Manaaki Whenua
Landcare Research

An implementation framework for ecological soil guideline values

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An implementation framework for ecological soil guideline values

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Jo Cavanagh, Garth Harmsworth

Manaaki Whenua – Landcare Research

Reviewed by:	*Approved for release by:*
Hadee Thompson-Morrison Researcher Manaaki Whenua – Landcare Research	John Triantafilis Portfolio Leader – Managing Land & Water Manaaki Whenua – Landcare Research

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Summary

Project and client

- This project has been undertaken with an Envirolink Tools Grant (C09X2206) for the Contaminated Land and Waste Special Interest Group and the Land Monitoring Forum.

Objective

- To develop a framework for implementing ecological soil guideline values (SGVs) for the protection of ecological receptors from negative contaminant effects under existing and future regulation, and incorporating te ao Māori (a Māori world view).

The process

- This project was overseen by an advisory group comprising representatives from territorial, unitary, and regional councils (including representation from the Contaminated Land and Waste Special Interest Group and the Land Monitoring Forum), 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 work included:
  - a policy and regulatory review of the proposed application of Eco-SGVs to inform potential implementation pathways
  - further exploration of the management of contaminated land and use of the Eco-SGVs from a te ao Māori perspective
  - an end-user workshop, held in June 2023, with representatives from different industry sectors, including contaminated land management, waste disposal to land, organic materials, and primary production, as well as central and local government, to gain feedback on the proposed implementation.

Policy and regulatory review

- Amending the National Environmental Standard for Assessing and Managing Soil Contaminants for the Protection of Human Health (NES-CS) before, or as, it is transitioned into the National Planning Framework of the Natural and Built Environment Bill (NBE) is likely to be the most effective and efficient approach to implementing the Eco-SGVs.
- Amending the NES-CS would include:
  - broadening the focus of the NES-CS to explicitly incorporate environmental effects, alongside human health, consistent with the purpose of the NBE Bill and the definition of contaminated land
  - incorporating into the methodology of the NES-CS Eco-SGVs any necessary guidance for applying them in the context of natural soil background concentrations (as outlined in this report).

- The development of a national policy statement (NPS), or equivalent direction in the National Planning Framework, is intended to guide outcomes and expectations for decision-making on contaminated land, providing alignment with the positive outcomes approach of the NBE, stating intended outcomes, and providing direction for how these should be achieved. An NPS (or equivalent) would also contribute to achieving more consistent application of the NES-CS for managing human health effects.
- Institutional issues that present barriers for contaminated land management generally, and that would also affect the implementation of the Eco-SGVs, were identified, and some alternatives proposed, including:
  - allocating to regional councils the function of managing all effects of contaminated land on the natural environment (including soil ecological effects)
  - integrating regional councils' and territorial authorities' expertise into a single team within each region, combined with an NBE plan that addresses contaminated land in an integrated and comprehensive way
  - creating a broader role for the Environmental Protection Authority in overseeing contaminated land management nationally.

Proposed application of Eco-SGVs

- An overview of the proposed revised application of the derived Eco-SGVs is shown in Table S1. The proposed uses are applicable across all land uses. Eco-SGVs are based on the level of protection nominally afforded, with different actions arising from exceedance of or non-compliance with these different values, depending on the purpose of the application.
- However, we 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 ecological receptors, regardless of contamination issues. In these cases it would be appropriate to assess the potential for leaching to groundwater or surface run-off to waterways (compacted areas).

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

Value name (protection level)	Protection of soil quality	Value name (protection level)	Management of contaminated land
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	Target value (95%)	Potential remediation targets (except copper and zinc)* Te ao Māori aspirations are met for maintaining and enhancing the mana and mauri of land, through remediation and ongoing management
Cessation limit (80%)	A cessation-of-inputs limit. Where active inputs are still occurring (e.g. use of copper fungicide on primary production land), there is a greater focus on landowners to demonstrate the health of the soil to continue inputs.	Investigation trigger (80%)	A soft trigger value for site investigation, leading to the identification of mitigation options (e.g. active management to reduce concentrations [copper, zinc, including assessment of offsite risks. Also used for identifying contaminated land where human health is not the driver (e.g. copper, zinc). Would assist Māori in assessment, monitoring, co-planning and remediation (e.g. onsite: to achieve te mana o te taiao, te mana o te whenua; offsite: to achieve te mana o te wai.
		Minimum-level target (60%)	Site investigation leading to remediation/management appropriate to the identified risk/effect. Consider cultural values for triggering action (e.g. early engagement with iwi/hapū, cultural impact assessments, early site investigations).

* It is likely that the most effective remedial action for elevated copper and zinc is the active management of soil, including general strategies for improving soil health, such as the addition of organic matter (to provide slow natural attenuation over time).

Notes: mana = authority, jurisdiction; tapu = restricted, off limits; mauri = life essence; iwi = tribe; hapū = subtribe; te ao Māori = Māori world view; Many of these concepts are discussed later in the text, and an explanatory list of core indigenous values/principles integral to understanding soil health is provided in Appendix 4.

Next steps for implementation

- For the protection of soil quality a key next step for implementing the Eco-SGVs within the primary sector is working with that sector to develop industry-relevant guidance documents on managing those key contaminants that have ongoing inputs to soil (notably copper and zinc).
- From a discharge consenting perspective the next step is to raise awareness with regional councils and consultants of the existence of the Eco-SGVs, and to encourage their use when setting discharge consents, where appropriate.
- For the management of contaminated land a key next step for implementing the Eco-SGVs is amending the NES-CS before, or as, it is transitioned into the National Planning Framework of the NBE by:
  - broadening the focus of the NES-CS to explicitly incorporate environmental effects, alongside human health
  - incorporating Eco-SGVs and any necessary guidance for their application into the methodology of the NES-CS and associated Contaminated Land Management Guidelines.
- The development of a national soils strategy would effect higher-level change and generate the impetus and pathway for effectively and sustainably managing our soils to achieve desired outcomes, such as soil security, soil health, economic prosperity, and human well-being. This approach should be based on a broader set of pluralistic societal values, bringing together values based on the strong relationship and connection New Zealanders have with soil and incorporating te ao Māori. An overarching national soils strategy would form a strong connector for drivers such as climate change, land-use practice, and land development, and their impacts on land, soils, freshwater, groundwater, ecosystem services, and human well-being and values.
- We recommend that the Contaminated Land and Waste Special Interest Group and the Land Monitoring Forum advocate to the Resource Managers Group and central government (Ministry for the Environment, Ministry for Primary Industries) for the development of a national soils strategy to achieve sustainable soils management and soil health across New Zealand.

1 Introduction

Currently there is limited protection for ecological receptors (including microbes, invertebrates, plants, and higher animals) in soils and their associated ecosystems from the effects of contaminants. Ecological soil guideline values (Eco-SGVs) provide a useful way to assess the potential impact of contaminants on these receptors and are critical for informing state of the environment soil quality reporting.

For this purpose, New Zealand-derived, risk-based guideline values are preferred (MfE 2011a). However, despite the extensive work carried out to derive and document New Zealand-specific risk-based values (through an Envirolink Tools Grant C09X1402 and two subsequent advice grants), councils remain reticent to use these SGVs, particularly for contaminated land management, in the absence of an agreed national direction and use in regulatory assessments.

This absence continues to result in an inconsistent national approach to the management and reporting of contaminants in soils, with a strong focus on human health protection at the expense of impacts on the environment. Current resource management reform is placing a greater focus on targets and limits in environmental settings, and this project will explore the use of Eco-SGVs in setting targets and limits in the soil environment.

A previous Envirolink-funded study (Cavanagh & Harmsworth 2022) identified options for using Eco-SGVs for protecting soil quality and for contaminated land management. That project also focused on incorporating te ao Māori (a Māori perspective) with regard to contaminants and land management, and on identifying where and how to use Eco-SGVs to assist Māori decision-making and achieve Māori aspirations. A key gap identified was a detailed policy and regulatory analysis of the proposed use of SGVs to understand the pathways for implementing the Eco-SGVs under current and proposed legislative changes.

Cavanagh and Harmsworth (2022) also identified further requirements related to the use of background concentrations of trace elements for the implementation of the Eco-SGVs, noting that additional data were now available to develop updated national estimates of background concentrations. A concurrent project has updated national estimates for background concentrations in New Zealand, resulting in updated Eco-SGVs as well as providing further evaluation of the use of background concentrations in the management of contaminated land (Cavanagh, McNeill et al. 2023).

This report draws on the use of Eco-SGVs proposed in Cavanagh & Harmsworth 2022, with updates to reflect (a) updated national estimates for background soil concentrations (Cavanagh, McNeill et al. 2023) and (b) a policy and regulatory review of options for implementing Eco-SGVs to provide a framework for their implementation under existing and future regulation. This framework further extends the exploration and inclusion of te ao Māori / mātauranga Māori (traditional Māori knowledge) in the management of contaminated land, with the development of a Māori assessment template during this project to incorporate Māori values, protocols, and site descriptions. This framework is currently being evaluated with iwi for application to contaminated site assessment (Sari Eru, EINZ, pers. comm.).

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 for both natural background concentrations and Eco-SGVs for common soil contaminants to help protect 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:

- 'Background soil concentrations of selected trace elements and organic contaminants in New Zealand' (Cavanagh et al. 2015)
- 'Development of soil guideline values for the protection of ecological receptors (Eco-SGVs): technical document' (Cavanagh & Munir 2016)
- '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 of the guidelines was undertaken, which addressed the technical aspects of the review comments and updated the methods to ensure consistency with international guidance (Envirolink Grant 1935-GSDC156). Cavanagh and Harmsworth (2022) re-evaluated the implementation of the Eco-SGVs in light of proposed resource management reform (i.e. the proposed Natural and Built Environment Bill, NBE). This resulted in updates to the proposed application of the Eco-SGVs, focusing on basing Eco-SGVs on different levels of protection to determine appropriate action to improve environmental outcomes.

2.1.1 Brief overview of the method for deriving Eco-SGVs

The approach to 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 SGVs 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 from 2014 to 2016 to provide input into the development of the method. The outcomes of these workshops resulted in the EC30 (the 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.

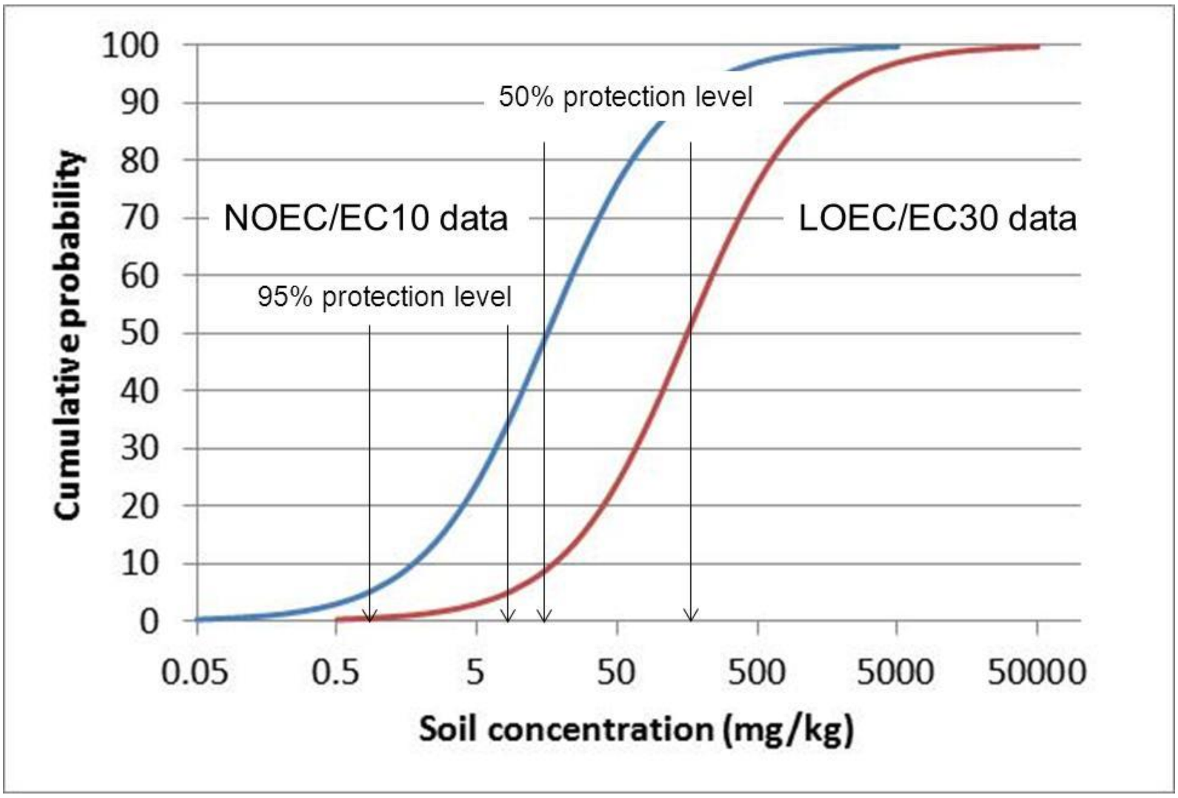

Figure 1. Hypothetical species-sensitivity distribution, illustrating the potential influence of the selection of different toxicity endpoints and protection levels on derived Eco-SGVs, ranging from c. 0.6 to c. 350 mg/kg in this example.

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.

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

1 Collate and screen the toxicity 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 2). Many normalisation relationships use pH

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

determined in calcium chloride ($CaCl_2$), 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 2) using relationships identified from the literature (see Cavanagh & Munir 2019 for details).

Table 2. 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 also 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 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 background concentration (BC) values: Eco-SGV = BC + ACL.

Eco-SGVs were developed for the 11 contaminants shown in Table 1. 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 residential/recreational and commercial/industrial land uses, Eco-SGVs based on a higher level of protection are also provided.

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

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

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 derived 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.

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. Cavanagh, McNeill et al. (2023) determined updated national estimates of rural ambient concentrations of trace elements using an extended data set that provides a better spatial distribution of samples than previous national estimates of background concentrations (Cavanagh et al. 2015). These authors also provide updated Eco-SGVs, based on the updated background concentration estimates, which are used in the current report.

2.2 Te ao Māori introduction

Māori describe, understand, and manage the environment in many different ways, but the term 'contaminant' from a Māori perspective, especially at the local level (whānau, hapū or iwi), is typically based on a distinct set of Māori cultural beliefs, concepts, and values that often give meanings and explanations that are different from those of the general non-indigenous population. Explaining impacts on the health of ecosystems, or on the health of humans, requires a conceptual grounding and understanding of te ao Māori and mātauranga Māori combined with science. The intricate links based on whakapapa (genealogy, interconnectedness) from the time of creation demonstrate interconnections and interdependencies with the environment and ecosystems, where human beings are part of, and located within, ecosystems (Harmsworth & Awatere 2013). This is generally a starting point for discussion and understanding with Māori.

On top of this is the need to understand broader holistic Māori values (including traditional, historical, and contemporary knowledge) and to learn specific local cultural values (e.g. wāhi ingoa=placenames, wāhi tapu=sacred sites), wāhi taonga=special treasured sites, tātai whenua=classifications of land, oneone= soils), when identifying and managing contaminated sites. Whakapapa and many Māori values also distinguish a 'natural state' from an anthropogenic, or human induced changed state (e.g. causing effects and impacts)'.

A summary of the relationship between Māori and soils is given in Harmsworth 2020b. A te ao Māori / mātauranga Māori perspective of soil health (Harmsworth 2018; Harmsworth 2022a, b) was explored through a Ministry of Business, Innovation and Employmentfunded Endeavour programme (C09X1613), 'Soil health and resilience: Oneone ora, tangata ora', which ran from 2016 to 2022. An overview of the research is available here: Kaupapa Māori » Manaaki Whenua (landcareresearch.co.nz), and of the wider research programme here: Soil health and resilience: oneone ora, tangata ora » Manaaki Whenua (landcareresearch.co.nz). A book of Māori perspectives, values, and knowledge of soil health *Te Mahi Oneone Hua Parakore: A Māori Soil Sovereignty and Wellbeing Handbook* (Hutchings & Smith 2020) was completed as part of the research programme and demonstrated the strong links between Māori well-being and soil (Harmsworth 2020a). The work also emphasised the importance of mana as a statement of Māori sovereignty, soil health, well-being, and food security (Hutchings 2015; Hutchings et al. 2018).

2.2.1 Ecosystems

There is consistency of thinking and understanding from a te ao Māori perspective about the identification, description, and integral nature of ecological soil receptors (including microbes, invertebrates, plants, and higher animals) linked to Māori values. This helps frame Māori understanding and decision-making to explain and respond to changes to soil and land ecosystems caused by internal and external drivers, including land use, climate, and human-induced impacts.

This aligns well with Māori beliefs and concepts that imply understanding elements or attributes within the ecosystem to sensitively detect change before that change can affect humans (Harmsworth & Awatere 2013; Harmsworth 2020a). Whether this is detrimental is a matter of perspective, understanding, and degree. Māori consistently, through their close relationships with the environment, detect subtle changes in the environment through specific tohu (indicators), such as flora and fauna, taonga (treasured) species, mahinga kai (harvested resources, cultivations), and māra kai (gardens, cultivated areas), to explain and regulate any environmental shifts through key concepts such as tapu, mana and mauri. These integral Māori concepts are often used within a regulatory framework to sustain and protect ecosystems in the long term from permanent damage, and to alleviate risk and harm (Pauling & Ataria 2010).

Tapu

Tapu means restricted, off-limits, forbidden, or sacred (Ataria et al. 2019) and was, and still is, enacted over an area, or people, as a permanent restriction to protect resources, ecosystems and people from harm, risk, illness, and ongoing damage. It usually follows specific local customary practice and activity (under kawa [marae protocol], tikanga [cultural practices]) by tangata whenua / mana whenua (people of the land / territorial rights) . When tapu is enacted over an area or site, it is a permanent restriction only lifted by certain people. These long-term restrictions are established to prevent harm to people and the environment, give respect to sacred sites, protect resources, and allow the resources in an area to recover from damage over time. They are also used to protect, retain, and elevate the mana of the resource, the object, or the person.

Rāhui (temporary prohibition) is used within this framework as a temporary restriction to safeguard sites, replenish sites and resources, restore or remediate sites, or respect sites in certain events (e.g. such as tragedy or harm). Again, there is an intention to regain, retain, and strengthen the mana of an area during this process (Hutchings et al. 2018).

