Marine Sediment Contaminant State and Trends in Tāmaki Makaurau / Auckland 2004-2023

State of the Environment Reporting

Hamish Allen

August 2025

Technical Report 2025/12

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Auckland Council
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ISSN 2230-4525 (Print)
ISSN 2230-4533 (Online)

ISBN 978-1-991377-72-2 (PDF)

The Peer Review Panel reviewed this report
Review completed on 20 August 2025 Reviewed by two reviewers
Approved for Auckland Council publication by: Name: Paul Klinac Position: General Manager, Engineering, Assets and Technical Advisory
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Date: 20 August 2025

Recommended citation
Allen, H. (2025). Marine sediment contaminant state and trends in Tāmaki Makaurau / Auckland 2004-2023. State of the environment reporting. Auckland Council technical report, TR2025/12

Cover image credits
Looking across the sandflats from Harbourview – Orangihina Park, Waitematā Harbour.
The upper reaches of Little Muddy Creek, Manukau Harbour. Photographs by H Allen.

Many thanks to Dr Jenni Gadd and Marcus Cameron for their thoughtful and constructive comments and edits which have markedly improved this report.

Executive summary

Contaminants can accumulate in the sediments of our harbours, estuaries, and beaches. When present at elevated levels, metals (such as copper and zinc), nutrients (like nitrogen and phosphorus) and organic compounds (like pesticides and hydrocarbons) can cause both acute and long-lasting harm to coastal ecosystems. These pollutants can reduce the diversity and abundance of animals that live on and within the sediment, disrupting key ecosystem functions and degrading ecological communities. Contaminants originate from various human activities and can enter the marine environment through multiple pathways, such as streams, urban stormwater, and industrial discharges. Understanding the distribution and levels of contaminants in marine sediments provides a useful marker of land use impacts on aquatic environments and ecosystem health.

Auckland Council monitors marine sediment contamination through the Regional Sediment Contaminant Monitoring Programme (RSCMP). The RSCMP assesses near-shore contamination and tracks how concentrations change over time. The programme focuses on key urban-related metal pollutants: copper, lead, zinc, arsenic, and mercury. Monitoring is carried out as part of fulfilling Auckland Council's legislative obligations to monitor and report on the state of the environment, and information gained is used to identify issues and inform policy development and environmental decision-making.

This report covers the period 2004 to 2023 and provides an assessment of contamination at 97 sites across the region. It compares concentrations to sediment quality guidelines to assess their potential impact on marine sediment ecosystems, and examines temporal trends in levels of copper, lead, zinc, and mud content.

Contaminant concentrations across Tāmaki Makaurau vary significantly. Sites are categorised using a traffic light system: 'red', 'amber' or 'green'. Most sites show relatively low contaminant levels, with three-quarters rated as 'green'. By this measure, the impact on animals living on and within the sediment is expected to be minimal. The remaining sites are classified as either 'amber', where levels are moderately elevated and ecological impacts may begin to appear, or 'red', where degraded ecology would be expected as a result of elevated concentrations.

Both current and historical land use in surrounding catchments, along with an estuary's physical characteristics (such as hydrodynamics, sediment accumulation, and sediment texture), influence contaminant levels at monitoring sites. While contaminant concentrations are generally fairly low across the region, elevated levels are found in areas with intensive urban and industrial use, particularly where such activities have been ongoing for a long time.

Contamination patterns are consistent with previous reporting. The highest levels are found along the southern coastline and sub-estuaries of the Central Waitematā, the Tāmaki Estuary, and, to a lesser extent, the Upper Waitematā and Māngere Inlet. Outside of the urban areas of Auckland and in the more exposed bodies of harbours, concentrations are low.

Zinc remains a contaminant of concern and is the metal most frequently detected at elevated concentrations. Copper and mercury are generally low, though levels can be moderately elevated in some areas. Lead is mostly at concentrations below those associated with ecological impacts, and arsenic does not appear to be causing significant effects at any sites. The contaminants measured are rarely elevated on their own, and there is a strong correlation between copper, lead, zinc, and mercury levels, suggesting a common major pathway (likely urban stormwater) into Auckland's estuaries. Mud content influences contaminant concentrations, with contaminated sites typically containing muddy sediments that are known to bind toxins, allowing them to accumulate.

At most sites, contaminant concentrations showed little change during the reporting period. Where changes were observed, these were typically slow and gradual, rather than abrupt. Overall, copper and lead concentrations show modest declines, suggesting some improvement in contamination levels, while zinc shows a slight increasing trend. General improvements in lead levels have been observed in successive reports since 2012, reflecting both continued progress and the gradual recovery of contaminated sediment. Trends appear to largely be site and metal specific. In the Māngere Inlet in the Manukau Harbour several sites are showing decreasing concentrations of copper and lead, suggesting broader improvements across this area.

The relative stability of metal concentrations in Auckland is encouraging, especially as urban pressures have risen dramatically over the monitoring period. While this may suggest that to date, these growing pressures are being offset by improvements in areas like vehicle emissions and stormwater management, maintaining broad spatial monitoring remains important. It allows for the detection of potential shifts in contaminant distribution, driven by expanding and intensifying urbanisation, changes in climate, and evolving sediment dynamics, and supports the ongoing evaluation of efforts to reduce contaminant inputs.

Marine sediment contaminant state and trends in Tāmaki Makaurau 2004 to 2023

73% Most sites show relatively low levels of metal contamination

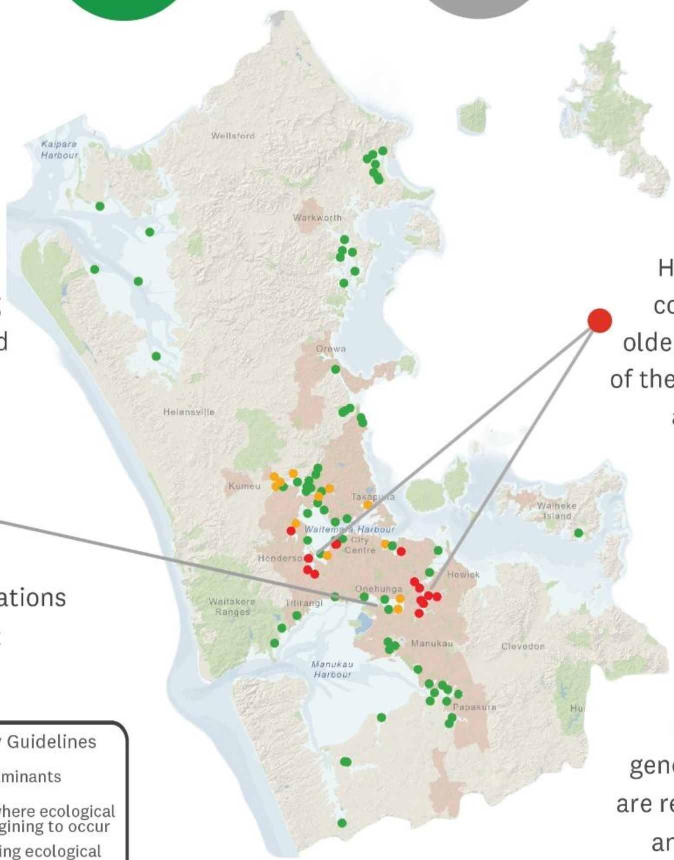
Concentrations are highest in catchments with a long history of industrial and urban use

Contaminants show a moderately strong correlation with mud

Hotspots of elevated concentrations in the older urban catchments of the Central Waitematā and Tāmaki Estuary

Improving concentrations in the Māngere Inlet

Concentrations are generally stable. There are relatively few trends and little evidence of distinct spatial patterns



Sediment Quality Guidelines

- Low level of contaminants
- Moderate levels where ecological effects may be begining to occur
- Levels likely causing ecological degradation

Sediment contaminant state at sampling sites in Tāmaki Makaurau

Contaminants are rarely elevated on their own

Zinc is the most common metal above high-level guideline values

Lead levels are generally in decline

Urban stormwater likely common pathway into the marine environment

Te Kaunihera o Tāmaki Makaurau
Auckland Council

Table of contents

List of figures

List of tables

1 Introduction

Tāmaki Makaurau is a largely marine region, characterised by its sheltered harbours, meandering estuaries, and exposed coastlines. Healthy harbours and estuaries are crucial for a range of ecological processes: they help regulate climate, support diverse biological communities, and provide essential ecosystem functions and services. Coastal regions are also important to people. They hold great spiritual and cultural significance for Māori, and serve as vital spaces for living, working, recreation, and connection with nature. However, human activities can have a significant impact on marine environments, generating pollutants which can compromise ecological health and disrupt natural processes and balance.

1.1 What are sediment contaminants and why monitor them?

Sediment contaminants can include a wide variety of substances. When elevated, metals such as copper and zinc, nutrients like nitrogen and phosphorus, and organic compounds including pesticides and hydrocarbons, can cause both acute and long-lasting harm to coastal ecosystems. In addition to these chemical stressors, sediment muddiness, caused by the accumulation of fine sediments, also poses a significant threat to coastal health by smothering habitats and altering sediment characteristics. These chemical contaminants and fine sediments can originate from a broad range of sources, and their concentration and distribution in Auckland's marine environment are influenced by several factors.

While some metals and organic compounds occur naturally through processes like the weathering of rock or geothermal activity, human activities and land use (such as industrial operations, vehicle wear, agrichemical use, and the degradation of some building materials), can elevate concentrations far beyond natural levels, turning them into harmful contaminants. Contaminants can be transported into the marine environment through various pathways, including in streams, in urban stormwater and wastewater discharges, as runoff from current and historical agricultural land use, and contained within landfill leachate[1]. Once in the marine environment, their distribution and accumulation are influenced by water flow, tides, wave action, biological processes and the texture and dynamics of sediments within our harbours and estuaries.

The build-up of contaminants is of concern because it can adversely affect ecological health. At elevated concentrations, contaminants can have a wide range of impacts on organisms. This can include affecting feeding rates (Townsend et al., 2009), reducing reproductive ability (Mann et al., 2009) and altering population attributes (De Silva et al.,

[1] Landfill leachate is caused by a process where liquid (typically rain) percolates through landfill waste, dissolving or entraining contaminants before it flows out of the waste material.

2021). Contaminated ecosystems typically show a reduced abundance and/or diversity of sensitive sediment-dwelling species, resulting in degraded communities dominated by species more tolerant of higher contaminant concentrations (see Figure 1-1). The effects can extend beyond the immediate area of contamination, as many of these species play crucial roles in the wider functioning of estuarine ecosystems and serve as a key food source for fish and birds in higher trophic levels.

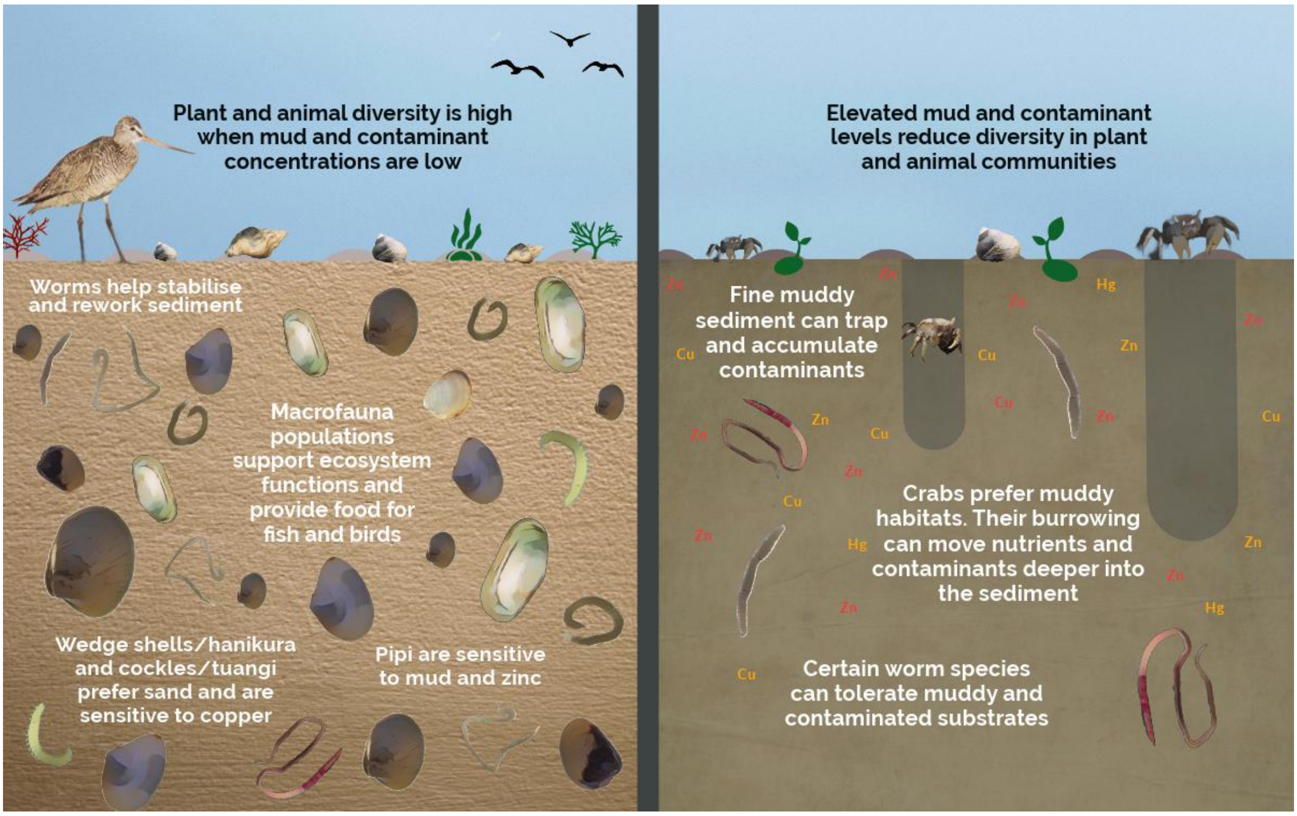


Figure 1-1. Graphic depicting a cross section of intertidal life in a sandy/low contaminant substrate (left), and a muddy/contaminated substrate (right).

Sediment acts as an effective integrator of contaminants from upstream sources and provides a useful marker of land use impacts on marine environments. Many contaminants do not degrade and accumulate in sediments, while others break down slowly, contributing to their gradual buildup over time. Because contaminant concentrations tend to change slowly, sediment quality serves as a reliable indicator of long-term environmental conditions and reduces the need for frequent sampling. Monitoring contaminant and muddiness levels, alongside seafloor ecology (Drylie, 2025a, 2025b) and coastal water quality (Kamke and Gadd, 2025), provides valuable insights into our impacts on aquatic health. This information also helps assess the effectiveness of resource management and remediation initiatives aimed at mitigating adverse effects.

1.2 The Regional Sediment Contaminant Monitoring Programme

Marine sediment contaminant monitoring in Auckland started in 1998 with 26 sites, and Auckland Council has since gathered data from over 120 harbour, estuary, and coastal locations. Today, approximately 80 sites are monitored regularly as part of the Regional Sediment Contaminant Monitoring Programme (RSCMP).

The RSCMP aims to achieve the following objectives:

1. Provide assessment of the state of near shore marine sediment contamination using relevant guidelines where applicable.
2. Maintain regionally representative coverage, with an emphasis on areas undergoing change.
3. Provide data which allows the changes (trends) in sediment quality to be assessed over time.
4. Undertake studies to increase understanding and identify new and developing marine sediment contamination issues.

Our monitoring has focused on measuring key contaminants associated with urban activities – the chemicals routinely analysed are metals – copper (Cu), lead (Pb), zinc (Zn), arsenic (As; a metalloid), and mercury (Hg). These chemicals can have contemporary sources, as well as historical sources, which can leave legacy concentrations in marine sediments (see Table 1-1 for a list of potential natural and man-made sources). The monitoring assesses the spatial distribution and temporal trends in these contaminants, and is carried out as part of legislative obligations, including those under section 35 of the Resource Management Act 1991. The monitoring also provides evidence of how the council is maintaining and enhancing the quality of the region's coastal environment. The data informs State of the Environment reporting, stormwater quality management, resource consenting, policy development, and public education.

It is important to note that the RSCMP assesses sediment contamination with regard to ecological impact only, it does not assess chemical concentrations with regard to human health. This is because the programme is designed with the aim of tracking changes in environmental quality and assessing risks to marine ecosystems. Human health risks are typically evaluated through other pathways, such as measuring contaminant concentrations in seafood, rather than through sediment monitoring.

Table 1-1. Potential natural and man-made sources of metals analysed in the RSCMP.

	Natural Sources	Man-made sources
Copper	• Natural biogeochemical processes (e.g., biological cycling and atmospheric deposition) • Weathering and erosion of soil and rock	• Urban stormwater (e.g., from vehicle use and some building materials). • Industrial and municipal wastewater • Agrichemical use • Marine activities (e.g., antifouling paints)
Lead	• Natural deposits in geological formations • Weathering and erosion of soil and rock	• Urban stormwater (e.g., from lead-based paints and some building materials) • Contaminated sediments and soil from historic land use and activities
Zinc	• Natural biogeochemical processes (e.g., biological cycling and atmospheric deposition) • Weathering and erosion of soil and rock	• Urban stormwater (e.g., from vehicle use and some building materials). • Industrial wastewater • Agrichemical use • Marine activities (e.g., zinc anodes and antifouling paints)
Arsenic	• Volcanic activity • Weathering and erosion of soil and rock • Hydrothermal vents	• Contaminated sediments from historic industrial practices and agrichemical use • Industrial wastewater • Treated timber
Mercury	• Volcanic activity • Geothermal activity • Weathering and erosion of soil and rock	• Extraction, refining and use of fuels and oil • Industrial wastewater • Stormwater (e.g., atmospheric mercury washed out by precipitation)

1.2.1 Monitoring sites

The RSCMP monitors a range of sites across Auckland's diverse catchment land uses and histories. As a key focus of the programme is to monitor urban impacts, most of the sites are in areas receiving run-off from predominantly urban catchments, such as the Tāmaki Estuary and the Manukau and Waitematā Harbours. The sites are situated in the intertidal zone – the area periodically covered and uncovered by the tides – and exhibit a range of sediment textures. Many can be 'muddy', with a significant proportion of silt and clay (particles <63µm). This reflects the accumulation of land derived fine sediment present in many urban estuarine locations.

In addition to data collected as part of the RSCMP, sediment contaminant sampling has also been carried out in conjunction with benthic ecology monitoring in a number of additional estuaries and harbours around the region as part of the 'Harbour Ecology' and 'East Coast Estuaries' monitoring programmes. This monitoring focuses on surface sediment characteristics and macrofauna to assess the ecological health of intertidal sandflats. Sampling for sediment contaminants at these sites is less frequent than at RSCMP sites, and as such the data record is not yet sufficient for trend analysis. However, they are suitable for inclusion in the 'state' assessment, markedly increasing the spatial coverage of our understanding of sediment contaminants across the region and providing for 'checks' in more rural areas. These checks ensure that the expected low level of metal contamination in these areas is in fact a reality. The data can also provide important baseline information for future assessments, especially in estuaries where urban development is planned within the catchment.

The locations of the sites monitored in the RSCMP, and associated programmes, are shown in Figure 1-2. For completeness, around ~20 sites are shown even though sediment contaminants have not been tested since the last report. These sites are in predominantly rural catchments along the east coast, including the Wairoa Embayment, and the Ōrewa, Pūhoi, Waiwera, Tūranga, Waikōpua and Mangemangeroa estuaries. The most recent data for these locations were presented in the previous state and trends report (Mills and Allen, 2021).

1.3 This report

This is the third time regional sediment contaminant state and trends have been reported in Tāmaki Makaurau. Mills et al (2012) reviewed data from 1998 to 2010, while data acquired between 2004 and 2019 were analysed in Mills and Allen (2021).

This report provides an updated assessment using data from 2004 to 2023 (inclusive).

This report covers the following areas:

1. Spatial patterns in sediment contaminant distribution (for copper, lead, zinc, arsenic and mercury) across the region and comparison of concentrations with sediment quality guidelines to assess the potential impacts on benthic ecosystem health, i.e. contaminant 'state'.
2. Temporal trends in total recoverable copper, lead, and zinc concentrations at sites where sufficient data is available.
3. Mud content (sediment <63µm) state at all sites and temporal trends at sites where sufficient data is available.
4. Comparison of state and trends with previous assessments.
5. Discussion of results within a regional context.

1.4 Supporting information

This report is one of a series of technical publications prepared in support of *Te oranga o te taiao o Tāmaki Makaurau – The health of Tāmaki Makaurau Auckland's Natural Environment in 2025: a synthesis of Auckland Council State of the Environment reporting*.

All related reports (past and present) are published on the Knowledge Auckland website.

All data supporting this report can be requested through our Environment Auckland Data Portal. Here you can also view live rainfall data and use several data explorer tools.

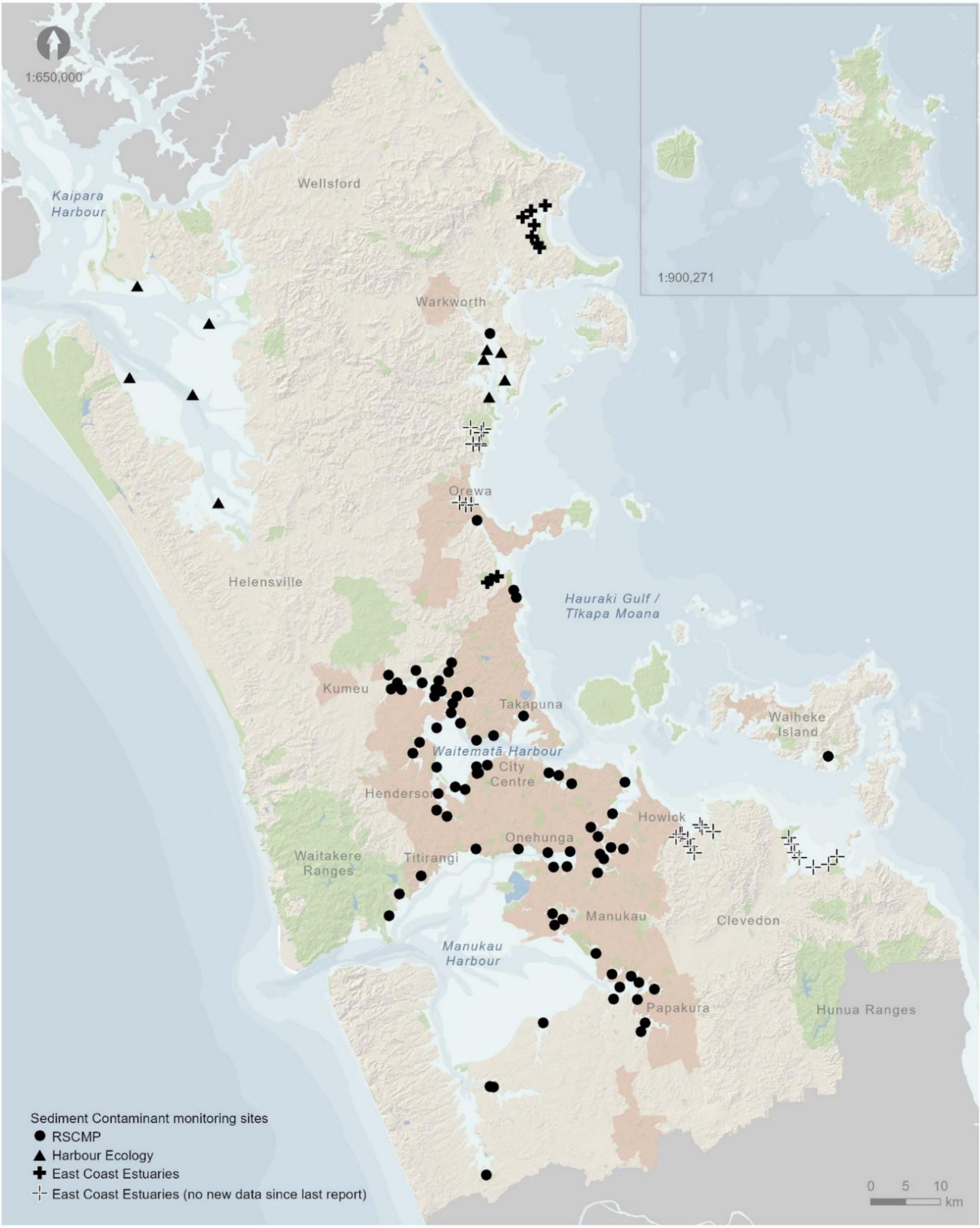


Figure 1-2. Site locations and associated programmes of sediment contaminant monitoring.

2 Methods

2.1 Sediment sampling

The sampling protocols used in the RSCMP are outlined in detail in the monitoring ‘blueprint’ document (ARC, 2004) and described briefly here.

Sampling involves the collection of five replicate samples from a site (site dimensions are typically 50m x 20m), with each replicate being made up from 10 sub-samples taken at regular intervals along two longitudinal transects. The sampling depth is <2cm, providing an integrated mixture of freshly deposited material and older sediment from slightly deeper in the profile. The sampling is designed to ‘smooth out’ spatial and short-term temporal variations in contaminant levels to facilitate trend detection. The multiple replicates taken from each site enable robust measures of ‘average’ concentrations to be calculated (medians are generally used for data analyses), as well as providing information on within-year data variability.

Sampling is conducted in October-November to align with the optimal timing for benthic ecology sampling which is conducted at the same time. The timing of the chemical contaminant sampling is not considered critical, because concentrations are not expected to vary greatly over short time intervals.

Sampling frequency follows a temporally nested monitoring approach, with sites sampled on a rotational basis every few years. Each sampling round focuses on a specific area or harbour (e.g., Central Waitematā Harbour, Tāmaki Estuary, Manukau Harbour), allowing for a comprehensive assessment of sediment contamination in that location within a given year.

2.2 Contaminants measured

2.2.1 Metals

The contaminants routinely analysed are total recoverable metals – copper (Cu), lead (Pb), zinc (Zn), arsenic (As; a metalloid), and mercury (Hg).

Total recoverable metals are extracted from the sediment by hot, strong acid digestion (HNO_3/HCl, USEPA Method 200.2). Samples are analysed on the <500µm (<0.5mm) fraction, which approximates the total sediment, with larger coarse particles – e.g. shell hash and gravel – removed to reduce data variability. Concentrations are presented in milligrams per kilogram (mg/kg) freeze-dried weight.

2.2.2 Organic contaminants

Persistent organic contaminants such as polycyclic aromatic hydrocarbons (PAHs), organochlorine pesticides (OCPs), and polychlorinated biphenyls (PCBs) have also been analysed at times in the RSCMP. These contaminants are scheduled to be analysed much less frequently than for metals and only at selected ‘at risk’ sites (see Mills, 2014a and 2014b). This is because ecosystem health is expected to be less sensitive to organic contaminants than metals at most sites as the concentrations are generally below relevant guidelines, and the analyses are much more expensive to reliably perform than for metals. It is also expected that OCP and PCB concentrations will be in decline as their widespread use is historic.

As with metals, samples are analysed on the <500 µm fraction. A sampling round of organic contaminants at selected sites was completed in 2024. These results will be reported separately from the routine metal analysis conducted annually as part of the RSCMP, which is the focus of this report

Emerging contaminants (ECs) are a wide ranging and evolving group of substances that include many organic chemicals (such as pharmaceuticals, pesticides, and industrial compounds) as well as microplastics. They are being increasingly recognised for their potential impacts on coastal and marine environments. Further details and research related to these contaminants are provided in Figure 2-1.

2.2.3 Particle size distribution

A composite sample, comprising 10 sub-samples collected from the top 2cm of sediment, is analysed for Particle Size Distribution (PSD). The PSD sample is representative of the same sediment layer used for contaminant analysis. Particle size is determined by wet sieving and pipette analysis (Gatehouse, 1971) and presented as percentage composition of gravel/shell hash (>2mm), coarse sand (500-2000µm), medium sand (250-500µm), fine sand (125-250µm), very fine sand (62.5-125µm), silt (3.9-62.5µm) and clay (<3.9µm).

PSD data are used in the RSCMP primarily to assess whether there have been changes in mud content (i.e., proportion of the sediment in the <63µm range; the sum of silt and clay) that may affect interpretation of the metals results. Trends in metals and mud content need to be considered together to assess the possible contribution of changing PSD to trends in metals over time.

