

# Surface sediment quality – chemical assessment

Assessment of surface water and sediment quality in the vicinity of power stations and coal ash repositories in Lake Macquarie, NSW



Department of Climate Change, Energy, the Environment and Water

#### Acknowledgement of Country

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We pay our respects to Elders past, present and emerging.

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### **Executive summary**

This report comprises an assessment of metal/metalloid contaminants within surface sediment in the southern section of Lake Macquarie, NSW. The primary aim of this investigation was to determine the current concentrations of metals in surface sediments to assess their distribution and the risk they pose to ecological receptors. The specific objectives were to:

- Determine metal concentrations and distributions within surface sediments adjacent to the power stations and, more broadly, within the southern section of Lake Macquarie.
- Undertake a screening assessment of the measured metal concentrations against Australian sediment quality guideline values (SQGVs) to identify contaminants of potential concern to the health of ecological receptors within surface sediments.
- Compare current metal contaminant concentrations in sediments to previous studies to examine any temporal changes.
- Provide recommendations to inform subsequent stages of this investigation (e.g., the consideration and selection of additional lines of evidence).

Surface sediments (the top 5 cm) were collected from 80 sites within Lake Macquarie (73 locations within the southern section and 7 within the northern section of the lake for reference). All samples were analysed to determine the total recoverable metal concentrations of 24 metals. Comparison of the total recoverable metal concentrations with the screening criteria identified 30 sites (38%) with one or more metals (As, Cd, Cu, Hg, Pb, Se, and Zn) exceeding the screening criteria (ANZG, 2018; Buchman, 2008). Sites, where one or more metals exceeded the screening criteria, were further analysed to determine the dilute acid-extractable metal concentrations (estimated bioavailable fraction) of nine metals. No sites within the southern section of Lake Macquarie exceeded the screening criteria based on their dilute acid-extractable metal concentrations. Two of the sites located within the northern section of the lake exceeded the SQGV for lead (ANZG, 2018) based on dilute acid-extractable metal concentrations.

Therefore, the results of this sediment quality screening assessment indicated that the estimated bioavailable concentration of metal contaminants in the southern section of Lake Macquarie are below screening criteria and, therefore, are likely to be a low risk to ecosystem health. While individual metal contaminant concentrations did not exceed screening criteria, spatial analysis has identified areas of the lake that have more than one metal contaminant elevated relative to other sites within the lake. Of particular interest is the area surrounding Pulbah Island and stretching between Wangi Wangi Point and Myuna Bay, which has elevated copper, lead, and zinc compared to other parts of the lake, while Myuna Bay and Wyee Bay have elevated copper and selenium concentrations.

While not the focus of this study, reference locations highlight that lead remains at a level of concern to ecosystem health within the northern section of Lake Macquarie. Generally, within the northern lake, the accumulation of metals increased along a south-north trajectory consistent with previous investigations and known historic industrial inputs of metals (especially the lead-zinc smelter) (Roach, 2005; Roy and Crawford, 1983).

A subset of the sampling locations (65 sites) was selected to align with sites chosen for a previous investigation of sediment metal concentrations carried out in 2011 by Schneider et al. (2016). While slight differences in sampling locations (± 50 m) and analytical techniques used between the studies prevented a robust statistical analysis, the datasets enabled a broad-level comparison of metal concentrations across the southern lake (rather than site-specific comparisons). Concentrations of arsenic and cadmium, when broadly considered, were lower or remained similar between 2011 and

2022. Concentrations of selenium measured in 2022 were lower in comparison to concentrations measured in 2011. The temporal trends in concentrations of copper, lead, and zinc were more variable across the lake. Generally, copper, lead, and zinc were lower or remained similar in all areas except for the northeast corner of the southern lake and surrounding Pulbah Island where higher concentrations were observed in 2022 compared to those measured in 2011.

The assessment of sediment ecosystem health will be further informed by the consideration of additional lines of evidence that will be evaluated within a weight-of-evidence framework. They will include an:

- Assessment of chronic toxicity to a representative sediment-dwelling organism to determine if sediment contaminants are causing biological effects (DCCEEW, 2024a).
- Assessment of effects on the benthic communities through a benthic invertebrate community survey to determine ecological condition (Dafforn et al., 2024).
- Investigation of present-day metal inputs to the southern lake by determining the concentration of metals within newly deposited sediments (DCCEEW, 2024b).

# Table of contents

Exec	cutive s	ummary	ii		
Tabl	e of coi	ntents	iv		
List	of table	25	V		
List	of figur	es	v		
Glos	sary of	acronyms and common terms	vii		
1.	Introd	uction	1		
	1.1	Project overview	1		
	1.2	Aims and objectives	1		
	1.3	Project location	1		
2.	Metho	ods	4		
	2.1	Site selection	4		
	2.2	Sediment collection	4		
	2.3	Sediment analyses	6		
	2.4	Identifying metal contaminants of potential concern	9		
3.	Result	S	10		
	3.1	Surface sediment screening assessment	10		
	3.2	Temporal changes in sediment metal concentrations	21		
4.	Conclu	ision	27		
5.	Refere	ences	28		
6.	Appen	dices	30		
	Append	30			
	Append	39			
	Append	41			
7.	Acknowledgements 48				

# List of tables

Table 1. Key geographical features of Lake Macquarie	3
Table 2. Summary of the methods used in the current study and Schneider et al. (2016) for determining the metal concentrations in the sediment	8
Table 3. Summary statistics of key physicochemical properties of the sediments collected from Lake Macquarie (n=80)	12
Table 4. Summary statistics for surface sediment total recoverable metal concentrations collected in Lake Macquarie, August 2022	14
Table 5. Summary statistics for surface sediment dilute acid-extractable metal concentrations collected within Lake Macquarie, August 2022.	15
Table 6. Sites with one or more exceedance of the screening criteria	16

# List of figures

Figure 1. Surface	sediment sampling locations (n=80) in Lake Macquarie	5
Figure 2. Total or	ganic carbon (TOC, %) in surface sediment, southern Lake Macquarie	13
Figure 3. The pro	portion of fine-grained particles (<63 μm particles, %) in surface sedimen southern Lake Macquarie	it, 13
Figure 4. Total re	coverable arsenic concentrations (mg/kg) in surface sediment, southern Lake Macquarie	17
Figure 5. Total re	coverable 'low-level' cadmium concentrations (mg/kg) in surface sedime southern Lake Macquarie	nt, 17
Figure 6. Total re	coverable copper concentrations (mg/kg) in surface sediment, southern Lake Macquarie	18
Figure 7. Total re	coverable mercury concentrations (μg/kg; note unit change) in surface sediment, southern Lake Macquarie	18
Figure 8. Total re	coverable lead concentrations (mg/kg) in surface sediment, southern Lak Macquarie	ke 19
Figure 9. Total re	coverable (low-level) selenium concentrations (mg/kg) in surface sedime southern Lake Macquarie	nt, 19
Figure 10. Total r	ecoverable zinc concentrations (mg/kg) in surface sediment, southern La Macquarie	ke 20
Figure 11. Compa	arison of past (2011) and present day (2022) total recoverable iron concentrations (mg/kg) in surface sediment, southern Lake Macquarie	22
Figure 12. Compa	arison of past (2011) and present day (2022) total recoverable manganes concentrations (mg/kg) in surface sediment, southern Lake Macquarie	e 22

5) 23
23
24
24
25
25
26

# Glossary of acronyms and common terms

Acronyms	
ANZG	Australian and New Zealand Governments
AVS	Acid volatile sulfide(s)
CoPC	Contaminants of potential concern
CV-AAS	Cold vapour atomic absorption spectrometry
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DQI	Data quality indicator
DW	Dry weight
EF	Environmental Forensics
EPA	Environment Protection Authority
GF-AAS	Graphite furnace atomic absorption spectrometry
ICP-OES	Inductively coupled plasma optical emission spectrometry
ICP-MS	Inductively coupled plasma mass spectrometry
LOR	Limit of reporting
NATA	National Association of Testing Authorities
NMI	National Measurement Institute
NSW	New South Wales
QA/QC	Quality assurance and quality control
RPD	Relative percentage difference
SAQP	Sampling, Analysis and Quality Plan
SEI	Science Economics and Insights
SQGV	Sediment quality guideline value
ТОС	Total organic carbon

Units	
cm	Centimetre
°C	Degree Celsius
μm	Micrometre
g/kg	Grams/kilogram
µg/kg	Micrograms/kilogram
mg/kg	Milligrams/kilogram
Μ	Molar
рН	Potential Hydrogen

Definitions*	
Aqua regia	A solution comprised of a 3:1 mixture of hydrochloric acid and nitric acid, respectively
Benthic	Referring to processes that occur on or within the sediment at the bottom of a water body
Bioavailable /bioavailable fraction	Able to be taken up by an organism / a relative measure of the proportion of a chemical that an organism is exposed to through water, sediment, soil, suspended particles, organic carbon and/or food
Catchment	The area of land that rain lands in and drains into waterways
Contaminants	Biological or chemical substances or entities, not normally present in a system, capable of producing an adverse effect in a biological system, seriously injuring structure or function
Ecosystem	A community of plants, animals, bacteria and the interrelated chemical and physical environment
Guideline value	Measurable quantity (threshold) or condition of an indicator for a specific community value below or, for some stressors, above which we consider to be a low risk of unacceptable effects occurring
Organism	Any living animal or plant; anything capable of carrying on life processes
Percentile	Interval in a graphical distribution that represents a given percentage of the data points
Sediment	Unconsolidated mineral and organic particulate material that is deposited at the bottom of a water body

\* Definitions adapted from Simpson and Batley (2016)

# 1. Introduction

### 1.1 Project overview

The Science and Insights Division (S&I) of the New South Wales (NSW) Department of Climate Change, Energy, the Environment and Water (DCCEEW) was engaged by the NSW Environment Protection Authority (EPA) to undertake an independent assessment of surface water and sediment quality within the southern section of Lake Macquarie, NSW, Australia. The main purpose of this investigation was to obtain information to facilitate the EPA's contribution to the NSW Government's response to the recommendations in the NSW Parliamentary Inquiry's report into the costs of remediation of coal ash repositories (Parliament of NSW, 2021). The information gathered herein provides a present-day assessment of the contamination status of Lake Macquarie against which future changes, impacts, and/or mitigation and remediation activities can be assessed.

