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Landcare Research

UPDATED User Guide: Background soil concentrations and soil guideline values for the protection of ecological receptors (Eco-SGVs) – Consultation draft

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Contents

Summary

Soil guideline values developed to protect terrestrial biota (soil microbes, invertebrates, plants, wildlife and livestock) (Eco-SGVs) provide a useful means to readily assess potential environmental impact. This Envirolink Tools Project was initiated to address the absence of national Eco-SGVs, which has resulted in inconsistency and a lack of clarity around protection of ecological receptors in soil, and a lack of focus on ensuring this protection in territorial and regional/unitary council functions. This user guide provides details developed to date on the intended application of Eco-SGVs.

Background soil concentrations were determined in this project as they were used to derive Eco-SGVs for trace elements, and they may be used as criteria to ensure environmental protection (e.g. cleanfill criteria). Understanding the variability in background concentrations of trace elements is critical to determining whether measured concentrations in different locations may be causing environmental harm. Information on background concentrations is intended to provide an initial assessment of background soil concentrations at relevant locations. Sampling at a location may be required to verify background concentration, particularly if it is to be used to ensure that discharge to land does not elevate substances above background concentrations.

The 'added-risk' approach has been used to derive Eco-SGVs for trace elements. In this approach, the acceptable contaminant limit is added to the background concentration of the site under assessment to derive the relevant Eco-SGVs. Eco-SGVs were developed for eleven contaminants (arsenic, boron, cadmium, chromium, copper, fluorine, lead, zinc, DDT, TPH and PAHs). Eco-SGVs are intended to inform remediation, where remediation is already occurring; to trigger further investigation in the event of significant exceedance (>2 times the relevant Eco-SGV over 25 m^2); and to identify contaminated land where environmental risk is being considered. In relation to protecting soil quality, the Eco-SGVs are intended to inform consent limits for discharge to land, as well as providing benchmarks for soil quality monitoring (e.g. State of the Environment monitoring).

Overall, this project has provided guidelines to assist in protecting the environment from soil contamination, which is a top priority for the Regional Waste and Contaminated Land Forum (RWCLF; refer Document #1779443 *Research priorities: Regional Waste and Contaminated Land Forum,* October 2010, held by the Waikato Regional Council). This work also assists in determining the extent of soil contamination and options for managing it, which is identified as a critical issue for both the Land Monitoring Forum (LMF) and the Land Management Group (LMG; refer *Alignment of Land Special Interest Groups and the National Land Resource Centre Priorities*, Weeks & Collins 2013). Finally, this work provides a nationally consistent method for determining soil contaminant levels and numbers, which is identified as 'high priority' in the Ministry for the Environment's 2007 Discussion Paper *Working towards a comprehensive policy framework for managing contaminated land in New Zealand*, which also recognises the absence of guidance for assessing the ecological impact of contaminants in soil.

Abbreviations/Glossary

ACL	added contaminant limit
AF	assessment factor
BC	background concentrations
BM	biomagnification
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
Eco-SGV	ecological soil guideline value
ECx	effect concentration – concentration at which x% effect has been observed
LOEC	lowest observed effect concentration toxicity endpoint
LRIS	Land Resource Information Systems – an online repository of information on environment and land resources of New Zealand (https://lris.scinfo.org.nz/)
NOEC	no observed effect concentration toxicity endpoint
PAH	Polycyclic aromatic hydrocarbons
PNEC	predicted no effect concentration – contaminant concentration below which no effects on ecological receptors are expected to be observed.
SINDI	online soil quality indicators database available at https://sindi.landcareresearch.co.nz/
SSD	Species sensitivity distribution – generated by fitting a statistical distribution function to the proportion of species affected by increasing contaminant concentrations
TPH	Total petroleum hydrocarbons

1 Introduction

Soil guideline values developed to protect terrestrial biota (soil microbes, invertebrates, plants, wildlife and livestock) (Eco-SGVs) provide a useful means to readily assess potential environmental impact. Some soil guideline values already exist in New Zealand, for example within the Timber Treatment Guidelines (MfE 2011a) or Biosolids Guidelines (NZWWA 2003), but these are for a limited number of contaminants and are based on inconsistent methodologies. The absence of national Eco-SGVs has resulted in inconsistency and a lack of clarity around protection of ecological receptors in soil, and a lack of focus on ensuring this protection in territorial and regional/unitary council functions.

To address these gaps, the Envirolink tools project 'Background concentrations and soil guideline values for the protection of ecological receptors' (Eco-SGV tools project) commenced in July 2014 with the objectives to

- develop nationally agreed methodologies for determining background soil concentrations of naturally occurring elements, and ecological soil guideline values (Eco-SGVs) for the protection of soil biota, such as soil microbes, plants and soil invertebrates
- use existing data to determine background concentrations and Eco-SGVs for multiple land-use scenarios
- develop clear guidance to follow in applying Eco-SGVs for different purposes to ensure they are applied correctly
- identify requirements for a database that enables ongoing input of trace element concentrations and links to existing soil quality databases (e.g. SINDI https://sindi.landcareresearch.co.nz/).

In essence, this project aims to develop Eco-SGVs for the most commonly encountered contaminants, and establish agreed methods for derivation such that values can subsequently be developed for other contaminants of concern as needed. Determination of background soil concentrations are included within this project as methodologies for deriving Eco-SGVs may include their use, or they may be used as criteria to ensuring environmental protection (e.g. cleanfill criteria).

This report provides guidance on the proposed application of background concentrations and Eco-SGVs, and includes consideration of the next steps required to enable uptake and use of this work. This document is the primary document that should be used in the application of Eco-SVGs and background concentrations. A further report (Cavanagh & Munir (2016) provides the detailed technical background to the development of Eco-SGVs, and an overview of the intended application. A final report provides the detailed technical background to the development of background concentrations for a suite of trace elements and organic contaminants, and database requirements (Cavanagh et al 2016). Information of background soil concentrations from specific locations is also available at LRIS (https://lris.scinfo.org.nz/).

1.1 Update 2019

In 2019, this User Guide and associated technical (Cavanagh and Munir 2016) were updated following review (Kim 2018) and the release of international guidance (OECD 2017) and tools to assist in the development of threshold values for soil (Oorts 2018). Briefly, these updates included revision of the EcoSGVs for copper, zinc and arsenic, and expression of boron EcoSGVs as hot-water soluble boron concentrations. Some changes in the text to improve clarity in some areas or around intended application including:

- explicitly stating that the fluorine EcoSGVs were not sufficiently robust for use
- that the EcoSGVs providing for additional protection against accumulation in the food chain are preferred for use for Cd and Pb (for residential and commercial landuse).
- that EcoSGVs do not take precedence over other criteria (e.g. soil contaminant standards for the protection of human health), and it is likely most appropriate that the lowest of the applicable values determines the ultimate action required at any site.

Full details are available in Cavanagh 2019.

2 Background

2.1 The problem

The absence of national Eco-SGVs has resulted in inconsistency and a lack of clarity around protection of ecological receptors in soil, and a lack of focus on ensuring this protection in territorial and regional/unitary council functions.

Specifically, under the Resource Management Act (Section 30), regional councils and unitary authorities have responsibilities to safeguard the life-supporting capacity of soil and ecosystems, and ensure any adverse effects on the environment are avoided or mitigated and do so by managing soil quality and land. This includes regulating the discharge of contaminants and managing contaminated land. A fundamental aspect of ensuring regional councils are able to fulfil these responsibilities is to have a clear understanding of the potential effect of hazardous substances on terrestrial biota. Similarly, under Section 31, territorial authorities have responsibilities that include the control of any actual or potential effects of the use, development, or protection of land, including contaminated land, essentially ensuring that land is ‘fit for purpose’. Clarity is required around the extent to which regional councils, territorial authorities and central government consider that these obligations are being effectively met in relation to the terrestrial environment to define the scale of the problem.

However, the lack of an effective tool for terrestrial ecological risk assessment is considered to have resulted in patchy and inconsistent approaches to environmental protection currently. As a result, developing national guidelines to protect the environment is a top priority for the Regional Waste and Contaminated Land Forum (RWCLF, refer Document #1779443 *Research priorities: Regional Waste and Contaminated*

Land Forum October 2010 held by the Waikato Regional Council). Furthermore, determining the extent of soil contamination and how to manage it are identified as a critical issue for both the Land Monitoring Forum (LMF) and the Land Management Group (LMG; refer *Alignment of Land Special Interest Groups and the National Land Resource Centre Priorities*, Weeks & Collins 2013). Finally, development of nationally consistent methods for determining soil contaminant levels and numbers is identified as 'high priority' in the Ministry for the Environment's 2007 Discussion Paper *Working towards a comprehensive policy framework for managing contaminated land in New Zealand*. That document formally recognises the absence of guidance for addressing ecological impacts of contaminants in soil.

2.2 Who is involved

Decision-making at a number of levels is required for the implementation and use of the background soil concentrations and Eco-SGVs developed in this project:

- Central Government (Ministry for the Environment, Ministry for Primary Industries) – establishing policy for the management of contaminated land and soil quality, including environmental reporting
- Regional councils
- policy and planning staff – establishing policy and planning rules to manage contaminated land, discharge to land (including stormwater and wastes) and providing protection for soil quality
- contaminated land and soil quality staff – providing advice for policy and planning rule development, and consenting for different activities involving discharge to land or off-site discharge
- consent and compliance staff – consenting different activities involving discharge to land or off-site discharge
- Territorial authorities – Environmental Health officers managing contaminated land.

The extent to which different decision-makers have been engaged throughout this project is discussed in the next section.

2.3 The Process

An advisory group comprised of representatives from the Regional Waste and Contaminated Land Forum, Land Monitoring Forum, Land Managers Group, the Ministry for the Environment and the Ministry for Primary Industries has overseen the project. The advisory group confirmed the range of receptors to be considered in the development of Eco-SGVs (Figure 1), and the contaminants for which Eco-SGVs were derived (Table 1). Contaminants selected have different physico-chemical properties and thus behave differently in the environment. Thus, contaminants selected included the most common contaminants as well as contaminants for which toxicity to livestock (fluoride) or bioaccumulation in wildlife (DDT) need also to be considered.

