Environment Southland Independent Monitoring Programme

Coastal Marine Area (CMA) Investigation Tiwai Point

Prepared for:

Environment Southland

Prepared by:

EHS Support

October 2023

Document Control

PROJECT DETAILS

Project No.	NZL.00445.000
Report Revision No.	Final V10
Date of Issue	24 October 2023
Project Manager	Warren Sharp
Project Director	Simon Hunt

REPORT DETAILS

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DISTRIBUTION LIST

Date	No. of Copies	Company/Organisation	Name	Issue Type
24 October 2023				e

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Acronyms

^{o}C	degrees Celcius
AEE	Assessment of Environmental Effects
bgl	below ground level
BTOC	below top of casing
BWC	bottom water column
CMA	coastal marine area
COC	constituents of concern
COPEC	contaminants of potential environmental concern
CSM	conceptual site model
DSI	Detailed Site Investigation
EC	electrical conductivity
EF	enrichment factors
GHD	GHD New Zealand Ltd.
GWCNZ	Groundwater Consultants New Zealand Ltd.
HMW	high molecular weight (PAHs)
HQ	hazard quotients
LMW	low molecular weight (PAHs)
MfE	Ministry for the Environment
NOD	North Outfall Drain
NZAS	New Zealand Aluminium Smelters Ltd.
NZHP	New Zealand Heritage Properties Ltd.
OC	organic carbon
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PSD	particle size distribution
PSI	Preliminary Site Investigation
QA/QC	Quality Assurance/Quality Control
RPD	relative percent difference
SAP	Sampling and Analysis Plan
SAQP	Sampling and Analysis Quality Plan Summary
SOD	South Outfall Drain
TEQ	toxic equivalency quotient
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TWC	top water column
SCL	spent cell lining
URS	URS New Zealand Ltd.

Units of Measure

Area	
ha	hectare
m^2	square metres
Density	
kg/m^3	kilograms per cubic metre
Electrical Conductance	
µS/cm	microsiemen per centimetre
dS/m	decisiemen per metre
mS/cm	millisiemen per centimetre
mV	millivolt
Length	
µm	micrometre
cm	centimetre
km	kilometre
m	metre
mm	millimetre
Mass	
µg	micrograms
g	gram
kg	kilogram
mg	milligram
t	metric tonne
Concentration by Mass	
µg/kg	microgram per kilogram
mg/kg	milligram per kilogram

Pressure	
kPa	kilopascals
Pa	Pascals
Temperature	
°C	degrees Celsius
°F	degrees Fahrenheit
K	kelvin
Velocity	
m/s	metres per second
Volume	
µL	microlitre
cL	centilitre
cm^3	cubic centimetre
GL	gigalitre
L	litres
m^3	cubic metre
mL	millilitres
ML	megalitre
Concentration by Volume	
µg/L	microgram per litre
mg/L	milligram per litre
ppmv	parts per million by volume
ppbv	parts per billion by volume

Periodic Table

Element	Symbol
Actinium	Ac
Aluminum	Al
Americium	Am
Antimony	Sb
Argon	Ar
Arsenic	As
Astatine	At
Barium	Ba
Berkelium	Bk
Beryllium	Be
Bismuth	Bi
Bohrium	Bh
Boron	B
Bromine	Br
Cadmium	Cd
Calcium	Ca
Californium	Cf
Carbon	C
Cerium	Ce
Cesium	Cs
Chlorine	Cl
Chromium	Cr
Cobalt	Co
Copernicium	Cn
Copper	Cu
Curium	Cm
Darmstadtium	Ds
Dubnium	Db
Dysprosium	Dy
Einsteinium	Es
Erbium	Er
Europium	Eu
Fermium	Fm
Flerovium	Fl
Fluorine	F
Francium	Fr
Gadolinium	Gd
Gallium	Ga
Germanium	Ge
Gold	Au
Hafnium	Hf

Element	Symbol
Hassium	Hs
Helium	He
Holmium	Ho
Hydrogen	H
Indium	In
Iodine	I
Iridium	Ir
Iron	Fe
Krypton	Kr
Lanthanum	La
Lawrencium	Lr
Lead	Pb
Lithium	Li
Livermorium	Lv
Lutetium	Lu
Magnesium	Mg
Manganese	Mn
Meitnerium	Mt
Mendelevium	Md
Mercury	Hg
Molybdenum	Mo
Neodymium	Nd
Neon	Ne
Neptunium	Np
Nickel	Ni
Nihonium	Nh
Niobium	Nb
Nitrogen	N
Nobelium	No
Oganesson	Og
Osmium	Os
Oxygen	O
Palladium	Pd
Phosphorus	P
Platinum	Pt
Plutonium	Pu
Polonium	Po
Potassium	K
Praseodymium	Pr
Promethium	Pm
Protactinium	Pa

Element	Symbol
Radium	Ra
Radon	Rn
Rhenium	Re
Rhodium	Rh
Roentgenium	Rg
Rubidium	Rb
Ruthenium	Ru
Rutherfordium	Rf
Samarium	Sm
Scandium	Sc
Seaborgium	Sg
Selenium	Se
Silicon	Si
Silver	Ag
Sodium	Na
Strontium	Sr
Sulfur	S
Tantalum	Ta
Technetium	Tc
Tellurium	Te
Tennessine	Ts
Terbium	Tb
Thallium	Tl
Thorium	Th
Thulium	Tm
Tin	Sn
Titanium	Ti
Tungsten	W
Ununoctium	Uuo
Ununpentium	Uup
Ununseptium	Uus
Ununtrium	Uut
Uranium	U
Vanadium	V
Xenon	Xe
Ytterbium	Yb
Yttrium	Y
Zinc	Zn
Zirconium	Zr

Executive Summary

Environment Southland (ES) commissioned an independent assessment of the Coastal Marine Area (CMA) surrounding the New Zealand Aluminium Smelter (NZAS) Tiwai Point aluminium smelter facility. This assessment was successfully completed by EHS Support New Zealand Ltd ("EHS Support") in January and February 2023, with supplementary work undertaken in early May 2023.

NZAS holds a suite of resource consents regulating its operation of the smelter facility, which includes consented discharge of contaminants into the marine environment adjacent to the facility. The purpose of the CMA monitoring completed by EHS Support was to obtain an understanding of the state of the environment in the CMA adjacent to the NZAS facility.

The assessment work comprised targeted investigation of key areas around the perimeter of the NZAS facility where the transport of contamination from the facility into the receiving environment is believed to be occurring or may have occurred historically. The key areas investigated comprised:

- Bluff Harbour downgradient of the north drain, west drain, and south drain (and associated foreshore areas).
- Foveaux Strait and Bluff Harbour adjacent to the NZAS Landfill (including the Haysoms Dross Storage area) and associated foreshore areas.
- Foveaux Strait downstream and adjacent to the Inalco and SCL pad areas and foreshore areas.

The CMA assessment has established a good understanding of the mechanisms (and complexities) by which contamination is migrating from the wider NZAS facility and into the broader receiving environment, has identified areas for further assessment, and opportunities for environmental improvement. The assessment has leveraged historic and recent environmental investigation work undertaken by NZAS. This work has provided an understanding of the on-site contamination conditions and contaminant discharges.

The key findings from the CMA assessment are as follows:

1. Sources of contamination exist within operational areas of smelter (as recorded in the NZAS detailed site investigation of the site and the landfill) that have generated wide-spread groundwater contamination that is discharging into the CMA.
2. The scale and nature of the contamination recorded in the CMA is less than expected given the age and extent of the NZAS operation(s). Potential adverse environmental effects may arise from contaminant discharges into Bluff Harbour, while potential effects within Foveaux Strait are likely to be less. The nature of the Bluff Harbour and Foveaux Strait receiving environments are different, however they both attenuate contaminant discharges to varying degrees.
3. The lateral extent of the groundwater contamination plume discharging from the landfill to Foveaux Strait is extensive (approximately 1 km wide) with the effects from this discharge currently being assessed through the re-consenting of the NZAS landfill.
4. Discharges of contaminants occur via the consented stormwater drains (above environmental screening values [ESV's]) posing potential chronic and acute effects to ecological receptors. The CMA assessment has not quantified the mass of the contaminant discharge (with the sediment discharge being carried out from the facility drains into the wider environment of Bluff Harbour).
5. Potential acute environmental effects occur during first flush stormwater events from the north drain with fluoride contamination potentially impacting ecological receptors including

fish and benthic invertebrates and aluminium contamination potentially impacting benthic invertebrates. Further work is warranted to identify if similar discharges exist at the west drain and south drain.

6. The CMA monitoring has shown there are first flush stormwater discharges from the north drain that extend beyond the mixing zones at concentrations greater than environmental screening values and consented limits. Sediment and pore water concentrations above environmental screening values extend beyond the mixing zones of the north drain and are not captured by the consent.
7. The results from the CMA assessment work suggest there are unlikely to be higher order or human health risks via contaminant bioaccumulation through the food chain. This determination requires further biological testing to provide a more affirmative conclusion.
8. Mass loadings and impacts to Bluff Harbour may have been exacerbated by drain sediment movement practices (currently undertaken as a Permitted Activity) where materials (including contaminated spoil) are spread above the low tide mark and may distribute sediment contamination further into the harbour than under normal depositional conditions. Further assessment work is required to assess this activity and the risks.
9. Groundwater discharges are occurring within the smelter domain and SCL pad areas that exceed groundwater environmental screening values. Whether this groundwater contamination discharge is posing a risk to Bluff Harbour and Foveaux Strait requires further study and will, in part, depend on cumulative effects of groundwater and stormwater/process water contamination discharges.
10. The scope of the CMA assessment was not able to fully assess the likely nature and extent of potential environmental effects within the CMA receiving environments down gradient of the landfill, Inalco area, and SCL pad area within Foveaux Strait. It is anticipated that complex geochemical processes will be occurring at the interface of the groundwater/leachate discharges and the receiving marine environment(s) at a greater distance/depth into Foveaux Strait than was achieved by the CMA work. This requires further consideration/work to assess potential risk(s) and is in part being addressed by the NZAS landfill consent application.
11. It is clear from the work undertaken that concentrations in various media exceed ecological screening values within the CMA to the west of the landfill (in Bluff Harbour). These effects are being assessed by the NZAS landfill consent application.
12. Soil contamination along most foreshore areas investigated recorded contaminant concentrations that could pose a potential terrestrial ecological risk (notably south and west drains, east landfill area, Inalco area, and SCL pad area).
13. The CMA assessment recorded similar contaminant concentrations in groundwater to the routine groundwater monitoring work undertaken by NZAS (in selected wells) and provides confidence in the integrity of this routine sampling work.
14. The CMA assessment of the stormwater discharge sampling suggests that the consent stormwater sampling is potentially under reporting contaminant concentrations beyond the mixing zone during certain flow conditions and does not address sediment or pore water contamination within the drains and broader receiving environment.
15. Given the ease of public access to Bluff Harbour and the discharge points for the stormwater drains measures should be implemented to warn the public of potential risk(s) associated with the discharge(s).
16. To improve the environmental performance of the smelter operations and reduce contaminant discharges, NZAS should focus on the following issues:
    a. Routine operation/housekeeping changes will yield improved stormwater quality and reduced groundwater contamination discharges.
    b. The establishment of retention/detention facilities that will facilitate the deposition of sediment prior to discharge to the receiving environment.

c. Improvements to waste handling and storage within the smelter domain (such as refractory bricks stored on an unsealed area and dust management) will yield improved stormwater quality and reduced groundwater contamination discharges.
d. Landfill capping will reduce groundwater contamination.
e. Improved maintenance of stormwater collection systems and focused/performance based environmental monitoring will yield improved stormwater quality. The drain mouth clearing process requires further assessment.

1 Introduction and Background

1.1 Introduction

EHS Support New Zealand Ltd ("EHS Support") has been retained by Environment Southland (ES) to provide technical assistance to support their management of the New Zealand Aluminium Smelters Ltd (NZAS) Tiwai Point manufacturing facility ("Site"). An independent assessment of the coastal marine area (CMA) that immediately surrounds the NZAS facility was identified as a key work task by ES in 2022 and EHS Support was commissioned to complete this work in late 2022. The CMA assessment has focussed on key areas where discharge(s) from the NZAS Site to the CMA may have occurred historically and/or could be occurring during current operations, namely:

- Downstream of the three stormwater drains (north, west, and south drains) that carry stormwater and process water from the smelter domain and discharge into the Bluff Harbour.
- Within Foveaux Strait and Bluff Harbour that abut and are downstream of the NZAS Landfill.
- Within Foveaux Strait that abuts and is downstream of the Inalco Processing Area (within the smelter domain) and Spent Cell Lining (SCL) Pad.

The locations of the CMA areas investigated are shown in **Figure 1**. Background locations (within Awarua Bay and Foveaux Strait) were also investigated, following discussions with ES on suitable locations, as part of the CMA assessment.

Environmental screening values (ESV's) were developed for various media to support the CMA assessment (as presented in **Appendix A**) and are discussed in **Section 5.2.1**.

This report presents the results from the independent CMA assessment and is structured as follows:

- Section 1– Introduction, Background and CMA Assessment Objectives.
- Section 2 – Site Setting. This section provides an overview of the environmental setting, Site history, and Site geology and hydrogeology.
- Section 3 – Initial Conceptual Site Model (CSM) and Legacy Environmental Investigations. This section presents an initial CSM for the NZAS facility and provides a review (based on spatial areas) of legacy environmental investigation and monitoring programmes.
- Section 4 – CMA Investigation Activities. This section summarises the field work programme.
- Section 5 – CMA Results. This section presents an overview of the field results and laboratory testing.
- Section 6 – CMA Results Discussion. This section describes and assesses the results against the screening values (SVs).
- Section 7 – Data Gaps and Uncertainties. This section highlights and discusses the key data gaps that still exist post completion of the CMA work and the uncertainties associated with the data.
- Section 8 – Revised Conceptual Site Model and Potential Risks. This section presents a revised CSM for the CMA area and considers (within the bounds of the study) the potential human health and environmental risks posed by the contamination.
- Section 9 – Smelter Management Issues. This section presents a range of options for improved environmental performance on the basis that independent advice has been sought.
- Section 10 – Summary and Conclusions.

- Section 11 – Limitations.
- Section 12 – Presents a summary of the key EHS Support staff and other support personnel involved with the CMA investigation.
- Section 13 – References.

This report is subject to the limitations presented in **Section 11**.

1.2 Background, Context, and CMA Assessment Objectives

Prior to and since operations commenced at the NZAS facility in 1971, NZAS has undertaken a range of environmental monitoring work on and off the Site to support resource consent applications, comply with resource consent conditions, and monitor environmental performance and discharges to the environment. It is understood that most of the results from this environmental assessment and monitoring work have been supplied to ES, and NZAS has recently made some of this information publicly available through their website.

In 2020, NZAS announced the potential closure of the smelter. To support this process, GHD New Zealand Ltd ("GHD") was retained by NZAS to undertake contaminated land assessment work within the smelter domain (excluding the NZAS Landfill, SCL pad, and CMA areas). The work and findings have been described in the following documents:

- NZAS Closure Preliminary Study. Contaminated Sites Preliminary Site Investigation Report (PSI). GHD. January 2021. (GHD, 2021a).
- NZAS Closure Preliminary Study – Sampling and Analysis Quality Plan Summary (SAQP). GHD. 7 April 2021. (GHD, 2021b).
- NZAS Closure Preliminary Study. Contaminated Sites Detailed Site Investigation Report (DSI). GHD. August 2021. (GHD, 2021c).

The SAQP was supplied to ES in April 2021 and the DSI was supplied on 11 August 2021. In late September 2021, EHS Support commenced a formal review of the SAQP and DSI which was supported by a site inspection in late 2021. EHS Support submitted the SAQP and DSI review report to ES on 13 September 2022 (EHS Support, 2022a).

The PSI, dated January 2021, is referenced in the DSI but was not supplied to ES with the DSI in August 2021. Rather, the PSI was supplied to ES in late February 2022; therefore, the review of the SAQP/DSI was undertaken without reference to the PSI. EHS Support has since reviewed the PSI and draft review findings were presented in the EHS Support report dated 21 April 2023 (EHS Support, 2023).

During the SAQP/DSI review, NZAS also supplied several historical contaminated Site investigation reports pertaining to the NZAS manufacturing facility, off-site environmental monitoring reports, and reports on waste disposal facilities (notably the landfill and the SCL waste pad). A number of these reports are referenced in the DSI. These reports were received by ES in late October 2021 and have since been reviewed by EHS Support. While historical investigation and compliance monitoring reports were available and reviewed, it should be noted that these data have not been supplied to ES in a single and comprehensive database which would enable a more holistic assessment of Site conditions, contaminant distribution, and historical trends.

These historical reports have provided invaluable information to support the assessment of Site contamination. The key findings from the review of the smelter domain PSI and DSI were as follows:

- The DSI was an initial contamination assessment of the manufacturing Site. The report stated that it aimed to provide an initial "snapshot" of the contamination status within the smelter domain. NZAS acknowledged that the DSI report provided a broad initial assessment of contamination within the manufacturing plant area and that additional investigation work would be required to support remediation of the Site and compliance with environmental regulations.
- The DSI (and the PSI to a lesser extent) did not focus on the NZAS Landfill and SCL pad areas or the CMA around the wider smelter facility (except for sediment sampling within the stormwater drains). This was noted as a critical data gap in the assessment of the wider facility.
- Most of the data contained in the legacy NZAS reports was not fully integrated into the DSI findings. This was also noted as a critical data gap and was needed to build a robust CSM for the wider Site area.
- An assessment of both discrete (point source) and passive discharges from the Site is required to determine mass loadings and potential risks in the receiving environment. This is particularly important for organic and inorganic constituents that have the potential for bioaccumulation and/or to bio-magnify.
- The assessment of human health and ecological risks needs to consider all sources, pathways, and exposure scenarios to provide a determination on the acceptable level of human and ecological risks. Furthermore, several of the constituents of potential concern are persistent and/or bio accumulative.
- Appropriate ecological screening criteria were needed to evaluate the significance of potential contaminant exposures to the receiving environment (terrestrial and aquatic).

The NZAS landfill holds a resource consent that expires on 8 December 2023 (Consent No: 202196). During pre-application meetings for this consent in December 2022 and January 2023 (and other ES/NZAS meetings), NZAS indicated that a significant amount of additional environmental investigation work was being undertaken on the wider NZAS facility and the CMA to better understand the nature and extent of contamination and potential effects. At the time of preparing the bulk of this report, while ES had requested these data from NZAS, other than high level summary data presented at meetings, the results from this work were not provided to ES. NZAS/GHD lodged their consent application for the landfill on 26 May 2023 (GHD, 2023). The assessment of environmental effects and supplementary documents have been reviewed and select data from these reports are included in this report.

To enable ES to fulfil its regulatory obligations, particularly to assist with managing the various NZAS resource consents and assessing potential off-site environmental and human health risks, ES identified the need to complete an independent assessment of the CMA surrounding the NZAS facility. The objectives of the independent CMA assessment are described in **Section 1.2.1**.

1.2.1 CMA Assessment Objectives

As noted above, NZAS historically invested heavily in comprehensive studies at the Site (principally in the 1990s and early 2000s). This work established a strong baseline understanding of constituent concentrations in the marine receiving environment. It is EHS Support's understanding that no comprehensive assessment of the foreshore areas has been conducted to date (acknowledging that all the investigations commissioned by NZAS have not been sighted). Instead, studies have typically been conducted to support resource consent applications, with the most recent studies completed in 2001, 2005 and 2023 (Stevens and Barter, 2005; Depree, 2001; GHD, 2023). Findings from these legacy studies, compliance monitoring within groundwater monitoring wells around the landfill (reported in the Annual Reports submitted to ES), recent work completed by GHD and EHS Support and the GHD landfill consent application (GHD, 2023) indicate the presence of contaminants of potential environmental concern (COPEC) at concentrations above relevant and applicable criteria in Site media (i.e., soil, sediment, groundwater, and surface water). The presence and magnitude of these impacts indicates that further evaluations of potential ecological and human health risks (associated with historical and current facility operations at NZAS) are required.

In particular, the GHD investigations identified complete exposure pathways to aquatic and terrestrial receptors (GHD, 2021c). For the marine setting, this would be associated with direct contact toxicity or dietary exposure pathways of aquatic organisms to COPECs (benthic organisms [e.g., mussels, invertebrates] and pelagic organisms [e.g., fish], and semi-aquatic birds). In the foreshore, this would be associated with direct contact or dietary exposure pathways of terrestrial organisms to COPECs (e.g., plants, invertebrates, soil processes, and predominately birds). For some contaminants (e.g., polychlorinated biphenyls [PCBs]), indirect exposures associated with bioaccumulation and biomagnification within the food chain are also a concern.

Based on information supplied as part of the EHS Support review of the GHD investigation work and supplementary information supplied by NZAS, it has become apparent that a more robust and integrated assessment of Site sources, migration pathways, and receptors is needed in terms of pathway completeness and exposure assessment. To this end, EHS Support developed a programme of work for ES that would provide insight into the nature of the CMA receiving environment and concentrations of COPECs within key areas surrounding the NZAS facility.

The scope of the work for this study was defined in the EHS Support proposal dated 11 November 2022, and an investigation methodology was presented in the draft Foreshore and Intertidal Multi-Matrix Sampling and Analysis Plan (SAP) that was issued to stakeholders (including NZAS) for review in late November 2022 (EHS Support, 2022b).

The SAP was finalised and endorsed in early January 2023 and the field work programme was undertaken from mid-January through early February 2023. Supplementary field work was undertaken in early May 2023 in the areas of the north, west and south drains.

The key EHS Support objectives of the CMA programme were as follows:

- Provide an independent assessment of contamination conditions at key perimeter locations around the NZAS smelter complex with a focus on areas where contaminants may be transported into the receiving environment.
- Establish the concentration of COPECs within the receiving environment.
- Identify any potential environmental risks posed by the COPECs and potential human health risks, principally through food gathering.
- Identify opportunities for improved environmental operational practices within the smelter complex.
- Verify the integrity of the routine groundwater and surface water sampling work being performed by NZAS.

To address the above objectives, the CMA field programme comprised the following tasks and focussed on the key assessment areas presented in **Figure 2**:

- Conduct initial focused aquatic sampling of sediment, sediment pore water, and surface water in the intertidal areas of:
    - Bluff Harbour downgradient of the north drain, west drain, and south drain;

  - Foveaux Strait and Bluff Harbour adjacent to the NZAS Landfill (including the Haysoms Dross Storage area); and
  - Foveaux Strait downstream and adjacent to the Inalco area and SCL pad areas.
- Conduct initial focused soil sampling in foreshore areas adjacent to the assessment areas listed above.
- Collect coincident groundwater samples from NZAS groundwater monitoring wells adjacent to the key CMA areas and install data-loggers to gain temporal groundwater level and electrical conductivity data.
- Identify and assess a representative background of sediment, surface water, sediment pore water, and soil conditions. **Figure 3** displays the location of the background sampling areas relative to the CMA assessment area.

2 Site Setting

The following section summarises the environmental setting, Site history, and geological and hydrogeological conditions of the Tiwai Peninsula.

2.1 Environmental Setting

The Tiwai Peninsula lies approximately 20 km south of Invercargill and comprises a mass of beach ridges extending east from Tiwai Point. The peninsula encloses Awarua Bay and Bluff Harbour to the north from Foveaux Strait to the south as shown in **Figure 1** (attached).

South Port New Zealand Ltd is located close to the entrance of Bluff Harbour (directly west of the NZAS facility) with the large, low-lying eastern arm, Awarua Bay, immediately to the east of the promontory. The wider Bluff Harbour and Awarua Bay receive discharges from various agricultural and industrial operations, as well as wider and more general run-off from roads, residential areas etc.

The Peninsula covers an approximate area of 2,400 ha and typically lies at an elevation of approximately 5 m to 10 m above mean sea level. The width of the peninsula varies between approximately 0.5 km in the NZAS Landfill area (close to Tiwai Point) to approximately 2.25 km east of the smelter domain.

Many features within the peninsula (e.g., sand dunes, dune deflation hollows, shell barrier beaches, shingle beaches, coastal turfs, stable sand dunes, and coastal cliffs) are recognised as rare ecosystems (Williams, 2007). The wider estuary is also of high quality, high value, and a naturally rare ecosystem (GHD, 2021d).

Climatically speaking, the area receives generally consistent rainfall (which averages around 75 mm per month) with the predominantly westerly winds (GHD, 2021c). While the climate is considered coastal and moderated by surrounding oceans, cold fronts can result in cold conditions with snowfall at sea level considered rare.

The NZAS facility occupies several land parcels within the western part of the Peninsula as shown in **Figure 1** (attached) and summarised in **Table 2-1** below.

Table 2-1 Summary of Land Ownership

Domain	Land Ownership	Legal Description	Area Ha (approximate)
Smelter Domain	NZAS Freehold Land	Lot 1 DP 13987	92
NZAS Landfill, wider smelter surrounds and Spent Cell Lining (SCL) Pad	Rio Tinto Aluminium New Zealand (RTANZ) Freehold Land	Lot 1 DP 13988	313
Wider Peninsula Area (east of the smelter facility)	RTANZ Leasehold Land from the Department of Conservation (DOC)	Section 1, Block XIV Campbeltown Hundred	1,667

2.2 Site History

Tiwai Peninsula was used by Māori (pre-European settlement) for a range of activities, particularly mahinga kai (notably sealing) and stone working (New Zealand Heritage Properties Ltd (NZHP), 2022). By the early 1800s, whalers and sealers were also using the Peninsula. Post-European settlement, Tiwai Point and the wider peninsula area was used for farming and a poultry farm, along with the establishment of a quarantine station and hospital (NZHP, 2022).