Mana

Mana means prestige, power, and authority. It is used in this report to signify the prominent position and status of soils as part of the ecosystem, and the importance of the soil ecosystem (including microbes, invertebrates, plants, and higher animals) to support human health and well-being and sustain ecosystems in a healthy, life-supporting state. Ecological receptors, therefore, become one way of retaining and strengthening the mana in a soil.

Traditionally mana and tapu were used together. Placing tapu elevated the mana over people and resources to sustain, maintain, and protect the health and status of the natural environment and keep people safe from harm or risk. The greater the mana one had, the greater the tapu. Mana can be applied to people and the environment. These terms (e.g. Te Mana o Te Wai, Te Mana o Te Taiao) are now being used consistently in national policy in New Zealand today in slightly different ways (e.g. NPS-FM, national policy statement of biodiversity).d Te Mana o Te Wai as a broad te ao Māori concept recognises the link between freshwater health, the environment (Taiao), and human health and wellbeing (whaiora, hauora, toiora, oranga),"restoring and preserving the balance" of the whole environment (Taiao) and people (tangata= people, hapori= communities) and elevates the importance of water as essential for human health and wellbeing.

Mauri

Within the ecosystem, mauri (life force, life principle, vitality, essence) is a key concept used to explain the inherent qualities or energy of a resource or system to sustain life and well-being. If the mauri is weak, the resource is often degraded or contaminated; if the mauri is strong, the system remains resilient and healthy. Traditionally, Māori believed that small shifts in the mauri or life force of any part of the environment (e.g. through use or misuse) would cause shifts in the mauri of immediately related components, which could eventually affect the whole system.

2.2.2 Perspectives of risk

If change is considered deleterious to health, the terms mōrearea, mate, or kino are commonly used to mean harm, hazard or danger. In terms of impacts on ecosystem health and human health, many of the same terms and explanations are used interchangeably. So illness, harm or hurt (mate, matemate, māuiui, mamae) or health (ora, oranga, hauora, waiora, toiora) may apply equally to the whenua (land), oneone (soil) or ecosystems (taiao), as with human health and well-being.

2.2.3 Māori and contamination

Māori have several terms and expressions that are close equivalents to the terms 'contaminated', 'contamination', and 'contaminated land'. Para, paru(a), whakaparu, whakakino(tia), and tūkino, are commonly applied to contaminated land. 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. Whenua parakino is also used for degraded or contaminated land (e.g. Waka Kotahi 2023). Such land is often placed under certain restrictions or regulation following assessment while its future use, or the activities associated with this land, are considered.

If land or soil are deemed contaminated, Māori often view this as defiled, degraded, or polluted, and the land should be managed or regulated under certain conditions and restrictions, many of these customary. Māori will often use tapu and rahui to protect resources (such as soil) from deterioration, contamination, and degradation or to help recover or rehabilitate the resource or site. The term 'wāhi tapu' may be used if that land is deemed sacred or spiritual, or can cause harm.

Traditionally, Māori saw the interaction with, and management of, their environment through an elaborate set of rules and regulations (under local tikanga, kawa, ritenga [customary practices]), which often passed from tapu (restricted or sacred) to semi or temporarily restricted states (rahui), to noa (without restriction) and whakanoa (removal of tapu) (Harmsworth & Awatere 2013; Ataria et al. 2019). A state of noa involved opening up resources or land and removing tapu restrictions. Cleaning, opening or releasing an area from pollution or contaminants requires identification and assessment in the first instance. The terms 'whakanoa' or 'noa' are still used as the opposite of tapu. Any removal of para (rubbish) or paru (dirt) can involve the negating effect of 'kore'. Hua parakore (Hutchings 2015; Hutchings et al. 2018) is a term commonly used as an aspirational state and verification system based on kaupapa Māori for reaching a pure state (in line with acceptable Māori standards and values) away from contaminants, pesticides, and pollutants.

Ecological guidelines and te ao Māori

Ecological soil receptors are regarded as very important for characterising and supporting the functioning of a healthy soil ecosystem, away from some contaminated, degraded or unhealthy state. The degree of protection afforded to these receptors in a soil is also essential when considering danger, harm, and risk to ecosystems and humans. They also help indicate what might be possible with remediation or restoration of a site, and what it might be restored back to and the levels of protection that can be returned.

Currently there is limited to negligible protection for ecological receptors in soil ecosystems and their associated life-forms from the effects of contaminants. Early detection and assessment should consider risk and perceived harm to ecosystems and humans under local tikanga, and should include a determination of the impacts on cultural values and Māori interests. This may be in relation to a natural background concentration of contaminant values as a reference point (section 2.1.2), or to provide guidance for risk management and mitigation based on elevated or additional contaminant levels (i.e. above background). An 'added-risk' approach has been used to derive Eco-SGVs for trace elements in this work.

The Eco-SGVs provide important data and guidance to understand elevated contaminant levels and what these might mean to ecosystems (not just human health) and to Māori values. The guidelines that inform impacts on ecological receptors could equally inform impacts on Māori values, the desired levels of protection required to sustain ecological receptors, and the desired levels of protection required to sustain Māori values such as taonga (e.g. soils, water, springs, species, habitats, ecosystems, places). This type of information is required to support decision-making and determining the steps towards remediation, before considering long-term site management.

Te ao Māori soil health indicators

Through the soil health research programme 'Soil health and resilience: Oneone ora, tangata ora' (C09X1613) (Stevenson et al. 2022; Stronge et al. 2023), key values and principles integral to understanding soil health were identified and some provisional Māori indicators of soil health were developed (Hutchings et al. 2018; Harmsworth 2018; Hutchings & Smith 2020; Harmsworth 2022a,b). In Cavanagh & Harmsworth 2022 we described some of these te ao Māori / mātauranga Māori indicators with specific application to the implementation of Eco-SGVs.

3 Objective

The objective of this project is to develop a framework to assist in the implementation of ecological soil guideline values. This specifically includes a detailed evaluation of policy and regulatory considerations for the use of Eco-SGVs proposed by Cavanagh and Harmsworth (2022).

4 Implementation framework for Eco-SGVs

4.1 Overview

The proposed usage is based on that originally proposed by Cavanagh and Harmsworth (2022), but it has been modified based on further considerations to address previously identified gaps, and the policy and regulatory review of contaminated land management undertaken by Mayhew (2023). Eco-SGVs can play a role in both the protection of soil quality and contaminated land management. Soil needs to be protected to prevent contamination, and remedial activities on contaminated land can improve soil quality (Figure 2).

Raising awareness of the state of the soil and activities that result in ongoing inputs of contaminants to the soil (e.g. the use of copper fungicides) can provide one approach to preventing soil contamination, while consenting discharges to land (e.g. of waste-water) provides another. When contaminated land is identified, investigation of the site occurs to identify the level of effect to inform any management or remedial action. A key point to note is that the Eco-SGVs should not be considered in isolation from guideline values to protect human health (such as the soil contaminant standards, SCS's), or for the protection of groundwater or compliance with food standards. Thus, for some applications it may be appropriate to develop combined values, or select a value based on protecting the most sensitive receptor.

Finally, it is not considered relevant to apply Eco-SGVs to any impervious/impermeable surfaces (such as land/soil that is sealed, compacted driveway areas). Protection of groundwater is likely to be most relevant in this case.

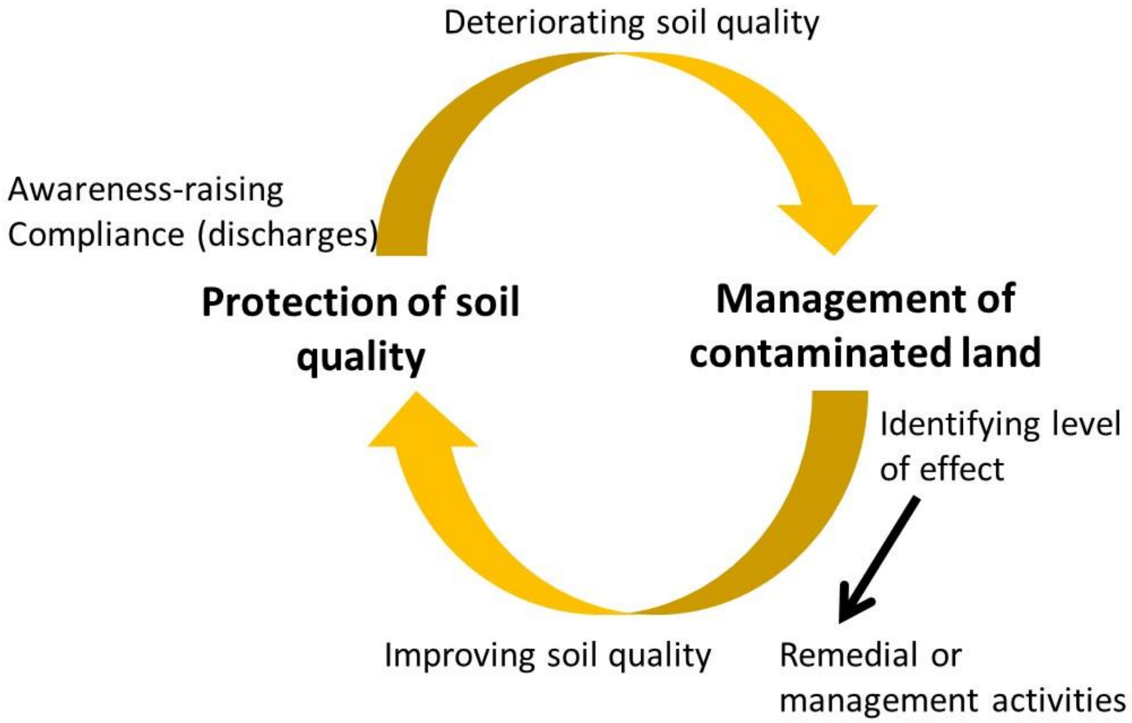

Figure 2. The protection of soil quality and contamination of land are integrally related, as failing to protect soil quality will result in contaminated land. Activities to protect soil quality include raising awareness of activities. When contaminated land is identified, the site is investigated to identify the level of effect to inform remedial or management activities.

4.1.1 Targets and limits

To inform the protection of soil quality and the management of contaminated land, three levels of Eco-SGVs, based on the nominal protection of 95%, 80%, and 60% of species, are proposed for use. These differing levels of protection serve different purposes depending on whether the focus is protection of soil health or management of contaminated land. With respect to protecting soil health, only the two higher protection levels are relevant and represent a trigger/limit value and an input cessation limit value. From a contaminated land management perspective, the different levels of protection represent target value, trigger value, and minimum level target. These terms are explained further below with respect to their application for the protection of soil health and contaminated land management; Figure 3 shows the relative level of effect signified at the different protection levels.

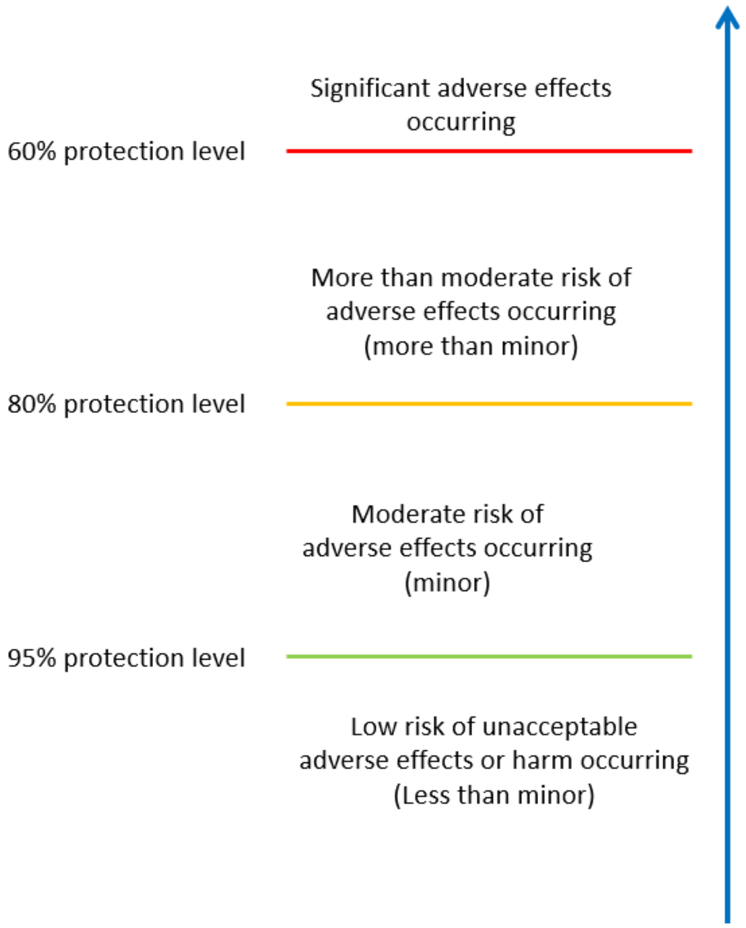

Figure 3. Illustration of the relative level of effect based on the different levels of protection.

Limit/target values

These values are derived on the basis of protecting 95% of ecological receptors from contaminant-related effects and are considered the concentration below which less than minor effects will occur. The values will be most relevant to primary production land, land receiving discharges (e.g. wastewater discharges), and conservation land.

Their primary use is anticipated to be assisting the protection of soil quality, such as through reporting on soil quality in regional council SOE 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). An assessment of the wider environmental impacts of proposed remedial activities should be undertaken to ensure remediation results in a net positive environmental outcome.

Input cessation limits / site investigation triggers

These values are derived on the basis of protecting 80% of ecological receptors from contaminant-related effects and are considered the concentration at which more than minor effects may start to occur. They are relevant to all land uses, and have equal application for the protection of soil and contaminated land management. For the protection of soil quality these values could appropriately be applied as 'cessation limits', such that ongoing deliberate inputs of contaminants (e.g. copper fungicides, wastewater discharge) ceases. Exceptions could be granted if an assessment of soil health – and specifically of soil biology (e.g. bacteria; fungi; invertebrates, including nematodes, mites, *Collembola*, worms) – demonstrates a functioning ecosystem.

For contaminated land management, these values would primarily be used to identify contaminated land in the context of risk to the environment under the Hazardous Activity and Industries List (HAIL, e.g. Category H and I; MfE 2023a). Further activity would involve consideration of options to reduce ongoing inputs of contaminants, potential remedial or management actions, or wider assessment of soil health (with a specific focus on soil biology). These values may also be relevant to consider for landfill waste acceptance criteria (e.g. managed or controlled landfills).

Minimum-level targets

These values are derived on the basis of protecting 60% of ecological receptors from contaminant-related effects and are 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 further investigation to determine the extent of impact and to ascertain appropriate management or remedial actions. An assessment of the wider environmental impacts of proposed remedial activities should be undertaken to ensure remediation results in a net environmental outcome.

4.1.2 Māori indicators/targets and limits

Many concepts underlie the development of Māori indicators that can be used in assessment, monitoring, and management (Harmsworth 2022a, b). Some of the key kaupapa Māori tools include the cultural health index, the mauri compass, the mauri model, and the abundance and condition of taonga species (Rainforth & Harmsworth 2019). These te ao Māori concepts are fundamental to developing indicators and attributes across land, soil, water, biodiversity, and other environments. Recurring themes and concepts through all these approaches include an in-depth understanding of Māori values such as whakapapa, mana, wairua (spirit), mauri, kaitiakitanga (guardianship), mahinga kai, māra kai, and taonga tuku iho. Key Māori values fundamental for understanding soil health are given and explained in Appendix 4. These values also provide the basis for the development of Māori soil health indicators.

Ecological soil receptors functioning alongside Māori indicators (or tohu) are useful tools for gauging and assessing change and degree of impact, especially reinforcing notions and explanations of 'contamination' (Cavanagh & Harmsworth 2022). The ecological soil receptors and guidelines given in this report would inform Māori decision-making, support mātauranga Māori, and be regarded as early warning signs (tohu) for deleterious change to Māori values relating to taiao (environment) and human well-being. Natural background levels of contaminants provide Māori with a reference or natural baseline state, which can be measured locally and regionally to gauge how far elevated or additional levels have shifted from (and above) natural background concentrations (often related to parent material and rock type). This is highly useful in supporting Māori decision-making and planning, and augmenting explanations and mātauranga Māori when assessing impacts on Māori values as part of the process of contaminated land identification, assessment, monitoring, reporting, and management.

Mauri is a key concept in te ao Māori, which indicates life energy, life support, and maintenance of well-being (Harmsworth & Awatere 2013; Harmsworth 2018; Rainforth & Harmsworth 2019; Harmsworth 2022a, b). Māori commonly use mauri as an assessment measure or tool for explaining whether something is becoming healthy or not, or is declining in health. Many common descriptions in management plans include statements such as 'restoring the mauri of the river', or 'restoring the mauri of the soil', generally from a polluted state to something better. This often means the mauri can be weak at a degraded site, and can be strengthened and maintained upon restoration or remediation.

The following states of mauri are often described: mauri noho (languishing), mauri rere (unsettled), mauri oho (activated), mauri tau (in balance), and mauri ora (flourishing). In terms of the protection given to ecosystems, and support for human well-being, different states of mauri, alongside Eco-SGVs, can help to explain and characterise the overall health of soil ecosystems through different levels of protection accorded to ecological soil receptors (see Table 3). A target limit of 95% protection might mean that the mauri (life essence, vitality) of the soil is being strengthened and maintained in the ecosystem (e.g. mauri oho, mauri ora), while a minimum target level of 60% could mean the mauri is languishing or weak (e.g. mauri noho, mauri rere, mauri ruha, mauri mate).

The discussion around the levels of protection of these receptors (e.g. at 95%, 80%, 60%) provides useful guidance for setting targets and limits, requiring transparent identification and assessment or the investigation of these sites of concern. For example, certain levels of protection could initiate an onsite investigation, or could be used to monitor a site where contamination is being managed or mitigated through specific actions or practices. Once identified, the removal or management of contaminants can be through a process, or set of practices, which maintains or decreases the contaminants or pollutants of a site, removing the danger or harm.

4.1.3 Overview of proposed application of Eco-SGVs

More detail on the proposed used of the Eco-SGVs for the protection of soil quality and the management of contaminated land is shown in Table 3, with further discussion provided in sections 4.3 and 4.4.

