Appendix F - Kainga Ora Housing New Zealand Conceptual Site Model (2024)

Kāinga Ora Conceptual Site Model – Residential Properties in Hamilton City

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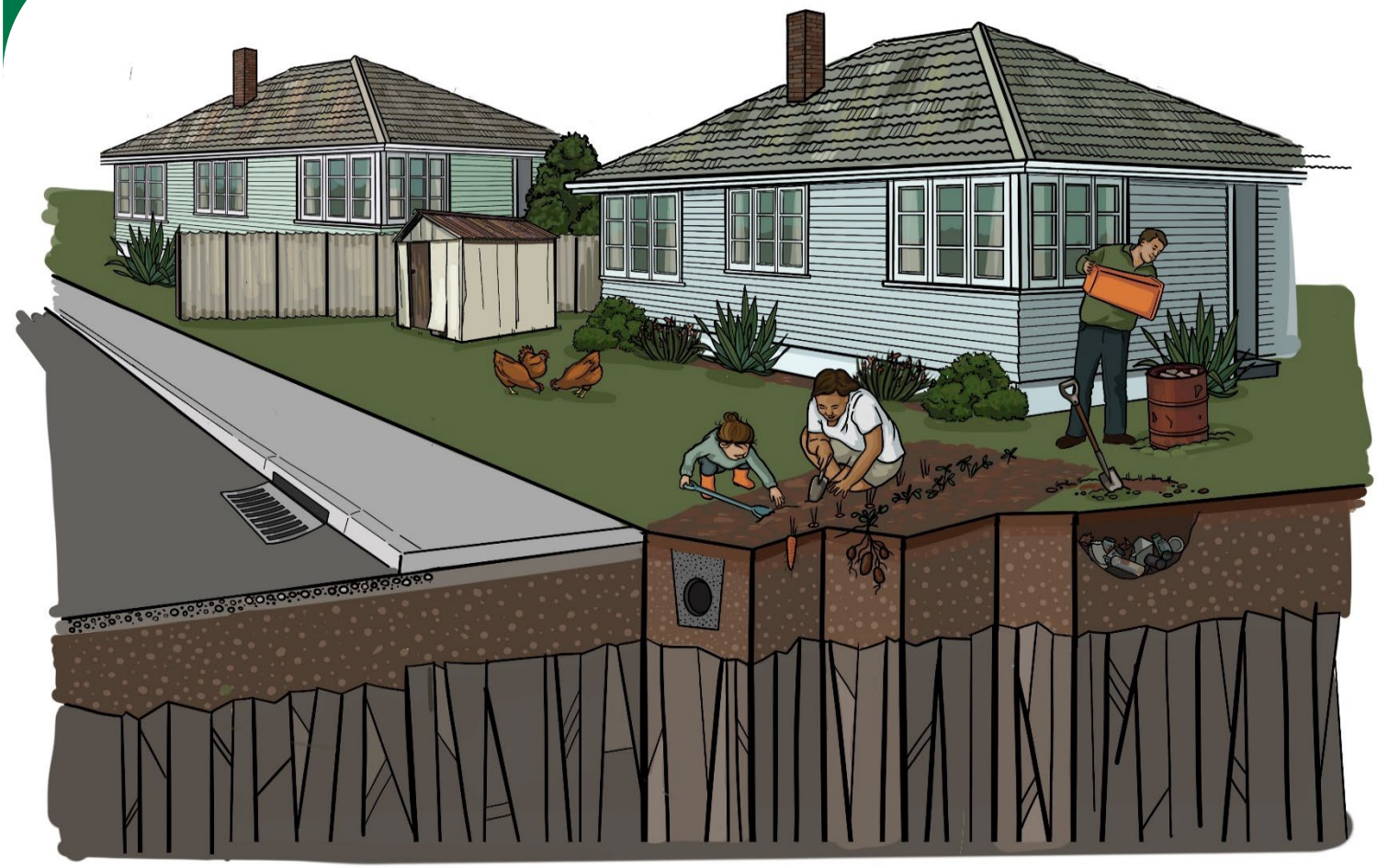

Kāinga Ora
Homes and Communities

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Acronyms

ACM	asbestos-containing materials
ATSDR	Agency for Toxic Substances and Disease Registry
bgl	below ground level
BRANZ	Building Research Association New Zealand
CCA	copper-chrome-arsenic
CLMG	Contaminated Land Management Guidelines
CoC	contaminates of concern
CSM	conceptual site model
DSI	Detailed Site Investigation
EPA	Environmental Protection Agency
GM	geometric mean
HAIL	Hazardous Activities and Industries List
HCC	Hamilton City Council
HSNO	Hazardous Substances and New Organisms Act 1996
m	meter
MfE	Ministry for the Environment
mg/kg	milligram per kilogram
MoU	Memorandum of Understanding
NES-CS	National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health
NR	not recorded
PSI	Preliminary Site Investigation
SAP	Sampling Analysis Plan
SCS	human health Soil Contaminant Standard(s)
SPR	Source-Pathway-Receptor
TEL	tetra ethyl lead
UCL	Upper Confidence Limit
USEPA	United States Environmental Protection Agency

1. Introduction

1.1. Introduction and Background

This Conceptual Site Model (CSM) for Kāinga Ora – Homes and Community (referred herein as Kāinga Ora) outlines the potential primary contaminants of concern (CoC) associated with Kāinga Ora residential properties located in Hamilton City. A Hamilton specific CSM was prepared for Hamilton City Council (HCC) to provide them with:

- Hamilton-specific information regarding contamination levels on Kāinga Ora properties.
- Further information on geogenic arsenic that may be present on some properties within Hamilton City.

This Hamilton-specific CSM is referenced in the Memorandum of Understanding (MoU) agreed between HCC and Kāinga Ora for the management of contaminated soil on Kāinga Ora redevelopment sites within the Hamilton City area.

This report reviews available data to identify potential sources of CoC and the pathways by which sensitive receptors may be exposed to these contaminants. The purpose of this document is to inform the generic sampling and analysis plan (SAP) (EHS Support New Zealand Ltd (EHS Support), 2024) for Kāinga Ora residential properties, which are going to be re-developed. This report does this by reviewing available data from Kāinga Ora investigations and literature to:

- Identify the primary CoC and the associated media to be sampled.
- Pathways that various receptors may be potentially exposed to and identifying the key sensitive receptors depending on whether the soil on the site will be re-used on another residential property or taken off-site for disposal.
- Identifying the 'typical' distribution of CoC in terms of the lateral distribution of lead from buildings and the vertical lead distribution within the soil profile. Lead is deemed a “marker” contaminant in that its spatial distribution and depth typically indicate where other elevated CoC is likely to be recorded around the dwelling.

This report has:

- Reviewed available published literature and data held by Kāinga Ora on the concentration of the CoC and their spatial distribution.
- Developed graphical spatial distribution diagrams of contaminant concentrations and a Source-Pathway-Receptor (SPR) diagram (**Attachment A**) to identify the spatial distribution, exposure pathways, and key sensitive receptors.

The above information is used to develop an understanding of the:

- Location of contamination around residential Kāinga Ora houses and the wider property.
- The key CoC.

- Identify the key receptors.

The generic CSM set out in this report is a “probability” generated model based on the statistics derived from the Kāinga Ora contamination database. From time to time this database will be updated which enable a review of the data used to generate the model. A key focus of the SAP (and the associated preliminary and detailed site investigation (PSI/DSI)) is to validate the probability based CSM.

1.2. Structure of this Report

The Kāinga Ora CSM report is set out as follows:

Section 2 – Provides background information on contamination in urban soils, with a particular focus on lead and asbestos.

Section 3 – This section presents an overview of the nature and extent of soil contamination on Kāinga Ora residential sites based on a review of Kāinga Ora soil contamination data.

Section 4 – This section describes the typical/generic exposure pathways that are likely to exist on a Kāinga Ora re-development site.

Section 5 – This section presents a generic CSM for typical Kāinga Ora residential properties.

Section 6 – This section presents recommendations for the investigation of Kāinga Ora residential properties that are subject to re-development work.

This report has been prepared by EHS Support New Zealand Ltd on behalf Kāinga Ora, the principal authors were Andrew Rumsby and Simon Hunt. Acknowledgement is given to Lisa Paton for the preparation of CSM schematics.

2. Background to Contaminants in Urban Soils

Urban residential soils have been shown to contain elevated concentrations of several inorganic elements compared to background soil concentrations (Meuser, 2010). The source of these inorganic elements can range from:

- Weathering and leaching of building products (i.e., copper-chrome-arsenic (CCA) treated timber, copper guttering and sporting, asbestos-containing materials (ACM), and galvanised roofing iron (zinc).
- Flaking and removal of lead-based paints.
- Deposition of fireplace ash or outdoor incineration of waste.
- Deposition of contaminated dust from industrial sources or vehicle emissions.
- Fertiliser and fungicide use which contain inorganic salts (particularly copper and zinc).
- Construction on historical fill materials or contaminated industrial sites (brownfield sites).

This section provides an overview of the likely CoC to be encountered on Kāinga Ora residential sites. In particular, the section principally focuses on lead, and to a lesser extent asbestos, because these CoC are the most significant and widespread contaminants found on residential sites, both from a human health risk and soil disposal perspective. In addition, lead contamination around the dwelling(s) on a property is a “marker” contaminant, in that its spatial distribution and depth, typically indicates where other elevated CoC are likely to be recorded around the dwelling.