Emerging contaminants

Emerging Contaminants (ECs) encompass a diverse array of chemicals that are not yet routinely monitored but have the potential to cause ecological and human health effects. Major sources of ECs include wastewater, stormwater, and runoff from agriculture and horticulture. An earlier scoping study of sediments from Auckland's estuaries found that EC concentrations were comparable to international levels, with elevated concentrations near wastewater discharges and sewage overflows (Stewart et al., 2014). Microplastics (particles <5mm) are pervasive and persistent environmental pollutants (MfE and Stats NZ, 2025; Gola et al., 2021). Research has shown widespread microplastic contamination across Auckland's beaches and coastlines (Bridson et al., 2020), raising concerns about their impact on ecological and human health. Sources of microplastics include synthetic textiles, vehicle tyre wear, packaging, personal care products, and the degradation of larger plastic items. The project 'Aotearoa Impacts and Mitigations of Microplastics (AIM2)' explored the effects and threats of microplastics to New Zealand's environment. Key findings revealed microplastics in remote marine areas, the persistence of biodegradable plastics marketed as eco-friendly, a wide range of chemical contaminants associated with microplastics, and the transfer of these harmful additives to marine ecosystems.

Despite research efforts, effective monitoring and management of ECs remains challenging. These contaminants often exist in complex mixtures, and there are significant knowledge gaps in identifying the highest-risk ECs (Stewart and Tremblay, 2024). A recent project 'Managing the risk of emerging contaminants' analysed water (using passive sampling devices) and sediment samples in the Whau Estuary. This project utilised an effects-based monitoring approach, combining bioassays and chemical fractionation to assess the biological activity of chemicals present (see Leusch et al., 2024). Stewart and Tremblay (2024) suggest that this approach could be a valuable tool for future EC monitoring, offering insights into potential effect mechanisms and risks posed by mixtures of chemicals.

The Global Estuaries Monitoring Programme, established under the United Nations Decade of Ocean Science (2021–2030), aims to standardise sampling and analysis methods for ECs. Involving around 35 countries, the first phase of this programme focusses on pharmaceuticals. Surface water samples from Manukau Harbour were collected in late 2023, with results expected in 2025. The findings from this first phase will inform future focus areas for the programme.

Whilst Auckland Council supports and assists various research projects associated with ECs, they are currently not part of routine RSCMP monitoring, and as such are not discussed further in this report.

Figure 2-1. Emerging Contaminants.

2.3 Quality assurance

A quality assurance (QA) process is conducted after each sampling round to check that the data are 'fit for purpose' – i.e. suitable for reliably assessing state and temporal trends. The current data acceptance guidelines include measures for:

- Potential sample contamination, as assessed from procedural blanks.
- Data accuracy, from analysis of Certified Reference Materials (CRM)[2].
- Year-to-year data consistency and within-year variability, as assessed principally from trend and variability analysis of CRM and Bulk Reference Sediment (BRS)[3].

The application of the QA protocols can be found in annual RSCMP monitoring reports (e.g., Allen, 2023b).

Generally, data quality across the monitoring time frame (and for the most recent results presented here) was found to be satisfactory for the purposes of the RSCMP. Previously, the QA process has identified some issues such as elevated zinc in data from 2017 to 2019. This was found to be due to changes in laboratory procedures and means that zinc results for 2017, 2018, and 2019 may be artificially higher than they really are because of analytical artefacts, rather than from real environmental causes. This issue now appears to be resolved, and trend analysis in BRS samples are continuing to show improved results (i.e., the percentage change each year has been decreasing since 2020). See Mills and Allen, 2021, for more detail.

2.4 State assessment and sediment quality guidelines

Contaminant 'state' refers to the concentration of contaminants present in sediment and is used to assess the likelihood of adverse ecological effects on benthic organisms. Sediment Quality Guidelines (SQGs) provide a useful framework for interpreting and presenting contaminant concentrations within the context of ecological risk, playing an important role in sediment quality assessment.

Contaminant concentrations are compared with three SQGs: the Australian and New Zealand Guidelines for fresh and marine water quality (ANZG, 2018) for all metals; the Auckland Council Environmental Response Criteria (ERC; ARC, 2004) for copper, lead and zinc; and the Threshold Effects Level / Probable Effects Level (TEL/PEL; MacDonald et al., 1996) for mercury. Relevant SQG values are summarised in Table 2-1 and outlined briefly below.

A note on arsenic: the application of more conservative guidelines (such as the TEL/PEL) for the metalloid arsenic have been deemed unsuitable for Auckland, as guideline values can sit below what is found to occur as reference concentrations in the region. As such, arsenic is

[2] Certified Reference Materials (CRM) are used to check data accuracy by comparing the lab-generated results with the certified concentrations and uncertainty limits for the reference materials. Several CRM samples (currently the CRM used is 'AGAL-10') are included in each analytical batch as 'unknowns' and analysed as for field samples.

[3] Bulk Reference Sediment (BRS) are 'in-house' reference materials made up from sediments sampled from two estuarine sites in 2011: one, more contaminated, muddy site from the Tāmaki Estuary, and another less contaminated sandy site from the Central Waitematā Harbour. Multiple replicates from each of these BRS are analysed with each batch of annual RSCMP monitoring samples and the results analysed to assess ongoing trends and variability.

compared with ANZG guidelines only. See Allen, 2023a, for more detail on the interpretation of arsenic concentrations under different sediment quality guidelines.

2.4.1 Australian and New Zealand Guidelines for fresh and marine water quality (ANZG)

The ANZG provides default guideline values (DGV), which indicate the concentrations below which there is a low risk of ecological effects occurring, and in contrast, 'upper' guideline values (GV-high), which indicate concentrations where you might expect to observe adverse toxicity-related effects. Detail of the origins of these values is provided in ANZG (2018).

2.4.2 Environmental Response Criteria (ERC)

The ERC are considered conservative thresholds, developed and refined specifically for the Auckland region (ARC, 2004). The ERC are the guidelines predominantly used in assessment of copper, lead, and zinc levels in the RSCMP. The rationale for selecting lower contaminant thresholds (when compared with the ANZG) is to provide an early warning of environmental degradation, allowing time for further investigations to take place and/or management responses to be properly assessed and implemented before more serious degradation can occur.

A summary of the meaning of the ERC are as follows:

- ERC Green sites reflect a low level of impact.
- ERC Amber sites are showing signs of contamination, having contaminants above a level at which adverse effects on benthic ecology may be starting to appear.
- ERC Red sites are higher impact sites where contaminant levels are elevated and impacts on benthic ecology are likely to be occurring.

2.4.3 Threshold Effects Level (TEL) and Probable Effects Level (PEL)

The TEL represents a contaminant concentration below which adverse effects on benthic organisms are unlikely to occur. Conversely, the PEL is intended to estimate the concentration above which adverse effects frequently occur in a large percentage of the benthic population. Because no ERC guidelines were derived for mercury, the TEL/PEL values are used in this report as conservative thresholds for its assessment.

Table 2-1. Sediment Quality Guidelines used in this report. Environmental Response Criteria (ERC), Threshold Effects Level/Probable Effects Level (TEL/PEL) and Australian and New Zealand Guidelines (ANZG) for metals. DGV = default guideline values, GV-high = guideline value high.

Metal	ERC (mg/kg)			ANZG (mg/kg)			TEL/PEL (mg/kg)		
	Green	Amber	Red	DGV		GV-high	TEL		PEL
Copper	<19	19 - 34	>34	<65	65 - 270	>270	Not applicable		
Lead	<30	30 - 50	>50	<50	50 - 220	>220	Not applicable		
Zinc	<124	124 - 150	>150	<200	200 - 410	>410	Not applicable		
Arsenic	No ERC values			<20	20 - 70	>70	Not applicable		
Mercury	No ERC values			<0.15	0.15 - 1	>1	<0.13	0.13 - 0.7	>0.7

The ANZG DGVs for copper (65 mg/kg) and zinc (200 mg/kg) are higher than the ERC red values (34 and 150 mg/kg respectively), while for lead the ANZG DGV (50mg/kg) is the same as the ERC red threshold. The ANZG DGVs are all higher than the ERC and TEL green-amber threshold values. The use of the TEL/PEL for mercury offers slightly more conservative thresholds in line with the ERC. As a result of the higher values, fewer sites will trigger the ANZG guideline thresholds for adverse ecological effects than the ERC or TEL/PEL.

2.4.4 Mud content

Assessment of a site's mud content (sediment particles in the silt and clay fraction; <63µm) follows the guidelines set by Land Air Water Aotearoa (LAWA, 2022). These split the percentage of mud content into categories based on how much impact it is likely to have on macrofaunal communities and ecosystem functions.

The categories are as follows: mud content ≤3% (supports healthy and diverse macrofauna communities), 3-10% (macrofaunal communities are most resilient with mud content below 10%), 10-30% (a decline in macrofaunal community resilience), 30-60% (macrofaunal communities become unbalanced), >60% (macrofaunal communities are degraded).

2.4.5 Regional reference values

The ANZG (2019) encourages the development of regionally specific guidelines for contaminant assessment. In cases where such guidelines are unavailable (as is the case for arsenic and mercury in Auckland), the ANZG recommends an interim 'reference site approach'. This involves calculating the 80th percentile of concentrations from appropriate reference sites, typically located in predominantly native forested catchments with minimal urban influence. However, sites in largely undisturbed ecosystems with long term marine sediment contaminant data records can be limited or absent. In such cases, an alternative approach using 'best available' reference sites – the least disturbed sites with sufficient data – can be used.

Although regional guidelines exist for copper, lead, and zinc, applying a reference site approach across all metals provides a useful estimate of near-background concentrations, which can then be compared with site-specific data to help assess potential anthropogenic impacts. Accordingly, 80th percentile values were calculated using data from three 'best available' reference sites: two muddy sites ('Big Muddy' in the outer Manukau Harbour and 'Weiti' on the East Coast Bays), and a sandier site ('Te Matuku' on Waiheke Island). These sites span the region spatially, and the weighting towards muddier sediments better represents the grain size typically found at most RSCMP sites. The resulting 80th percentile concentrations, based on 92 samples for copper, lead, and zinc, and 59 samples for arsenic and mercury, are presented in Table 2-2.

Table 2-2. Reference values for copper, lead, zinc, arsenic and mercury derived from three RSCMP 'best available' reference sites.

Metal	Reference value (mg/kg)
Copper	11.9
Lead	9.5
Zinc	60.9
Arsenic	11.8
Mercury	0.046

Note: the reference values presented here are intended as a guide only. This reflects both the use of 'best available' reference sites (see ANZG, 2019) and the fact that natural background concentrations can vary across the region due to factors such as catchment geology, sediment type, and sediment origin.

2.4.6 Sites used for state assessment

A total of 97 sites have been included for state assessment in this report (see Figure 1-2). All sites have been sampled in the last four years (i.e., between 2020 and 2023 (inclusive); since the last regional state assessment). The exception is the Kaipara Harbour, where five sites were sampled in 2019 and analysed in 2020. This data was obtained too late for inclusion in the previous state and trends report and so it is included here.

Sites are spread across the region with the following allocations between harbours and estuaries:

- 27 sites in Manukau Harbour
- 21 sites in Central Waitematā Harbour
- 15 sites in Upper Waitematā Harbour
- 9 sites in Tāmaki Estuary
- 7 sites in Whangateau Harbour
- 6 sites in East Coast Bays
- 6 sites in Mahurangi Harbour
- 5 sites in Kaipara Harbour
- 1 site in Tāmaki Strait

2.5 Trend assessment

A key component of the RSCMP is the assessment of contaminant changes over time. Trend assessment aims to determine whether concentrations are increasing, decreasing, or remaining constant, and the rate at which any changes are occurring. Assessment involves undertaking statistical analysis of the monitoring data to obtain the 'trend slopes' (magnitude of change per year, and the direction of change) and a measure of the likelihood of these changes over time being real (whether the changes are more likely to be attributable to chance, given the data variability in relation to the magnitude of the change).

The number of data points in the time series record used for trend assessment is still relatively small due to the multi-year sampling intervals. A total of 60 sites with at least five samples (the minimum number we considered acceptable for trend assessment) are included in trend analysis. The number of sites and number of samplings for the 2004-2023 data set ranged from five to 11 (most sites had eight or nine samples) and are shown in Table 2-3.

Table 2-3. Number of samples and number of sites used in trend analysis for copper, lead and zinc.

Number of samples	Number of sites
11	8
10	6
9	17
8	14
7	6
6	7
5	2

This report presents the trend analysis for the metals copper, lead, and zinc, and mud content. Arsenic and mercury data sets are still relatively small to perform robust trend analysis, with most sites sampled just four or five times since routine monitoring of these chemicals began in 2012. Due to the fewer number of samples, arsenic and mercury data have been analysed as preliminary trends. These were recently reported for data up until 2021 (Allen, 2023a) and a summary of those findings is provided in the trend discussion section of this report (section 4.3).

Trends have been analysed using median concentrations from the five replicates measured from each sampling round at each site. The trend data set had a common core time period for most sites. The start dates were generally either 2004 or 2005, with the most recent sampling being between 2020 and 2023 (inclusive). The exceptions to this are four sites in the Manukau Harbour where sampling started in either 2008 (Pāhurehure Upper, Pāhurehure Middle, and Papakura Lower), or 2012 (Waimāhia Central).

Particle size distribution (PSD) trends are primarily used to help interpret metal concentration trends and assess whether observed changes in metal concentrations could be linked to changes in sediment texture. The exact number of PSD samples does not always align with the number of contaminant samples. In earlier years, the sites sampled for PSD varied depending on contaminant levels, meaning not all sites were sampled in each round. As a result, some sites have fewer PSD samples than metal samples. A total of twenty out of the 60 sites used for trend analysis had fewer PSD samples (typically one or two) than metal samples. However, only sites with at least five samples were included in the trend assessment, ensuring that despite the slight discrepancies, the PSD data are deemed acceptable for use.

2.5.1 Data used for trend assessment

Trends for total recoverable copper, lead, zinc (using median values) and mud content (using a single composite sample) at 60 sites were analysed. The locations of these sites are shown in Figure 2-2. The majority of sites included in trend analysis are within the urban area of Auckland, with few ‘rural’ sites (such as those in the east coast estuaries), having had sufficient samples to undertake analysis. Additional detail on the data used and trend analysis results are presented in summary tables in section 7.2.

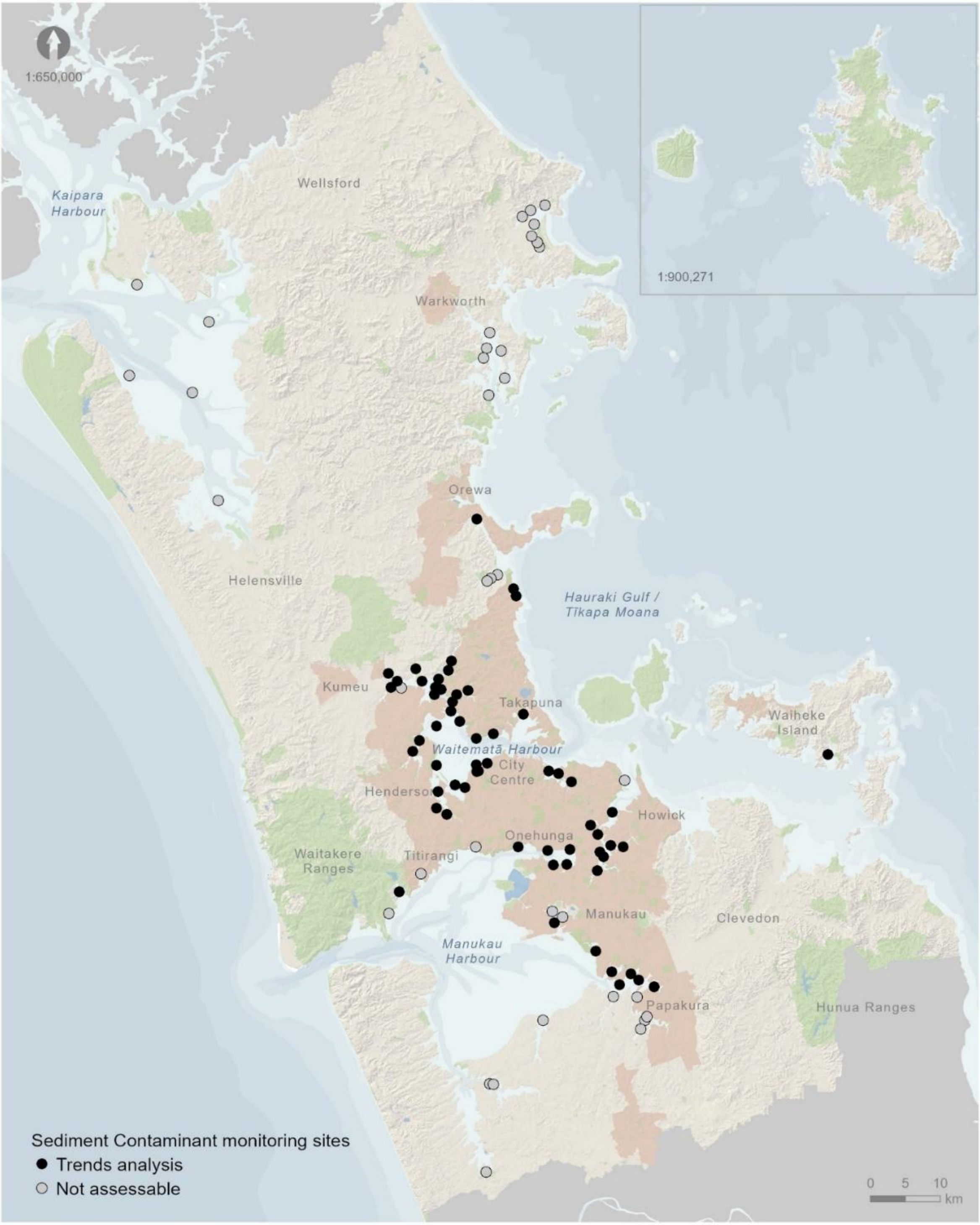


Figure 2-2. Locations of the 60 monitoring sites used for trends analysis.

2.5.2 Statistical analysis

The significance of linear trends was assessed with the non-parametric Mann-Kendall test. The magnitude (or 'rate of change') was obtained from the Sen Slope estimate. The Sen Slope is the median slope of all the slopes between all the data pairs in the data set (excluding ties, in values or in time). All analyses were performed in Time Trends software (Version 11; Jowett Consulting Ltd).

The likelihood of the trend being increasing or decreasing was assessed from the Sen Slope probability. Likelihood was categorised into five groups, as described by Land, Air, Water Aotearoa (LAWA, 2019) as follows:

- 'very likely' increasing or decreasing trends, where the Sen Slope probability is **90-100%**. For contaminants, an increasing trend reflects a degrading or worsening state, while a decreasing trend indicates improving conditions,
- 'likely' increasing or decreasing trends (Sen Slope probability **67-90%**). The lower certainty reflects the fact that while there is an indication of a trend, there is less statistical support for it,
- 'indeterminate' trends, where the Sen Slope probability is **<67%**, reflecting insufficient evidence to confidently determine if there is an improving or degrading trend.

This approach is consistent with that used for the previous trend assessment for the RSCMP programme (Mills and Allen, 2021), for national water quality monitoring trend assessment and reporting (LAWA, 2019) and is the recommended method for analysis of temporal trends in environmental data, including for coastal and estuarine variables (Larned et al., 2021).

As for the previous trend assessment (Mills and Allen, 2021), trend magnitudes have been calculated as absolute values (in units of mg/kg per year for metals and per cent of sediment particles <63µm per year for mud content) and a threshold of **±2%** of the median per year and '**very likely'** probability has been used to define 'meaningfulness'. Trends meeting this threshold were considered to be reliable and potentially have 'real world' significance.

2.5.3 Interpreting trend data: a cautionary note

A range of factors needs to be considered when analysing and interpreting trends from monitoring data. While the monitoring data collected to date is comprehensive, it does have some limitations.

Ideally, all monitoring data would be acquired at the same frequency, using the same sampling methodology, and the samples analysed by the same laboratory methods. However, this is rarely the case over the time scales required to build robust sediment contaminant data sets, and the RSCMP has seen some changes in laboratory analytical methods used between the programmes prior to 2009, and a lack of benchmarking for the data record prior to 2011 (when the BRS quality assurance protocol was introduced).

Additionally, the number of samples at each site is still relatively small, as sampling is fairly infrequent. This means that trends are sensitive to the effects of additional data, although to a lesser degree now compared with previous trend assessments which relied on fewer samples. As the sampling record grows over time, the sensitivity of the calculated trends to new monitoring data will decrease, improving the robustness of trend assessments.

The trend data offer a general view of directional and magnitude changes over time and results have been discussed in this context. Detailed assessments of specific sites should account for data variability and any anomalies. Where significant trends are identified in this report, further ecological investigation may be warranted using a 'multiple lines of evidence' approach as recommended by ANZG (2018). Trend analysis is one part of a broader assessment that includes trends in ecological health, as well as changes in land use and contaminant management.

3 Results

3.1 Contaminant state

Contaminant state was assessed by examining the most recent total recoverable metals data for copper, lead, zinc, arsenic, and mercury. These data were then compared against sediment quality guidelines (SQGs) to assess potential impacts on benthic fauna. The most recent mud content state has been assessed according to LAWA guidelines.

Overall, there was a relatively low level of marine sediment metal contamination across the region, with 71 of the 97 sites (~73%) rated green – i.e., with no metal concentrations exceeding SQG thresholds. Based on this measure, the risk to benthic aquatic life from metal contamination is expected to be low at most sites. Twelve of the 97 sites (~12%) were rated as amber, i.e., having at least one metal with slightly elevated concentrations where adverse effects on benthic ecology may be starting to appear, while 14 sites (~14%) fell into the ERC red category. At these sites, it is expected that ecological degradation will be occurring as a result of elevated concentrations.

Each metal is described below and concentrations at all sites are presented in Figure 3-1 to Figure 3-5, alongside relevant sediment quality guidelines and the Auckland reference value. The percentage of sites with each contaminant state for each metal is presented in Figure 3-6.

Zinc concentrations show considerable variation across the region, ranging from just 5.6 mg/kg at a site in Whangateau estuary, to 253 mg/kg at site Middlemore in the Tāmaki Estuary (Figure 3-1). A total of 14 sites were in the ERC red category, a further five were within the ERC amber threshold, and 78 were in the ERC-green category. No sites triggered the ANZG GV-high value (>410 mg/kg) and seven fell above the ANZG DGV (>200 mg/kg). Just over half the sites included in this assessment (51 out of 97; 53%) were above the zinc reference value of 60.9 mg/kg.

Copper exceeded the ERC red level at just one site and at 16 sites exceeded the ERC amber category (Figure 3-2). The remaining 80 sites were in the ERC green category. The lowest values were found at sites in the Kaipara and Whangateau Harbours (<1 mg/kg), with the highest at site Whau Upper in the Central Waitematā (39.4 mg/kg). No sites were close to triggering either the ANZG DGV (>65 mg/kg), or ANZG GV-high (>270 mg/kg) values. Thirty-three sites (34%) were above the copper reference value of 11.9 mg/kg.

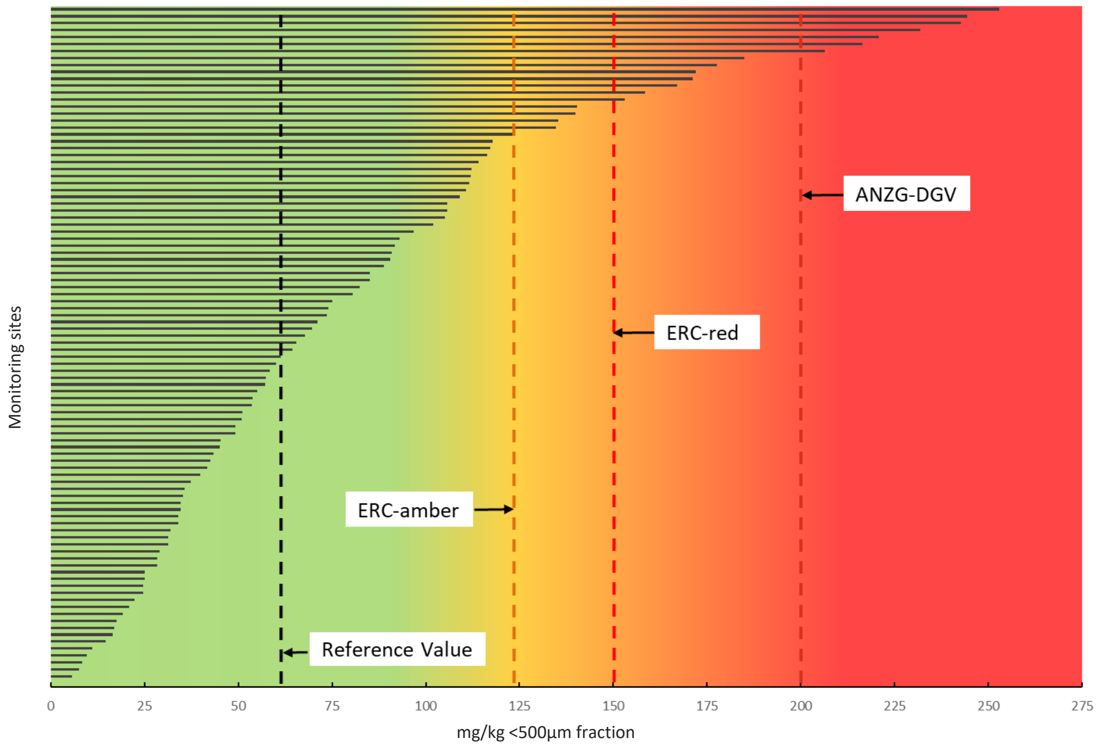


Figure 3-1. State of total recoverable zinc at all sites. Sites ordered from high to low concentration. Dashed lines show relevant sediment quality guidelines and the Auckland reference value. Concentrations are in mg/kg for the <500µm fraction.

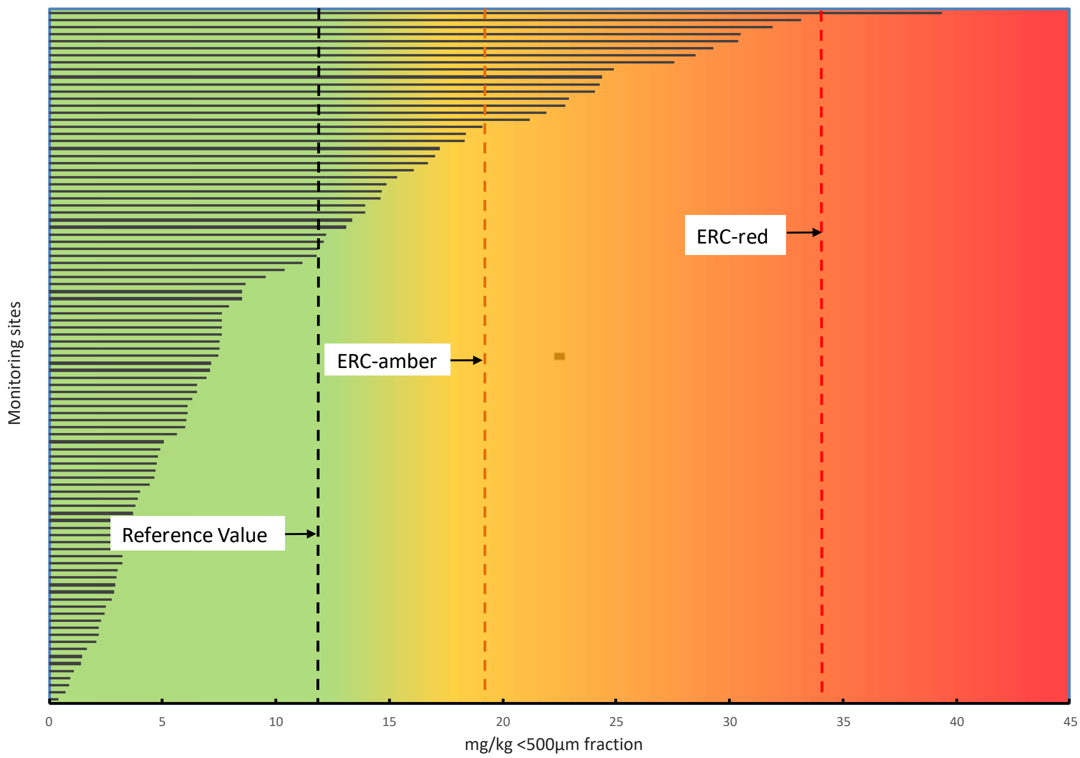


Figure 3-2. State of total recoverable copper at all sites. Sites ordered from high to low concentration. Dashed lines show relevant sediment quality guidelines and the Auckland reference value. Concentrations are in mg/kg for the <500µm fraction.

