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 ALEC DONALD MACKAY ON BEHALF OF HORIZONS REGIONAL COUNCIL

1. INTRODUCTION

My qualifications/experience

1. My full name is Alec Donald Mackay. I have a Doctor of Philosophy (PhD) degree in Soil Science from Massey University, Palmerston North, New Zealand. I also hold a Bachelor of Agricultural Science Honours Degree from Massey University.

2. I have worked as a Post-Doctoral Scientist in the Agronomy Department of Purdue University, Indiana, US (1982-84); Research Scientist, DSIR Grasslands, Palmerston North (1985-90); Research Scientist/Officer-in-charge, DSIR Ballantrae Hill Country Research Station (1990-92); Research Scientist/Officer in Charge, AgResearch Ballantrae Hill Country Research Station (1992-95); and Research Scientist and Programme Leader, AgResearch Grasslands (1996-2007).3. My current position is as a Principal Scientist and Programme Leader in the Climate, Land and Environmental Group of AgResearch, based on the Grasslands campus in Palmerston North. The current focus of my research is on exploring the relationship between farm production and the environment, with a particular focus on the impacts of land use on those soil properties (eg. physical integrity of organic matter content) and processes that regulate the soil's supporting, provisioning and regulating services. Developing approaches for valuing the soil's natural capital and ecosystem services is a new science domain. Research also extends to land management, including active involvement in the Sustainable Land Use Initiative (SLUI) with Horizons Regional Council; an approach to resource management based on development of natural capital; whole farm planning (ie. Meat & Wool New Zealand's Land and Environment Plan (LEP) Tool Kit; and environmental planning and reporting through Project Green (www.projectgreen.co.nz), which aims to develop a minimum, voluntary New Zealand standard for sustainable production for sheep, beef cattle, deer and goat supply. I was a principal in the development of the SUBS (Soils Underpinning Business Success) education package, which was developed to assist land managers gain a few simple, easily learned skills for describing and mapping their own soils.

3. Since 2004 I have been a member of the Sustainable Land Use Research Initiative (SLURI), a cross-organisational group that aims to provide scientific information on soils and land use.

4. I am a Fellow of the New Zealand Society of Soil Science and the Immediate Past President. I have published more than 80 research publications, more than 140

conference papers and more than 30 significant client reports, and over the last 15 years I have been involved in supervision of 18 post-graduate students.

5. I have provided expertise to Horizons since its establishment, through being heavily involved in the development of the Sustainable Land Use Initiative (SLUI) and more recently through assisting in developing the Farmer-Applied Resource Management Strategy (FARMs) for nutrient management. I have also been retained by Horizons on an ongoing basis to continue the development (eg. on-farm monitoring programme) and evolution (eg. refinements to the Whole Farm Plan template) for use in SLUI and FARMs.

6. 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

7. I have provided expertise to Horizons in the development of the Sustainable Land Use Initiative (SLUI) since its conception in September 2004 and in the development of the water quality component of the Proposed One Plan.

Scope of evidence

8. My evidence focuses on nutrient allocation regimes and is in three parts:
    i. The case for using an approach based on natural capital for a nutrient allocation regime.
    ii. The science behind the natural capital approach.
    iii. Refinements to the natural capital approach.

11. The evidence draws heavily on two reports prepared by the Sustainable Land Use Research Initiative (SLURI) cross-organisational team for Horizons:
    i. Farm Strategies for Contaminant Management (Clothier *et al*., 2007). This report covers an investigation of the sources of diffuse Nitrogen (N) and Phosphorus (P) losses from the dominant land uses contributing to N and P loadings in Horizons' Water Management Zones (WMZs). The report established what the target best management practices (BMPs) are for sheep and beef, and dairying to ensure that water quality in Horizons' WMZs move towards their quality criteria. It examined a number of options: grandparenting (ie. the capping of farm N leaching losses at levels based on emissions from current land use or the average of

emissions from land use in previous years), limiting intensive land uses, allocation of an N-loss limit per hectare, and allocation of an N-loss limit based on the soil's natural capital) for defining an N leaching loss limit that could underpin a nutrient allocation regime; and

ii. Implementation of FARM strategies for Contaminant Management. Further questions (Mackay *et al*., 2008). This report includes an analysis of the impact that information used at differing levels (ie. Class, Subclass and Unit) in the extended legends of the Land Use Capability (LUC) worksheets has on the calculation of the N leaching loss limits and the N loading in the river. It also examines mitigation options available for reducing N leaching losses beyond the root zone change within each LUC class, and investigates the N leaching loss limits required to achieve the water quality standard in the Upper Manawatu and Mangatainoka Rivers as detailed in the Proposed One Plan, Schedule D, Table D.17. It also reports on the appropriateness of a single table for N leaching loss limits for all catchments.

2. EXECUTIVE SUMMARY OF EVIDENCE

The Case For Using An Approach Based On Natural Capital For A Nutrient Allocation Regime

12. The allocation of an N-loss limit based on the soil's natural capital was identified as the option that best met the dual requirements for continued economic growth and ongoing flexibility in land use in Horizons' Region, while meeting water quality targets. This approach was subsequently adopted and formed the basis for the N-loss limit contained in Rule 13-1 in the Proposed One Plan (POP). The natural capital based approach recognises that land is a finite resource and that land-based industries are the basis of our economic wellbeing. The approach captures all the land within a Water Management Zone (WMZ) that contributes to the water quality outcome. It is portable beyond the target catchments, providing land owners with timely messages on resource management.

The dual requirements for continued economic growth and ongoing flexibility in land use in the Region while meeting water quality targets.

13. There is a finite area of land available for primary production locally, regionally and globally. Highly productive soils require centuries to develop under natural conditions and in New Zealand such highly productive soils are limited to 1.28 million hectares or 5% of total area. There are significant future opportunities for continued growth in the

Region's land-based sectors and these benefits would flow on to the wider New Zealand economy, through increased exports. An integral and underlying part of any policy initiative to protect water must be retaining the ability for future economic growth and flexible land use options. For example, a policy that placed a moratorium on the expansion of intensive farming practices and a limit on N leaching losses from less intensive farming systems in the Upper Manawatu catchment would limit the potential expansion of irrigated sheep and beef farming, dairying, cropping, horticulture, and commercial vegetable growing in the catchment. By limiting land use options for individual producers, such a policy would raise issues of equity, in addition to restricting industry growth strategies, and rural and regional development. The likely effects of taking this approach can be calculated in the following example, using dairying as an example of an intensive farming system: by utilising the same mix of Land Use Capability (LUC) classes currently used by the existing dairy industry in the Upper Manawatu catchment, the area under dairying could be increased from 20,000 ha to more than 40,000 ha. Assuming an average stocking rate of 2.5 cows per ha, with each cow producing 340 kg of milk solids per year and a payout of $5 per ha, the additional 24,800 ha under dairying would inject an additional $105 million into the regional economy.

14. Increased production (eg. milk solids and stock live weight per hectare) and efficiency gains (eg. cows or stock units per labour unit and lambs per ewe) have been the basis for the ongoing success, profitability and competitiveness of the pastoral industry in New Zealand over the last 50 years. Increased farm size has been the other key strategy that has enabled producers to remain profitable. These strategies are not likely to change in the foreseeable future, thus forcing producers to continue to search for additional efficiency gains. This will result in them having to continue pushing their businesses beyond current production levels and beyond the inherent carrying capacity of their land holdings, through additional inputs such as N fertiliser, irrigation and supplementary bought-in feed.

15. Retention of growth and land use options is therefore critical to the future viability of the Region's land-based industries. At the same time, the "do nothing" option with regards to N leaching losses will further accelerate the current trends in increasing N leaching from farms and the resulting decline in water quality in the already affected Water Management Zones. More catchments will be put at risk. The objective of improving water quality therefore cannot be achieved unless N leaching losses are addressed.

What options are available for addressing N leaching losses to water bodies?

16. Potential options for addressing N leaching losses to water bodies were evaluated against the criteria used to assess the natural capital based approach. These included: placing limits on intensive land use, benchmarking, nutrient use efficiency, input-based controls, best management practices, grandparenting (ie. the capping of farm N leaching losses at levels based on emissions from current land use or the average of emissions from land use in previous years) and N allocation based on land area. The following discussion is limited to options for addressing N losses and does not address P losses. The need for specific targets for N and not for P can be explained by comparing the chemistry and behaviour of the two nutrients in soil.

17. **Placing limits on the N leaching losses from existing intensive land uses only:** This offers an option for preventing further decline in water quality, providing -there is no further expansion of intensive land uses or increases in N losses from the less intensive land uses in the catchment. It rewards those landowners with the largest N leaching losses and protects the capital investments contributing to those N leaching losses, if used as the basis for the allocation of the N loss limit. It puts at risk the capital investments of landowners not currently generating significant N losses, but with the opportunity to do so. This approach would also disadvantage landowners who had been actively conserving N.

18. In addition to a moratorium on any further expansion of intensive land uses and any increase in N losses from less intensive land uses, both of which would have to be monitored, a strategy would have to be developed for reducing N leaching losses from farms within the priority catchments, where N loadings in the water body are above the standard. The approach is linked to current land use and, as a consequence, may not necessarily encourage the best use of the land resources in the catchment for the required water quality outcomes. It has the potential to seriously reduce future land development and land use change.

19. **Benchmarking each sector**: This approach would enable landowners and the land-based industries to identify their individual and collective contributions to the current N loading and to monitor changes over time. This would provide an early indicator of future environmental impacts and could be used to quantify the impact of current environmental best practices on N loadings, while making available information that might be required to meet any market requirements related to nutrient management. The concept of benchmarking the ‘typical’ or ‘average’ farm within a sector and then

working towards a planned reduction of N leaching losses brings with it challenges. To be effective, benchmarking will require the establishment of an N loss allocation for each sector in each catchment and a mechanism for changing that allocation when land use changes. The approach is linked to current land use and, as a consequence, may not necessarily encourage the best use of the land resources in the catchment for the required water quality outcomes. It has the potential to seriously reduce future land development and land use change.

20. Operationalizing the **Nutrient use efficiency** approach would require each producer in a catchment to have a "target or limit". This brings with it a significant number of challenges, including establishing the initial N allocation for each sector and then to each landowner in that sector; and in reallocating and recalculating N use efficiencies to accommodate land use change between existing and new land uses within the catchment.

21. **Input-based controls:** Many inputs could be controlled to limit the risk of N leaching losses to the environment. While these are relatively easy to describe and quantify, there are a number of major technical difficulties when assessing effectiveness. Chief among these is predicting effectiveness from farm to farm, and verification of the level of implementation of any input controls.

22. **Best practices nutrient management**: Along with nutrient budgeting and planning, mitigation technologies, industry initiatives (eg. Clean Streams Accord) and Environmental Management Systems (EMS), best practices nutrient management has the potential to reduce losses of sediment, P, and faecal material and with the inclusion of specific targets, N from intensive agriculture. Many of these practices are listed in the FARM strategy.

23. **Grandparenting:** The capping of farm N leaching losses at levels based on emissions from current land use or the average of emissions from land use in previous years (eg. the last 3-5 years) would immediately stop any further increase in N leaching and any further decline in water quality, assuming no lag. Existing landowners would be limited to their historic N leaching losses, enabling them to continue their existing land uses without requiring additional N rights. On that basis there would be no upfront costs and, as far as practicable, the viability of existing land uses would not be significantly compromised. However, using N leaching losses calculated as part of the grandparenting process as the basis for the subsequent allocations has significant disadvantages. It recognises landowners with the largest N leaching losses and protects the capital investments contributing to those losses, while putting at risk the capital

investments of landowners not currently generating significant N losses, but with the opportunity to so. This approach would also disadvantage landowners who had been actively conserving N, for example by using Best Management Practices (BMPs).

24. The major weaknesses with grandparenting as an approach if it becomes the basis for the subsequent allocation of the N loss limit, is it does not consider the future and locks in current land use. It fails to recognise that land is a finite resource and fails to assess land use options in the catchment against the desired water quality outcomes. It also puts the future viability of all farms at risk, by failing to allow growth options and flexibility in land use.

25. **N allocation based on land area:** The average N leaching loss permissible for each of the 129,638 hectares in the Upper Manawatu Water Management Zone in the Proposed One Plan in Year 1, would be 13.2 kgN/ha below the root zone. If all the land resources in the catchment were the same (ie. they had the same natural capital and were providing the same ecosystems services to the community), all land owners would receive the same N-limit allocation per hectare. This would be a very simple, effective and equitable approach for all landowners in the catchment. It would negate the need to develop policy for each land use and would address the major challenge identified with all the other approaches, ie. setting the initial N-limit allocation.

26. However, the flat N-limit allocation approach has a major disadvantage because it fails to recognise differences between land types. Landscapes in the Upper Manawatu catchment range from flat to rolling to steep and by treating all land the same, the flat N allocation approach fails to recognise these differences. Within landscapes (ie. flat, rolling hills) the characteristics of the soils vary greatly in their inherent productive capacity and versatility. They represent a large component of the natural capital on which New Zealand's economy and environment depends. Contrary to popular belief, the area of versatile and elite soils represents less than 5% of New Zealand's soils while more than 65% of the country's soils have at least one physical limitation to productivity under pastoral uses. Common features of many soils derived from alluvium, loess, volcanic materials, coastal sands or in eroding hill and steep lands are their young age, weakly developed soil structure, poor drainage, limited water-holding capacity and limited nutrient/pollutant absorption capacity. This would suggest that treating all land the same would fail to recognise that some soils are capable of producing more, and hence are of greater value to the economy, than others which are less productive and more fragile.