While most Kāinga Ora sites are not located on former historical industrial sites (brownfield sites), some have been built on former horticultural land. Consequently, these properties may have an elevated concentration of persistent organic pesticides in the near surface soil.

For most Kāinga Ora residential sites built between the late 1950s and 1980s, asbestos, copper, lead, and zinc are the key soil CoCs principally derived from the building materials used to construct the dwellings. On some residential sites, elevated arsenic concentrations have been found in soils. Various sources exist for the arsenic contamination (CCA treated timber, disposal of fireplace ash), arsenic-containing paint pigments (i.e., Scheele's green and as a white paint extender), naturally elevated arsenic (geogenic) and use of arsenic-based pesticides (either lead arsenate pesticides for control of coddling moth or monomethyl arsenate weedkillers) in many cases the source has not been definitively established.

Chromium may also be elevated in soils around some residential properties due to the weathering of CCA-treated wood. However, the human health soil contaminant standards (SCS – Ministry for the Environment (MfE), 2012) are much lower for arsenic than chromium, and so soils identified as being impacted by chromium are typically identified for removal from the site because of high arsenic (and sometimes copper) concentrations. Therefore, analysis of chromium in the soil is unnecessary.

Meuser (2010) also identified that cadmium, nickel, and vanadium might be slightly elevated in some residential soils; they typically are not present in concentrations above background levels or levels of health concern (Meuser, 2010). Hence these elements are not considered as CoC's on Kāinga Ora sites.

Migration of ground gases and vapour onto a Kāinga Ora property may be an issue at some sites, particularly within 50 m of a Light Non-Aqueous Phase Liquid (LNAPL) plume or 200 m of a closed landfill. During the PSI process the SQEP needs to confirm if there is the potential that the site could be HAIL Category H.

Further discussion on the selection of analytes during the intrusive investigation work is given in **Sections 5** and **6.**

2.1. Asbestos in Soils

Asbestos-based products were used in New Zealand to construct residential homes from the 1920s to the mid-1980s (BRANZ, 2017). The BRANZ guideline indicates that many New Zealand houses built between the 1940s and the 1970s used ACMs within the roofing and cladding materials (BRANZ, 2017). Therefore, it is likely Kāinga Ora built houses during this period could contain ACM.

Kāinga Ora building materials have been reasonably well maintained/painted and so there is limited chance that physical weathering of the ACM has resulted in high levels of asbestos fibres being deposited in soils around dwellings and other structures. As with the lead paint, the nature of ACM building materials varies between properties, and so there is obviously a greater potential for asbestos in soil impacts to be recorded around properties that have used a significant amount of ACM in their construction. This situation typically occurs with asbestos roofing and guttering, where downpipes discharge to the ground, not a reticulated stormwater system.

Building activities, such as the burial of ACM residues on-site, can result in ACM impacted soils beyond the building halo. Also, fires and demolition of buildings can also result in more widespread contamination on a residential property.

2.2. Lead

Lead is a toxic naturally occurring trace element which has been documented to cause neurological, renal, cardiovascular, haematological, immunological, reproductive, and developmental effects (ATSDR, 2020). Lead affects the developing brain and nervous system of young children, who are of greatest risk of ingesting lead contaminated dust and soil.

Historically, lead has been used on residential houses for several purposes, including leaded paints, lead-headed roofing nails, lead flashing, and roof covering. The use of lead-based paint, in particular, has resulted in elevating the concentration of lead in soil (Battelle Memorial Institue, 1998), (Brown, 2016), (Miekle, 1998) (Ministry of Health, 2021).

The drip line (curtilage) area around a building can be the location of a localised elevation in lead concentrations from several different sources, including:

- Discharges from downpipes and leaky guttering during storm events of fine-grained dust deposited on the building roof.
- Leaching and weathering of lead-based products used in roofing materials (such as flashing and nail heads) or stabilising agents in PVC guttering/downpipes.
- The deterioration and improper removal of lead-based paints and primers from a building's roofing materials, exterior walls, and woodwork.

Since lead is a toxic and persistent environmental pollutant, the historical release of lead from a dwelling can be an ongoing health concern many years after the lead sources (paint or building products) have been removed from the building.

2.2.1. Lead-based Paints

Lead-based paint has been used from before the 1840s until 1983. Ready-mixed paints did not become available until after the 1920s; prior to their introduction, painters would mix the ingredients together (Standeven, 2011). However, hand mixing is an inexact science and could result in varying lead concentrations in the paint. Lithophone (zinc sulfide and barium sulfide with a small amount of zinc oxide) was introduced to paints post the 1880s and began replacing white lead paints for interior uses (Standeven, 2011). Between 1900 to 1960s, zinc oxides were often added to paints in combination/or as a replacement for white lead, which resulted in a decrease in the concentration of lead in paints (Standeven, 2011).

Lead-based paint used in New Zealand was originally manufactured in the United Kingdom (UK). However, during World War 1, the export of lead-based paints from the UK was banned. The UK's ban on exporting lead-based paints resulted in countries like Australia and New Zealand manufacturing their own paints soon afterwards. The International Labour Office held the third session of the International Labour Conference in 1921, which recommended prohibiting the use of white lead and lead sulfate-containing paint with greater than 2% metallic lead by weight and that white lead should only be sold as a paste containing no more than 90% white lead or as a ready-made paint (ILO, 1927). However, there is no evidence that this recommendation was ever ratified by New Zealand.

Before 1945, lead carbonate (white lead) was extensively used as a pigment in exterior household paints (Ministry of Health, 2021). However, after World War 2, rutile ($Ti0_2$) began replacing white lead as it had superior tinting, opaqueness, and durability (Standeven, 2011).

The lead content in house paints before the 1950s could be highly variable but was typically between 1-30% lead ((AS/NZS 4361.2, 2017) (Kennedy, 1988) (Malpress, 1988) (Scott, 1983) (Reeves, 1982) (DSIR, 1954)). Post the 1950s, the induction of water-based and latex paints containing other pigmenting agents such as ZnO, TiO2 and lithophone, as well as changes in the formulation of paints, resulted in the lower lead content in the paint. In 1965, the Australian government, as part of the Standard for the Uniform Scheduling of Drugs and Poisons (SUSDP) policy, recommended that paint containing more than 1% lead by weight should not be used for interior painting (Department of

Climate Change, Energy, the Environment and Water, 2023). ln 1969, when the Australian Standard Specification for Paints recommended that white lead pigment should not be used for household paints (AS/NZS 4361.2, 2017). After this date, other lead pigments such as red lead (lead oxide)(used as a steel/wood primer), calcium plumbate (roofing applications) and lead zinc-titanium oxide pigments were still used in some paints, but regulations in the late 1970s to 1990s progressively lowered the lead content in household paints (AS/NZS 4361.2, 2017) (Scott, 1983).

A summary of the evolution of lead-based paint regulations in New Zealand is outlined below:

- The NZ introduced requirements to label lead in paint in 1937 (paints with more than 4% w/w lead required a warning label as per the requirements of The Poisons (general) regulations 1937).
- Queensland, Australia restricted lead concentrations in paint to 5% w/w in 1922 for surfaces accessible to children.
- White lead (some paints could contain up to 50% white lead pigment[1] by weight) was used as extensively a pigment of paint before 1945 (Ministry of Health, 2021).
- New Zealand introduced restrictions through several import tariffs in 1958 (Customs Tariff (oxides of zinc and white lead) Order 1958. Warning labels were added to labels on paint cans containing more than 5% lead under The Poisons (General) Regulations 1964 Amendment No 1 1966.
- The Toxic Substances Act 1979 banned using white lead in New Zealand paints.
- In 1983, the lead content in domestic/residential paint was restricted to 0.5% w/w lead in paint.
- In 1993 the maximum allowable concentration in residential house paint was lower to 0.25% w/w lead in paint.
- In 2023, NZ EPA proposed lowering the lead content in paints to 90 ppm lead in paint (w/w) (in line with the recommendation from the UNEP).

Currently, lead in paint is regulated under the Group Standards for Surface and Coatings and Colourants, Hazardous Substances and New Organisms Act 1996 (HSNO), limiting lead to a maximum concentration of 0.1% (1,000 ppm) w/w lead in paint. However, it is proposed by the NZ EPA to reduce lead in paints to 90 ppm w/w lead in paint (NZ EPA, 2023).

Kennedy et al. (Kennedy, 1988) surveyed exterior house wall paint samples in Auckland suburbs in the 1980s and reported geometric mean (GM) concentrations by house age. Kennedy found that:

- Houses built before 1899 had a GM lead concentration above 10% w/w (dry weight).
- Houses built between 1900 and 1959 had GM concentrations between 1 and 10 % w/w (dry weight).
- Houses built between 1960 and 1979 had GM lead concentration at 0.1% w/w (dry weight).
- Houses built in 1980 and 1984 had a GM lead concentration of 0.003% w/w (dry weight).

[1] After 1930 White lead pigment was mainly comprised of a paste containing approximately 90 to 93% lead carbonate and 7 to 10% turpentine (ILO, 1927), (US DoC, 1945) (Heitman, 2004)

Therefore, houses built before the 1980s may have been painted with lead-based paints, which could generate elevated lead concentrations in soil (particularly within the dwelling's drip line area). Residential houses built before 1945 could potentially have very high soil lead concentrations within the drip line as the lead content in paint was significantly higher before tariffs, regulations, and more modern formulations controlled the amount of lead in paint.

