Review of, and recommendations for, the proposed New Zealand Cadmium Management Strategy and Tiered Fertiliser Management System

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1. Executive Summary

The application of phosphatic fertilisers to agricultural soils is vital to the ongoing success of New Zealand agriculture. Yet, these fertilisers contain contaminants including cadmium (Cd) and thus there is the potential for harmful effects to occur to agricultural production systems, the environment and human health. The Cadmium Working Group (CWG) was established to address the potential issue of increasing Cd concentrations. The CWG developed a Cadmium Management Strategy (CMS), a key component of which is the Tiered Fertiliser Management System (TFMS). The purpose of the current project was to review the CMS and the TFMS and to address a specific set of Terms of Reference including providing recommendations for the limits (‘a’, ‘b’ and ‘c’) that are central to the TFMS.

The key recommendations of this project are:

- That the TFMS is an appropriate means to address the issue of Cd in New Zealand agricultural soils and produce and maintaining the sustainability of these soils;
- The ‘a’ limit should be the 99th percentile of the New Zealand background soil concentrations of Cd which is 0.6 mg Cd/kg;
- The ‘b’ limit should be 1.0 mg Cd/kg;
- The ‘c’ limit should be 1.8 mg Cd/kg;
- An additional limit termed ‘b2’ which is 1.4 mg Cd/kg is also recommended. Farms that have soil Cd concentrations greater than this limit should have the absolute minimum amount of phosphatic fertiliser added to them during the interim seven year period that will permit the average yield of that crop in that region to grow.
- That two different sampling depths be used in the screening assessment of Cd soil concentrations. These are 0 – 7.5 cm depth for non- or irregularly cultivated[1] agricultural land and 0 – 15 cm depth for regularly cultivated land[2]. Irrespective of the above generalisation the sampling depth to be used in screening assessments is that typically used for soil fertility work for the agricultural sector in question;
- That the two depths used in the screening assessment also be used in the definitive assessment of soil Cd concentrations;
- That the Regional Councils modify their soil sampling strategies so that at no additional cost they can develop relationships between the Cd soil concentrations based on 0 – 7.5 cm, 0 – 10 cm and 0 – 15 cm depth samples.

In addition, to addressing the Terms of Reference a number of additional recommendations were made that relate to the TFMS and CMS in general. These are that:

- explicit guidance needs to be provided on how to determine if a particular limit has been exceeded;
- the TFMS be a highly flexible framework which encourages or at least provides stakeholders with the opportunity to undertake further, more intensive, rigorous and environmentally realistic sampling and analyses;
- a method for archiving the Cd soil concentration data be developed and in doing this the issues of privacy and reasonable public access should be considered;
- it would be very beneficial if information on Cd could be included in the training systems of existing instruments such as the Overseer training and into the NZ GAP program;

[1] Land that is not subject to vertical mixing of the soil or only undergoes mixing infrequently (once every 5 – 10 years). Examples would be dairy pasture and fruit and nut crops.
[2] Land that is subject to vertical mixing of the soil by any means (e.g., ploughing) at least once every two years. An example would be vegetable production.

- more complex and realistic models, such as critical load models be used to determine modified management practices as these permit the assessment of future risk due to continued inputs.
- site-specific risk assessments be permitted once limit 'c' is reached or exceeded and that the results of this form the basis for decisions on whether further phosphatic fertiliser and Cd additions are permitted.
- the research undertaken in the seven year 'interim' period should aim to develop soil-specific soil quality guidelines.

2. Background

As a result of concerns about cadmium (Cd) in agricultural soils and produce New Zealand established a Cadmium Working Group (CWG) consisting of representatives of New Zealand Government Departments, Regional Councils, the Fertiliser Industry and agricultural organisations. The CWG wrote a report which summarised the current situation regarding Cd in agriculture soils and produce (CWG, 2008). Dr Michael Warne (Centre for Environmental Contaminants Research, CSIRO) was approached by Dr Gerald Rys (Senior Scientist, New Zealand Ministry of Agriculture and Forestry) to review this report (Warne, 2007). Subsequently, the CWG developed a Cadmium Management Strategy (CMS) (MAF, 2010) which outlines a method of maintaining the long-term sustainability of New Zealand agriculture with regard to Cd contamination. The CMS includes as a component a Tiered Fertiliser Management System (TFMS). Dr Warne was employed to review the CMS including the TFMS. The review was to address a set of Terms of References (Attachment 1). This report provides the responses to the Terms of Reference. The structure of this report will be that each term of reference will be stated (in italics) and this will then be followed by the response. Some additional comments related to the CMS and TFMS that address issues other than those covered by the Terms of Reference are also included.

3. Responses to the Terms of Reference

3.1 FIRST TERM OF REFERENCE

To provide your expert opinion on whether the tiered fertiliser management system would be an appropriate approach for the purposes of:

- providing long-term (sustainable) protection of soil health,

I believe that the TFMS is an excellent means of managing the potential issue of Cd in New Zealand agricultural soils and produce. The proposed TFMS with its three limits (a, b and c) and four levels has been designed so that it should take farmers a period of at least 50 years to proceed from level two to level three (exceeding the 'b' limit) and another fifty years to proceed from level three to level four (exceeding the 'c' limit). However, the TFMS is sufficiently flexible that this period could be extended or reduced as desired. Thus, the TFMS aims to maintain the long-term health and viability of New Zealand's agricultural soils. While 100 years may not seem that long – it is a long-term goal in terms of managing a resource. The key to the success of the TFMS is the selection of the limits and providing a flexible system that sets default minimum standards but encourages and rewards stakeholders that do further more detailed work. Another key to the success of the TFMS will be having data available to monitor how the Cd soil concentrations are tracking over time and to determine if the desired period of protection will be achieved or if further more stringent management practices may need to be implemented. The CMS (MAF, 2009), which supports the TFMS, will play an important role in educating stakeholders about the potential issue of Cd and this will facilitate changes is farming practices to achieve the long-term sustainability of New Zealand agricultural soils.

- **ensuring that cadmium levels continue to remain within a range which is acceptable for sustainable agricultural production in the next seven years**.

  The TFMS provides a framework that will enable New Zealand to ensure that cadmium concentrations remain within an acceptable range. Environment Waikato (Environment Waikato, 2010) has estimated that on average soil Cd concentrations increase by 7 µg Cd/kg/year. Similar estimates of Cd accumulation ranging from 4.3 to 6.6 µg Cd/kg/yr have been determined (CWG, 2008). Therefore, in the seven year before the final limit 'a' will be derived on average soil Cd concentrations will increase by approximately 30 to 49 µg Cd/kg. Given, that background concentrations of Cd in New Zealand range upto approximately 800 µg/kg and the 99 %ile is 600 µg/kg these potential increases are not large.

  The key to ensuring that the Cd concentrations remain within an acceptable range during the 'interim' seven year period is the selection of 'interim' values for the 'a', 'b' and 'c' limits. To achieve this aim it would probably be best to err on the conservative side and have interim values for 'a', 'b' and 'c' that are likely to be lower than those that would be generated during the 'interim' period. However, it is not possible to know exactly what values will be generated, as little is known about the sensitivity of New Zealand organisms (Cavanagh and O'Halloran, 2006). The issue of selecting values for the 'a', 'b' and 'c' limits is dealt with in detail later in this report.

- **ensuring that cadmium levels do not restrict any foreseeable future land use**

  I do not see that any method, short of removing all Cd from New Zealand agricultural soils would be able to achieve the aim of not restricting any foreseeable future land use. This is partly due to the terms being used. What one person may deem foreseeable another might not. Another reason is that with time new discoveries are made and scientific knowledge develops that often, but not always, leads to lower limits for contaminants being developed. Also increasingly, non-science based arguments are affecting farming practices through trade barriers – for example consumer concerns about clean produce are leading companies to develop their own guidelines and limits.

  Basing the 'b' and 'c' limits on SQGs for human and environmental health that consider all potential exposure pathways would as far as possible, given the provisos in the preceding paragraph, protect future land-uses. If, however, the limits are based on SQGs that do not consider all potential exposure pathways then the ability to protect all foreseeable land uses may decrease. Whether the ability to protect all foreseeable land uses decreases or not depends on how important the unconsidered exposure pathways are. The ability to protect future land uses would not be affected if all the pathways that are currently not considered, turn out to not be less sensitive than the considered pathways. Conversely, if an unconsidered pathway turns out to be more sensitive than the considered pathways, then the ability to protect for all foreseeable land uses may be compromised. It is therefore important that the best possible SQGs are used to set the final 'b' and 'c' values.

