Manaaki Whenua
Landcare Research

Managing potentially contaminated soils in the Tasman District

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Managing potentially contaminated soils in the Tasman District

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Contents

Summary

Project and client

- Tasman District Council (TDC) is currently updating its Environment Plan and has sought advice to enable the appropriate management of potentially contaminated soil removed from sites.
- Specifically, TDC is seeking a technical update of previously developed interim cleanfill criteria and advice on the application of soil guideline values to enable the beneficial use of this 'surplus' soil while ensuring the wider environment is protected.
- Manaaki Whenua – Landcare Research (MWLR) was contracted to carry out this work, which was undertaken in June 2021 under Envirolink small advice grant 2147-TSDC178.

Objectives

- To provide a technical update to the interim cleanfill criteria developed in the 2015 Envirolink report (Cavanagh 2015).
- To provide advice on the application of soil guideline values to enable the beneficial use of potentially contaminated soil.

Methods

- Data from national background values from Cavanagh et al. 2015 and data from a regional survey undertaken by GNS Science in 2017 were used to update previous background concentrations.
- Ecological criteria were updated using ecological soil guideline values provided in Cavanagh 2019a.
- The *Technical Guidelines for Disposal to Land* (WasteMinz 2018) were also considered in developing the revised criteria.

Results and conclusions

- Analysis of the results from soil sampling by GNS Science in 2017 confirmed that there are areas in the Tasman District, outside of the recognised Dun Mountain mineral belt, where soils appear to be elevated in nickel, chromium, and to a lesser extent copper. These elevated concentrations probably represent the 'downstream' influence of geological materials derived from this mineral belt through erosion and pedological processes.
- Comparison of the previous background concentrations developed from a limited sampling set with background concentrations developed from a national data set by Cavanagh et al. (2015) suggests some change is warranted. However, further work is currently being undertaken by GNS Science and MWLR that will further develop national estimates of naturally occurring (background) concentrations that would be relevant to consider. This research is anticipated to be completed no later than 30 June 2022.

- Ecological criteria were updated using soil guideline values for the protection of ecological receptors (Eco-SGVs) for both non-production land and agricultural production land. Eco-SGVs for these land-use categories provide different levels of protection for soil biota but are not considered to restrict land use in any way. There is a proposal for a future Envirolink large advice grant (LAG) that intends to further evaluate the policy aspects to be considered for the application of the Eco-SGVs.
- Various options for revised 'cleanfill' criteria are presented and represent more or less precautionary values that could be selected, depending on the policy and planning context in which these values are applied. TDC is currently considering the appropriate context in their plan change revisions.
- In considering the context of application, some emphasis should be given to enabling the beneficial use of lightly contaminated soil in recognition of the value of (particularly) surface soils. This would also meet central government aspirations to move towards a more circular economy. It may be appropriate to consider controls on the source of materials to which any more permissive criteria to enable beneficial use apply to ensure the value attributed to surface soils is realised (e.g. to soils from ex-production land which would generally be considered to be fully functional soils).
- Finally, the report raises a question about the relevance of having separate classes for Class 4 (controlled fill) and Class 5 (cleanfill), given that both landfill types are not intended to impose any restrictions on future land use. At a national level it would be relevant to consider whether there is merit in combining the proposed Class 4 and Class 5 landfills into one class, with waste acceptance criteria based on ensuring protection of the most sensitive receptor (people or ecological receptors). More stringent criteria could apply where these landfills might be placed in more sensitive environments (e.g. close to waterways or groundwater).

Recommendations

- It is important to recognise that work is being undertaken, or is imminent, that would be relevant for TDC to consider before adopting any of the revised criteria outlined in this report. This current or imminent work relates to the further development of national estimates of naturally occurring concentrations of trace elements, and a policy evaluation of the application of the ecological soil guideline values.
- Further evaluation (including data analysis and additional sample collection) should be carried out to delineate areas of, and establish appropriate criteria for managing soils with, naturally elevated concentrations of copper, nickel and chromium that probably arise from the Dun Mountain mineral belt through erosion and pedological processes
- In a policy and planning context, greater consideration should be given to enabling the use of potentially contaminated soil, and to recognising these soils (particularly surface soils) as potential resources rather than waste. Following on from this, greater attention should be given to defining potentially contaminated or contaminated soils in relevant policies and plans.

1 Introduction

Tasman District Council (TDC) is currently updating its Environment Plan. A critical component of this revision is to ensure the appropriate management of potentially contaminated soil removed from sites. This includes the management of soil disposed to cleanfill or otherwise used (e.g. for reserves that are close to sensitive receiving environments such as watercourses, wetlands or shallow groundwater).

The soil of concern may arise from:

- production land, which is exempt from consideration under the National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health Regulations 2011 (NES-CS), or
- other soil that contains contaminants that are above background concentrations and therefore triggers assessment under the NES-CS, even if it does not pose a human health risk and is surplus to requirements for use onsite.

However, such soil, which is often topsoil, may still be considered good-quality soil, and so disposal to landfills may simply be wasting this resource.

TDC is seeking advice to enable the beneficial use of this 'surplus' soil while ensuring the wider environment is protected. The advice comprises two components:

- a technical update to the 2015 Envirolink report *Background Concentrations of Trace Elements and Options for Managing Soil Quality in the Tasman and Nelson Districts*, which provides interim cleanfill criteria recommendations for the Tasman/Nelson region
- recommendations on the application of soil guideline values (background concentrations, ecological soil guideline values, cleanfill criteria) in future plans to achieve the above objective.

2 Background

2.1 The 2015 Envirolink report

To assist with managing soil quality in the Tasman and Nelson Districts, a previous advice grant suggested an approach to developing interim cleanfill criteria (Cavanagh 2015). The rationale for the approach is outlined below.