Table 1 Priority contaminants for the development of Eco-SGVs

Inorganic contaminants	Organic compounds
Arsenic (As)	Dichlorodiphenyltrichloroethane (DDT)
Boron (B)	Total petroleum hydrocarbon (TPH)
Copper (Cu)	Polycyclic aromatic hydrocarbons (PAH)
Cadmium (Cd)	
Chromium (Cr)	
Fluoride (F)	
Lead (Pb)	
Zinc (Zn)	

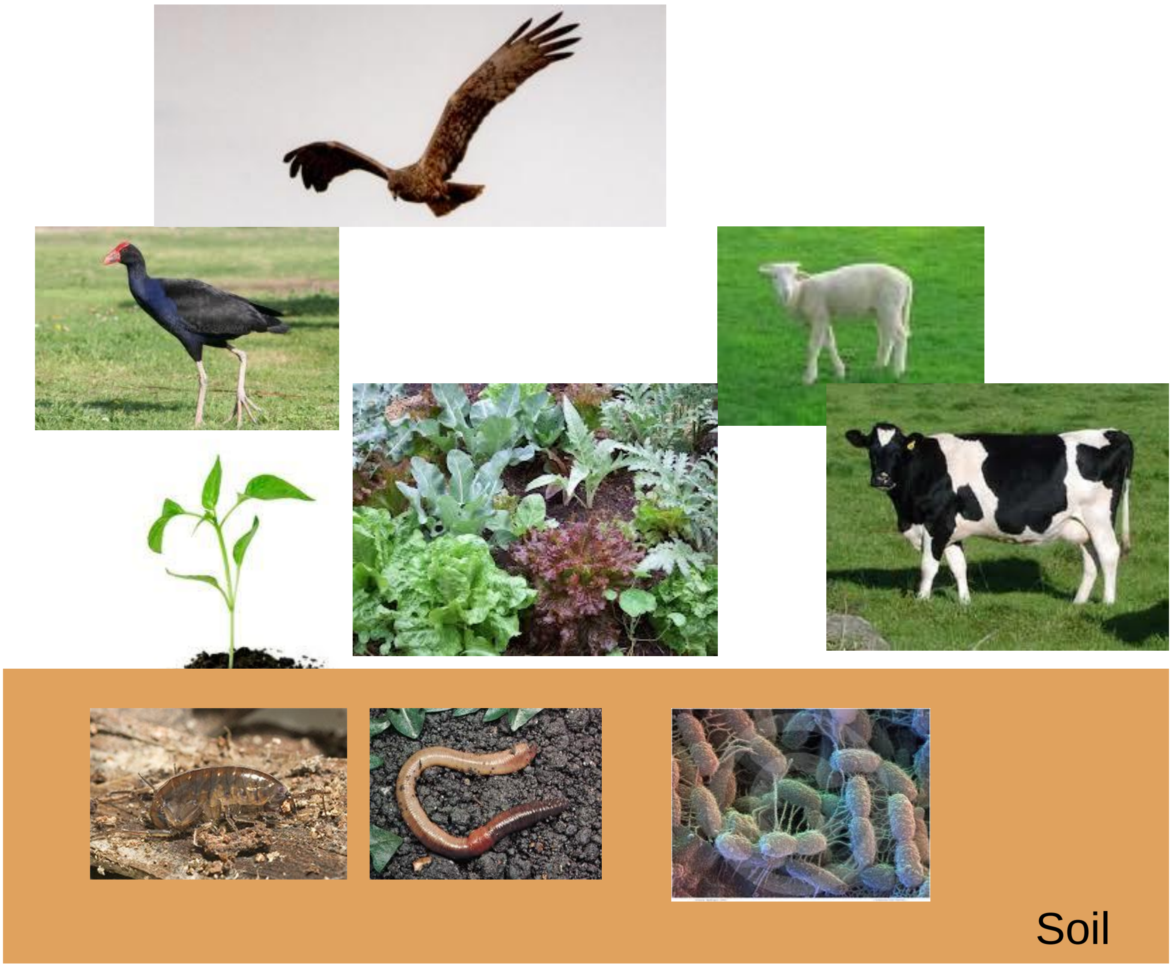

Figure 1 Receptors to be considered in the development of ecological soil guideline values.

Actual values for Eco-SGVs are determined by decisions can be made about the toxicological data used and the level of protection afforded by the Eco-SGVs. 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 were held to provide input to the development of the methodology. These workshops were held with

- regional councils (contaminated land, soil quality and policy, March 2015)
- organic waste sector (March 2015)
- contaminated land practitioners (April 2015).

Prior to the workshops, a discussion document was circulated. This report provided the details of the proposed approach and developed a range of Eco-SGVs for copper and zinc to illustrate how decisions on the toxicological data and level of protection afforded affected the actual value.

To obtain further insight into implementation of the Eco-SGVs, presentations were also made to regional council Policy Managers Special Interest Group (SIG), Compliance & Enforcement SIG and the Consent Managers SIG. Presentations have also been given to the Australasian Land and Groundwater Association (Auckland July 2015, Christchurch November 2015), the WasteMINZ conference (October 2015) and the Fertiliser & Lime Research Centre (FLRC) Workshop to enable stakeholder feedback. Finally, presentations have been given at a scientific conference (Society of Environmental Toxicology and Chemistry, August 2015) to provide technical peer review of the proposed approach. Regular updates have also been provided to the Cadmium Management Group, comprised of representatives of central and local government and agricultural industry sector groups who are overseeing the national management of soil cadmium. Nonetheless, it is recognised that further steps are required to enable implementation of this work, and these are outlined in section 6.

2.4 Related projects

There are two related projects that have been undertaken ('Land disposal guidelines') or are nearing completion ('Beneficial use of organic waste') for which the determination of background soil concentrations and development of Eco-SGVs have relevance. As consistency in updated soil limits and Eco-SGVs is required to avoid confusion among regulators and industry, it is intended that this Envirolink Tools project complements rather than conflicts with this other work. Specifically, it is anticipated that the *application* of waste criteria/soil limits is specified within the particular guidelines, but that the *methodology* or information (e.g. background soil concentrations) developed in this project is used to inform the criteria or limit-setting where these relate to background soil concentrations or protection of ecological receptors.

A key difference between developing Eco-SGVs and developing criteria for cleanfills, managed fills, application of biosolids to land, etc. is that for the latter all potential impacts – i.e. to human health, leaching to groundwater, protection of soil biota – should be considered. For some contaminants, human health impacts or leaching to groundwater may pose a greater potential risk than the impact on ecological receptors, and be the defining point for setting relevant criteria.

This section provides a brief overview of the current status of the two projects, and identifies the relationship between the information generated in the Envirolink Tools Project and waste acceptance criteria/soil limits used by these related projects.

2.4.1 Land disposal guidelines

Technical Guidelines for Disposal to Land have been completed and are available on the WasteMINZ website (http://www.wasteminz.org.nz/pubs/technical-guidelines-for-disposal-to-land-april-2016/). The document provides technical guidance on siting, design, construction, operation, and monitoring for disposal to land, and classifies landfills into four types:

- Class 4 Landfill – Cleanfill
- Class 3 Landfill – Managed/Controlled Fill
- Class 2 Landfill – C&D Landfill or Industrial Waste Landfill
- Class 1 Landfill – Municipal Solid Waste Landfill or Industrial Waste Landfill.

Of most relevance to the Envirolink Tools Project are Classes 3 and 4, as no liners are required for these landfills, enabling direct contact of the surrounding soil with the landfilled materials. Class 4 landfills accept materials such as virgin excavated natural materials (VENM), which include soils, clays, gravels and rocks, and limited amounts of inert manufactured materials (e.g. concrete, brick, tiles) and incidental or attached biodegradable materials (e.g. vegetation). The definition of cleanfill states that 'when discharged to the environment clean fill material will not have a detectable effect relative to the background', and regional background concentrations are the specified waste acceptance limits to be used for trace elements (Appendix C in WasteMINZ 2016). Appendix C provides an overview of the development of waste acceptance criteria, which includes consideration of leaching potential, human health exposure, and exposure of ecological receptors, and Appendix G (in WasteMINZ 2016) provides Class 4 waste acceptance criteria, using regional background concentrations for key inorganic elements in Auckland and Wellington as examples, and specified criteria for selected organic contaminants. Background soil concentrations developed in the current study will assist in providing background soil concentrations for specific locations and other regions.

It should also be noted that approaches used by regional councils to date for cleanfill criteria have been variable (e.g. either based on background concentrations alone or a combination of background concentrations and Eco-SGVs).

A Class 3 landfill accepts managed/controlled fill materials, which are considered to be predominantly cleanfill materials but also other inert materials and soils with chemical contaminants in excess of local background concentrations, but with specified maximum total concentrations. Appendix C (in WasteMINZ 2016) identifies the exposure pathways, relevant criteria for each pathway (value and source), and the limiting exposure pathway. The final criteria are provided in Appendix F (in WasteMINZ 2016) and are a mix of criteria for the protection of human health, ecological receptors, and aquatic receptors.

2.4.2 Guideline on the beneficial use of organic waste

A guideline to facilitate the beneficial use of organic waste – which includes updating of the soil limits to protect human health and the environment in the Biosolids Guidelines (NZWWA 2003) – is currently being developed through industry and research groups (WaterNZ, WasteMINZ, Centre for Integrated Biowaste Research (CIBR), and the Land

Treatment Collective (LTC)) together with representation from the Ministry for the Environment, Ministry for Primary Industries, Ministry of Health, and an environmental NGO. This project is currently in progress and review of contaminants of concern (metals, pathogens and organic contaminants) for the application of organic wastes to land has been undertaken to identify the specific contaminants of concern, and relevant existing national and international soil guideline values. A draft guideline has been developed for the project's steering group, and a second draft is currently being prepared based on feedback from that group. (N Walmsley, WaterNZ, pers. comm.). Consultation on the draft is expected during the 3rd quarter of 2016.

