Exploring the implementation of ecological soil guideline values for soil contaminants

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Exploring the implementation of ecological soil guideline values for soil contaminants

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Summary

Project and client

- This project has been undertaken with Envirolink funding for a medium advice grant for Marlborough District Council (2214-MLDC162).

Objectives

- This project aimed to identify gaps, stakeholders, and a pathway for the implementation of ecological soil guidelines values (Eco-SGVs) for the:
  - management of contaminated land
  - management of surplus soils from development sites
  - assessment of soil quality
  - disposal of waste to land

  under current and proposed legislation.
- The project included a specific focus on incorporating te ao Māori / mātauranga Māori.

The process

- This project was overseen by an advisory group comprising representatives from territorial, unitary, and regional councils (including representation from the regional council Waste and Contaminated Land and Land Monitoring Forum special interest groups), central government (Ministry for the Environment, Ministry for Primary Industries, Department of Conservation), the Wasteminz Contaminated land special interest group, and a Māori representative.
- The outline of work included:
  - a brief review of the application of ecological criteria in different international jurisdictions
  - an assessment of the practicality of application by evaluating the Eco-SGVs against regional council state of the environment soil quality monitoring, and soil contaminant data obtained through contaminated land investigations
  - a workshop with central and local government and Māori representatives, which was held on 8 February 2022 to identify desired outcomes from the application of Eco-SGVs in different contexts, and to identify potential issues or constraints associated with these application/s (arising from this workshop was a basic framework for the proposed application of Eco-SGVs in different contexts, such as contaminated land management, which was further tested with attendees in a subsequent workshop held on 31 March 2022)
  - an end-user workshop, which was held on 6 April 2022 with representatives from different industry sectors, including contaminated land management, waste disposal to land, organic materials and primary production, to gain feedback on the proposed use.

Proposed application of Eco-SGVs

- An overview of the proposed revised applications for the derived Eco-SGVs, based on the workshops, is shown in Table S1.
- The proposed uses have been simplified to target values, trigger values, and limit values, which are applicable across all land uses. In other words, Eco-SGVs are not differentiated on the basis of land use, but rather on the basis of the level of protection nominally afforded, with different actions arising from exceedance/non-compliance of these different values, depending on the purpose of application.

Table S1. Overview of proposed application of Eco-SGVs for different purposes

Value name (protection level)	Protection of soil quality	Contaminated land management
Target 'limit' (95%)	Regional council state of the environment monitoring Discharge consents, including for the application of wastes (e.g. biosolids, cleanfill, managed fill) to land, and compost/mulch products Iwi/hapū/Māori achieve soil health goals, reflecting cultural values	Potential remediation targets (except copper and zinc)* Te ao Māori aspirations are met for maintaining mauri
Investigation trigger (80%)	NA	A 'soft' trigger value for site investigation, leading to identification for mitigation options. (For example, where the source can be decreased, active management to reduce concentrations (copper, zinc) includes assessment of offsite risks. Also used for identifying contaminated land where human health is not the driver (e.g. copper, zinc). May assist Māori in co-management plans.
Limit value (60%)	NA	Site investigation leading to remediation or management appropriate to the identified risk or effect.

* It is likely that most effective remedial action for elevated copper and zinc is active management of soil (to provide slow natural attenuation over time).

Next steps

- There is a component of technical work required relating to the use of background soil concentrations. This includes consideration of the revised background soils (which is currently being developed through a concurrent project) and addressing when to adjust Eco-SGVs, regional vs national determination of background soils, identification of mineralised areas, and evaluation of the 95th percentile background vs Eco-SGV (based on median background concentration), which is particularly relevant to the development of cleanfill criteria.
- A second component relates to guidance materials and the fit with future legislation and policy, including te ao Māori and mātauranga Māori. These next steps can be undertaken to some extent within an Envirolink Tools project proposal that will commence on 1 July 2022.

1 Introduction

Ecological soil guideline values (Eco-SGVs) developed to protect terrestrial biota (soil microbes, invertebrates, plants, wildlife, and livestock) from the negative effects of contaminants provide a useful means to readily assess potential environmental impact. Some soil guideline values already exist in New Zealand; for example, in the timber treatment guidelines (MfE 1997) and biosolids guidelines (NZWWA 2003), but these are for a limited number of contaminants and are based on inconsistent methods. The absence of national Eco-SGVs has resulted in inconsistency and a lack of clarity relating to the protection of ecological receptors in soil, and a lack of focus on ensuring this protection in territorial and regional / unitary council functions.

Soil guideline values for the protection of soil biota have been identified as a top priority by the Contaminated Land and Waste Special Interest Group, and they are also identified as a critical issue for both the Land Monitoring and the Land Management Group special interest groups. The Ministry for the Environment's 2006 discussion paper *Working Towards a Comprehensive Policy Framework for Managing Contaminated Land in New Zealand* (MfE 2006) also recognises the absence of guidance for assessing the ecological impact of contaminants in soil. Critically, under the current resource management reform there is a focus on environmental restoration/enhancement, determining the ecological value of land, and enabling development within environmental limits.

Despite the extensive work already done there remains a reticence by councils to use Eco-SGVs – particularly for contaminated land management purposes – in the absence of an agreed national direction and use in regulatory assessments. This project provides a first step in exploring the role that Eco-SGVs can play in setting environmental targets and limits using a nationally consistent method. It provides a more detailed assessment of the benefits and challenges of alternative proposed regulatory applications, and identifies pathways for consistent national implementation (which will be further progressed through a proposed Tools project).

This project also considers and incorporates a te ao Māori perspective, building on previous relevant work (e.g. mātauranga Māori, soil health, land contamination, biowaste), exploring current and potential Māori issues pertinent to contaminants and land management, and identifying the need for Eco-SGV soil guidelines to be developed that underpin Māori decision-making and achieve Māori aspirations. Some specific examples are given, along with a background to te ao Māori soil health work.

The project has been undertaken with Envirolink funding for a medium advice grant for the Marlborough District Council (2214-MLDC162).

2 Background

2.1 Ecological soil guideline values

Before 2016 there were no New Zealand-based soil guidelines for protecting ecological receptors, which resulted in an inconsistent national approach to the management and reporting of contaminants in soils. Envirolink Tools Grant C09X1402 funded the development of New Zealand guidance on both natural background concentrations and Eco-SGVs for common soil contaminants to assist in protecting ecological receptors (including microbes, invertebrates, plants, and higher animals) in soils and their associated ecosystems.

This resulted in the following three documents being produced by Landcare Research over the period July 2014 to June 2016:

- ‘Development of soil guideline values for the protection of ecological receptors (Eco-SGVs): Technical document’ (Cavanagh & Munir 2016)
- ‘Background soil concentrations of selected trace elements and organic contaminants in New Zealand’ (Cavanagh et al. 2015)
- ‘User guide: Background soil concentrations and soil guideline values for the protection of ecological receptors (Eco-SGVs) – Consultation draft’ (Cavanagh 2016).

This work resulted in the development of guideline values for 11 contaminants (eight inorganic and four organic, see Table 1) for five land-use categories (areas of ecological significance, non-food production land, agricultural land, recreational/residential land, commercial/industrial land), with criteria for the different land-use categories based on different protection levels for ecological receptors.

Table 1. Contaminants used in the development of Eco-SGVs

Inorganic contaminants	Organic compounds
Arsenic (As)	Dichlorodiphenyltrichloroethane (DDT)
Boron (B)	Total petroleum hydrocarbon (TPH)
Copper (Cu)	Polycyclic aromatic hydrocarbons (PAHs) – represented by fluoranthene and benzo(a)pyrene
Cadmium (Cd)	
Chromium (Cr)	
Fluorine (F)	
Lead (Pb)	
Zinc (Zn)	

Subsequently, a peer review of the three guideline documents was undertaken by Dr Nick Kim of Massey University between December 2017 and June 2018 (Envirolink Medium Advice Grant 1847-MLDC139). In response, in 2019 a technical update was undertaken of the guidelines, which addressed the technical aspects of the review comments and updated the methods to ensure consistency with international guidance (Envirolink Grant 1935-GSDC156).

2.1.1 Brief overview of the method for deriving Eco-SGVs

The approach for deriving Eco-SGVs builds on earlier recommendations for a proposed approach for cadmium (Cd) (MPI 2012), which were developed further in Cavanagh 2014. The rationale for the approach was to ensure consistency between Australian and New Zealand approaches for deriving soil guideline values for the protection of terrestrial ecological receptors, and also with the Australian and New Zealand Water Quality guidelines (MPI 2012).

The actual values of Eco-SGVs are ultimately determined by decisions made about the toxicological data used and the level of protection afforded (Figure 1). Because these decisions are more a matter of policy and consensus rather than science, and should take into account the intended application of the Eco-SGVs, a series of workshops was held over 2014 to 2016 to provide input into the development of the method. The outcomes of these workshops resulted in the EC30 (effective concentration at which effects are observed in 30% of the test population) being the agreed toxicological endpoint, and that ageing and leaching would also be taken into account. Eco-SGVs were also derived for fresh contamination for copper (Cu) and zinc (Zn), which are key contaminants in stormwater discharge that may be applied to land.

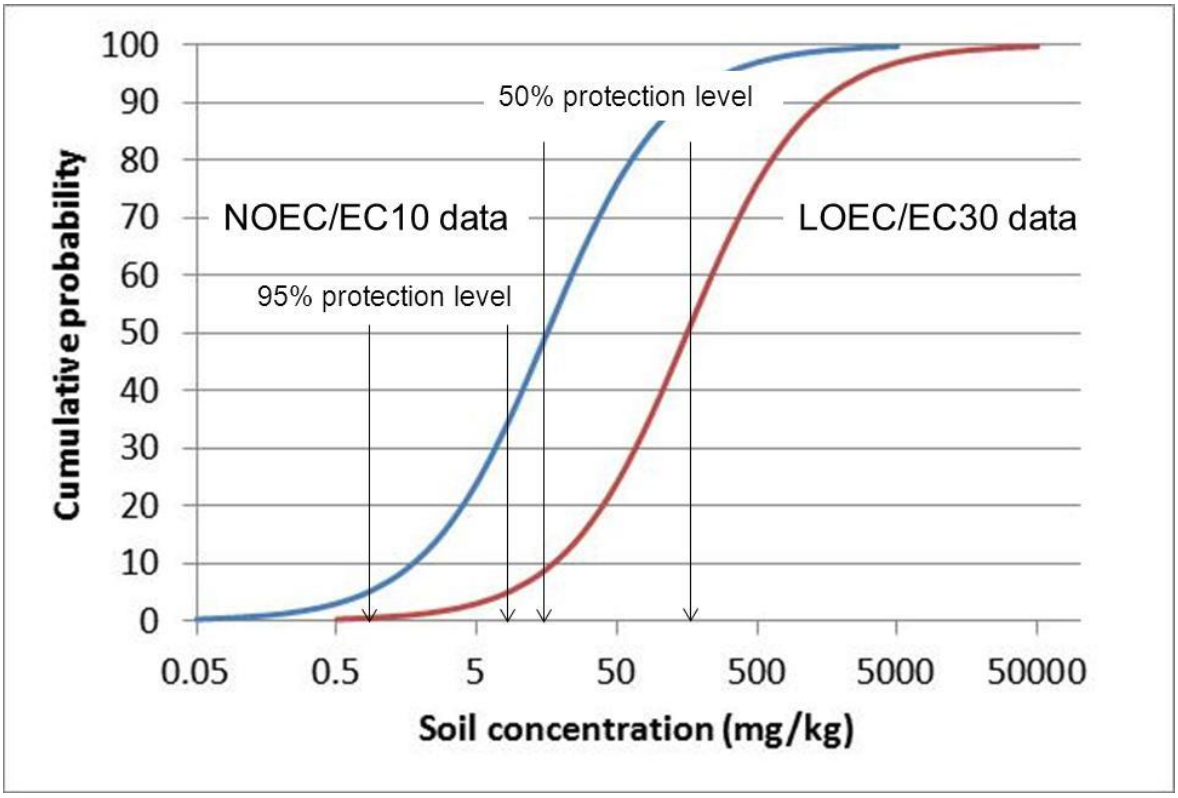

Figure 1. Hypothetical species-sensitivity distribution, illustrating the potential influence of the selection of different toxicity endpoints and protection levels on derived Eco-SGVs, ranging from c. 0.6 to c. 350 mg/kg in this example.

NOEC = No observed effect concentration; LOEC = lowest observed effect concentrations; EC10/30 = concentration at which 10/30% of the population is affected.

In addition, different levels of protection were developed for different land uses, which was considered to provide a cost-effective and pragmatic approach to contaminant management. Land-use categories for which Eco-SGVs were developed arose out of workshop discussions with regional councils and stakeholders. A summary of the land-use categories and levels of protection is provided in Table 2, alongside the land-use categories used in the National Environmental Standard for Assessing and Managing Contaminants in Soil (NES-CS).

Table 2. Summary of land-use categories, land use covered under the National Environmental Standard for Assessing and Managing Contaminants in Soil (NES-CS), receptors covered, and level of protection of plants, soil processes, and invertebrates for Eco-SGVs

Land use	NES-CS land use	Additional land uses covered / description	Receptors covered	Level of protection (%)[a]	
				Plants	Soil processes/ invertebrates
Commercial /industrial	High-density residential Commercial/ industrial outdoor worker	Road reserves. All commercial/industrial and high-density residential land use, including under paved areas. Highly artificial ecosystems, but soils should still support the basic soil processes and be able to recover if land use changes.	Soil microbes, plants, invertebrates Soil and food ingestion Trigger for off-site impacts	60 (65)	60 (65)
Residential and recreational areas	Rural residential/lifestyle block (25% produce consumption) Residential (10% produce consumption) Recreational areas	Modified ecosystems but for which there is still an expectation that important species and functions can be maintained.	Soil microbes, plants, invertebrates, wildlife	80 (85)	80 (85)
Agriculture, including pasture, horticulture and cropping	Production land[b]	All food production land. The protection of crop species is required to maintain the sustainability of agricultural land. Soil processes and soil invertebrates are highly important to ensure nutrient cycling to sustain crop species, but tillage and use of pesticides mean it is not realistic to have the same level of protection as for plant species.	Soil microbes, plants, invertebrates, wildlife and livestock	95 (99)	80[c] (85)

Land use	NES-CS land use	Additional land uses covered / description	Receptors covered	Level of protection (%)[a]	
				Plants	Soil processes/ invertebrates
Non-food production land	Production land	All non-food production land (e.g. production forestry) to which waste could be applied and which does not fall into other land-use categories. Similar to agricultural land, although tillage and pesticide application are not expected to affect soil processes and soil invertebrates, enabling a higher level of protection for these organisms.	Soil microbes, plants, invertebrates, wildlife	95 (99)	95 (99)
Ecologically sensitive areas	NA	National parks, designated ecologically sensitive areas; near-pristine ecosystems that should remain in that condition.	Soil microbes, plants, invertebrates, wildlife	99	99

[a] This is based on using EC30/LOEC toxicity data and aged contamination for all applications except discharge of stormwater, for which contamination should be considered fresh. (Due to the high organic load in organic wastes such as chicken manure, it is considered that aged contamination is appropriate.) The value in brackets is the level of protection that should be provided for biomagnifying contaminants. Due to mathematical constraints, if the level of protection is 95%, the increased level of protection is 99%.

[b] NES regulations state: 'If the land that is potentially or actually affected by contaminants is production land, the regulations **do not apply** to:

a. soil sampling or soil disturbance (except on parts of production land used for residential purposes)

b. subdivision or change of use (except where that would result in production land being used for a different purpose, eg, for residential land use).'

[c] The lower protection level is in recognition of intentional pesticide application and cultivation effects.

NA = not applicable.

Eco-SGVs were developed using the following method (with further details provided in Cavanagh & Munir 2019).

1 Collate and screen the data.

2 Standardise the toxicity data to EC30,[1] the preferred toxicological endpoint for deriving Eco-SGVs in New Zealand, which is consistent with the approach used to derive ecological investigation levels in Australia (NEPC 2013).

3 Incorporate an ageing/leaching factor for aged contaminants.

4 Normalise the toxicity data to New Zealand reference soils. Three reference soils were defined for New Zealand: typical soil, sensitive soil, and tolerant soil (with the general soil properties provided in Table 3). Many normalisation relationships use pH

[1] EC30 = effective concentration at which there is a 30% decrease in the endpoint being assessed.

determined in $CaCl_2$, and effective cation-exchange capacity (eCEC, which is CEC at the pH of the soil), so the soil properties were adjusted to these values (Table 3) using relationships identified from the literature (see Cavanagh & Munir 2019 for details).

Table 3. Soil characteristics for New Zealand reference soils to be used to normalise toxicity data. Properties were determined from the National Soils Database.

Soil property	Sensitive soil (Recent soil)	Typical soil (Brown soil)	Tolerant soil (Allophanic soil)
pH (H_2O)	5.0	5.4	5.5
Clay (%)	17	21	23
CEC (cmol/kg)	13	20	30
Org. carbon (%)	3.1	4.6	9.4

5 Calculate an added contaminant limit (ACL) by either the species sensitivity distribution or assessment factor approach, depending on available toxicity data. The BurrliOZ programme[2] was used to derive ACLs in this report. This software preferentially uses the Burr Type III method to determine the species sensitivity distribution, and it was used to derive the Australian and New Zealand Water Quality Guidelines (Warne et al. 2018).

6 Account for secondary poisoning.

7 Determine the background concentration (BC) of the contaminant in the soil (based on Cavanagh et al. 2015, with information for specific locations available from Land Resource Information Systems (https://lris.scinfo.org.nz/).

8 Calculate the Eco-SGV by summing the ACL and BC values: Eco-SGV = BC + ACL.

Eco-SGVs were developed for 11 contaminants: arsenic (As), boron (B), cadmium (Cd), chromium (Cr), lead (Pb), copper (Cu), zinc (Zn), dichlorodiphenyltrichloroethane (DDT), total petroleum hydrocarbon (TPH), and polycyclic aromatic hydrocarbons (PAHs). Provisional ACLs were also developed for fluorine, but given the uncertainty of the estimates they are not recommended for use.