> *Consistent with other cleanfill guidance, a fundamental driver is that cleanfill should not create contaminated land, noting that the RMA definition of contaminated land encompasses both human and ecological receptors (e.g. soil invertebrates, plants and soil microbial health). Further, the RMA specifies that land that has a hazardous substance that 'is reasonably likely to have significant adverse effects on the environment' is contaminated land.*

> *As such, cleanfill should not create contaminated land in relation to the most sensitive receptor class at a site. This decision also needs to allow an adequate margin for sample heterogeneity (spatial differences in concentrations), sampling error, and analytical error, to avoid inadvertent deposition of contaminated soil. Conversely, it would not be justifiable to reject material for cleanfill disposal that contained less of a naturally occurring hazardous substance than is usually found as part of the upper end of the local background range.*
>
> *Cleanfill thresholds therefore should:*
>
> - *be less than the guideline values that could be used to define significant adverse effects for the most sensitive receptor class*
> - *allow an adequate margin for error, so that exceeding a cleanfill threshold by a minor margin will not inadvertently allow deposition of contaminated soil*
> - *not be lower than the 95th percentile of the local background range.*
>
> *Further, where a guideline indicating significant adverse effects was greater than the 95th percentile of the local background, the approach adopted was to develop criteria half-way between these two figures, and in so doing provide a 'buffer' to ensure that exceeding a cleanfill threshold by a minor margin does not inadvertently allow for deposition of contaminated soil. This approach provides assurance that the future use of land will not be impacted.*

Cavanagh (2015) provides a discussion on the choice of the upper limit for the background concentrations and notes that 'for the current work, 99th percentile concentrations were used as the upper limits as compared to the 95th upper confidence level of the 95th percentile concentrations (95UCL), which … often equalled the maximum measured concentration'. This choice partly reflects the limited data available to determine background concentrations at the time.

Soil contaminant standards for rural residential land use were used as the human health criteria, while ecological soil guideline values were based on 'minimal risk' guideline values for the protection of ecological receptors developed by Cavanagh and O'Halloran (2006). The minimal-risk values are aimed at protecting 95% of species in an ecosystem from detrimental effects. For naturally occurring concentrations, an 'added-risk approach' was used whereby minimal-risk concentrations are *added* to the determined background concentrations.

The interim cleanfill criteria developed for the Tasman/Nelson region by Cavanagh (2015) are shown in Table 1.

Table 1. Interim cleanfill criteria recommended by Cavanagh (2015)

Element	N	99th percentile	Cleanfill criteria based on protection of ecological receptors	Cleanfill criteria based on protection of human health	Recommended cleanfill criteria
As[1]	47	11	20.6	12.8	12
Cd	29	0.90	1.7	0.75	0.75
Cr-hi[2]	8	183	*	*	-
Cr-lo[3]	21	93.5	140	-	140
Cu	43	41.5	85.4	-	85
Pb	48	33	86.4	93.2	86
Ni-hi[2]	8	274.4	*	*	-
Ni-lo[3]	21	53.4	88	91.5	88
Zn	29	141.5	308	-	300

As = arsenic; Cd = cadmium; CR = chromium; CU = copper; NI = nickel; Pb = lead; Zn = zinc.

[1] Arsenic concentrations excluding the elevated point (18 mg/kg).

[2] Subgroup of sites with apparently naturally elevated Cr and Ni concentrations.

[3] Subgroup of sites with apparently normal concentrations of Cr and Ni.

*Given the small number of samples in these groups, no cleanfill criteria are given.

Cavanagh (2015) also provided a number of recommendations, including that the proposed criteria be reviewed after completion of a Ministry of Business, Innovation and Employment Envirolink Tools project ‘Background concentrations and soil guideline values for the protection of ecological receptors’. Other recommendations were that additional sampling and analysis were required to develop more robust estimates of background concentrations in the region, particularly for areas that appeared to be elevated in nickel and chromium.

3 Objectives

- To provide a technical update to the interim cleanfill criteria developed in the 2015 Envirolink report (Cavanagh 2015).
- To provide advice on the application of soil guideline values to enable the beneficial use of potentially contaminated soil.

4 Methods

The update of background concentrations draws on national background values developed in a previous Envirolink Tools project (Cavanagh et al. 2015) and available at PBC - Predicted Background Soil Concentrations, New Zealand - Landcare Research Limited | New Zealand | Environment and Land GIS | LRIS Portal (scinfo.org.nz). Background concentrations relevant to the Tasman district were examined in detail.

Data from a regional survey undertaken by GNS Science in 2017 were also assessed. This survey included an 8 km grid 'regional' survey and 2 km grid 'Rotoroa' and 'Richmond' surveys, predominantly in areas with indigenous vegetation (GNS Science 2017). Samples were collected at three depths: 0–2 cm (termed the O-depth), 2–20 cm (A-depth), and 50–70 cm (B-depth). Selected O-depth samples were analysed for trace elements via aqua regia digestion by Bureau Veritas in Canada using data provided by Tasman District Council. All A- and B-depth samples were analysed in the same manner by Bureau Veritas, and data were accessed from the New Zealand Petroleum and Minerals website.

Data for the A-depth were analysed for this project. Specifically, data for soils from the Tasman district were grouped into selected geological groupings used in Cavanagh et al. 2015 based on the lithology identified in the downloaded data. Lithology was not identified for all samples. The geological groupings used by Cavanagh et al. (2015) were based on rock groups from QMAP[1], a geological map of New Zealand, and were termed Chemical4 groupings For each dominant geological group in the Tasman District (sandstone, granite, gravels, and Dun Mountain and ultramafics), the median and 95th percentile concentrations for surface (2–20 cm) soils were determined using Excel.

Ecological criteria were updated using ecological soil guideline values (Eco-SGVs) provided in Cavanagh 2019a, and the *Technical Guidelines for Disposal to Land* (WasteMinz 2018) were considered in the development of options to be considered in updating the previously developed criteria.

These data and reports, and discussions with TDC staff, were used to present considerations for the application of soil guideline values when managing potentially contaminated soil.

5 Results

5.1 Updating the criteria from the 2015 report

5.1.1 Background concentrations

Cavanagh et al. 2015 provided a comprehensive approach to developing estimates of naturally occurring concentrations of trace elements at a national level, based on the analysis of data collated across New Zealand. Trace element concentrations were typically generated from aqua regia-type extractions and analysis by Inductively Coupled Plasma - Mass Spectrometry. Generalised Least Squares modelling was used to develop predicted concentration distributions using a rock-group geological grouping, *Chemical4,* derived from QMAP. The modelling was used to generate the predicted background concentration distribution (described by the effective estimates of median, 5th and 95th percentile) for individual Chemical4 classes. More detail of the approach used is provided in Appendix 1,

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[1] QMAP. 1:250,000 Geological Map of New Zealand / Geological Maps / Maps / Products / Home - GNS Science

with further details in Cavanagh et al. 2015. A summary of median and 95% concentrations for the key trace elements across all geological groupings is shown in Table 2.

Table 2. Summary of background concentrations of key trace elements, as determined by Cavanagh et al. 2015

Trace element	Median range (mg/kg)		95th percentile range (mg/kg)	
As	2.1	4.1	8.9	17
Cd	0.05	0.1	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

The distribution of the individual Chemical4 geological groups across Tasman and Marlborough is shown in Figure 1, with land use in the Tasman district shown in Figure 2.