EHS Support has not had access to NZAS records to establish the development history of the smelter facility; therefore, the summary presented below is principally taken from the GHD PSI (GHD, 2021a), Aurecon New Zealand Ltd.'s (Aurecon, 2020) report on Tiwai Point for Treasury, NZAS Remediation Infographic released in 2020 (NZAS,2020), NZAS Air Discharge Consent Assessment of Environmental Effects (AEE – NZAS, 2005a), and NZAS Landfill Consent AEE's (NZAS, 2003; GHD, 2023).

In the late 1960s, construction of the NZAS facility commenced, with the facility becoming operational in April 1971. The Manapōuri hydro-electric power station supplies power to the smelter, with the refined bauxite being transported to Tiwai Point from Australia. Water for the plant is extracted from a well field located east of the main manufacturing plant that is situated on Department of Conservation (DOC)-leased land.

It is understood that a former wetland area occupied the central and west areas of the smelter domain area and that this was excavated and backfilled with locally won soils (assumed). Historical aerial photographs of the smelter before and after construction are presented in **Appendix B** to show the extent of the legacy wetland area.

NZAS background information indicates that the manufacturing facility was developed in four stages:

- Stage 1 comprised establishment of the initial facilities.
- Stages 2 to 4 increased production by progressively expanding these facilities.

Stage 1 was completed in November 1971 and involved construction of the following:

- Wharf and ship unloading facilities and raw materials storage sheds.
- Green carbon plant, carbon baking furnace, and carbon rodding room.
- Construction of Potline No. 1 and the main stack; and
- Metal products casting facilities, maintenance workshops, and the main store.

Stage 2 (first facility expansion) involved construction of the first half of Potline No. 2. This was commissioned in October 1972. Stage 3 expansion involved the construction of the second half of Potline No. 2, plus the addition of another carbon baking furnace and an expansion to the metal products casting facilities. These facilities were commissioned in July 1976. Stage 4 work (third facility expansion) involved construction of Potline No. 3 commissioned in August 1983, and additions or alterations to facilities as follows:

- Extensions and additions to raw materials storage sheds.
- Additions to the green carbon plant
- Additional carbon baking furnace.
- Additions to the metal products casting facilities.
- Additions to ancillary services.

An upgrade to the NZAS facility in 1995/1996 involved the construction of Potline No. 4. Other additions or alterations to facilities included:

- Decommissioning of Carbon Baking Furnace No. 3, commissioning of Carbon Baking Furnace No. 4, and an additional casting facility in metal products.
- Conversion from use of solid pitch to liquid pitch.

- Addition of a dry scrubbing fume treatment system

At commencement of operations, the NZAS facility was producing approximately 150,000 tonnes/year of aluminium metal, with current production stated as being 335,405 tonnes/year in 2020 (NZAS website, 2023).

The NZAS Landfill is located southwest of the smelter domain as shown in **Figure 1** (attached) and covers an area of approximately 15.5 ha. It is understood that the landfill likely commenced operations in 1970 during construction of the smelter, with the landfill receiving wastes once the facility became operational. The NZAS landfill comprises a series of industrial “mono-cells”. The cells are unlined and there is no leachate collection; therefore, the site area has operated as a “dilute and disperse” landfill. Nominal capping of waste materials with natural soils and re-vegetation has occurred, except for the carbon cell which has been capped with an impermeable geo-membrane (NZAS, 2021b). NZAS terminated disposal operations at the landfill in 2022. Over its operational life, the landfill is understood to have received (but not limited to) the following wastes based on the AEE submitted for the 1995 and 2003 landfill consent applications (NZAS, 1995 and 2003):

- Anode butts.
- Asbestos-containing materials (disposed in a designated asbestos disposal area) and mineral fibre.
- Ash and clinker residues.
- Carbons fines and dross powder, including aluminium dross powder.
- Concrete, gravel, and other clean fill that cannot be reused.
- Floor sweepings.
- General non-classified wastes.
- Green waste.
- Iron slag and steel waste.
- Refractory bricks.
- Resistor coke.
- Pit cleanings with a high liquid content.

Other activities conducted within the confines of the landfill have included the bioremediation of hydrocarbon contaminated materials (historically) and truck washing. While historical documents have referenced potential PCB oil handling activities at the landfill, it has not been definitively determined that PCB oils have been handled and managed in the landfill. However, based on the age of the Site it is known that PCB-containing oils were probably used at the Site, as both a dielectric fluid (in transformers and rectifiers) and as hydraulic fluids. PCBs were recorded in the landfilled waste by GHD, as documented in their 2023 report.

In their historic consent applications for the landfill (NZAS, 1995 and 2003), NZAS described various Site operations/initiatives that were undertaken to minimise the disposal of Site-generated wastes to landfill through the reuse and recycling of materials such as anode carbon material, out of specification aluminium, bag house dust, refractory bricks, timber, and cardboard.

NZAS estimated that the landfill contains approximately 800,000 m^3 of waste, of which there is estimated to be 33,500 tonnes of dross residue and 100,000 tonnes of carbon fines (NZAS, 2022).

Abutting the eastern boundary of the NZAS Landfill is the Haysoms Dross Landfill Cell. This landfill comprises an engineered cell (unlined but capped and covered with an impermeable membrane in 2009-2010) it was originally constructed in 2003 to manage dross waste processed by a third party that went into liquidation. An agreement was reached between the local regulators, the Crown, and

NZAS to construct the on-site landfill cell. Aurecon 2020 estimated that 16,000 m^3 of waste is held within the cell.

SCL waste (generated from the spent cell lining) was initially stored (between the mid-1970s and 1992) in an uncovered manner on concrete pads located to the southeast of the smelter domain area shown in **Figure 1**. Leachate generated by the SCL was collected and treated for discharge to Foveaux Strait. Following issues with groundwater contamination originating from the SCL pads, the waste stockpiles were combined and the SCL stockpiles were capped. Since 1992, SCL waste has been stored in purpose-built sheds located in the southeast corner of the smelter domain. Periodically, SCL is transported overseas for recycling. Dross arisings are processed on Site. Dross residues that were bagged and stored off-Site previously were repatriated back to Site in 2021. Carbon fines are currently the only new material that is bagged and stored on-Site. NZAS estimates that approximately 220,000 m^3 of SCL waste is stored on-site (NZAS, 2022).

During the 1990s, processed aluminium dross waste (estimated at 21,000 tonnes) was stored in the landfill. Additions of processed dross in the landfill ended in the late 1990s.

NZAS has committed to the processing/treatment of SCL and dross wastes, and/or the export of these materials for a beneficial use. At the time of preparing this report, specific details concerning off-site transport of these wastes are unknown. It is understood that newly generated materials, including carbon fines, are bagged, and stored in containers at the Site. Following closure of the landfill in 2022, other waste materials from the NZAS facility are transported off-site to repositories, facilities, or organisations approved to handle such material for management and disposal.

2.3 Geology and Hydrogeology

2.3.1 Geology

Published geological maps and geological assessments (Turnbull and Allibone, 2003; GHD, 2021d) of the Tiwai Peninsula area have recorded the following stratigraphic sequence underlying the NZAS facility:

- Quaternary aged unconsolidated beach deposits (principally comprising pea gravels (rounded quartz gravel) and sands).
- Greenhills Group Middle Permian aged intrusive comprising basalt, keratophyre, diorite, schist, and granite.

As noted in **Section 2.2**, the central area of the smelter domain previously comprised a wetland feature that is believed to have been excavated and infilled with locally won materials (i.e., pea gravel) during construction of the facility. Fill materials (while being difficult to distinguish from the in-situ natural soils) should be expected across much of the smelter operational area as noted in the GHD bore logs (GHD, 2021c). Inspection of the wider site area also suggests that extensive earthwork occurred during construction of the NZAS facility, which would have modified Site topography and near surface geology.

Drilling work by GHD for the DSI (GHD, 2021c) confirmed the reported geology and proved the superficial deposits to a depth of approximately 9.45 m below ground level (bgl). Due to the nature of the underlying soils (i.e., pea gravel) and the drilling technique employed to meet the investigation objectives, no significant structure/bedding within the underlying deposits was recorded on the GHD bore logs other than changes in geology. The bore logs from earlier investigation work undertaken in the 1990s (Woodward Clyde, 1994) recorded similar conditions.

In simple terms, the near surface geology underlying the NZAS facility area appears to comprise the following (Woodward Clyde, 1994; GHD, 2023):

- Landfill area – pea gravel and sand units with some silt and peat units typically extending 3m to 7.5 m bgl and underlain by the Greenhills Group.
- Smelter domain and SCL pad areas – interbedded pea gravel and sand units to approximately 6 m bgl, with gravelly sands extending from 6 m to 14 m bgl. At 16 m bgl and on, the geology becomes more poorly sorted, and sands become more cohesive with clay, silt, and pea gravel. The GHD logs note multiple, thin layers and inclusions of peat and organic soils (up to approximately 0.5 m thick).

It is understood that NZAS/GHD have undertaken a more in-depth geo-hydrogeological study of the Smelter facility area; however, at the time of writing this report, this information was not available.

During inspection of exposed beach deposits in the cliffs (approximately 3 m in height) fronting Bluff Harbour (between the north and south drains), EHS Support recorded bedding within the pea gravel units, with evidence of finer grained soils lying on top of coarser grained materials, iron oxide staining, and organic layers. Photographs of the beach deposits are shown in **Appendix C**.

Active sand dune and back-beach ridge fields comprised of sand and gravel are mapped along Foveaux Strait Beach that is located along the south side of the Smelter facility and the east area of the peninsula (GHD, 2021d). These are described as prograde beach ridges (Kirk and Lauder, 2000) and are shown schematically in **Figure 4**.

Drilling work within the NZAS well field area undertaken in the late 1970s recorded older sediments below the sands (at depths of approximately 16 m to 25 m bgl) that were comprised of clays, sandy mudstones, sandstones, and lignites (Groundwater Consultants New Zealand Ltd [GWCNZ], 1990). This unit extended approximately 65 m bgl and is believed to rest on the underlying Greenhills Group under the Smelter facility area.

The Greenhills Group forms the basement bedrock of the local area. The Greenhills Group crops at the southwestern end of the peninsula and along the northside of the landfill that abuts Bluff Harbour. In the early 1990s, drilling work typically recorded the Greenhills Group at depths of approximately 5 m bgl within the landfill area (Woodward Clyde, 1994; GHD, 2023). The Woodward Clyde bore log records indicate that the Greenhills Group is weathered to clay at the surface of this unit in certain areas. As noted above, the Greenhills Group was also encountered under the main peninsula area (NZAS well field area).

2.3.2 Hydrogeology

The superficial soils underlying the peninsula form a shallow, unconfined aquifer system. Within the Smelter domain area and areas to the east, two discrete water bearing units have been described – an upper pea gravel unit with high permeability and a lower sand unit with moderate to high permeability. Groundwater assessment work undertaken by GWCNZ in 1990 has shown that the underlying aquifer system is comprised of freshwater originating from rainfall recharge, with some seawater intrusion at the peripheries of the peninsula (GWCNZ, 1990). Groundwater flow along the peninsula appears to generally follow the axis of the landmass with groundwater flowing to the north and south/east, fluxing into both Bluff Harbour and Foveaux Strait.

There are several features across the peninsula that influence this CSM, as summarised below:

- Modifications to the original Smelter domain landform (i.e., the excavation and backfilling of the former wetland area) will have influenced groundwater flow patterns within this area of the Site.
- The large sealed/covered area of the Smelter domain will inhibit recharge to the underlying aquifer system. Leakage from reticulated stormwater pipes, high use water activities (such as wash facilities), and stormwater soakage areas will potentially create local areas of recharge.
- In the southern area of the peninsula (NZAS landfill area and further southwest), bedrock crops/sub-crops at a relatively shallow depth and is likely to influence the direction of groundwater flow in localised areas.
- The three main stormwater drains at the Site that carry stormwater and process water into Bluff Harbour are unlined and will recharge the underlying aquifer system.
- In the east area of the peninsula lies the NZAS well field that abstracts groundwater for use within the facility, which will influence groundwater levels and flow in this area of the Site.

Further discussion of the groundwater characteristics using the domain areas defined by GHD in their DSI is provided in the sections below.

2.3.2.1 Smelter Domain Groundwater Characteristics

Groundwater within the Smelter domain area typically lies between 3m to 5m bgl (GHD, 2021c). Groundwater contours for the Smelter complex area have been presented in both Woodward Clyde (1994) and GHD (2021c) studies. Neither of these studies extensively measured groundwater levels over a period of time to understand the effects of impermeable cover, recharge from the stormwater drains, and/or tidal fluctuations. In general, the earlier Woodward Clyde groundwater contours provide a more convincing assessment of groundwater flow within the Smelter complex area shown in **Figure 5** and suggest that there is a groundwater trough within the central area of the Smelter domain with a groundwater flux to the west. Around the peripheries of the Smelter domain, groundwater flows towards Bluff Harbour and Foveaux Strait.

In 1994, Woodward Clyde noted that groundwater seeped on the Bluff Harbour Beach between the west and south drains. EHS Support studied the seeps that were visible at low tide during the recent field work programme and concluded that they were an expression of groundwater fluxing into Bluff Harbour. This flux was noted along much of the beach abutting the west area of the Smelter domain. The seeps were more visible/evident where depressions in the beach occurred.

2.3.2.2 NZAS Landfill Groundwater Characteristics

Groundwater within the landfill area typically lies at about 5 m bgl. Groundwater contours prepared by Woodward Clyde (1994) URS New Zealand Ltd (URS, 2009) and GHD (2023) show groundwater fluxing to both the north/northwest into Bluff Harbour and to the south into Foveaux Strait in **Figure 6**. Groundwater modelling by GHD in 2023 estimates that 95 percent of recharge (groundwater and leachate) flows east into Foveaux Strait, with approximately 5 percent discharging north into Bluff Harbour. Groundwater travel times from the landfill to Foveaux Strait were estimated (by Woodward Clyde in 1994) at 75 m to 150 m per year, while slower travel times of approximately 9 m to 18 m per year were estimated for the discharge into Bluff Harbour.

2.3.2.3 SCL Pad Groundwater Characteristics

Within the area of the SCL pad, groundwater has been recorded at depths of approximately 3 m to 5m bgl (Minenco Pty Ltd [Minenco], 1995) and flows in a southerly direction into Foveaux Strait.

Groundwater monitoring work undertaken by Woodward Clyde in the early 1990s and Minenco in 1995 indicate that the superficial units form two aquifer systems – an overlying pea gravel aquifer and a lower, more fine-grained sand aquifer. Woodward Clyde (1994) estimated that groundwater travel times in the pea gravel aquifer were approximately 510 m per year (+/-110 m). Within the finer grained unit, they were in the order of 33 m per year to 186 m per year.

3 Initial Smelter Conceptual Site Model and Legacy Environmental Investigations

3.1 Smelter Operations

An overview of the smelting process is presented below (principally taken from/adapted from the NZAS air discharge consent AEE [NZAS, 2005a]). Operational procedures associated with the environmental management of smelter have not been sighted but it is understood that NZAS uses a number of external certification schemes that requires NZAS to set objectives and targets that aim for continuous improvement (NZAS, 2005b).

NZAS produces primary aluminium metal from alumina ore using the Hall-Heroult reduction process. The NZAS facility includes four potlines and can produce approximately 350,000 tonnes of aluminium metal per year at full production. Molten aluminium is siphoned from the cells and transported in a molten state to a casting facility where it is held in a holding furnace. All metal produced is cast on-site into various sizes and forms (sows, tees, slabs, billets, and ingots). The facility operates 24 hours a day, 7 days per week, with approximately 60% of the cast metal shipped directly from the Site via the NZAS Wharf. The remaining metal is transported by truck off-Site. Most of the finished metal is exported.

Aluminium is created from alumina (refined bauxite ore sourced from Australia) using an electrochemical reduction process. NZAS receives supplies of the raw material, aluminium oxide, by ship at its deep-water pier. It is transferred to the plant by covered belt conveyor. Other raw materials include calcined petroleum coke, petroleum pitch and cast iron used in the manufacture of anodes, and aluminium fluoride and cryolite used in aluminium potlines.

Aluminium oxide is reduced to pure aluminium in carbon-lined, steel cells containing molten cryolite. Both anodes and cathodes are made of carbon. The replaceable carbon anodes, which are consumed during the smelting process, are made on-site by using petroleum coke, coal tar pitch (liquid), and reused anode material. The components are heated, mixed, and vibrated into blocks. These blocks are then baked in furnaces at temperatures of typically 1,100°C to 1,200°C. The cathodes are typically purchased from Japan or China. The refractory lining of the cells is also purchased externally.

The reduction process occurs in cells. Each cell consists of a carbon-lined steel shell acting as the cathode. The carbon-lined shell contains molten electrolyte (bath), which is a modified cryolite (Na_3AlF_6). Alumina is dissolved in this bath. Carbon anodes are suspended from superstructures above the cells and then immersed in the bath. A high electrical current flows between the anodes and the cathode, maintaining the cell and its contents at an operation temperature of approximately 970 degrees Celsius (°C), providing energy for the cell reaction. Anodes are consumed during the reduction process through a reaction with oxygen to form carbon dioxide; therefore, the anodes are replaced approximately every 25 days.

The cells are connected in an electrical series. The completed series is called a potline. NZAS has four potlines. Three of the four potlines contain 208 cells each, while the other potline contains 48 cells, resulting in a total of 672 cells; however, all the NZAS cells may not operate at any given time depending on availability of electrical energy or process requirements.

3.2 Waste Generation and Environmental Discharges

During the manufacturing processes, several key waste streams are generated that require management and operational practices, resulting in discharges of contaminants to the environment. Key discharges to the environment are shown schematically in the pictorial CSM presented in **Figure 7**. NZAS has several resource consents issued by ES that regulate the operation of the NZAS facility (**Table 3-1**). Compliance monitoring for the consents is undertaken by NZAS and reported to ES in an annual monitoring report (typically by 31 March the following year). These reports are posted on the NZAS website and typically comprise summary data. Field sheets, sampling methodologies, laboratory reports, and Quality Assurance/Quality Control (QA/QC) assessments are not provided.

Table 3-1 NZAS Resource Consents

Consent Type/Discharge	Consent No.	Expiry Date
NZAS Landfill – to discharge contaminants onto or into land, including the Haysom's Dross Cell.	202196	8 December 2023
To discharge contaminants to the air from an aluminium smelter and related activities	203378	6 June 2031
To discharge treated effluent to the coastal marine area	203379	6 June 2031
Discharge treated sewage to land	203376	6 June 2031
Stormwater – discharge stormwater and process water (via North, West, and South Drains) to land and Bluff Harbour.	203373	6 June 2031
To occupy the foreshore/seabed with a discharge pipe for treated effluent	203375	6 June 2031
To discharge stormwater and process water to land in circumstances where it may enter water	202727	8 October 2039
To take and use groundwater for industrial supply	202958	12 September 2040

3.2.1 Key Waste Streams

There are several key waste streams that are generated at the Site, which contain impurities and/or COPECs at high concentration. Some of these, such as SCL and Dross, have been discussed above and were historically landfilled and/or are currently being stored/managed at the Site. SCL and Dross are significant fluoride sources that can contain cyanide, aluminium, and other inorganic impurities. Other waste materials generated on-site include:

- Alumina (under cell materials).
- Bath materials generated from the operation of the cells (sodium fluoride rich materials).
- Bricks/refractory from refurbishment of the carbon bakes.
- Floor sweeping from potlines and cast house which comprise a combination of waste materials unsuitable for reprocessing.
- Carbon dusts/coke from the rodding area, ball mills, and green anode mill.
- Cathodes that cannot be reprocessed at the Site and spent anode materials not suitable for recycling.
- Drain sediment (including materials from water separators, major open drains, and catch basins in operational areas of the Site).
- Dust collector bags.
- Furnace slag.

The materials include a broad range of potential contaminants from polycyclic aromatic hydrocarbon (PAH)s associated with the use of pitch to manufacture the cathodes and anodes, inorganic impurities (e.g., fluoride and cyanide), and alumina and reacted aluminium species (i.e., aluminium fluoride). In addition to wastes containing contaminants, a broad range of other solid waste streams are generated at the Site associated with operations. These include:

- Man-made mineral fibres (MMMF) – used to repair refractory cell walls in furnaces. MMMF is placed in a separate cell. Asbestos materials from small component insulation from the 1970s are double bagged and placed in a dedicated cell within the Landfill site in accordance with NZ regulatory authorities.
- Plastic materials.
- Paper/cardboard (non-recyclable).
- Reject bath materials not suitable for reprocessing.
- Rubber.
- Sand.
- Steel.
- Textiles.
- Timber.

In conjunction with the solid waste stream, a range of liquid wastes are generated from ancillary activities and repairs and maintenance. These include:

- Used oils.
- Liquid spillage (creosote and tar residues from the green mill).
- Hydraulic oils.
- Sludges and cleaning liquids from cooling tower maintenance activities.
- Condensate from compressors (where captured).
- Surplus (or contact) cooling waters from green mill and casting.
- Wash waters from pressure washing and steam cleaning operations.

All these wastes are stored, managed, treated, and disposed of by NZAS.

3.2.2 Operational Environmental Discharges

Given the scale and nature of the smelter operation there are multiple activities (and opportunities) for release of contaminants to the environment during the manufacturing process. Based on typical smelter operations (and on the basis that EHS Support has not formally audited the facility) a summary of possible (and key) releases are listed below:

- Losses from alumina storage and transfer and raw material spillage.
- SCL management, including emissions from cell refurbishment activities, and the handling and storage of SCL.
- Air emissions and deposition from potlines (including roof vents and leaks from the fume system).
- Management of solid wastes within the smelter and rodding rooms where alumina (under cell material or surface spillage/floor sweeping/catchment basin solids) and off specification carbon are managed.
- Dross handling and storage from the casting operations.
- Storage and handling of solid wastes.
- Legacy polychlorinated biphenyl (PCB) management, including wastes from the rectifier yard, and historic disposal of PCBs/PCB oils.

3.2.3 Liquid Discharges

Stormwater generated within the Smelter domain is directed to three stormwater drains (north, west, and south drains) that discharge into Bluff Harbour and are consented through ES Consent No. 203373. It is understood that these drains receive stormwater flow from a reticulated stormwater system within the Smelter domain. There is also a stormwater discharge to ground in the southern portion of the power supply switchyard (Consent No. 202727).

The drains are unlined (having been excavated into the underlying pea gravel) and are equipped with an oil trap and weir structure at the point of discharge to the receiving environment. The south drain travels along the southern boundary of the Smelter domain area and discharges into a legacy wetland area (assumed to be part of the original wetland that pre-dated the NZAS facility) before discharging into Bluff Harbour. Other than this wetland feature and capture of sediment behind the weir structures, no other treatment is believed to be applied to the discharge of stormwater. Little or no information is available on how the drains are maintained; however, it understood that the outlets from the drains to the marine environment are subject to blocking by tidal deposition of pea gravel on the foreshore, and that these channels are routinely opened/diverted by the removal or disturbance of materials to allow the drains to function. This activity is allowed for under rule 7.4.2.1 of ES's Regional Coastal Plan for Southland (ES, 2013). This rule presents a series of Permitted Activity controls to comply with regarding the clearing/removal of spoil from the mouth area of the drains and that any excavated spoil is removed or spread over non-vegetated areas. ES records indicate that NZAS typically clear longshore drift material from the mouth of the north and west drains on average at least five times a year (averaged over the last five years).

Investigation work documented in Woodward Clyde (1995) indicates that the north drain has the largest catchment area (approximately 26 ha) and an estimated average stormwater inflow of 775 m^3/day. The south and west drains have smaller catchment areas of approximately 22.5 ha and 7.5 ha, respectively. The stormwater discharge from the Site will contact various industrial processes and activities and be contaminated with a range of COPECs. In addition, aerial deposition from the stack and the potline louvres (which are consented through ES Consent No. 203378) will also contribute to the contaminant load within the stormwater discharge.

The consent for the discharge of stormwater allows for the discharge of processed water, described as cooling, washing, and flushing water (up to 4,500 m^3/day) to land and the coastal marine area (Consent No. 203373). It is assumed that processed water includes contact and non-contact cooling water for metal casting and anode production. Dry scrubbers are used at the Site for gases (from the smelting process) that reacted with alumina, which is then fed back into the smelting process. The fume treatment system (dry scrubbers) do not use water as a scrubbing medium. Because of the unlined nature of the stormwater drains, there will be a loss of stormwater/process water to groundwater through soakage.

The stormwater discharge consent requires each drain discharge (for the three drains) to be sampled weekly and samples analysed for total suspended solids (TSS), fluoride, electrical conductivity (EC), and pH, while the edge of the mixing zone for each drain (which is 50 m from the shore and referred to as the coastal monitoring point) should be sampled weekly either side of high tide and at a depth of 0.3 m. The coastal monitoring samples are to be tested for fluoride, conductivity, and pH. The quarterly average of the coastal monitoring samples should not exceed 2 mg/L fluoride and any representative samples collected should not exceed 5 mg/L fluoride. The drain discharge samples should not exceed a TSS concentration of 30 mg/L.

Sewage from the Site is treated and applied to land. It is consented through ES Consent No. 203376. The NZAS sewerage system collects wastewater from various sources on the smelter Site, including toilets, washrooms, showers, laboratories, canteens, and kitchens. The NZAS sewage treatment plant provides a secondary treatment process. Solids from the treatment process are transferred off-site, while liquids are applied to land through infiltration.