Lead concentrations exceeded the ERC red level at just one site and at seven sites exceeded the ERC amber category. A total of 89 sites were in the ERC green category (Figure 3-3). As with copper, the lowest values have been observed in the Whangateau Harbour (from 0.6 mg/kg), and the highest was at site Whau Upper (53 mg/kg). Just one site sits above the ANZG DGV (>50 mg/kg; the same value as the ERC red). A total of 58 sites (60%) were above the reference value of 9.5 mg/kg.

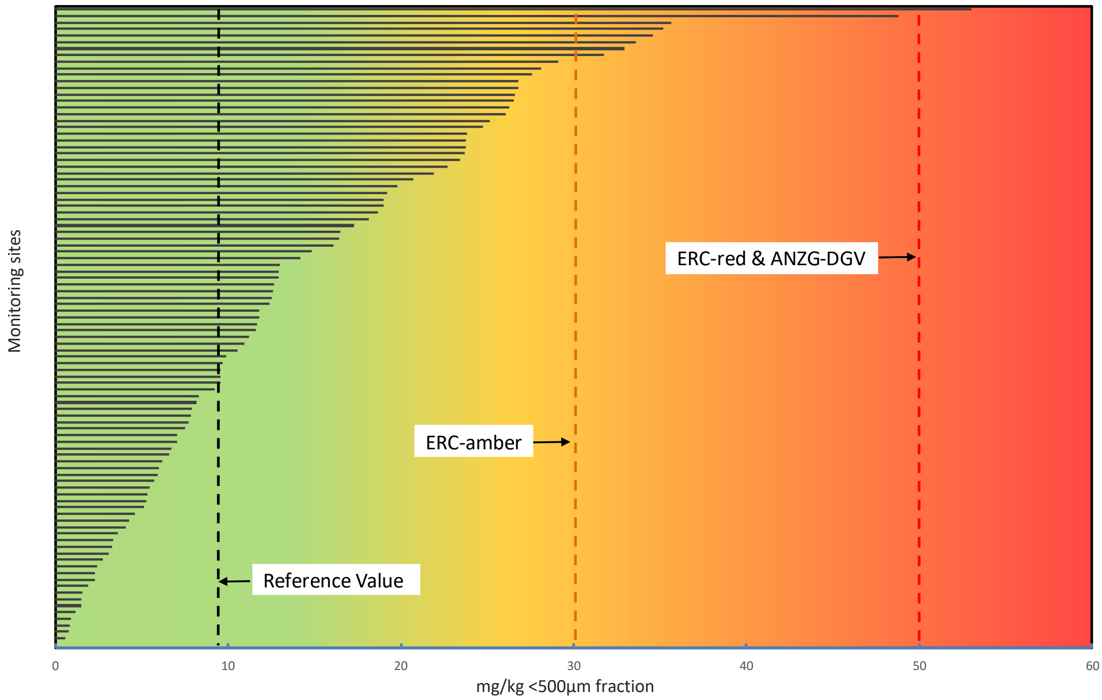


Figure 3-3. State of total recoverable lead at all sites. Sites ordered from high to low concentration. Dashed lines show relevant sediment quality guidelines and the Auckland reference value. Concentrations are in mg/kg for the <500µm fraction.

Mercury is generally low across the region (Figure 3-4). At 28 out of 97 sites (29%), concentrations were below the laboratory detection limit of 0.02 mg/kg. Detectable concentrations ranged from just above this limit at sites in the East Coast Bays and Kaipara Harbours, to 0.221 mg/kg at site Meola Inner in the Central Waitematā. Mercury is the metal most commonly exceeding amber level SQGs, with a total of 21 sites (22%) above the TEL concentration (>0.013 mg/kg). A smaller number of sites (13 out of 97; 13%) were above the slightly higher ANZG DGV (>0.015 mg/kg). The majority of these were located in the Central and Upper Waitematā and the Tāmaki Estuary. A total of 40 sites (41%) were above the reference value of 0.046 mg/kg. Encouragingly, no sites were close to triggering either the PEL (>0.7 mg/kg) or ANZG GV-high values (> 1 mg/kg).

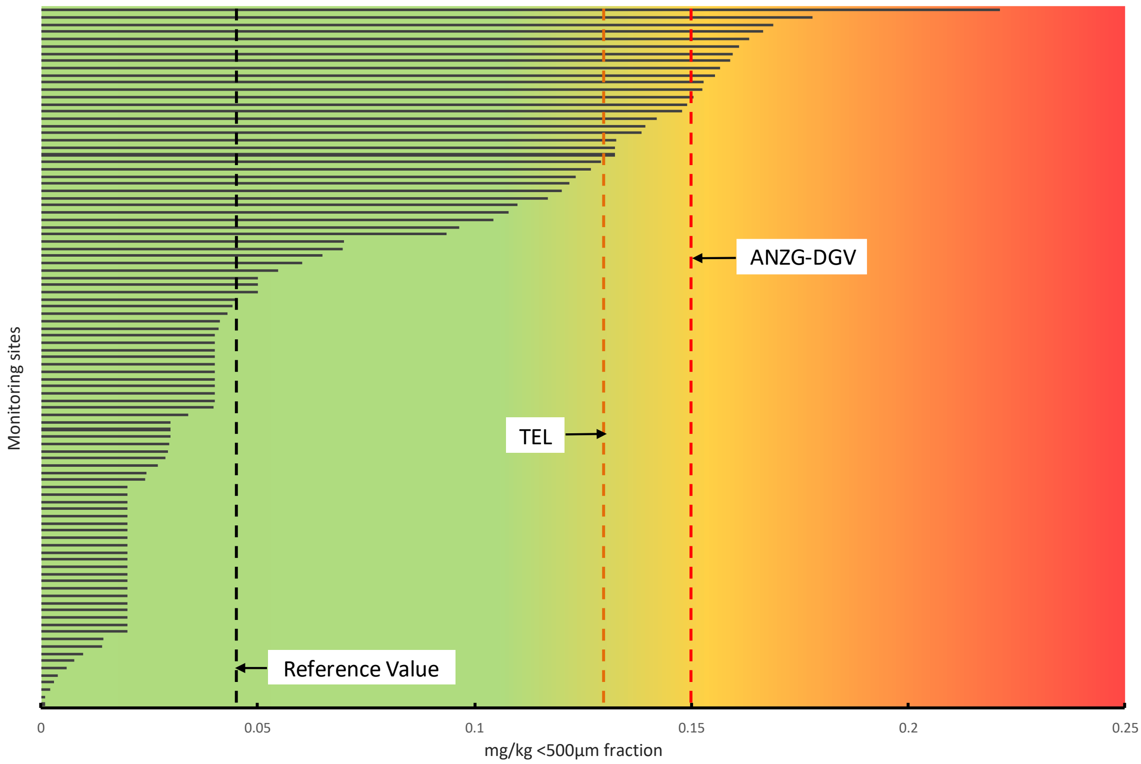


Figure 3-4. State of total recoverable mercury at all sites. Sites ordered from high to low concentration. Dashed lines show relevant sediment quality guidelines and the Auckland reference value. Concentrations are in mg/kg for the <500µm fraction.

Concentrations of **arsenic** (Figure 3-5) ranged between 1.35 mg/kg at a site in the Whangateau Harbour and 17.57 mg/kg at site Lucas Creek in the Upper Waitematā Harbour. Relatively few sites (24 out of 97; 25%) were above the reference value concentration (11.8 mg/kg), while no exceedances of the ANZG DGV threshold (20 mg/kg) were recorded, and consequently, no sites were remotely close to exceeding the ANZG GV-high value of 70 mg/kg.

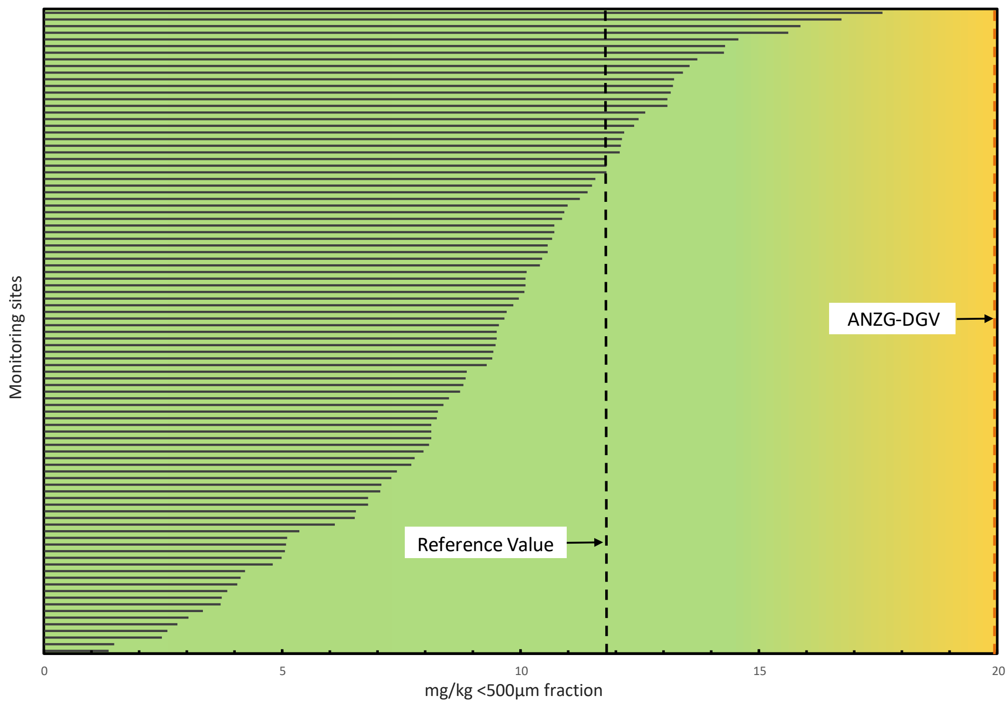


Figure 3-5. State of total recoverable arsenic at all sites. Sites ordered from high to low concentration. Dashed lines show relevant sediment quality guidelines and the Auckland reference value. Concentrations are in mg/kg for the <500µm fraction.

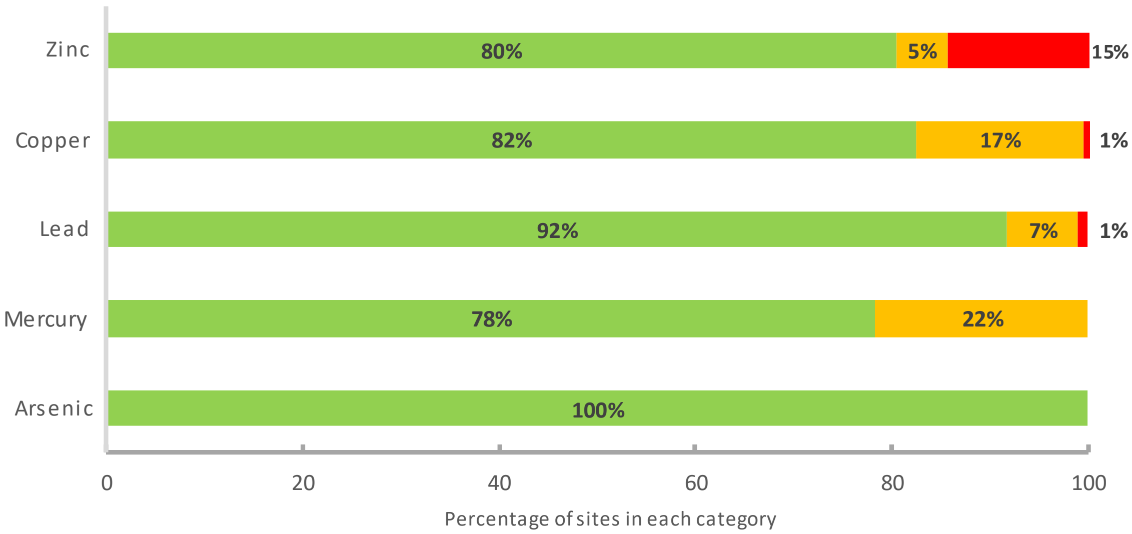


Figure 3-6. Percentage of contaminant state for all sites. Sediment quality guidelines used are the ERC for copper, lead and zinc, the TEL/PEL for mercury, and the ANZG for arsenic.

RSCMP sites seldom showed elevated concentrations of a single metal. Out of the 26 sites with elevated concentrations, only six have a single metal exceeding a threshold – three sites with only mercury exceedances and three with only zinc. It is more common for sites to show elevated levels of multiple metals, with eight sites exceeding SQGs for two metals, five sites for three metals, and seven sites for four metals.

Mud content results (Figure 3-7 and Figure 3-8) indicated a widespread fine sediment impact across monitoring sites when assessed according to LAWA guidelines. Macrofaunal communities tend to be most resilient when mud content is below 10%. Only 20 sites meet this condition, while 52 sites show mud content exceeding 30%, where the presence of fine sediments is likely contributing to an imbalance in the benthic community.

Mud content also influences the state of metal contaminants. Sites with high mud levels typically have higher contaminant concentrations. All sites exceeding SQGs showed increased mud content, with 20 out of the 26 sites having mud content above 60%. The remaining sites have mud content ranging from 10% to 30% (two sites) or 30% to 60% (four sites).

Note that mud content data for sites outside the RSCMP (i.e., those in the Harbour Ecology and East Coast Estuaries Programmes) are presented both in this report and in the associated state and trends reports for harbour and estuarine ecology (Drylie, 2025a, 2025b). There may be minor discrepancies, as the data presented here were collected during the same sampling events as sediment contaminant monitoring. In contrast, the data used in the harbour and estuarine ecology reports may have been collected at different times, as part of separate routine ecological monitoring.

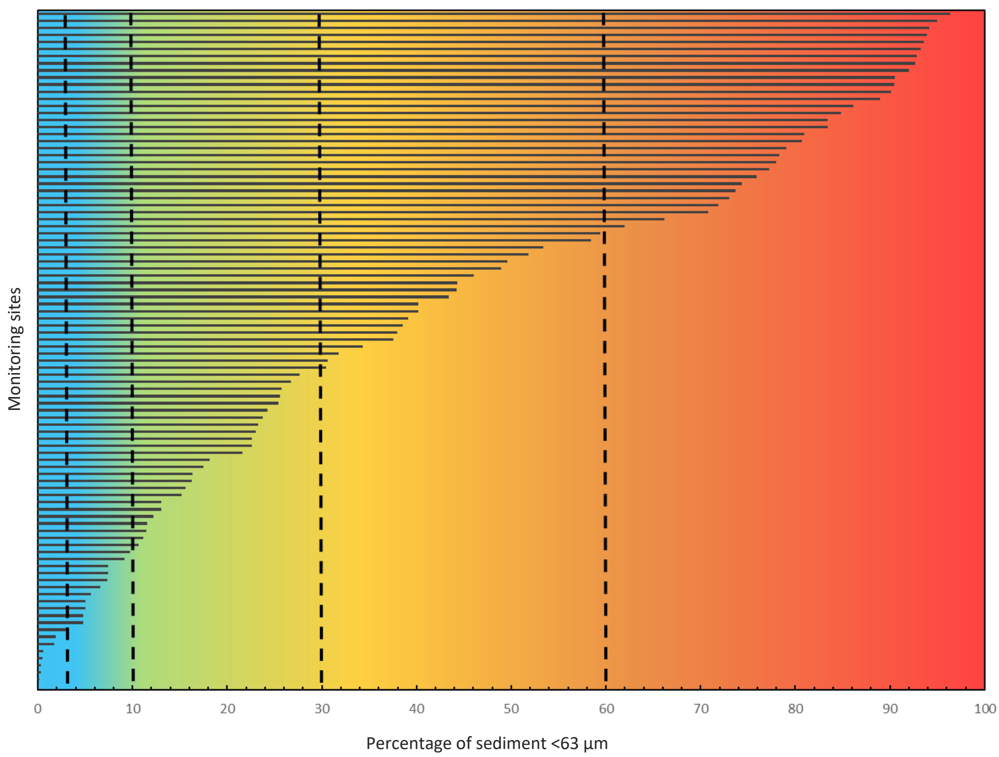


Figure 3-7. State for mud content (percentage of sediment particles in the silt and clay fraction; <63 µm) at all sites. Sites ordered from high to low concentration. Dashed lines show LAWA categories.

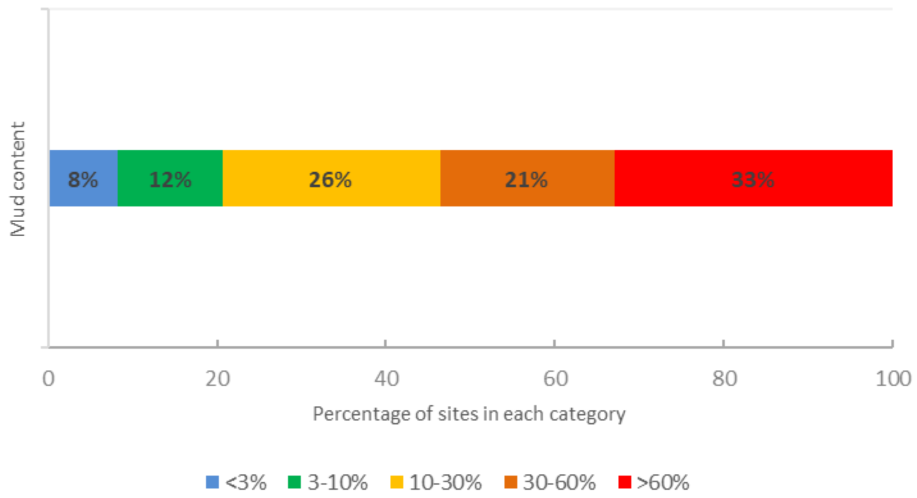


Figure 3-8. Percentage of each mud content (sediment particles in the silt and clay fraction; <63 µm) category for all sites based on LAWA categories.

3.1.1 Additional metals in selected rural and urban sites

At times, additional metals have been analysed at selected sites to assess potential impacts in areas that may be facing unique pressures. **Cadmium**, a common chemical found in phosphate fertilizers and potentially toxic to aquatic life at elevated concentrations, was analysed at rural sites in Mahurangi Harbour in 2022. Low levels were observed, with two sites recording concentrations below the lab detection limit and the remaining four sites with concentrations well below guideline thresholds (Allen, 2023b). The metals **cadmium**, **chromium**, **nickel**, and **silver** were analysed at urban sites in the Whau Estuary in 2023. The Whau, a tidal creek located in the south-west of the Waitematā Harbour, lies within a highly urbanised catchment receiving multiple pollution sources. Analysis of these metals allowed for a broader assessment of metal contamination in an impacted urban estuary. All additional metals analysed were well below guideline thresholds, indicating little impact on benthic ecology (Allen, 2024).

3.1.2 Changes in state over time

Changes in state over time at RSCMP sites have been examined by compiling the ERC – state history from each monitoring round for each site, based on total recoverable copper, lead and zinc data only.

In general, contaminant state has remained relatively stable at most sites, with very few consistent changes over time (see the State History Table, Appendix 7.1.2 for detail). Occasionally, when concentrations are near guideline thresholds, small variations above or below these levels can result in the state oscillating between categories (such as copper changing between amber and green categories at site Lucas Upper, and zinc changing between amber and red at site Anns Creek). In 2025, only six sites have shown a consistent change in ERC-state. Where these long-term changes have been observed, they have all been improvements. Very occasionally, instances of abrupt change in concentration have resulted in a subsequent change in state. For example, between 2020 and 2023, lead levels increased by 22% at Whau Upper (changing the SQG category from amber to red), while declining by 41% at Whau Wairau (changing from red to amber). Further monitoring at these sites is needed to determine whether the changes are consistent or isolated occurrences.

The sites where there has been a definitive change over time in contaminant state are:

- Māngere Cemetery (Māngere Inlet, Manukau Harbour), where the concentration of copper, lead and zinc have dropped sufficiently over time to improve the state from amber in 1998 (and red in 2001) to green (since 2013).
- Tararata (Māngere Inlet, Manukau Harbour), where copper and zinc concentrations in the ERC amber category in 2005, dropped to green in 2019 and have remained in that category since.
- Anns Creek (Māngere Inlet, Manukau Harbour), where ERC red levels of copper and zinc in 2003 have improved to amber zinc levels and green copper levels since 2021.
- Awatea (Hobson Bay, Central Waitematā), where lead levels have dropped from amber between 2004-2011 to green since 2013.
- Shoal Bay Hillcrest, in the muddy upper reaches of Shoal Bay (Central Waitematā Harbour), where lead has decreased sufficiently over time to change the state from amber (2004 to 2012) to green (since 2015).
- Opposite Hobsonville (Upper Waitematā Harbour), where lead levels reduced from amber in 2005 to green from 2018, and copper levels from amber in 2005 to green from 2013 onwards.

3.2 Contaminant correlation

To explore relationships between individual metal concentrations, as well as between metal concentrations and mud content, the Pearson correlation coefficient (r) was calculated for all metals and mud content (particle size <63 µm) (Table 3-1). Pearson correlation measures the strength and direction of the linear relationship between two variables, with values ranging between $r = 0$ (no relationship) and $r = 1$ (a strong relationship).

Copper, lead, and zinc showed a very strong correlation (r >0.90), indicating a positive linear relationship between these metals. Mercury was also strongly correlated with these metals, with values between r 0.85 and r 0.93. In comparison, the correlation between these metals and the metalloid arsenic is fairly weak, with values between r 0.34 and r 0.47.

All contaminants showed some correlation with mud, indicating particle size is likely having some influence on their spatial distribution and concentration. Values were stronger for copper, lead and zinc (between r 0.62 and r 0.68), than they were for arsenic (r 0.55) and mercury (r 0.54).

Table 3-1. Pearson correlation coefficient results for metal concentrations of copper, lead, zinc, arsenic and mercury, and mud content. Bolded values have *r* values >0.80. All values are statistically significant with P values <0.05. *N* = 97.

	Copper	Lead	Zinc	Arsenic	Mercury	Mud
Copper		**0.91**	**0.90**	0.44	**0.87**	0.68
Lead	**0.91**		**0.92**	0.47	**0.93**	0.62
Zinc	**0.90**	**0.92**		0.46	**0.84**	0.63
Arsenic	0.44	0.47	0.46		0.34	0.55
Mercury	**0.87**	**0.93**	**0.84**	0.34		0.54
Mud	0.68	0.62	0.63	0.55	0.54	

3.3 Spatial patterns

The spatial distribution of state (based on SQG categories) for each individual metal and mud content are shown in Figure 3-9 and Figure 3-10.

In general, amber/red categories are found at muddy upper estuary sites, particularly those receiving run-off from the older urban and industrial catchments. This is particularly evident in the Tāmaki and Whau estuaries, where several sites in the upper and mid reaches contain multiple elevated metals. Likewise, several sheltered sites along the southern shoreline of the Central Waitematā (from Henderson Creek to Coxs Bay) show some level of contamination, as does the upper reaches of Hobson Bay. Just two sites in the Manukau Harbour, in the upper reaches of the Māngere Inlet, show moderately elevated zinc levels. Sites in sandier and more exposed locations in the body of harbours, at the mouths of estuaries, and in rural locations, generally have low concentrations and fall within the ERC green category.

A percentage breakdown of SQG categories for different areas is shown in Figure 3-11. The Central Waitematā and Tāmaki Estuary show the highest number of occurrences of metals exceeding SQGs, with a relatively low level of contamination across other areas.

More details and commentary on the spatial patterns observed in the Central and Upper Waitematā Harbour, Manukau Harbour, and Tāmaki Estuary is presented in the next sections, alongside maps for each area.

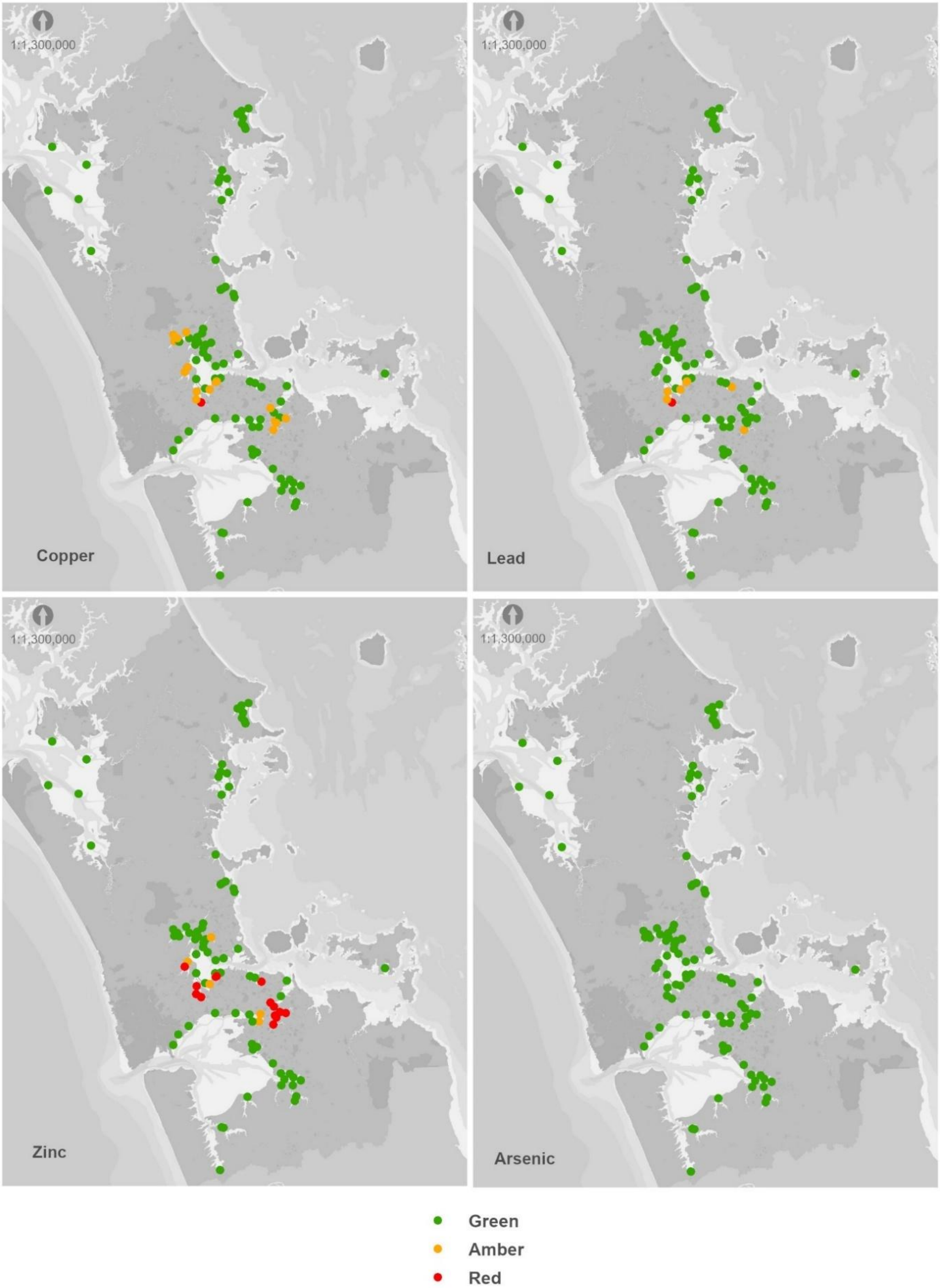


Figure 3-9. Map of contaminant state for copper, lead, and zinc (based on the ERC), and arsenic (based on the ANZG).