Generic ACLs were developed for As, B, Cr, Cd and Pb and are considered applicable to all soil types for the appropriate land use. Because Cd biomagnifies in the food chain, Eco-SGVs are based on a higher protection level compared to non-biomagnifying contaminants. Although Pb is not considered to biomagnify *per se*, there may be potential for secondary poisoning to occur at higher Pb concentrations. Therefore, for the residential/recreational and commercial/industrial land uses, Eco-SGVs based on a higher level of protection are also provided.

[2] https://research.csiro.au/software/burrlioz/

Eco-SGVs were developed for the three reference soils only for Cu and Zn. In addition, because Cu and Zn are present in urban stormwater, which may be discharged to land in a form similar to that in freshly spiked soils, Eco-SGVs for fresh and aged contamination were also developed for Cu and Zn.

2.1.2 Background concentrations and Eco-SGVs

The 'added-risk' approach has been used to derive Eco-SGVs for trace elements. This approach considers the availability of the background concentrations of a contaminant to be zero, or sufficiently close to zero that it makes no practical difference, and that it is the added anthropogenic amounts that are of primary concern for toxicity considerations (e.g. Crommentuijn et al. 1997). Because Eco-SGVs are developed by adding the contaminant limit developed by considering the toxicity of the contaminant (referred to as the added contaminant limit, or ACL) to the background concentration, regional variations in background concentrations are taken into account.

The background concentrations determined in Cavanagh et al. 2015 are effectively the naturally occurring concentrations, because the premise of the analysis is that background soil concentrations are predominantly influenced by the underlying geology. Naturally occurring background concentrations differ from ambient concentrations, which arise from diffuse or non-point sources via general anthropogenic activity not attributed to industrial or commercial land use. While ambient background concentrations are preferred for the development of Eco-SGVs, particularly in urban areas, these must be determined on the basis of measured concentrations. Currently there are insufficient data to robustly determine ambient concentrations of contaminants of concern across New Zealand.

With respect to deriving Eco-SGVs, the median, rather than the 95th percentile has been used as the background concentration, consistent with NEPC 2013. The addition of the ACL to an upper limit of background concentration will result in the derived Eco-SGV being under-protective for the majority of soils

2.2 Te ao Māori and contaminants

Māori describe and understand the environment using many of the same words and explanations as used for human health and illness (ngā kupu Māori). The terms 'oranga', 'ora', 'hauora', 'toiora' and 'waiora' are widely used for expressing a state of health or well-being, while 'whaiora' is used to mean seeking well-being. The terms 'matemate' and 'mauiui' are commonly used to express being unhealthy or illness.

In terms of contaminants, contaminated or polluted land needs to be expressed through a te ao Māori lens in terms of a 'defiled' state or condition. This is usually expressed by the term 'tapu' (Ataria et al. 2019), meaning restricted, forbidden or off-limits, or 'mōrearea' and 'kino', which can mean dangerous or harmful. Tapu was enacted over an area, or people, to protect people from harm and illness and to follow custom (tikanga), especially to sustain, maintain, and elevate mana (power, prestige, authority). Mana can be applied to people and the environment, such as land and water (e.g. te mana o te wai, te mana o te taiao). Mana and tapu often went hand in hand.

In terms of contaminated or polluted land or soil, the terms para, paru(a), whakaparu, whakakino(tia), and tūkino, are commonly applied. For example, 'tūkinotanga ā taiao' is used to describe polluting an area or an environment. Para whakakino is used to describe a pollutant, and pollution can therefore be described as parahanga, paru, tiko, pokenga, or tūkinotanga.

In terms of cleaning or releasing an area from pollution or contaminants, terms such as 'hua parakore' (Hutchings 2015) or 'noa' are commonly used, referring to the removal, or negating (kore) the effect, of a defiled or contaminated state. Traditionally, Māori saw their environment through an elaborate set of rules and regulations, called ritenga, which often passed from tapu (restricted) to semi or temporary restricted states (rahui), to whakanoa (Ataria et al. 2019), which involved an opening up of resources or land from tapu. A release from tapu was carried out through local tikanga and kawa (lores and customs) dictated to, and set, by tangata whenua and mana whenua (people belonging to a defined area of land or whenua). The removal or management of contaminants can be through a process, or set of practices, which removes or decreases the contaminants or pollutants of a site, removing the danger or harm.

Traditionally Māori have several references to what makes good land, fertile land, healthy versus unhealthy land, and infertile, limited or degraded land. Many of these terms are still used today. Healthy land, remediated land, or regenerated land (whenua) can be expressed as whenua ora, mauri ora, taiao ora, or te oranga o te taiao.

2.2.1 Soil health

Soil health from a te ao Māori / mātauranga Māori perspective was explored through an MBIE-funded Endeavour programme (2016–2022) 'Soil health and resilience: Oneone ora, tangata ora' (Hutchings et al. 2018; Harmsworth 2018; Hutchings & Smith 2020). An overview of the research is available here: Kaupapa Māori » Manaaki Whenua (landcareresearch.co.nz), and the wider research programme here: Soil health and resilience: oneone ora, tangata ora » Manaaki Whenua (landcareresearch.co.nz). *Te Mahi Oneone Hua Parakore: A Māori Soil Sovereignty and Wellbeing Handbook* (Hutchings & Smith 2020) was developed through the research programme and provides a te ao Māori perspective of soil health and well-being, and emphasises the mana of soil as a statement of Māori soil sovereignty and soil health.[3] Through this research programme, key values and principles integral to the understanding of soil health from a Māori perspective were identified and provisional indicators of soil health were developed. These indicators are described in more detail in the 'Māori indicators of soil health' section below.

[3] Te Mahi Oneone Hua Parakore: A Māori Soil Sovereignty and Wellbeing Handbook - Freerange Press (projectfreerange.com)).

2.2.2 Māori indicators of soil health

Provisional Māori indicators (tohu) of soil health have been developed through the 'Soil health and resilience: oneone ora, tangata ora' research programme,[4] building on values and principles identified through wānanga (workshops), research wānanga, hui, focus groups, case studies, and a literature review. We describe some of these te ao Māori / mātauranga Māori indicators, with specific application to the implementation of ecological soil values, below

Mauri

'Mauri' refers to an internal essence, vitality, or life force; for example, a healthy, functioning soil 'fit for purpose' and sustaining life, energy, well-being, and health (mauri ora, whenua ora). It is often used to refer to the capacity or condition of a soil to function as a living, healthy ecosystem that can sustain mauri. As an indicator it measures the total 'living ecosystem' of interconnections and interdependencies between soil, plants, invertebrates, animals, microbes, and people (e.g. Eco-SGVs). It includes whakapapa, the strength of connection (ancestral lineage) or the relationship between humans and soil.

Mauri is intended to be used to find a state of balance in the total (whole) system. When there are small shifts in the components (inter-related parts) of the system (e.g. contaminants, toxicity), the whole system can be put out of balance.

Specific indicator questions/pātai: Māori wish to know:

- How can we use ecological soil guideline values to sustain the mauri of the environment, a soil, or a proposed waste site / landfill?
- Will the Eco-SGvs help us understand a more holistic view of soils and taiao, and reduce the risk and harm from contaminants?

Mana

'Mana' means force, energy, power, and prestige. It is a state of people and the resource. When used in relation to the environment (e.g. te mana o te taiao, te mana o te wai), it elevates the status or importance of the resource to 'a living entity with rights' next to people. When applied to people, it gives rights or mana to make decisions of benefit to the resource or the environment (through kaitiakitanga – environmental guardianship). As an indicator it can be used to measure the success or impact of making decisions of benefit to the land (whenua, Papatūānuku), and the quality of those decisions. For example, has the land or soil been treated or remediated satisfactorily in relation to cultural values? Mana may take place as an action through, for example, soil management guidelines, tikanga, and best practice.

[4] Māori indicators of soil health » Manaaki Whenua (landcareresearch.co.nz),

Specific indicator questions/patai: Māori wish to know:

- How can Māori groups use Eco-SGVs to make decisions (under their mana) and achieve healthy soils and healthy foods, and elevate the mana of the resource?
- How can Eco-SGVs be used to improve soil management and reduce the risk and harm from contaminants?

Mahinga kai and māra kai

Mahinga kai and māra kai are important Māori food-growing, harvest, and collection sites or areas. These are a measure or indicator expressing a state of healthy food to a healthy environment. It provides a measure of what constitutes a te ao Māori concept of health, implying healthy soil ecosystems are a foundation of healthy plants and animals, and healthy food supports human wellbeing. Eco-SGVs could be used to guide the management of such sites (e.g. by providing a link between healthy soil, healthy food, and healthy people).

For example, Māori approaches such as Hua Parakore (Hutchings 2015) seek to assess soil contaminants before growing food, and to remove and manage contaminants (e.g. removal of pesticides, artificial fertilisers) in order to sustain gardening/organics that reflects cultural values. Hua Parakore also identifies a range of best land and tikanga practices, consistent with te ao Māori, that ensures Māori aspirations are met.

Specific indicator questions/patai: Māori wish to know:

- Are there contaminants in the food we eat?
- What contaminants?
- How can we ensure healthy food (kai) for our community?

Oranga/ora

Oranga/ora is a measure of health, again reflecting the living ecosystem and expressing the links between all parts of the system. It can be used to measure food safety and food health derived from soil (e.g. a soil free from pesticides and contaminants, to meet food safety standards). It may provide a good measure of linking soil management guidelines and Eco-SGvs to human health values.

Specific indicator questions/patai: Māori wish to know:

- How do ecological soil values link to human health values?
- Can Eco-SGV targets and limits be used to describe a healthy soil at a given site?
- How does this support human health?

3 Objectives

This project aimed to identify gaps, stakeholders, and a pathway for the implementation of Eco-SGVs for the management of contaminated land, the management of surplus soils from development sites, assessing soil quality, and disposal of waste to land under current legislation, as well as under resource management reform, and includes a specific focus on incorporating te ao Māori.

4 The process

This project has been overseen by an advisory group comprising representatives from local, unitary, and regional councils (including representation from the regional council Waste and Contaminated Land and Land Monitoring Forum special interest groups), central government (Ministry for the Environment [MfE], Ministry for Primary Industries [MPI], Department of Conservation {DOC]), the Wasteminz Contaminated land special interest group, and a Māori representative.

The work has included the following.

- A brief review of the application of ecological criteria in different international jurisdictions was carried out to assess whether any significant changes have occurred after the reviews undertaken by Cavanagh (2012) and Cavanagh and Wright (2014). Cavanagh (2012) reviewed the specific methods used to derive ecological soil guideline values in various international jurisdictions, while Cavanagh and Wright (2014) reviewed contaminated land management frameworks in New Zealand and selected international jurisdictions.
- The practicality of application was assessed by evaluating the Eco-SGVs against regional council SOE soil quality monitoring, and soil contaminant data obtained through contaminated land investigations from a range of councils, to determine the frequency of exceedance for Eco-SGVs set at different protection levels.
- A workshop was held with 28 central government (MfE, DOC, MPI) and local government and Māori representatives on 8 February 2022 to identify desired outcomes from the application of Eco-SGVs in different contexts, and to identify potential issues or constraints associated with these applications. A summary of the desired outcomes and issues raised is provided in Appendix 1. Arising from this workshop was a basic framework for the proposed application of Eco-SGVs in different contexts (e.g. soil quality, contaminated land management), which was further tested with attendees in a subsequent workshop held on 31 March 2022.
- The advisory group and workshop identified a full range of stakeholders for whom EcoSGVs could help inform environmental management under the forthcoming resource management reform from different industry sectors that may be directly or indirectly 'impacted' by some of the proposed uses. An end-user workshop was held on 6 April 2022 with approximately 104 representatives from different industry sectors, including contaminated land management, waste disposal to land, organic materials, and primary production. The areas of interest and the organisation/area within an organisation represented by attendees are shown in Table 4. This workshop

was intended to ground-truth and identify issues and constraints associated with the proposed applications developed from the preceding workshops.

Table 4. Areas of interest and organisations represented by attendees at the end-user workshop on 6 April 2022

Main area of interest (*n* = 104)	% respondents	Organisation/ area within organisation (*n* = 98)	% respondents
Contaminated land management	67	Contaminated land / environmental consultancy	53
SOE monitoring / special non-regulatory use	1	Waste management company or consultancy	8
Primary production	4	Organic materials sector/ company	4
Organic materials, including disposal to land	13	Regional or unitary council	14
Discharge consenting	6	City or district council	6
Waste acceptance criteria / landfills	9	Primary industry	4
Other	1	Other	10

This project had a specific focus on exploring te ao Māori and its relationship to soil contaminants and the implementation of soil guideline values. Previous work (e.g. mātauranga Māori, soil health, land contamination, biowaste) was used to scope, identify, and understand current and potential Māori issues and likely impacts on cultural values (e.g. from waste, pollution, contaminants, and degradation).

During the project, and at all workshops, key aspects of mātauranga Māori (e.g. Māori knowledge of soils and land), specific cultural values, and key Māori environmental concepts, frameworks, and approaches that can be used in soil guidelines and land management (especially to manage contaminant/toxicity issues) were discussed and summarised. Key cultural considerations and issues were identified, drawing on experience using a range of sources, including specific local examples, iwi and hapū management plans and policy, and follow-up discussion through networks and other associations. This provided an essential conceptual underpinning for, and guidance on, how science-led and technical Eco-SGV guidelines could be used alongside, and incorporate, te ao Māori / mātauranga Māori to assess cultural impact and environmental impact (from Māori), and how to respond to cultural issues and meet Māori expectations and aspirations.

The proposed usage, incorporating te ao Maori perspectives and end-user feedback, is presented in section 6.

5 Review of the international status of guideline values to protect ecological receptors

A brief scan across international literature did not indicate any significant changes from the application of Eco-SGVs outlined in Cavanagh 2012 and Cavanagh & Wright 2014, and summarised in Table 5 for selected international jurisdictions. However, direct contact with consultants (Amy Brooks, Jo Wilding Cambridge Environmental Assessments) provided further insight into the assessment of contaminant impacts on ecological receptors in the UK, and this is summarised below.

Table 5. Overview of the use of soil guideline values for the protection of ecological receptors in selected international jurisdictions

Jurisdiction	Guideline value name	Basis of derivation	Application	Primary reference
Australia	Ecological investigation level	Developed for ecological receptors with different protection levels for three land uses (national parks, urban residential/ recreational, commercial/ industrial). Varies depending on soil physico-chemical properties.	Applies to the top 2 m of soil, and triggers further investigation in the event of non-compliance.	NEPC 2013
Netherlands	Intervention value	Developed for human (residential with garden exposure scenario) and ecological receptors (at a 50% protection level)	Non-compliance triggers assessment of the urgency of remediation, with 'maximal' values for residential and industrial land use set to enable reuse of contaminated soils.	MHSPE 2011
Canada	Soil quality guideline	Developed for both ecological and human receptors associated with 4 land-use categories (agricultural, residential, commercial, industrial).	Voluntary application with federal, provincial or territorial authority having jurisdiction to see whether a CCME guideline applies to their area of interest. Soil with contaminants present at the guideline levels will provide a healthy functioning ecosystem capable of sustaining the current and likely future uses of the site by ecological receptors and humans.	CCME 2006
United Kingdom	Soil screening values	Developed for ecological receptors.	Used primarily for land-spreading of waste-derived materials. Ecological risk assessment approaches are used for the management of contaminated land (see text below table for more details)	Environment Agency 2014
United States	Ecological soil screening level – Eco-SSL*	Separate Eco-SSLs developed for 4 types of ecological receptors: plant, soil, mammalian, and avian.	Used in the assessment of brownfield (potentially contaminated) sites. The Eco-SSLs are soil-screening values, and specifically are not applicable as clean-up levels	US EPA 2005

* Ecological Soil Screening Level (Eco-SSL) Guidance and Documents | US EPA

In the United Kingdom there are two regimes for how contaminated land (typically referred to as brownfields) investigations are undertaken. One is Part 2A of the Environmental Protection Act 1990, which addresses sites that have historically been developed but on which the land may now pose a significant risk (where 'significant' is defined in the legislation) to identified receptors, which includes ecological receptors. The other is through the planning regime, involving proactive risk assessment and remediation before any redevelopment, and here the aim is to be protective at a much lower level of risk (minimal or low risk). [5]

Under Part 2A ecological systems are considered as follows:

> Section 78A(4): 'Harm' means harm to the health of living organisms or other interference with the ecological systems of which they form part and, in the case of man, includes harm to his property.[6]

Ecological systems have very specific definitions and relate to specified protected areas; for example, a site of special scientific interest (under s. 28 of the Wildlife and Countryside Act 1981), or a national nature reserve (under s.35 of the 1981 Act), an area of special protection for birds (under s.3 of the 1981 Act). In practice, partly due to this niche definition, the focus is normally on human health or controlled waters (i.e. surface waters / groundwater). For the latter, the quality of aquatic ecosystems, or terrestrial ecosystems directly depending on aquatic ecosystems, should be considered.

Under the planning regime, where brownfields land is being redeveloped for a defined land use (e.g. commercial, residential), then ecological receptors may be considered, but only where there are statutory, designated sites (e.g. SSSI (sites of special scientific interest), RAMSAR sites, Local Nature Reserves) on-site or in the vicinity (e.g. an on-site source could be affecting an off-site receptor through contaminant migration). In practice the risks posed to ecological receptors are rarely considered, largely because if remediation is being undertaken, driven by identified risks to human health or controlled waters, then it would generally be assumed this would mean any potential risks to ecological receptors would be removed because the contaminant source(s) would be remediated.

Soil-screening values have been developed for land-spreading of waste-derived materials (Environment Agency 2022) and in this regard are analogous to the beneficial use of organic materials for productive land (WaterNZ 2017)

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[5] https://www.gov.uk/government/publications/national-planning-policy-framework--2

[6] Part 2A https://www.gov.uk/government/publications/contaminated-land-statutory-guidance. (This is the guidance for England and Wales, it is slightly different in Scotland.)

6 Assessing the practicalities of application

To assess the practicalities of application of Eco-SGVs, the Eco-SGVs outlined in Cavanagh 2019 were assessed against data from regional council state of the environment (SOE) soil-quality and contaminated land site investigation reports.