2.2.2. Lead in New Zealand Residential Soils

Lead occurs naturally in soils, typically at concentrations from 2 to 65 mg/kg (Auckland Council, 2001). Background concentrations of lead vary across the country, with some soil types having lead concentrations of less than 25 mg/kg. However, anthropogenic activities such as vehicle emissions, lead paint on houses, lead arsenate pesticides, incineration of wastes, and air emissions from industrial activities have elevated lead concentrations in urban soils (Mielke H. G., 2019).

Soil can be contaminated by leaded paint particles from deterioration or damage to exterior lead-based paintwork or improperly removing lead paint (Te Whatu Ora, 2024). The Ministry of Health (Ministry of Health, 2021) indicates that most soil contamination will occur within 1 to 2 metres of the building containing lead-based paints, whilst the USEPA/HUD indicates that the majority occurs within the dripline of the house. Dumping or burning of building debris contaminated by lead-based paint or disposal of ash from fires may also result in hotspots in urban gardens (Te Whatu Ora, 2024).

Several studies have found that around older houses (particularly pre-1960s), the concentration of lead in soil is much higher within the house's dripline than in other locations within the section (Clickner, 1995) (Schwarz, 2012). Studies undertaken in New Zealand have found that older houses (pre-1950s) have a significantly higher lead concentration in soils (Ashrafzadeh, 2018).

A summary of several studies on urban/residential lead soil concentrations within New Zealand is presented in **Table 2-1**.

Table 2-1 Lead in New Zealand Residential Soil

Location	Geomean (mg/kg)	Range (mg/kg)	Reference
Christchurch (before1890)	664 (average n=5)	420-7,000	(Jordan, 1975)
Christchurch (1890-1909)	2,407 (average n=21)	350-15,500	(Jordan, 1975)
Christchurch (1910-1929)	1,732(Average n=52)	50-6,000	(Jordan, 1975)
Christchurch (1939-1949)	829 (Average n=31)	140-2,500	(Jordan, 1975)
Christchurch (1950-1974)	277 (average n=42)	30-2,200	(Jordan, 1975)
Christchurch (pre-1950s home)	282	NR	(Ashrafzadeh, 2018)
Christchurch (all houses)	137	22.6-2,615	(Ashrafzadeh, 2018)
Ashburton		Typical Range (300-600 mg/kg – maximum 5,946 mg/kg)	(Malloch Environmental Limited, 2018)
Dunedin	131.1	35-2,354	(Turnball, 2019)
Palmerston North	207.6	11.5-9,571	(Blunden, 2020)
Lead Sunderland District (dripline 0-1 m)	NR	26-16,800	(Golder, 2013)
Lead-Sunderland District (non-dripline)	NR	16-1,100	(Golder, 2013)
Hobsonville	NR	5.4-16,800	(PDP, 2013)
National	51.79	6.8-2,600	(PDP, 2021)

Table Notes:
All soil lead values are reported in mg/kg (dry weight) unless indicated.
NR = not recorded
Golder = Golder Associates New Zealand Ltd
PDP = Pattle Delamore Partners Ltd

3. Factors Affecting the Kāinga Ora Residential Conceptual Site Model

Kāinga Ora has actively been investigating residential re-development sites nationally for the last 5+ years and for the last 3-4 years, a significant amount of the investigation work has been undertaken by a small group of contractors who have used a similar investigation methodology.

Kāinga Ora residential soil contamination data has been collated into a comprehensive database that has been used to provide insight into the nature of the contamination on Kāinga Ora sites. A summary of the key findings from this study and the issues that informed the development of the generic CSM is given below. This section discusses the following issues:

1. Age of Kāinga Ora housing stock, nature of their use, and external factors.
2. Contaminants of concern.
3. Contamination impact within the dwelling dripline and extent.
4. Contamination depth.
5. Impact from vehicle emissions (principally within the front yard areas).

3.1. General Considerations

The vast majority of the Kāinga Ora housing stock dates from post the 2nd World War and from the late 1950s onwards. Based on the discussion presented in **Section 2**, the paint used in the construction and maintenance of these legacy Kāinga Ora dwellings would have had a relatively low lead concentration (in the order of 1% w/w). This potentially contrasts with older residential buildings that exist across much of New Zealand, dating from the late 19th Century and early 20th Century, which would have used paint with significantly higher lead concentrations.

Kāinga Ora dwellings have been routinely maintained over their operational life (unlike private ownership, which is often variable), and so this activity would limit the likelihood of the release of lead paint and asbestos from the building fabric and the generation of contaminated soil. It must be acknowledged that variable historic maintenance practices may have contributed to elevated lead and asbestos concentrations on select Kāinga Ora properties.

Based on a review of background literature and the Kāinga Ora contaminated land database, the CoC on residential sites comprises the following compounds unless the PSI suggests there could be other CoC's:

- Trace elements – arsenic, copper, lead, and zinc.
- Asbestos.

3.2. Site Wide and Dripline Contamination Data

A summary of soil lead concentrations on Kāinga Ora residential properties across the country and within Hamilton City is shown in **Table 3-1**. The data presented is for residential properties developed between the 1950s and 1980s for the surface soils across the whole of the property and data for surface soils at the edge of the dripline (1 m from the dwelling). The soil samples were all collected between ground level and 0.1 m bgl.

Table 3-1 Analysis of Lead in Urban Surficial Soils (0-0.1m bgl) around Kāinga Ora Properties (around New Zealand and within Hamilton)

Descriptive statistics	Concentration of Soil Lead (all samples) (mg/kg)	Concentration of Soil Lead (Hamilton) (mg/kg)	Concentration of Soil Lead within 2 m of Dwelling (mg/kg)	Concentration of Soil Lead within 2 m of Dwelling (mg/kg) (Hamilton only)
Minimum	2.7	3.6	5.2	4.7
Maximum	32,000	3,800	4,600	3,800
Mean	147	88	209	266
Geometric Mean	68	42	91	98
95% UCL of mean (95% Chebsyshev UCL)	172	129	275	495
Standard Derivation	528	229	424	536
25 Percentile	32	20	37	28
Median	57	34	78	102
75 Percentile	132	77	187	270
90 percentiles	300	180	435	490
95 percentiles	500	270	815	1,035
99 percentiles	1,240	794	2,315	2,756
Percentage of results above 210 mg/kg	16%	8%	23%	30%
Percentage above 250 mg/kg (no produce)	13%	6%	20%	27%
Percentage above High density residential (500 mg/kg)	5%	2%	8.7%	10%

A bullet point summary of the Kāinga Ora data[2] is given below:

- The all-soil sample data indicates that the lead in soils on Kāinga Ora properties tends to be elevated above background for lead (typical background in New Zealand is less than 40 to 65 mg/kg).
- The average (GM) and 50 % percentile lead concentration is slightly higher than the typical background concentration[3]. However, the 95% Upper Confidence Limit (UCL) of the mean indicates that Kāinga Ora residential soils will be above background levels.
- Higher lead concentrations were recorded within the dripline area (i.e., within 2 m of the dwelling).
- Approximately 16% of the all-soils data exceeded the National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health (NES-CS) SCS (10% homegrown produce) of 210 mg/kg (MfE, 2012), while approximately 23% of the samples collected within the curtilage may exceed SCS (10% homegrown produce).
- Approximately 5% of samples in the all-soils data exceeded the National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health (NES-CS) SCS High-density residential, while approximately 9% of samples collected from within the curtilage area exceeds the SCS (High Density).
- The data indicates that the lead concentrations in surface soils on Kāinga Ora Hamilton properties are very similar to the lead soil concentrations encountered in the rest of Kāinga Ora-wide New Zealand properties.

3.3. Depth of Lead Contamination

The Ministry of Health (2021) indicates that after the deposition of lead particles onto the soil surface, the particulate matter binds with the soil matrix and limits lead mobility to less than 5 cm of soil depth. However, it notes that the extent of lead-soil binding depends on soil type, organic content, and soil pH.

The USEPA recommends that lead soil samples should be collected from 0.15 m (6 inches) depth but do not need to extend more than 0.6 m (24 inches) (USEPA, 2003). The USEPA recommendation indicates that lead paint contamination should be relatively shallow.

Jack Blunden investigated the vertical distribution of lead in residential soils in Palmerston North in 2020 (Blunden, 2020). This study found that the concentration of lead in soil decreased with depth. However, soil lead concentrations could still exceed the NES-CS SCS for residential lead (10% homegrown produce) of 210 mg/kg at a depth of 0.2 m. However, at a depth greater than 0.2 m below the ground surface, Blunden found that the soil lead concentrations were less than 210 mg/kg

[2] Based upon 17,239 datapoints from over 1,200 properties across the country typically build between 1940 to 1980 (although there are a small number of houses built before 1940s within this dataset).
[3] This appears to be the influence of one outlier datapoint of 31,300 mg/kg, if this datapoint is excluded from the dataset the geometric mean of the data is 54 mg/kg and the 95% Upper confidence limit of the mean for the dataset is 181.7 mg/kg.

(**Figure 3-1** – this figure uses a boxplot and information on interpreting a box plot is given in **Attachment B**). The properties investigated by Blunden were not Kāinga Ora properties, rather they comprised private residential dwellings built between 1900s to 1950s. Therefore, the concentration of lead in soils are likely to be higher than observed on Kāinga Ora properties.