3.3 Initial Conceptual Site Model

Given the nature of the environmental setting for the NZAS facility and mode of operation, the following initial contamination CSM is presented to provide a basis for the scope of the independent CMA investigation. The CSM described below, covering the whole of the smelter complex, is similar to the CSM presented in the GHD DSI (GHD, 2021c).

The operation of the NZAS manufacturing facility and storage of waste materials (notably the NZAS Landfill and SCL pad) have resulted in near surface soil contamination in select areas and shallow groundwater contamination that is migrating towards and into Bluff Harbour and Foveaux Strait. The nature and extent are detailed in the following documents that have been provided by NZAS:

- Smelter domain area – The GHD DSI (GHD, 2021c) provides a recent benchmark of contamination conditions within the smelter domain area. An earlier assessment of groundwater contamination within this area of the Site is presented in Woodward Clyde (1994).
- NZAS Landfill – NZAS has documented groundwater contamination conditions within the landfill area in their annual compliance reports (NZAS website 1995 – 2021). Summaries of landfill groundwater contamination conditions were also presented in URS (2009) and Woodward Clyde (1994).
- SCL pad – NZAS has presented a summary of their monitoring data in a 2021 report (NZAS, 2021a and 2021b) and historical data is presented in Woodward Clyde (1994), Minenco (1995), and the NZAS annual compliance reports (NZAS website 1995 – 2021).

Based on EHS Support's knowledge of smelting activities and the above investigation and assessment work on the NZAS facility, the key COPECs are:

- Fluoride (fluorspar, cryolite and bath materials).
- Cyanide (Total, weak acid dissociable [WAD], and free cyanide).
- PAHs and Total Petroleum Hydrocarbons (TPH – associated with the use of pitch or general oil and fuel storage and handling).
- Aluminium and reacted aluminium (aluminium fluoride).
- Metals impurities associated with the impurities present in alumina, and potential alloying of aluminium in the casting operations.
- Asbestos (associated with its historical use as insulation).
- PCBs associated with the historic presence in dielectric fluids and hydraulic oils.
- Dioxins and furans as a by-product from the manufacturing process.

At the time of preparing this initial CSM the GHD landfill assessment was not available (GHD, 2023). This has since been reviewed and where appropriate findings and investigation data are referenced in this report.

Key findings and considerations (particularly in how they relate to the assessment of the CMA) are described below.

3.3.1 Holistic Overview

During the preparation of this report, NZAS did not provide all the results from their comprehensive groundwater assessment that is currently being conducted, nor have they integrated their historical and routine investigation/monitoring results into a holistic assessment of contamination at the facility. The results and findings of part of the groundwater assessment and other investigations into the landfill and foreshore were made available to ES through the 2023 NZAS Landfill Consent Application (Consent #202196; GHD, 2023). The primary COPECs associated with aluminium smelting operations are aluminium, fluoride, and cyanide. Based on its widespread use and presence in raw materials and wastes, as well as its high solubility, an iso-contour plan of shallow groundwater fluoride concentrations is presented in **Figure 8** for the combined NZAS Landfill, SCL Pad and smelter domain area to visualise the nature and extent of contamination at the NZAS facility. Additional iso-contours were produced for the smelter domain area for aluminium (**Figure 9**). The groundwater data is taken from NZAS Landfill leachate monitoring data (NZAS, 2021), the DSI (GHD, 2021c) and the SCL Groundwater Status Report (NZAS, 2021a). The fluoride iso-contour plan (**Figure 8**) is principally based on the DSI and NZAS groundwater monitoring data (the integrity of which [for select wells during the CMA assessment] was shown to be acceptable). The aluminium iso-contour plan (**Figure 9**) is based on the DSI data. Aluminium impacts are also widespread but its lower solubility under circum-neutral conditions limits its ability to define groundwater plumes emanating from the Site. Aluminium and its reacted forms are a COC, with aluminium fluoride particularly toxic to aquatic organisms at low pH.

These iso-contour plans provide a simple interpretation of what are very large and complex plume(s) of groundwater contamination. There will be multiple sources of fluoride and aluminium contamination entering the shallow groundwater system (with groundwater typically lying 3 m to 5 m bgl); however, it demonstrates where key groundwater contamination is currently known to be present within the smelter domain, NZAS landfill and SCL Pad areas as well as its proximity to the CMA. Similarly, groundwater patterns exist for other key COCs, namely PAHs (GHD, 2021c).

Investigation work in the SCL Pad area identified high contaminant concentrations at depth with the underlying aquifer system because of denser contaminated leachate being generated by the SCL. Additional work within the NZAS landfill areas have considered the generation of denser areas of groundwater contamination and the results from the smelter domain area have yet to be received.

3.3.2 NZAS Landfill Leachate Contamination

The historical environmental assessment work on the landfill demonstrates that previously there would have been significant discharges of key COPECs to groundwater and into Foveaux Strait and Bluff Harbour. Because the landfill has been operated using a dilute and disperse management approach, groundwater contamination concentrations have declined significantly, particularly over the last 5 years (as a consequence of leaching of contaminants from the waste and an absence of a fully engineered landfill cap). These processes have recently been described and documented in the GHD 2023 landfill report (GHD, 2023).

Fluoride in the groundwater monitoring wells along the downgradient edge of the leachate plume entering Foveaux Strait (based on recent NZAS monitoring data [NZAS, 2021b]) are in the range of 0.15 mg/L and 57 mg/L, with most wells yielding concentrations above 20 mg/L. These wells are shown in the iso-concentration contours plan presented in **Figure 8**.

Based on the information currently provided by NZAS/GHD, they have concluded that various geochemical and physical processes will be occurring at the point of discharge to the marine environment that will mitigate any potential adverse effects. This work is currently under review as part of the landfill consent application.

Work undertaken in the early 1990s (Woodward Clyde, 1994), and more recently by GHD (in their 2023 landfill report), indicated that there was a greater level of groundwater flux into Foveaux Strait compared to Bluff Harbour, with the latter having reduced groundwater travel times. Given the differences between the two receiving environments, additional work is needed to address potential adverse effects in these areas. The potential may also exist for groundwater plumes (and a potentially denser sinking plume, as was noted in the SCL pad area) to exist within areas of the landfill.

In addition to the flux of groundwater/leachate discharging into Bluff Harbour and Foveaux Strait from the landfill, it is also conceivable (given the nature of the landfill) that there could be surface water overland flow discharges as well as windblown deposition of Site-related constituents entering the terrestrial environment abutting the landfill and the marine environment.

3.3.3 Smelter Domain

The Smelter domain covers a large area (approximately 92 ha), much of which is covered with buildings and pavement. The GHD DSI indicates that there are multiple contamination sources within the Site areas that are leaching to groundwater, with the nature and distribution of contamination consistent with the nature of the manufacturing activities that are known to occur.

Large plumes of fluoride and aluminium groundwater contamination lie below the main manufacturing complex (**Figures 8** and **9**), with the contaminant concentrations declining as the plumes migrate towards Foveaux Strait and Bluff Harbour. The perimeter of the facility that abuts Foveaux Strait and Bluff Harbour is unsealed with recharge to the groundwater system also occurring in these areas. Key contamination areas identified include:

- Inalco area (which comprises dross treatment areas, SCL storage warehouses etc.).
- Refractory brick storage area.
- Washdown facility.

The nature and extent of the groundwater contamination plume described by the GHD DSI is an interpretation based on a limited distribution of groundwater monitoring wells and spot groundwater sampling events (GHD, 2021c). Groundwater monitoring of the smelter domain as part of the NZAS comprehensive groundwater assessment has been completed, however, all of this data have not been made available to ES. To fully understand the significance of the discharges, additional work may be needed including (but not limited to) assessment of temporal changes in constituent concentration levels, influence of tidal effects, recharge from the stormwater drains, and quantification of mass fluxes (especially for bioaccumulative contaminants) into the receiving environment.

The GHD soil and groundwater contamination data (GHD, 2021c) and summary iso-contour groundwater contamination plans (**Figures 8 and 9**) suggest there could be a potential groundwater to marine water discharge risk from the following COPECs:

- Fluoride
- Aluminium
- PAHs

A key discharge (and probably the discharge with the highest mass loading) from the smelter domain to the marine receiving environment is the discharge of stormwater and process water via the north, west, and south drains (their locations are shown in **Figure 1**). It is likely that several mechanisms could be occurring at the point of discharge from the drains to Bluff Harbour, in that:

- Surface water discharges will occur daily at the north and west drain (regardless of rainfall events) because these drains also discharge process water. The south drain does not consistently discharge to the coastal marina area.
- Stormwater events, particularly “first flush” events after dry periods, have the potential to discharge a significant mass of contaminants in both surface water and sediment. This has previously been documented by NZAS in the 2005 Drain Discharge Consent Application AEE, which cites a study by Bioresearches (1995) indicating that “fluoride concentrations increased significantly in the first flush wet weather samples” (NZAS, 2005a).
- The drains will recharge the shallow groundwater system along their length, particularly at the point of discharge where water is held behind the weir structures.

As a consequence, depending on the nature of the mouth of each drain (at the point of discharge) and the immediate receiving environment, there could be a complicated mix of sediment and pore water contamination from the deposition of sediment entrained in the stormwater, pore water contamination from the flux of contaminated groundwater (either derived from the wider smelter complex or recharge from the drains), impacted surface water from stormwater, groundwater impacts, and partitioning from sediment into surface water. This is further complicated by the potential for stratified contamination of the marine surface water as a lens of fresh stormwater discharges over denser marine waters and partitioning between phases over time.

The nature, concentration, and distribution of sediment and pore water contamination downgradient of north and west drain outfall areas are influenced by the work NZAS undertakes to maintain each drain opening, in particular the extent of excavation and re-distribution of contamination. The south drain is not routinely excavated.

3.3.4 SCL Pad Area

The SCL pad covers an area of approximately 1.5 ha and serves as a repository for some of the legacy SCL waste. The SCL pad is capped with an engineered impermeable membrane that was installed in 1992 to prevent leachate generation. It is located approximately 70 m to 80 m from the Foveaux Strait beach. Leachate generated by the pad is collected, treated, and discharged to Foveaux Strait. Leaching from the SCL pad has historically created a plume of leachate contamination (principally contaminated with fluoride, cyanide, and ammonia) that is migrating towards and discharging into Foveaux Strait. Work undertaken by Woodward Clyde in the early 1990s (Woodward Clyde, 1994) identified that the leachate being generated due to contaminant concentrations was denser than the surrounding freshwater groundwater and receiving marine water; therefore, the leachate created a denser plume of contamination within the lower sand aquifer in addition to contamination of the upper pea gravel aquifer. NZAS has adopted an attenuation management approach to the SCL pad leachate plume based on a remedial options assessment completed by Minenco in 1995 and based on approval granted by Environment Southland on 11 October 1995. NZAS routinely monitors key groundwater monitoring wells to ensure contaminant concentrations are declining and not posing an effect through attenuation in the receiving environment.

The most recent NZAS SCL pad monitoring data is from December 2020 (NZAS, 2021) and recorded the following contaminant concentrations within the SCL pad area and dune area (70 m to 80 m from the pad).

- SCL pad area – Shallow groundwater (pea gravel aquifer) yielded a maximum fluoride concentration of 39 mg/L and total and free cyanide concentrations of 2.8 mg/L and 0.17 mg/L, respectively. Deeper groundwater in the sand aquifer yielded a fluoride concentration of 1.5 mg/L and total and free cyanide concentrations of <0.25 mg/L and <0.01 mg/L, respectively.
- Dune area – Shallow groundwater (pea gravel aquifer) yielded a fluoride concentration of 0.7 mg/L and total and free cyanide concentrations of 0.808 mg/L and <0.01 mg/L. Deeper groundwater in the sand aquifer yielded a fluoride concentration of 12 mg/L and total and free cyanide concentrations of 24 mg/L and 0.016 mg/L, respectively.
- Deeper groundwater in the dune area sand aquifer has concentrations of fluoride and free cyanide that are above the EHS Support ESVs of 1.5 mg/L and 0.002 mg/L, respectively.

The NZAS monitoring data indicate that while contaminant concentrations in the groundwater plume discharging from the SCL pad have reduced significantly over the years, there is still an ongoing discharge into the Foveaux Strait beach area.

4 CMA Investigation Activities

The independent CMA investigation was carried out in accordance with the SAP (EHS Support, 2022c). A detailed overview of the field activities can be found in **Appendix D**. The field work programme included:

- Groundwater elevation and EC monitoring.
- Groundwater sampling from selected NZAS monitoring wells.
- Collection of surface, sub-surface, and deep sediment samples in the CMA and background areas.
- Soil sampling in the foreshore and background areas.
- Collection of surface water at varying depth intervals with co-located pore water samples.

Figure 2 illustrates the CMA investigation sampling locations. **Figure 3** illustrates the sampled background locations relative to the CMA sampling locations, with **Figures 11 and 12** indicating background sampling locations. Field sample logs are provided as appendices for the following matrices:

- **Appendix E** – Groundwater.
- **Appendix F** – Sediment bore logs.
- **Appendix G** – Surface water and pore water field forms.

4.1 CMA Scope

The field programme included an assessment of sediment, pore water, surface water, and groundwater in the key assessment areas (**Figure 2**, attached). **Appendix D** details the activities completed as part of this investigation. Deviations from the SAP are summarised in **Section 4.5**. The objectives of the field programme included:

- Conducting initial focused sampling of sediment, pore water, and surface water in the intertidal area of:
  - Bluff Harbour downgradient of the north, west, and south drains.
  - Bluff Harbour and Foveaux Strait adjacent to the NZAS Landfill and Foveaux Strait adjacent to the Haysoms Dross Storage area.
  - Foveaux Strait downgradient and adjacent to the Inalco area and SCL pad areas.
- Conduct initial focused soil sampling in foreshore areas adjacent/upgradient to the assessment areas.
- Identify and characterise representative background sediment, surface water, pore water, and soil conditions (two locations – Awarua Bay [inner harbour] and Foveaux Strait).

Surface water, pore water, soil, and sediment samples were successfully collected from the north, south, and west drains, west and east landfills, Inalco and SCL pad areas, and background areas. Final sampling locations are displayed in **Figure 2, 11, and 12**.

Surface water and pore water samples were collected during outgoing tidal periods along the Awarua Bay (including background stations), Bluff Harbour, and Foveaux Strait coastlines (including background stations). Surface water samples along Awarua Bay and Bluff Harbour were collected at the top (TWC) and bottom (BWC) of the water column. Surface water samples along Foveaux Strait were collected at one depth interval (approximately 0.1 m below water surface) due to the high energy environment and observed mixing that occurs in the CMA along Foveaux Strait. Pore water samples were collected at one depth interval (0.1 m depth). Surface water sampling was generally undertaken during dry weather, the exception to this being collection of the aqueous samples collected from the west drain during a period of inclement weather (sustained precipitation with high energy tidal fluctuations), and a first flush event captured from the north drain (refer **Section 4.5**).

Sediment samples were collected at three depth intervals (0-0.1 m, 0.1-0.5 cm, and 0.5-1 m) at each sample station along Awarua Bay (including background stations) and Bluff Harbour to evaluate risk to aquatic receptors and to assess whether legacy deposition had occurred. Sediment samples along Foveaux Strait (including background stations) were only collected at surface intervals due to the higher energy environment of the Foveaux Strait that would limit fine grain deposition and minimise the historical deposition that could accumulate at depth. Sediment samples were collected during low or outgoing tidal periods along the Awarua Bay, Bluff Harbour, and Foveaux Strait coastlines. Soil samples were collected at one depth interval per sample station (0-10 cm) in the foreshore area adjacent/upgradient to the CMA assessment areas or background area.

4.2 Previous Independent Assessment Work

Following review of the DSI, ES and EHS Support completed two observation events (14-15 February 2022 and 21-22 February 2022) of supplementary field work that GHD was undertaking on the smelter domain. The observation events witnessed groundwater, surface water, and sediment sampling. During this field work, EHS Support collected duplicate samples of select media and these were submitted to an alternate accredited laboratory for inter-lab comparison testing. The results from these observation events and inter-laboratory testing were presented in the EHS Support letter report dated 30 March 2022 (EHS Support, 2022d).

4.3 Investigation Reconnaissance and Preliminary Groundwater Assessment

EHS Support undertook an initial appraisal and reconnaissance of the CMA area on 10 November 2022 and met with NZAS to discuss Site access and logistics for the CMA work programme. This work was used to support development of the SAP.

In late December 2022, data loggers (water level and EC) were installed in key groundwater monitoring wells that lie on NZAS and DOC land: monitoring wells A51, A53, A56, L_MW_B18, and MW 4/5, located on the Foveaux Strait side of the Site, and monitoring wells A63, E_MW_B7, and I_MW_B1 located adjacent to inner harbour CMA sampling locations. Well locations are provided on **Figure 2**. The loggers were removed in early January 2023, the wells gauged with an EC probe and groundwater samples were collected for laboratory analysis. Results from the data logger deployment are provided in **Appendix E** and discussed in **Section 6.4**.

4.4 CMA Investigation Timeline and Logistics

The bulk of the independent CMA work programme was undertaken between 16 January and 3 February 2023. Prior to undertaking the field work, approvals were obtained from NZAS to access their land. The work was completed in accordance with an archaeological management plan prepared by NZHPL in late 2022 (NZHPL, 2022). The EHS Support field work was stewarded by NZHPL as needed to ensure that archaeologically sensitive areas were protected. Supplementary assessment work was undertaken in the area of the stormwater drains on 3 and 4 May 2023. Photographs of the some of the field work practices are presented in **Appendix C**.

4.5 Deviations to the 2022 CMA SAP

Deviations to the in-field work associated with the 2022 CMA SAP (EHS Support, 2022c) were minimal and additive to the initial CMA scope, including the collection of additional information to better understand conditions within the CMA during baseline and "first flush" stormwater conditions. Field deviations included:

- Stormwater samples were collected from the north drain during a "first flush" event (on 2 February 2023). "First flush" samples were collected after 48 hours of no precipitation followed by a precipitation event. The receiving estuary water body was flat/calm (no waves) at the time of first flush discharge. The National Institute of Water and Atmospheric research (NIWA) monitoring station for this area malfunctioned and therefore was unable to provide accurate rainfall information.
- Apparent groundwater seeps were identified in the CMA between the west drain and south drain. Water quality parameters were recorded for apparent seeps and a sample was collected from the area with the greatest volume of discharge. Samples were collected at low tide.
- Shallow groundwater was collected in the north and west drains from 0-10 cm bgl using the same protocol for collecting pore water. Water quality parameters were recorded for each sample collected. Samples were collected with no overlying water in areas adjacent to previously collected pore water samples.
- Test pit transects from the north and west drains were excavated to document the lateral extent of possible impacts (visible staining) to the shallow subsurface CMA environment. Sediment samples were collected intermittently and analysed for PAHs, fluoride, and cyanide (**Figure 10**).
- Tidal levels did not drop to a safe level to collect a sediment core from 100 m downgradient of the west drain outfall; however, a surface interval sediment sample was collected along with pore water and surface water at this location. An additional sediment core was collected 75 m from the west drain outfall to characterize the spatial distribution of constituents in the receiving environment.
- Sediment samples collected at south drain (SOD)-01 were not analysed at the deep sediment interval (50-100 cm) due to cancelled analysis by the laboratory.
- Surface water was collected for one depth in the south drain due to a limited amount of overlying water during the outgoing tide.
- Select sediment samples were analysed for particle size distribution (PSD), PCBs, and dioxins/furans.
- Supplementary surface water and pore water samples were collected downstream from the three stormwater drains on 3 and 4 May 2023.

5 CMA Results

5.1 Introduction

This section summarises the field observations and results from the independent CMA monitoring programme and presents a discussion of the results collectively (for the various media sampled) based on the key sample locations.

The laboratory analysis of the CMA assessment sampled media was undertaken by a combination of Eurofins New Zealand Ltd (bulk of the laboratory testing) and Watercare Laboratory Services Ltd (based in Auckland). Both laboratories are IANZ accredited. The laboratory data was generally provided in electronic format and so it is not included in the report.

The results and findings from the field and laboratory QA/QC assessment is provided in **Appendices E, F, G, H,** and **I**.

A summary of the analytical results from the CMA investigation are provided as attached tables by matrix:

- Summary of Results by Area and Matrix – **Table 1.**
- Comparison of Soil Analytical Results to Ecological Screening Values – **Table 2.**
- Comparison of Sediment Analytical Results to Ecological Screening Values – **Table 3.**
- Comparison of Groundwater Analytical Results to Ecological Screening Values **Table 4.**
- Comparison of Pore Water Analytical Results to Ecological Screening Values – **Table 5.**
- Comparison of Surface Water Analytical Results to Ecological Screening Values – **Table 6.**
- First Flush Hazard Quotients and Enrichment Factors – **Table 7.**
- Surface Water Supplemental Sampling – **Table 8.**
- Pore Water Supplemental Sampling – **Table 9.**
- Sub-Surface Aqueous Samples Hazard Quotients and Enrichment Factors – **Table 10.**
- Test Pits Sediment Samples Hazard Quotients and Enrichment Factors – **Table 11.**
- Laboratory Comparison of Fluoride Detections in Groundwater, Pore Water, and Surface Water – **Table 12.**

The constituent results for the key samples locations (separated into sampled media) are presented in the following attached figures:

- Awarua Bay Background – **Figures 11a – 11c.**
- Foveaux Strait Background – **Figures 12a – 12c.**
- North Drain – **Figures 13a – 13d.**
- West Drain – **Figures 14a – 14d.**
- South Drain – **Figures 15a – 15d.**
- Landfill Assessment Area – **Figures 16a – 16c.**
- Inalco Assessment Area – **Figures 17a – 17c.**
- SCL Pad Area – **Figures 18a – 18c.**
- Sub-surface Aqueous– **Figure 19 – 20.**
- Groundwater – **Figure 21.**

Cross sections along each line of the sample stations used in the investigation of the north, west and south drains showing fluoride concentrations for surface water and pore water are presented in **Figure 22**.

To aid with interpretation of the results, select constituent concentrations recorded across aqueous investigation media are shown together graphically in the following attached figures:

- Aqueous analytical results compared to ESVs - **Figures 23-27.**

5.2 Application of Screening Values

To assess the environmental quality of the sediment, groundwater, marine surface water, and pore water samples collected during the CMA investigation the constituent concentrations have been compared to available environmental effects thresholds.

Appendix A presents the environmental effects thresholds utilised for the different media sampled. The term threshold is a general term that can include standards (a legally enforceable value), criteria (a standard in the Clean Water Act in the United States), and guidelines (a threshold which typically has no regulatory status). Although guidelines, such as those produced by legacy ANZECC (2000) (which have been replaced by ANZG, 2018), are included in Regional Plans/Water Plans issued by Regional Councils and therefore have regulatory status..

The threshold values utilised originate from a range of national and international sources. In general, the groundwater thresholds represent the 80th percent level of species protection (ANZG, 2018) and the marine surface water and pore water typically represent the 95th percent level of species protection (ANZG, 2018). The marine surface water thresholds are being applied to the immediate near shore surface water and pore water that exists in the area where aqueous discharges from the NZAS facility typically occur. Higher quality thresholds would need to be applied to marine waters that lie further out within Bluff Harbour and Foveaux Strait.

To provide guidance for the extensive number of contaminants of concern involved in the CMA study, these differences are recognised and are discussed in **Appendix A**. It is important to note that the values for particular media, such as marine surface water, may include guidance developed using different processes. A hierarchical process was followed in assessing the thresholds used (e.g., similar to that presented in MfE, 2011). To simplify the presentation of the various types of environmental thresholds used in this report, they are collectively referred to as Environmental Screening Values (ESVs).

A summary of the methodology used to derive the soil eco ESVs is also included in **Appendix A**.

The focus of the CMA assessment has been on ecological risk. Human health risk issues have principally been considered through uptake within the food chain for a range of COPECs that may bioaccumulate (namely dioxin/furans, PCBs, and PAHs). This assessment is presented in **Appendix J**. A simple Tier 1 human health risk comparison of the data for the terrestrial soils (collected from the foreshore study areas) has been made against the recreational Soil Contaminant Standards developed for the National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health (MfE, 2012), namely arsenic, cadmium, chromium, lead, mercury, and PAHs (benzo(a)pyrene toxic equivalency quotient [TEQ]). Aluminium concentrations have been conservatively compared to the USEPA Regional Screening Levels for a residential setting (7,700 mg/kg) because recreational values are not available. Fluoride concentrations have been compared to the Canadian Council of Ministers of the Environment (CCME, 2023) recreational health risk concentration (400 mg/kg). The eco ESVs are lower than the human health risk screening criteria and so if applied will be protective of human health.

5.2.1 Comparison to Screening Values and Background

Hazard quotients (HQ) and enrichment factors (EF) have been used to describe the magnitude of exceedance relative to the media specific ESVs and background concentrations, respectively, and are explained below.

- HQs were calculated for constituents by dividing the recorded concentration by the respective SV. For example, the recorded sediment concentrations are divided by the sediment screening values presented in Appendix A. An HQ greater than 1 indicates an exceedance of the ESV and therefore constitutes potential risk to ecological receptors from exposure to site media. The SVs generated are typically for chronic situations/exposure, hence an HQ greater than 1 suggests a potential chronic risk. While acute SVs have not been generated, it could be assumed that an HQ greater than 10 would suggest that significant effects could arise from prolonged exposure.
- EFs were calculated for constituents by dividing the mean detected concentrations by the mean of the detected background concentration by matrix. For example, the mean of the contaminant concentrations in the sediment samples collected from the areas of the drains in Bluff Harbour have been divided by the mean of the Awarua Bay background concentrations. The EF value provides a relative indication of site related concentrations relative to a background area. An EF of greater than 1 for a particular constituent in a specific medium would indicate that mean concentrations in the CMA assessment area are greater than the mean concentrations in the associated background (i.e., mean pore water aluminium concentrations in the north drain would be compared to mean pore water aluminium concentrations in the Awarua Bay background area). Hence an EF greater than 1 may serve as an additional line of evidence for site related contamination. It may also suggest that further investigation may be required, especially if the constituent does not have an ESV.