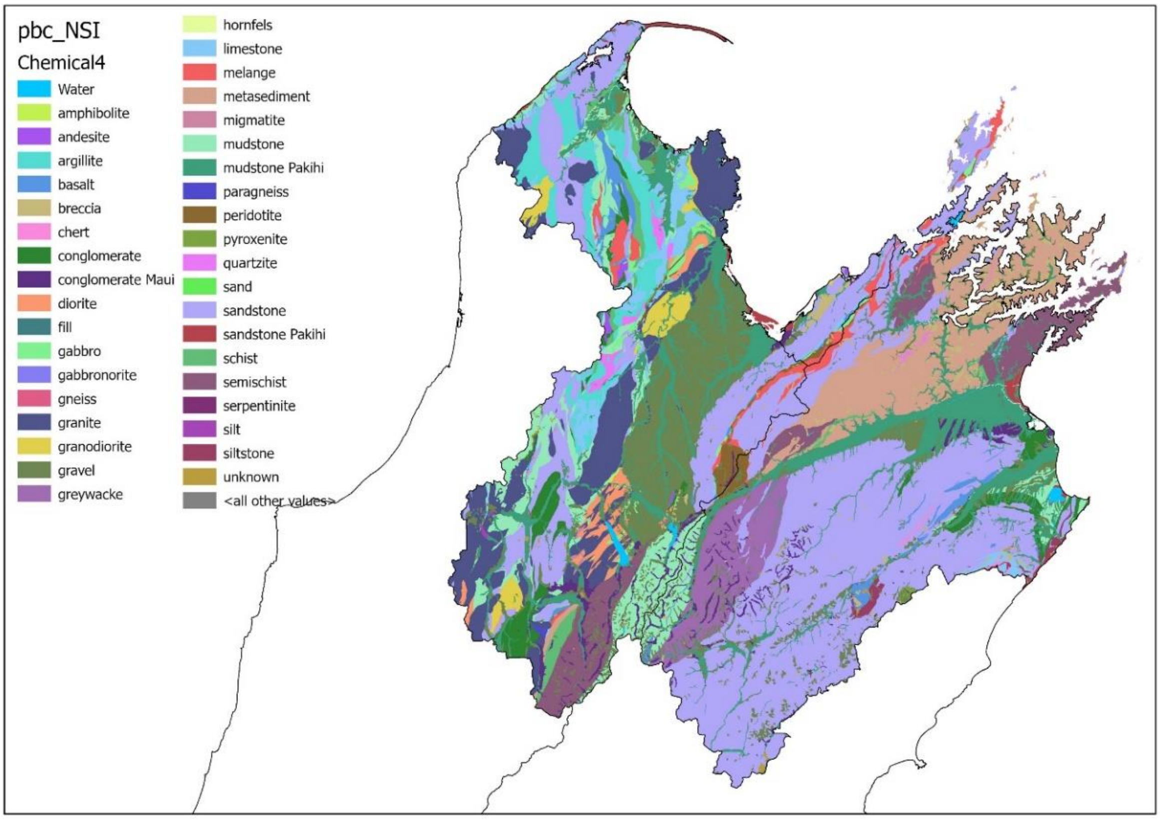

Figure 1. Distribution of Chemical4 geological groups across the Tasman and Marlborough regions.

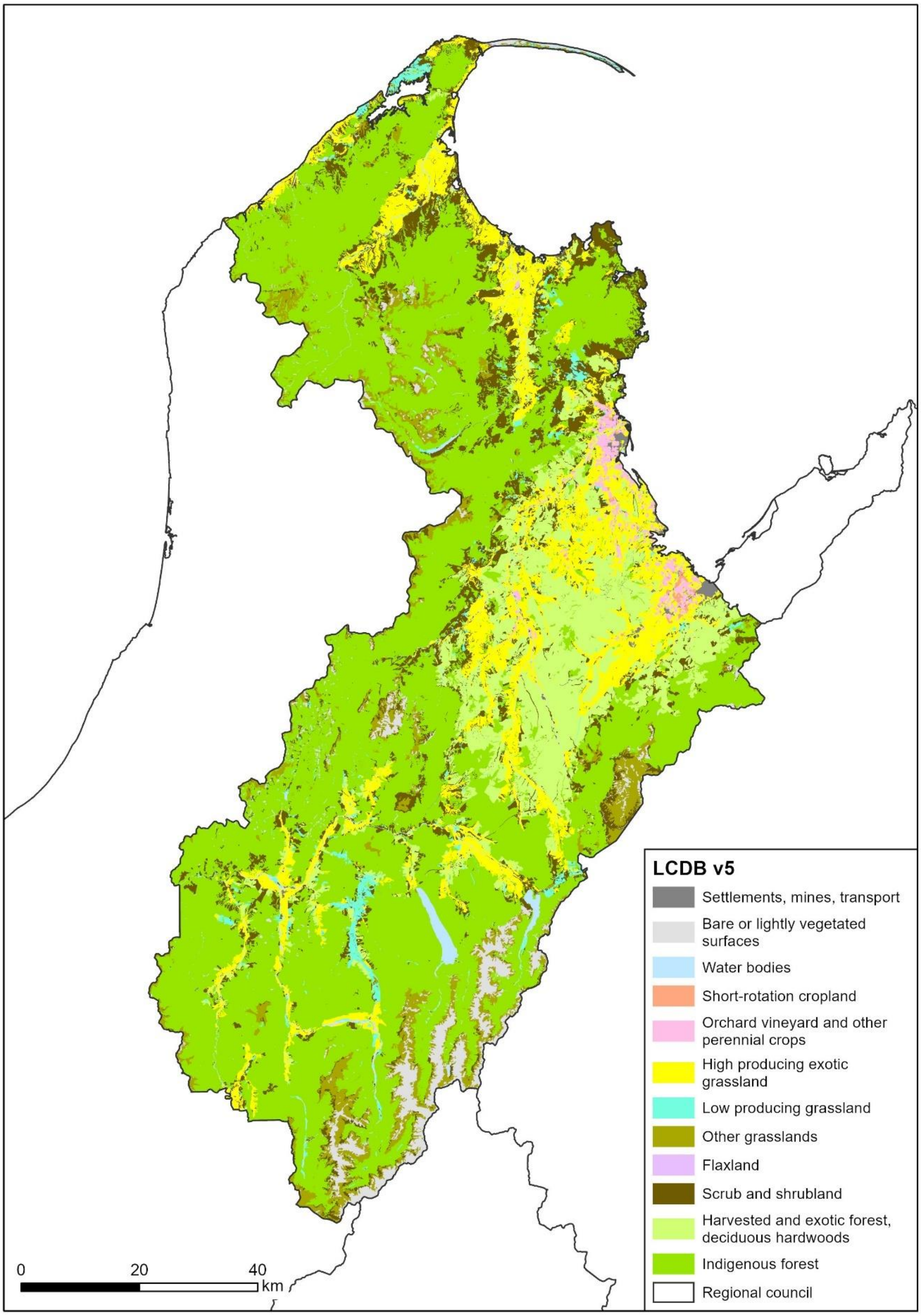

Figure 2. Overview of land cover in the Tasman District using Land Cover Database version 5 (LCDB5).