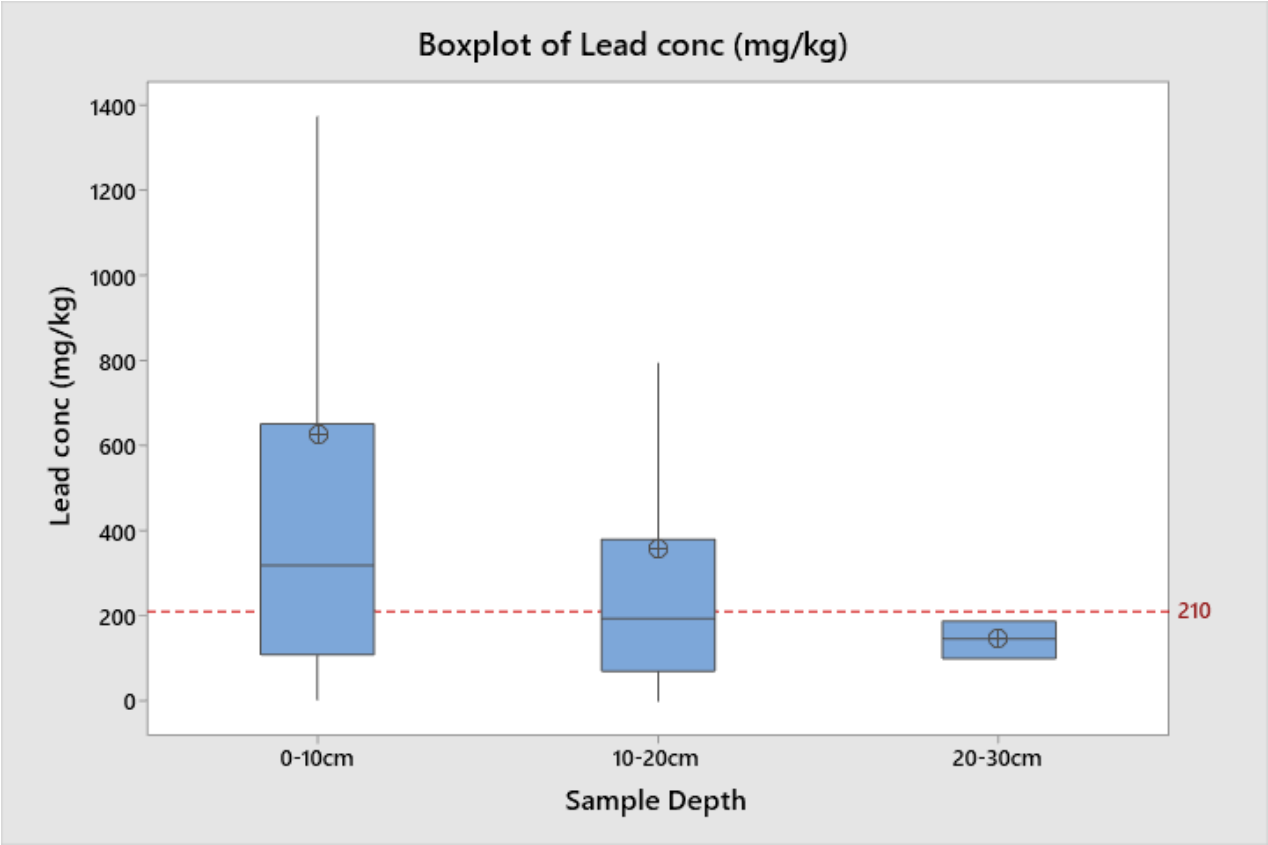

Figure 3-1 Box plot of Soil Lead Concentrations from Residential Properties in Palmerston North (from (Blunden, 2020)).

Kāinga Ora has undertaken a similar study for soils collected from its properties. **Figure 3-2** shows the vertical distribution of soil lead at sample locations where surficial soil exceeded 65 mg/kg (i.e., above likely maximum background concentrations). Samples used to generate the data in **Figure 3-2** were collected from 36 Kāinga Ora properties from Auckland, Waikato, Taranaki, Manawatū, Wellington, Marlborough, and Nelson-Tasman districts. **Figure 3-2** shows the average soil lead concentration at various depths. A summary of the data used to generate these figures is presented in **Table 3-2.**

An initial sampling depth of between 0.075 m and 0.1 m was selected as Contaminated Land Management Guidelines No. 5 states the upper 0.075 m represents the depth of soil that people are typically exposed to in their day-to-day activities (Ministry for the Environment, 2021).

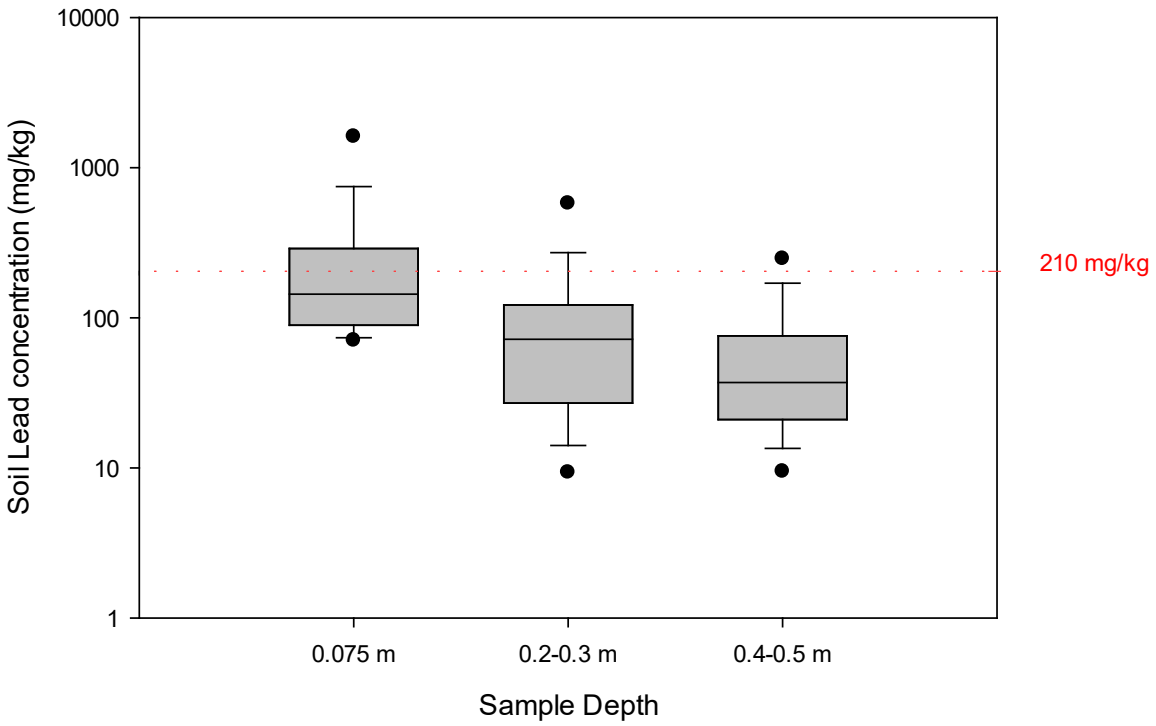

Figure 3-2 Box Plot of Kāinga Ora Soil Lead Concentrations versus Depth

The data collected by Kāinga Ora shows that the highest soil lead concentrations are found within 0.075 m bgl of the soil profile. Concentrations of soil lead decrease with depth and are below NES-CS low density residential SCS of 210 mg/kg at most sites at depths of 0.2 m to 0.3 m below ground level (bgl) (**Figure 3-2** and **Table 3-2**). However, at some sites, soil-lead concentrations can exceed NES-CS low density residential SCS of 210 mg/kg at 0.5 m bgl.

Table 3-2 Analysis of Soil Lead Concentrations around Kāinga Ora Properties (built between 1950 to 1980s)

Descriptive Statistics	Soil Sample Depth		
	0-0.075 m bgl	0.2-0.3 m bgl	0.4-0.5 m bgl
Minimum	34	3.1	3.9
Maximum	3,600	1,500	560
Mean	336	131	70.8
Geometric Mean	187.8	64.19	41.5
95% UCL of mean (95% Chebyshev UCL)	534.8	209.2	117.7
Standard Derivation	533.4	209.6	98.1
25 Percentile	89.50	27	21

Descriptive Statistics	Soil Sample Depth		
	0-0.075 m bgl	0.2-0.3 m bgl	0.4-0.5 m bgl
Median	144	72	37
75 Percentile	290	122	76
90 percentiles	728	264	145
95 percentiles	1,472	546	240
Percentage of results above 210 mg/kg	35.8%	12.4%	7.2%
Table Notes: All soil lead values are reported in mg/kg (dry weight) unless indicated.			

3.4. Distance of Lead Soil from the Dwelling

The USEPA defines the size of a typical building contaminant halo zone to be within the dripline of the building (0.15 to 0.75 m from the exterior wall of a building) (USEPA, 2003). The Ministry of Health states that typically lead-based paint hazard generates hotspots 1 m or 2 m away from the exterior wall (Ministry of Health, 2021).

To better understand the size of a typical lead halo zone around dwellings, Kāinga Ora undertook sampling around various properties in several different locations across New Zealand to define the extent of the lead halo around dwellings. A summary of this sampling programme results is presented in **Table 3-3**.