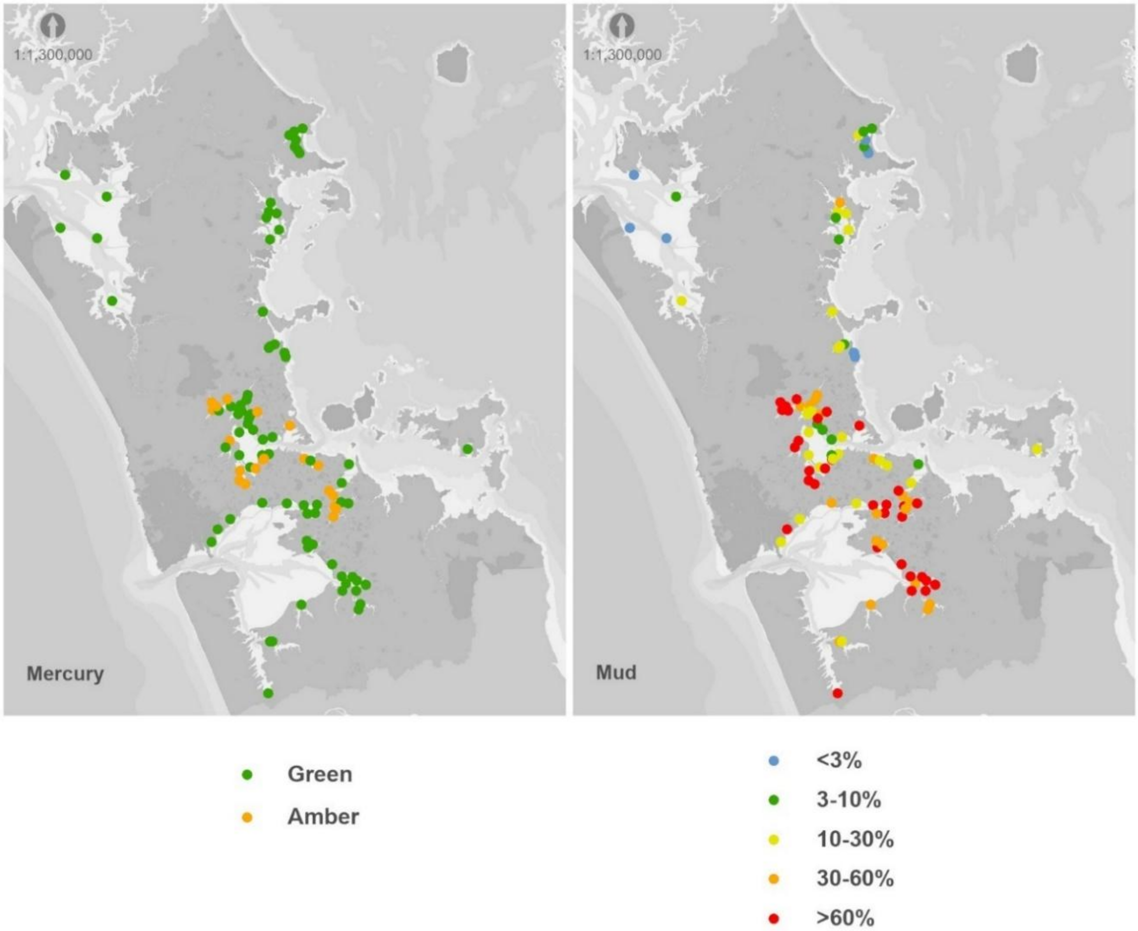


Figure 3-10. Map of mercury state (left; based on the TEL/PEL), and mud content (right; based on LAWA categories).

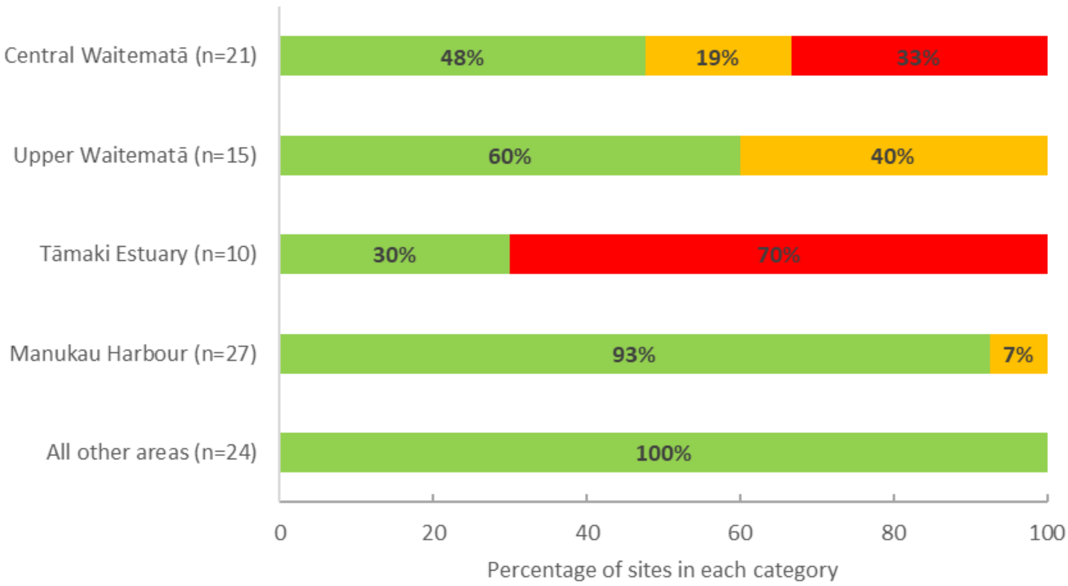


Figure 3-11. Per cent of all sediment quality guideline grades at sites within each geographical area. Sediment quality guidelines used are the ERC for copper, lead and zinc, the TEL/PEL for mercury, and the ANZG for arsenic.

3.3.1 Upper Waitematā Harbour

The Upper Waitematā generally exhibits low levels of contamination, with the exception of two metals: copper and mercury (Figure 3-12). At six sites – Brigham Creek, Rangitōpuni Creek, Opposite Hobsonville, Hellyers Upper, Upper Main Channel and Pāremoremo – concentrations exceed sediment quality thresholds reaching the ERC and/or TEL amber categories. This area has a longstanding history of elevated copper levels, with concentrations exceeding what would typically be expected for the predominantly rural surrounding land use. The cause or causes of these moderately elevated concentrations are unknown, however in the case of copper, it is possible that largely historic copper-based pesticide and herbicide use in horticultural areas (e.g., Gaw et al., 2006) may have been a contributing factor.

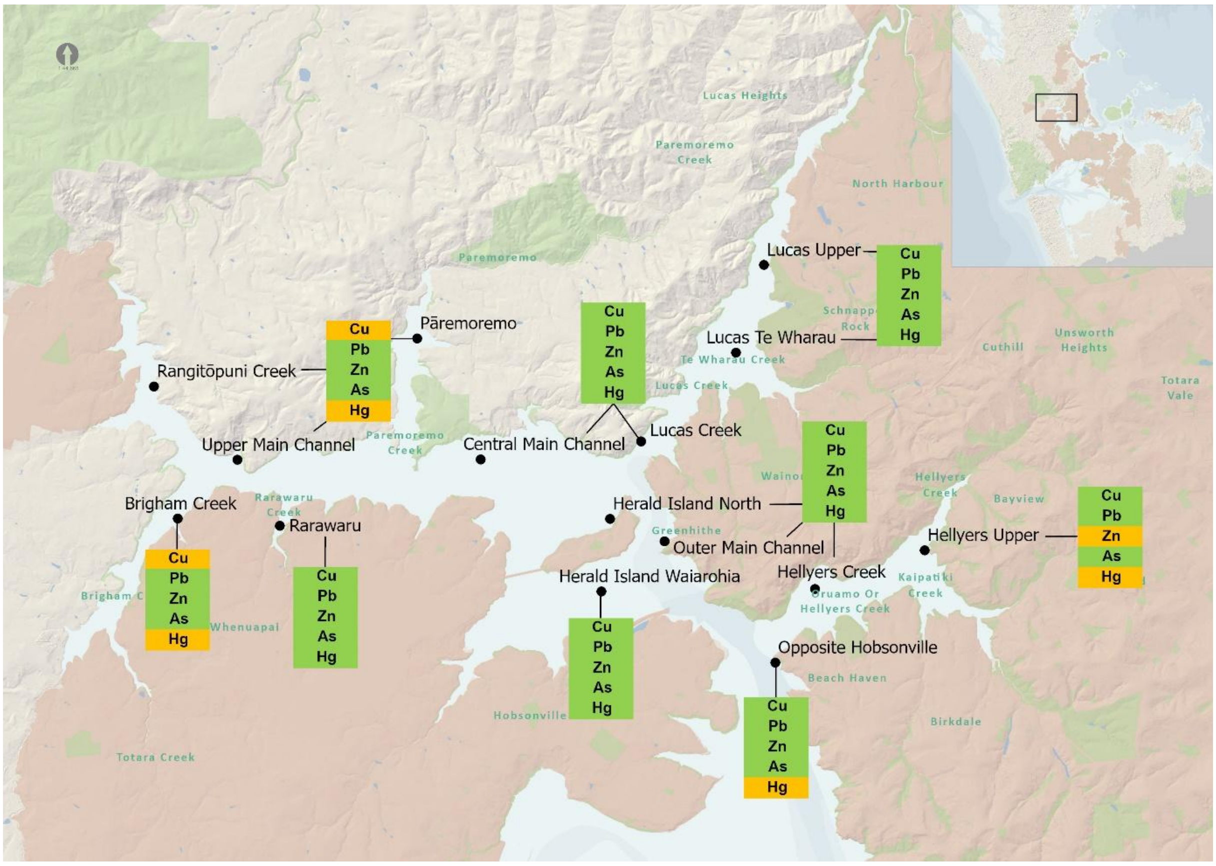


Figure 3-12. Location of sites and state of metals sampled in the Upper Waitematā Harbour. Metals are copper (Cu), lead (Pb), zinc (Zn), arsenic (As), and mercury (Hg). The colour band for metals indicates the green, amber or red category based on sediment quality guidelines. Sediment quality guidelines used are the ERC for Cu, Pb and Zn, the TEL/PEL for Hg, and the ANZG for As. Inset map shows regional location.

3.3.2 Central Waitematā Harbour

Sediment contamination in the Central Waitematā varies widely, with some sites in sub estuaries among the most heavily impacted in the region (Figure 3-13). At seven sites at least one metal, most commonly zinc, is in the ERC/TEL red category, while at four other sites at least one metal is in the ERC/TEL amber category. The catchment surrounding the harbour is largely urbanised, and the highest concentrations are found at muddy, sheltered sites receiving runoff from older urban and industrial areas. These land uses have negatively impacted sediment quality in adjacent marine environments, such as in the Whau Estuary and at sites west of the city centre (Motions, Meola Inner, and Oakley Creek). Lower contaminant concentrations at sites like Whau Entrance and Meola Outer are likely due to their sandier sediment and more exposed, higher-energy locations, where contaminants are less likely to settle and accumulate and are more readily dispersed.

Most sites monitored along the northern shoreline contain sandy textured substrate and low metal concentrations. These sites' relative exposure, low mud content, and smaller catchment have likely all contributed to the current low levels of metals observed. The exception is site Shoal Bay Hillcrest, tucked in the semi-sheltered upper reaches of a bay in the north-east of the harbour, which has high mud levels (77%), a larger more intensified urban catchment, and moderately elevated mercury levels.

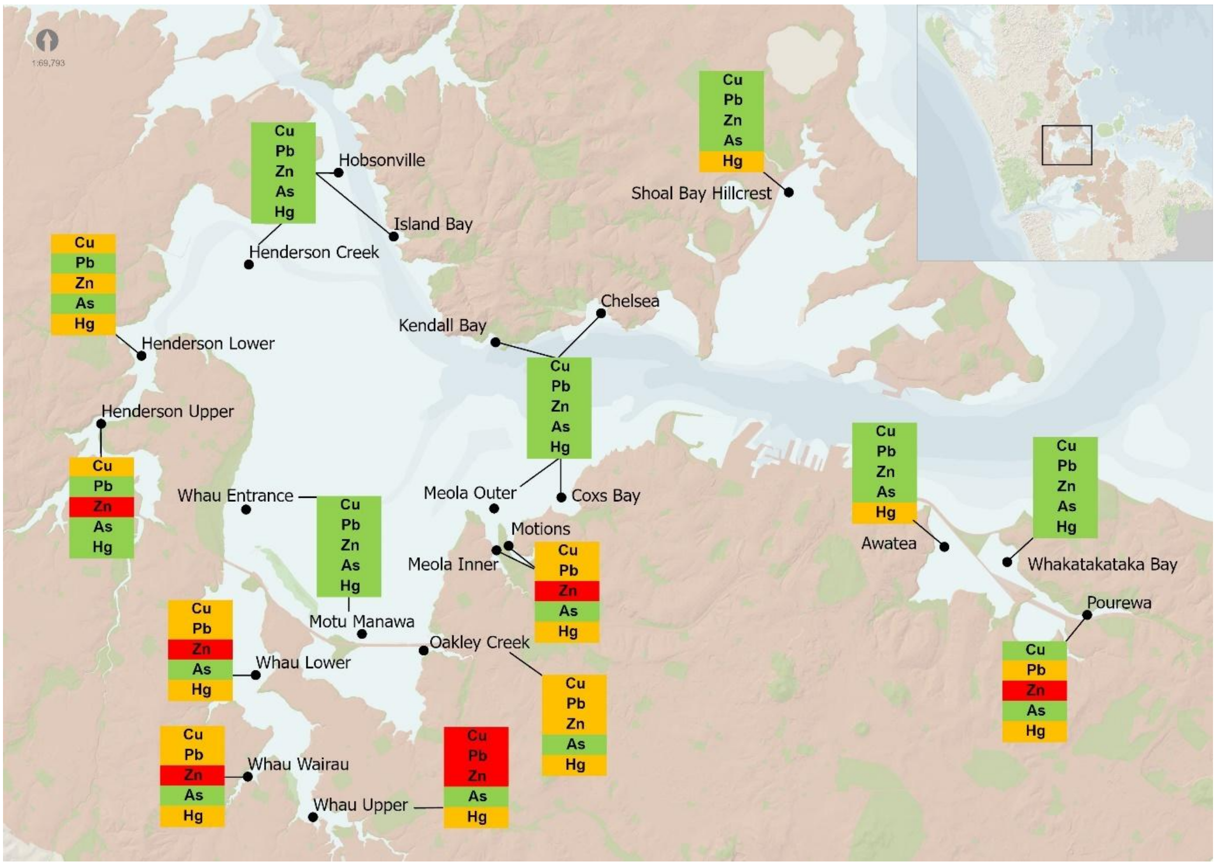


Figure 3-13. Location of sites and state of metals sampled in the Central Waitematā Harbour. Metals are copper (Cu), lead (Pb), zinc (Zn), arsenic (As), and mercury (Hg). The colour band for metals indicates the green, amber or red category based on sediment quality guidelines. Guidelines used are the ERC for Cu, Pb and Zn, the TEL/PEL for Hg, and the ANZG for As. Inset map shows regional location.

Hobson Bay (a tidal inlet on the southern shoreline close to the mouth of the Waitematā) showed varying contaminant concentrations. Site Pourewa in the muddy upper reaches is by far the most impacted site, while the sites in the lower reaches (Whakatakataka Bay and

Awatea) have relatively low concentrations. As described above, this is likely a result of the coarser particles and greater tidal and wave energy present in the lower reaches of the inlet.

3.3.3 Tāmaki Estuary and Tāmaki Strait

The Tāmaki Estuary shows a wide range of sediment contamination (Figure 3-14). It demonstrates a contamination gradient, where levels decrease as you move out from the inner estuary zones into adjacent outer zones closer to the estuary mouth.

Zinc is elevated at several sites in the upper estuary, surrounded by catchment that contains intensive industrial, commercial and residential areas. As is seen in the Central Waitematā, the pressures associated with this type of land use have cumulatively had a negative impact on sediment quality, with several sites triggering amber and/or red threshold levels since monitoring began. Low levels at sites Benghazi and Roberta Reserve are likely a reflection of these sites' location in the more exposed lower reaches, and the considerably lower mud content levels here compared to the other sites in this estuary.

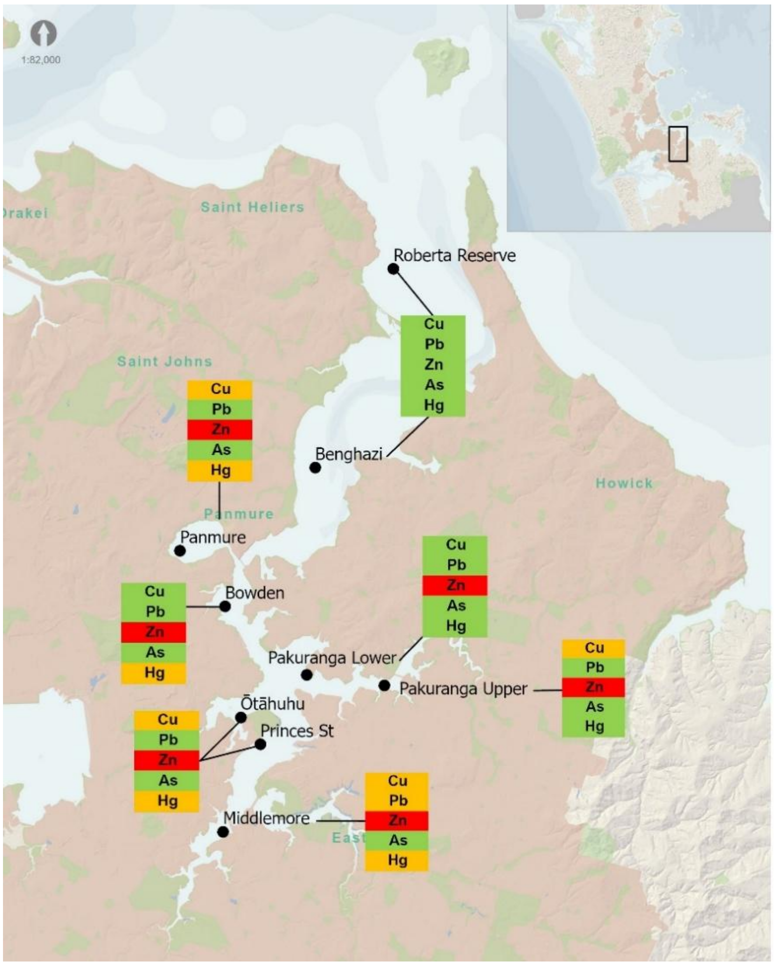


Figure 3-14. Location of sites and state of metals sampled in the Tāmaki Estuary. Metals are copper (Cu), lead (Pb), zinc (Zn), arsenic (As), and mercury (Hg). The colour band for metals indicates the green, amber or red category based on sediment quality guidelines. Sediment quality guidelines used are the ERC for Cu, Pb and Zn, the TEL/PEL for Hg, and the ANZG for As. Inset map shows regional location.

Results from site Te Matuku, located in the Tāmaki Strait on Waiheke Island's south-east coast (not shown in figure due to scale), showed concentrations well below guideline levels.

3.3.4 Manukau Harbour

Overall, there is currently a low level of metal contamination across the Manukau Harbour, with 25 of 27 sites (93%) in the green category (Figure 3-15). This is likely due in part to both the large tidal movement and huge volume of regularly mixed water flushing through channels and aiding in the removal of contaminants, and the relatively small proportion of urban area in the catchment (just 20% landcover).

Sites that have higher contaminant levels are in the Māngere Inlet, in the muddy, low energy upper reaches of the harbour. Here, elevated zinc concentrations result in two sites (Harania and Anns Creek) in the ERC amber range.

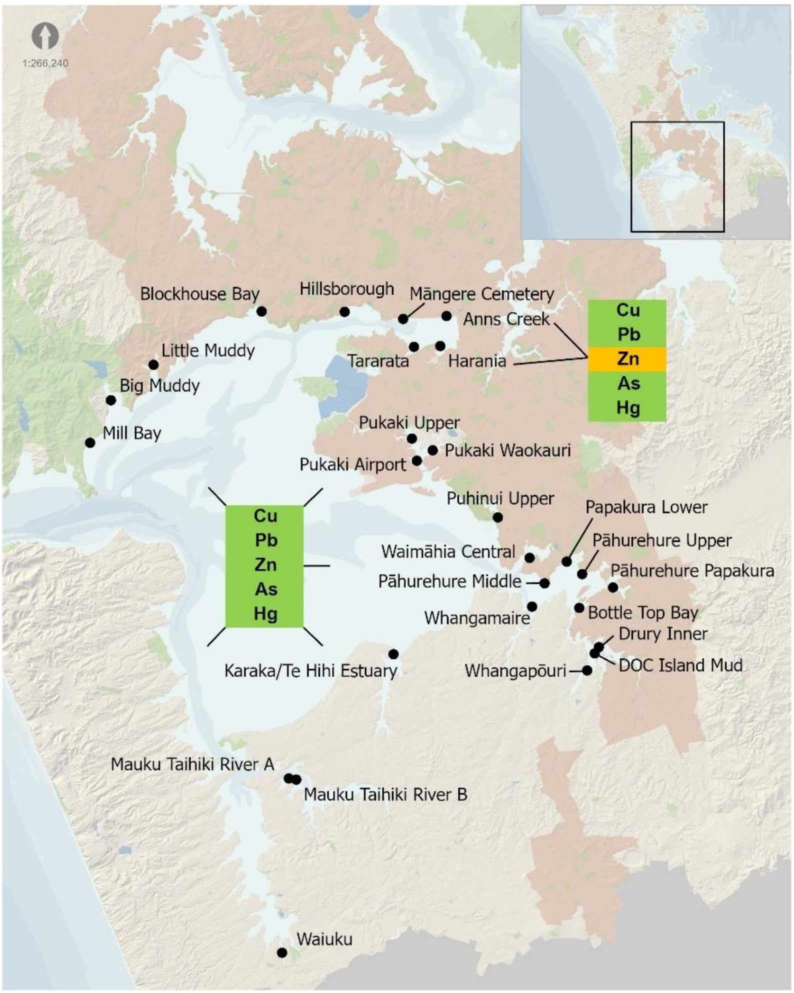


Figure 3-15. Location of sites and state of metals sampled in the Manukau Harbour. Metals are copper (Cu), lead (Pb), zinc (Zn), arsenic (As), and mercury (Hg). The colour band for metals indicates the green, amber or red category based on sediment quality guidelines. Sediment quality guidelines used are the ERC for Cu, Pb and Zn, the TEL/PEL for Hg, and the ANZG for As. Inset map shows regional location.

The Māngere Inlet has shown elevated levels of several metals (most commonly zinc) since monitoring began. The surrounding catchment is intensively developed and has a long history of commercial and industrial use. Contaminant levels here are improving. Several sites have dropped down in SQG category over time (see changes in state – section 3.1.2) and are showing 'meaningful' improving trends for copper and lead (see section 3.4.2). These ongoing decreases may be due to improved industrial site, stormwater, and waste management in the catchment.

Potential pressures from urban growth prompted the establishment of four monitoring sites in 2019 along the Harbour's southern shoreline at Te Hihi Estuary, Taihiki River, and Whangamaire. Although these sites are currently in mostly rural areas, parts of the surrounding catchments are either undergoing development, or are planned for future development. Monitoring adjacent marine ecosystems will help assess how land use changes affect sediment contamination in these areas.

3.3.5 Kaipara and Mahurangi Harbour, Whangateau Estuary and the East Coast Bays

The sites sampled in the Kaipara and Mahurangi Harbours, Whangateau Estuary, and East Coast Bays (including sites in Ōkura Estuary, Weiti River, and on Long Bay beach) exhibited low levels of all measured contaminants. Notably, Kaipara and Whangateau recorded some of the lowest concentrations across the region (see State Tables in Appendix 7.1). None of the sites in these areas exceeded any of the applied threshold guidelines, and no distinct spatial patterns were observed within each harbour. The relatively low level of urban land use in the surrounding catchments is likely to have kept metal contamination low in these locations. Where we do see site specific differences in contaminant concentrations, these are typically associated with higher mud content, however, even at these sites, levels remain well below those where impacts on ecology would be expected. Given the low levels and lack of spatial patterns observed across these areas, individual maps have not been included.

3.4 Trends

3.4.1 Regional overview

The distribution of trends across the 60 sites assessed is summarised graphically for all trend data, and for 'very likely' (i.e., probabilities >90%) trends only (Figure 3-16).

The magnitude of trends was generally small. The median trends for all sites (Table 3-2 A) showed slight increases for mud (0.2% per year) and zinc (0.7% per year), while copper (-0.2% per year) and lead (-0.9% per year) showed modest decreases. The range of trend magnitude was wider for mud, varying from -4.7% to 14.5% per year, compared to metals, where copper had the largest range, fluctuating between -4.9% and 5.5% per year.

The median trends with a 'very likely' probability were slightly larger than those observed for the overall trend data but followed the same general pattern. For 'very likely' trends (Table 3-2 B), mud and zinc showed small increases (both 1.2%), while copper and lead showed small decreases of -1.2% and -1.3% respectively.

Note that some of the increasing trends shown for zinc may be associated with the elevated results obtained for 2017, 2018, and 2019 monitoring data (see Mills and Allen (2021), for more detail). The magnitude of zinc trends may therefore be slightly smaller than what is shown in Figure 3-16.

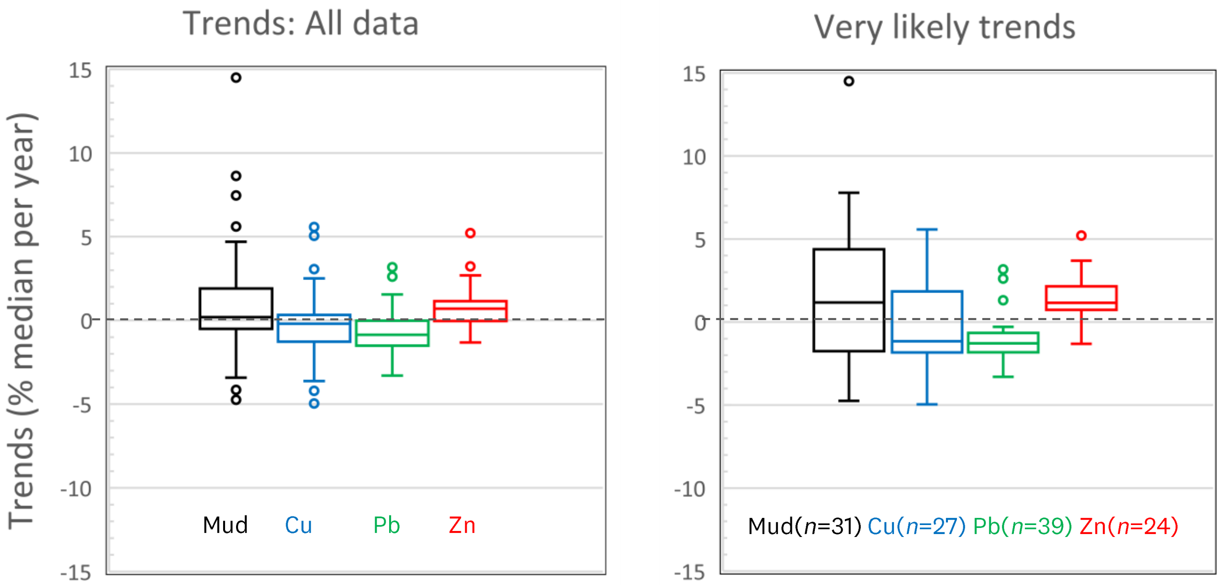


Figure 3-16. Distribution of trends in mud content, and copper, lead, and zinc from all trend data (left), and for 'very likely' trends only (right) for the period 2004-2023.

Table 3-2. Trend magnitude for all trend data (A) and 'very likely' trends only (B) for the period 2004-2023.

A. All trends

Analyte	Trend magnitude		
	median	largest decrease	largest increase
Mud (*n* =60)			
% <63µm per year	0.1	-2.8	2.5
% median per year	0.2	-4.7	14.5
Copper (n=60)			
mg/kg per year	0.0	-0.8	0.4
% median per year	-0.2	-5.0	5.6
Lead (n=60)			
mg/kg per year	-0.2	0.0	0.4
% median per year	-0.9	-3.3	3.2
Zinc (n=60)			
mg/kg per year	0.5	-1.5	4.4
% median per year	0.7	-1.3	5.2

B. Very likely trends

Analyte	Trend magnitude		
	median	largest decrease	largest increase
Mud (*n* =31)			
% <63µm per year	0.2	-2.8	2.5
% median per year	1.2	-4.7	14.5
Copper (*n* =27)			
mg/kg per year	-0.1	-0.8	0.4
% median per year	-1.2	-5.0	5.6
Lead (*n* =39)			
mg/kg per year	-0.3	0.0	0.4
% median per year	-1.3	-3.3	3.2
Zinc (*n* =24)			
mg/kg per year	1.2	-1.5	4.4
% median per year	1.2	-1.3	5.2

Across all sites there were comparatively few 'meaningful' trends in metal or mud concentrations that reached the 'very likely' probability and ±2% per year significance threshold (Table 3-3).

Mud had the highest number of sites showing 'very likely' trends (31 in total; 18 worsening and 13 improving). Mud content also showed the greatest number of sites with 'meaningful' trends (very likely category and >2% magnitude per year), with six sites showing 'very likely' improving trends and 13 'very likely' worsening.