27. The market recognises differences in the inherent natural capital of a soil, with land containing the more versatile and elite soils commanding higher prices. Land values are a product of current economic conditions, product prices, and the potential for future production gains, which are the sum of the soils' natural capital (eg. texture, organic matter content, soil depth, etc) and added capital (eg. technologies that address N and P deficiencies, low pH and toxicities through to technologies such as drainage, irrigation and flood control schemes to assist in water regulation, and infrastructure, including buildings, tracks and fences).

28. In addition to differences in productive capacity, soils vary in their ability to absorb nutrients, pesticides and wastes. Soils form the critical link between the atmosphere, a land use and water quality by regulating the time span between rain falling on the land and reaching streams, rivers and aquifers. Not only does the soil store and transmit enormous quantities of water, but it also acts as a renovator and sink for pollutants. High nutrient absorption capacity and pollutant assimilation are related to the Cation Exchange Capacity (CEC) and organic matter content of a soil (SOM), both of which increase the soil's capacity to absorb and assimilate chemical and organic inputs. Soils with high natural capital have high absorption capacity and primary production potential, and minimal adverse environmental impacts. Soils with lower natural capital, such as shallow and stony or sandy soils, have limited ability to store nutrients and water. Shallow or sandy soils require more frequent irrigation and additional nutrients for crop production to compensate for losses and inefficiencies. On these soils, there are greater risks that soluble nutrients and pesticides will pass beyond the reach of plant roots and adversely affect water quality.

29. Rather than assuming all land in a catchment is the same, an alternative approach is to recognise differences between soils and allocate the N-limit based on the soils' natural capital.

3. THE SCIENCE BEHIND THE NATURAL CAPITAL APPROACH

30. This is a new approach for which direct methods for calculating a soil's natural capital are still in development. Dominati *et al*. (2009) proposed a draft framework for classifying and measuring soil natural capital and ecosystem services, based on current understanding of soil forming processes, soil taxonomy and classification, soil processes, and the links between climate and land use.

31. In the absence of a method for calculating a soil's natural capital, a proxy that serves as a useful alternative is the ability of the soil to sustain a legume-based pasture that fixes

N biologically under optimum management and before the introduction of additional technologies. A legume-based pasture is a self-regulating biological system with an upper limit on the amount of N that can be fixed, retained, cycled, and made available for plant growth. The legume pasture dry matter base provides one indicator of the underlying productive capacity of the soil, taking into account the influence of new plant germplasm and the use of phosphorus, sulphur and potassium fertilisers, lime inputs, trace elements and technologies to control pests and weeds. It reflects the underlying capacity of soil to retain and supply nutrients and water, and the capacity of the soil to provide an environment to sustain legume and grass growth under the pressure of grazing animals.

32. Estimates of the potential productive capacity of a legume-based pasture fixing N biologically under a "typical sheep and beef farming system" for each Land Use Capability (LUC) unit in New Zealand are listed under "attainable potential carrying capacity" in the extended legend of the Land Use Capability worksheets, which are based on the capability for long-term sheep and beef livestock production.

33. Using the productivity indices (ie. attainable potential carrying capacity) listed in the extended legend of the LUC worksheets for calculating the natural capital of soils is a new application of the information in the extended legend. It reflects the evolving nature of sustainable land management, with the necessity to set limits on emissions from land to both air and water (in this case emissions to water, and specifically nitrate leaching losses beyond the root zone). It also demonstrates the potential utility of the information in the extended legend to advance sustainable land management. An attraction of the approach is that the extended legend of the LRI is already established as the basis for land development and evaluation, and the information in the extended legend is available throughout the New Zealand.

34. The N leaching loss limit for a given land unit can be calculated using the potential animal stocking rate that can be sustained by a legume-based pasture fixing N biologically, under optimum management and before the introduction of additional technologies. Using the land units listed in the extended legend of the LUC worksheets' '"attainable potential livestock carrying capacity" as a proxy for the soil's natural capital, stocking rates were transformed to pasture production and used in the OVERSEER® nutrient budget model to calculate N leaching losses under a pastoral use.

35. For soils on LUC Classes I and II land, the calculated N leaching loss was 30 kgN/ha and 27.4 kgN/ha, respectively; this decreased to 23.5 kgN/ha and 17.5 kgN/ha for soils

on LUC Classes III and IV land, respectively.

36. If all the soils in the Upper Manawatu catchment were farmed at 90% of their potential as listed in the extended legend, and assuming a transmission coefficient of 0.5 for all land classes, the N loading in the river would be 921 tonnes annually. This is higher than the river's current N loading. When the potential production is limited to 75% on all LUC classes, the resulting N load in the river is very close to the present loading (Table 3). A significant amount of the most intensively farmed Class II and Class III land in the Upper Manawatu catchment currently would be operating at above 75% of potential, while a significant area of the Class IV and Class VII land would be operating at below 75% of potential.

37. The driver for N leaching loss limits can be changed from resources efficiency to one that recognises the necessity to add greater flexibility to landscapes that have little natural capital and lack versatility in either land use options and/or mitigation strategies. The trade-off between resource efficiency and retention of land use options is examined further in the last section of this evidence.

38. The major strength of this approach is that in calculating the N leaching loss limit it considers the whole catchment and is not prescriptive. It is not linked to current land use, but rather linked to the underlying land resources in the catchment. The approach does not target a land use or intensity of use, and it does not place limits on inputs; rather it allocates N leaching loss limits to each LUC unit based on the biophysical potential of the natural capital of the soils. It treats farms with the same land resources in the same manner, regardless of current use. It disadvantages high input, highly productive farms on soils with little inherent natural capital (eg. sand country, gravels and steep land soil) to limit N leaching, even when BMPs have been followed.

39. In catchments that have no existing water quality problems, landowners can be provided with an indication of the level of production and associated N leaching loss that would be permissible before mitigation practices would have to become an integral part of ongoing farming practices.

4. REFINEMENTS TO THE NATURAL CAPITAL APPROACH

40. The evidence in this section addresses a series of specific questions on the calculation of the N loss limit and the implications of this for the N loading in the river.

How does the LUC model change if differing levels of detail are used?

41. The net result of utilising more detailed landscape and rainfall data in the calculation of N leaching loss limits is a more accurate picture of the contribution of each land unit to N leaching and N loading in the river. This could be used to provide greater detail to assist landowners in the calculation of their N-loss limit and for making adjustments to Table 13.2 of the Proposed One Plan. Using the Upper Manawatu catchment as an example, the calculated N leaching loss at the LUC class, LUC subclass and LUC unit level, using the average rainfall value for the catchment, produced the same N loadings in the river when summed for the whole catchment. However, there were large differences in contribution to N leaching losses at the subclass level and particularly at the unit level, compared with the average for the class. This is highlighted in Figure 2 of the report by Mackay *et al*. (2008).

42. Use of an average rainfall value in the calculation of the N leaching loss will tend to overestimate losses for landscapes receiving less than the average rainfall, and underestimate losses from the higher rainfall zones in the catchment that have the same level of fertility and stocking rate. When additional soil information (eg. drainage class) and slope information (ie. flat, rolling, hill, steep), along with rainfall beyond the average for the catchment (eg. in 200 mm bands across the catchment) are included in the calculation of the N leaching loss, the contribution from each LUC unit changes further (see Figure 2 of Mackay *et al*., 2008), as does the N loading to the river (see Figure 3 of Mackay *et al*., 2008).

Flat and rolling landscapes with hill and steep land

43. As a general rule for flat and rolling landscapes within a catchment that also include hill and steep land, adding more detailed biophysical information, while assuming the same attenuation factor from land to river for all land units, will reduce the calculated N leaching loss and loadings into the river from soils. This is a consequence of the inclusion of less versatile soils (identified by more detailed mapping), use of actual rainfall (which is often lower than the catchment's average rainfall) and low slope classes. Inclusion of soil drainage classes would either increase or reduce the calculated N leaching losses.

44. As a general rule for hill and steep landscapes within a catchment that also include flat and rolling country, adding more detailed biophysical information, while assuming the same attenuation factor from land to river for all land units, will increase the N leaching loss and loadings into the river from soils. This is a consequence of the inclusion of more versatile soils (identified by more detailed mapping), use of actual rainfall (which is often higher than the catchment's average rainfall) and higher slope classes.

45. The findings of the FARMs test farm project (Manderson & Mackay, 2008) evaluated the effect of using the New Zealand Land Resource Inventory (NZLRI), which contains land information at the 1:50,000 scale, with that obtained by an on-farm survey, which could be at scales less than 1:5,000. It is worth noting that there is inherently more uncertainty in the available information about soils on hill and steep land, suggesting that landowners with these landscapes should consider more detailed mapping before making a decision on the scale at which to calculate their N leaching loss limit. Dr Andrew Manderson covers this issue in detail in his evidence.

How do mitigation options change with Land Use Capability Class?

46. To address this question it is first necessary to introduce the following concepts with respect to the behaviour of soils within each Class and the effects, on production levels and the environment, of production technologies developed to overcome "limitations to use".

The ability to realise and sustain the productive potential of soils

47. Agricultural production on elite and versatile soils (Classes I and II) with high natural capital requires lower levels of inputs (eg. fossil fuels, fertilisers and irrigation water) per unit of output than soils with little natural capital.

48. Under particular land uses, soils with limited natural capital can attain a similar level of productivity to soils with high natural capital. For example, shallow soils under irrigation can attain the same levels of pasture production as versatile soils. The productive capacity of soils on LUC Classes I and II, and on LUC Classes III and IV (through the use of feed pads and stand-off areas when soils are wet), is not generally constrained by the physical limitations of the soils. However, the physical integrity of soils found on Classes VI and VII will often define the upper limits of production.

The environmental impact of a soil operating at its natural potential

49. Emissions (eg. N leaching losses) will be higher on coarse textured, weakly developed, stony soils and soils on slopes, compared with elite soils. This rule will not be universal, because there will be trade-off. As a generalisation, the amount of product per unit of input will be greater, and the emissions resulting from the added production will be less, on an elite soil (ie. high natural capital) when comparing all soils at the same level of potential.

Production beyond the soil's natural capital

50. A number of very effective technologies are available (eg. cultivation, drainage and irrigation) to lift the productive capacity of soils on flat and rolling landscapes beyond their natural capital compared with soils found in hill country and steep land. There are also more technologies (eg. feed pads and N fertiliser) that are available for sustaining production to compensate for the lack of natural capital of soils on flat and rolling landscapes. The cost of technologies generally increases, as does their production benefit, as the natural capital of a soil declines.

Mitigating nitrogen losses in soils operating beyond their natural productive capacity

51. Technologies (eg. cultivation, drainage and irrigation) used as substitutes for a lack of productive capacity (eg. weakly developed soil structure and limited water available to plants) of soils will lead to increased N loss, through a combination of increased production and greater leaching volumes. The number and efficacy of mitigation options for compensating for the limited capacity of soils to retain N in the topsoil horizons decline as the natural capital of soils becomes more limited. Soils on which production technologies have their biggest impact on production levels will also be those landscapes that provide the greatest challenge in mitigating N leaching losses.

Relationship between N loss mitigation options and the natural capital of soil grouped by LUC class

52. The number of options for mitigating N losses decreases as the producer moves from soils in LUC Classes I and II to those in Class III and greater. The absolute cost of mitigation (eg. application costs) and/or the cost of mitigation as a function of production and income from land increases as the limitations to use increase. From a purely

biophysical stance, landowners on elite soils have no limitations to use and hence flexibility in their choice of land uses. Landowners on elite soils have a full range of options to mitigate N losses whereas on all other soils there are fewer effective options available. As the natural capital of the soil declines, the available land use options decline, along with the range and cost competitiveness of the mitigation options.

53. If the question is limited to, "What is the most efficient use of resources with the least environmental impact?" the N leaching loss limit should be weighted towards those soils with the greatest natural capital.

54. If the goal is to sustain rural communities into the future, a case for allocating higher N loss limits to soils with little natural capital would be required. This would be designed to retain the limited land use options and flexibility available to landowners on these landscapes.

Catchment level outcomes of Table 13.2 of the Proposed One Plan

What would the values have to look like to achieve the absolute standard in this timeframe?

55. Using the Upper Manawatu catchment as an example, the N loss limit permissible to achieve the river's long-term water quality target, as set in Schedule D, Table D.17 of the Proposed One Plan, of 358,000 kg N is under 6 kg N/ha if all land is treated the same and assuming an attenuation of 0.5 from land to water. Bringing that analysis back to the initial water quality targets set for Year 1 of the Proposed One Plan for the Upper Manawatu River (859,000 kg N) and again treating all land the same, the N leaching loss limit for each hectare would be 13.2 kg N/ha, again assuming an attenuation of 0.5 from land to water in each catchment.

Is achievement of the absolute water quality standard achievable by management on farm using available best management practice?