Table 3-3 Kāinga Ora Lead Halo Analysis

Descriptive Statistics	Distance from Exterior Wall	
	1 m	2 m
Minimum	68	38
Maximum	3,300	110
Mean	519.9	64.55
Geometric Mean	233.1	62.37
95% UCL of mean (95% Chebyshev UCL)	1,292	89
Standard Derivation	867.4	18.61
25 Percentile	87.5	54.5
Median	154	61

Descriptive Statistics	Distance from Exterior Wall	
	1 m	2 m
75 Percentile	471.3	71
90 percentiles	943	77
95 percentiles	2,785	93.5
Percentage of results above 210 mg/kg	45.8%	0
Table Notes: All soil lead values are reported in mg/kg (dry weight) unless indicated.		

The soils data presented is where the dripline data exceeded 65 mg/kg (maximum background) and so the soils are deemed to be impacted by lead paint.

Based on the data presented in **Table 3-3**, the extent of the typical lead halo around a dwelling is between 1 m to 2 m from the exterior wall.

3.5. Distance of Lead Soil from Roadways

Tetra ethyl lead (TEL) was added to gasoline (petrol) in the United States in 1920s to prevent knocking in automotive engines (Ngiagu 1990). By 1970s approximately 720 billion litres of leaded gasoline were being sold each year (Ngiagu 1990) and by the time leaded fuel had been phased out by 1990 over 10 million tonnes of lead had been discharged into the environment by motor vehicle emissions (Mielke 1998). As noted above, vehicle emissions are often cited as a source of lead impact on properties that front onto roadways.

TEL was phased out in most New Zealand fuels in 1996 and since then roadside soil lead concentrations have decreased (Wilson, 2008). Work undertaken by Ward et al in the 1970s showed a dramatic decrease of soil lead concentrations within a few metres of the road (Ward, 1979).

Kāinga Ora soil data collected from the front yards area of properties is presented in **Table 3-4.** Over 80% of soils collected from the front yard areas of Kāinga Ora properties had soil lead concentrations below background levels, and only 1.2% of all soil samples collected from the front yard areas exceeded the NES low-density residential SCS of 210 mg/kg. There is no evidence that roadside vehicle emissions or diffuse contamination from vehicles (tyre/brake wear contaminants – zinc and copper) are having a significant impact on soil quality on Kāinga Ora properties.

Table 3-4 Kāinga Ora Soil Lead Concentrations within Front Yard Area (based upon 840 samples collected from 228 properties nationwide)

Descriptive Statistics	Soil Lead Concentrations (mg/kg dry weight)
Minimum	6.8
Maximum	840
Mean	54.5
Geometric Mean	39.25
95% UCL of mean (95% Chebyshev UCL)	73.05
Standard Derivation	70.58
25 Percentile	25
Median	34
75 Percentile	54.5
90 percentiles	95.2
95 percentiles	163.9
Percentage of results above 210 mg/kg	1.2%
Table Notes: All soil lead values are reported in mg/kg (dry weight) unless indicated.	

3.6. Other Inorganic Elements

Due to the use of a variety of inorganic elements in building metals (such as treated timber, galvanised iron, and paint) several other inorganic elements can be found in elevated concentration is residential soils. These elements include arsenic (treated timber), copper (treated timber, spouting and fungicides) and zinc (galvanised iron and fungicides). Analysis of cadmium and chromium in soils indicates while they may be present in soils, they are highly unlikely (less than 1%) to exceed human health criteria[4] and therefore are not considered contaminants of concern.

Table 3-5 Analysis of Selected Metals in Urban Surficial Soils (0-0.1m bgl) around Kāinga Ora Properties (all properties)[1]

Descriptive statistics	As (mg/kg)	Cr [2] (mg/kg)	Cu (mg/kg)	Zn (mg/kg)
Minimum	0.9	2	2	4
Maximum	1,250	770	114,000	15,600
Mean	10.7	49.7	76	179
Geometric Mean	NC	40.7	NC	NC
Standard Derivation	29	35.9	1,285	386
25 Percentile	3.6	27	17	54
Median	6	45	32	100
75 Percentile	9	64	56	196
90 percentiles	17	85	96	370
95 percentiles	28	103	140	548
99 percentiles	86	160	390	1,190
Percentage of results above NES (10% produce) Residential Soils mg/kg	8%	0.08%[2]	NGV	NGV

Table Notes:

1. All soil results are reported in mg/kg (dry weight) unless indicated.
2. Soil Guideline value for chromium (VI) of 460 mg/kg for residential soils
3. NC= Not Calculated
4. NGV = No Guideline Value

[4] Also, at sites where either cadmium or chromium exceed NES guideline values arsenic or lead also exceed NES guidelines, therefore these two elements do not drive remediation decision making.

Table 3-6 presents the same data but only for Kainga Ora properties in Hamilton City. The concentration of chromium, copper, and zinc in soils around Kainga Ora Hamilton properties compared to those encountered elsewhere in New Zealand. However, the concentrations of arsenic in the soil around Hamilton Kainga Ora properties is higher than the concentration of arsenic typically found elsewhere in the country on Kāinga Ora properties.

Table 3-6 Analysis of Selected Metals in Urban Surficial Soils (0-0.1 m bgl) around Kāinga Ora Properties (Hamilton Only)[1]

Descriptive statistics	As (mg/kg)	Cr (mg/kg)	Cu (mg/kg)	Zn (mg/kg)
Minimum	2.5	3.5	4.3	13
Maximum	580	135	10,000	1,100
Mean	19	11	48	129
Geometric Mean	13	9.6	19	95
Standard Derivation	30	11	475	118
25 Percentile	8	7	11	60
Median	12	9	16	95
75 Percentile	19	12	29	158
90 percentiles	38	17	54	244
95 percentiles	51	25	76	331
99 percentiles	110	43	134	560
Percentage of results above NES (10% produce) Residential Soils mg/kg	25%	0.0%[2]	NGV	NGV
Percentage of results above NES (High Density) Residential Soils mg/kg	7%	0.0%[3]	NGV	NGV

Table Notes:

1. All soil results are reported in mg/kg (dry weight) unless indicated.
2. Soil Guideline value for chromium (VI) of 460 mg/kg for residential soils
3. Soil Guideline value for chromium (VI) of 1,500 mg/kg for high density residential soils

3.6.1. Geogenic Arsenic

When the arsenic concentration in surficial soils in Hamilton are compared to arsenic concentration in in surficial soils from the rest of the country (excluding Rotorua) there appears to be an “excess” of arsenic within the soils on Hamilton residential house sites (see **Table 3-7**).

Table 3-7 Analysis of Arsenic in Urban Surficial Soils (0-0.1 m bgl) around Kāinga Ora Properties in Hamilton and the Rest of the Country (excluding Rotorua)[1].

Descriptive statistics	As - Hamilton Only (mg/kg)	As - Rest of the Country (mg/kg)
Minimum	2.5	<2
Maximum	580	570
Mean	19	10
Geometric Mean	13	6
Standard Derivation	30	21
25 Percentile	8	4
Median	12	6
75 Percentile	19	9
95% UCL	24	11
90 percentiles	38	16
95 percentiles	51	25
99 percentiles	110	79
Percentage of samples above WRC background (>6.8 mg/kg) (Waikato Regional Council, 2019)	85%	15-43%[2]
Percentage of results above NES (10% produce) Residential Soils mg/kg	25%	7.6%
Percentage of results above NES (High Density) Residential Soils mg/kg	7%	2%

Table Notes:

1. All soil results are reported in mg/kg (dry weight) unless indicated.
2. Background values for arsenic in soil from the rest of the country have been compared to Auckland (Auckland Council, 2001) and Waikato Background ranges (Waikato Regional Council, 2019).

Approximately 85% of soil samples collected from residential properties in Hamilton City do not meet Waikato Regional background values for inorganic arsenic (less than 6.8 mg/kg). This may indicate that the Waikato Regional Background values are inappropriate for Hamilton City.

3.6.2. Soils deeper than 0.6 m

On non-HAIL sites, elevated arsenic concentrations in deep subsurface soils are likely due to the presence of geogenic arsenic. In Hamilton, subsoils are likely to have more high arsenic concentration than what is typical for the rest of New Zealand, with approximately 14% of soil samples[5] collected by Kāinga Ora exceeding the NES-CS high-density residential value compared with 4% for the rest of the country (See **Table 3-8**).

Table 3-8 Analysis of Arsenic in Urban Surficial Soils (0.4-0.5 m bgl) around Kāinga Ora Properties in Hamilton and the Rest of the Country (excluding Rotorua)[1].

Descriptive statistics	As - Hamilton Only (mg/kg)	As - Rest of the Country (mg/kg)
Minimum	2.5	<2
Maximum	120	460[2]
Mean	25.4	11.9
Geometric Mean	19.15	5.9
Standard Derivation	72	32
25 Percentile	11	3
Median	19	5
75 Percentile	32	11
95 percentiles	67	36
Percentage of results above NES (10% produce) Residential Soils mg/kg	50%	16%
Percentage of results above NES high-density Residential Soils mg/kg	13.6%	4.6%

Table Notes:

1. All soil results are reported in mg/kg (dry weight) unless indicated.
2. Statistical Outlier

Soils deeper than 0.6 m pose less risk to residents than near-surface soils, as they are less frequently contacted by site users and beyond the root-feeding zone of most vegetables. **Table 3-9** provides

[5] Based upon a sample size of 44 soil samples, which meets the minimum number of 30+ soil samples to specify a background value as specified by ISO 19258 Soil Quality – Guidance on the Determination of Background Values

information on the potential depth that may influence soil intermixing and human exposure to contaminated soil, and **Table 3-10** provides information on the typical depths of various vegetables.

