Manaaki Whenua
Landcare Research

Review: Soil replacement or retention requirements of unitary and territorial authorities and their adequacy from an ecosystem services perspective

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Executive summary

The Parliamentary Commissioner for the Environment requested Manaaki Whenua – Landcare Research collate information on the proposed and operative requirements of councils from the most populous cities of New Zealand, as well as relevant national documents, relating to topsoil/soil specifications for residential developments. This commentary summarises key findings and discusses potential impacts on key ecosystem services including storm-water retention and the life-supporting capacity of urban soils.

Council plans rarely specified topsoil depth under residential developments. Instead, such specifications were contained in council-related documents, e.g. regional codes of practice for subdivisions. Specifications were more common for topsoil under council assets than non-council assets. Required depths were shallower under grass (50-300 mm) compared to trees (450-1000 mm) and other planted areas (100-500 mm). Specifications for soil protection during development were included in less than half of the documents reviewed.

Definitions of topsoil and/or soil were included in only 5 (of 39) documents reviewed although 16 documents included specification of topsoil and/or soil properties. There was considerable variation in the specifications between the documents reviewed, and many documents included ill-defined terms and components, e.g. 'organic matter' and 'base material that can sustain growth'. Most guidance documents did not define or specifically refer to rooting depth or root zone, an important component for the provision of trees and perennial woody plants.

A greater level of ecosystem services can be provided by deep topsoils (c. 300 mm) combined with deep, freely drained rooting depths. These two characteristics underpin versatile and productive soils that allow a wide range of plants, including larger plants, to thrive. However, most soil specifications for urban grassed areas – the most extensive topsoiled areas in urban developments – specify shallow topsoils that are vulnerable to drought in summer/dry periods and to water-logged conditions in winter/wet periods. Deeper soils are needed for drought-resilience and attenuation of stormwater from extreme weather events as well as to physically support and anchor trees. Furthermore, the cost of retrofitting green infrastructure is reduced when topsoil and rooting depths are already sufficient to support the growth of large trees. Specifications for urban soils used for food or fibre production were not found in any of the documents reviewed.

The National Environmental Standard for Assessing and Managing Contaminants, as well geotechnical requirements can strongly influence the management of soils in residential developments. In particular, these factors can lead to the generation of surplus soils (soils that are generated through land development processes and primarily end up in landfill), and creation of residential areas with thin soils with low versatility for plant growth. Geotechnical requirements and greenfield residential

developments have been identified as important drivers of surplus soil generation, along with infrastructure development.

We suggest that to develop a higher level of ecological services in residential subdivisions, urban soil specifications should be developed that:

- use consistent national terminology and reduce the variation in both definitions and specifications across regional and TLAs
- better specify soils (and root zones) that enable deep rooted tree growth and attenuation of large rainfall events
- are future-proofed and therefore require minimum topsoil depth and rooting depths under most greenspaces that provide for 'more than grass' and greater ecosystems services (e.g. flood and drought resilience and food production). This would also decrease the cost of future green infrastructure retrofits and urban food production.

1. Background

The Parliamentary Commissioner for the Environment is enquiring into the drivers of the practice of soil stripping in residential development and its potential impact in terms of the stormwater retention and life-supporting value of urban soil. To assist in this evaluation the Commissioner contracted Manaaki Whenua — Landcare Research to collate selected councils' proposed and operative requirements relating to topsoil/soil, covering the most populous cities in New Zealand.

The requirements reviewed are those that apply to residential subdivisions (e.g. through district plan provisions, subdivision codes of practice or equivalent and they were tabulated in a spreadsheet. These requirements include reserves and streetscapes, and stormwater infrastructure within large-scale residential subdivisions. They also include requirements from other relevant authorities (e.g. Auckland Transport and Waka Kotahi – NZ Transport Agency) relating to elements within road corridors in, or adjacent to, subdivisions. Requirements outlined in NZS4404:2010 *Land Development and Subdivision Infrastructure* have been included because they contain national criteria for the design and construction of land development and subdivision.

Information from the following unitary and territorial local authorities was collated, representing Tier 1 urban environments, as defined under the National Policy Statement for Urban Development: Auckland Council, Waikato District Council, Hamilton City Council, Tauranga City Council, Western Bay of Plenty District Council, Waipā District Council, Wellington City Council, Hutt City Council, Upper Hutt City Council, Porirua City Council, Kāpiti Coast District Council, Christchurch City Council, Selwyn District Council, and Waimakariri District Council.

Relevant documents from Auckland Transport and Waikato Local Authority Shared Services were reviewed where they related to the development of infrastructure within urban residential areas. A full list of documents reviewed is provided in Appendix 1.

This memorandum accompanies the spreadsheet file and provides commentary on the measures of soil/topsoil quality used, how these vary, and the implications for ecosystem services provided by green spaces, specifically:

- suitability for growing trees and other large vegetation, which contribute disproportionately to the moderation of peak temperatures (heat island effect) and noise, the filtering of air, attenuation of stormwater, and the provision of biodiversity and wellbeing

- stormwater infiltration, detention, retention, and filtering[1]
- wastewater application, whereby the soil filters wastewater (although this is generally restricted to large lots, older residential areas without central sewage schemes, and peri-urban areas)
- drought resilience and reduced irrigation requirements
- food/fibre/rongoā production, particularly in community gardens and urban farms[2].

A brief commentary on how the National Environmental Standard for Assessing and Managing Contaminants (NES-SC), the Hazardous Activity and Industries List (HAIL), and NZ4431:2022 ('Engineered fill construction for light-weight structures') interact with soil disturbance through residential sub-division is also provided.

2. Key findings

Three types of documents were reviewed:

- council plans – proposed and operative
- council-related documents that accompanied plans (e.g. codes of practice)
- national documents (e.g. NZS4404:2010).