The scope of works outlined in the Sampling, Analysis, and Quality Plan (SAQP) (DPE, 2023) has been developed to: (i) determine present-day concentrations of metals and metalloids (hereafter referred to as "metals" for simplicity) and nutrients to assess surface water quality; (ii) delineate the extent of metal contamination in sediments; and (iii) assess the potential risks to ecological receptors in the vicinity of the power stations, coal ash repositories, and more broadly within the southern section of Lake Macquarie. The project was broken up into a series of stages, as described in the SAQP (DPE, 2023).

The current report provides a screening level risk assessment and an indication of surface sediment quality following a single high-resolution sampling event carried out in Lake Macquarie in August 2022.

### 1.2 Aims and objectives

The primary aim of the surface sediment quality investigation was to measure the current concentration of metals in surface sediments within southern Lake Macquarie and assess the risk they pose to ecological receptors.

The specific objectives to be addressed were to:

- Determine metal concentrations and distributions within surface sediment adjacent to the power stations and, more broadly, within the southern section of Lake Macquarie.
- Conduct a screening assessment of the measured metal concentrations against Australian guideline values to identify contaminants of potential concern (CoPC) to the health of ecological receptors within surface sediments.
- Compare current metal contaminant concentrations in sediments to previous studies to examine any temporal changes.
- Provide recommendations to inform subsequent stages of this investigation (e.g., the consideration and selection of additional lines of evidence).

### 1.3 Project location

Lake Macquarie (Awaba) is the largest coastal saltwater lake in the Southern Hemisphere. It is located in the Lower Hunter Region of NSW, Australia, approximately 90 km north of Sydney. The

lake is described as a temperate, wave-dominated barrier estuary with a small tidal range (maximum tidal range of around 30 cm) and a permanent entrance connecting it to the Pacific Ocean at Swansea Channel. Shallow waters exist between Swansea and Wangi Wangi Point and allow for the lake to be operationally defined into northern and southern sections about this latitudinal axis. Key geographical features of Lake Macquarie are summarised in Table 1.

Former and current heavy industries have largely been situated on the northern, western, and southern shores of the lake. In the northern section of the lake, the most significant industries have included a lead and zinc smelter, a fertiliser plant, a steel foundry, collieries, and wastewater treatment works (Batley, 1987). In the southern section of the lake, the most significant industries have included coal-fired power stations, coal washeries and wastewater treatment works (Batley, 1987). The Vales Point Power Station (established in 1963, currently operated by Delta Electricity), the Eraring Power Station (established in 1981, currently operated by Origin Energy), and the decommissioned Wangi Power Station (operated between 1956 and 1986) are the three coal-fired power stations that have been situated on the southern shores of Lake Macquarie.

A recent review of studies that have investigated metal contamination in Lake Macquarie sediments identified that the metals of potential ecological concern in the northern section of the lake are primarily cadmium, lead, zinc, and to a lesser extent selenium, and copper, and in the southern section of the lake they are primarily selenium and to a lesser extent lead, cadmium, copper, and zinc (DPIE, 2020). Some of the earlier studies identified the power stations as a significant source of the metal contaminants in the southern lake, such as from untreated discharges from the ash repositories (see DPIE, 2020 and references therein). These findings led to the implementation of improved coal ash handling procedures at the Vales Point Power Station ash dam in 1995 and changes to ash dam management at Eraring Power Station in the late 1990s (DPIE, 2020). The last comprehensive investigation of sediment metal concentrations in the southern section of Lake Macquarie was carried out in 2011 by Schneider et al. (2016). The findings of the current study will be compared to Schneider et al. (2016) to update our understanding of the present-day distribution and deposition of metals in the southern section of Lake Macquarie.

#### Table 1. Key geographical features of Lake Macquarie

Characteristics	Value	Reference
Average lake volume	666 GL	DPIE, 2020
Maximum depth	13 m	DPIE, 2020
Average depth	8 m	DPIE, 2020
Length of shoreline perimeter	170 km	DPIE, 2020
Total surface flows from catchment (estimate)	85 GL/y	DPIE, 2020
Estuary surface area	113 km²	Roper et al., 2011
Catchment surface area	604 km <sup>2</sup>	Roper et al., 2011
Annual rainfall (1975-2007)	988 mm	Roper et al., 2011
Annual evaporation (1975-2007)	1516 mm	Roper et al., 2011
Tidal flushing time	249.9 days	Roper et al., 2011

# 2. Methods

### 2.1 Site selection

A total of 80 sites were sampled, with 73 collected within the southern section and seven within the northern section of Lake Macquarie. Site selection was guided by three main factors: (1) to provide broad spatial coverage of the southern lake, (2) the need to examine specific areas of interest (proximity to known or suspected inputs), and (3) to provide consistency with previous studies to allow for comparisons of surface sediment quality through time. Most of the sampling sites (n=65) in southern Lake Macquarie were selected to align with sites chosen for a previous investigation of sediment metal concentrations carried out in 2011 by Schneider et al. (2016). Sampling sites (n=7) in northern Lake Macquarie were similarly guided by the site selection of Roach et al. (2005). The surface sediment sampling locations are provided in Figure 1. Proposed sampling sites were also provided to the Hunter Community Environment Centre for input.

The resolution of the sampling sites within the southern section of the lake was chosen to provide an indication of the relative differences in sediment metal concentrations spatially across the lake rather than provide precise concentration ranges of metals for a particular area. This permitted the production of sediment contaminant contour maps which provide a visual representation of the contaminant concentrations and distributions within the surface sediment. The contaminant contour maps provide an approximation of the concentrations that would be expected in sediments between the sites sampled.

### 2.2 Sediment collection

The sediment samples were collected during the first week of August 2022. All sediments were sampled from a boat, using either a hand-held piston corer where the water depth was generally less than 3 m, or a winch-mounted gravity corer where the water depth was greater than 3 m with a polyvinylchloride tube (approximately 400 mm long x 70 mm wide) attached. The core was gently lifted to the surface and while still in the water the base of the core was plugged with a foam stopper. The top 5 cm of the core was extruded onboard the boat by slowly pushing the core down a wooden plunger and collecting the extruded sediment into a new plastic zip-lock bag with a plastic spoon. Unrepresentative materials (such as litter, twigs, and large stones and shells) were removed by hand-picking. The sediment sample was then homogenised and split into three containers (two zip-lock bags and one glass jar) and stored on ice during sampling. Once on land, one of the zip-lock bag aliquots was transferred to a portable freezer (-20°C), while the other two containers were transferred to a portable fridge (4°C) for transport to the Environmental Forensics Laboratory, Lidcombe, NSW where they were similarly stored until analysis.



Figure 1. Surface sediment sampling locations (n=80) in Lake Macquarie. Blue points indicate sites replicated from the study of Schneider et al. (2016), purple points indicate additional sites added in the southern section of the lake and orange points indicate reference sites added to the northern section of the lake.

A duplicate core sample was collected at a rate of 1 in 20 samples. After sampling, all reusable sampling equipment was thoroughly rinsed with site seawater to remove all sediment. Reusable sampling equipment was then also rinsed at the new site before sample collection.

### 2.3 Sediment analyses

Four samples contained coarse particles (>2mm) and were pressed sieved through an acid-washed nylon mesh (2 mm) before analyses were performed (they were Samples M1, M3, M18, and M19).

Three different chemical extractions were performed in the current study for determining metal concentrations of the sediment as summarised in Table 2. All 80 sediment samples were analysed for total-recoverable metals (Ag, As, B, Ba, Be, Cd, Co, Cr, Cu, Fe, Li, Mn, Mo, Ni, Pb, Sb, Se, Sn, Sr, Ti, Tl, V, Zn, and Hg) by the primary laboratory. All 80 sediment samples were subsequently re-analysed for total-recoverable cadmium and selenium by the secondary laboratory which had a lower limit of reporting (LOR) (results of the secondary laboratory are distinguished intext from those of the primary laboratory by the adjective 'low-level'). A subset of the sediment samples were analysed for dilute acid-extractable metals (1M hydrochloric acid (HCl) for 1 h) by the secondary laboratory. In Section 3.2 the total recoverable metal results from the current study are compared to those of Schneider et al. (2016). A summary of the chemical extraction technique used by Schneider et al. (2016) is also provided in Table 2. All measurements were expressed as milligrams per kilogram and on a dry weight basis (mg/kg DW).

The particle size distribution of the sediment was determined using laser diffraction techniques (Horiba LA 960-particle size distribution analyser). The sediment was added to the circulating high purity water, ultrasonicated, and the suspended particles passed through a quartz cell. Light from the red and blue lasers refracts different-sized particles at different angles and the amount of light refracted at each angle is detected by the instrument and used in a mathematical model to determine the particle size present. Particle size was grouped into the three categories of <2  $\mu$ m diameter (clay fraction), 2 to 63  $\mu$ m diameter (fine silt fraction), and 63  $\mu$ m to 2 mm diameter (sand fraction). It is noted that fine sediments (e.g., the clay and silt fraction operationally defined as <63  $\mu$ m) are typically those that are most heavily contaminated due to their high surface area, and because of their surface chemistry they are more likely to adsorb organic and heavy metal contaminants. This fraction is also considered a suitable representation of the sediment materials that are mostly readily resuspended and/or potentially ingested by organisms. Therefore, a fourth category, described as the proportion of fine-grained sediments (<63  $\mu$ m diameter) was created for data analysis purposes.

The moisture content of the sediment was determined by oven drying a known amount of sediment at  $105 \pm 5$ °C overnight. Moisture content was calculated from the loss of weight after drying and expressed as the percent moisture of the original (wet) weight of the sample.

An approximation of sediment pH was determined by measuring the pH of the sediment (dried at 40°C and finely ground) suspended in 0.5 M calcium chloride (CaCl<sub>2</sub>) solution. The ratio of dry sediment and 0.5 M CaCl<sub>2</sub> was 1:5. A bench-top pH meter (Orion Star A211) with a pH electrode (RossTM Sure-Flow Combination Model 8165BNWP) was used.

Total organic carbon (TOC) was determined on dried and finely ground samples by high-temperature catalytic combustion with a non-dispersive infrared sensor.