Table 3-9 Depth of Various Soil Disturbance Activities

Soil Disturbance Activity	Depth of soil which may influence exposure
Dust Generation	100 mm
Grass root zone	150 mm
Garden corps root zone	200-600 mm[1]
Earthworms	400 mm
Burrowing animals	Generally less than 500 mm[2]
Gardening Activities	Generally less than 460 mm but (Up to 600 mm)
Digging by pets	600 mm
Service trench for electrical conduit	600 mm

Table Notes:

Based on data from BRE (2004) Cover Systems for Land Regeneration: Thickness Design of Cover System for Contaminated Land.

1. For depths of various garden corps, see **Table 3-10**.
2. Rabbit burrows can be deeper but are generally less than 1 m deep.

Table 3-10 Effective Plant Root Depth

Plant	Root Feeding Zone
Beans	400-600 mm
Beetroot	300-460 mm
Broccoli	460-600 mm
Brussel Sprouts	460-600 mm
Cabbages	460-600 mm
Celery	600 mm
Cucumbers	460-600 mm
Lettuces	150-460 mm
Onions	300 mm
Peas	460-600 mm
Potatoes (including kumaras)	300-1,000 mm
Raddish	300 mm
Spinach	460-600 mm
Sweet Corn	600-900 mm
Tomatoes	600-1,200 mm
Table Notes: Based upon data within NZS 5103 (1973), which has been updated data from (Iwana, 2008)	

For most garden crops, the root feeding zone depth is less than 600 mm[6]; therefore, it is unlikely that a person would be exposed to deep soil contamination (greater than 600 mm) via produce consumption. Direct contact with soil by gardening activities (such as gardening or kids digging in soil) will likely be limited to the upper 600 mm of soil. Likewise, bioturbation (via earthworms, burrowing animals or pets) is also likely limited to the upper 600 mm of soil. Therefore, dermal contact and soil ingestion are not likely to occur in soils deeper than 600 mm.

Soil deeper than 600 mm may occasionally be disturbed during construction activities or repairs of deeply buried service. However, these activities will likely be of short duration and very infrequent

[6] While some corps like sweet corn and Tomatos root zone can extend beyond 600 mm, the establishment of a physical barrier layer can be used to prevent the root zone beyond 600 mm while still allowing sufficient soil depth to grow these plants.

(acute-type exposure), and exposure/management of surplus soils will be controlled by the Ongoing Site Management Plan administered by Kāinga Ora if contamination is present at depth.

As significant amounts of dermal, produce, or soil ingestion are highly unlikely to occur when contamination is deeper than 600 mm, Kāinga Ora believes that the 10% produce exposure pathway for residential properties is not an appropriate soil contaminant standard for soils deeper than 600 mm. Therefore, under regulation 7(3) of NES-CS, the high-density residential SCS is a more appropriate standard for assessing the risk of exposure to these soils. It is still highly conservative, as it overestimates the exposure frequency and duration that is likely to occur to the deeper soils in a Kāinga Ora residential setting, but it still is protective of small children.

BRE Technical Report 465: Cover Systems for Land Regeneration (BRE, 2004) can be used to design a simple cover system for contamination deeper than 600 mm. This document provides advice on determining the depth of the cover system and providing a physical barrier at the base of the cover, as well as advice on when such a cover system may be inappropriate. BRE 465 provides a spreadsheet that allows the consultant to calculate the appropriate soil quality and cover thickness depending on the concentration of the contaminant present and the potential intermixing scenario.

3.7. Hazardous Activities and Industrial (HAIL) as Additional Contaminant Sources

Historical land use (such as residential sites being developed on legacy horticultural land, former industrial sites, or old landfill sites) can result in elevated concentrations of various contaminants in the soils on a site, or contaminants could be migrating onto a Kāinga Ora site. CoC associated with HAIL impacts depend on the type of HAIL activity, and the PSI report must describe the likely nature and form of HAIL-related CoC and the potential extent of the re-development property.

4. Potential Exposure Pathways

A CSM considers potential exposure pathways between the source and the receptor. Risk to human health only exists when those exposure pathways are present. If the potential exposure pathway is incomplete or does not exist, then the pathway is said to be incomplete.

For some exposure pathways such as dermal absorption or inhalation of trace elements such as arsenic, copper, lead and zinc, the Methodology (Ministry for the Environment, 2011) indicates these are relatively insignificant exposure pathways. However, soil ingestion and consumption of homegrown produce are the major exposure pathways for trace elements in a residential setting.

For asbestos, inhalation of asbestos fibres is the only exposure pathway of toxicological concern (BRANZ, 2017) (Government of Western Australia, 2021).

Children are at most risk of lead toxicity due to their lower body weight, and they are more susceptible to the effects of lead toxicity than adults (Ministry of Health, 2021) (ATSDR, 2020). In addition, they can have higher soil ingestion rates than adults (Ministry for the Environment, 2011). As material lead can be transferred from the mother to the fetus during pregnancy, unborn children are also vulnerable to lead developmental and neurotoxicity effects. Therefore, pregnant women are also potentially sensitive receptors.

For asbestos, there is no evidence currently to suggest that children are more susceptible to the effects of inhaling asbestos fibres than adults. Therefore, the most sensitive receptor to asbestos in soils on a residential property would depend on an individual's activities (i.e., mowing lawns, digging in gardens, etc.) and could be either an adult or a child.

5. Conceptual Site Model

The CSM considers the current and future land uses and how the CoC identified in **Sections 2, 3** and **4** could pose a risk to human health.

Based on the information reviewed in **Section 2** and **Section 3 of** this report, a summary CSM for Kāinga Ora residential properties is presented in **Table 5-1**. In addition, an SPR diagram is presented in **Appendix A** and pictorial CSMs are presented in **Figures 5-1** and **5-2** for existing and re-developed (high-density land use) Kāinga Ora residential properties, respectively. These pictorial CSM's show the types of anthropogenic contamination that could be present on Kāinga Ora properties. Note that geogenic arsenic is not included in the CSM below as it is an example of naturally high background concentrations rather than anthropogenic contamination.

Table 5-1 Conceptual Site Model

Release Source	Contaminant of Concern	Exposure Source	Exposure Route	Key Receptor	Other Receptors
Lead-based paint (released due to deterioration or removal activities)	Lead	Impacted soils	Soil ingestion	Child	Adults/Site Workers
Weathering of building materials	Trace elements (As, Cu, Pb and Zn)		Produce ingestion	Child	Adults
Asbestos Containing Materials (ACM)	Asbestos fibres and ACM	Impacted soils	Inhalation	All site users and workers	

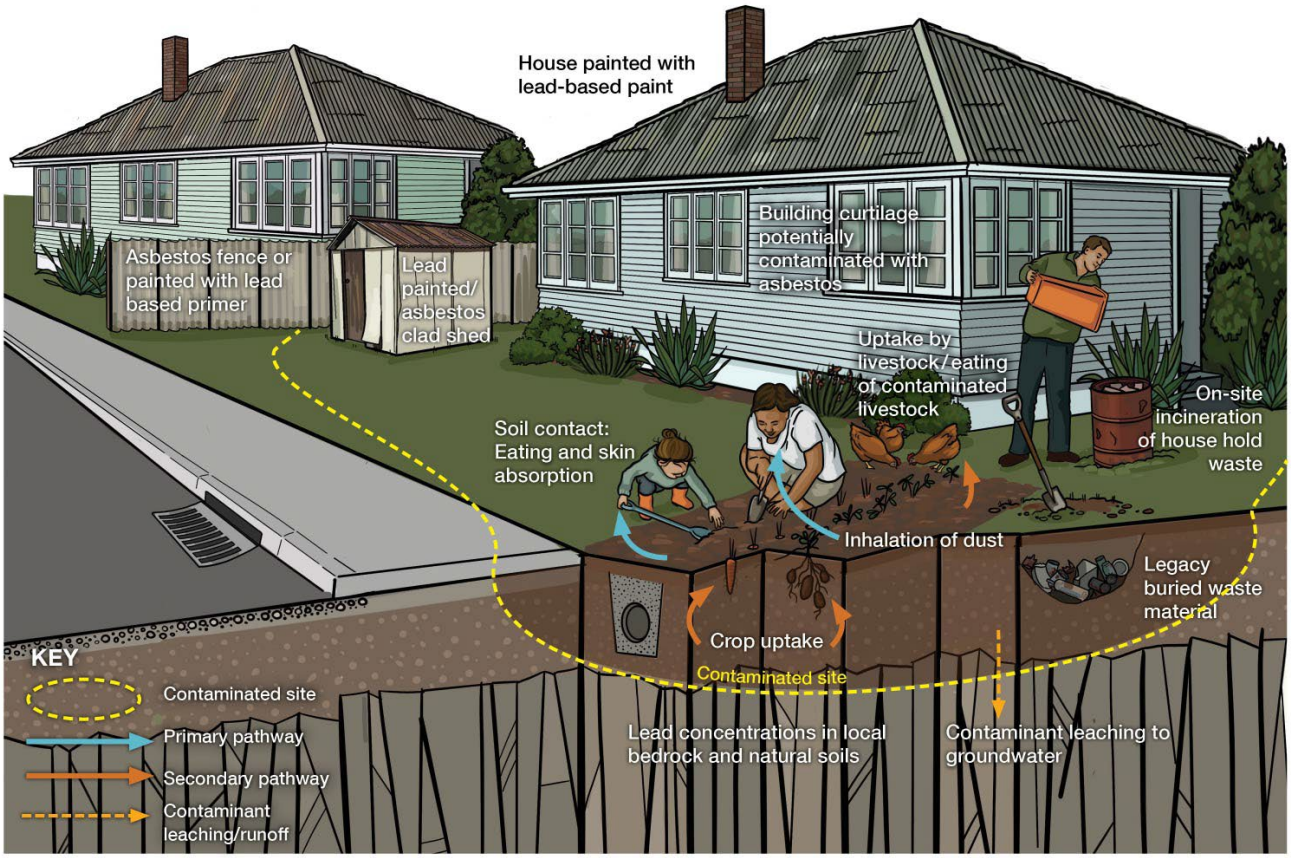

Figure 5-1 Pictorial Conceptual Site Model – Existing Kāinga Ora Residential Property