These contained varying levels of detail and specification for topsoil depth under a range of vegetation types. They are summarised in Table 1 and discussed in the following subsections. Appendix 1 details which documents fall into which category.

Table 1. Documents reviewed that specified topsoil depth under vegetated areas in urban developments, and details on topsoil use in urban developments. Ranges of specified topsoil depths are given for each vegetation type alongside the number of documents that included specifications.

		No. of council plans (n = 20)	No. of council-related documents (n = 17)	No. of national documents (n = 2)
Council assets	Grass specifications	0	14 (50–300 mm)	2 (100 mm)
	Tree specifications [a]	3 (500–1000 mm)	9 (450–1,000 mm; 8 to >15 m^3)	2 (1,000–2,000 mm)
	Other planted area specifications	1 (400 mm)	10 (100–500 mm)	1 (300 mm)
Non-council assets	Grass specifications	0	10 (50–300 mm)	1 (100 mm)
	Tree specifications [a]	0	6 (450–1,000 mm; (>15 m^3)	1 (1,000 mm)
	Other planted area specifications	0	7 (100–500 mm)	0
Definition of soil/topsoil		1	3	1
Properties of soil/topsoil		1	13	2
Specification of soil protection		7	8	2
Specification of root zone soil protection		1	1	0
Specification of compost addition		0	4	1
Specifications for stormwater devices [b]		1[c]	2	1

[a] Tree specifications may include both topsoil depth and volume.

[1] Infiltration: movement of water into a soil; filtering: linked to water purification; retention: water stored in soil against gravity.

[2] For example, www.urbanforaging.co.nz.

[b] This work has only captured stormwater device specifications where they are contained in the primary documents reviewed alongside other topsoil depth specifications.

[c] Does not specify topsoil depths, but does specify that a permeable nature is needed in planted areas for stormwater purposes.

2.1 Definitions vary

Definitions and terms used to describe soil and/or topsoil vary considerably across the documents assessed. Plans and specifications may also include components that are not defined (e.g. 'organic matter', 'humus', 'manure', 'mature compost', and 'base material that can sustain growth' (NZS4404:2010, *Upper Hutt City Council Code of Practice for Civil Engineering Works*), or 'base soil' (*Waipā District Development and Subdivision Manual 2015*[3], Waikato Local Authority Shared Services' *Regional Infrastructure Technical Specifications 2018*).

Descriptions of soil may include separate specification of the layers forming a soil profile, such as mulch or erosion fabrics (Figure 1), underlying sands (sometimes used as filter layers), gravels and/or drainage layers. Including these layers is important because they can provide, enhance, or protect specific ecosystem services. For example, organic mulches can provide habitat for soil organisms and enhance plant health, reduce supplemental irrigation, attenuate stormwater contaminants, and increase resilience to surface compaction.

Most guidance does not define 'rooting depths' or include reference to specific root zones, which for deeper rooted plants includes weathered soil layers that occur naturally below topsoils and are not enriched in organic matter (unless an Organic Soil, such as peat). This absence of specification is most clearly shown in guidelines from several councils, including Kāpiti Coast District Council and Waka Kotahi's NZTA P39 requirement for 1,000 mm of 'topsoil' for tree pits and replaced tree root zones. Specifying subsoil properties within the desired 'root zone' depth is important to deliver ecosystem services that require 'more than topsoil'. Leake and Haege (2014) explain the problems created by placing topsoil, particularly compost-enriched topsoils, at depths where air exchange is slow and/or water can pond. In both cases the risk of anaerobic soil conditions and consequent plant stress is increased. This is why they recommend earth-worked greenspaces that support gardens, shrubs and trees should have root zones made from topsoil over subsoils (Appendix 2). If a root zone depth is not specified, topsoil is likely to be placed over un-ameliorated subgrade fill which typically has low permeability, low pore space, minimal ability to store or retain stormwater and, high soil strength. Roots cannot enter such materials unless they are de-compacted. When the topsoil depth over such subgrade materials is shallow, only short, shallow-rooted plants that are tolerant of drought and water-logging can thrive (e.g., pasture and flat weeds). Waterlogging can be reduced by sloping and cambering surfaces and/or adding artificial drainage.

Waikato Local Authority Shared Services is one of the few authorities that distinguish topsoil from underlying soils (166 mm topsoil plus 166 mm 'base soil' for landscape bedding), and supports these guidelines with cross-sections (Figure 1). They are also one of the few authorities to provide a specification for making 'modified backfill soil' using suitable on-site topsoil[4] (i.e. by adding sand and council-approved compost). Both features support the reuse of on-site soils instead of their removal and replacement post-development. Specific guidance has also been developed to support the identification and reuse of suitable subsoils elsewhere; Ross (2007) developed such guidance for the Auckland region.

[3] The Waipā District Development and Subdivision Manual 2015 has been superseded by the Waikato Local Authority Shared Services' Regional Infrastructure Technical Specifications 2018 and formed the basis of the specifications now contained in the Regional Infrastructure Technical Specifications.

[4] Defined as 'good quality, friable topsoil from the site'.