Comparison of land use in the Tasman District (Figure 2) with the distribution of geological groups indicates that the key geological groups underpinning anthropogenic land use are sandstone, gravel, mudstone pākihi and mudstone, mainly surrounding Waimea, Motueka, Tākaka and Aorere river valleys (Figures 1 and 2). These geological groups are the dominant groups across the Tasman District (Table 3). Granite is another dominant geological group in the Tasman district, although this largely underlies indigenous forest (Figures 1 and 2).

Table 3. The total area of derived Chemical4 geological classes in the Tasman District

Chemical4	Area (km^2)	% of total area
Sandstone	1,590	16.5
Gravel	1,514	15.7
Granite	1,493	15.5
Mudstone Pākihi	926	9.6
Mudstone	817	8.5
Argillite	586	6.1
Limestone	394	4.1
Semischist	393	4.1
Conglomerate	291	3.0
Schist	247	2.6
Granodiorite	241	2.5
Diorite	193	2.0
Conglomerate Maui	163	1.7
Melange	145	1.5
Basalt	133	1.4
Gabbro	95	0.98
Peridotite	91	0.94
Quartzite	84	0.87
Sandstone Pākihi	47	0.49
Water	44	0.45
Metasediment	28	0.30
Andesite	27	0.28
Breccia	22	0.23
Various	55	0.57

The distribution of samples collected for the GNS Science sampling (Figures 2 and 3) shows that the majority of sites are located in indigenous vegetation. Similarly, land-use information captured during sampling also indicated the majority of sites were native vegetation. Hence, land use is not expected to markedly influence the trace element concentrations in these samples.

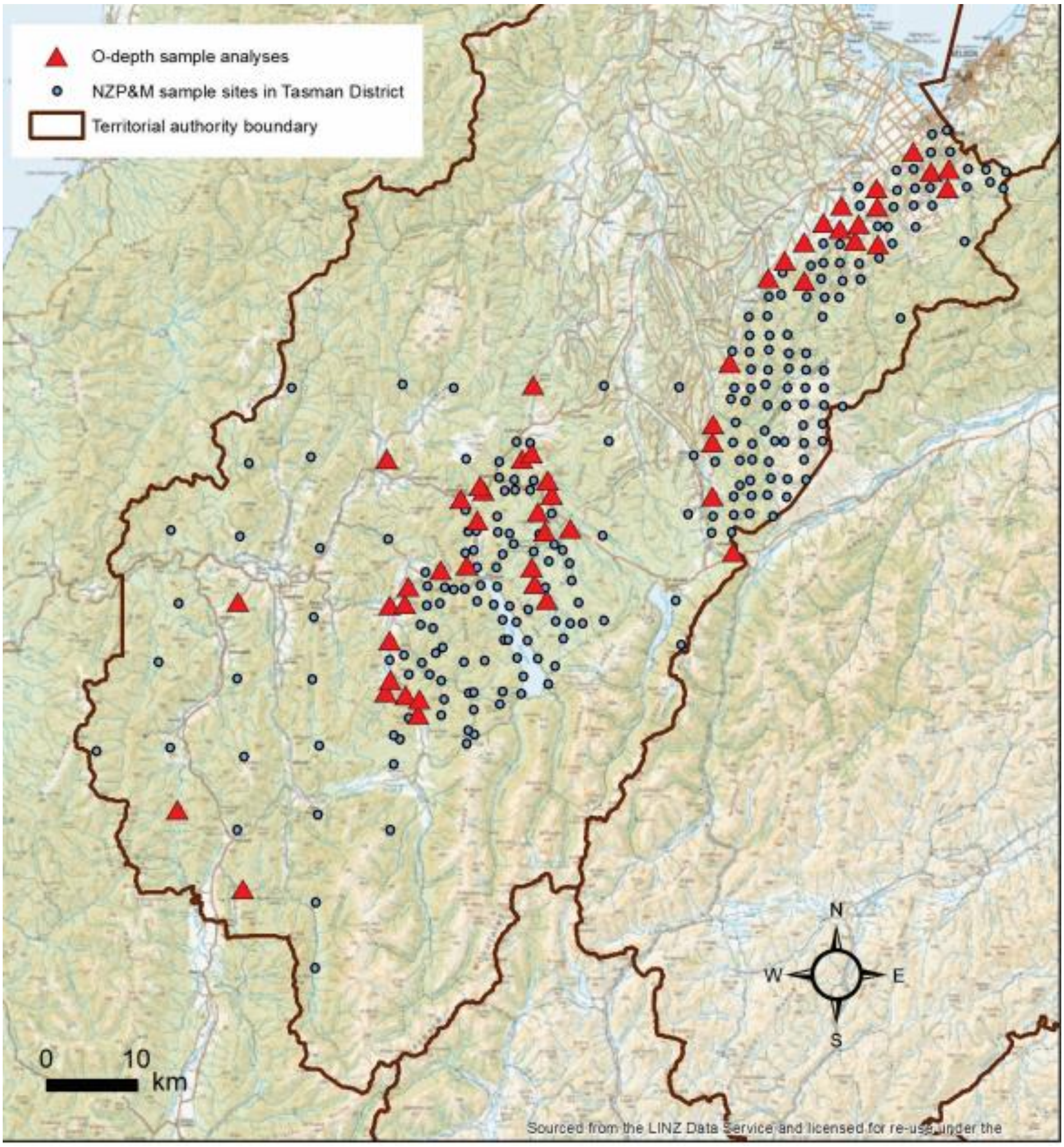

Figure 3. Location of samples collected by GNS for the New Zealand Petroleum & Minerals geochemical survey in the Tasman region. Samples from 2–20cm and 50–70 cm depths were collected. Red triangles indicate samples from O-depth (0–2 cm), which were analysed for Tasman District Council. (Source: GNZ Science 2017b).