Matrix results from CMA sample locations along the Bluff Harbour were compared to Awarua Bay background area means. While matrix results from CMA sample locations along the Foveaux Strait were compared to Foveaux Strait background area means. **Table 5-1** identifies the background area that CMA assessment areas were compared to.

Table 5-1 Background Areas used for Comparison to CMA Assessment Area Media

Background Area	CMA Assessment Area
Awarua Bay Background	North Drain
	West Drain
	South Drain
	West Landfill
Foveaux Strait Background	East Landfill
	Inalco Area
	SCL Pad

5.3 Background Locations

CMA assessment background areas were identified in Awarua Bay and along the Foveaux Strait (**Figure 3**). The locations were principally selected on the similarities in the nature of the receiving environments being investigated in the independent assessment (as noted in **Table 5-1**) and distance from the NZAS smelter (that was considered beyond the likely range of atmospheric deposition from the NZAS main stack).

5.3.1 Awarua Bay Background Location (BAB)

The Awarua Bay inner harbour background location lies within the eastern end of the Bay, comprised of a low energy tidal flat environment (south of Awarua Bay Road), and is located approximately 9 km northeast of the smelter. The background sampling areas are shown on **Figure 3** (attached) and the background sample locations are shown in **Figure 11a-11c**. A photograph of the background location is shown in Photograph 4 presented in **Appendix C.**

Sediment samples collected from the sample stations showed the sediment to comprise fine to coarse sand, with coarse gravels visible at surface (proved to a depth of 1 m bgl). The tidal flat area was hard packed. Limited organic material was observed within the sediment bores (confirmed by TOC analysis, which returned TOC concentrations of 0.3% or less in sediment samples).

Soil samples were collected from the foreshore area, upgradient from the water and sediment sampling locations. Evidence of marine life (invertebrates [crabs], snails, fish) were observed during sampling.

The Awarua Bay background surface water and pore water samples recorded a small number of ESV exceedances (for dissolved compounds), notably:

- Copper and arsenic in pore water at one sample station (BAB-03), recording concentrations of 0.023 mg/L and 0.006 mg/L, respectively.
- Copper in surface water at one sample station (BAB-01) recording a concentration of 0.004 mg/L.

The majority of the sediment samples recorded trace element concentrations below the ESVs and often below the laboratory limit of reporting (LOR). Trace concentrations of aluminium, arsenic, cadmium, chromium, cobalt, copper, lead, nickel, and zinc were recorded. The maximum mercury concentration of 0.05 mg/kg.

Select sediment samples from the Awarua Bay background area were submitted for analysis of dioxins and furans. The dioxin and furan analysis generally yielded non-detect concentrations except for two compounds, 1.2.3.4.6.7.8-HpCDD and 1.2.3.4.6.7.8-HpCDF (which recorded maximum concentrations of 3.3 pg/g and 2.1 pg/g, respectively). These compounds were detected in concentrations less than what was observed in on site-media collected from within the main assessment areas as part of this investigation. An assessment of the dioxin and furan results is provided in **Appendix J**.

The foreshore soil samples recorded constituent concentrations that were below the ESVs except for boron at two locations, recording concentrations of 10 mg/kg and 14 mg/kg. Aluminium soil concentrations ranged from 2,700 mg/kg to 3,100 mg/kg (below the ESV) and soil pH ranged from 6 to 6.4. Trace concentrations of PAHs were recorded in the background soils with maximum low and high MW PAH concentrations of 0.05 mg/kg and 2.43 mg/kg being recorded, respectively.

The background soil concentrations recorded similar trace element concentrations to median background concentrations presented on the LRIS Database for this site area (namely for arsenic, cadmium, copper, chromium, lead, nickel, and zinc).

GHD collected background data for the NZAS 2023 landfill consent application (**Appendix K**; GHD, 2023) from a similar background location to the EHS Support Awarua Bay background location. The GHD data recorded similar background COPEC concentrations to EHS Support, with some of the differences likely to be a result of LOR and laboratory or collection methods.

5.3.2 Foveaux Strait Background (BFS)

The Foveaux Strait background location was located approximately 25 km east of the smelter and comprised a moderate to steeply sloping coastal surf beach (moderate to high energy environment). Sediment samples comprised surficial predominantly coarse beach sands with no observed organic material (reported TOC as non-detect or at the detection limit of 0.1%). The background sampling areas are shown on **Figure 3** and the background sample locations are shown in **Figures 12a-12c**. A photograph of the background location is shown in Photographs 1, 2 and 3 presented in **Appendix C.**

Soil samples were collected from the rear fore dune area elevated above water and sediment sampling locations. No bird or marine life was observed during sampling works.

The Foveaux Strait background samples (for surface water, pore water, and sediment) recorded a small number of ESV exceedances, notably:

- Aluminium in surface water and pore water at all three sample stations, recording concentrations of between 0.16 – 0.99 mg/L and 0.21 – 1.1 mg/L, respectively.
- Cobalt, copper, free cyanide, and zinc in surface water and pore water in at least one of the sample stations recording maximum concentrations of 0.002 mg/L, 0.002 mg/L, 0.005 mg/L and 0.01 mg/L, respectively.

Sediment samples were not submitted for dioxin and furan analysis from the Foveaux Strait background area.

The foreshore soil samples recorded constituent concentrations that were below the ESVs. Aluminium soil concentrations ranged from 1,900 mg/kg to 2,100 mg/kg (below the ESV) and soil pH ranged from 7.6 to 7.8. PAH concentrations in background soils were below the laboratory reporting limits.

The background soil concentrations recorded similar trace element concentrations to median background concentrations presented on the LRIS Database for this site area (namely arsenic, cadmium, copper, chromium, lead, nickel, and zinc).

5.4 Bluff Harbour – Overview North, West and South Drains

Contaminant concentrations across the sampled media generally decreased from each drain outfall to beyond the edge of the consented mixing zone. Contaminant concentrations for sediment, surface water, and pore water were typically greatest in the most upgradient locations at or immediately below the drain outfalls (**Figures 2** and **22**). This suggests that the risk to aquatic receptors in the receiving environment may be greatest in the most upgradient areas near the outfalls (notably within the allowable mixing zone); however, exceedances of sediment and aqueous phase ESVs in the north drain and west drain were also recorded downgradient of the outfalls, towards the edge of the mixing zones (**Figure 22**), indicating that there is potential for risk to aquatic receptors within the full receiving environment for these drains.

The key contaminants of concern noted from the drain discharges generally reflect the activities being undertaken within the respective drain catchments. The north drain and west drain CMA environments are characterised by detections of inorganic elements (including metals and fluoride) as well as PAHs above ESVs. These compounds were detected in both aqueous (surface water and pore water) and solid phase (soil and sediment) media. The south drain was observed to be consistently disconnected from the CMA and therefore presents a different discharge profile. The south drain CMA environment had less detections of site related contaminants above ESVs than the north drain or west drain. However, the south drain can be characterised by detections of several metals, fluoride, and isolated individual PAH compound detections above ESVs.

The north drain discharge is distinguished from other drain discharges by rainfall-based discharge observed during the investigation. Concentrations of site-related constituents in surface water discharged from the north drain during the so-called “first flush” of rainfall events were orders of magnitude greater than non-rainfall conditions. Several constituents including dissolved aluminium and fluoride were recorded orders of magnitude above their respective ESVs immediately upgradient of the outfall as well as beyond the mixing zone (100 m from the outfall). Further discussion of the implications of the first flush event are provided in **Section 5.4.3**.

Drain maintenance and clearing of tidal deposition downgradient of the drain outfalls occur frequently – namely the north and west drains. Clearance within the drains (upgradient of the weir) occurs less frequently at a rate of every 5 years in the south drain and every 3 years in the west drain. The north drain has not been cleared upgradient of the weir within the last 25 years. At the time of preparing this report, ES records indicate that the NZAS drain mouth areas have been cleared four times in 2023. These clearings occurred between the initial CMA investigation in January/February 2023 and the May 2023 sampling. The frequent redistribution of depositional sediment from the drains that occurred in early 2023 is likely to have removed or dispersed the sampling locations that were assessed during the initial CMA investigation. Additional surface water and pore water samples were collected in May 2023 following intermittent clearing work. The results of the supplemental sampling and implications of the NZAS clearing activities in each drain area is summarised in the sections below.

5.5 Bluff Harbour – North Drain

5.5.1 North Drain Setting

The north drain comprises a series of straight channels that stretch back into the north area of the smelter and as described in **Section 3**, it has the largest catchment of the three stormwater drains (estimated to comprise an area of approximately 26 ha). A drainage weir and separator arrangement is located approximately 150 m upstream from the drain outfall and is set within an incised channel (estimated to be 5 m deep). The drain discharges onto the beach and foreshore and is bounded either side by foredunes. Photographs of the north drain location are shown in Photographs 21, 22, 23, 24, 25 and 26 presented in **Appendix C**.

The north drain discharges Site-related process and stormwater from areas that include the pot-rooms, dry scrubbers and carbon rodding area, and compressor house # 2. The north drain also contains stormwater and process water from the northern part of the power supply, reduction lines, fume scrubbing area, north and west side of the change house. It has been reported that water received by the north drain is likely to contain fluoride and particulates (including alumina dust) (GHD, 2021c).

The north drain sampling location typically comprises a low energy (inner harbour) beach/tidal flat environment. This environment can transition to a higher energy environment based on weather conditions. Surface water flow was consistently observed from the drain during the course of the January/February 2023 and May 2023 sampling activities, with the drain depth/flow appearing to be primarily dependent on the tidal state, with increased flow observed during and immediately following a rainfall event. The tidal flats were exposed approximately 150 m from the drain discharge point at low tide.

Sediment samples were collected via cores from the shallow beach leading into tidal flats and the tidal flat. Sediment comprised sand and gravel with particle size distribution analysis on selected samples recording an average of >53% weight/weight >2 mm sized sediment. The sediments contained very little organic material (with the exception of sample NOD-SE-04-0.1-0.5 cm (TOC of 27%) and sample NOD-SE-05-0.1-0.5 cm [NOD of 6.3%]), with TOC results typically less than 0.6%. Cawthron (2005) mapped this area of Bluff Harbour as gravel field, with the CMA sampling confirming the documented mapping. The tidal flat area was hard packed during the early 2023 sampling event. During additional sampling in May 2023, the drain areas from the discharge point and over 100 m into the tidal zone had had been mechanically cleared/opened (by excavator) with sediment appearing to have been pushed to the sides of the drain and spread out across the tidal flats within the mid to low tide zone, and surface sediment very soft underfoot (**Appendix C**).

Stockpiled materials (coarse sand/gravel) understood to result from historical cleaning events downgradient of the drain outfall were present against the bank immediately north and south of the drain. Dark grey/black staining was observed in sediments along and adjacent to the drain mouth (extending out into the CMA and laterally in both directions [west and east] from the drain mouth). The beach at this location abuts onto a vertical bank, with soil samples collected from surface at the top of bank, elevated a few metres above the beach/tidal flat area. Evidence of marine life (invertebrates [crabs], snails, and fish) were observed during both the January/February and May 2023 sampling events.

A significant increase in surface water flow was observed in the north drain during a ‘first flush’ event on 2 February 2023 (**Section 4.5**), with a freshwater lens recorded on top of seawater and extending over 100 m from the drain outfall discharge during this event.

5.5.2 North Drain Investigation Results

Discharge of Site-related surface water and sediment contamination was documented in the DSI (GHD, 2021c) and the supplemental EHS Support work undertaken in early 2022 also documented elevated contaminant concentrations in the drain (water and sediment). The conditions documented during the CMA assessment were similar to and expand on the earlier studies.

The CMA assessment results are presented in following attached figures:

- **Figure 13a** and **13b** – Solid matrices (soil and sediment).
- **Figure 13c –** Aqueous matrices (surface water and pore water).
- **Figure 13d** – May 2023 resampling event.
- **Figure 22** – Aqueous matrices along the line of the sampling stations.
- **Figures 23 – 27** – Aqueous matrices shown schematically.

The distribution of Site-related constituents within the receiving environment is observed through the north drain drainage sequence (from the outfall to the edge of the consented mixing zone and beyond) and appears to occur principally due to the discharge of stormwater. Stormwater discharge from the north drain carries total and dissolved constituents from the Site, which have accumulated in sediment. The area sampled, particularly close to the drain outfall, is likely to have been disturbed by the NZAS maintenance activities.

A "first flush" stormwater event was monitored during the CMA assessment. The results from this event are detailed on **Figure 13c** (attached) and the results are described separately in **Section 5.4.3**.

The media contamination downgradient of the drain outfall is characterised as follows.

5.5.2.1 Surface Water

The surface water is characterised by concentrations of aluminium, boron, copper, and fluoride yielding HQ's above 1. Concentrations of arsenic, cadmium, cobalt, manganese, nickel, and zinc were recorded below their respective ESVs, but all above background (i.e., EF>1). The contaminant concentrations during normal flow/discharge conditions (non-storm event) were reasonably well mixed within the water column within the receiving environment (as defined by the bottom and top of water column concentrations – both for Site derived contaminants and chloride [indicative of marine water]).

The key ESV exceedances within the surface water were as follows (and shown schematically in **Figures 22-27**):

- Aluminium exceedances of the ESV were noted extending from the drain outfall out to sample station NOD-4 (concentration of 0.09 mg/L – some 100 m from the drain outfall; **Figure 23**).
- Copper exceedances of the ESV were recorded extending to sample station NOD-5, yielding a maximum concentration of 0.005 mg/L (HQ's of 3.8 for copper at NOD-05, respectively; **Figure 25**).
- Fluoride above the ESV was recorded at the drain outfall (maximum 2.04 mg/L, HQ = 1.4; **Figure 26**).

5.5.2.2 Sediment

The north drain receiving environment is a low energy environment and allows for the accumulation of sediment discharged from the north drain throughout the drainage receiving environment. The CMA investigation suggests that the bulk of the sediment is likely to be discharged into wider Bluff Harbour (given the low % of fine-grained sediment in the immediate area of the north and west drain outlets).

The concentration of Site-related constituents in sediment were typically greatest near the outfall of the drain and reduced with distance into the foreshore area. There was an increase in the fluoride sediment concentrations at sample stations NOD-04 and 05 (100 m and 125 m from the drain outfall), which may be influenced by a combination of groundwater fluoride and disturbance of the sediments by NZAS.

ESV exceedances of arsenic, cadmium, lead, nickel, and zinc were recorded at the drain outfall (NOD-01 at surface). Exceedances of nickel in the surface sediments persisted to monitoring station NOD-05 (125 m downstream of the drain outfall).

Additional exceedances of ESVs in sediment in the north drain include total PAHs and select PAH compounds. The PAH sediment contamination was generally confined to the surface sediment (down to a depth of 0.1 m) and in the immediate drain outfall area. The concentration of total PAHs (the detected sum of the USEPA priority list of 16 PAHs) exceeded the ESV in the surface sediment of the north drain outfall and the 100 m location at NOD-04.

Select north drain sediment samples were also analysed for PCBs, dioxin/furans, and TPH given the nature of the catchment (i.e., potential contaminant load) that discharges into the drain (both historically and currently). Non-detect concentrations of PCBs and TPH were recorded in all samples tested. Dioxin-like PCBs were detected in north drain sediment. The dioxin and furan analysis yielded detectable concentrations. An assessment of the dioxin and furan results is provided in **Appendix J**.

5.5.2.3 Pore Water

The north drain outfall pore water is characterised by exceedances of ESVs of aluminium (**Figure 23**), arsenic (**Figure 24**), copper (**Figure 25**), cobalt, fluoride (**Figure 26**), and iron. Exceedances of ESVs were observed in pore water for boron, copper, and fluoride with exceedances for fluoride still being recorded 125 m from the drain outfall (sampling station NOD-05) and beyond the consented mixing zone. This situation is shown schematically in **Figure 22** (attached).

Exceedances of ESVs were noted within the north drain pore water as follows:

- Copper and fluoride concentrations yielded HQs >1 from the drain outfall (NOD-01) out to sample station NOD-05 (located 125 m from the drain outfall). In particular, fluoride concentrations of 8.89 mg/L and 4.22 mg/L, above the ESV, were being recorded 100 m and 125 m from the drain outfall, respectively (**Figure 25** and **Figure 26**).
- Aluminium concentrations with HQs > 1 were recorded from the north drain outfall extending to sample station NOD-04 (100 m from the drain outfall), with cobalt and iron yielding HQ values greater than 1 immediately downstream of the drain outfall (NOD-02; **Figure 23**).

5.5.2.4 Foreshore Soils

The foreshore soils typically recorded trace elements and PAHs at low concentrations and below the ESVs. A fluoride concentration of 210 mg/kg was recorded at one sample location (NOD-SO-03) which was the only COPEC recorded on the foreshore soils above the ESVs. The north drain foreshore soils yielded contaminant concentrations below the human health screening levels.

5.5.3 North Drain First Flush Investigation Results

First flush data from the north drain recorded high concentrations of constituents at or near the point of acute toxicity for select trace elements. This combined with more extensive sediment and pore water concentrations in and around the discharge location provides indications that impacts to ecological communities (presence and abundance as well as bioaccumulation) are potential concerns. Photographs from the first flush event (Photographs 27, 28, 29 and 30) and presented in **Appendix C**. First flush events have previously been documented by NZAS in the 2005 Drain Discharge Consent Application AEE, which cites a study by Bioresearches (1995) indicating that “fluoride concentrations increased significantly in the first flush wet weather samples” (NZAS, 2005a).

During the first flush event sediment was discharged from the north drain and deposited at each sample station in the north drain sequence. Surface water samples collected from the north drain during this event recorded constituents up to 100 m from the outfall at concentrations orders of magnitude greater than under normal baseline discharge conditions (**Table 7**; **Figure 13c, Figure 22 and 23**), in particular:

- Dissolved aluminium concentrations in surface water collected at TWC in NOD-04 (100 m from the outfall) were 19 mg/L and non-detect under first flush and baseline conditions, respectively (**Figure 23**).
- Fluoride concentrations in surface water collected at the TWC in NOD-04 were 23.4 mg/L and 0.95 mg/L during first flush and baseline conditions, respectively (**Figure 26**).
- Dissolved concentrations of copper, cobalt, and nickel in the first flush samples were observed to exceed their respective ESVs in north drain surface water 100 m from the outfall. Except for copper, these constituents did not exceed their respective ESVs under baseline conditions, further illustrating the potential risk associated with episodic precipitation-based discharge events.

The flushing effect observed at the north drain indicates that a source area for fluoride, aluminium, copper, cobalt, and nickel is present upgradient of this drainage feature.

5.5.4 North Drain Additional Sampling Investigation Results

Additional pore water and surface water samples were collected during May 2023 following a clearing performed downgradient of the drain outfall on the north drain. Clearing activities occur multiple times during the year in the drains. The 2023 clearings would have modified the environment that was originally sampled during the CMA investigation. A comparison to the initial CMA investigation results is presented in **Table 8** and **Table 9** for surface water and pore water, respectively. Data is presented spatially on **Figure 13d**. Photographs of the north drain area post the clearing work are presented in **Appendix C** (Photographs 33, 34, 35 and 36).

Pore water samples collected after the NZAS clearing activities were comparable for aluminium in resampled locations. Pore water copper and fluoride concentrations at the north drain outfall (NOD-01) in May 2023 were an order of magnitude less than samples collected during the initial CMA investigation sampling. Copper in pore water at NOD-04 (100 m downgradient) was not detected in the May 2023 sampling; however, it was detected above the ESV in the initial CMA sampling.

Trace method analysis for PAHs in pore water samples collected in May 2023 identified several PAH compounds that were detected above the ESV in pore water. Select PAH compounds are presented on **Figure 13d**.

The May 2023 surface water dissolved aluminium concentration at NOD-01 was nearly double the preliminary CMA investigation result. Surface water fluoride concentrations in the north drain outfall were below the ESV during the May 2023 sampling. There were no detections of PAH in surface water during the May 2023 sampling.

5.6 Bluff Harbour – West Drain

5.6.1 West Drain Setting

The west drain comprises a short length of straight channel (approximately 100 m in length) that is assumed to connect to the reticulated stormwater system in and around the carbon bake area. The west drain collects storm water and process water from the green carbon area, carbon bake area, reconstruction area, stores laydown area, change house, HFO and liquid pitch storage area, and administration building area. A drainage weir and separator arrangement is located at the start of the drain approximately 100 m upstream from the drain outfall and is set within an incised channel (approximately 5 m deep). The drain discharges onto the beach and foreshore that is bounded either side by foredunes. Waste concrete beams and mined dunnite rock have been placed at the mouth of the drain to reduce erosion.

The west drain sampling area typically comprises a low energy (inner harbour) beach/tidal flat environment. This environment can transition to a higher energy environment based on weather conditions. Surface water flow was observed from the drain during the course of January/February 2023 and May 2023 sampling works, with the drain depth/flow appearing to be primarily dependent on the tidal state, with increased flow observed during a rainfall event.

The tidal flats were exposed over 100 m from the drain discharge point at low tide. Sediment samples were collected via cores from the shallow beach leading into tidal flats and the tidal flat. Sediment was comprised gravels with some sand and limited organic material (TOC <0.5 %). Cawthron (2005) mapped the downgradient Bluff Harbour area as gravel field, with the CMA sampling confirming the documented mapping. The tidal flat area was hard packed during the early 2023 sampling event.

During additional sampling conducted May 2023 the drain area from the high-water zone to the mid-tidal zone had been mechanically cleared/opened with sediment appearing to have been pushed to the sides of the drain or spread out across the beach/tidal flats within the mid tide area, and surface sediment soft underfoot. Apparently stockpiled materials (coarse sand/gravel), understood to result from historical drain cleaning events is present against the bank immediately north of drain. Dark grey/black staining was observed in sediments along and adjacent to the drain.

The beach at this location abuts onto a vertical bank (foredunes), with soil samples collected from surface at the top of bank, elevated a few metres above the beach/tidal flat area. Birds and evidence of marine life (invertebrates [crabs], snails, fish) were observed during the sampling events.

Photographs of the west drain area post the clearing work are presented in **Appendix C** (Photographs 14 through to 20).

5.6.2 Investigation Results

Discharge of Site-related surface water and sediment contamination was documented in the DSI (GHD, 2021c) and the supplemental EHS Support work undertaken in early 2022 also documented elevated contaminant concentrations in the drain (water and sediment). CMA investigation sampling occurred in the west drain during a period of light but sustained precipitation. The high energy conditions in the receiving environment (large waves) were likely responsible for greater proportion of mixing than would be expected during baseline conditions of discharge (i.e., non-precipitation event).

The results are presented in following attached figures:

- **Figure 14a** and **14b** – Solid matrices (soil and sediment).
- **Figure 14c** – Aqueous matrices (surface water and pore water).
- **Figure 14d** – May 2023 resampling event.
- **Figures 23 – 27** – Aqueous matrices shown schematically.

The distribution of Site-related constituents within the receiving environment is observed through the west drain drainage sequence (from the outfall to the edge of the consented mixing zone and beyond) and appears to occur principally due to the discharge of stormwater and site-related process water. The area sampled, particularly close to the drain outfall, is likely to have been disturbed by the NZAS maintenance activities.

The media contamination downgradient of the drain outfall is characterised as follows:

5.6.2.1 Surface water

The surface water in the west drain is characterised by concentrations of aluminium, boron, copper, fluoride, iron, and zinc exceeding their respective ESVs and yielding HQ's above 1. Concentrations of arsenic, manganese, and nickel were recorded below their respective ESV, but above background (i.e., EF>1). The concentrations recorded from samples collected during investigation activities were well mixed within the water column (as defined by the TWC and BWC concentrations – both for Site derived constituents and chloride, indicating the mixing of ocean water and less saline water being discharged from the drain). Samples were collected in the west drain during a period of light, but continuous rainfall. The resulting receiving environment was subjected to high energy wave fluctuations, which could serve as the primary mechanism for mixing.

The key ESV exceedances within the surface water were as follows:

- Aluminium, boron, copper, fluoride, iron, and zinc exceedances of the ESVs were noted extending from the drain outfall out to sample station WOD-5 (yielding maximum concentration of 0.76 mg/L, 6 mg/L, 0.01 mg/L, 1.4 mg/L, 1.1 mg/L, and 0.014 mg/L –100 m from the drain outfall, respectively; **Figure 23**, **Figures 25-27**).
- Fluoride above the ESV was recoded at the drain outfall (maximum 2.87 mg/L). **Figure 22** (attached) presents the aqueous fluoride concentrations along the line of the sampling stations.

5.6.2.2 Sediment

The sediment contaminant concentrations were typically greatest at the drain outfall and concentrations were observed to decrease with distance from the outfall into the foreshore area. ESV exceedances of fluoride were recorded in the sub-surface (0.1-0.5 m depth) and deep (0.5-1 m depth) sediment samples at station WOD-04 (75 m from the drain outfall) – yielding a maximum concentration of 460 mg/kg). PAH ESV exceedances extended out to sample station WOD-04 (75 m from the drain outfall). Trace element concentrations above background, yielding EFs >1, were recorded for cadmium and zinc.