6.1 Regional council state of the environment soil quality data

Using regional council SOE soil quality data collated for *Our Land 2021* (MfE 2021a), data collected for sites between 2010 and 2018 (the latest available) were extracted. The land uses specified in regional council SOE reporting were grouped for comparison with the Eco-SGV land uses shown in Table 2. Agricultural land (dairy, drystock, cropping, and horticulture land uses) were compared to both the non-food production land 95% protection level (shown as agricultural production land in Table 2) and the Eco-SGV agricultural land mixed-protection level.

Table 6. Mapping of SOE soil quality land-use classes to Eco-SGV land-use classes

SOE soil quality land use	Eco-SGV land use (level of protection)
Indigenous vegetation	Areas of ecological significance (99%)
Exotic forestry	Non-food production land (95%)
Agricultural land – dairy, drystock, cropping, orchard/vineyard	Agricultural land (95%) Agricultural land (95% plants, 80% microbes and invertebrates)
Urban open space (Auckland Council only), lifestyle (Auckland Council only)	Residential/recreational area (80%)

The Eco-SGVs shown in Table 7 are those given in Cavanagh 2019 for the land use relevant for comparison with the regional council SOE soil quality data. These Eco-SGVs are based on the lowest median background concentrations, as determined by Cavanagh et al. (2015).

Table 7. Eco-SGVs (mg/kg) for different land uses using the lowest median background concentrations. Values for Cu and Zn apply to typical soils, and values shown in brackets apply to sensitive soils. Eco-SGVs should be based on background concentrations relevant to the site under assessment and are considered applicable to all soil types.

Land use (% protection)	As Eco-SGV$_{(EC30)}$ (mg/kg)	Cu Eco-SGV$_{(EC30)}$ (mg/kg)	Cd Eco-SGV$_{BM*}$ (mg/kg)	Cr Eco-SGV$_{(EC30)}$ (mg/kg)	Pb Eco-SGV$_{(EC30)}$ (mg/kg)	Zn Eco-SGV$_{(EC30)}$ (mg/kg)
Areas of ecological significance (99%)	6	45	1.5	100	55	120
Non-food production land (95%)	20	100 (85)	1.5	190	280	170 (130)
Agricultural land (95% plants, 80% microbes and invertebrates)	20	220 (150)	1.5	300	530	190 (150)
Residential/ recreational area (80%)	60	240 (180)	12	390	900	300 (260)

BM* = bio-magnification

Comparison of the trace element concentrations from the regional councils' SOE monitoring with the relevant Eco-SGVs is shown in Table 8. This comparison shows that 13 of the undisturbed indigenous vegetation sites have As concentrations that are higher than the Eco-SGV for areas of ecological significance – although given the low value of the Eco-SGV this more likely reflects the stringency of the Eco-SGV based on the 99% protection level rather than a significant impact, and suggests these values may not be practical to use.

Trace element concentrations in forestry sites did not exceed the relevant Eco-SGVs (95% protection level and non-production land), and similarly there were no exceedances of Eco-SGVs for residential/recreational land use (80% protection level) for lifestyle and urban parks.

The greatest number of SOE soil quality sites fall into the agricultural sites category: a small number of these sites exceeded the Eco-SGVs for As, Cu, Cd, and Zn, with the greatest number of exceedances observed for Cu and when assessed against the 95% protection level Eco-SGV. Overall, the low level of non-compliance with the Eco-SGVs in the different land-use categories suggests the Eco-SGVs are not overly conservative and are practical for use in the assessment of SOE soil quality data.

Table 8. Number of SOE soil-quality monitoring sites exceeding the Eco-SGV for the different land-use categories and contaminants; *n* refers to the total number of sites in each category, the number in brackets refers to the number of sites for Cd; Cu and Zn show exceedances for Eco-SGVs for typical and sensitive soils.

Land use (% protection)	*n*	As (mg/kg)	Cu (mg/kg)	Cd (mg/kg)	Cr (mg/kg)	Pb (mg/kg)	Zn (mg/kg)
Areas of ecological significance (99%)	100	13	2	0	2	2	0
Non-food production land (95%)	71 (79[1])	0	0	0	0	0	0
Agricultural land (95%)	596 (631[a])	8	12 (14[2])	4	0	0	2 (2[b])
Agricultural land (95% plants, 80% microbes and invertebrates)	596 (631[a])	8	3 (6[b])	4	0	0	1 (2[b])
Residential/ recreational area (80%)	17+35	0	0	0	0	0	1

[1] Number of sites for Cd.

[2] Number of sites exceeding the Eco-SGV for sensitive soils.

6.2 Contaminated site investigations

To provide an indication of the extent to which Eco-SGVs might be exceeded in contaminated land investigations, detailed site investigations were requested from regional councils, Christchurch City Council, and the NZ Defence Force. Specifically, five or more ‘representative’ detailed site investigations were requested from each of the following existing land-use classes:

- rural/agricultural
- urban residential
- commercial/industrial.

Additional details on the studies were requested, including:

- the purpose of the investigation (e.g. NES purposes, or others such as due diligence, health risk assessment, etc.)
- the existing land use and proposed future land use, if any (e.g. rural to rural residential, urban residential sub-division)
- a general description of the sampling approach (e.g. targeted/hot-spot sampling or systematic/grid sampling; what area the sampling represents).

Site investigations for rural residential and residential land uses were predominantly sampled for subdivision/higher density residential and confirmation of HAIL classification. Commercial/industrial generally stayed commercially industrial and were often sealed. Metal contaminants were the primary contaminants assessed, while B, PAH, and DDTs were not frequently analysed and were not further assessed. These studies were collated to enable evaluation against the Eco-SGVs shown in Table 9, with rural and urban site investigation assessed against the non-food production land (95% protection level) Eco-SGVs and residential/recreational land use (80% protection) Eco-SGVs, while the commercial industrial land use was assessed against the commercial land (60% protection) Eco-SGVs. The number of studies obtained for each category is shown in Table 10

Table 9. Eco-SGVs (mg/kg) for different land uses using the lowest median background concentrations. Values shown in brackets for Cu and Zn values are for sensitive soils. Eco-SGVs should be based on background concentrations relevant to the site under assessment and are considered applicable to all soil types.

Land use (% protection)	As Eco-SGV$_{(EC30)}$ (mg/kg)	Cu Eco-SGV$_{(EC30)}$ (mg/kg)	Cd Eco-SGV$_{BM**}$ (mg/kg)	Cr Eco-SGV$_{(EC30)}$ (mg/kg)	Pb Eco-SGV$_{(EC30)}$ (mg/kg)	Zn Eco-SGV$_{(EC30)}$ (mg/kg)
Non-food production land (95%)	20	100 (85)	1.5	190	280	170 (130)
Residential/ recreational area (80%)	60	240 (180)	12	390	900*	300 (260)
Commercial/ industrial (60%)	150	420	33	650	2,500*	480

*indicates the Eco-SGV was based on bio-magnification

Table 10. Summary of the number of studies

Rural	Urban	Commercial
33	30	49

These studies were challenging to compare to the Eco-SGVs for several reasons, including:

- variability in the quality of the investigations
- collection and analysis of composite versus discrete samples
- most undertook targeted sampling to identify hot-spots of concern, which varied in areal extent and depth of contamination
- variable depths were analysed, and sometimes surface soil was not assessed at all.

To provide an indicative assessment of the frequency of exceedance, concentrations from discrete samples were treated the same as composite samples and no differentiation was made between the different depths of sampling. Thus, *n* in Table 11 refers to the total number of *samples* that were compared to the Eco-SGVs, and the number of exceedances of the Eco-SGVs refers to the total samples, not sites that have concentrations higher than the relevant Eco-SGV.

In addition to comparison with the Eco-SGVs, comparison was also made with the soil contaminant Standards for the Protection of Human Health for the relevant land use (MfE 2011b). As shown in Table 11, not surprisingly the 95% protection level Eco-SGV was the one most often exceeded, with As, Cu, Pb, and Zn being the key contaminants for which exceedances occurred. At the 80% protection level, protection of human health is the greater consideration for As and Pb (i.e. the soil contamination standard (SCS) is lower than the Eco-SGV for residential and recreational land uses). Similarly, protection of human health is the main driver for managing As and Pb at commercial industrial sites, and it was not applicable to compare those samples with Eco-SGVs.

The greatest number of exceedances were, again not surprisingly, observed for Cu and Zn, which do not present a human health risk but can be toxic to ecological receptors if present at elevated concentrations. Overall, the relatively low frequency of exceedance of the Eco-SGVs, and the fact that protection of human health remains the dominant consideration for some contaminants, suggests that the Eco-SGVs are practical for use in contaminated land investigations.

Table 11. Number of samples from detailed site investigations exceeding the Eco-SGV for the different land-use categories and contaminants; *n* refers to the total number of samples in each category. Values in italics indicate the contaminants and land uses for which soil contaminant standards for the protection of human health are lower than the Eco-SGVs.

Land use (% protection)	As (mg/kg)	Cu (mg/kg)	Cd (mg/kg)	Cr (mg/kg)	Pb (mg/kg)	Zn (mg/kg)
n	75	69	55	57	76	58
Non-food production land (95%)	36	24	7	2	*20*	31
Residential/recreational area (80%)	*19*	11	1	0	*12*	22
n	68	69	62	68	73	71
Commercial/industrial (60%)	NA	15	1	4	NA	28

7 Proposed application of Eco-SGVs

7.1 Overview

Building on the workshop discussion and additional feedback from attendees, the proposed revised applications for Eco-SGVs are shown in Table 12. The proposed usage has been simplified to target values, trigger values, and limit values, which are applicable across all land uses. (In other words, Eco-SGVs are not differentiated on the basis of land use, but rather on the basis of the level of protection nominally afforded with different actions arising from exceedance/non-compliance of these different values and depending on the purpose of application.) The terms 'target values', 'trigger values' and 'limit values' are explained below.

Target value/limit

These values are derived on the basis of protecting 95% of ecological receptors from contaminant-related effects and are considered the concentration below which no more than minor effects will occur. The primary use is anticipated in the protection of soil quality, such as reporting on soil quality in regional council SOE soil quality monitoring, setting LIMITS for discharge consents (i.e. effectively being a pollute-up-to limit), setting soil limits for soil amendments, setting contaminant limits for compost/mulch products that may be used as soil replacements, and potentially for some landfill waste acceptance criteria (e.g. cleanfill). For contaminated land management these values may be potential remediation targets (*except* for Cu and Zn, for which it is likely that the most effective remedial action is active management of soil though natural attenuation over time).

Site investigation trigger

This value is derived on the basis of protecting 80% of ecological receptors from contaminant-related effects and is considered the concentration at which more than minor effects may start to occur. The primary use is anticipated to be the management of potentially contaminated land, specifically as a 'soft' trigger' value to require consideration of options to reduce ongoing inputs of contaminants, or potential remedial or management actions. These values may also be relevant to consider for landfill waste acceptance criteria (e.g. managed or controlled landfills).

Limit value

This value is derived on the basis of protecting 60% of ecological receptors from contaminant-related effects and is considered the concentration at which more than minor effects are likely to occur and/or significant adverse effects are occurring. The primary use is anticipated to be for the management of potentially contaminated land, and this is a concentration at which there is a greater expectation of action, including in the form of further investigation to determine the extent of impact and to ascertain appropriate management or remedial actions.

Table 12. Overview of proposed application of Eco-SGVs for different purposes

Value name (protection level)	Protection of soil quality	Contaminated land management
Target 'limit' (95%)	Regional council state of the environment monitoring Discharge consents, including for application of wastes (e.g. biosolids, cleanfill, managed fill) to land, and compost/mulch products Iwi/hapū/Māori achieve soil health goals, reflecting cultural values	Potential remediation targets (except Cu, Zn)* Te ao Māori aspirations are met for maintaining mauri
Investigation trigger (80%)	NA	A 'soft' trigger value for site investigation, leading to identification of mitigation options (e.g. where the source can be reduced, active management to reduce concentrations (Cu, Zn), including assessment of offsite risks. Also used for identifying contaminated land where human health is not the driver (e.g. Cu, Zn).
Limit value (60%)	NA	Site investigation leading to remediation/management appropriate to the identified risk/effect

* It is likely that the most effective remedial action for elevated Cu and Zn is active management of soil (to provide slow natural attenuation over time).

Some proposed applications for the protection of soil quality have links with existing industry-led technical guidelines, specifically *Technical Guidelines for Disposal to Land* (Wasteminz 2018) and *Guidelines for the Beneficial Use of Organic Materials on Productive Land* (WaterNZ 2017). Thus, the proposed application of Eco-SGVs in those guidelines (e.g. for setting waste acceptance criteria, setting soil limits) needs to be consistent with the usage developed through this process.

The values associated with these different target, investigation trigger, and limit values are provided in Tables 13–15, with the soil contaminant standards (SCS) for the protection of human health provided in Table 16 for comparison. The values shown in Tables 2 and 3 incorporate naturally occurring (background) concentrations of these trace elements. It is proposed that for most monitoring and assessments, initial comparison should be made with the values in Tables 2 and 3 and for aged contamination. Depending on the application, and the contaminant, it may also be appropriate to vary the Eco-SGV depending on site background. Finally, it is not intended that the Eco-SGVs be considered in isolation from guideline values to protect human health (such as the SCSs), or for the protection of groundwater. Thus, for some applications it may be appropriate to develop combined values, or select a value based on protecting the most sensitive receptor.

Further detail on the proposed applications is provided after in sections 7.3.

Table 13. Eco-SGVs (mg/kg) developed for selected contaminants for the lowest median background concentration. Eco-SGVs should be based on background concentrations relevant to the site under assessment and are considered applicable to all soil types.[1]

Value name (% protection)	As Eco-SGV[2] $_{(EC30)}$ (mg/kg)	B Eco-SGV $_{(EC30)}$ [3] (mg/kg)	Cd Eco-SGV $_{BM}$ [4] (mg/kg)	Cr Eco-SGV[5] $_{(EC30)}$ (mg/kg)	Pb Eco-SGV[6] $_{(EC30)}$ (mg/kg)
Target value (95%)	20	7	1.5	190	*280*
Investigation trigger (80%)	60	15	12	390	900[7]
Limit value (60%)	150	15	33	650	2,500[7]

[1] This may be the median background concentration for the relevant geological grouping obtained from https://lris.scinfo.org.nz/, or other site-specific information, if available

[2] Median background concentration range: 2.2–4 mg/kg.

[3] Hot-water soluble B; background B concentrations are expected to be negligible, although low concentrations (1–3 mg/kg) are typical for agricultural soils to which B may have been added for agronomic purposes.

[4] Median background concentration range: 0.05–0.1mg/kg.

[5] Median background concentration range: 9–27 mg/kg.

[6] Background concentration range: 7–15 mg/kg.

[7] An extra 5% protection applied to each land use to provide protection against secondary poisoning.

BM = biomagnification.

Table 14. Eco-SGVs (mg/kg) developed for fresh and aged Cu and Zn contamination in the three New Zealand reference soils, using the lowest median background concentration for Cu and Zn.[a] Eco-SGVs should be based on background concentrations relevant to the site under assessment.[b]

Land use (% protection)	Cu Eco-SGV$_{(EC30)}$ Typical soil		Cu Eco-SGV$_{(EC30)}$ Sensitive soil		Cu Eco-SGV$_{(EC30)}$ Tolerant soil		Zn Eco-SGV$_{(EC30)}$ Typical soil		Zn Eco-SGV$_{(EC30)}$ Sensitive soil		Zn Eco-SGV$_{(EC30)}$ Tolerant soil	
	fresh	aged	fresh	aged	fresh	aged	fresh	aged	fresh	aged	fresh	aged
Target value (95%)	55	100	45	85	65	120	80	170	75	150	95	230
Investigation trigger (80%)	120	240	95	180	170	340	130	300	90	260	160	380
Limit value (60%)	220	420	160	320	320	630	210	480	110	430	250	620

[a] Median background concentration range for Cu: 7–25 mg/kg; median background concentration range for Zn: 24 – 44 mg/kg

[b] This may be the median background concentration for the relevant geological grouping obtained from https://lris.scinfo.org.nz/, or other site-specific information if available

There were limited toxicity data available for the organic contaminants. Utilisation of older studies (i.e. pre-1970) yielded additional data for DDT, and this was sufficient to use the SSD approach for deriving ACLs. Note that DDE, the main degradation product of DDT, is the main residue typically present in soils as a result of the historical use of DDT. However, a dearth of data on the toxicity of DDE to soil microbes, plants, and invertebrates precludes the development of an Eco-SGV for DDE.

To address this, and given the observation of marked biomagnification of DDE in a New Zealand food chain, more conservative DDT Eco-SGVs were recommended for use. In this case, the Eco-SGVs were based on the NOEC/EC10 toxicity endpoints and accounted for biomagnification (i.e. a higher protection level was used to set the Eco-SGV).

Eco-SGVs developed for TPH and PAHs (fluoranthene, benzo(a)pyrene) are recommended for use as screening criteria only, as these compounds are typically present as mixtures of varying composition (and therefore toxicity), and they are based on limited toxicity data.

Table 15. Eco-SGVs (mg/kg) developed for organic contaminants

Land use (% protection)	Total petroleum hydrocarbons (TPH)[a]						DDTs	Polycyclic aromatic hydrocarbons (PAH)	
	F1	F2	F3		F4			Fluoranthene	Benzo(a)pyrene
			Fine[b]	Coarse[c]	Fine	Coarse			
Target value (95%)	110	70	1,300	300	2,500	1,700	2.4	27	2.8
Investigation trigger (80%)	130	110	1,300	300	2,500	1,700	4.8	89	22
Limit value (60%)	170	140	2,500	1,700	6,600	3,300	11	190	47

[a] F1: C7–C9, F2: >C9–C15, F3: >C15–C36 and F4: >C36; see also Cavanagh & Munir 2016, section 4.10.

[b] Fine-grained soils are those that contain greater than 50% by mass of particles less than 75 µm (mean diameter).

[c] Coarse-grained soils are those that contain greater than 50% by mass of particles greater than 75 µm (mean diameter).