Despite the limitations stated above I believe that the TFMS provides a rigorous management framework that is scientifically based and that is probably the best way to not restrict foreseeable future land uses.

It is the potential receptors, the potential exposure pathways associated with each land use and the level of protection that is desired that determines the appropriate magnitude of the Cd soil quality guidelines. Some jurisdictions have adopted a multifunctional approach so that the lowest guideline for all land-uses is adopted so that all land-uses are protected now and into the future (e.g. the Netherlands). Other jurisdictions have adopted a land-use based approach in which each land use has its own set of guidelines. It is typically assumed in residential land uses that there is a house on the land, the inhibitants can have direct contact with the soil and it may or may not assume that a certain percentage (typically 10%) of the food consumed by the inhabitants was grown on site. Therefore, the contribution of food to the guideline in residential scenarios is relatively small. The same assumptions apply to agricultural settings but in addition all of the food that is produced is consumed somewhere therefore the contribution of food to the guideline will be considerably larger than in the residuential land use and therefore the agricultural soil quality guideline is likely to be lower than the residential guideline. This is certainly the case with the Canadian soil quality guidelines for Cd (the agricultural guideline is 1.4 mg/kg while that for residential/parkland and commercial/industrial are 10 and 22 mg/kg respectively). Therefore, at least in the case of Cd by adopting the agricultural land use soil quality guideline other land uses (at least residential/parkland and commercial/industrial) are also being protected.

The TFMS also has a range of features which add to its overall strength and ability to address the potential issue of Cd in New Zealand agricultural soils. These are that it:

1. Is risk-based

In the vast majority of developed nations, risk-based approaches are the standard way of dealing with environmental issues including contaminants. This approach acknowledges that all human activities have some adverse environmental impacts, that decisions have to be made that balance out human benefits against environmental harm and that it is impossible to ensure the environment does not face any risk without compromising current living standards and future development. Examples of the risk-based approach being incorporated into environmental management include the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ, 2000), the Australian and New Zealand Food Quality Standards (FSANZ, 2005), the Proposed New Zealand National Environmental Standards for Assessing and Managing Contaminants in Soils (MfE, 2010a), Soil Quality Guidelines to protect the ecology derived for Regional Councils (e.g., Cavanagh 2006a; Cavanagh and O’Halloran, 2006;), the guidelines for biosolids amended soils developed by the Australian National Biosolids Research Program (Warne et al., 2007), the proposed Australian soil quality guidelines for contaminated sites (Heemsbergen et al., 2008; Warne et al., 2009) and conducting risk assessments of contaminated sites.

2. Is tiered

The tiered approach means that the severity of the fertiliser/Cd management options reflect the risk that the soil Cd poses to human and environmental health. The tiered approach also rewards those that are pro-active and take the most sustainable approach to managing their farms.

3. Is flexible

The method is not prescriptive and therefore there are a range of management strategies available for farmers to select. It places the emphasis on achieving the desired goal rather than on the means of obtaining the goal. This flexibility should also increase stakeholder ownership of the decisions and outcomes.

4. Involves all the major stakeholders

Farmers, the fertiliser industry, Regional Councils New Zealand government departments will all be involved in the successful implementation of the TFMS. This is appropriate as these are the stakeholders who will be most affected by implementation of the TFMS. Omitting any one of these stakeholders would be greatly increase the likelihood of the TFMS failing.

5. Builds on existing systems

The recommended TFMS has two types of sampling procedures: a screening assessment and a definitive assessment. Both of these will be taking advantage of the existing soil sampling services provided to farmers by the Fertiliser Industry. These monitoring programs are well designed, have appropriate methodologies and quality assurance and quality control procedures and are accepted.

However, additional more detailed information on these sampling methods should be provided as part of the TFMS. In addition, it would be beneficial if simple to use software programs or Excel® spreadsheets were developed to permit assessment of the best management practices to adopt. For example, the existing Cd balance® program could be modified for this purpose and then added to the Overseer® model. The advantage of this being that Overseer® is universally accepted, used and understood within New Zealand.

6. Is consistent with the New Zealand Cadmium Management Strategy

Having read both the NZ CMS (MAF, 2009) and the TFMS I believe that the TFMS is entirely consistent with the intent of the NZ CMS and will meet the aims of the NZ CMS.

7. **Is consistent with the New Zealand regulatory and policy framework**

The TFMS is consistent with the Resource Management Act (RMA) which is the main regulatory implement for the control of contaminants in New Zealand. The purpose of the RMA is to

> "promote the sustainable management of natural and physical resources"
> (RMA, Part 2 Purpose and Principles, 5 Purpose, 1)

and to protect both human health and ecosystems (RMA, Part 2 Purpose and Principles, 5 Purpose, 2). It is for this reason that the Proposed National Environmental Standards (MfE, 2010a) have been developed. The establishment of the CWG and development of 'a', 'b' and 'c' limits is consistent with this approach.

8. Acknowledges limitations in the current data and information and proposes a seven year period in which an interim approach will be used with the aim of conducting research to develop limits based on New Zealand data

New Zealand, like Australia, has many unique and emblematic native flora and fauna. There is a "paucity of data relating to New Zealand soils or organisms" (Cavanagh and O'Halloran, 2006, p. 6). It is possible that deriving SQGs without New Zealand toxicity data may not provide the desired level of protection to New Zealand soils and organisms. It is therefore very important that during the seven year 'interim' period that research on the environments impacts of Cd on New Zealand soils and organisms be conducted.

Similarly, there may be issues relating to the human health impacts of Cd that are unique to New Zealand for example: different diets, exposure pathways, and populations with different sensitivities. Two Ministry for the Environment reports (MfE, 2010a, b) have assessed whether overseas data are adequate and appropriate, however further reseach may be necessary during the interim phase. Any such research needs to be carefully co-ordinated and designed in order to address the key issues at the appropriate scale and with appropriate detail. Ensuring the funding necessary for this in a timeframe that will permit the work to be completed within the seven year 'interim' period is a crucial part of the NZ CMS.

9. It is addressing the potential issue of Cd before it becomes a problem and the aim is to prevent Cd becoming a problem

Whilst there may currently be individual farms or portions of farms in New Zealand where Cd soil concentrations are well above the natural background concentrations and approaching concentrations that may cause concern, overall this is not the case. Agriculture is vital to the economy of New Zealand and it is therefore absolutely essential that the potential issue of Cd is managed effectively before it becomes a problem. Having highly contaminated farms would be detrimental to the image of New Zealand agricultural produce and would adversely affect sales.

In addition, at present all phosphatic fertilisers contain Cd and therefore it is not possible to obtain the benefits associated with phosphatic fertiliser use without introducing Cd. Therefore it is important that stakeholders become aware of this potential issue and its ramifications should their soil Cd concentrations become too high.

10. Aims to provide long-term (at least 100 years) protection

The NZ CMS and the TFMS both take a long-term approach to the Cd issue. This is essential because once the Cd is introduced to a soil it will remain there essentially forever and will have implications not just to this generation but future generations.

11, Could be adopted, with appropriate modifications, for other contaminant issues in agricultural soils

The TFMS is a framework for addressing contaminant issues. It could equally be applied to other contaminants in agricultural soils or to contaminants in other environmental compartments (e.g. water or sediment) in order to manage their concentrations.

12. Indirectly will also address the issue of other contaminants in mineral fertilisers being added to agricultural soils

Mineral fertilisers are not merely contaminated by Cd, but by a variety of other contaminants including chromium, fluorine, lead and nickel (Sorvaari et al., 2009). By controlling the inputs of Cd from phosphatic fertilisers, the addition of all other contaminants present in phosphatic fertilisers will also be controlled and reduced. However, without a similar TFMS for the other contaminants in phosphatic fertilisers these contaminants will not be directly managed. The other contaminant that raises concern in phosphatic fertilisers is fluorine and in the future it may be warranted to develop a TFMS for it.

3.2 SECOND TERM OF REFERENCE

To provide your expert opinion on the alternative "a", "b" and "c" values that have been proposed to define the management tiers in the context of the purpose for which each values would be used.

Two sets of limits have been proposed and presented for review. The first was that proposed by the Fertiliser Industry while a second set has been proposed by Environment Waikato (Table 1). The merits of the proposed values for each limit will be discussed separately. Then alternative values for the limits will be discussed and recommendations made.

Table 1. The cut-off limits proposed by various proponents for the tiered fertiliser management scheme (TFMS).