Comparison of the estimated background concentrations for the dominant geological groupings (sandstone, gravel, mudstone, mudstone pākahi and granite, Table 3) and from the GNS sampling reveal the greatest difference in chromium and nickel concentrations for sandstone and gravels, with median and 95th percentile concentrations markedly higher for the GNS (Tasman-specific) samples (Table 4). Median concentrations for copper and zinc were also higher in the GNS samples, although 95th percentile concentrations were lower. These elevated concentrations probably reflect the 'downstream' influence of the so-called Dun Mountain mineral belt or Ultramafic group, which contains higher concentrations of nickel and chromium, in particular, but also copper and to a lesser extent zinc (Table 5), in the surrounding sandstone and gravels, although further analysis is required to delineate the area of influence.

Table 4. Summary of trace element background concentrations (mg/kg) determined for primary geological groupings in the Tasman District from Cavanagh et al. 2015, and as determined from results from sampling undertaken by GNS in 2017

Trace element	Chemical4 geological group	Cavanagh et al. 2015			GNS sampling		
		n	median	95%ile	*n*	median	95%ile
Arsenic	SandStn	*131*	2.8	11.8	*94*	2.8	7.35
	gravel	*393*	2.9	12.1	*23*	3.6	8.26
	granite	-	-	-	*68*	1.1	9.5
	MudStnPakihi	*87*	2.4	10.0	-	-	-
	MudStn	*65*	4.1	17.0	-	-	-
Copper	SandStn	*131*	14.2	60.9	*94*	20.5	54.8
	gravel	*229*	10.0	42.9	*23*	15.4	32.4
	granite	-	-	-	*68*	12.5	41.4
	MudStnPakihi	*37*	11.2	48.1	-	-	-
	MudStn	*68*	9.8	41.8	-	-	-
Chromium	SandStn	*150*	12.8	62.1	*94*	50.5	240.6
	gravel	*556*	16.6	80.2	*23*	60.0	203.6
	granite	-	-	-	*68*	83.8	286.8
	MudStnPakihi	*106*	11.8	56.9	-	-	-
	MudStn	*94*	13.2	63.8	-	-	-
Lead	SandSt	*145*	10.4	38.0	*94*	9.7	16.2
	gravel	*499*	12.2	44.3	*23*	12.4	20.6
	granite	-	-	-	*68*	7.9	19.7
	MudStnPakihi	*106*	7.1	25.8	-	-	-
	MudStn	*80*	10.6	38.6	-	-	-
Nickel	SandSt	*150*	6.1	34.4	*94*	15.8	143.0
	gravel	*539*	8.0	45.0	*23*	16.1	153.9
	granite	-	-	-	*68*	10.3	26.2
	MudStnPakihi	*100*	6.2	35.2	-	-	-
	MudStn	*82*	7.0	39.2	-	-	-
Zinc	SandStn	*44*	34.5	143.1	*94*	47.5	89.6
	gravel	*99*	44.1	182.8	*23*	55.7	91.6
	granite	-	-	-	*68*	34.5	72.0
	MudStnPakihi	*11*	23.6	98.0	-	-	-
	MudStn	*31*	27.0	112.1	-	-	-

Table 5. Median and 95th percentile trace element concentrations for samples representative of the Dun mountain mineral belt (identified lithologies of Dun Mountain Ophiolite, mafic and ultramafic materials)

Parameter	Trace element					
	As	Cu	Cr	Pb	Ni	Zn
Median	1	25.4	486.2	2.4	1938	48.7
95th percentile	4.6	105	1673	13.8	3053	70.3

5.1.2 Ecological soil guideline values

An Envirolink tools project to develop soil guideline values for the protection of ecological receptors (soil microbes, invertebrates, plants, wildlife and livestock) was completed in 2016. This work was subsequently updated in 2019 (Cavanagh 2019a) to take review comments and international developments into account (Cavanagh 2019b). This work developed ecological soil guideline values (Eco-SGVs) for five land uses based on differing levels of protection for the soil biota (Table 6). For copper and zinc, sufficient toxicity data were available to enable development of Eco-SGVs for three soil types, categorised as sensitive, typical, and tolerant, based on soil characteristics that influence the availability of contaminants (organic matter, pH, clay content).

Further details of the methodology used are provided in Appendix 2, and a summary of the Eco-SGVs developed for trace elements for non-production land (95% protection for all receptors) and agricultural land (95% protection for plants, 80% protection for microbes and invertebrates) are provided in Table 7. These Eco-SGVs are based on using the lowest predicted median background concentration for each individual trace element. As DDT residues are common contaminants in soils from horticultural sites, which are a common source of soils in the Tasman district, the Eco-SGVs for DDTs are also provided in Table 7.

Table 6. 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 (Source: Cavanagh 2019a)

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 that 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 are not expected to affect soil processes and soil invertebrates, enabling a higher level of protection for these organisms.	Soil microbes, plants, invertebrates, wildlife	95 (99)	95 (99)
Ecologically sensitive areas	NA	National Parks, designated ecologically sensitive areas. Near-pristine ecosystems that should remain in that condition.	Soil microbes, plants, invertebrates, wildlife	99	99

[1] 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, e.g. for residential land use).'

[3] Lower protection level in recognition of intentional pesticide application, and cultivation effects.

NA = not applicable

Table 7. Summary of Eco-SGVs for non-production land (95% protection for plants, microbes and invertebrates (Source: Cavanagh 2019)

Element	Median Eco-SGV	Eco-SGV	Eco-SGV Ag land
As	2	17[1]	18[1]
Cd	0.7	1.5	1.5
Cr	9	190	300
Cu	7	100	220
Pb	7	280	530
Ni	4	ND	ND
Zn	25	170	190
DDT residues	1.1	1.1	1.9

ND =not determined [1]These values are the non-rounded values from Cavanagh and Munir 2019.

5.1.3 Technical guidelines for waste disposal to land

Another relevant document to consider in updating the interim cleanfill criteria is the *Technical Guidelines for Waste Disposal to Land* (WasteMINZ 2018). These guidelines were developed after extensive consultation with councils and practitioners, although they have not currently been endorsed by the Ministry for the Environment. These guidelines identify five categories of landfill:

- Class 1 – Landfill: Municipal Solid Waste Landfill
- Class 2 – Landfill: Construction &Demolition Landfill
- Class 3 – Landfill: Managed Fill
- Class 4 – Landfill: Controlled Fill
- Class 5 – Landfill: Clean Fill.