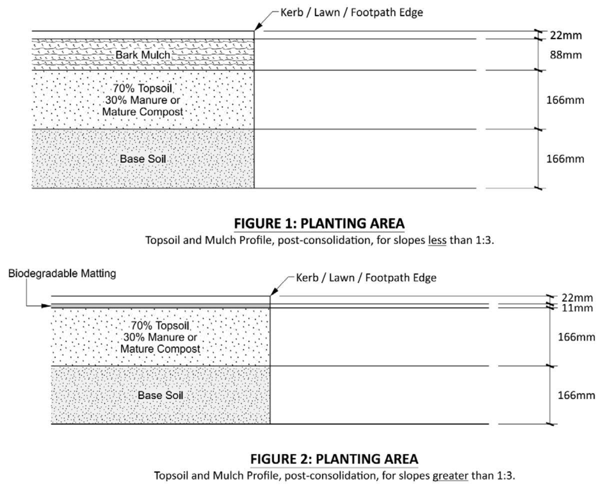

Figure 1. Diagrams for planting areas from *Waikato Local Authority Shared Services' Regional Infrastructure Technical Specifications 2018* **specifying the layers and depths required for planting areas, depending on the gradient of the planting area.**

2.2 Standards, specifications, and guidelines for topsoil/soil quality vary

Soil standards are highly variable across the council documents assessed. Most guidance documents do not appear to require explicit verification that soils meet the required standard.[5] An exception is Waka Kotahi's NZTA P39, which specifies the sampling method to be used for soils (section 3.2) and the person/s responsible for assessing and approving the soils used in landscaping.[6]

Some specifications in council documents also lack clarity; for example, 'first grade topsoil', 'first quality topsoil', 'loam of good quality', 'high quality loam', 'loam topsoil', 'friable'[7] and are rarely linked to the intended function of the soil. In contrast, some descriptors more clearly describe important soil criteria; for example, 'fit for purpose' (providing the purpose is well defined), 'biologically active', 'free of undesirable material', 'fertile' 'capable of supporting vigorous growth', 'free of weeds, straw or herbicide residue' (taken from the *Auckland Design Manual 2021* and the *Auckland Transport Code of Practice*). Further direction (detailed in the accompanying spreadsheet) is given in the *Auckland Design Manual 2021* about specific measures of these properties, and requirements for soil testing (if sourced on-site), or approval by council (if sourced off-site).

Guidance is included in some specifications; for example, Auckland Transport requires a 'medium sandy loam texture' and NZTA P39 requires 'sand (20–75%): silt (5–20%): clay (5–30%)'. However, such guidance can reduce the use of local soils in areas where soils with these specifications are not readily available, or lead to unsuitable amendments being used to bring a local soil up to specification. For example, Auckland has few natural sandy loams, but it does have crumb-structured, free-draining clay loams (e.g. Granular Soils found around Pukekohe and Mangere) and silt loams (e.g. Allophanic Soils

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[5] Although in some cases specific manufactured or supplied soils or soil components (e.g. mulch or compost) are 'approved' by councils.

[6] For example, 'the Contractor shall obtain a sample load of not less than five cubic metres (or similar approved sample) for inspection by the landscape architect. The accepted sample is to be retained on side for comparison with subsequent loads. Prior to inspection the sample must have been analysed... (by a New Zealand laboratory).'; 'Topsoil, whether existing site topsoil or topsoil proposed for use on the site, shall be tested... The Contractor shall provide a report from the soil testing laboratory and topsoil analysis of physical and chemical properties as below. Samples for analysis shall be representative of the soil being offered and 10 equal samples shall be taken and well-mixed. From this mixture a 1 kg sample shall be sent to the analyst...'.

[7] 'Friable' has a specific meaning in soil description, referring to a failure class that describes soil consistence (Milne et al. 1995), but it is unclear if guidance documents mentioning 'friable' soil/topsoil are referring to this definition or to a generally crumbly structure.

found scattered across Auckland) that have similar permeability and could be suitable for stormwater devices such as rain gardens.[8]

Specifying soil permeability or drainage characteristics, rather than texture, provides greater certainty of required stormwater treatment and plant growth. This specification complements a description of the desired outcome. For example, *Hamilton City Operative District Plan 2023* states that 'planting areas' shall be 'of a permeable nature for stormwater purposes'. Waipā District Council requires a 'free-draining loam'. Note that delivery of ecosystem services such as stormwater management is supported by specifying a permeability range (Fassman et al. 2013).

Many specifications do not specify the composition of 'topsoil', which is particularly important for trees. While most natural topsoils have moderate levels of organic matter (c. 20% by volume), and this is stable, manufactured topsoils may have high volumes (>40%) of organic matter provided by adding composts. Some plans specify 50% compost amendment (by volume) to replaced topsoils (e.g. Waikato Local Authority, Western Bay of Plenty DC, Selwyn DC, Waimakariri DC, Waipā DC).

However, no specifications provide an upper level of organic matter, and high proportions of compost (i.e. more than 5–8% by weight, or c. 30% by volume, depending on the rate of decomposition or recalcitrance of the organic matter and ongoing inputs from living plants[9]) are unlikely to be sustained in a perennial landscape unless soils are wetlands (where decomposition is slowed by anaerobic and acidic conditions), or there are regular organic inputs (e.g. annual beds). Excess organic matter content in topsoils mean soils shrink over time as organic matter decomposes and is not replaced. It also means the depth of soil reduces over time and the amount of water stored in soil may decrease. These effects are exacerbated where thin topsoils (e.g. 100 mm) are placed on compacted or low-permeability soils that create perched water tables and/or do not enable root penetration, as both increase plant stress.

Shrinkage of soils with high levels of organic matter is exacerbated in tree pits if the whole profile is 'topsoil'. Also, high organic matter subsoils can be harmful, because organic matter increases consumption of oxygen by decomposing organisms. Such depletion is more severe at depth due to slower oxygen diffusion through soil pore spaces and is exacerbated if drainage is poor (because diffusion through water is much slower than through air) (Leake & Haege 2014).

2.2.1 Depths and soil profiles required for different landscaping vary

Grasses have shallower root systems hence can grow well in thinner soils whereas, deeper soils are needed for shrubs and trees to thrive. Soil depths and profiles required in plans and standard can be linked to the asset owner (i.e. council or developer/private land), the location, and/or the landscape asset being established. Specific soil depths are most commonly linked to the function of supporting plant growth, and less commonly to other functions, such as temporary erosion control (e.g. Waikato District Council's *Erosion and Sediment Control* guidelines).