3 Background soil concentrations

Information on background concentrations produced in this report is intended to provide an initial assessment of background soil concentrations at relevant locations, as well as being used in the development of Eco-SGVs. A separate report details the determination of background soil concentrations across New Zealand (Cavanagh et al. 2015). Existing data, primarily sourced from regional councils, was used to examine the relationship of trace element concentration (As, Cd, Cr, Cu, Pb, Ni, Zn) with a geological unit classification, Chemical4, originating from GNS Science's QMAP 1:250 000 Geological Map of New Zealand GIS dataset (Heron 2014). Chemical4 is based on the QMAP ROCK_GROUP classification but further subdivides some on an age basis (i.e. older sedimentary rocks from their Miocene and younger rock and sediment equivalents, Maui and Pakihi supergroups) (Mortimer et al. 2014). Chemical4 provided the best fit for the combined data and was used to generate predicted background concentration distribution (described by the effective median, 5^{th} and 95^{th} percentile estimates) for the individual trace elements for the individual Chemical4 subgroups. Predictions for Chemical4 subgroups with few underlying samples ($n < 30$) are considered less reliable and for $n < 10$, unreliable. In addition, areas that may have naturally occurring high concentrations of trace elements were identified through data retrieved from the New Zealand Petroleum & Minerals (NZP&M) Open File Metallic Minerals Geochemical Database (Crown Minerals 2009) and the Petlab Geoanalytical Database hosted by GNS Science (http://pet.gns.cri.nz). These data are presented as maps to illustrate currently identified areas of elevated concentrations in relation to the spatial distribution of soil samples in Cavanagh et al. (2016).

The areas for which background concentration data are typically available are shown in Figure 2, with a summary of the range in concentrations for different trace elements in Table 2 and more details in Appendix A. Specific information for a given location can be obtained from LRIS (https://lris.scinfo.org.nz/).

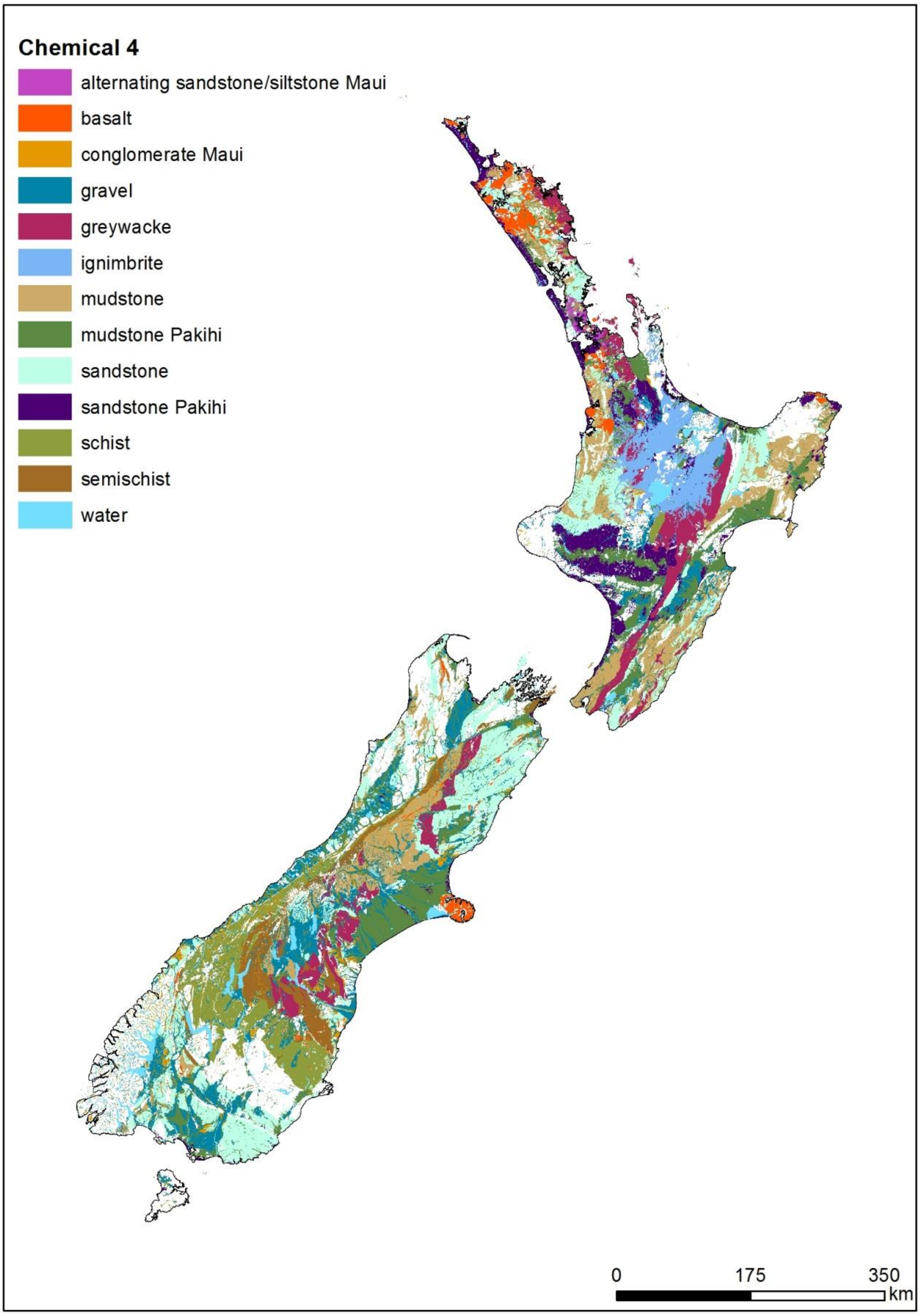

Figure 2 Areas for which predicted concentration ranges are typically available for Chemical4 subgroups (with n >30) from the QMAP geological map GIS dataset. Areas for which no data is available are shown in white.

Table 2 Summary of the range in median and 95th percentile background concentrations for geological groupings with n > 30 (see also Appendix A)

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

Most organic contaminants of interest for the management of contaminated land are xenobiotics, hence they have no natural background concentration. An exception is the polycyclic aromatic hydrocarbons (PAHs), which may naturally occur through bushfires as well as occurring naturally in coal, crude oil and fuel. Cavanagh et al. (2016) collated existing data on PAHs and DDTs and provide preliminary estimates of ambient PAH concentrations in urban areas. While the widespread historical usage of DDT on pastoral land can be said to have given rise to an ambient concentration of DDT and its metabolites, the concentration at a given location is inherently dependent on historical usage at that location and so is too variable to be able to provide an estimate of ambient concentrations. Eco-SGVs for DDT are anticipated to provide a more useful point of comparison to determine whether any action should be undertaken.

Further sampling and analysis is required to refine the predicted background concentrations, including:

- further analysis of the sedimentary subgroups (e.g. gravel, sand, mud) to determine the extent to which erosion of mineralised rocks is contributing to elevated concentrations in soils within those sedimentary subgroups
- further sampling and analysis of soils within sub-groups for which no data (in particular areas underlain by granite and diorite as these groups comprise the largest area for which no data is available) or limited data (n < 30) to determine background concentrations or to refine predicted concentrations
- additional sampling and analysis in locations that fall within the mineralised zones to more adequately confirm the likely background concentrations in these areas
- additional systematic sampling and analysis to more robustly determine ambient concentrations of PAHs in urban areas.

3.1 Application of background concentrations

Understanding the variability in background concentrations of trace elements is critical to determining whether measured concentrations in different locations may be causing environmental harm. Typically, an upper concentration limit is defined that includes a high proportion of the data and is likely to exclude the very high results that would be associated with point source contamination. The upper confidence limit (UCL) for the 95th percentile is probably the most widely used threshold for determining upper limits for background concentrations (e.g. NREPC 2004; Cave et al. 2012), although the 99th percentile is also used if the dataset is sufficiently large (Diamond et al. 2009), and there is little difference between the UCLs of the 95th and 99th percentiles (Diamond et al. 2009). There are some statistical tools available to calculate the UCL of the 95th percentile, such as ProUCL developed by US Environment Protection Agency (US EPA 2013). Cave et al. (2012) also provide the code used for the statistical package R to determine the UCL of 95th percentiles. The current work (Cavanagh et al. 2016) has generated the 95th percentile concentrations as the upper limit of concentrations, recognising that further testing is required to validate predictions.

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

3.1.1 Cleanfills

The *Technical Guidelines for Disposal to Land* (WasteMINZ 2016) definition of cleanfills states that 'when discharged to the environment clean fill material will not have a detectable effect relative to the background'. Regional and regional background concentrations are the specified waste acceptance limits to be used for trace elements (Appendix C) with Appendix G providing regional background concentrations for Auckland and Wellington. These values are the maximum concentrations from the dataset provided in ARC (2001) and URS (2003), respectively. These data form part of the dataset used to generate predicted background concentrations in Cavanagh et al. (2016). Specified criteria for selected organic contaminants are also provided in WasteMINZ (2016).

It is recommended that the 95th percentile concentrations are used as the point of comparison with site data for the initial assessment of sites being considered as locations for cleanfills. Additional sampling should be undertaken to verify background concentrations at the site. These concentrations in turn should be used to establish cleanfill acceptance criteria as outlined in WasteMINZ (2016).

3.1.2 Contaminated land assessment

For contaminated land investigations, the upper 95th confidence limit of the arithmetic mean and an upper limit of background concentration may be used. If sufficient samples are available ($n > 10$) the upper 95th confidence limit of the arithmetic mean is used as the point for comparison of concentrations for a site under investigation with background concentrations (US EPA 2013). In this case, the upper 95th confidence limit of the mean of the background concentrations is the point of comparison. These values have not been determined in this study. An individual sample may also be compared to an upper value of the background concentration to determine whether it is likely to be contaminated (i.e. is above this upper limit, even if the site average is the same as the background concentration). It is recommended that the 95th percentile background concentrations are used as the point of comparison for the upper limit of background concentrations in the initial assessment.

It is also noted that section 5(9) of the *National Environmental Standard for assessing and managing contaminants in soil* (NES) states that the '…regulations do not apply to a piece of land …. about which a detailed site investigation exists that demonstrates that any contaminants in or on the piece of land are at, or below, background concentrations'. The converse of this is that if a detailed site investigation exists that demonstrates that contaminants in or on the piece of land are above background concentrations, the regulations could apply, as the land may have been subject to intentional or accidental release of a hazardous substance (HAIL category I) if no other HAIL activities are obvious. In this case, the 95th percentile concentrations may be used as the point of comparison for the upper limit of background concentration. For the NES to continue to be applicable it then needs to be determined whether the hazardous substance could be a risk to human health or the environment. For the former, the NES soil contaminant standards for the protection of human heath (SCS_{health}) are applicable while for the latter, the Eco-SGVs are applicable (see also section 4.2.1).