The *Guidelines* set out various criteria for the location and management of sites, including waste acceptance criteria (WAC) for all classes except Class 3, which are currently under development (pers. comm., Jonathan Caldwell, Waikato Regional Council, June 2021). Class 4 and Class 5 landfills are intended to have unrestricted future use, and so are the most relevant to consider further here.

The recommended WAC for a Class 4 landfill took into consideration human health (NES-CS SCS, and drinking-water), ecological soil criteria (Cavanagh 2006), potential for leaching based on a partitioning coefficient (Kd), and assumed dilution from drinking-water standard (human health) or ANZECC[2] guidelines (for ecological criteria). Kd values can vary markedly for different soils, and the technical guidelines do not specify the source of

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[2] Australian and New Zealand Environment and Conservation Council

information for the Kd values used, so criteria developed on this basis cannot be critically evaluated.

A summary of the WAC is given in Table 8, along with the basis for the selected criteria, as provided in the *Guidelines*. Eco-SGVs for non-production land (protection of 95% of plants and invertebrate species, and microbial functions) are used to provide 'revised' WAC following the same approach as the *Guidelines*. Slightly less conservative values of agricultural land use (protection of 95% of plant species, and 80% of microbial functions and invertebrate species) could also be used to develop revised WAC. Criteria for DDT residues are included, as these are a common contaminant in soils previously used for horticulture.

Table 8. Summary of landfill Class 4 waste acceptance criteria (WAC, mg/kg) and their basis from Wasteminz 2018, and revised waste criteria using updated Eco-SGV criteria

Contaminant	WAC (mg/kg)	Basis for criteria	Revised Eco-SGV criteria[1] (mg/kg)	Revised WAC (mg/kg)	Basis for revised WAC
As	17	Human health	17	unchanged	NA
Cd	0.8	Human health	1.5	unchanged	NA
Cr	290	Human health	190	190	Ecological
Cu	>44	>leaching or background	100	unchanged	NA
Pb	>60	>60 (ecological) or background	280	160[2]	Human health
Ni	310	Human health leaching	NA	[130]	Human health[3]
Zn	400	Leaching	170	170	Ecological
DDT residues	0.7	Ecological	1.1	1.1	Ecological

[1] Using Eco-SGV values from Cavanagh and Munir 2019 for non-production land, which provides protection of 95% protection of plant and invertebrate species and microbial functions.

[2] NES-CS SCS for rural residential land use.

[3] Based on the UK value Suitable 4 use levels (S4UL) value for nickel for residential with home grown produce (LQM/CIEH 2015).

NA = not applicable.

Class 5 landfills accept only cleanfill material, and background concentrations are suggested as the WAC. The *Guidelines* indicate that background concentrations should be region-specific, but as a default provide the 99th percentile concentration of national background concentrations (from Appendix 6 in MfE 2011) if regional data are unavailable.

A significant conundrum is posed by the *Guidelines* (and earlier cleanfill guidance, MfE 2002) specification that cleanfill is 'Virgin excavated natural materials (VENM) such as clay, soil and rock that are *free of .... hazardous substances*' (italics added). Many trace elements are considered hazardous substances and are naturally occurring. Therefore, under this specification, no excavated natural materials could ever be considered cleanfill because they can never be free from trace elements.

5.2 Considerations in the application of soil guideline values to enable the appropriate management of potentially contaminated soil

When thinking about potentially contaminated soil there can be a tendency to focus on the contaminants, which tends to result in more conservative criteria being established to ensure protection of human health and the environment without thinking about how those materials can otherwise be beneficially used. Topsoil is generally considered a valuable resource, particularly in agricultural environments, with much effort given to managing soils, and most biological functioning occurs in the top 25–30 cm (Bardgett & Van Puten 2014; US EPA 2015). Consideration should therefore be given to ensuring that, where practicable, all efforts be made to beneficially use surface soils that are surplus to requirements. This focus also meets central government and New Zealand business aspirations 'to accelerate New Zealand's transition to a circular economy[3,4], which requires better utilisation of our wastes.

Current management of potentially contaminated soil has also led to some illogical outcomes, such as that it is acceptable to leave soil on a residential property and grow vegetables for human consumption, but it is unacceptable for that soil to be disposed in a cleanfill, because some contaminants are present at concentrations above recognised background concentrations. Anecdotally, this is a widespread issue, particularly where excess soil is generated from the subdivision of ex-production land for residential purposes.

In some cases this soil may initially be managed, under relevant consents, within a large-scale subdivision, thereby avoiding the need for removal of soil. However, the same illogical outcome may arise when topsoil is required to be removed during construction of a house on a smaller section of that subdivision. Recognition of some of these illogical outcomes led to the second phase of this project being to consider the application of soil guideline values to enable the beneficial use of these potentially contaminated soils.

Achieving this objective requires that it be a stated purpose in relevant policy and planning documents. Following on from this, there needs to be a more specific consideration or definition of what is considered 'contaminated soil'. There are two potential definitions that can be derived from existing legislation or guidance.

The NES-CS, section 5(9), specifies that 'These 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'. This implies a definition of contaminated soil as soil that contains contaminants above background concentrations. The associated *User Guide* (MfE 2012) provides no guidance on what upper limit may be appropriate, and further notes that national data on background soil are sparse.

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[3] Ōhanga āmiomio – Circular economy | Ministry for the Environment

[4] The low carbon circular economy – Sustainable Business Network

Another definition is that provided in the *Technical Guidelines for Waste Disposal to Land* (WasteMINZ 2018), where contaminated soil is defined as that which is removed from contaminated land, where contaminated land is as defined under the RMA as land that has a hazardous substance in or on it that 'has ... [or] is *reasonably likely* to have *significant adverse effects* on the environment' (italics added).

The latter definition is potentially more logical but requires consideration of how effects on human health and environment might practically be defined in this case (i.e. for soil disturbance). In the first instance, Soil Contaminant Standards (for the most sensitive land use, rural residential) could be used as the basis for identifying human health effects; in a similar way, ecological soil guideline values for most sensitive land use could be used to identify where environmental effects might arise. While neither of these criteria specifically ensures protection for aquatic systems, this could be managed by controls on the placement of soil to avoid the movement of contaminants into surface water or groundwater. These criteria also need to allow for flexibility in managing soils with elevated naturally occurring concentrations, such as in mineralised soils.