For comparison, the SCS for the protection of human health are shown in Table 16.

Table 16. Soil contaminant standards for protection of human health (MFE 2011d) for selected contaminants

Land use (% protection)	As (mg/kg)	Cd (mg/kg)	Cr (VI) (mg/kg)	Pb (mg/kg)	BaP* (mg/kg)	DDT (mg/kg)
Rural residential/lifestyle (25% produce consumption)	17	0.8	290	160	6	45
Residential 10% produce	20	3	460	210	10	70
High-density residential	45	230	1,500	500	24	240
Recreational area (80%)	80	400	2,700	880	40	400
Commercial/ industrial outdoor/ industrial outdoor work	70	1,300	6,300	3,300	35	1,000

* BaP-equivalent

7.2 Considering te ao Māori

It is important to understand Māori perspectives, knowledge, and values in all aspects of land management (addressing, for example, what is soil health? how do Māori understand contaminated land? what criteria do they use to assess and explain contaminants?). An understanding of te ao Māori / mātauranga Māori is essential for developing soil guidelines that are useful and effective in considering cultural issues, interests, and needs.

Tools, methods, and guidance in this work will help inform Māori decision-making and guide best practice for land management that reflects cultural values, and the management of contaminants (e.g. waste disposal and treatment, land remediation). This work also provides a foundation and stepping-stone for any national policy development and frameworks for managing contaminated land in New Zealand.

A key component of developing soil guidelines will be setting criteria (e.g. values, attributes, targets, and limits) that are culturally acceptable, complementary to te ao Māori, and meet Māori aspirations and needs. This will support our understanding of soil quality and soil health and its links to cultural values, and Māori health and well-being. It will also help inform the use, management, and remediation of soils (oneone) and land (whenua).

A broader, more holistic soil health perspective and use of Eco-SGVs (i.e. ecological understanding) is consistent with Māori concepts, values, and knowledge using a soil ecosystem approach of understanding links and interconnections in the whole system. The goal of soil health and protection of terrestrial and ecological biota (e.g. soil microbes, invertebrates, plants, wildlife, and livestock) from the negative effects of contaminants using Eco-SGVs provides a useful way to understand and assess potential environmental and cultural impacts.

From a te ao Māori perspective it is also essential to link the terrestrial biota and Eco-SGVs to human health and well-being in a way that sees human beings as part of the whole soil ecosystem. One specific application raised in this work would be to provide better links between ecological receptors and human health values using the right framing (criteria, language, resources, documentation) that clearly links the management of contaminants to achieving desired ecological, environmental, and cultural outcomes (taiao, te oranga o te taiao, te mana o te wai) and human health outcomes (hauora, toiora, tangata oranga).

Current and potential impacts of contaminants on cultural values can be illustrated through a variety of specific local examples (e.g. papakāinga: Māori communities, settlements, and housing), food harvest areas (e.g. māra kai and mahinga kai), offsite impacts on water quality (e.g. nitrates), and the mauri and other cultural values (e.g. taonga species, habitats) of a water bodies, culturally important and significant sites (e.g. sensitive areas, wāhi tapu, marae).

Therefore a key application would be to use cultural values and ecological soil guidelines to improve the management/rehabilitation of soils in culturally important or significant areas. An example of a cultural issue raised at workshops is the potential mixing of soils (contaminated soils with uncontaminated soils, or soils from two different geographical areas with different whakapapa or tribal ancestral links).

7.3 Fit with current and future legislation and policy

The Resource Management Act 1991 (RMA) is the primary piece of current legislation under which discharges to the environment (s.15) and contaminated land are managed by regional and local councils (s.30, s.31). Through the RMA, the Resource Management (National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health) Regulations 2011 (referred to hereafter as the NES) were gazetted on 13 October 2011 and took effect on 1 January 2012. The policy objective of the NES is to ensure land affected by contaminants in soil is appropriately identified and assessed when soil disturbance and/or land development activities take place and, if necessary, remediated or the contaminants contained to make the land safe for human use.

The NES creates statutory guidance for the following guidelines:

- *Contaminated Land Management Guidelines No. 1 – Reporting on Contaminated Sites in New Zealand* (Ministry for the Environment 2021b)
- *Contaminated Land Management Guidelines No. 2 – Hierarchy and Application in New Zealand of Environmental Guideline Values* (Ministry for the Environment, 2011b)
- *Contaminated Land Management Guidelines No. 5 – Site Investigation and Analysis of Soils* (Ministry for the Environment 2021c, CLMG#5)
- *Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand* (Ministry for the Environment 2011c)
- *Methodology for Deriving Standards for Contaminants in Soil to Protect Human Health* (Ministry for the Environment 2011d).

To assist in implementing the NES, a user guide was developed (MfE 2012), and additional guidance documents are available.[7] Further discussion on the application of Eco-SGVs under the current legislation is provided in section 7.6.2.

The Eco-SGVs also have relevance for the Environment Reporting Act (ERA), which is currently being amended but has mandatory requirements for SOE monitoring across all domains, including assessment and reporting of land and soil health.

National policy frameworks and legislation are increasingly referring to the inclusion of te ao Māori and mātauranga Māori, and the recognition and responsibilities under the Treaty of Waitangi. Exploration and understanding of te ao Māori concepts in this work will help us develop useful and meaningful soil management guidelines and practices that can give effect to key concepts, such as te mana o te wai (NPS-FM); te mana o te taiao, under national biodiversity strategies and proposed policy; and te oranga o te taiao (purpose) in the new RMA reforms (proposed Natural and Built Environments Act, Strategic Planning Act). Similarly, Māori inclusion and decision-making roles are visible in the ERA amendments for mandatory requirements of SOE monitoring across all domains, assessment and reporting of land and soil health, and application to any new soils policy for Highly Productive Land[8] (NPS-HPL).

In terms of RM reform,[9] the Natural and Built Environment Act (NBEA) is one of the three core pieces of legislation – along with Spatial Planning Act (SPA) and a new Climate Adaptation Act (CAA) – that will replace the RMA. The SPA and CAA are intended to be released by the end of the year alongside the final draft of the NBEA. The intention is for the Minister for the Environment to prepare a National Planning Framework under the

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[7] See Contaminated land | Ministry for the Environment.

[8] This is still proposed and has yet to be gazetted

[9] This section is largely adapted from Highlights from the proposed Natural and Built Environments Act (buddlefindlay.com)

NBEA and provide for land use and set environmental limits and outcomes. Councils will develop regional spatial strategies under the SPA, which will identify areas of land suitable for development and infrastructure, and those that need to be protected. The CAA is proposed as specific climate change adaptation legislation to address the complex issues associated with managed retreat and funding of adaptation.

The NBEA's proposed purpose (as set out in the exposure draft in 2021) is two-fold: to uphold te oranga o te taiao, including by protecting and enhancing the natural environment; and enabling people and communities to use the environment in a way that supports present and future generations. The NBEA has an emphasis on ensuring that positive outcomes for the environment are identified and promoted rather than just enabling development where adverse effects can be avoided, remedied or mitigated. The new National Planning Framework (NPF) would include provisions to resolve conflicts between environmental outcomes, particularly on matters of national importance where national or regional *consistency* is required.

It is proposed that the NBEA include a mandatory set of national policies and standards that aim to protect the ecological integrity of the natural environment and protect human health with mandatory environmental limits prescribed in a National Planning Framework. These limits must at least cover air, biodiversity, coastal waters, estuaries, fresh water, and soil, and may represent:

- 'the minimum biophysical state of the natural environment or of a specified part of that environment', or
- 'the maximum amount of harm or stress that may be permitted on the natural environment or on a specified part of that environment'.

Ecological integrity is currently defined in the exposure draft as the ability of an ecosystem to support and maintain:

a its composition: the natural diversity of indigenous species, habitats, and communities that make up the ecosystem; and

b its structure: the biotic and abiotic physical features of an ecosystem; and

c its functions: the ecological and physical functions and processes of an ecosystem; and

d its resilience to the adverse impacts of natural or human disturbances.

The current project can help to inform the proposed new National Planning Framework and any mandatory standards. It can also be used in the development of guidance materials to enable use under the existing policy and regulatory regime as an interim measure. This could provide the opportunity to 'test' use in preparation for the pending legislative changes. The Eco-SGVs based on differing levels of protection could potentially be used to provide targets and limits for certain aspects of the soil environment.

7.4 Considerations for the general use of the Eco-SGVs

7.4.1 Background concentrations

As stated in the technical documents, the Eco-SGVs for naturally occurring contaminants (i.e. metals and metalloids) have been developed using the 'added-risk' approach. This approach considers that soil biota are adapted to the naturally occurring concentrations of potential contaminants and that it is the 'added' anthropogenic component that drives toxicity responses. This approach allows for variation in the Eco-SGVs based on variation in naturally occurring background concentrations. The Eco-SGVs shown in Tables 2 and 3 are based on the lowest median concentration for all geological settings determined by Cavanagh et al. (2015), with the range of median and 95the percentile values shown in Table 17.

Table 17. Summary of the range of median and 95th percentile background concentrations for geological groupings with *n* > 30

Trace element	Median range (mg/kg)		95th percentile range (mg/kg)	
As	2.1	4.1	8.9	17
Cd	0.05	0.10	0.05	0.49
Cu	6.7	25	29	108
Cr	8.6	27	41	129
Pb	6.8	16	25	56
Ni	4.4	14	25	77
Zn	25	44	102	183

Source: Cavanagh et al 2015.

However, some pragmatism is required to determine when variation should be 'allowed' to avoid overly complex application of the Eco-SGVs. This judgement has been made by considering both the median range and the proportional contribution of the natural background concentration to the Eco-SGV using the background concentrations determined by Cavanagh et al. (2015). Specifically, if the range in median concentration is >5 mg/kg and the contribution of the highest median background concentration to the Eco-SGV is >10%, then it is appropriate to modify the Eco-SGV. This results in 'allowable' variation in Eco-SGV being constrained to Cu, Cr, and Zn for the target Eco-SGVs (95% protection level), and Cu and Zn only for site investigation triggers (80% protection level).

This 'allowable' variation could be constrained to the median background concentrations determined by Cavanagh et al. 2015[10] for specific locations, to provide clarity and consistency between councils. Further work is required to 'merge' or transition information

[10] Available at PBC - Predicted Background Soil Concentrations, New Zealand - Landcare Research Limited | New Zealand | Environment and Land GIS | LRIS Portal (scinfo.org.nz)

on regional background concentrations (e.g. ARC 2000; GWRC 2003), noting that data from these studies were used by Cavanagh et al. (2015) to determine background concentrations nationally.

There is an exception to this approach for land that is located within mineralised areas. In these cases it may be appropriate for on-site determination to verify the applicability of adjusting the Eco-SGV based on background concentration variation. These areas are identified generally in Cavanagh et al. 2015 and are reproduced in Appendix 2. Further consideration is also required in relation to background concentrations in urban areas, for which the ambient background concentration of certain contaminants may be elevated as a result of emissions from diffuse anthropogenic combustion sources (e.g. vehicles, domestic woodburners) and historical use of leaded petrol. However, there are limited data available to determine ambient background concentrations in urban areas.

In rural areas the organochlorine pesticide DDT was widely used in pastoral agriculture and horticulture in the 1950s–60s, and while such uses had largely ceased by the mid-1970s (Buckland et al. 1998), residues (primarily pp-dichlorodiphenyldichloroethylene, pp-DDE) still persist in agricultural soils (e.g. Boul 1995; Buckland et al. 1998; Gaw et al. 2006; numerous contaminated land site investigation reports). This historical, widespread use of DDT has resulted in the ubiquitous presence of DDT residues in soil that should be considered as ambient background concentrations of these residues. The challenge is that historical use can be highly variable between sites, making determination of 'the' ambient background concentration problematic (Cavanagh et al. 2015).

Finally, it should be noted that an MWLR-funded project is currently being undertaken to update the predicted background concentrations determined by Cavanagh et al. (2015) using a more extensive data set of samples collected across New Zealand, predominantly from conservation and grazing land. Analysis for this project will take into account some of the comments raised during workshop discussions on background soil concentrations, in particular on geological groupings used for prediction. This project is due for completion by 30 June 2022. However, further technical work will be required to more extensively evaluate the application of background soil concentrations to address other comments made during workshop discussions.

Further discussion on the use of background concentrations in different contexts is provided in Appendix 2.

7.4.2 Depth of application

Further detail to be worked through involves the depth of soil to which it is appropriate for Eco-SGVs to apply. It is usually considered that the bulk of soil biological activity occurs in the upper 30 cm of soil (US EPA 2015), although soil microbes, invertebrates and plant roots can all be present at greater depths. Rather than consider the depth to which Eco-SGVs apply, it might be more relevant to consider at what depths or conditions contaminant leaching to groundwater should be given more consideration in environmental assessments.

7.4.3 Variation in soil properties

A further consideration is whether, for Cu and Zn, the initial assessment should be for Eco-SGVs for sensitive soil, and then, if exceeded, evaluated against other soil types where appropriate information is available (note definition of sensitive, typical etc is based on additional soil properties typically not measured for soil quality monitoring (clay, CEC) or in contaminated land investigations (pH, C, CEC, clay). The soil properties describing the different soil types are shown in Table 18.

Table 18. Soil characteristics for New Zealand reference soils to be used to normalise toxicity data. Properties were determined from the National Soils Database.

Soil property	Sensitive soil	Typical soil	Tolerant soil
pH (H_2O)	5.0	5.4	5.5
pH ($CaCl_2$)*	4.5	4.8	4.9
Clay (%)	17	21	23
CEC (cmol/kg)	13	20	30
eCEC (cmol.kg)*	15	19.5	30.1
Org. carbon (%)	3.1	4.6	9.4

* Values typically required for use in toxicity-regressions (normalisation) relationships.

7.5 Detail of proposed applications to protect soil quality

The main purposes for using Eco-SGVs for the protection of soil quality can be grouped into three general categories:

- *awareness-raising*, where the main outcome of not meeting the target values (95% protection) is to signal to the land manager/owner that soil ecosystem health may start being compromised and to consider whether there are ongoing inputs of contaminants that could be reduced (this usage includes application for regional council SOE soil quality monitoring, production land, and other 'special non-regulatory' uses, such as māra kai, community gardens)
- *compliance*, which refers to applications such as rules and standards set in regional plans, and consents to discharge to land and landfill waste acceptance criteria.
- *soil amendment and replacement*.

Further details are provided below.

7.5.1 Awareness-raising

Regional council SOE monitoring

The target values provided in Tables 2 and 3 can be used to assess the soil quality of samples collected through regional council SOE monitoring programmes. Where these target values are not met, some further evaluation of whether the Eco-SGV should be adjusted to account for variation in background concentrations may be warranted. Regardless, not meeting a target can provide the trigger for further evaluation and assessment of potential inputs and opportunities to reduce these if they are ongoing (e.g. Cu as a fungicide, Zn for facial eczema treatment). Relevant guidance materials / fact sheets could be created and provided to land managers or owners (e.g. MPI 2020a, b),

Production land

The use of Eco-SGVs for production land is anticipated to be similar to that for SOE monitoring for samples that are collected in an appropriate manner (i.e. are representative of a specific paddock or field). The anticipated use is non-regulatory, with the aim of extending land manager awareness of potential negative effects on productivity and soil health arising from accumulated contaminants, some of which may also be essential nutrients (Cu, Zn). Appropriate guidance materials / fact sheets could be made available through primary sector organisations similar to what has been developed for managing Cd (e.g. MPI 2020a, b).

Te ao Māori perspectives and other non-regulatory uses

It is important for Māori to understand scientific concepts and knowledge of soils and ecological receptors in a 'meaningful way' and be able to apply and use target values to inform decision-making and practice. Information may have to be customised for Māori to promote uptake and use. This is part of awareness-raising. Māori will utilise this information, alongside tikanga Māori and mātauranga Māori, to ascertain needs, and make sense of their environments (taiao, kaitiakitanga) to assess cultural impact. Māori may wish to use this information in their own land management decision-making roles (e.g. land manager/owner, Māori land blocks, tribal rohe, papakāinga, māra kai, mahinga kai), or utilise it within cultural monitoring approaches by also having access to council-quality SOE monitoring data and results.

Māori groups may wish to use and apply Eco-SGVs and guidelines in their own regulatory and compliance networks (tribal iwi/hapū policy, planning, frameworks) or in relation to current and proposed national legislation and policy. There may be a central role for Māori in consenting and regulating in the future (e.g. collaboration, partnership, co-management, co-governance) to achieve desired local, regional and community outcomes that respect and protect Māori cultural values and achieve desired and shared outcomes.

A further specific application of particular interest to Māori is in relation to the soil quality for māra kai. In this case, the application goes beyond simply considering soil 'health' from a contamination perspective, and also links to information about human health, including potential contaminant uptake into food crops. This information would also be of interest for the wider public, including for community gardens, and could be provided as guidance materials / fact sheets provided through appropriate forums.

7.5.2 Compliance

Māori will assess the impact (e.g. from contaminants, degradation, pollution) against their social, cultural, environmental and economic values within a te ao Māori world-view framing and have firm ideas and opinions on setting criteria and acceptable standards for managing discharges to land, land to water, and landfill waste acceptance, to minimise impacts on cultural values and meet aspirations (cultural, environmental, social, and economic).

Discharge consenting

An effective use of Eco-SGVs for discharge consents is as limits set in regional plans or through the assessment of discharge consents using guidance. That is, the rate and concentration of the discharge (wastewater or solid waste, such as organic waste) should not result in target values being exceeded in the soil receiving the discharge. For As, Pb, and Cd, other factors (protection of human health, ensuring compliance with food standards – for Cd in particular) may be appropriate to consider.

In setting discharge consent limits, it may be appropriate to specify a depth of application for these values, and to ensure the potential leaching to groundwater is considered. A further consideration may be the appropriate consent limit for soils where the 95th percentile value for naturally occurring background concentrations is higher than the Eco-SGV, which is based on the median background concentration.