3.1.3 Discharge to land

With any discharge to land, where it is desired that the discharges does not result in concentrations of substance above the background concentration, it is important to understand the variability in background concentrations to enable relevant consent conditions to be set. Once again the 95th percentile is recommended as the upper limit of background concentrations for the initial assessment.

4 Ecological soil guideline values (Eco-SGVs)

4.1 Derivation of Eco-SGVs

The approach for deriving Eco-SGVs builds on earlier recommendations for a proposed approach for cadmium (MPI 2012) that are developed further in Cavanagh (2014). The rationale for this was that it would ensure consistency between Australian and New Zealand approaches for deriving soil guideline values for the protection of terrestrial ecological receptors, and also with the Australian and New Zealand Water Quality guidelines (ANZECC/ARMCANZ 2000) (MPI 2012).

As noted earlier, actual values of Eco-SGVs are ultimately determined by decisions made about the toxicological data used and the level of protection afforded (Figure 3). As 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 were held to provide input to the development of the methodology. The outcomes of these workshops are outlined below.

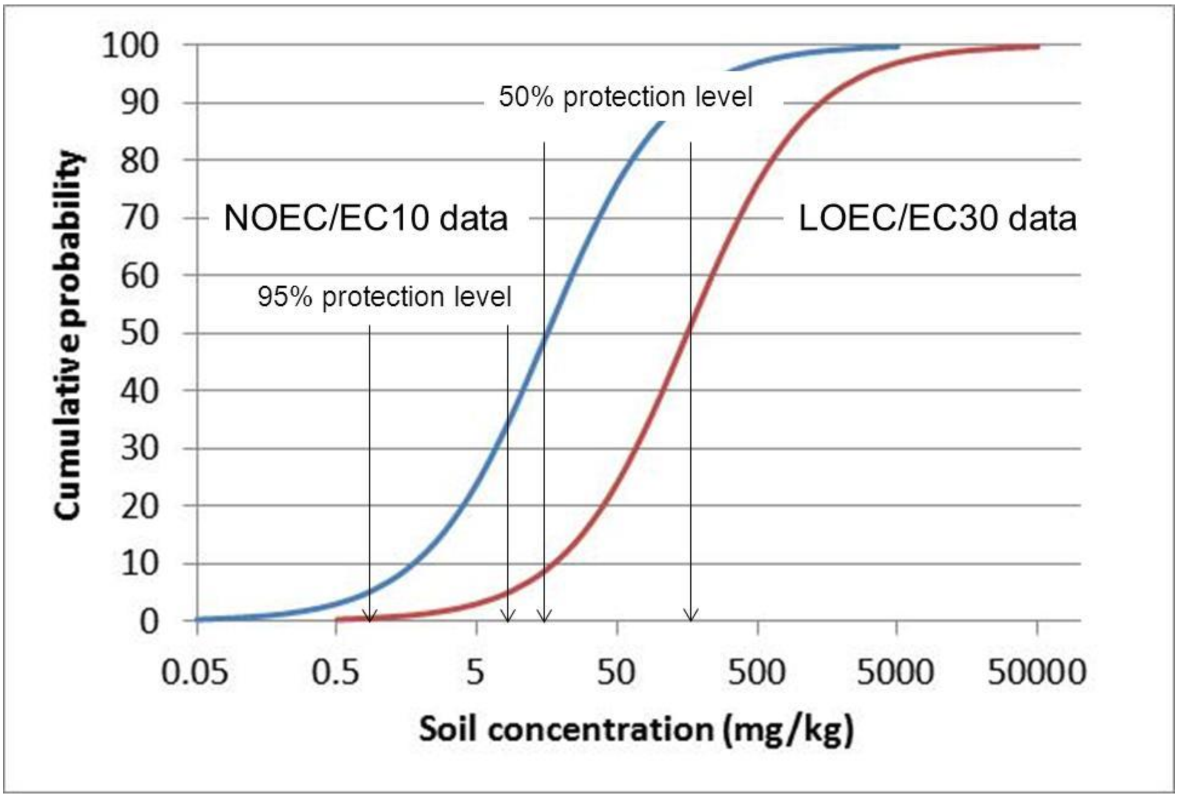

Figure 3. Hypothetical species-sensitivity distribution, illustrating the potential influence of the selection of different toxicity endpoints and protection levels on derived Eco-SGVs, ranging from c. 0.6 to c. 350 mg/kg in this example.

Choice of toxicological endpoint: Eco-SGVs may be derived using different toxicological endpoints. Most often the NOEC (no-observed effect concentration) or EC10 (effective concentration at which effects are observed in 10% of the test population) is used. Other endpoints may be used such as the LOEC (lowest observed effect concentration), EC30 (effective concentration at which effects are observed in 30% of the test population), EC50 (effective concentration at which effects are observed in the 50% of the population) or LC50 (the concentration at which mortality is observed in 50% of the population). For the current work, Eco-SGVs were agreed to be derived on the basis of EC30 values, taking account of ageing and leaching effects. An exception to this is that Eco-SGVs should also be derived for fresh contamination for copper and zinc, which are key contaminants in stormwater discharge that may be applied to land.

Level of protection: Different land uses have specific functions and species that should be protected in order to ensure the land can continue to be used for that purpose. Providing different levels of protection based on different land uses provides a cost-effective and pragmatic approach to contaminant management. The functions and species for protection include plants, soil microbial processes, soil and terrestrial invertebrates, and vertebrates. Further, there are multiple potential exposure pathways for terrestrial ecosystems, although not all exposure pathways will be relevant for all land uses. For example, exposure pathways that involve biomagnification are unlikely to be relevant to small industrial sites, as their surface area is limited. The extent to which the species and ecological functions will be protected can be expressed as a hypothetical percentage of species/ecological functions (e.g. 99% or 95%) using species sensitivity distribution (SSD) statistical methods. Land use categories for which Eco-SGVs were developed arose out of workshop discussions with regional councils and stakeholders. A summary of the land use categories and level of protection is shown in Table 3 and described more below. The land use categories used in the NES are also shown to facilitate relevance for contaminated land assessments.

Commercial and industrial land

Commercial and industrial land includes high-density residential land. Ecosystems in commercial/industrial lands can be highly artificial. However, soils should still support the basic soil processes and should be able to recover if land use changes. Therefore, 60% of species will be protected for non-biomagnifying contaminants present in commercial/industrial land and 65% for contaminants that show biomagnification potential, following the National Environmental Protection Council schedule (NEPC 2013).

Residential and recreational areas

Residential lands and recreational areas (e.g. sports field, parks) are modified ecosystems but ones which still retain many important functions and species that stakeholders would expect to be maintained. For example, it would be reasonable to expect that such land uses should sustain plant growth of both introduced (ornamental, vegetables) and native species. To ensure viable growth of plant species, not only should plant toxicity data be considered but also soil health (e.g. nutrient cycling and microbial functions). Nutrient cycling in soil ecosystems is essential for plant growth and therefore both micro-organisms and soil invertebrates should be protected. Micro-organisms are responsible for many processes regarding nutrient cycling, such as decomposition of organic matter, and N and P cycling processes. Soil invertebrates have a number of important functions including interacting with micro-organisms involved in nutrient cycling and modifying soil structure. In addition, many birds and small terrestrial animals feed on plants and soil invertebrates in urban areas. Therefore, secondary poisoning for some contaminants should be assessed to ensure adequate protection is provided to organisms high in urban food chains.

As urban residential lands are modified ecosystems, it would not be warranted or realistic to protect 95% of species and functions. Yet a reasonably high degree of protection is required to maintain the desired receptors and ecological functions. Following NEPC (2013), protection of 80% of species and soil microbial processes was considered appropriate for this land use. For contaminants with a potential for biomagnification, the percentage of species protected should be raised by 5% to 85%.

Agricultural land

The protection of crop species is vital to maintaining the sustainability of agricultural land and therefore 95% of the crop and grass species will be protected for this land use. Other plant species were not used in the derivation of agricultural soil quality guidelines. Soil processes and soil invertebrates are highly important to ensure nutrient cycling to sustain crop species. However, tillage and the use of pesticides/herbicides make it unrealistic to protect 95% of soil processes and soil invertebrates and therefore only 80% of these should be protected (Heemsbergen et al. 2009). The lower of these two values is selected as the final Eco-SGV. If a contaminant shows biomagnification potential, the percentage of species protected should be raised to 98% for crop species and 85% for soil processes and soil invertebrates.

Non-food production land

This category captures land to which waste could be applied, but which doesn't fall into other categories. Forestry is a specific example of land use in this category. To ensure sustainability of this land use, 95% soil processes and soil invertebrates as well as plants are protected for this land use. In contrast to agriculture, land management practices are not expected to significantly impact on soil processes and soil invertebrates. For contaminants with a potential for biomagnification, the percentage of species protected should be raised to 98%.

Ecologically sensitive areas

Ecologically sensitive areas may include national parks or other areas designated by councils. These areas have near pristine ecosystems and should remain in that condition. As far as possible, it should be ensured that these ecosystems are not affected by soil contamination. Therefore the highest level of protection, 99% of species, is assigned to these areas.

