the worst of 7e. These units have been combined into a land grouping named Overlay 3A, which is used to identify the location of target land on individual farms and to assist with assessing landowner eligibility for grant assistance. An example of Overlay 3A land on farmland is

shown in Figure 3, represented by polygons with red perimeters. The importance of the East Coast Forestry Project and its objectives was strengthened when tree planting of Overlay 3A erosion-prone land became a component of Gisborne District Council's District Plan. Hence, there is now a legal requirement for land owners/managers to establish and maintain effective vegetation cover (trees or shrubs) on Overlay 3A land on their farms.



**Figure 3.** Overlay 3A land (red polygons) on selected farmland in Gisborne District Council's administrative area (Lynn *et al.*, 2009)

### Meat & Wool New Zealand's Land & Environmental Plan Tool kit (M&WNZ LEP Tool Kit)

26. The M&WNZ LEP Tool Kit provides a methodology for assessing a farm's land and environmental issues, and deciding how those issues will be managed. A documented record is produced. The Tool Kit was developed for the meat and wool sector and it is voluntary for New Zealand sheep and beef farmers. It comprises three levels:
- Level 1: Introductory, basic farm mapping and risk assessment, 'do it yourself';
  - Level 2: More detailed assessment across a wider range of issues; and
  - Level 3: Advanced level, comprehensive farm plan with specialist professional input required.

27. A Level 1 LEP is deemed sufficient for many New Zealand sheep and beef farmers at this stage (M&WNZ, *pers. comm.*, March 2009). Level 3 documentation includes a description of the principles of LRI, an overview of the components of the LUC classification, and the types of information available in extended legends. A slide showing one relevant page was included in a presentation (approved by M&WNZ) that I made to attendees at seven LUC awareness workshops around New Zealand in March and April 2009 (Figure 4).
28. The M&WNZ LEP Tool kit is being show-cased at M&WNZ monitor farms at 28 locations around New Zealand, eg. at Elmore Station in Gisborne District (Conservation Quorum, 2008).

### **Recent projects in relation to Land Use Capability**

29. Horizons has facilitated three projects recently that involve the use of the LUC classification. There may be other projects involving the classification, but I am not aware of them. The three projects have arisen through the establishment of Horizons' Sustainable Land Use Initiative (SLUI) following the February 2004 storm event and the recognised need to address long-term sustainable management of the Region's landscapes. Funding from the Foundation for Research, Science and Technology's Envirolink programme has enabled the projects to be conducted. An outline of the projects follows.