All analyses were performed by NATA-accredited laboratories using established standard operating procedures. NATA-accredited analyses for compliance with ISO/IEC 17025 – Testing (i.e., results issued in accordance with NATA's quality assurance and quality control (QA/QC) requirements) included those for total recoverable metals, total recoverable 'low-level' cadmium and selenium, moisture content, pH in solids, total organic carbon, and excluded those for particle size and dilute

acid-extractable metals (1M HCl method). Depending on the procedure, laboratory QA/QC procedures may include reagent or preparation blanks, spike blanks, certified reference materials and matrix spike duplicates and were compared to the laboratory's established criteria. A summary of the QA/QC and data quality assessment is captured in Appendix A – Data quality assessment.

Table 2. Summary of the methods used in the current study and Schneider et al. (2016) for determining the metal concentrations in the sediment

Method	Sample	Reagents	Digestion	Detection	Reporting limits
Total recoverable metals	0.5 g oven- dried sediment <sup>a</sup>	7.5 mL conc. HNO <sub>3</sub> , 1.5 mL conc. H <sub>2</sub> O <sub>2</sub> , 5 mL conc. HCl	Digestion block at 95°C for 2 h in open digestion tube	ICP-OES	Ag = 0.6, As = 3, B = 10, Ba = 1, Be = 1, Cd = 1, Co = 1, Cr = 1, Cu = 3, Fe = 4, Li = 5, Mn = 2, Mo = 1, Ni = 2, Pb = 2, Sb = 1, Se = 4, Sn = 2, Sr = 3, Ti = 1, TI = 1, V = 1, Zn = 3 (all in mg/kg)
Total recoverable Hg	0.5-1 g wet sediment <sup>a</sup>	5 mL aqua regia, 15 mL 5% KMnO₄, 6 mL 12% HONH₃Cl	Digestion block at 95°C for 30 min in open digestion tube	CV-AAS	Hg = 10 μg/kg
Total recoverable 'low-level' Cd and Se*	4-5 g wet sediment <sup>a</sup>	3 mL conc. HNO₃, 3 mL conc. HCl,	90-98°C for 1.5 h in a closed digestion tube	ICP-MS	Cd = 0.1 mg/kg, Se = 0.1 mg/kg
Dilute acid-extractable metals (1M HCl method)	5 g wet sediment <sup>a</sup>	60 mL 1M HCl	Cold extraction for 1 h in a closed digestion tube	ICP-OES or CV- AAS (Hg)	As = 0.1, Cd = 0.1, Cr = 0.01, Cu = 0.01, Pb = 0.01, Hg = 0.01, Ni = 0.1, Zn = 0.1, Se = 0.1 (all in mg/kg)
Total recoverable metals (method of Schneider et al., (2016))	0.2 g freeze- dried sediment <sup>b</sup>	1 mL conc. HNO₃ 2 mL conc. HCl	Microwave oven at 120°C for at least 15 min in closed digestion tube	ICP-MS with As and Se cross- checked with GF-AAS	Not reported

CV-AAS = cold vapour atomic absorption spectrometry; GF-AAS = graphite furnace atomic absorption spectrometry; ICP-MS = inductively coupled plasma mass spectrometry; ICP-OES = inductively coupled plasma optical emission spectrometry.

\* Due to particular interest in the cadmium and selenium concentrations across the southern lake, these the two metals were re-analysed (after finding that some sites were below the reporting limits of the primary laboratory method) by the secondary laboratory using low-level detection techniques

<sup>a</sup> Surface sediment (top 5 cm, particle size <2 mm) collected August 2022

<sup>b</sup> Surface sediment (top 5 cm, particle size <2 mm) collected February 2011

### 2.4 Identifying metal contaminants of potential concern

For the purpose of screening sediment quality, the revised Australian and New Zealand Guidelines for Fresh and Marine Quality provide sediment quality guideline values (SQGVs) (ANZG, 2018) to predict the adverse biological effects caused by contaminated sediments (Appendix B – Screening criteria). The SQGVs are aimed at protecting sediment ecological health and remobilisation of contaminants into the water column and/or food chains. The SQGVs are indicative of concentrations below which adverse effects rarely occur, whilst the SQGV-high represents concentrations above which effects frequently occur in exposed macrofauna.

The application of the SQGVs involves a tiered (or decision tree) assessment framework, in keeping with the risk-based approach introduced with the water quality guidelines. The following approach is outlined in Simpson and Batley (2016) and ANZG (2018). The first-level screening compares the SQGV with the measured value for the total recoverable contaminant concentration in the sediment. These measurements are made on the <2 mm sediment fraction to exclude materials with low capacity for binding contaminants (e.g., coarse sand, gravel, shells, rocks and other large debris). If the SQGV is exceeded (and above the background concentration for the area), then the next level of screening considers the fraction of the contaminant that is likely to be bioavailable or can be transformed and mobilised in a bioavailable form (based on chemical measurements). The dilute acid-extractable metal concentration (1M HCl method) provides a useful measure of the potentially bioavailable metals.

For metals without a SQGV, LORs were used as initial screening criteria to assess the contaminant concentrations in the sediments. If required, this was followed by comparing the measured concentrations across the lake to identify whether there were locations with concentrations that were considered elevated with respect to the surrounding environment. No SQGV was available for selenium for the protection of biota within sediments in Australia. Given selenium is a particular metal of interest for the southern lake, consideration of available international guidelines for selenium was made (Table A8). A conservative approach was taken and the lowest of these values (1 mg Se/kg dry weight) has been selected as the screening criterion (Buchman, 2008).

Descriptive statistics were determined for summarising the data and included the minimum and/or maximum, as well as the 50<sup>th</sup> (median) and or 95<sup>th</sup> percentiles for interpreting the spread of the data. The 50<sup>th</sup> (or 95<sup>th</sup>) percentile in the dataset has a value greater than or equal to 50% (or 95%) of the data. Values below the LOR were substituted as half of the LOR for calculating descriptive statistics.

# 3. Results

### 3.1 Surface sediment screening assessment

All sediment contaminant data and supporting physicochemical data are provided in the Supplementary information. The data quality assessment is captured in Appendix A – Data quality assessment. The physicochemical properties of the sediments collected across the lake are summarised in Table 3. TOC and the proportion of fine-grained sediments ( $<63 \mu$ m) were highly correlated (0.88, n=80), displaying a similar distribution pattern across the lake (Figure 2 and Figure 3). TOC and proportion fine-grained sediments ( $<63 \mu$ m diameter) were generally greatest within the deeper lake sediments and lowest around the near-shore areas of the southern section of the lake.

The total recoverable metal concentrations of the sediments collected across the lake are summarised and compared against their respective screening criteria in Table 4. Four metals (Ag, Cr, Ni, and Sb) were below their respective SQGV suggesting that these metals are unlikely to be having an adverse biological effect on the benthic assemblages at the sites sampled. Seven metals (As, Cd, Cu, Hg, Pb, Se, and Zn) exceeded their respective screening criteria at one or more sites, identifying them as metals that require additional investigation. Overall, total recoverable metal concentrations exceeded one or more screening criteria at 30 sites. The spatial distributions of these seven metals within southern Lake Macquarie are presented in contour maps for arsenic (Figure 4), cadmium (Figure 5), copper (Figure 6), mercury (Figure 7), lead (Figure 8), selenium (Figure 9) and zinc (Figure 10) and are discussed below. SQGVs were not available for the screening of 13 metals (Ba, Be, B, Co, Fe, Li, Mn, Mo, Sn, Sr, Ti, Tl, and V). Contour maps for these 13 metals without SQGVs and the metals with concentrations all below the screening criteria have been provided in Appendix C – Supplementary contour maps for completeness.

The 95<sup>th</sup> percentile of the total recoverable metal concentrations for arsenic, cadmium and selenium fell below their respective screening criteria.

- Inspection of the data showed that total recoverable arsenic exceeded the SQGV (20 mg/kg) at only one site (M65, 24 mg/kg) and no sites exceeded the arsenic SQGV-high of 70 mg/kg. Site M65 is located near Cams Wharf on the southeast side of the lake.
- Total recoverable cadmium exceeded the SQGV (1.5 mg/kg) at three sites (R05, 2 mg/kg; R06, 2 mg/kg; R07, 3 mg/kg) all of which were located in the northern section of the lake. Total recoverable 'low-level' cadmium resulted in slightly lower cadmium concentrations, with no sites exceeding the SQGV. No sites exceeded the cadmium SQGV-high of 10 mg/kg for either extraction method.
- Total recoverable selenium was below the detection limit (<4 mg/kg) for all sites. Total recoverable 'low-level' selenium had three samples equal to the adopted screening criterion (1 mg/kg).

The 95<sup>th</sup> percentile of the total recoverable metal concentrations for copper, mercury, lead, and zinc exceeded their respective SQGVs.

- For copper, 12 sites (15%) exceeded the SQGV of 65 mg/kg (maximum total recoverable copper concentration of 84 mg/kg at M10), but no sites exceeded the SQGV-high of 270 mg/kg. All exceedances were in the southern section of the lake. Two main hotspots were observed, one near Wyee Point and another spanning between Myuna Bay and Wangi Wangi Point.
- For mercury, five sites (6%) exceeded the SQGV of 0.15 mg/kg. No sites exceeded the mercury SQGV-high of 1.0 mg/kg. All exceedances were in the northern section of the lake.
- For lead, 14 sites (18%) exceeded the SQGV of 50 mg/kg and a single site (R07, 270 mg/kg) exceeded the SQGV-high of 220 mg/kg.

- For zinc, two sites (3%) were equal to, and 24 sites (30%) exceeded the SQGV of 200 mg/kg. A single site (R07, 470 mg/kg) exceeded the SQGV-high of 410 mg/kg.
- For lead and zinc, seven and 18 of the exceedances, respectively, were in the southern section of the lake (Figure 8 and Figure 10). Site R07 is in the northern section of Lake Macquarie near Croudace Bay and was the most northerly site sampled. In the northern section of the bay, all seven sampling locations exceeded the lead SQGV, and six exceeded the zinc SQGV. There was a gradient of increasing total recoverable lead and zinc concentrations heading north in the lake.