When all trends are considered, copper and lead have a high proportion of 'likely' improving, 'very likely' improving, or 'indeterminate' trends (a total of 46 and 52 sites out of 60 sites respectively). Lead had by far the largest number of 'very likely' improving trends (35 in total), followed by 18 for copper. Copper (six sites) and lead (five sites) also had a similar number of sites showing meaningful improving trends (i.e. 'very likely' improving trends and >2% per year), and few sites showing meaningful worsening trends (i.e. 'very likely' worsening trends and >2% per year) (just four for copper and two for lead).

Zinc shows a total of 21 sites with 'very likely' worsening trends, seven of which reach the 'meaningful' category. Conversely, no sites showed 'meaningful' improving trends, and just three sites reached the 'very likely' improving category.

Table 3-3. Numbers of sites within trend likelihood categories. Data are listed for all trend data and for trends greater than the ±2% of the median per year 'meaningfulness' threshold.

	Mud		Copper		Lead		Zinc	
Trend likelihood category	All trends	>2% per yr	All trends	>2% per yr	All trends	>2% per yr	All trends	>2% per yr
Total sites	60	20	60	11	60	7	60	7
Very likely improving (P 90 - 100%)	13	6	18	6	35	5	3	0
Likely improving (P 67 - 90%)	6	0	13	1	8	0	8	0
Indeterminate (P <67%)	11	0	15	0	9	0	10	0
Likely worsening (P 67 - 90%)	12	1	5	0	4	0	18	0
Very likely worsening (P 90 - 100%)	18	13	9	4	4	2	21	7

3.4.2 Spatial patterns and trends at individual monitoring sites

Trend likelihood and magnitude data for the metals copper, lead, and zinc, and mud content across all 60 monitoring sites are presented graphically in Figure 3-17 and detailed further in trend tables in Appendix 7.2.

Overall, the distribution of trends appears to be more specific to individual sites and contaminants, rather than to broader geographic locations, and there are relatively few distinct patterns (Figure 3-17). Sites can exhibit trends regardless of their location (i.e., sites in the upper reaches of estuaries and those in more exposed higher energy locations) and estuaries can contain sites showing both improving and degrading trends (e.g., the Upper Waitematā has sites with both improving and degrading concentrations of copper). The exceptions to this are the Māngere Inlet in the Manukau Harbour, where several sites show 'meaningful' improving copper and lead concentrations, and possibly also Pāhurehure Inlet, where five sites show worsening zinc levels, but only two of these reach the 'meaningful' threshold.

A summary of trends at sites exhibiting at least one 'meaningful' trend (very likely probability and a change greater than ±2% of the median per year) is provided in Table 3-4 and in greater detail in Table 3-5. Individual plots for these significant trends are presented in Appendix 7.3.

Eight sites had meaningful worsening trends for metals (i.e. 'very likely' increasing metals' concentrations >2% median per year):

- Three sites in the Central Waitematā Harbour – Coxs Bay (copper, lead, and zinc), Kendall Bay (copper), and Whau Entrance (copper and zinc).
- Two sites in the Tāmaki Estuary – Benghazi (zinc) and Middlemore (zinc).
- One site in the Upper Waitematā Harbour – Herald Island Waiarohia (copper, lead and zinc).
- Two sites in the Manukau Harbour – Waimāhia Central (zinc) and Pāhurehure Middle (copper and zinc).

These sites include a mix of sediment types: those with relatively sandy sediment, including Kendall Bay, Coxs Bay, Whau Entrance, Herald Island Waiarohia, and Benghazi, and the remaining sites (Middlemore, Waimāhia Central, and Pāhurehure Middle), which have muddier substrates. Most sites showing increasing trends in metal concentrations also show concurrent increasing trends in mud content. It's possible that at these sites, increasing trends in metals may be influenced by increasing fine sediment, providing more surface area for metals to bind and accumulate (see section 3.2). The exceptions to this are sites Benghazi, Middlemore, and Waimāhia Central, where zinc increases are occurring without 'meaningful' increases in mud.

Seven sites had meaningful improving trends for metals (i.e. 'very likely' decreasing metal concentrations >2% median per year). At one site (Pakuranga Upper), these decreases were observed alongside decreasing mud content. The sites with meaningful improving trends for metals include:

- Four sites in the Manukau Harbour – Anns Creek (copper and lead), Harania (copper), Māngere Cemetery (copper and lead) and Tararata (copper and lead). These sites are all muddy sites in Māngere Inlet, in the upper reaches of the harbour.
- One site in the Tāmaki Estuary – Pakuranga Upper (copper and lead).
- Two sites in the Upper Waitematā Harbour – Outer Main Channel (lead), and Lucas Te Wharau (copper).

A total of 19 sites show 'meaningful' trends in mud content. At 12 sites these are just changes in mud and are currently not associated with meaningful changes in copper, lead or zinc contamination. Of the 13 'very likely' increasing trends, six are at sites in the Central Waitematā, four in the Upper Waitematā Harbour, two in the Manukau Harbour (both in the Pāhurehure Inlet) and one in the Tāmaki Strait (site Te Matuku). 'Very likely' decreasing trends are observed at two sites in the Central Waitematā, one site in the Manukau, one site in the Tāmaki Estuary, one site on the East Coast bays, and one site in the Upper Waitematā. Aside from site Pāhurehure Papakura (48% mud content), increases in mud are occurring at sites with relatively low mud content concentrations (between 4.5% and 28%).

Except for increasing zinc at site Middlemore (ERC red) and decreasing copper at site Pakuranga Upper (ERC amber), all other metals trends are occurring where contaminants are currently in the ERC green category.

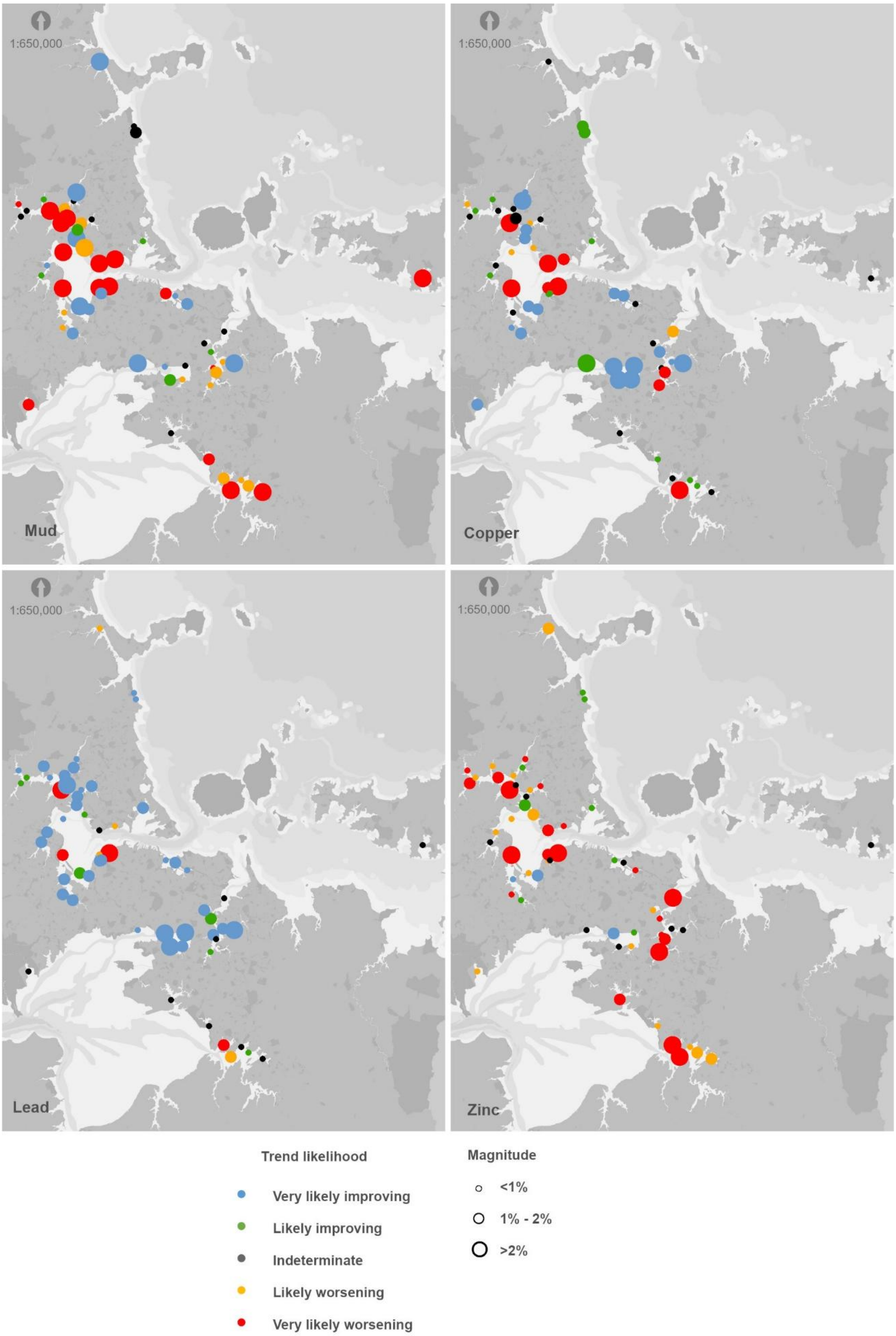


Figure 3-17. Trend likelihood and magnitude in mud content, copper, lead and zinc between 2004 and 2023.

Table 3-4. Summary of sites where meaningful (>2% median per year, very likely probability) increasing (▲) or decreasing (▼) trends in metals or mud concentrations were recorded.

Site	Location	Meaningful Trends			
		Mud	Copper	Lead	Zinc
Chelsea	Central Waitematā	▲			
Coxs Bay	Central Waitematā	▲	▲	▲	▲
Henderson Creek	Central Waitematā	▲			
Hobsonville	Central Waitematā	▼			
Kendall Bay	Central Waitematā	▲	▲		
Meola Outer	Central Waitematā	▲			
Motu Manawa	Central Waitematā	▼			
Whau Entrance	Central Waitematā	▲	▲		▲
Weiti	East Coast Bays	▼			
Anns Creek	Manukau		▼	▼	
Harania	Manukau		▼		
Hillsborough	Manukau	▼			
Māngere Cemetery	Manukau		▼	▼	
Pāhurehure Middle	Manukau	▲	▲		▲
Pāhurehure Papakura	Manukau	▲			
Tararata	Manukau		▼	▼	
Waimāhia Central	Manukau				▲
Benghazi	Tāmaki Estuary				▲
Middlemore	Tāmaki Estuary				▲
Pakuranga Upper	Tāmaki Estuary	▼	▼	▼	
Te Matuku	Tāmaki Strait	▲			
Central Main Channel	Upper Waitematā	▲			
Herald Island North	Upper Waitematā	▲			
Herald Island Waiarohia	Upper Waitematā	▲	▲	▲	▲
Lucas Te Wharau	Upper Waitematā		▼		
Lucas Upper	Upper Waitematā	▼			
Outer Main Channel	Upper Waitematā	▲		▼	

Table 3-5. Summary of trends in mud content and metals at sites with at least one 'meaningful' trend (very likely probability and >±2% of median per year).

Site name	Harbour	Mud Content		Copper		Lead		Zinc	
		% annual change	Trend likelihood	% annual change	Trend likelihood	% annual change	Trend likelihood	% annual change	Trend likelihood
Chelsea	Central Waitematā Hbr	**3.2**	**Very likely worsening**	1.8	Very likely worsening	0.2	Likely worsening	0.7	Very likely worsening
Coxs Bay	Central Waitematā Hbr	**4.7**	**Very likely worsening**	**5.6**	**Very likely worsening**	**2.6**	**Very likely worsening**	**3.2**	**Very likely worsening**
Henderson Creek	Central Waitematā Hbr	**3.8**	**Very likely worsening**	0.6	Likely worsening	-0.7	Very likely improving	0.5	Likely worsening
Kendall Bay	Central Waitematā Hbr	**3.0**	**Very likely worsening**	**2.4**	**Very likely worsening**	0.1	Indeterminate	1.7	Very likely worsening
Meola Outer	Central Waitematā Hbr	**4.6**	**Very likely worsening**	1.9	Very likely worsening	0.4	Likely worsening	1.8	Very likely worsening
Motu Manawa	Central Waitematā Hbr	**-3.4**	**Very likely improving**	-1.3	Very likely improving	-1.5	Likely improving	0.5	Likely worsening
Whau Entrance	Central Waitematā Hbr	**7.5**	**Very likely worsening**	**2.5**	**Very likely worsening**	1.6	Very likely worsening	**2.5**	**Very likely worsening**
Weiti	East Coast Bays	**-2.9**	**Very likely improving**	-0.1	Indeterminate	0.4	Likely worsening	1.0	Likely worsening
Anns Creek	Manukau Harbour	0.1	Indeterminate	**-4.2**	**Very likely improving**	**-2.7**	**Very likely improving**	-0.2	Likely improving
Harania	Manukau Harbour	0.2	Likely worsening	**-2.7**	**Very likely improving**	-2.0	Very likely improving	0.8	Likely worsening
Hillsborough	Manukau Harbour	**-4.7**	**Very likely improving**	-2.0	Likely improving	-0.9	Very likely improving	0.0	Indeterminate
Māngere Cemetery	Manukau Harbour	-0.6	Very likely improving	**-5.0**	**Very likely improving**	**-3.1**	**Very likely improving**	-1.3	Very likely improving
Pāhurehure Middle	Manukau Harbour	**14.5**	**Very likely worsening**	**5.1**	**Very likely worsening**	1.4	Likely worsening	**3.7**	**Very likely worsening**
Pāhurehure Papakura	Manukau Harbour	**3.9**	**Very likely worsening**	0.1	Indeterminate	0.4	Indeterminate	1.4	Likely worsening
Tararata	Manukau Harbour	-1.3	Likely improving	**-3.6**	**Very likely improving**	**-3.3**	**Very likely improving**	-0.1	Indeterminate
Waimāhia Central	Manukau Harbour	1.9	Likely worsening	0.3	Indeterminate	1.3	Very likely worsening	**2.7**	**Very likely worsening**
Benghazi	Tāmaki Estuary	0.1	Indeterminate	1.8	Likely worsening	0.8	Indeterminate	**2.2**	**Very likely worsening**
Middlemore	Tāmaki Estuary	0.9	Likely worsening	1.1	Very likely worsening	-0.3	Likely improving	**2.1**	**Very likely worsening**
Pakuranga Upper	Tāmaki Estuary	**-4.7**	**Very likely improving**	**-2.8**	**Very likely improving**	**-2.1**	**Very likely improving**	-0.2	Indeterminate
Te Matuku	Tāmaki Strait	**4.4**	**Very likely worsening**	-0.1	Indeterminate	0.0	Indeterminate	0.1	Indeterminate
Central Main Channel	Upper Waitematā Hbr	**2.4**	**Very likely worsening**	0.0	Indeterminate	-0.3	Very likely improving	1.2	Very likely worsening
Herald Island North	Upper Waitematā Hbr	**7.7**	**Very likely worsening**	-0.5	Likely improving	-0.5	Likely improving	0.8	Likely worsening
Herald Island Waiarohia	Upper Waitematā Hbr	**5.6**	**Very likely worsening**	**3.1**	**Very likely worsening**	**3.2**	**Very likely worsening**	**5.2**	**Very likely worsening**
Hobsonville	Upper Waitematā Hbr	**-4.1**	**Very likely improving**	-1.8	Very likely improving	-1.3	Very likely improving	-1.0	Likely improving
Lucas Te Wharau	Upper Waitematā Hbr	-0.4	Indeterminate	**-2.0**	**Very likely improving**	-1.2	Very likely improving	-0.3	Likely improving
Lucas Upper	Upper Waitematā Hbr	**-2.0**	**Very likely improving**	-0.5	Very likely improving	-0.9	Very likely improving	0.7	Very likely worsening
Outer Main Channel	Upper Waitematā Hbr	**7.8**	**Very likely worsening**	-1.0	Indeterminate	**-2.3**	**Very likely improving**	0.0	Indeterminate

Colour coding is very likely worsening, likely worsening, likely improving, very likely improving, and indeterminate. **Bolded** values are trends > ±2% of median per year and of 'very likely' probability.

4 Discussion

4.1 Contaminant state

Contaminant state was assessed at 97 sites across Tāmaki Makaurau. Overall, metal contamination is relatively low, with approximately 73% of sites rated as 'green' based on all monitored metals. According to this assessment, the risk to benthic life at these sites is expected to be low. At ~12% of sites rated as 'amber', slightly elevated concentrations may be starting to impact ecological health, and at ~14% of sites rated as 'red', ecological degradation due to high metal concentrations is likely to be occurring. Contaminant state has remained largely stable at most sites over the monitoring period, with few consistent changes observed.

Most sites have **copper** concentrations below that where ecological impacts would be expected. Small pockets in mostly urban areas reach moderately elevated levels, and just one site in the upper reaches of the Whau Estuary reaches the higher ERC red level threshold. Urban runoff from buildings, roads, and industrial areas are likely contributors of copper to Auckland's marine environment, with potential sources including vehicle brake linings and the breakdown of some building materials. In addition to land-based sources, copper can also be released through marine activities, particularly from antifouling paints applied to boat hulls. Research in the Waitematā has shown several marinas had elevated copper concentrations in water compared to ambient harbour levels (Gadd and Cameron, 2012). Previous use of copper-based agrichemicals and past industrial activities could also have left some legacy contamination in marine sediments.

Based on sediment quality guidelines, **lead** levels are relatively low across the region. Concentrations exceed the ERC red level at just one site and surpass the ERC amber threshold at seven sites. The major sources of lead contamination (such as petrol and paints) are now largely historic. The persistence of elevated contaminant levels at certain sites may be due to ongoing, localised inputs from land-based activities or remnants of historical contamination. In some cases, physical processes such as sediment scouring, tidal movement, or wave action may expose and resuspend previously buried contaminated sediments.

Zinc remains a contaminant of concern and is the metal most often surpassing the ERC red threshold, with exceedances at 14 sites. Zinc is commonly used across urban activities and can enter the marine environment through various sources. These can include from industrial activities, as runoff from some building materials, vehicle brake and tyre wear, and from natural processes. Outside of low-energy urban areas, zinc levels are low, reflecting the impact anthropogenic activities have on concentrations.

Broadly speaking, **mercury** contamination is low, with no sites exceeding the upper limits outlined in sediment quality guidelines. However, mercury does reach amber levels at more sites than any other metal. This is largely in urban areas along the southern part of the Waitematā and in the upper Tāmaki Estuary. The Ministry for the Environment reports mercury outputs to water in New Zealand are largely dominated by waste disposal, particularly wastewater discharges (Bingham and Simpson, 2022). It is likely that in Auckland, elevated mercury levels are driven in part by wastewater discharges or overflows, along with potential remnants of historic industrial practices, contributing to moderately elevated concentrations in some urban marine areas.

Arsenic concentrations in marine sediment vary slightly across the region but do not appear to be significantly affecting ecological health. Most sites are around expected reference levels, and none exceed the ANZG DGV. Interestingly, arsenic concentrations are higher at some sandier sites with otherwise low contaminant levels, compared to concentrations at urban, muddy sites that have elevated levels of other metals. No specific areas show higher concentrations than others (e.g., arsenic is not notably elevated in either urban or rural areas), and due to the low correlation with other contaminants, it is unlikely that the stormwater network is a major contributor.

At times, additional metals have been analysed at selected rural and urban sites to better understand potential impacts in areas that may be facing unique environmental pressures. In 2022, cadmium (commonly found in fertilizers and toxic to aquatic life at high levels) was measured at rural sites in Mahurangi Harbour, with all results well below guideline thresholds. In 2023, cadmium, chromium, nickel, and silver were analysed in the urban Whau Estuary. These metals also showed low concentrations, indicating minimal impact on benthic ecology. This is promising given the historic and contemporary pollutant load in the estuary, where several other metals are elevated above guideline thresholds.

4.2 Spatial patterns

While the overall level of metal contamination across the region is fairly low, localised areas do show elevated concentrations. The spatial pattern remains essentially the same as previously reported (i.e., Mills and Allen, 2021). Concentrations are typically elevated in the upper reaches of estuaries draining highly urbanised catchments. This is not a recent phenomenon (see Mills et al., 2012), nor is it unique to Auckland, with similar patterns observed in other large urban areas such as Sydney Harbour (Birch, 2017). Contaminant concentrations are elevated in the muddy, inner estuary zones of the Central Waitematā Harbour and Tāmaki Estuary, and to a much lesser degree in the Upper Waitematā Harbour and Māngere Inlet (Manukau Harbour). Within several smaller estuaries, metal and mud concentrations follow a gradient that extends from the sheltered upper estuary (typically muddy settling zones) where concentrations are generally highest, decreasing (in both mud and metal contamination) as you move towards the estuary mouth. At sites located in predominantly rural catchments or in the main body of harbours, contaminant concentrations are generally low. This is likely due to either the low level of urban activity in the surrounding area, or the site's location in an environment with higher exposure and energy levels, where contaminants are more readily dispersed and less likely to settle and accumulate, or a combination of both these factors.

A strong correlation is observed between the metals copper, lead, zinc, and mercury. Given that most of the contamination in Auckland is concentrated in estuaries located in heavily urbanised areas, it is plausible then that these metals share a common pathway (i.e., urban stormwater) into the marine environment. The metals copper, lead, and zinc also show a strong correlation with mud content. Metals are typically more prevalent in muddier sediments than in sandy substrates. This can be attributed to several factors, including: the tendency of low-energy, muddy environments to trap and accumulate contaminants; the large surface area of fine particles, which offers more opportunities for contaminants to adhere; and the strong attraction of metals to ionic exchange sites found on iron and manganese coatings common on clay and silt particles (Ongley, 1996).

4.3 Trends

Trends for the 2004-2023 period were assessed at 60 sites with five or more samplings. A threshold of >±2% of the median per year and 'very likely' probability was used to define 'meaningfulness', indicating trends meeting this threshold were considered to be reliable and have 'real world' significance.

Relatively few sites showed significant trends in total recoverable copper, lead, or zinc concentrations, with most sites exhibiting minimal change. Overall, modest decreases in copper and lead concentrations suggest a slight improvement in contamination levels for these metals. Conversely, zinc concentrations showed a slight increasing trend.

Results indicated that trend occurrences were largely site-specific, with few discernible spatial patterns for any metal. The main exceptions to this are the Māngere Inlet in the Manukau Harbour, where several sites show 'meaningful' improvements in copper and lead concentrations, and possibly also the Pāhurehure Inlet, where five sites exhibit worsening zinc levels, though only two reach the 'meaningful' threshold. Several sites showing increasing trends in metals are also showing increasing trends in mud content (e.g., Herald Island, Pāhurehure Middle, Whau Entrance, Coxs Bay, Kendall Bay). All these sites currently have relatively low mud content (below 31%) and generally low metal content (all in the green category). Given the present low mud levels, these sites are more vulnerable to the effects of fine sediment accumulation which can also be associated with higher metal concentrations. Although overall increasing trends are relatively few, their occurrence at sites with currently low levels of contamination is of some concern, as it suggests these areas may be vulnerable to further degradation and worsening conditions over time.

Lead levels are generally decreasing, continuing the pattern reported in previous state and trend assessments (see Mills et al., 2012, and Mills and Allen, 2021). This decrease has been attributed in earlier reports to the removal of lead from petrol in the mid-1990's. Many other sources of lead are now also historic, such as paints and plumbing systems. As these materials are replaced overtime, continuing reductions would be expected.

For the most part, trend results for copper, lead, and zinc have changed little since the last report published in 2021. In 2025, there was a slight decrease in the number of sites showing 'meaningful' trends in these metals – 15 sites compared to 18 in 2021. Of these 15 sites, 11 exhibited the same trend direction and involved mostly the same metals as they did in 2021. The general similarity in results is not overly surprising, given the low number of additional data points at most sites (just an additional one or two samplings) in the time between assessments.

A preliminary trend assessment for arsenic and mercury was undertaken in 2023 at 48 sites using data collected between 2012 and 2021 (Allen, 2023a). The collection of arsenic and mercury data has only been undertaken consistently since 2012, compared with 2004 for copper, lead and zinc, and therefore the data set is much smaller than for the other metals. Relatively few sites (just seven for arsenic and 11 for mercury) showed 'meaningful' trends. These were largely worsening trends for arsenic and improving trends for mercury. While these results served as a preliminary assessment, the sample size is too small to be considered robust, and further monitoring is required to enable a more definitive understanding of trend direction and magnitude for these chemicals (see Allen, 2023a, for more detail). Since just one additional sampling round has been completed at some sites since this assessment, trend analysis of arsenic and mercury was not undertaken for this report.

4.4 Summary and general discussion

Sediment contamination across Tāmaki Makaurau varies significantly. Compared to other regions in Aotearoa, Auckland shows a wider range of contaminant levels, with more sites exceeding guideline thresholds (see the 'Estuary Health' topic on LAWA). This is likely due to its high degree of urbanisation and network of intertidal harbours and estuaries, which are highly influenced by surrounding land use. While contamination levels are generally low, there are pockets of elevated concentrations, particularly in the upper reaches of estuaries. These elevated areas are typically characterised by muddy substrates and surrounded by catchments with a long history of intensive urban and/or industrial use. Based on sediment quality guidelines, these zones in the Central Waitematā Harbour and Tāmaki Estuary, are likely to experience adverse effects on benthic organisms as a result of metal concentrations. In contrast, the lowest concentrations are typically found in estuaries with rural or forested catchments and on more exposed beaches. Both contemporary and historic land use in surrounding catchments, along with an estuary's physical characteristics (such as hydrodynamics, sediment accumulation and sediment texture), play key roles in the types and levels of contaminants found in marine receiving environments around the region.

At certain sites, metals such as copper, lead, zinc, and mercury can reach levels where impacts on benthic ecology are possible. In fewer cases, individual metals (most commonly zinc) are at concentrations where impacts are likely. Arsenic levels are generally low and are below the threshold associated with potential ecological effects. Lead continues to show decreasing concentrations at many sites, as has been the case since the monitoring programme began. This reflects both positive progress and highlights the slow recovery of contaminated sediments. When tested, other metals like cadmium, chromium, nickel, and silver have shown levels well below guideline thresholds.

Results from this long-term monitoring program indicate that metal contamination has remained largely stable, with any changes occurring slowly and gradually. This general stability is encouraging, especially given Auckland's growing urban pressures, including population growth, increased vehicle use, and ongoing development. Significant changes in contaminant concentrations have been rare, and even rarer still is for these changes to occur abruptly. There have been isolated instances of abrupt change occurring – for example, between 2020 and 2023 lead concentrations increased by 22% at site Whau Upper and decreased by 41% at site Whau Wairau. These differences between sites in relatively close proximity, highlight the site-specific nature of sediment contamination and the fine-scale dynamics that can occur within an estuary.

Sediment Quality Guidelines (SQGs) provide a useful measure and means to interpret and present contaminant concentrations and are an important tool in assessing sediment quality. However, they are not without their limitations. Ideally, SQGs would pinpoint the exact concentration where sediments cause biological effects, but these effects are rarely clearly delineated and vary between species. The 'transition zone' between no effect and harm can span a wide range and may not reflect the sensitivity of all species in an ecosystem. Additionally, SQGs are primarily based on acute toxicity data. This has the potential to overlook chronic effects on macrofauna communities. Chronic toxicity measures may provide a more realistic assessment, given the slow accumulation and recovery of contaminants in Auckland's marine sediments. As noted by the ANZG, when assessing benthic health, SQGs are designed to contribute as one line of evidence within a broader weight-of-evidence approach. In line with this, sediment contaminant sampling has generally been conducted alongside benthic ecology sampling (see Drylie, 2025a, 2025b) and particle size distribution analysis, allowing multiple lines of evidence to inform benthic health assessments.

Studies in Auckland (Hewitt et al., 2009) and Tauranga (Tremblay et al., 2017) found changes in benthic communities along contaminant gradients for copper, lead, and zinc, below ANZG and TEL thresholds. This may result from multiple stressors, depth-dependent responses, species interactions, or varying species susceptibility at different life stages. In addition to impacts from metals, many RSCMP sites are also experiencing high mud content. Research shows macrofaunal communities are most resilient when mud content is below 10% and above 25% start to show major declines in ecological health. These impacts are further exacerbated when coupled with elevated metal contamination (Rodil et al., 2013). Mud content is therefore likely a key stressor in conjunction with metals at sites with moderately elevated concentrations.