Soil specifications for road corridors or berms are commonly differentiated from other planted areas. Clarity about soil depths for different berm landscape assets is provided by cross-sections showing soil placement on different slopes adjacent to kerbs in some districts (Figure 1). The categories of landscape assets on berms and other areas include:

(a) 'grass' or 'grassed area';

(b) 'garden beds', 'shrub beds', 'landscape bedding', 'annual bedding', and 'amenity planting', and;

(c) 'tree' or 'tree pit'.

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[8] Ross (2007) also recommended identification and salvage of permeable subsoil horizons for use in green spaces and stormwater devices.

[9] Different soils, plants, and climates can sustain different levels of organic matter.

Landscaping could include multiple assets (e.g. 'revegetation planting', 'park', 'open space' or 'urban subdivision').

Topsoil/soil depths for grassed areas are typically – but not always – substantially shallower than those for other assets. Grass is typically required to be placed on 75, 100, or 150 mm topsoil.[10] An exception is the *Auckland Design Manual 2021*, which requires a minimum 250 mm topsoil for council grass assets and 300 mm topsoil for 'parks'. Topsoil specifications for garden beds and areas with shrubs are typically twice the depth of topsoil (i.e. 75 mm under grass becomes 150 to 300 mm in Waikato, Wellington, and Christchurch; 150 mm under grass becomes 500 mm in Auckland Transport's 'amenity plantings'). Topsoil depth requirements typically increase again for trees to between 450 and 1,000 mm, and this may be combined with minimum rooting volumes.

In terms of providing certainty versus direction and setting soil standards, some codes provide minimum or recommended standards, as well as 'ideal', or 'nice to have' topsoil depths. Terms such as 'shall' and 'must' provide certainty in plans, while words like 'should', 'consider', 'ideally' and 'recommend' provide direction but not absolute specification. For example, the *Auckland Transport Code of Practice 2013* states that berms in grass should have 'settled' topsoil depth of 150 mm minimum, 'ideally 250 to 350 mm.' The minimum soil volume for trees is 8 m^3, but 10 m^3 is recommended, and '(where possible) 15 m^3 or greater'. Although allowing smaller soil volumes may allow trees to be included in areas that would otherwise be treeless, these smaller volumes risk increasing tree stress (particularly drought stress) and restricting tree growth (i.e. smaller trees) unless factors such as drought are otherwise ameliorated (e.g. by passive watering from stormwater or by irrigation).

Another risk with specifying minimum depths is that these depths and associated volume become the default design, particularly when a large rooting volume is expensive to create. In these conditions, particularly where soil conditions outside the planted pits prevent root growth, only small trees (e.g. ornamental cherries) and/or trees tolerant of restricted root zones (e.g. pōhutukawa) can be planted that are likely to thrive.[11] However, some soils and tree pit designs enable tree roots to grow into adjacent favourable soils, increasing tree resilience; in sites with older infrastructure,[12] tree roots may access and exploit water, drainage, and/or waste-water infrastructure to overcome restrictions imposed by small root volumes – which is beneficial for trees but not necessarily desirable for infrastructure maintenance.

Deeper topsoils and rooting depths (and larger root volumes) typically support vegetation that delivers a greater range and 'intensity' of ecosystem services. Some ecosystem services are primarily provided by soils (e.g. soil biodiversity resides largely in the soil and organic mulch layers, where present), while others are primarily delivered by the plants the soils support. Maximum topsoil or soil depths were not specified in any document, although some documents identify limitations imposed by steeper slopes (e.g. mulches are replaced by erosion matting on steeper slopes; Figure 1), and maximum mulch depths are often included. Topsoils can be retained on steeper slopes using specific surface treatments to encourage 'keying in' (e.g. scarification or roughening subsoils, or creating planting pockets), specialised engineering treatments (e.g. terracing, gabions, and geogrids), and vegetation establishment methods (e.g. rolled sod, living 'brush' walls and fascining).

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[10] Note that topsoil depths can vary over time, depending on the level of compaction or settling, the organic matter component, and plant growth/inputs. To minimise the risk of undue settling, some specifications require soil depth to be measured 'settled' or 'compacted'.

[11] Adequate soil volumes depend on tree species and the underlying soils, climate, and whether tree roots can explore areas out of the tree pit. For example, pōhutukawa (and to some extent tōtara) can tolerate compacted, dry, restricted roots and will become small trees, whereas trees intolerant of drought (such as pūriri and beech) require much larger root systems and/or irrigation.

[12] Newer pipes are continuous plastic with few joins installed, and continuous drivers minimise loose soil trenches. Both factors limit root penetration compared with old clay/concrete pipes installed using continuous trenches.

2.3 Protection of soils, including around retained trees and vegetation

Protection of soils around trees that are retained is important for protecting the health of the trees, but is not covered in many plans. Waikato Local Authority Shared Services, and Waimakariri and Auckland Councils include protection measures for soils within the root zones of existing trees, while several other councils, including Hamilton City Council and all of those in the Wellington region, have protection measures only for soil within the root zones of 'notable' or 'significant' trees that are typically specified in district plans. The *Auckland Unitary Plan* (2023, section E16) restricts excavation under protected root zones to 10% of the protected root zone area, increasing to 20% if an arborist is present.

The (now superseded) *Proposed Auckland Unitary Plan* (2013) was the only one that contained specific rules related to managing root pathogens (specifically kauri dieback), although the national requirements for managing this pathogen, which come into effect in August 2023, will affect all councils with kauri in their jurisdiction. This national pest management plan[13] includes standards for setbacks (related to distance from the drip zone), exclusion of domestic stock, and standards of public footpaths to reduce the spread of this disease.

Waka Kotahi's NZTA P39 landscape standard (section 7.3.3) requires 'protection measures in accordance with designation / resource consent conditions, retained trees fenced and dripline and existing levels to be retained'.