Table 3. Overview of proposed application of Eco-SGVs for different purposes

Value name (protection level)	Protection of soil quality	Value name (protection level)	Management of contaminated land
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.	Target value (95%)	Potential remediation targets (except Cu, Zn).* Te ao Māori aspirations are met for maintaining and enhancing mana and mauri, remediation and ongoing-management.
Cessation limit (80%)	A cessation-of-inputs limit. Where active inputs are still occurring (e.g. use of copper fungicide on primary production land), there is a greater focus on landowners to demonstrate health of soil to continue inputs.	Investigation trigger (80%)	A soft trigger value for site investigation, leading to the identification of mitigation options (e.g. active management to reduce concentrations [Cu, Zn]), including assessment of off-site risks. Also used to identify contaminated land where human health is not the driver (e.g. Cu, Zn). Would assist Māori in assessment, monitoring, and co-planning and remediation (e.g. on-site: to achieve te mana o te taiao, te mana o te whenua; off-site: to achieve te mana o te wai).
		Minimum-level target (60%)	Site investigation leading to remediation/management appropriate to the identified risk/effect. Consider cultural values for triggering action (e.g. early engagement with iwi or hapū, cultural impact assessments, early site investigations).

* It is likely that the most effective remedial action for elevated Cu and Zn is the active management of soil, including general strategies aimed at improving soil health, such as the addition of organic matter (to provide slow natural attenuation over time).

Some further applications for the protection of soil quality have links with existing industry-led technical guidelines, specifically *Technical Guidelines for Disposal to Land* (WasteMINZ 2022) and *Guidelines for the Beneficial Use of Organic Materials on Productive Land* (WaterNZ 2017). 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.

4.1.4 Ecological soil guideline values

The Eco-SGVs associated with the different levels of protection for inorganic and organic contaminants are provided in Tables 4 to 6, with the soil contaminant standards (SCS's) for the protection of human health provided in Table 7 for comparison. The values shown in Tables 4 and 5 incorporate the median ambient background concentrations of these trace elements determined by Cavanagh, McNeil et al. (2023) and shown in Table 8. We propose that for most monitoring and assessments, initial comparison should be made with the values in Tables 4 to 6. Depending on the application, and the contaminant, it may also be appropriate to vary the Eco-SGV depending on site background concentrations or other soil properties (e.g. pH). (See section 4.2 for further details.)

Table 4. Eco-SGVs (mg/kg) developed for selected contaminants based on the estimated median ambient concentration. Eco-SGVs may be adjusted up, based on background concentrations shown in Table 8, as applicable to the location of the site.

% protection	As Eco-SGV (mg/kg)	B Eco-SGV (mg/kg)	B-HWS Eco-SGV (mg/kg)	Cd Eco-SGV (mg/kg)	Cd Eco-SGV_{BM}* (mg/kg)	Cr Eco-SGV (mg/kg)	Pb Eco-SGV (mg/kg)	Pb Eco-SGVBM* (mg/kg)
95%	20	14	7	5	1.5	200	290	290
80%	60	22	15	17	12	400	1290	900[1]
60%	150	25	17	40	35	660	3060	2,500[1]

* An extra 5% protection applied to each land use to provide protection against secondary poisoning.

Notes: see Table 1 for an explanation of the element symbols. BM = biomagnification; B-HWS = boron – hot-water soluble.

Table 5. Eco-SGVs (mg/kg) developed for Cu and Zn contamination in the three New Zealand reference soils based on the estimated median ambient concentration. Eco-SGVs may be adjusted based on background concentrations shown in Tables 8 and 9, as applicable to the location of the site.

% protection	Cu Eco-SGV typical soil	Cu Eco-SGV sensitive soil*	Cu Eco-SGV tolerant soil	Zn Eco-SGV typical soil	Zn Eco-SGV sensitive soil*	Zn Eco-SGV tolerant soil
95%	110	**95**	135	200	**180**	250
80%	245	**190**	350	320	**285**	410
60%	430	**330**	640	510	**450**	645

* Suggested default Eco-SGV. See also section 4.2.3 for adjustment based on soil pH, C, CEC.

There were limited toxicity data available for the organic contaminants. Utilisation of older studies (pre-1970) yielded additional data for DDT,[3] and this was sufficient to use the species sensitivity distribution approach for deriving ACLs. Note that DDE,[4] the main

[3] Dichlorodiphenyltrichloroethane.

[4] Dichlorodiphenyldichloroethylene.

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[5] and PAHs[6] (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 the Eco-SGVs are based on limited toxicity data.

Table 6. Eco-SGVs (mg/kg) developed for organic contaminants

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

[a] Carbon number range F1: C7–C9, F2: >C9–C15, F3: >C15–C36, 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's for the protection of human health are shown in Table 7: no limits exist for B, Cu or Zn, and SCS's are often lower than the Eco-SGVs for land uses that are likely to have a reasonable proportion of open space (i.e. rural residential, residential, and recreational areas).

[5] Total petroleum hydrocarbons.

[6] Polycyclic aromatic hydrocarbons

Table 7. Soil contaminant standards for the protection of human health for selected contaminants

Land use	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	400	2,700	880	40	400
Commercial / industrial outdoor / industrial outdoor work	70	1,300	6,300	3,300	35	1,000

Source: MfE 2011b.

* Benzo(a)pyrene-equivalent.

4.2 Considerations for the general use of the Eco-SGVs

4.2.1 Background concentrations

National estimates of background soil concentrations were recently updated by Cavanagh, McNeil et al. (2023), with an example of the final output provided in Figure 4. Specifically, a series of maps was produced that present the rural ambient concentrations of individual trace elements based on the percentile (median, 90th, 95th, and 99th) of the predicted range. The median concentrations are used to develop the default Eco-SGVs shown in Tables 4 to 6. Greater emphasis was placed on identifying areas with higher ambient concentrations, and in particular on identifying areas that are naturally elevated – effectively those areas with predicted concentrations >99th percentile estimates. These estimates are produced on a 1 × 1 km basis. In some regions, significant small-scale variations are anticipated to occur and may warrant site-specific investigations to determine background concentrations. These data are intended to be available via Land Resource Information Systems (LRIS).

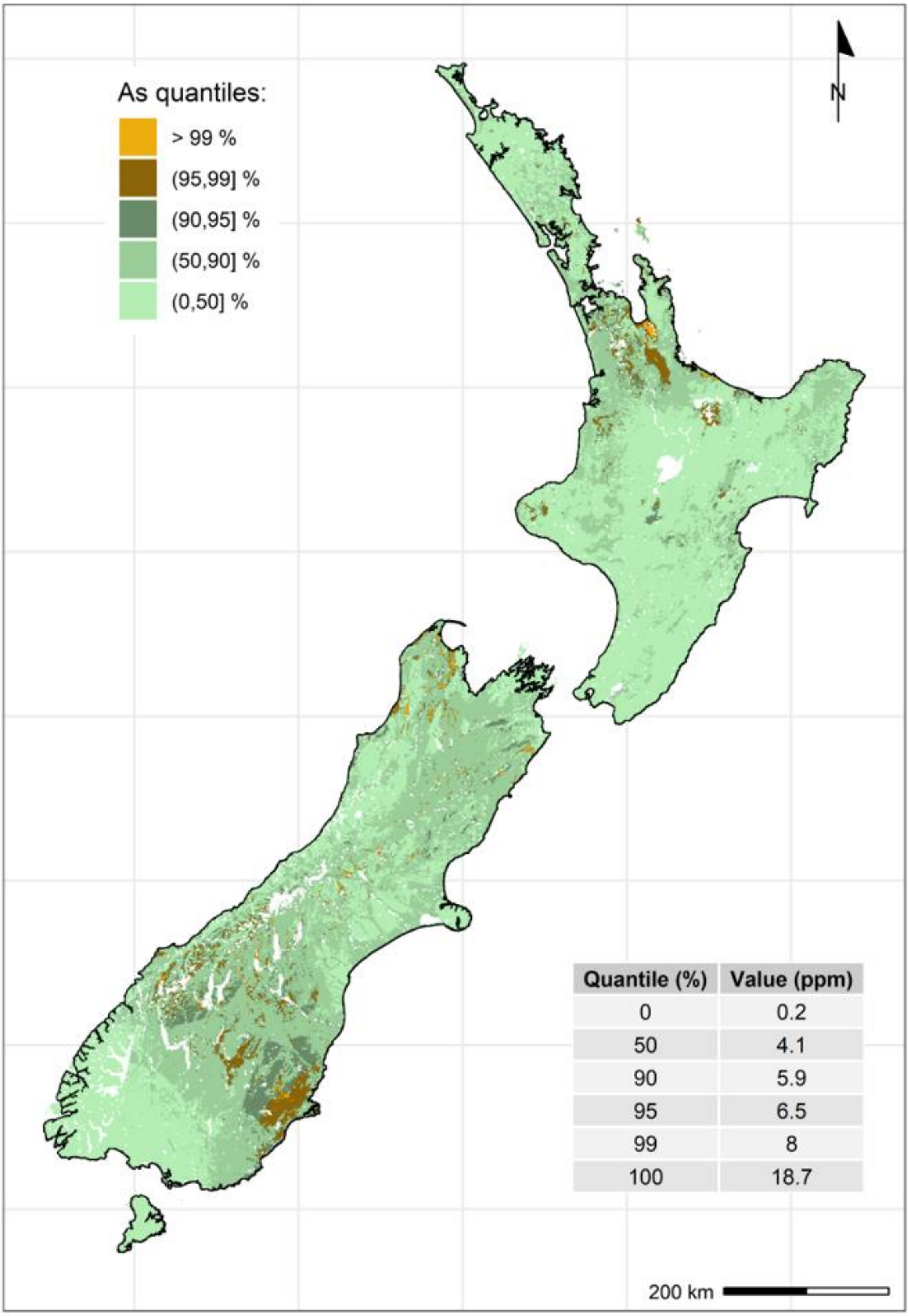

Figure 4. Predicted ambient background concentration of arsenic across New Zealand. Concentrations are presented as quantile ranges of predicted ambient concentrations.

As stated in the technical document (Cavanagh and Munir 2019), 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. In turn, this approach allows for variation in the Eco-SGVs based on variation in background concentrations. The Eco-SGVs shown in Tables 4 and 5 are based on the median rural ambient background concentration determined by Cavanagh, McNeill et al. (2023). Some pragmatism is required to determine when it is acceptable to modify the Eco-SGVs based on background concentrations to avoid overly complex application of the Eco-SGVs. This judgement has been made by considering both the percentile range and the proportional contribution of the natural background concentration to the Eco-SGV.

Specifically, we recommended that background concentration adjustment only be acceptable for the 95% protection values. Given the lower protection level, and that background concentrations generally comprise a small proportion of the 80% and 60% protection values, adjustment of background soils is not warranted. For the 95% protection values, the general rule used to adjust for background was that the difference between median concentration and the upper percentiles was >10 mg/kg, and where background comprised c. >10% of the Eco-SGV.

The full suite of revised background concentrations is shown in Table 8, with bolded values showing the percentile concentrations that are accepted for modification of the 95% protection level Eco-SGVs; the modified Eco-SGV values are shown in Table 9.

Table 8. A summary of relevant statistics for the range in ambient concentrations (mg/kg) of selected trace elements using an extended data set

Element	Minimum	Median	90th percentile	95th percentile*	99th percentile*	Maximum
As	0.22	**4.1**	5.9	6.5	8.0	18.7
B	0.6	4.6	12	**16**	**23**	83
Cd	0.01	**0.08**	0.2	0.29	0.35	0.58
Cr	1.96	**16**	25	**30**	**68**	765
Cu	3.8	**16**	24	**28**	**39**	76
Ni	1.4	9	14	16	42	590
Pb	1.3	**11**	17	19	21	30
Zn	11.2	**48**	**63**	**68**	**80**	100

* We recommend that the 95th and 99th percentile be used as a default value for these areas initially, but it may be appropriate to undertake site-specific determination of background concentrations.

Table 9. Summary of accepted background-adjusted Eco-SGVs

Element	90th percentile Eco-SGV (mg/kg)	95th percentile Eco-SGV (mg/kg)	99th percentile Eco-SGV (mg/kg)
B	-	25	40
Cr	-	215	270
Cu – typical soil	-	120	150
Cu – sensitive soil	-	105	135
Cu – tolerant soil	-	150	175
Zn – typical soil	215	220	230
Zn – sensitive soil	190	200	210
Zn – tolerant soil	265	270	330

Further work is required to 'merge' or transition information on regional background concentrations in Auckland (ARC 2001), Wellington (URS 2003), and Christchurch[7] (Tonkin & Taylor 2006, 2007), given the current use of these data in regional plans. Data from these regional studies were included in the data used by Cavanagh McNeill et al. (2023) to determine background concentrations nationally, and these authors provide a specific comparison of the nationally predicted concentrations with these regional studies.

The estimates provided by Cavanagh, McNeill et al. (2023) are based on rural ambient concentrations, and it is anticipated that urban ambient background concentrations of certain contaminants (in particular Pb) may be elevated as a result of emissions from diffuse anthropogenic combustion sources (e.g. domestic woodburners and historical use of leaded petrol). However, given the anticipated poorer state of urban soils, it is not considered appropriate to further elevate the Eco-SGVs through using higher urban ambient background concentrations – noting, also, the limited data with which to validly determine an urban ambient concentration.

In rural areas the organochlorine pesticide DDT was widely used in pastoral agriculture and horticulture in the 1950s–1960s, and while such uses had largely ceased by the mid-1970s (Buckland et al. 1998), residues (primarily pp-DDE) still persist in agricultural soils (e.g. Boul 1995; Buckland et al. 1998; Gaw et al. 2006; plus 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).

Further discussion on the use of background concentrations is provided in Cavanagh, McNeill et al. 2023.

[7] https://opendata.canterburymaps.govt.nz/datasets/ecan::soil-trace-elements-level-2/about

4.2.2 Depth of application

The bulk of soil biological activity occurs in the upper 30 cm of soil (US EPA 2015). The Eco-SGVs are therefore most relevant for the upper soil depths, although soil microbes, invertebrates, and plant roots can all be present at greater depths. Particularly when considering soil at depth, it would be relevant to consider Eco-SGVs alongside depths or conditions that may lead to contaminant leaching to groundwater.

4.2.3 Variation in soil properties

It is recommended that any initial assessment should be for Eco-SGVs for sensitive soil, and then, if exceeded, evaluated against other soil types based on the pH, carbon, and CEC of the soil. The soil properties describing the different soil types are shown in Table 10.

Table 10. 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-regression (normalisation) relationships.

4.3 Detailed implementation 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 value (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.

4.3.1 Awareness-raising

Regional council state of the environment monitoring

The target values provided in Tables 4 and 5 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 and/or fact sheets could be created and provided to land managers or owners (e.g. MPI 2020a).

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 managers' 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 and/or fact sheets could be made available through primary sector organisations, similar to what has been developed for managing Cd (e.g. MPI 2020a).

We recommend that the 80% protection-level Eco-SGVs for Cu and Zn also be included in guidance materials for primary sector groups as cessation limits, to provide greater emphasis on when it may be appropriate to reduce or cease inputs of Cu and Zn that are being actively applied. We suggest that the focus of action be based on ensuring soil health, in particular through the assessment of soil biology (bacteria, fungi, and/or invertebrates, including nematodes, mites, *Collembola*, worms), rather than a specific focus on the abiotic components of soil.

Consideration of soil pH, carbon content, and CEC will also allow the selection of Cu and Zn Eco-SGVs for the soil type present at the site. The focus of the assessment is to provide assurance that any further inputs of Cu and Zn will not negatively affect the soil community.

A summary of the Eco-SGV targets and cessation limits is shown in Table 11; the SCS for the protection of human health (SCS) for rural residential land use are shown where these are lower than the Eco-SGVs. It should be noted that the National Environmental Standard for the protection of human health (NES-SC) does not apply to production land, and hence the SCSs are not applicable. However, the SCSs may become relevant if sub-division to residential properties occurs. It should also be noted that when the land remains production land, Cd concentrations lower than 0.8 mg/kg, along with managing other soil properties and/or plant cultivars, may be required to enable compliance with food standards particularly if high Cd-accumulating crops (e.g. spinach) are being grown (see also Cavanagh et al 2019, Gray et al 2019 a, b, Cadmium Management Group 2020).

Table 11. Default targets for the assessment of soil quality and cessation limits for ongoing agricultural inputs, based on protection of ecological receptors for key contaminants (it may be appropriate to vary these based on background soil concentration and soil properties; see section 4). Values in italics are based on protection of human health using SCSs for rural residential land use and provide an illustration of when ecological receptors are not the most sensitive receptor. The SCSs are not applicable to production land but may become relevant if sub-division to residential properties occurs.

Contaminant	Target limit (mg/kg)	Cessation limit (mg/kg)
As	20 (*17*)	NA
B	14[a], 7[b]	NA
Cd	1.5 *(0.8)*[c]	NA
Cr	190	NA
Cu[d]	95 (110, 135)	190 (245, 350)
Pb	280 *(250)*	NA
Zn[d]	180 (200, 220)	285 (320, 410)

[a] Total boron.

[b] Hot-water soluble boron.

[c] Concentrations lower than 0.8 mg/kg, along with managing other soil properties and/or plant cultivars, may be required to enable compliance with food standards, particularly if high Cd-accumulating crops (e.g. spinach) are being grown. See also Cadmium Management Group 2020.

[d] The relevant value to use depends on the pH, carbon content, and CEC of soil. If this information is not available, the lowest value should be used as the default target or cessation limit.

NA = not applicable

Te ao Māori perspectives and other non-regulatory uses

It is important for Māori to understand scientific concepts and information on soils and ecological receptors in a 'meaningful way' (sometimes required inside te ao Māori, kaupapa Māori concepts, frameworks, and models), and to 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, mātauranga Māori, and Māori values to make sense of their environments (taiao), assess cultural impact, and determine responses as part of environmental practices under kaitiakitanga (environmental guardianship)). Māori will often want to use this information in their own land management decision-making roles (e.g. land manager/owner, Māori land blocks, tribal rohe, papakāinga (home bases), māra kai, mahinga kai), or utilise it within cultural monitoring approaches by also having access to regional council SOE monitoring data and results.

Māori groups may find it useful to use and apply Eco-SGVs and guidelines in their own regulatory and compliance networks (iwi and 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. through collaboration, partnership, co-management, co-governance) to achieve desired local, regional, and community outcomes that respect and protect Māori cultural values and achieve desired or shared outcomes.