In isolation, individual chemical concentrations at most sites in Auckland currently pose a low risk to benthic fauna, with the exception of sites where concentrations fall above the red (and also possibly amber) thresholds. However, even at slightly elevated levels, metal concentrations can be contributing to the cumulative pressures of various contaminants that can be present in some marine sediments. The full extent of this impact is unclear, but the combined effects are almost certainly greater than the sum of their individual parts. Given the uncertainty around the combined effects of multiple contaminants on benthic health, a cautious approach to sediment quality assessment is warranted. This is especially important since sites with elevated levels often exceed guidelines for several substances at once, and impacts from metals have been observed even below conservative thresholds such as the TEL. These considerations reinforce the importance of applying conservative sediment quality guidelines, such as those primarily used in the RSCMP.

In the coming years, spatial patterns of contamination in Auckland may shift. As estuaries infill with sediment, a higher proportion of stream and river derived sediment (and associated contaminants) might be exported into the middle and lower reaches of estuaries, as opposed to settling in the upper reaches as occurs in most locations currently. This process may be a driver of the observed increases of mud content at the site Whau Entrance at the mouth of the Whau Estuary. Additionally, land-use changes resulting from urbanisation in predominantly rural catchments has the potential to increase contaminant loads in these areas if not managed carefully and proactively. Climate change will introduce further complexities to contaminant levels and spatial patterns, including an increased risk of event-based contamination from extreme weather events and the potential exposure of buried contaminants due to increased erosion along our waterways (see Figure 4-1). For these reasons, maintaining broad spatial monitoring of sediment contaminants is important to track and understand potential shifts in contaminant distribution and changes over time.

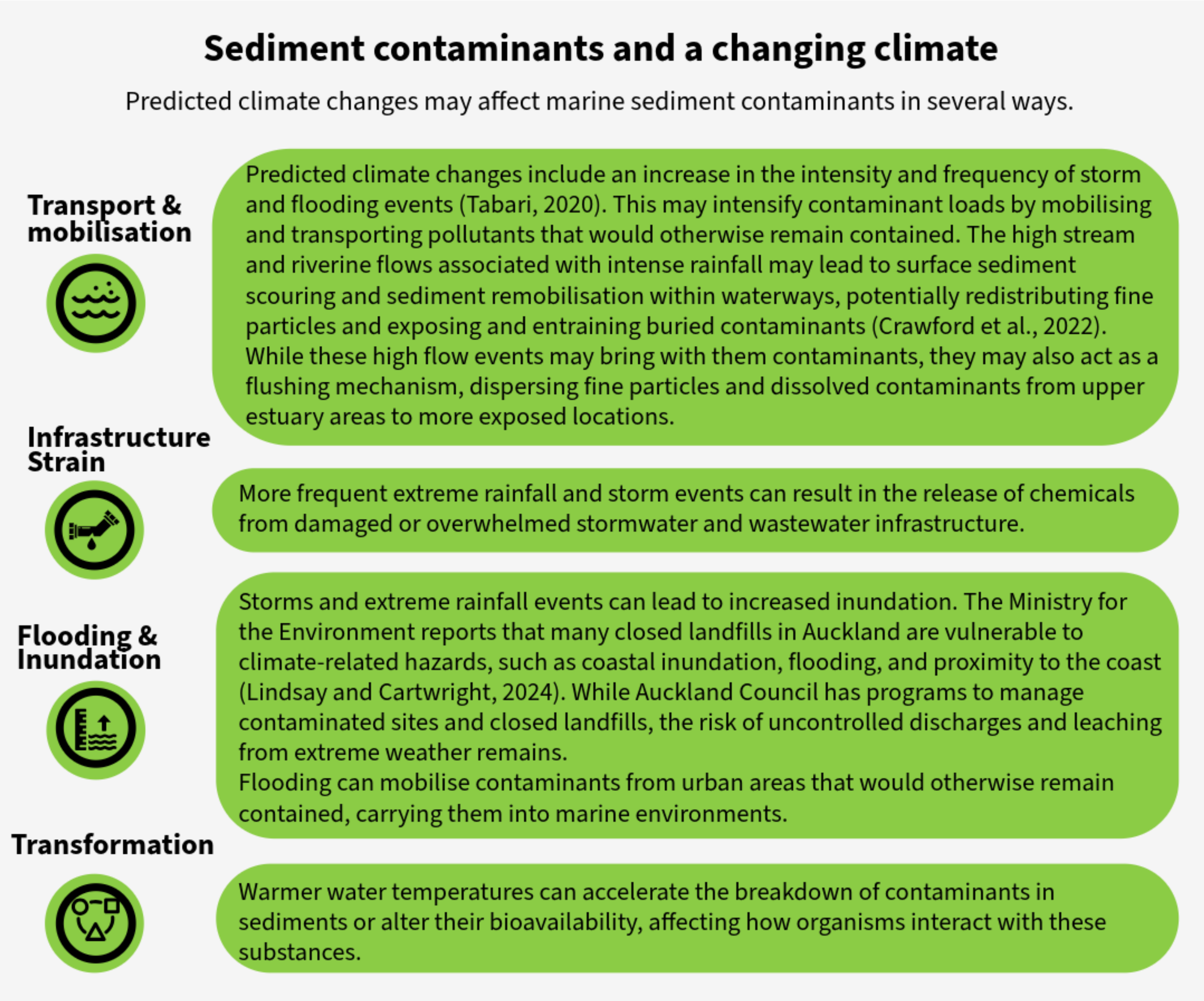


Figure 4-1. Potential effects of predicted climate changes on sediment contamination.

In early 2023, Auckland experienced two extreme weather events with heavy rainfall causing widespread flooding, particularly in suburbs around the Central Waitematā Harbour. Although it is difficult to directly link the extreme weather events to RSCMP observations, the stable results at most Central Waitematā sites in 2023 – compared to samples from three to four years earlier – suggest that widespread, persistent increases (or decreases) in metal concentrations (at least for those analysed here post these events) did not occur.

Reducing metal discharges – particularly from diffuse sources like stormwater – is challenging and complex. It is also crucial for ecosystem and human health and ensuring resilient healthy environments into the future. Individuals, communities, industries and governments all have a role to play. Auckland Council undertakes and supports a wide range of activities aimed at reducing contaminants. These include physical works projects such as storm and wastewater upgrades, active management of landfill leachate, education programmes, and supporting cleaner transport options and environmental restoration activities. By design, the RSCMP does not pinpoint specific sources of contamination; rather, it offers a more holistic assessment of land use impacts on coastal ecosystems, helping to gauge the extent of these impacts regionally and the effectiveness of mitigation strategies.

Figure 4-2 outlines some Auckland Council initiatives, along with actions that individuals and households can take to help reduce contaminant inputs.

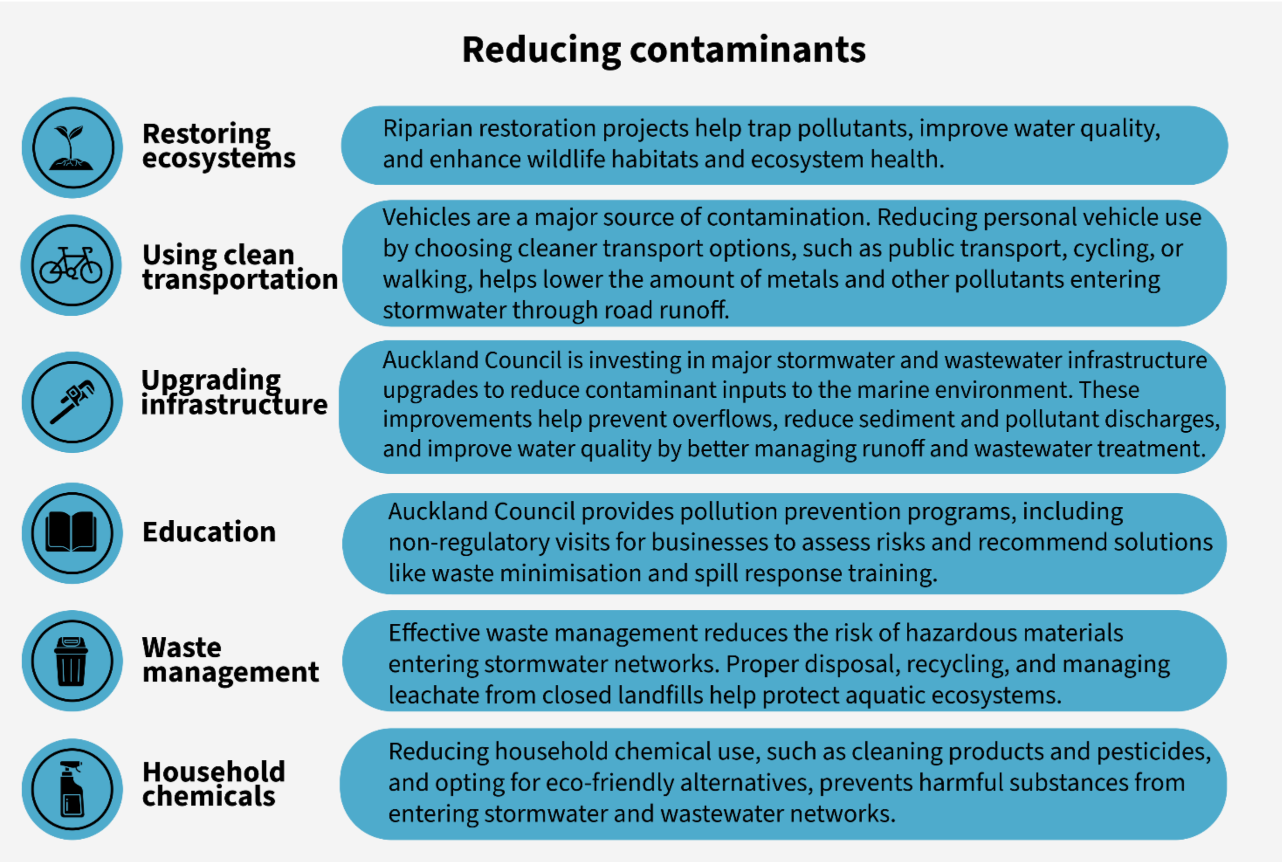


Figure 4-2. Reducing contaminants.

5 Acknowledgements

Many people have contributed to sediment contaminant monitoring across the region since 1998.

Special thanks to Diffuse Sources Ltd (Bruce Williamson and Geoff Mills), who, in conjunction with ARC and AC staff, conducted much of the programme design, field sampling, sample preparation, site establishment, quality assurance, protocol design, and earlier reporting.

Thanks to Katie Cartner, Greg Olsen, and the dedicated team of marine technicians at NIWA (Hamilton), for their efforts managing and undertaking field sampling, and for overseeing the sample processing and laboratory analysis.

Thanks to the many environmental specialists and scientists in Auckland Council's Environmental Evaluation and Monitoring Unit (EEMU; and its predecessor, RIMU) for giving their time and expertise in sampling, reporting, quality control processes, and data management over the years.

Laboratory services have been provided by RJ Hill Laboratories and NIWA (Hamilton).

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7 Appendix

7.1 State tables

7.1.1 State table for monitoring sites analysed between 2020 and 2023. State/colour is based on ERC categories for total recoverable copper (Cu), lead (Pb), and zinc (Zn), TEL/PEL categories for mercury (Hg), and ANZG categories for arsenic. Concentrations are in mg/kg (freeze dried <500µm fraction). Mud content is the percentage of sediment particles <63 µm. Mud state is based on LAWA guidelines.

		Mud Content	ERC			TEL	ANZG
Site name	**Harbour**	**% <63 um**	**Cu**	**Pb**	**Zn**	**Hg**	**As**
Whangateau Estuary 1	Whangateau Estuary	1.9	0.7	0.8	7.5	<0.02	1.5
Whangateau Estuary 2	Whangateau Estuary	0.3	0.4	0.6	5.6	<0.02	1.3
Whangateau Estuary 3	Whangateau Estuary	5.0	1.4	1.2	11.0	<0.02	2.5
Whangateau Estuary 4	Whangateau Estuary	1.7	1.0	0.9	9.6	<0.02	2.6
Whangateau Estuary 5	Whangateau Estuary	13.0	3.6	2.3	24.7	<0.02	4.1
Whangateau Estuary 6	Whangateau Estuary	7.4	2.2	1.6	14.7	<0.02	3.0
Whangateau Estuary 7	Whangateau Estuary	9.2	3.0	1.5	16.5	<0.02	2.8
Jamiesons Bay	Mahurangi Harbour	4.8	6.1	5.3	37.4	<0.02	8.0
Dyers Creek	Mahurangi Harbour	7.4	2.4	1.9	17.6	<0.02	4.8
Mid Harbour	Mahurangi Harbour	11.1	6.1	5.8	43.4	0.024	15.9
Te Kapa Inlet	Mahurangi Harbour	21.6	5.6	4.1	35.6	<0.02	9.7
Cowans Bay	Mahurangi Harbour	25.7	3.7	3.3	28.4	<0.02	10.1
Hamilton Landing	Mahurangi Harbour	46.0	6.3	5.2	34.0	0.030	10.9
Kaipara Flats	Kaipara	0.3	1.1	1.5	17.0	<0.02	5.1
Haratahi Creek	Kaipara	0.5	2.2	2.3	25.0	<0.02	6.8
Te Ngaio Point	Kaipara	0.6	0.9	0.9	8.3	<0.02	4.2
Kakarai Flats	Kaipara	4.8	2.5	2.4	28.3	<0.02	6.1
Kaipara Bank	Kaipara	26.7	3.7	3.6	35.3	<0.02	8.5
Vaughan Beach	East Coast Bays	0.0	1.4	2.7	21.0	<0.02	10.6
Awaruku Beach	East Coast Bays	0.1	1.7	3.3	22.4	<0.02	12.1
Ōkura Estuary 3	East Coast Bays	5.06	2.1	3.1	19.1	<0.02	5.1
Ōkura Estuary 7	East Coast Bays	11.6	3.2	4.3	25.0	<0.02	5.4
Ōkura Estuary 9	East Coast Bays	23.7	4.8	5.9	34.7	0.029	6.5
Weiti	East Coast Bays	22.6	11.9	9.6	60.1	0.041	8.3
Herald Island Waiarohia	Upper Waitematā Hbr	15.2	4.7	8.1	31.4	0.044	3.7
Herald Island North	Upper Waitematā Hbr	22.6	7.6	14.2	58.5	0.065	8.8
Outer Main Channel	Upper Waitematā Hbr	24.3	16.1	12.9	55.1	0.07	9.5
Central Main Channel	Upper Waitematā Hbr	34.3	13.1	25.2	116.3	0.129	14.3
Lucas Creek	Upper Waitematā Hbr	37.6	13.9	21.9	105.7	0.104	17.6
Lucas Te Wharau	Upper Waitematā Hbr	48.9	14.9	19	91.0	0.11	9.4
Hellyers Creek	Upper Waitematā Hbr	53.4	13.9	19.0	91.8	0.123	8.1
Lucas Upper	Upper Waitematā Hbr	58.4	17.0	18.7	110.8	0.108	9.7
Rarawaru	Upper Waitematā Hbr	70.8	18.4	23.4	93.0	0.127	10.4
Opposite Hobsonville	Upper Waitematā Hbr	60.3	16.7	26.6	112.0	0.169	11.4
Hellyers Upper	Upper Waitematā Hbr	71.9	12.2	28.1	134.6	0.142	11.8
Upper Main Channel	Upper Waitematā Hbr	89.0	22.9	26.1	111.5	0.153	11.8
Brigham Creek	Upper Waitematā Hbr	93.2	22.8	24.7	117.1	0.152	12.1
Pāremoremo	Upper Waitematā Hbr	93.9	21.9	22.7	102.0	0.132	12.2
Rangitōpuni Creek	Upper Waitematā Hbr	96.3	24.3	23.8	114.0	0.139	10.7
Kendall Bay	Central Waitematā Hbr	5.6	4.7	7.5	39.7	0.024	12.1
Meola Outer	Central Waitematā Hbr	7.5	4.4	9.7	45.3	0.040	3.7
Island Bay	Central Waitematā Hbr	9.8	7.1	11.2	57.3	0.045	11.0
Chelsea	Central Waitematā Hbr	11.4	6.9	13.0	51.1	0.055	7.1
Coxs Bay	Central Waitematā Hbr	12.2	10.4	20.7	105.7	0.094	3.8
Henderson Creek	Central Waitematā Hbr	16.3	7.5	16.5	74.0	0.043	13.1
Motu Manawa	Central Waitematā Hbr	16.4	6.5	12.6	67.9	0.070	5.0

State table continued.

Site name	Harbour	Mud Content	ERC			TEL	ANZG
		% <63 um	Cu	Pb	Zn	Hg	As
Whau Entrance	Central Waitematā Hbr	18.2	4.9	8.3	41.7	0.041	3.3
Whakatakataka Bay	Central Waitematā Hbr	23.2	6.5	16.1	85.1	0.117	7.1
Pourewa	Central Waitematā Hbr	25.4	14.6	33.0	177.7	0.160	15.6
Motions	Central Waitematā Hbr	25.6	19.1	33.6	206.4	0.159	7.4
Awatea	Central Waitematā Hbr	38.5	11.2	26.5	105.0	0.161	8.1
Meola Inner	Central Waitematā Hbr	61.9	28.5	48.8	242.8	0.221	10.1
Whau Upper	Central Waitematā Hbr	75.9	39.4	53.0	220.8	0.167	13.2
Shoal Bay Hillcrest	Central Waitematā Hbr	77.3	15.3	23.7	96.8	0.163	9.5
Henderson Upper	Central Waitematā Hbr	78.3	31.9	29.1	167.1	0.122	12.6
Oakley Creek	Central Waitematā Hbr	79.1	24.0	35.6	139.8	0.151	11.5
Whau Wairau	Central Waitematā Hbr	80.7	30.4	35.2	244.3	0.178	13.5
Henderson Lower	Central Waitematā Hbr	92.7	30.5	26.3	135.4	0.139	13.1
Whau Lower	Central Waitematā Hbr	92.9	24.9	34.6	153.0	0.157	10.7
Hobsonville	Central Waitematā Hbr	3.1	2.8	6.0	24.5	0.027	4.0
Roberta Reserve	Tāmaki Estuary	6.6	3.8	7.0	42.6	0.029	8.4
Benghazi	Tāmaki Estuary	13.0	7.4	11.8	80.6	0.060	6.8
Bowden	Tāmaki Estuary	43.4	18.3	23.8	216.5	0.133	10.4
Pakuranga Lower	Tāmaki Estuary	44.2	17.2	19.2	158.4	0.096	8.1
Princes St	Tāmaki Estuary	51.8	21.2	23.8	172.0	0.133	9.5
Pakuranga Upper	Tāmaki Estuary	73.7	27.6	26.8	231.8	0.120	9.5
Middlemore	Tāmaki Estuary	74.4	33.2	31.7	253.0	0.148	10.0
Panmure	Tāmaki Estuary	84.9	24.4	26.8	171.1	0.155	8.8
Ōtāhuhu	Tāmaki Estuary	94.2	29.3	27.6	184.8	0.149	9.3
Te Matuku	Tāmaki Strait	15.6	2.9	7.1	32.0	0.034	5.0
Mill Bay	Manukau Harbour	10.7	3.7	7.9	50.8	<0.02	13.1
Hillsborough	Manukau Harbour	17.5	6.1	10.6	64.4	0.02	9.4
Mauku/Taihiki River B	Manukau Harbour	23.1	2.3	4.6	29.1	<0.02	6.5
Little Muddy	Manukau Harbour	27.7	9.6	12.6	71.0	0.04	16.7
Doc Island Mud	Manukau Harbour	30.5	3.4	6.7	49.3	0.02	8.9
Blockhouse Bay	Manukau Harbour	30.6	3.9	9.9	57.2	<0.02	7.3
Pāhurehure Middle	Manukau Harbour	31.7	3.5	7.7	49.2	<0.02	12.5
Whangapōuri	Manukau Harbour	37.9	5.1	9.2	53.9	0.03	10.1
Karaka/ Te Hihi Estuary	Manukau Harbour	39.1	3.0	5.3	34.7	<0.02	8.1
Pukaki Upper	Manukau Harbour	40.1	4.0	6.6	45.1	<0.02	7.8
Mauku/Taihiki River A	Manukau Harbour	40.2	2.9	5.5	34.0	<0.02	7.7
Drury Inner	Manukau Harbour	44.3	6.0	9.6	65.6	0.04	10.6
Pukaki Waokauri	Manukau Harbour	49.6	4.7	7.9	53.6	0.02	8.7
Tararata	Manukau Harbour	59.4	12.1	16.4	117.9	0.04	9.8
Pāhurehure Papakura	Manukau Harbour	66.2	7.5	13.0	85.2	0.04	11.6
Bottle Top Bay	Manukau Harbour	73.0	7.6	11.7	73.6	0.04	11.8
Waiuku	Manukau Harbour	77.9	8.5	14.8	90.5	0.05	14.6
Big Muddy	Manukau Harbour	80.9	8.5	9.6	61.3	0.03	12.4
Pāhurehure Upper	Manukau Harbour	83.4	8.0	12.4	88.9	0.04	13.7
Pukaki Airport	Manukau Harbour	83.4	7.2	11.0	69.8	0.03	13.2
Māngere Cemetery	Manukau Harbour	86.1	11.8	17.3	112.1	0.04	11.2
Waimāhia Central	Manukau Harbour	90.1	7.6	11.6	82.5	0.04	13.4
Harania	Manukau Harbour	90.4	13.4	18.1	123.7	0.05	10.7
Whangamaire	Manukau Harbour	90.5	3.2	6.2	31.3	<0.02	8.2
Puhinui Upper	Manukau Harbour	92.0	8.7	12.7	109.1	0.04	14.3
Anns Creek	Manukau Harbour	93.6	14.7	19.8	140.4	0.05	10.9
Papakura Lower	Manukau Harbour	95.0	7.6	11.8	75.2	0.04	10.1

7.1.2 State history table for RSCMP sites. State/colour is based on ERC categories for total recoverable copper (Cu), lead (Pb), and zinc (Zn) concentrations. State-determining metal(s) are given for amber and red categories.

		Year																									
Site name	Location	2023	2022	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998
Hamilton Landing	Mahurangi Harbour																										
Awaruku Beach	East Coast Bays																										
Vaughans Beach	East Coast Bays																										
Weiti	East Coast Bays																										
Brigham Creek	Upper Waitematā Hbr		Cu		Cu		Cu		Cu			Cu		Cu		Cu	Cu	Cu	Cu	Cu							
Central Main Channel	Upper Waitematā Hbr						Zn																				
Hellyers Upper	Upper Waitematā Hbr				Zn		Cu Zn					Cu Pb Zn		Cu Pb Zn		Cu Pb Zn	Cu Pb Zn	Cu Pb Zn	Cu Pb	Cu Pb							
Hellyers Creek	Upper Waitematā Hbr																										
Herald Island North	Upper Waitematā Hbr																										
Herald Island Waiarohia	Upper Waitematā Hbr																										
Lucas Te Wharau	Upper Waitematā Hbr															Cu											
Lucas Upper	Upper Waitematā Hbr				Cu							Cu		Cu				Cu		Cu		Cu		Cu		Cu	Cu
Lucas Creek	Upper Waitematā Hbr																										
Outer Main Channel	Upper Waitematā Hbr																										
Pāremoremo	Upper Waitematā Hbr		Cu		Cu		Cu		Cu			Cu		Cu				Cu		Cu		Cu		Cu		Cu	Cu
Rangitōpuni Creek	Upper Waitematā Hbr		Cu		Cu		Cu		Cu			Cu		Cu		Cu	Cu	Cu	Cu	Cu							
Upper Main Channel	Upper Waitematā Hbr				Cu		Cu		Cu			Cu		Cu		Cu	Cu	Cu	Cu	Cu							
Opposite HBV	Upper Waitematā Hbr								Pb			Pb		Cu Pb		Cu Pb	Cu Pb	Cu Pb	Cu Pb	Cu Pb							
Rarawaru	Upper Waitematā Hbr																										
Chelsea	Central Waitematā Hbr																										
Coxs Bay	Central Waitematā Hbr																										
Henderson Creek	Central Waitematā Hbr																										
Henderson Lower	Central Waitematā Hbr	Cu Zn				Zn		Cu Zn		Cu Zn			Cu Zn		Cu Pb Zn		Cu Pb Zn		Cu Pb Zn		Cu Pb Zn		Cu Pb Zn				
Kendall Bay	Central Waitematā Hbr																										
Meola Outer	Central Waitematā Hbr																										
Meola Reef	Central Waitematā Hbr																										
Shoal Bay Hillcrest	Central Waitematā Hbr												Pb		Pb		Cu Pb Zn				Pb						
Whau Entrance	Central Waitematā Hbr																										
Henderson Upper	Central Waitematā Hbr				Zn		Zn		Zn			Cu Pb Zn		Zn		Cu Pb Zn		Zn		Zn		Cu Zn		Zn		Cu Zn	Cu Zn
Island Bay	Central Waitematā Hbr																										
Meola Inner	Central Waitematā Hbr	Zn			Pb Zn		Zn		Pb Zn			Pb Zn		Pb Zn		Pb Zn		Pb Zn		Cu Pb Zn		Pb Zn		Pb Zn		Cu Pb Zn	Cu Pb Zn
Motions	Central Waitematā Hbr	Zn			Zn		Zn		Zn			Zn		Zn		Zn		Zn		Zn		Pb Zn		Pb Zn		Zn	Pb Zn
Oakley Creek	Central Waitematā Hbr	Cu Pb Zn			Cu Pb Zn		Zn		Cu Pb Zn			Cu Pb Zn		Zn		Cu Pb Zn		Zn		Zn		Zn		Zn		Cu Pb Zn	Pb Zn
Motu Manawa	Central Waitematā Hbr																										
Shoal Bay Upper	Central Waitematā Hbr																										
Whau Lower	Central Waitematā Hbr	Zn			Zn		Zn		Cu Pb Zn			Zn		Zn		Zn		Zn		Zn		Pb Zn		Zn		Cu Pb Zn	Pb Zn
Whau Upper	Central Waitematā Hbr	Cu Pb Zn			Zn		Zn		Pb Zn			Pb Zn		Zn		Cu Pb Zn		Cu Pb Zn		Cu Pb Zn		Cu Pb Zn		Cu Pb Zn		Cu Pb Zn	Cu Pb Zn
Whau Wairau	Central Waitematā Hbr	Zn			Cu Pb Zn		Zn		Pb Zn			Pb Zn		Zn		Cu Pb Zn		Cu Pb Zn		Cu Pb Zn		Cu Pb Zn		Cu Pb Zn		Cu Pb Zn	Cu Pb Zn
Whakatakataka Bay	Central Waitematā Hbr																										
Awatea	Central Waitematā Hbr													Pb			Pb				Pb						
Pourewa	Central Waitematā Hbr	Zn						Zn					Zn		Zn		Zn		Zn		Zn		Zn				
Hobsonville	Central Waitematā Hbr																										

State history table continued.