Example LAND USE CAPABILITY map and EXTENDED LEGEND

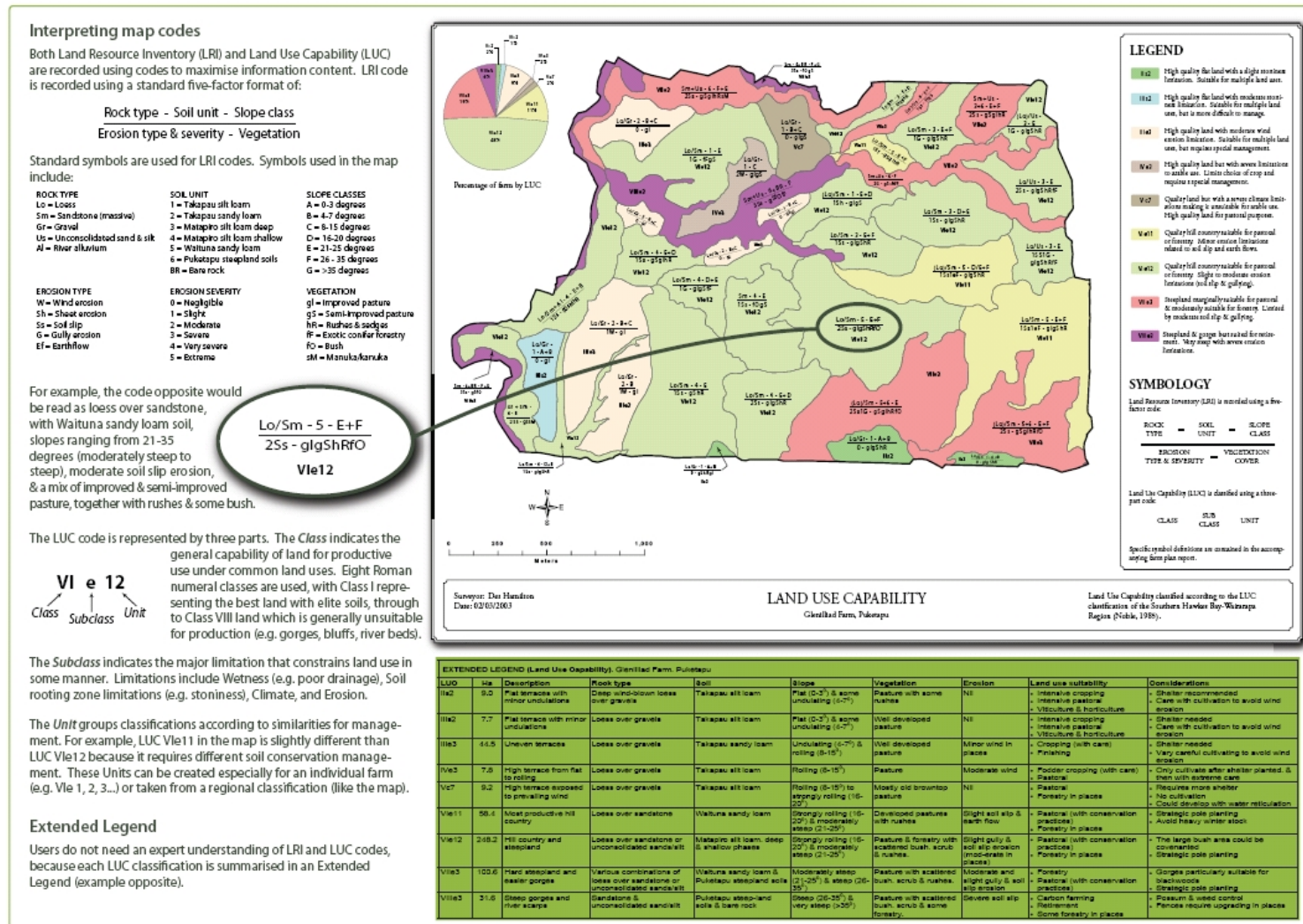


Figure 4. Page from M&WNZ's Level 3 LEP Tool Kit, outlining principles of Land Resource Inventory (LRI) and Land Use Capability (LUC) classification.

## **Updating the Land Use Capability Handbook – a scoping report**

30. Horizons regards the availability of a modern Land Use Capability (LUC) handbook as an important tool to assist with achieving the objectives of its Sustainable Land Use Initiative (SLUI). In 2006, it requested AgResearch (lead agency), Landcare Research and HortResearch, through an Envirolink Medium Advice Grant (Application No. HZLC08), to prepare a scoping report to: 1) identify gaps in current versus recommended sustainable land use in Horizons' Region; 2) identify any changes required in the LUC classification, based on recent scientific advances and other knowledge and experience; 3) survey opinions from Horizons and neighbouring Regional Councils on desired components of a new LUC handbook; and 4) recommend an appropriate work programme (Douglas *et al.*, 2006).
  
31. Interviews were conducted in March-May 2006 with lower North Island land managers from Horizons, Hawke's Bay and Greater Wellington Regional Councils, and with consultants from LandVision Ltd. Key recommendations were that: 1) a bound, hardcopy LUC handbook be produced; 2) hill country classes V to VIII be redefined and areas of classes, subclasses and units be revised nationally at 1: 50,000 scale; 3) classes and subclasses be standardised nationally and LUC units standardised separately within the North and South Islands; and 4) include in the handbook details of the new definitions and relevant summary data, new photographs, new examples of applications of appropriate management for LUC units, and sections on such issues as stock-carrying capacity and tree site indices (Douglas *et al.*, 2006). A realistic timeframe for an implementation project was likely 18-24 months.