A further definition that might enable a tighter policy focus on beneficial use is that of 'lightly contaminated soil'. Lightly contaminated soil could be considered soil that contains contaminants above background but below agreed or relevant human health and ecological criteria. In the context of enabling beneficial use, it might be appropriate to consider alternative human health and ecological criteria (i.e. not simply the most protective). These criteria could be based on land use, including reasonably foreseeable future land use, at the site at which the soil is placed (other than where soil is being placed in a landfill), taking account of the potential for contaminant movement into aquatic systems.

5.2.1 Considerations enabling the beneficial use of lightly contaminated soils

To maintain a focus on preventing the formation of contaminated land while enabling beneficial use, it might be useful to consider placing controls on the source of soils for which beneficial use should be enabled. Specifically, it might be relevant to be more permissive for soils generated from ex-agricultural land (excluding that from pesticide and fertiliser storage areas), and less permissive for soils generated from industrial sites such as timber treatment sites; these latter soils would be expected to have a wider range of potential contaminants and fewer beneficial attributes associated with surface soils. Similarly, it might be relevant to be less permissive for soils resulting from excavation at depth, which would also be expected to have fewer beneficial attributes than surface soils.

Different management approaches could also be considered for essential elements, particularly copper and zinc, compared to non-essential elements. Copper and zinc are widely recognised as being essential for biological functioning (and globally there are recognised zinc deficiencies in people). Nickel and chromium also have recognised biological functions. However, arsenic, lead and cadmium have largely unknown or no biological function and are generally considered non-essential elements.

In this regard, a better approach to managing surface soils with elevated copper and zinc is to actively manage the soils for biological productivity, which can then result in a slow decrease in concentrations over time, rather than burying at depth, where limited biological activity can occur. However, some caution would need to be applied, as copper and zinc are often considered more mobile and are relatively more toxic in aquatic systems than other trace elements. Thus, appropriate controls should be placed on the use or placement of soils with elevated copper and zinc in close proximity to aquatic systems (surface water or groundwater).

Soil mixing is an approach that has been adopted to reduce contaminant concentrations in stockpiled soil to enable the use of that soil elsewhere, or disposal in a cleanfill, as opposed to disposal of that material in a Class 1 or 2 landfills. Whether this is an acceptable practice probably hinges on the extent to which mixing maintains or destroys the inherent value (in terms of biological activity and soil function) of the topsoil resource. It may also be relevant to consider the contaminant concentration range of the soils being mixed to avoid the potential creation of contaminant hot-spots. In assessing the suitability of soils for beneficial use or disposal to cleanfills, it could be appropriate to consider average concentrations of a stockpile, as well as maximum concentrations in individual samples.

However, a potentially significant barrier to enabling the beneficial use of lightly contaminated soil is the requirement under the NES-CS that soil be removed to an *authorised* facility. While there is no specific definition of what constitutes an authorised facility in the NES-SC, or in the associated *User Guide*, it is generally taken to mean some form of consented landfill. It is unclear how a more liberal interpretation of 'authorised facility' could be specified in regional plans to enable beneficial uses such as imported topsoil for residential, commercial or industrial sites, or for landscaper suppliers.

5.3 Options for revised 'cleanfill' criteria

There are a number of choices that can be made in establishing criteria for landfills. Each one is technically correct but reflects a different level of conservativeness. Cleanfill is traditionally based on an upper limit of background concentrations, although Cavanagh (2013a, 2015) proposed criteria based on protecting the most sensitive receptor (people or soil biota) and allowing for a buffer to ensure that exceeding a cleanfill threshold by a minor margin does not inadvertently allow for deposition of contaminated soil.

Generic Eco-SGVs developed by Cavanagh and Munir (2019) utilised the lowest median concentration for background concentrations, but the added-risk approach used allows for the incorporation of alternative (e.g. higher) background concentrations that might be more relevant in a regional or localised context. Further, Eco-SGVs were developed for different land uses based on differing levels of protection. The Eco-SGVs for non-production land and agricultural production land both allow for unrestricted use of a site but provide different levels of protection: non-production land provides protection for 95% of plant species, while agricultural EcoSGVs provide protection for 95% of plants and 80% of microbes and invertebrates. As both allow for the unrestricted use of land, they can both be used to develop 'cleanfill' criteria. Human health criteria are based on soil contaminant standards (SCS) for rural residential land use.

All of these criteria are shown in Table 9. Following Cavanagh 2015, the most sensitive receptor should be used to establish cleanfill criteria.

In the context of avoiding illogical outcomes described in the previous section, and enabling the beneficial use of lightly contaminated soil, it is debateable whether the use of a buffer, as described in Cavanagh 2015, is still appropriate.

It should be noted that the previous approach of Cavanagh (2015), and some of the options proposed here, is more akin to the approach used for setting waste acceptance criteria for the Class 4 landfills, as outlined in the *Technical Guidelines*. Given that Classes 4 and 5 are intended to have unrestricted land use after the activity has ceased and appear to have minimal differences in the requirements, an optimal approach might be to effectively combine Classes 4 and 5 but adopt more stringent criteria (e.g. background concentration, where there is a need to place a landfill in sensitive location, such as close to waterways).

Ultimately, the development of appropriate revised 'cleanfill' criteria depends on the policy and planning context in which they are intended to be used, which is currently being considered by TDC.

Table 9. Options for revised cleanfill criteria[1]

Element	Median[2] (mg/kg)	95th percentile[2] (mg/kg)	Revised Eco-SGV criteria[3] mg/kg)	Regional median[4] (mg/kg)	Regional 95th percentile[4] mg/kg)	Regional Eco-SGV[5] (mg/kg)	Human health[6] (mg/kg)
As	2.1	8.9	17 (18)	1.1 – 3.6	7.4–9.5	16 (17)	17
Cd	0.05	0.05	1.5 (1.5)	ND	ND	1.5 (1.5)	0.8
Cr	6.7	29	190 (300)	50-84	203-290	220 (355)	290
Cu	8.6	41	100 (220)	12-20	32-55	105 (225)	NL
Pb	6.8	25	280 (530)	7.9-12.4	16-20	280 (530)	160
Ni	4.4	25	ND	10-17	26-154	ND	130
Zn	25	102	170 (190)	34-48	72-92	180 (200)	NL
DDT residues	NA	NA	1.1 (1.9)	NA	NA	1.1 (1.9)	45

[1] Criteria could be based on upper limits for background concentrations or the lowest of the relevant Eco-SGV and human health criteria. Note that higher naturally occurring concentrations, particularly for Ni and Cr, may be present in areas influenced by the Dun Mountain Ultramafic group - refer to Table 5 for more detail.