56. On-farm management using best management practices available could not achieve the long-term water quality target set in the Proposed One Plan for the Upper Manawatu River of 358,000 kg N (ie. under 6 kg N/ha if all land is treated the same and assuming an attenuation of 0.5 from land to water). Attempting to achieve the absolute water quality standard would cause massive upheaval, because it would require radical changes to current land uses. The only land uses that could continue unchanged would

be land under native or exotic forest, scrubland and extensive sheep and beef. For intensive livestock, radical and unrealistic changes would be required.

Is it appropriate to have a single table for nitrogen loss limits for all catchments? If not then why not?

57. Adjustments would be required in the N loss values in the Table in recognition of the differences in the areal extent of soils and rainfall between catchments and the impact this will have of N loadings. The structure of Table 13.2 would remain the same, as would the catchment management planning process.

Are the values in Table 13.2 of the Proposed One Plan appropriate for conversion to intensive land uses as well as in target catchments, in reference to FARMs test farms?

58. In the first instance, the N loss limit values in Table 13.2 of the Proposed One Plan for the target catchments would be appropriate for defining thresholds for land being converted to an intensive land use in landscapes outside the target catchments. As the proportion of land under intensive land use expanded a catchment management plan would need to be developed to ensure the required water quality outcomes are achievable and at the same time retaining ongoing growth and land use options.

5. EVIDENCE

What are the options for addressing N leaching losses to water bodies?

59. My evidence is in three parts.

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B. The science behind the natural capital approach.
C. Refinements to the natural capital approach.

60. The evidence draws heavily on two reports prepared by the Sustainable Land Use Research Initiative (SLURI) cross-organisational team for Horizons:

i. Farm Strategies for Contaminant Management (Clothier *et al*., 2007). This report covers an investigation of the sources of diffuse Nitrogen (N) and Phosphorus (P) losses from the dominant land uses contributing to N and P loadings in Horizons' Water Management Zones (WMZs). The report established what the target best management practices (BMPs) are for sheep and beef, and dairying to ensure that water quality in Horizons' WMZs move towards their quality criteria. It examined a number of options: grandparenting (ie. the capping of farm N leaching losses at levels based on emissions from current land use or the average of emissions from land use in previous years), limiting intensive land uses, allocation of an N-loss limit per hectare, and allocation of an N-loss limit based on the soil's natural capital) for defining an N leaching loss limit that could underpin a nutrient allocation regime; and

ii. Implementation of FARM strategies for Contaminant Management. Further questions (Mackay *et al*., 2008). This report includes an analysis of the impact that information used at differing levels (ie. class, subclass and unit) in the extended legends of the Land Use Capability (LUC) worksheets has on the calculation of the N leaching loss limits and the N loading in the river. It also examines mitigation options available for reducing N leaching losses beyond the root zone change within each LUC class, and investigates the N leaching loss limits required to achieve the water quality standard in the Upper Manawatu and Mangatainoka Rivers as detailed in the Proposed One Plan, Schedule D, Table D.1. It also reports on the appropriateness of a single table for N leaching loss limits for all catchments.

A. THE CASE FOR USING A NATURAL CAPITAL APPROACH FOR A NUTRIENT ALLOCATION REGIME

61. The allocation of an N-loss limit based on the natural capital of soils was identified in the report by Clothier *et al.* (2007) as the option that best met the dual requirements for continued economic growth and ongoing flexibility in land use in the Region, while meeting water quality targets. This approach was subsequently adopted and formed the basis for the N loss limit contained in Rule 13-1 in the Proposed One Plan. The natural capital based approach recognises that land is a finite resource and land-based industries are the basis of the Region's economic wellbeing. The approach retains ongoing flexibility in land use and management options for the targeted water quality outcome. It encourages the most efficient use of the Region's natural resources, again for the targeted water quality outcome, while allowing for a trade-off between resource efficiency and retention of farm businesses on less versatile landscapes. It does not prescribe a land use or place limits on inputs. The approach captures all the land within a Water Management Zone (WMZ) that contributes to the water quality outcome. It is portable beyond the priority catchments and sends important messages (ie. it does not reward the biggest polluter, does not penalise conservative behaviours and does not disadvantage owners of undeveloped land) and timely signals (eg. it establishes a target

for mitigation practices and defines a threshold above which the capital investment in increasing production must be extended to mitigation technologies, including significant modifications to farm design).

62. Globally, humans use about 8.7 billion hectares of land. About 3.2 billion hectares are potentially arable, of which a little less than half is used to grow crops. The remaining 1.7 billion hectares of potentially arable land, along with most non-arable land, function as pasture, forest and woodland. Land degradation is widespread and the overall pace of degradation has accelerated in the past 50 years. Productivity has declined substantially on approximately 16% of agricultural land in developing countries, especially on crop land in Africa and Central America, pasture in Africa, and forests in Central America. Almost 75% of Central America's agricultural land has been seriously degraded, as has 20% of Africa's and 11% of Asia's. Gardner (2000) reports that the decline in the global area harvested for grain, combined with the increase in world population, has steadily reduced the area of grain harvested per capita from 0.2 ha in 1965 to 0.11 ha in 1999. Grains supply more than half the calories and protein eaten directly by humans. Thus grain growing area tracks the resource base of the dominant component of the global food supply. It has been estimated that the minimum per capita arable land area needed for an adequate diet is 0.5 hectare under a modest level of inputs (Lal & Pierce, 1991). The land-to-people ratio argument is further compounded by the serious and global problem of soil degradation. This all points to land as a finite resource, and that should be considered in any decision that is likely to affect its use.

The dual requirements for continued economic growth and ongoing flexibility in land use in the Region while meeting water quality targets.

63. There is a finite area of land available for primary production regionally, nationally and globally. Highly productive soil requires centuries to develop under natural conditions. Our most productive soils have taken thousands of years to form, with the most versatile soils (LUC Classes I and II) in New Zealand limited to 1.277 million ha or 5% of total area (Mackay, 2008). In a report prepared for Horizons on future growth, Agriculture New Zealand (Anonymous, 2005) highlighted the opportunity for continued growth in the Region's land-based sectors. These benefits would not be limited to Horizons' Region but would flow through to the wider national economy, through increased exports. An integral and underlying part of any policy initiative to protect water must be the retention of options for land development and land use. For example, a policy that placed a moratorium on the expansion of intensive farming practices and a limit on N leaching losses from less intensive farming systems in the Upper Manawatu catchment would

limit the potential expansion of irrigated sheep and beef farming, dairying, cropping, horticulture, and commercial vegetable growing in the catchment.

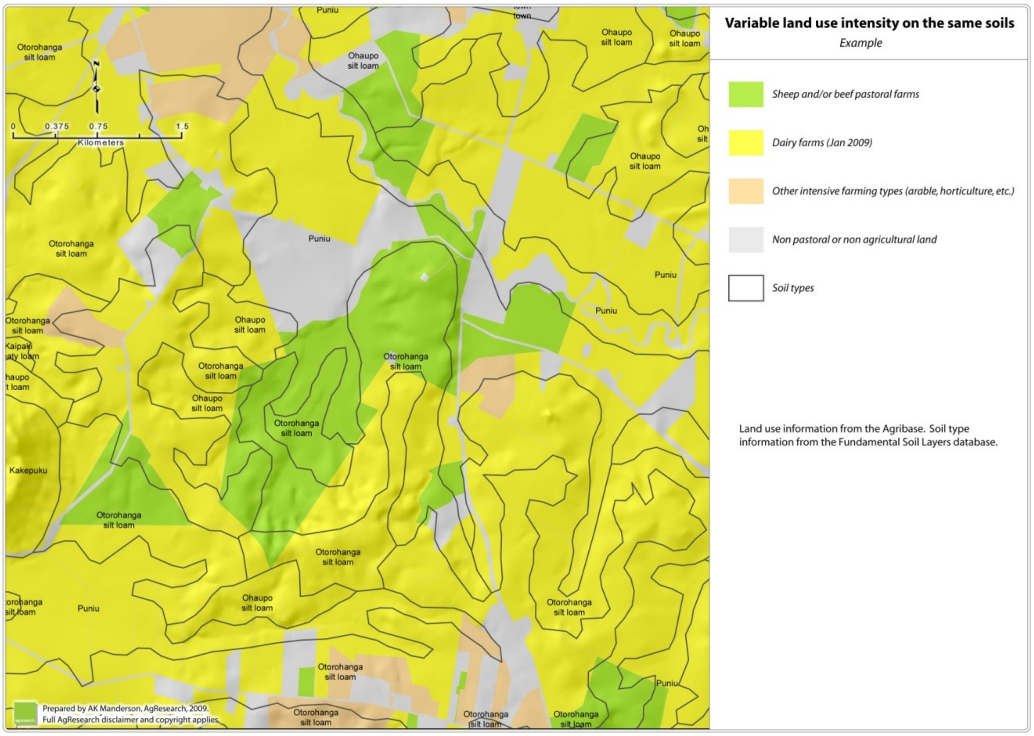


Figure 1. Land with the same natural capital under different land uses.

64. It would also limit land use options for individual producers (Figure 1), which raises issues of equity, restrict the scope of industry growth strategies (Figure 2a) and constrain rural community development and the regional economy (Figure 2b).

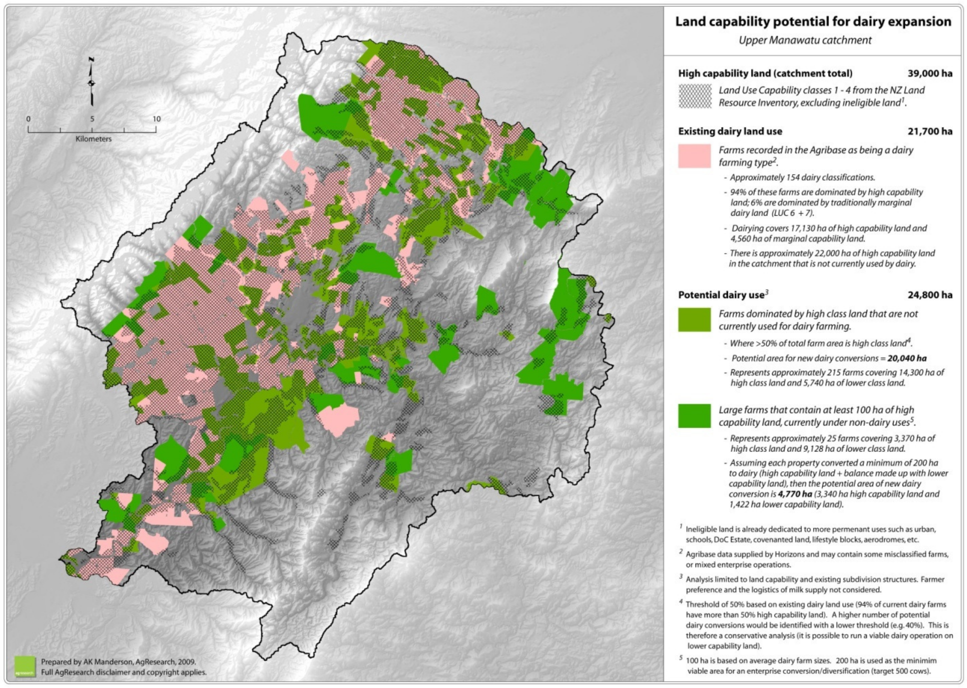


Figure 2a Existing (pink) and potential (light and dark green) extent by area of dairying in the Upper Manawatu catchment (NB: this assumes utilisation of all the Land Use Capability (LUC) classes in the catchment currently used for dairying.)

65. Figure 1 shows the implications for individual landowners of a moratorium on the expansion of intensive farming practices and a limit on N leaching losses from less intensive farming systems. Low intensity sheep and beef farms can be seen among intensive land uses on similar land classes, but if N leaching losses from current land uses on similar soils were used as a basis for a nutrient allocation regime, these properties with less intensive land use would be disadvantaged because they would effectively lose the potential for intensification already enjoyed by their neighbouring enterprises.

66. Utilising the same LUC class mix currently used by the existing dairy industry in the Upper Manawatu catchment, the area under dairying as an example of intensive farming system could be increased from 20,000 to more than 40,000 ha (Fig.2a). Assuming an average stocking rate of 2.5 cows per ha, with each cow producing 340 kg milk solids (MS) per year and a payout of $5.00 per ha, the additional 24,800 ha under dairying would inject an additional $105 million into the regional economy.

67. This lost opportunity is not limited to the Upper Manawatu River catchment. All the Region's priority WMZs would be affected by a moratorium on the expansion of intensive farming practices and a limit on N leaching losses from less intensive farming systems (Figure 2b). To provide an indication of the scale of the impact, 891 of the 2,652 farms within the priority zones identified as having high capability land are dairy farms; this leaves 1,761 non-dairy pastoral farms that have a high capability for potential dairy conversion. Extending that analysis beyond the priority WMZs would see that number jump again.

68. Farm Strategies for Contaminant Management (Clothier *et al*., 2007), a study conducted for Horizons by SLURI, established the contribution of non-point source N loading from dairying and sheep and beef farming in the Upper Manawatu catchment. In that study the N loading in the Upper Manawatu River from the average dairy farm was found to be 15.4 kg/ha/yr. For sheep and beef the N loading was a much smaller 3.9 kg/ha/yr. More than 90% of the total N in the river is from these two non-point sources, with dairying contributing about half of the loading, despite only representing 16.3% of land use in the catchment, whereas sheep and beef cover 77.3% of the catchment area.