Both Waimakariri District Council's engineering code of practice and Selwyn District Council's subdivision guide include statements to the effect that it is important to protect and maintain soil structure and function during soil-disturbing activities, but neither provides specific guidance or regulation on how best to achieve this. Some guidance on stockpiling is provided in Waka Kotahi's NZTA P39 specification, and the *Auckland Design Manual 2021* cross-references guidance in Auckland Regional Council's technical report 2009/083 (Lewis et al. 2010 Chapter 2).

3 Commentary on ecosystem service provision

3.1 Providing greater resilience through urban soil specifications

Deep topsoils (c. 300 mm) combined with deep, freely drained rooting depths (>600 to 900 mm, which includes topsoil depth) underpin highly versatile and productive soils (Hewitt 2004). This means a wide range of plants can be grown with lower water and nutrient inputs and a greater certainty of successful outcomes. Such highly versatile soils generally also provide greater ecosystem services than shallow, poorly drained soils, particularly services linked to regulation (climate and flood mitigation, storm runoff treatment, and carbon storage), provisioning services (food and fibre) and, by supporting trees, greater cultural services (notably well-being).

However, most soil specifications for urban grassed areas specify minimum, shallow topsoils (75 to 250 mm). When this is combined with shallow root zones (i.e. roots largely restricted to topsoil, as is typical of heavily earth-worked sites), plants are more vulnerable to drought and to waterlogged conditions, and only a narrow range can be grown successfully. Such plants are usually those that are very short (e.g. grass, herbs, succulents) and tolerant of drought. These include annual species and some bulbs that 'avoid' drought by not having leaves during summer (annuals set seed, bulbs survive below-

[13] *Biosecurity (National PA Pest Management Plan) Order* 2022 https://www.kauriprotection.co.nz/national-plan/about-the-plan/.

ground[14]). Maintaining growth in such shallow soils usually requires higher inputs (irrigation and/or fertilisation). The ecosystem services are consequently likely to be lower. Shallow rooting depths also increase the risk of trees falling over, particularly where roots cannot spread over large distances.

Further, thinner topsoil/soil for 'grassed' areas increases the cost of retrofitting green infrastructure that require greater topsoil and root zone depths to deliver the ecosystem services required e.g. for shrubs and trees. This cost of retrofitting is greatest where specified topsoil depths for grass are more disparate relative to those required for shrubs (or trees). In other words, the cost of retrofitting is higher where grass specification provides for 75 mm topsoil compared to 250 mm of topsoil. Shallow topsoil specifications for grassed areas reduce the cost of construction of grassed areas where topsoils are imported[15], while the deep topsoil requirements for trees can be a disincentive to providing for trees. This is sometimes addressed by requiring a minimum number of street trees per 100 linear metres of berm; for example, the Waikato Local Authority Shared Services *Regional Infrastructure Technical Specifications 2018* requires one street tree per residential property equivalent. We suggest a complementary approach would be to specify a minimum mature tree canopy cover, as tree canopy area provides key ecosystem services such as stormwater interception, summer heat moderation, and provision of shade, and indirectly enhances people's well-being and health. Canopy can be readily quantified and reported through aerial imagery (e.g. PCE 2023).

A canopy specification would also encourage provision of the soil volumes needed to support tree canopies, especially large tree canopies. The *Auckland Design Manual 2021* specifies a soil volume standard (which probably applies only to council assets) being 'sufficient for the lifetime of the tree'. In contrast, some other councils specify soil volumes based on the size of the container the tree is supplied in (at planting). If soils outside the tree pit are unfavourable (which is common for many earth-worked urban areas, particularly in berms), then trees planted into these small volumes are likely to be constrained.

Drought stress linked to small root volumes can be alleviated using runoff from adjacent impervious areas if trees are planted 'below-grade' (e.g. in stormwater planters or tree pits). In some cases the depth to which topsoil can be applied is limited by the cost of retaining adjacent structures (especially on berms), but in other cases topsoil depth can be increased using bunds and mounds. These features can enhance ecosystem services such as noise attenuation and traffic separation (Figure 2).

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[14] The impact of soil depth on the range of species and plant biomass is most easily shown on green roofs, where soils <100 mm depth support a narrow range of species and have increased risk of poor plant coverage, hence the Auckland guidance that new green roofs must have at least 100 mm of 'soil' (Fassman-Beck & Simcock 2013).

[15] Imported topsoils typically cost \$55 to \$105/m^3 at retail rates, plus delivery.

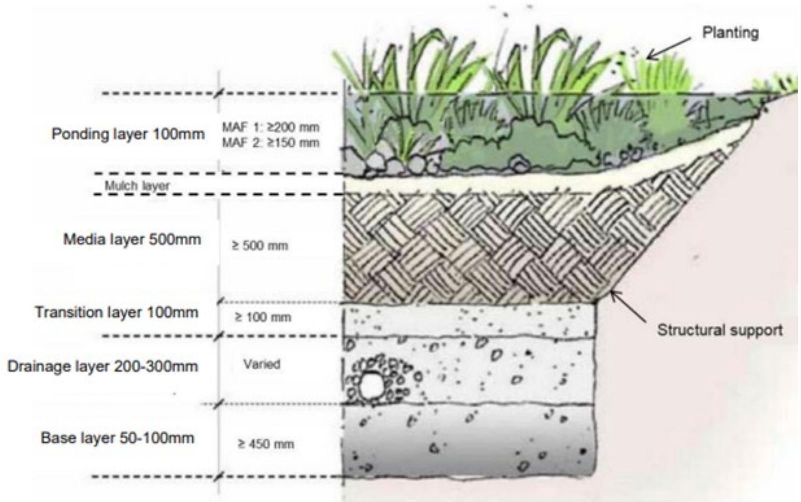
 

Figure 2. Adequate depth of soil for trees has been created in this rehabilitated quarry that now contains a residential development by using retaining walls (left), mounds edged with boulders (right), and bunds (not shown); grass has shallower soil. Stonefields, Auckland 2023.