Where the discharge is solid waste to land (e.g. organic waste products), the nutrient loading associated with the waste application may also need to be considered. Further details of this application should be covered in relevant guidelines (e.g. WaterNZ 2017). This draft guideline updates the biosolids guidelines (NZWWA 2003) and extends application to a wider range of organic waste derived products. It references the previously developed Eco-SGVs (for agricultural land use), under section 9.7 (soil replacement requirements), with the recommendation that:

> in the rural environment; the product must meet the Guide product concentration limits and the nitrogen application limits based on the land type i.e. 'ordinary' or degraded. The soil should be measured before and after to ensure that the Eco-SGV limits are maintained.

While this information is provided in the section on soil replacement, the reference to the nitrogen application limits suggests, instead, that this use is as a soil amendment rather than complete soil replacement. Further, given the change in the proposed use of the Eco-SGVs, the values used in WaterNZ 2017 are no longer consistent with the intended use. WaterNZ 2017 also includes recommendations for 'true' soil replacement in the urban environment, and this is discussed in the next section.

Table 19. Proposed limits for soils receiving discharges (mg/kg) based on protection of ecological receptors for key contaminants. Values in italics are those that may be lowered to ensure protection of human health based on SCS for rural residential land use.

Contaminant	Soil discharge consent limit (mg/kg)
As	20 (*17*)
B	7
Cd	1.5 *(0.8)* *
Cr	190
Cu – aged	100
Pb	280 *(250)*
Zn – aged	170

* Limits may be lower to ensure compliance with food stands (Cd).

Landfills and waste acceptance criteria

The application of Eco-SGVs in relation to landfills primarily sits within the development of waste acceptance criteria for different landfills. Conceptually, waste acceptance criteria should be developed by considering protection of human health from direct contact (or inhalation of volatiles), potential for leaching into groundwater (including that used for drinking water), and organisms living in or on the soil (ecological receptors), and be based on the most sensitive receptor. These criteria should be appropriate to landfill construction, the nature of the wastes, and potential future land use (i.e. unrestricted or restricted to certain land uses).

The *Technical Guidelines for Disposal to Land* (Wasteminz 2018) have been completed and are available on the WasteMINZ website.[11] The document provides technical guidance on siting, design, construction, operation, and monitoring for disposal to land, and classifies landfills into five types:

- Class 1 Landfill – Municipal Solid Waste Landfill or Industrial Waste Landfill.
- Class 2 Landfill – Construction & Demolition Landfill or Industrial Waste Landfill
- Class 3 Landfill – Managed Fill
- Class 4 Landfill – Controlled Fill
- Class 5 Landfill – Cleanfill.

Of most relevance to the current Envirolink Project are Classes 3 to 5, as no liners are required for these landfills, enabling direct contact of the surrounding soil with the landfilled materials. For classes 4 and 5 it is intended that there be unrestricted future land use. No mention is made of future land use for Class 3 landfills: see Appendix C in Wasteminz 2018. Appendix C provides an overview of the development of waste

[11] http://www.wasteminz.org.nz/pubs/technical-guidelines-for-disposal-to-land-april-2016/.

acceptance criteria, which includes consideration of leaching potential, human health exposure, and exposure of ecological receptors. No waste acceptance criteria are available for class 3 landfills in Wasteminz 2018, although it is understood these are being developed. Appendix G in Wasteminz 2018 provides class 4 waste acceptance criteria, which include consideration of ecological receptors, using values obtained from Cavanagh 2006. There is clearly an opportunity to ensure consistency in application of Eco-SGVs between the current project and any further development of waste acceptance criteria in a disposal to landfill context.

Appendix H in Wasteminz 2018 provides class 5 waste acceptance criteria, using regional background concentrations for key inorganic elements in Auckland and Wellington as examples, and specified criteria for selected organic contaminants. The revised background soil concentrations being developed through the current background soils project funded by MWLR could assist in providing background soil concentrations for specific locations and other regions.

It should also be noted that approaches used by regional councils for cleanfill criteria have been variable, based either on background concentrations alone or on a combination of background concentrations and Eco-SGVs (e.g. Cavanagh 2021, 2013), or on concentrations that are not lower than the 95th percentile of the regional background and not exceeding the lower of protective thresholds for the most sensitive receptor (i.e. the lower of human health or ecological thresholds, (Waikato Regional Council undated).

Finally, Māori consider soil disposal, the mixing of soils, and soil replacement in the context of Māori beliefs, values, and mātauranga Māori (and issues raised accordingly), reflect a range of cultural values, especially whakapapa (ancestral lineage of all parts of nature, interconnections and inter-dependencies), and this is considered within a whole taiao, ecosystem, soil health framework. Therefore, acceptance criteria will be considered in relation to cultural values through assessed and perceived cultural impact. This has specific application in the context of waste acceptance criteria for different landfills, but also where soil is imported onto sites as part of remediation processes (see also section 7.5.3).

7.5.3 Soil amendment and replacement

Organic products, including those derived from waste materials, may be applied as soil amendments and not require a discharge consent. In this case, the rate and depth of application of the product should be taken into account to ensure the amendment does not result in Eco-SGVs. As noted above, the rate of application may also need to consider the nutrient loading. Further details of this application should be covered in relevant guidelines (e.g. WaterNZ 2017).

Where compost/organic products could be used as soil replacements, the target values/limits for tolerant soil (% carbon 9.4, and pH>5.4) could be used for Cu and Zn, given the high organic carbon content of these products. As for the potential discharge consent limits, the values for As and Pb may be lowered to ensure protection of human health. Given the high organic carbon content of these products, it is not considered necessary to lower the limits to ensure compliance with food standards for Cd. These values are shown in Table 20.

However, note that there is a marked discrepancy between these and the New Zealand compost standard contaminant limits (Table 20), particularly for boron (B). Further revised values could be developed using an even higher carbon concentration, if needed, and may reduce the difference in contaminant limits for most contaminants. However, the B values require further investigation, because essentiality and toxicity of boron to plants can be overlapping, meaning that setting robust limits is problematic.

Table 20. Potential compost quality (mg/kg) limits for inorganic contaminants based on Eco-SGVs for 'tolerant' soils and the New Zealand compost standard contaminant limits. Bolded values indicate the contaminant limits that are different from the Eco-SGV-based compost quality limits. Italics indicate soil concentrations to protect human health (SCS for rural residential land use).

Contaminant	Potential compost quality limits (mg/kg)	NZ compost standard contaminant limits (mg/kg)
As	20 *(17)*	20
B	7	**<200**
Cd	1.5	3
Cr	190	**600**
Cu	120	**300**
Pb	280 *(160)*	250
Zn	230	**300**

Note that WaterNZ (2017) recommend that where organic materials are used for soil replacement in the urban environment, the product concentration should meet the Eco-SGV concentrations, except for Zn. In this case, using the soil limit of 300 mg/kg from the 2003 biosolids guidelines is suggested to avoid limiting the application of home compost – based on data from compost produced from urban green waste and food waste that had Zn concentrations up to 300 mg/kg. As noted above, the Eco-SGVs specified were those previously derived for agricultural land and which are no longer used.

7.6 Contaminated land management

The use of Eco-SGVs in contaminated land management is arguably their most predominant use. To enable the use of Eco-SGVs in the near term, it is considered that outlining their use in contaminated land management (which sits alongside current regulation) will be most useful. This allows Eco-SGVs to be used sooner and enables 'testing' of the proposed use ahead of incorporation into pending legislation or regulation.

Specifically, given the signalled changes to resource management legislation, it is anticipated that a guidance document (similar to existing contaminated land management guidelines) that outlines assessment of soil ecological receptors, including the use of Eco-SGVs, for contaminated land management, will be most useful in the short term while also informing the development of future policy and legislation.

In this regard it is anticipated that the triggers for contaminated land assessment under the NES are sufficient to consider the potential effects on soil ecological receptors. The additional aspect is that there would be a need to explicitly consider soil ecological receptors during site investigations. Detailed site investigations should provide the data to compare to Eco-SGVs, with the guidance in CLMG#5 regarding comparison of site investigation data to guideline values also applicable to Eco-SGVs (e.g. the 95% upper confidence limit of the arithmetic mean; 95% UCL) should be used for interpreting data against an SCS or alternative guideline value. The key difference to the current situation is the need to consider soil ecological receptors in assessing the potential risk/effect and in developing remedial management plans. Materially, this requires specific consideration of the potential negative effects arising from elevated concentrations of Cu and Zn as common contaminants, but which are not limiting from a human health perspective.

A key difference from the current contaminated land management regime is that the same Eco-SGVs apply to different land uses, with differing levels of protection of ecological receptors informing the action taken as a result of non-compliance. An exception is that for commercial/industrial land it is proposed that the Eco-SGVs not apply to any impervious/impermeable surfaces (such as land/soil that is sealed, compacted driveway areas), given the unsuitability of these environments for any ecological receptors regardless of contamination issues. In these cases it may still be appropriate to assess the potential for leaching to groundwater, or sediment movement into surface waters.

The proposed actions associated with non-compliance with Eco-SGVs based on different protection levels are shown in Table 21. Note that the use of Eco-SGVs set at a 95% protection level is proposed primarily as a potential remediation target, the exception being for Cu and Zn. The reason for this exclusion is that Cu and Zn are also essential nutrients. Therefore, provided there are no adverse effects arising from Cu and Zn concentrations, the best course of action is to actively manage the soil and retain it in place.

Table 21. Anticipated source of information for the use of Eco-SGVs and actions associated with exceeding Eco-SGVs for different protection levels in contaminated land management regime

Value name	Information source	Action in event of non-compliance
Target value (95%)	DSI	No action, other than potentially providing information to the land manager about improving soil quality. Can be potential remediation targets (except for Cu and Zn).
Site investigation trigger – 'soft' action level	DSI	Site investigation report includes assessment of options for mitigating risk (e.g. reducing any ongoing inputs of Cu and Zn), as well as assessment of potential off-site risks. Advice given on actions to remediate or reduce contaminant concentrations or mitigate risk to land-owner/ manager. These values might be relevant to use to identify contaminated land for all land uses except commercial/industrial.
Limit value – 'hard' action level	DSI, further investigation / risk assessment	The intent is that non-compliance at this level gives rise to a greater requirement to further assess the effect from contaminants, including off-site risks and risk mitigation. The incentive for risk assessment over 'dig and dump' is that demonstration of no effect or no risk can provide the basis for no further action (and therefore reduced cost). This value might also be relevant to use as the basis for identifying contaminated commercial/industrial land.

DSI – Detailed site investigation

7.6.1 Te ao Māori

Contaminated land, waste disposal, and the mixing of soils pose significant and increasing issues for Māori. There are already a number of high-profile cases involving iwi/hapū across New Zealand, including the Mapua clean-up (MfE 2011a), Ngāi Tahu values for dealing with waste (Pauling & Ataria 2010), and Whakatane sawmill waste and mātauranga Māori (Jaram 2009). Many potential issues are emerging (e.g. Dome Valley, north of Auckland) where iwi/hapū are at the forefront of articulating the issue through to management and decision-making.

The Eco-SGVs provide another tool that can sit alongside tikanga Māori and mātauranga Māori for managing waste and contaminants through the sampling and assessment of soil, and the implementation of EcoSGVs (e.g. targets and limits) to inform and guide decision-making. Māori need this type of information to inform them of the degree of contamination of a site (para, paru), its toxicity, and the best methods and practices for healing Papatūānuku (earth mother) and whenua (land) that manage and alleviate contaminants to acceptable levels in line with cultural values. Eco-SGVs are therefore important beyond just the protection and management of soil quality and soil health, and guidelines and tools should be developed in conjunction with Māori to maximise uptake in a meaningful way to underpin Māori decision-making and soil and resource management, and help achieve Māori aspirations.

Land management

Māori are very interested in using and applying Eco-SGVs, both broadly and locally. This is sospecially for assessing cultural and environmental impacts and using targets and limits to guide contaminated land management activities for soil disposal and land remediation/restoration in line with cultural values (e.g. back to a culturally acceptable state or level, and what that looks like).

It is important to have a broad understanding of te ao Māori / mātauranga Māori when using and applying Eco-SGVs in land management with Māori groups (iwi/hapū, marae, Māori organisations) to ensure it will enhance the 'testing' and application of the proposed use – ahead of any incorporation of future legislation or regulation (e.g. Treaty of Waitangi, new RMA reforms, NPS-FM, national soils policy, NES). A te ao Māori view is crucial for both understanding te ao Māori / mātauranga Māori as a knowledge base in soil and land management, but also for addressing critical issues (e.g. waste minimisation, land disposal, contaminant management) and implementing solutions and best practice (e.g. land remediation).

The Eco-SGVs and criteria will provide another tool in the toolbox for Māori decision-making to achieve Māori aspirations. Eco-SGVs have particular application for protecting and managing cultural values through improved understanding of mātauranga Māori-based cultural and environmental values, and the management/rehabilitation of soils in culturally important and sensitive areas.

7.6.2 Barriers for implementation

There are barriers for the implementation of the Eco-SGVs, the most obvious being the transitional state of national legislation. This affects the clarity of the intended application and timing of when the Eco-SGVs might be implemented within the regulatory regime, and whether that use is along the lines of what has been proposed in this report. Most significantly, it affects the ability, willingness, and impetus to utilise the Eco-SGVs ahead of that time.

As noted earlier, developing a guidance document that outlines the use of Eco-SGVs in contaminated land management alongside current regulation would enable Eco-SGVs to be used sooner, and enable 'testing' of the proposed use ahead of incorporation into pending legislation or regulation. It is envisaged this guidance document could be similar to existing contaminated land management guidelines for use by councils and contaminated land practitioners.

Regional councils and territorial authorities have some overlapping functions with respect to contaminated land, with territorial authorities under s. 31(b) having the responsibility for:

- '…the control of any actual or potential effects of the use, development, or protection of land, including for the purpose of—….
- (iia). the prevention or mitigation of any adverse effects of the development, subdivision, or use of contaminated land…'

Under s30(1)(ca), regional councils have the function of investigating land for the purposes of identifying and monitoring contaminated land. They also have functions under s30(c)(i) for the control of the use of land for the purpose of soil conservation, which includes the physical, chemical, and biological qualities of soil (although practically the majority of policies related to soil conservation are focused on erosion control), and under 30(f) for the control of discharges of contaminants into land or onto land, air, or water, and discharges of water into water.

The principal means of controlling contaminated land used by territorial authorities is the NES-CS. However, practically, the release of the NES-CS in 2011 limited the consideration of territorial authorities to the protection of human health when assessing contaminated land. Quite simply, there would be no mandatory obligation for territorial authorities to consider Eco-SGVs when assessing an application under the NES-CS, unless the NES-CS were amended. Also, practically, unless there is clear direction within council policies or plans and rules to consider the wider environmental effects associated with contaminated land, there is no mandatory obligation for territorial authorities to consider Eco-SGVs.

A final key challenge, and a limitation in the existing regime, is that many territorial authorities are simply too small for it to be reasonably expected that territorial authority staff have sufficient technical expertise to be able to adequately assess reports based on protection of human health, let alone including consideration for ecological receptors. To address this limitation, currently many territorial authorities seek input from, or are supported by, the relevant regional council, and/or contract the assessment out to experienced contaminated land practitioners. Our working model for implementing the guidance would be to have the regional council provide support to territorial authorities for the assessment of ecological receptors.

8 Guidance for applying Eco-SGVs

Further guidance is required to enable Eco-SGVs to be consistently and appropriately applied in the different contexts (e.g. awareness-raising, compliance, contaminated land management), and to avoid a sole focus on the numbers without consideration of the overall outcomes desired to be achieved (i.e. improved environmental outcomes). The form this guidance takes will depend on the purpose of the intended application.

This guidance should consider how to use the Eco-SGVs when assessing environmental and cultural impact, and how they will be used to underpin and inform Māori decision-making and partnerships with regional councils. This includes considering can we make the information more meaningful to Māori by incorporating te ao Māori / mātauranga Māori concepts, knowledge, values and indicators? e.g. understanding baselines (i.e. background soil concentrations) and anthropogenic 'elevated' contaminant levels, using Eco-SGvs for assessment of impact, using targets and limits to regulate and manage, and the application of standards, guidelines and best practice for land remediation - how to restore land (whenua) and soil back to something culturally acceptable – 'healing Papatūānuku' – that reflects cultural values.

8.1 Protection of soil quality

As noted earlier, the role of Eco-SGVs in the protection of soil quality can be grouped into:

- awareness-raising
- compliance
- soil replacement.

Guidance on awareness raising would include general information of potential effects of contaminants and considerations to decrease sources and integrate consideration of protection of human health and compliance with food standards, as appropriate (e.g. MWLR 2020a, b) as well as being developed for application in Māori contexts (e.g. papakāinga, māra kai). Application in compliance settings may include specific technical reports, but also links to existing industry-based guidelines, including the *Technical Guidelines for Disposal to Land* (Wasteminz 2018), and the *Guidelines for Beneficial use of Organic Materials on Productive Land* (WaterNZ 2017). Similarly, guidance on the application of the Eco-SGVs where soil is amended or replaced with organic materials should be included in WaterNZ 2017, and greater consistency with the Eco-SGVs and the NZ compost standards would be appropriate.