69. The N leaching loss from below the root zone in the Upper Manawatu catchment, calculated using the OVERSEER nutrient budget model, was found to be 31 kgN/ha for the average dairy farm and 7 kgN/ha for the average sheep and beef farm (Clothier *et al*., 2007). Using an N transmission coefficient of 0.5 for both, dairying and sheep and beef operations, a direct link could be made between land use and management decisions as these influence N losses and loadings in the river. With that link it is possible to examine the impact of ongoing intensification of pasture-based agriculture on water quality and also to examine the benefits of adopting mitigation practices (Dr Brent Clothier's evidence provides more details).

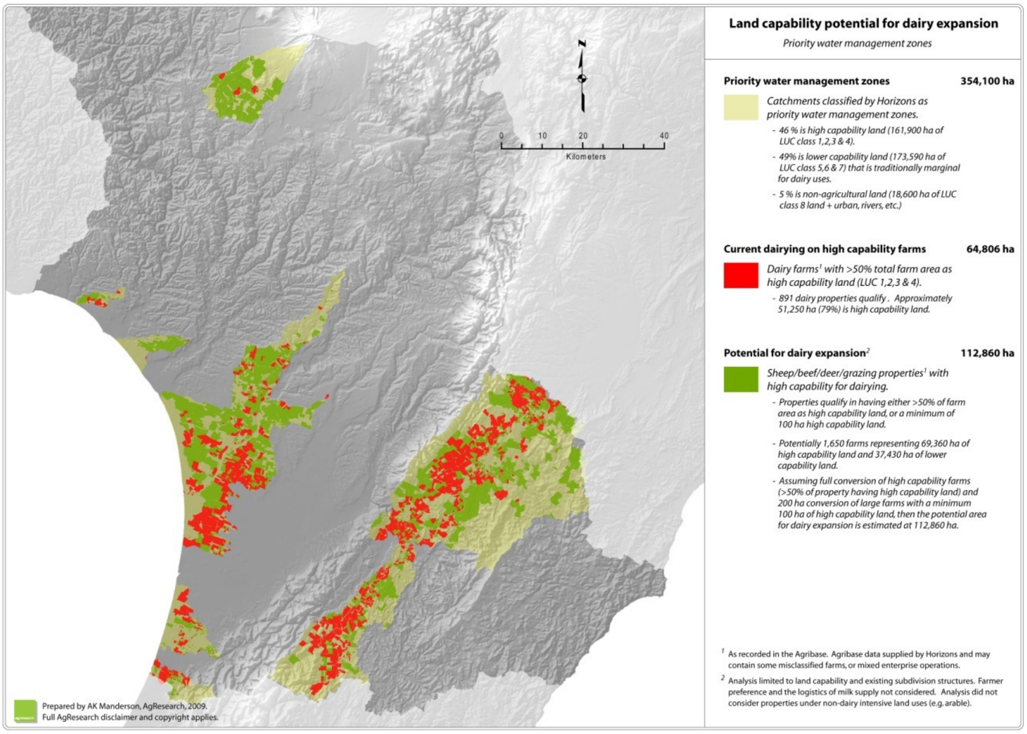


Figure 2b. Implications of a moratorium on the expansion of intensive farming practices and a limit on N leaching losses from less intensive farming systems on potential future expansion of intensive land uses in the Region's priority Water Management Zones

70. If dairy farms were to intensify to achieve an average of 1,200 kg milk solids (MS) per ha^{-1} the leaching loss of N is predicted to be 49 kg-N ha^{-1} yr^{-1}; this would result in a 33% increase in N-loading in the Manawatu River coming from the Hopelands sub-catchment.

71. If the average sheep/beef farming stocking rate increased to 12.2 stock units (SU) per ha^{-1}, which is a possible scenario over the next decade, the leaching loss of N is predicted to be 9 kg-N ha^{-1} yr^{-1}. This would lead to N-loading in the river increasing by about 8.4%.

72. The Upper Manawatu catchment has 31,580 ha of land better than Class III with only 20,534 ha currently used for dairying. If dairying were to expand to all Class III or better lands, the N loading at Hopelands, emanating from the entire catchment would increase by 17.8%. This assumes the average N leaching loss from each dairy farm was 31 kgN/ha/yr and current management practices prevailed. If there were also

simultaneous production increases in dairy and sheep and beef, this number would be even bigger. This indicates that to do nothing is not an option.

73. Production (eg. milk solids per ha, liveweight per ha) and efficiency gains (eg. cows or stock units per labour unit, lambs per ewe) has been the basis for the ongoing success, profitability and competitiveness of the pastoral industry in New Zealand over the last 50 years. Increasing farm size has been the other key strategy used by producers to remain profitable. These strategies are not likely to change in the foreseeable future, thus forcing producers to continue to search for additional efficiency gains and to continue to have to push their businesses beyond current production levels and beyond the inherent carrying capacity of their land holdings, through additional inputs (eg. N fertiliser, irrigation, bought-in feed). (Dr Roger Parfitt's evidence provides additional information on previous and future industry growth strategies and the implications for emissions). Retention of growth and land use options is therefore critical to the future viability of the Region's land-based industries. At the same time, the "do nothing" option with regards to N leaching losses will further accelerate the current trends in increasing N leaching from farms and the resulting decline in water quality in the already affected WMZs. More catchments will be put at risk. The objective of improving water quality therefore cannot be achieved unless N leaching losses are addressed (Anonymous, 2007a). Therefore, the "do nothing" option will not achieve the objective of improving water quality. Additionally, the emergence of, or suggestion of legislation aimed at setting limits or thresholds on N loss above which mitigation is required suggests that to do nothing is no longer an option.

74. Horizons is one of a number of regional councils around New Zealand proposing to address farm nutrient losses through Regional Plan rules. For example, Variation 5 to the Environment Waikato Regional Plan contains new policy and rules to manage land use in the Lake Taupo catchment. The new rules serve to cap the amount of N leached from farmland, with the cap based on the previous history of N loss from each farm (ie. grandparenting). Rules in Environment Bay of Plenty's Proposed Regional Water and Land Plan, particularly Rule 11, propose to cap farm nutrient (N and P) losses at levels based on mid-2001 to mid-2004 land use. The basis of Rule 11 is that farmers cannot intensify land use unless they can keep nutrient losses within the 2001-2004 emissions. In the South Island, Environment Canterbury intends over time to move to a zone-based approach to groundwater quality and Environment Southland proposes to address non-point source discharges to achieve a 10% improvement in water quality by 2015.

What options are available for addressing N leaching losses to water bodies?

75. The options described and discussed in the report prepared by the SLURI team for Horizons Regional Council Farm Strategies for Contaminant Management (Clothier *et al*., 2007) are expanded upon here to include benchmarking, nutrient use efficiency and best management practices, in addition to grandparenting and limiting intensive land uses. Each approach was evaluated against the criteria used to assess the natural capital based approach described earlier. The following discussion is limited to options for addressing N losses and does not address P losses.

76. The need for specific targets for N but not for P can be explained by comparing the chemistry of the two nutrients in soil and how they enter water. Phosphorus is a specifically sorbed anion tightly held by the soil, while nitrate-N is a weakly sorbed anion and, as a consequence, is easily leached. In grazing systems the loss of N is due to leaching of nitrate, originating from urine patches, down through the soil to below the roots. This occurs mainly during the period of the year (usually May to September) when net drainage occurs. The amount of nitrate-N leaching losses from a grazed pasture is a function of the number of animal urine patches, which increases with higher animal production and stocking rates (Ledgard, 2001). Best management practice, as it currently stands, does not place a limit on the number of animals or the number of urinations. Hence, as animal numbers and production increase, so do N leaching losses, even under best management practices. With the exception of soils (eg. cracking clays) that demonstrate preferential flow, P loss occurs largely via surface run-off. Phosphorus is lost in two forms, soil-bound and dissolved-P, with the former often the dominant (60-90%) mechanism in less intensively farmed hill catchments. In comparison with N losses, the quantities of P lost are smaller and a significant proportion of the P lost on an annual basis can occur during single-storm events (Parfitt *et al*., 2009).

Placing limits on the N leaching losses from existing intensive land uses only

77. Placing a limit on the N leaching losses from existing intensive land uses only offers an option for stopping further decline in water quality, assuming no lag and no further expansion of intensive land uses or increases in emissions from the less intensive land uses in the catchment. Clothier *et al*. (2007) provide some indication of the impact this policy approach might have on water quality in the Upper Manawatu catchment.

78. In the short-term, significant reductions in the N loading in the Upper Manawatu River could be achieved by a focus on intensive dairy operations, as existing mitigation options offer the potential to reduce N losses on the average dairy farm by up to one third (Clothier *et al.*, 2007). While this approach offers a short-term policy option for Horizons, it is based on the assumption that there will be no further conversion of sheep and beef to more intensive land uses (eg. cropping, commercial vegetable growing and dairying), despite significant scope for land use change, or any further intensification of the sheep and beef sector. All of these have the potential to increase the N leaching losses and N loading in the river.

79. The focus on existing intensive land uses is closely aligned to the grandparenting option, if the N leaching losses calculated as part of the process were to become the basis for subsequent N limits or allocation of the public utility (N assimilation capacity of surface water body). It recognises and rewards the landowner with the largest N leaching loss and protects the capital investments contributing to that N leaching loss. It puts at risk the capital investments of landowners not currently generating significant N losses, but who have the opportunity to intensify production and thereby increase N losses. It also disadvantages landowners who had actively conserved N, for example by using BMPs, and it does not consider the best uses of the other natural resources within the catchment. For example, no assessment of the efficiency of utilisation of the land resources within the catchment against the current and desired water quality outcomes is considered. Rather than provide guidance to landowners outside the priority catchments who have the potential to exacerbate the current N loss challenge, it sends the wrong messages.

80. In addition to a moratorium on any further expansion of intensive land uses and any increase in N losses from less intensive land uses, both of which would have to be monitored, a strategy would be required for reducing N leaching losses from farms within the priority catchments where N loadings in the water body are above the standard.

81. The approach is linked to current land use and, as a consequence, may not necessarily encourage the best use of the land resources in the catchment for the required water quality outcomes. It has the potential to seriously reduce future land development and land use change.

Sector benchmarking

82. Benchmarking each sector would enable landowners and the land-based industries to identify their individual and collective contributions to the current N loading and to monitor changes over time. This would provide an early indicator of future environmental impacts and could be used to quantify the impact of current environmental best practices on N loadings, while making available information that might be required to meet any market requirements related to nutrient management. Benchmarks of N and P losses from typical farms in key agro-ecosystems, using the OVERSEER nutrient budgeting model, are being used within the environmental programme of the Pastoral 21 sector group to first quantify the contribution to the current environmental problem and then to assess the effectiveness of mitigation tools developed in other parts of the programme. The Dairy Industry Strategy for Sustainable Environmental Management (Dairy Environment Review Group, 2006) was designed to benchmark N and P losses for current typical dairy practice, and over a 10-year period mitigation solutions would be developed to reduce N losses by 50% and P losses by 50-80%.

83. The concept of benchmarking the ‘typical’ or ‘average’ farm within a sector and then working towards a planned reduction of N leaching losses brings with it challenges. To be effective, benchmarking will require the establishment of an N loss allocation for each sector in each catchment and a mechanism for changing that allocation when land use changes. A mechanism for setting allocations for new land uses would also be required. If the initial N leaching loss limit for each sector and each farm within a sector is allocated on the basis of the initial benchmarking exercise, it does not consider the most efficient use of the resources in the catchment for the required water quality outcome. It has the potential to seriously reduce future land development and land use change

Nutrient use efficiency

84. There are numerous types of nutrient use efficiency and they can be expressed in a number of different ways, including: 1) input based (produce N/total input N); 2) output based (eg. kg N leached/kg product; kg N leached/$ effective farm surplus); and 3) effective on-farm land area used (eg. kgN/ha) (Wedderburn, 2008).

85. Tillman *et al.* (2008) have devised an nutrient efficiency index, which they define as the ratio of financial return per unit of N leached, calculated by dividing the amount of N leached in kg/ha by milk solid (MS) production in tonnes/ha. The authors refer to the index as an environmental efficiency index, though it is more correctly described as a

production efficiency index. Tillman *et al*. (2008) suggest that the approach would be deemed to be more palatable, and offer more flexibility to farmers, than imposing an N cap. They indicate that it would allow easy comparison between farms and enable farmers to gauge their performance relative to other farmers. Such an index, according to Tillman *et al.* (2008) would be easy for a regional council to implement and monitor, as all the required information is readily available. The approach provides industry with an indicator that could be used to encourage adoption of practices that increase the efficiency of N use within the farm system, conserve N, and have the potential to reduce N losses to the wider environment. It offers an approach for gauging the production efficiency of the business in producing milk against the loss of N (fertiliser N + legume N + mineralised N) from the pasture as nitrate in leachate.

86. At this stage in its development as an approach, it does not consider the influence of soil type, climate, feed source and a wide range of other management practices that are likely to impact on nutrient use efficiency. Failure to incorporate some of these factors will heavily favour specific farm systems in specific environments. At the extreme, the most efficient nutrient use system would be a cut-and-carry system with animals housed on a pad and with all effluent collected and processed. Farms on high class soils would also be advantaged by the approach. Landowners on soils with limited natural capital and high rainfall would be seriously disadvantaged.