Select west drain sediment samples were also analysed for PCBs, dioxin/furans, and TPH given the nature of the catchment (i.e., potential contaminant load) that discharges into the drain (both historically and currently). Non-detect concentrations of PCBs and TPH were recorded in all samples tested. Dioxin-like PCBs were detected in West Drain sediment. The dioxin and furan analysis yielded detectable concentrations. An assessment of the dioxin and furan results is provided in **Appendix J**.

5.6.2.3 Pore Water

The pore water in the west drain is characterised by elevated concentrations of copper, iron, and zinc with HQ>1 values recorded in the drain outfall. HQ values >1 for copper and iron were still being recorded 100 m from the drain outfall (sampling station WOD-05).

Exceedances of ESVs were noted within the west drain pore water are as follows:

- Copper, iron, and zinc concentrations yielded HQs >1 at the drain outfall (WOD-01) with concentrations observed to decrease towards sample station WOD-05 (located 100 m from the drain outfall). Boron in pore water slightly exceeded the reference value 25 m from the outfall (WOD-02).
- Iron and copper concentrations with a HQ>1 were recorded extending to sample station WOD-05 (100 m from the drain outfall).

5.6.2.4 Foreshore Soils

The foreshore soils typically recorded trace elements at low concentrations and below the ESVs. Trace concentrations of individual PAHs were recorded in both foreshore soil samples, with both the LMW and HMW ESVs being exceeded (maximum concentrations of 60.6 mg/kg and 3.46 mg/kg being recorded, respectively). The west drain foreshore soils yielded contaminant concentrations below the human health screening levels.

5.6.3 West Drain Additional Sampling Investigation Results

Additional pore water and surface water samples were collected during May 2023 following a clearing downgradient of the west drain outfall. As described above, clearing activities occur multiple times during the year in the drains. The 2023 clearings would have modified the environment that was originally sampled during the CMA investigation. A comparison to the initial CMA investigation results is presented in **Table 8** and **Table 9** for surface water and pore water, respectively. Data is presented spatially on **Figure 14d**.

Pore water samples collected after the NZAS clearing activities were comparable for aluminium in resampled locations (non-detect; however, at different detection limits). Pore water copper concentrations at the west drain outfall (WOD-01) in May 2023 were an order of magnitude less than samples collected during the initial CMA investigation sampling. Copper in pore water at WOD-04 (75 m downgradient) was not detected in the May 2023 sampling; however, it was detected above the ESV in the initial CMA sampling at WOD-05 (100 m from the outfall). Fluoride was detected above the ESV in pore water sampled from WOD-01 (4.26 mg/L), however was detected below the ESV in the initial CMA sampling (0.7 mg/L).

Trace method analysis for PAHs identified several PAH compounds that were detected above the ESV in pore water in each of the May 2023 sampled locations. Select PAH compounds in exceedance are shown on **Figure 14d**.

The May 2023 surface water trace element concentrations (including aluminium, copper, and fluoride) at WOD-01 were orders of magnitude less than the preliminary CMA investigation results. Surface water fluoride concentrations in the north drain outfall were above the ESV during the initial CMA sampling but were observed below the ESV in samples collected during the May 2023 sampling. There were detections and ESV exceedances of individual PAHs in surface water during the May 2023 sampling at WOD-01 in both the TWC and BWC locations.

5.7 Bluff Harbour – South Drain

5.7.1 South Drain Setting

The south drain discharges into what is believed to be part of a natural wetland that lies south of the jetty/conveyor (as noted in **Section 3**). The drain is approximately 0.5 km long and runs along the south side of the site, with the weir/separator arrangement lying southwest of the alumina store.

The distance from the weir to the drain outfall that discharge onto the beach/foreshore is approximately 300 m and the drain outfall is bounded either side by foredunes.

The south drain sampling location is typically a low energy (inner harbour) beach/tidal flat environment. This environment can transition to a higher energy environment based on weather conditions. Bedrock outcrops within the tidal area west of the drain location. No surface water flow was observed from the drain during the January/February 2023 or May 2023 sampling events. The tidal flats were exposed over 100 m from the drain discharge point at low tide. Photographs of the south drain area are presented in **Appendix C** (Photographs 11 and 12).

Sediment samples were collected via bores in the tidal flat area and comprised hard packed fine gravel at surface, with gravels with sand recorded at depth, close the discharge point. Limited organic material was recorded within the sediment (TOC <0.5%). Cawthron (2005) mapped the downgradient Bluff Harbour area as gravel field grading to firm sand and mud, with the CMA sampling confirming the documented mapping. The south drain beach / tidal flat area abuts onto a vertical bank, with soil samples collected from surface at the top of bank, elevated a few metres above the beach/tidal flat area.

Evidence of marine life (invertebrates [crabs], snails, fish) were observed during the sampling event.

5.7.2 *Investigation Results*

Discharge of Site-related surface water and sediment contamination was documented in the DSI (GHD, 2021c) and the EHS Support work undertaken in early 2022 also documented elevated contaminant concentrations of site related constituents in the receiving environment of the drain (water and sediment). CMA investigation sampling occurred during a period when the south drain was hydraulically disconnected from the receiving environment (i.e., no flow from the south drain was observed). The south drain does not likely exhibit direct connectivity to the receiving environment under baseline conditions (i.e., no precipitation or atypical discharge occurring).

The results are presented in following attached figures:

- **Figure 15a** and **15b** – Solid matrices (soil and sediment).
- **Figure 15c** – Aqueous matrices (surface water, pore water, and apparent groundwater seep).
- **Figure 15d** – May 2023 resampling event.
- **Figures 23 – 27** – Aqueous matrices shown schematically.

The distribution of Site-related constituents within the receiving environment was not observed as clearly in the south drain as it was in the north or west drain. The lack of direct connectivity also suggests the influence of other site related discharge (i.e., west drain discharge or discharge from the landfill) that may be observed in the mixing zone of the south drain.

GHD as part of the NZAS 2023 landfill consent application (GHD, 2023) collected surface water, sediment, and beach groundwater (similar to the EHS Support pore water samples) from sample stations close to the south drain outfall (**Appendix K**). The GHD sampling was not as comprehensive as the EHS Support work undertaken in this area, while GHD tested for a wider range of determinants. The GHD work recorded similar contaminant concentrations to those recorded by EHS Support. Of note was the PFAS testing which recorded compounds below the LORs for sediment and beach groundwater and surface water. GHD also collected a south drain surface water sample (exact sample location is unknown) which recorded fluoride and aluminium concentrations of 4.8 mg/L and 1.97 mg/L, respectively which are above the ESVs.

The media contamination downgradient of the drain outfall is characterised as follows:

5.7.2.1 Surface water

The surface water in the south drain is characterised by concentrations of boron and copper exceeding their respective ESVs in at least one location and yielding HQ's above 1. Concentrations of aluminium and arsenic were recorded below their respective ESV, but above background (i.e., EF>1). The concentrations recorded from samples collected during investigation activities were well mixed within the water column (as defined by the TWC and BWC concentrations – both for Site derived constituents and chloride). Chloride concentrations of surface water samples in the south drain mixing zone were approximately at background ocean concentrations of chloride, further highlighting the lack of a fresh water source due to a lack of connectivity of the south drain to the receiving environment.

The key ESV exceedances within the surface water were as follows (see **Figures 23-27)**:

- Boron exceedances of the ESVs were noted extending from the drain outfall out to sample station SOD-4. Surface water boron concentrations exceeded the ESV at each station in both TWC and BWC locations.
- Copper was detected and exceeded the ESV in one location in the south drain (SOD-02).

5.7.2.2 Sediment

The sediment contaminant concentrations were typically greatest at the drain outfall and concentrations were observed to decrease with distance from the outfall into the foreshore area. ESV exceedances were only observed at south drain station SOD-03, approximately 60 m from the drain outfall. An ESV exceedance of fluoride was recorded in the sub-surface (0.1-0.5 m depth) sediment sample at station SOD-03 – yielding a maximum concentration of 570 mg/kg). PAHs were only detected at sample station SOD-03 in the surface interval with a PAH ESV exceedance at sample station SOD-03 in the surficial layer (0-0.1 m). Trace element concentrations above background, yielding EFs >1, were recorded for cadmium and zinc.

Select south drain sediment samples were also analysed for PCBs, dioxin/furans, and TPH given the nature of the catchment (i.e., potential contaminant load) that discharges into the drain (both historically and currently). Non-detect concentrations of PCBs and TPH were recorded in all samples tested. Dioxin-like PCBs were detected in South Drain sediment. The dioxin and furan analysis yielded detectable concentrations. An in-depth assessment of the dioxin and furan results is provided in **Appendix J**.

5.7.2.3 Pore Water

The pore water in the south drain is characterised by elevated concentrations of aluminium, boron, iron, and zinc. Exceedances of ESVs were noted within the south drain pore water are as follows:

- Aluminium, boron, iron, and zinc concentrations yielded HQs >1 at the drain outfall (SOD-01) with concentrations observed to decrease towards sample station SOD-04 (located 100 m from the drain outfall).

5.7.2.4 Apparent Groundwater Seep

An apparent groundwater seep ("seep") was also noted flowing from the beach mid-way between the south and west drains and this was sampled during the CMA assessment (**Figure 15c**, attached, and Photograph 11 in **Appendix C**). Water quality parameters were recorded for the water flowing from the bank and a sample was collected for analysis.

The seep recorded a fluoride concentration of 1.56 mg/L (above the ESV and ANZECC 80% equivalent). The chloride concentration in the seep was 350 mg/L, which is above the chloride concentrations recorded in wells I_MW_B1 and E_MW_B7 (52 mg/L and 97 mg/L, respectively and also elevated relative to groundwater) but below a typical sea water concentration of about 19,000 mg/L. The seep recorded trace element concentrations below the laboratory limits of reporting (**Table 10**).

5.7.2.5 Foreshore Soils

The foreshore soils typically recorded trace elements at low concentrations and below the ESVs, except for fluoride and zinc. Trace concentrations of individual PAHs were recorded in both foreshore soil samples, with both the LMW and HMW ESVs being exceeded (maximum concentrations of 314 mg/kg and 26.55 mg/kg being recorded, respectively). The south drain foreshore soils yielded contaminant concentrations below the human health screening levels, except for PAHs (recording a BaP TEQ above the screening value).

5.7.3 South Drain Additional Sampling Investigation Results

Additional pore water samples were collected during May 2023. A comparison to the initial CMA investigation results is presented in **Table 8**. Data is presented spatially on **Figure 15d**.

Results from pore water samples collected in May were distinct from the initial CMA sampling results. Pore water copper concentrations from samples collected in May 2023 were detected in both locations whereas the initial CMA investigation samples were non-detect at the reporting limit. Additionally, fluoride concentrations in the most upgradient station (SOD-01) were observed above the ESV (3.1 mg/L). There is no comparable fluoride data for this station from the CMA investigation.

There were no detections of PAHs in south drain pore water using trace method analysis.

5.8 Bluff Harbour Drains Groundwater

The original SAP for the CMA investigation identify key NZAS groundwater monitoring wells adjacent to the CMA sample locations that were to be sampled. However, because NZAS was undertaking their own CMA/groundwater assessment, EHS Support's ability to assess the groundwater conditions adjacent to the three drains was constrained by groundwater monitoring well access. During the course of the CMA assessment groundwater monitoring was undertaken in the following two groundwater monitoring wells (with access provided by NZAS):

- Monitoring Well I_MW_B1 – located midway between the north and west drain. The well is located inland from the drains, lying approximately 250 m and 400 m from the weir structures for the north and west drains, respectively.
- Monitoring Well E_MW_B7 – located close the west drain. The well is located approximately 100 m from the coast and approximately 50 m from the west drain weir structure.

The groundwater monitoring data for the two wells is summarised as follows:

- Well I_MW_B1 – groundwater levels were typically recorded at approximately 3.5 m below top of casing (BTOC) and showed some tidal influence (but not as pronounced or cyclical as would be expected). Groundwater EC fluctuated between approximately 275 and 325 µS/cm.

- Well E_MW_B7 – groundwater levels were typically recorded at approximately 3.4 m BTOC and showed minor tidal influence (potentially dampened by the presence/head of water held within the west drain). Groundwater EC fluctuated between approximately 275 and 325 µS/cm, with groundwater electrical conductivity measurements showing good evidence of tidal influence. Increases in groundwater EC were often noted following rainfall events (increasing from 300 to 325 µS/cm).

The aluminium concentrations recorded in the two wells exceeded the groundwater ESVs, yielding concentrations of between 0.63 and 1.6 mg/L. The concentration of total iron in in I_MW_B1 was also above the groundwater ESV (0.3 mg/L), yielding a concentration of 67 mg/L. Dissolved iron in I_MW_B6 was recorded as 61 mg/L.

Trace element concentrations of arsenic, chromium, copper, fluoride, manganese, vanadium, and zinc were above laboratory detection limits in the groundwater sampled (but not necessarily in both wells).

Aqueous sub-surface samples were collected in the north and west drain beach areas under low tide (no-overlaying surface water) conditions (**Figure 19** and **Figure 20**). These samples were thought to be representative of groundwater fluxing into the marine environment. The chloride concentrations measured suggest that the north drain samples were likely to be sea water (yielding chloride concentrations of 20,000 to 21,000 mg/L), while the samples collected from the west drain recorded chloride concentrations of 6,900 and 11,000 mg/L indicating that the water sampled likely comprised co-mingled groundwater, sea water, and pore water. As such, constituent concentrations in these samples were conservatively screened against the 95% ESVs (**Table 10**).

The detection of several constituents including fluoride, aluminium, manganese, nickel, and zinc in the sub-surface aqueous samples collected suggest contributions from more than one source including upgradient groundwater (**Table 10**, attached). Of particular note was the fluoride concentration recorded at sample location NOD-4, approximately 100 m downstream from the mouth of the north drain that recorded a concentration of 9.37 mg/L (yielding a HQ >1).

Similarly, as described in **Section 5.7.2.4**, a groundwater seep was noted between the west and south drains that also suggests a flux of groundwater contamination into Bluff Harbour.

5.9 NZAS Landfill Overview – West Landfill (WLF) and East Landfill (ELF)

For the purpose of the CMA investigation, the NZAS landfill assessment area was subdivided into two assessment areas: the west landfill (WLF – Bluff Harbour) and east landfill (ELF – Foveaux Strait). The landfill assessment areas are documented locations for local fish and shellfish gathering activities and are therefore considered important pathways where both human health and ecological impacts may occur.

Contaminant concentration profiles between the WLF and ELF varied across the sampled media. Contaminant concentrations for sediment, surface water, and pore water samples collected as part of the CMA investigation were typically greatest in the WLF sample stations (**Figures 16a-16c**) compared to the ELF area (Foveaux Strait beach). However, potential limitations in the investigation scope (in particular the ability to target the zone of groundwater discharge to the marine environment [within Foveaux Strait]) means higher contaminant concentrations may occur within the Foveaux Strait beach area than those recorded during the CMA assessment.

The initial results suggest that the risk to aquatic receptors in the receiving environment may be greatest in the lower energy environments within Bluff Harbour; however, given that the majority of the landfill leachate contamination plume flux discharges to the east to Foveaux Strait (GHD, 2023; Woodward-Clyde 1994), further work is warranted to determine the exact nature of the discharge (i.e., emergence of contamination in the receiving environment). This assessment is currently being performed by NZAS/GHD as part of the landfill consent application.

The key contaminants of concern noted from the landfill reflect the composition of the waste disposed of within the landfill and can be characterised as follows:

Trace element concentrations in groundwater from the ELF monitoring wells exceeded ESVs for several constituents including fluoride, aluminium, and iron (**Table 1**). Concentrations of trace elements in exceedance of ESVs were proportional to data provided by NZAS in the 2023 landfill consent application and historical monitoring results (**Appendix K**; GHD, 2023).

PAHs were primarily detected in the east landfill soil and west landfill sediment reflecting the nature of the activities that occur with the catchment for this portion of the landfill including run off and aerial deposition from landfill stages associated with storage of PAH containing materials including refractory bricks, and process-related oils disposed of in the landfill (NZAS, 2023).

As of the publication of this report, NZAS and GHD have submitted a 5-year consent application for the landfill (GHD, 2023). The landfill consent application contained a revised hydrologic conceptual site model (HCSM) for the NZAS landfill and surrounding areas. The HCSM provided additional insight into the dynamics of the landfill groundwater contamination plumes and concentrations of COPECs in various media in the receiving environment. A summary of this information is incorporated (where appropriate) into the findings below.

5.9.1 NZAS Landfill Setting

The NZAS landfill sits on the western end of Tiwai Peninsula and comprises multiple cells that have been filled with site generated wastes that have been closed, levelled, and contoured in stages (NZAS, 2023). The landfill is effectively comprised of a series of mono-cells each containing different wastes. The cells are unlined and only two cells have been completed with an engineered cap. To the east of the landfill lies the Haysoms Dross Landfill Cell (**Section 2.1**) which comprises a separate landfill equipped with an engineered cap.

A registry of the waste contained in each stage is provided in the NZAS 2023 Landfill consent application (NZAS, 2023) and is summarised in **Section 3.2**. Leachate generated by the landfill is a documented source of contamination to the downgradient areas (GHD, 2023; URS, 2009), with the majority of the leachate fluxing into Foveaux Strait and a minor volume of leachate discharging into Buff Harbour.

The WLF and ELF sampling locations are characteristic of the conditions within Bluff Harbour and along the Foveaux Strait beach, respectively. The WLF area sampling area is generally a low energy beach/tidal flat environment with the facility wharf and conveyor immediately north of the beach. Bedrock outcrops within the west beach area and significant outcrops occur at the southwest end of the ELF beach (i.e., Tiwai Point). The ELF area sampling location comprised a moderate to steeply sloping coastal beach (intermediate energy environment). Photographs 8 and 10 in **Appendix C** show the ELF and WLF sampling areas.

5.9.2 *Investigation Results*

The results from the CMA assessment of the WLF and ELF areas are presented in following attached figures:

- **Figure 16a** and **16b** – Solid matrices (soil and sediment).
- **Figure 16c** – Aqueous matrices (surface water and pore water).
- **Figures 23 – 27** – Aqueous matrices shown schematically.

The media contamination within the WLF and ELF receiving environments are characterised as follows:

5.9.2.1 Surface Water and Pore Water

The surface water within the ELF sampling area (Foveaux Strait) generally recorded concentrations of most COPECs below the LOR. Fluoride and chloride concentrations were typical of ocean water (suggesting that the elevated fluoride concentration groundwater contamination discharging from the landfill is not occurring at surface within the area of the sampling locations). Trace concentrations of arsenic (maximum concentration 0.001 mg/L) were recorded in the surface water. The pore water samples yielded similar contaminant concentrations to the surface water samples. As a result, there were no exceedances of the ESVs in either surface water or pore water.

The GHD 2023 investigation work (**Appendix K**; GHD, 2023) recorded similar contaminant concentrations at their Foveaux Strait sample stations for surface water and beach groundwater (similar to the EHS Support pore water samples) to the EHS Support investigation results. The GHD investigation work was spatially more extensive, and the laboratory testing covered an expanded constituent list. Some of the differences in concentrations recorded between EHS Support and GHD work can be potentially attributed to differences in laboratory precision. Trace concentrations of barium, boron, lithium, and molybdenum were recorded in the GHD surface water samples (**Appendix K**; GHD, 2023).

Generally, constituents measured in surface water and pore water samples collected from within Bluff Harbour (WLF) yielded greater concentrations than Foveaux Strait. This suggests there is less dilution occurring within the Bluff Harbour environment (lower energy environment) and that the discharge of groundwater contamination into the harbour is likely occurring relatively close to the foreshore. Fluoride concentrations were typical of marine waters except for the pore water sample collected from sample station WLF-02 which recorded a concentration of 1.45 mg/L (just below the ESV). Boron concentrations in both surface water and pore water at sample station WLF-01 were above the reference value (concentrations ranging between 5.6 mg/L and 7.1 mg/L).

As with the ELF area, the GHD investigation work for the WLF area was more spatially and analytically comprehensive than the investigation activities completed by EHS Support. The GHD 2023 investigation recorded compounds in surface water and beach groundwater above the LORs and ESVs (**Appendix K**; GHD, 2023), including:

- Aluminium (dissolved) – beach groundwater recorded a maximum concentration of 1.97 mg/L.
- Boron – surface water and beach groundwater recorded maximum concentrations of 5.08 mg/L and 4.69 mg/L, respectively.
- Copper – surface water and beach groundwater recorded maximum concentrations of 0.0042 mg/L, and 0.006 mg/L, respectively.
- Fluoride – beach groundwater recorded a maximum concentration of 10.9 mg/L.

A number of other compounds were recorded by GHD at detectable concentrations for which ESVs were not developed by EHS Support, including molybdenum, and vanadium.

5.9.2.2 Sediment

The ELF sediment samples comprised surficial predominantly coarse beach sands with limited organic material (reported TOC up to 3.3 %). Because of sampling constraints (i.e., high energy beach environment), only near surface (surface to 0.1 m depth) samples were collected. Minimal bird and marine life were observed during sampling works.

Sediment contaminant concentrations were typically very low in the ELF sediments, with all COPECs (where detected) recording EF's less than or just above 1 (yielding similar concentrations to background). Of note was the sediment pH which ranged between 9 and 9.2 (alkaline) at all three sediment sampling stations.

The "CMA" sediment samples collected by GHD as part of the landfill consent application on Foveaux Strait beach (ELF area) recorded similar COPEC concentrations to the EHS Support investigation results (GHD, 2023). GHD sediment samples were predominately collected at surficial intervals (0 m-0.1 m), with deeper sediment samples (0.1 m-0.5 m) at select sample stations. Some of the determinant concentration differences are likely to result from differences in precision between the two laboratories used. Higher sediment fluoride concentrations were recorded by GHD (maximum 1,400 mg/kg, recorded at 0.5 m depth) (**Appendix K**; GHD, 2023). Sediment pH results from the GHD investigation were approximately more neutral (6.9-8.3) than results from the EHS Support investigation. The reason for this pH variation is not apparent.

The EHS Support WLF sediment samples were collected via bores from the tidal flat area and comprised a mix of coarse and finer grained materials at surface. Sediment cores comprised sands with fine grained silt and peat (TOC up to 46%) layers. Particle size distribution analysis on two selected samples indicated less than 6% weight/weight (wt/wt) over 2 mm in size indicating generally finer grain deposition than observed in other assessment areas. Cawthron (2005) mapped the downgradient Bluff Harbour area as gravel field grading to firm sand and mud. The CMA sampling confirmed the documented mapping. Soil samples were collected inland from the beach, slightly elevated above the beach / tidal flat area. Evidence of marine life (invertebrates (crabs), snails, fish) were observed during the sampling event.

The concentration of Site-related constituents in the WLF sediment were typically greatest at depth (i.e., in the sub-surface and deep intervals). The WLF assessment area is a low energy environment and allows for the accumulation of sediment (acknowledging that the weather conditions can create a high energy environment).

ESV exceedances of fluoride and mercury were recorded in the west landfill area. Additional exceedances of ESVs in sediment in the west landfill include select PAH compounds. PAHs were detected primarily in the sub-surface and deep interval. WLF-02, located downgradient of potential overland flow paths from the landfill was observed to have the greatest concentration of PAH detections and exceedances. In particular dibenz(a,h)anthracene recorded a HQ of 105.

Select sediment samples from the WLF area were also tested for PCBs and TPH and the results yielded concentrations below the LORs (**Appendix H**).

The GHD sediment samples within the WLF area were collected in a similar manner as described above for the ELF area (GHD sediment samples were predominately collected at surficial intervals [0 m-0.1 m], with deeper sediment samples [0.1 m-0.5 m] at select sample stations). The GHD work recorded similar COPEC concentrations to the EHS Support investigation in the surface sediment samples with elevated concentrations (above the 80th percentile of GHD background) for fluoride and manganese recorded in two samples (**Appendix K**; GHD, 2023). Select WLF sediment samples were also analysed for PCBs and dioxin-like PCBs. Non-detect concentrations of PCBs were recorded in all samples tested. There were isolated detections of dioxin-like PCBs in the WLF sediment. A detailed assessment of these results is provided in **Appendix J**.

5.9.2.3 Foreshore Soils

The ELF foreshore soils typically recorded COPECs at low concentrations and below the ESVs, except for arsenic and fluoride which recorded maximum concentrations of 13 mg/kg and 570 mg/kg, respectively. Concentrations of individual PAHs were recorded in all foreshore soil samples, with both the LMW and HMW ESVs being exceeded (maximum concentrations of 72.2 mg/kg and 4.78 mg/kg being recorded, respectively).

The WLF foreshore soils typically recorded COPECs at low concentrations and below the ESVs, except for fluoride which recorded maximum concentrations of 210 mg/kg. Trace concentrations of individual PAHs were only recorded in one of the foreshore soil samples, with the LMW and HMW concentrations lying below the ESVs.

The landfill foreshore soils yielded contaminant concentrations below the human health screening levels except for a fluoride concentration recorded in one sample in the ELF area (570 mg/kg).

5.9.2.4 Landfill Groundwater

NZAS made available four groundwater monitoring wells within the landfill area for EHS Support to monitor during the CMA work, as listed below:

- Monitoring Well A63 – located north of the landfill and lying approximately 200 m east of the west landfill CMA sampling area and 300 m west of the south drain sampling area.
- Monitoring Wells A51, A53, and A56 – located within the foredune area (above Foveaux Strait beach) east and downgradient of the landfill.