Site name	Location	2023	2022	Year																					
		2023	2022	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998
Benghazi	Tāmaki Estuary																										
Panmure	Tāmaki Estuary		Zn			Zn		Zn					Zn		Zn		Zn		Zn		Cu Pb Zn		Zn				
Middlemore	Tāmaki Estuary		Zn		Zn		Zn		Zn			Zn		Zn		Zn		Zn		Zn		Zn		Zn		Zn	Cu Pb Zn
Pakuranga Lower	Tāmaki Estuary		Zn		Zn		Zn		Zn			Zn		Zn		Zn		Zn		Cu Zn				Zn		Cu Zn	Cu Zn
Pakuranga Upper	Tāmaki Estuary		Zn				Zn		Zn			Zn		Zn		Zn		Zn		Cu Zn		Zn		Zn		Cu Zn	Zn
Princes St	Tāmaki Estuary		Zn		Zn			Zn		Zn			Zn		Zn		Zn		Zn		Zn						
Bowden	Tāmaki Estuary		Zn					Zn		Zn			Zn		Zn		Zn		Zn		Zn						
Ōtāhuhu	Tāmaki Estuary		Zn					Zn					Zn		Zn		Zn		Zn		Zn						
Roberta Reserve	Tāmaki Estuary																										
Te Matuku	Tāmaki Strait																										
Bottle Top Bay	Manukau Harbour																										
DOC Island Mud	Manukau Harbour																										
Drury Inner	Manukau Harbour																										
Harania	Manukau Harbour			Zn		Zn		Zn		Zn					Zn					Cu							
Karaka / Te Hihi estuary	Manukau Harbour																										
Mauku/ Taihiki River A	Manukau Harbour																										
Mauku/ Taihiki River B	Manukau Harbour																										
Pāhurehure Middle	Manukau Harbour																										
Pāhurehure Upper	Manukau Harbour																										
Papakura Lower	Manukau Harbour																										
Puhinui Upper	Manukau Harbour																										
Pukaki Airport	Manukau Harbour																										
Tararata	Manukau Harbour							Zn							Zn					Cu Zn							
Waimāhia Central	Manukau Harbour					Zn																					
Whangamaire	Manukau Harbour																										
Whangapōuri	Manukau Harbour																										
Hillsborough	Manukau Harbour																										
Mill Bay	Manukau Harbour																										
Waiuku	Manukau Harbour																										
Anns Creek	Manukau Harbour			Zn			Zn		Zn			Zn		Zn		Cu Zn		Cu Zn		Zn		Cu Zn		Cu Zn		Cu Zn	Cu Zn
Big Muddy	Manukau Harbour																										
Blockhouse Bay	Manukau Harbour																										
Little Muddy	Manukau Harbour																										
Māngere Cemetery	Manukau Harbour													Cu Zn				Cu Zn		Cu Zn		Cu Pb Zn		Cu Zn		Cu Pb Zn	Cu Pb Zn
Pāhurehure Papakura	Manukau Harbour																										
Pukaki Upper	Manukau Harbour																										
Pukaki Waokauri	Manukau Harbour																										

7.2 Trend tables

7.2.1 Trends in mud content (% <63 µm by weight). Data are median annual rates of change (% median per year). Trend likelihood is assessed from Sen Slope probabilities and categorised as 'very likely' (>90%), 'likely' (67-90%), and 'indeterminate' (<67%). Highlighted rows have a 'meaningful' trend (very likely probability and >±2% of median per year).

Site name	Harbour	Start year	End year	Number of samples	Median % <63µm	Percent annual change	Sen slope probability	Trend likelihood LAWA category
Awaruku Beach	East Coast Bays	2010	2022	5	0.4	-1.2	0.50	Indeterminate
Vaughan Beach	East Coast Bays	2010	2022	5	0.2	-0.5	0.50	Indeterminate
Weiti	**East Coast Bays**	**2009**	**2022**	**7**	**26.7**	**-2.9**	**0.99**	**Very likely improving**
Brigham Creek	Upper Waitematā	2006	2022	9	87.5	0.2	0.54	Indeterminate
Central Main Channel	**Upper Waitematā**	**2005**	**2022**	**11**	**27.4**	**2.4**	**0.99**	**Very likely worsening**
Hellyers Creek	Upper Waitematā	2005	2022	11	46.7	1.3	0.88	Likely worsening
Hellyers Upper	Upper Waitematā	2005	2020	10	79.1	-0.2	0.61	Indeterminate
Herald Island North	**Upper Waitematā**	**2005**	**2020**	**10**	**9.7**	**7.7**	**1.00**	**Very likely worsening**
Herald Island Waiarohia	**Upper Waitematā**	**2005**	**2022**	**11**	**14.0**	**5.6**	**0.99**	**Very likely worsening**
Lucas Creek	Upper Waitematā	2005	2022	11	30.1	1.2	0.74	Likely worsening
Lucas Te Wharau	Upper Waitematā	2005	2020	10	45.9	-0.4	0.67	Indeterminate
Lucas Upper	**Upper Waitematā**	**2005**	**2022**	**8**	**71.3**	**-2.0**	**1.00**	**Very likely improving**
Opposite Hobsonville	Upper Waitematā	2005	2020	10	73.1	-1.0	0.84	Likely improving
Outer Main Channel	**Upper Waitematā**	**2005**	**2020**	**10**	**14.7**	**7.8**	**0.99**	**Very likely worsening**
Pāremoremo	Upper Waitematā	2005	2022	9	95.0	-0.1	0.78	Likely improving
Rangitōpuni Creek	Upper Waitematā	2005	2022	11	95.8	0.2	0.96	Very likely worsening
Upper Main Channel	Upper Waitematā	2005	2020	10	85.2	0.0	0.50	Indeterminate
Awatea	Central Waitematā	2004	2023	7	32.7	1.8	0.90	Very likely worsening
Chelsea	**Central Waitematā**	**2004**	**2023**	**9**	**8.8**	**3.2**	**0.94**	**Very likely worsening**
Coxs Bay	**Central Waitematā**	**2004**	**2023**	**9**	**8.3**	**4.7**	**1.00**	**Very likely worsening**
Henderson Creek	**Central Waitematā**	**2004**	**2023**	**6**	**9.0**	**3.8**	**0.91**	**Very likely worsening**
Henderson Lower	Central Waitematā	2004	2023	9	91.3	-0.2	0.93	Very likely improving
Henderson Upper	Central Waitematā	2005	2020	8	76.1	-0.6	0.89	Likely improving
Hobsonville	**Central Waitematā**	**2009**	**2022**	**7**	**3.5**	**-4.1**	**0.95**	**Very likely improving**
Island Bay	Central Waitematā	2012	2023	4	6.3	8.6	0.78	Likely worsening
Kendall Bay	**Central Waitematā**	**2004**	**2023**	**8**	**5.6**	**3.0**	**0.93**	**Very likely worsening**
Meola Inner	Central Waitematā	2005	2023	9	62.7	0.0	0.58	Indeterminate
Meola Outer	**Central Waitematā**	**2004**	**2023**	**8**	**4.5**	**4.6**	**1.00**	**Very likely worsening**
Motions	Central Waitematā	2005	2023	9	23.2	-1.0	0.91	Very likely improving
Motu Manawa	**Central Waitematā**	**2005**	**2023**	**8**	**33.6**	**-3.4**	**0.96**	**Very likely improving**
Oakley Creek	Central Waitematā	2005	2023	9	84.2	-1.3	1.00	Very likely improving
Pourewa	Central Waitematā	2004	2023	7	33.0	-1.8	0.95	Very likely improving
Shoal Bay Hillcrest	Central Waitematā	2004	2023	9	86.6	-0.2	0.82	Likely improving
Whakatakataka Bay	Central Waitematā	2009	2023	6	23.5	-0.5	0.96	Very likely improving
Whau Entrance	**Central Waitematā**	**2004**	**2023**	**9**	**13.2**	**7.5**	**1.00**	**Very likely worsening**
Whau Lower	Central Waitematā	2005	2023	9	92.9	0.1	0.81	Likely worsening
Whau Upper	Central Waitematā	2005	2023	9	63.0	-1.8	0.91	Very likely improving
Whau Wairau	Central Waitematā	2005	2023	9	73.6	0.5	0.88	Likely worsening
Anns Creek	Manukau Harbour	2005	2021	8	86.9	0.1	0.50	Indeterminate
Big Muddy	Manukau Harbour	2009	2021	5	76.5	1.3	0.97	Very likely worsening
Harania	Manukau Harbour	2010	2021	5	88.4	0.2	0.75	Likely worsening
Hillsborough	**Manukau Harbour**	**2004**	**2021**	**6**	**33.7**	**-4.7**	**0.98**	**Very likely improving**
Māngere Cemetery	Manukau Harbour	2005	2021	8	87.8	-0.6	0.95	Very likely improving
Pāhurehure Middle	**Manukau Harbour**	**2012**	**2021**	**5**	**13.8**	**14.5**	**0.91**	**Very likely worsening**
Pāhurehure Papakura	**Manukau Harbour**	**2009**	**2021**	**6**	**48.0**	**3.9**	**0.94**	**Very likely worsening**
Pāhurehure Upper	Manukau Harbour	2012	2021	5	75.2	1.1	0.89	Likely worsening
Papakura Lower	Manukau Harbour	2012	2021	5	89.8	0.7	0.76	Likely worsening
Puhinui Upper	Manukau Harbour	2009	2021	6	81.2	1.2	0.91	Very likely worsening
Pukaki Airport	Manukau Harbour	2009	2021	6	81.5	0.3	0.60	Indeterminate
Tararata	Manukau Harbour	2010	2021	5	92.2	-1.3	0.88	Likely improving
Waimāhia Central	Manukau Harbour	2012	2021	5	85.8	1.9	0.79	Likely worsening
Benghazi	Tāmaki Estuary	2004	2022	9	24.5	0.1	0.50	Indeterminate
Bowden	Tāmaki Estuary	2004	2022	8	50.2	-0.4	0.69	Likely improving
Middlemore	Tāmaki Estuary	2005	2022	9	59.0	0.9	0.71	Likely worsening
Ōtāhuhu	Tāmaki Estuary	2004	2022	7	90.0	0.4	0.95	Very likely worsening
Pakuranga Lower	Tāmaki Estuary	2009	2022	7	43.1	0.2	0.69	Likely worsening
Pakuranga Upper	**Tāmaki Estuary**	**2005**	**2022**	**8**	**59.8**	**-4.7**	**0.96**	**Very likely improving**
Panmure	Tāmaki Estuary	2004	2022	8	83.5	0.0	0.63	Indeterminate
Princes St	Tāmaki Estuary	2004	2022	9	43.2	1.3	0.82	Likely worsening
Te Matuku	**Tāmaki Strait**	**2009**	**2022**	**7**	**13.9**	**4.4**	**0.95**	**Very likely worsening**

7.2.2 Trend data table for total recoverable copper. Data are median annual rates of change (% median per year). Trend likelihood is assessed from Sen Slope probabilities and categorised as 'very likely' (>90%), 'likely' (67-90%), and 'indeterminate' (<67%). Highlighted rows have a 'meaningful' trend (very likely probability and >±2% of median per year).

Site name	Harbour	Start year	End year	Number of samples	Median value (mg/kg)	Percent annual change	Sen slope probability	Trend likelihood LAWA category
Awaruku Beach	East Coast Bays	2005	2022	7	2.0	-1.3	0.86	Likely improving
Vaughan Beach	East Coast Bays	2005	2022	7	1.6	-1.4	0.87	Likely improving
Weiti	East Coast Bays	2005	2022	9	12.1	-0.1	0.58	Indeterminate
Brigham Creek	Upper Waitematā	2005	2022	11	21.2	0.1	0.59	Indeterminate
Central Main Channel	Upper Waitematā	2005	2022	11	12.8	0.0	0.56	Indeterminate
Hellyers Creek	Upper Waitematā	2005	2022	11	13.5	0.3	0.69	Likely worsening
Hellyers Upper	Upper Waitematā	2005	2020	11	21.0	0.0	0.59	Indeterminate
Herald Island North	Upper Waitematā	2005	2020	10	6.6	-0.5	0.71	Likely improving
Herald Island Waiarohia	**Upper Waitematā**	**2005**	**2022**	**11**	**4.4**	**3.1**	**0.98**	**Very likely worsening**
Lucas Creek	Upper Waitematā	2005	2022	11	13.0	-0.2	0.66	Indeterminate
Lucas Te Wharau	**Upper Waitematā**	**2005**	**2020**	**10**	**15.0**	**-2.0**	**0.96**	**Very likely improving**
Lucas Upper	Upper Waitematā	2005	2022	8	19.6	-0.5	0.96	Very likely improving
Opposite Hobsonville	Upper Waitematā	2005	2020	10	20.4	-1.8	0.99	Very likely improving
Outer Main Channel	Upper Waitematā	2005	2020	10	12.1	-1.0	0.59	Indeterminate
Pāremoremo	Upper Waitematā	2005	2022	10	21.9	-0.5	0.85	Likely improving
Rangitōpuni Creek	Upper Waitematā	2005	2022	11	23.4	0.1	0.73	Likely worsening
Upper Main Channel	Upper Waitematā	2005	2020	10	22.3	-0.2	0.79	Likely improving
Awatea	Central Waitematā	2004	2023	7	11.0	-1.5	0.90	Very likely improving
Chelsea	Central Waitematā	2004	2023	9	6.0	1.8	0.99	Very likely worsening
Coxs Bay	**Central Waitematā**	**2004**	**2023**	**9**	**5.7**	**5.6**	**1.00**	**Very likely worsening**
Henderson Creek	Central Waitematā	2004	2023	8	6.8	0.6	0.87	Likely worsening
Henderson Lower	Central Waitematā	2004	2023	9	28.9	0.4	0.65	Indeterminate
Henderson Upper	Central Waitematā	2005	2020	8	31.0	-0.1	0.70	Likely improving
Hobsonville	Central Waitematā	2005	2022	11	2.7	-1.8	0.94	Very likely improving
Island Bay	Central Waitematā	2007	2023	5	6.2	0.9	0.77	Likely worsening
Kendall Bay	**Central Waitematā**	**2004**	**2023**	**8**	**4.6**	**2.4**	**0.99**	**Very likely worsening**
Meola Inner	Central Waitematā	2005	2023	9	30.1	-0.7	0.85	Likely improving
Meola Outer	Central Waitematā	2004	2023	8	3.9	1.9	0.97	Very likely worsening
Motions	Central Waitematā	2005	2023	9	17.8	-0.9	0.74	Likely improving
Motu Manawa	Central Waitematā	2005	2023	8	9.8	-1.3	0.91	Very likely improving
Oakley Creek	Central Waitematā	2005	2023	9	24.0	-1.2	0.99	Very likely improving
Pourewa	Central Waitematā	2004	2023	7	14.0	-0.2	0.62	Indeterminate
Shoal Bay Hillcrest	Central Waitematā	2004	2023	9	17.0	-0.6	0.86	Likely improving
Whakatakataka Bay	Central Waitematā	2009	2023	6	6.5	-1.3	0.94	Very likely improving
Whau Entrance	**Central Waitematā**	**2004**	**2023**	**9**	**4.4**	**2.5**	**0.95**	**Very likely worsening**
Whau Lower	Central Waitematā	2005	2023	9	24.2	0.0	0.50	Indeterminate
Whau Upper	Central Waitematā	2005	2023	9	32.0	-1.3	0.95	Very likely improving
Whau Wairau	Central Waitematā	2005	2023	9	39.0	-0.7	0.91	Very likely improving
Anns Creek	**Manukau Harbour**	**2005**	**2021**	**8**	**18.5**	**-4.2**	**1.00**	**Very likely improving**
Big Muddy	Manukau Harbour	2005	2021	7	9.1	-1.1	0.94	Very likely improving
Harania	**Manukau Harbour**	**2005**	**2021**	**6**	**17.1**	**-2.7**	**0.99**	**Very likely improving**
Hillsborough	Manukau Harbour	2004	2021	6	7.2	-2.0	0.87	Likely improving
Māngere Cemetery	**Manukau Harbour**	**2005**	**2021**	**8**	**16.8**	**-5.0**	**1.00**	**Very likely improving**
Pāhurehure Middle	**Manukau Harbour**	**2008**	**2021**	**6**	**2.2**	**5.1**	**0.96**	**Very likely worsening**
Pāhurehure Papakura	Manukau Harbour	2005	2021	8	6.4	0.1	0.50	Indeterminate
Pāhurehure Upper	Manukau Harbour	2008	2021	6	8.0	-0.2	0.70	Likely improving
Papakura Lower	Manukau Harbour	2008	2021	6	8.0	-0.6	0.78	Likely improving
Puhinui Upper	Manukau Harbour	2005	2021	8	9.2	-0.2	0.77	Likely improving
Pukaki Airport	Manukau Harbour	2005	2021	8	7.6	-0.1	0.66	Indeterminate
Tararata	**Manukau Harbour**	**2005**	**2021**	**6**	**14.2**	**-3.6**	**0.98**	**Very likely improving**
Waimāhia Central	Manukau Harbour	2012	2021	5	7.5	0.3	0.66	Indeterminate
Benghazi	Tāmaki Estuary	2004	2022	9	9.5	1.8	0.73	Likely worsening
Bowden	Tāmaki Estuary	2004	2022	8	21.7	-1.3	0.94	Very likely improving
Middlemore	Tāmaki Estuary	2005	2022	9	26.0	1.1	0.95	Very likely worsening
Ōtāhuhu	Tāmaki Estuary	2004	2022	7	28.9	0.1	0.57	Indeterminate
Pakuranga Lower	Tāmaki Estuary	2005	2022	9	17.2	-0.9	0.93	Very likely improving
Pakuranga Upper	**Tāmaki Estuary**	**2005**	**2022**	**8**	**25.0**	**-2.8**	**0.95**	**Very likely improving**
Panmure	Tāmaki Estuary	2004	2022	8	24.9	0.0	0.50	Indeterminate
Princes St	Tāmaki Estuary	2004	2022	9	20.5	1.8	0.92	Very likely worsening
Te Matuku	Tāmaki Strait	2005	2022	9	2.8	-0.1	0.66	Indeterminate

7.2.3 Trend data table for total recoverable lead. Data are median annual rates of change (% median per year). Trend likelihood is assessed from Sen Slope probabilities and categorised as 'very likely' (>90%), 'likely' (67-90%), and 'indeterminate' (<67%). Highlighted rows have a 'meaningful' trend (very likely probability and >±2% of median per year).

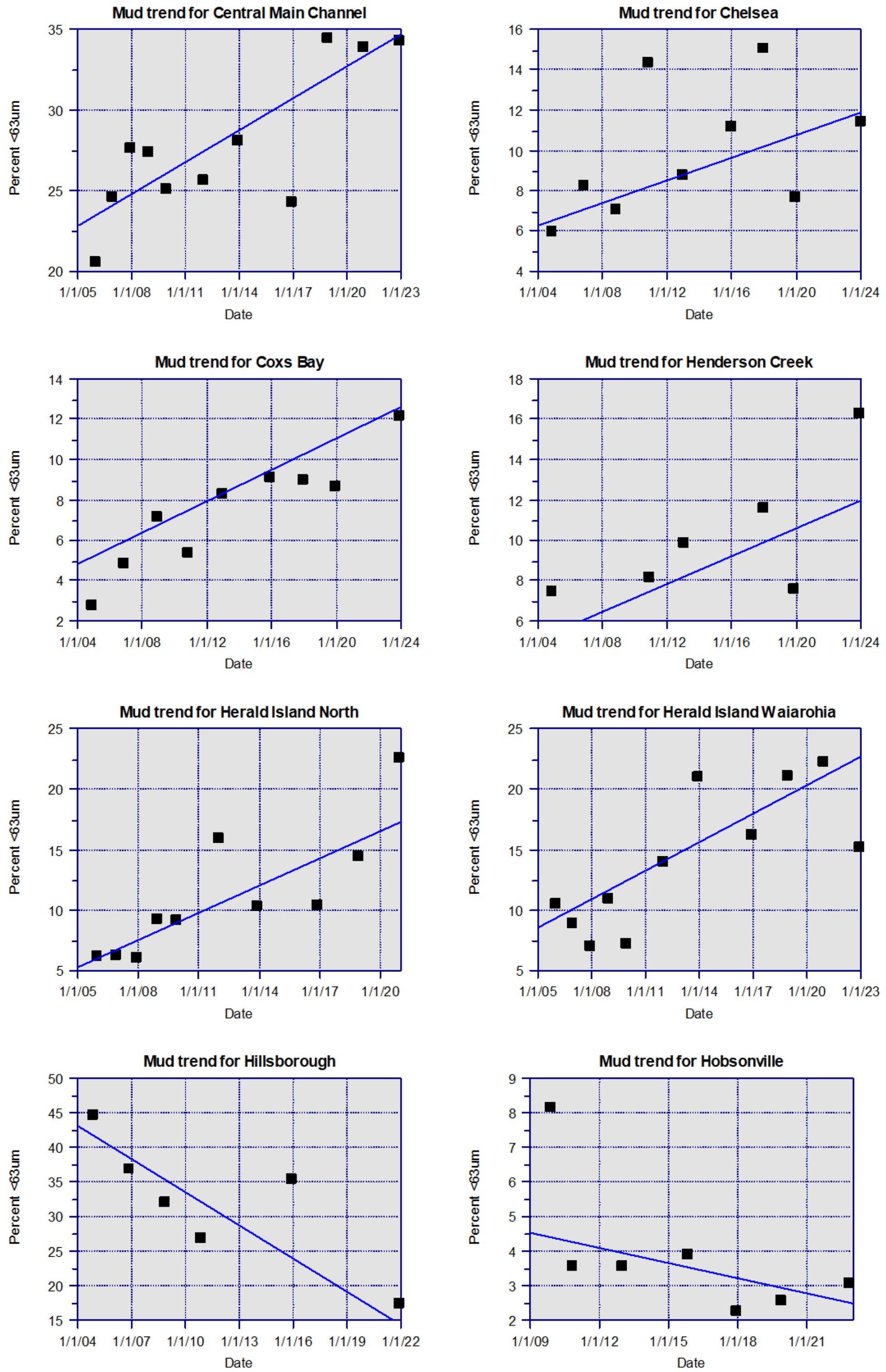
Site name	Harbour	Start year	End year	Number of samples	Median value (mg/kg)	Percent annual change	Sen slope probability	Trend likelihood LAWA category
Awaruku Beach	East Coast Bays	2005	2022	7	3.6	-0.5	0.91	Very likely improving
Vaughan Beach	East Coast Bays	2005	2022	7	2.9	-0.6	0.93	Very likely improving
Weiti	East Coast Bays	2005	2022	9	9.0	0.4	0.74	Likely worsening
Brigham Creek	Upper Waitematā	2005	2022	11	25.0	-0.5	0.88	Likely improving
Central Main Channel	Upper Waitematā	2005	2022	11	26.5	-0.3	0.93	Very likely improving
Hellyers Creek	Upper Waitematā	2005	2022	11	20.2	-0.9	0.98	Very likely improving
Hellyers Upper	Upper Waitematā	2005	2020	11	31.0	-1.5	0.95	Very likely improving
Herald Island North	Upper Waitematā	2005	2020	10	13.9	-0.5	0.67	Likely improving
Herald Island Waiarohia	**Upper Waitematā**	**2005**	**2022**	**11**	**7.0**	**3.2**	**0.99**	**Very likely worsening**
Lucas Creek	Upper Waitematā	2005	2022	11	24.0	-1.3	0.99	Very likely improving
Lucas Te Wharau	Upper Waitematā	2005	2020	**10**	20.0	-1.2	0.99	Very likely improving
Lucas Upper	Upper Waitematā	2005	2022	8	21.6	-0.9	0.96	Very likely improving
Opposite Hobsonville	Upper Waitematā	2005	2020	10	31.3	-1.4	1.00	Very likely improving
Outer Main Channel	**Upper Waitematā**	**2005**	**2020**	**10**	**16.9**	**-2.3**	**0.98**	**Very likely improving**
Pāremoremo	Upper Waitematā	2005	2022	10	25.4	-1.2	0.99	Very likely improving
Rangitōpuni Creek	Upper Waitematā	2005	2022	11	25.0	-0.4	0.91	Very likely improving
Upper Main Channel	Upper Waitematā	2005	2020	10	26.0	-0.3	0.67	Likely improving
Awatea	Central Waitematā	2004	2023	7	29.0	-1.0	0.96	Very likely improving
Chelsea	Central Waitematā	2004	2023	9	12.7	0.2	0.74	Likely worsening
Coxs Bay	**Central Waitematā**	**2004**	**2023**	**9**	**14.1**	**2.6**	**0.96**	**Very likely worsening**
Henderson Creek	Central Waitematā	2004	2023	8	18.3	-0.7	0.92	Very likely improving
Henderson Lower	Central Waitematā	2004	2023	9	29.9	-1.4	1.00	Very likely improving
Henderson Upper	Central Waitematā	2005	2020	8	31.0	-1.7	1.00	Very likely improving
Hobsonville	Central Waitematā	2005	2022	11	6.3	-1.3	0.97	Very likely improving
Island Bay	Central Waitematā	2007	2023	5	12.0	-0.5	0.86	Likely improving
Kendall Bay	Central Waitematā	2004	2023	**8**	7.5	0.1	0.61	Indeterminate
Meola Inner	Central Waitematā	2005	2023	9	54.5	-1.6	0.99	Very likely improving
Meola Outer	Central Waitematā	2004	2023	8	9.3	0.4	0.89	Likely worsening
Motions	Central Waitematā	2005	2023	9	36.9	-1.8	0.99	Very likely improving
Motu Manawa	Central Waitematā	2005	2023	8	18.8	-1.5	0.88	Likely improving
Oakley Creek	Central Waitematā	2005	2023	9	38.0	-1.6	1.00	Very likely improving
Pourewa	Central Waitematā	2004	2023	7	34.0	-0.5	0.93	Very likely improving
Shoal Bay Hillcrest	Central Waitematā	2004	2023	9	28.3	-1.9	1.00	Very likely improving
Whakatakataka Bay	Central Waitematā	2009	2023	6	17.1	-1.8	0.99	Very likely improving
Whau Entrance	Central Waitematā	2004	2023	9	8.3	1.6	0.95	Very likely worsening
Whau Lower	Central Waitematā	2005	2023	9	37.6	-1.0	0.99	Very likely improving
Whau Upper	Central Waitematā	2005	2023	9	54.9	-1.9	1.00	Very likely improving
Whau Wairau	Central Waitematā	2005	2023	9	54.8	-1.3	0.98	Very likely improving
Anns Creek	**Manukau Harbour**	**2005**	**2021**	**8**	**24.6**	**-2.7**	**1.00**	**Very likely improving**
Big Muddy	Manukau Harbour	2005	2021	7	9.6	0.0	0.50	Indeterminate
Harania	Manukau Harbour	2005	2021	**6**	21.2	-2.0	0.98	Very likely improving
Hillsborough	Manukau Harbour	2004	2021	6	11.4	-0.9	0.91	Very likely improving
Māngere Cemetery	**Manukau Harbour**	**2005**	**2021**	**8**	**21.3**	**-3.1**	**1.00**	**Very likely improving**
Pāhurehure Middle	Manukau Harbour	2008	2021	**6**	6.5	1.4	0.85	Likely worsening
Pāhurehure Papakura	Manukau Harbour	2005	2021	8	12.2	0.4	0.60	Indeterminate
Pāhurehure Upper	Manukau Harbour	2008	2021	6	12.4	-0.2	0.86	Likely improving
Papakura Lower	Manukau Harbour	2008	2021	6	12.3	-0.1	0.63	Indeterminate
Puhinui Upper	Manukau Harbour	2005	2021	8	12.3	-0.1	0.63	Indeterminate
Pukaki Airport	Manukau Harbour	2005	2021	8	11.0	0.1	0.60	Indeterminate
Tararata	**Manukau Harbour**	**2005**	**2021**	**6**	**18.1**	**-3.3**	**0.98**	**Very likely improving**
Waimāhia Central	Manukau Harbour	2012	2021	5	10.9	1.3	0.95	Very likely worsening
Benghazi	Tāmaki Estuary	2004	2022	9	15.3	0.8	0.62	Indeterminate
Bowden	Tāmaki Estuary	2004	2022	8	28.9	-1.0	0.89	Likely improving
Middlemore	Tāmaki Estuary	2005	2022	9	31.7	-0.3	0.80	Likely improving
Ōtāhuhu	Tāmaki Estuary	2004	2022	7	32.0	-1.3	0.98	Very likely improving
Pakuranga Lower	Tāmaki Estuary	2005	2022	9	22.0	-1.9	0.99	Very likely improving
Pakuranga Upper	**Tāmaki Estuary**	**2005**	**2022**	**8**	**28.9**	**-2.1**	**0.98**	**Very likely improving**
Panmure	Tāmaki Estuary	2004	2022	8	31.8	-1.2	1.00	Very likely improving
Princes St	Tāmaki Estuary	2004	2022	9	23.8	0.3	0.55	Indeterminate
Te Matuku	Tāmaki Strait	2005	2022	9	6.8	0.0	0.50	Indeterminate

7.2.4 Trend data table for total recoverable zinc. Data are median annual rates of change (% median per year). Trend likelihood is assessed from Sen Slope probabilities and categorised as 'very likely' (>90%), 'likely' (67-90%), and 'indeterminate' (<67%). Highlighted rows have a 'meaningful' trend (very likely probability and >±2% of median per year).