Analysis of the dilute acid-extractable metal concentrations of the <2 mm fraction was performed for sites with one or more exceedance of the screening criteria, and the results are summarised and compared against their respective screening criteria in Table 5. Only one metal, lead, exceeded the SQGV. The dilute acid-extractable lead concentration showed the estimated bioavailable concentration exceeded the SQGV at two of the sites (R06 and R07), suggesting a potential for adverse biological effects on benthic assemblages at these sites. The dilute acid-extractable concentrations of As, Cd, Cu, Hg, and Zn suggest that the estimated bioavailable fractions for these metals are not at concentrations likely to have adverse biological effects on benthic assemblages.

In summary, no sites within the southern section of Lake Macquarie exceeded SQGVs based on the dilute acid-extractable metal concentrations. A summary of the assessment outcome is provided in Table 6. The dilute acid-extractable metal concentrations measured in the current study did not identify any metal CoPC for the southern section of Lake Macquarie.

Table 3. Summary statistics of key physicochemical properties of the sediments collected from Lake Macquarie (n=80)

Parameter	Minimum	Median	Maximum
Total organic carbon <sup>a</sup> (%)	0.12	2.1	4.4
Particle size <sup>b</sup> (%)			
<2 µm (clay fraction)	0	11	27
2-63 μm (fine silt fraction)	3.9	75	94
63 μm - 2 mm (sand fraction)	0.5	10	96
Particle size (<63 µm, %) <sup>c</sup>	3.9	91	100
Moisture content (%, at 105°C)	20	68	78
pH <sup>d</sup>	7.2	8.1	8.7

<sup>a</sup> Combustion method

<sup>b</sup> Sediments with particles >2 mm were sieved before analyses (n=4)

<sup>c</sup> The <63 μm sediment particle size fraction (clay and silt) is considered a suitable representation of the sediment materials that are most readily resuspended or potentially ingested by organisms

 $^{d}$  pH was determined via the pH in soil methods (0.5M CaCl<sub>2</sub> extract) and due to the limitations of this approach for sediments the values are provided as an indicative value only



Figure 2. Total organic carbon (TOC, %) in surface sediment, southern Lake Macquarie. Red squares indicate sampling locations.



Figure 3. The proportion of fine-grained particles (<63 µm particles, %) in surface sediment, southern Lake Macquarie. Red squares indicate sampling locations.

Table 4. Summary statistics for surface sediment total recoverable metal concentrations collected in Lake Macquarie, August 2022. ANZG (2018) sediment quality guideline values (SQGVs) have been applied as screening criteria unless otherwise indicated. Values that exceed the SQGV or the SQGV-high are indicated by bold font and bold purple font, respectively.

Analyte	Screening criteria		Total recoverable metals (mg/kg, n=80ª)			
	SQGV	SQGV-high	50 <sup>th</sup> percentile	95 <sup>th</sup> percentile	Maximum	
Ag	1.0	4.0	< 0.6	< 0.6	< 0.6	
As	20	70	13	17	24	
Ва	-	-	15	22	110	
Ве	-	-	1	2	2	
В	-	-	49	64	120	
Cd	1.5	10	< 1	1	3	
Cd ('low-level') <sup>b</sup>	1.5	10	0.2	0.5	0.9	
Со	-	-	7	11	12	
Cr	80	370	20	28	30	
Cu	65	270	44	74	84	
Fe	-	-	23,000	31,000	33,000	
Hg	0.15	1.0	0.053	0.18	0.91	
Li	-	-	26	42	44	
Mn	-	-	210	430	520	
Мо	-	-	< 1	3	11	
Ni	21	52	9	14	16	
Pb	50	220	22	72	270	
Sb	2.0	25	< 1	< 1	< 1	
Se		1 <sup>c</sup>	< 4	< 4	< 4	
Se ('low-level') <sup>b</sup>		1 <sup>c</sup>	0.4	0.9	1.0	
Sn	-	-	< 2	< 2	2	
Sr	-	-	76	160	550	
Ti	-	-	33	56	66	
ТІ	-	-	< 2	< 2	< 2	
V	-	-	39	53	55	
Zn	200	410	130	300	470	

Table footnotes appear on the following page

<sup>a</sup> The summary statistics include data collected from both the southern (n=63) and northern (n=7) sections of Lake Macquarie. Values below the limit of reporting (LOR) were substituted as half of the LOR for calculating summary statistics.

<sup>b</sup> Analyses of total recoverable cadmium and selenium were repeated using the secondary laboratory to provide lower quantification limits

<sup>c</sup> Adopted screening criterion (Buchman, 2008)

Table 5. Summary statistics for surface sediment dilute acid-extractable metal concentrations collected within Lake Macquarie, August 2022. ANZG (2018) sediment quality guideline values (SQGVs) have been applied as screening criteria unless otherwise indicated. Values that exceed the SQGV are indicated by **bold** font. No values exceeded the SQGV-high.

Analyte	Screening criteria (mg/kg)		Dilute acid-extractable metals <sup>a</sup> (mg/kg, n=28 <sup>b</sup> )			
	SQGV	SQGV-high	50 <sup>th</sup> percentile	95 <sup>th</sup> percentile	Maximum	
As	20	70	2	5	6	
Cd	1.5	10	0.2	0.6	1.1	
Cr	80	370	2	5	5	
Cu	65	270	14	46	61	
Hg	0.15	1.0	< 0.01	0.02	0.05	
Ni	21	52	2	4	4	
Pb	50	220	16	47	100	
Se	1	Lc	< 0.1	0.2	0.3	
Zn	200	410	76	150	170	

 $^{\rm a}\, 1M$  HCl for 1 h

<sup>b</sup> The summary statistics include data collected from both the southern (n=21) and northern (n=7) sections of Lake Macquarie. Values below the limit of reporting (LOR) were substituted as half of the LOR for calculating summary statistics.

<sup>c</sup> Adopted screening criterion (Buchman, 2008)

No. of metals exceeding screening criteria	Assessment based on total recoverable metal concentrations of the <2 mm fraction	Assessment based on dilute acid-extractable metal concentrations of the <2 mm fraction
1	M65 (As > SQGV) M07, M11, M22, M26 (Cu > SQGV) R04 (Pb > SQGV) M41, M47, M48, M50, M51, M63, M67 (Zn > SQGV)	R06, R07 (Pb > SQGV)
2	M10, M17, M40, M43 (Cu and Zn > SQGV) M53, M60, M64, R02 (Pb and Zn > SQGV)	NA
3	M42, M44, M45, M58 (Cu, Pb, and Zn > SQGV) R01, R03 (Hg, Pb, and Zn > SQGV)	NA
4	R05, R06 (Cd, Hg, Pb, and Zn > SQGV) R07 (Cd and Hg > SQGV; Pb and Zn > SQGV-high)	NA
Additional notes	M01, M21 (Se = screening criterion <sup>a</sup> ) M11 (Zn = SQGV, Se = screening criterion <sup>a</sup> ) M30 (Zn = SQGV)	NA

#### Table 6. Sites with one or more exceedance of the screening criteria

NA = Not applicable; SQGV = Sediment quality guideline value (ANZG, 2018).

<sup>a</sup> Adopted screening criterion (Buchman, 2008)



Figure 4. Total recoverable arsenic concentrations (mg/kg) in surface sediment, southern Lake Macquarie. Sites exceeding the ANZG (2018) sediment quality guideline value (SQGV) are indicated with a solid red square.



Figure 5. Total recoverable 'low-level' cadmium concentrations (mg/kg) in surface sediment, southern Lake Macquarie. No sites in the southern lake exceeded the ANZG (2018) sediment quality guideline value (SQGV).



Figure 6. Total recoverable copper concentrations (mg/kg) in surface sediment, southern Lake Macquarie. Sites exceeding the ANZG (2018) sediment quality guideline value (SQGV) are indicated with a solid red square.



Figure 7. Total recoverable mercury concentrations ( $\mu$ g/kg; note unit change) in surface sediment, southern Lake Macquarie. Sites exceeding the ANZG (2018) sediment quality guideline value (SQGV) are indicated with a solid red square.



Figure 8. Total recoverable lead concentrations (mg/kg) in surface sediment, southern Lake Macquarie. Sites exceeding the ANZG (2018) sediment quality guideline value (SQGV) are indicated with a solid red square.



Figure 9. Total recoverable (low-level) selenium concentrations (mg/kg) in surface sediment, southern Lake Macquarie. Sites equal to the Buchman (2008) sediment quality guideline value (SQGV) are indicated with a solid red circle.



Figure 10. Total recoverable zinc concentrations (mg/kg) in surface sediment, southern Lake Macquarie. Sites equal to (M11 and M30) or exceeding the ANZG (2018) sediment quality guideline value (SQGV) are indicated with a solid red circle or square, respectively.

### 3.2 Temporal changes in sediment metal concentrations

Total recoverable metal concentrations in the surface sediments for the southern section of Lake Macquarie from 2011 (Schneider et al., 2016) and 2022 (the current study) were compared. Target sediment sampling locations between the two studies (n = 65) were the same, and the actual versus the target site were generally within approximately 50 m of each other allowing for broad level comparison of metal concentrations across the southern lake (rather than site specific comparisons). Metal extraction techniques differed slightly between the two studies (a comparison is provided in Table 2). Both extraction methods used strong acids and high temperature digestion conditions and are recognised as not being complete/exhaustive extractions but reflect the portion of acid-soluble metals in non-residual forms (exchangeable, carbonate-bound, reducible form associated with Fe/Mn oxyhydroxides, oxidisable form bound to organic matters and sulfides) (Tessier et al., 1979). Metals associated with the residual form are not expected to be released to the surrounding water over a reasonable time span under natural environmental conditions (Tessier et al., 1979).

Comparisons of important physicochemical properties of the sediment between the two-sampling events were included for total recoverable iron (Figure 11) and manganese (Figure 12), and TOC (Figure 13). Iron, manganese, and organic carbon all play an important role in influencing metal distribution in sediments by their affinity for complexation and adsorption of metals. The measured total recoverable iron and manganese concentrations showed a consistent pattern but were generally lower (or remained similar within the northeast corner of the southern section of the lake) at many sites in 2022 compared to 2011. The TOC content also showed a consistent pattern between the studies but was generally lower in 2022 compared to 2011.