The groundwater monitoring data for the wells is summarised as follows:

- Well A63 – groundwater levels were typically recorded at approximately 1 m BTOC and showed no real tidal influence. Groundwater EC was typically in the order of 520 µS/cm.
- Well A51 – groundwater levels were typically recorded at approximately 3.5 m BTOC and showed minor tidal influence. Groundwater EC fluctuated between approximately 520 and 640 µS/cm, with groundwater electrical conductivity measurements showing good evidence of tidal influence.
- Well A53 – groundwater levels were typically recorded at approximately 4.5 m BTOC and showed minor tidal influence. Groundwater EC fluctuated around 1,100 µS/cm, with groundwater EC measurements showing good evidence of tidal influence.
- Well A56 – groundwater levels were typically recorded at approximately 4 m BTOC and showed minor tidal influence. Groundwater EC reduced from approximately 1,700 µS/cm to 1,200 µS/cm over the monitoring period, with groundwater EC measurements showing good evidence of tidal influence.

The wells east of the landfill recorded elevated aluminium (maximum 2.7 mg/L), fluoride (maximum 19.2 mg/L), and iron (maximum 7.8 mg/L) concentrations and exceeded the 80% ANZECC equivalent criteria (**Table 4; Figure 21**). While Well A63 only recorded an iron concentration above the 80% ANZECC equivalent criteria.

5.10 SCL Pad (SCL) and Inalco (ISA)

As with the Foveaux Strait background location, the Inalco and SCL Pad CMA sampling areas comprised a moderate to steeply sloping coastal beach (sampling locations shared the same beach). Sediment samples comprised surficial predominantly coarse beach sands with limited organic material (reported TOC up to 3.3 %). Soil samples were collected from the rear foredune area elevated above water and sediment sampling locations. Minimal marine life was observed during sampling works. Photographs 5 and 6 in **Appendix C** show the SCL pad CMA area and Photograph 8 shows the Inalco sampling area.

5.10.1 Investigation Results

The Inalco area samples were collected downgradient (approximately 200 m) of the Inalco storage area, which contains the diesel trailer storage area, Inalco facility and bagged goods store, cooling stacks, SCL storage sheds, former external storage area, and former cell bottom/aluminium swarf and cathode bar laydown areas. Potential pathways associated with this area include leaching of soil contamination to groundwater, migration of contaminated soils or dusts via stormwater to the south drain and aeolian transport of dust and particulates.

The SCL pad is a known area of discharge of Site-related constituents including cyanide and fluoride (NZAS, 2021a). NZAS maintains a consented discharge of treated effluent from the effluent treatment plant into the Foveaux Strait. No wet material is currently stored in the SCL pad; however, there are documented historical discharges of SCL pad leachate. Groundwater monitoring of the SCL pad area is undertaken by NAZS and the contamination is managed by the capacity of the SCL pad area to dilute and attenuate concentrations of leachate naturally.

The results are presented in following figures by matrix and area. Attached figures by area and matrix are presented as follows:

Inalco Area (ISA):

- **Figure 17a** and **17b** – Solid matrices (soil and sediment).
- **Figure 17c** – Aqueous matrices (surface water and pore water).

SCL pad (SCL):

- **Figure 18a** and **18b** – Solid matrices (soil and sediment).
- **Figure 18c** – Aqueous matrices (surface water and pore water).

The distribution of Site-related constituents within the receiving environment is observed along the Foveaux Strait and is subjected to mixing from the high energy environment present. Distribution of constituents appears to occur principally due to the discharge of stormwater and groundwater from the Inalco Area and SCL Pad.

The media contamination downgradient of the assessment areas is characterised as follows.

5.10.1.1 Surface Water

There were no surface water ESV exceedances within Foveaux Strait and down gradient of the Inalco area and minimal exceedances of ESVs in the surface water from downgradient of the SCL Pad. Surface water ESVs for aluminium and boron were exceeded downgradient of the SCL Pad and concentrations of zinc was recorded below its respective ESVs, but above background in the SCL pad area (i.e., EF>1).

5.10.1.2 Sediment

There were no exceedances of ESVs in the sediment in the assessment areas along Foveaux Strait (Inalco or SCL Pad areas). Concentrations of arsenic and vanadium were recorded below their respective ESVs, but above background in both assessment areas (i.e., EF>1). Fluoride was observed below the ESV but greater than background in the SCL Pad area. Sediment PAH concentrations were below the LOR in both assessment areas.

5.10.1.3 Pore Water

There were minimal exceedances of ESVs in pore water from the assessment areas along Foveaux Strait. Pore water downgradient of the SCL Pad was observed to exceed the ESV for boron. Concentrations of zinc were recorded below their respective ESVs, but above background in the SCL Pad area (i.e., EF>1).

5.10.1.4 Foreshore Soils

The foreshore soils down gradient of the Inalco area typically recorded COPECs at low concentrations and below the ESVs, except for arsenic and LMW and HMW PAHs, recording maximum concentrations of 9.8 mg/kg, 30.1 mg/kg, and 3.02 mg/kg, respectively. Similarly, the foreshore soils down gradient of the SCL Pad typically recorded COPECs at low concentrations and below the ESVs, except for arsenic, fluoride and HMW PAHs, recording maximum concentrations of 8.5 mg/kg, 7,300 mg/kg, and 14.92 mg/kg, respectively. The Inalco area foreshore soils yielded contaminant concentrations below the human health screening levels, while the SCL pad area recorded an aluminium (12,000 mg/kg) and fluoride (730 mg/kg) concentrations above the risk screening values.

5.11 Inalco Area and SCL Pad Groundwater

One groundwater monitoring well (Well L_MW_B18) downgradient of the Inalco Area was monitored during the CMA work programme. The groundwater monitoring data for this well is summarised as follows:

- Groundwater levels were typically recorded at approximately 4.5 m BTOC and showed minor tidal influence. Groundwater EC fluctuated between 455 µS/cm to 475 µS/cm over the monitoring period. The groundwater EC monitoring showed evidence of tidal influence.
- Trace element concentrations of arsenic, boron, copper, fluoride, and iron above laboratory detection limits were recorded in the groundwater sampled from this well.

One groundwater monitoring well (Well 4-5) downgradient of the SCL Pad was monitored during the CMA work programme. The groundwater monitoring data for this well is summarised as follows:

- Groundwater levels were typically recorded at approximately 4 m BTOC and showed no real tidal influence. Groundwater EC declined from about 900 µS/cm to 500 µS/cm over the

monitoring period. The groundwater electrical conductivity monitoring showed evidence of tidal influence.
- Elevated aluminium concentrations were recorded that exceeded the groundwater ESV.
- Due to laboratory issues, fluoride was not re-analysed at this location and is therefore not discussed as part of these results.

6 CMA Results – Summary Discussion

The independent CMA assessment collected groundwater, surface water, pore water, sediment, and soil samples in the assessment areas downgradient from and adjacent to the NZAS aluminium smelter located on Tiwai Point. Co-located surface water, pore water, and sediment samples were collected within the assessment areas to provide multiple lines of evidence to evaluate ecological risk in the receiving environment (**Figure 2**). Pore water samples were collected at the same interval as surface sediment samples to better understand the potential risk to aquatic receptors for constituents without ESV in sediment (i.e., fluoride and aluminium). Samples were compared to the ESVs derived in **Appendix A**. Exceedances of ESVs varied by sample matrix and location. Discussion on the exposure conditions and identified COPECs in each environmental matrix and assessment area is provided in the sections below.

6.1 Smelter Domain Drains

6.1.1 Distribution of COPECs in the Mixing Zones

Site-related COPECs including fluoride, aluminium, and trace metals exceeded ESVs in sediment, surface water, and pore water in discharge areas downstream of each of the three drains. The frequency of detection and frequency of ESV exceedances were greatest downstream of the north drain. Under baseflow discharge conditions (i.e., normal operating conditions), exceedances of aluminium, fluoride, and other trace metals occurred in pore water and surface water immediately below the outfall and up to 100 m downgradient. Based on the frequency and magnitude of exceedances of the ESVs, risk to aquatic receptors in the drains is primarily driven by fluoride, aluminium, and select trace metals. This is based on the frequency and magnitude of exceedances of the ESVs in pore water, surface water, and surface sediment, where it is most likely that aquatic receptors will be exposed.

The north drain receiving environment is generally a low energy environment and allows for the accumulation of sediment discharged from the north drain throughout the drainage receiving environment. The CMA investigation suggests that the bulk of the sediment is likely to be discharged into wider Bluff Harbour (given the low % of fine-grained sediment in the immediate area of the north and west drain outlets). This was observed particularly during the first flush event when sediment was discharged from the north drain and deposited at each sample station in the north drain sequence. Surface water samples collected from the north drain outfall during the first flush event showed that COPECs were present up to 100 m from the outfall at concentrations orders of magnitude greater than under baseline conditions (**Table 7**; **Figure 13c**), in particular:

- Dissolved aluminium concentrations in surface water collected at TWC in NOD-04 were 19 mg/L and non-detect under first flush and baseline conditions, respectively.
- Fluoride concentrations in surface water collected at TWC in NOD-04 were 23.4 mg/L and 0.95 mg/L during first flush and baseline conditions, respectively.
- Dissolved concentrations of copper, cobalt, and nickel in the first flush samples were observed to exceed their ESVs in north drain surface water 100 m from the outfall. Except for copper, these constituents did not exceed their respective ESVs under baseline conditions, further illustrating the potential risk associated with episodic precipitation-based discharge events.
- The highly elevated concentration of aluminium and fluoride recorded during the first flush event in the north drain could cause acute effects and result in mortality from fluoride (fish and benthic invertebrates) and aluminium (benthic invertebrates).

The flushing effect observed at the north drain outfall indicates that a source area for fluoride, aluminium, copper, cobalt, and nickel is present upgradient of this drainage feature.

Aqueous sub-surface samples were collected in the north drain beach area under low tide (no-overlaying surface water) conditions at NOD-03 and NOD-04, 50 m and 100 m from the outfall, respectively (**Figure 19**). The detection of several constituents including fluoride, aluminium, manganese, nickel, and zinc in the sub-surface aqueous samples collected suggest the contributions from more than one source likely including sea water, pore water, and upgradient shallow groundwater (**Table 10** and **Figure 22**). As such, constituent concentrations in these samples were conservatively screened against the 95% ESVs (**Table 10**).

West drain surface water discharge concentrations of fluoride exceeded the ESV in both the TWC and BWC positions at the drain mouth and 75 m out from the drain mouth (with mixed concentrations above and below the ESV recording at the in between sampling stations). Dissolved aluminium concentrations in west drain surface water exceeded the ESV at each location within the drainage receiving environment (up to 100 m from the drain mouth). Dissolved concentrations of copper and zinc were observed to exceed their respective ESVs in the west drain surface water discharge, indicating the presence of a source area upgradient in the drainage feature. There was one detection and exceedance of a PAH compound observed across the Site. Benzo(a)anthracene at the TWC position of WOD-01 (outfall location) exceeded the ESV with a HQ of 222. This result aligns with the historical record of PAHs detected in the west drain.

Additional exceedances of aqueous ESVs include boron, copper, iron, and zinc in pore water collected at WOD-01 (west drain outfall location) and WOD-02 (25 m downgradient). Detections of these metals in the west drain were greater than background pore water (EF >1). Manganese concentrations in pore water were generally greater than surface water. The magnitude of difference in detections of manganese in pore water and not surface water suggests contributions from a different source, including upgradient groundwater. This is further substantiated by the concentration of manganese in sub-surface aqueous samples collected at the WOD-01 location under low tide (no-overlaying surface water) conditions (**Figure 20**). Fluoride, iron, aluminium, and zinc were also observed to exceed their respective ESVs in the sub-surface aqueous samples collected adjacent to WOD-01 and WOD-02.

Concentrations of fluoride in the south drain assessment area surface water were similar to background fluoride concentrations in the Awarua Bay background area with EFs less than or equal to 1. Exceedances of aqueous ESVs in the south drain included aluminium, cadmium, copper, and zinc. Dissolved copper exceeded the ESV in surface water at SOD-02 in the TWC position. South drain discharge dissolved copper was greater than background (EF >1). Most aqueous exceedances in the south drain discharge were observed in pore water. Based on the minimal discharge observed from the south drain outfall to the receiving environment, it is possible that the principal source of constituents in this assessment area is not the drain outfall and could be groundwater.

A groundwater seep was identified north of the south drain discharge. Water quality parameters were collected along with a seep sample to determine the potential source areas of this volume discharging directly to the CMA. Analytical results from the seep sample indicated fluoride concentrations above the ESV. The chloride concentration from the seep (350 mg/L) was less than observed ocean water (approximately 19,000 mg/L) suggesting that it was groundwater discharging from an upgradient area. As such, constituent concentrations in the seep sample were screened against the 80% ESVs (**Table 10**).

The south drain outfall exhibited minimal connectivity to the receiving environment during the field investigation under variable tidal conditions. It is likely that discharge from the south drain only occurs during precipitation events. There was continuous connectivity from the north drain and west drain to the receiving environment under variable tidal conditions (with these drains likely to be receiving a steady discharge of process water). Discharge was observed to flow from the west drain towards the south drain assessment area. Further work is recommended to constrain the effects of discharge events on the receiving environment, including:

- Quantifying the contributions of the south drain relative to the west drain discharge to the receiving environment of Bluff Harbour.
- Constraining the magnitude of COPEC discharge during flushing events within the receiving environments of the drains.

6.1.2 Fresh Water Lens

Surface water samples in the discharge areas from the drains were collected at two depths in the TWC and BWC to assess the potential for a freshwater lens to occur during discharge events. The presence of a freshwater lens in the drains has been documented in the application and AEE associated with the 2005 discharge consent for the drains (NZAS, 2005a). The AEE cites a report by Bioresearches (1995) that documented the presence of distinct, buoyant freshwater on the water surface and notes that the current consent requirements for sampling in the drains may not fully capture the presence of freshwater discharge from the drains in the receiving environment (NZAS, 2005b).

Chloride was used as a tracer to determine if there was a freshwater lens discharging from the drains into the mixing zone. Chloride concentrations in ocean water range from approximately 19,000 to 20,000 mg/L (Millero et al., 2008). There is not sufficient evidence to suggest an appreciable difference in concentrations from the top and bottom of the water column during normal operating conditions; however, there is evidence to suggest that during stormwater discharge events, a freshwater lens is present within the receiving environment mixing zone. A first flush surface water sample was collected immediately following a precipitation event in north drain.

Surface water collected upgradient from the north drain outfall had a chloride concentration of 36 mg/L. Surface water samples collected 100 m from the outfall immediately following a precipitation event had chloride concentrations of 3,600 mg/L and 20,000 mg/L at TWC and BWC, respectively. The difference between TWC and BWC chloride concentrations suggests the presence of a freshwater lens is occurring because of discharge from the drain. This variability in chloride concentrations was not observed during baseline conditions.

West drain surface water discharge samples collected during a precipitation event did not provide clear evidence that a freshwater lens was present throughout the mixing zone; however, this may in part be due to weather conditions at the time of sampling (strong onshore winds and waves present). Chloride concentrations in the west drain sequence ranged from 13,000 mg/L at the outfall to 20,000 mg/L at the edge of the mixing zone. The gradient from brackish water to marine water appears to occur within proximity of the outfall. Chloride concentrations are approximately representative of marine waters between 25 m and 50 m from the outfall.

It is likely that a freshwater lens is present within the mixing zone of the drains during greater than baseline discharges (with minimal wave action); however, under baseline conditions, there is not sufficient evidence to support the presence of a freshwater lens in the mixing zones of the drains.

6.1.3 Foreshore Soils

Soil samples were collected in the foreshore area upgradient of the smelter domain drains to better understand the potential pathways for Site-related constituents to discharge into the CMA. Soil samples targeted apparent areas of deposition from clearing activities downgradient of the drain outfalls and apparent overland flow paths.

Soil constituents in exceedance of ESVs were similar between all drains. LMW/HMW PAH compounds (as sum of detected PAH compounds) were observed to exceed the ESV for soils in the west drain and south drain. This is consistent with the understanding of Site-related activities in the upgradient areas of the foreshore. Fluoride was the only constituent observed to exceed the soil ESVs in the north drain. Fluoride and zinc were also observed to exceed the ESV in south drain soils. PAH sum exceedances of soil ESVs were the greatest in magnitude. The presence of exceedances of ESVs for fluoride, zinc, and PAHs suggests that there are potentially complete pathways from the Site to the CMA receiving environment foreshore areas.

Soil conditions met the narrative conditions outlined in **Appendix A** for aluminium, therefore aluminium concentrations in CMA assessment soils were compared to background aluminium concentrations. Aluminium concentrations were marginally greater than background aluminium concentrations in the drains; however, soil pH at these locations was within the narrative range for insolubility of aluminium in soils; therefore, there is minimal potential for risk associated with aluminium in soils in the foreshore area upgradient of the drains.

There are several constituents in soil that did not exceed or have a ESV in the foreshore area of the drains. Several of these constituents had concentrations greater than background concentrations. These constituents include arsenic, total chromium, cobalt, copper, iron, nickel, titanium, and vanadium. Further assessment is warranted to determine the potential for risk associated with these constituents with respect to environmental receptors.

The foreshore soils in the drains areas of the smelter complex were below the human health risk screening values, except for the PAHs within the south drain area.

6.2 Landfill

6.2.1 CMA Assessment Area

Co-located surface water, pore water, and sediment samples were collected from within the CMA of the WLF and ELF assessment areas to better constrain the distribution of Site-related constituents being discharged into the receiving environment, primarily from landfill leachate. Sediment samples were collected at surface, sub-surface, and deep intervals in the WLF to evaluate risk to aquatic receptors and to assess whether legacy deposition had occurred. Sediment samples in the ELF were only collected at surface intervals due to the high energy environment of the Foveaux Strait that would limit fine grain deposition and minimise the historical deposition that could accumulate at depth.

Surface water and pore water samples were collected to assess potential exposure conditions to organisms that may be present in the receiving environment. Surface water was collected at the TWC and BWC in the WLF area (Bluff Harbour). Surface water was collected at one interval in the ELF because of the high energy conditions in Foveaux Strait. Pore water samples were collected at the same interval as surface sediment samples to better understand the potential risk to aquatic receptors for constituents without ESVs in sediment (i.e., aluminium).

Exceedances of Site-related COPECs ESVs were observed in sediment and pore water in the WLF and pore water in the ELF. Boron exceeded the ESVs in pore water in the WLF and there were several exceedances of ESVs in sediment, including fluoride, mercury, and several PAH compounds. The greatest magnitude of ESV exceedances were observed for PAHs in west landfill sediment. Mercury was detected in the deep sediment interval of WLF-02 (West Landfill) at a concentration of 0.38 mg/kg (HQ = 2.5). West landfill sediment mercury concentrations were greater than background concentrations (EF > 1). There were no other exceedances of sediment ESVs in the east landfill or west landfill CMA; however, several constituents were observed at concentrations greater than background concentrations (EF >1) in CMA assessment media.

ELF sediment trace elements including arsenic, iron, manganese, and vanadium were observed at concentrations greater than background (EF >1). The greatest magnitude of difference between the background and East Landfill was observed for arsenic. The EF for arsenic in East Landfill sediment was 2.8. West Landfill sediment metals including aluminium, cadmium, total chromium, copper, iron, lead, manganese, nickel, titanium, vanadium, and zinc were observed at concentrations greater than background with EFs ranging from 1.1 to 1.9. The greatest EF was observed for cadmium and lead in west landfill sediment. Given that these constituents did not exceed an ESV yet were identified at concentrations greater than background sediment, additional work is recommended to constrain the potential for ecological risk of these constituents relative to background concentrations.

There were no detections of total recoverable fluoride in the east landfill sediment; however, soluble fluoride was detected at concentrations in the east landfill and were greater than background with EFs ranging from 2.6 to 18. The greatest concentration of soluble fluoride was observed at ELF-02, which is downgradient of NZAS landfill groundwater monitoring well A54. A54 was not sampled as part of this investigation; however, available records for this monitoring well (NZAS, 2021) indicate that concentrations of fluoride range between 5.8 mg/L and 25 mg/L, with the most recent available data showing concentrations of 20 mg/L and 21 mg/L in 2020. Pore water in the ELF had concentrations of fluoride at or below background concentrations in the range of known concentrations of sea water. This would suggest that upgradient sources of fluoride are discharging at lower depths or are dispersing immediately upon discharge into the CMA.

Total recoverable fluoride was detected in WLF sediment in WLF-02 at the surface and deep sediment intervals. The WLF-02 deep interval sediment exceeded the ESV for total recoverable fluoride (HQ = 1.1). Total recoverable fluoride in WLF sediment was greater than background with an EF of 1.3. The soluble fluoride concentration observed in the deep sediment sample at WLF-02 was proportionally greater than the surface sediment interval soluble fluoride concentration. Soluble fluoride was not detected in background sediment; therefore, no comparison was made to background. Concentrations of soluble fluoride in the ELF and WLF suggest that the phase of fluoride that would interact directly with aquatic receptors is present at concentrations greater than background. Future work is recommended to determine the potential effect that soluble fluoride concentrations in sediment would have on receptors in the receiving environment.

6.2.2 Foreshore Soils

Soil samples were collected in the east and west landfill locations to better understand the potential pathways for Site-related constituents to discharge into the CMA. Soil sample locations targeted visible overland flow pathways from the landfill.

Soil constituents in exceedance of ESVs were distinct between east and west landfill samples. Arsenic, total recoverable fluoride, and LMW/HMW PAH compounds were observed to exceed the ESV for soils in the east landfill. Fluoride was the only constituent observed to exceed the soil ESVs in the west landfill. The magnitude of east landfill fluoride detections and exceedances was greater than west landfill detections.

The presence of arsenic, fluoride, and PAH compound concentrations in exceedance of ESV suggests that there are potentially complete pathways from the landfill to the CMA receiving environment to the east. Further investigation is warranted to determine the potential pathways from the landfill to the west.

Soil conditions met the narrative conditions outlined in **Appendix A** for aluminium; therefore, aluminium concentrations in CMA assessment soils were compared to background aluminium concentrations. Aluminium concentrations were marginally greater than background aluminium concentrations in west landfill locations WLF-SO-03 and WLF-SO-03. The concentrations of aluminium in east landfill soils were up to 3.3 times greater than background concentrations; however, soil pH at these locations (5.7 to 7.1 in the east landfill and 5.9 to 7.6 in the west landfill) were within the narrative range for insolubility of aluminium in soils. Further assessment is warranted to determine the potential for risk associated with aluminium in soils in the east landfill.

There are several constituents that did not exceed or have an ESV in east or west landfill soils with concentrations greater than background concentrations. These constituents include cadmium, total chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, titanium, vanadium, and benzo(a)pyrene TEQ. Several PAH compounds were observed at concentrations above background concentrations. Further assessment is warranted to determine the potential for ecological risk associated with these constituents.

The foreshore soils in the landfill area were below the human health risk screening values.

6.3 Inalco Area and SCL Pad

6.3.1 CMA Assessment Area

Samples collected in the Inalco and SCL pad areas were predominately sediment samples based on the understanding of transport pathways from the upgradient areas to the CMA and the high energy nature of the Foveaux Strait. Surface water and pore water samples were collected at selected sediment locations in each area (**Figure 2**) and at one depth interval to assess the potential risk to aquatic receptors immediately downgradient of the Inalco storage yard and the SCL storage pad. Pore water samples were collected to assess potential exposure conditions to organisms that may be present in the receiving environment and were collected at the same interval as surface sediment samples to better understand the potential risk to aquatic receptors for constituents without ESVs in sediment (i.e., fluoride and aluminium).

There were minimal exceedances of ESVs in the CMA assessment areas of the Inalco and SCL Pad areas. Dissolved aluminium exceeded the ESV for surface water at SCL-02 with a HQ of 1.2; however, the concentrations observed at this assessment area were less than background surface water concentrations (EF <1). The zinc concentration in surface water was greater than background (EF >1). Boron was observed to exceed the ESV in SCL pad pore water and surface water. The SCL pad area pore water boron concentration was 2.8 times greater than background concentrations. SCL pad surface water boron concentrations were of approximately the same magnitude greater than background.

There are several constituents that did not exceed or have a ESV in the Inalco or SCL Pad areas. Several of these constituents in sediment, pore water, and surface water were observed at concentrations greater than background concentrations. Magnesium, and zinc were each observed at concentrations greater than background (EF >1) in the aqueous phase. Calcium and copper were observed at concentrations greater than background in pore water. Calcium and magnesium are approximately within known background concentrations of sea water and are marginally greater than Site background concentrations. Further assessment is warranted to determine the potential for risk associated with copper to aquatic receptors.

Arsenic and vanadium in sediment were observed at concentrations greater than background in both Inalco and SCL areas. Total recoverable and soluble fluoride were observed at concentrations greater than background in the SCL pad area. Further assessment is warranted to determine the potential for risk associated with these constituents to aquatic receptors.

6.3.2 Foreshore Soils

Soil samples were collected in the Inalco and SCL pad areas to better understand the potential pathways for Site-related constituents to discharge into the CMA from upgradient Site locations.

Soil constituents in exceedance of ESVs were similar between the Inalco and SCL pad samples. Arsenic and LMW/HMW PAH compounds were observed to exceed the ESV for soils in the Inalco and SCL pad area soils. Total recoverable fluoride was observed to exceed the ESV in SCL Pad soils at SCL-SO-01 (HQ = 1.3) and SCL-SO-02 (HQ = 44). HMW PAH compounds were observed to have the greatest magnitude of exceedance in the Inalco area with HQs ranging from 4.4 to 8.2. Arsenic concentrations in soil were observed to exceed the ESV (HQs ranging from 1.2 to 1.7) and were greater than background concentrations (EFs ranging from 1.9 to 2.8). The presence of arsenic, total recoverable fluoride, and PAH compound concentrations in exceedance of ESVs suggests that there are potentially complete pathways from upgradient Site features to the CMA receiving environment to the south. Total recoverable fluoride concentrations in the SCL Pad were the greatest magnitude observed across Site soils sampled during the CMA assessment. The distribution of fluoride in the SCL Pad area highlights the heterogeneity of soils in the area and warrants additional investigation into the spatial distribution of fluoride concentrations in soil.