3.2 Stormwater detention/retention

The reviewed documents mainly focussed on soil specification in relation to grass or vegetation with only three documents specifying soil depths in relation to stormwater management (Waikato Local Authority Shared Service's 2018 *Regional Infrastructure Technical Specifications*, Auckland Council's *Auckland Design Manual* and Waka Kotahi NZTA P39 Standard). However, increasingly stormwater treatment devices such as bioretention rain gardens and infiltration/detention basins are used in urban areas and residential sub-divisions for water quality and flood mitigation. These devices have separate detailed guidance on the depth, organic content, permeability, and/or void space within their 'soil' and drainage layers, e.g. Figure 3[16], that tend to be either detailed in separate documents typically not referred to by the reference documents, or make up separate chapters/sections of the reviewed council-related documents and do not contain topsoil depth specifications.

[16] For information on the life span and maintenance of such features, see https://www.landcareresearch.co.nz/discover-our-research/environment/sustainable-society-and-policy/activating-water-sensitive-urban-design-for-healthy-resilient-communities/,
particularly the report on maintenance. The six reports (without case studies, walking tours) are also found here: https://buildingbetter.nz/publications/water/activating_wsud_for_healthy_resilient_communities_discovery_phase



Item	Detention, retention and water quality device	Water quality only device
Organic matter	10–30% v/v	0.5 - 5% v/v
Plant available water	>100 mm (for 600 mm substrate depth)	>100 mm (for 600 mm substrate depth)
Saturated hydraulic conductivity (Ks)	Between 50 mm/hr and 300 mm/hr	≤1000 mm/hr
pH range	6.0 – 7.5	
Particle size distribution	100% < 25 mm 90–100% < 10 mm < 5% < 0.05 mm	
Total nitrogen	< 1,000 mg/kg	
Orthophosphate (PO43-)	< 80 mg/kg	
Total phosphorus	Leachate testing required if > 100 mg/kg	
Total copper	≤ 80 mg/kg	
Total zinc	≤ 200 mg/kg	

Figure 3. Top: cross-section of rain garden showing five different layers (each of which has a specific function and specification). Bottom: suggested rain garden (bioretention) media specifications. (Source: GD01 Auckland)

Stormwater management is provided by both plants and soil and topsoils generally store more water per unit volume than subsoils due to their organic matter content.[17] Deeper topsoils, and deeper soils generally, provide more stormwater volume attenuation for larger events than shallow topsoils, although water storage capacity can be delivered by deeper rooting depths.

In some areas such as Auckland, flood modelling takes account of soils by classifying them by hydrologic soil group (HSG)[18] using three key criteria (where available): the saturated hydraulic conductivity of the least transmissive layer, depth to water-impermeable layer, and depth to high water table. Typical large-scale subdivision practices convert HSG 1 (low runoff potential) and HSG 2 (moderate runoff potential) to HSG 4 (high runoff potential) by decreasing the depth to a water-impermeable layer (Gregory et al. 2006; Burford 2008; Simcock 2009). Stormwater models also take account of the surface cover; short covers such as grass create runoff earlier and/or from smaller events than tall covers such

[17] An exception is Pumice Soils, which can store water within pumice grains, and coarse-textured subsoils with large void spaces, which can temporarily store water before it drains under gravity (e.g. 'structural soils' used in some stormwater devices).

[18] The method to define HSG is specified in USDA NRCS (2009). Current HSG Maps of Auckland combine HSG 3 and 4, yielding three classes (Burford 2008).

as trees. Hence applying topsoil at a depth only sufficient to support grass exacerbates stormwater runoff.

3.3 Food and fibre production

Specifications for urban soils used for food and fibre production were not found in any of the documents reviewed. Many fruit trees and crops have specific rooting depth and drainage requirements and are irrigated to reduce the adverse effects of drought on production (Hewitt 2004). General landscaping or tree requirements may also support soils for food and fibre production. However, in many cases, areas with 'minimum' topsoil specification for grass could require substantial investments to upgrade them to the quality required for food production, particularly where topsoils are less than 300 mm depth, root penetration is less than 600 mm depth (900 mm for crops needing well-drained soils, such as avocados and stonefruit), and/or drainage is unsuitable.

4 Soil contaminants and geotechnical considerations for residential developments

The NES-SC regulations apply to land that is being subdivided or undergoing a change in land use (e.g. from primary production to residential), where it is identified that land is having, has had, or is more likely than not to have had, an activity or industry described in the Hazardous Activities and Industry List (HAIL) (MfE 2011a; 2023) on it. The HAIL includes some categories that can specifically apply to greenfield residential developments, including:

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

There is great variability among environmental consultants and councils as to when category I applies, which can result in more or fewer sites being identified as HAIL.

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

A particularly problematic clause of the NES-SC appears to be 5(9), which states:

> *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 clause was ranked as the third most important driver for the generation of surplus soils (soils generated through land development processes and unable to be used on-site) at a recent workshop held with a wide range of end-users, including contaminated land practitioners and local authorities; [19]

[19] Draft guidance on the sustainable management of surplus soils, virtual workshop held in June 2023 and hosted by Manaaki Whenua – Landcare Research. See appendix 1 of Cavanagh et al. 2023 for more detail.

geotechnical requirements and cleanfill criteria based on background soil contaminant concentrations[20] were considered the first and second-most important drivers for generating surplus soils. Greenfield residential developments were considered to be the second-greatest source for surplus soil generation, after infrastructure development.

There is a requirement that the land must have been identified as having, having had, or is more likely than not to have had a HAIL activity on it, for this clause to apply. However, this clause appears to often be interpreted as indicating that the NES-SC does apply to this land with concentrations above background, even if they are below any relevant human health criteria[21] or environmental guideline.