Comparisons of the total recoverable metal concentrations are presented for arsenic (Figure 14), cadmium (Figure 15), copper (Figure 16), lead (Figure 17), selenium (Figure 18), and zinc (Figure 19) and are discussed below (mercury was not measured by Schneider et al. (2016). Concentrations of arsenic and cadmium, when broadly considered, were lower or remained similar between 2011 and 2022. In 2011 the arsenic SQGV was exceeded at ten sites compared to a single site in 2022. In 2011 the cadmium SQGV was exceeded at seven sites compared to no sites in 2022. Concentrations of selenium measured in 2022 were lower in comparison to concentrations measured in 2011. In 2011, the screening criteria for selenium was exceeded at 57 sites compared to three sites being equal to the value in 2022.

The temporal trends in concentrations of copper, lead, and zinc were a lot more variable across the lake. Generally, copper, lead and zinc were lower or remained similar in all areas except for the northeast corner of the southern lake and surrounding Pulbah Island where higher concentrations were observed in 2022 compared to those measured in 2011. In 2011 the lead SQGV was exceed at two sites, this has increased to seven sites in 2022 with two new sites within Wyee Bay and the rest within the northeast corner, surrounding Pulbah Island now with exceedances. In 2011 the copper SQGV was exceed at seven sites, this has increased to 12 sites in 2022 with new sites within the northeast corner, surrounding Pulbah Island now with exceedances. In 2011, the zinc SQGV was exceed at 19 sites and remains similar at 18 sites in 2022, however, the sites with exceedances have shifted with less sites near Eraring and Vales Point Power Stations exceeding and more sites within the northeast corner surrounding Pulbah Island now with exceedances.

Schneider et al. (2016) found that, in 2011, the highest metal concentrations were present in the most proximal sediment deposition zones to the power stations. In 2022, the highest metal concentrations were found to occur within the northeast corner of the southern section of Lake Macquarie. There is a gradient of metal concentration in the southern lake that is highest closest to the area where the southern and northern sections of the lake meet, which may suggest the transport of sediment metals (such as copper, lead, and zinc) from the northern section of the lake to the southern section of the lake has occurred.



Figure 11. Comparison of past (2011) and present day (2022) total recoverable iron concentrations (mg/kg) in surface sediment, southern Lake Macquarie. The 2011 data are from Schneider et al. (2016).



Figure 12. Comparison of past (2011) and present day (2022) total recoverable manganese concentrations (mg/kg) in surface sediment, southern Lake Macquarie. The 2011 data are from Schneider et al. (2016).



Figure 13. Comparison of past (2011) and present day (2022) total organic carbon (TOC) (%) in surface sediment, southern Lake Macquarie. The 2011 data are from Schneider et al. (2016).



Figure 14. Comparison of past (2011) and present day (2022) total recoverable arsenic concentrations (mg/kg) in surface sediment, southern Lake Macquarie. The black horizontal line represents the ANZG (2018) sediment quality guideline value (SQGV). The 2011 data are from Schneider et al. (2016).



Figure 15. Comparison of past (2011) and present day (2022) total recoverable cadmium concentrations (mg/kg) in surface sediment, southern Lake Macquarie. The black horizontal line represents the ANZG (2018) sediment quality guideline value (SQGV). The 2011 data are from Schneider et al. (2016).



Figure 16. Comparison of past (2011) and present day (2022) total recoverable copper concentrations (mg/kg) in surface sediment, southern Lake Macquarie. The black horizontal line represents the ANZG (2018) sediment quality guideline value (SQGV). The 2011 data are from Schneider et al. (2016).



Figure 17. Comparison of past (2011) and present day (2022) total recoverable lead concentrations (mg/kg) in surface sediment, southern Lake Macquarie. The black horizontal line represents the ANZG (2018) sediment quality guideline value (SQGV). The 2011 data are from Schneider et al. (2016).



Figure 18. Comparison of past (2011) and present day (2022) total recoverable selenium concentrations (mg/kg) in surface sediment, southern Lake Macquarie. The black horizontal line represents the Buchman (2008) sediment quality guideline value (SQGV). The 2011 data are from Schneider et al. (2016).



Figure 19. Comparison of past (2011) and present day (2022) total recoverable zinc concentrations (mg/kg) in surface sediment, southern Lake Macquarie. The black horizontal line represents the ANZG (2018) sediment quality guideline value (SQGV). The 2011 data are from Schneider et al. (2016).

### 4. Conclusion

The results of this sediment quality screening assessment indicate that the estimated bioavailable concentration of metal contaminants in the southern section of Lake Macquarie are below sediment quality guideline values and therefore are likely to present a low risk to ecosystem health. While individual metal contaminant concentrations did not exceed screening criteria, spatial analysis has identified areas of the lake that have more than one metal contaminant elevated relative to other sites within the lake. Of particular interest is the area surrounding Pulbah Island and stretching between Wangi Wangi Point and Myuna Bay, which has elevated copper, lead, and zinc concentrations. While Myuna Bay and Wyee Bay have elevated copper and selenium.

While not the focus of this study, reference locations highlight that lead remains at a level of concern to ecosystem health within the northern section of Lake Macquarie. Generally, within the northern lake the accumulation of metals increased along a south-north trajectory consistent with previous investigations and known historic industrial inputs of metals (especially the lead-zinc smelter) (Roach, 2005; Roy and Crawford, 1983).

Comparison of the total recoverable metal concentrations measured in the current study against those determined in 2011 by Schneider et al. (2016) identified several changes in metal concentrations with time. Concentrations of arsenic and cadmium when broadly considered were lower or remained similar between 2011 and 2022. Concentrations of selenium measured in 2022 were lower compared to concentrations measured in 2011, with all sites now at or below the screening criterion. This is most likely due to in situ methylation of selenium and losses to the overlying water and atmosphere as dimethyl selenide as found by Ellwood et al. (2016).

The difference in concentrations of copper, lead, and zinc were more variable across the lake between 2011 and 2022. Copper, lead, and zinc were lower or remained similar in all areas except for the northeast corner of the southern lake and surrounding Pulbah Island where higher concentrations were observed in 2022 compared to those measured in 2011.

The assessment of sediment ecosystem health will be further informed by the consideration of additional lines of evidence. The additional lines of evidence that will be collected as part of this investigation include an:

- 1. Assessment of chronic toxicity to a representative sediment-dwelling organism to determine if sediment contaminants are causing biological effects (DCCEEW, 2024a).
- 2. Assessment of effects on the benthic community through a benthic invertebrate community survey to determine ecological condition (Dafforn et al., 2024).
- 3. Investigation of present-day metal inputs to the southern lake by determining the concentration of metals within newly deposited sediments (DCCEEW, 2024b).

A final synthesis report will be prepared, which will consider all lines of evidence investigated as part of the assessment of surface water and sediment quality within the southern section of Lake Macquarie.

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# 6. Appendices

### Appendix A – Data quality assessment

#### Quality assurance and quality control measures

QA procedures were established for this project to maximise sample integrity and included the use of:

- standard procedures for sediment sampling and analyses.
- appropriate equipment cleaning procedures between each sampling location.
- a new pair of disposable nitrile gloves for each sampling location.
- laboratory supplied sampling containers and storage procedures appropriate for each analysis type.

QC procedures were established to check the success of QA and are used to classify the validity of the laboratory data.

Laboratory QC included the use laboratory reagent or preparation blanks, spike blanks, certified reference materials (CRMs), laboratory duplicates, and matrix spike duplicates which had to comply with the laboratory's established criteria of acceptance for reporting. The CRMs used by the primary laboratory were CRM036-50G (Sigma Aldrich) for total recoverable metal analysis, ERM - CC141 (Choice Analytical) for total recoverable mercury analysis, and DUKE STANDARDS Microsphere Size standards (Thermo) for particle size determination.

Field QC included the collection of:

- one field duplicate sample (intra-laboratory analysis) for every twenty primary samples for the analysis of pH, particle size distribution, moisture content, TOC, total recoverable metals, dilute acid-extractable metals.
- one field duplicate sample (inter-laboratory analysis) for every twenty primary samples for the analysis of total recoverable metals.

The field duplicate samples were labelled to conceal their relationships to the primary sample. The field duplicate was used to identify variation in analyte concentrations between samples collected from the same sampling point. The data quality indicator (DQI) was for the primary and duplicated samples to be within the specified relative percentage difference (RPD) for the method. RPD is calculated as follows:

RPD (%) =  $\frac{\text{(difference between sample duplicates)}}{\text{(average of sample duplicates)}} \times 100$ 

The National Assessment Guidelines for Dredging (NADG, 2009) recommends that for field duplicates (i.e., two separate samples taken at the same location) should agree within an RPD of ±50% (unless the sediment are very heterogenous or greatly differing in grain size). If the RPD for a measured analyte falls outside of these limits, the value of the measured analyte shall be flagged as an estimate rather than a precise value (NAGD 2009). Low levels of contaminants (<10 times the LOR) can exaggerate the RPD and this will be taken into consideration.

#### Data quality

#### Assessment of laboratory QA/QC

The primary laboratory's QC analytical results are presented in Table A1 and summarised below:

- For total recoverable metal analysis, ten laboratory duplicates (split samples) were analysed and returned acceptable RPD for reporting of <9.52%. Ten spike recoveries were performed and returned acceptable recoveries of 76.41 to 106.29%. The certified reference material had acceptable recoveries for all metals investigated of between 78.22 and 109.38%.
- For total recoverable mercury analysis, six laboratory duplicates (split samples) were analysed and returned acceptable RPD for reporting of <4.65%. Six spike recoveries were performed and returned acceptable recoveries of 93.55 to 99.65%. The certified reference material had acceptable recovery of 100.41%.
- For moisture content analysis, six laboratory duplicates (split samples) were analysed and returned acceptable RPD for reporting of <3.77%.
- For pH in solids analysis, nine laboratory duplicates (split samples) were analysed and returned acceptable RPD for reporting of <0.62%.
- For particle size analysis, the certified reference material results were within the specified range.

The secondary laboratory's QC analytical results are presented in Table A2 and Table A3 and summarised below:

- For total recoverable 'low-level' cadmium and selenium analysis, two laboratory duplicates (split samples) were analysed and returned acceptable RPD for reporting of <12%. Two spike recoveries were performed and returned acceptable recoveries of 98 to 113%.
- For total organic carbon analysis, nine laboratory duplicates (split samples) were analysed and returned acceptable RPD for reporting of <15%. Five spike recoveries were performed and returned acceptable recoveries of 86 to 106%.

The quality control data are satisfactory for both the primary and secondary laboratory; therefore, the analytical data is acceptably reliable for the purpose of the investigation.