Type of limit	Fertiliser Industry proposed limit	Source of proposed limit	Environment Waikato proposed limit	Source of proposed limit
a	0.8	Max natural background concentrations1	0.6	99% percentile of natural background concentrations1
b	1.4	Canadian SQG (human and ecological)	1.0	NZ biosolids guideline
c	3.8	Canadian SQG (ecological)	1.4	Canadian SQG (human and ecological)

1. Both of these proposed 'a' limits are based upon the cadmium soil concentration data collated in Taylor et al., 2007.

3.2.1 Limit 'a'

The Fertiliser Industry proposed 'a' limit is 0.8 mg/kg which is based on the maximum recorded NZ natural background Cd soil concentration, that had been rounded up from 0.77 mg/kg. There is disagreement amongst members of the CWG on the reliability of some of the highest 'natural background concentrations' due to potential contamination by phosphatic fertilisers. Irrespective of the preceding argument, using the highest recorded natural background approach is not a conservative approach (one that favours the environment). An alternative would be to use a percentile of the natural background concentrations. Widely used percentiles in environmental management and regulation include the 50^{th}, 90^{th}, 95^{th} and 99^{th}. The percentile approach was used by Environment Waikato (EW) that proposed the 'a' value be the 99th percentile of NZ environmental background concentrations which corresponds to 0.6 mg Cd/kg.

In determining what percentile of the background Cd concentrations should be adopted four factors were considered. These are:

- How quickly from the date of implementing the TFMS one wishes farmers to commence managing Cd inputs. Choosing a low 'a' limit will mean more farmers have to commence managing Cd inputs to their soils earlier than if a higher 'a' limit is chosen.
- How rapidly the management actions need to reduce Cd inputs in order to deliver the aimed for 100 years protection. The higher the 'a' value is set, the smaller the concentration can increase before reaching limit 'b' and ultimately 'c'. If the aim of taking 50 years for Cd soil concentrations to increase from level 'a' to 'b' and another 50 years from 'b' to 'c' is to be met, then having a higher 'a' cut-off value will mean tighter restrictions on the application of phosphatic fertilisers with potential implications for yields and profitability;
- The potential costs associated with there being differences between the interim and final 'a' limits. If the final 'a' limit is higher than the interim 'a' limit then some farmers will have had to limit Cd and fertiliser inputs that could potentially result in decreased yields and profitability. If however, the final 'a' limit is lower than the interim limit then the farmers will not have suffered any potential yield and financial loses but may immediately have to commence limiting Cd and fertiliser inputs. The latter option is potentially worse for the environment, as soil Cd concentrations will continue to increase during the seven year 'interim' period before the final limit 'a' is derived. However, Environment Waikato (2010) have estimated that the average annual increase in soil Cd concentration is only 7 µg Cd/kg/year and similar estimates are reported in the CWG report (CWG, 2008).

Therefore, in the seven years before the final limit 'a' will be derived on average soil Cd concentrations will increase by 30 to 49 µg Cd/kg.
- Resistance to, and problems with, changing the limit. It is quite likely that the final 'a' limit will be different to the interim 'a' value. From both a regulatory and user point of view a decrease would not be viewed favourably. It would probably be easier to manage the situation and explain the change if the final 'a' limit was larger than the interim.

Overall, I do not believe that the exact value of the 'a' limit makes a huge difference, as it is only the starting point for the TFMS. Having considered all the preceding information and arguments I believe that either the 95 or 99 percentile of the NZ background soil Cd concentrations would be appropriate as the 'a' limit. This would minimise the number of farms that would immediately have to commence managing Cd and fertiliser inputs, but would still provide an incentive for farmers to be aware of the CMS and its potential implications for them.

3.2.2 Limit 'b'

The Fertiliser Industry recommended a value of 1.4 mg/kg be adopted for the 'b' limit. This value is both the final Canadian SQG (the lower of the SQGs for human health and ecological health) and the Canadian human health SQG (based on soil ingestion). Thus, in the view of Environment Canada this value provides sufficient protection of both human and environmental health. Higher concentrations will not provide the desired degree of protection. However, it should be noted that the human health SQG only accounts for the soil ingestion and soil – plant – human exposure pathways (CCME, 1999). Specifically it does not consider off-site migration to groundwater nor the soil – agriculture produce (e.g., kidney and liver in ruminants[3]) exposure pathway (CCME, 1999) which it states should be considered on a site specific basis.

Environment Waikato proposed a 'b' value of 1 mg/kg which was obtained from two sources: the New Zealand Biosolids guideline (NZWWA, 2003) and a study by Cavanagh and O'Halloran (2006). In both of these documents the majority of the information used to derive the recommended limit of 1 mg/kg was not from New Zealand. In addition, the limit derived by Cavanagh and O'Halloran (2006) only considers on-site ecological receptors (off-site impacts to aquatic ecosystems were not included). However, the authors state that the proposed limit 'will also provide protection of off-site aquatic receptors, as minimal dilution of eroded soil would be required to meet sediment quality criteria" (Cavanagh and O'Halloran, 2006, p.37). This comparison was only made to sediment quality guidelines and not water quality guidelines, so how protective the proposed limit would be for aquatic ecosystems is still questionable. A further limitation of this study is that it does not consider human health issues. Nonetheless, it provides a risk-based estimate of the soil concentration of Cd below which there is minimal risk.

It is not clear exactly how the NZ biosolids guideline for Cd was derived. It is stated that the lowest observed adverse effect concentration (LOAEC) was preferred (NZWWA, 2003) and that the limit was set "primarily to minimise Cd concentrations in animal and crop products and to avoid international barriers to trade" (NZWWA, 2003, p 116). In addition it "should also protect the microbial population of the soil (Chandler et al., 1995), and should not result in significant leaching of Cd from the soil to groundwater" (NZWWA, 2003, p. 116). However, they later state the data for Cd leaching from field soils are scarce.

[3] The uptake of Cd into ruminants is concentrated predominantly into the kidney and livers. However, this issue is effectively addressed through an existing New Zealand program where kidneys and livers of ruminants older than 30 months are destroyed and do not enter the marketplace.

3.2.3 Limit 'c'

The Fertiliser Industry proposed 'c' value of 3.8 mg/kg is the Canadian SQG for ecological health and therefore does not provide what the Canadians consider an appropriate level of protection to human health (as the human health based SQG is 1.4 mg/kg). The Resource Management Act (RMA) states that the purpose of the Act is to

> "promote the sustainable management of natural and physical resources" (RMA, Part 2 Purpose and Principles, 5 Purpose, 1)

where sustainable management was defined as

> "managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural wellbeing and for their health and safety while –
>
> (a) sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; and
>
> (b) safeguarding the life-supporting capacity of air, water, soil and ecosystems: and
>
> (c) avoiding, remedying, or managing any adverse effects of activities on the environment"
>
> (RMA, Part 2 Purpose and Principles, 5 Purpose, 2)

Thus the RMA adopts a very broad view of environmental sustainability that includes both human and ecological health. Given this, the adoption of a value of 3.8 mg/kg is, in my opinion, not appropriate for a 'c' limit as it does not provide the appropriate level of protection desired by Environment Canada (that developed the SQG) for human health. The alternate proposed 'b' limit of 1.4 mg/kg (the final Environment Canada SQG) is more reasonable given that the value is designed to protect both human and environmental health.

3.2.4 Discussion of Other Options for the 'a', 'b' and 'c' Levels

Soil quality guidelines from other jurisdictions are available for Cd in agricultural soil. These include: Austria, Belgium, Czechoslovakia, Denmark, France, Germany, Japan, Netherlands, Spain and the United Kingdom. The values are presented in Table 2. In examining the various SQGs a number of factors should be kept in mind. These issues are very clearly stated by Merrington and Schoeters (*in press*) (they refer to SQGs as Soil Quality Standards, SQS)

> "The protection goals of SQS, derivation methods and frameworks within which they are used differ between countries and regions. This diversity reflects genuine technical differences that must be taken into account in the development of Standards for different soil types or for different receptors (e.g., humans, livestock or soil flora and fauna). However, much Standard-setting has been developed in a piecemeal fashion with limited consistency in the levels of protection sought (even within the same country), or the scientific data and methods used to derive or interpret them. ……. These differences can lead to the implementation of substantially different values and of different risk assessment results using the same empirical data and the same protection goals, which must mean that their application is either over- or under-precautionary in at least some situations. The ramifications of inappropriate SQS may be considerable. For example, along with environmental implications there are also economic and social effects upon business and property development."

Further Merrington et al. (*in press*) make the following statement about comparing SQGs.

> "comparing the numerical values of SQS from across jurisdictions, without reference to the context in which they are to be used or how they have been derived, is a meaningless exercise."