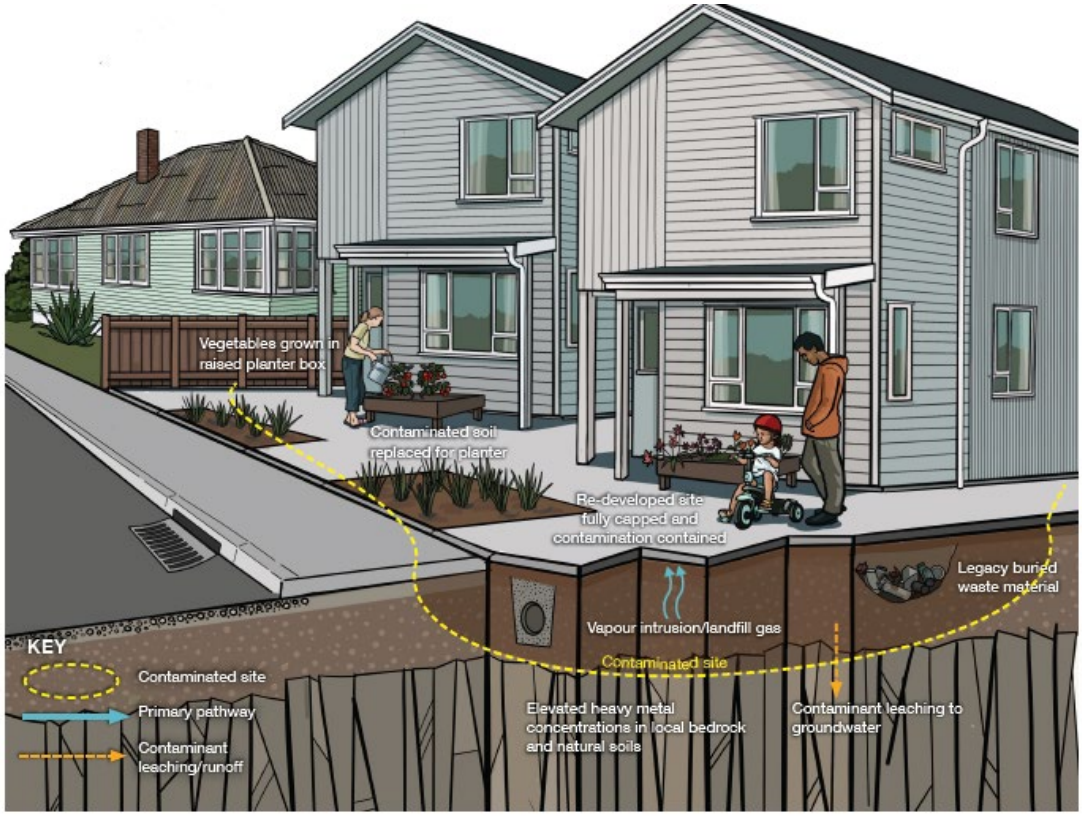

Figure 5-2 Pictorial Conceptual Site Model – Re-Developed Kāinga Ora Residential Property

6. HAIL Category I

HAIL Category I land is defined as any other land that has been subject to the intentional or accidental release of a hazardous substances in sufficient quantities that it could be a risk to human health or the environment. Therefore, HAIL Category I land is a catch-all HAIL category that is designed to encompass land that is not otherwise captured by another HAIL category.

It should be acknowledged that the NES-CS SCSs are health risk screening criteria, and that exceedance of these criteria does not necessarily indicate a health risk exists. Rather, an exceedance of an SCS (from a health risk assessment perspective) should prompt additional investigation work to understand whether a potential risk exists.

The HAIL does not directly list residential properties. Rather, practitioners often use the following categories to classify residential properties as being on the HAIL:

1. Category E. Mineral Extraction, Refining and Reprocessing, Storage and Use. E.1 Asbestos product manufacture or disposal including sites with buildings containing asbestos products known to be in a deteriorated condition; and/or
2. Category I. Any other land that has been subject to the intentional or accidental release of a hazardous in sufficient quantity that it could be a risk to human health or the environment. The MfE (2023) HAIL guidance states that HAIL I applies when “the contamination is likely to be, or have been, at or above the applicable soil contaminant standard and environmental guideline value for the land.” For most KOHC re-development work the applicable soil contaimant standard is high density residential soil contaimants standards.

Due to the historical use of asbestos or lead in paint some regulators and consultants consider wooden houses of a certain age to be HAIL Category I.

Consequently, there is significant confusion nationally on whether re-development on residential properties is captured by the NES-CS. The following discussion presents Kāinga Ora’s interpretation of compliance with the NES-CS and supporting documents.

As stated above, Kāinga Ora properties typically date from the late 1950s onwards, have been relatively well maintained, and have been managed by Kāinga Ora and its legacy organisations. The nature and distribution of contamination on Kāinga Ora properties will be different to older residential properties and to a certain extent different to private residential properties of a similar age/vintage to the Kāinga Ora properties. Therefore, this discussion and interpretation of compliance with the NES-CS is particular to Kāinga Ora re-development sites.

Because Kāinga Ora properties have been and are relatively well maintained, ACM building products on these properties will generally not be in a deteriorated condition. As such, HAIL Category E would

not apply to Kāinga Ora properties except in very extreme cases which would be identified during the site visit/inspection stage of the PSI/DSI process.

As noted above, HAIL Category I requires the contamination "to be in sufficient quantity that it could be a risk to human health". However, the Kāinga Ora contamination database and human health risk assessment work outlined above in **Section 3** suggests that Category I should not necessarily be applied to Kāinga Ora properties as there is insufficient evidence to conclude that soil contaminant concentrations (notably lead) are present in sufficient quantities that could be a risk to human health. This determination is based on the following reasons:

1. The Kāinga Ora database assessment work described above clearly demonstrates it is more likely than not (in terms of compliance with Regulation 7 (c)) that Kāinga Ora properties with residential houses built after the 1950s will have soil lead concentrations outside the halo areas that are significantly less than NES-CS low-density residential SCS of 210 mg/kg.

2. While more elevated (albeit localised) contaminant concentrations (notably lead) are recorded within the halo area. The Ministry of Health (in their document The Environmental Case Management of Lead-exposed Persons, MoH, 2021) suggest that for soil lead levels in the range of 1,000 to 3,000 mg/kg, that soil removal is probably not indicated (*required)* and that other measures (such as covering or behaviour modification) may suffice to manage risks to children. The Kāinga Ora 95th percentile lead concentration for lead within the halo areas fall below this value (815mg/kg – **Table 3-1**).

While Kāinga Ora does not consider that residential properties should be classified as HAIL I land, for the purposes of the MoU with HCC, Kāinga Ora properties shall be classified as HAIL Category I if it has been subject to:

a) a confirmed on-site release of hazardous substances or contaminants and
b) the contamination is likely to be, or have been, at or above the applicable soil contaminant standard and environmental guideline value for the land.

Based on the above definition, for a piece of land to be classified as HAIL land the contaminant must be released in sufficient quantities to cause a hazard. Ministry for the Environment Contaminated Land Management Guideline No.5 (MfE, 2021b) states that 95% upper confidence limit of the mean (UCL) should be used for interpreting soil data against guideline values where appropriate data sets are available. Therefore, a Kāinga Ora property shall not be classified has HAIL I land if:

1. All reported concentrations are at or below the applicable guideline value, or
2. The 95% UCL of the data set are at or below the applicable guideline value, and
3. No individual result is more than twice the applicable guideline value.

For most Kāinga Ora re-development properties, the applicable guideline value is the high-density residential land use SCS.

7. Summary and Recommendations

This report has reviewed available data to develop a defensible CSM for the re-development of Kāinga Ora properties in Hamilton. In addition, the information presented can be used to inform the development of a generic SAP for Kāinga Ora properties.

This report reviewed literature and data on soil contamination around Kāinga Ora residential properties and found:

- The primary sources of contamination on residential properties are:
  - Weathering of paint and building materials.
  - Maintenance activities, such as removal of paint.
  - Fire, demolition, and building activities result in the cutting or damage of building material, resulting in the release of contaminants.
- Secondary sources of contamination on residential properties can include:
  - Burning or disposal of refuse on-site.
  - Importation of contaminated fill material onto a property.
  - Historical HAIL activities.
- Asbestos, arsenic, copper, lead, and zinc are the key CoC.
- In Hamilton City, some soils may be naturally elevated in arsenic, and Waikato Regional Council background values for inorganic elements may not be appropriate for Hamilton City.
- Lead soil concentration on Kāinga Ora properties is typically less than 172 mg/kg, less than 10% of soil samples collected from Kāinga Ora properties exceeded the lead NES-CS SCS for residential land use of 210 mg/kg and less than 2% of soil samples exceeded the lead NES-CS SCS for high-density residential land use (500 mg/kg).
- The surface soil within 1 m to 2 m of a residential house can have elevated concentrations of lead (and potentially other contaminants listed above). Typically, soil lead concentrations within this 'halo' zone are less than 400 mg/kg. However, approximately 10% of soil sampled within this halo exceeded the lead NES-CS SCS for 500 mg/kg residential land use on Kāinga Ora properties. A similar situation is likely to exist for other structures on a residential property (depending on age and construction).
- Elevated soil lead concentrations are typically limited to the upper 0.1 m of soils. Therefore, exceedances of the lead NES-CS SCS for 210 mg/kg or 500 mg/kg residential land use/high density residential guidelines are rarely found in soils samples collected from a depth of 0.3 m or deeper (unless a HAIL activity has occurred on the property or there has been importation of contaminated fill material or burial of waste material).