Table A1. Summary of the primary laboratory's quality control results (laboratory duplicates, spike recoveries, and/or certified reference materials) for total recoverable metals, moisture content, pH in solids, and particle size. RPD is the relative percentage difference.

Project: 20220239						
QUALITY CONTROL:	-					
-	-					
	es - RPD (n = 10)	Spike r	ecoveries	(n = 10)	Certified reference	
Total recoverable metals	Max	Average	Max	Min	Average	% Recovery
Silver	5.41%	2.98%	103.94%	89.48%	99.26%	103.37%
Arsenic	5.13%	1.93%	106.29%	91.98%	101.38%	101.53%
Boron	5.41%	1.89%	96.64%	81.77%	90.96%	95.72%
Barium	5.13%	1.09%	105.20%	76.41%	98.54%	95.10%
Beryllium	5.41%	0.54%	101.04%	88.87%	98.13%	103.23%
Calcium	NA	NA	NA	NA	NA	99.09%
Cadmium	5.13%	1.00%	106.09%	92.65%	101.58%	101.14%
Cobalt	4.88%	0.49%	102.06%	89.63%	98.29%	98.77%
Chromium	4.44%	0.89%	104.33%	87.92%	98.32%	94.75%
Copper	5.13%	2.24%	101.68%	87.38%	97.16%	99.64%
Iron	6.45%	1.74%	NA	NA	NA	96.92%
Lithium	6.06%	1.93%	NT	NT	NT	98.67%
Magnesium	6.90%	2.29%	NA	NA	NA	101.91%
Manganese	3.92%	1.12%	101.57%	84.90%	96.28%	78.22%
Molybdenum	5.71%	2.14%	99.75%	86.12%	95.79%	103.15%
Nickel	5.13%	1.91%	101.80%	90.31%	98.72%	97.71%
Phosphorus	5.41%	2.16%	NT	NT	NT	84.41%
Lead	5.13%	1.78%	103.31%	91.69%	99.80%	101.34%
Sulphur	5.88%	1.37%	NT	NT	NT	109.38%
Antimony	9.52%	3.81%	NA	NA	NA	98.18%
Selenium	5.41%	2.03%	104.08%	89.54%	99.17%	102.86%
Strontium	NT	NT	NT	NT	NT	96.17%
Titanium	NA	NA	NA	NA	NA	98.65%
Thallium	5.41%	2.62%	100.07%	88.67%	96.12%	101.56%
Vanadium	5.13%	2.22%	100.67%	87.47%	96.38%	95.39%
Zinc	4.26%	1.23%	103.31%	88.03%	97.90%	101.35%
	Dunlingt	PDD(n - C)	Cuilton		(n - C)	Contified reference
		2 020			$(\Pi = 0)$	
Total recoverable mercury	4.65%	2.02%	99.65%	93.55%	96.61%	100.41%
	Duplicat	es - RPD (n = 6)				
Moisture	3.77%	1.36%				
	Duplicat	$e_{0} = PPD (n - 0)$				
nH	0 620/	∩ 210/				
ри 1	0.02%	0.51%				
	Cortifi	ied reference				
Particle size	Mean					
101 um STD	100.2	101 + 1 7				
1.0 µm STD	1 0/19	$1036 \pm 0.024$				
1.0 µ.11 01 D	1.040	1.000 0.024				

Table A2. Summary of the secondary laboratory's quality control results (laboratory duplicates and spike recoveries) for total recoverable 'low-level' cadmium and selenium analyses. RPD is the relative percentage difference.

Client Reference: 20220239										
QUALITY	CONTROL: Acid E	Extractabl	e metals in soil			Du	plicate		Spike Re	covery %
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-1	310232-2
Date prepared	•			16/11/2022	1	16/11/2022	16/11/2022		16/11/2022	16/11/2022
Date analysed				16/11/2022	1	16/11/2022	16/11/2022		16/11/2022	16/11/2022
Cadmium - low level	mg/kg	0.1	Metals-022	<0.1	1	0.9	0.8	12	105	98
Selenium - Iow level	mg/kg	0.1	Metals-022	<0.1	1	1	0.9	11	113	108
Silver	mg/kg	1	Metals-020	<1	81	<1	<1	0	[NT]	[NT]
Aluminium	mg/kg	10	Metals-020	<10	81	4700	4500	4	[NT]	[NT]
Arsenic	mg/kg	4	Metals-020	<4	81	<4	<4	0	[NT]	[NT]
Cobalt	mg/kg	1	Metals-020	<1	81	2	2	0	[NT]	[NT]
Chromlum	mg/kg	1	Metals-020	<1	81	6	6	0	[NT]	[NT]
Copper	mg/kg	1	Metals-020	<1	81	26	24	8	[NT]	[NT]
Iron	mg/kg	10	Metals-020	<10	81	8600	7600	12	[NT]	[NT]
Mercury	mg/kg	0.1	Metals-021	<0.1	81	<0.1	<0.1	0	[NT]	[NT]
Manganese	mg/kg	1	Metals-020	<1	81	100	100	0	[NT]	[NT]
Nickel	mg/kg	1	Metals-020	<1	81	3	2	40	[NT]	[NT]
Lead	mg/kg	1	Metals-020	<1	81	7	6	15	[NT]	[NT]
Antimony	mg/kg	7	Metals-020	<7	81	<7	<7	0	[NT]	[NT]
Vanadium	mg/kg	1	Metals-020	<1	81	11	10	10	[NT]	[NT]
Zinc	mg/kg	1	Metals-020	<1	81	44	41	7	[NT]	[NT]
QUALITY	CONTROL: Acid E	Extractabl	e metals in soil		_	Du	plicate		Spike Re	coverv %
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-2	310232-22
Date prepared	•			[NT]	12	16/11/2022	16/11/2022		16/11/2022	16/11/2022
Date analysed				[NT]	12	16/11/2022	16/11/2022		16/11/2022	16/11/2022
Cadmium - low level	mg/kg	0.1	Metals-022	[NT]	12	0.4	0.4	0	105	98
Selenium - low level	mg/kg	0.1	Metals-022	[NT]	12	0.9	1	11	109	99

Table A3. Summary of the secondary laboratory's quality control results (laboratory duplicates and spike recoveries) for total organic carbon analyses. RPD is the relative percentage difference.