One method for determining the suitability of the collated SQGs (Table 2) was to compare the NZ background soil Cd concentrations with the SQGs that demark the separation point between clean soils and those soils in which toxic effects might potentially occur. If the SQGs were below the 99%ile of the NZ background soil Cd concentration data they were deemed to be unsuitable (as they are below the recommended 'a' limit). This was the case for Austria, Czechoslovakia, Denmark, Germany, Netherlands and the USEPA Eco-SSLs. The method used to derive the Eco-SSLs is internally inconsistent however, when a consistent method is used (see Attachment 2) the Eco-SSL becomes 13 mg/kg which is too high. In the case of France the SQG is also too high and thus it is inappropriate for the TFMS. The justification for saying the Eco-SSL and French values is too high is that Cavanagh and O'Halloran derived a 'serious risk level' (which would theoretically protect only 50% of terrestrial organisms) of 12 mg/kg.

The countries that appeared to have reasonable SQGs (i.e., they were larger than the 99%ile of NZ background Cd soil concentrations) were Belgium, Japan, Spain, and the United Kingdom. However, the Japanese value was derived only to cover agricultural soils growing rice (where the soil is generally anaerobic and the soil chemistry is dramatically different to aerobic conditions) and thus this has limited applicability to New Zealand. The SQGs for Spain were omitted because they are largely a collation of SQGs from other jurisdictions and therefore no consistent method has been used in their derivation. The remaining SQGs (i.e., 1 to 1.8 mg/kg) were all designed to protect either human health or human and environmental health and thus they are consistent with the aims of the RMA. The SQGs that only protect human health are appropriate for the TFMS because toxic effects occur in humans at lower concentrations than cause toxicity to micro-organisms and plants and this is reflected in the fact that the Canadian SQG for human health is lower (1.4 mg/kg) than the SQG for environmental health (3.8 mg/kg) (CCME, 1999).

3.2.5 Suitability of the Australian Guidelines for Biosolids Amended Soils

Australia currently has a guideline for biosolids amended soils of 1 mg/kg (SA EPA 1997; EPA Victoria, 2004; DPIWE, 1999; WA DEP, 2002 NRMMC, 2004), which is consistent with the NZ biosolids guideline for Cd and the work of Cavanagh and O'Halloran (2006). However, more recently the Australian National Biosolids Research Program (NBRP) found that the critical soil Cd concentration, which is the soil concentration that causes Cd wheat[4] grain concentrations to equal or exceed the FSANZ limit of 0.1 mg/kg, varied as a function of soil pH and clay content

Critical soil Cd conc (mg/kg) = 0.067 pH + 0.015 clay content (%) – 0.12 $r^2 = 0.85$

[4] Nine different cultivars of bread wheat (*Triticum aestivum*) were used to generate the relationship. The cultivars were Aroona, Yitpee-Crickoff, Callingiri, Kennedy, Whistle, Chara-Drysdale, Dollarbird, Hartog, and Frame.

Table 2. The soil quality guidelines for cadmium (Cd) in agricultural soil that have been adopted by various jurisdictions.

Country	Cd SQG (mg/kg)	Comment
Austria[1]	0.5/1	The first value is the screening value and the second is the remediation value. An additional set of limits are provided but these are not appropriate as they are less than the 99%ile of the NZ Cd soil background concentrations.
Belgium[2]	1.2/2	The first value is the SQG while the second is remediation guideline.
Czechoslovakia[3]	0.4 / 0.4	These are not appropriate as they are below the 99%ile of NZ Cd soil background concentrations.
Denmark[4]	0.5/5	The first value is a trigger value and a remediation value while the second is the intervention value which if exceeded requires clean-up.
France[5]	10/20	These limits are very high and therefore not appropriate. These limits were not derived using a method consistent with the EU Technical Guidance Document (ECB, 2003)[6].
Germany[7]	0.04 / 0.1	These are tissue based limits and therefore not appropriate. Also they are less than the 99%ile of NZ Cd soil background concentrations and therefore are not appropriate.
Japan[8]	1	Only applies to soil growing rice with no risk to groundwater. This is not appropriate for NZ.
Netherlands[9]	0.6 / 13	The first value is the long-term aspirational goal and the second is the intervention value which if exceeded requires clean-up.
Spain[10]	2 / 7 3 / 10	Values were selected from other jurisdictions. No consistent method used.
United Kingdom[11]	1.8	The pH dependent values were removed. This value applies to allotments.
USEPA EcoSSLs[12]	0.36	These only protect ecosystems, not humans. There are inconsistencies in the way the Eco-SSLs are calculated (see later in this report).

1. ÖNORM S 2088-2: 2000 06 01: N Altlasten – Gefährdungsabschätzung für das Schutzgut Boden. Available from: http://www.umweltbundesamt.at/fileadmin/site/umweltkontrolle/2001/E-06_boden.pdf. 2. VLAREBO, 2008. 3 Statisticka ročenkna životního prostředí Českérepubliky, 1998. 4. MILJØMINISTERIET, 2010. 5. available from http://www.sites-polles.developpement-durable.gouvr.fr/Librairie/ActesConferences/consoil05/cdrom/pdf/RP-52276-FR.pdf. 6. All EU member countries are required to derive SQGs consistent with the TGD (EC, 2003). 7 available from: http://www.umweltbundesamt.de/boden-und-altlasten/boden/downloads/Pruefwerte_Massnahmenwerte.pdf. 8. Japanese Ministry of the Environment, 1994. 9. RIVM rapport 711701053 available from http://www.rivm.nl/bibliotheek/rapporten/711701053.pdf. and Staatscourant, 2009. 10. These are not values for Spain but rather for the Andalucia Autonomous Government available from: http://www.juntaeandalucia.es/medioambiente/web/Bloques_Tematicos/estado_Y_Calidad_De Los Recursos_Naturales/Suelo/Criterios_pdf/Elementos.pdf 11. Environment Agency, 2009. 12. USEPA, 2005.

The NBRP also found that the bioavailability of Cd from biosolids was 2.5 to 10 times lower than that of Cd from soluble metal salts (McLaughlin et al., 2006). The difference in bioavailability was directly proportional to the total Cd soil concentration (McLaughlin et al., 2006). By combining these two pieces of information they were able to derive soil-specific guidelines for biosolids amended soils (Table 3). These values range from 0.3 mg/kg (for soils with a pH of 4.5 and a clay content of 5%) up to 2.6 mg/kg (for soils with a pH of 8.5 and 50% clay content) (Warne et al., 2007). This approach has thus derived a limit for Cd in biosolids amended soils based on the soil – plant – human exposure pathway.

Table 3. Suggested maximum permitted total cadmium (Cd) concentrations in soils receiving biosolids to ensure wheat grain does not exceed the Australian and New Zealand cadmium food standard for wheat of 0.1 mg/kg (FSANZ, 2005).

pH	Clay content (%)		
	5	25	50
	mg Cd/kg soil		
4.5	0.3	0.9	1.6
5.5	0.6	1.1	1.8
6.5	0.9	1.4	2.1
7.5	1.1	1.6	2.3
8.5	1.4	1.9	2.6

These values are currently being adopted by various state regulatory authorities (e.g. South Australia, Western Australia and Victoria) as they update their biosolids guidelines. It is important to note that the above matrix of values are based solely on protecting human health from the ingestion of agricultural produce grown in biosolids amended soils (i.e., the soil – plant – human exposure pathway). As can be seen the value of 1 mg Cd/kg that was adopted in Australia (SA EPA 1997; EPA Victoria, 2004; DPIWE, 1999; WA DEP, 2002 NRMMC, 2004) and New Zealand (NZWWA, 2003) and is proposed for the 'b' limit does not provide sufficient protection for all soil types and overprotects other soils. Given the variability of New Zealand's agricultural soils this variation in plant uptake of Cd is also likely to be relevant.

There are some limitations to the limits proposed by the NBRP including:

- the soil-specific limits have not formally been adopted nationally; and
- the soil-specific limits only consider public health via the consumption of grain (i.e., the soil – plant – human exposure pathway). They do not consider uptake to humans by soil ingestion or consumption of animal products.

It was noted before that the difference in the bioavailability of Cd as a metal salt and in biosolids ranged between 2.5 to 10. If the lowest difference in bioavailability (i.e., 2.5) is used to correct the NBRP proposed limits for biosolids amended soils to limits for soil then the values presented in Table 3 would all be divided by 2.5 and would thus range from 0.12 to 1.02 mg/kg. These values are equivalent to the Environment Canada agricultural soil SQG, except that they are based solely on wheat. Thus the upper limit for Cd in agricultural soils derived by the NBRP (i.e., 1 mg/kg) is similar to the Canadian SQG (1.4 mg/kg).