87. The nutrient use efficiency approach, used alone, offers little utility. This can best be illustrated by comparing two dairy producers: Farm 1, producing 800 kg MS/ha and leaching 25 kg N/ha (nutrient use efficiency of 32 kg N/1,000 kg MS); and Farm 2, producing 1,200 kg MS/ha and leaching 37.5 kg N/ha (nutrient use efficiency of 32 kg N/1,000 kg MS). While the N use efficiency is the same for both scenarios, milk production is 50% higher and N leaching loss 48% higher on Farm 2. For the nutrient use efficiency approach to be effective as a tool in effecting change in water quality Tillman *et al*. (2008) recognised that *"it would require each dairy farmer in a catchment to have a target or a limit".*

88. Operationalizing the N use efficiency approach for managing catchment N outcomes brings with it a significant number of challenges. It would require imposing an N use efficiency requirement on all farms in all the primary industries using land within a catchment (eg. <25 kgN/1,000 kg MS, <15kgN/250kg lamb carcass, <15kgN/65 kg wool, <15kgN/1,000 kg potatoes, etc). A mechanism would be required for establishing the initial N allocation to each sector and then to each landowner in that sector. It would also require developing a mechanism that could re-allocate and recalculate N use

efficiencies to accommodate land use change between existing and new land uses within the catchment.

89. Allowance would also have to be made for differences in soils and rainfall within the catchment, otherwise farm systems on specific soil types and in specific climates, both of which impact on N leaching, would be heavily favoured or disadvantaged. The approach would also have to be tailored to individual catchments, because along with changes in the water quality targets will come changes in climate, landscape and land use, all of which will influence the N leaching losses and N use efficiencies.

90. If the initial allocation of the N leaching loss limit is based on emissions from current land-based businesses in the catchment, the issues raised with the use of options for limiting intensive land use, benchmarking and grandparenting also apply.

Input-based controls

91. Many inputs could be controlled to limit the risk of N leaching losses to the environment. While these are relatively easy to describe and quantify, there are a number of major technical difficulties when assessing effectiveness. Chief among these is predicting effectiveness from farm to farm, and verification of the level of implementation of any input control.

92. Further, imposing rigid input-based controls (eg. no-till cultivation only, no N fertiliser inputs in May-July, zero grazing in June) will vary in effectiveness. This is because each farm system is a unique assemblage of resources (eg. land, water, enterprises and human capacity), is found in a unique spatial location, and is responding continuously to a range of drivers including climate and markets. Farms are complex system that are constantly trading-off between short-term and long-term economic, environmental and social goals. All of these will influence the outcome. The impact of imposing input-based controls on individual business would be highly variable. For example, it could limit the ability of producers to develop and implement the most cost-effective mitigation strategies compatible with their farm system. It could impose restrictions unnecessarily (eg. for a livestock farmer operating within acceptable limits). To be effective, an input-based approach will need to be tailored for different climate zones, landscapes, land uses and specific enterprises. It would also require a mechanism for addressing land use change, and some type of trigger before the input control is invoked (eg. using >50 kgN/ha/yr, stocking rate, etc). These modifications make this approach less attractive, especially when weighed against the intended outcomes.

93. Verification of adherence to the input-based specifications (eg. timing of N fertiliser application, maximum stocking rate and number of cultivation passes) brings with it challenges in both policy and quantification of effectiveness.

Best management practice

94. Best practices nutrient management, nutrient budgeting and planning, mitigation technologies, industry initiatives (eg. Clean Streams Accord) and Environmental Management Systems (EMS) have the potential to reduce the losses of sediment, P and faecal material and with the inclusion of specific targets, N, from intensive agriculture. These can have specific targets for N loss. The need for specific targets for N but not for P was explained earlier.

95. The Primary Sector Water Partnership has produced a plan of action for the sustainable management of freshwater resources. Its aim is that by 2013, 80% of the nutrients applied to the land are managed through quality assured nutrient management plans and budgets. A secondary aim is that by 2016, 1.7 million hectares of intensively farmed land will focus on improved environmental outcomes through operating nutrient budgets and nutrient management plans within their broader farm management plans. At this stage, the latter goal contains no specific targets or thresholds for nutrients. BMPs therefore have limited utility until N leaching loss targets are included. Addition of N loss limits to BMPs, as currently proposed by the horticultural industry to address N leaching losses from commercial vegetable operations, offers the pastoral industry an approach for addressing the current weakness of BMPs.

Grandparenting

96. Grandparenting is the capping of farm N leaching losses at levels based on emissions from current land use or the average of emissions from land use in previous years (eg. the last 3-5 years). It immediately stops any further increase in N leaching and any further decline in water quality, assuming there is no lag.

97. Grandparenting limits all landowners to their historic N leaching loss. Existing landowners can continue their existing land uses without needing to obtain additional N rights. On that basis there is no upfront cost. It also ensures that as far as practicable, the viability of existing land uses is not significantly compromised. These factors, along with the degree of certainty of achieving the outcome, appear to have been important

elements in the choice of this allocation option by Environment Waikato to address N leaching into Lake Taupo (Anonymous, 2007b).

98. However, using N leaching losses calculated as part of the grandparenting process as the basis for the subsequent allocations has significant disadvantages. It recognises landowners with the largest N leaching losses and protects the capital investments contributing to those losses, while putting at risk the capital investments of landowners not currently generating significant N losses, but with the opportunity to so. This approach would also disadvantage landowners who had been actively conserving N, for example by using Best Management Practices (BMPs). In effect there are "windfall gains" for the worst polluters and "windfall losses" to others. In the case of the Upper Manawatu catchment, a small percentage of landowners would receive windfall gains.

99. A further concern with the grandparenting approach is the messages it sends to landowners outside the target catchments (ie. wealth and future options are captured by the worst polluters). It has the potential to discourage rather than encourage sustainable practices.

100. The major weaknesses of grandparenting, if it becomes the basis for the N limits or allocation of the public utility (N assimilation capacity of surface water body) is it does not consider the future and locks in current land use. It fails to recognise that land is a finite resource and fails to assess land use options in the catchment against the desired water quality outcomes. It also puts the future viability of all farms at risk, by failing to allow growth options and flexibility in land use.

N allocation based on land area

101. The average N leaching loss permissible for each of the 129,638 hectares in the Upper Manawatu Water Management Zone in the Proposed One Plan in Year 1, would be 13.2 kgN/ha below the root zone. If all the land resources in the catchment were the same (ie. they had the same natural capital and were providing the same ecosystems services to the community), all land owners would receive the same N-limit allocation per hectare. This would be a very simple, effective and equitable approach for all landowners in the catchment. It would negate the need to develop policy for each land use and would address the major challenge identified with all the other approaches, ie. setting the initial N-limit allocation.

Table 1. Characteristics of the Upper Manawatu and Mangatainoka catchments

Parameter	Upper Manawatu	Mangatainoka
Size of catchment (ha)	129,638	47,871
Current N loadings (kg N)	745,000	603,000
Proposed One Plan Year 1 N loadings (kg N)	859,000	360,000
N loss limit to achieve the Proposed One Plan loadings, Year 1 (kg/ha)[1]	13.2	15
Long-term water quality standard (kg N)	358,000	248,000
N loss/ha (kg)[2]	5.5	10.4
N loadings when all land units are operating at 75% of potential[3]	1,004,000	503,000

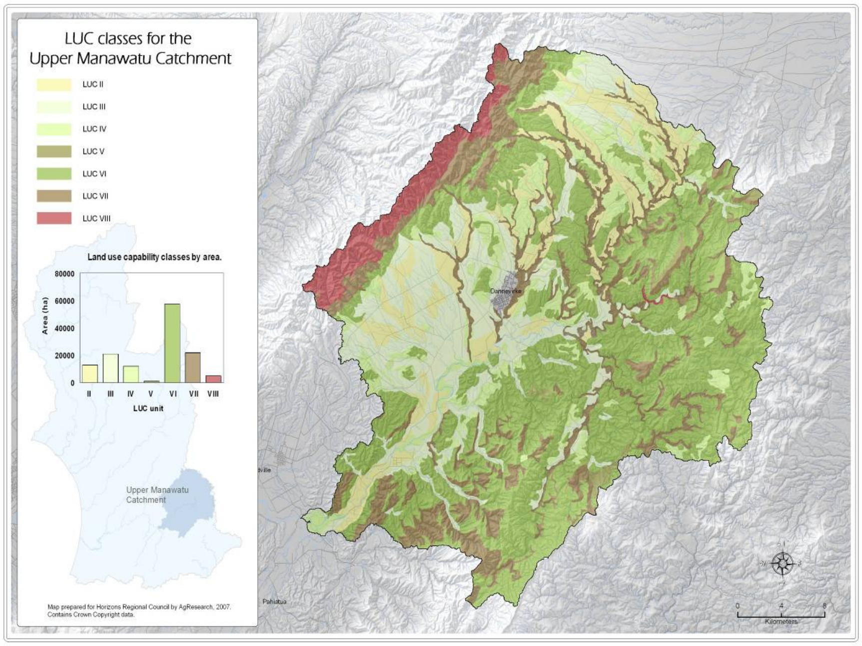
[1] Treating each ha in the catchment the same and assuming the transmission coefficient is 0.5.

[2] Treating each ha in the catchment the same and assuming the transmission coefficient is 0.5.

[3] N loading when all land units in the catchment are operating at 75% of potential production, assuming an attenuation factor of 0.5.

Land is not all the same

102. Landscapes in the Upper Manawatu catchment range from flat to rolling to steep (Figure 3). Treating all land the same fails to recognise these differences. New Zealand enjoys a remarkable diversity of landscapes and soils (Molloy, 1998). The land area of New Zealand covers 26 million hectares, of which half is in pastoral agriculture and forestry. There are 6.5 million ha of flat and rolling land classes in pastoral and forestry. Hill and steep land covers the remaining 6.6 million ha, of which 5.2 million ha is in pastoral agriculture (Mackay, 2008).



Map prepared for Horizons Regional Council by AgResearch, 2007. Contains Crown Copyright data.

Figure 3. Land Use Capability (LUC) classes for the Upper Manawatu catchment.

103. Within landscapes (eg. flat, rolling hills) the characteristics of the soils vary greatly in their inherent productive capacity and versatility. They represent a large component of the natural capital on which New Zealand's economy and environment depends. Contrary to popular belief, the area of versatile and elite soils represents less than 5% of New Zealand's soils. More than 65% of the soils have at least one physical limitation to productivity under a pastoral use. For example, approximately 2 million ha of poorly or imperfectly drained soils are farmed in New Zealand. Common features of many of our soils derived from alluvium, loess, volcanic materials, coastal sands or in eroding hill and steep lands are their young age, weakly developed soil structure, poor drainage, limited water-holding capacity and limited nutrient/pollutant absorption capacity. This would suggest that treating all land the same would fail to recognise that some soils are capable of producing more than soils that are less productive and more fragile. Hence, the more capable soils are of greater value to the economy. The market recognises differences in the inherent natural capital of soils, with the more versatile and elite soils commanding a higher price. Land values are a function of current and future potential production levels, which are the sum of the soils' inherent natural capital (eg. texture, organic matter content and soil depth) and added capital. Added capital can be technologies that address nutrient deficiencies (ie. N and P) and low pH and toxicities (liming); through to technologies such as drainage, irrigation and flood control schemes to assist in water regulation; and infrastructure, including buildings, tracks and fences.

Table 2. Potential for leaching losses for soils varying in Profile-Available Water (PAW) and Cation Exchange Capacity (CEC), within the upper 0.6 metres soil depth. The shaded areas correspond to soils with LUC Classes I and II. (Derived from Webb & Wilson, 1994).

PAW (mm)	**Cation Exchange Capacity (meq/100g)**		
	>12	**6-12**	**<6**
>250	**minimal**	**minimal**	
150-250	**minimal**	**minimal**	moderate
90-150	**slight**	**slight**	severe
60-90	moderate	moderate	severe
30-60	severe	severe	v severe
<30		severe	v severe

104. In addition to differences in productive capacity, soils vary in their ability to absorb nutrients, pesticides and wastes. Soils form the critical link between atmosphere, land use and water quality by regulating the time span between rain falling on the land and reaching streams, rivers and aquifers. Not only does the soil store and transmit enormous quantities of water, but it also acts as a renovator and sink for pollutants.

High nutrient absorption capacity and pollutant assimilation are related to the Cation Exchange Capacity (CEC) and organic matter content of a soil, both of which increase the soil's capacity to absorb and assimilate chemical and organic inputs. Soils with high natural capital have high absorption capacity and primary production levels, and minimal adverse environmental impacts. Soils with lower natural capital, such as shallow and stony, or sandy soils have limited ability to store nutrients and water. Shallow or sandy soils require more frequent irrigation and additional nutrients for crop production to compensate for losses and inefficiencies. On these soils there are greater risks that soluble nutrients and pesticides will pass beyond the reach of plant roots and adversely affect water quality (Table 2).

105. An alternative approach to assuming land is the same is to recognise differences between soils and allocate the N-limit based on the soils' natural capital.

B. THE SCIENCE BEHIND THE NATURAL CAPITAL APPROACH

106. This is a new approach, for which direct methods for calculating a soil's natural capital are still in development. Dominati *et al*. (2009) proposed a draft framework for classifying and measuring soil natural capital and ecosystem services, based on current understanding of soil forming processes, soil taxonomy and classification, soil processes, and the links between climate and land use.