Table 3. Summary of land use categories, land use covered under the National Environmental Standard for Assessing and Managing Contaminants in Soil (NES), receptors covered and level of protection of plants, soil processes and invertebrates for Eco-SGVs

Land use	NES land use	Additional land uses covered/Description	Receptors covered	Level of protection (%)[1]	
				Plants	Soil processes/ invertebrates
Commercial /Industrial	High density residential, Commercial / industrial outdoor worker	Road reserves. All commercial/industrial and high-density residential land use, including under paved areas. Highly artificial ecosystems but soils should still support the basic soil processes and be able to recover if land use changes.	Soil microbes, plants, invertebrates Soil and food ingestion, Trigger for off-site impacts	60 (65)	60 (65)
Residential and recreational areas	Rural residential/lifestyle block (25% produce consumption) Residential (10% produce consumption) Recreational areas	Modified ecosystems but for which there is still an expectation that important species and functions can be maintained.	Soil microbes, plants, invertebrates, wildlife	80 (85)	80 (85)
Agriculture, including pasture, horticulture and cropping	Production land[2]	All food production land. The protection of crop species is required to maintain the sustainability of agricultural land. Soil processes and soil invertebrates are highly important to ensure nutrient cycling to sustain crop species but tillage and use of pesticides mean it is not realistic to have the same level of protection as for plant species.	Soil microbes, plants, invertebrates, wildlife and livestock	95 (99)	80[3] (85)
Non-food production land	Production land	All non-food production land (e.g. production forestry) to which waste could be applied and which does not fall into other land use categories. Similar to agricultural land, although tillage and pesticide application is not expected to affect soil processes and soil invertebrates, enabling a higher level of protection for these organisms.	Soil microbes, plants, invertebrates, wildlife	95 (99)	95 (99)
Ecologically sensitive areas	NA	National Parks, designated ecologically sensitive areas. Near-pristine ecosystems that should remain in that condition.	Soil microbes, plants, invertebrates, wildlife	99	99

[1] This is based on using EC30/LOEC toxicity data and aged contamination for all applications except discharge of stormwater, for which contamination should be considered fresh (due to the high organic load in organic wastes such as chicken manure, it is considered that aged contamination is appropriate). The value in brackets is the level of protection that should be provided for biomagnifying contaminants. Due to mathematical constraints, if the level of protection is 95%, the increased level of protection is 99%.
[2] NES regulations state: If the land that is potentially or actually affected by contaminants is production land, the regulations **do not apply** to:
a. soil sampling or soil disturbance (except on parts of production land used for residential purposes)
b. subdivision or change of use (except where that would result in production land being used for a different purpose, eg, for residential land use).
[3]lower protection level in recognition of intentional pesticide application, and cultivation effects; NA –Not applicable.

4.1.1 Background concentrations and Eco-SGVs

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

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

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

4.1.2 Methodology Overview

Eco-SGVs were developed using the following methodology:

1 Collation and screening of the data

Data collated and evaluated for development of the Australian Ecological Investigation Levels (NEPC 2013) as well as under the REACH programme (EC 2007, 2008; ECI 2008; LDAI 2008) was compiled as a first step. Additional data was provided by Cavanagh and O'Halloran (2006), Cavanagh (2006) and by literature review to identify any more recent studies (in particular from 2009 onwards).

2 Standardisation of the toxicity data

The LOEC/EC EC30[1] is the preferred toxicological endpoint for deriving Eco-SGVs in New Zealand, and is consistent with the approach used to derive Ecological investigation levels in Australia (NEPC 2013). To maximise the data available to

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

derive Eco-SGVs, toxicity data were converted to LOEC/EC30 using conversion factors where required.

3 Incorporation of an ageing/leaching factor for aged contaminants

Ageing and leaching processes tend to decrease the toxicity of contaminants added to soil. To more adequately reflect field effects, Eco-SGVs for most contaminants are developed for aged/leached contamination only. Copper and zinc are the exceptions as these contaminants may be present in wastes such as stormwater discharged to land, and in a form that is similar to freshly spiked soils used for toxicity testing.

4 Normalisation of the toxicity data to New Zealand reference soils

Normalisation relationships attempt to minimise the effect of soil characteristics on the toxicity data so the resulting toxicity data will more closely reflect the inherent sensitivity of the test species to the contaminant. Normalisation should only be undertaken where there are sufficient data to use the SSD method (this was the case only for copper and zinc). Three reference soils were defined for New Zealand – typical soil, sensitive soil and tolerant soil – with the general soil properties provided in Table 4. Many normalisation relationships use pH determined in $CaCl_2$, and effective cation-exchange capacity (eCEC, which is CEC at the pH of the soil), so the soil properties were adjusted to these values (Table 4) using relationships identified from the literature (see Cavanagh & Munir 2016 for details).

Table 4 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
pH ($CaCl_2$)[1]	4.5	4.8	4.9
Clay (%)	17	21	23
CEC (cmol/kg)	13	20	30
eCEC (cmol.kg)[1]	15	19.5	30.1
Org. Carbon (%)	3.1	4.6	9.4

[1]Values typically required for use in toxicity-regressions (normalisation) relationships

5 Calculation of an added contaminant limit (ACL) by either the species sensitivity distribution (SSD) or assessment factor (AF) approach, depending on the toxicity data.

If sufficient data are available, the preferred methodology is the use of a species sensitivity distribution (SSD) as this is a risk-based approach. Where insufficient data are available the assessment factor approach should be used, noting this also has minimum data requirements. There were sufficient data to use the SSD approach for all inorganic contaminants.

If sufficient data are available, the preferred methodology is the use of a species sensitivity distribution (SSD), because this is a risk-based approach. Where insufficient data are available, the assessment factor approach should be used, although this also has minimum data requirements. There were sufficient data to use the SSD approach for all inorganic contaminants.

Where normalised plant and invertebrate toxicity data are used, SSD methods employ a single numerical value (geomean) to describe each species for the most sensitive endpoint, where different endpoints have been used.

Where toxicity data cannot be normalised, all screened data were retained to more adequately represent the variation in toxicity associated with variation in soil properties. Geomeans were not calculated for microbial processes, as different soils effectively represent different microbial communities, which may therefore respond differently.

The BurrliOZ programme[2] was used to derive added contaminant limits (ACLs) in this report. This software preferentially uses the Burr Type III method to determine the SSD and was used to derive the Australian and New Zealand Water Quality Guidelines (WQG) (ANZECC & ARMCANZ 2000, Warne et al 2018).

6 Accounting for secondary poisoning

The approach adopted here to address secondary poisoning and transfer through the food chain is to increase the level of protection (i.e. the percentage of species and/or soil processes to be protected) by 5% (i.e. to 85% from 80%). Due to mathematical constraints, if the level of protection is 95%, the increased level of protection is 99%. This is a pragmatic approach but not necessarily scientifically rigorous, and may result in values that are under- or over-protective. However, this approach recognises the paucity of New Zealand data available fora food-web approach, which is often used internationally. This approach is consistent with that used in NEPC (2013), which in turn is consistent with the approach used in the Australian and New Zealand water quality guidelines (ANZECC & ARMCANZ 2000, Warne et al 2018)

7 Determination of the background concentration (BC) of the contaminant in the soil

Background concentrations were determined in Cavanagh et al. (2015), with information for specific locations available from LRIS (https://lris.scinfo.org.nz/).

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

To facilitate ease of reading and use, the final Eco-SGVs were rounded using the following scheme:

- all values <2 were rounded off to the nearest 0.1
- all values between 2 and 10 were rounded off to the nearest whole number

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

- all values between 10 and 100 were rounded off to the nearest multiple of 5
- all values between 100 and 1000 were rounded off to the nearest multiple of 10

Eco-SGVs were developed for eleven contaminants (arsenic, boron, cadmium, chromium, lead (Table 5), copper, zinc (Table 6), TPH, DDT and PAHs (Table 7). Provisional ACLs were also developed for fluorine, however given the uncertainty of the estimates, they are not recommended for use.

Generic ACLs were developed for As, B, Cr, Cd and Pb (Table 5) and are considered applicable to all soil types for the appropriate land use. As Cd biomagnifies in the food chain, Eco-SGVs are based on a higher protection level compared to non-biomagnifying contaminants. While Pb is not considered to biomagnify per se, there may be potential for secondary poisoning to occur at higher Pb concentrations; thus for the 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 copper and zinc (Table 6). In addition, as Cu and Zn are present in urban stormwater, which may be discharged to land in a form similar to that in freshly spiked soils, Eco-SGVs for fresh and aged contamination were also developed for Cu and Zn.

There were limited toxicity data available for the organic contaminants. Utilisation of older studies (i.e. pre-1970) yielded additional data for DDT, and sufficient to use the SSD approach for deriving ACLs. It is noted that DDE, the main degradation product of DDT, is the main residue typically present in soils as a result of the historical use of DDT. However, a dearth of data on the toxicity of DDE to soil microbes, plants and invertebrates precludes the development of an Eco-SGV for DDE. To address this, and given the observation of marked biomagnification of DDE in a New Zealand food chain, more conservative DDT Eco-SGVs were recommended for use. In this case, the Eco-SGVs were based on the NOEC/EC10 toxicity endpoints, and accounted for biomagnification (i.e. a higher protection level was used to set the Eco-SGV).

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

Table 5 Eco-SGVs (mg/kg) developed for arsenic (As), boron (B), cadmium (Cd), chromium (Cr), and lead (Pb) for the lowest median background concentration. Eco-SGVs should be based on background concentrations relevant to the site under assessment and are considered applicable to all soil types1.

Land use (% protection)	As Eco-SGV[2] $_{(EC30)}$ (mg/kg)	B Eco-SGV $_{(EC30)}$ [3] (mg/kg)	Cd Eco-SGV $_{BM}$ [4] (mg/kg)	Cr Eco-SGV[5] $_{(EC30)}$ (mg/kg)	Pb Eco-SGV[6] $_{(EC30)}$ (mg/kg)
Areas of ecological significance (99%)	6	4	1.5	100	55
Non-food production land (95%)	20	7	1.5	190	280
Agricultural land (95% plants, 80% microbes and invertebrates)	20	6	1.5	300	530
Residential/recreational area (80%)	60	15	12	390	900[7]
Commercial/industrial (60%)	150	15	33	650	2500[7]

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

[2]Median background concentration range: 2.2-4 mg/kg; [3] Hot-water soluble B; background B concentrations are expected to be negligible although low concentrations (1-3 mg/kg) are typical for agricultural soils to which B may have been added for agronomic purposes; [4]Median background concentration range: 0.05-0.1mg/kg, BM – biomagnification; [5]Median background concentration range: 9-27 mg/kg; [6]Background concentration range: 7-15 mg/kg; [7] an extra 5% protection applied to each land use to provide protection against secondary poisoning; na – not available

Table 6 Eco-SGVs (mg/kg) developed for fresh and aged copper (Cu) and zinc (Zn) contamination in the three New Zealand reference soils, using the lowest median background concentration for Cu and Zn[1]. Eco-SGVs should be based on background concentrations relevant to the site under assessment2. Fresh values are applicable where discharge of stormwater or non-organic liquid wastes onto soil is being assessed.