The Canadian human health SQG for urban soils was derived based solely on the soil ingestion pathway (which "does not explicitly address the uptake of metal contaminants into produce" (CCME, 1999, p. 5) which resulted in a value of 14 mg/kg. This value was then divided by a safety factor of ten resulting in the SQG human health for agricultural soils of 1.4 mg/kg. The use of the safety factor was justified on the basis that unpublished data by

Ferguson (Nottingham-Trent University) indicated that bioconcentration factors (BCFs, the ratio of the concentration of Cd in the edible portion of food crops to the total soil Cd concentration where the plants were grown in) for leafy vegetables “may exceed 10 in soils below pH 5.5” (CCME, 1999, p. 5). In contrast, the Australian National Biosolids Research Program (McLaughlin et al. 2006) reported BCF values of 1 to 0.1 for a variety of cultivars of bread wheat (*Triticum aetivus*) grown in a range of Australian agricultural soils with soil Cd concentrations ranging from 0.1 to 1 mg/kg. Despite the differences in the BCFs used, the upper Cd limits derived for Australian soils from the NBRP and the Canadian SQGs are similar.

3.2.6 Other considerations

A number of additional factors were taken into consideration in making the recommendations for the ‘b’ and ‘c’ limits. These considerations are discussed in the following material:

1. The fertiliser industry and farmer organisations are very concerned about farms being classified as contaminated for both legal reasons and also issues associated with the reputation of New Zealand agricultural produce (e.g. Furness, 2010).
2. Some of the industry stakeholders expressed a desire that the ‘c’ limit be set at such a level that there is a margin of safety between it and the concentration which denotes a contaminated soil. If this was done it would be one means of preventing farms being classified as contaminated. Rather, farms that reached or exceeded the ‘c’ limit would be classed as not being suitable for additional phosphatic fertiliser inputs.
3. The potential costs associated with their being differences between the interim and final ‘b’ and ‘c’ limits. If the final limit is higher than the interim limit then some farmers may have had to (1) limit Cd and fertiliser inputs that could potentially result in decreased yields or (2) used more expensive high analysis fertilisers both of which could adversely affect profitability. If however, the final ‘b’ or ‘c’ limit is lower than the interim limit then the farmers will not have suffered any potential yield and financial loses but may immediately have to commence limiting Cd inputs. The latter option is potentially worse for the environment, as soil Cd concentrations will continue to increase during the seven year ‘interim’ period before the final limits are derived. However, Environment Waikato (2010) have estimated that the average annual increase in soil Cd concentration is only 7 µg Cd/kg/year. Therefore, in the seven year before the final limits will be derived, on average, soil Cd concentrations will increase by 49 µg Cd/kg.
4. Resistance to and problems with changing the limit. It is quite likely that the final limits will be different to the interim limits. From both a regulatory and user point of view a decrease is not looked upon favourably. It would probably be easier to manage the situation and explain if the final limit was larger than the interim.

3.2.7 Recommended limit ‘a , ‘b’ and ‘c’ values

Given the preceding discussion the ‘a’, ‘b’ and ‘c’ limits presented in Table 4 are recommended. It is also suggested to have an additional limit for the interim period – ‘b2’. The recommended ‘a’, ‘b’ and ‘c’ limits will function in exactly the way set out in the TFMS. However, once the soil Cd concentration equals or exceeds ‘b2’ (i.e., 1.4 mg/kg) it is recommended that during the seven year ‘interim’ period the absolute minimum amount of phosphatic fertiliser (and hence Cd) be added that will permit the average yield of that crop in that region and soil type to grow. Alternately, the minimum phosphatic application rate could be determined as the point at which crop yield increases or plateaus off, expressed as a function phosphatic application rate.

The ‘c’ limit of 1.8 mg/kg (the UK SQG) was recommended as it represents a balance between the need to protect human and environmental health for the long-term and the desire to not unnecessarily impact on farmer livelihoods until there is certainty that the limits are the most appropriate for New Zealand soil ecosystems and humans.

Table 4. Recommended soil concentrations of cadmium for the various limits to be applied within the Tiered Fertiliser Management System

Limit	Concentration (mg/kg)
a	0.6
b	1.0
b2	1.4
c	1.8

Late in conducting this review the Joint Food and Agriculture Organisation/World Health Organisation Expert Committee on Food Additivies (JECFA) released a new tolerable intake value of 25 µg/kg body weight/month which replaced the existing value of 7 µg/kg body weight/week (JECFA, 2010) available. Given the very minor change in the JECFA value it is unlikely the English will modify their limit and it is considered reasonable to retain the recommended ‘c’ limit of 1.8 mg/kg.

3.3 THIRD TERM OF REFERENCE

Is the choice of “a” cadmium level in soil appropriate to reflect the upper range of natural background levels of cadmium in New Zealand soils? How does this value compare to the range of natural background values reported internationally?

I believe it is appropriate that the ‘a’ limit be based on background concentrations of Cd in New Zealand agricultural soil as the ‘a’ limit is merely the point at which farms enter into the portion of the TFMS that requires some changes to their fertiliser practices. If a higher ‘a’ limit is set then the management strategies required to ensure it takes at least 50 years to reach the ‘b’ limit will have to be more restrictive. I believe that having farmers enter into the level where management is required relatively early will highten their awareness of the Cd issue and may lead to enhanced outcomes where farmers have greater flexibility in their management options.

Background soil concentrations of Cd are highly variable reflecting the geology of the parent rocks that created the soil. The reported values for NZ range from 0.0 to 0.77 mg/kg (Taylor et al., 2007; Cadmium Working Group, 2008). The Cadmium Working Group Report One (Cadmium Working Group, 2008) collated Cd background soil concentration data for countries including Australia, Canada, Denmark, Great Britain, Japan and the USA. These ranged from 0.01 to 6.6 mg/kg. McLaughlin (2002) compiled background soil Cd concentrations across Europe and reported that they ranged from approximately 0.05 to 20 mg/kg. Hamon et al. (2004) measured background soil Cd concentrations in remote Australian locations. They found the Cd soil concentrations ranged from 0.10 to 0.46 mg/kg with mean and 99%ile values of 0.12 and 0.41 mg/kg respectively. The range of background Cd soil concentrations measured in New Zealand lie completely within this range of background concentrations for other countries, in fact they lie at the lower range of background concentrations reported in the literature.

The recommended concentration for limit ‘a’ of 0.6 mg/kg is higher than the reported average values for most of the above countries, the exceptions being Canada and the UK which were essentially the same and considerably larger, respectively. Nonetheless, the recommended ‘a’ concentration is still well within the range of background values reported for other countries.

3.4 FOURTH TERM OF REFERENCE

The upper "c" values proposed are drawn from the Canadian (CCME) environmental quality guidelines for agricultural land. In one case the proposed "c" value is based on the guideline that was adopted by Canada and is designed to protect both human and ecological health. In the other case it is based on a check-value for protection of ecological receptors in soil which was not adopted by Canada, and which is also higher than Canada's previously adopted figure. Is the use of either figure in line with the Framework for development of interim guidelines for cadmium? Is the transfer of these Canadian values to the New Zealand situation reasonable in terms of soils, pathways, and receptors? Or are other countries values (for example US EPA) for cadmium in agricultural soils more relevant for application to the management of diffuse cadmium accumulation in productive agricultural soils?

This point has already been addressed.

3.5 FIFTH TERM OF REFERENCE

While there is no evidence that cadmium is impacting on groundwater in New Zealand, there has been limited monitoring undertaken. To address this gap the CWG has proposed further monitoring and research on groundwater for the seven-year review, but it wishes to ensure that groundwater is protected to the extent that is practicable and reasonable in the meantime. Do the Canadian or other international soil guideline protocols explicitly provide for the protection of groundwater? If not, do the soil values suggested sufficiently safeguard protection for groundwater pending the development of full risk based guidelines in 7 years?

The Environment Canada SQGs, the US EPA Eco-SSLs, the Dutch SQGs and neither the proposed or current Australian guidelines for soil and biosolids amended soils consider off-site migration of Cd. Both the Dutch (Van der Meent, 1993) and the USEPA (USEPA, 1996) have developed methods to account for the potential adverse environmental effects to aquatic ecosystems from off-site migration but neither organisation uses them to derive SQGs. An excellent review of international methodologies used to protect groundwaters is provided in Cavanagh (2006b). Generally, impacts associated with off-site migration are considered in higher tier risk assessments rather than in the derivation of generic SQGs.