Although this clause does not necessarily lead to the additional disturbance of soil on the site over and above what was planned, capture of this soil under the NES-SC means that where soil is surplus to requirements on-site, under clause 8(3)e soil taken away in the course of the activity must be disposed of at a facility authorised to receive soil of that kind to be a permitted activity, which is commonly taken to be a landfill; if it is not a landfill, the 'facility' requires authorisation.

This requirement contrasts with the discretion allowed in transport, disposal, and tracking of soil and other materials taken away in the course of the activity under controlled, restricted discretionary or discretionary activities (Regs 9–11). Further discussion on the NES-SC in the context of 'surplus' soils – and also noting issues arising from institutional arrangements in the management of contaminated land under the Resource management Act and Natural and Built Environment Bill – is provided in Mayhew (2023). Further, where soil concentrations of key contaminants are above background concentrations, the soil is no longer eligible for disposal at cleanfills that use background concentrations as waste acceptance criteria[22] (e.g. WasteMINZ 2022).

As noted above, meeting geotechnical requirements is a key issue resulting in the generation of surplus soils: the standard NZ4431:2022 'Engineered fill', specifies the geotechnical criteria associated with engineered fill for residential developments. Topsoil is identified as a natural material that comprises the O and A horizons, as specified in the *Australian Soil and Land Survey Handbook* (National Committee on Soil and Terrain 2009). Thereafter, materials are defined based on their texture and condition. The condition assessment also includes 'unsuitable' materials based on either physical or chemical (primarily soil contamination) properties.

5 Recommendations

To develop a higher level of ecological services in residential subdivisions, urban soil specifications should be developed that:

- use consistent national terminology and reduce the variation in both definitions and specifications across regional and TLAs
- better specify soils (and root zones) that enable deep rooted tree growth and attenuation of large rainfall events,
- are future-proofed and therefore require minimum topsoil depth and rooting depths under most greenspaces that provide for 'more than grass' and greater ecosystems services (e.g. flood and drought resilience and food production). This would also decrease the cost of future green infrastructure retrofits and urban food production.

[20] See WasteMINZ 2022 for further information on landfill waste acceptance criteria.
[21] In particular, the Soil Contaminant Standards specified in MfE 2011b.
[22] Different waste acceptance criteria for cleanfill have been adopted by different councils, including those based on the most sensitive human health or ecological receptor (WRC 2022).

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Appendix One: Documents reviewed

Council/authority	Document title and year	Document type	Link
Auckland Council	*Auckland Unitary Plan Updated 2023*	Council plan	https://unitaryplan.aucklandcouncil.govt.nz/pages/plan/Book.aspx?exhibit=AucklandUnitaryPlan_Print
	Proposed Auckland Unitary Plan 2013; replaced by *Decisions Versions 2016*	Council plan	https://unitaryplan.aucklandcouncil.govt.nz/pages/plan/book.aspx?exhibit=ProposedAucklandUnitaryPlan_Print
	Auckland Design Manual 2021	Council-related document	https://content.aucklanddesignmanual.co.nz/regulations/codes-of-practice/Documents/Auckland%20CoP%20Chp%207%20-%20Landscape.pdf
Auckland Transport	*Auckland Transport Code of Practice 2013* – Chapter 14, Landscaping	Council-related document	https://at.govt.nz/media/310048/Section_14_Landscaping.pdf
Waikato Local Authority Shared Services (applies to Waikato, Hamilton, Waipā Councils and others)	*Regional Infrastructure Technical Specifications 2018*	Council-related document	https://www.colabsolutions.govt.nz/wp-content/uploads/2019/01/Regional-Infrastructure-Technical-Specification-V1.0.pdf
Waikato District Council	*Waikato District Council Operative District Plan 2021*	Council plan	https://www.waikatodistrict.govt.nz/your-council/plans-policies-and-bylaws/plans/waikato-district-plan/operative-district-plan
	Proposed Waikato District Plan 2022	Council plan	https://www.waikatodistrict.govt.nz/your-council/plans-policies-and-bylaws/plans/waikato-district-plan/district-plan-review
	Erosion and Sediment Control: Guidelines for Soil Disturbing Activities 2009	Council-related document	https://waikatoregion.govt.nz/assets/WRC/WRC-2019/TR0902.pdf
Hamilton City Council	*Hamilton City Operative District Plan 2023*	Council plan	https://hamilton.isoplan.co.nz/eplan/rules/0/89/0/0/0/72
Waipā District Council	*Waipā District Plan 2016*	Council plan	https://www.waipadc.govt.nz/our-council/waipa-district-plan/waipa-district-plan

	Waipā District Development and Subdivision Manual 2015	Council-related document	https://www.waipadc.govt.nz/repository/libraries/id:26zgz4o7s1cxbyk7hfo7/hierarchy/our-services/planning-and-resource-consents/developmentandsubdivision/documents/Waipa%20District%20Development%20and%20Subdivision%20Manual%202015.pdf?preview=%222020-03-05T23%3A21%3A52.0507058%2B00%3A00%22&e=_8c4Mlg_TkHFvmDla5OqlY0KUC-OEMd5e3ewCkuy0zcKTuxq2GSS8o590_DlPzl9gGB3YqnXSqBtOPxrKi_A_yiTVT8c_I2hrjsDyn_0FJ8%3D
Tauranga City Council	*Tauranga City Plan 2023*	Council plan	https://cityplan.tauranga.govt.nz/eplan/rules/0/24/0/0/0/50
	Tauranga District Council Code of Practice for Development 2002	Council-related document	https://www.tauranga.govt.nz/Portals/0/data/future/strategic_planning/idc/files/2002/cop2002.pdf
	Tauranga City Infrastructure Development Code – Design Standards 2014	Council-related document	https://www.tauranga.govt.nz/Portals/0/data/future/strategic_planning/idc/files/2014/04_design_standards/04_design_standards.pdf
	Tauranga City Infrastructure Development Code – Construction Standards 2014	Council-related document	https://www.tauranga.govt.nz/Portals/0/data/future/strategic_planning/idc/files/2014/05_construction_standards/05_construction_standards.pdf
Western Bay of Plenty District Council	*Current Operative District Plan 2012*	Council plan	https://eplan.westernbay.govt.nz/eplan/rules/0/49/0/0/0/77
	2009 Development Code	Council-related document	https://www.westernbay.govt.nz/property-rates-and-building/development-engineering/development-code-2009
Wellington City Council	*Wellington City Current District Plan 2021 and Design Guides 2014*	Council plan	https://wellington.govt.nz/your-council/plans-policies-and-bylaws/district-plan/current-district-plan/district-plan-pdfs
	Wellington City Proposed District Plan 2023	Council plan	https://eplan.wellington.govt.nz/proposed/rules/0/301/0/0/0/32