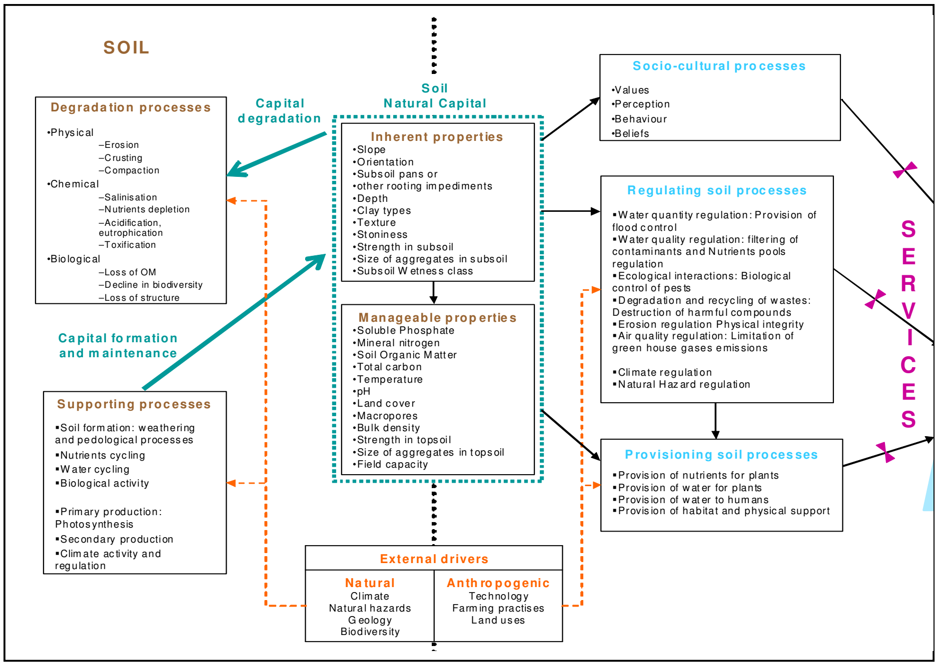


Figure 4. Draft framework for ecosystem services provision from soils' natural capital.

107. The framework shows how the natural capital of soils is embodied by soil properties, how supporting processes ensure the formation and maintenance of that capital, and how degradation processes influence natural capital depletion (Figure 4). A soil provides a range of provisioning services that contribute directly to productivity and economy (eg. nutrient and water supply, growing medium, physical structure for supporting plants and animals). They also provide a range of supporting regulating services (eg. nitrate and greenhouse gas emissions, temperature control, and flood protection). The framework of Dominat *et al.* (2009) also shows that soil services are end roles of ecosystems in the fulfilment of human needs. They are underpinned by provisioning and regulating processes that provide flows of goods or services. Sparling *et al.* (2005) attempted to place a monetary value on soil organic matter and Clothier *et al.* (2008) attempted to calculate the natural capital value of the ecosystem services provided by macro-pores in soils. Physical attributes, along with organic matter, regulate most soil services. Costanza *et al.* (1997) estimated the annual value of 17 terrestrial ecosystem services, all involving the soil-plant-atmosphere system, at US$5.74 trillion, which is about one third of the annual gross global economic productivity.

108. In the absence of a method for calculating a soil's natural capital, a proxy that serves as a useful alternate is the ability of the soil to sustain a legume-based pasture fixing N biologically under optimum management and before the introduction of additional technologies (eg. N fertilisers, effluent and manures, intensive cropping and irrigation). A legume-based pasture is a self-regulating biological system with an upper limit on the amount of N that can be fixed, retained, cycled and made available for plant growth. The legume pasture dry matter base provides one indicator of the underlying productive capacity of the soil. It includes the influence of new plant germplasm, phosphorus, sulphur and potassium fertilisers, lime inputs, trace elements and technologies to control pests and weeds. The legume pasture dry matter base also reflects the underlying capacity of soil to retain and supply nutrients and water, and the capacity of the soil to provide an environment to sustain legume and grass growth under the pressure of the grazing animal. The introduction of technologies, including irrigation, drainage, N fertiliser, wintering pads, off-farm grazing and imported feeds has the potential to lift pasture and livestock production levels significantly above the inherent productive capacity of a basic legume-based pasture system.

109. Estimates of the potential productive capacity of a legume-based pasture fixing N biologically under a "typical sheep and beef farming system" for each LUC unit in New Zealand are listed in the extended legend of the LUC worksheets under "attainable potential carrying capacity". The definition of the attainable potential carrying capacity is

the number of stock units per hectare capable of being carried on a particular LUC unit, assessed within the limits of the technology of the time (ie. 1980s) and given favourable socio-economic conditions. The definition was designed for typical sheep and beef farming systems (ie. not dairying, cropping or other systems). The technique used for establishing the attainable potential carrying capacity was based on an assessment of representative LUC units by advisory officers of the then Ministry of Agriculture and Fisheries together with NZ Land Resource Inventory specialists from the Land Resources Group (LRG) of the Ministry of Works and Development (LRG, 1981). For national consistency the following criteria were adhered to: 1) the land was assumed to be managed exclusively for livestock grazing; 2) only on-farm feed cropping was considered; 3) it was assumed livestock were carried all year, except for on the high country; and 4) it was assumed that each LUC unit was managed as a discrete entity.

Land Use Capability (LUC)

110. A background to the LUC classification system is provided in the evidence of Grant Douglas. Evidence here covers the use of the information contained within the extended legend of the LUC classification as a basis for quantifying the natural capital of soils. LUC classification is a transparent, robust, science-based approach that has been used to advance sustainable land development and management in New Zealand since 1952. It has national coverage and application. From the LUC survey handbook, LUC classification is defined as "*a systematic arrangement of different land according to those properties that determine its capacity for long-term sustained production*". Assessment of long-term sustained production using the LUC classification is based on an interpretation of the physical information in a Land Resource Inventory (LRI). This is compiled from a field assessment of rock type, soils, slope, erosion type and severities, and vegetation cover at any one location. The inventory is supplemented with information on climate, flood risk, erosion history and the effects of past practices and productivity indices for livestock and *Pinus radiata*. The five factors (ie. rock type, soils, slope, erosion type and severities, and vegetation cover) mentioned above are mapped simultaneously within the limits of scale. A new map unit is drawn whenever one of the physical factors alters. The 'art' of this form of appraisal is judging the degree of variability that is acceptable before creating a new unit.

111. At the broadest grouping, the LUC classification categorises land into eight classes according to long-term capability to sustain one or more productive uses. The general capability for sustained production of the eight LUC classes is summarised in Table 13 (page 77) in the 3rd edition of the LUC Survey Handbook (Lynn *et al.*, 2009). The five

factors collectively provide an insight into the long-term capability to sustain one or more productive uses. For example, assessing the risk of erosion is a product of slope, erosion risk and climate. Any one factor has limited value on its own. Productive capacity is a product of soil texture, drainage, stoniness, depth, climate, and slope. Again, any one factor has limited utility on its own. It is feasible to use the broadest grouping, LUC Class to define the potential for leaching losses and sorption capacity (pollutants, nutrients) of soils, based on information on soil texture, depth, stoniness, drainage, and climate. Webb & Wilson (1994) established that the majority of soils within LUC Classes II and II have high Profile Available Water (PAW) and Cation Exchange Capacity (CEC) (Table 1) and, as a consequence, would have a greater capacity to limit leaching and nutrient losses. Anion Storage Capacity (ASC) would range from low to high. The soils with very low ASC, often referred to as high P loss soils, would fall outside Classes I and II. Lilburne & Webb (2000) ran simulations of crop growth and nitrogen cycling to show that shallow soils (Class III soils) leach 2-3 times more nitrate than deep soils (Classes I and II) under dryland cropping.

112. Each LUC class can be further categorised, using one of four subclasses, based on the dominant limitation (ie. erodibility, wetness, soil, and climate). All four limitations have a major impact on long-term sustained production. For example, the wetness limitation is due to either a high water table, slow internal drainage, and/or frequent flooding. This limits plant growth through a lack of soil aeration. The soil limitation occurs where the major restriction is within the rooting depth, due to a shallow soil profile, stoniness, subsurface pan, poor soil texture and structural conditions, through to low water-holding capacity. The climate limitation can be a short growing season, inadequate or excess rainfall, frost and snow, through to exposure to strong winds. In Horizons' Region, erodibility is the single biggest limitation, followed by soil, wetness and lastly climate. This is shown in Figure 11 (page 82) in the 3rd edition of the LUC Survey Handbook (Lynn *et al.*, 2009).

113. The LUC unit is the most detailed component of the LUC classification. It is the management level in the classification and so the degree of detail depends on the scale of mapping, the intended purpose, etc. Information relevant to each LUC unit is documented in an extended legend. The legend includes a summary of Land Resource Inventory (LRI), climate, land use, factors influencing land use, and productivity indices. It is important to note that classification of land according to its capability for long-term production, based on its physical limitations and site-specific management, provides the most reliable basis on which to advance sustainable land management.

114. The productivity indices (ie. attainable potential carrying capacity) listed in the extended legend of the LUC worksheets, are based on the capability for long-term sheep and beef livestock production. Their use for calculating the natural capital of soils is a new application of the information in the extend legend. It reflects the evolving nature of sustainable land management, with the necessity to set limits on emissions from land to both air and water. In this case it concerns the emissions to water and specifically nitrate leaching losses beyond the root zone. It also demonstrates the potential utility of the information in the extended legend to advance sustainable land management. An attraction of the approach is that it is the basis for land development and evaluation in New Zealand, and the information in the extended legend is available throughout the country.

Calculation of the N loss limit

115. The N leaching loss limit for a given land unit can be calculated using the potential animal stocking rate that can be sustained by a legume-based pasture fixing N biologically, under optimum management and before the introduction of additional technologies. Using the land units listed in the extended legend of the LUC worksheets' '"attainable potential livestock carrying capacity" as a proxy for the soil's natural capital, stocking rates were transformed to pasture production and used in the OVERSEER® nutrient budget model to calculate N leaching loss under a pastoral use (Clothier *et al*., 2007).

116. For example, using the Upper Manawatu Water Management Zone (WMZ) as a case study, the N leaching losses of the soils in the catchment were calculated using the potential stocking rate that could be sustained by a well managed legume-based sward, taken from the extended legend of the LUC worksheets' "attainable potential livestock carrying capacity" for the North Island, as a proxy for natural capital of the soil in each LUC unit.

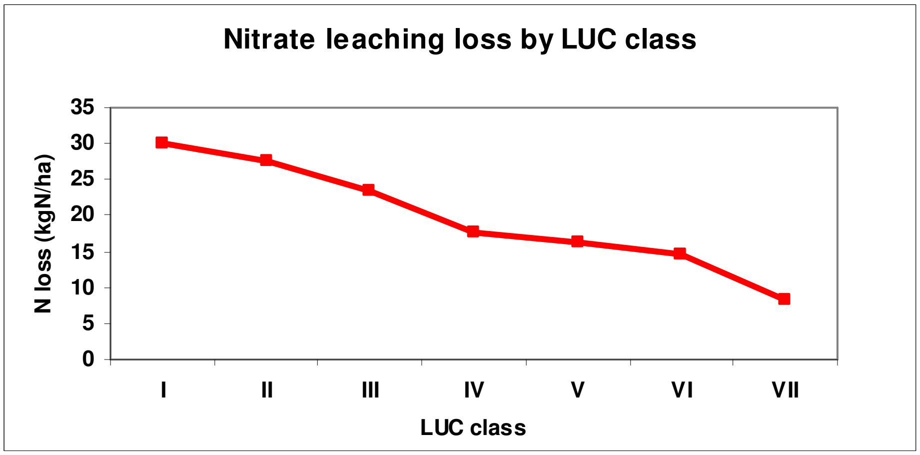


Figure 5. Nitrate leaching loss calculated using OVERSEER (developed dairy operation, annual rainfall 1,200 mm) associated with the potential livestock carrying capacity listed in the extended legend for LUC Classes I-VII in the North Island.

117. The potential livestock carrying capacities for the Upper Manawatu WMZ were transformed to pasture production and used in the OVERSEER nutrient budget model to calculate N leaching losses under a pastoral use. Figure 5 shows the N losses by leaching calculated from the OVERSEER model, summarised for LUC Classes I-VII for the North Island and used in the Upper Manawatu WMZ. As the limitations to use increase (ie. in Classes I to VII) the underlying productive capacity and ability of the soil to sustain a legume-based pasture system declines, as does the potential N leaching loss.

118. For LUC Classes I and II the calculated N leaching loss was 30 kgN/ha and 27.4 kgN/ha, decreasing to 23.5 kgN/ha and 17.5 kgN/ha for soils on Classes III and IV land. Nitrate leaching losses reported from dairy pastoral systems in New Zealand range from 15-115 kg-N/ha[1], with 40 kg-N/ha often used as an average value. (Meneer *et al.,* 2004) and Campbell (2009) from Environment Waikato also reported the value of 40 kgN/ha as the amount of N leached from a typical dairy farm in the Waikato Region. They indicated that in order to achieve the Regional Policy Statement objective of no net decline in water quality, that figure must be reduced to approximately 22-26 kgN/ha/yr. More than 70% of dairy farms in the Waikato Region are on Class I-IV land.