Land use (% protection)	Cu Eco-SGV $_{(EC30)}$ Typical soil		Cu Eco-SGV $_{(EC30)}$ Sensitive soil		Cu Eco-SGV $_{(EC30)}$ Tolerant soil		Zn Eco-SGV $_{(EC30)}$ Typical soil		Zn Eco-SGV $_{(EC30)}$ Sensitive soil		Zn Eco-SGV $_{(EC30)}$ Tolerant soil	
	fresh	aged	fresh	aged	fresh	aged	fresh	aged	fresh	aged	fresh	aged
Areas of ecological significance (99%)	25	45	25	45	25	45	50	120	60	110	70	160
Non-food production land (95%)	55	100	45	85	65	120	800	170	75	150	95	230
Agricultural land (95% plants, 80% microbes and invertebrates)	110	220	80	150	170	340	95	190	75	130	120	265
Residential/recreational area (80%)	120	240	95	180	170	340	130	300	90	260	160	380
Commercial/industrial (60%)	220	420	160	320	320	630	210	480	110	430	250	620

[1]Median background concentration range for Cu: 7 – 25 mg/kg; Median background concentration range for Zn: 24 – 44 mg/kg
[2] This may be the median background concentration for the relevant geological grouping obtained from https://lris.scinfo.org.nz/, or other site-specific information, if available

Table 7 Eco-SGVs (mg/kg) developed for organic contaminants

Land use (% protection)	Total petroleum hydrocarbons (TPH)[1]						DDT	Polycyclic aromatic hydrocarbons (PAH)	
	F1	F2	F3		F4			Fluoranthene	Benzo(a)pyrene
			Fine[2]	Coarse[3]	Fine	Coarse			
Areas of ecological significance (99%)	66	45	-	-	-		1.1	7.6	2.8
Non-food production land (95%)	110	70	1300	300	2500	1700	2.4	27	2.8
Agricultural land (95% plants, 80% microbes and invertebrates)	110	70	1300	300	2500	1700	1.9	27	2.8
Residential/recreational area (80%)	130	110	1300	300	2500	1700	4.8	89	22
Commercial/industrial (60%)	170	140	2500	1700	6600	3300	11	190	47

[1] F1: C7–C9, F2: >C9–C15, F3: >C15–C36 and F4: >C36; see also Cavanagh and Munir (2016), section 4.10.
[2] Fine-grained soils are those which contain greater than 50% by mass of particles less than 75 μm (mean diameter).
[3] Coarse-grained soils are those which contain greater than 50% by mass of particles greater than 75 μm (mean diameter).

4.2 Application of Eco-SGVs

An overview of the intended application of Eco-SGVs is provided in Table 8.

Table 8 Proposed application of Eco-SGVs for each land-use category and purpose

Land-use category	Contaminated land management	Protection of Soil quality
Commercial /Industrial	Inform remediation standards[1] –specifically the quality of any soil imported onto site Trigger further site investigation, including off-site effects, in the event of significant exceedance[2]	na
Residential and recreational areas	As above Identification of contaminated land	Consent limits for application of wastes (e.g. biosolids, cleanfill, managed fill) to land Regional council State of the Environment monitoring
Agriculture	As above[3]	As above
Non-food production land	As above[3]	As above
Ecologically sensitive areas	As above[3]	As above

[1] noting that Eco-SGVs for copper and zinc, in particular, should not automatically be applied as remediation standards – the effect of excavation and disposal of soil should be considered relative to the effect of actively managing the land to reduce concentrations over time.

[2] >2 times the Eco-SGV over an area of 25 m^2

[3] Typically for small areas of contamination such as sheep dips, spray sheds.

na – not applicable

It is not intended that Eco-SGVs override other existing regulatory or management values, such as soil contaminant standards for the protection of human health, and trigger values used in the Tiered Fertiliser Management System for cadmium. It is likely most appropriate that the lowest of the applicable values determines the ultimate action required at any site.

4.2.1 Management of contaminated land

The primary applications of Eco-SGVs for the management of contaminated land are to

> *inform remediation standards* (primarily through setting standards for the quality of any soil imported onto site) where remediation is already occurring. Where remediation is occurring, the Eco-SGVs are to be met for any soil to be imported onto site. Where *in situ* remediation is occurring, Eco-SGVs may be used as default remediation criteria with the exception of copper and zinc. As copper and zinc are also essential elements, consideration should be given to remediation criteria that allow for active management of land to reduce concentrations over time, providing that no off-site effects may occur.

instigate further investigation, including off-site effects, where there is significant exceedance of Eco-SGVs. A significant exceedance is considered to be 2 times the Eco-SGV over an area of 25 m^2 and is based on the criteria for identifying a hotspot (MfE 2011c) for an area over which negative effects might be noticed. The need to determine whether a significant exceedance may be occurring is anticipated to be triggered by the results of an initial site investigation. This site investigation should cover key areas where elevated concentrations may give rise to concern, e.g. vegetable garden on a residential site, an area where offsite movement may contaminate a stream, or an area of contamination adjacent to an ecologically sensitive area. It is not intended that exceedance of an Eco-SGV will drive remediation unless further investigation determines on-site or off-site effects are occurring.

identify contaminated land. As discussed in section 3.1.2, if a site investigation indicates that concentrations of a substance in or on a piece of land are above background concentrations, the NES could apply, as the land may have been subject to intentional or accidental release of a hazardous substance (HAIL category I) if no other HAIL activities are obvious. For the NES to continue to be applicable, it then needs to be determined whether the hazardous substance could be a risk to human health or the environment. For the latter, the Eco-SGVs developed in this study are applicable to determine whether a risk to the environment exists. Based on the *Contaminated land management guidelines No. 2: Hierarchy and application in New Zealand of environmental guideline values*, the Eco-SGVs developed in this project should be selected first as they are New Zealand risk-based values.

4.3 Protection of soil quality

The primary applications of Eco-SGVs for protecting soil quality are to

inform consent limits for discharge to land including the application of wastes (e.g. managed fill, cleanfill, organic wastes, stormwater) to land, and in this respect are 'pollute-up-to' criteria. As such, it may be appropriate to consider a higher level of protection than is used for assessing contaminated land. Cleanfills and managed fills provide a useful means to dispose of uncontaminated or minimally contaminated material, and reduce the amount of material potentially disposed of to landfill. Similarly, the application of biowastes, such as municipal biosolids, to land provides for their beneficial use, as well as reducing the amount of material disposed of to landfill. However, there is a statutory requirement to ensure concentrations of any potential contaminants in the clean/managed fill or biowastes do not result in detrimental effects on soil biota (i.e. to ensure any adverse effects on the environment are avoided or mitigated). Eco-SGVs are only one component for consideration in setting criteria for waste disposal, as protection of human health and groundwater resources should also be considered and the most sensitive receptor protected. Where stormwater or other non-organic liquid wastes are being discharged to land, Eco-SGVs for fresh contamination should be used.

provide a benchmark for assessing soil quality to indicate whether or not measured trace element concentrations may give rise to negative environmental impacts. This is particularly relevant for regional council State of the Environment soil quality monitoring. Ultimately, this benchmarking could be linked to ecosystem services (i.e. exceedance indicates a certain ecosystem service or level of services may be impacted).

5 Database development

In determining background concentrations of trace elements for this project, substantial effort has been placed in collating trace element data from regional councils across New Zealand. Much of this information is collected from sites used for State of the Environment monitoring, for which additional soil quality parameters (pH, mineralisable N, total C, total N, Olsen P, bulk density, macroporosity) are collected, and which informs the soil quality indicators website, SINDI (https://sindi.landcareresearch.co.nz/). Partly to ensure the ongoing utility of such collated material and partly recognising that additional information is available for the sites for which trace element data is available, consideration was given to how trace element data could be captured in a database, and subsequently used. It is also recognised that there are various ongoing conversations about the capture of soils data in databases, including within the *Environmental Monitoring and Reporting* project, as well as in the context of a National Soils database (Landcare Research, National Land Resource Centre). These conversations are 'bigger' than the current project, and the purpose of capturing information within this project is to provide an input to these larger, ongoing conversations. Cavanagh et al. (2015) provide detail on the considerations of what and how trace element (or other contaminant) data should be captured, and highlight that processes for the compilation of trace element data from disparate sources have been developed and have been used to compile current trace elements data from regional council sources. These processes could be extended to other soils data.

There are effectively two data streams that can inform a database that captures data on trace elements (and other contaminants) in soil – soil quality monitoring and contaminated land investigations.

The collation of soil quality monitoring data is comparatively easy, as it typically comes only from regional council soil quality monitoring groups (although it may be undertaken for different purposes, such as State of the Environment Reporting or specific investigations on soil quality), and thus requires only that data be consistently formatted (see below) to enable input into a database.

To systematically capture the data from contaminated land investigations is not an insignificant task as it is typically received in a report format (cf. data tables) from multiple parties (e.g. consultants) by multiple parties (territorial authorities and regional councils). Thus consideration needs to be given to how the data provided in the reports can be readily input to a database or whether additional data (i.e. data tables) are required. Further, systems need to be developed at both territorial authority and regional council level to ensure that the data are being captured in a systematic manner. In the first instance, the capture of the site location, and the fact that an investigation report exists, would be helpful. Additional studies, such as to inform local background concentrations, may also be available. It is anticipated that these will usually be regional council driven, and thus it would be comparatively easy to ensure data consistency and format to facilitate input into a database.

Funding for the construction, data input and ongoing maintenance of a database is a critical consideration for the success of any developed database. Consideration of how data from multiple sources (i.e. different regional councils) is input to a (central) database or is used (no central database) is an ongoing conversation in some of the other related projects. Ongoing data input is particularly important for contaminated land investigations, for which remedial activities may have occurred on a given site, changing the concentrations initially reported.

6 Implementation

To assist in further understanding council needs and drivers for implementation and use of the Eco-SGVs and background concentrations, a short survey was distributed to councils via the Regional Waste and Contaminated Land Forum and Land Monitoring Forums (Appendix B). Three questions were asked to elicit feedback:

- Does the outlined application cover the needs for your council? Please consider the needs for policy, regulation, environmental protection, SOE, remediation functions, etc.
- Given your council's processes for managing contaminated land and soil quality, where and how would you anticipate these guideline values would be used?
- What is needed by your council's policy and planning staff to implement these values?