However, cadmium is not a highly soluble metal and it tends to bind strongly to soil particulate matter, particularly clays and organic matter (e.g., Kabata-Pendias and Pendias, 2001; McLaughlin et al., 2006). This is reflected in the fact that the vast majority of Cd added by mineral fertilisers is found in the top 10 centimetres of soil. Also the Australian NBRP found no evidence of the downward migration of Cd added to soils (McLaughlin, CSIRO, *pers. comm.*).

Given the above, it is likely that the recommended 'a, b and c' limits will provide adequate protection to aquatic ecosystems. However, the protection will be reduced in soils that have low soil pH and/or low clay content and/or low organic carbon content. If there are limited funds available for surface and ground water monitoring priority should be given to sampling in areas that have low soil pH and/or low clay content and/or low organic carbon content soils.

3.6 SIXTH TERM OF REFERENCE

Two sampling programmes are proposed – soil screening and sampling to determine the properties status within the fertiliser management tier (definitive confirmation)

A soil sampling depth of 15cm has been selected as the definitive value for use in determining the fertiliser management tier into which a property is placed. The choice of 15cm has been based on the standard sampling undertaken by fertiliser representatives for horticultural / arable soils and is reflective of the majority of soil biomass (7.5 cm sampling depth has been selected for screening purposes in pastoral soils as it matches standard sampling procedures for pasture). Are these sampling depths appropriate given the aims of the Cadmium Management Strategy and the use of the Canadian or any other soil guideline values?

The sampling depth proposed for soil screening purposes is 0-7.5 cm for pastoral soils and 0-15 cm for horticultural soils. Do you have any problems with use of these depths?. If so please elaborate.

It is not ideal, from a scientific point of view, that two different sampling depths be used to determine the Cd soil concentrations. This is because it is possible for soils that have not been ploughed or experienced any other form of vertical mixing, the 0 - 15cm Cd soil concentrations will be as little as half that of the 0 - 7.5 cm depth samples (this would happen if all the soil Cd was in the top 7.5 cm and therefore if a 0 - 15 cm sample was collected it would have double the mass of soil compared to a 0 – 7.5 cm sample). However, while pastoral soils are not ploughed annually, they are ploughed approximately every 5 – 7 years as part of the pasture rejuvenation activities. Cultivated soils are frequently ploughed. So in both cases, at least some mixing is likely to have occurred and this will mitigate the problem mentioned above.

The reasons that two sampling depths have been proposed is that these are the depths the fertiliser industry currently samples as part of their monitoring and advisory services for farmers. The fertiliser industry has developed relationships between the nutrient concentrations at these depths and crop/pasture yields. If depths other than these were sampled there would be considerable cost imposed on the fertiliser industry to develop new relationships. In contrast, if the two proposed sampling depths are adopted there would be minimal additional cost to farmers and/or the fertiliser industry – as no additional samples would need to be collected or prepared. The only additional cost would be for the Cd soil analysis. In addition, these sampling methods are well established and there are well developed QAQC practices already in place.

As indicated above there are scientific advantages to having a single common sampling depth. But moving to a single depth could make a large amount of historical data redundant, which is also not desirable.

If there is concern about the different depths producing potentially different soil Cd concentrations then the following would be an appropriate way of addressing this issue:

1. the default method would be to double the concentration measured in the 0 – 15 cm depth samples (to account for the potential dilution due to the additional 7.5 cm of soil)
2. alternately a farmer could undertake additional testing and if that proves the 0 - 15 cm depth sample has the same concentration as the 0 - 7.5 cm sample then the default method would not be necessary.

The farmer could prove the 0 – 15 cm sampling is appropriate by collecting a sample at 7.5cm depth and then in the same hole collecting a sample a further sample (7.5 – 15 cm deep). If the soil Cd concentration is the same in both the 0 – 7.5 cm and the 7.5 – 15 cm samples then there is a uniform distribution of soil Cd and either the 0 – 7.5 or the 0 – 15 cm samples could be used in all subsequent analyses without correcting the concentration using the default method.

In conclusion, the two sampling depths are appropriate for the screening level of assessment. This is further supported by MfE (2004) Contaminated Land Management Guideline #5. It is recommended that the soil Cd concentration measured in the 0 – 15 cm samples be doubled (to make it comparable with the 0 – 7.5 cm samples) unless there is evidence that the concentration of Cd in the 0 – 7.5 and 0 – 15 samples have the same concentration. The screening level assessment is appropriate for levels 1 and 2 of the TFMS (i.e. for Cd concentrations below limit 'a' and 'b') and therefore all farmland must be assessed using methods that at least meet the screening level requirements. However, farmers should be encouraged to conduct definitive assessment on all or part of their farms if they so desire even if their farm lies below the 'b' limit.

3.7 SEVENTH TERM OF REFERENCE

For definitive confirmation to determine which fertiliser management tier a property should be placed, two different soil sampling depths (0-10 cm and 0-15 cm) have been proposed. The first of these (0-10 cm) is used by regional councils for "state of the environment" soil sampling across the range of land uses. The second of these (0-7.5cm) for pastoral soils and 0-15cm for horticultural soils has been based on the standard sampling undertaken by fertiliser representatives for horticultural / arable soils and is reflective of the majority of soil biomass (7.5 cm sampling depth has been selected for screening purposes in pastoral soils as it matches standard sampling procedures for pasture).

An important issue in making a decision on this issue is the need to have Cd soil concentration data collected and analysed using a consistent method. The reason for this is that the TFMS aims to manage Cd accumulation in NZ agricultural soils over a period of at least 100 years. In order to determine how stringent any management actions should be and to assess the success of any adopted management actions concentration data measured using the same consistent method are required. Given this and the previous recommendations on the sampling depths to be used for the screening assessment, the recommended depths for the definitive assessment should also be 0 – 7.5 cm for non-or irregularly cultivate land (e.g., dairy) and the 0 – 15 cm for regularly cultivated land (e.g., vegetables).

This leaves the issue of the different sampling depth (0- 10 cm) that is being used by Regional Councils for their State of the Environment Reporting. There is a considerable amount of data that has already been generated using this method and it would be a waste to lose this. Yet at the same time it would be best if this data were relatable to the data being collected under the TFMS. The best way to achieve this is for the Regional Councils to commence collecting samples at multiple depths over the seven year 'interim' period and to develop relationships between the Cd soil concentrations determined at 0 – 7.5 cm, 0 – 10 cm and 0 –15 cm. This could be achieved at no additional cost to Regional Councils by reducing the number of samples they collect and analyse each year at the 0 – 10 cm depth and using the saved samples to collect and analyse samples at either the 0 – 7.5 cm or 0 - 15 cm depth. The sites to be sampled at 0 – 10 cm depth should be selected on a random basis. Then at randomly selected sites used for the 0 – 10 cm sampling, samples at the 0 – 10 cm and/or 0 – 15 cm depths should also be collected. Hopefully, high quality relationships (i.e. where the coefficient of determination (r^2) is ≥ 0.8) can be developed between the Cd concentrations at the different depths. These relationships could be developed at a Regional Council level and/or nationally. Having such relationships would permit the Regional Council data to be adjusted and provide estimates of Cd soil concentrations at the 0 – 7.5 cm depth and at the 0 – 15 cm depth.

Alternately, the Regional Councils could change their sampling depths to match those used in the screening and definitive assessments. If this was done, it would still be preferable to develop the conversion relationships (mentioned in the preceding paragraph) so that the existing 0 – 10 cm depth Cd soil concentration data is not made redundant.

3.8 EIGHTH TERM OF REFERENCE

In the context of the "a", "b" and "c" values that you prefer and their origins, is there a technical case for preferring one of these soil sampling depths over the other? Are there any risks with the sampling depth being either too shallow or too deep? Would it be preferable instead to align definitive sampling depths with the screening depths?

I am not aware of any reason to prefer one sampling depth over another. The key issue is to sample soils that are in the root zone of plants so that the measured soil Cd concentrations are relevant to those the plants are exposed to. There are potential problems, if soils have not been vertically mixed, that the concentrations obtained from different sampling depths may not be comparable. But I believe that the recommended strategy for sampling in the screening and definitive assessments addresses all the key issues associated with having three different sampling depths proposed. As stated in the response to the seventh Term of Reference, it is recommended that the same sampling depths be used for both the screening and definitive sampling procedures.