119. The landscape in the Upper Manawatu catchment is dominated by Class VI land, with sheep and beef the dominant land use in the sub-catchments above Weber Road If all the soils in the Upper Manawatu catchment were farmed at 90% of potential as listed in

the extended legend, and assuming a transmission coefficient of 0.5 for all land classes, the N loading in the river would be 921 tonnes annually. This is higher than its current N loading. The calculation in Table 3 was limited to the use of the potential production for the “average” soil in each LUC class.

120. When potential production is limited to 75% on all LUC classes, the resulting N load in the river is very close to the present loading (Table 3). A significant amount of the most intensively farmed Classes II and III land in the Upper Manawatu catchment would be currently operating above 75% of its potential, while a significant area of the Classes IV and VII land would be operating below 75% of its potential. . The N loss values in Table 3(column 5) provide an N leaching loss limit for each LUC class, above which mitigation would be required to prevent further contamination. If the long-term goal is a reduction on the current N loading in the river, then an adjustment can be made to the percentage of potential production that is permissible before a mitigation strategy must be initiated. The major strength of this approach is that in calculating the N leaching loss limit it considers the whole catchment and is not prescriptive. It is not linked to current land use, but rather linked to the underlying land resources in the catchment.

121. The natural capital based approach does not target a land use, intensity of use, or place a limit on inputs; rather it allocates N leaching loss limits to each landscape unit based on the biophysical potential of natural capital of the soils. It treats farms with the same land resources in the same manner regardless of current use (Figure 1). It disadvantages high input, highly productive farms on soils with little inherent natural capital (eg. sand country, gravels, steepland soil) to limit N leaching even when BMPs have been followed and in this regard could be regarded as inequitable (Anonymous, 2007b).

122. In catchments with no water quality problems at the present time, landowners can be provided with an indication of the level of production and associated N leaching loss that would be permissible before mitigation practices would have to become an integral part of ongoing farming practices.

123. The approach offers the opportunity to engage directly and in a very transparent way with landowners and the wider community in setting the targets. The driver for N leaching loss limits can be changed from resources efficiency to one that recognises the necessity to add greater flexibility to landscapes that have little natural capital and lack versatility in either land use options and/or mitigation strategies. The trade-off between

resource efficiency and retention of land use options is examined further in the last section of this evidence.

Table 3. Area of each LUC Class, calculated N loss associated with the potential productivity of the soils in each LUC class calculated using Overseer, and the contribution of the soils in each LUC class to the N loading in Upper Manawatu River, and average N loss per ha per year if each LUC class is farmed at 90% and 75% of potential.

LUC class	**Area (ha)**	**N Loss based on potential production (kgN/ha/yr)**	**Fraction of potential**	**Nitrate loss limit kgN/ha/yr**	**Transmission coefficient**	**Total N loading in river (kg N/yr)**	**Fraction of potential**	**Nitrate loss limit kgN/ha/yr**	**Transmission to efficient**	**Total N loading in river (kg N/yr)**
II	12,424	27.4	0.9	24.7	0.5	153,348	0.75	20.6	0.5	127,790
III	20,257	23.5	0.9	21.1	0.5	213,978	0.75	17.6	0.5	178,315
IV	11,508	17.5	0.9	15.8	0.5	90,729	0.75	13.1	0.5	75,608
V	907	16.3	0.9	14.7	0.5	6,666	0.75	12.3	0.5	5,555
VI	57,254	14.5	0.9	13.1	0.5	373,897	0.75	10.9	0.5	311,580
VII	22,108	8.3	0.9	7.5	0.5	82,431	0.75	6.2	0.5	68,693
VIII	5,180	0.0	0.9	0.0	0.5	0	0.75	0.0	0.5	0
Total	**129,638**					**921,049**				**767,541**

C. REFINEMENTS TO THE NATURAL CAPITAL APPROACH

124. The evidence in this section draws heavily on the report prepared by SLURI for Horizons titled Implementation of FARM strategies for contaminant management. Further questions (Mackay *et al.*, 2008). It addresses a series of specific questions on the calculation of the N loss limit and the implications of this for the N loading in the river.

How does the LUC model change if differing levels of detail are used?

125. The net result of utilising more detailed landscape and rainfall data in the calculation of N leaching losses is a more accurate picture of the contribution of each land unit to N leaching. This could be used to provide detail to assist landowners in the calculation of their N-loss limit and for making adjustments to Table 13.2 in the Proposed One Plan to ensure the dual desired outcomes of economic growth and improving water quality are realised.

LUC class, LUC subclass and LUC unit scales

126. Using the Upper Manawatu catchment as an example, the calculated N leaching loss at the LUC class, LUC subclass and LUC unit levels, using the average rainfall value for the catchment, produced the same N loadings in the river when summed for the whole catchment. In the calculation, the potential livestock carrying capacities at the LUC class and LUC subclass level were summed from data held on each LUC unit. There were large differences in calculated N leaching losses at the subclass scale and particularly at the unit scale, compared with the average for the class. This is highlighted in Figure 2 of the report by Mackay *et al*. (2008). The LUC class is the broadest grouping of the capability classification. It includes an assessment of the land's capability for use and takes into account its physical limitations and its versatility for sustained production. The LUC subclass is a subcategory of the class through which the main kind of physical limitation or hazard to use is identified. The unit is the most detailed component of the LUC classification system and groups together areas where similar land inventories have been mapped, which require the same management, are suitable for the same kind of use, and have similar potential yields. As one moves from the LUC class, to subclass and then to unit level, more information is available and used in classification.

127. When additional soil information (eg. drainage class), slope (eg. flat, rolling, hill, and steep) and rainfall beyond the average for the catchment (eg. in 200 mm bands across the catchment) are included in the calculation of the N leaching loss, the contribution

from each LUC unit changes (see Figure 2 of Mackay *et al.*, 2008). The N loading to the river also changes (see Figure 3 of Mackay *et al.,* 2008).

Rainfall

128. Annual rainfall in the Upper Manawatu catchment varies from 1,000 to 3,000 mm and the area weighted average rainfall is 1,357 mm. A closer examination of rainfall in the catchment reveals that the distribution is skewed to the hill and steep land landscape units. Use of an average rainfall value in the calculation of the N leaching loss will tend to overestimate the N leaching loss on the landscapes that receive less than the average rainfall, while underestimating the N leaching losses from the higher rainfall zones at the same level of fertility and stocking rate. Given the influence of rainfall on N leaching and its contribution to the N loading in the river, an average rainfall value for the catchment (1,357 mm) should not be used. Instead, a rainfall database held by the Regional Council should be used (see the evidence of Dr Jon Roygard).

Slope

129. N leaching losses increase with increasing slope. Inclusion of slope in the calculation of the N leaching loss and potential N loadings in the river, like rainfall, also provides more site-specific information on the biophysical factors contributing to N leaching loss.

Flat and rolling landscapes with hill and steep land

130. As a general rule, on flat and rolling landscapes within a catchment that also includes hill and steep land, adding more detailed biophysical information will reduce the calculated N leaching loss and loadings into the river from soils (assuming the same attenuation factor from land to river for all land units). This reduction in N leaching loss and loadings occurs as a consequence of the inclusion of less versatile soils (identified by more detailed mapping), use of actual rainfall (which is often lower than the catchment's average rainfall) and low slope classes. Inclusion of soil drainage class would either increase or reduce the calculated N leaching loss.

131. As a general rule in hill and steep land within a catchment that also includes flat and rolling country, adding more detailed biophysical information, will increase the N leaching loss and loadings into the river from soils (assuming the same attenuation factor from land to river for all land units). This increase in the N leaching loss and loadings occurs as a consequence of the inclusion of more versatile soils (identified by

more detailed mapping), use of actual rainfall (which is often higher than the catchment's average rainfall) and higher slope classes.

132. Inclusion of more detailed soil, landscape and climate information helps provide a more accurate description of the contribution to N leaching losses from landscape units; it is not about defining the N loading in the river, which is achieved by defining the percentage of potential attainable production of the land that can be farmed while still achieving the water quality outcome targets for that water body. On that basis, landowners should have the option of calculating their N leaching loss limit from the NZLRI or from more detailed biophysical resource information (eg. soil type, slope, drainage class, climate data, and production potential) to address spatial inaccuracies in the land resource information and the limitation of using average rainfall information.

133. The findings of the FARM strategy test farm project (Manderson & Mackay, 2008) evaluated the effect of using the NZLRI, which contains land information at a 1:50,000 scale, with that obtained by an on-farm survey, which could be at scales less than 1:5,000. It is worth noting that there is inherently more uncertainty in the available soils information for hill and steep land, suggesting that landowners on these landscapes should consider more detailed mapping before making a decision on the scale at which to calculate their N leaching loss limit.

How do mitigation options change with Land Use Capability class?

134. To address this question it is first necessary to introduce the following concepts with respect to the behaviour of soils within each class, in response to production technologies developed to overcome "limitations to use" on production levels and the environment.

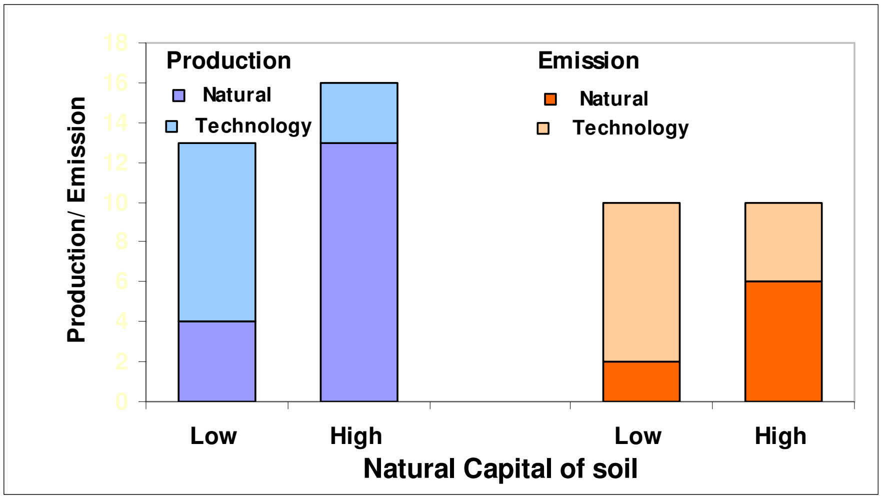


Figure 6. Production and emissions from a well managed legume pasture top dressed with P and sulphur fertiliser, before the introduction of production technologies (eg. irrigation) on soils of low and high natural capital (Ballantine & Mackay, 2008).

The ability to realise and sustain the productive potential of soils

135. Elite and versatile soils (Classes I and II) with high natural capital will produce more and require less input for output at a given level of production. Agricultural production on versatile soils (ie. with high natural capital) requires lower levels of inputs (eg. fossil fuels, fertilisers and irrigation water) per unit of output than soils with lower versatility (ie. with low natural capital). There is abundant evidence for differences in crop yield from different soils with the same inputs. For example, Webb & Purves (1983) demonstrated that there is a close relationship between soil depth and crop yield under dryland conditions. There is good evidence to show that nutrient response is influenced by the natural capital of a soil. Oberle & Keeney (1990) demonstrated that soils not rated as LUC Classes I or II required greater amounts of N fertiliser to obtain equivalent yields to those achieved by the better soils.

136. Soils with high natural capital for pastoral agriculture include those with deep silt loam textured, free-draining top soils (eg. yellow brown loams and brown soils). Soils with limited natural capital for pastoral agriculture include those with poorly developed structures (eg. podzol), shallow soil horizons and shallow plant rooting depth (eg. stony soils), weak cation and anion storage and supply capacities (eg. coastal sands) and low water holding capacity (eg. gravels, pumice). These soils with limited natural capital will require proportionately more inputs in their development and maintenance.

137. Soils with limited natural capital under particular land uses can sometimes attain a level of productivity equal to soil with high natural capital. For example, shallow soils under irrigation can attain pasture production and dairy production equal to production on versatile soils. For the production of a broad range of crops, soil with high natural capital represents land with the greatest soil quality, environmental protection, productive capacity, and highest life-supporting capacity.

138. The use of feed pads and stand-off areas when soils on LUC Classes I and II, and on Classes III and IV, are wet, means their productive capacity is not generally constrained by the physical limitations of the soils. However, this is not the case for soils found on LUC Classes VI and VII, where the physical integrity of the soil will often define the upper limit of production. Once a soil is at its potential, more resource will be required to sustain its physical integrity while maintaining plant numbers and vigour.

The environmental impact of a soil operating at its natural potential

139. Compared with elite soils, emissions (eg. N leaching losses) will be higher on coarse textured, weakly developed, stony soils and soils on slopes (Figure 6). This rule is not universal, because there will be trade-offs. For example, soils with weakly developed structures and poor drainage could potentially lose more N as nitrous oxide than as nitrate.