## **Land Use Capability Survey Handbook third edition**

32. Following the scoping report (Douglas *et al.*, 2006), Horizons was a joint champion with Hawke's Bay Regional Council in securing an Envirolink Tools project (Contract No. AGRX0604 for \$360,000 incl. GST) to produce an updated third edition of the Land Use Capability Survey Handbook. Key justifications were: 1) renewed interest in LUC as a management tool, particularly at the farm scale (eg. SLUI focus); 2) the methodology, assessment criteria, definitions and descriptions of the LUC system were difficult to source; and 3) the second edition of the Land Use Capability Survey Handbook printed in 1971 (reprinted 1974) was out of print, out of date, and the text was more than 38 years old. A science team comprising AgResearch (lead agency), Landcare Research and GNS Science was responsible for producing the handbook and worked closely with Horizons and other Regional Councils. In-kind contributions from Regional Councils

were estimated at more than \$190,000. The project commenced in March 2007 and ended in March 2009. The five-member steering group for the project included Grant Cooper, Land Manager, Horizons Regional Council. Horizons were involved throughout the project, including attendance at three project workshops at different stages and reviewing draft sections.

33. Objectives for the third edition of the Land Use Capability Survey Handbook were to: 1) produce a handbook of LUC classifications and standards, that are applicable nationally, for on-farm, catchment and regional planning purposes; 2) provide a step-by-step procedural manual for conducting LUC surveys; 3) include knowledge from science and applied management over the last 30-plus years; and 4) provide standards for the next decade and beyond.
34. The handbook revision gave the opportunity to: 1) provide objective definitions and LUC standards for all LUC assessment; 2) improve LUC class and subclass definitions; 3) provide guidelines for assessing erosion severity; and 4) add new underpinning scientific information and links to key databases. The third edition of the handbook provides a basis for ensuring accuracy and repeatability of application reinforces that the LUC classification is an objective assessment based on good science, and describes a classification process that is transparent, robust, and able to be defended. A significant contribution is combining inventory and LUC assessment criteria, definitions and descriptions into one publication.
35. Significant changes in the third edition of the Land Use Capability Survey Handbook compared with the second edition include: 1) strengthened and more objective definitions of LUC classes and subclasses; 2) redefined LUC Class 5 land so that it now includes 'e' subclass to accommodate land with a slight erosion limitation under permanent vegetation; 3) greater detail on erosion types and criteria to quantify erosion severity; 4) detailed descriptions of inventory factors and reference to source documents; 5) sections on survey guidelines for farm surveys and extensive LRI/LUC surveys; and 6) discussion of scale and its implications for interpretation. I can comment on each of these changes, but lack detailed knowledge.
36. Less significant changes in the third edition compared with the second edition include: 1) modernised terminologies and metrics; 2) change in LUC class numbering from Roman to Arabic; 3) land use types fully defined for all classes; 4) new examples of applications at farm, catchment and regional scale; 4) update and comprehensive Glossary of Terms, Reference List, Further Reading, and web links; 5) modern colour photographs of LUC

classes and subclasses; 6) examples of correlating LUC units within Regional Council boundaries; and 6) no recommended standard colours for LUC classes.

37. In early 2009, Horizons was responsible for securing an Envirolink Medium Advice Grant (Project 667-HZLC65) to assist with the printing of 750 copies of the third edition of the Land Use Capability Survey Handbook. The handbook is in A5 format, comprises 163 pages, is spiral bound, and has waterproof covers and water- and tear-resistant pages. The handbook has been endorsed by the New Zealand Association of Resource Management (NZARM) and the New Zealand Society of Soil Science, and both organisations contributed towards printing.

### **LUC correlation project for Horizons' Region**

38. Within Horizons' Region there are significant parts of three regional LUC classifications (Taranaki-Manawatu, southern Hawke's Bay-Wairarapa, and Wellington), and fragments of three other regional classifications (Waikato, Bay of Plenty–Volcanic Plateau, and northern Hawke's Bay). This overlap hinders a consistent Region-wide approach. In late 2008, Horizons, through an Envirolink Medium Advice Grant (Project 617–HZLC63), contracted Landcare Research and GNS Science to conduct a LUC correlation of all existing New Zealand Land Resource Inventory LUC units within the Region and produce a single classification of Horizons' LUC units. The work was conducted from October to December 2008 and the single classification produced comprised approximately 282 LUC units (Harmsworth and Page, 2009). Further information on this project is available from Dr Jon Roygard, Horizons Regional Council.