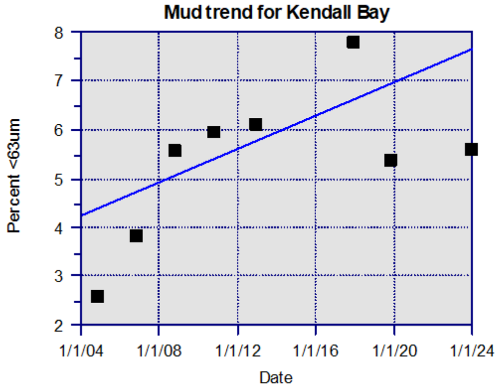
Site name	Harbour	Start year	End year	Number of samples	Median value (mg/kg)	Percent annual change	Sen slope probability	Trend likelihood LAWA category
Awaruku Beach	East Coast Bays	2005	2022	7	23.7	-0.3	0.78	Likely improving
Vaughan Beach	East Coast Bays	2005	2022	7	21.0	-0.1	0.86	Likely improving
Weiti	East Coast Bays	2005	2022	9	54.0	1.0	0.76	Likely worsening
Brigham Creek	Upper Waitematā	2005	2022	11	102.2	1.2	0.99	Very likely worsening
Central Main Channel	Upper Waitematā	2005	2022	11	107.0	1.2	1.00	Very likely worsening
Hellyers Creek	Upper Waitematā	2005	2022	11	85.5	0.4	0.78	Likely worsening
Hellyers Upper	Upper Waitematā	2005	2020	11	131.0	0.7	0.91	Very likely worsening
Herald Island North	Upper Waitematā	2005	2020	10	51.7	0.8	0.86	Likely worsening
Herald Island Waiarohia	**Upper Waitematā**	**2005**	**2022**	**11**	**22.0**	**5.2**	**0.99**	**Very likely worsening**
Lucas Creek	Upper Waitematā	2005	2022	11	102.2	0.5	0.69	Likely worsening
Lucas Te Wharau	Upper Waitematā	2005	2020	10	82.4	-0.3	0.79	Likely improving
Lucas Upper	Upper Waitematā	2005	2022	8	107.6	0.7	0.94	Very likely worsening
Opposite Hobsonville	Upper Waitematā	2005	2020	10	115.5	0.0	0.53	Indeterminate
Outer Main Channel	Upper Waitematā	2005	2020	10	62.0	0.0	0.57	Indeterminate
Pāremoremo	Upper Waitematā	2005	2022	10	100.0	0.4	0.75	Likely worsening
Rangitōpuni Creek	Upper Waitematā	2005	2022	11	105.0	0.9	0.98	Very likely worsening
Upper Main Channel	Upper Waitematā	2005	2020	10	98.8	0.9	0.80	Likely worsening
Awatea	Central Waitematā	2004	2023	7	105.0	-0.4	0.88	Likely improving
Henderson Creek	Central Waitematā	2004	2023	8	74.6	0.5	0.69	Likely worsening
Chelsea	Central Waitematā	2004	2023	9	46.3	0.7	0.98	Very likely worsening
Coxs Bay	**Central Waitematā**	**2004**	**2023**	**9**	**75.9**	**3.2**	**0.99**	**Very likely worsening**
Henderson Lower	Central Waitematā	2004	2023	9	147.0	0.2	0.68	Likely worsening
Henderson Upper	Central Waitematā	2005	2020	8	166.6	-0.1	0.64	Indeterminate
Hobsonville	Central Waitematā	2005	2022	11	23.7	-1.0	0.84	Likely improving
Island Bay	Central Waitematā	2007	2023	5	54.0	1.3	0.73	Likely worsening
Kendall Bay	Central Waitematā	2004	2023	8	32.6	1.7	0.97	Very likely worsening
Meola Inner	Central Waitematā	2005	2023	9	242.8	0.2	0.74	Likely worsening
Meola Outer	Central Waitematā	2004	2023	8	37.8	1.8	0.99	Very likely worsening
Motions	Central Waitematā	2005	2023	9	239.0	0.0	0.66	Indeterminate
Motu Manawa	Central Waitematā	2005	2023	8	79.5	0.5	0.71	Likely worsening
Oakley Creek	Central Waitematā	2005	2023	9	150.0	-1.0	0.98	Very likely improving
Pourewa	Central Waitematā	2004	2023	7	165.0	0.7	0.99	Very likely worsening
Shoal Bay Hillcrest	Central Waitematā	2004	2023	9	108.9	-0.2	0.70	Likely improving
Whakatakataka Bay	Central Waitematā	2009	2023	6	85.0	0.1	0.58	Indeterminate
Whau Entrance	**Central Waitematā**	**2004**	**2023**	**9**	**37.5**	**2.5**	**0.99**	**Very likely worsening**
Whau Lower	Central Waitematā	2005	2023	9	161.0	-0.4	0.93	Very likely improving
Whau Upper	Central Waitematā	2005	2023	9	256.7	-0.5	0.89	Likely improving
Whau Wairau	Central Waitematā	2005	2023	9	230.0	0.9	0.98	Very likely worsening
Anns Creek	Manukau Harbour	2005	2021	8	145.2	-0.2	0.81	Likely improving
Big Muddy	Manukau Harbour	2005	2021	7	61.0	0.6	0.88	Likely worsening
Harania	Manukau Harbour	2005	2021	6	135.6	0.8	0.84	Likely worsening
Hillsborough	Manukau Harbour	2004	2021	6	63.9	0.0	0.62	Indeterminate
Māngere Cemetery	Manukau Harbour	2005	2021	8	113.5	-1.3	0.96	Very likely improving
Pāhurehure Middle	**Manukau Harbour**	**2008**	**2021**	**6**	**36.4**	**3.7**	**0.96**	**Very likely worsening**
Pāhurehure Papakura	Manukau Harbour	2005	2021	8	66.1	1.4	0.77	Likely worsening
Pāhurehure Upper	Manukau Harbour	2008	2021	6	80.4	1.2	0.80	Likely worsening
Papakura Lower	Manukau Harbour	2008	2021	6	75.6	0.7	0.70	Likely worsening
Puhinui Upper	Manukau Harbour	2005	2021	8	109.6	0.4	0.77	Likely worsening
Pukaki Airport	Manukau Harbour	2005	2021	8	64.5	1.5	0.97	Very likely worsening
Tararata	Manukau Harbour	2005	2021	6	126.5	-0.1	0.65	Indeterminate
Waimāhia Central	**Manukau Harbour**	**2012**	**2021**	**5**	**75.7**	**2.7**	**0.93**	**Very likely worsening**
Benghazi	**Tāmaki Estuary**	**2004**	**2022**	**9**	**80.6**	**2.2**	**0.96**	**Very likely worsening**
Bowden	Tāmaki Estuary	2004	2022	8	198.5	0.9	0.95	Very likely worsening
Middlemore	**Tāmaki Estuary**	**2005**	**2022**	**9**	**196.0**	**2.1**	**1.00**	**Very likely worsening**
Ōtāhuhu	Tāmaki Estuary	2004	2022	7	177.6	0.8	0.93	Very likely worsening
Pakuranga Lower	Tāmaki Estuary	2005	2022	9	161.0	0.2	0.61	Indeterminate
Pakuranga Upper	Tāmaki Estuary	2005	2022	8	218.7	-0.2	0.62	Indeterminate
Panmure	Tāmaki Estuary	2004	2022	8	178.6	0.8	0.80	Likely worsening
Princes St	Tāmaki Estuary	2004	2022	9	170.0	1.2	0.98	Very likely worsening
Te Matuku	Tāmaki Strait	2005	2022	9	30.8	0.1	0.66	Indeterminate

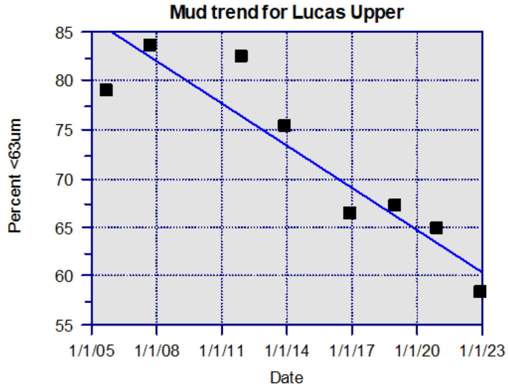
7.3 Trend plots

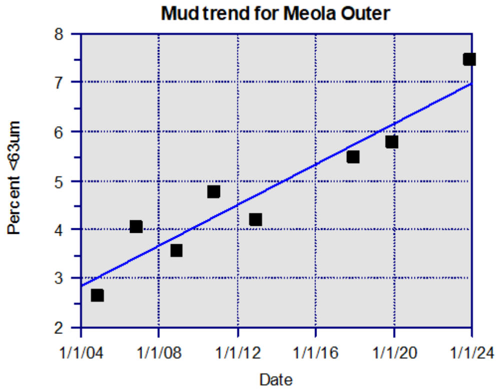
7.3.1 Mud content trend plots for sites with meaningful trends (>±2% median per year and very likely probability). The data plotted are median values from each sampling. The trend line is the Sen Slope.

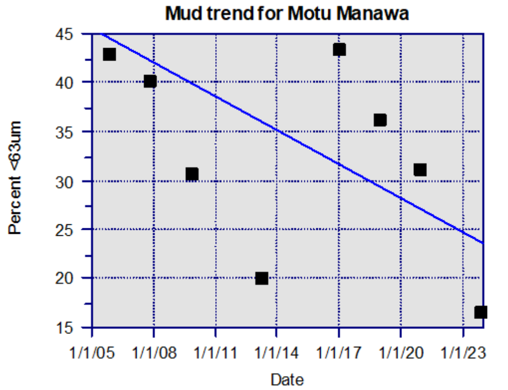


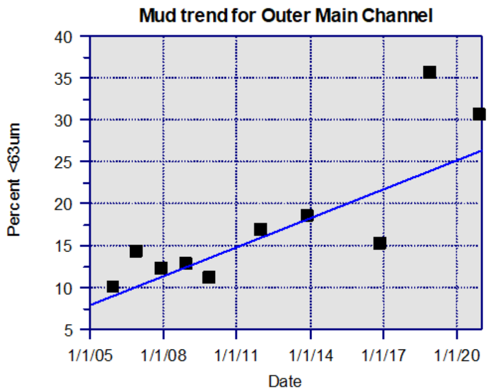
Mud trend plots continued.

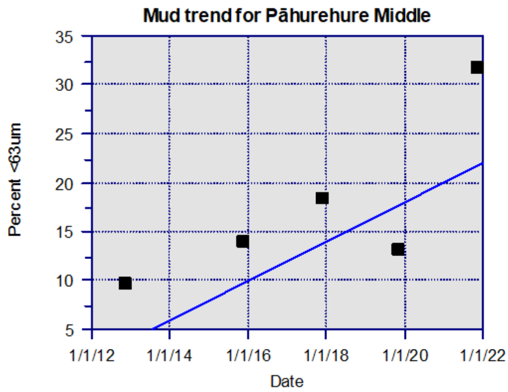


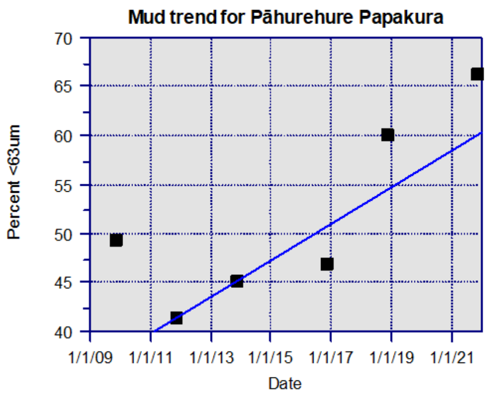


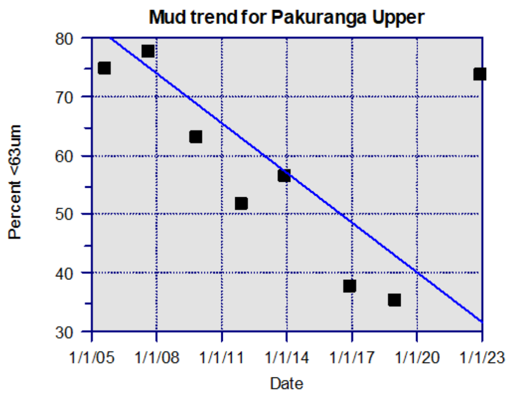




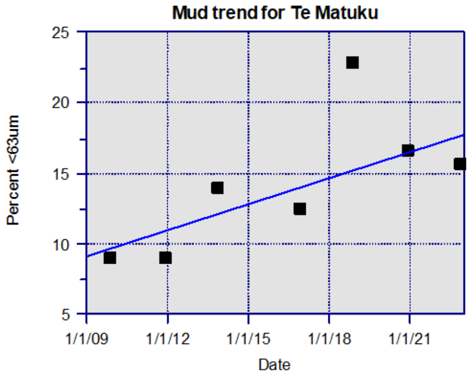


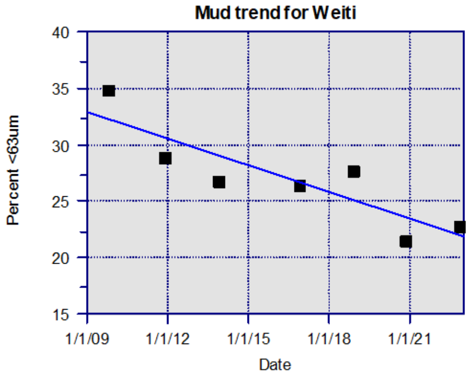


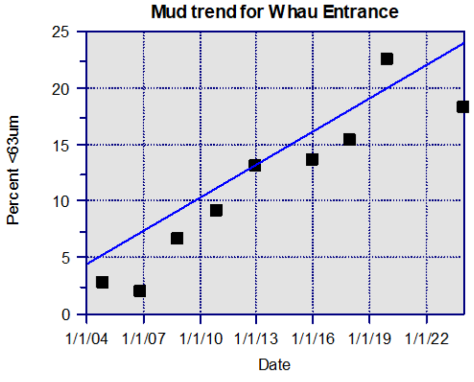




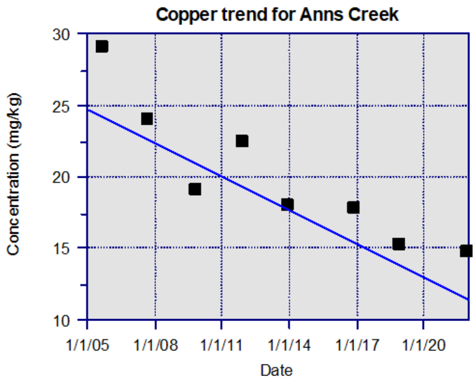
Mud trend plots continued.

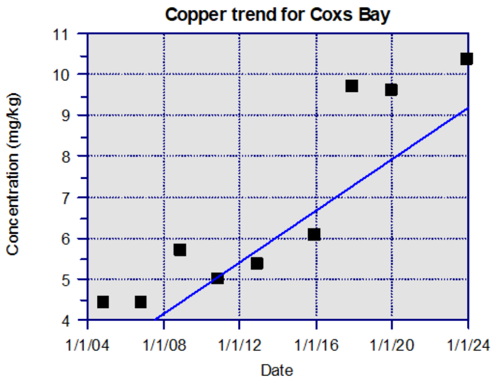


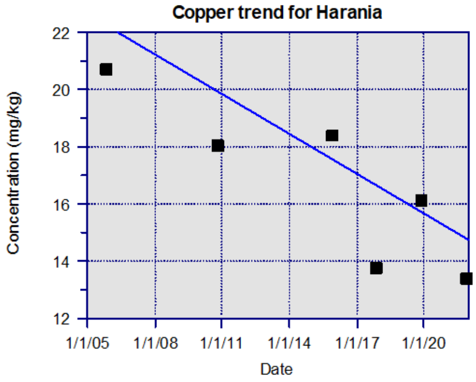


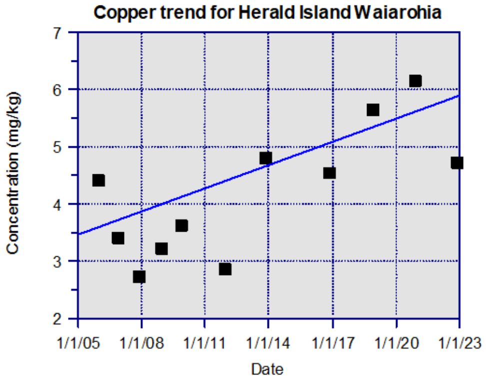


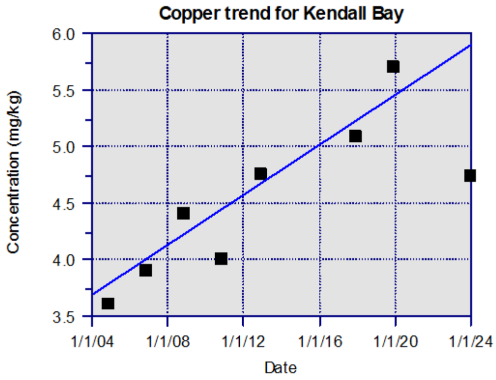
7.3.2 Trends in copper for sites with meaningful trends (>±2% median per year and very likely probability). The data plotted are median values from each sampling. The trend line is the Sen Slope.

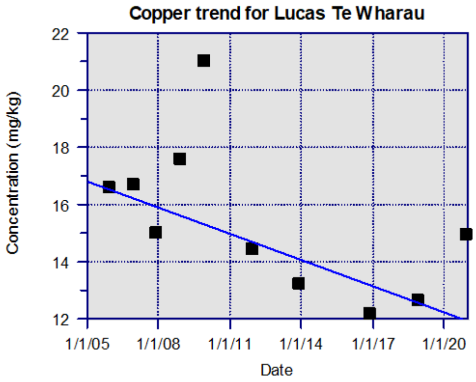


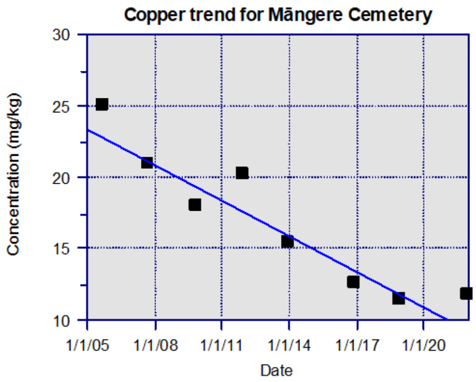


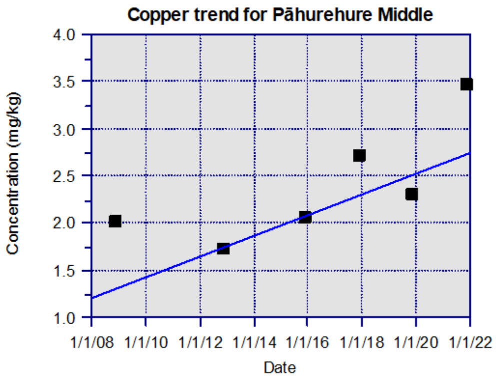




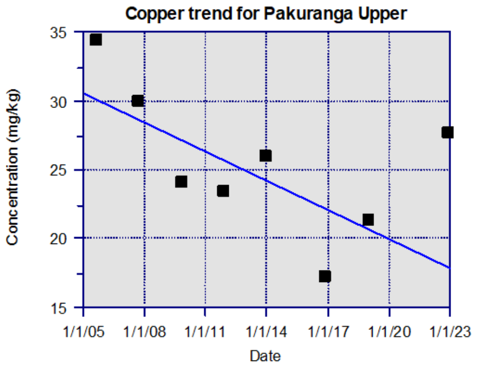


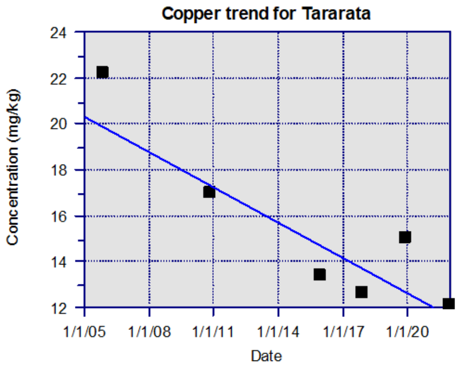


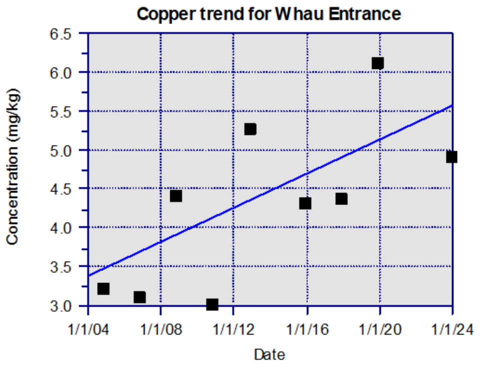




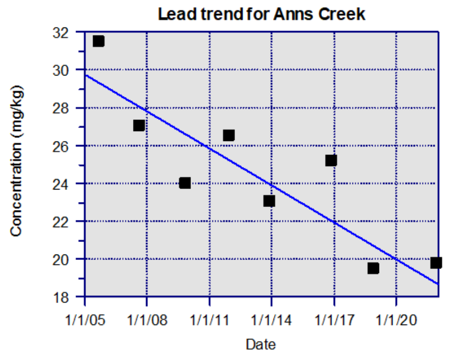
Copper trend plots continued.

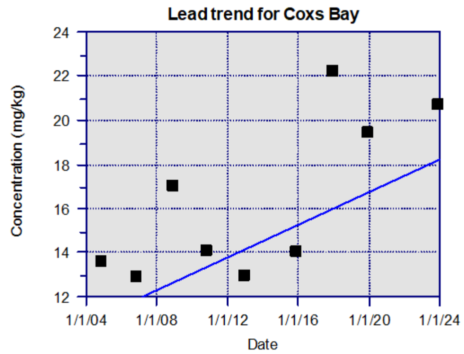


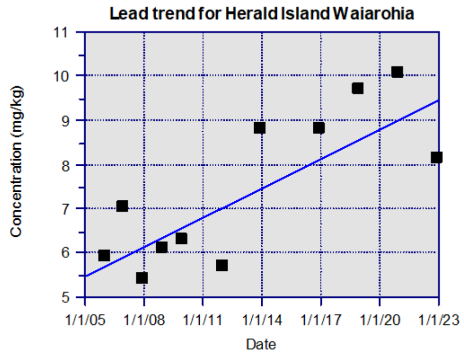


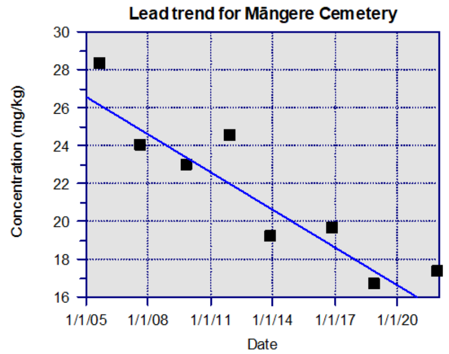


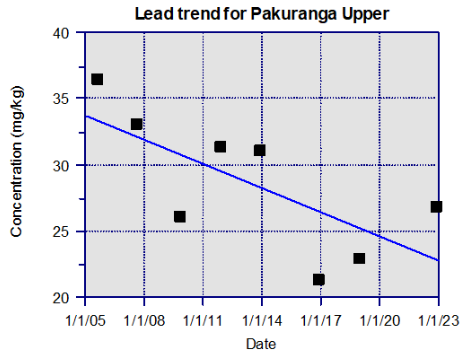
7.3.3 Trends in lead for sites with meaningful trends (>±2% median per year and very likely probability). The data plotted are median values from each sampling. The trend line is the Sen Slope.

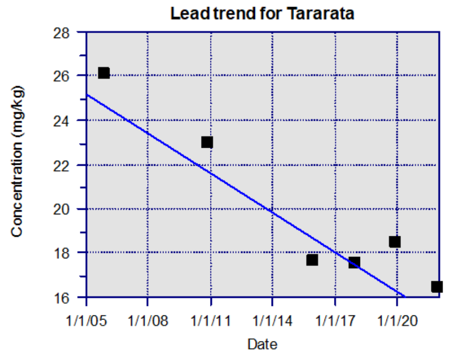


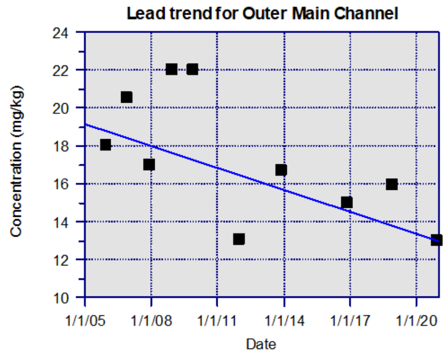




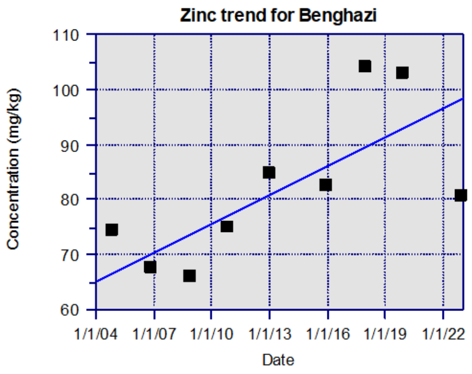


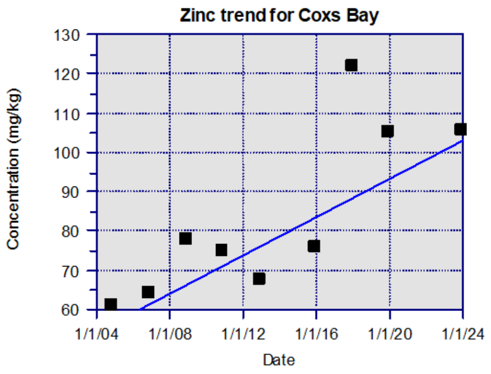


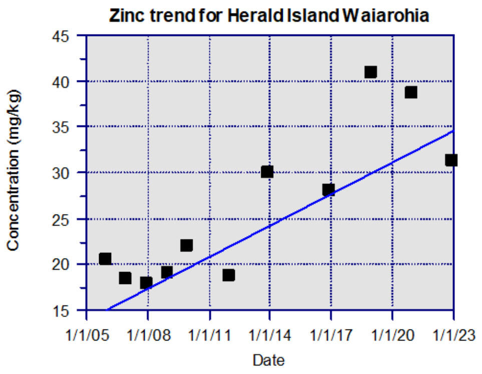


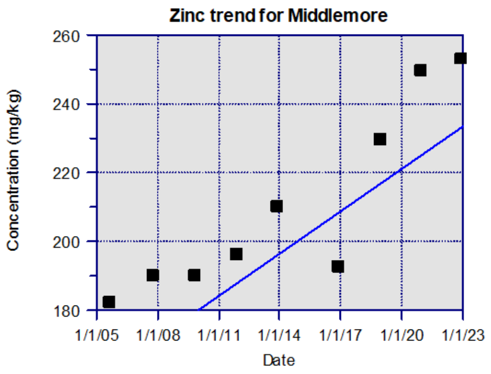


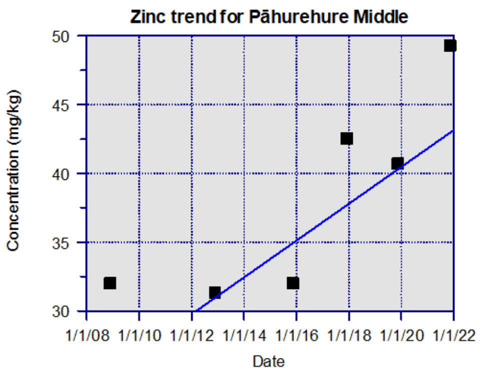
7.3.4 Trends in zinc for sites with meaningful trends (>±2% median per year and very likely probability). The data plotted are median values from each sampling. The trend line is the Sen Slope.

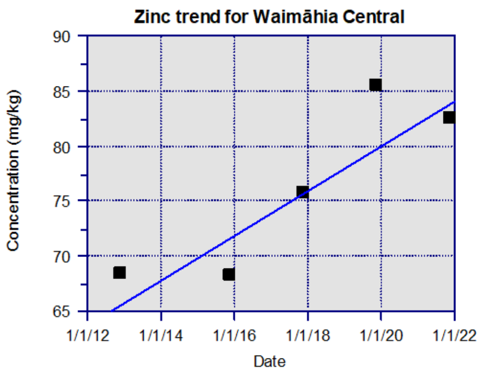


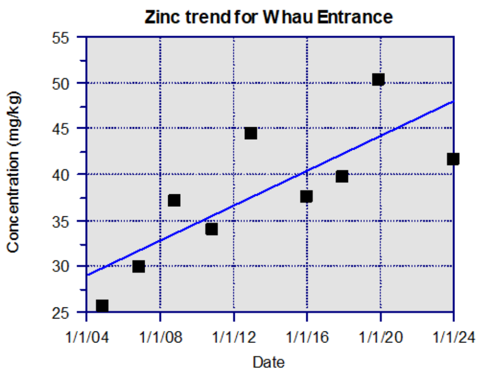












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