Based on the above information, a generic SPR CSM has been developed for Kāinga Ora resiential properties presented in **Attachment A** and are shown pictorially in **Figures 5-1** and **5-2**.

As noted above, the generic CSM developed is described as a probability-based model. Therefore, the key aim of any investigation that uses the model is to verify the model assumptions before commencing the fieldwork programme and use the intrusive investigation to validate the model.

It is recommended that the generic SAP for the investigation of Kāinga Ora residential properties be based upon the key CoC identified in this report and that investigation work:

- Targets surficial soils (0.075 m depth) on residential properties, with additional samples collected at 0.3 m and 0.5 m to verify the vertical distribution of contaminants.
- The primary hotspot on residential properties is within 1 m to 2 m of buildings erected on the site.
- Surface trace element soil contamination concentrations should be assessed using 95% UCL.

It is also recommended that a PSI be undertaken before sampling to validate the assumptions in this report/CSM to:

- Determine if the property has been subject to the importation of fill material (in addition to standard sub-grade materials that have been used for house construction).
- Determine whether a historic HAIL activity has occurred on the site.
- Determine whether a fire or demolition of buildings/structures has occurred on the property, which may have resulted in additional hotspots for investigation.

Based on the results from the PSI, the scope of the investigation on a Kāinga Ora property may need to be expanded.

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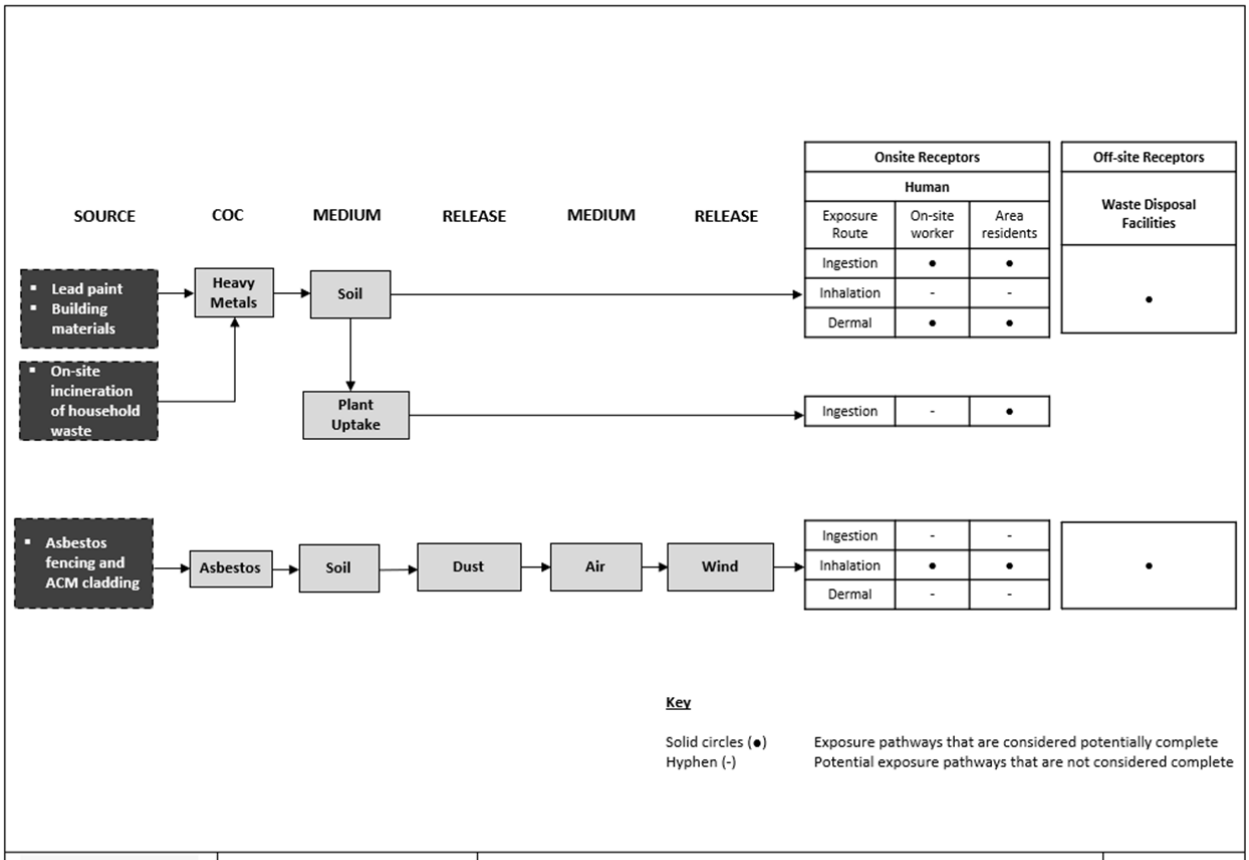
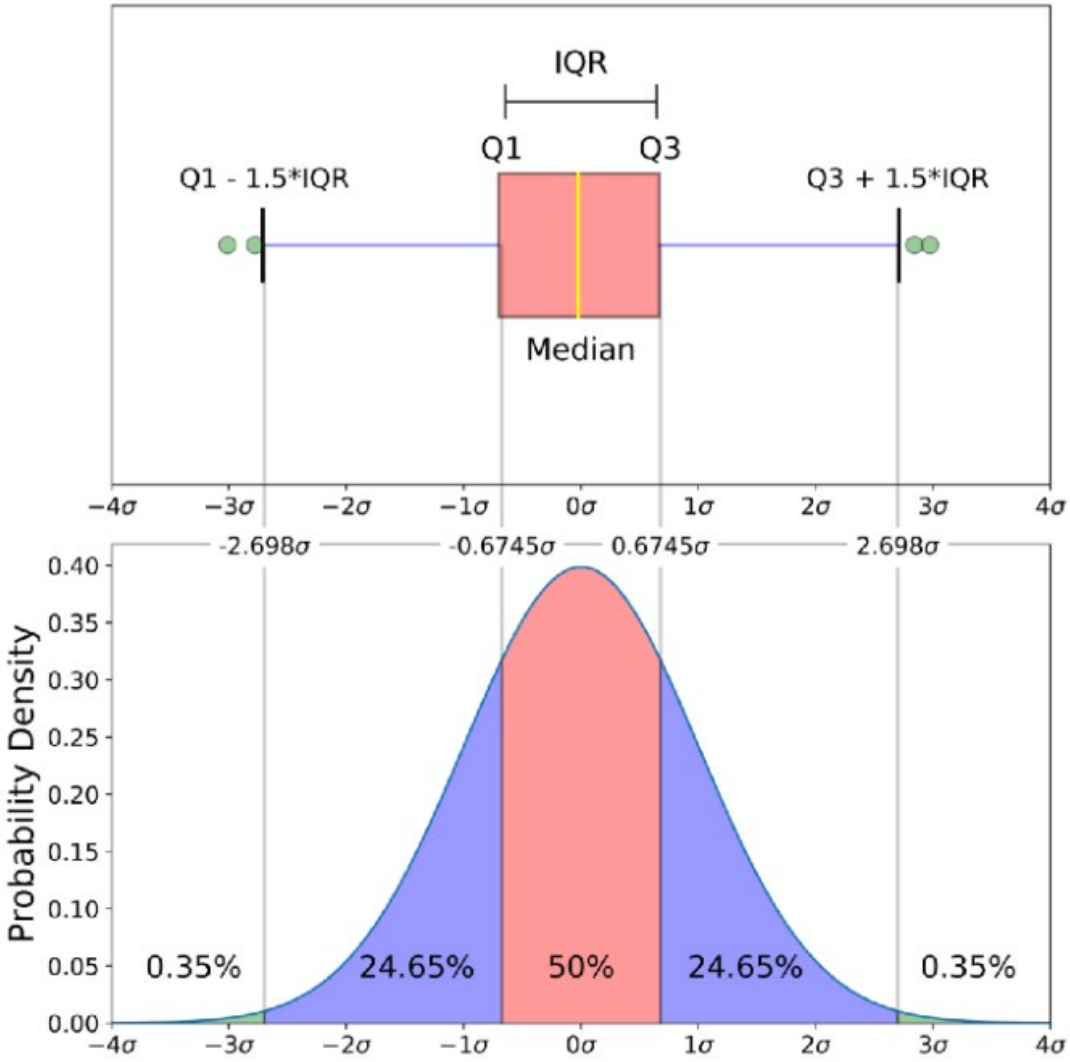
Attachment A – Geneic Conceptual Site Model



Attachment B – Intrepreting Box Plots



Comparison of a boxplot of a nearly normal distribution and a probability density function (pdf) for a normal distribution