A further specific application of particular interest to Māori is in relation to the health, quality, and condition of a soil for uses such as māra kai and mahinga kai (gardens, food harvest areas, harvest of cultural resources). In this case, the application goes beyond simply considering soil 'health' from a contamination perspective, and needs to link to information about human health, taking into account the potential contaminant uptake into food systems, such as crops, and the food chain itself to ensure healthy food and healthy people (Hutchings 2015; Harmsworth 2020a; Hutchings & Smith 2020). Māori also need to know the type of contaminant(s) and their origins/sources (e.g. are they sourced from trace elements, agri-chemicals, human waste, or other) to evaluate and assess using cultural standards guided by tikanga and kawa (customary practice and process).

Guidance

Guidance on awareness-raising would include general information of the potential effects of contaminants and whether to decrease sources and integrate consideration of the protection of human health and compliance with food standards, as appropriate (e.g. MWLR 2020a, b), as well as being developed for specific application in Māori contexts (e.g. papakāinga, māra kai, mahinga kai). Community gardens are also an area of great interest for the wider community.

4.3.2 Compliance

Māori will assess the impact (e.g. from contaminants, degradation, pollution) to their social, cultural, environmental and economic values within a te ao Māori world-view framing. They will have firm ideas about and opinions on setting criteria and acceptable standards for managing discharges to land, from 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. In other words, 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, particularly where these may be lower than the Eco-SGVs.

In setting discharge consent limits, it may also be appropriate to specify a depth of application for these values, and to ensure potential leaching to groundwater is considered. The Eco-SGVs set should take into account the anticipated background concentrations of the area of discharge, soil pH, carbon content, and CEC capacity (see section 4.2.3).

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).

WaterNZ 2017 is a draft document that updates the biosolids guidelines (NZWWA 2003) and extends their 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.*

Although 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 a 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 (4.3.3).

A summary of proposed discharge limits based on the Eco-SGVs is shown in Table 12; the soil contaminant standards for the protection of human health (SCS) for rural residential land-use shown where these are lower than the Eco-SGVs. It should be noted that the National Environmental Standard for the protection of human health (NES-SC) does not apply to production land, and hence the SCSs are not applicable. However, the SCSs may become relevant if sub-division to residential properties occurs. It should also be noted that when the land remains production land, Cd concentrations lower than 0.8 mg/kg, along with managing other soil properties and/or plant cultivars, may be required to enable compliance with food standards particularly if high Cd-accumulating crops (e.g. spinach) are being grown (see also Cavanagh et al 2019, Gray et al 2019 a, b, Cadmium Management Group 2020).

Table 12. Proposed default limits for soils receiving discharges (mg/kg) based on protection of ecological receptors for key contaminants – it may be appropriate to vary these based on background soil concentration and soil properties (see section 4.2). Values in italics are based on protection of human health using SCSs for rural residential land use and provide an illustration of when ecological receptors are not the most sensitive receptor. The SCSs are not applicable to production land but may become relevant if sub-division to residential properties occurs.

Contaminant	Soil discharge consent limit (mg/kg)
As	20 (*17*)
B	14[a], 7[b]
Cd	1.5 (*0.8*) [c]
Cr	190
Cu	95 (110, 135)[d]
Pb	280 (*250*)
Zn	180 (200, 220)[d]

[a] Total boron.

[b] Hot-water soluble boron.

[c] Concentrations lower than 0.8 mg/kg, along with managing other soil properties and/or plant cultivars may be required to enable compliance with food standards, particularly if high Cd-accumulating crops (e.g. spinach) are being grown. See also Cadmium Management Group 2020.
[d] The relevant value to use depends on the pH, carbon content, and CEC of soil. If this information is not available, the lowest value should be used as the default target.

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 2022) have been completed and are available on the WasteMINZ website.[8] This latest revision of the guidelines (revision 3) was undertaken to provide waste acceptance criteria (WAC) for Class 3 fills and to address issues raised by the Regional Waste and Contaminated Land Officers Forum (now the Contaminated Land and Waste Special Interest Group). 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 use of Eco-SGVs 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, although it is implied there will be some constraint on future land use in Appendix C in Wasteminz 2022. This appendix provides an overview of the development of waste acceptance criteria, which includes consideration of leaching potential, human health exposure, and exposure of ecological receptors. Class 3 (managed fill) is based only on protection of the groundwater drinking-water and aquatic environment protection pathways. Class 4 waste acceptance criteria include consideration of ecological receptors, using values from Cavanagh 2019 and Cavanagh 2006 (for Ni).

Class 5 waste acceptance criteria are based on background soil concentrations, using regional background concentrations for key inorganic elements in Auckland and Wellington as examples, and specified criteria for selected organic contaminants. The

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

revised background soil concentrations provided by Cavanagh, McNeill et al. (2023) would be useful to consider here.

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 2022).

Finally, Māori consider that soil disposal, the mixing of soils, and soil replacement in the context of Māori beliefs, values, and mātauranga Māori (and issues raised accordingly) can affect a large range of cultural values. Many issues are related to the key concept of whakapapa (ancestral lineage of all parts of nature, interconnections, and inter-dependencies), which considers the whole system, in which soils are just one part. Therefore, acceptance criteria will be considered in relation to a range of cultural values by way of assessed and perceived cultural impact. This has specific application for developing waste acceptance criteria for different landfills – where Māori may wish to use a wider set of criteria related to values, and also where soil is imported onto sites as part of remediation processes (see also Cavanagh, Harmsworth et al. 2023).

Guidance

Guidance for compliance settings may include specific technical reports, but links should also be made to existing industry-based guidelines, including the *Technical Guidelines for Disposal to Land* (WasteMINZ 2022), and the *Guidelines for Beneficial use of Organic Materials on Productive Land* (WaterNZ 2017).

4.3.3 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 being exceeded. 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 (9.4% carbon and pH>5.4) could be used for Cu and Zn, given the high organic carbon content of these products. To ensure protection of human health it may be relevant to use the SCS for As and Pb, which may be lower. 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. The potential compost quality limits that could be used are shown in Table 13.

However, note that there is a marked discrepancy between these potential limits and the New Zealand compost standard contaminant limits (Table 13), 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 B to plants can be overlapping, meaning that setting robust limits is problematic. The Eco-SGV values are based on hot-water soluble boron, whereas the boron concentration in the compost standard is based on total boron.

Table 13. Potential compost quality limits (mg/kg) for inorganic contaminants based on Eco-SGVs for 'tolerant' soils and the New Zealand compost standard contaminant limits. Bolded values indicate the compost standard contaminant limits that are markedly higher than 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	14[a], 7[b]	**<200**
Cd	1.5	3
Cr	190	**600**
Cu	120	**300**
Pb	280 *(160)*	250
Zn	230	**300**

[a] Total boron.

[b] Hot-water soluble boron concentrations.

WaterNZ (2017) recommend that where organic materials are used for soil replacement in the urban environment, the product concentration should meet the Eco-SGV (for agricultural land use) concentrations, except for Zn. In this case, WaterNZ (2017) recommends using the soil limit of 300 mg/kg from the 2003 biosolids guidelines 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 are no longer used.

When the draft document is finalised, guidance on the application of Eco-SGVs where soil is amended or replaced with organic materials should be included. Greater consistency with the Eco-SGVs and the New Zealand compost standards would be appropriate.

4.4 Implementation for the management of contaminated land

The use of Eco-SGVs in contaminated land management is arguably their most predominant use. This was the focus for the policy and regulatory review of Mayhew (2023). A key point from that report is that amending the NES-CS before, or as, it is transitioned into the National Planning Framework of the NBE is likely to be the most effective and efficient approach for implementing the Eco-SGVs. This is partly because, under the RMA, nothing precludes the use of Eco-SGVs (see also Cavanagh & Harmsworth 2022), but they haven't been widely adopted. Thus, without regulatory impetus the use of Eco-SGVs has the potential to continue to be viewed as effectively optional.

Specifically, these amendments would include:

- broadening the focus of the NES-CS to explicitly incorporate environmental effects, alongside human health – consistent with the purpose of the NBE and the definition of contaminated land
- agreement on, and incorporation into, the 'methodology' of the NES-CS (MfE 2011b), Eco-SGVs, and any necessary guidance for applying them in the context of natural soil background concentrations (as outlined in this report).

The triggers for contaminated land assessment under the NES-CS are mostly sufficient to trigger assessment of the potential effects on soil ecological receptors. In addition, under the NBE there is the requirement that contaminated land be managed to prevent harm to human health *and the environment*; as well as to minimise any further harm to human health and the environment (s.416 (c)), potentially providing an avenue by which contaminated land that does not trigger the NES-CS (e.g. contaminated sites that undergo sub-division or land-use change) can also be managed.

The key change from the current regime is the requirement 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 *Contaminated Land Management Guidelines No. 5* (CLMG#5, MfE 2021) regarding comparison of site investigation data to guideline values also applicable to Eco-SGVs. (The 95% upper confidence limit of the arithmetic mean of concentrations at the site under investigation should be used for interpreting data against an SCS or alternative guideline value.) Furthermore, soil ecological receptors would need to be considered when assessing the potential risk/effect and in developing remedial management plans. 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.

Another key difference to 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 supporting any ecological receptors, regardless of contamination issues. In these cases it would still be appropriate to assess the potential for leaching to groundwater, or sediment movement into surface waters.

4.4.1 Eco-SGVs and environmental limits and targets under the NBE

Environmental limits and targets are a central component of the NBE. Under the NBE, environmental limits must be set for soil to prevent the ecological integrity of the natural environment from degrading from the state it was in at the commencement of that part of the proposed Act. In this respect, the use of Eco-SGVs is not relevant for setting limits for contaminated land (i.e. land that is already contaminated), but they are relevant to the setting of limits to protect soil quality. Targets are set to help improve the state of the natural environment, with minimum-level targets set where the associated environmental limit is set at a level that represents unacceptable degradation of the natural environment.

In considering the application of Eco-SGVs, the intent of soil guideline values for contaminants should not be forgotten (i.e. that they provide an initial indication of the potential for negative environmental effects). As such, targets (mandatory, discretionary or minimum level) should be qualitative to describe the outcomes sought, rather than simply numerical. Qualitative environmental targets should incorporate risk and desirable outcomes to avoid managing soil contaminant levels alone. This allows consideration of the risk that is posed to enable and provide for *in situ* management, the derivation of site-specific SGVs/SCS's, and best management options. If quantitative environmental targets are set, these should be set clearly in a framework that provides for risk-based assessment and considers broader environmental outcomes. (See Mayhew 2023 for further details.)

4.4.2 Māori and contaminated land

Traditionally, Māori had many references to what constitutes healthy land, good land, and fertile land, and what constitutes unhealthy, degraded, polluted, infertile, or limited land (Harmsworth 2022a, b). Many of these terms are still used widely today. The Māori world view provides a holistic understanding of ecosystems, forming an essential knowledge base and models (e.g. Te Whare Tapa Whā as used widely in Māori health; Harmsworth 2020a) for understanding the links between ecosystem health and human health and well-being (Harmsworth 2020a). Equally, Māori wish to understand what constitutes unhealthy and what might cause harm and illness (mate, kino, māuiui).

Māori wish to be involved in the management of contaminated sites and land from the earliest stage, especially within distinct tribal geographical areas (whānau, hapū, iwi) and on Māori land (whenua Māori blocks, Māori trusts and incorporations). Early engagement with Māori and identification of existing and potential sites of contamination are stressed in this report. Also, an early understanding of Māori issues and aspirations in certain areas and locations is essential. This could include, for example, land handed back to iwi Māori under Treaty claims settlement, or land under kaitiakitanga and mana whenua responsibilities, where both on-site and off-site effects are being considered and assessed.

Identification of sites

As land is increasingly developed in New Zealand it is important to know where contaminated land is located so that people and communities are not exposed to contaminants that may affect their health and put them at risk. To help with identifying potentially contaminated land, the Ministry for the Environment has compiled a list of activities and industries commonly associated with contaminated land. This list is called the Hazardous Activities and Industries List (HAIL). Local authorities use the HAIL to identify potentially contaminated sites. Further investigation of an individual site is required to determine whether the site is indeed contaminated.

The Resource Management (National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health) Regulation 2011, commonly referred to as the NES-CS, is a national standard relating to the identification and remediation of contaminated land. It has a focus on human health rather than ecosystem health. The NES-CS guidelines for human health (and standards) therefore apply to any HAIL land with a potentially contaminating activity. Māori need access to accurate information on contaminated land and sites. They can then overlay or intersect these contaminated sites with cultural values and cultural heritage layers and mapping.

Māori want to be involved in the early identification and assessment of sites (e.g. those identified in the HAIL). Early engagement with Māori (e.g. tangata whenua, mana whenua, kaitiaki, whānau, hapū, iwi) is one way of ensuring te ao Māori and mātauranga Māori are taken into account, and local issues, perspectives, values, and knowledge are acknowledged, understood, and incorporated into assessments and site investigations. It will also be very important in the early stages to understand Māori aspirations for many of these 'contaminated' or 'potentially contaminated' sites and how they are to be managed and monitored.

Cultural impact assessments

Under a range of current legislation (Resource Management Act, Hazardous Substances and New Organisms Act) and policy (regional and district plans), a requirement to obtain a consent often requires a cultural impact assessment (CIA) to be undertaken in a specific area. These CIAs are usually carried out by local whānau, hapū, iwi, or mana whenua, or under the guidance and kaupapa/direction of iwi, hapū, or mana whenua where a third party may undertake the work (e.g. private consultants working on behalf of local Māori groups). The CIA can follow a number of different formats. Most of the focus is on responses to specific issues (e.g. contamination, pollution), and on describing in detail impacts and cumulative effects on cultural values, resources, and associated interests, which may be over a larger catchment area and will generally investigate on-site and off-site effects on cultural values across a landscape (land, river, lakes, estuarine and coastal/marine).

In terms of definition, a CIA is a report documenting Māori cultural values of, interests in, and associations with an area or resource, and the potential impacts of a proposed activity on these. CIAs are a tool to facilitate meaningful and effective participation of Māori in impact assessment. A CIA should be regarded as technical advice. Some iwi and/or hapū use the terms 'tangata whenua impact assessment', or 'tangata whenua effects assessment' to describe the impact assessment process and report.

Cultural values reports (CVRs) are variations of CIAs. These can be used to assess or provide background information when preparing plans. CVRs can identify and describe values pertaining to an area or resource. They differ from CIAs in that they may not include a description of effects because they do not relate to a specific activity. However, they may address broad-level impacts of development occurring or anticipated in that area. CVRs can provide direction on the relevant issues and how these should best be addressed.

Management of contaminated sites

Contaminated site management should describe three essential components: the source, the pathway, and the receptor.

- The source refers to the source(s) of the contaminant(s) present that could affect a receptor.
- The pathway is a means by which a receptor can be exposed to, or affected by, a contaminant under current or proposed land use.
- The receptor can be any organism, population or ecosystem that could be affected by the contaminant, including humans.

Within the current contaminated site investigation framework (from a reporting perspective), contaminated site management is broadly classified into four main stages:

1 preliminary site investigation

2 detailed site investigation

3 remediation process: site remedial action plan

4 site validation and ongoing monitoring and management.

The purpose of a preliminary risk assessment or site investigation is generally to establish the previous uses of the land under consideration, or of land nearby or adjacent to it, and to identify potential sources of contamination, receptors, and pathways. All land contaminant assessments or preliminary risk assessments should be carried out by a suitably qualified and experienced practitioner.

When engaging with Māori on contaminated land/site investigation or management, collaborative guidelines should be followed for:

1 engagement or collaboration with Māori (e.g. tangata whenua, mana wheua, whānau, hapū, iwi, kaitiaki)

2 culturally acceptable guidelines for the actual site investigation, assessment, remediation, monitoring, and ongoing management.

Both should be under the auspices of tikanga and kawa (local protocols, custom, steps, and process) and should clearly identify the groups to work with and how the relationship will be developed and maintained (e.g. the Hononga ki te Iwi framework, Waka Kotahi 2023). A large number of collaborative guidelines for working with iwi and hapū have been developed with various regional councils, territorial local authorities, consultancy firms, and government agencies in New Zealand (e.g. Waka Kotahi 2023).

From a te ao Māori perspective, guidelines are proposed in this report for the early engagement of Māori in preliminary contaminated land and soils investigation, and could extend from preliminary to detailed assessment, to planning, remediation, monitoring, reporting and management. At an early stage the preliminary assessment can then confirm whether the land is of interest to Māori (e.g. under Māori claim, rights, or control), affecting Māori values, or affecting Māori health. More detailed collaborative assessment would provide an improved mechanism for giving effect to the Treaty of Waitangi by providing a broader knowledge base of mātauranga Māori, values, issues, and cultural perspectives.

This could include information on tikanga and kawa, ritenga (local Māori regulations and rules), Māori values associated with a site, area, or catchment, Māori issues, and Māori goals, and aspirations, to help facilitate, for example, co-design for planning remediation, and mātauranga Māori-based monitoring, identifying shared goals, and ongoing planning and management.

Te ao Māori guidelines could involve four main steps with associated questions (patai):

Step 1: *Identification of contaminated sites (from resource management environmental guidelines, use of HAIL, and te ao Māori): preliminary assessment*

- Who are tangata whenua / mana whenua (whānau, hapū, iwi, kaitiaki) for the area?
- Person to person contact.
- What are Māori issues in the area?
- How do Māori (whānau, hapū, iwi) first identify at-risk sites?
- What constitutes ‘contaminated’?
- How do Māori understand harm? Risk? Assess it?
- Assessment of risk to the environment (ecosystems).
- Preliminary sampling?
- Trace elements, background concentrations?
- Eco-SGVs?
- Elevated levels of contaminants?
- Limits?
- Assessment of risk to human health?
- The role of NES?

Step 2: *Detailed assessment (with Māori) confirming a contaminated site*

- Historical and traditional information (e.g. Māori values, historical and traditional sites, Māori customary use, customary activities (e.g. papakāinga, mahinga kai, māra kai, wāhi tapu, wāhi taonga, historical narratives and contaminants, identifying high-risk cultural/historical sites.
- Detailed site description and sampling.

Step 3: *Remediation of contaminated sites*

- Māori cultural aspirations?
- Māori values?
- What does Māori remediation/restoration look like?
- Co-designed remediation plan?
- Whāinga, objectives, goals for the site; set of actions and practices?
- Minimising the contamination caused by currently operating sites?
- Use of Eco-SGVs?
- Standards?