MUTY CONT

Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-1	[NT]
Date prepared				18/08/2022	1	18/08/2022	18/08/2022		18/08/2022	
Date analysed	-			18/08/2022	1	18/08/2022	18/08/2022		18/08/2022	
Total Organic Carbon (Combustion)	mg/kg	100	Inorg-128	<100	1	25000	25000	0	86	
QUALITY	Y CONTROL	: Misc Inc	org - Soil			Du	plicate		Spike Re	covery %
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-2	[NT]
Date prepared				[NT]	11	18/08/2022	18/08/2022		18/08/2022	
Date analysed				[NT]	11	18/08/2022	18/08/2022		18/08/2022	
Total Organic Carbon (Combustion)	mg/kg	100	Inorg-128	[NT]	11	24000	24000	0	101	
		· Mine Inc	vra - Soil	1		Du	plicato		Soika Pa	cover/ %
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-3	[NT]
Date prepared				[NT]	21	18/08/2022	18/08/2022		18/08/2022	[NT]
Date analysed				[NT]	21	18/08/2022	18/08/2022		18/08/2022	
Total Organic Carbon (Combustion)	mg/kg	100	Inorg-128	[NT]	21	28000	27000	4	89	
QUALITY	Y CONTROL	: Misc Inc	org - Soil			Du	plicate		Spike Re	covery %
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-4	[NT]
Date prepared				[NT]	31	18/08/2022	18/08/2022		18/08/2022	
Date analysed				[NT]	31	18/08/2022	18/08/2022		18/08/2022	
Total Organic Carbon (Combustion)	mg/kg	100	Inorg-128	[NT]	31	18000	16000	12	101	
	CONTROL	Missing	ra Sail	1		Du	plicato		Spike De	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-5	[NT]
Date prepared				[NT]	41	18/08/2022	18/08/2022		18/08/2022	[NT]
Date analysed				[NT]	41	18/08/2022	18/08/2022		18/08/2022	
Total Organic Carbon (Combustion)	mg/kg	100	Inorg-128	[NT]	41	20000	20000	0	106	
QUALITY	Y CONTROL	: Misc Ino	org - Soil			Du	plicate		Spike Re	covery %
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	[NT]	[NT]
Date prepared	-			[NT]	51	18/08/2022	18/08/2022			
Date analysed				[NT]	51	18/08/2022	18/08/2022		[642]	
Total Organic Carbon (Combustion)	mg/kg	100	Inorg-128	[NT]	64					
0100117										
		· Mico Inc	vra Soil		51	7300	6900	0	Soika Do	coupry %
Test Description	CONTROL Units	: Misc Inc PQL	rg - Soil Method	Blank	#	7300 Du Base	6900 plicate Dup.	RPD	Spike Re	covery %
Test Description Date prepared	CONTROL Units	Misc Inc PQL	org - Soil Method	Blank	# 61	7300 Du Base 18/08/2022	6900 plicate Dup. 18/08/2022	RPD	Spike Re [NT]	covery % [NT]
Test Description Date prepared Date analysed	CONTROL Units	PQL	org - Soil Method	Blank (NT) (NT)	# 61 61	7300 Du Base 18/08/2022 18/08/2022	6900 plicate Dup. 18/08/2022 18/08/2022	RPD	Spike Re [NT] [NT]	covery % [NT] [NT]
Test Description Date prepared Date analysed Total Organic Carbon (Combustion)	CONTROL Units - - mg/kg	PQL	rg - Soil Method Inorg-128	Blank           [NT]           [NT]           [NT]	# 61 61	7300 Du Base 18/08/2022 18/08/2022 24000	6900 plicate Dup. 18/08/2022 18/08/2022 25000	6 RPD	(NT) (NT) (NT) (NT)	(NT) (NT) (NT) (NT)
Test Description Date prepared Date analysed Total Organic Carbon (Combustion)	CONTROL Units - - mg/kg	PQL	rg - Soil Method Inorg-128	Blank           [NT]           [NT]           [NT]	# 61 61 61	7300 Du Base 18/08/2022 18/08/2022 24000	6900 plicate Dup. 18/08/2022 18/08/2022 25000	RPD	Spike Re [NT] [NT] [NT] [NT]	Covery % [NT] [NT] [NT]
Test Description Date prepared Date analysed Total Organic Carbon (Combustion)	Y CONTROL Units mg/kg	Misc Inc PQL 100	rg - Soil Method Inorg-128	Blank [T] [NT] [NT]	# 61 61	7300 Du Base 18/08/2022 18/08/2022 24000	6900 plicate Dup. 18/08/2022 18/08/2022 25000	6 RPD	Spike Re [NT] [NT] [NT] Spike Re	COVERY % [NT] [NT] [NT] [NT]
Test Description Date prepared Date analysed Total Organic Carbon (Combustion) QUALITY Test Description	Y CONTROL Units - mg/kg Y CONTROL Units	Misc Ind PQL 100	rg - Soil Method Inorg-128 org - Soil Method	Blank [NT] [NT] [NT] Blank	# 61 61 61	7300 Du Base 18/08/2022 18/08/2022 24000 Du Base	6900 plicate Dup. 18/08/2022 18/08/2022 25000 plicate Dup.	RPD 4	Spike Re [NT] [NT] [NT] [NT] Spike Re [NT]	covery % [NT] [NT] [NT] [NT] covery % [NT]
Test Description Date prepared Date analysed Total Organic Carbon (Combustion) QUALITY Test Description Date prepared	CONTROL Units - mg/kg CONTROL Units	Misc Inc PQL 100	rg - Soil Method Inorg-128 org - Soil Method	Blank [NT] [NT] [NT] Blank [NT]	# 61 61 61 #	7300 Du Base 18/08/2022 24000 Du Base 18/08/2022	6900 plicate Dup. 18/08/2022 25000 plicate Dup. 18/08/2022	RPD 4	Spike Re [NT] [NT] [NT] [NT] Spike Re [NT] [NT]	Covery % [NT] [NT] [NT] [NT] Covery % [NT] [NT]
Test Description Date prepared Date analysed Total Organic Carbon (Combustion)	CONTROL Units - mg/kg Y CONTROL Units -	: Misc Ind PQL 100 : Misc Ind PQL	rg - Soil Method Inorg-128 org - Soil Method	Blank (NT) (NT) (NT) Blank (NT) (NT)	# 61 61 61 61 71	7300 Du Base 18/08/2022 24000 Du Base 18/08/2022 18/08/2022	6900 plicate Dup. 18/08/2022 25000 plicate Dup. 18/08/2022 18/08/2022 18/08/2022	4 RPD	Spike Re [NT] [NT] [NT] [NT] Spike Re [NT] [NT]	covery % [NT] [NT] [NT] [NT] covery % [NT] [NT]
Test Description Date prepared Date analysed Total Organic Carbon (Combustion)	CONTROL Units  - mg/kg  CONTROL Units  - mg/kg	Misc Inc PQL 100 : Misc Inc PQL 100	rg - Soil Method Inorg-128 Org - Soil Method Inorg-128	Blank [NT] [NT] Blank [NT] [NT] [NT] [NT] [NT] [NT] [NT] [NT]	# 61 61 61 71 71 71	7300 Du Base 18/08/2022 18/08/2022 24000 Du Base 18/08/2022 18/08/2022 18/08/2022 18/08/2022	6900 plicate Dup. 18/08/2022 18/08/2022 25000 plicate Dup. 18/08/2022 18/08/2022 18/08/2022 18/08/2022 14/00	a RPD 4 RPD	Spike Re [NT] [NT] [NT] [NT] Spike Re [NT] [NT] [NT] [NT]	Covery % [NT] [NT] [NT] [NT] Covery % [NT] [NT] [NT] [NT] [NT] [NT] [NT] [NT]
Test Description Date prepared Date analysed Total Organic Carbon (Combustion)	Y CONTROL Units - mg/kg Y CONTROL Units - - mg/kg	Misc Inc PQL 100	rg - Soil Method Inorg-128 org - Soil Method Inorg-128	ВІалк [ГТ] [NT] [NT] ВІалк [NT] [NT] [NT]	# 61 61 61 71 71 71	7300	6900 plicate Dup. 18/08/2022 18/08/2022 25000 plicate Dup. 18/08/2022 18/08/2022 18/08/2022 18/08/2022 18/08/2022	8 RPD 4 RPD	Spike Re [NT] [NT] [NT] [NT] Spike Re [NT] [NT] [NT] [NT]	Covery % [NT] [NT] [NT] [NT] [NT] [NT] [NT] [NT]
Test Description Date prepared Date analysed Total Organic Carbon (Combustion)  QUALIT Test Description Date analysed Total Organic Carbon (Combustion)  QUALIT	Y CONTROL Units - mg/kg Y CONTROL Units - mg/kg Y CONTROL	Misc Inc PQL 100 Misc Inc PQL 100	rg - Soil Method Inorg-128 org - Soil Method Inorg-128	Вlank [NT] [NT] [NT] Вlank [NT] [NT] [NT]	# 61 61 61 71 71 71	7300 Du Base 18/08/2022 24000 Du Base 18/08/2022 18/08/2022 18/08/2022 1200	6900 plicate Dup. 18/08/2022 18/08/2022 25000 plicate Dup. 18/08/2022 18/08/2022 18/08/2022 14/00 plicate	RPD 4 RPD 15	Spike Re [NT] [NT] [NT] [NT] Spike Re [NT] [NT] [NT] Spike Re	covery % [NT] [NT] [NT] [NT] [NT] [NT] [NT] [NT]
Test Description Date prepared Date analysed Total Organic Carbon (Combustion)	CONTROL     Units     -     mg/kg     VCONTROL     Units     -     mg/kg     YCONTROL     Units     -     mg/kg     VCONTROL     Units	Misc Inc PQL 100 Misc Inc PQL 100	rg - Soil Method Inorg-128 org - Soil Method Inorg-128 org - Soil Method	Blank [NT] [NT] Blank [NT] [NT] [NT] Blank	# 61 61 61 71 71 71 71	7300  Du Base  18/08/2022 24000  Du Base  18/08/2022 24000  Du Base  18/08/2022 18/08/2022 18/08/2022 18/08/2022 18/08/2022 18/08/2022 1200  Du Base	6900 plicate Dup. 18/08/2022 25000 plicate Dup. 18/08/2022 18/08/2022 18/08/2022 18/08/2022 18/08/2022 18/08/2022 18/08/2022	RPD 4 RPD 15 RPD	Spike Re [NT] [NT] [NT] [NT] Spike Re [NT] [NT] Spike Re [NT]	Covery % [NT] [NT] [NT] [NT] [NT] [NT] [NT] [NT]
Test Description Date prepared Date analysed Total Organic Carbon (Combustion)	CONTROL     Units     -     mg/kg     CONTROL     Units     -     mg/kg     CONTROL     Units     CONTROL     Units     CONTROL     Units     CONTROL     Units     CONTROL     Units     CONTROL     CONTROL	: Misc Inc PQL 100 : Misc Inc PQL 100 : Misc Inc PQL	rg - Soil Method Inorg-128 Org - Soil Method Inorg-128	Blank [NT] [NT] [NT] Blank [NT] [NT] [NT] [NT] [NT] [NT] [NT] [NT]	# 61 61 61 71 71 71 71 81	7300 Du Base 18/08/2022 24000 Du Base 18/08/2022 18/08/2022 1200 Du Base 18/08/2022	6900 plicate Dup. 18/08/2022 25000 plicate Dup. 18/08/2022 18/08/2022 14/00 plicate Dup. 18/08/2022 14/00 plicate Dup. 18/08/2022	RPD 4 RPD 15	Spike Re [NT] [NT] [NT] [NT] [NT] [NT] [NT] [NT]	Covery % [NT] [NT] [NT] [NT] [NT] [NT] [NT] [NT]
Test Description Date prepared Date analysed Total Organic Carbon (Combustion)	Y CONTROL Units - mg/kg Y CONTROL Units - mg/kg Y CONTROL Units -	Misc Ind PQL 100 : Misc Ind PQL 100 : Misc Ind PQL	rg - Soil Method Inorg-128 org - Soil Method Inorg-128	Blank [NT] [NT] Blank [NT] [NT] [NT] [NT] [NT] [NT] [NT] [NT]	# 61 61 61 71 71 71 71 81 81	7300	6900 plicate Dup. 18/08/2022 18/08/2022 25000 plicate Dup. 18/08/2022 18/08/2022 18/08/2022 18/08/2022 18/08/2022 18/08/2022	6 RPD 4 RPD 15 RPD	Spike Re [NT] [NT] [NT] [NT] [NT] [NT] [NT] [NT]	Covery % [NT] [NT] [NT] [NT] [NT] [NT] [NT] [NT]
Test Description Date prepared Date analysed Total Organic Carbon (Combustion)	CONTROL Units  CONTROL Units CONTROL Units CONTROL Units CONTROL Units CONTROL Units CONTROL UNITS CONTROL	Misc Inc PQL 100 Misc Inc PQL 100 Misc Inc PQL 100	rg - Soil Method Inorg-128 org - Soil Method Inorg-128 org - Soil Method	Blank [ [ [ [ [ [ [ [ [ [ [ [ [ [ [ [ [ [ [	# 61 61 61 71 71 71 71 81 81 81	7300	6900 plicate Dup. 18/08/2022 18/08/2022 25000 plicate Dup. 18/08/2022 18/08/2022 18/08/2022 18/08/2022 18/08/2022 18/08/2022 18/08/2022 18/08/2022	<ul> <li>RPD</li> <li>4</li> <li>RPD</li> <li>15</li> <li>RPD</li> <li>6</li> </ul>	Spike Re           [NT]           [NT]           [NT]           [NT]           [NT]           Spike Re           [NT]           [NT]	Covery % [NT] [NT] [NT] [NT] [NT] [NT] [NT] [NT]

#### Assessment of field QA/QC

Surface sediment was collected from 80 sites for the screening risk assessment. Therefore, at four sites duplicate samples were collected (these were sites A03, M43, M70 and R02 and correspond to samples DUP01, DUP02, DUP03 and DUP04, respectively). Field sampling QC analytical results are provided in the Supplementary information and are summarised below:

- The four intra-laboratory field duplicates were analysed for pH by the primary laboratory and met the DQI (Table A4).
- The four intra-laboratory field duplicates were analysed for particle size by the primary laboratory. The DQI was met for the <2  $\mu$ m (clay fraction) and the 2-63  $\mu$ m (fine silt fraction) but exceeded for the 63  $\mu$ m 2 mm (sand fraction) (Table A4). The variability arising between the primary sample and the duplicated sample may be attributed to sample heterogeneity.
- The four intra-laboratory field duplicates were analysed for moisture content by the secondary laboratory and met the DQI (Table A4).
- The four intra-laboratory field duplicates were analysed for TOC by the secondary laboratory and the DQI was exceeded (Table A4.) The variability arising between the primary sample and the duplicated sample may be attributed to sample heterogeneity.
- The four intra-laboratory field duplicates were analysed for total recoverable metals by the primary laboratory and 'low-level' Cd and Se by the secondary laboratory. The only exceedance that occurred between the primary and duplicated samples involved low concentrations that are only marginally greater than their respective LOR (within 1-2 times the LOR) and are thus deemed acceptable in RPD data quality assessments (Table A5).
- Two intra-laboratory field duplicates were analysed for dilute acid-extractable (1M HCl for 1 h) metals by the secondary laboratory. The RPDs for the primary and the duplicated samples were generally within 50%, except for four instances. Differences observed were between 1 to 2.25 times and indicate that minor differences in the estimated bioavailability may be attributed to sample heterogeneity (Table A6).
- The four inter-laboratory duplicates were analysed by both the primary laboratory and the secondary laboratory for total recoverable metals. Due to slightly different extraction techniques of the two laboratories, differences in the measured total recoverable metal results were observed (Supplementary information). The primary laboratory results were consistently greater than that of the secondary laboratory which is likely attributed to the different extraction methods used (summarised in Table 2). Both laboratories participate in the National Measurement Institute (NMI) yearly proficiency testing program which compares performance of around 30 laboratories, and both consistently meet the NATA accreditation requirements for total recoverable metal analyses. The total recoverable metal results presented in the current study, from the primary laboratory, present a more conservative approach to the screening assessment.

Table A4. Summary of intra-laboratory field duplicate for key physicochemical properties of the sediments, relative percentage difference (%RPD) (n=4)

Parameter	Min % RDP	Max % RDP	Mean % RDP	Duplicate samples that exceeded the DQI
Total organic carbon <sup>a</sup> (%)	14	114	66	M70 (0.7%) and DUP03 (2.4%) = 114% RDP; R02 (2.5%) and DUP04 (0.8%) = 102% RDP
Particle size <sup>b</sup> (%)				
<2 µm (clay fraction)	0	15	6	NA
2-63 μm (fine silt fraction)	1	17	7	NA
63 μm - 2 mm (sand fraction)	1	123	64	A03 (18%) and DUP01 (4.3%) = 123% RDP; M43 (1%) and DUP02 (0.3%) = 108% RDP
Moisture content (%)	1	31	12	NA
pH <sup>c</sup>	0	2	1	NA

DQI = Data quality indicator, RDP <50%, NA = Not applicable

<sup>a</sup> Combustion method

<sup>b</sup> Sediments with particles >2mm were sieved before analyses (n=4)

<sup>c</sup> pH was determined via the pH in soil methods (0.01M CaCl<sub>2</sub> extract) and is provided as an indicative value only

Table A5. Summary of intra-laboratory field duplicates for total recoverable metals, relative percentage difference (%RPD) (n=4)

	Min % RDP	Max % RDP	Samples that exceeded the DQI			
Aluminium	7	38	NA			
Arsenic	6	24	NA			
Barium	0	24	NA			
Beryllium	NA results < LOI	R or equal to the	LOR			
Boron	0	15	NA			
Cadmium	NA results < LO	R or equal to the LOR				
Cadmium (low level)*	0	67	A03 (0.2 mg/kg) and DUP01 (0.1 mg/kg); M43 (0.1 mg/kg) and DUP02 (0.2 mg/kg) (exceedances within 1-2 times the LOR)			
Chromium	0	34	NA			
Cobalt	0	12	NA			
Copper	0	37	NA			
Iron	3	17	NA			
Lead	0	31	NA			
Lithium	0	32	NA			
Magnesium	0	34	NA			
Manganese	0	15	NA			
Mercury	4	23	NA			
Molybdenum	0	67	R02 (1 mg/kg) and DUP04 (2 mg/kg) (exceedances within 1-2 times the LOR)			
Nickel	0	22	NA			
Selenium	NA – all results	< LOR				
Selenium (low level)*	0	29	NA			
Silver	NA – all results	< LOR				
Strontium	2	28	NA			
Sulfur	3	19	NA			
Thallium	NA – all results	< LOR				
Tin	NA – all results	< LOR				
Titanium	6	25	NA			
Vanadium	2	27	NA			
Zinc	3	27	NA			

DQI = Data quality indicator, RDP <50%; LOR = Limit of reporting; NA = Not applicable;

\* Secondary laboratory (all other metals analysed by the primary laboratory)

Table A6. Summary of intra-laboratory field duplicates for dilute acid extractable (1M HCl for 1 h) metals, relative percentage difference (%RPD) (n=2)

	Max % RDP	Samples that exceeded the DQI
Arsenic	40	NA
Cadmium	67	M43 (0.1 mg/kg) and DUP02 (0.2 mg/kg) = 67% RDP; R02 (0.6 mg/kg) and DUP04 (0.3 mg/kg) = 67% RDP
Chromium	40	NA
Copper	77	R02 (18 mg/kg) and DUP04 (8 mg/kg) = 77% RDP
Lead	36	NA
Mercury	NA – all results < LOR	
Nickel	67	M43 (1 mg/kg) and DUP02 (2 mg/kg) = 67% RDP
Selenium	NA – all results < LOR	
Zinc	30	NA

DQI = Data quality indicator (RDP < 50%), LOR = Limit of reporting, NA = Not applicable

### Appendix B – Screening criteria

Metal/Metalloid	SQGV (mg/kg dry weight) <sup>a</sup>	SQGV-high (mg/kg dry weight) <sup>b</sup>
Antimony	2.0	25
Arsenic	20	70
Cadmium	1.5	10
Chromium	80	370
Copper	65	270
Lead	50	220
Mercury (inorganic)	0.15	1.0
Nickel	21	52
Silver	1.0	4.0
Zinc	200	410

Table A7. Recommended sediment quality guideline values (SQGVs) for metals and metalloids (ANZG, 2018)

<sup>a</sup> SQGV is indicative of concentrations below which adverse effects rarely occur, it is primarily adapted from the 'effects range low' values of Long et al. (1995)

<sup>b</sup> SQGV-high represents concentrations above which effects frequently occur in exposed macrofauna, it is primarily adapted from the 'effects range medium' (ERL/ERM) values of Long et al. (1995)

#### Table A8. Screening criteria for selenium in sediment

Location - Description	Criteria	Guideline derivation approach/notes	Reference
North America - Apparent effect threshold (marine sediment)	1 mg/kg (dry weight)	Based on observed toxicity bioassay results in amphipods.	Buchman, 2008. Screening Quick Reference Tables, NOAA OR&R Report 08-1, Office of Response and Restoration Division, National Oceanic and atmospheric Administration, Seattle WA. Originally provided in Chapter 173-204 WAC, Sediment Management Standards, Dept of Ecology, State of Washington, 1991/95
British Columbia - Sediment alert concentration (fresh and marine sediment)	2 mg/kg (dry weight)	Weight of evidence; lowest published toxicity thresholds, no uncertainty factor applied; insufficient data for full guidelines at this time.	Beatty and Russo, 2014. Ambient Water Quality Guidelines for Selenium, Technical Report, Update. British Columbia, Ministry of Environment.
Europe - Predicted no effect concentration (marine sediment)	6.2 mg/kg (dry weight)	Derived by equilibrium partitioning method.	ECHA, 2016. Selenium Registration Dossier. European Chemical agency, https://echa.europa.eu

#### Appendix C – Supplementary contour maps

Contour maps based on the total recoverable metal concentration of the surface sediment are presented below for the metals with concentrations all below SQGVs or for which SQGVs are not available. For the majority of the metals (Cr, Co, Fe, Li, Mn, Ni, Ti, and V) enrichment of the metals relative to other sites within the lake occurred in tandem with the deeper, siltier sediments with higher TOC. Barium concentrations were slightly elevated at the western end of Bonnells Bay and Wyee Bay. Boron was also elevated at the western end of Bonnells Bay and the southern end of Chain Valley Bay. Molybdenum showed elevated concentrations at the southern end of Wyee Point. Strontium had six main locations with elevated concentrations.



Figure A1. Total recoverable barium concentrations (mg/kg) in surface sediment, southern Lake Macquarie. Red squares indicate sampling locations.



Figure A2. Total recoverable boron concentrations (mg/kg) in surface sediment, southern Lake Macquarie. Red squares indicate sampling locations.



Figure A3. Total recoverable chromium concentrations (mg/kg) in surface sediment, southern Lake Macquarie. Red squares indicate sampling locations.



Figure A4. Total recoverable cobalt concentrations (mg/kg) in surface sediment, southern Lake Macquarie. Red squares indicate sampling locations.



Figure A5. Total recoverable iron concentrations (g/kg; note unit change) in surface sediment, southern Lake Macquarie. Red squares indicate sampling locations.



Figure A6. Total recoverable lithium concentrations (mg/kg) in surface sediment, southern Lake Macquarie. Red squares indicate sampling locations.



Figure A7. Total recoverable manganese concentrations (mg/kg) in surface sediment, southern Lake Macquarie. Red squares indicate sampling locations.



Figure A8. Total recoverable molybdenum concentrations (mg/kg) in surface sediment, southern Lake Macquarie. Red squares indicate sampling locations.



Figure A9. Total recoverable nickel concentrations (mg/kg) in surface sediment, southern Lake Macquarie. Red squares indicate sampling locations.



Figure A10. Total recoverable strontium concentrations (mg/kg) in surface sediment, southern Lake Macquarie. Red squares indicate sampling locations.



Figure A11. Total recoverable titanium concentrations (mg/kg) in surface sediment, southern Lake Macquarie. Red squares indicate sampling locations.



Figure A12. Total recoverable vanadium concentrations (mg/kg) in surface sediment, southern Lake Macquarie. Red squares indicate sampling locations.

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