	Wellington City Council Code of Practice for Land Development 2012	Council-related document	https://wellington.govt.nz/-/media/property-rates-and-building/urban-development/files/complete.pdf
Porirua City Council	*Porirua City Operative District Plan 1999* (updates dating to 2022)	Council plan	https://storage.googleapis.com/pcc-wagtail-media/documents/Operative_District_Plan_-_13_May_2022.pdf
	Porirua City Proposed District Plan 2022	Council plan	https://eplan.poriruacity.govt.nz/districtplan/rules/0/160/0/0/0/141
	Porirua City Council Code of Land Development and Subdivision Engineering 2010	Council-related document	https://ndhadeliver.natlib.govt.nz/delivery/DeliveryManagerServlet?dps_pid=IE1552129
Hutt City Council	*City of Lower Hutt District Plan Updated 2022*	Council plan	http://eplan.huttcity.govt.nz/Common/Common/terms.aspx
Upper Hutt City Council	*Upper Hutt Operative District Plan 2021*	Council plan	https://www.upperhuttcity.com/files/assets/public/districtplan/operative-district-plan/nps-district-plan-october-2021.pdf
	Upper Hutt City Council Code of Practice for Civil Engineering Works 1998	Council-related document	https://www.upperhuttcity.com/files/assets/public/services/code-of-practice-for-civil-engineering-works.pdf
Kāpiti Coast District Council	*Kāpiti Coast Operative District Plan 2021*	Council plan	https://www.kapiticoast.govt.nz/your-council/forms-documents/district-plan/operative-district-plan-2021/
	Kāpiti Coast District Council Subdivision and Development Principles and Requirements 2012	Council-related document	https://www.kapiticoast.govt.nz/media/oofdisis/subdivision_and_development_principles_and_requirements__2012.pdf
Christchurch City Council	*Christchurch District Plan* (updated 2022)	Council plan	https://districtplan.ccc.govt.nz/pages/plan/book.aspx?exhibit=DistrictPlan
	Christchurch City Council Construction Standard Specification 2022	Council-related document	https://ccc.govt.nz/consents-and-licences/construction-requirements/construction-standard-

			specifications/download-the-css/
Selwyn District Council	*Selwyn District Plan (Operative) 2016*	Council plan	https://eplan.selwyn.govt.nz/eplan/rules/0/3/0/0/0/215
	Proposed District Plan 2020	Council plan	https://eplan.selwyn.govt.nz/review/rules/0/494/0/0/0/152
	Engineering Code of Practice 2022	Council-related document	https://www.selwyn.govt.nz/property-And-building/resource-consent/subdivision/code-of-practice
	SDC Subdivision Design Guide	Council-related document	https://www.selwyn.govt.nz/__data/assets/pdf_file/0016/15163/ADOPTED-SDC-Subdivision-Design-Guide.pdf
Waimakariri District Council	*Waimakariri District Plan (Operative) 2023*	Council plan	https://waimakariri.isoplan.co.nz/eplan/rules/0/23/0/0/0/72
	Proposed District Plan 2021	Council plan	https://waimakariri.isoplan.co.nz/draft/rules/0/232/0/0/0/226
	Engineering Code of Practice 2009	Council-related document	https://www.waimakariri.govt.nz/__data/assets/pdf_file/0024/86271/Engineering-Code-of-Practice-Full-Document-July-2020.PDF
Waka Kotahi New Zealand Transport Agency	NZTA P39 *Standard Specification for Highway Landscape Treatments 2013*	National document	https://www.nzta.govt.nz/assets/resources/landscape-treatments/docs/nzta-p39-standard-specification-landscape-treatments.pdf
Standards New Zealand Te Mana Tautikanga o Aotearoa	NZS4404:2010 *New Zealand Standard for Land Development and Subdivision Infrastructure 2010*	National document	https://www.standards.govt.nz/shop/nzs-44042010/

Appendix Two: Layers of an Engineered Soil and their function. Adapted from Leake and Haege 2014.

Layer	General properties	Function
Topsoil	Permeable (friable or granular) Enriched in organic matter Biologically active with suitable nutrient reserves	Aeration Water infiltration and permeability Moisture holding, nutrient reserve Fine root anchoring
Subsoil (Root zone)	Adequate permeability Low organic matter Moisture holding	Firm root anchorage Adequate aeration Adequate permeability and moisture holding
Subgrade	No or little root entry Firm incompressible base May be permeable or impermeable	Support buildings and structures Some subgrades provide drainage and moisture reserve. Often artificially drained

Notes:

1 - The topsoil and subsoil together form the total potential rooting depth, generally.

2 - The depth of the topsoils and total rooting depth needs to increase as the mature plant height increases, i.e. shallow-rooted grasses and groundcovers can grow in shallow soils but gardens and trees require deeper soils.

3 - The subsoil layer on top of the subgrade may be manufactured from: reserved natural subsoil from the original site; site topsoil with no added organic matter; or ameliorated subgrade. Subgrades are typically ameliorated (improved) to form a subsoil by cultivation to loosen and roughen, removing non-soil debris (roots, rubbish, rock, fill), and/or applying lime or gypsum.