Soil conditions met the narrative conditions outlined in **Appendix A** for aluminium; therefore, aluminium concentrations in CMA assessment soils were compared to background aluminium concentrations. Aluminium concentrations in SCL pad soils were less than or equal to background aluminium concentrations, except for SCL-SO-02, which had an aluminium concentration of 12,000 mg/kg, six times greater than background soil concentrations. Inalco area soil samples had aluminium concentrations ranging from 2,700 mg/kg to 5,200 mg/kg. The EF for Inalco area soil aluminium was 2; however, soil pH at these locations (5.8-6.3) were within the narrative range for insolubility of aluminium in soils. Further assessment is warranted to determine the potential for risk associated with aluminium in soils in the Inalco and SCL pad areas.

There are several constituents that did not exceed or have a ESV in east landfill or west landfill soils with concentrations greater than background concentrations. These constituents include cadmium, total chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, titanium, vanadium, and zinc. Further assessment is warranted to determine the potential for ecological risk associated with these constituents.

The foreshore soils in the Inalco and SCL pad were below the human health risk screening values, except for the aluminium in the SCL pad area.

6.4 NZAS Groundwater Monitoring Wells

Groundwater samples were collected from selected monitoring wells to provide collated / concurrent groundwater contamination data for the CMA assessment, and to verify the integrity of the routine groundwater being performed by NZAS. Results from the groundwater sampling completed as part of this investigation are generally within the historical range of available data for landfill monitoring wells received in 2021 and data published in the DSI (NZAS, 2021; GHD 2022) indicating NZAS groundwater monitoring results are likely to be representative of site conditions.

EC monitoring results in particular suggest tidal flux is likely to be occurring, with limited co-incident groundwater level change likely due to the highly permeable nature of the aquifer(s). Three landfill monitoring wells were sampled as part of this investigation to provide context to the groundwater discharge that is occurring from the landfill leachate into the CMA. Groundwater samples collected from monitoring wells A51, A53, and A56 confirm previous investigation and reporting results from 2020 indicating that groundwater leachate is still discharging into the Foveaux Strait and that concentrations have not decreased substantially.

7 Data Gaps and Uncertainties

The independent CMA assessment aimed to provide ES with a targeted assessment of key areas of the wider NZAS smelter complex that were potentially impacted by historic and current discharges of contamination. As noted in **Section 1** through to **Section 3**, a large amount of background data pertaining to the Site (that had been provided by ES and NZAS) was used to support development of the SAP for the CMA assessment.

Having completed the CMA assessment, a number of data gaps and uncertainties have been identified that should be addressed by further assessment work (whether that is undertaken by NZAS, ES or others). Environmental investigations are iterative in manner and the need for supplemental investigation is to be expected. A summary of key data gaps and uncertainties is presented below in terms of general findings and then specific issues relating the CMA work.

7.1 General Findings

The scope of the CMA assessment evolved through discussions with ES and NZAS staff and was principally informed by the review of the DSI (as detailed in EHS Support 2022c). In undertaking the CMA assessment and following interpretation of the collated data, several data gaps were identified that constrained the assessment and that need to be addressed in the future to provide a fuller assessment of potential impacts to the CMA. A number of these issues remain and are described below:

- A key data gap identified in the DSI review was the absence of an integrated hydrogeological CSM of the wider smelter complex. The iso-contour plans developed from this assessment (**Figures 8** and **9**) aimed to highlight this issue, but the integration of other hydrogeology data (for example data collected by GHD) was beyond the scope of the CMA work. It is understood that GHD is preparing this for NZAS. The absence of detailed information on groundwater flow direction, groundwater elevations, hydraulic connectivity between the stormwater drains (and other surface water features), and geological and structural controls on groundwater flow (such as bedrock influences within the landfill areas, presence different aquifer systems etc.) was an impediment to the design and implementation of the CMA assessment. The recent consent application and AEE submitted for than landfill (GHD, 2023) has assisted with and provided a more integrated assessment across the wider facility and landfill complex.
- The DSI review also identified the lack of integration of historical environmental data for the wider smelter complex as a data gap. The absence of integrated data also constrained the CMA assessment because this data is a critical step in defining trends and potential risks (from COPEC's and spatial areas). In addition, a lot of the historic monitoring data for the smelter Site is presented without supporting information on sampling methodologies, well construction information etc. This situation created a level of uncertainty with respect to the integrity of this historical monitoring data. The CMA work has validated (as far as was possible) that the NZAS groundwater monitoring work is producing credible results. Whereas the surface water sampling work down gradient of the stormwater drain discharges suggests that the NZAS stormwater sampling work is likely to be under reporting the concentration of COPECs within in the discharge (particularly given that only indicator parameters are monitored).

- While the CMA assessment has been able to characterise contaminant concentrations in various media at key locations, the absence of groundwater flux data and hydraulic data for the drains has constrained the ability to assess the mass flux of contaminant discharges. In turn this has limited the ability to assess environmental impact, particularly cumulative effects, and the potential for bioaccumulative effects based on loadings to the receiving environment.
- Project constraints (such as timeline, budget, access etc.) impacted the CMA assessment in that:
    - A “one off” sampling event was undertaken with limited ability to collect temporal data except for the groundwater monitoring well datalogger information and additional surface water and pore water data downstream of the drains in early May 2023.
    - The availability of NZAS groundwater monitoring wells, in which co-incident groundwater data could be collected relative to CMA assessment work, was constrained because of groundwater monitoring work being undertaken by NZAS.
    - Initial detection limit constraints for select compounds (particularly PAHs) caused by the laboratory created some uncertainty on the level of potential impact from these contaminants. Additional samples were collected to determine the distribution of PAHs using trace methods in May 2023 which assisted with resolving this data gap.

7.2 Fluoride Results

A critical uncertainty to the analytical resolution of samples collected as part of this investigation involved the initial erred analysis and subsequent reanalysis of aqueous fluoride. Fluoride is a known COPEC for this Site; therefore, results for this constituent are subject to additional scrutiny. It was apparent that the original results delivered by the initial testing laboratory did not accurately analyse fluoride in the aqueous phase. Investigation into this matter by the laboratory determined that aqueous marine (ocean) samples were not pre-treated as is required by the method. Upon confirmation of this error, aqueous fluoride samples were re-analysed by a second laboratory. Samples that were subject to re-analysis were out of the recommended hold time for fluoride.

Fluoride is a conservative element in natural waters and there is a low probability that fluoride concentrations would significantly change from sample collection to the time of re-analysis by second laboratory. The second laboratory provided comment that fluoride is relatively stable beyond the standard 28 days hold time and indicated they had confidence in the reported results. Therefore, it was recommended that the discussion around fluoride concentrations in samples collected as part of this investigation reference the re-analysis results by the second laboratory that were pre-treated for marine waters. Aqueous fluoride results considered in this reporting are the re-analysis results by the second laboratory. The additional marine water sampling undertaken in early May 2023 were consistent with the earlier data and validates the integrity of the fluoride laboratory test results used in the report (recording concentrations that are within a similar range).

7.3 Boron Screening Assessment

The evaluation of boron in pore water and surface water yielded results ranging from non-detect to 9.2 mg/L across the CMA investigation areas. Non-detect values for boron in marine water are not expected given that boron concentrations in normal seawater typically range from 4.5 to 5.1 mg/L (ANZECC & ARMCANZ, 2000; Howe, 1998), and this provides uncertainty to the analytical resolution associated with the aqueous boron results.

ANZG does not currently have a promulgated DGV for boron in marine waters that could be adopted as the screening criteria in pore water and surface water. Therefore, an appropriate approach to assessing boron in the CMA investigation areas is to adopt a regionally representative background value of 5.1 mg/L (ANZECC & ARMCANZ, 2000). This value is appropriate for screening level assessments, but since it is not a promulgated risk-based value, exceedances of this value do not necessarily indicate the presence of unacceptable risk.

Multiple robust, risk-based ecological criteria currently exist for boron in freshwater settings with guideline values around 7.5 mg/L. Some examples include 7.2 mg/L (Michigan DEQ, 2021; USEPA Region IV, 2018), 7.6 mg/L (Illinois EPA, 2012) and 7.7 mg/L(Indiana DEM, 2013). Each of these guideline values are considered Tier I final chronic values and have strong technical support based on peer reviewed toxicity data compiled from numerous studies. Given that boron is less toxic in marine environments than freshwater environments the CMA investigation results for boron are not likely to represent an unacceptable risk to aquatic receptors. It is expected that a promulgated marine water guideline value for boron would be greater than the background value of 5.1 mg/L and greater than the robust freshwater guideline values ranging from 7.2 to 7.7 mg/L..

7.4 Detection Limits

Several aqueous phase analytes that were measured as part of this investigation were compared to ESVs that were greater than the detection limit achieved by the laboratory. Analytes in the aqueous phase with laboratory detection limits greater than their respective ESVs are summarised in **Table 7-1** below.

Table 7-1 Summary of Aqueous Phase Constituents where Detection Limits are Greater than ESVs

Analyte	Laboratory Detection Limit (µg/L)	ESV (µg/L)
Metals		
Cyanide (Free)	5	4
PAHs		
Benzo(a)anthracene	1/0.1	0.018
Benzo(b)fluoranthene	1/0.1	0.06
Benzo(g,h,i)perylene	1/0.1	0.012
Benzo(k)fluoranthene	1/0.1	0.06
Dibenz(a,h)anthracene	1/0.1	0.01
Indeno(1,2,3-c,d)pyrene	1/0.1	0.012

Table Notes:
Laboratory detection limits presented 1/0.1 – first laboratory (January 2023 data)/second laboratory (May 2023 data)

Solid phase analytes had detection limits that were generally greater than the ESV, except for several individual PAH compounds. The detection limit for in soil and sediment was 0.03 mg/kg for each PAH compounds except for naphthalene, which has a detection limit of 0.1 mg/kg. PAHs were additionally assessed as the sum of PAH.

Table 7-2 Summary of Solid Phase Constituents where Detection Limits are Greater than ESVs

Analytes	Laboratory Detection Limit (mg/kg)	Sediment ESV (mg/kg)
Acenaphthene	0.03	0.00671
Acenaphthylene	0.03	0.00587
Dibenz(a,h)anthracene	0.03	0.00622
Fluorene	0.03	0.0212
Indeno(1,2,3-c,d)pyrene	0.03	0.017
Naphthalene	0.1	0.0346

Concentrations that are detected above the reported detection limits for the analytes listed in **Table 7-1** and **Table 7-2** are confirmed exceedances of their respective ESV; however, for results that are non-detect at the given reporting limits, there is uncertainty as to their concentration in relation to the ESV value.

Given that the detection limits are greater than ESVs, it is not possible to determine if the concentration of a non-detected result is truly an exceedance. Non-detect results for the analytes listed in **Table 7-1** and **Table 7-2** should not be considered as exceedances.

8 Revised Conceptual Site Model and Potential Risks

The CMA assessment work has provided greater insight into the mechanism and concentration of COPEC's that are being transported from the smelter operation and into the environment surrounding the facility. The area surrounding the smelter includes sensitive coastal, foreshore and aquatic habitats with access to the public for recreational and food gathering activities. A broad range of sensitive receptors exist in this setting including the public and aquatic, terrestrial and avian receptors.

Set out below is a revised summary CSM for the areas investigated during the CMA assessment and consideration of environmental and human health risks in the areas investigated.

8.1 Smelter Domain

The CMA assessment work did not focus on the smelter domain and so the CSM for this area remains unchanged from the discussion presented in **Section 3.3.3**. The principal contaminated areas, denoted by their original names from the GHD DSI report, are as follows and the key COPECs are fluoride and aluminium:

- Zone B – Inalco Yard.
- Zone C – Southern Yards.
- Zone D – Solid Storage and Wharf.
- Zone F – Carbon.

The location of these impacted areas correlates with the soil results for the CMA foreshore areas and documented areas of groundwater contamination within the smelter domain (detailed in the DSI). It is understood that NZAS has undertaken additional groundwater contamination investigation works to further assess the extent of this contamination. This work will hopefully better define the flux of groundwater contamination discharging into Bluff Harbour.

8.2 Foreshore Areas

The foreshore areas adjacent to the CMA investigation locations principally comprised dunes lying at approximately 5 m AMSL. These areas were subject to a limited surface soil sampling exercise with granular soils (sand and pea gravel) encountered having variable vegetative cover. The sample locations, given the smelter history, are likely to lie within areas modified by historic earthworks, but according to GHD (2021d) they have high to very high vegetation and habitat ecological value.

Each of the areas investigated yielded elevated concentrations of COPEC's, typically comprising aluminium, fluoride, and PAHs. The key impacted areas were adjacent to the south and west drains, downgradient of the east landfill area, downgradient of the Inalco area, and downgradient of the SCL pad.

The COPEC concentrations observed in foreshore soils, when compared to the terrestrial ESV's (**Table 1**), suggest that the contamination potentially poses effects to plants, soil invertebrates, and soil microbes and could result in growth, reproduction, soil process and survival impacts (with impacts varying based on contaminant). Each of the areas investigated yielded soils with a pH that was typically near neutral to acidic (ranging between 5.5-7.8) indicating that aluminium is not likely to be mobile and therefore not likely to be readily bioavailable (**Table 2**).

There is unlikely to be significant public access to these areas while the site continues to operate, and so these soils are unlikely to pose a public human health risk. The soil contamination will be contributing (to some degree) to the downgradient groundwater contamination particularly given the soil fluoride concentration exceed the soil leaching to groundwater ESVs presented in **Table 2**.

The smelter processes that have generated the contaminated soil have not been assessed as part of the CMA assessment. However, the contaminant sources are likely to comprise a mix of historic stormwater run-off and overland flow, dust blow from the wider facility (either historic or current), and/or atmospheric discharge from the process stacks (either historic or current) and fugitive emissions from the louvered roofline vents.

Additional investigation work is required to better characterise the nature and extent of the soil contamination and additional ecological and human health risk assessment may be needed (above the use the terrestrial eco ESVs and Tier 1 human health risk criteria) to characterise the risk. Regardless, it is considered likely that some form of mitigation will be needed to address the risks posed by the contamination.

8.3 Bluff Harbour and Stormwater Drain Discharges

The discharge areas for the three stormwater drains within Bluff Harbour were the key focus for the CMA assessment work given the known significant mass of the contaminant discharged from smelter stormwater drains.

Along the edge of the smelter domain that abuts Bluff Harbour (between the north drain and south drain) shallow groundwater within the underlying pea gravel aquifer discharges into the Harbour. The shallow groundwater system lies at a depth of approximately 3 m to 4 m bgl and is tidally influenced (based on in well EC measurements and groundwater level data – **Appendix E**). A combination of the NZAS, DSI and EHS Support data indicates there is a flux of groundwater contamination migrating towards and potentially discharging to the Harbour, with this evidenced by the groundwater seeps noted between the west and south drain. The apparent groundwater seep was observed during the CMA investigation (**Figure 2** and **15c**, attached). Water quality parameters and samples were collected from this location and at other locations along the beach. Fluoride concentrations from the samples collected were noted to exceed the aqueous ESV suggesting that fluoride laden groundwater is discharging directly to the Harbour (**Table 11** and **Figure 15c**). The fluoride concentration recorded in the seep is higher than was recorded in the nearby groundwater monitoring wells (**Figure 21**).

The stormwater and facility process water discharging into the Bluff Harbour (via the three stormwater drains) is derived from a large catchment (with the north drain having the largest catchment of 26 ha) with the discharge carrying a variable contaminant load. These discharges are consented. The drains are unlined and contaminated water will infiltrate/discharge to groundwater along their length (which is also consented). Depending on the invert of the base of each drain length and the local groundwater elevation there may be areas where the drains also receive groundwater.

The three drains are equipped with weir structures that control flow and retain sediment. Given the proximity of the weir structures to the north and west drain outlets to Bluff Harbour (i.e., lying some 150 m and 40 m, respectively upstream from the high tide mark/drain mouth) then it is likely that the head of retained drain water will recharge shallow groundwater in the vicinity of each drain mouth. Slightly different conditions are likely to occur within the south drain because this discharges to a wetland feature before discharging to Bluff Harbour (with the recharge occurring upstream of the wetland).

At the discharge areas for the north and west drains there could be a flux of combined contaminated groundwater and recharged contaminated drain water entering the CMA along with the discharge from the drains (water and sediment). This assumption is partly evidenced by the lower chloride concentrations recorded within the drain mouth of the west drain and fluoride sub-surface aqueous data for the north drain (**Figures 19** and **20,** attached). A similar situation is likely to occur at the south drain discharge point. However, observations during the EHS Support CMA assessment work indicates that the north and west drains flow/discharge regardless of rainfall events (assumed to reflect process water discharges), while the south drain seems to flow only during storm events.

Bluff Harbour is a relatively shallow water body immediately abutting the smelter domain, with the high tide mark typically lying some 10 m from the dunes/foreshore and the low tide mark extending some 100 m to 150 m out from the high tide mark. The area of the south drain is more sheltered by Tiwai Peninsula.

The Harbour substrate adjacent to the north and west drains is mapped as a gravel field (Cawthron, 2004), while the substrate adjacent to the south drain is mapped as a gravel field grading to firm sand and mud between high and low tide marks. The CMA assessment work confirmed the Cawthron mapping and has shown the sediment in the area of the north and west drains (down to a depth of 1 m) and was typically comprised of gravel with sand that contained minimal TOC in the south and west drain. North drain TOC concentrations were generally comparable to the west and south drains, with the exception of two sub-surface sediment samples that were 27% and 6.3% TOC.

The absence of fine-grained material in the sediment downgradient of the drain outlets (particularly the north and west drains) suggests the sediment discharged from the drains is not necessarily accumulating in the immediate receiving environment. Rather, sediment is being carried further out into the wider Bluff Harbour. This situation was noted by Cawthron in their 2005 summary (Cawthron, 2005).

The COPEC's discharging from the drains reflect the catchments they drain within the smelter complex, as summarised below:

- North Drain – process and stormwater from areas including the pot-rooms, dry scrubbers and carbon rodding area, and compressor house # 2. The north drain also receives the greatest influence of surface water from unsealed on-site drainage areas.
- West Drain – stormwater runoff from the pitch store (contains SCL), green carbon, carbon rodding, coke store and carbon bake. Additionally, the west drain receives process water from the anode cooling and ball mill cooling circuit. It is understood that historically higher concentrations of PAHs are likely to have been discharged via this drain (Cawthron, 2005) but changes in the pitch (pencil pitch to liquid pitch) likely reduced PAH loading to this drain.
- South Drain – stormwater from the metal yard, workshops, castings/logistics area, and the alumina store. This drain also receives process water from the castings/logistics products area. The south drain runs adjacent to the southern boundary of the NZAS smelter and abuts the Inalco storage area.

The combined flux of contamination into the CMA at each drain mouth has created an area of sediment and pore water contamination that extends from the outfall to beyond the approximate edge of the consented mixing zone. The width of the sediment/pore water contamination plume originating from the drains cannot accurately be defined given the scope of work completed and the possibility of concurrent groundwater discharge from the upgradient areas near the Site. The absence of organic material within the receiving sediment may account for the lower-than-expected PAH concentration recorded.

NZAS routinely excavate and re-distribute accumulated spoil from the mouth areas of each drain (to allow the drain flow/discharge). ES records indicate that the removal work typically occurs five times a year (averaged over the last five years) (dependant on gravel movement in bay). The soil/sediment excavation is undertaken as a Permitted Activity through ES's rule 7.4.2.1 in the Regional Coastal Plan. The scale of the disturbance was noted during the CMA monitoring event completed in May 2023 and indicates that disturbance may extend some 100 m or more below high tide mark but not beyond the low tide mark (**Appendix C**). It should be noted that improvements to stormwater and sediment management/treatment upstream of the drains would likely reduce the amount of contaminated sediment deposited in the CMA that is available to be spread during these routine maintenance activities.

The process of maintenance of these drains and the potential spreading of contaminated sediment from the drains into the broader receiving environment increases the size of the potential exposure area and potential effects on aquatic and benthic receptors. These sediment spreading activities within the north drain appear to have spread aluminium and fluoride rich materials outside of the regulated mixing zone for the drain and critically result in uncertainty as to whether the nature and extent of impacts have been adequately defined.

Marine surface water monitoring during normal flow conditions generally encountered an even distribution of contaminants throughout the marine water column (top and bottom of the water column). However, even during minor rainfall events, a more buoyant freshwater layer was found to form on the marine water body and carry a contaminated layer out some 100+m from the drain mouth (as evidenced in the north drain recording a fluoride concentration of 26.4 mg/L from the drain mouth). The Cawthron review (Cawthron, 2005) noted a similar outcome but also during calm conditions.

During first-flush stormwater events (as was recorded during the CMA assessment on 2 February 2023 in the north drain) a contaminant load greater than previously assessed during baseline conditions was recorded entering the CMA. The first flush discharge extended approximately 250 m from the drain mouth.

The consented discharge from the drains is premised on an allowable mixing zone (extending 50 m from each drain mouth), relying on dilution and dispersion to mitigate effects within downgradient marine water. The consent monitoring focusses on measuring sub-surface marine water concentration indicator parameters (pH, EC, and fluoride) at the edge of the mixing zone 2 hours either side of high tide. The consent requires the quarterly average fluoride concentration at the edge of the mixing zone not to exceed 2 mg/L and the spot fluoride concentration not to exceed 5 mg/L.

The CMA assessment work recorded contamination in surface water beyond the mixing zone (at concentrations that exceeded the ESV) downgradient of the north drain outfall during a rainfall event at 23.4 mg/L and 4.21 mg/L in the top and bottom of the water column (NOD-04), respectively. The pore water concentrations recorded during the CMA assessment work also recorded fluoride concentrations above of the ESV in the north drain up to 100 m from the drain mouth. The west and south drain pore water concentrations were below the fluoride ESVs at the time of this investigation.

In terms of assessing environmental and human health risk from the drain discharges the CMA assessment sampling work indicates the following:

- Exceedances of ESVs were recorded in all drain discharges and in the immediate receiving environments (for surface water, sediment, and pore water) and may pose potential chronic environmental effects. A broad range of direct effects could occur including decline in population (associated with impaired reproduction and /or mortality and avoidance) and indirect effects from the bioaccumulation/biomagnification of contaminants in the food chain.
- The first flush stormwater discharge events carry a significant mass of contaminant into the marine environment. Potential acute environmental effects occur during first flush stormwater events from the drains (as evidenced in the north drain) with fluoride contamination potentially impacting fish and benthic invertebrates and aluminium contamination potentially impacting benthic invertebrates.
- Initial assessment work (based on the EHS Support sampling results) suggests that human health risks from bioaccumulation through the food chain (via fish and shellfish gathering and consumption) are not likely to occur (when considering PAH, PCB, and dioxin/furan uptake within sediment). However, additional work is warranted to confirm these initial findings. A technical summary is presented **Appendix J**.
- Given the ease of public access to Bluff Harbour and the discharge points for the stormwater drains (particularly the north and west drains) measures should be implemented to warn the public of potential risk(s) associated with the discharge(s). While the human health risks have not been quantified in terms of water and sediment contamination within the drain discharge areas, it is noted that the concentration of aluminium and fluoride recorded during the first flush event in the north drain are an order of magnitude greater than the New Zealand drinking water standards (Water Services Regulations, 2022) and could pose a potential risk (following the screening recommendations presented in the Australian Government National Health and Medical Research Council Guidelines for Managing Risks in Recreational Water, 2008).

Monitoring the discharge(s) from the drains is complex because of the variable composition of the discharge (volume and contaminant load) and the nature of the receiving environments (tide, current, wind etc.). The current consent spot/grab sampling aimed to provide a pragmatic sampling solution to verify performance of the mixing zone, however, this sampling approach appears to be under reporting the contaminant concentrations. Similar conclusions were raised by Cawthron in their 2005 review. In addition, the current consent conditions and monitoring only focuses on marine surface water and does not include pore water which considers potential effects on benthic biota.

The CMA assessment has identified areas and opportunities for environmental improvement that would be in keeping with certified management systems that are believed to be used by the smelter facility. Some of the areas for improvement could be implemented outside of the current consenting regime. The key issues that warrant further consideration are listed below:

- More focused environmental monitoring to understand the mass of the contaminant discharge (flow monitoring and concentration), first flush events, and performance of the mixing zone (monitoring on an ebb tide and the direction of flow).
- Targeted sampling of fish and shellfish tissue is recommended to provide a dataset that is robust enough to enable the direct assessment of fishing and shellfish gathering on human health. This assessment would determine the potential risks of consumption on the general population and sensitive components of the population (for example children) as well as

determine (if applicable) the maximum number of fish and shellfish meals that could be consumed before potential deleterious effects.

- Supplemental shoreline sampling is needed to better define the potential extent of impacts from the drain maintenance activities and provide data to inform a risk assessment. As part of this sampling, it is recommended that benthic surveys be conducted to support development of the detailed ecological risk assessment recommended above.
- Assessment of improved operational practices to reduce contaminant load being discharged and treatment options.