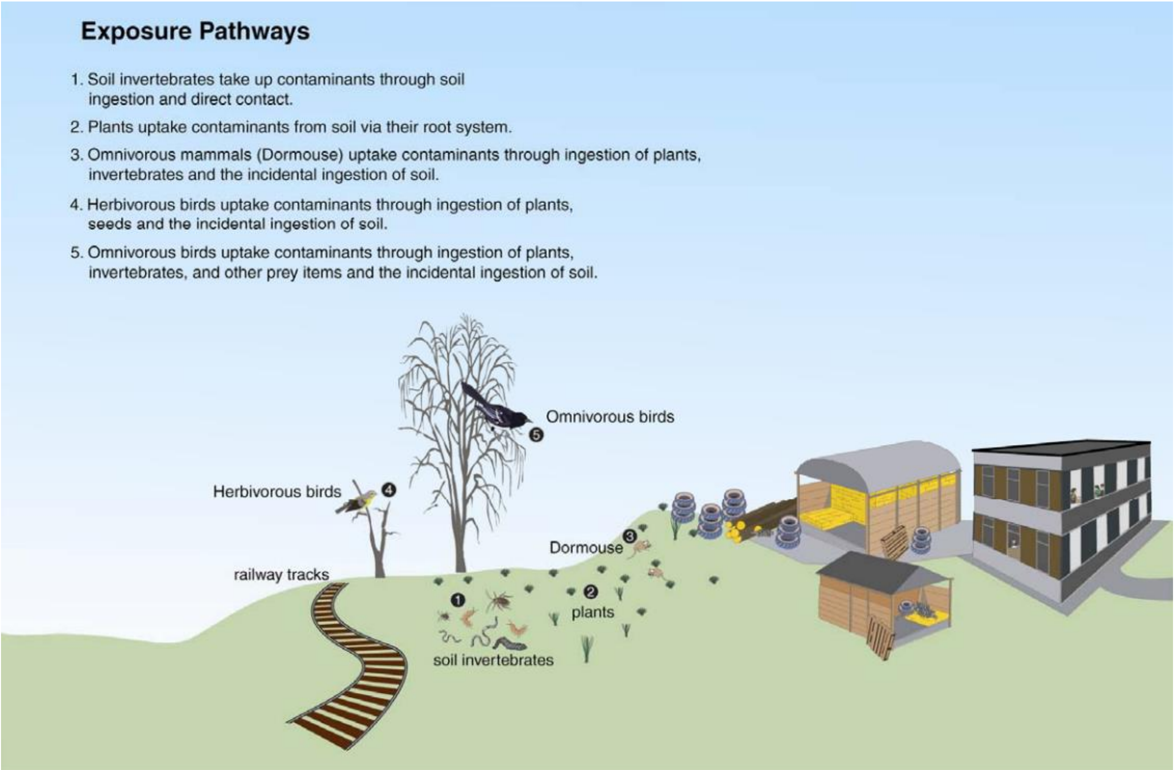
8.2 Contaminated land management

Given the signalled changes to resource management legislation, it is anticipated that a guidance document (similar to existing contaminated land management guidelines) that outlines assessment of soil ecological receptors, including the use of Eco-SGVs, for contaminated land management could be useful in the short term while also informing the development of future policy and legislation. This guidance would be intended for use by contaminated land practitioners and should include:

- sampling and consideration of ecological receptors for contaminated site investigations, including conceptual site models
- depth of application and consideration of protection of groundwater
- use of background soil concentrations to modify Eco-SGVs
- application of the Eco-SGVs (e.g. Table 12
- further site investigations.

8.2.1 Conceptual site models

Inclusion of ecological receptors in a conceptual site model should be reasonably straight-forward, in that the general principles of considering exposure pathways are the same as those required for protection of human health, and are outlined in CLMG#5 (MfE 2021b) and shown pictorially in Figure 2. In most cases the dominant ecological receptors for consideration will be soil microbes, soil invertebrates and plants, as visitation by birds or other wildlife will be more transient. The exceptions to this will be for contaminated sites located in conservation areas such as some abandoned mine sites.



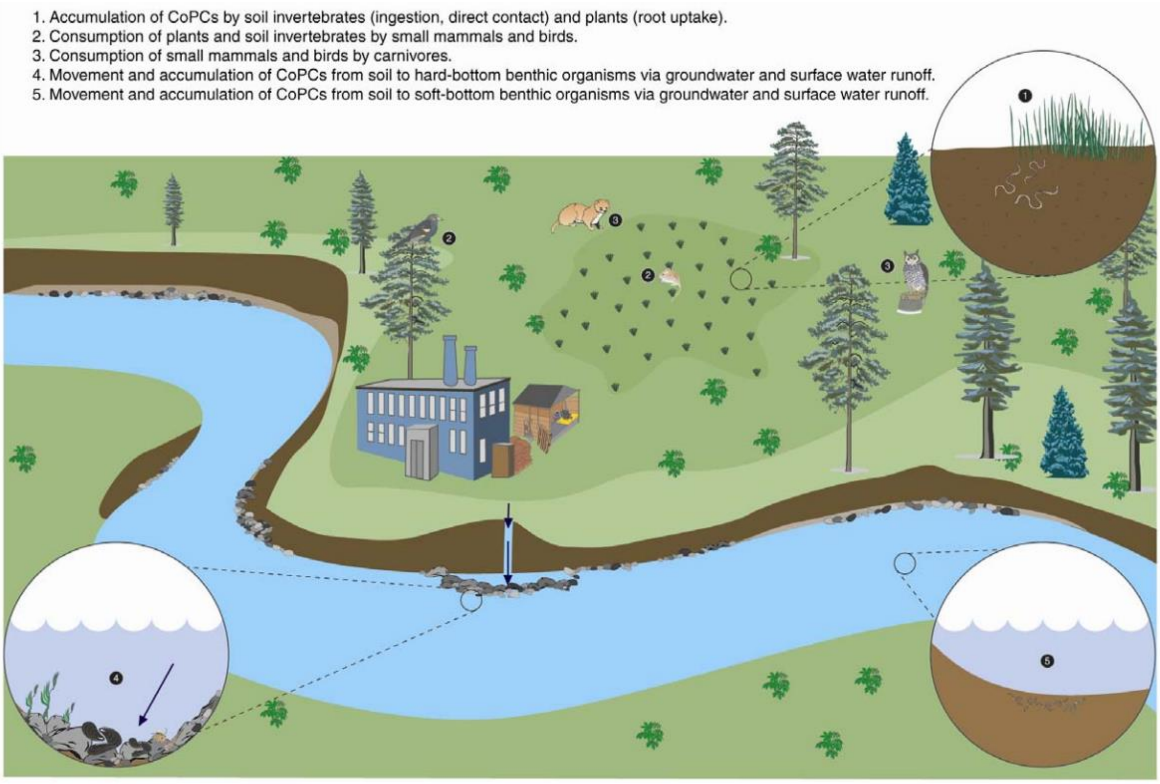


Figure 2. Pictorial conceptual site models for ecological risk assessment relevant to a contaminated site in the United Kingdom, showing exposure pathways for on-site and off-site ecological receptors. (Source: Environment Agency 2014)

8.2.2 Application of the Eco-SGVs

There are several aspects of the comparison of Eco-SGVs to measured soil concentrations – some of this will be covered in CLMG#5, but other aspects require further consideration. This includes further specification of the use of background soil concentration in relation to modifying the Eco-SGVs applied, including identification of mineralised areas, which can have elevated background concentrations; addressing approaches where 95% percentile background concentrations are higher than Eco-SGVs (and the frequency of this occurrence); and the depth to which Eco-SGVs should be applied, and how this relates to waste acceptance criteria for landfills.

8.2.3 Combined human health and ecological values

It is not intended that Eco-SGVs override human health soil contaminant standards in the assessment of contaminated land. Thus, to implement Eco-SGVs as described in Table 12, for the land uses specified in the *Methodology* for soil contamination standards (SCS) (MfE 2011d), a potential option is to combine SCS for human health and the Eco-SGVs. Tables 22–23 provide these combined ecological receptor values by combining the Eco-SGVs for different protection levels with the SCS for the respective land use. Where the human health/SCS is exceeded, management is based on current practices. Where Eco-SGVs are the trigger, actions specified in Table 21 should be taken. If this approach is adopted it would also be appropriate to develop human health values that enable a similar buffer between 'soft' and 'hard' triggers for action.

Application of the combined values should also allow for the disaggregation of these values and allow for only human health (or only ecological receptors) to be considered, where appropriate. In this regard it might be useful to consider what the appropriate 'exposure scenario' might be under which consideration of soil ecological receptors is not applicable, given that the primary ecological receptors under consideration are soil microbes, plants, and soil invertebrates, all of which might reasonably be expected to be present at all sites with garden or grassed areas.

Table 22. Combined target values; italics indicate that protection of human health (based on the SCS) will be the main driver for subsequent action on the site. Note: for contaminated land management purposes these values are intended to be primarily applicable for use as remediation targets (except Cu and Zn).

Potential interim values	As (mg/kg)	Cd (mg/kg)	Cr III (mg/kg)	Pb (mg/kg)	BaP only (mg/kg)	DDT (mg/kg)	B	Cu	Zn
Rural residential / lifestyle (25% produce consumption)	*17*	*0.8*	190	*160*	2.8	*2.4*	7	100	170
Residential 10% produce	20	1.5	190	*210*	2.8	2.4	7	100	170
High-density residential	20	1.5	190	280	2.8	2.4	7	100	170
Recreational area (80%)	20	1.5	190	280	2.8	2.4	7	100	170
Commercial/ industrial outdoor/ industrial outdoor work	20	1.5	190	280	2.8	2.4	7	100	170

Table 23. Combined site investigation trigger values; italics indicate that protection of human health (based on the SCS) will be the main driver for subsequent action on the site.

Potential interim values	As (mg/kg)	Cd (mg/kg)	Cr III (mg/kg)	Pb (mg/kg)	BaP only (mg/kg)	DDT (mg/kg)	B	Cu	Zn
Rural residential / lifestyle (25% produce consumption)	*17*	*0.8*	390	*160*	22	4.8	15	240	300
Residential 10% produce	*20*	*3*	390	*210*	22	4.8	15	240	300
High-density residential	*45*	12	390	*500*	22	4.8	15	240	300
Recreational area (80%)	60	12	390	*880*	22	4.8	15	240	300
Commercial/ industrial outdoor/ industrial outdoor work	60	12	390	900	22	4.8	15	240	300

9 Next steps

9.1 Key next steps arising from this project

There is a component of technical work required for the use of background soil concentrations. This includes consideration of the revised background soils, currently being developed through another project, which is also addressing:

- when it should be relevant to adjust Eco-SGVs
- regional vs national determination of background soils (e.g. comparison of revised background soil concentrations to existing regional studies, such as ARC 2000, GWRC 2003)
- identification of mineralised areas
- evaluation of the 95th percentile background vs Eco-SGV (based on median background concentration), which is particularly relevant to the development of cleanfill criteria.

The second component relates to guidance materials and the fit with pending legislation and policy, including te ao Māori and mātauranga Māori. We see this work as providing a pivotal foundation and stepping-stone for any national policy development and frameworks for managing contaminated land in New Zealand. It will enable exploration of potential targets and limits to protect the ecological integrity of the soils and enable enhancement of the environment. The exploration of te ao Māori/mātauranga Māori also meets requirements of proposed legislation and current and proposed national and regional policy.

Most iwi and hapū in New Zealand have developed, or are developing, their own planning and policy documents and provisions within respective tribal areas in order to effectively manage resources, put into practice kaitiakitanga (environmental and cultural guardianship), and form partnerships with councils to manage resources and address key issues (e.g. cultural heritage, climate change, biodiversity, soils, land remediation/waste). Much of this work with tangata whenua, iwi, and hapū and Māori organisations (Māori sector groups, Māori enterprises, trusts, and incorporations) is guided in relation to the Treaty of Waitangi and occasionally by specific Treaty settlements and legislation, usually local and regional (e.g. Waikato River, Ureweras, Whanganui River).

From te ao Māori and mātauranga Māori there are also several key areas that we can expand and explore in more detail including:

- *sampling and further site investigation* – soil sampling programmes should consider and add some culturally important and significant areas (e.g. papakāinga, māra kai, mahinga kai) as part of an overall sampling strategy
- *application and implementation* – it would be pertinent and helpful to develop site and case study examples of best practice, some involving the incorporation of tikanga Māori / mātauranga Māori to show collaboration and cultural interests and values.

We recommend that Māori representatives and experts be at the table when developing soil management guidelines and understanding application. We should broaden the 'community of interest' of researchers, policy and planning representatives, and land management and contaminant experts from this work to a community of practice involving Māori and other key stakeholders.

9.2 Proposed Tools project

The next steps in relation to guidance and fit with future legislation and policy can be undertaken to some extent within an Envirolink Tools project proposal that will commence on 1 July 2022.

The project will be overseen by the advisory group for the current advice grant project. To the extent possible, the project will undertake a detailed policy and regulatory analysis of the implementation of soil guideline values to protect ecological receptors (including soil microbes, plants, soil invertebrates and higher animals) to inform the use of these values in current and future legislation and policy. The output will be a framework, with associated guidance, for implementing these guideline values, which will ideally be appropriate for both existing and future regulation. For the latter, the setting of environmental targets and limits to ensure ecological integrity is protected, and a focus on environmental improvement is a fundamental shift from current legislation.

This project will commence with an advisory group meeting to understand the state of development of future policy, and what guidance can most usefully assist in developing this legislation and policy.

This project will continue the focus on enabling te ao Māori / mātauranga Māori to be used alongside science to better inform soils policy, regulation, and resource management, for which there is a high level of interest (Harmsworth 2021 – Envirolink Grant: 2141-NLCC117). An intent will be to develop specific 'relevant' case studies to show that mātauranga Māori can be used in a complementary way alongside science (i.e. linking mātauranga Māori and science). This will help to progress the understanding, use, and awareness of te ao Māori / mātauranga Māori to inform soils policy, regulation, and resource management, and to address specific Māori issues, incorporate te ao Māori knowledge and concepts, and improve soil management locally, regionally, and nationally (e.g. within and across tribal rohe, Māori land).

The Eco-SGV application framework will be tested by addressing the emerging practice of the sustainable management of 'surplus soils' to achieve better overall environmental outcomes. In the project, surplus soils are defined as those that have been identified as being surplus to on-site requirements as a result of soil disturbance, such as land sub-division or remediation of lightly contaminated sites (i.e. where soils just exceed soil contaminant standards or are above background), and are removed off-site despite posing little risk and having beneficial use if kept on-site.

A workshop will be held early in the project with a wide range of stakeholder to start unpacking the drivers and barriers to enabling sustainable management (reducing the generation of these soils, enabling beneficial reuse for improved environmental outcomes). A key outcome of the work is to minimise the disposal to landfill of soils that could otherwise be beneficially used. The output of this aspect of the tool is the development of a comprehensive guide for councils, Māori, and industry to enable the sustainable management of surplus soils that includes:

- guidance on defining and characterising surplus soils
- a context for the guide, including an overview of 'ISO 18504:2017 Soil quality – sustainable remediation', relevant New Zealand guidelines, and regulatory setting
- te ao Māori knowledge, perspectives, values, and principles to inform the sustainable management of national and regional soils policy and regulation
- outlining the benefits and risks associated with different soil management options and beneficial uses, including the potential for minimising generation of surplus soils through remaining *in situ*
- case studies illustrating examples of beneficial use, and of missed opportunities arising from soil disposal
- a decision support framework for managing surplus soils that identifies explicit trade-offs being made, and integrates te ao Māori concepts and knowledge related to surplus soils.

10 Acknowledgements

Participants in the two workshops are thanked for their comments and discussion on the potential implementation of the Eco-SGVs. Thanks to Gina Sweetman (Sweetman Planning Services) for providing input and advice on fit with current legislation, including barriers to implementation in the report. Thanks also to the Advisory Group members Kirsten Forsyth, Isla Hepburn, Bruce Croucher (MfE), Kok Hong Wan (MPI), Rachel Rait (DOC), Jonathan Caldwell (Waikato Regional Council), Sarah Brand (Marlborough District Council), Matthew Taylor (Land Monitoring Forum, Waikato Regional Council), and Isobel Stout (Christchurch City Council) for discussions on the implementation of the Eco-SGvs and providing comments on a draft of the report. Additional thanks go to Isobel Stout (Christchurch City Council) for compiling contaminated land investigation data, along with Kiran Munir (MWLR), who also reviewed the draft report.

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Appendix 1: Workshop summary

Summary from Māori and central and local government workshop, 8 February 2022.

28 Attendees.

The workshop comprised presentations and discussions, with a Mural whiteboard used for workshop sessions and for capturing responses. These responses were grouped under the themes specified for each of the relevant questions asked and outlined below.

Workshop session 1:

What are the desired outcomes from the use of Eco-SGVs?

- *Management of land/soil* – benchmark for soil quality, assisting land-use planning, setting policy directions
- *Legislation/policy* – comments mainly focused on NES 'upgrade', NBA
- *Māori perspective* – dealing with culturally significant sites, māra kai, mahinga kai
- *General* – healthy biodiverse soils, increasing awareness of soil, protecting soil resource, connecting human health and environment
- *Considerations* – connection to NPS-FM/water, consideration at catchments scales
- *Out of scope* – setting criteria for protection of water quality

How could Eco-SGVs be used?

- *Contaminated land/discharge to land* – identification of contaminated land, use on register, triggers and limits, disposal to land, consent conditions
- *Remediation* – targets for improvement, prioritisation of areas for rehabilitation,
- *Surplus soils* – aiding reuse of soil, guidance for facilitating use
- *SOE monitoring/NPS HPL* – benchmark, assessing trends, tools to assist sustainable management of soils
- *Māori perspective* – remediation/bioremediation based on Māori values, linking to human health / Māori wellbeing, caution around mixing of soils
- *Connectivity with water* – NPS-FM, drinking water NES, catchment-scale management

What actions should be triggered as a result of non-compliance?

- *Contaminated land* – further testing, risk assessment, remediation/long-term management, enforcement in event of significant effect
- *Land use/management* – behaviour change, working with land managers, ensure land is suitable for use
- *SOE/soil quality* – understand site-specific, then regional/national, policy change
- *Connectivity with water/farm plans* – viewed as being important to include/incorporate/align with farm plan requirements
- *Challenges* – who would enforce?, timing of application in relation to development of land

What should constitute non-compliance with Eco-SGV?

- *General* – main comment was depending on context and extent of risk/effect
- *Consenting* – consistent failure to meet consent conditions
- (Actions from non-compliance – incorporated above)

Workshop session 2

Are the proposed land-use categories (and associated levels of protection) appropriate? Are there potential additions; e.g. customary use? Is any differentiation on the basis of land use appropriate?

- *Limits/targets* – discussion on use as targets and limits, concern over the 'gap' between 60% and 95% protection if those adopted as limit and target
- *Land use* – comments ranged from inclusion of additional land use (e.g. undisturbed natural) and more clearly defining land uses generally, and in relation to NES-SC to simplifying land-use categories
- *Māori perspectives* – mahinga kai and mana whenua sensitive land are important, consider cultural impact analysis as part of this, mixing of soils is a concern, monitoring is important, consider how this can be used to support Māori decision-making about protection and enhancement of soils locally

How should background soil concentrations be used?