Responses were received from six councils. It is hoped that this document addresses some of the points raised by the councils, particularly in relation to providing greater guidance around intended use, clarity of where this work sits in relation to other contaminated land management guidelines, and specification of the problem that is intended to be addressed. A consistent comment in the feedback was the need for national endorsement or direction in the approach to enable implementation and consistency in application across region; this point was also made during feedback from presentations given to regional council Policy Managers Special Interest Group (SIG), Compliance & Enforcement SIG and the Consent Managers SIG.

Some aspects raised have not been covered and are beyond this project although they require resolution. For example, how should a site that exceed Eco-SGVs but for which no action is required, be listed on contaminated sites registers? It is recognised that different councils can have different views on the extent to which environmental protection of soil biota and other terrestrial biota is currently taken into account, and whether it is sufficient. A consensus view between councils and central government on this is required to fully ascertain the scale of the problem being addressed by this project. This is also because there is currently no restriction on protection of terrestrial biota being taken into account in the management of contaminated land; for example HAIL category I requires that environmental risk be considered in confirming whether land that has concentrations above background concentration requires management under the NES. Further, the ability to grow plants is arguably a key component of residential land being 'fit for purpose'.

Nonetheless, to date, protection of terrestrial biota is rarely considered in the management of contaminated land. In some cases the environmental risk can be taken to mean the risk to ground or surface water arising from off-site discharge from a contaminated site as opposed to the environmental risk posed to terrestrial biota.

Similarly, in the assessment of soil quality, the biological impact of trace elements and other contaminants is rarely considered. Instead, physico-chemical parameters are largely used, with one measure of microbial activity (mineralisable-N) used to provide a biological measure of soil quality. Thus, there is a gap in the assessment of soil quality as determined by soil biology.

6.1 Next steps

Three key next steps are recommended prior to the use of these background concentrations and Eco-SGVs:

- International peer review of the derivation methodology for the Eco-SGVs, taking into account the intended applications.
- Wider consultation with regional councils, industry groups (e.g. contaminated land practitioners, waste industry, organic waste sector) and other stakeholders on the currently proposed application for background soil concentrations and Eco-SGVs. The latter would ensure complementarity and consistency with other sector developed guidelines, including *Technical Guidelines for Disposal to Land* (WasteMinz 2016), and guidelines for the beneficial use of organic waste (under development).
- Ultimately, the development of national policy for the protection of soil quality and contaminated land management that is inclusive of protection of terrestrial biota to enable effective and consistent uptake and use of the background soil concentrations and Eco-SGVs developed in this work.

7 Summary

This user guide has provided details developed to date on the intended application of soil guideline values developed to protect terrestrial biota (soil microbes, invertebrates, plants, wildlife and livestock) (Eco-SGVs). These values provide a useful means to readily assess potential environmental impact of soil contaminants.

Background soil concentrations were determined in this project as they were used to derive Eco-SGVs for trace elements, and they may be used as criteria in ensuring environmental protection (e.g. cleanfill criteria). Understanding the variability in background concentrations of trace elements is critical to determining whether measured concentrations in different locations may be causing environmental harm. Information on background concentrations is intended to provide an initial assessment of background soil concentrations at relevant locations. Sampling at a location may be required to verify background concentration, particularly if it is to be used to ensure that discharge to land does not elevate substances above background concentrations.

The 'added-risk' approach has been used to derive Eco-SGVs for trace elements. In this case the acceptable contaminant limit is added to the background concentration of the site under assessment to derive the relevant Eco-SGVs. Eco-SGVs were developed for eleven contaminants (arsenic, boron, cadmium, chromium, copper, fluorine, lead, zinc, DDT, TPH and PAHs). Eco-SGVs are intended to inform remediation where remediation is already occurring; to trigger further investigation in the event of significant exceedance (>2.5 times the relevant Eco-SGV over 25 m^2); and can be used to identify contaminated land where environmental risk is being considered. In relation to protecting soil quality, the Eco-SGVs are intended to inform consent limits for discharge to land, as well as providing benchmarks for soil quality monitoring (e.g. State of the Environment monitoring).

Overall, this project has provided guidelines to assist in protecting the environment from soil contamination, which is a top priority for the Regional Waste and Contaminated Land Forum (RWCLF, refer Document #1779443 *Research priorities: Regional Waste and Contaminated Land Forum* October 2010 held by the Waikato Regional Council). This work also assists in determining the extent of soil contamination and options for managing it, which is identified as a critical issue for both the Land Monitoring Forum (LMF) and the Land Management Group (LMG, Refer *Alignment of Land Special Interest Groups and the National Land Resource Centre Priorities*, Weeks & Collins 2013). Finally, this work provides a nationally consistent method for determining soil contaminant levels and numbers, which is identified as 'high priority' in the Ministry for the Environment's 2007 Discussion Paper *Working towards a comprehensive policy framework for managing contaminated land in New Zealand* that also recognises the absence of guidance for assessing the ecological impact of contaminants in soil.

8 References

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Appendix A – Predicted background soil concentrations

Table 9 Predicted background concentrations (median and 95th quantile estimates) for arsenic, cadmium and copper in each of the Chemical4 factor levels. n = number of samples. Estimated concentrations for sub-groups with n <30 are considered less reliable and for n <10, unreliable

Arsenic				Cadmium				Copper			
Chemical4 Factor	**n**	**median**	**95%**	**Chemical4 Factor**	**n**	**median**	**95%**	**Chemical4 Factor**	**n**	**median**	**95%**
gravel	393	2.88	12.06	gravel	101	0.066	0.34	gravel	229	10.00	42.85
SandStnPakihi	137	3.03	12.67	SandStn	43	0.061	0.31	SandStn	131	14.19	60.85
SandStn	131	2.81	11.77	SandStnPakihi	38	0.054	0.28	CongMaui	109	11.05	47.36
CongMaui	109	2.64	11.04	greywacke	36	0.059	0.30	SandStnPakihi	80	9.37	40.17
ignimbrite	91	3.91	16.38	ignimbrite	31	0.096	0.49	Sch	73	7.69	32.95
MudStnPakihi	87	2.38	9.97	MudStn	28	0.091	0.46	MudStn	68	9.76	41.83
Sch	72	2.58	10.80	AltSandStnSiltStnMaui	25	0.041	0.21	AltSandStnSiltStnMaui	56	6.71	28.77
MudStn	65	4.05	16.95	Sch	19	0.016	0.08	ignimbrite	51	9.83	42.16
greywacke	45	3.53	14.76	basalt	18	0.101	0.51	greywacke	38	12.14	52.03
basalt	41	2.12	8.87	andesite	16	0.089	0.45	MudStnPakihi	37	11.23	48.14
AltSandStnSiltStnMaui	37	3.03	12.67	CongMaui	15	0.085	0.43	basalt	35	25.27	108.3
semiSch	34	2.30	9.63	Cong	12	0.065	0.33	semiSch	34	7.28	31.19
andesite	22	3.16	13.24	MudStnPakihi	11	0.065	0.33	sand	28	7.88	33.78
sand	18	8.07	33.77	melange	10	0.069	0.35	andesite	20	14.50	62.17
Cong	17	2.28	9.54	semiSch	10	0.055	0.28	Cong	17	5.82	24.95
rhyolite	15	3.63	15.19	sand	8	0.099	0.50	scoria	16	23.98	102.8
limestone	12	4.14	17.32	limestone	6	0.19	0.97	limestone	11	11.14	47.77
mud	11	4.17	17.47	rhyolite	4	0.27	1.40	tuff	11	19.84	85.05
SiltStn	9	3.45	14.42	breccia	3	0.047	0.24	rhyolite	9	11.92	51.12

Arsenic				Cadmium				Copper			
Chemical4 Factor	n	median	95%	Chemical4 Factor	n	median	95%	Chemical4 Factor	n	median	95%
melange	6	5.20	21.75	metaSed	3	0.078	0.40	SiltStn	9	16.52	70.82
volcanics	5	3.05	12.75	till	3	0.039	0.20	volcanics	8	10.26	43.98
peat	4	2.49	10.42	agglomerate	2	0.12	0.60	peat	6	12.10	51.89
AltSandStnMudStn	3	3.78	15.82	AltSandStnMudStn	2	0.051	0.26	melange	5	11.88	50.94
breccia	3	5.65	23.64	argillite	2	0.078	0.40	silt	5	8.73	37.42
metaSed	3	0.55	2.28	gabbro	2	0.058	0.30	mud	4	12.63	54.13
till	3	4.79	20.06	mud	2	0.065	0.33	AltSandStnMudStn	3	10.07	43.18
gabbro	2	1.16	4.86	peat	2	0.034	0.18	breccia	3	17.61	75.52
tuff	2	3.42	14.32	tuff	2	0.034	0.18	metaSed	3	6.13	26.29
peridotite	1	1.95	8.18	scoria	1	0.402	2.05	till	3	8.98	38.49
pyroclastics	1	2.36	9.89	silt	1	0.026	0.13	gabbro	2	4.56	19.57
scoria	1	5.03	21.08	tonalite	1	0.07	0.36	fill	1	10.37	44.45
silt	1	2.65	11.08	volcanics	1	0.17	0.84	peridotite	1	15.99	68.55
tonalite	1	1.25	5.23					pyroclastics	1	21.06	90.29
								tonalite	1	30.19	129.4

Table 10 Predicted background concentrations (median and 95th quantile estimates) for chromium and lead in each of the Chemical4 factor levels for which data is available. n = number of samples. Estimated concentrations for sub-groups with n <30 are considered less reliable and for n <10, unreliable