[2] Based on the lowest median and lowest 95th percentile concentrations (i.e. more conservative values) determined by Cavanagh et al. (2015). Note: the 99th percentile was not calculated in this work.

[3] Based on 95% protection for all receptors and the lowest median background concentration determined by Cavanagh et al (2015). Criteria shown in brackets are the agricultural criteria, which provide 95% protection for plants and 80% for microbes and invertebrates.

[4] Based on preliminary analysis: the range is for the dominant geological groups underlying the existing land use shown in Table 4. Further analysis is still required to develop more robust estimates, particularly for delineating areas with naturally elevated concentrations.

[5] Based on the lowest regional median concentration determined in this study and 95% protection for all receptors from Cavanagh and Munir (2019). Criteria shown in brackets are the agricultural criteria, which provide 95% protection for plants and 80% for microbes and invertebrates.

[6] Soil Contaminant Standard for rural residential land use.

ND = not determined; NL = not limiting; NA = not applicable as not a naturally occurring substance, but ambient concentrations are often specified as being 0.48 mg/kg based on Gaw 2003.

6 Conclusions

This report has provided a technical update to the previously derived interim cleanfill criteria (Cavanagh 2015). The updates incorporate regional background concentrations based on national estimates developed by Cavanagh et al. (2015) and recent sampling by GNS Science in 2017, and ecological criteria using those provided in Cavanagh 2019a.

For background concentrations this suggests some changes to upper limits from those previously developed from a limited sampling set. However, further work is currently being undertaken by GNS Science and Manaaki Whenua – Landcare Research that will further develop national estimates of naturally occurring (background) concentrations, which would be relevant to consider. This research is anticipated to be completed by 30 June 2022. Regardless, the current study has confirmed that there are areas in the Tasman District, outside of the recognised Dun Mountain mineral belt, where soils are naturally elevated in nickel, chromium and, to a lesser extent, copper. These elevations probably represent the ‘downstream’ influence of geological materials derived from this mineral belt through erosion and pedological processes. Further analysis of the data from the 2017 GNS Science sampling programme may help to better delineate the areas of elevated concentrations, although it is likely that additional sampling and analysis are also required.

Ecological criteria were updated using Eco-SGVs for non-production land and agricultural production land. These provide different levels of protection for soil biota, but are not considered to restrict land use in any way. There is a proposal for a future Envirolink large advice grant (LAG) that intends to further evaluate the policy aspects to be considered for the application of the Eco-SGVs, including what the appropriate level/s of protection might be. The current project provides a useful illustration of the potential application of the Eco-SGVs and specific aspects that could be considered. The LAG would also help to test some of the thinking outlined in this report, which in turn could help TDC further develop their thinking on the appropriate management of potentially contaminated soils.

Various options for revised ‘cleanfill’ criteria are presented here and represent more or less precautionary values that could be selected, depending on the policy and planning context in which these numbers are applied; TDC is currently considering this in their plan change revisions. In considering the context of application, some focus should be given to enabling the beneficial use of lightly contaminated soil in recognition of the value of (particularly) topsoils (0–30 cm). This would also help meet central government aspirations to move towards a more circular economy. It may be appropriate to consider some form of source control to ensure that any more permissive criteria to enable beneficial use are not abused, and the value attributed to surface soils is realised.

Finally, the report raises a question about the relevance of having separate classes for Class 4 (controlled fill) and Class 5 (cleanfill), given that both landfill types are not intended to impose any restrictions on future land use. At a national level it would be relevant to consider whether there is merit in combining the proposed Class 4 and 5 landfills into one class, with waste acceptance criteria based on ensuring protection of the most sensitive receptor (people or ecological receptors). More stringent criteria could apply where these landfills might be placed in more sensitive environments (e.g. close to waterways or groundwater).

7 Recommendations

- It is important to recognise that work is being undertaken, or is imminent, that would be relevant for TDC to consider before adopting any of the revised criteria outlined in this report. This current or imminent work relates to the further development of national estimates of naturally occurring concentrations of trace elements, based on analysis of additional samples, which will fill spatial gaps identified in previous work, and a potential LAG to undertake a policy evaluation of the application of the ecological soil guideline values.
- Further evaluation (including data analysis and additional sample collection) should be carried out to delineate areas of, and establish appropriate criteria for managing soils with, naturally elevated concentrations of copper, nickel and chromium that probably arises from the Dun Mountain mineral belt through erosion and pedological processes.
- In a policy and planning context, greater consideration should be given to enabling the use of potentially contaminated soil, and to recognising these soils (particularly surface soils) as potential resources rather than waste. Following on from this, greater attention should be given to defining potentially contaminated or contaminated soils in relevant policies and plans.

8 Acknowledgements

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Appendix 1 – Overview of approach to determining background concentrations by Cavanagh et al. 2015

Cavanagh et al (2015) compiled data on selected trace element and organic contaminant concentrations from regional council soil quality monitoring data and regional studies to determine background soil concentrations. Additional data from a grid-based soil geochemistry sampling programme in Southland and Otago, conducted by GNS Science (Rattenbury et al. 2014), were also used. Data from only the most recent sampling of a given site were used for subsequent data analysis.

The statistical package R was used to assess the influence of land use and individual pedological and geological parameters on the key trace elements (arsenic, cadmium, chromium, copper, lead, nickel, and zinc) using regression analysis, after initial testing for spatial correlation of the data for each data set. Final estimates of background concentrations were based on the two data sets (regional council data and GNS Science Southland–Otago data) being combined, and aggregating some land-use classes to provide a larger background data set that was subsequently analysed using regression analysis, after initial testing for spatial correlation of the data.

Generalised Least Squares modelling was used to develop predicted concentration distributions. A rock-group-based parameter, Chemical4 (derived from QMAP groupings), was found to provide the best fit for the combined data and was used to generate predicted background concentration distribution (described by the effective median, 5th and 95th percentile estimates) for the individual trace elements.

These predictions provide a first-pass estimate of trace element background concentrations across most of New Zealand. Predictions for Chemical4 subgroups with few underlying samples ($n < 30$) are considered less reliable and for $n < 10$, unreliable.

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

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

Appendix 2 – Overview of the method for deriving ecological soil guidelines values

The following excerpt is taken from Cavanagh 2019a.

9.1.1 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

9.1.2 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[5] 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 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

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

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[6] 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)

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

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
- 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