- Consideration of areas with naturally elevated concentrations, including adaptation of soil biota

Appendix 2: Mineralised areas and further details on background concentrations

Areas of mineralisation

The following areas of mineralisation were identified by Cavanagh et al. (2015) through comparison of the location of samples with elevated trace element concentrations in rocks or soils captured either in the Crown Minerals database or the PETLAB database. The distribution of the regional council soil sampling locations indicates that some soil sampling has been undertaken in regions where concentrations might be naturally elevated.

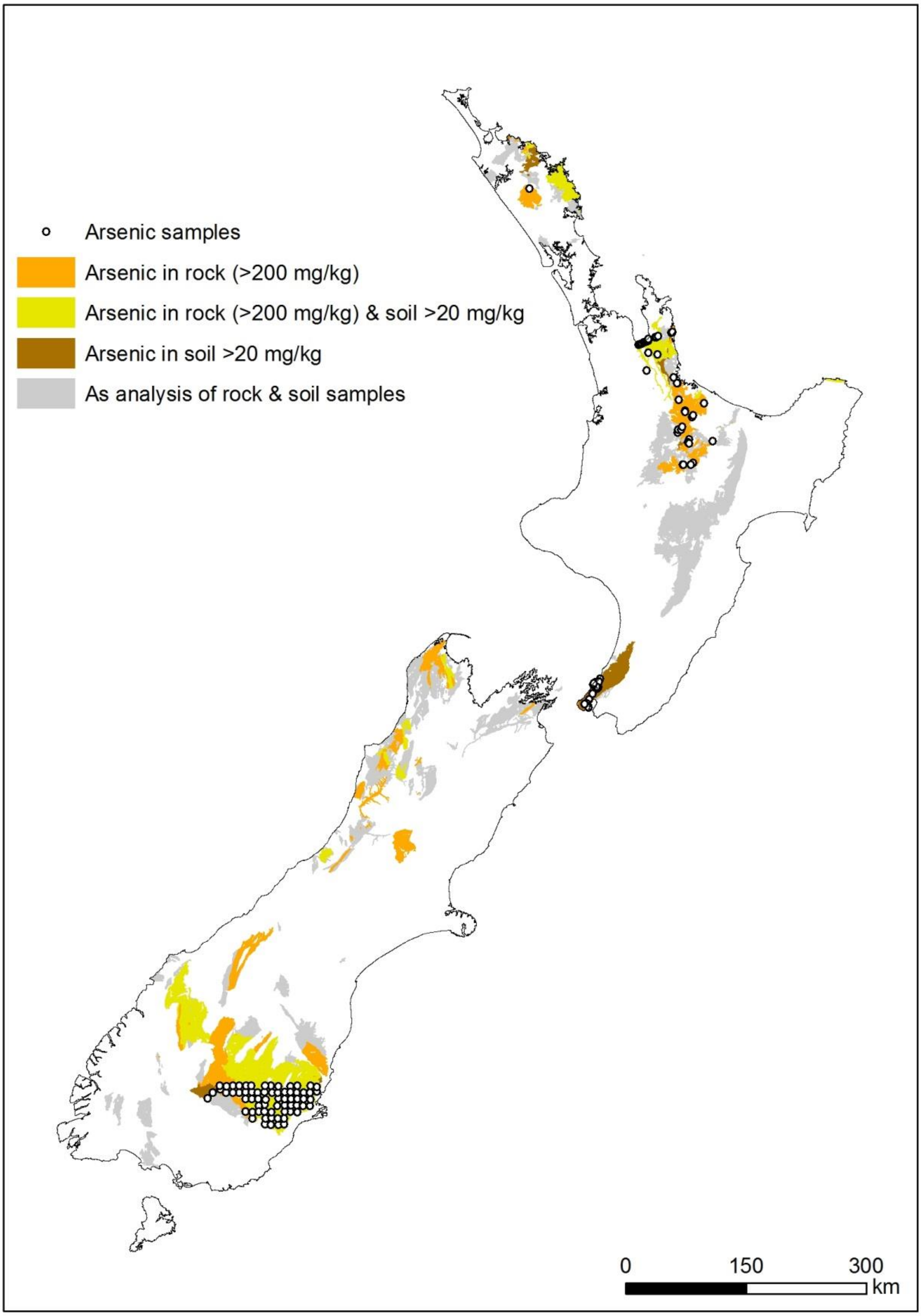

Figure A1. Identification of arsenic-mineralised areas from rock and soil samples from the Crown Minerals database, and rock samples from GNS Science's PETLAB database, applied to the surrounding QMAP map unit polygon. This potentially highlights areas of elevated background soil concentration. Dots show the location of samples in the data set of Cavanagh et al. (2015) that have been collected from within the identified mineralised areas.

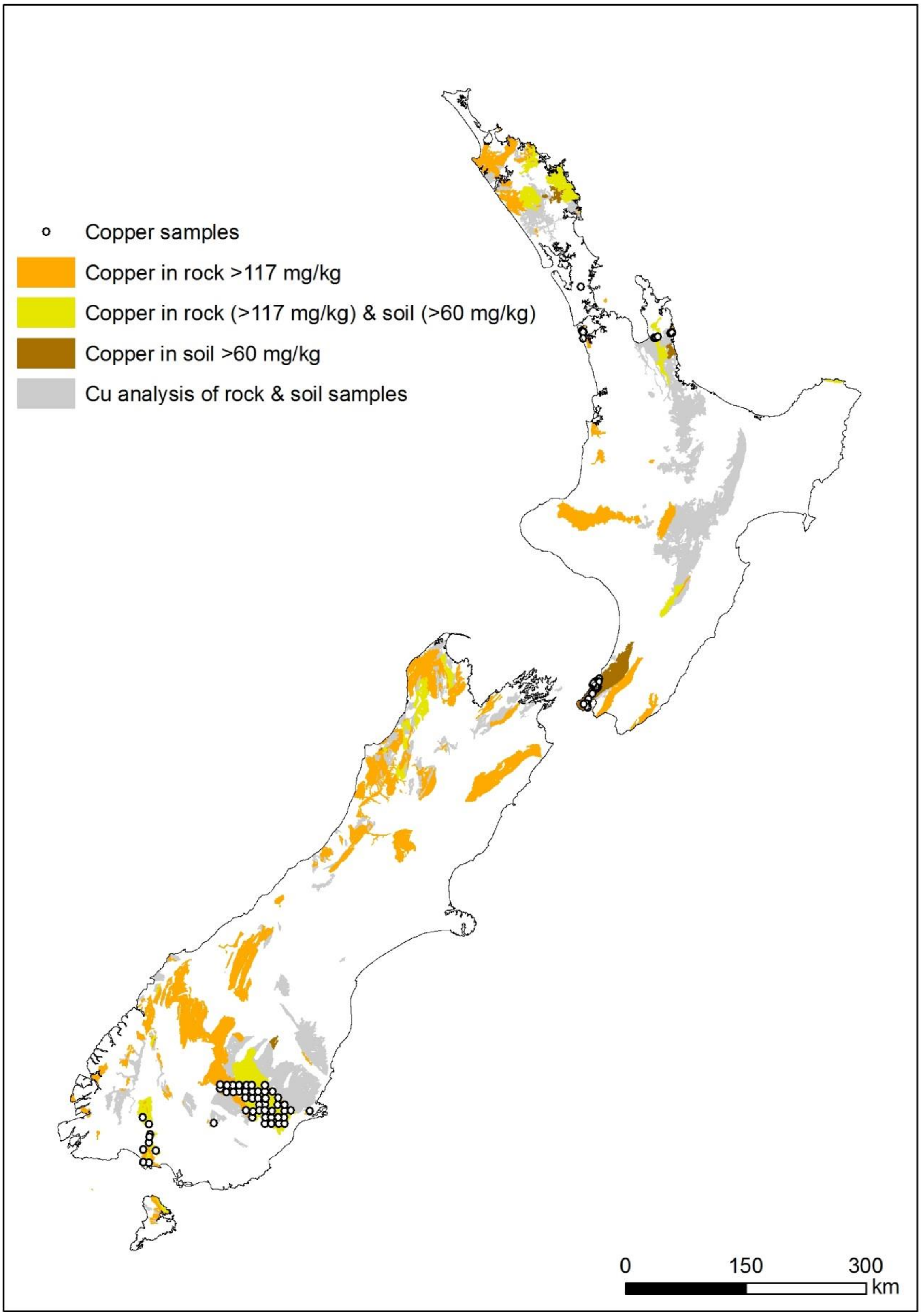

Figure A2. Identification of copper-mineralised areas from rock and soil samples from the Crown Minerals database, and rock samples from GNS Science's PETLAB database, applied to the surrounding QMAP map unit polygon. This potentially highlights areas of elevated background soil concentration. Dots show the location of samples in the data set of Cavanagh et al. (2015) that have been collected from within the identified mineralised areas.

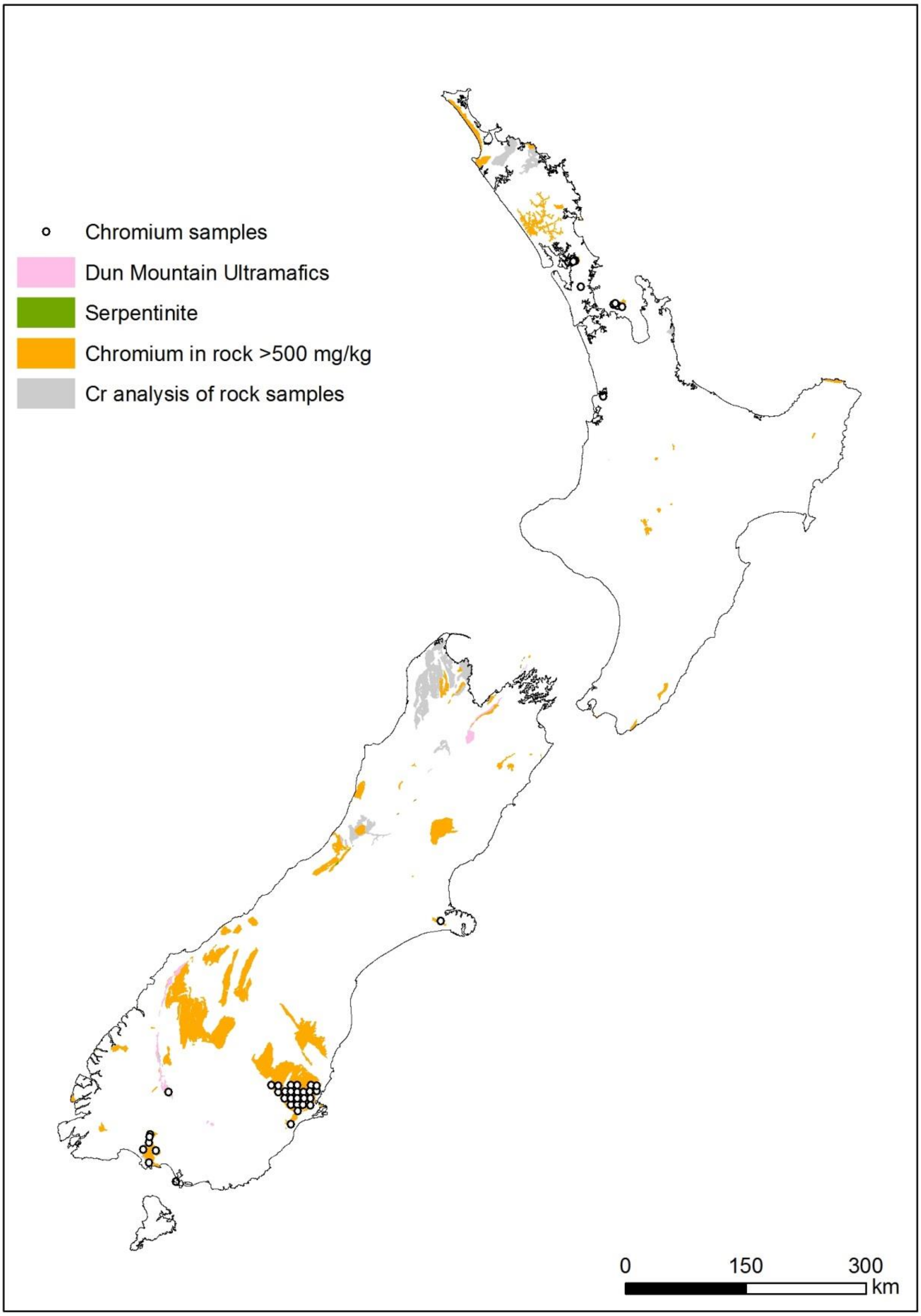

Figure A3. Identification of chromium-mineralised areas (note: the area of serpentinite is very small) from rock and soil samples from the Crown Minerals database, and rock samples from GNS Science's PETLAB database, applied to the surrounding QMAP map unit polygon. This potentially highlights areas of elevated background soil concentration. Dots show the location of samples in the data set of Cavanagh et al. (2015) that have been collected from within the identified mineralised areas.

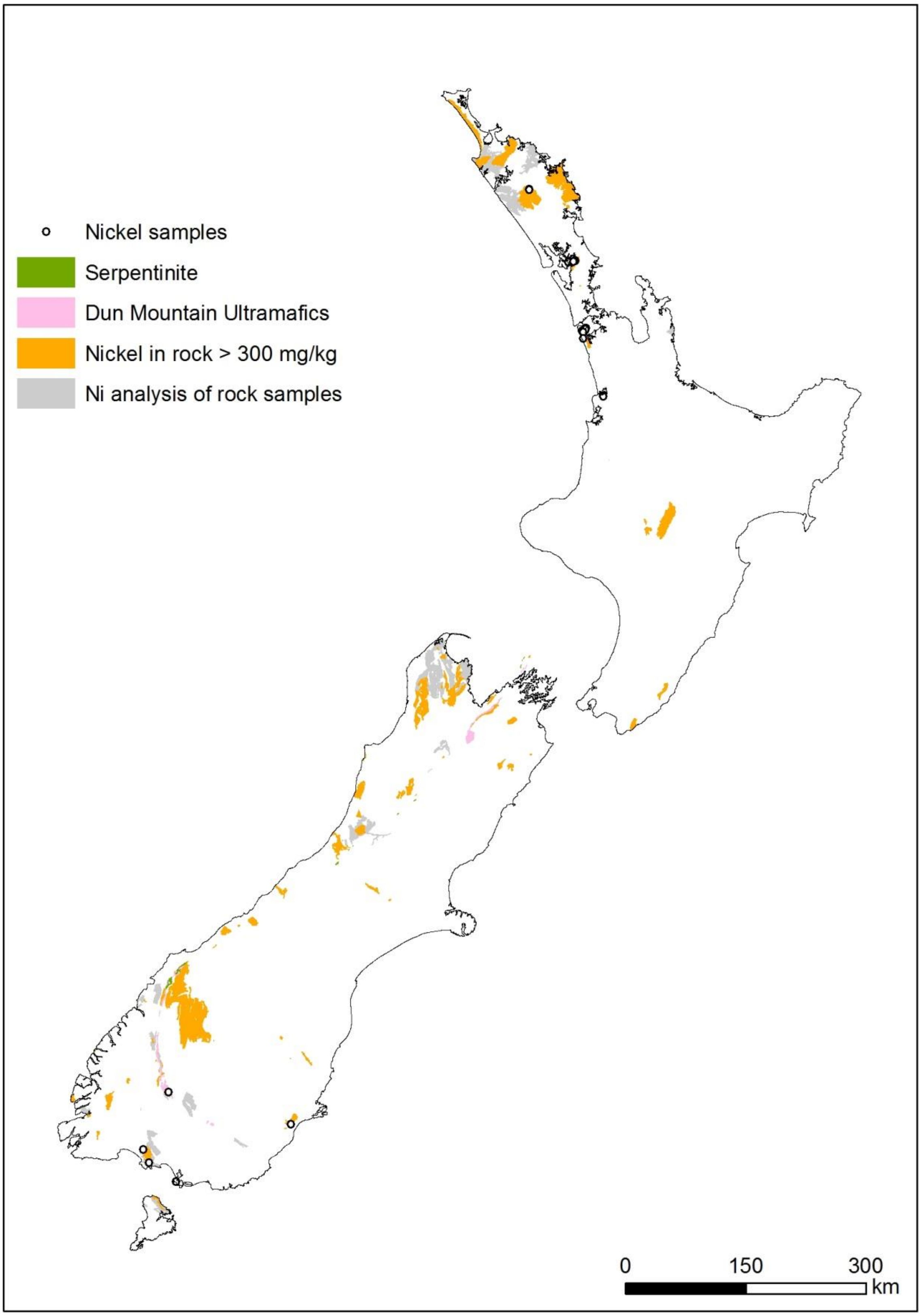

Figure A4. Identification of nickel-mineralised areas (note: the area of serpentinite is very small) from rock and soil samples from the Crown Minerals database, and rock samples from GNS Science's PETLAB database, applied to the surrounding QMAP map unit polygon. This potentially highlights areas of elevated background soil concentration. Dots show the location of samples in the data set of Cavanagh et al. (2015) that have been collected from within the identified mineralised areas.