- Limits and targets?
- Use of cultural indicators?

Step 4: *Ongoing monitoring and management*

- Co-designed management plan for site.
- Cultural monitoring next to science?
- Use of cultural indicators?
- Use of Eco-SGVs? Standards?
- Limits and targets?
- To help monitor and assess through time.
- Use of tikanga/kawa regulation (e.g. tapu, rāhui, noa).
- Use of concepts mauri, mana, wairua, kaitiakitanga.

A te ao Māori framework and model, developed as a template for Māori engagement and assessment in contaminated land projects (mainly at site level), was discussed and developed for interim use in this project (Sari Eru, EINZ, pers. comm.). The framework is developed to document information for the three current contaminated site management components: the source, the pathway, and the receptor. It is structured to include questions and follows a model of early engagement, and includes:

- identification of the specific area being investigated
- the people being engaged with (e.g. tangata whenua, hapū, iwi)
- the correct engagement practices under tikanga, and documentation of best practice
- identification and summarising of local Māori values and mātauranga Māori for contaminated site investigation and planning.

This information can then be used for early site assessment and validation, and subsequently to inform any longer-term remediation and ongoing site management. The framework is intended to be used under current practices and approaches (e.g. RMA) but could be modified for use in proposed legislation (e.g. NBE) as it develops. This te ao Māori framework is presently in draft form and is being trialled with one iwi (Sari Eru, EINZ, pers. comm., June 2023).

Remediating whenua and soils

Māori have a strong interest in rehabilitating or remediating areas and sites considered contaminated or degraded. Māori aspirations for these sites are in accordance with Māori values, and are usually measured against culturally acceptable standards and benchmarks set around a prescribed end use, interest, or activity (e.g. to protect and manage Māori values, to restore customary values, to restore specific taonga species and habitats, mahinga kai, māra kai, to restore specific cultural sites). Māori indicators or tohu (e.g. mātauranga Māori-based kaupapa) alongside science-based indicators are useful when monitoring and remediating sites, and an early discussion on targets and limits and what they mean from a Māori perspective is recommended.

Many expressions and concepts are used when remediating or restoring land and resources. This usually follows a desire and expressions for healing Papatūānuku (earth mother), similar to the way people describe elevating the role of nature in our lives, and living with, respecting, and giving back to nature. There are many actions or practices we can implement when healing Papatūānuku or whenua. Māori terms may include 'whenua haumanu' for reviving, rejuvenating, healing, restoring the land to health. Giving health to the environment, restoring health, is often whaiora, whakaoraora, whakaora whenua, whakaora taiao, or whakamahu if healing a specific area. Restoring land or regenerating whenua and soils often uses terms such as whakaora taiao, mauri whenua ora, whenua tupu hou, whakatipu anō, or toitū whenua. Healthy land or whenua can often be expressed as whenua ora or mauri ora, with an explicit connection to people (tangata ora, hauora, waiora). Once reaching health, the environment should be cared for and sustained to achieve long-term aspirations and states of whanake taiao, toitū te whenua, te ao turoa, te oranga o te taiao, te mana te taiao (to sustain the land and soils in a permanent healthy state). Elevating the mana, mauri, and wairua of the environment, land or soils are all implicit and interconnected values and concepts in giving and sustaining health.

4.4.3 Use of Eco-SGVs

Conceptual site model

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 the protection of human health, and are outlined in CLMG#5 (MfE 2021) and shown pictorially in Figure 5. In most cases the dominant on-site ecological receptors for consideration will be soil microbes, soil invertebrates, and plants, as visits 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.

As noted earlier, we propose that 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 would still be appropriate to assess the potential for leaching to groundwater, or sediment movement into surface waters.

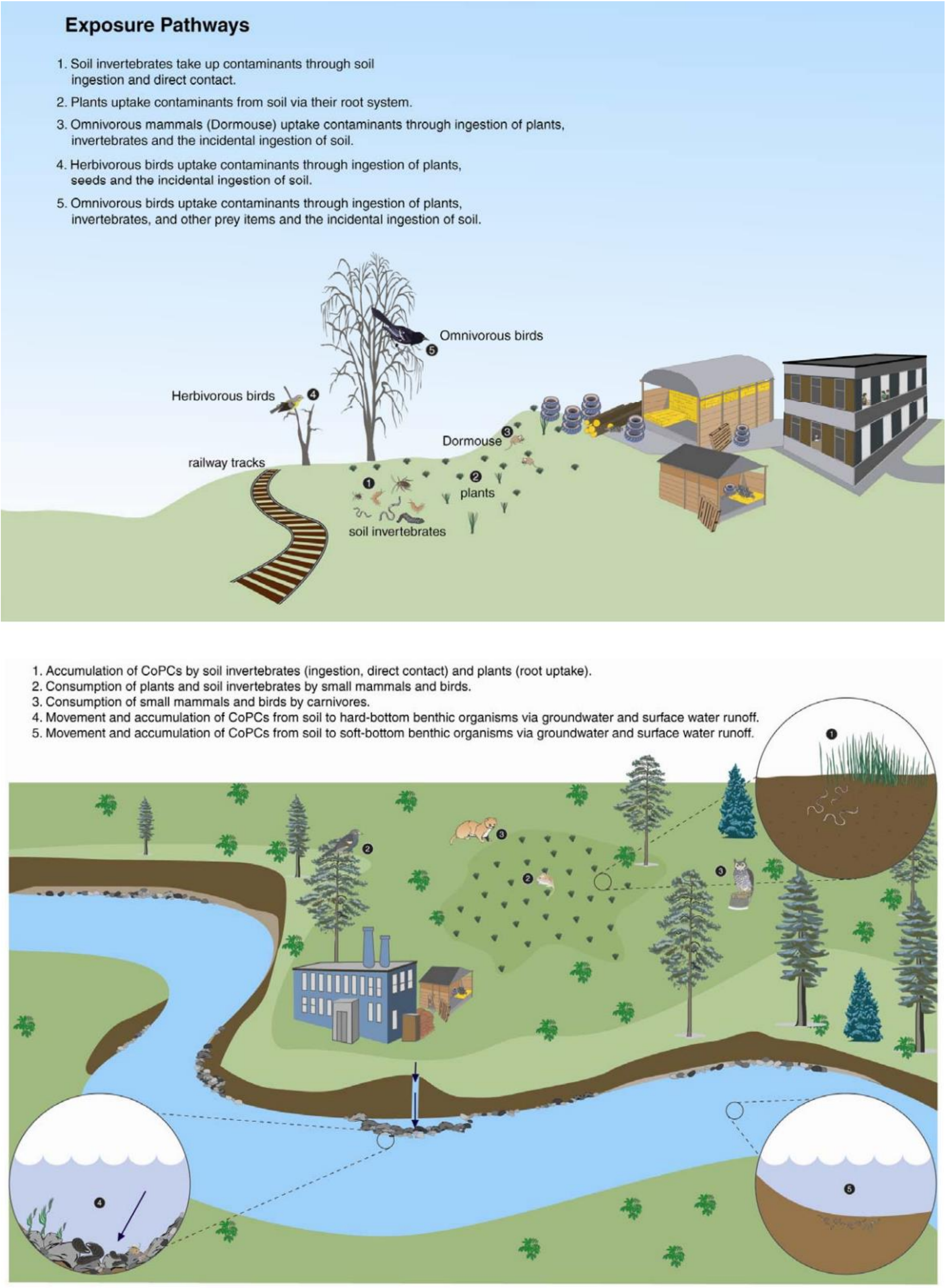

Figure 5. Pictorial conceptual site models for ecological risk assessment relevant to a contaminated site in the United Kingdom, showing exposure pathways for on-site and off-site ecological receptors. (Source: Environment Agency 2014)

Actions associated with non-compliance with Eco-SGVs

The proposed actions associated with non-compliance with Eco-SGVs based on different protection levels are shown in Table 14. 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 these exclusions is that Cu and Zn are also essential nutrients. Therefore, provided there are no unacceptable adverse effects arising from Cu and Zn concentrations, the best course of action is to actively manage the soil and retain it in place.

Values may be modified based on background concentrations or pH, carbon content, and CEC (Cu and Zn only) to identify what soil type (sensitive, typical, tolerant) most closely relates to soil at the site being investigated.

Table 14. Anticipated source of information for the use of Eco-SGVs and actions associated with exceeding Eco-SGVs for different protection levels in a contaminated land management regime

Value name (% protection)	Information source	Action in event of non-compliance	Māori information requirements, actions, and goals
Target limit value (95%)	DSI	Nothing other than potentially providing information to the land manager about improving soil quality. Can be potential remediation targets (except for Cu and Zn).	Information on cultural values, to protect and maintain cultural values and achieve standards. Information to protect and maintain mauri and mana of soil, targets, and limits (e.g. te mana o te taiao, restore mauri).
Site investigation trigger (80%) – soft action level	DSI	Identification of contaminated land for all land uses except commercial/industrial. Site investigation report that includes assessment of options for mitigating risk (e.g. reducing any ongoing inputs such as Cu Zn), as well as assessment of potential off-site risks. Advice on actions to remediate/reduce contaminant concentrations and/or mitigate risks to the land owner/manager.	Reports/assessment: identify cultural values, culturally acceptable options for mitigating risk and achieving cultural values/standards. Identification and assessment of potential offsite risks. Advice on actions to remediate/reduce contaminants concentrations/mitigate risks to reach cultural standards (based on cultural values/impacts).
Minimum level target (60%)	DSI, further investigation / risk assessment	The intent is that non-compliance at this level gives rise to a greater requirement to further assess the risks/effects from contaminants, including off-site risks, and risk mitigation. The incentive for risk assessment over 'dig and dump' is that demonstrating no effect or no risk can provide the basis for no further action (and therefore reduce cost).	Early cultural concerns may not be raised unless some type of early alert is given or investigation is carried out (e.g. a CIA). Risk assessment of cultural values / risk mitigation for values. Cultural values can be considered (e.g. cultural impact assessment).

DSI = detailed site investigation

Te ao Māori and Eco-SGVs

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 for 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.

Māori are very interested in using and applying Eco-SGVs, both broadly and locally. This is important 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 some culturally acceptable state or level). This is also important for addressing critical issues (e.g. waste minimisation, land disposal, contaminant management) and implementing solutions and best practice (e.g. land remediation).

It is essential to have some understanding of te ao Māori / mātauranga Māori when working with Māori groups (iwi, hapū, marae, Māori organisations) on the management/rehabilitation of soils, especially in culturally important and sensitive areas. Māori knowledge, including Māori values, provides an underpinning for resource management. Eco-SGVs have particular application for protecting and managing ecological values, which are often strongly connected to Māori cultural values.

Current and potential impacts of contaminants on cultural values can be illustrated through a variety of specific local examples, such as food harvest areas (e.g. māra kai and mahinga kai), in Māori settlement and housing areas (e.g. papakāinga, marae, urban settlement, māra kai), impacts on water quality and cultural values (e.g. nutrients, mauri, mana, taonga species), and culturally important and significant sites (e.g. culturally sensitive areas: wāhi tapu, urupā, pā, wahi tupuna). The Eco-SGVs and criteria can provide another tool in the toolbox for Māori decision-making to ensure culturally acceptable standards are met through ‘testing and assessment’, setting ‘targets and limits’, and in relation to proposed use and activity so that Māori aspirations can be met.

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 14, for the land uses specified in the *Methodology* for soil contamination standards (SCS’s) (MfE 2011b), a potential option is to combine SCS’s for human health and the Eco-SGVs. Tables 15 and 16 provide these combined ecological receptor values by combining the Eco-SGVs for different protection levels with the SCS’s 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 14 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 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 where it is *not* applicable to consider soil ecological receptors. However, 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, it is expected the eco-sgvs would apply to all soil environments (noting the exclusion of compacted areas, such as unsealed roadways, car-parks).

Table 15. 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.

Potential interim values	As (mg/kg)	Cd (mg/kg)	Cr III (mg/kg)	Pb (mg/kg)	BaP[1] only (mg/kg)	DDT (mg/kg)	B[2]	Cu	Zn
Rural residential / lifestyle (25% produce consumption)	*17*	*0.8*	200	*160*	2.8	*2.4*	7	95	180
Residential (10% produce)	20	1.5	200	*210*	2.8	2.4	7	95	180
High-density residential	20	1.5	200	290	2.8	2.4	7	95	180
Recreational area (80%)	20	1.5	200	290	2.8	2.4	7	95	180
Commercial/ industrial outdoor/ industrial outdoor work	20	1.5	200	290	2.8	2.4	7	95	180

Note: for contaminated land management purposes these values are intended to be primarily applicable for use as remediation targets (except Cu and Zn).

[1]B(a)P – Benzo(a)pyrene

[2] Hot-water soluble boron.

Table 16. 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[1] only (mg/kg)	DDT (mg/kg)	B[2]	Cu	Zn
Rural residential / lifestyle (25% produce consumption)	*17*	*0.8*	400	*160*	22	4.8	15	190	285
Residential (10% produce)	*20*	*3*	400	*210*	22	4.8	15	190	285
High-density residential	*45*	12	400	*500*	22	4.8	15	190	285
Recreational area (80%)	60	12	400	*880*	22	4.8	15	190	285
Commercial/ industrial outdoor/ industrial outdoor work	60	12	400	900	22	4.8	15	190	285

[1]B(a)P – Benzo(a)pyrene

[2] Hot-water soluble boron.

4.4.4 Barriers to implementation

As also noted in Cavanagh & Harmsworth 2022, Mayhew 2023 identified various institutional issues that provide barriers to dealing with contaminated land generally, and that will also have an impact on the implementation of Eco-SGVs. These include:

- inconsistent approaches across regulatory authorities
- lack of resourcing and expertise, particularly in small territorial authorities
- whether the division of functions for contaminated land management across regional councils and territorial authorities best achieves an integrated, efficient, and effective approach to managing contaminated land.

Options for alternative management regimes for contaminated land with a view to achieving more integrated and consistent outcomes that better align expertise with the management of the adverse effects at issue include (Mayhew 2023):

1 allocating to regional councils the function of managing all effects of contaminated land on the natural environment (including soil ecological effects)

2 integrating regional councils’ and territorial authorities’ expertise into a single team within each region, combined with an NBE plan that addresses contaminated land in an integrated and comprehensive way

3 a broader role for the Environmental Protection Authority in overseeing contaminated land management nationally.

4.5 Developing a national policy statement or a national soils strategy

Mayhew (2023) proposed developing a national policy statement, or equivalent direction in the National Planning Framework, to guide outcomes and expectations for decision-making for contaminated land. The benefits of a national policy statement were considered not to solely relate to better managing of ecological effects, but to also contribute to achieving more consistent application of the NES-CS for managing human health effects. Mayhew (2023) also identified the value of a national policy statement or similar that recognises the beneficial attributes of soil as a resource, promoting its re-use where possible in preference to the removal and disposal of soil. This would be beneficial in reducing the amount of soil disposed at landfills. (See also Cavanagh, Harmsworth et al. 2023 for further discussion on this topic.)

An alternative to a national policy statement for contaminated land could be a national soils strategy that provides a higher-level strategic approach to generate the impetus and clear objectives for managing soils, such that soils are more protected and valued, and improved soil health and environmental outcomes are realised. There are multiple current activities that highlight the need for a strategic approach for improving environmental outcomes centred around soil, including:

- recognition of the lack of improvement in soil quality monitored through SOE soil quality monitoring (MfE 2022; Cavanagh, Thompson-Morrison et al. 2023)
- the inclusion in the recently released Waste Minimisation Strategy of a goal that contaminated land be remediated and managed to reduce waste and emissions and to enhance the environment, with a specific priority to reduce the volume of soil disposed to landfill[9] (MfE 2023b)
- the Parliamentary Commissioner for the Environment undertaking further investigation of the use of urban soils, following an assessment of urban green-space (PCE 2023).

The EU soils strategy, and in particular the objectives outlined for the EU Mission: A Soil Deal for Europe,[10] provides a useful illustration of the higher-level objectives that could be set for a broader range of issues associated with soil, including reducing pollution and enhancing restoration (Figure 6). The development of an Australia–New Zealand national soil strategy would help provide an essential framing for values, issues, and priorities for the sustainable management of soil under the NBE, but would also explicitly provide the links with other aspects of the environment that are intricately interconnected to soils, including land use, ecosystem health and resilience, nutrients, climate change and carbon, biodiversity, and fresh- and ground-water quality.

Such a strategic approach should be based on a broader set of pluralistic societal values, bringing together other values based on the strong relationship and connection New Zealanders have with soils, and incorporating te ao Māori (Stronge et al. 2023). It should

[9] https://environment.govt.nz/assets/publications/Te-rautaki-para-Waste-strategy.pdf

[10] https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe/soil-health-and-food_en

also be based on a broader range of knowledge, including local farmer knowledge, mātauranga Māori next to science, and technical knowledge. An overarching national soils strategy would:

- clearly identify needs, issues, and challenges
- determine key priorities and desired outcomes
- develop goals and objectives aligned to a specific set of actions and practices (e.g. best practice) to achieve long-term, sustainable soil management and protection.

A strategy would be a useful way to show the interconnections and inter-dependencies between different parts of the environment/ecosystems, and the links between soils and human health and well-being. It would form a strong connector for drivers such as climate change, land-use practice, and land development, and their impacts on land, soils, freshwater, groundwater, ecosystem services, and human well-being and values.

The 8 Mission objectives

1. reduce desertification
2. conserve soil organic carbon stocks
3. stop soil sealing and increase re-use of urban soils
4. reduce soil pollution and enhance restoration
5. prevent erosion
6. improve soil structure to enhance soil biodiversity
7. reduce the EU global footprint on soils
8. improve soil literacy in society

Figure 6. Key objectives for the EU Mission: A Soil Deal for Europe

5 Next steps for implementation

5.1 Protection of soil quality

A key next step towards implementing the Eco-SGVs within the primary sector is to work with that sector to develop industry-relevant guidance documents on managing key contaminants that have ongoing inputs to soil (notably Cu and Zn). From a discharge consenting perspective, the next step is to raise awareness of the existence of the Eco-SGVs, and to encourage their use in the setting of discharge consents, where appropriate.