4 Additional points

Decisions on modifying farm fertiliser practices and ultimately on whether any further phosphatic fertilisers can be added will be made based on whether measured concentrations are below, equal or exceed the various limits (a, b and c). Therefore very explicit guidance needs to be provided on how to determine if a particular limit has been exceeded. Any such guidance must take into account the high degree of spatial heterogeneity in contaminant concentrations and soil physicochemical properties that is typical in soils. While more complex and potentially confusing for many users a statistical based method would be the most rigorous. It would be good if worked examples were also included. Also a statistically based method that uses a measure of variability such as the 95$^{\%}$ confidence intervals, standard deviation or standand error rewards those that undertake additional work, because as the number of samples increases the variability will decrease (all other factors being the same).

It is strongly recommended that the TFMS be a flexible framework which in essence outlines the minimum requirements, but at the same time encourages or at least provides stakeholders with the opportunity to undertake further, more intensive, rigorous and environmentally realistic sampling and analyses. This additional work could then be used to provide sufficient evidence that less restrictive measures may be approved. For example, if more intensive sampling was undertaken and it was justified, based on the results, then smaller portions of the farm might enter different levels within the TFMS and ultimately only portions of the farm may not be permitted to have any further phosphatic fertiliser additions.

As the CMS and TFMS aim to manage Cd over a period of at least 100 years there is the need to archive soil samples and the results of the chemical analyses. In terms of soil archiving it is probably only necessary to retain the most recent sample. This is in case the sample, for some reason needs to be re-analysed. The actual logistics of archiving the soils needs to carefully considered. Having the farmers responsible for this, is certainly very cost effective, but may well lead to the loss of many samples. Probably more important is the issue of archiving the concentration data. Preferably this should be done at one central repository. However, there are concerns that if the data was held by any entity receiving government funding that private information may become publically available. The issue of privacy versus reasonable public access requires careful consideration. It would be worth the additional set-up costs if an automated system could be developed so that the data was sent electronically from the chemical analysis laboratories to the repository – with no retyping being required.

It would be very beneficial if information on Cd could be included in the training systems of existing instruments such as the Overseer training and into the NZ GAP program. There may also be other programs where information on Cd and both the CMS and TFMS could be incorporated.

As Cd soil concentrations increase and get above the ‘b’ limit, the potential financial costs and the significance to farmers of decisions will increase. Particularly in developing modified fertiliser practices it may be appropriate for more complex and realistic models, such as critical load models (e.g. Lofts et al. 2007) to be used. These models “permit the precautionary assessment of risk due to future inputs” (Lofts et al., 2007, p 6327).

It is absolutely crucial that all stakeholders realise if the SQGs that are adopted, either in the interim or finally, are generic or soil-specific as they are very different. Generic SQGs are designed to apply across the whole of a jurisdiction, irrespective of the properties of the soil at a particular farm/site. In other words a single numerical value for each contaminant applies to all soils. Environment Canada acknowledges that their SQGs “are for general guidance only” (CCME, 1999, p.1). Soil-specific SQGs take into account the affect that soil physicochemical properties have on metal toxicity and bioavailability. With soil-specific guidelines, there is a matrix of values one for each combination of soil properties, rather than a single value as with generic SQGs.

If generic SQGs are adopted into the TFMS then it should be made very clear in the documentation that is released with the CMS and TFMS that if the minimum standards, as set out in the documents, are followed then once the ‘c’ limit is exceeded that no further Cd and phosphatic fertiliser can be added to the farm or portion of a farm. Environment Canada states that “site-specific conditions should be considered in the application of these (generic) values”. Therefore, if stakeholders wish to undertake a site-specific risk assessment and this proves that the prescribed levels of protection for both human and environmental health are being met, despite exceeding the ‘c’ limit, then further additions of phosphatic fertiliser, and hence Cd, can be permitted. Obviously, the site-specific assessment will need to be of a very high calibre and follow the exact methods that were used to derive the SQG (for both human and environmental health) and be subject to independent expert review. In other words the onus is on the owner of the farm to scientifically prove that it is acceptable to add further phosphatic fertiliser to their land.

We know that soil physicochemical properties control the bioavailability and toxicity of metals in soils (e.g. McLaughlin et al., 2006; Broos et al., 2007; Warne et al., 2008a, 2008b). It is therefore possible to derive soil-specific limits, as with the proposed Australian guidelines for biosolids amended soils (Warne et al., 2007), the proposed Australian soil quality guidelines for ecosystem health (Warne et al., 2009) and the Flemish SQGs (VLAREBO, 2008). It is therefore recommended that the research conducted during the ‘interim’ period be designed so that it can derive soil-specific guidelines. If this was done it would provide a system whereby, for relatively minimal cost, farm owners could assess if further additions of phosphatic fertiliser and Cd could be made. It would also provide a simple means for regulators to manage and approve such cases. In fact, if soil-specific ‘b’ and ‘c’ limits could be derived then they could be used right from the very beginning of the implementation of the CMS and TFMS. Obviously good record management would be crucial to keep a record of any such site-specific deviations from the standard limits.

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ATTACHMENT 1 – TERMS OF REFERENCE

Cadmium Management Strategy

Soil Cadmium Management Guidelines

Brief for peer reviewer

BACKGROUND

The Cadmium Working Group (CWG) is in the process of developing a Cadmium Management Strategy (CMS) for the management of cadmium in New Zealand's agricultural soils. This strategy addresses governance arrangements, monitoring, management and mitigation, and research. Because of uncertainties around the impact of cadmium on ecological and groundwater receptors, human health and farm ecosystems, the strategy will be interim pending further research and review in seven years time starting from 2010.

The Cadmium Management Strategy for application to productive agricultural soils engages a two pronged approach addressing both the bio-availability of soil cadmium and the rate of accumulation in soil. A key part of the CMS will be guidelines for managing the accumulation of cadmium in soils as a result of fertiliser application. A tiered system of managing fertiliser is proposed as a mechanism that will enable the build-up of cadmium to be minimised and to ensure safe and sustainable levels of cadmium in soils. The management tiers are to be defined by the cadmium concentration in the soil. The selection of these values is intended to be aligned with the protocol outlined in the document in Appendix 2 of the strategy titled *Framework for development of interim guidelines for cadmium*.

The interim Cadmium Management Strategy is intended to operate for the seven-year period until the review of the entire strategy is undertaken in 2017. At that stage it is intended that the impacts of cadmium on farm systems, human health, ecological and groundwater receptors will be better understood, and a review of the regulatory framework for managing hazardous substances in soils will have been, or will be, being undertaken. At the review stage (2017) it is intended that a full New Zealand risk-based guideline (or guidelines) for cadmium in soil will have been developed and be ready for implementation and the desirability of integrating the tiered soil management system part of the CMS into the regulatory framework will be assessed.

The Cadmium Management Strategy as proposed will have the endorsement of all its members. For the tiered soil management system to be endorsed by all its members (which include central and local government representatives) it needs to be subject to an independent technical review. The system requires independent review to ensure that the proposal is transparent, robust and scientifically defendable.

AIMS

The main aims of the review are as follows:

1. To provide your expert opinion on whether the tiered fertiliser management system would be an appropriate approach for the purposes of:
- providing long-term (sustainable) protection of soil health, and
- ensuring that cadmium levels continue to remain within a range which is acceptable for sustainable agricultural production in the next seven years.
- ensuring that cadmium levels do not restrict any foreseeable future land use

2. To provide your expert opinion on the alternative “a”, “b”, and “c” values that have been proposed to define the management tiers in the context of the purpose for which each value would be used.

In forming these opinions, you should allow for uncertainties surrounding the impacts of cadmium in soil, the extent to which a precautionary approach would be warranted in light of such uncertainties, and the proposed knowledge development and review in seven years. For each “a”, “b” and “c” value you are encouraged to outline strengths or weaknesses of the figures proposed, and also suggest an alternative figure if that seems more appropriate. Reasons for any final recommendations should be clearly stated.