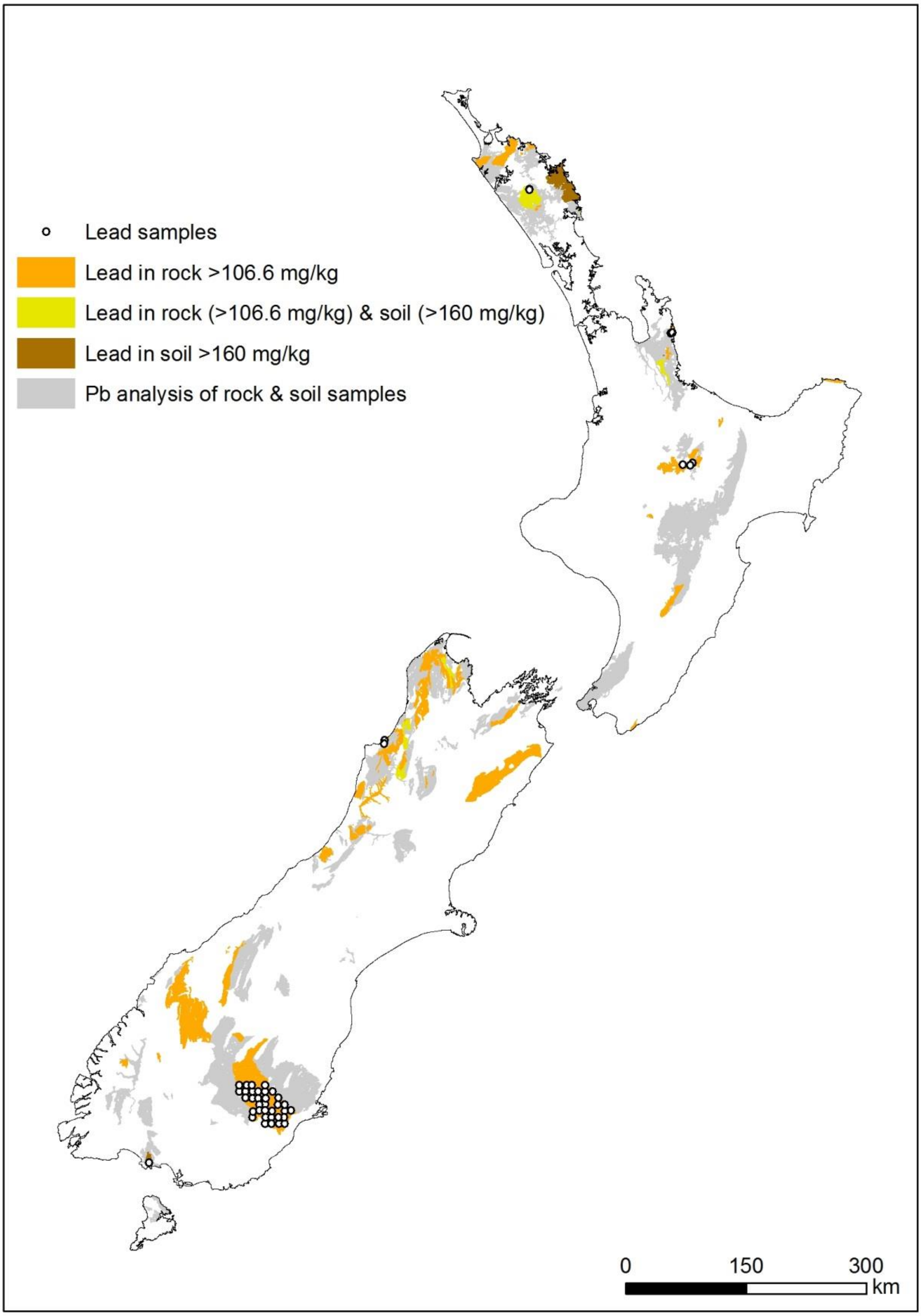

Figure A5. Identification of lead-mineralised areas from rock and soil samples from the Crown Minerals database, and rock samples from GNS Science's PETLAB database, applied to the surrounding QMAP map unit polygon. This potentially highlights areas of elevated background soil concentration. Dots show the location of samples in the data set of Cavanagh et al. (2015) that have been collected from within the identified mineralised areas.

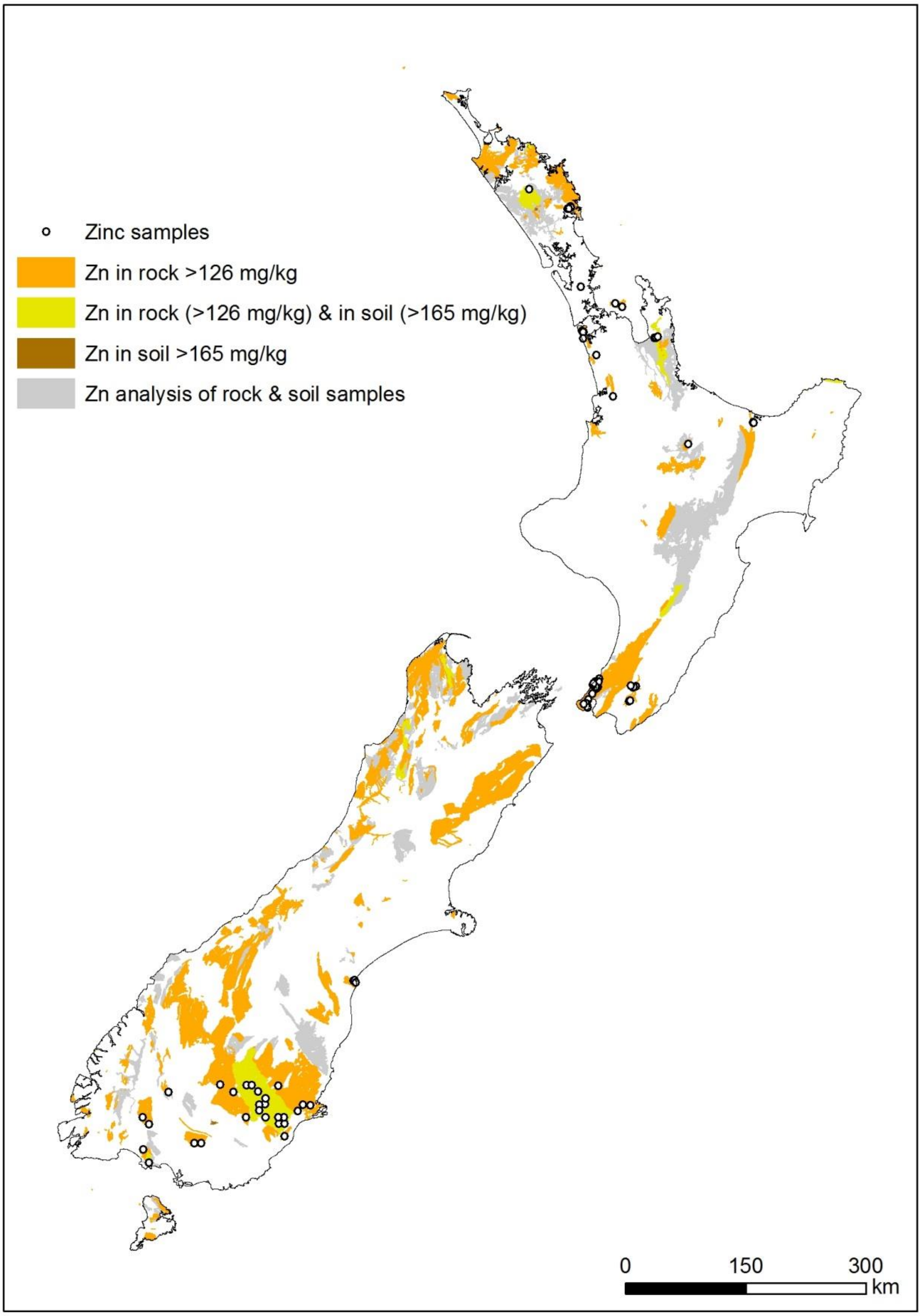

Figure A6. Identification of zinc-mineralised areas from rock and soil samples from the Crown Minerals database, and rock samples from GNS Science's PETLAB database, applied to the surrounding QMAP map unit polygon. This potentially highlights areas of elevated background soil concentration. Dots show the location of samples in the data set of Cavanagh et al. (2015) that have been collected from within the identified mineralised areas.

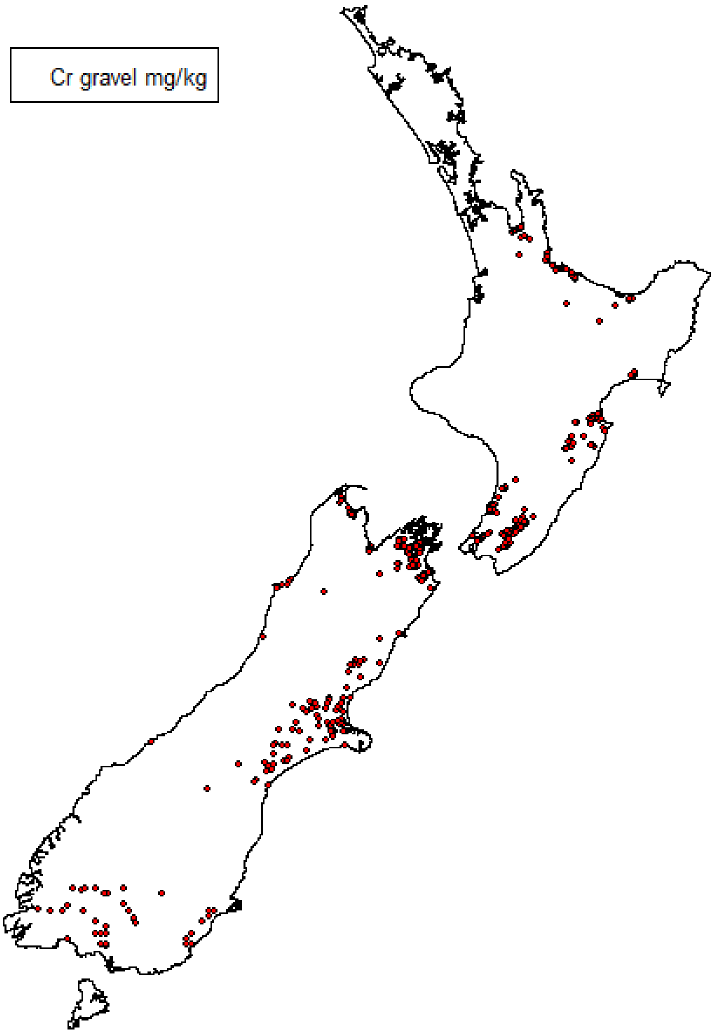

Figure A7. Sample locations within the gravel subgroup for chromium (Cr).

Additional information on the application of background soil concentrations

Note: this is largely excerpted from the user guide consultation draft LandCare Report (envirolink.govt.nz)]

The areas for which background concentration data are typically available are shown in Figure A8, with a summary of the range in concentrations for different trace elements in Table A1. Specific information for a given location can be obtained from LRIS (https://lris.scinfo.org.nz/).

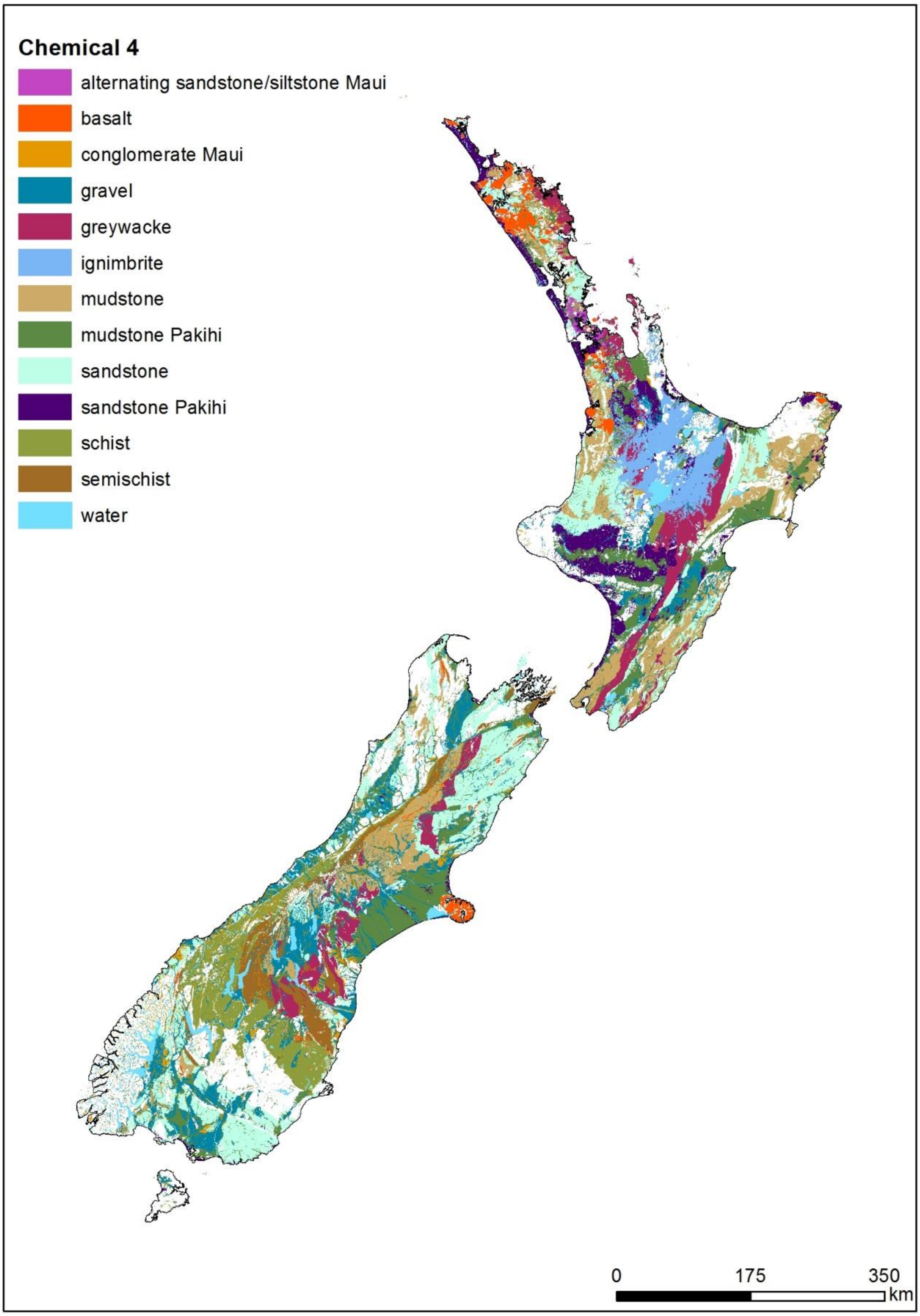

Figure A8. Areas for which predicted concentration ranges are typically available for Chemical4 subgroups (with *n* >30) from the QMAP geological map GIS data set. Areas for which no data are available are shown in white.

Table A1. Summary of the range in median and 95th percentile background concentrations for geological groupings with *n* > 30.

Trace element	Median range (mg/kg)		95th percentile range (mg/kg)	
As	2.1	4.1	8.9	17
Cd	0.05	0.10	0.05	0.49
Cu	6.7	25	29	108
Cr	8.6	27	41	129
Pb	6.8	16	25	56
Ni	4.4	14	25	77
Zn	25	44	102	183

Most organic contaminants of interest for the management of contaminated land are xenobiotics, so they have no natural background concentration. An exception is the polycyclic aromatic hydrocarbons (PAHs), which may naturally occur through bushfires as well as occurring naturally in coal, crude oil, and fuel. Cavanagh et al. (2016) collated existing data on PAHs and DDTs and provided preliminary estimates of ambient PAH concentrations in urban areas.

Although the widespread historical use of DDT on pastoral land can be said to have given rise to an ambient concentration of DDT and its metabolites, the concentration at a given location is inherently dependent on historical usage at that location and so is arguably too variable or patchy to be able to provide an estimate of ambient concentrations. Eco-SGVs for DDT are anticipated to provide a more useful point of comparison to determine whether any action should be undertaken.

Application of background concentrations.

Understanding the variability in background concentrations of trace elements is critical for determining whether measured concentrations in different locations may be causing environmental harm. Typically, an upper concentration limit is defined that includes a high proportion of the data and is likely to exclude the very high results that would be associated with point source contamination.

The upper confidence limit (UCL) for the 95th percentile is probably the most widely used threshold for determining upper limits for background concentrations (e.g. NREPC 2004; Cave et al. 2012), although the 99th percentile is also used if the data set is sufficiently large (Diamond et al. 2009), and there is little difference between the UCLs of the 95th and 99th percentiles (Diamond et al. 2009). There are some statistical tools available to calculate the UCL of the 95th percentile, such as ProUCL developed by US Environment Protection Agency (US EPA 2013). Cave et al. (2012) also provide the code used for the statistical package R to determine the UCL of 95th percentiles. Cavanagh et al. (2015) generated the 95th percentile concentrations as the upper limit of concentrations, recognising that further testing is required to validate predictions.

Information on background concentrations is intended to provide an initial assessment of background soil concentrations at relevant locations. Sampling at a location may be required to verify background concentration, particularly if it is to be used to ensure that discharge to land does not elevate substances above background concentrations.

Contaminated land assessment

For contaminated land investigations, the upper 95th confidence limit of the arithmetic mean and an upper limit of background concentration may be used. If sufficient samples are available (n > 10), the upper 95th confidence limit of the arithmetic mean is used as the point for comparison of concentrations for a site under investigation with background concentrations (US EPA 2013). In this case, the upper 95th confidence limit of the mean of the background concentrations is the point of comparison. These values were not determined in Cavanagh et al. 2015.

An individual sample may also be compared to an upper value of the background concentration to determine whether it is likely to be contaminated (i.e. is above this upper limit, even if the site average is the same as the background concentration). It is recommended that the 95th percentile background concentrations be used as the point of comparison for the upper limit of background concentrations in the initial assessment.

It is also noted that section 5(9) of the *National Environmental Standard for Assessing and Managing Contaminants in Soil* (NES) states that the 'regulations do not apply to a piece of land …. about which a detailed site investigation exists that demonstrates that any contaminants in or on the piece of land are at, or below, background concentrations'. The converse of this is that if a detailed site investigation exists that demonstrates that contaminants in or on the piece of land are above background concentrations, the regulations could apply, as the land may have been subject to intentional or accidental release of a hazardous substance (HAIL category I) if no other HAIL activities are obvious. In this case, the 95th percentile concentrations may be used as the point of comparison for the upper limit of background concentration. For the NES to continue to be applicable it then needs to be determined whether the hazardous substance could be a risk to human health or the environment. For the former, the NES soil contaminant standards for the protection of human heath (SCS_{health}) are applicable, while for the latter, the Eco-SGVs are applicable.

Appendix 2 references

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