### **Implications of Land Use Capability Survey Handbook third edition for Horizons' Region**

39. Land Use Capability classification is a method regularly used by Horizons. Ability to use the system is considered a valuable prerequisite for Environmental Management Officers (Soils), especially as it relates to the effective delivery of the Sustainable Land Use Initiative (SLUI), and the provision of defensible and sound advice to landholders regarding soil conservation, land capability and sustainable land use. Less well known is the use of LUC in policy support and development, be it for Region-wide assessment of environmental risk, prioritised targeting of Horizons' resources for greatest effect, or as the fundamental basis of new policy instruments. Examples include Erosion Management Areas (EMA), N-loss limit derived from catchment LUC, and LUC used as

a basis of Whole Farm Plans and FARMS (Farmer Applied Resource Management Strategy) (see evidence by Dr Andrew Manderson).

40. The third edition handbook has both operational and technical implications. Operationally, it represents both a training and reference resource, a function previously inadequately filled by the out-dated and difficult to source second edition handbook (published 1971, reprinted 1974).
  - a. The new handbook is a training resource for trainees and staff employed by Horizons, especially for those working in the area of land management.
  - b. With Horizons' increasing use of the LUC system, it is expected more untrained staff will encounter or make use of LUC. In this case, the handbook represents a technical reference that is important for policy makers, planners, communications staff, and GIS technicians who need to understand the lineage and limitations of the LUC data and information before they make use of them. The handbook has been written and designed in a way that makes it readable by experts and non-experts alike.
  - c. The handbook is also a technical reference for agricultural service providers who supply information and advice to the farming community. Likewise, farmers themselves may use it to learn more about LUC in response to recent Horizons' policy initiatives (particularly SLUI and FARMS).
  - d. The handbook provides improved standards (Clauses 26 and 27), thereby ensuring more effective, fair and consistent use of the system throughout the Region.
  
41. Technically, two points are noteworthy.
  - a. Centre pivot irrigation is now explicitly recognised as a permanent form of irrigation, thereby allowing LUC surveyors to classify land with centre pivot irrigation as having higher capability. Within FARMS, eligible land (eg. some sand country) will therefore have more permissive N-loss limits.
  - b. LUC Class 5 land can now be classified with an erodibility limitation. This was not permitted previously, which resulted in the LUC Class 5 classification being under-utilised (ie. only 0.2 % of Horizons' Region is currently classified as LUC Class 5). In practice, surveyors were forced to designate either LUC Class 4e or Class 6e on a technicality. Being able to classify 5e land will allow the LUC system to be applied more fairly and correctly across the Region. It will also permit the improved calculation of FARMS N-loss limits, especially when large areas of marginal land are implicated (see evidence by Dr Andrew Manderson regarding recalculation of N-caps for the hill country farm).



#### 4. REFERENCES

- Conservation Quorum 2009. Land and environmental plans. *Conservation Quorum* 51:1-4.
- Douglas, G.; Dymond, J.; McIvor, I. 2008. Monitoring and reporting of whole farm plans as a tool for affecting land use change. Project funded by Envirolink Medium Advice Grant. 40 p.
- Douglas, G. Harmsworth, G, McIvor, I. 2006. Updating the Land Use Capability Handbook – a scoping report. Prepared for Horizons Regional Council. Envirolink Project, 25p.
- Harmsworth, G.; Page, M. 2009. Correlation of Land Use Capability (LUC) Units into a Single LUC Classification for the Horizons Regional Council Area. Landcare Research Contract Report: LC0809/082. Report prepared for Horizons Regional Council. February 2009. 83p.
- Lynn, I.H.; Manderson, A.K.; Page, M.J.; Harmsworth, G.R.; Eyles G.O.; Douglas, G.B.; Mackay, A.D.; Newsome, P.J.F. 2009. Land Use Capability Survey Handbook – a New Zealand handbook for the classification of land 3rd ed. Hamilton, AgResearch; Lincoln, Landcare Research; Lower Hutt, GNS Science. 163p.
- Manderson, A.K.; Mackay, A.D.; Palmer, A.P. 2007. Environmental whole farm management plans: Their character, diversity, and use as agri-environmental indicators in New Zealand. *Journal of Environmental Management* 82: 319-331.
- National Water and Soil Conservation Organisation (NWASCO) 1979. Our Land Resources. Wellington, National Water and Soil Conservation Organisation. 79p.
- Soil Conservation and Rivers Control Council (SCRCC) 1971. Land Use Capability Survey Handbook 2<sup>nd</sup> edition. Water and Soil Division, Ministry of Works, Wellington.

Dr Grant Douglas

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