Chromium				Lead			
Chemical4 Factor	**n**	**median**	**95%**	**Chemical4 Factor**	**n**	**median**	**95%**
gravel	556	16.56	80.15	gravel	499	12.20	44.34
SandStnPakihi	172	12.50	60.50	SandStnPakihi	160	8.27	30.08
SandStn	150	12.83	62.07	SandStn	145	10.44	37.96
CongMaui	124	12.57	60.82	CongMaui	116	10.67	38.80
MudStnPakihi	106	11.76	56.88	MudStnPakihi	106	7.11	25.83
ignimbrite	100	13.92	67.35	ignimbrite	99	6.82	24.79
MudStn	94	13.19	63.83	MudStn	80	10.60	38.55
basalt	76	26.56	128.5	Sch	72	10.79	39.23
Sch	73	10.95	53.00	basalt	52	15.50	56.34
AltSandStn/SiltStnMaui	59	8.56	41.39	greywacke	45	10.02	36.43
sand	46	13.98	67.65	sand	43	12.85	46.71
greywacke	45	13.66	66.08	AltSandStn/SiltStnMaui	37	7.18	26.10
semiSch	35	10.80	52.26	semiSch	34	9.35	34.01
andesite	23	10.68	51.67	andesite	23	10.24	37.22
Cong	17	15.01	72.62	Cong	17	10.60	38.52
scoria	17	22.51	108.92	breccia	15	5.78	21.02
breccia	16	17.53	84.80	rhyolite	15	9.10	33.09
rhyolite	15	20.84	100.84	mud	14	14.15	51.45
mud	14	15.26	73.83	limestone	12	10.59	38.49
limestone	12	17.74	85.84	SiltStn	10	11.56	42.01

Chromium				Lead			
Chemical4 Factor	n	median	95%	Chemical4 Factor	n	median	95%
tuff	12	27.14	131.3	peat	7	8.79	31.97
SiltStn	10	11.00	53.21	melange	6	77.84	283.0
peat	9	12.45	60.24	volcanics	5	17.76	64.56
volcanics	8	16.00	77.40	agglomerate	3	14.96	54.39
melange	6	54.17	262.1	AltSandStnMudStn	3	5.88	21.37
silt	6	23.99	116.1	metaSed	3	7.26	26.40
agglomerate	4	17.18	83.15	till	3	9.76	35.47
till	4	24.11	116.7	tuff	3	13.86	50.39
AltSandStnMudStn	3	5.66	27.38	gabbro	2	5.92	21.51
metaSed	3	13.06	63.20	silt	2	14.45	52.54
gabbro	2	7.26	35.10	peridotite	1	66.16	240.5
fill	1	16.87	81.62	pyroclastics	1	154.62	562.1
peridotite	1	28.68	138.8	scoria	1	95.38	346.7
pyroclastics	1	20.51	99.26	tonalite	1	5.69	20.68
tonalite	1	6.51	31.50				

Table 11 Predicted background concentrations (median and 95th quantile estimates) for nickel and zinc in each of the Chemical4 factor levels for which data is available. n = number of samples. Estimated concentrations for sub-groups with n <30 are considered less reliable and for n <10, unreliable

Nickel				Zinc			
Chemical4 Factor	**n**	**median**	**95%**	**Chemical4 Factor**	**n**	**median**	**95%**
gravel	539	7.98	44.96	gravel	99	44.06	182.8
SandStnPakihi	162	5.83	32.88	SandStn	44	34.50	143.1
SandStn	150	6.10	34.38	SandStnPakihi	38	24.53	101.8
CongMaui	122	5.93	33.42	ignimbrite	32	31.25	129.7
ignimbrite	100	5.99	33.75	MudStn	31	27.02	112.1
MudStnPakihi	100	6.24	35.15	greywacke	27	29.35	121.8
MudStn	82	6.96	39.21	AltSandStn/SiltStnMaui	25	19.68	81.66
Sch	73	4.71	26.52	basalt	20	71.29	295.8
basalt	72	13.74	77.43	Sch	19	31.70	131.5
greywacke	45	5.30	29.86	andesite	16	44.59	185.0
sand	38	4.88	27.49	CongMaui	15	46.03	191.0
AltSandStn/SiltStnMaui	37	5.16	29.07	sand	15	34.86	144.7
semiSch	35	4.36	24.58	Cong	11	24.43	101.4
andesite	22	6.38	35.98	MudStnPakihi	11	23.61	97.97
Cong	17	4.97	28.02	semiSch	7	24.86	103.2
breccia	16	5.61	31.60	limestone	5	53.93	223.8
rhyolite	15	10.19	57.44	melange	5	22.71	94.24
mud	14	8.85	49.90	rhyolite	4	38.55	160.0
limestone	12	9.36	52.78	breccia	3	49.88	207.0
SiltStn	10	5.81	32.74	metaSed	3	23.69	98.29

Nickel				Zinc			
Chemical4 Factor	**n**	**median**	**95%**	**Chemical4 Factor**	**n**	**median**	**95%**
volcanics	8	8.42	47.45	AltSandStnMudStn	2	20.91	86.77
peat	7	7.60	42.83	gabbro	2	13.03	54.05
melange	6	14.92	84.10	mud	2	45.92	190.5
agglomerate	4	3.99	22.49	peat	2	26.73	110.9
till	4	5.33	30.02	tuff	2	55.93	232.1
AltSandStnMudStn	3	1.92	10.83	agglomerate	1	35.60	147.7
metaSed	3	5.24	29.55	scoria	1	409.09	1697.5
gabbro	2	1.90	10.69	silt	1	40.26	167.0
silt	2	17.29	97.44	till	1	52.95	219.7
tuff	2	11.92	67.18	tonalite	1	34.54	143.3
peridotite	1	21.67	122.2	volcanics	1	26.74	110.9
pyroclastics	1	27.38	154.3				
scoria	1	20.06	113.1				
tonalite	1	3.01	16.95				

Appendix B – Council survey

Background soil concentrations and methodology for developing soil guideline values for the protection of ecological receptors – Envirolink Tools Grant: C09X1402

Introduction

Soil guideline values developed to protect soil biota (Eco-SGVs) provide a useful means to readily assess potential environmental impact. Some soil guideline values already exist, for example within the Timber Treatment Guidelines (MfE 2011) or Biosolids Guidelines (NZWWA 2003), but these are for a limited number of contaminants and are based on inconsistent methodologies. The absence of national Eco-SGVs has resulted in inconsistency and a lack of clarity around protection of ecological receptors in soil, and a lack of focus on ensuring this protection in territorial and regional/unitary council functions.

This project aims to develop Eco-SGVs for arsenic, copper, cadmium, chromium, fluoride, lead, zinc, DDT, total petroleum hydrocarbon (TPH), and polycyclic aromatic hydrocarbons (PAH) and establish agreed methods for derivation such that values can subsequently be developed for other contaminants of concern as needed. Determination of background soil concentrations are included within this project as methodologies for deriving Eco-SGVs may include their use, or they may be used as criteria to ensuring environmental protection (e.g. cleanfill criteria). Several workshops have been held with regional council staff, contaminated land practitioners and the organic waste sector to increase awareness of the project and feed into the development of the Eco-SGVs and their intended application. The further technical development of the Eco-SGVs based on the intended application (below) is currently underway. This summary outlines the intended application of the Eco-SGVs to start conversation on how the Eco-SGVs can be consistently implemented by councils, particularly in the absence of a national tool.

Intended application

Contaminated land

- In principle, the Eco-SGVs are intended to inform remediation where remediation is already occurring (primarily through setting standards for the quality of any soil imported onto site) or to instigate further investigation where there is significant exceedance of Eco-SGVs.
- It is not intended that exceedance of the Eco-SGV will drive remediation unless further investigation determines on-site or off-site effects are occurring. Guidance on what constitutes significant exceedance is required (and will be provided within this project – this is an area for discussion), and will likely relate to level of exceedance (e.g. 2.5× Eco-SGV) and the area of significantly elevated concentrations.

Protection of soil quality

- Eco-SGVs are intended to inform consent limits for application of wastes (e.g. managed fill, cleanfill), organic wastes e.g. biosolids) i.e. are 'pollute-up-to' criteria. *In setting criteria for waste disposal, protection of human health and groundwater resources should also be considered. Thus, Eco-SGVs are only one component for consideration.*
- Eco-SGVs are also intended to provide a benchmark for assessing soil quality over time in relation to regional council State of the Environment monitoring. Ultimately this could also be linked to ecosystem services (i.e. exceedance indicates a certain ecosystem service may be impacted). Table 12 provides a summary of agreed land-use categories, and proposed application of Eco-SGVs.

Table 12 Summary of land-use categories for Eco-SGV application, land uses covered, level of protection of plant soil processes and invertebrates and proposed application of Eco-SGVs

Land use	NES land use	Additional land uses covered/Description	Level of protection[1]		Contaminated land	Soil quality
			Plants	Soil process and invertebrates		
Commercial/ Industrial	High density residential, Commercial/industrial outdoor worker	Road reserves, All commercial/industrial land use, including under paved areas.	60%	60%	Inform remediation standards[2] – specifically the quality of any soil imported onto site Trigger further site investigation, including off-site effects, in the event of significant exceedance	NA
Residential and recreational areas	Rural residential/lifestyle block (25% produce consumption) Residential (10% produce consumption) Recreation		80%	80%	As above	Consent limits for application of wastes (e.g. biosolids, cleanfill, managed fill) to land Regional Council monitoring
Agriculture	NA	All food-production land	95%	80% (lower protection level in recognition of intentional pesticide application, and cultivation effects)	NA[3]	As above
Non-food production land	NA	All non-food production land (e.g. production forestry) to which waste could be applied and which do not fall in other land-use categories	95%	95%	Trigger further site investigation, including off-site effects, in the event of significant exceedance	As above
Ecologically sensitive areas	NA	National Parks, designated ecologically sensitive areas	99%	99%	As for agriculture?	As above

[1] This is based on using EC30/LOEC toxicity data and aged contamination for all applications except discharge of stormwater, for which contamination should be considered fresh (due to the high organic load in organic wastes such as chicken manure, it is considered that aged contamination is appropriate)
[2]Noting that Eco-SGVs for copper and zinc, in particular, should not automatically be applied as remediation standards – the effect of excavation and disposal of soil should be considered relative to the effect of actively managing the land to reduce concentrations over time.
[3]NA –Not applicable.

Questions to consider:

Does the outlined application cover the needs for your council? Please consider the needs for policy, regulation, environmental protection, SOE, remediation functions, etc.

Given your councils processes for managing contaminated land and soil quality, where and how would you anticipate these guideline values would be used?

What is needed by your council's policy and planning staff to implement these values?