8.4 Landfill Area

The initial CSM for the landfill (**Section 3.3.2**) indicated that most of the landfill leachate generated by the landfill cells is discharging into Foveaux Strait (96%), with minimal discharge to the Bluff Harbour (4%). Based on the NZAS data there is variable concentration leachate discharging into both Foveaux Strait and Bluff Harbour. Recent work completed by GHD as part of the NZAS Landfill consent application AEE (GHD, 2023) reiterates these findings. However, the AEE suggests that the majority of the leachate plume has discharged from beneath the landfill. There is not adequate evidence to suggest that the plume has dissipated to the extent implied in the AEE. A separate report will be filed with ES with a comprehensive review of the findings of the Landfill consent AEE.

The CMA assessment work has investigated both receiving environments, with the work within the Foveaux Strait beach constrained by the nature of the beach and the practicality of completing the investigation work.

The Foveaux Strait beach area downgradient of the landfill (ELF) comprises an exposed steep intermediate energy environment (with a large tidal range), with the beach being formed from pea gravel. While the Bluff Harbour receiving environment (WLF) comprises a low energy shallow harbour environment, with the sediment sampling work encountering fine grained sediment with a high TOC content (up to 46%).

The sediment and pore water sampling within the ELF area generally yielded no concentrations that exceeded an ESV. While the WLF sediment and porewater sampling yielded concentrations of fluoride, boron, mercury, and several PAH compounds that exceeded their respective ESV. Sediment collected in the East Landfill was observed to have concentrations of Site-related COPECs including arsenic, iron, manganese, and vanadium at concentrations greater than background (EF >1). West Landfill sediment metals including aluminium, cadmium, total chromium, copper, iron, lead, manganese, nickel, titanium, vanadium, and zinc were observed at concentrations greater than background with EFs ranging from 1.1 to 1.9.

The scope of the CMA assessment was not able to conclusively assess the nature and extent of potential environmental effects within the receiving environments down gradient of the landfill within Foveaux Strait. It is clear from the work undertaken that concentrations in various media exceed ESVs to the west of the landfill (in Bluff Harbour) which potentially triggers the need for further assessment.

The elevation at which groundwater/leachate contamination is discharging into the Foveaux Strait beach is unknown because relative groundwater elevation data for the NZAS wells located along the line of dunes behind the beach has not been sourced. Groundwater monitoring of selected NZAS wells located immediately downgradient of the landfill indicates that groundwater along the dune area lies between 1-4 m bgl. However, there is currently only limited data on the nature of the leachate flux into Foveaux Strait and Bluff Harbour. Data gaps included the following (but not limited to):

- Vertical profile of the leachate plume, in particular whether a denser high concentrate leachate plume is migrating along the pea gravel bedrock interface (as has been experienced at the SCL pad).
- The influence of the underlying bedrock profile on groundwater/leachate flow directions.
- It is anticipated that complex geochemical processes will be occurring at the interface of the groundwater/leachate discharge and the receiving marine environment. It was beyond the scope of the CMA assessment to fully characterise these processes, however understanding these processes will be critical in further assessing potential adverse effects from the leachate discharge.

8.5 Downgradient of the Inalco Area

The area downgradient of the Inalco area comprises a flat densely vegetated area between the smelter boundary and the foreshore area. The CMA area downgradient of the Inalco area is a moderate to steeply sloping coastal beach. The initial CSM (**Section 3**) for the Inalco area is considered within the CSM for the greater smelter domain. Within the smelter domain, the GHD DSI indicated that there are multiple contamination sources within the Site that are leaching to groundwater, with the nature and distribution of contamination reflecting the nature of the manufacturing activities that are known to occur. Large plumes of fluoride and aluminium groundwater contamination lie below the main manufacturing complex, with contaminant concentrations declining as the contamination plume migrates towards Foveaux Strait (**Figures 8** and **9**, attached). Potential pathways associated with the Inalco area include leaching of soil contamination to groundwater, migration of contaminated soils or dusts via storm water to the south drain and aeolian transport of dust and particulates.

Tiwai Point was surveyed to determine areas of ecological significance as part of the NZAS closure assessment (GHD, 2021d). The results of the ecological survey indicated that parts of the Inalco area within the smelter domain are considered as seasonally very high value areas. Therefore, the revised CSM will need to consider these areas within the smelter domain to be ecologically valuable and should be compared to the ecological screening values. This refined context is critical to the assessment of smelter domain area specifically the Inalco area in the context of current exposure routes and possible post-closure plans for the Site.

The CMA assessment work recorded contamination associated primarily within the foreshore soils. There were no exceedances of the ESV in the Inalco area sediment, pore water, or surface water. Ecological risk is primarily associated with from soil to terrestrial and avian ecological receptors. This requires further assessment to establish potential risks and whether mitigation is needed.

8.6 SCL Pad Area

The initial CSM for the SCL pad identified historical and ongoing discharge of groundwater from the SCL pad to the downgradient areas of Foveaux Strait beach. This discharge is being managed by a natural attenuation approach agreed upon by ES historically (NZAS, 2020). The NZAS monitoring data indicates that while contaminant concentrations in the groundwater plume discharging from the SCL pad have reduced significantly over the years, there is still an ongoing discharge into the Foveaux Strait beach area.

The Foveaux Strait beach area downgradient of the SCL pad comprises an exposed steep high energy environment (with a large tidal range), with the beach being formed from pea gravel and containing minimal TOC (less than 0.1%). Findings from the CMA assessment indicated that ecological risk downgradient of the SCL pad is primarily associated with foreshore soil and potentially groundwater. Groundwater collected from the SCL pad at monitoring well 4-5 was the only instance where each phase of cyanide (total cyanide, free cyanide, and WAD cyanide) was detected during the CMA assessment.

The scope of the CMA assessment was not able to conclusively assess the nature and extent of potential environmental effects within the receiving environments down gradient of the SCL Pad. It is clear from the work undertaken that concentrations in various media exceed ESVs which triggers the need for further assessment.

The elevation at which groundwater/leachate contamination is discharging into the Foveaux Strait beach is unknown because relative groundwater elevation data for the NZAS wells located along the line of dunes behind the beach has not been sourced. Groundwater monitoring of selected NZAS wells located immediately downgradient of the SCL pad indicates that groundwater along the dune area lies approximately 3-4 m bgl. Data gaps included the following (but not limited to):

- It is anticipated that complex geochemical processes will be occurring at the interface of the groundwater/leachate discharge and the receiving marine environment. It was beyond the scope of the CMA assessment to fully characterise these processes, however understanding these processes will be critical in further assessing potential adverse effects from the leachate discharge.

Anecdotal evidence (namely discussions with NZAS and GHD during initial site inspections) suggests that erosion of the beach area adjacent to SCL pad is occurring at a higher rate than other areas of the smelter. The impact of the coastal erosion and sea level change on the SCL pad area would appear to be an area of concern.

9 Smelter Management Issues

Based on the EHS Support review of the various NZAS documents pertaining to the wider smelter complex, Site inspections undertaken in 2021, and the results from the CMA assessment the following issues (from an independent perspective) have been noted in relation to ES's on-going regulatory management of the wider smelter area. The management issues are presented as opportunities for improved environmental outcomes and potentially dovetail with certified environmental management systems that are used by NZAS.

The management issues are presented as issues that are deemed to apply the wider facility rather than specific spatial areas (Facility Wide) and then issues that are more particular to specific spatial areas/activities.

Facility Wide

- Soil contamination above the terrestrial ESV was recorded within a majority of the CMA areas investigated (notably south and west drains, east landfill area, Inalco area, and SCL pad area). These impacts in peripheral areas are consistent with the sources and higher levels of impacts observed in interior portions of the operational facility (DSI). On the basis that the CMA soil sampling exercise was limited in scope, further assessment is needed to define the extent of this contamination and assess risk. In addition, some of the elevated contaminant concentrations recorded will be potentially contributing to groundwater contamination fluxing into the CMA. Based on the GHD work and works completed by EHS Support, identification and possible remediation of soils that may contribute to groundwater contamination may be needed. NZAS should undertake assessment work (if this has not been undertaken as part of recent assessment work) to establish the source(s) of the contamination (such as overland flow paths, dust/wind blow from the landfill, wharf conveyor etc.) and implement mitigation, as needed. It is likely that improved management practices/housekeeping and implementation of a Site wide environmental management plan (if one is not already in place) would assist in reducing future contamination of these areas.
- The various groundwater studies undertaken by NZAS and their retained environmental consultants (dating back to the 1990s) have identified extensive plumes of groundwater contamination originating from various activities and areas of the wider smelter complex. The source of some of this groundwater contamination is consented through the landfill and stormwater discharge consents, while other parts of the groundwater contamination plumes may not to be consented. Supplementary NZAS studies will assist in clarifying this situation.
- NZAS has an extensive network of groundwater monitoring wells that are routinely monitored to verify the nature and extent of groundwater contamination within the wider smelter complex and the concentration fluxing into the marine environment. Observations by EHS Support during the CMA investigation suggest that a number of these wells need upgrade and/or replacement to enable representative groundwater samples to be collected. EHS Support understands that NZAS has undertaken a programme of supplementary groundwater monitoring well installation work which will hopefully replace and/or upgrade existing wells and expand the groundwater monitoring well network. It is recommended that a consensus as to which groundwater monitoring wells are needed for long term monitoring purposes is agreed upon.
- The CMA groundwater monitoring (of select NZAS wells) yielded comparable results to the NZAS routine groundwater monitoring work and has provided independent verification of their work.
- Assessment of data collected as part of the CMA investigation has demonstrated that mass discharges of constituents above SV's are occurring to the receiving environment as surface water, sediment, and groundwater. This is particularly noted within the receiving environment of each of the three drains. Further management and monitoring needs to

consider the cumulative/total mass loading to the environment (especially Bluff Harbour) and set appropriate management limits to address concerns with bioaccumulation of constituents.

Smelter Domain

- The CMA assessment work has verified that while discharge from the drains is a consented activity, there may be contaminants discharging through the three-smelter stormwater drains into the CMA (particularly the north and west drains).
- The contaminant concentrations in these discharges are elevated above environmental ESVs (including outside of the consented mixing zone) and suggest complete pathways exist that pose potential adverse environmental effects. The volume of the discharges was not quantified and the NZAS consent monitoring has no requirement to measure flow (this is a key data gap). The absence of flow data precludes assessment of mass flux and total maximum loads to the receiving environment and ideally improved monitoring would address this deficiency.
- First flush data for the north drain identified fluoride concentrations at much greater concentrations than non-discharging conditions, indicating a potential for acute toxicity that needs to be evaluated. Further assessment of acute toxicity and direct toxicity assessments of first flush discharges should be considered. In addition, a quantitative risk assessment should be completed on the sediment pore water to determine potential risks to benthic receptors.
- There appears to be daily/regular flow from the north and west drains (assumed to be process water) into the CMA which is also likely to be discharging to groundwater and fluxing into Bluff Harbour. In addition, episodic discharges occur during rainfall events, with particularly high contaminant concentrations discharging during first flush events which could pose acute ecological effects.
- The assessment data demonstrates significant transport of constituents into the receiving environment as solids/sediment. This reflects the nature of Site practices, the construction of the drains (especially the north drain) and the absence of retention and settling structures. Improved housekeeping practices and potential modifications to the stormwater system (including detention structures) should be considered to better contain solids/sediment to the Site.
- Based on the results from the CMA assessment, the current environmental monitoring programme (required by the current stormwater discharge consent [No. 203373]) appears not fit for purpose in terms of monitoring potential adverse effects. It is anticipated that a more thorough assessment of contaminant load discharging through storm events, coupled with an assessment of the contaminant load within the process water is needed.
- NZAS routinely excavate (and presumably re-distribute rather than remove) accumulated spoil from the mouth areas of the north and west drains. The soil/sediment removal is undertaken as a Permitted Activity through ES's rule 7.4.2.1 in their Regional Coastal Plan. A site visit conducted by Environment Southland staff (20 July 2023) found this work to be compliant with the permitted activity requirements.
- While it is unknown whether NZAS will secure a renewed electricity supply contract (and operate beyond 2024), regardless (and in the interests of continual improvement) NZAS should be encouraged to adopt improved operating practices, including (but not limited to):
    - Maintenance of the drains (particularly removal of sediment behind the weirs etc.) to reduce contaminant flux.
    - Implement better management processes for the discharge of stormwater prior to discharge.
    - Improvements to stormwater retention systems including the addition or modification of ponds and engineered wetlands.

  - Improvements to Site wide operational practices to reduce stormwater contact with contaminated materials.

NZAS Landfill

- On the basis that the landfill is in process of being re-consented (with the current consent [No. 202196] expiring on 8 December 2023) then various landfill management initiatives and improvements will likely arise through this process.
- As a minimum, the following management issues should be considered on the basis that NZAS has terminated disposal activities within the landfill:
  - Capping to reduce leachate generation and flux.
  - Capping will also improve potential contaminant migration through dust blow, stormwater run-off etc.
  - Implement processes to ensure that any recycling/recovery of waste as part of possible landfill rehabilitation work needs to be well managed and monitored because of potential increased flux of contaminants into the CMA.
- The long-term integrity of the landfill area needs to be assessed in term of its resilience to the effects from climate change and coastal erosion.

Inalco Area

- The CMA assessment work detected contamination downgradient of the Inalco area and current SCL storage warehouse (regardless of fact that a forested area separates the operational areas from the CMA assessment area). Given the magnitude of impacts observed in shallow soils within the Inalco area and off-site transport (including aeolian transport), improved operational practices are needed to reduce the impact downgradient and proximal to these operations.

SCL Pad Area

- NZAS has a large volume of SCL encapsulated within the SCL Pad. If not already in place, NZAS should implement some form of management strategy/process to ensure the integrity of the capped waste is maintained, particularly if NZAS commences with removal and recycling activities. The routine groundwater monitoring NZAS undertakes within the SCL Pad area is one line of evidence that can be used to verify that the containment system has not been compromised.
- The management philosophy for the legacy groundwater contamination plume originating from the SCL Pad is based on monitored natural attenuation. While ES agreed to this management approach in principle (via their correspondence dated 14 February 2006), this correspondence pre-dates the introduction of the ES Proposed Southland Water and Land Plan Part A in 2018. Consequently, NZAS may need to apply for a consent to comply with the necessary rules.
- It is understood that NZAS is exploring options to remove and recycle the SCL waste stored on the SCL Pad. Given the nature of the waste this is a complex process but should be encouraged given the proximity of the SCL Pad to the CMA and the potential for the Pad to be affected climate change (sea level rise) and coastal erosion.

10 Summary and Conclusions

The key findings from the CMA assessment are listed below:

1. Sources of contamination exist within operational areas of smelter (as recorded in the NZAS/GHD detailed site investigation of the smelter site and landfill) that have generated wide-spread groundwater contamination that is discharging into the CMA.
2. The scale and nature of the contamination recorded in the CMA is less than expected given the age and extent of the NZAS operation(s). The potential for adverse environmental effects to arise from site-wide contaminant discharges exist within Bluff Harbour, while potential effects within Foveaux Strait are likely to be less. The nature of the Bluff Harbour and Foveaux Strait receiving environments are different, however they both attenuate contaminant discharges to varying degrees (through a mix of physical and chemical processes).
3. The lateral extent of the groundwater contamination plume discharging from the landfill to Foveaux Strait is extensive (approximately 1 km wide) with the effects from this discharge currently being assessed through the re-consenting of the NZAS landfill.
4. Discharges of contaminants are occurring via the consented stormwater drains (above ESV's) posing potential chronic and acute effects to ecological receptors. The CMA assessment has not quantified the mass of the contaminant discharge (with the sediment discharge being carried out into the wider Bluff Harbour), as this was beyond the work scope of the project.
5. Potential acute environmental effects occur during first flush stormwater events discharging from the north drain with fluoride contamination potentially impacting ecological receptors such as fish and benthic invertebrates and aluminium contaminations potentially impacting benthic invertebrates. Further work is warranted to identify if similar discharges exist at the west and south drains.
6. The CMA monitoring has shown there are first flush stormwater discharges from the north drain that extend beyond the mixing zone at concentrations greater than the ESV and consented limits. Sediment and pore water concentrations above ESVs extend beyond the mixing zones of the north drain and are not captured by the consent.
7. The results from the CMA assessment work suggest there are unlikely to be higher order or human health risks via contaminant bioaccumulation through the food chain. This determination requires further biological testing to provide a more affirmative conclusion.
8. Mass loadings and impacts to Bluff Harbour may have been exacerbated by drain sediment movement practices (currently undertaken as a Permitted Activity under rule 7.4.2.1 of ES's Regional Coastal Plan) where materials (including contaminated spoil) are spread above the low tide mark and may distribute sediment contamination further into the harbour than under normal depositional conditions. Further assessment work is required to assess this activity and the risks.
9. Groundwater discharges are occurring within the smelter domain and SCL pad areas that exceed the groundwater ESVs. Whether this non-consented groundwater contamination discharge is posing a risk to Bluff Harbour and Foveaux Strait requires further study and will, in part, depend on cumulative effects of groundwater and stormwater/process water contamination discharges.
10. The scope of the CMA assessment was not able to fully assess the likely nature and extent of potential environmental effects within the CMA receiving environments down gradient of the landfill, Inalco area, and SCL pad area within Foveaux Strait. It is anticipated that complex geochemical processes will be occurring at the interface of the groundwater/leachate discharges and the receiving marine environment(s) at a greater distance/depth into Foveaux Strait than was achieved by the CMA work. This requires further consideration/work to assess potential risk(s) and is in part being addressed by the NZAS landfill consent application.

11. It is clear from the work undertaken that concentrations in various media exceed ecological screening values within the CMA to the west of the landfill (in Bluff Harbour). These effects are being assessed by the NZAS landfill consent application.
12. Soil contamination along most foreshore areas investigated (i.e., DOC land butting against the smelter) recorded contaminant concentrations that could pose a potential terrestrial ecological risk (notably south and west drains, east landfill area, Inalco area, and SCL pad area). This contamination has arisen from internal smelter operations/practices. This soil contamination potentially poses effects to plants, soil invertebrates, and soil microbes and could result in growth, reproduction, soil process, and survival impacts (impacts vary based on contaminant).
13. The CMA assessment yielded similar contaminant concentrations to the routine groundwater monitoring work undertaken by NZAS (in selected wells) and has provided confidence in the integrity of this routine sampling work.
14. The CMA assessment of the stormwater discharge sampling suggests that the consent stormwater sampling is potentially under reporting contaminant concentrations beyond the mixing zone during certain flow conditions and does not address sediment or pore water contamination.
15. Given the ease of public access to Bluff Harbour and the discharge points for the stormwater drains measures should be implemented to warn the public of potential risk(s) associated with the discharge(s).
16. To improve the environmental performance of the smelter operations and reduce contaminant discharges, NZAS should focus on the issues listed below. While these improvements have not been discussed with NZAS, they may have been implemented or NZAS may intend to implement these (or similar) improvements. Plus, they are in-keeping with the certified environmental management systems that the smelter is believed to use.
    - Routine operation/housekeeping changes will yield improved stormwater quality and reduced groundwater contamination discharges.
    - Improvements to waste handling and storage within the smelter domain (such as refractory bricks stored on an unsealed area), and dust management will yield improved stormwater quality and reduced groundwater contamination discharges.
    - Landfill capping will reduce groundwater contamination discharges.
    - Improved maintenance of stormwater collection systems and focused/performance based environmental monitoring will yield improved stormwater quality. The drain mouth clearing process requires further assessment.

11 Limitations

The CMA assessment work has been undertaken in accordance with the Umbrella Contract between ES and EHS Support, dated 2 August 2021. The scope of work for the assessment was set out in EHS Support's email dated 15 November 2022.

EHS Support has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of Environment Southland and only those third parties who have been authorised in writing by EHS Support to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 15 November 2022.

The methodology adopted and sources of information used by EHS Support are outlined in this report. EHS Support has made no independent verification of this information beyond the agreed scope of works and EHS Support assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to EHS Support was false.

This report was issued on 24 October 2023 and is based on the conditions encountered and information reviewed at the time of preparation. EHS Support disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

This report contains information obtained by inspection, sampling, testing or other means of investigation. This information is directly relevant only to the points in the ground where they were obtained at the time of the assessment. The behaviour of groundwater and some aspects of contaminants in soil and groundwater are complex. EHS Support's conclusions are based upon the analytical data presented in this report and our experience. Future advances regarding the understanding of chemicals and their behaviour, and changes in regulations affecting their management, could impact our conclusions and recommendations regarding their potential presence on this Site.

Where conditions encountered at the Site are subsequently found to differ significantly from those anticipated in this report, EHS must be notified of any such findings and be provided with an opportunity to review the recommendations of this report.

Whilst to the best of our knowledge information contained in this report is accurate at the date of issue, subsurface conditions, including groundwater levels, can change in a limited time; therefore, this document and the information contained herein should only be regarded as valid at the time of the investigation unless otherwise explicitly stated in this report.

12 EHS Support

The CMA investigation work performed by EHS Support was undertaken by a mix of New Zealand based experienced practitioners and specialist technical staff based in the United States. The work has also benefitted from support provided by Kennedy Environmental Ltd.

The technical work associated with assessing the environmental data and report preparation was undertaken by various staff in New Zealand and the United States. During the course of the preparation of the report it was subject to a variety of QA/QC checks and reviews that are used by consultants performing work on complex projects.

The key staff involved in the project are listed below and were responsible for the technical review of elements of the project/report relevant to their areas of technical expertise.

Simon Hunt acted as Project Director and was the key interface between ES and EHS Support. Simon has over 35 years of international environmental and contaminated land management experience. He holds a BSc Hons majoring in geology, a MSc and DIC in environmental technology, is a Chartered Geologist, and a Certified Environmental Practitioner-Site Contamination Specialist. Simon has a vast amount of experience assessing and remediating highly complex industrial sites that has been gained in Europe, Australasia, and Asia (both as a consultant and in industry).

Warren Sharp acted as the EHS Support Project Manager and oversaw the bulk of the field programme. Warren is a contaminated land specialist with over 25 years' experience in the investigation, risk assessment, remediation and consenting of contaminated sites. Warren has attained Certified Environmental Practitioner-Site Contaminated Specialist certification. Warren has worked on contaminated site projects locally and internationally in a variety of sectors including the assessment and remediation of sites associated with asbestos, petroleum hydrocarbons, timber treatment activities, chemical and pesticide disposal, landfills, and a wide variety of other industrial and commercial facilities.

Nigel Goulding has worked extensively over the last 28 years in both investigation and remediation of complex industrial sites, including aluminium smelters. These projects have included refineries and large petro-chemical impacted sites and aluminium refining and process facilities throughout the US, Asia Pacific, and Europe. Nigel started his career in New Zealand and has extended work assignments in Australia, USA, and Europe. Nigel has functioned as a technical director on numerous projects, working with peers and senior management within client organisations (as well as other consultant personnel) to develop investigation, assessment, and feasibility studies designed to define and manage environmental liabilities and potential financial expenditures.

Gary Long is an ecologist with over 20 years of experience working on ecological risk assessments in aquatic, terrestrial, and wetland environments. His work focuses primarily on ecological risk assessment, risk-based remedial decision making, and natural resource damage assessment (NRDA) for contaminated sites regulated in the U.S. under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Resource Conservation and Recovery Act (RCRA), and state voluntary programs. Gary also has done extensive work throughout Australia under the National Environment Protection Measures (NEPM) framework and in New Zealand under MfE guidance and Australian and New Zealand Guidelines (ANZG). He has developed site-specific risk assessment strategies for these sites involving the design and implementation of sediment/pore water quality, surface water quality, ecotoxicological, tissue residue, and biological community studies. In his role as technical leader on these projects, Gary has successfully participated in negotiations with state and federal regulators to develop risk assessment strategies, support the selection of risk-based remedial alternatives, and design long-term monitoring programs.

Dana McCue is an environmental professional with over 30 years of experience in human health risk assessment (HHRA), site investigation, remediation, and environmental chemistry. She received a Bachelor of Science in Biochemistry from Florida State University and a Master of Public Health, with an emphasis in Environmental and Occupational Health, from Emory University. As a Senior Risk Assessor at EHS Support, Dana has provided assistance to clients on HHRA and exposure assessment issues for sites located throughout the United States, Canada, Mexico, South America, Europe, Asia, Australia, and New Zealand. Responsibilities include investigation and remedial design support; preparation of baseline and site-specific risk assessments; development of conceptual site models; risk-based prioritization; vapor intrusion evaluations (including modelling); emerging contaminant evaluations (e.g., PFAS); preparation or review of toxicologic profiles; and development of site-specific screening levels for chemicals of concern.

Maxwell Landsman-Gerjoi is a US based ecologist with experience assessing ecological risk at aluminium smelters. Max provided on the ground support to the field work programme and back-office support managing the chemical testing database. He is an experienced in soil, sediment, water, and gas sampling for a broad range of compounds and related statistical analyses. Maxwell has experience in designing and implementing field programs on various scales within the United States and New Zealand. Maxwell’s specific areas of expertise include data collection, analysis, and interpretation for metals, volatile organic compounds (VOCs), PCBs, PAHs, and PFAS.

Paul Kennedy, from Kennedy Environmental Ltd, is an environmental consultant with over 40 years of experience working within New Zealand on coastal ecology and contaminants in those environments. He has provided technical and review support through the project as required. His experience includes evaluation of water quality, soils, estuarine and coastal sediments in natural environments and within ports, urban areas, and contaminated environments. His contaminant experience has included most trace elements especially those that bioaccumulate and a wide range of persistent organic compounds. He has a BSc (Hons) in ecology from Victoria University and has worked predominantly as a consultant in New Zealand and international consultancies.

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