5.2 Management of contaminated land

As noted earlier, amending the NES-CS before, or as, it is transitioned into the National Planning Framework of the future NBE Act is likely to be the most effective and efficient approach for implementing the Eco-SGVs. Without this national regulatory impetus, utilisation of the Eco-SGVs will be patchy and ineffective. Specifically, amending the NES-CS would include:

- broadening the focus of the NES-CS to explicitly incorporate environmental effects, alongside human health – consistent with the purpose of the NBE and the definition of contaminated land
- agreement on, and incorporation into the 'methodology' of the NES-CS (MfE 2011b), Eco-SGVs, and any necessary guidance for applying them in the context of natural soil background concentrations (as outlined in this report).

5.3 Developing a national soils strategy

This project has highlighted the need for higher-level policy to guide outcomes and expectations for decision-making for contaminated land to ensure optimal outcomes are achieved. More broadly, a higher-level strategic approach is urgently required in New Zealand to generate the impetus and pathway for effectively and sustainably managing our soils, to achieve desired outcomes such as soil security, soil health, economic prosperity, and human well-being.

This approach should be based on a broader set of pluralistic societal values, bringing together other values based on the strong relationship and connection New Zealanders have with soils, and incorporating te ao Māori (Stronge et al. 2023). An overarching national soils strategy would form a strong connector for drivers such as climate change, land-use practice, and land development, and their impacts on land, soils, freshwater, groundwater, ecosystem services, and human well-being and values.

We recommend that the Contaminated Land and Waste Special Interest Group and the Land Monitoring Forum advocate to the Resource Managers Group and central government (Ministry for the Environment, Ministry for Primary Industries) for the development of a national soils strategy to achieve sustainable soils management and soil health across New Zealand. A longer-term soil monitoring programme to measure progress and key indicators (e.g. soil health, soil carbon, contaminated land) should also be considered as essential and integral within this higher-level, integrated approach.

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Appendix 1 – Overview of the management of contaminated sites

The NES for Assessing and Managing Soil Contaminants for the Protection of Human Health (NES-CS) regulations are the primary piece of legislation relating to the management of contaminated sites. These regulations apply to land, where it is identified that land is, has, or is more likely than not to have had, an activity or industry described in the Hazardous Activities and Industry List (HAIL) (MfE 2011c, 2023) on it. Common contaminants include heavy metals such as arsenic or lead, persistent pesticides such as DDT, petroleum hydrocarbons and asbestos. Some common contaminating activities include:

- Horticulture, such as market gardens and glasshouses
- landfilling
- rubbish tipping and burning
- automotive repair and panel beating
- storage of treated timber.

The HAIL includes:

- Category A10 – 'Persistent pesticide bulk storage or use including sport turfs, market gardens, orchards, glass houses or spray sheds
- Category H – 'Any land that has been subject to the migration of hazardous substances from adjacent land in sufficient quantity that it could be a risk to human health or the environment'
- Category I – 'Any other land that has been subject to the intentional or accidental release of a hazardous substance in sufficient quantity that it could be a risk to human health or the environment'.

There is great variability among environmental consultants and councils as to when category I applies.

Establishing whether the site is a HAIL site is most commonly undertaken through a preliminary site investigation (Reg. 6(3)), typically undertaken by a contaminated land practitioner. For subdivision or land-use change to be a permitted activity, a preliminary site investigation must be carried out and must state 'that it is highly unlikely that there will be a risk to human health if the activity is done to the piece of land'. If a residential development is not considered to be a permitted activity, a detailed site investigation must be undertaken to determine the level of soil contamination through soil testing. This assessment then determines whether the activity is a controlled, restricted discretionary, or discretionary activity.

The NES-CS establishes five specific land development activities that may trigger the *requirement to perform a site investigation for potential contamination***.** These activities are:

- removal or replacement of an underground fuel storage system and associated soil

- soil sampling
- soil disturbance
- subdivision of land
- change in land use.

If there is no indication of a previous HAIL activity (or the potential for it) in the council records, then the NES-CS does not apply, and any planned development activity can be carried out as a permitted activity.

Appendix 2 – Updated and background-adjusted ecological soil guideline values

This section is adapted from Cavanagh, McNeill et al. (2023) and provides detail on the revised Eco-SGVs, including relevant background concentration adjustments. As noted in the main report, it is recommended that background concentration adjustment only be applied for the 95% protection values, partly because background concentrations generally comprised only a small proportion of the 80% and 60% protection values, but also because it was considered inappropriate to enable further adjustment of values associated with lower levels of protection. For the 95% protection values, background adjustment was only considered relevant for those contaminants for which the difference between median concentration and the upper percentiles was >10 mg/kg, and where background concentration comprised >10% of the Eco-SGV.

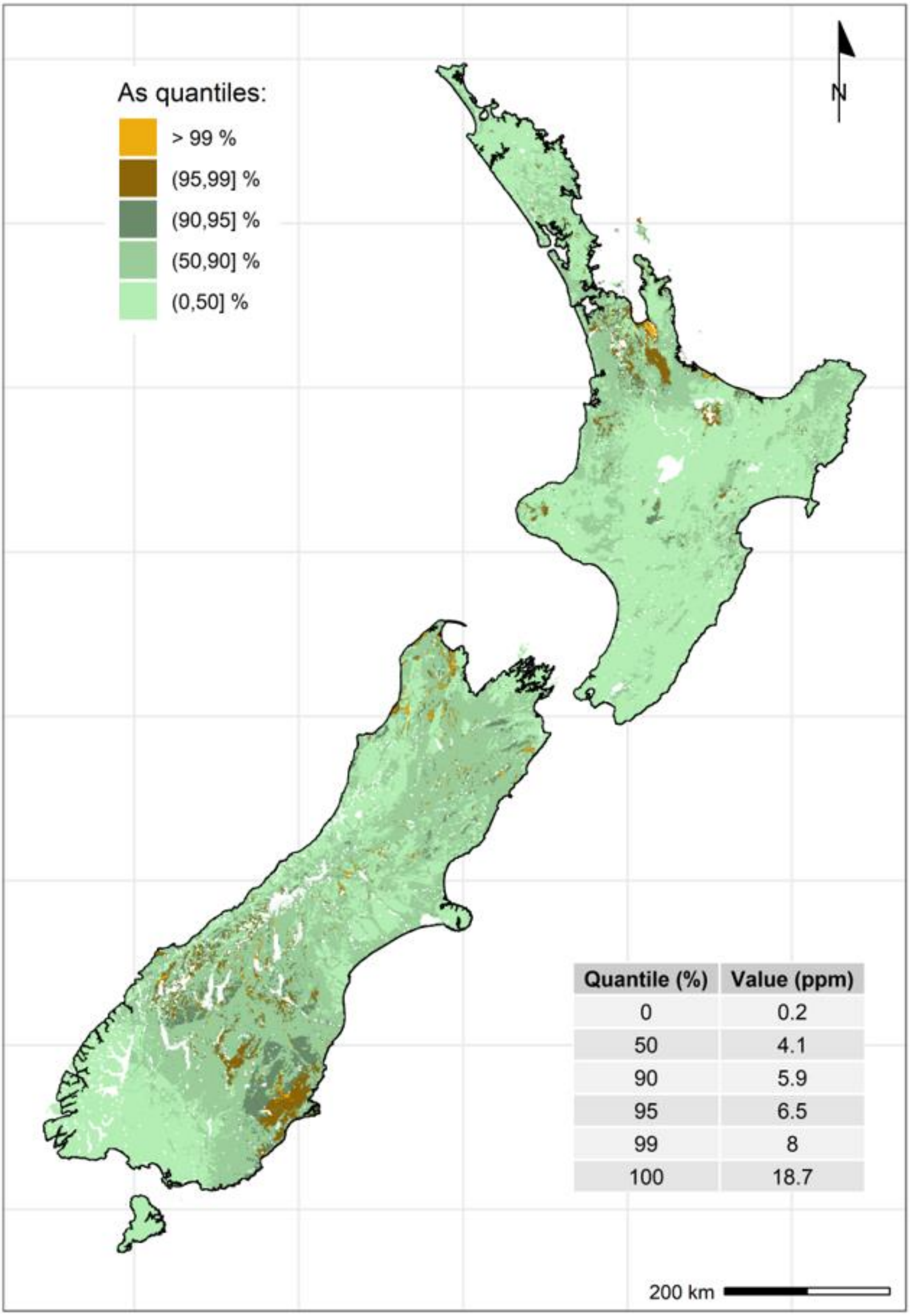
Arsenic

The predicted background (rural ambient) concentrations for As are summarised in Table A1, with the spatial variation in concentrations across New Zealand shown in Figure A1. Given the small range in predicted ambient concentrations for As, it is not recommended that Eco-SGVs be adjusted for background concentrations, except in areas where there are recognised significant small-scale elevations in naturally occurring concentrations. In these cases, site-specific determination of background concentrations is probably required. The revised Eco-SGVs based on updated median background concentrations and the derived added concentrations limits determined for As by Cavanagh and Munir (2019) at the different protection levels are shown in Table A2.

Table A1. Summary of predicted background (rural ambient) concentrations for As. The bolded value shows the concentration used to derive Eco-SGVs.

Element	Min	Median	90th	95th	99th*	Max
As	0.22	**4.1**	5.9	6.5	8.0	18.7

* It is recommended that the 99th percentile be used as a default value for these areas initially. Where there is recognised to be significant local small-scale elevation in background concentrations, it may be appropriate to undertake site-specific determination of background concentrations.



Quantile (%)	Value (ppm)
0	0.2
50	4.1
90	5.9
95	6.5
99	8
100	18.7

Figure A1. Filled contour plot of As concentrations across New Zealand, with contours at the 50, 90, 95, and 99.5 percentiles of the predicted values. The table in the lower right shows the values associated with common quantiles, including the 0 and 100% quantiles (the minimum and maximum, respectively). (Source: Cavanagh, McNeill et al. 2023)

Table 17. Eco-SGVs for As based on median background concentration and added contaminant limits (ACL) at three protection levels

Protection level[a]	Median background concentration[b] (mg/kg)	ACL[c] $_{(EC30)}$ (mg/kg	Eco-SGV[d] (mg/kg)
95%	4.1	15	20
80%		55	60
60%		144	150

[a] These protection levels equate to the non-food production land (95%), residential/recreational area (80%), and commercial/industrial area (60%) land uses from Cavanagh & Munir 2019.

[b] It is recommended that the median be used as a default value. Where there is recognised to be significant local small-scale elevation in background concentrations, it may be appropriate to undertake site-specific determination of background concentrations.

[c] From Cavanagh & Munir 2019.

[d] Values have been rounded.

Boron

The predicted background (rural ambient) concentrations for B are summarised in Table A3, with the spatial variation in concentrations across New Zealand shown in Figure A2. Based on the range in rural ambient concentrations for B, background adjustment for Eco-SGVs based on total B concentrations is recommended in areas identified as being above the 95th percentile of modelled estimates. ACLs for B are based on both total and hot-water-soluble B (HWS-B, Table A4), although the contribution of background HWS-B is considered to be negligible (Cavanagh & Munir 2019), so Eco-SGVs based on HWS-B do not change. Values for Eco-SGVs based on revised predicted median background concentrations for the different protection levels are shown in Table A4, with background-adjusted 95% protection level Eco-SGVs shown in Table A5.

Table A3. Summary of predicted background (rural ambient) concentrations for B. Bolded concentrations show the values used to develop Eco-SGVs.

Element	Min	Median	90th	95th	99th*	Max
B	0.6	**4.6**	12	**16**	**23**	83

* It is recommended that the 99th percentile be used as a default value for these areas initially. Where there is recognised to be significant local small-scale elevation in background concentrations, it may be appropriate to undertake site-specific determination of background concentrations.

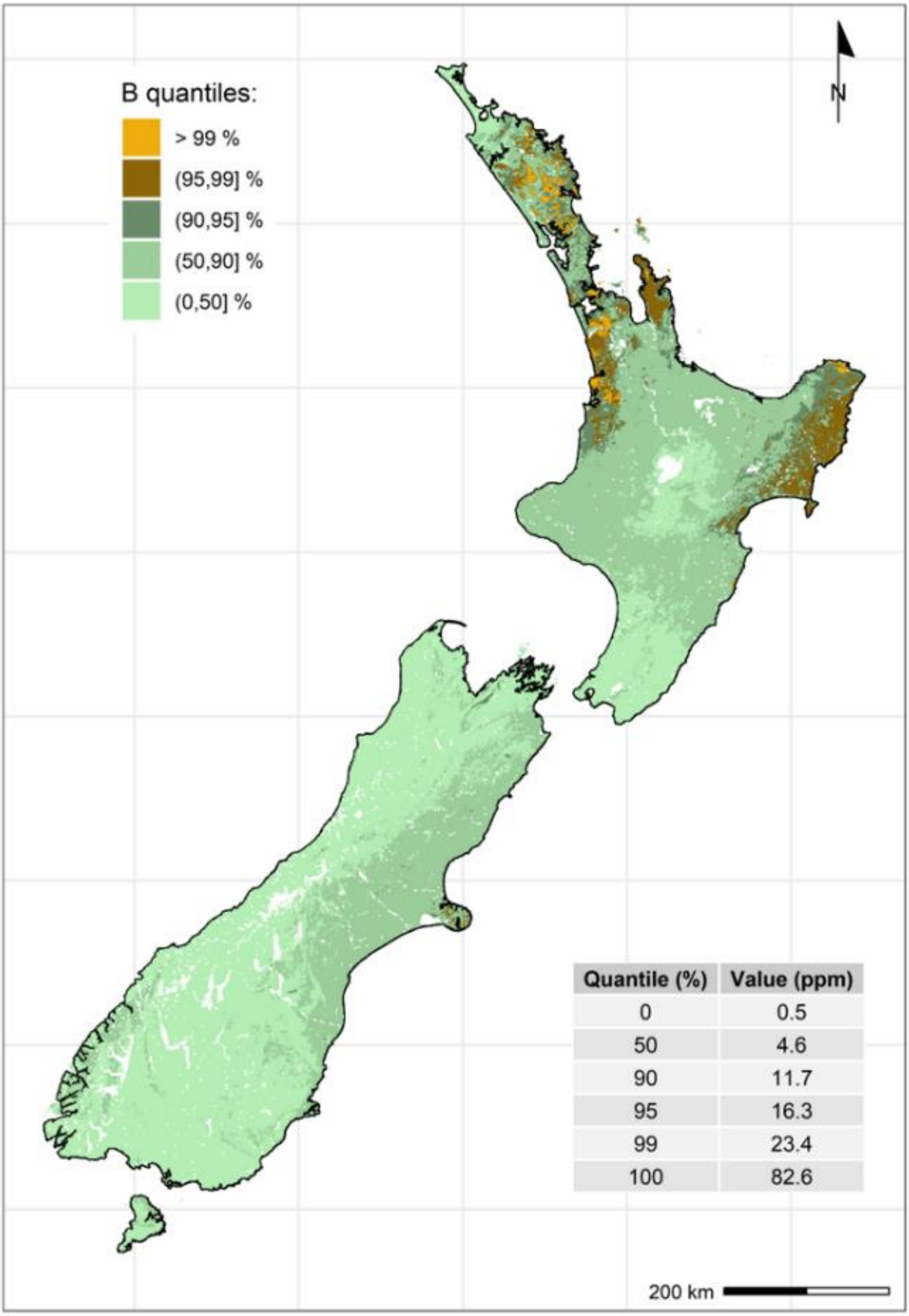


Figure A2. Filled contour plot of B concentrations across New Zealand, with contours at the 50, 90, 95, and 99.5 percentiles of the predicted values. The table in the lower right shows the values associated with common quantiles, including the 0 and 100% quantiles (the minimum and maximum, respectively). (Source: Cavanagh, McNeill et al. 2023)

Table A4. Eco-SGVs for B based on median background concentration and added contaminant limits (ACLs) expressed as total B and hot-water-soluble (HWS) B concentrations at three protection levels

Protection level[a]	Median background concentration (mg/kg)	ACL[b] $_{(EC30)}$ (mg/kg)	Eco-SGV[c] $_{(EC30)}$ (mg/kg)	HWS-B Eco-SGV[d] $_{(EC30)}$ (mg/kg)
95%	4.6	9.7	14	7
80%	4.6	17	22	14
60%	4.6	21	26	17

[a] These protection levels equate to the non-food production land (95%), residential/recreational area (80%), and commercial/industrial area (60%) land uses from Cavanagh & Munir 2019.

[b] From Cavanagh & Munir 2019.

[c] Values have been rounded.

[d] Based on hot-water-soluble B concentrations; the contribution of background HWS-B is considered to be negligible.

Table A5. Background-adjusted 95% protection level Eco-SGVs for B based on the 95th and 99th percentile predicted background concentrations and the ACL for total B[a]

Background concentration percentile	Background concentration (mg/kg)	ACL[b] $_{(EC30)}$ (mg/kg)	Eco-SGV[c] $_{(EC30}$
95th	16	9.7	26
99th[d]	23	9.7	33

[a] The contribution of background HWS-B is considered to be negligible, so Eco-SGVs associated with HWS-B do not vary with background concentration.

[b] See Table A4.

[c] Values have been rounded.

[d] It is recommended that the 99th percentile be used as a default value for these areas initially. Where there is recognised to be significant local small-scale elevation in background concentrations, it may be appropriate to undertake site-specific determination of background concentrations.

Cadmium

The predicted background (rural ambient) concentrations for Cd are summarised in Table A6, with the spatial variation in concentrations across New Zealand shown in Figure A3. Given the low rural ambient concentrations for Cd, background concentrations are not used in the derivation of Eco-SGVs. Given that Eco-SGVs based on providing protection for biomagnification are lower than those based on total Cd, these are the recommended Eco-SGVs for use (Table A7).

Table A6. Summary of predicted background (rural ambient) concentrations for Cd.