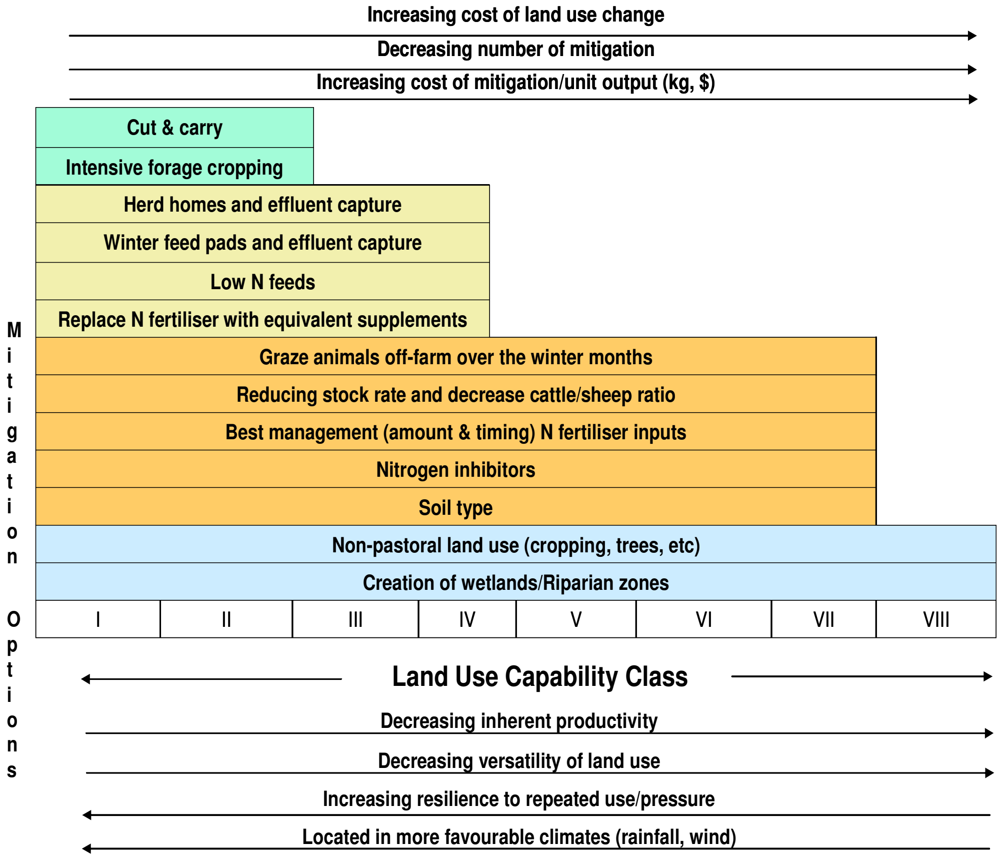


Figure 7. Number and alignment of the mitigation options with the soils in each LUC class

140. As a generalisation, the amount of product per unit of input will be greater, and the emissions resulting from the added production will be less on an elite soil (ie. with high natural capital), when comparing all soils at the same level of potential.

Production beyond the soil's natural capital

141. A number of very effective technologies are available (eg. cultivation, drainage and irrigation) to lift the productive capacity of soils on flat and rolling landscapes beyond their natural capital, compared with soils found in hill country and steep land. There are also more technologies available for sustaining production to compensate for the lack of natural capital of soils on flat and rolling landscapes (eg. feed pads and N fertiliser). The cost of technologies generally increases, as does the production benefit, as the natural capital of a soil declines.

Mitigating nitrogen losses in soils operating beyond their natural productive capacity

142. Technologies (eg. cultivation, drainage and irrigation) used as substitutes for the lack of productive capacity (eg. weakly developed soil structure, limited profile available water) of soils will lead to increased N loss, through a combination of increased production and greater leaching volumes. The number and efficacy of mitigation options for compensating for the limited capacity of soils to retain N in the topsoil horizons declines as the natural capital of soils becomes more limited. Soils on which production technologies have their biggest impact on production levels will also be those landscapes that provide the greatest challenge in mitigating N leaching losses.

Relationship between mitigation options and the natural capital of soils, grouped by LUC class

143. A summary of the mitigation options available and the alignment of the mitigation options with the soils in each of the LUC classes is presented in Figure 7. The number of mitigation options decreases as the producer moves from soils in LUC Classes I and II to those in Classes III and greater. The absolute cost of mitigation (eg. application costs) and/or the cost of mitigation as a function of production, and income from land, increases as the limitations to use increase. The findings from the FARMs test farms project (Manderson & Mackay, 2008) demonstrate that the effectiveness, suitability, cost and acceptability of each mitigation option varies between farms. Evidence will be presented by a number of other experts on mitigation options, their efficiency and cost effectiveness.

144. From a purely biophysical stance, landowners on elite soils have no limitations to use and hence flexibility in their choice of land uses. Landowners on elite soils have available to them the full range of mitigation options. In comparison, on all other soils, the mitigation tool box will be less effective. As the natural capital of the soil declines, the available land use options decline, as does the range and cost competitiveness of the mitigation options.

145. If the question is limited to, “What is the most efficient use of resources with the least environmental impact?” the N leaching loss limit should be weighted towards those soils with the greatest natural capital.

146. If the goal is to sustain rural communities into the future, a case for allocating a higher N loss limit to soils with little natural capital would be required, in order to retain the limited land use options and flexibility available for landowners on these landscapes.

Catchment level outcomes of Table 13.2 of the Proposed One Plan

147. This section explores what the N loss limits would have to be to achieve the absolute standard in this time frame set out in the POP, examines if the absolute water quality standard is achievable by on-farm management utilising available best management practice; examines if it is appropriate to have a single table for nitrogen loss limits for all catchments and if not what are the values in Table 13.2 of the Proposed One Plan appropriate for conversion to intensive land uses as well as in target catchments in reference to test farms.

What would the values have to look like to achieve the absolute standard in this timeframe set out in the POP?

148. Using the Upper Manawatu catchment as an example, the N loss limit permissible to achieve the river's long-term water quality target, as set in the Proposed One Plan, of 358,000 kg N is under 6 kg N/ha if all land is treated the same and assuming an attenuation of 0.5 from land to water. Bringing that analysis back to the initial water quality targets set for Year 1 of the Proposed One Plan for the Upper Manawatu River (859,000 kg N) and again treating all land the same, the N leaching loss limit for each hectare would be 13.2 kg N/ha, again assuming an attenuation of 0.5 from land to water in each catchment. If all the land within the Upper Manawatu catchment was operating at 75% of potential production, and assuming an attenuation factor of 0.5, then the N loading would be 1,004,000 kg N, which is 1.17 times the immediate N loading limit set for the Upper Manawatu Water Management Zone (ie. 859,000 kg N) and 2.8 times the long-term N loading limit set for the UMWMZ (ie. 358,000 kg N) by Horizons in consultation with community.

Is the absolute water quality standard achievable by management on farm using available best management practice?

149. Management on farm using best management practices available would not be able to achieve the long-term water quality target set for Upper Manawatu River in the Proposed One Plan of 358,000 kg N, which is under 6 kg N/ha if all land is treated the

same and assuming an attenuation of 0.5 from land to water. Other evidence covers what reductions are possible and at what cost.

150. Attempting to achieve the absolute water quality standard would cause massive upheaval, because it would require massive changes to current land uses. The only land uses that could continue unchanged would be land under native or exotic forest, scrubland and extensive sheep and beef. For intensive livestock, radical changes would be required. For example, the only mitigation option that would come close to the achieving the required target would be shifting from grazing *in situ* to a 100% cut-and-carry system with animals fed on a pad where all dung and urine was collected.

Is it appropriate to have a single table for nitrogen loss limits for all catchments? If not then why not?

151. The structure of Table 13.2 of the Proposed One Plan would remain the same, as would the process used to populate the table. Adjustments to the table would be in recognition of the changes in the soils and landscape units and rainfall zones as new catchments were brought in and covered by Rule 13-1 of the Proposed One Plan. A comparison of the Upper Manawatu and Mangatainoka Water Management Zones provides an example to reinforce this point. Both the topography (ie. landscape units and slopes) and soil types (ie. drainage classes) in the Upper Manawatu vary significantly from those found in the Mangatainoka catchment. The Upper Manawatu catchment is dominated by Class VI land, whereas the Mangatainoka catchment has significant areas (18,500 ha) of flat and rolling landscape units. Average annual rainfall in the Upper Manawatu is 1,357 mm (range 1,000-3000 mm) compared with 1,789 mm (range 1,000-3,500 mm) for the Mangatainoka. All of these factors affect N leaching losses and N loading. Adjustments would be required in the N loss values in the Table in recognition of the differences in the areal extent of soils and in rainfall between catchments. The structure of Table 13.2 would remain the same, as would the catchment management planning process.

Are the values in Table 13.2 of the Proposed One Plan appropriate for conversion to intensive land uses as well as in target catchments, in reference to FARMs test farms?

152. In the first instance, the N loss limit values in Table 13.2 of the Proposed One Plan for the target catchments would be appropriate for defining thresholds for land being converted to an intensive land use in landscapes outside the target catchments. As the

proportion of land under intensive land use expanded a catchment management plan would need to be developed. The catchment management plan would include the following tasks (see Figure 8):

Task 1: **Inventories.** The boundaries and area of the Water Management Zone (WMZ), NZLRI database, including the worksheets containing the extended legend, major land uses and areas in non-agricultural use, list of point source discharge points and quantities, and rainfall in 200 mm isohyets for the WMZ.

Task 2: **Community of interest.** Identify landowners in the WMZ who are interested in acting as test farms to establish the challenges and opportunities; establish a WMZ based community-of-interest group to discuss the proposed targets, timescale and roll-out; engage with key stakeholder (eg. sectors and service providers); review the FARM strategy to ensure all issues are adequately covered and all mitigation options listed are available.

Task 3: **Nitrogen loading, targets and farm N losses.** Summary of the river's flow rates, lake volumes/levels, inflow rates, resident times, outfall rates and N concentrations in water in each water body; this information is used to calculate the N loadings in the WMZ. (The framework report by Roygard & McArthur (2008) provides a methodology for this task, current nitrogen loading for the WMZ, the standard (nitrogen loading target) and justifications for the standard for the WMZ. Also list the nitrogen leaching loss from each of the major land uses in the WMZ and from point discharges.

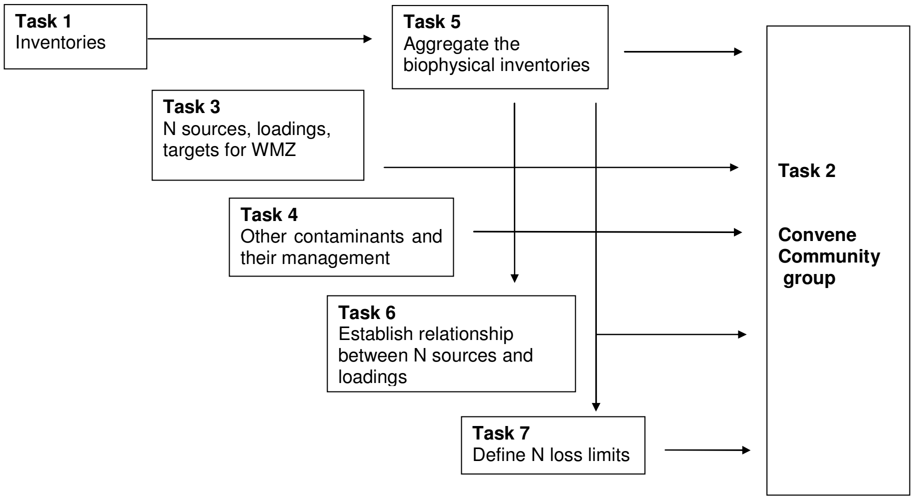


Figure 8. Schematic diagram of the tasks to develop a catchment management plan

Task 4: Other contaminants and their management. List other potential contaminants contributing to poor water quality (eg. sediment, P and faecal matter) in the WMZ, and current levels of contamination; list current and future mitigation options (eg. Clean Streams Accord and Whole farm Plans) for the WMZ.

Task 5: Aggregate the biophysical inventories. List the areas (in hectares) and potential productivity of each LUC class, subclass and unit in the WMZ; list the areas (ha), potential productivity, drainage class and slope of all LUC units in the WMZ catchment; describe rainfall in 200 mm isohyets for the WMZ and develop a set of rules defining the rainfall bands (eg. for the Upper Manawatu WMZ)

Task 6: Calculate N loading in the river from each land use, transmission coefficient and the potential N loss limit for each land unit. In catchments with multiple N water quality sampling sites, calculate the contribution from the major land use to the N loading in the water body. If that is not available, use the N loading values from existing catchments, establish the transmission coefficient by calculating the N loss for each land use using OVERSEER, and expressing it as a percentage of the N loading in the river for each land use. If that is not available, use the transmission coefficient values from existing catchments and calculate the N leaching loss limit for each soil in the catchment, using OVERSEER, by LUC class, subclass and unit, and for each unit, using detailed biophysical and rainfall data.

Task 7: Establish the N loss limit for each land unit. Establish the relationship between the potential N loss limit for each LUC class, subclass and unit, and for each unit, using detailed biophysical and rainfall data and the N loadings in the river, calculate the percentage of potential use of each land unit that is permissible to achieve the current N loading, and the rate of change required in the potential use of each land unit each year to move towards the standard (ie. N loading target for the WMZ) over time. Include data to demonstrate the influence of a differential percentage of potential use for each land unit in achieving the N loading target.

153. Catchment planning would be initiated as the proportion of land under intensive land use expanded to ensure the required water quality outcomes are achievable and at the same time retaining ongoing growth and land use options.

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