In addition to forming an overall view on the soil management system, the CWG also seeks your expert comment on the following specific points:
- Is the choice of “a” cadmium level in soil appropriate to reflect the upper range of natural background levels of cadmium in New Zealand soils? How does this value compare to the range of natural background values reported internationally?
- The upper “c” values proposed are drawn from the Canadian (CCME) environmental quality guidelines for agricultural land. In one case the proposed “c” value is based on the guideline that was adopted by Canada and is designed to protect both human and ecological health. In the other case it is based on a check-value for protection of ecological receptors in soil which was not adopted by Canada, and which is also higher than Canada’s previously adopted figure. Is the use of either figure in line with the *Framework for development of interim guidelines for cadmium*? Is the transfer of these Canadian values to the New Zealand situation reasonable in terms of soils, pathways, and receptors? Or are other countries values (for example US EPA) for cadmium in agricultural soils more relevant for application to the management of diffuse cadmium accumulation in productive agricultural soils?
- While there is no evidence that cadmium is impacting on groundwater in New Zealand, there has been limited monitoring undertaken. To address this gap the CWG has proposed further monitoring and research on groundwater for the seven-year review, but it wishes to ensure that groundwater is protected to the extent that is practicable and reasonable in the meantime. Do the Canadian or other international soil guideline protocols explicitly provide for the protection of groundwater? If not, do the soil values suggested sufficiently safeguard protection for groundwater pending the development of full risk based guidelines in 7 years?
- Two sampling programmes are proposed – soil screening – [what is this for?] and sampling to determine the properties status within the fertiliser management tier (definitive confirmation)
- A soil sampling depth of 15cm has been selected as the definitive value for use in determining the fertiliser management tier into which a property is placed. The choice of 15cm has been based on the standard sampling undertaken by fertiliser representatives for

horticultural / arable soils and is reflective of the majority of soil biomass (7.5 cm sampling depth has been selected for screening purposes in pastoral soils as it matches standard sampling procedures for pasture). Are these sampling depths appropriate given the aims of the Cadmium Management Strategy and the use of the Canadian or any other soil guideline values?

- The sampling depth proposed for soil screening purposes is 0-7.5 cm for pastoral soils and 0-15 cm for horticultural soils. Do you have any problems with use of these depths?. If so please elaborate.
- For definitive confirmation to determine which fertiliser management tier a property should be placed, two different soil sampling depths (0-10 cm and 0-15 cm) have been proposed. The first of these (0-10 cm) is used by regional councils for "state of the environment" soil sampling across the range of land uses. The second of these (0-7.5cm) for pastoral soils and 0-15cm for horticultural soils has been based on the standard sampling undertaken by fertiliser representatives for horticultural / arable soils and is reflective of the majority of soil biomass (7.5 cm sampling depth has been selected for screening purposes in pastoral soils as it matches standard sampling procedures for pasture).
- In the context of the "a", "b" and "c" values that you prefer and their origins, is there a technical case for preferring one of these soil sampling depths over the other? Are there any risks with the sampling depth being either too shallow or too deep? Would it be preferable instead to align definitive sampling depths with the screening depths?

In reaching your assessment, you should take into account the context of the Cadmium Management Strategy, in particular:

- The assessments of the first CWG report
- Its place in the draft Cadmium Management Strategy
- The *Framework for development of interim soil guidelines for cadmium*
- The "as low as reasonably attainable" principle (ALARA) as it might be applied to management of hazardous substances in productive agricultural soils
- Farm management practices in New Zealand
- The Proposed National Environmental Standard for Assessing and Managing Contaminants in Soil (although note that this Standard will not include New Zealand's agricultural soils).
- The intended review in seven years and intended development and adoption of NZ risk based guidelines?
- Risk-based protection of an adequate range of receptors, including ecological receptors and niches (*e.g.* microbial health, invertebrates, plants, insectivores such as, birds), regional groundwater, and human health. Values derived which protect human health, environmental values and farm ecosystems.
- Other methodologies used to derive acceptable values in agricultural soils in other countries.
- The acceptable soil guideline values derived in other countries that may be relevant to NZ agricultural land.
- Regulatory considerations associated with the suitability of using particular guidelines in the context of the strategy, for example: some guidelines are designed as "may be filled up to" figures where others are "should be clean down to" values. Some may trigger a need for immediate intervention whereas others would be regarded as "further investigation" thresholds.

METHOD

The reviewer should

- read documentation provided
- access any information they have available to them either provided by the CWG or from other sources
- use relevant sources of overseas information, reports and contacts with relevant experts and regulatory agencies
- interview any members of the CWG in full session as necessary. Each CGW member be given the same opportunity to respond to the same inquiries.
- form, where possible, a professional opinion on each of the questions raised above.

Any discussion with other parties should be declared/ reported to the CWG to ensure transparency. You should keep in mind that most of the documentation provided may still be in draft stage, and subject to confidentiality within the CWG. Any such discussions should be limited to essential areas of clarification only.

Output

You should supply a report to the CWG that addresses the issues raised above and answers the specific questions raised by the CWG. It should give the CWG clarity on the key question of the suitability and reasonableness of the fertiliser management strategy for managing soil cadmium accumulation in the New Zealand context over the next seven years and/or provide alternatives. You shall do this by comparing and contrasting the proposed strategy with other international strategies for productive agricultural soils. In so doing, the reviewer may provide recommendations in relation to the strategy.

Opinions you form in your review should be clearly identified, and should be constrained to your own area of professional expertise. Facts and reasons upon which each opinion has been based should be provided. If you are not able to form an opinion between two alternatives, it would be useful to outline reasons for this, and whether either option would suffice.

You are not asked to form opinions on subjects that fall outside your own area of expertise. If it becomes apparent that one or more questions are in this category, this issue should be identified.

A statement about potential conflicts of interest (or their lack) should be made in your report. Any conflicts of interest or matters that may be perceived as conflicts of interest, inducements or coercion, should be identified. As a technical review, your report is not expected to include opinion about any wider political questions relating to the presence of cadmium in agriculture.

CONFIDENTIALITY

All documentation provided to the reviewer, and the report provided by the reviewer to the CWG, are considered confidential at this stage. However all documentation is discoverable under the Official Information Act, and once the Cadmium Management Strategy is released the review will be made available publicly.

TIMELINE

The draft review will be required by 12 June 2010. A final review will be required within three weeks of receipt of comments on the draft review.

CONTACT

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A full list of CWG members is available on request.

ATTACHMENT 2 – COMMENTS ON THE METHOD USED TO CALCULATE THE ECO-SSLS

The USE EPA states that these particular limits "are the concentrations of contaminants in soil that are protective of ecological receptors that commonly come into contact with soil or ingest biota that live in or on soil" and as they "are presumed to provide adequate protection of terrestrial ecosystems" (USEPA, 2005, p.1) It is generally stated that they are calculated as the geometric mean of the most bioavailable toxicity data. But this is not strictly correct. Eco-SSLs are calculated separately for plants, soil invertebrates, birds and mammals and then the lowest of these is adopted as the final Eco-SSL. For plants and invertebrates the Eco-SSLs are calculated as the geometric means of the toxicity data for the highest bioavailability class. Whereas, the birds and mammals a different approach is used. For each group of organisms they first calculate the geometric mean and then use models to convert this diet based toxicity data (mg Cd/kg body weight/day) to soil concentrations (mg/kg). However, this conversion to soil concentrations is only done for three representative species and then the lowest of these values is adopted as the Eco-SSL for that group of organisms. I believe that this is not an appropriate procedure as it is not consistent with the calculation method for plants and invertebrates. The Eco-SSLs for birds and mammals would be calculated using the geometric mean of the three values for birds and mammals if the method was consistent with that used for plants and invertebrates. If this method of calculation was adopted the Eco-SSL(birds) would increase from 0.77 to 13 mg/kg. Similarly, the Eco-SSL(mammals) would increase from 0.36 to 24 mg/kg. If the lowest of the Eco-SSL(plant) (32 mg/kg), Eco-SSL(invertebrate) (140 mg/kg) and the recalculated Eco-SLL(bird) and Eco-SSL(mammal) was adopted then the Eco-SSL would be 13.

The method of calculating the Eco-SSL does not provide an estimate of the degree of protection that is provided (e.g. % of species) and it will vary for each contaminant. However, it is possible to determine the percentage of protection that is provided. The recalculated Eco-SSL generated in the preceding paragraph, would protect 87% of species.

The Eco-SSLs use maximum acceptable toxic concentration (MATC) values which are the geometric mean of the no observed effect concentration (NOEC) and lowest observed effect concentration (LOEC) data. NOEC data typically correspond to a 10 to 30% effect (Moore and Caux, 1997; USEPA, 1991; Hoekstra and Van Ewijk, 1993a). Thus MATC values will correspond to even higher percent effects. It is questionable that such toxicity data is appropriate given the aims of the Cd management strategy.

Also the toxicity data only measures chronic effects on organisms such as growth, reproduction. They do not consider any human health issues.

The USEPA Eco-SSLs are not deemed appropriate for use in the TFMS because:

1. they do not consider human health issues;
2. the method for their calculation is not internally consistent;
3. the type of toxicity data is unlikely to provide an appropriate level of protection; and
4. they do not consider micro-organisms or microbial processes e.g., nutrient cycling.