Element	Min	Median	90th	95th	99th	Max
Cd	0.01	0.1	0.2	0.29	0.35	0.58

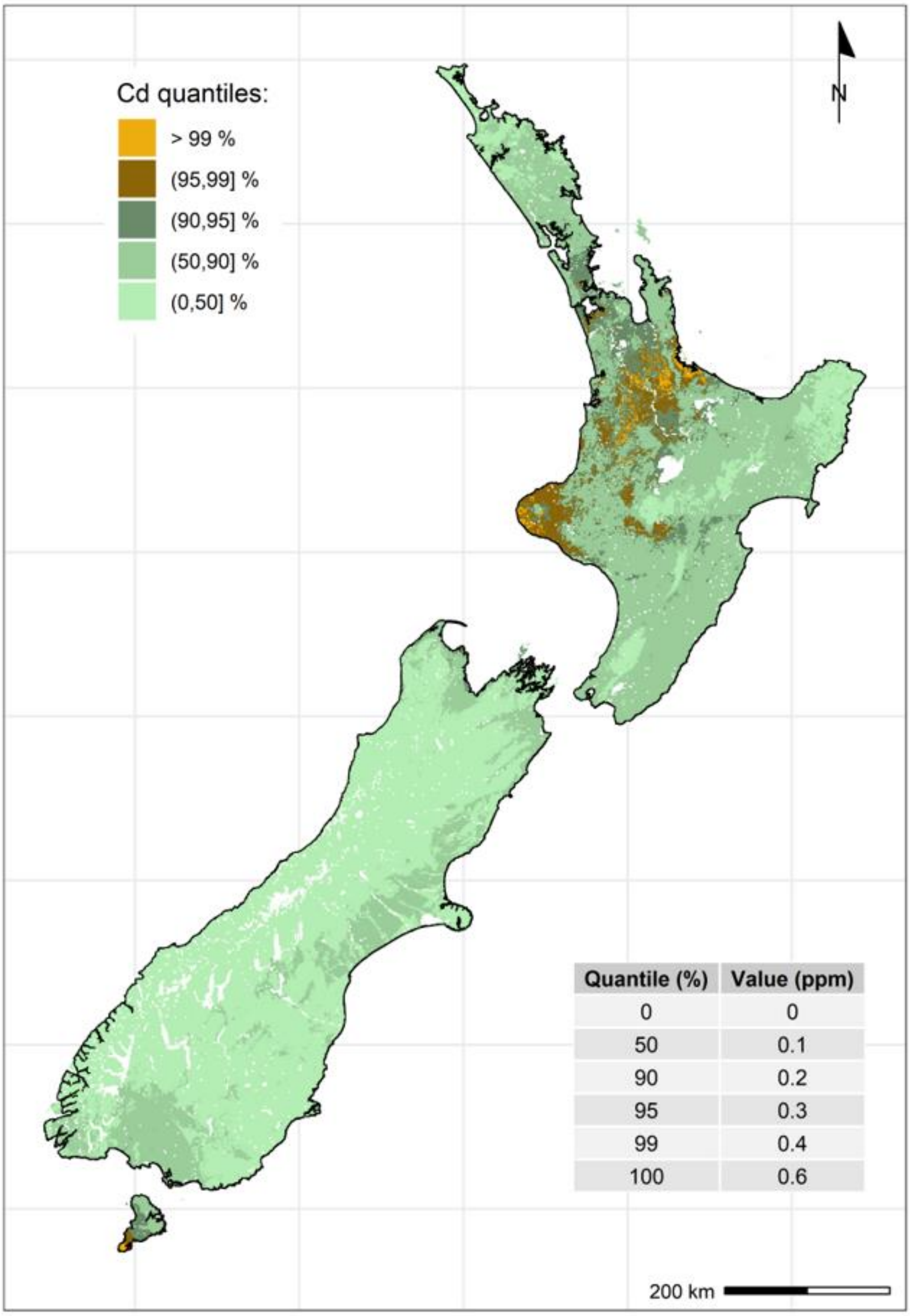


Figure 7. Filled contour plot of Cd concentration across New Zealand, with contours at the 50, 90, 95, and 99.5 percentiles of the predicted values. The table in the lower right shows the values associated with common quantiles, including the 0 and 100% quantiles (the minimum and maximum, respectively). (Source: Cavanagh, McNeill et al. 2023)

Table A7. Eco-SGVs for Cd based on median background concentration and added contaminant limits (ACLs), based on total Cd, and allowing for protection for biomagnification at three protection levels.

Protection level[a]	Median background concentration (mg/kg)	ACL[b] $_{(EC30)}$ (mg/kg)	Eco-SGV[c] (mg/kg)	ACL[b] $_{(EC30BM)}$ (mg/kg)	Eco-SGV$_{BM}$[c] (mg/kg)
95%	0.1	4.8	4.8	1.5	1.5
80%	0.1	17	17	12	12
60%	0.1	40	40	33	33

[a] These protection levels equate to the non-food production land (95%), residential/recreational area (80%), and commercial/industrial area (60%) land uses from Cavanagh & Munir 2019.

[b] From Cavanagh & Munir 2019.

[c] Values have been rounded.

BM = protective of exposure via biomagnification.

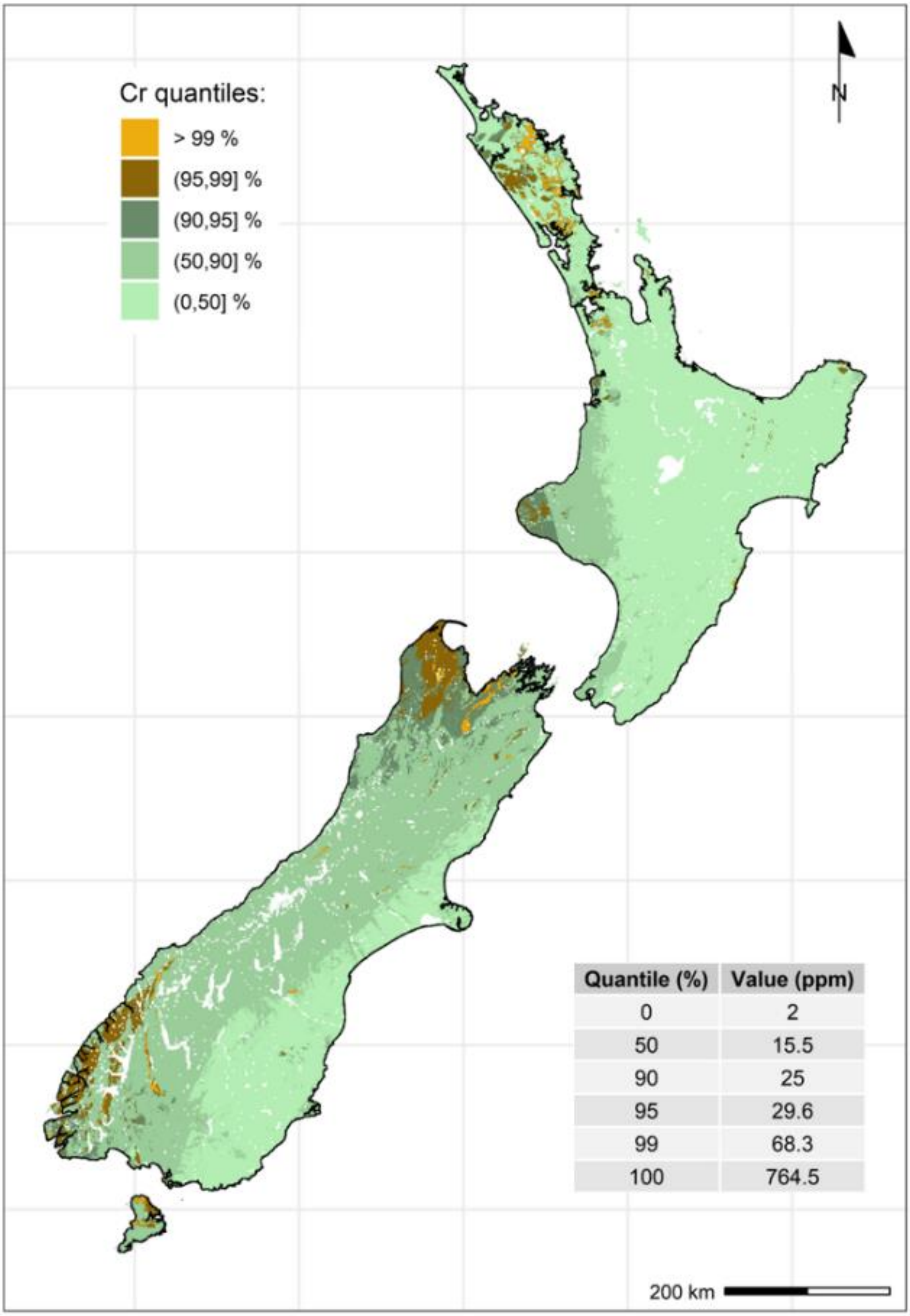
Chromium

The predicted background (rural ambient) concentrations for Cr are summarised in Table A8, with the spatial variation in concentrations across New Zealand shown in Figure A4. Based on the range in rural ambient concentrations for Cr, background adjustment for Eco-SGVs is recommended in areas identified as being above the 95th percentile of modelled estimates. Where there are recognised significant small-scale elevations in naturally occurring concentrations, it may be appropriate to undertake site-specific determination of background concentrations. Values for Eco-SGVs based on revised predicted median background concentrations for the different protection levels are shown in Table A9, with background-adjusted 95% protection level Eco-SGVs shown in Table A10.

Table A8. Summary of predicted background (rural ambient) concentrations for Cr. Bolded concentrations show the values used to develop Eco-SGVs.

Element	Min	Median	90th	95th	99th*	Max
Cr	1.96	**16**	25	**30**	**68**	765

* It is recommended that the 99th percentile be used as a default value for these areas initially. Where there is recognised to be significant local small-scale elevation in background concentrations, it may be appropriate to undertake site-specific determination of background concentrations.



Quantile (%)	Value (ppm)
0	2
50	15.5
90	25
95	29.6
99	68.3
100	764.5

Figure A4. Filled contour plot of Cr concentrations across New Zealand, with contours at the 50, 90, 95, and 99.5 percentiles of the predicted values. The table in the lower right shows the values associated with common quantiles, including the 0 and 100% quantiles (the minimum and maximum, respectively). (Source: Cavanagh, McNeill et al. 2023).

Table A9. Eco-SGVs for Cr based on median background concentration and added contaminant limits at three protection levels

Protection level[a]	Median background concentration (mg/kg)	ACL[b] (EC30) (mg/kg)	Eco-SGV[c] (EC30) (mg/kg)
95%	16	184	200
80%	16	382	400
60%	16	641	660

[a] These protection levels equate to the non-food production land (95%), residential/recreational area (80%), and commercial/industrial area (60%) land uses from Cavanagh & Munir 2019.

[b] From Cavanagh & Munir 2019.

[c] Values have been rounded.

Table A10. Summary of background-adjusted 95% protection Eco-SGVs based on the 95th and 99th percentile predicted background concentrations and the ACL for Cr.

Background concentration percentile	Background concentration (mg/kg)	ACL[a](EC30) (mg/kg)	Eco-SGV[b](EC30) (mg/kg)
95th	30	184	215
99th[c]	68	184	250

[a] See Table A9.

[b] Values have been rounded.

[c] It is recommended that 99th percentile be used as a default value for these areas initially. Where there is recognised to be significant local small-scale elevation in background concentrations, it may be appropriate to undertake site-specific determination of background concentrations.

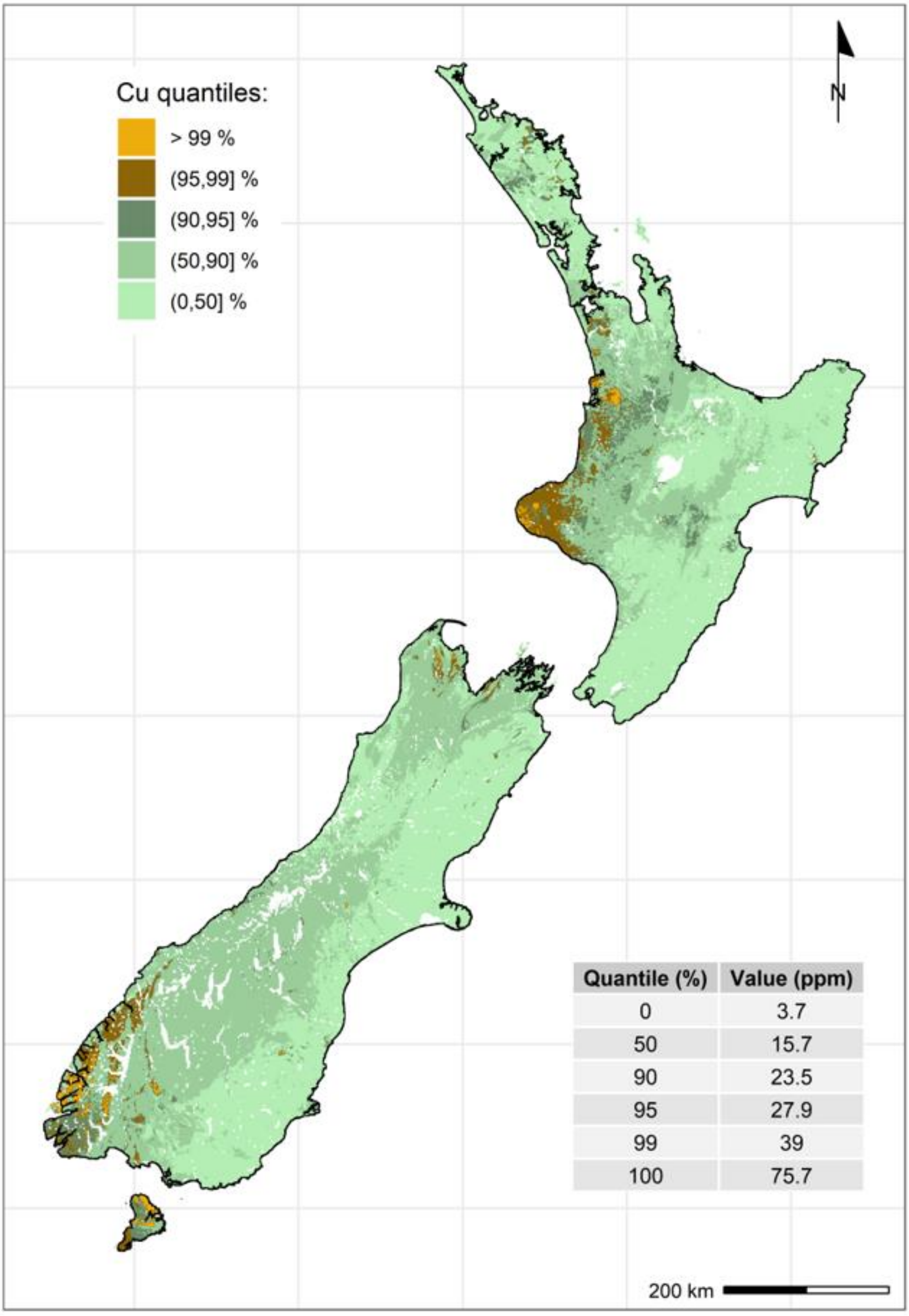
Copper

The predicted background (rural ambient) concentrations for Cu are summarised in Table A11, with the spatial variation in concentrations across New Zealand shown in Figure A5. Based on the range in rural ambient concentrations for Cu, background adjustment for Eco-SGVs is recommended in areas identified as being above the 95th percentile of modelled estimates. Where there are recognised significant small-scale elevations in naturally occurring concentrations, it may be appropriate to undertake site-specific determination of background concentrations. There were sufficient toxicity data to derive added contaminant limits for three reference soils (Table A12, see Cavanagh & Munir 2019 for further details). Values for Eco-SGVs based on revised predicted median background concentrations for the different protection levels are shown in Table A13, with background-adjusted 95% protection-level Eco-SGVs shown in Table A14. (See Cavanagh & Harmsworth 2023 for more details on the application of the Eco-SGVs.)

Table A11. Summary of predicted background (rural ambient) concentrations for Cu. Bolded concentrations show the values used to develop Eco-SGVs.

Element	Min	Median	90th	95th	99th *	Max
Cu	3.8	**16**	24	**28**	**39**	76

* It is recommended that the 99th percentile be used as a default value for these areas initially. Where there is recognised to be significant local small-scale elevation in background concentrations it may be appropriate to undertake site-specific determination of background concentrations.



Quantile (%)	Value (ppm)
0	3.7
50	15.7
90	23.5
95	27.9
99	39
100	75.7

Figure A5. Filled contour plot of Cu concentrations across New Zealand, with contours at the 50, 90, 95, and 99.5 percentiles of the predicted values. The table in the lower right shows the values associated with common quantiles, including the 0 and 100% quantiles (the minimum and maximum, respectively). (Source: Cavanagh, McNeill et al. 2023).

Table A12. Added concentration limits (ACL) derived for Cu using LOEC/EC30 toxicological endpoints for aged contamination and the typical, sensitive, and tolerant New Zealand reference soils and three protection levels

Protection level (%)*	$ACL_{(EC30)}$ Typical soil (mg/kg)	$ACL_{(EC30)}$ Sensitive soil (mg/kg)	$ACL_{(EC30)}$ Tolerant soil (mg/kg)
95%	108	55	90
80%	197	120	412
60%	339	250	600

* These protection levels equate to the non-food production land (95%), residential/recreational area (80%), and commercial/industrial area (60%) land uses. (Source: Cavanagh & Munir 2019)

Table A13. Eco-SGVs for Cu based on median background concentrations and added contaminant limits developed for the three New Zealand reference soils at three protection levels

Protection level (%)	Median background concentration (mg/kg)	Eco-SGV[a] $_{(EC30)}$ typical soil	Eco-SGV[a] $_{(EC30)}$ sensitive soil[b]	Eco-SGV[a] $_{(EC30)}$ tolerant soil
95%	16	110	**95**	135
80%	16	245	**190**	350
60%	16	430	**330**	640

[a] Values have been rounded.

[b] Suggested default Eco-SGV.

Table A14. Summary of background-adjusted 95th protection values Eco-SGVs for the three New Zealand reference soils, based on the estimated 95th and 99th percentile ambient concentrations

Percentile background concentration	Background concentration (mg/kg)	Eco-SGV[a] $_{(EC30)}$ typical soil	Eco-SGV[a] $_{(EC30)}$ sensitive soil[b]	Eco-SGV[a] $_{(EC30)}$ tolerant soil
95th%	28	125	**110**	150
99th%	39	135	**120**	160

[a] Values have been rounded.

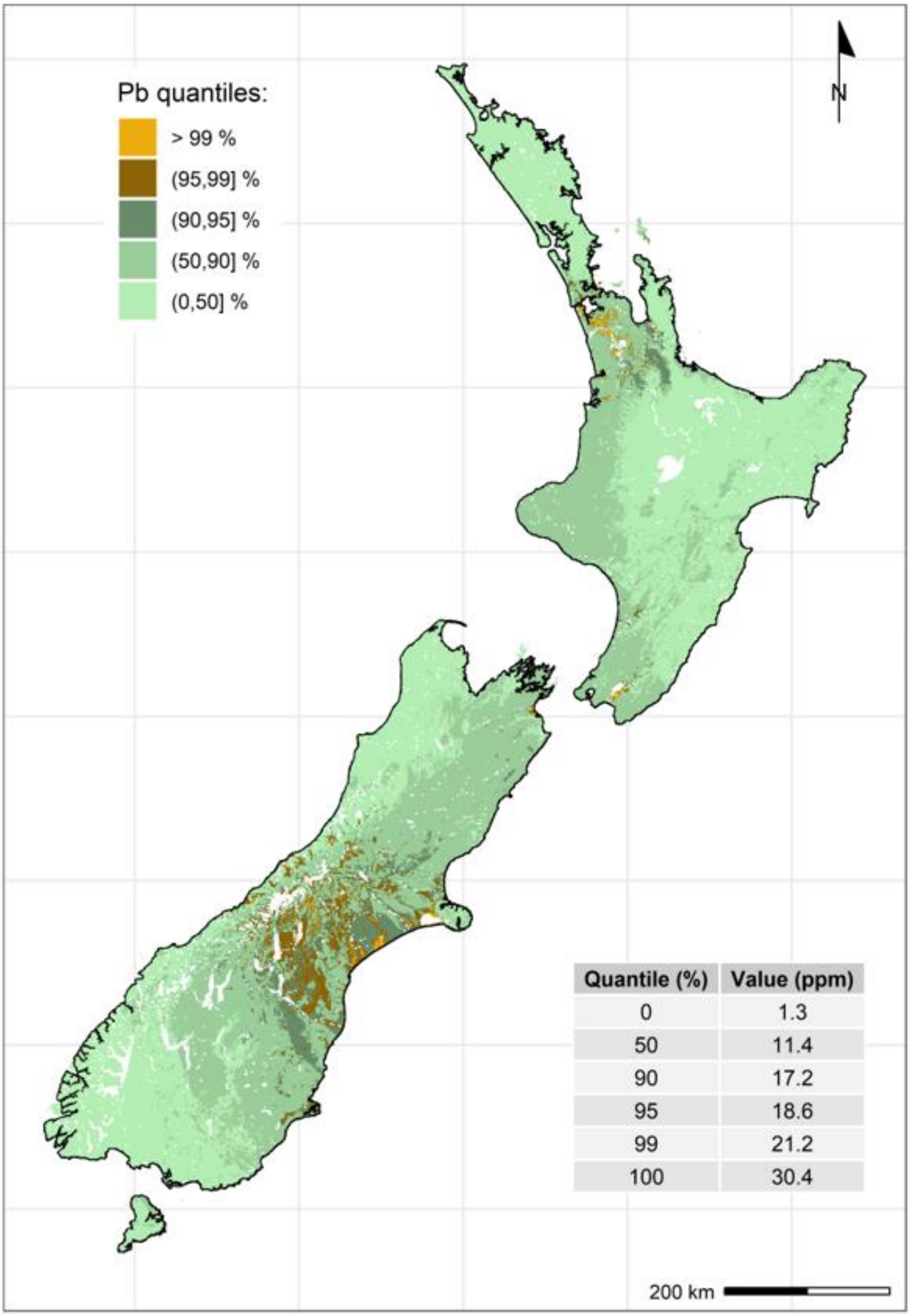
[b] Suggested default Eco-SGV.

Lead

The predicted background (rural ambient) concentrations for Pb are summarised in Table A15, with the spatial variation in concentrations across New Zealand shown in Figure A6. Given the small range in predicted ambient concentrations for Pb it is not recommended that Eco-SGVs be adjusted for background concentrations. Values for Eco-SGVs based on revised predicted median background concentrations for the different protection levels are shown in Table A16. Given that Eco-SGVs based on providing protection for biomagnification are lower than for total Pb for the lower protection levels (80%, 60%), these are the recommended Eco-SGVs for use at those protection levels. See Cavanagh & Harmsworth 2023 for more details on the application of the Eco-SGVs.

Table A15. Summary of predicted background (rural ambient) concentrations for Pb. The bolded concentration shows the value used to develop Eco-SGVs.

Element	Min	Median	90th	95th	99th	Max
Pb	1.3	**11**	17	19	21	30



Quantile (%)	Value (ppm)
0	1.3
50	11.4
90	17.2
95	18.6
99	21.2
100	30.4

Figure A6. Filled contour plot of Pb concentrations across New Zealand, with contours at the 50, 90, 95, and 99.5 percentiles of the predicted values. The table in the lower right shows the values associated with common quantiles, including the 0 and 100% quantiles (the minimum and maximum, respectively). (Source: Cavanagh, McNeill et al. 2023).

Table A16. Eco-SGVs for Pb based on median background concentration and added contaminant limits based on total Pb, and allowing for protection for biomagnification at three protection levels

Protection level[a] (%)	Median background concentration (mg/kg)	ACL[b] $_{(EC30)}$ (mg/kg)	Eco-SGV[c] $_{(EC30)}$ (mg/kg)	ACL[b] $_{(BM)}$ (mg/kg)	Eco-SGV[c] $_{BM}$ (mg/kg)
95%	11	275	290		NA
80%	11	1276	1290		900
60%	11	3049	3060		2500

[a] These protection levels equate to the non-food production land (95%), residential/recreational area (80%), and commercial/industrial area (60%) land uses from Cavanagh & Munir 2019.

[b] From Cavanagh & Munir 2019.

[c] Values have been rounded.

BM = protective of exposure via biomagnification, recommended for use to account for secondary poisoning at high concentrations of Pb.

Zinc

The predicted background (rural ambient) concentrations for Zn are summarised in Table A17, with the spatial variation in concentrations across New Zealand shown in Figure A7. Based on the range in rural ambient concentrations for Zn, background adjustment for Eco-SGVs is recommended in areas identified as being above the 95th percentile of modelled estimates. Where there are recognised significant small-scale elevations in naturally occurring concentrations, it may be appropriate to undertake site-specific determination of background concentrations. There were sufficient toxicity data to derive added contaminant limits for three reference soils (Table A18, see Cavanagh & Munir 2019 for further details). Values for Eco-SGVs based on revised predicted median background concentrations for the different protection levels are shown in Table A19, with background-adjusted 95% protection level Eco-SGVs shown in Table A20. (See Cavanagh & Harmsworth 2023 for more details on the application of the Eco-SGVs.)

Table A17. Summary of predicted background (rural ambient) concentrations for Zn. Bolded concentrations show the values used to develop Eco-SGVs.

Element	Min	Median	90th	95th	99th*	Max
Zn	11.2	**48**	**63**	**68**	**80**	100

* It is recommended that the 99th percentile be used as a default value for these areas initially. Where there is recognised to be significant local small-scale elevation in background concentrations, it may be appropriate to undertake site-specific determination of background concentrations.

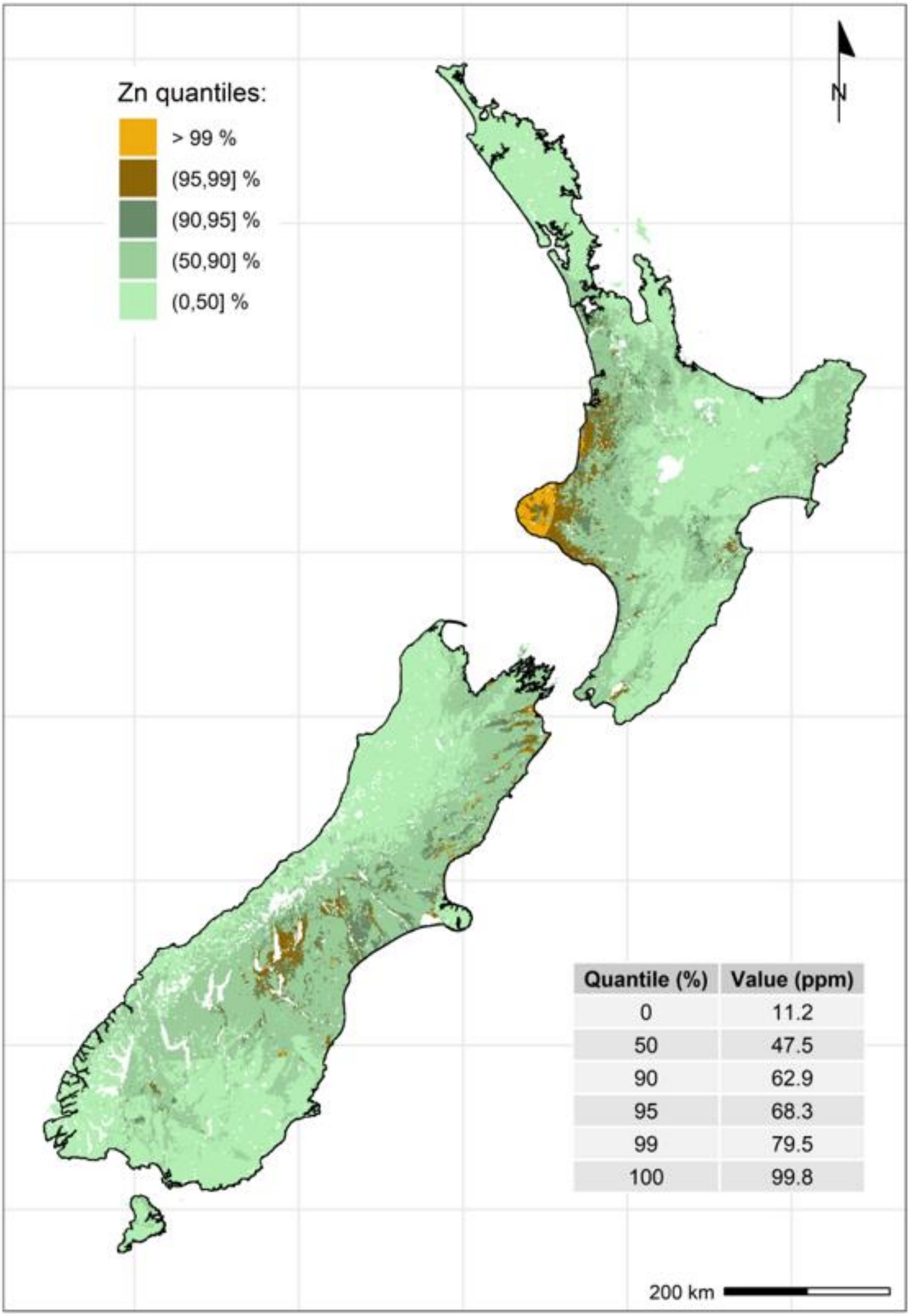


Figure A7. Filled contour plot of Zn concentrations across New Zealand, with contours at the 50, 90, 95, and 99.5 percentiles of the predicted values. The table in the lower right shows the values associated with common quantiles, including the 0 and 100% quantiles (the minimum and maximum, respectively). (Source: Cavanagh, McNeill et al. 2023).

Table A18. Added concentration limits (ACLs) derived for Zn using LOEC/EC30 toxicological endpoints for aged contamination for the typical, sensitive, and tolerant New Zealand reference soils.

% protection*	$ACL_{(EC30aged)}$ typical (mg/kg)	$ACL_{(EC30aged)}$ sensitive (mg/kg)	$ACL_{(EC30aged)}$ tolerant (mg/kg)
95%	152	131	203
80%	273	236	361
60%	463	404	597

* These protection levels equate to the non-food production land (95%), residential/recreational area (80%), and commercial/industrial area (60%) land uses.

Source: Cavanagh & Munir 2019.

Table A19. Eco-SGVs for Zn based on median background concentrations and added contaminant limits developed for the three New Zealand reference soils at three protection levels.

Value name (% protection)	Median background concentration (mg/kg)	$Eco\text{-}SGV_{(EC30)}$ typical soil	$Eco\text{-}SGV_{(EC30)}$ sensitive soil*	$Eco\text{-}SGV_{(EC30)}$ Tolerant soil
95%	48	200	**180**	250
80%	48	320	**285**	410
60%	48	510	**450**	645

* Suggested default Eco-SGV; see also section 4.2.3.

Table A20. Background-adjusted 95th protection values Eco-SGVs for Zn for the three New Zealand reference soils based on the estimated 90th, 95th and 99th percentile ambient concentrations

Percentile background concentration	Background concentration (mg/kg)	Zn $Eco\text{-}SGV_{(EC30)}$ typical soil	Zn $Eco\text{-}SGV_{(EC30)}$ sensitive soil*	Zn $Eco\text{-}SGV_{(EC30)}$ tolerant soil
90^{th}	63	215	**195**	265
95^{th}	68	220	**200**	270
99^{th}	80	230	**210**	280

* Suggested default Eco-SGV; see also section 4.2.3.

Appendix 3 – Natural and Built Environment Bill

The Natural and Built Environment Bill (NBE) is one of three key pieces of legislation that comprise resource management reform. Under resource management reform, and in particular the NBE, environmental limits and targets are a primary means to prevent further environmental degradation and drive environmental improvements. Limits and targets will be set across six mandatory matters: air, soil, indigenous biodiversity, freshwater, estuaries, and coastal waters, and they may also be set for other matters. The purpose of environmental limits is to protect human health and prevent the ecological integrity of the natural environment degrading from its current state.

The purpose of the Act is to:

- a enable the use, development, and protection of the environment in a way that—
  - i supports the well-being of present generations without compromising the well-being of future generations; and
  - ii promotes outcomes for the benefit of the environment; and
  - iii complies with environmental limits and their associated targets; and
  - iv manages adverse effects; and
- b recognise and uphold te Oranga o te Taiao.

To assist with achieving the purpose of the Act, national planning framework and all plans must provide for various system outcomes (s.5), with the following most relevant in the context of the management of soils:

- a) the protection or, if degraded, restoration, of—
  - i the ecological integrity, mana, and mauri of .....soils....
- c) well-functioning urban and rural areas that are responsive to the diverse and changing needs of people and communities in a way that promotes—
  - ii the use and development of land for a variety of activities, including for housing, business use, and primary production; and ....
- d) [the availability of highly productive land for land-based primary production...]

Note that for (d) above there is no specification regarding the quality of this highly productive land (which is based on the land-use capability assessment and is independent of the current quality of that land).

Ecological integrity is defined in the NBE as being the:

... ability of the natural environment to support and maintain the following:

- representation: the occurrence and extent of ecosystems and indigenous species and their habitats; and
- composition: the natural diversity and abundance of indigenous species, habitats, and communities; and

- structure: the biotic and abiotic physical features of ecosystems; and
- functions: the ecological and physical functions and processes of ecosystems.

The purpose of setting environmental limits is to prevent the ecological integrity of the natural environment from degrading *from the state it was in* at the commencement of the relevant part of the Act, or to protect human health. However, minimum-level targets may be set if the associated environmental limit is set at a level that represents unacceptable degradation of the natural environment (s.50).

Environmental limits may be set in relation to ecological integrity of the natural environment or to human health, and must be set as a minimum biophysical state or the maximum amount of harm or stress to the natural environment that may be permitted in a management unit. They may be qualitative or quantitative, and set at different levels for different management units – although management units are currently not defined. Environmental limits must also be set in a way that integrates more than one of the aspects of the natural environment (air, indigenous biodiversity, coastal waters, estuaries, freshwater, soil).

The purpose of setting targets is to assist in improving the state of the natural and built environment. There is greater flexibility in what a target may look like, with it being specified that a target —

c is able to be measured; and

d must be achieved by a specified time; and

e is designed to assist in achieving—

  i a system outcome; or

  ii a framework outcome; or

  iii in relation to a target set in a plan, a plan outcome specified in the plan.

Further, a target may be expressed as a series of steps, each with a time limit, designed to achieve progressive improvement over time. *Mandatory* targets 'must … be set for each aspect of the environment for which a limit is set … and at a level equal to or better than that of the associated environmental limit'; *discretionary* targets may be set for other matters if they are relevant for achieving a system outcome, a framework outcome, or a plan outcome.

Appendix 4 – Core indigenous values/principles integral to understanding soil health

Table A1. Core indigenous values/principles integral to understanding soil health

Māori core values/principles	Description
Whakapapa	Recognising the ancestral links or lineage of the soil originating from the Māori belief system (Papatūānuku and Ranginui, te ao mārama, and atua (gods, deities, domains)) and links to tangata whenua (e.g. whānau, hapū, iwi). Strengthens understanding of interdependencies and interconnections between ecosystems, plants, animals, and humans.
Mana	Power, prestige, and authority. Giving respect to the soil resource, elevating the importance and prestige of soils, thereby giving them mana. Also the mana, authority, and responsibilities of human beings to care for, govern, protect, and manage the soil resource in accordance with local tikanga and kawa (customs and values). Recognises the Treaty of Waitangi as an over-arching framework to reinforce this mana.
Mauri	Life force or energy, vitality and continued capacity of a soil to sustain/support healthy living ecosystems, including the basis or support for human well-being. For example, a well-functioning soil ecosystem has the capacity to maintain interconnections between the physical, chemical, and biological components of soil, plants, animals, microbes, and people and to restore balance in the system to sustain health and well-being.
Wairua	The spiritual dimension, soul, connection to soil and land – helps provide the glue to maintain and strengthen mana and mauri to achieve a healthy soil and human well-being, through spiritual endeavour and practice.
Taonga tuku iho	Soil is a treasure passed down through the generations and has an ancestral lineage and connection. Soil health can be maintained by building inter-generational capacity to care for the soil resource through kaitiakitanga (e.g. values-driven guardianship to give wise land-use options that sustain soil health and well-being).
Maramataka	Based on the Māori lunar calendar, climate, weather, and seasonal variations, guiding cultivation, and planting and harvesting activities.
Māra kai / mahinga kai	The ability of soil to provide healthy food (kai) for sustenance and well-being.
Oranga, hauora, waiora, toiora	The ability of a soil to provide and ensure health and well-being of whenua (land), plants, animals, and humans A well-functioning soil free of harmful pollutants, contaminants, pathogens, and toxicity.
Tau utuutu	Giving back what you take; an active exercise of benefit to the resource (e.g. soil) through environmental guardianship (kaitiakitanga), shown through careful management and practice.
Kaitiakitanga	Cultural and environmental guardianship, as a responsibility to protect and manage the environment embracing all the values above.